Appendix A

NOP Scoping and Other Public Meetings

Appendix A
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A.1 Introduction

This appendix summarizes the public involvement activities implemented during the pre-scoping and scoping phase of the environmental review process for the amendments to the Bay-Delta Plan. Public input on the proposed amendments to the Bay Delta Plan was sought to help prioritize objectives and evaluate alternatives. Public involvement was part of the environmental review process and allowed the following:

- Identify and involve interested stakeholders
- Identify issues and concerns of stakeholders
- Notify stakeholders of the proposed plan as required by California Environmental Quality Act (CEQA) and National Environmental Policy Act (NEPA) standards

A.2 Notice of Preparation

CEQA requires the preparation and circulation of a Notice of Preparation (NOP) at the onset of the environmental review process. An NOP must provide sufficient information describing a project and potentially significant environmental impacts such that it enables responsible agencies to provide a meaningful response. At minimum, the NOP needs to include:

- Brief description of the proposed project
- Description of the proposed project's location
- Probable environmental effects of the proposed project
- Date, time, and place of the public hearing
- Address where documents or files relating to the proposed project are available for review
- Address where written comments on the scope of the SED may be sent
- Deadline for submitting comments

In accordance with CEQA, the State Water Board issued an NOP on February 13, 2009, indicating that an SED would be prepared. The NOP was posted on the State Water Board's website at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/. The scoping period extended between February 13 to March 19, 2009. A revised NOP was issued on April 1, 2011, and posted on the State Water Board's website. The scoping period for the revised NOP extended between April 1 and May 23, 2011.

A.3 Scoping Meetings

Scoping is the process by which input is solicited from agencies and stakeholders on the nature and extent of issues and impacts to be addressed in an SED and the methods by which they will be evaluated. Scoping assists with identifying the range of actions, alternatives, environmental effects, methods of assessment, and mitigation measures to be analyzed in greater detail. It also helps eliminate those issues that are not relevant to the decision at hand. Two public scoping meetings for were conducted on March 30, 2009 and June 6, 2011. Notice of the scoping meetings was included in the NOP and revised NOP.

A.4 Other Public Meetings

In addition to the scoping meetings conducted in March of 2009 and June of 2011, other public meetings and workshops were held to facilitate the water quality control planning process. Below is a list of the meetings and workshops.

- April 22, 2009: Public Staff Workshop Concerning Potential Amendments to Bay-Delta Plan Relating to southern Delta Salinity and San Joaquin Flow Objectives
- August 13, 2009: Public Staff Workshop and Availability of Draft Study Report regarding Salt Tolerance in Southern Sacramento-San Joaquin River Delta
- November 22, 2010: Notice of Opportunity for Public Comment for any additional information related to the San Joaquin River flow and southern Delta salinity objectives included in the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary
- January 6 and 7, 2011: Presentation and Discussion of Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives
- March 20, 2012: Informational Session on the Substitute Environmental Document for Potential Changes to the San Joaquin River Flow and Southern Delta Water Quality Objectives and Associated Program of Implementation

A.5 NOP Scoping Comments

Brief summaries of comment topics received on the NOP during the two scoping periods (February 13 through March 19, 2009, and April 1 through May 23, 2011) are presented in Table A-1. Copies of all written comments and the transcripts of oral comments received during the scoping periods and at the scoping meetings and other public meetings are on the State Water Boards Website at http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/.

Table A-1 Summary of Scoping Comments

Date	Comment Summary	SED Chapter
The Bay Institute		
Commenter: Gary Bobker, Program Director		
19-Mar-09	San Joaquin River flow objectives need to be considered in conjunction with Delta export criteria.	Chapter 3, Alternatives Description
19-Mar-09	San Joaquin River flow objectives need to be considered in conjunction with the Plan's narrative objective for salmon protection.	Chapter 3, Alternatives Description
19-Mar-09	In amending water rights to implement the flow objectives, the Board should not exclude any major water rights holders or water users from potentially being required to help meet these objectives.	Chapter 3, Alternatives Description
19-Mar-09	In amending water rights to implement the flow objectives, the effect of changing release patterns from upstream storage facilities on instream biological resources in each sub-basin should be evaluated, in order to ensure that compliance with downstream requirements occurs in a manner that avoids adverse impacts to those instream resources.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 8, Terrestrial Biological Resources
Commenter: Gary Bobker, Program Director; John Cain, Conservation Director		
23-May-11	The Institute strongly agrees that more flows and more natural flows are needed in the San Joaquin River.	Chapter 3, Alternatives Description
23-May-11	The draft narrative objective is too imprecise and broad to ensure full protection of beneficial uses. Beneficial uses outside of the February–June period are inadequately protected by the draft narrative objective.	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	Specify that the flow rate for the February–June Vernalis objective be a designated percentage of unimpaired runoff (including an initial rate and an adaptive range).	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Specify the initial flow rate and the adaptive range based on the best available scientific information for protecting fish and wildlife beneficial uses.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix K
23-May-11	Clarify the relationship between flow conditions and other measures for purposes of adaptive management of the flow rate in the objective.	Chapter 3, Alternatives Description; Chapter 16, Evaluation of Other Indirect and Additional Actions; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix K
23-May-11	Include an objective for July–January period base flows.	-
23-May-11	The Institute supports the proposal to link Vernalis flows to the unimpaired hydrology of the San Joaquin River basin.	-
23-May-11	The Vernalis flow objectives should be amended from a cfs flow rate by water year type to a specific (or range) percentage of unimpaired runoff flow rate from the San Joaquin basin.	Chapter 3, Alternatives Description
23-May-11	If the SED adopts a percentage range, then the initial condition should be determined by the best available scientific evidence.	Chapter 3, Alternatives Description
23-May-11	Based on literature in Appendix A of the comment letter, the Institute suggests that the minimum initial flow rate be set at a level that supports Chinook positive population growth in every year (i.e., flows ≥5000cfs in all weeks of April and May) until the abundance target is met (see Table 1).	Chapter 3, Alternatives Description
23-May-11	The initial flow rate should include adequate spring outmigration flows. Flows >10,000 cfs that occur for at least two weeks during the juvenile migration period in at least 80% of years are the minimum necessary to support the abundance target (see Table 1).	Chapter 3, Alternatives Description
23-May-11	The initial flow rate should include flows that frequently inundate San Joaquin floodplains during the fall run juvenile migration period—specifically, flows that exceed 25,000 cfs for at least two weeks in 60% of years (see Table 1).	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	If the SED adopts a flow rate percent that is lower than the 2010 public trust flow criterion, then the document should 1) detail the basis for doing so; 2) identify the impact to the Public Trust; 3) provide for adequate review and comment; and 4) ensure the rate is not detrimental to beneficial uses.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	The Vernalis flow objectives should include a runoff percentage flow rate. The runoff percentage flow rate should either be directly included in the narrative objective along with biological criteria, or separately expressed as a numeric objective in the Plan.	Chapter 3, Alternatives Description
23-May-11	The objective to maintain a viable native population should be made more specific and include biological criteria for other salmonid and other species.	Chapter 3, Alternatives Description
23-May-11	The objective to maintain flows together with "other reasonably controllable measures" is too vague and should be revised to reduce or eliminate the effects of stressors (e.g., DO, contaminates, run-off).	Chapter 3, Alternatives Description
23-May-11	The best scientific information should be used to evaluate the relative effect of implementing flow rates against the effect of other reasonably controllable measures.	Chapter 5, Surface Hydrology, and Water Quality; Chapter 7, Aquatic Biological Resources;
23-May-11	The program of implementation should 1) describe the process by which the SWRCB will collect and evaluate data and 2) discuss how the flow rate will be adaptively changed.	Chapter 3, Alternatives Description
23-May-11	It is critical the implementation program develop clear linkages between the measures, the stressors they are designed to alleviate, and the projected outcomes of the measure.	-
23-May-11	Institute suggests using a logic chain framework to develop the implementation program.	-
23-May-11	Full compliance with the salmon doubling criteria should be achieved by the completion of the FERC proceedings on the Merced and Tuolumne Rivers, or no later than 2020 (same as flow objective).	-
23-May-11	In addition to the salmon doubling, maintenance of the spatial diversity of fall run Chinook salmon in the Central Valley should be considered as biological criteria.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Restoration and maintenance of Chinook salmon spawning, rearing, and migration conditions in the San Joaquin will contribute to maintenance of the spatial extent characteristic of viable populations.	-
23-May-11	Identify actions that will support or improve natural patterns of life history diversity among salmon and critical thresholds of population productivity.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	The narrative objective should identify biological criteria for steelhead, Sacramento splittail, and both green and white sturgeon.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources
23-May-11	The narrative objective should identify biological criteria for the maintenance of the lower San Joaquin River as a spawning ground, rearing habitat, and/or migration corridor.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	Flow conditions for Steelhead should 1) maintain 10,000 steelhead in the San Joaquin Basin; 2) maintain a minimum of 2,500 adults/year in the tributaries; and 3) ensure steelhead adults and juveniles are able to migrate to/from spawning and rearing habitats through the lower San Joaquin River.	Chapter 3, Alternatives Description
23-May-11	The Vernalis objectives should include flows to support Splittail spawning, rearing, and migration to/from spawning habitats in the lower San Joaquin River.	Chapter 3, Alternatives Description
23-May-11	The flows to support splittail should 1) inundate critical spawning and rearing habitats for a minimum of 30–45 days during the spawning period; 2) maintain a migration corridor in the lower San Joaquin River for juvenile and adult splittail; 3) occur once every Sacramento splittail generation; 4) produce inundations that would last at least 30–45 days of functional floodplain habitat; 5) maintain desired flow conditions within the area of inundated floodplain for 1–3 months.	Chapter 3, Alternatives Description
23-May-11	The fish and wildlife trustee agencies (CDFG and USFWS) should define a performance metric that can discriminate between a successful and a limited spawning event for splittail.	-
23-May-11	Flow conditions for Green and white sturgeon should promote spawning in the San Joaquin basin at least three times within the each 20-year period.	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The flows to support Sturgeon should 1) be in excess of 6400 cfs November –May for at least one month; 2) be > 20,000 cfs for at least one month between April and June during years where these sturgeon attraction flows occur; 3) occur once every 7 years	Chapter 3, Alternatives Description
23-May-11	Spawning success of sturgeon should be determined by presence of YOY sturgeon in traditional fish sampling programs or through analysis of bone microchemistry/isotopes.	Chapter 3, Alternatives Description
23-May-11	The February—June narrative objective must include the following biological thresholds: Achieve Chinook Productivity: Flows (≥ 5000 cfs) to support an average daily water temperatures of 65°F (18.3°C) or lower on all days April 1–May 31 in the lower San Joaquin River in all years (see Table 2); Achieve Chinook Spatial Extent: Flows (≥ 2,000 cfs) to limit or eliminate migration impairment for migratory fish species. (See Table 2).	Chapter 3, Alternatives Description
23-May-11	The July–January narrative objective must include the following biological thresholds: Achieve Chinook/sturgeon Spatial Extent: Average weekly flows in excess of 2,000 cfs in all weeks of all years during the San Joaquin River fall run Chinook salmon upstream migration period (see Table 2); Achieve Chinook/sturgeon Spatial Extent: Inflows in excess of 2,000 cfs August–March in the two years following spawning migrations when juvenile emigration from the San Joaquin would occur (see Table 2); Achieve steelhead Productivity: Attraction pulse flows at Vernalis for steelhead that occur for several weeks between late August and early November (see Table 2).	Chapter 3, Alternatives Description
23-May-11	The following language is proposed for the July–January Vernalis flow objective: "Minimum average flow rate of 2,000 cfs in all years."	Chapter 3, Alternatives Description
California Department of Fish and Game		
Commenter: Carl Wilcox, Chief, Water Branch		
19-Mar-09	In developing specific flow recommendations, the State Water Board should consider splitting the flow water quality objectives issue into several sub-issues illustrative of the factors that influence the complex relationship between river flow and migration, spawning, and other fish and wildlife beneficial uses.	Chapter 3, Alternatives Description
19-Mar-09	When considering the baseline or alternatives analysis, the State Water Board should use specific definable and measurable metrics to evaluate impact potential (such as fall-run Chinook salmon smolt survival rate or juvenile fall-run Chinook salmon production abundance etc.). Based on the assessment of each of these factors, the State Water Board staff should be able to develop scientifically defensible flow recommendations for the San Joaquin River. The Department will be providing data and information in the coming weeks to support the State Water Board's assessment of SJR flow water quality objectives.	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
19-Mar-09	The State Water Board should consider a range of feasible alternatives for implementing flow-related water quality objectives for the San Joaquin River. These alternatives should consider at least: Implementation of objectives by water right holders; implementation of objectives using existing study based design (i.e., the existing Vernalis Adaptive Management Program [VAMP]); use of another approach for implementing flow objectives that builds on the successes of VAMP (such as managing flow in the SJR basin to hit flow targets at Vernalis) and avoids VAMP's limitations (e.g., so far the VAMP has not produced its intended study results).	Chapter 3, Alternatives Description
19-Mar-09	Any study based design should be flexible enough to seek and incorporate a change in flows and/or study design (i.e., allow for adaptive management) as necessary to apply emerging information.	Chapter 3, Alternatives Description
19-Mar-09	The State Water Board should explicitly evaluate the environmental effects of any new flow water quality objectives on riparian habitat and floodplain habitat.	Chapter 6, Flooding, Sediment, and Erosion; Chapter 7, Aquatic Biological Resources, and Chapter 8, Terrestrial Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
19-Mar-09	This evaluation of potential environmental effects should include an assessment of longer term climate change impacts on the hydrology of the system, to the riparian corridor, and on the ecological services provided by the SJR.	Chapter 14, Energy and Greenhouse Gases
Commenter: Scott Cantrell, Water Branch Acting Chief		
23-May-11	DFG agrees with the direction of the revised NOP and supports increased water flows and more natural pattern in the San Joaquin watershed.	-
23-May-11	DFG supports the use of a narrative value for the San Joaquin River fish and wildlife flow objective.	-
23-May-11	DFG agrees the fish and wildlife objective should be based on maintaining flow conditions in the River sufficient to support natural production of viable fish populations.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	DFG recommends the fish and wildlife criteria be focused on juvenile salmon production, and then secondarily on adult salmon.	Chapter 3, Alternatives Description and Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	The base flows must provide adequate adult spawning and juvenile rearing habitat, as well as unimpeded fish passage from the tributaries to the Delta.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	The Coordinated Operations Group and adaptive management strategy should focus on providing flows to protect all fish life stages	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	DFG supports Vernalis compliance locations and the additional geographic scope of the NOP. Compliance point(s) should ensure flow benefits to fish are provided through the tributaries and downstream to Vernalis.	-
23-May-11	The lower rim dams/reservoirs reduce water flows and elevate water temperatures in the lower San Joaquin River; these affects prevent sufficient production of juvenile salmon. The SED will need to demonstrate how flows will be maintained in the San Joaquin River and tributaries (so as to support sufficient production of juvenile salmon).	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	Narrative language that limits diversions of more flow than is necessary for a covered benefit use should be included in the SED.	Chapter 3, Alternatives Description
23-May-11	The NOP does not indicate the percent of unimpaired flows (UIF) to be evaluated. DFG recommends current conditions be the baseline and two alternative flow rates be considered: 40% UIF and 60% UIF[1].	Chapter 3, Alternatives Description

[1] Any reference in this appendix to 20% Unimpaired, 40% Unimpaired, and 60% Unimpaired is the same as LSJR Alternative 2, LSJR Alternative 3, and LSJR Alternative 4, respectively. Any reference to 1.0 EC Objective and 1.4 EC Objective is the same as SDWQ Alternative 2 and SDWQ Alternative 3, respectively.

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	It is not clear how the percent UIF will be calculated. DFG recommends using the example provided in the Feb 7, 2011 comment letter, which uses a 3-day averaging period with a 3-day lag.	Chapter 3, Alternatives Description
23-May-11	Additional discussion on how key issues related to the determination of percent UIF for the project alternatives and adaptive management program should be provided. Specifically 1) range of variables 2) use of a percent UIF that may not be measureable and 3) affect to inflow to export (I/E) ratios.	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix K
23-May-11	DFG supports the formation of a coordinated operations group (COG) and San Joaquin River Monitoring and Evaluation Program (SJRMEP), but will need additional funding to participate.	Chapter 3, Alternatives Description
23-May-11	DFG recommends the following be clarified/provided regarding the COG and SJRMEDP: 1) how the groups will be supported (including an evaluation of alternatives); 2) definition of agency roles; 3) information on the process used for decision making; 4) information on the development of definable and measurable goals; and 5) information on safeguards to assure strong scientific standards.	Chapter 3, Alternatives Description
23-May-11	A clear and concise definition of adaptive management should be developed.	Chapter 3, Alternatives Description; Appendix K
23-May-11	Describe how the amendment process will be coordinated/integrated with the Federal Energy Regulatory Commission (FERC).	Chapter 1, Introduction; Chapter 3, Alternatives Description; Chapter 23, Antidegradation Analysis
23-May-11	Urgent action to address vulnerable populations of fall-run Chinook in the San Joaquin River tributaries is needed. Consider increasing instream flows in the Merced and Tuolumne River prior to issuance of the FERC licenses.	-
23-May-11	Explain how the SWRCB will use its Public Trust and Clean Water Act authority to ensure future FERC license instream flow terms are in agreement Bay-Delta Plan standards.	Chapter 1, Introduction; Chapter 3, Alternatives Description
23-May-11	Describe how coordination/integration with other state and federal programs (e.g., San Joaquin River Restoration Program, Central Valley Project Improvement Act) will be managed.	Chapter 1, Introduction; Chapter 3, Alternatives Description; Chapter 23, Antidegradation Analysis
23-May-11	Provide a more robust description of how SWRCB will phase the implementation of the flow objectives and the projected timeline.	Chapter 3, Alternatives Description; Appendix K
23-May-11	DWR recommends the project timeline be front loaded with action to quickly stabilize the anadromous fish population.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	DWR supports changes to the southern Delta agricultural water quality objectives but recommends all actions that result in an increase in flows do not also increase the salt loading downstream.	Chapter 5, Surface Hydrology and Water Quality
California Department of Transportation		
Commenter: Gary Arnold, Statewide Local Development-Intergovernmental Review Coordinator		
19-Mar-09	CalTrans would like to establish ongoing consultation and collaboration with the State Water Board to ensure existing Best Management Practices related to water quality and runoff in the relevant area are coordinated with the State Water Board's updates where applicable.	-
California Department of Water Resources		
Commenter: Erick Soderlund, Staff Counsel		
19-Mar-09	It is an appropriate time to review and potentially modify South Delta salinity objectives.	-
19-Mar-09	DWR supports a staged approach.	-
19-Mar-09	Recommends that SWB narrow its scope of review to focus on South Delta salinity and prepare an EIR for the single purpose of proceeding with review and potential modifications to the South Delta salinity objectives and WR implementing those objectives.	-
19-Mar-09	Baseline must take into account existing conditions and problems associated with diverting water from Bay-Delta.	Chapter 2, Water Resources; Chapter 3, Alternatives Description; All
19-Mar-09	No project alternative should address existing conditions as well as future consequences of current objectives, which requires the SWB to study future consequences of implementation of the current South Delta salinity objectives and program of implementation, such as effects on supply and fish.	Chapter 3, Alternatives Description; Chapter 15, No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1); Appendix D
19-Mar-09	DWR recommends the SWB consider the following: variations in precipitation and hydrology each year; WQ on SJR upstream of the South Delta.	Chapter 5, Surface Hydrology and Water Quality; Appendix F.1
19-Mar-09	DWR recommends the SWB consider the following: influence and characterization of dischargers into the SJR; effects of local dischargers into South Delta channels; and illegal water diversion affecting the South Delta salinity and flows; illegal diversions affecting the South Delta salinity and flows.	Chapter 5, Surface Hydrology and Water Quality

Table A-1. Continued

Date	Comment Summary	SED Chapter
19-Mar-09	DWR recommends the SWB consider the following: variation in WQ needs of crops during different growth stages; relationship between leaching, rainfall, applied WQ, and crop production in South Delta.	Chapter 11, Agricultural Resources
19-Mar-09	DWR believes that SWB should review these objectives following other actions (ESA consultation with NMFS) that may affect this review.	-
19-Mar-09	DWR believes more time is needed to determine the best course of action for establishing SJRF objectives that protect all relevant beneficial uses, such as the BO to protect several salmonid species and green sturgeon, expected in June 2009.	-
19-Mar-09	Need for SJRF entering Delta may change depending on outcomes of BDCP.	Chapter 5, Surface Hydrology and Water Quality
19-Mar-09	DWR recommends that the SWB postpone beginning any EIR of the SJRF objectives until NMFS is issued this summer, and a draft BDCP is scheduled to be available for public review this summer.	-
Commenter: Erick Soderlund, Staff Counsel		
23-May-11	DWR questions whether: 1) "flow-only" objectives are appropriate in a water quality control plan, and 2) if considered appropriate, are "flow-only" objectives the best approach to efficiently manage the system to protect those beneficial uses.	-
23-May-11	Conflict between the basic purposes of the Porter-Cologne Water Quality Control Act (Water Code § 13000 et seq.) (Porter-Cologne Act) and proposed the project. Essentially, by making flow itself a water quality objective, the State Water Board has expanded the scope of the Porter-Cologne Act beyond that which it was intended to control.	Chapter 1, Introduction; Chapter 3, Alternatives Description; Chapter 23, Antidegradation Analysis
23-May-11	It is imperative that the State Water Board distinguish those problems and/or solutions which have flow patterns or diversions at their root from those which are inherently connected with flow itself.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality
23-May-11	DWR recommends that the State Water Board adapt its current approach to allow for the development of objectives that are based on causal mechanisms, such as habitat, predation and diversion avoidance, etc., where flow may be used to achieve an objective but is not necessarily the objective itself.	Chapter 3, Alternatives Description; Chapter 1, Introduction; Chapter 16, Evaluation of Other Indirect and Additional Actions
23-May-11	It is DWR's understanding that an appropriate life-cycle model has not yet been developed for salmonids. Nonetheless the lack of such a model should not prevent the State Water Board from recognizing its necessity in this process and even encouraging the fishery agencies to develop an appropriate model.	Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Throughout the process to review and potentially modify the San Joaquin River flow objectives, the State Water Board has stated that a comprehensive discussion or analysis of such issues as the flow split at the Head of Older River (HOR) and the effects of diversion by DWR and the U.S. Bureau of Reclamation (USBR) on flows through Old and Middle Rivers (OMR) is not necessary because these issues are not the subject of the State Water Board's current review. DWR has agreed with the Board that these issues are outside the scope of the current review but they continue to be discussed as possible issues for future proceedings.	-
23-May-11	DWR provides information in these comments to help inform the Board of the current studies regarding SWP and CVP operations and impacts on salmonid survival in the Delta.	Chapter 7, Aquatic Biological Resources
23-May-11	The conclusions in the Draft Technical Report on OMR are not supported by the best available science and the Draft Report should be revised.	Appendix C
23-May-11	Kimmerer and Nobriga 2008 article and other PTM studies analyzing salmon smolts in the Delta do not support the concept that the export facilities create a "zone of influence" effecting salmonid smelt behavior. In addition, nowhere do the authors state or make any assertion that supports the statement contained in the Draft Technical Report that "any fish that enters the central or southern Delta has a high probability of being entrained and lost at the pumps. DWR respectfully requests that this statement be removed from the report, since it is not an accurate statement as to the conclusion of the report, and scientific studies do not support it.	Chapter 7, Aquatic Biological Resources; Appendix C
23-May-11	Researchers have analyzed the relationship between project exports and salmonid survival. The studies conducted during that time have either failed to establish any significant statistical relationship between exports and survival, or, more surprisingly, have shown a positive relationship between exports and survival. While studies fail to show a statistically significant relationship between exports and salmonid survival, studies have shown a positive relationship between San Joaquin River flows and survival.	Chapter 7, Aquatic Biological Resources

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	DWR believes there are several hurdles that must be overcome before water project operators can use computed unimpaired flow for real time operations. DWR offers the following recommendations: A. The methods developed to date for computing unimpaired flows will require revisiting to overcome deficiencies in the current assumptions and to standardize and streamline the different data sources. B. The uncertainty inherent in measuring the observed data (e.g., streamflows, precipitation) and computed parameters (e.g., evapotranspiration, depletions, stream-aquifer interaction) needs to be considered. Also, the quicker a computed value for unimpaired flow is required, the greater the number of assumptions needed to determine the value. Therefore, establishing the standards so that the errors made in the forecast mode can be rectified in hindsight should be considered. C. Remote sensing and telemetered data have a great potential to be part of the process; however, the maturity of the technology for real-time operations will need to be assessed. D. Buy-in from stakeholders on an agreed upon approach is essential for successful implementation.	Chapter 3, Alternatives Description; Appendix C
23-May-11	There is a serious question whether water levels and, to a lesser extent, water circulation are proper subjects of water quality objectives.	Chapter 1, Introduction; Chapter 3, Alternatives Description; Appendix C
23-May-11	It is unclear whether water circulation is appropriately addressed in the water quality context. More importantly, however, is that the current proposal makes no effort to quantify the impacts of the SWP and the CVP on water circulation in the southern Delta and, instead, assumes it is sufficient for them to be fully responsible for implementing this new objective.	Chapter 1, Introduction; Chapter 3, Alternatives Description; Appendix C
23-May-11	The potential draft modifications to the numerical salinity objectives accurately reflect the current state of knowledge, are reasonably protective of agricultural beneficial uses, and DWR supports their implementation.	-
23-May-11	While the Board no doubt has the authority to take action necessary to protect the consumptive uses in the southern Delta, the approach to make water levels a water quality objective is flawed by equating its water quality planning function with the protection of water rights.	Chapter 1, Introduction; Chapter 3, Alternatives Description; Appendix C
23-May-11	DWR is conducting and will provide to the Board a computer modeling analysis that will illustrate the effects SWP and CVP pumping has on circulation, in general, and on the creation or movement of null zones.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Responsibility for achieving the objectives should be assigned among several entities shown to affect southern Delta salinity, and not just the projects. DWR finds it unreasonable that the State Water Board would even entertain assigning responsibility to DWR and the USBR to develop and implement an operations plan that will "avoid localized concentration of salts associated with agricultural water use and municipal discharges."	Chapter 3, Alternatives Description
23-May-11	The Board should develop a comprehensive program to implement such an objective "which will include the projects and other users along the watercourse."	Chapter 3, Alternatives Description
23-May-11	Any additional reporting and studying requirements be evaluated in conjunction with the many reports, monitoring and coordination DWR currently conducts in response to State Water Board requirements.	-
California Water Impact Network/California Sportfishing Protection Alliance/AquAlliance		
Commenter: Carolee Krieger, President, California Water Impact Network; Bill Jennings, Chairman, California Sportfishing Protection Alliance;		
8-July-08	Questions related to the strategic workplan published by the State Water Board including but not limited to: how much water does the Delta need; how will a comprehensive Delta monitoring plan be created; when will fish screens be installed on Delta export pumps; when will new conditions on export pumping be implemented; how will salt loading in the San Joaquin River and Delta be addressed; when will water storage levels be increased to protect river flows in dry years.	-
8-July-08	Provided specific comments on Draft Strategic Workplan, including but not limited to: water quality and contaminant control; once through cooling; sediment objectives; invasive species management; blue green algae; ambient ammonia concentrations; selenium; comprehensive monitoring program; san Joaquin river flows and southern delta salinity; and comprehensive review of Bay Delta Plan, water rights, and requirements to protect fish and the public trust.	-
8-July-08	Draft Strategic workplan fails to use its legal authority to protect California's environment and economy.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
Commenter: Carolee Krieger, President, California Water Impact Network; Bill Jennings, Chairman, California Sportfishing Protection Alliance;		
10-June-09	Includes detailed comments regarding the State Water Board's draft staff report for the Periodic Review of the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary.	-
10-June-09	Comments recommend a complete revision of the Water Quality Control Plan, including but not limited to: minimum incorporated reasonable and prudent measures contained in the Salmon and Delta Smelt biological opinions; eliminate the Vernalis Adaptive Management and return to D-1641 pulse flows; evaluate how much water is necessary for Bay-Delta ecosystem health; develop and implement fish screen criteria; develop and implement plan for fish doubling narrative; rescind the waiver of the agricultural water quality standards; consider adoption of land retirement program; conduct water right investigation; provide dedicated cold water storage; investigate salt loading; prevent redirected impacts to Trinity River and other tributaries; develop selenium standards; develop focus on water use efficiency; create comprehensive monitoring program.	-
Commenter: Carolee Krieger, President, California Water Impact Network; Bill Jennings, Chairman, California Sportfishing Protection Alliance;		
6-Dec-10	Includes detailed comments on the SJR Technical Report and attachments related to the detailed comments from others regarding the SJR Technical Report.	Appendix C
6-Dec-10	Temperature needs to be addressed by river reach and identify the spatial and temporal extent of temperature.	Appendix C
6-Dec-10	Omission of upstream flow contributions from the Upper San Joaquin River is unexplained and unjustified.	Appendix C
6-Dec-10	The range of alternatives examined is inadequate and the technical report should address the discrepancy between it and the Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem and include and analyze a 75% unimpaired flow.	Appendix C
6-Dec-10	Build on the Central Valley Water Quality Control Board evaluation of salinity published in 2006.	Appendix C
6-Dec-10	The technical report should explicitly identify the additional need for modeling and studies that will be required before the Hoffman report conclusions can be used.	Appendix C
6-Dec-10	The technical report ignores other chemical constituents and should include information necessary to support an antidegradation analysis for proposed alternative that would increase concentration or residence time and lower water quality.	Appendix C
6-Dec-10	The technical report and SED need to address the consequences of altered flow regimes on constituents found in the San Joaquin River and the Delta.	Appendix C; Chapter 7, Aquatic Biological Resources

Table A-1. Continued

Date	Comment Summary	SED Chapter
6-Dec-10	Technical report needs to identify the requirements necessary to protect fish in each tributary and impacts to specific water users in specific tributaries from implementation of whatever flow regime is identified to be sufficiently protective.	Appendix C; Chapter 3, Alternatives Description; Chapter 13, Service Providers
6-Dec-10	If results from CalSim II modeling are relied upon in the technical report, the assumptions behind the model runs and limitations of the model output must be made explicitly clear.	Appendix C; Appendix F.1.
Commenter: Carolee Krieger, President, California Water Impact Network; Bill Jennings, Chairman, California Sportfishing Protection Alliance; Barbara Vlamis, Executive Director, AquAlliance		
8-Feb-11	To recover fish abundances, it will be essential for the Board to restrict Delta export pumping, increase tributary and mainstem flows of Central Valley rivers, establish sustainable controls on salinity and contaminant sources upstream in the San Joaquin River basin, and invest in restoring critical floodplain and streambank habitat along the mainstem and the tributaries that fish can use to rear and grow and survive migration through the Delta to the Pacific Ocean.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
8-Feb-11	Each proposed flow regime for Vernalis should be analyzed under the following CEQA alternatives: 1) A determined large percent of Vernalis flows is met from New Melones, 2) Responsibility for Vernalis flows is divided among the main tributaries proportional to unimpaired flows from each tributary, and 3) Responsibility for Vernalis flows is divided among the main tributaries and the upper San Joaquin proportional to unimpaired flows.	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
8-Feb-11	The central decision the Board will need to make involves the question of balancing protection of the public trust with other Beneficial Uses of water reliant on the Delta.	-
8-Feb-11	The SED must evaluate a range of alternatives, including a no export and reduced export alternative, and take into account (CWC 85021) reducing reliance on the Delta.	Chapter 3, Alternatives Description
8-Feb-11	The SED must address the over appropriation of water in the Central Valley.	-
Commenter: Carolee Krieger, CWIN President; Bill Jennings, CSPA Chairman; and Barbara Valmis, AA Executive Director		
23-May-11	The Board should incorporate into preparation of the SED its full informational and video record from the Delta Flow Criteria proceeding from January–April 2010. The Board's Delta Flow Criteria Report (August 2010) can and should be used in preparation of the SED.	-
23-May-11	It is the beneficial uses which must receive Board attention in the process of public trust balancing and analysis. The Board's duty now is to credibly balance all of the beneficial uses of water in the estuary so that public trust resources are protected, and so that reasonable uses and methods of diversion of water are employed by all water users.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The exclusion of the upper San Joaquin River basin above the river's confluence with the Merced River is not adequately explained.	Chapter 1, Introduction; Chapter 3, Alternatives Description
23-May-11	The Board fails to specify a proposed project for its SJR flow criteria. It does not specify a proposed flow standard as a percent of unimpaired flow in the river basin at Vernalis and does not explicitly discuss compliance points on tributaries.	Chapter 3, Alternatives Description
23-May-11	The Board does not include an alternative that would require the bypass of 75% of unimpaired flow on the SJR (even though this was considered on the Sacramento River in the Delta Flow Criteria Report). The SWRCB should explain a 75% criterion in the SED or justify why it is unreasonable.	Chapter 3, Alternatives Description
23-May-11	The proposed San Joaquin River flow language in NOP Attachment 2 does not consider that San Joaquin River exports from Friant Dam to Kern County are an important cause of flow deficiencies to the Delta and of South Delta salinity problems.	Chapter 3, Alternatives Description
23-May-11	The Board offers new salinity criteria for interior South Delta locations that would increase allowable salinity (as measured by Electrical Conductivity) by 40–43%, in order to reduce potential violations of salinity objectives by the California Department of Water Resources and the US Bureau of Reclamation. This does not solve salinity problems in the Delta; instead, it defines them away. The Board provides no salinity source control program for agricultural drainage discharged from the western San Joaquin Valley.	Chapter 3, Alternatives Description; Appendix C
23-May-11	The Board has not provided adequate rationale to justify excluding the San Joaquin River above its confluence with the Merced River (the "upper San Joaquin River") from the "project area" for purposes of environmental evaluation of proposed San Joaquin River flow criteria.	Chapter 3, Alternatives Description
23-May-11	In its Water Rights Orders 2010-0029 and 2009-0058-DWR, the Board authorized interim schedules for "experimental flows" sought by the parties to the San Joaquin River Restoration Program and settlement agreement. At minimum, these interim flows should be incorporated into the project description, so that it is clear that upper San Joaquin River flows will contribute to solving flow and water quality problems in the Delta.	Chapter 3, Alternatives Description; Chapter 15, No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1)
23-May-11	There needs to be a basic description in the SED of how future contributions from the upper San Joaquin River will contribute to improving the health of the Bay-Delta estuary (in the form of project alternatives).	All and Chapter 15, No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1)
23-May-11	The NOP's project description of "X percent of unimpaired flow" is not a legally adequate project description for the February through June time period. The State Water Resources Control Board should commit to specified flow criteria for the project description and use the SED's required Alternatives analysis to evaluate the efficacy of alternative percentages of unimpaired flow criteria against the project description.	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Each alternative should include the upper San Joaquin River basin as part of the project area for the San Joaquin River flow and the South Delta salinity objectives revision.	Chapter 3, Alternatives Description
23-May-11	Each alternative should be studied at the same level of detail as that required for the project description.	All
23-May-11	The document should identify an environmentally superior alternative, as required by the California Environmental Quality Act, and specify criteria applied by the Board in the SED.	Chapter 18, Summary of Impacts
23-May-11	The Board should address terrestrial habitat components that address ecological function in addition to flow and salinity parameters, such as floodplain inundation, etc.	Chapter 7, Aquatic Biological Resources; Chapter 8, Terrestrial Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	The Board should include a 75% of unimpaired flow at Vernalis flow alternative.	Chapter 3, Alternatives Description
23-May-11	The Board should also analyze 20, 40, and 60% of unimpaired flow at Vernalis flow alternatives.	Chapter 3, Alternatives Description
23-May-11	The Board should evaluate the feasibility and impacts of ending exports from Friant Dam through the Friant-Kern Canal out of the San Joaquin River basin to Tulare, Kings, and Kern counties, to see what potential beneficial impacts this would have on the Bay-Delta estuary, San Joaquin River flows, and Bureau of Reclamation compliance with existing and proposed south Delta salinity standards.	Chapter 3, Alternatives Description
23-May-11	The Board should evaluate the feasibility and impacts of reducing or ending diversions on the Tuolumne River by the City and County of San Francisco, replacing all or part of San Francisco's supplies with water diverted through the Contra Costa Canal for storage at Los Vaqueros, or through new facilities to a new alternative west-of-Delta storage reservoir. In either case, conveyance from west-of-Delta storage would be made through interties to the South Bay Aqueduct and/or San Francisco's existing water delivery system.	Chapter 13, Service Providers; Chapter 16, Evaluation of Other Indirect and Additional Actions
23-May-11	A "Zero Friant Exports" alternative should be analyzed in a second alternative in combination with the San Francisco west-of-Delta storage alternative.	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Each flow alternative should be analyzed with two salinity scenarios: existing south Delta salinity objectives and proposed objectives.	Chapter 5, Surface Hydrology, and Water Quality; Chapter 15, No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1); Appendix D; Appendix F.1.
23-May-11	Each alternative should be analyzed with the assumption that there would be no water transfers forthcoming from the Sacramento Valley under either a drought water bank framework or a long-term water transfer program framework. Similarly, no new diversions from the Sacramento River or new storage in the Sacramento Valley should be included either.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality
23-May-11	Each alternative should be analyzed with the inclusion of a complete shutdown or very low volume of export pumps at both the Banks and Jones pumping plants during periods when anadromous fish and other listed species are present, in place of the installation of temporary barriers in South Delta channels.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality
23-May-11	Each alternative should be analyzed with an Irrigated Lands Program scenario that assumes full compliance by agricultural drainage dischargers throughout the San Joaquin Valley.	Chapter 11, Agricultural Resources; Chapter 17, Cumulative Impacts, Growth-Inducing Effects, and Irreversible Commitment of Resources
23-May-11	The SED should describe life histories of all listed species as fully as possible.	Chapter 7, Aquatic Biological Resources; Chapter 8, Terrestrial Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	The SED should summarize all existing local fishery restoration efforts on major tributary streams, including the salmon restoration flows and stocking of the upper San Joaquin River under auspices of the San Joaquin River Restoration Program.	Chapter 7, Aquatic Biological Resources; Chapter 16, Evaluation of Other Indirect and Additional Actions
23-May-11	The SED should describe the impacts to anadromous and other aquatic fish species of the proposed revisions to the Bay-Delta Water Quality Control Plan of changes in water quality resulting from its implementation, including in particular the effects on aquatic biota of changes in South Delta salinity standards.	Chapter 7, Aquatic Biological Resources

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The SED must include a listing of the major water rights holders and state and federal project water contractors in the San Joaquin River basin, together with their permitted or licensed diversion rates and contributions to storage, and a description of how they receive their supplies.	Chapter 2, Water Resources
23-May-11	In the Setting, the SED should address the historical/unimpaired flow (near-natural) hydrograph with alterations to the hydrograph resulting from all component streams of the San Joaquin River and Delta by rim reservoir and Delta pumping operations.	Chapter 2, Water Resources; Chapter 5, Surface Hydrology and Water Quality
23-May-11	If CalSim II and/or III are to be used to estimate water supply impacts from changes in reservoir and Delta pumping operations, the SED should fully disclose methodological and data limitations of the modeling effort, and should use sensitivity analysis to show the relative volatility of water supply impacts that results from changes in key assumptions. The Board should build into the SED's time schedule the peer review of all CalSim II and III modeling results, in order to increase the public's confidence in how best to interpret the water supply impact results.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Appendix F.1
23-May-11	The analysis in the SED should quantify the degree to which each water right holder is deprived of water supply under each alternative (discuss how reliable are historic and anticipated deliveries, and the face value of water rights, given a range of flows contemplated by the State Water Board in its project description and alternatives).	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality
23-May-11	The SED should include and evaluate reasonable climate change scenarios for the San Joaquin River basin flows.	Chapter 14. Energy and Greenhouse Gases
23-May-11	The Setting section of the SED should describe the magnitude and general locations of groundwater overdraft prevalent in the San Joaquin Valley and San Joaquin River basin.	Chapter 9, Groundwater Resources
23-May-11	The Setting should characterize which streams reaches are gaining flows from groundwater and which are losing flows to groundwater.	Chapter 9, Groundwater Resources
23-May-11	The SED should describe expected effects on groundwater levels in geographically differentiated locations.	Chapter 9, Groundwater Resources
23-May-11	The SED should include and evaluate reasonable climate change scenarios for the groundwater resources of the San Joaquin River basin.	Chapter 9, Groundwater Resources; Chapter 14, Energy and Greenhouse Gases
23-May-11	The SED should provide in its Setting section adequate descriptions of the State Water Resources Control Board's antidegradation policies, total mean daily load requirements, areas where agricultural waivers of discharge requirements are in place, and other regulatory programs that indicate the full range of the State Board's regulatory authority and capacity in the San Joaquin River Basin.	Chapter 23, Antidegradation Analysis
23-May-11	Mitigation measures should identify programmatic objectives for the State Water Resources Control Board that will avoid or reduce impacts to less than significant levels.	All

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The Board's SED must address the impacts to South Delta agricultural diverters and irrigators of relaxing the Board's salinity objective, and accordingly justify this proposed relaxation in light of the Board's stated antidegradation policy.	Chapter 11, Agricultural Resources
23-May-11	Rather than proposing a revision in the salinity standards at this time, the Board should be arranging for peer review of the report and its underlying models, and funding the necessary comprehensive studies to eliminate the significant data gaps acknowledged by Dr. Hoffman.	Appendix C
23-May-11	As a matter of statewide water policy, cost-effectiveness, and the public trust resource protection of the San Joaquin River and the agricultural beneficial uses of the South Delta, it is essential to focus source control efforts on agricultural drainage dischargers located in the western San Joaquin Valley.	Chapter 3, Alternatives Description; Chapter 11, Agricultural Resources
23-May-11	Our organizations note that the Bureau's estimate of flow volumes needed to meet the more stringent irrigation season salinity standard brackets the amount of water involved in our combined "Zero Friant" and rerouted San Francisco flow volumes, 1.3 million acre-feet. This further suggests that our proposed combined alternative merits study in the SED.	Chapter 3, Alternatives Description
23-May-11	The Land Use Setting section should identify floodplains along all the major tributaries and upper San Joaquin River that would be inundated, and the anticipated frequency with which they would be inundated for purposes of slowing and dispersing flood flows and providing floodplain habitat for juvenile salmon preparing to migrate out of the San Joaquin River basin with spring flows.	Chapter 6, Flooding, Sediment, and Erosion; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The State Water Resources Control Board should include the following in its analysis of cumulative impacts: • Federal Energy Regulatory Commission potential instream flows and other related water quality studies that have been or will be conducted in relation to relicensing processes under way for the Oroville Facilities the Merced River Project, and the Don Pedro Project. • U.S. Bureau of Reclamation and California Department of Water Resources compliance with the modified Cease and Desist Order in the Board's Water Rights Order 2010-0002. • U.S. Fish and Wildlife Service review of the federal Endangered Species Act status of the Sacramento splittail. • U.S. National Marine Fisheries Service's Biological Opinions for operation of the Trinity River Division (both 2000 opinion and their upcoming opinion, provided it is timely for SED preparation). • U.S. Bureau of Reclamation and San Luis-Delta Mendota Water Authority discharges of salt, selenium, and boron from the Grasslands Bypass Project, and their cumulative impact on Delta salinity objectives, as well as impacts on efforts to restore Chinook salmon to the San Joaquin River upstream of the Merced River.	Chapter 17, Cumulative Impacts, Growth-Inducting Effects, and Irreversible Commitment of Resources
Central Delta Water Agency		
Commenter: Dante John Nomellini, Jr., Attorney for the CDWA		
1-Oct-08	The implementation plan for the southern Delta salinity and San Joaquin River flow objectives needs to be modified to address Term 91.	Chapter 3, Alternatives Description, Appendix K
1-Oct-08	The implementation plan needs to consider and define the project's legal responsibilities with regard to providing salinity control for the southern Delta and San Joaquin River flows before any consideration is given to imposing salinity control or flow burdens on any other water right holder.	Chapter 3, Alternatives Description, Appendix K
Commenter: Dante John Nomellini, Jr., Attorney for the CDWA		
19-Mar-09	Project too broad—NOP premature. Insufficient information to determine scope and significance of effects of this project. NOP should be set aside until proposed project is developed enough to be described in a future NOP.	Chapter 3, Alternatives Description
19-Mar-09	Farming operations in South Delta act as a salt reservoir and improve Delta water quality. Refer to DWR's July 1956 Report No. 4, which describes causes of salinity degradation and actions that improve salinity conditions and finds that agricultural practices in the Delta lowlands enhance rather than degrade water en route to Tracy Pumping Plant.	Chapter 11, Agricultural Resources

Table A-1. Continued

Date	Comment Summary	SED Chapter
19-Mar-09	Farming operations in South Delta improve Delta water quality. Groundwater underlying farmlands in the southern Delta is very high and wild vegetation consumes more water than farming operations, as recognized in D-990, 1961, pg. 46.	Chapter 11, Agricultural Resources
19-Mar-09	This process must consider applicable laws and policies related to protecting and promoting South Delta farming operations. Environmental documentation should fully acknowledge laws and policies applicable to topics of southern Delta salinity and SJRF objectives and measures to implement those objectives.	Chapter 11, Agricultural Resources
19-Mar-09	Cumulative impacts should be included in NOP's list of potential environmental effects.	Chapter 17, Cumulative Impacts, Growth-Inducting Effects, and Irreversible Commitment of Resources
Commenter: Dante John Nomellini, Jr., Attorney for the CDWA		
6-April-09	Joined in comments submitted by South Delta Water Agency.	Appendix C
6-April-09	Improvement of water quality for all beneficial uses should be the goal and exports of water from the Delta to the west side of the San Joaquin Valley contribute to the degradation of the San Joaquin River and are the source of the problem. The CVP deliveries assisted by the SWP coordinated operations and joint points of diversion are the causes of the salinity problem and should be required to mitigate their impacts to the River before others are required to do so.	-
Commenter: Dante John Nomellini, Jr., Attorney for the CDWA		
22-April-09	The Notice of Preparation pursuant to CEQA for any potential amendments to the southern Delta salinity and San Joaquin River flow objectives was prematurely issued.	-
22-April-09	Farming operations in the southern Delta act as a salt reservoir and improve Delta water quality.	Chapter 11, Agricultural Resources; Appendix C
22-April-09	Farming operations in the southern Delta also improve Delta water quantity.	Chapter 11, Agricultural Resources; Appendix C
22-April-09	This process must discuss and consider all applicable laws and policies related to protecting and promoting southern Delta farming operations.	Chapter 11, Agricultural Resources
22-April-09	The implementation plan for the southern Delta salinity and San Joaquin River flow objectives needs to be modified to forthrightly address Term 91.	
22-April-09	The implementation plan needs to consider and define the project's legal responsibilities with regard to providing salinity control for the southern Delta and San Joaquin River flows before any consideration is given to imposing salinity control or flow burdens on any other water right holder.	Appendix K

Table A-1. Continued

Date	Comment Summary	SED Chapter
6-Dec-10	CVP deliveries assisted by the SWP coordinated operations and joint point of diversions are the cause of the degradation of the San Joaquin River. The CVP/SWP should be required to mitigate their impacts on the San Joaquin River before others are required to modify their actions. Portion of the water exported from the Delta by the projects should be required to restore the San Joaquin River water quality.	Chapter 1, Introduction and Chapter 3, Alternatives Description
23-May-11	Previous comments made during the public staff workshop on April 6, 2009 are hereby incorporated.	-
23-May-11	CDWA also incorporates December 6, 2010 comments titled, "San Joaquin River Technical Report Comments."	-
23-May-11	Commenters are unable to provide "specific detail" due to the paucity of information regarding "water rights and other actions" spoken of in the NOP.	-
23-May-11	What is the "intended purpose" of the San Joaquin River flows once they pass Vernalis and where is the evidence to support that purpose?	Chapter 3, Alternatives Description, Appendix K
23-May-11	The SWRCB must comply with all applicable laws and priorities associated with imposing flow restrictions or water diversions.	Chapter 3, Alternatives Description, Appendix K
23-May-11	Consider and fully discuss and analyze in the EIR the following (before the SWRCB can lawfully impose responsibility to meet a flow objective on any Delta water user): SWP and CVP must take full responsibility for mitigations including impacts from reverse or reduced flows, drainage into the SJ River from the west side of the SJ Valley, and damage to spawning areas.	Chapter 3, Alternatives Description
23-May-11	Consider and fully discuss and analyze in the EIR the following (before the SWRCB can lawfully impose responsibility to meet a flow objective on any Delta water user): SWP and CVP must provide adequate salinity control.	Chapter 3, Alternatives Description
23-May-11	Consider and fully discuss and analyze in the EIR the following (before the SWRCB can lawfully impose responsibility to meet a flow objective on any Delta water user): The CVPIA burdens are those of CVP.	-
23-May-11	Consider and fully discuss and analyze in the EIR the following (before the SWRCB can lawfully impose responsibility to meet a flow objective on any Delta water user): SWP and CVP responsible for fish and wildlife preservation with enhanced costs attributed to the State General Fund.	Chapter 20, Economic Analyses
23-May-11	Consider and fully discuss and analyze in the EIR the following (before the SWRCB can lawfully impose responsibility to meet a flow objective on any Delta water user): SWP and CVP must maintain adequate water supply while controlling for salinity by managing releases of storage into the Delta.	Chapter 3, Alternatives Description
23-May-11	Consider and fully discuss and analyze in the EIR the following (before the SWRCB can lawfully impose responsibility to meet a flow objective on any Delta water user): In allocating the burden within the SWP and CVP, the uses within the Delta and other watersheds of origin must be accorded priority over exports.	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Consider and fully discuss and analyze in the EIR the following (before the SWRCB can lawfully impose responsibility to meet a flow objective on any Delta water user): Tributaries above Delta would hold remaining burden allocable among other water users. Exporters other than SWP and CVP must yield priority to users within the Delta.	Chapter 3, Alternatives Description
23-May-11	Consider and fully discuss and analyze in the EIR the following (before the SWRCB can lawfully impose responsibility to meet a flow objective on any Delta water user): If a user yields water that can be replaced with SWP or CVP water, then they should provide said water so long as it's truly stored water.	Chapter 3, Alternatives Description
23-May-11	SWRCB has been wrongfully imposing responsibility on Term 91 water rights holders and this must stop until the SWRCB addresses the propriety of such an imposition in its water quality control plan and subsequent water rights proceedings. Such imposition (as imposing responsibility on term 91 water rights holders) should also be analyzed in the EIR.	Chapter 3, Alternatives Description
23-May-11	Questions regarding Term 91 Water Rights including: What specific water quality objective is the Term 91 water right holder being held responsible for? Does the Term 91 water right holder's water use actually negatively impact those water quality objectives? Is it legal to impose those responsibilities on a water right holder to meet SWRCB objectives?	-
23-May-11	It is not clear that Term 91 agricultural users impact salinity objectives and may actually be a benefit.	-
23-May-11	Agricultural use in Delta may benefit outflow as the SWRCB recognized in its Decision 990 (page 46).	Chapter 11, Agricultural Resources
23-May-11	Reclamation of Delta waters has reduced plants that consume more water than crops grown on these lands. Therefore, water consumption has likely decreased and more stream flow entering Delta reaches the lower end to repel saline invasion.	Chapter 11, Agricultural Resources
23-May-11	SWRCB has not said who is responsible to meet Bay-Delta water quality plan objectives on Term 91 water right holders in its 1995 or 2006 water quality control plans or subsequent proceedings.	-
23-May-11	The current imposition of responsibility to meet existing water quality objectives on Term 91 water rights holders is contrary to law as is any future imposition of responsibility on holders of southern Delta salinity requirements.	-
Central Valley Clean Water Association		
Commenter: Debbie Webster, Executive Officer		
19-Mar-09	The State Water Board must evaluate the water quality objectives and program of implementation as applicable to municipal wastewater discharges in accordance with Water Code Sections 13000 and 13241. Specifically, the Board must address the changes made to the 2006 Plan that have implications on POTWs.	Chapter 13, Service Providers; Chapter 16, Evaluation of Other Indirect and Additional Actions

Table A-1. Continued

Date	Comment Summary	SED Chapter
19-Mar-09	The State Water Board must consider the environmental effects of the existing, new or revised objectives and implementation program as well as project alternatives with regard to POTWs. For example, if POTWs are required to meet more stringent requirements that require construction of new treatment facilities etc. those impacts must be addressed.	Chapter 13, Service Providers; Chapter 16, Evaluation of Other Indirect and Additional Actions
19-Mar-09	The State Water Board should coordinate with the CV-SALTS and the Drinking Water Policy Development Processes.	Chapter 17, Cumulative Impacts, Growth-Inducting Effects, and Irreversible Commitment of Resources; Chapter23, Antidegradation Analysis
Commenter: Debbie Webster, Executive Officer		
23-May-11	The State Water Board should adopt the southern Delta salinity objectives in a manner consistent with the Writ of Mandate directing it to conduct the required Water Code Section 13241 analysis.	Chapter 13, Service Providers; Chapter 16, Evaluation of Other Indirect and Additional Actions
23-May-11	Because the State Water Board did not conduct the required Water Code analysis when it established the southern Delta salinity objectives, the State Water Board should conduct such an analysis as part of its current review of the 2006 Bay-Delta Plan.	All
23-May-11	The board is required to analyze specific factors when developing water quality objectives pursuant to Water Code Section 13241, and must develop a comprehensive implementation plan under Water Code Section 13242. The factors that the State Water Board must consider when it adopts water quality objectives include: (a) Past, present, and probable future beneficial uses of water. (b) Environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto. (c) Water quality conditions that could reasonably be achieved through the coordinated control of all factors, which affect water quality in the area. (d) Economic considerations. (e) The need for developing housing within the region. (f) The need to develop and use recycled water. (Wat. Code, § 13241.)	All
23-May-11	The board must assess the costs of an adopted or amended objective based on: (1) whether it is being attained; (2) the methods available to achieve compliance if the objective is not being attained; and (3) the costs of those methods.	Chapter 20, Economic Analyses; Chapter 16, Evaluation of Other Indirect and Additional Actions
23-May-11	The State Water Board has an "affirmative duty" to consider any information on compliance costs or other economic impacts provided by the regulated community and other interested parties. If the potential economic impacts are significant, the State Water Board must articulate why the objective is necessary to protect beneficial uses in a reasonable manner despite the adverse consequences. Where an amended objective is at issue, the associated staff report or resolution may address the economic considerations.	Chapter 20, Economic Analyses

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	To comply with Water Code Section 13241, the State Water Board should use modeling tools for the Delta and Delta watershed (e.g., DSM2, WARMF) with some refinements. Specifically, the modeling tools should be used to assess 1) water quality conditions that could reasonably be achieved through the coordinated control of all factors which affect water quality in the southern Delta; 2) the incremental impact that salinity controls on POTWs will have on southern Delta salinity levels as an element of the "coordinated control for all factors;" and, 3) if it is reasonable to require costly POTW improvements that would produce incremental effects.	Chapter 5, Surface Hydrology and Water Quality; Chapter 20, Economic Analyses
23-May-11	The affirmative duty to regulate water quality reasonably requires the State Water Board to consider the costs of compliance. Consider the economic factors related specifically to wastewater dischargers. Undertake an analysis as to the costs of applying the southern Delta salinity objectives to POTWs or locations beyond the original compliance locations. Consider information regarding the need and costs of installing and operating advanced treatment technologies. For example the costs associated with treatment technologies, such as microfiltration/reverse osmosis. The State Water Board must carefully balance the environmental and economic factors when undertaking a Section 13241 analysis to ensure its regulations are ultimately reasonable as applied to POTWs.	Chapter 20, Economic Analyses; Chapter 16, Evaluation of Other Indirect and Additional Actions
23-May-11	The State Water Board must develop an adequate program of implementation that describes the actions necessary for municipal dischargers to achieve the EC objectives, provides a reasonable time schedule for the actions to be taken, and includes a description of the monitoring required to determine their compliance.	Chapter 3, Alternatives Description, Appendix K
23-May-11	CVCWA supports the proposed removal of the minimal implementation plan requirements in the 2006 Bay-Delta Plan that requires the Central Valley Regional Water Board to impose discharge controls on in-Delta discharges of salts by agricultural, domestic, and municipal dischargers. However, the draft program of implementation in the NOP fails to provide clear direction as to how EC water quality objectives shall be applied to POTWs. If the State Water Board intends to delay application of the southern Delta EC objectives to POTWs until the Central Valley's CV-SALTS program has been fully implemented, which CVCWA would support, then the program of implementation needs to state this clearly.	Chapter 3, Alternatives Description, Appendix K
23-May-11	Also, the program of implementation needs to include a clear schedule of compliance for POTWs to comply with either the existing southern Delta EC objectives, those proposed in the revised NOP, or whatever is ultimately adopted by the State Water Board or through CV-SALTS. In the absence of clear direction and schedule of compliance, POTWs will be subject to the southern Delta water quality objectives immediately because the State Water Board's compliance schedule policy would not apply.	Chapter 3, Alternatives Description, Appendix K

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Further, as part of the CEQA environmental review process, an assessment of the potential environmental effects of how POTWs would comply with the southern Delta salinity objectives should consider impacts that may result from the need to modify or expand treatment facilities, or obtain alternative water supply sources (i.e., switching from groundwater to surface water, or drilling into deeper aquifers for less saline waters).	Chapter 13, Service Providers; Chapter 20, Economic Analyses; Chapter 16, Evaluation of Other Indirect and Additional Actions
23-May-11	Support the State Water Board's consideration of recent scientific studies. Specifically, the State Water Board should continue to consider the recent study indicating that the 700 mhos/cm is more restrictive than necessary.	-
23-May-11	The State Water Board should also consider the available information regarding the extent to which POTWs contribute to existing salinity levels in the Delta. POTW discharges are minor contributors to the salinity in the southern Delta (supported by studies). The Board should evaluate discharges from POTWs and take into account that the effect of POTW discharges on Delta salinity levels is minute as compared to other sources. Consider all pertinent information and studies prior to adopting objectives.	Chapter 5, Surface Hydrology and Water Quality; Appendix C; Appendix F.2
Central Valley Salinity Coalition		
Commenter: Daniel Cozad, Executive Director		
16-Mar-09	The State Water Board should integrate its planning for southern Delta salinity and San Joaquin River flows with the CVSALTs effort.	Chapter 3, Alternatives Description
16-Mar-09	Account for the cumulative effects of the ongoing planning and regulatory efforts of the CVSALTs.	Chapter 17, Cumulative Impacts, Growth-Inducting Effects, and Irreversible Commitment of Resources
Chowchilla Water District		
Commenter: Gary W. Sawyers, Sawyers & Holland Attorneys-at-Law		
23-May-11	Improper pre-determination of the Board's plan of implementation (Section 1 of 2 of SJTA's comments).	Chapter 1, Introduction; Chapter 3, Alternatives Description
23-May-11	The impropriety of utilizing the FERC process to implement flow objectives (Section 2 of SJTA's comments).	Chapter 1, Introduction; Chapter 3, Alternatives Description
23-May-11	The urgent need for the Board to address illegal downstream diversions before imposing new flow-related obligations on upstream water rights holders (Section 4 of the SJTA's comments).	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The need for scientifically supported flow regimes that reflect current conditions (described generally in Sections 7-9 of SJTA's comments).	Chapter 3, Alternatives Description
23-May-11	Flow responsibility allocations must include an analysis of impacts vs. benefits and impacts must be assessed and considered regardless of the allocation methodology.	All
23-May-11	If responsibility for the new Vernalis flow requirements is determined based solely on a water rights priority system, impacts will not be equally distributed among water rights holders in the San Joaquin River Basin. Disproportional allocation would result, effectively drying up junior appropriators.	Chapter 1, Introduction; Chapter 3, Alternatives Description; Appendix K
23-May-11	Providing flows for the Chowchilla River system would be inefficient while depriving a substantial area of critically needed and irreplaceable water supplies.	-
23-May-11	Concern regarding the Chowchilla River include: Providing flows for the Chowchilla River system would create a false pathway for salmon; Small contributions from the Chowchilla River to meet new standards would impact the Chowchilla system far more than any benefit derived; and Chowchilla is committed to substantial flows to the San Joaquin River as mandated by the San Joaquin River Restoration Program. Additional flows would be devastating to Chowchilla and those it serves.	-
23-May-11	The impropriety of utilizing the FERC process to implement flow objectives (Section 2 of SJTA's comments).	Chapter 3, Alternatives Description; Chapter 23, Antidegradation Analysis
Contra Costa County Department of Conservation and Development		
Commenter: John Greitzer, Department of Conservation and Development		
23-May-11	The county supports setting flow requirements at Vernalis, but requests these requirements be quantitative for all four major tributaries in the San Joaquin Valley watershed.	Chapter 3, Alternatives Description
23-May-11	The DWR's estimates of unimpaired runoff are accurate enough to be the basis of quantitative flow rates. The failed Salmon Population objective is evidence enough to avoid using of a narrative objective for flow rates.	Chapter 3, Alternatives Description
23-May-11	The SWRCB should not rely on the San Joaquin River Restoration Program to determine flow rates needed to restore spring-run Chinook—quantitative minimum flow rates for the upper San Joaquin River Basin should be adopted as soon as possible.	Chapter 3, Alternatives Description
23-May-11	A minimum of 20% of the unimpaired flows should be bypassed through the tributary reservoirs at all times.	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The SED should analyze an alternative based on the following principles: 1) Each of the four major eastside tributaries bypass at least 20% of unimpaired flow (consistent with Public Trust statues). 2) Additional unimpaired flows to meet higher Vernalis flow requirements should be based on water right priority with the San Joaquin Watershed. 3) A flow requirement should be used to determine whether even more flow is necessary to restore fish populations.	Chapter 3, Alternatives Description
23-May-11	Relaxing the south Delta agricultural objectives would degrade the Delta as a source of drinking water and impact in-Delta water users and Delta ecosystem.	Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers
23-May-11	The following two alternatives should be analyzed related to agricultural objectives for South Delta agriculture: 1) Objectives at Vernalis are 0.6 mmhos/cm from April–August and 0.85 mmhos/cm from September–March 2) Objectives for all four South Delta agricultural areas are 0.6 mmhos/cm from April–August and 0.85 mmhos/cm from September–March. Analysis of the agricultural objectives will likely disclose there will be no added costs to SWP or CVP exporters.	Chapter 3, Alternatives Description
Contra Costa Water District		
Commenter: Greg Gartell, Assistant General Manager		
5-Jan-11	There are municipal intakes in the southern Delta and the CCWD pumping does not have a major effect on OMR flows.	Chapter 5, Surface Hydrology and Water Quality
Commenter: Leah Orloff, Water Resources Manager		
8-Feb-11	Regarding evaluating the success of proposed changes to flows the Board should utilize metrics that recognize the cyclical nature of salmon populations (i.e. boom-bust). It may be more appropriate to use metrics that ensure environmental conditions can sustain fish populations rather than fish population metrics.	Chapter 7, Aquatic Biological Resources
8-Feb-11	Adjust actions on an annual basis in an adaptive management framework: increased spring outmigration flows, increased fall attraction flows, adequate temperatures along the SJR and its tributaries, and sufficient flow to mobilize fine sediment.	Chapter 7, Aquatic Biological Resources
8-Feb-11	CCWD does not support the relaxation of water quality standards in the Southern Delta	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
8-Feb-11	The Draft Technical Report does not adequately address impacts on municipal users as a result of poorer water quality. An analysis should be included in the SED of municipal impacts, with mitigation measures proposed, where impacts can be avoided. Impacts include decreased water supply reliability and degraded water quality, increased energy use and greenhouse gas emissions.	Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers; Chapter 16, Evaluation of Other Indirect and Additional Actions; Chapter 22, Integrated Discussion of Potential Municipal and Domestic Water Supply Management Options
8-Feb-11	CCWD pumping does not have a major effect on OMR flows	Chapter 5, Surface Hydrology and Water Quality
Commenter: Leah Orloff, Water Resources Manager		
20-May-11	CCWD does not support the relaxation of water quality objectives in the southern Delta.	-
20-May-11	Relaxing water quality objectives could result in degraded water quality and is counter to the 2009 Delta Reform Act and State and Federal anti-degradation policy.	Chapter 23, Antidegradation Analysis
20-May-11	The water quality objectives in the NOP would allow higher salinity levels than those presented in the "Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives." The CCWD commented on this report to document the impacts increased salinity levels would have on CCWD operations. Further relaxation of water quality objectives would exacerbate these impacts.	Chapter 5, Surface Hydrology and Water Quality
20-May-11	The comments previously submitted by CCWD on the draft technical report should be considered in preparing the SED (included as an appendix to the comment letter).	-
20-May-11	The SED should include an analysis of the potential impacts the proposed alternative flow and salinity objectives will have on municipal users in the Delta.	Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers
20-May-11	The increase in salinity objectives outside the flow objective window, July–January, could lead to degraded water quality and impact beneficial uses.	Chapter 5, Surface Hydrology and Water Quality; Chapter 7, Aquatic Biological Resources; Chapter 11, Agricultural Resources; Chapter 13, Service Providers

Table A-1. Continued

Date	Comment Summary	SED Chapter
20-May-11	Salinity increases at CCWD intakes would both decrease filling of Los Vaqueros Reservoir and increase the need for blending water, resulting in more frequent occasions when CCWD would be unable to meet the delivered water quality goal. Water releases from Los Vaqueros Reservoir to meet water quality objectives would reduce the amount of water available to CCWD during a drought or a catastrophic event.	Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers
20-May-11	CCWD's operating permits contain limitations on diversions from the Delta to protect sensitive species; the benefit afforded to these species through the limitations may decrease if less water is available due to increased salinity.	Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers
20-May-11	Increased salinity at CCWD intakes would require increased releases, which use energy and generate GHG emissions.	Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers
20-May-11	The SED should include a multiyear, monthly time series of flows and water quality with and without the proposed changes in flow and salinity objectives at each municipal intake in the Delta.	Chapter 5, Surface Hydrology and Water Quality; Appendix F.1
20-May-11	The SED should include a sufficient range of hydrologic conditions.	Chapter 5, Surface Hydrology and Water Quality; Appendix F.1
20-May-11	The SED should disclose monthly and seasonal water quality impacts.	Chapter 5, Surface Hydrology and Water Quality
20-May-11	The water quality objectives would minimize the benefit of the Middle River Intake by increasing fall salinity. The SED should include mitigation measures that will mitigate any impacts to a less than significant level.	Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers
Delta Stewardship Council		
Commenter: P. Joseph Grindstaff, Executive Director		
23-May-11	DSC supports and encourages the timely development and enforcement of both flow objectives for protecting fish and wildlife beneficial uses, and water quality objectives for salinity for protecting agricultural uses.	-
23-May-11	DSC supports providing more natural flow conditions, including temporal and spatial patterns, along with using an adaptive management approach to achieve optimal flow conditions to protect fish and wildlife beneficial uses while minimizing water supply costs.	-
23-May-11	DSC encourages the involvement of Natural Resource Agency staff and stakeholders in developing adaptive management and long-term management of SJR flows.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	DSC supports the proposed development of a comprehensive monitoring, special studies, evaluation, and reporting program to inform real-time adaptive management flow recommendations.	-
23-May-11	DSC encourages the SWRCB to work closely with DSC to help ensure that the proposed SJR monitoring and evaluation program is based on the best available science.	-
23-May-11	DSC supports the proposed approach for development and implementation of salinity objectives and the proposal for special studies, monitoring and reporting requirements.	-
23-May-11	DSC recommends that the State Water Board adopt the proposed salinity and flow based objectives as quickly as possible as a first step in revising the remainder of the water quality objectives in the Bay-Delta Plan.	-
23-May-11	DSC recommends an amended Bay-Delta Plan that specifies control actions for implementation by water rights holders, including DWR and Reclamation, since it is clear that the salinity regime in the Delta is driven by both natural flows and water management.	Chapter 3, Alternatives Description; Appendix K
23-May-11	DSC recommends that the Board adopt flow-based criteria for the SJR and the remainder of the Delta that support achievement of coequal goals.	-
Friant Water Authority		
Commenter: D. Zackary Smith, Attorney for FWA		
23-May-11	The ability for junior appropriators downstream of senior appropriators to divert water released to meet objectives needs to be addressed in this process.	Chapter 1, Introduction; Chapter 3, Alternatives Description
23-May-11	Diversion and consumptive use below Vernalis violates the objectives, even if they are met at Vernalis. This problem manifested in VAMP experiment and must be addressed here.	Chapter 3, Alternatives Description
23-May-11	Riparian diversions should cease or be limited based on unimpaired natural flows when stored water is released to meet downstream objectives, and junior appropriator should cease diversion when senior appropriator releases water to meet objectives. State Water Board should implement an enforcement program before additional releases are required.	Chapter 3, Alternatives Description
23-May-11	If a pure water rights priority approach is used, an impact analysis must be done to show that benefits outweigh the costs.	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Chapter 20, Economic Analyses

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Tributary by tributary evaluation of flow regimes must be scientifically supported for the benefit of fishery management programs.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Chapter 20, Economic Analyses
23-May-11	VAMP should be extended until new flow regimes are implemented.	-
23-May-11	The SED and this process must recognize the Water Management Goal of the Settlement.	-
G. Fred Lee and Associates		
Commenter: G. Fred Lee and Anna Jones-Lee		
22-May-11	The 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento San Joaquin Delta Estuary (Bay-Delta) (2006 Bay-Delta Plan) fails to address two of the SJRJ Delta flow issues that need to be addressed as part of protecting/enhancing the fall run of Chinook Salmon that spawn in the SJR tributaries. 1) Maintaining the flow of the SIR through the Deep Water Ship Channel (DWSC) to eliminate/greatly reduce the low DO conditions that inhibit the fall run of Chinook Salmon to SIR eastside tributaries. 2) Maintaining the flow of SJR water that is present in the SJR at Vernalis so that the Chinook salmon home stream water chemical signal is present at the confluence of the SJR with the Sacramento River.	Chapter 3, Alternatives Description
22-May-11	The SWRCB should prohibit the diversion of SJR water that would cause SJR DWSC flows to decrease below about 1,000 cfs.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality
22-May-11	The SWRCB should require that at least some of the SJR water present at Vernalis be allowed to pass all the way down the SJR to its confluence with the Sacramento River in the Western Delta.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality
22-May-11	With adequate flow of the SJR through the DWSC, and by allowing an appropriate averaging of DO water quality objective compliance it is possible to eliminate the current residual low-DO problem in the DWSC. The DSC should consider these issues in developing a Directed Action that impacts the amount of SJR flow through the DWSC.	Chapter 3, Alternatives Description
22-May-11	It is critical that DSC establish a program that requires that the SWRCB management of the IEP Delta monitoring of the Delta channels be focused on evaluating the impact of permitted water diversions on Delta water quality and Delta resources as required in D-1641.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
National Marine Fisheries Service (NMFS), Formerly National Oceanic and Atmospheric Administration (NOAA)		
Commenter: Maria Rea, Supervisor, Central Valley Office		
23-May-11	More modeling may be needed in order to evaluate effects of the proposed plan without more specific parameters on percent of unimpaired flows and cfs values.	Chapter 4, Introduction to Analysis; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendices F.1 andF.2
23-May-11	Additional modeling should be done to evaluate water temperatures that would be expected with new flow standards.	Chapter 4, Introduction to Analysis; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix F.1
23-May-11	Table 3 should include the federally listed Central Valley steelhead and add flow regimes that would benefit the steelhead.	Chapter 7, Aquatic Biological Resources
23-May-11	Concerned regarding reliance on FERC proceedings to implement appropriate flow due to conflicting mandates and objectives.	Chapter 3, Alternatives Description; Appendix K
23-May-11	Also, FERC relicensing for Tuolumne and Merced Rivers will not be completed until 2016 and SWRCB's narrative flow objectives will need to be decided before that. It would also result in delays of benefits to severely depressed anadromous fish populations.	Chapter 3, Alternatives Description; Appendix K
23-May-11	NMFS recommends that the SWRCB consider a greater range of options, including the Bay Delta Conservation Plan and Delta Plan.	Chapter 3, Alternatives Description
23-May-11	While NMFS supports the natural flow regime, establishing flows as a percentage of unimpaired flow may result in unsuitable flows for anadromous fish year round. NMFS recommends the SWRCB consider year-round flows when determining percentages of unimpaired flows.	Chapter 3, Alternatives Description
23-May-11	NMFS is supportive of the Coordinated Operations Group (COG)[2] management for flows from February–June.	-

[2] The Coordinated Operations Group (COG) is now the STM Working Group.

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Concerned that COG will only focus on the adaptive management for flows during February–June.	-
23-May-11	Concerned that due to divergent interests of the COG, they may be unable to reach an agreement on flows in a timely manner, if at all.	-
23-May-11	NMFS would like to see clearer guidance regarding the decision-making process for COG.	-
23-May-11	The USFWS should be considered as a potential group member because of their expertise/authority related to anadromous fish.	-
23-May-11	The SJRMEP will include, at a minimum, monitoring, special studies, evaluations of flow on viability of fish populations, including abundance, spatial extent, diversity and productivity.	-
23-May-11	The effect of flow during different times of the year will help determine adaptive management and future changes to the San Joaquin River flow objectives.	-
23-May-11	NMFS agrees that the SJRMEP should integrate and coordinate with existing monitoring and special studies programs on the SJ River watershed.	-
Natural Resource Defense Council		
Commenter: Doug Obegi, Staff Attorney		
23-May-11	NRDC supports the NOP, but believes the narrative approach for the fish and wildlife objective is inadequate, based on experience of the existing salmon doubling.	Chapter 3, Alternatives Description
23-May-11	The quantities objectives should be included in the Final NOP. The quantitative objectives should: 1) increase flows and provide more natural variability at Vernalis and in the three San Joaquin River tributaries; 2) include a narrow range of unimpaired flow conditions; and 3) include a minimum and maximum flow condition.	Chapter 3, Alternatives Description
23-May-11	NRDC suggests a narrow range of water quality objectives, as opposed to a single value, to allow for adaptive management.	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	A minimum and maximum flow value should ensure an increase in flow volumes relative to existing conditions; the max value should be set at 20,000 cfs at Vernalis.	Chapter 3, Alternatives Description
23-May-11	NRDC agrees that the program should consider measures to address stressors, but suggests removing the phrase "together with other reasonably controlled measures…Watershed." This statement is too vague.	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Flow conditions are the most important driver of ecosystem health and salmon abundance. Therefore, other measures, like restrictions on the CVP/SWP operations, should be considered in other proceedings or as part of the adaptive management program.	Chapter 18, Summary of Impacts and Comparison of Alternatives; Chapter 5, Surface Hydrology and Water Quality; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	NRDC supports the expansion of the geographic scope of the NOP to include Stanislaus, Tuolumne, and Merced Rivers.	-
23-May-11	NRDC recommends that quantified objectives for productivity and other attributes of the fall Chinook, as well as quantified objectives for abundance and attributes of other species, be developed.	Chapter 5, Alternatives Description; Appendix K
23-May-11	The adaptive management program should explicitly link flow conditions to achieving biological objectives (consider the Logic Chain Approach)	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix K
23-May-11	NRDC agrees with DWR and expert witnesses that San Joaquin River inflows are a critically important factor in determining the abundance and survival of salmon and steelhead, and therefore NRDC supports efforts to increase river inflows.	-
23-May-11	NRDC believes additional protections, beyond increased inflows, are needed to 1) project the Public Trust; 2) achieve salmon doubling requirements. NRDC hopes these actions will be addressed in the Bay-Delta Water Quality Control Plan.	-
Northern California Water Association		
Commenter: Todd Manley, Director of Government Relations		
19-Mar-09	NCWA emphasizes that any Bay-Delta Plan updates related to Southern Delta salinity and San Joaquin River flow objectives must ensure that they do not result in any increased river flow objectives for the Sacramento River or other re-directed impacts to the Sacramento River Basin.	Chapter 5, Surface Hydrology and Water Quality
19-Mar-09	NCWA intends to continue to participate in the process and will provide more detailed comments on other issues relating to the Sacramento River basin.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
San Francisco Public Utilities Commission		
County of San Joaquin and San Joaquin County Flood Control and Water Conservation District		
Commenter: Deanne Gillick, Attorney-at-Law		
19-Mar-09	Reliance on BDCP inappropriate, as it is being developed to protect Delta exports by SWP & CVP.	-
19-Mar-09	Impacts on SJ County's economy, industries, agriculture, wildlife, fisheries and recreation must be fully analyzed in the EIR/S.	Chapter 7, Aquatic Biological Resources; Chapter 8, Terrestrial Biological Resources; Chapter 10, Recreational Resources and Aesthetics; Chapter 11, Agricultural Resources; Chapter 16, Evaluation of Other Indirect and Additional Actions; Chapter 20, Economic Analyses
19-Mar-09	Any negative changes to salinity objectives will impact assimilative capacity of SJR and legal dischargers and diverters within county and must be evaluated in EIR/S.	Chapter 5, Surface Hydrology and Water Quality
19-Mar-09	The groundwater basin is not in a condition to meet current demand. Due to overdraft conditions, salt water has intruded into the basin and threatens long-term viability of groundwater use within the county.	Chapter 9, Groundwater Resources
19-Mar-09	County objects USBR and DWR's current level of reliance on New Melones to meet SDS and SJRF objectives due to decreased water available to farmers overlying the groundwater basin and that impact on the groundwater basin.	Chapter 9, Groundwater Resources
19-Mar-09	Salinity objectives should not be relaxed, and effects of CVP imported salts to SJR, decreased SJRF due to CVP operations, and salts in Delta channels due to altered flow patterns from pumps should be included within any environmental documentation.	Chapter 5, Surface Hydrology and Water Quality; Appendix C and F.2
19-Mar-09	Minimum flows and water levels should be analyzed in the EIR/S and standards established by SWRCB for water quality and quantity to protect beneficial uses and support agricultural uses.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Chapter 11, Agricultural Resources

Table A-1. Continued

Date	Comment Summary	SED Chapter
19-Mar-09	Potential impacts of decreased WQ and flows to levees, infrastructure, F&W, recreation, economy need to be fully evaluated in EIR/S.	Chapter 6, Flooding, Sediment and Erosion; Chapter 7, Aquatic Biological Resources; Chapter 8, Terrestrial Biological Resources; Chapter 10, Recreational Resources and Aesthetics; Chapter 11, Agricultural Resources; Chapter 20, Economic Analyses
19-Mar-09	Factors outside of the Delta that impact salinity in the Delta need to be evaluated in EIR/S.	Chapter 5, Surface Hydrology and Water Quality; Appendix C and F.2
Commenter: DeeAnn Gillick, Attorney-at-Law		
23-May-11	The county supports meeting flow requirements on the San Joaquin River through sources other than the Stanislaus River.	-
23-May-11	The Water Board should evaluate and require flow contributions from the mainstream San Joaquin River. The Water Board should establish enforcement standards for the upper watershed portion of the river.	Chapter 3, Alternatives Description
23-May-11	The Water Board's rational for not evaluating flows from the upper San Joaquin is not justified; you cannot ignore one segment of the river just because the San Joaquin Restoration Program is pending.	Chapter 3, Alternatives Description; Appendix K
23-May-11	The county does not support the Water Board in becoming involved in the regulation of groundwater. Expansion of the Water Board's authority over groundwater would be costly to the state and water users. Groundwater management should remain at the local level.	Chapter 3, Alternatives Description; Chapter 9, Groundwater Resources
23-May-11	Control of groundwater by the Water Board would in excess of the Board's statutory authority and require changes to State law (commenter cites page 4 of the Draft San Joaquin River Fish and Wildlife Flow Objectives."	Chapter 3, Alternatives Description; Chapter 9, Groundwater Resources
23-May-11	The county does not support the proposal to increase the interior Delta salinity objectives. The objectives are in place to project water quality, pursuant to the Delta Protection Statute, Water Code Sections 12200 et seq.	Chapter 3, Alternatives Description; Chapter 11, Agricultural Resources
23-May-11	The Hoffman report (used by the Water Board) does not support increasing the salinity objectives. Rather, it concludes additional information is needed to properly understand water quality needs in the Delta and potential agricultural effects of increased salinity.	Chapter 11, Agricultural Resources; Appendix E

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The Hoffman Report's conclusion that water quality standards can be increased due to observed irrigation efficiencies (page 101) cannot be supported by factual evidence from monitoring stations.	Chapter 11, Agricultural Resources; Appendix E
23-May-11	The Hoffman Report relies on leaching fractions from drainage areas no affected by shallow, salty groundwater.	Chapter 11, Agricultural Resources; Appendix E
23-May-11	The county believes the Hoffman report is flawed and inaccurate and should not be used by the Water Board.	-
23-May-11	The county supports adoption of a narrative standard for southern Delta salinity objectives.	-
23-May-11	The current salinity problem is caused by contributions of CVP imported salts; decreased River flows due to CVP operations; and salt concentrations in the Delta channels due to CVP and SWP pumps.	Chapter 5, Surface Hydrology and Water Quality
23-May-11	Flow and circulation within the South Delta must be addressed as it contributes to salinity problems; the current flow is affected by export projects.	Chapter 5, Surface Hydrology and Water Quality; Appendix C, F.2
23-May-11	The county supports the requirement for DWR and USBR to develop mitigation to improve South Delta circulation and water levels to meet water quality and agricultural needs.	-
San Joaquin River Exchange Contractors Water Authority		
Commenter: Paul R. Minasian, Attorney for SJRECWA		
20-May-11	Past Board orders and statements require it to review and revise (if needed) the numeric salinity standards at Vernalis and three interior Delta locations. However, the NOP states that no such review or consideration will occur, in lieu of focusing on a more natural flow pattern.	Chapter 3, Alternatives Description
20-May-11	The Board is in violation of CEQA if continues with current salinity approach. The SWRCB by its past orders and determinations must consider alternative numeric salinity standards and their impacts in its functional equivalent document. The NOP and scoping document impermissibly exclude alternatives, which must be examined under CEQA. No other alternatives are mentioned, and no method of appraising the different impacts and alternatives of different numeric salinity standards or flows that differ from natural pre-human development and presence are suggested.	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
20-May-11	The SWRCB has refused to consider and develop evidence of environmental consequences of more natural flow regimes (or more or colder water), in particular the actual and increased numbers and health of fish that cold water or high flows actually benefit. Again, this violates CEQA.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
20-May-11	The SWRCB, under CEQA, must develop baseline analysis and alternatives itself, not rely on others to do formulate alternatives. The notion that natural is better cannot be simply assumed. The SWRCB has not developed a process to assess this conclusion and consider alternatives.	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
San Joaquin River Group Authority		
San Joaquin Tributaries Association		
Commenter: Tom O'Laughlin, Attorney-at-Law		
23-May-11	The narrative objectives should not include the Anadromous Fish Restoration Program doubling goal. The Narrative Objective should not include the term "viable native."	Chapter 3, Alternatives Description
23-May-11	Objective period should be March 15–May 15, not February–June	Chapter 3, Alternatives Description
23-May-11	The natural flow regime is not applicable to a highly physically altered basin and should not be considered (evidence cited in Appendix A of the comment letter).	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Population control of nonnative predators should be the primary management tool.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 16, Evaluation of Other Indirect and Additional Actions; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
23-May-11	The state water board doubling goal is inadequate and does not represent the best science.	Chapter 3, Alternatives Description
23-May-11	The "escapement data" used to develop the doubling goal is flawed because: 1) a large portion of the data was hatchery fish; 2) there was no constant fractional marking during the baseline period; and 3) data was collected using bias and unreliable methods.	Chapter 3, Alternatives Description; Appendix C
23-May-11	There is no evidence that instream management and habitat improvements will enable the doubling goal to be met.	Appendix C
23-May-11	The natural production estimate does not provide agencies with an adequate tool to evaluate how soon the doubling goals may be met because it does not include information on 1) origins of fish; 2) age structure; and 3) measurement errors of escapement surveys.	Appendix C
23-May-11	The doubling goal could be met in the near term if ocean harvest was eliminated for several years.	Appendix C
23-May-11	There are few, if any, native salmonid populations in the SJ basin. It is therefore misleading to assume management objectives will support "native" stocks and increased "genetic diversity". The following supports this statement: 1) Offsite releases of hatchery fish have documented benefits (e.g., increased survival), but also negative effectives (e.g., loss of genetic diversity in the natural stock); 2) A large number of hatchery fish were observed in the Stanislaus River in 2009. Given that neither the Stanislaus nor the Tuolumne River have hatcheries, a portion of in-river spawning salmon in the SJ basin must have strayed from their hatchery of origin; 3) Research by ICF Jones & Stokes demonstrates the high rate of straying amongst hatchery fish. Other independent assessments indicate that off-site releases have considerably higher rates of straying and that the rates vary by hatchery. 4) Small contributions from segregated hatchery programs to natural populations can reduce fitness; 5) Hatchery programs are only warranted if the increases in population outweigh the associated fitness loss; and 6) The Central Valley Chinook are homogenized due to hatchery programs.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The majority of fry migrate by mid-March and all juveniles by May 15. The primary cue to migrate is not winter runoff but increased turbidity—there is not a strong response associated with reservoir managed flows as they do not increase turbidity.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
23-May-11	Non-flood flows in the SJ Basin will not accomplish natural flow regime benefits such as supporting native fish, natural food webs, habitat connectivity, floodplain inundation, fluvial hydrogeomorphological processes, and improved temperatures.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
23-May-11	Salmonids are known to adapt to manipulated flow regimes. As such, altering the flow regime will not provide tangible benefits.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
23-May-11	It is important that the project focus on ways to manage flows that will actually produce benefits to salmonids (e.g., inundate floodplains that no longer exist, provide channel maintenance).	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
23-May-11	Flow does not explain low survival rates of juvenile salmon in the South Delta (evidence provided in Appendix A of comment letter).	-
23-May-11	Flows of up to 25,000 cfs have not been shown to increase juvenile salmon survival.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Studies suggest that high predation rates in the lower SJ River and South Delta are the primary factor to low survival, not flow rates. Predator control is the primary mechanism that should be considered by the Board to meet water quality objectives.	Chapter 7, Aquatic Biological Resources; Chapter 16, Evaluation of Other Indirect and Additional Actions; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
San Luis and Delta-Mendota Water Authority and Westlands Water District		
Commenter: Jon D. Rubin, Attorney for SLDMWA		
23-May-11	The State Water Board lacks authority to regulate flow, water level, and circulation under the Clean Water Act or Porter-Cologne Act.	Chapter 1, Introduction; Appendix K
23-May-11	The Authority and Westlands request that the Board insert a section on life-cycle modeling into the implementation program.	Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix K
23-May-11	A science plan should be developed to support life-cycle models, including four main components: 1) Identification of available life-cycle models or salmon, steelhead, and smelt species dependent on the Delta, with recommendations for development and prioritization of new models. 2) Identification and synthesis of statistical analysis of existing data, with recommendations for additional data development that will either improve existing life-cycle models or assist with the development of new ones. 3) Identification of hypotheses that if tested will improve life-cycle models or assist with the development of new ones. 4) Description of how the results of analyses from these models and other analytical tools can be integrated to ensure that effects of actions are considered in context with the many species dependent at least in part on the Delta.	Chapter 4, Introduction to Analysis; Chapter 7, Aquatic Biological Resources
23-May-11	The State Water Board must define the baseline	Chapter 4, Introduction to Analysis; Appendix F.1
23-May-11	In the case of the SJR, the Board will need to consider alternatives protective of beneficial uses that are not flow-centric and evaluate alternatives that have varying degrees of protection and costs.	Chapter 3, Alternatives Description; Chapter 16, Evaluation of Other Indirect and Additional Actions; Chapter 20, Economic Analyses

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	State Water Board must evaluate direct and indirect effects caused by changes in water supply that may be available to areas served by the Authority's member agencies including land fallowing, reduced employment, reduced land value, reduced crop production, increased groundwater, and reduced air quality.	Chapter 9, Groundwater Resources; Chapter 11, Agricultural Resources; Chapter 14, Energy and Greenhouse Gases; Chapter 20, Economic Analyses; Appendices B and G
South Delta Water Agency		
Commenter: John Herrick, Counsel and Manager		
20-Mar-09	SDWA adopts the comments submitted by CDWA.	See CDWA.
20-Mar-09	NOP is premature given the lack of defined project, the necessity of maintain and/or improving the requirements for salinity protection, and the need to establish and increase minimum flows on the San Joaquin River.	-
Commenter: John Herrick, Counsel and Manager		
22-April-09	Existing objectives were developed with input from a panel of experts. The current effort does not provide for that; it only asks for new information.	-
22-April-09	Underlying scientific principles and soils and crops have not changed substantially since the existing objectives were adopted. So why change now?	-
22-April-09	Until Dr. Hoffman's report is completed there is no basis for suggesting changes to the standards.	-
22-April-09	There is no proposed CEQA project upon which to comment on or propose alternatives.	-
22-April-09	Information was already submitted to the CDO and other processes. Only an independent peer-review of soil salinity models can assure useful output.	-
22-April-09	Prior submittals provide evidence of damage to crop yields when salinity exceeds standards, and the SWRCB has not taken any action to enforce.	-
22-April-09	There is information indicating that a more protective standard may be needed during seed germination and during September through March.	-
22-April-09	Those responsible for importing salts to the San Joaquin River and decreasing flows should be required to mitigate their impacts.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
22-April-09	It appears that current flow standards have not been protective of either salmon or steelhead. The SWRCB should consider proposals like the Delta Corridors, which reconnects the SJR with the Bay.	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
22-April-09	The SDWA submitted the 1980 report on the effect of the CVP, and the SWRCB may need to update how increased consumptive use on the tributaries has affected Delta inflow.	-
22-April-09	Pre-CVP and SWP salinity levels in the San Joaquin River and Delta were lower than they are today. Delta users should not be limited by upstream activities that increase salinity.	Chapter 5, Surface Hydrology and Water Quality; Appendix F.2
22-April-09	The CVP and SWP operations have changed flow patterns in the south Delta and created null zones with higher salinity	Chapter 5, Surface Hydrology and Water Quality; Appendix F.2
22-April-09	A decrease of cross-Delta flows would not allow standards to be met in the central or southern Delta.	Chapter 5, Surface Hydrology and Water Quality; Appendix F.2
Commenter: John Herrick, Counsel and Manager		
6-Dec-10	Comments regarding the draft technical report; the analysis does not discuss the required investigations associated with the potential changes to the objectives such as anti-degradation rules/policies; no discussion of legal limits and mandates which affect how much flow may be necessary with respect to Biological Opinions/federal mandates; no mention of sources of impacts on beneficial uses.	Appendix C
6-Dec-10	Documents specific changes to the different sections of the draft technical report.	Appendix C
Commenter: John Herrick, Counsel and Manager		
23-May-11	Further investigation and analysis into the water quality necessary to protect southern Delta agriculture is needed.	Chapter 3, Alternatives Description; Chapter 11, Agricultural Resources
23-May-11	The Hoffman Report contains numerous flaws and should not be used to support project conclusions. Moreover, the analysis is based on data that does not represent the project area. The following flaws are noted: - Leaching fractions are based on drainage information form areas not subject to shallow, salty ground water. - An applied water quality of 0.7 ED standard is assumed. There is no basis to propose any relaxation to the standards as the NOP is based on faulty conclusions and data within the Hoffman Report.	Chapter 11, Agricultural Resources; Appendix E

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The Hoffman Report concluded that an adequate amount of water was flowing through the soil profile for the removal of salts. Laboratory data contradicts this conclusion. Thus, the Hoffman Report does not contain reliable information on which to base a change in the salinity standards.	Chapter 11, Agricultural Resources; Appendix E
23-May-11	The Hoffman Report fails to take into consideration agricultural practices that may affect the ability to apply irrigation water and allow additional time for percolation.	Chapter 11, Agricultural Resources; Appendix E
23-May-11	The SED should contain a peer review of the Hoffman Report so that independent experts can confirm and comment on the serious problems in the Report.	Chapter 11, Agricultural Resources; Appendix E
23-May-11	The Hoffman Report fails to explain examples on crop damage in the area due to high salt concentrations.	Chapter 11, Agricultural Resources; Appendix E
23-May-11	There is no basis to propose any changes to the water quality standards until further testing and experimentation can be done. Currently, the analysis includes no information on water quality outside of the project monitoring. Because the compliance zones are not located in the stagnant or null zones, the quality of water being used by diverters, and thus potential leaching rates, are unknown.	-
23-May-11	The proposed changes would allow for a degradation of water quality at compliance locations, but includes no analysis on how this degradation of water quality would affect null zones.	Chapter 5, Surface Hydrology and Water Quality
23-May-11	SDWA supports the narrative flow standard, but suggests it further be developed to provide a more specific set of actions and a rigid timetable.	Chapter 3, Alternatives Description
23-May-11	To ensure salinity objectives are enforced and implemented, export limitations should eventually be linked to meeting the standards, with an automatic decrease or shut down when exceedances occur.	Chapter 3, Alternatives Description
23-May-11	The SED should include an analysis of the effects of proposed changes in export facilities, both on an existing and future time horizon (as required be CEQA).	Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers; Appendix F.1
23-May-11	Any change in southern Delta exports would result in less CVP salt being removed from the area, and a worsening of the water for local diverters.	-
23-May-11	An anti-degradation analysis is required.	Chapter 23, Antidegradation Analysis
23-May-11	The effects of allowing worse water quality will also affect other beneficial uses.	Chapter 5, Surface Hydrology and Water Quality; Chapter 11, Agricultural Resources; Chapter 13, Service Providers
23-May-11	SDWA has not provided any expert witness or other materials relating to fishery needs/flows on the San Joaquin River.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The SED should take into consideration the actual and purported "conservation" efforts by the upstream agencies and other parties, which will result in less flow in the river at many times.	Chapter 5, Surface Hydrology and Water Quality; Chapter 7, Aquatic Biological Resources; Chapter 17, Cumulative Impacts, Growth-Inducting Effects, and Irreversible Commitment of Resources
23-May-11	The analysis should not go forward until the USBR complies with the directives of HR 2828.	Chapter 5, Surface Hydrology and Water Quality
23-May-11	The amounts of water needed for fish and for salinity control will be different once the Bureau complies with the law and makes the discretionary decisions about how much less New Melones water it will use for these purposes.	-
State Water Contractors		
Commenter: Terry Erlewine, General Manager		
23-May-11	SWP operations do not impact either the timing or quantity of flows in the San Joaquin River at Vernalis because the state operates no storage or diversion facilities on the San Joaquin River.	-
23-May-11	The SWC suggests the Environmental Document recognize that the program of implementation contain no SWP obligations related to flows.	Chapter 3, Alternatives Description
23-May-11	The proposed flow prescriptions must be scientifically justified.	Appendix C
23-May-11	The water quality objectives do not address underlying stressors that may violate the CWA and Porter-Cologne Water Quality Control Act.	Chapter 3, Alternatives Description
23-May-11	A collective technical team should be assembled and guided by the following principles: 1) focus on ecological processes and mechanism for fish abundance, and 2) keep the modeling as simple as possible.	-
23-May-11	A full scientific analysis of the expected benefits over the life cycle of the fish of concern from any proposed flow increase needs to be included in the CEQA documentation.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	The requirement for a flow rate downstream of Vernalis implies that juvenile salmonids will survive through the Delta if flows are not impacted by diversion. The SWC is aware of no scientific data that support such a statement.	-
23-May-11	The downstream flow rate is too vague and does not allow for appropriate comment.	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	As the San Joaquin River passes Vernalis, it moves into an area where tidal action overwhelms river flows. In this tidally dominated area, migratory fish do not respond to changes in flow.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	Changes in flow patterns likely have an undetectable effect on migrating juvenile salmonids and provide little reason to expect adverse impacts caused by the export diversions.	Chapter 7, Aquatic Biological Resources; Appendix C
23-May-11	Junctions along the San Joaquin River are relatively insensitive to increasing exports.	Chapter 7, Aquatic Biological Resources
23-May-11	The DSM2 HYDRO model to predict fish movement is superior to using Particle Tracking Modeling (PTM).	-
23-May-11	The Delta Passage Model illustrates the effects of exports on salmon survival are very small relative to nonproject stressors.	-
23-May-11	The SWC suggests that the Board identify 1) scientific evidence it has to support its belief regarding the effects of in-Delta diversions on juvenile Salmonid migration; 2) lifecycle factors that could be affected by in-Delta and export diversions during particular time periods; 3) mechanisms at play; and 4) monitoring and testing schemes to evaluate effects.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
23-May-11	Adoption of a flow objective for the San Joaquin River below Vernalis would be unreasonable without additional scientific analysis.	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
23-May-11	Table 2 should be modified to remove both the ―from and ―to references to the column labeled ―Compliance Locations and footnote 5	Chapter 3, Alternatives Description; Appendix K
23-May-11	Plans to re-evaluate whether compliance stations properly reflect water quality throughout the South Delta could be clearly by expanding the paragraph discussing this subject in the middle of page 4.	Chapter 3, Alternatives Description, Appendix K
23-May-11	There is no scientific support the conclusion that elevated salinity in the southern Delta is caused in part by diversions of water by the SWP. DSM2 studies show that SWP diversions improve water quality in some areas of the southern Delta and are neutral, at worst, in the rest of the southern Delta.	Chapter 5, Surface Hydrology and Water Quality

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Reduction in pumping by the SWP would likely have far greater negative consequences for southern Delta water quality than current operations	Chapter 5, Surface Hydrology and Water Quality
23-May-11	Water level issues do not fall within the purview of the Porter-Cologne Act; they are rather water rights issues. Reference to water levels should be stricken from the RNOP and, instead, be reserved for consideration during future water rights proceedings	Chapter 1, Introduction; Chapter 3, Alternatives Description; Appendix K
23-May-11	Studies on water circulation salinity conditions should not fall solely on the SWP and CVP water users. The Board should consider an alternative that provide for these studies to be carried out by the State Board itself, with cooperation from DWR and southern Delta water users.	Chapter 3, Alternatives Description
23-May-11	SWC considers the State Board's proposed approach to southern Delta circulation/salinity issues to be seriously flawed.	-
23-May-11	SWC is developing additional DSM2 model runs that will examine circulation and null zones under varied conditions and pumping rates. SWC believes the DSM2 runs will show that the problems facing in-Delta diverters are caused by in-Delta diversions in excess of the available flow at Vernalis and that circulation problems and null zones are a function of these excess diversion rates and the bathymetry of the southern Delta channels, not export project operations.	Appendix F.1 and F.2
23-May-11	There is no evidence that export project operations need to be regulated, or that regulation will resolve southern Delta salinity issues. The Board should focus on finding the actual cause of southern Delta circulation problems rather than starting with a presumption that the export projects are primarily at fault.	Chapter 3, Alternatives Description
Stanislaus County Environmental Review Committee		
Commenter: Raul Mendez, Senior Management Consultant		
25-Mar-09	No comments.	-
Stockton East Water District		
Commenter: Karna E. Harrigfeld, Attorney-at-Law, Herum/Crabtree		
18-Mar-09	Must include thorough investigation of all sources of salt entering Delta.	Chapter 5, Surface Hydrology and Water Quality; Appendix F.2
18-Mar-09	Must discuss adverse impacts to beneficial uses protected by salinity objectives and analyze and attribute responsibility to water rights holders from these impacts.	Chapter 5, Surface Hydrology and Water Quality
18-Mar-09	Salinity problem caused by deliveries from San Luis Unit of CVP. This should be analyzed as an alternative.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Appendix F.2

Table A-1. Continued

Date	Comment Summary	SED Chapter
18-Mar-09	Salinity also caused by discharges from wetlands/ refuges.	Chapter 5, Surface Hydrology and Water Quality
18-Mar-09	Vernalis salinity objective cannot be maintained by continued releases from New Melones.	Chapter 3, Alternatives Description
18-Mar-09	Salinity control actions such as subsurface storage of drainage, land retirement, and out of valley disposal should be evaluated.	Chapter 3, Alternatives Description
18-Mar-09	Evaluate and attribute responsibility to water rights holders for impacts associated with flow objectives.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers
18-Mar-09	Identify specific mitigation measures if appropriate.	All
Commenter: Karna E. Harrigfeld, Attorney-at-Law, Herum/Crabtree		
23-May-11	The following comments are regarding Attachment 2-Draft San Joaquin River Fish and Wildlife Objectives: 1) What "other reasonably controllable measures" are being evaluated? 2) And how do they compare to the alleged need for more flow? 3) If using other controllable measures leads to doubling of Chinook salmon, the SED evaluate reduction in flows on tributaries? 4) What does the SWB mean by "natural Production" and what are "viable native SJ River watershed fish? 5) How does SWB define native migratory SJ River fish populations and are "hatchery" fish included?	Chapter 3, Alternatives Description; Chapter 16, Evaluation of Other Indirect and Additional Actions; Appendix K
23-May-11	On what "decisional document" does the SWB determine that more natural pattern of flow is needed from February–June to achieve the narrative SJ River flow objective? And what "decisional document" was used to support the conclusion that more flow is needed from existing salmon and steelhead trout bearing tributaries to Vernalis in order to provide connectivity with the Delta and more closely "mimic the natural hydrographic condition?"	Appendix C
23-May-11	The Draft Technical Report (DTR) was highly criticized as being woefully inadequate and not based on the best science such as the DFG San Joaquin River Fall-run Chinook Salmon Population Model which was discredited by the Scientific Peer Review panel.	-
23-May-11	The DTR fails to consider many significant factors that have contributed to the decline of the fishery other than flows such as predation, introduction of nonnative species, pollution, highly modified Delta conditions, temperature, and dissolved oxygen.	Chapter 7, Aquatic Biological Resources; Appendix C
23-May-11	The best available science should be used to evaluate what protections are needed for SJ River fish and wildlife beneficial uses.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The SWB has no legal, factual, or practicable authority to exclude water from the Upper SJ River as contributing to meet any new SJ River flow or salinity objective. The Upper SJ River watershed comprises more than 30% of the unimpaired flow and excluding it is fundamentally unfair and illegal.	Chapter 3, Alternatives Description
23-May-11	Obtain additional information to inform specific instream flow needs on the Stanislaus River.	-
23-May-11	Any alternative evaluated in the SED that includes flow contribution from New Melones Reservoir must recognize that due to a court order issued when original water rights were issued, the New Melones Reservoir must be limited to 1,250 cfs for the protection of agricultural users along the Stanislaus river.	Chapter 6, Flooding, Sediment and Erosion; Chapter 11, Agricultural Resources
23-May-11	The following comments are regarding Attachment 3-Draft Southern Delta Agricultural Water Quality Objectives: The salinity objective at Vernalis violates both state and federal law (CWA and Public Law 108-361) because the objective is not required for "reasonable protection" of agricultural uses at Vernalis. Proposing a Vernalis salinity objective that this overprotective of agricultural beneficial uses exceeds the authority granted the SWB under the Water Code.	Chapter 1, Introduction; Chapter 3, Alternatives Description; Chapter 23, Antidegradation Analysis
23-May-11	The SED must provide a reasonable range of alternatives to the project. As such, failure to consider a range of potential salinity levels at Vernalis violates CEQA.	Chapter 3, Alternatives Description
23-May-11	The range presented by the Hoffman Report supporting an evaluation for a water quality objective of anywhere from 0.9-1.4 EC, may be protective of agricultural beneficial uses in the Southern Delta, and this range must be evaluated.	Chapter 3, Alternatives Description
23-May-11	Other alternatives must be analyzed. The salinity problems are caused by deliveries from the San Luis Unit of the CVP.	Chapter 3, Alternatives Description
23-May-11	Completion of a drain was a condition of authorizing the San Luis Unit and because deliveries were made without provision for a drain, pollution of the SJ River has resulted.	Chapter 5, Surface Hydrology and Water Quality
23-May-11	One of the alternatives for achieving the Vernalis salinity objective should be the imposition of a condition on the San Luis Unit permits to release water to comply with Vernalis salinity objective.	Chapter 3, Alternatives Description
23-May-11	SED must also analyze reducing or eliminating discharges caused from wetlands and wildlife refuges. One mitigation is to require the wetland/wildlife refuges to reserve a portion of their water supply for use to dilute discharge in the spring.	Chapter 5, Surface Hydrology and Water Quality

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	SED must also analyze agricultural and tile drainage caused from west side agricultural interests. The Grasslands Bypass and West Side Drainage Projects have had success reducing salinity.	Chapter 5, Surface Hydrology and Water Quality; Chapter 11, Agricultural Resources; Chapter 17, Cumulative Impacts, Growth-Inducting Effects, and Irreversible Commitment of Resources
23-May-11	Additional salinity controls such as subsurface storage of drainage, land retirement and out of valley disposal should also be considered.	Chapter 3, Alternatives Description; Chapter 13, Service Providers; Chapter 16, Evaluation of Other Indirect and Additional Actions
23-May-11	Adoption of salinity objectives for the entire river and implementation through waste disposal permits that would prohibit discharge rather than control its timing should also be considered.	Chapter 3, Alternatives Description
23-May-11	Maintaining the Vernalis salinity objective violates California Constitution's prohibition against the unreasonable use of water. The "[u]se of upstream water to wash our salts downstream is an unreasonable use of water." (*Jordan v. City of Santa Barbara* (1996); *Antioch v. Williams Irrigation District* (1922).	Chapter 1, Introduction; Chapter 23, Antidegradation Analysis
23-May-11	Maintaining the Vernalis salinity objective imposes a disproportionate burden on New Melones Reservoir. Other means have not been successful and the dilution flows released from New Melones have been the sole means by which the Vernalis objective has been met. As such, the New Melones CVP contractors (which include Stockton East) have had their water supply reduced and the burden has fallen on these contractors which have not caused the problem.	Chapter 3, Alternatives Description
23-May-11	40 CFR 131.10(a) states, "in no case shall a State adopt waste transport or waste assimilation as a designated use for any water of the United States." By admitting that the Vernalis salinity object is not for protection of agriculture, but to provide dilution flow for downstream, is in contradiction and violates federal law.	Chapter 1, Introduction; Chapter 23, Antidegradation Analysis
23-May-11	The Vernalis objective also violates the Congressional directive contained in H.R. 2828 to reduce the use of New Melones Reservoir to meet the existing Bay-Delta water quality objectives.	Chapter 5, Surface Hydrology and Water Quality; Chapter 23, Antidegradation Analysis ,

Table A-1. Continued

Date	Comment Summary	SED Chapter
City of Tracy		
Commenter: Melissa A. Thorme, Special Counsel for City of Tracy		
20-May-11	Supportive of the modified salinity objectives proposed. Requests that the SWRCB carefully consider and balance each of the factors in Water Code Section 13241 when establishing EC objectives: economic impact to farmers and dischargers, the reasonably achievable water quality conditions, and potential impacts of the objectives and the activities to meet the objectives.	Chapter 3, Alternatives Description; Chapter 13, Service Providers; Chapter 16, Evaluation of Other Indirect and Additional Actions; Chapter 20, Economic Analyses
20-May-11	Objectives should be set to apply only at identified, permitted water diversion points used to extract water from the SJR or Delta for irrigation or municipal supply and only as long-term (6-month or annual) averages.	Chapter 3, Alternatives Description
20-May-11	Alternatively, explicit mixing zones, dilution credit, or other variance provisions should be included in the Delta Plan amendments incorporating the revised objectives, as should compliance schedules allowing dischargers time to come into compliance.	Chapter 3, Alternatives Description
20-May-11	The SWRCB should not over-regulate municipal dischargers because they have not been demonstrated to be the major drivers of salinity in the Delta, and should incorporate necessary regulatory flexibility into salinity objectives adopted.	Chapter 3, Alternatives Description; Chapter 13, Service Providers; Chapter 16, Evaluation of Other Indirect and Additional Actions
20-May-11	As part of the plan to implement the EC objectives, the SWRCB should describe the actions all dischargers must take to meet the objectives (including municipalities), provide a schedule for implementation of recommended actions, and describe the surveillance required to determine compliance.	Chapter 3, Alternatives Description; Chapter 13, Service Providers; Chapter 16, Evaluation of Other Indirect and Additional Actions
U.S. Department of the Interior on Behalf of U.S. Bureau of Reclamation and U.S. Fish and Wildlife Service		
6-Dec-10	Comments made on the Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives. Comments include: establishing biological and ecosystem goals and objectives; use of the natural hydrograph; adaptive management; tributary flows; changing environmental conditions; San Joaquin River outflow as a component of Delta outflow; hydrology and water supply including reservoir storage and management. Comments made regarding salinity objectives include these topics: drinking water supplies and riparian rights.	Appendix C
8-Feb-11	DOI supports the Board's consideration of flow objectives based on the percent Unimpaired flow, and these flows originating from the three main SJR tributaries.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
8-Feb-11	The Board should consider apportioning responsibility for mainstem instream flow among as many water users as possible and opposes any assignment of responsibility only on water rights of the CVP.	-
8-Feb-11	The Board should consider: 1) setting well-defined goals, 2) increasing flows to double populations of salmonids, 3) using the natural hydrograph to guide flow decisions, 4) the importance of Delta and tributary flows to salmonids, 5) utilizing appropriate modeling to evaluate flow alternatives, 6) developing an adaptive management framework supported by a strong science program.	Chapter 1, Introduction; Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C, D, F.1, and F.2
23-May-11	Interior recommends that the SWRCB concentrate efforts in the early phases of implementation to ensure the rapid stabilization of anadromous fish populations.	Chapter 3, Alternatives Description; Appendix K
23-May-11	Interior supports the Board's consideration of implementing the narrative salmon doubling goal.	-
23-May-11	Interior supports the addition of compliance stations on the tributaries.	-
23-May-11	Interior is in favor of focusing the first stage of implementation on the salmon bearing tributaries while allowing the reintroduction of salmon in the upper San Joaquin.	-
23-May-11	Interior agrees that flow contributions from salmon bearing tributaries are key to ensuring a healthy ecosystem and equitable program of implementation.	-
23-May-11	Interior supports the Board's use of adaptive management, but notes that "true" adaptive management is a scientific process dependent upon testing hypotheses.	-
23-May-11	It appears that the San Joaquin River Monitoring Evaluation Program is geared more toward adaptive management, while the coordinated operations group is geared toward informing flexible flow schedules.	-
23-May-11	The environmental analysis should 1) identify what proportion of unimpaired flow is needed to meet the salmon doubling goal; 2) identify beneficial effects in terms of specific and measurable biological objectives; 3) evaluate alternative programs of implementation; and 4) analyze impacts to storage and reservoir purpose tradeoffs.	Chapter 1, Introduction; Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Chapter 7, Aquatic Biological Resources; Chapter 19; Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C, D, F.1, and F.2

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Reservoir purpose tradeoffs are best accomplished through the use of a general investigations (GI) type model.	-
23-May-11	Consider all flow related salmonid life-cycle requirements to determine the appropriate level of unimpaired flow needed in the mainstream, tributaries, and Delta to achieve the stated doubling goal.	Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	Identify the "other reasonably controllable measures" and clarify who will fund and enforce the control of these other measures.	Chapter 3, Alternatives Description; Chapter 16, Evaluation of Other Indirect and Additional Actions; Appendix K
23-May-11	The narrative salmon doubling goal should be broken down into specific biological objectives.	Chapter 3, Alternatives Description
23-May-11	Provide the flows that are hypothesized to meet these biological/survival objectives.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Appendix F.1
23-May-11	Ensure that biological objectives can be monitored and successes and failures evaluated.	Chapter 3, Alternatives Description
23-May-11	Interior suggests the development and use of conceptual and other types of models (e.g., empirical and life-cycle) to help determine the flows necessary to meet the biological objectives.	Chapter 7, Aquatic Biological Resources; Chapter 19, Evaluation of Additional Compliance Actions and Other Indirect Actions
23-May-11	Provide the needed flows for all life-stages of salmonids on each of the San Joaquin tributaries.	Chapter 7, Aquatic Biological Resources; Chapter 19, Evaluation of Additional Compliance Actions and Other Indirect Actions
23-May-11	Clarify the relationship and integration that is expected to occur with the Federal Energy Regulatory Commission hydropower relicensing processes on the Tuolumne and Merced Rivers.	Chapter 3, Alternatives Description; Appendix K
23-May-11	Document the tributary flows needed to meet the salmon doubling goals in the Tuolumne and Merced Rivers during the FERC Section 401 certification process.	-
23-May-11	Adopt measures to ensure that the tributary flows reach Vernalis and beyond.	Chapter 3, Alternatives Description; Appendix K

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Compliance points should be equitable.	Chapter 3, Alternatives Description
23-May-11	A broad range of San Joaquin River flow objectives (20%–80% of unimpaired flow) needs to be analyzed.	Chapter 3, Alternatives Description; Appendix C
23-May-11	Alternatives should be based on the functional features of the natural hydrograph and a range of unimpaired flow volumes.	Chapter 3, Alternatives Description; Appendix C
23-May-11	Establishing a flow objective at a higher percentage of unimpaired flow than is initially required would allow for both phasing over time and experimentation within a range of unimpaired flows for the implementation of the adaptive management process.	Chapter 3, Alternatives Description
23-May-11	Monitoring must be in place and robust enough to detect differences in the biological objectives given the various percentages of unimpaired flow tested.	Chapter 3, Alternatives Description;
23-May-11	Year-round flows are needed to meet salmonid life-stage requirements.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Appendix C
23-May-11	During prolonged droughts, a percentage of unimpaired flows will be unsuitable. During these times, higher portions of unimpaired flow may be required.	Chapter 3, Alternatives Description; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30; Chapter 21, Drought Evaluation
23-May-11	Exports levels should be part of a basin plan. A range of exports and other permitted diversions should be modeled when analyzing Vernalis flow alternatives.	Chapter 1, Introduction; Chapter 3, Alternatives Description
23-May-11	Use an adaptive management to determine the flow objective as a percentage of unimpaired flow over the long-term. Adaptive management should include: 1) modeling; 2) hypothesis testing; 3) monitoring; 4) research on specific objectives; 5) flexible metrics; and 6) range of unimpaired flows. Create an adaptive management planning group as part of SJRMEP to guide the process.	Chapter 3, Alternatives Description; Appendix K
23-May-11	Secure funding for the multi-year plan.	-

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	The COG should include members from Reclamation, FWS, DWR, Fish and Game, NMFS, and staff from the San Joaquin River tributaries. The goals and objectives of the COG should be clearly articulated.	Chapter 3, Alternatives Description; Appendix K
23-May-11	Alterations to the regulated flow regimes of the mainstream San Joaquin River and its tributaries could have system operations impacts statewide.	-
23-May-11	Adopt a holistic approach for analyzing the operational and environmental impacts of revising San Joaquin River flow and southern Delta salinity objectives.	All
23-May-11	Recession rates of approximately 1 inch elevation per day administered intermittently during the spring and summer should be an additional consideration for the flow objective.	Chapter 3, Alternatives Description
23-May-11	Analyze the effects of altered operations on the downstream thermal regime. If necessary, refine the thermal standards to coincide with the expected changes in flow patterns on the mainstream and the tributaries.	Chapter 5, Surface Hydrology and Water Quality; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	Ensure compliance with existing water temperature standards.	Chapter 5, Surface Hydrology and Water Quality; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
23-May-11	During the environmental analysis, consider that the San Joaquin River and its tributaries are impaired by numerous reservoirs.	Chapter 2, Water Resources; Chapter 5, Surface Hydrology and Water Quality; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	A responsible analysis of San Joaquin River flow objectives should include an analysis of reservoir purposes, operations, and reoperations.	Chapter 2, Water Resources; Chapter 4, Introduction to Analysis; Chapter 5, Surface Hydrology and Water Quality; Chapter 7, Aquatic Biological Resources; Appendices C and F.1
23-May-11	Interior supports development of a program of implementation, which allows New Melones Reservoir to be operated in a sustainable manner over the long term.	-
23-May-11	Indexing flow objectives to water year type does not necessarily result in prudent reservoir operations.	-
23-May-11	Model and evaluate reservoir impacts to drought planning during the alternative flow objective and program of implementation analysis.	Chapter 5, Surface Hydrology and Water Quality; Chapter 21, Drought Evaluation; Appendix F.1
23-May-11	Address the potential impacts to all federally authorized purposes of New Melones Reservoir. Impacts include: water supply, fish and wildlife, flood control, power production, water quality, temperature controls, and recreation.	Chapter 5, Surface Hydrology and Water Quality; Chapter 6, Flooding, Sediment, and Erosion; Chapter 7, Aquatic Biological Resources; Chapter 8, Terrestrial Biological Resources; Chapter 10, Recreational Resources and Aesthetics; Chapter 13, Service Providers; Chapter 14, Energy and Greenhouse Gases
23-May-11	Review the benefits and trade-offs of reservoirs.	Chapter 20, Economic Analyses
23-May-11	The annual adaptive management plan should not only consider inflow forecasts, but also carryover storage in decisions on tributary flow requirements.	Chapter 3, Alternatives Description
23-May-11	Interior supports the establishment of the SJRMEP.	-
23-May-11	The Board's conclusion that only the CVP and the SWP will implement the salinity objectives is premature and does not comport with the Board's stated finding, other established facts regarding causes of elevated salinity, and state and federal law.	Chapter 1, Introduction; Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Interior requests that the Board make available the scientific studies and information relied upon by the Board to determine the following: 1) Circulation and water levels are directly related to salinity levels in the southern Delta and thus appropriate metrics of and control variables for salinity management; 2) The SWP and CVP are the only responsible parties for circulation and water level impacts to the southern Delta; 3) The actions of the SWP and CVP are solely responsible for salinity impairment; 4) Contributions of local diversions and discharges to southern Delta salinity are minor; and 5) Changes to the San Joaquin River flow regime from February through June will improve salinity in the southern Delta.	-
23-May-11	The Board needs to further explore the following issue related to the new flow management scheme: 1) Impact of using a percentage of unimpaired flow to manage ecosystem needs on the historic salinity profile.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Appendix F.2
23-May-11	The Board needs to further explore the following issue related to the new flow management scheme: 2) Opportunities or obstacles of the salinity profile on long term salinity control.	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Appendix F.2
23-May-11	The Board needs to further explore the following issue related to the new flow management scheme: 3) Total water cost to meet the ecosystem needs.	Chapter 20, Economic Analyses
23-May-11	The Board needs to further explore the following issue related to the new flow management scheme: 4) Dr. Hoffman's conclusions regarding rainfall and salinity crop tolerance.	Chapter 11, Agricultural Resources; Appendix C and E
23-May-11	Include opportunities for salinity management when establishing the southern Delta salinity compliance objectives.	Chapter 3, Alternatives Description
23-May-11	Consider relaxing the target from December–March to facilitate the export of salt during high flow conditions.	Chapter 3, Alternatives Description; Chapter 11, Agricultural Resources
23-May-11	Please provide clarification on the following program component: how does the Board anticipate enforcing compliance along a “stretch” of river?	Chapter 3, Alternatives Description
23-May-11	Please provide clarification on the following program component: 2) How will the Board define/quantify “circulation”? At what time scale and what unit of measurement?	Chapter 3, Alternatives Description
23-May-11	Please provide clarification on the following program component: 3) How will null zone violations be measured? How many? When? Where?	Chapter 3, Alternatives Description
23-May-11	Please provide clarification on the following program component: 4) How will the southern Delta salinity objectives be enforced?	Chapter 3, Alternatives Description
23-May-11	Please provide clarification on the following program component: 5) Who are the responsible parties for the null zones?	Chapter 3, Alternatives Description

Table A-1. Continued

Date	Comment Summary	SED Chapter
23-May-11	Please provide clarification on the following program component: 6) Who will pay for the additional studies and monitoring of the channels?	Chapter 3, Alternatives Description
23-May-11	Place the southern Delta salinity compliance issues under the CV-SALTS program. A holistic approach (like the SALTS program) will enable an effective, comprehensive, and integrated salinity management plan. Using the SALTS program is consistent with California Water Code Section 13241 (c) and will not burden the CVP or SWP.	Chapter 3, Alternatives Description
U.S. Environmental Protection Agency		
Commenter: Karen Schwinn, Associate Director, Water Division		
19-Mar-09	Agree a comprehensive evaluation is needed but question whether beneficial uses would be protected by regulatory provisions of WQCP.	-
19-Mar-09	The State Water Board should consider drinking water in the Delta.	Chapter 5, Surface Hydrology and Water Quality; Chapter 13, Service Providers
19-Mar-09	The State Water Board should consider restoration of SJR (Friant).	Chapter 3, Alternatives Description; Chapter 5, Surface Hydrology and Water Quality; Chapter 7, Aquatic Biological Resources; Chapter 17, Cumulative Impacts, Growth-Inducting Effects, and Irreversible Commitment of Resources
19-Mar-09	The State Water Board should consider replacing VAMP.	Chapter 3, Alternatives Description
19-Mar-09	It is recommended that State Water Board consider SJ Tributaries (need for a more integrated view of SJR and its tributaries).	Chapter 3, Alternatives Description
19-Mar-09	It is recommended that State Water Board consider reviewing Delta outflow standard.	Chapter 1, Introduction; Appendix K
19-Mar-09	It is recommended that State Water Board consider new biological information concerning Delta outflow since 1995 Plan.	Appendix C; Chapter 7, Aquatic Biological Resources; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30

Table A-1. Continued

Date	Comment Summary	SED Chapter
19-Mar-09	It is recommended that the State Water Board consider include spring and fall requirements.	Chapter 3, Alternatives Description; Chapter 19, Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30
19-Mar-09	It is recommended that the State Water Board consider upstream regulatory measures.	Chapter 3, Alternatives Description

- = Beyond Scope of the document and/or not related to impact analysis

Appendix B

State Water Board's Environmental Checklist

Appendix B
State Water Board's Environmental Checklist

Environmental Checklist Form
Appendix A to the State Water Board's CEQA Regulations
Cal. Code. Regs., tit. 23, div. 3, ch. 27 sections 3720–3781

The Project

1 **Project Title:** Update to the Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary: 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

2 **Lead Agency Name and Address:**

State Water Resources Control Board

C/O Division of Water Rights

1001 I Street, 14th Floor, Sacramento CA 95814

3 **Contact Person and Phone Number:**

Katheryn Landau, Environmental Scientist

(916) 341- 5588

4 **Project Location—Plan Area and Extended Plan Area:** The State Water Resources Control Board (State Water Board) is proposing amendments to the 2006 *Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary* (2006 Bay-Delta Plan) to address: San Joaquin River (SJR) flow water quality objectives for the protection of fish and wildlife beneficial uses; water quality objectives for the protection of southern Delta agricultural beneficial uses; and respective programs of implementation for the water quality objectives. The plan area, defined below, encompasses the areas where the proposed plan amendments[1] apply to protect the beneficial uses.

- Stanislaus River Watershed from and including New Melones Reservoir to the confluence of the Lower San Joaquin River (LSJR).
- Tuolumne River Watershed from and including New Don Pedro Reservoir to the confluence of the LSJR.
- Merced River Watershed from and including Lake McClure to the confluence with the LSJR.
- Mainstem of the LSJR between its confluence with the Merced River downstream to Vernalis.
- Areas that receive a portion of their water supply from and that are contiguous with the above areas.

[1] These plan amendments are the *project* as defined in State CEQA Guidelines, Section 15378.

- The Southern Delta, including the SJR from Vernalis to Brandt Bridge; Middle River from Old River to Victoria Canal; and Old River/Grant Line Canal from the Head of Old River to West Canal.

The flow requirements would be released from the three rim dams[2] on the three eastside tributaries[3] in the plan area. These rim dams are the farthest upstream impediments to fish. The State Water Board would evaluate, in a subsequent water right proceeding, imposing responsibility on surface water users who divert surface water from the Stanislaus, Tuolumne, and Merced River Watersheds above the rim dams in accordance with the water right priority system and applicable law. As such, the plan amendments have the potential to affect areas within the watersheds that receive a portion of their water supply from these areas. These areas are referred to as the extended plan area and are listed below.

- Stanislaus River Watershed upstream of New Melones Reservoir: Alpine, Calaveras, and Tuolumne Counties.
- Tuolumne River Watershed upstream of New Don Pedro: Tuolumne County.
- Merced River Watershed upstream of Lake McClure: Mariposa and Madera Counties.

Finally, the plan amendments also have the potential to affect areas outside of the plan area or extended plan area that obtain beneficial use of water from the Stanislaus, Tuolumne, and Merced Rivers, and the LSJR downstream of the Merced River, but are not contiguous with the plan area or extended plan area.

- City and County of San Francisco (CCSF).
- Any other area served by water delivered from the plan area or extended plan area not otherwise listed above.

Communities within close proximity of the various rivers, rim dams, reservoirs, and counties in the plan area and extended plan area are summarized below (rivers from south to north).

- LSJR: Merced, Stanislaus, and San Joaquin Counties.
- Merced River: Merced, Mariposa, and Madera Counties.
- Lake McClure and New Exchequer Dam on the Merced River: Mariposa County, unincorporated communities of Snelling and Granite Springs.
- Tuolumne River: Tuolumne and Stanislaus Counties.
- New Don Pedro Reservoir and Dam on the Tuolumne River: Tuolumne County, in proximity to unincorporated communities of La Grange, Chinese Camp, Moccasin, Blanchard, and Jamestown.
- Stanislaus River: Calaveras, Tuolumne, and San Joaquin Counties.
- New Melones Reservoir and Dam on the Stanislaus River: Calaveras and Tuolumne Counties, in proximity to communities of Angels Camp[4], Copperopolis,[5] Columbia,[3] Sonora,[2] Jamestown,[3] Copper Cove,[3] and Knights Ferry.[3]

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[2] In this document, the term *rim dams* is used when referencing the three major dams and reservoirs on each of the eastside tributaries: New Melones Dam and Reservoir on the Stanislaus River; New Don Pedro Dam and Reservoir on the Tuolumne River; and New Exchequer Dam and Lake McClure on the Merced River.

[3] In this document, the term *three eastside tributaries* refers to the Stanislaus, Tuolumne, and Merced Rivers.

[4] Incorporated community.

[5] Unincorporated community.

The flow requirements are not expected to result in a decrease to the baseline annual Central Valley Project (CVP) or State Water Project (SWP) exports because the annual inflow of the LSJR into the southern Delta is expected to increase. The potential change to exports is expected to have a very limited effect on the CVP/ SWP export service areas since minor increases in exports under the flow requirements are not considered to be growth inducing (see recirculated substitute environmental document [SED] Chapter 17, *Cumulative Impacts, Growth Inducing Effects, and Irreversible Commitment of Resources*, for more information). Therefore, the CVP/SWP export service areas are not included in the plan area and are not further discussed in the checklist.

5 **Description of Project:** The State Water Board is proposing amendments to the 2006 Bay-Delta Plan to address: SJR flow water quality objectives for the protection of fish and wildlife beneficial uses; water quality objectives for the protection of southern Delta agricultural beneficial uses; and respective programs of implementation for the water quality objectives. The plan amendments include potential changes to the monitoring and special studies program included in the 2006 Bay-Delta Plan. The flow requirements and the water quality objectives are summarized below. A detailed description of the water quality objectives is found in the SED, Chapter 3, *Alternatives Description*, and Appendix K, *Revised Water Quality Control Plan*.

Flow Water Quality Objectives: The plan amendments would establish narrative and numeric flow objectives that would maintain flow conditions from the SJR Watershed to the Delta at Vernalis sufficient to support and maintain the natural production of viable native SJR fish populations migrating through the Delta. The plan amendments also include a program of implementation.

The program of implementation would implement the flow objectives by requiring a minimum base flow and a percent of unimpaired flow[6] from each of the Stanislaus, Tuolumne and Merced Rivers from February–June and allow for adaptive adjustments within the numeric water quality objective range. The program of implementation provides that the flow objectives would be implemented through water rights actions and water quality actions, including Federal Energy Regulatory Commission hydropower licensing processes. The program provides that the required percentage of unimpaired flow would cease to apply during periods when flows from that tributary could cause or contribute to flooding or other related public safety concerns, as determined by the State Water Board in consultation with other agencies or entities with expertise in flood management. The program of implementation allows for minimum reservoir carryover storage targets or other requirements to help ensure that providing flows to meet the flow objectives will not have adverse temperature or other impacts on fish and wildlife or, if feasible, on other beneficial uses.

The program of implementation, as summarized above (see Appendix K for the complete program), applies to the plan area and the extended plan area. Under the program of implementation for the extended plan area there could be changes to upstream reservoir

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[6]*Unimpaired flow* represents the water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. It differs from natural flow because unimpaired flow is the flow that occurs at a specific location under the current configuration of channels, levees, floodplain, wetlands, deforestation and urbanization.

levels and river flows, particularly in drier years. However, the increased frequency of lower reservoir levels and the related physical changes, in the extended plan area would be limited by the program of implementation, which states that the State Water Board will include minimum reservoir carryover storage targets or other requirements to help ensure that providing flows to meet the flow objectives will not have adverse temperature or other impacts on fish and wildlife or other beneficial uses. The program of implementation also states that the State Water Board will take actions as necessary to ensure that implementation of the flow objectives does not impact supplies of water for minimum health and safety needs, particularly during drought periods. Accordingly, when the State Water Board implements the flow requirements, it will consider impacts on fish, wildlife and other beneficial uses and health and safety needs, along with water right priority. Any project-level proceeding would require compliance with the California Environmental Quality Act (CEQA), and the State Water Board would consider project-specific impacts associated with lower reservoir levels, and mitigate any significant impacts.

Southern Delta Water Quality Objectives: The water quality objectives would set the numeric interior southern Delta compliance stations to either 1.0 deciSiemens per meter (dS/m) or 1.4 dS/m. The program of implementation for the water quality objectives includes the following requirements (see Appendix K for the complete program): continue to implement conditions of U.S. Bureau of Reclamation's water rights in compliance with the salinity objective at Vernalis; continue the operation of agricultural barriers at Grant Line Canal, Middle River, and Old River at Tracy or other measures to address the impacts of export operation on water levels and salinity; complete the monitoring special study, modeling improvement plan, and monitoring and reporting protocol; develop and implement a comprehensive operations plan; and Central Valley Regional Water Quality Control Board's (Central Valley Water Board's) discharge controls on in-Delta salt discharges.

The water quality objective for salinity for the three interior compliance stations is currently 0.7 dS/m April–August and 1.0 dS/m September–March (30-day average). Although these objectives have not always been met in the southern Delta, the historical salinity in the southern Delta generally ranges between 0.2 dS/m and 1.2 dS/m during all months of the year. There is a strong relationship between salinity measured at Vernalis and salinity measured in the southern Delta. Generally, the salinity in the southern Delta increases by a maximum of 0.2 dS/m above the Vernalis salinity. Thus, when the Vernalis meets the current water quality objective for salinity, the salinity in the southern Delta is maintained between 0.7 dS/m and 1.2 dS/m (based on the historical monthly EC[7] (salinity record). Because the program of implementation would maintain existing water quality objectives for salinity at Vernalis, it is expected that salinity levels in the southern Delta would remain within the general historical range (0.2 dS/m–1.2 dS/m), and there would be no change from baseline. Furthermore, the program of implementation for the water quality objectives would result in a continuation of maintaining water levels in the southern Delta. This could require continued operation of the temporary barriers in the southern Delta. Therefore, there is no expected change from baseline associated with the operation of the barriers.

[7] In this document, EC is *electrical conductivity*, which is generally expressed in deciSiemens per meter (dS/m). Measurement of EC is a widely accepted indirect method to determine the salinity of water, which is the concentration of dissolved salts (often expressed in parts per thousand or parts per million). EC and salinity are therefore used interchangeably in this document.

Other Indirect Actions, Additional Actions, and Methods of Compliance: Since the proposed water quality objectives could be considered performance standards under Public Resources Code (Pub. Resources Code) Section 21159, an evaluation of the environmental impacts related to reasonably foreseeable methods of compliance with the water quality objectives is required. The evaluation is based on the State Water Board's checklist and is in SED chapters, including Chapter 16, *Evaluation of Other Indirect and Additional Actions,* for the methods of compliance associated with the salinity water quality objectives.

6 **Evaluation of the Environmental Impacts in the Checklist:** The following presents the requirements of the State Water Board with respect to the checklist.

1. The State Water Board must complete an environmental checklist prior to the adoption of plans or policies for the Basin/208 Planning program as certified by the Secretary for Natural Resources. The Environmental Checklist may be modified as appropriate to meet the particular circumstances of a project. (23 CCR § 3777a(2).) The checklist becomes a part of the SED.
2. For each environmental category in the checklist, the State Water Board must determine whether the project will cause any adverse impact.
   - i "Potentially Significant Impact" applies if there is a fair argument that an impact, including those associated with the reasonably foreseeable methods of compliance with the water quality objectives, may be significant. If there are any "Potentially Significant Impact" entries on the checklist, they must be evaluated in the SED or other written documentation, including an analysis of reasonable alternatives and mitigation measures to avoid or reduce any significant or potentially significant adverse impact.
   - ii "Less than Significant with Mitigation Incorporated" applies if the State Water Board or another agency incorporates mitigation measures into the SED that will reduce an impact that is "Potentially Significant" to a "Less than Significant Impact." If the State Water Board does not require the specific mitigation measures itself, then they must be certain that the other agency will in fact incorporate those measures.
   - iii "Less than Significant" applies if the impact will be less than significant, and mitigation is therefore not required.
   - iv If there will be no impact, check the box under "No Impact."
3. The State Water Board must provide a brief explanation for each "Potentially Significant," "Less than Significant with Mitigation Incorporated," "Less than Significant'" or "No Impact" determination in the checklist. The explanation may be included in the written report described in Section 3777(a)(1) or in the checklist itself. The explanation of each issue should identify: (a) the significance criteria or threshold, if any, used to evaluate each question; and (b) the specific mitigation measure(s) identified, if any, to reduce the impact on less than significant. The State Water Board may determine the significance of the impact by considering factual evidence, agency standards, or thresholds. If the "No Impact" box is checked, the State Water Board should briefly provide the basis for that answer.

4. The State Water Board must include mandatory findings of significance if required by State CEQA Guidelines Section 15065.
5. The State Water Board should provide references used to identify potential impacts, including a list of any individuals contacted.

Issues

A significance determination for each environmental issue for the water quality objectives for flow (sometimes hereinafter referred to as the flow requirements) and salinity is provided based upon an assessment of impacts. Each environmental issue contains multiple thresholds, and a checkmark in the table indicates the significance determination under each threshold. An impact is not considered potentially significant if the magnitude and/or possibility of occurrence are below the applied threshold of significance or would be considered speculative. An impact also is not considered potentially significant if mitigation could reduce the impact to a less-than-significant level. Those impacts determined to be potentially significant for the water quality objectives are included for further analysis of the SED. As such, potential impacts described in Chapter 16, *Evaluation of Other Indirect and Additional Actions*, are not considered in this appendix. Resources evaluated in Chapter 16 include all of those on the checklist (i.e., aesthetics, agricultural resources, air quality, biological resources, cultural resources, geology/soils, greenhouse gases, hazards and hazardous materials, hydrology and water quality, land use and planning, mineral resources, noise, population and housing, public services, recreation, transportation and traffic, and utility and service systems).

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
I. AESTHETICS[8] Would the project:				
a) Have a substantial adverse effect on a scenic vista?[9]	☑	❒	❒	❒

Discussion

Scenic vistas are areas which have aesthetic value based on their visual characteristics to the greater public and are generally designated by land use documents, such as county general plans. A general description of scenic vistas designated by county general plans within the proximity of the SJR and three eastside tributary rivers is provided for reference below. No specific scenic vistas are designated except for the Merced River and SJR corridors located in the foothills and mountains of the Sierra Nevada in the plan area and extended plan area. The counties in the plan area and extended plan area contain varying provisions in their general plans designating and protecting scenic vistas. Specific scenic vistas are not designated in the *County of Calaveras General Plan* (County of Calaveras 1996). However, the general plan does state that most of the county contains topographic variations and resources that contribute to the county's scenic quality and rural character. These resources include reservoirs, rivers and streams, rolling hills with oak habitat, ridgelines, and forests. Goal V-6 in the general plan calls for the preservation and protection of the scenic qualities of Calaveras County (County of Calaveras 1996). New Melones Reservoir is located in the incorporated city of Angels Camp in Calaveras County. The *General Plan of Angels Camp* does not designate specific scenic vistas (City of Angels Camp 2009). Policies included in the *San Joaquin County General Plan* provide for the protection of views of waterways and preservation of outstanding scenic vistas but do not designate specific scenic vistas (County of San Joaquin 2010). General plans for the counties of Tuolumne and Stanislaus do not designate specific scenic vistas (County of Tuolumne 1996; County of Stanislaus 2011). The *General Plan of the County of Mariposa* does not designate specific scenic vistas (County of Mariposa 2006a). However, the general plan contains policies that provide for the establishment of measures for the protection of large-scale views and viewsheds through comprehensive development standards (County of Mariposa 2006b). Standards must take into account the scenic aspect of the county to conserve designated views and viewsheds (County of Mariposa 2006b). Scenic vistas are generally identified in the *Merced County General Plan* (County of Merced 2012). These scenic vistas include the Merced River and SJR corridors. Goal NR-4 in the plan calls for the protection of scenic resources and vistas (County of Merced 2011). The *General Plan of the County of Madera* does not designate specific scenic vistas (Madera County 1995). The Alpine County General Plan does not designate specific scenic vistas, but

[8] The potentially significant aesthetic impacts are related to recreationalists and, therefore, are addressed in SED Chapter 10, *Recreational Resources and Aesthetics.*

[9] Unless expressly noted otherwise, the questions represent thresholds of significance for purposes of evaluating potential impacts.

does acknowledge the scenic resources of the county contribute to the overall value of the county (County of Alpine 2009).

In the extended plan area, 89 miles of the Tuolumne River and 122 miles of the Merced Rivers are classified as wild and scenic with the rivers contributing to the views of the surrounding landscape (National Wild and Scenic Rivers System 2016). The Stanislaus River is not classified as wild and scenic (National Wild and Scenic Rivers System 2016).

Flow: The flow requirements could change the volume of water in the three eastside tributaries and LSJR in the plan area. However, flows would generally remain within the range of historic levels with annual and interannual variation. Viewers of the river corridors in the plan area would be expected to experience views similar to the existing ones, with peak flows and full rivers during winter storms when reservoirs spill water and lower flows during the late summer and fall when water may be diverted for irrigation or other beneficial uses in the plan area. Therefore, the change in flows in the rivers in the plan area would not significantly alter or adversely change the baseline surrounding landscapes viewed from scenic vistas and are considered less than significant.

Flow in Merced and Tuolumne Rivers contribute to the wild and scenic designations on the Tuolumne and Merced. These rivers, along with the Stanislaus River, contribute to the intact, complete, and vivid views of natural landscapes in the extended plan area. These views generally comprise of expansive views of the natural landscape, including glaciated peaks, lakes, alpine and subalpine meadows, canyons and the rivers, depending on the location in the extended plan area. The Stanislaus and Tuolumne River flows are primarily controlled by numerous upstream reservoirs in the extended plan area, depending on different needs and the time of year (National Wild and Scenic Rivers System 2016). It is anticipated these rivers would continue to be controlled, as such, under the flow requirements; however, decreases in river flows that could occur under the flow requirements could have a substantial adverse effect on a scenic vista particularly on the Merced and Tuolumne, given the official designations. As such, impacts would be potentially significant and are addressed in SED Chapter 10, *Recreational Resources and Aesthetics.*

Surface water elevations at reservoirs may be modified by the flow requirements in the plan area and extended plan area. The surface water elevations currently experience wide fluctuations and no scenic vistas have been designated around the rim reservoirs. However, the reservoirs have been identified as contributing to the scenic quality of the landscapes in the various watersheds; therefore, changes in surface water elevation at the reservoirs that may substantially degrade visual character and quality will be addressed under Threshold I(c). Under baseline conditions, the reservoirs in the extended plan area experience substantial reductions in reservoir elevation level, depending on operational needs (USGS 2016 [Reservoir Gage Data]). However, because they are smaller than the rim reservoirs, substantial decreases in reservoir elevation could greatly affect sensitive viewers (i.e., recreationists). As such, substantial decrease reservoir elevations in the extended plan area could result in altering views associated with wild and scenic designations on the Tuolumne and Merced Rivers and could change the views on the Stanislaus River. Impacts would be potentially significant and are addressed in SED Chapter 10.

The flow requirements could result in a reduction in irrigation water to existing agricultural lands, primarily in the plan area, that could result in a change to agricultural production or the types of agricultural uses. However, agricultural land that is under active production is regularly modified throughout the year. The landscape and views of agricultural land are continually changing with the types of crops grown, which is dictated by numerous variables, such as the seasons and economy.

Therefore, any changes to agricultural crop type or production are not expected to have a substantial adverse effect on an existing scenic vista that may afford views of the agricultural areas, primarily in the plan area.

Southern Delta Water Quality: The existing salinity of the southern Delta would remain within the general historical range of salinity (i.e., 0.2 dS/m–1.2 dS/m). This is because the water quality objective at Vernalis would continue to be met through the program of implementation. The water quality objectives would have no potential to impact scenic vistas in the southern Delta because it is anticipated that baseline water quality conditions would meet the water quality objectives. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Substantially damage scenic resources, including, but not limited to, trees, rock outcroppings, and historic buildings within a state scenic highway?	☑	❒	❒	❒

Discussion

One of the largest viewer groups affected by changes along a state scenic highway is the travelers along the roadways. Many of the roadways in close proximity to the reservoirs and along the rivers serve as commercial and commuter routes, as well as scenic routes used by recreationists. Viewers who frequently commute via these roadways generally have low visual sensitivity to their surroundings. The passing landscape becomes familiar, and their attention is typically focused elsewhere. At standard roadway speeds, views are fleeting, and travelers are more aware of surrounding traffic, road signs, the automobile's interior, and other visual features of the environment. However, these roadways also may be traveled for their scenic qualities, and recreational travelers on such roadways are likely to have moderate sensitivity because they seek out such routes for their aesthetic viewsheds. Therefore, viewers traveling along state designated scenic highways for recreational purposes are considered moderately sensitive to the views they experience because these views typically are comprised of specific aesthetic resources (e.g., landscapes with variable topography, trees, rocks, etc.). Existing designated state scenic highways in the plan area that could have their views affected as a result of implementing the flow requirements or water quality objectives are described below.

- State Route 49 is an eligible state scenic highway route within the plan area and extended plan area. It extends through Calaveras, Tuolumne, Mariposa, and Madera Counties within the general proximity of the Stanislaus River, New Melones Reservoir, and Tulloch Reservoir; the Tuolumne River and New Don Pedro Reservoir; and the Merced River, Lake McClure, and New Exchequer Dam (Caltrans 2011a). The eligible portion of State Route 49, traveling from north to south, begins in Calaveras County, crosses New Melones Reservoir, the Tuolumne County line, the Tuolumne River as the river enters New Don Pedro Reservoir, the Merced River as it enters Lake McClure, and extends to the southern Mariposa County line (Caltrans 2011a). Views available to viewers using the roadway generally consist of the eastern Sierra Nevada, comprised of variable topography (mountains, hills, valleys, meadows), trees, rocks, etc. Some rural residential buildings are interspersed along this route along with small towns. The following reservoirs and rivers are visible as the road crosses them: New Melones Reservoir in Calaveras County, Tuolumne River in Tuolumne County, and the Merced River in Mariposa County. The Stanislaus River and Tulloch Reservoir are generally not visible from this route because of intervening landscape and topography (e.g., elevation changes associated with hills and trees). The surface water elevation in the reservoirs is influenced by seasonal changes and the seasonal operation of the dams and this seasonal variation creates an area of exposed sediment with no vegetation growing (also known as the fluctuation zone).

- The eligible portion of State Route 108 begins at the junction of State Route 49, east of New Melones and New Don Pedro in the extended plan area, and travels past Sonora to the northern Tuolumne County line (Caltrans 2011a).
- State Route 4 (also known as Ebbetts Pass Highway) is officially designated as a State Scenic Highway and a National Scenic Byway along the Stanislaus River in the extended plan area (Caltrans 2016; DOT 2016). It extends northward from Calaveras county, east of Arnold, to the Alpine County line and then to State Route 89.
- State Route 140 is officially designated as a State Scenic Highway along the Merced River in the extended plan area (Caltrans 2016). It extends northward from the Mariposa Town planning area to the west boundary of the El Portal town planning area.
- State Route 120 is officially designated as a Connecting Federal Highway and National Scenic Byway along the Merced River in the extended plan area (Caltrans 2016). This route is within Yosemite National Park and offers views of Merced River Canyon and the park.
- Interstate 5 is a state-designated highway route within general proximity of the LSJR. The interstate is designated in the following areas: approximately15 miles in Merced County from State Route 152 to the Stanislaus County line, approximately 28 miles in Stanislaus County from the Merced County line to the San Joaquin County line, and approximately 0.7 mile in San Joaquin County from the Stanislaus County line to Interstate 580 (Caltrans 2011b). This route is located in California's Central Valley, paralleling the Delta-Mendota Canal and the California Aqueduct (Caltrans 2011b).
- There is one state-designated scenic highway route in the southern Delta located in San Joaquin County (Caltrans 2011b). It consists of approximately 0.7 mile of Interstate 5 extending from the Stanislaus County line to Interstate 580 (Caltrans 2011b). Views in this area are comprised of flat agricultural lands and some foothills with interspersed suburban/urban development.

Flow: Viewers of the rim reservoirs traveling along eligible highway 49 currently view the fluctuation zone as water elevations in the reservoirs change due to release schedules. Flows in the rivers and reservoirs would not have the ability to substantially damage scenic resources such as trees, rock outcroppings, and historic buildings adjacent to the scenic road because it is expected water would remain within existing channels and existing rim reservoirs. Views currently are affected by the fluctuation zones and flows in the rivers continually adjust depending on release schedules and the time of year. Furthermore, the State Route 49 currently is only eligible as a scenic highway and not fully designated. The LSJR is generally located more than 5 miles to the east of Interstate 5 and generally is not visible to viewers traveling along the freeway as a result of distance and atmospheric conditions (e.g., weather or haze). Therefore, impacts would be less than significant.

However, in the extended plan area, the reservoirs are typically smaller than the rim reservoirs and greater fluctuations in elevation levels could result in a substantial change to views from designated

State Routes 4, 140 and 120 and eligible State Route 108. In addition, views of the different rivers from Routes 4, 140, 120, contribute greatly to the scenic quality of the routes. As such, impacts would be potentially significant. As such, they are discussed in SED Chapter 10, *Recreational Resources and Aesthetics.*

Southern Delta Water Quality: A change in the water quality objectives would not result in an impact on viewers using the designated section of Interstate 5. The existing salinity of the southern Delta would remain within the historical range of salinity under either objective. This is because the salinity objective at Vernalis would continue to be met under the program of implementation. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Substantially degrade the existing visual character or quality of the site and its surroundings?	☑	❒	❒	❒

Discussion

The visual character and quality of an area is influenced by the different land uses within a view, the intactness (i.e., completeness) of a view, and the vividness (i.e., how the view stands out) of a view. Visual character and quality in relation to the plan area and extended plan area and the flow requirements and water quality objectives is discussed below.

Flow: The new flow requirements would apply to rivers currently located in the mountains and foothills of the eastern Sierra Nevada. The visual character and quality of these areas is generally characterized by intact and vivid views of mountains, foothills, trees, and other topographical features and natural resources. As the rivers leave the foothills and enter the valley, the visual character and quality is generally characterized by less intact and vivid views of flatter land that has less topographic and is interrupted by development along the rivers, such as business buildings and residential homes, as well as flat agricultural land. Due to the variability of rivers and the dynamic shoreline, viewers are generally less sensitive to changes in river height, and are affected only by severely high or low flows. Although the flow requirements would alter the flows in the river, and thus potentially the water level and appearance, these differences would not constitute a significant change in the visual quality of the plan area because flows would generally be higher when compared to baseline, in the plan area. Furthermore, given the existing variability of the volume and duration of river flows viewers would not be sensitive to these changes. Therefore, the flow requirements would not significantly degrade the visual character or quality of the rivers within the landscape, and impacts would be less than significant.

However, as discussed in Threshold I(a), the rivers in the extended plan area contribute to the expansive views of the natural landscape in the extended plan area. Substantial reductions of flow in the rivers could substantially degrade the existing visual character or quality of the reservoirs by recreationists. As such, impacts would be potentially significant and this impact is addressed in SED Chapter 10, *Recreational Resources and Aesthetics*.

The flow requirements could result in a decrease in reservoir surface water elevations, potentially during recreational periods in the plan area and extended plan area when sensitive viewers are most likely to be affected by changing views. This could substantially degrade the existing visual character or quality of the reservoirs experienced by recreationists using the reservoirs. Therefore, impacts would be potentially significant and this impact is addressed in SED Chapter 10.

As discussed above in Threshold I(a), the flow requirements could result in a change to the type of agricultural lands, primarily in the plan area, as a result of potential modifications to surface water diversions. However, agricultural land that is under active production is regularly modified throughout the year. The landscape and views of agricultural land is continually changing with the types of crops grown, which is dictated by numerous variables, such as the seasons and economy. Therefore, any changes to agricultural crop type or production are not expected to result in a substantial degradation of the existing visual character or quality of agricultural lands, primarily in the plan area, and the impact is therefore considered less than significant.

Southern Delta Water Quality: The water quality objectives would apply to salinity in the southern Delta. The southern Delta is comprised of relatively intact and vivid views of primarily rural land with vast areas of open space and flat agricultural land interspersed with the waterways and levees. Trees and other nonagricultural vegetation are also prevalent along waterways. Views become more suburban and urban around the city of Tracy and other smaller municipal areas with increasing commercial buildings, roads, and residential homes. A change to the water quality objectives would not result in a substantial degradation of the existing visual character and quality of the southern Delta. The existing salinity of the southern Delta would remain within the general historical range of salinity under the water quality objectives because the salinity objective at Vernalis would continue to be met under the program of implementation. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Create a new source of substantial light or glare which would adversely affect day or nighttime views in the area?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives would not produce light or glare. The flow requirements would alter the volume of water in existing rivers during different times of the year. The salinity of the southern Delta would remain within the general historical range of salinity under the water quality objectives. This is because the water quality objective for salinity at Vernalis would continue to be met. Neither would result in light or glare. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
II. AGRICULTURE AND FOREST RESOURCES: In determining whether impacts on agricultural resources are significant environmental effects, lead agencies may refer to the California Agricultural Land Evaluation and Site Assessment Model (California Department of Conservation 1997), prepared by the California Department of Conservation, as an optional model to use in assessing impacts on agriculture and farmland. In determining whether impacts on forest resources, such as timberland, are significant environmental effects, lead agencies may refer to information compiled by the California Department of Forestry and Fire Protection regarding the state's inventory of forest land, including the Forest and Range Assessment Project and Forest Legacy Assessment Project, as well as forest carbon measurement methodology in forest protocols adopted by the California Air Resources Board (ARB).				
Would the project:				
a) Convert Prime Farmland, Unique Farmland, or Farmland of Statewide Importance (Farmland), as shown on the maps prepared pursuant to the Farmland Mapping and Monitoring Program of the California Resources Agency, to nonagricultural use?	☑	❐	❐	❐

Discussion

Flow: The flow requirements on the three eastside tributaries, including the program of implementation (e.g., water rights proceeding), could result in a decrease in surface water diversions, many of which are used to supply irrigation water to agricultural lands within the plan area and extended plan area. The flow requirements could result in a potential loss of Prime Farmland, Unique Farmland, or Farmland of Statewide Importance as these types of agricultural land categories primarily rely on irrigation water. A loss of these types of agricultural lands could result by conversion to nonagricultural uses. Potentially significant impacts could occur; therefore, this issue is addressed in SED Chapter 11, *Agricultural Resources*.

Southern Delta Water Quality: Agricultural uses in the southern Delta currently use water diverted from existing waterways and rely on suitable water quality to irrigate existing crops. Historically, the salinity in the southern Delta ranges from approximately 0.2 dS/m to 1.2 dS/m. Therefore, generally the water quality in the southern Delta sometimes has higher salinity when compared to the current water quality objective. Southern Delta water quality is currently suitable for all crops being farmed in the southern Delta. Southern Delta salinity would remain within the general historical range of salinity because the water quality objective for salinity at Vernalis would continue to be met. Thus, salinity on the LSJR and the southern Delta is not expected to substantially change. However, salt-sensitive crops, such as dry beans, could be affected. Potentially significant impacts could occur; therefore, this issue is addressed in SED Chapter 11, *Agricultural Resources*.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Conflict with existing zoning for agricultural use or a Williamson Act contract?	☑	❐	❐	❐

Discussion

Flow: The flow requirements on the three eastside tributaries, including the program of implementation (e.g., water rights proceeding), could result in a decrease in surface water diversions, many of which are used to supply irrigation water to agricultural lands within the plan area and extended plan area. Potentially significant impacts on agricultural lands under Williamson Act contract resulting from changes in flow requirements are addressed in SED Chapter 11, *Agricultural Resources*.

Southern Delta Water Quality: Agricultural uses in the southern Delta currently divert water from existing waterways and rely on suitable water quality to irrigate existing crops, including crops under Williamson Act contracts. Potentially significant impacts on agricultural lands under Williamson Act contract resulting from changes in water quality objectives for the southern Delta are addressed in SED Chapter 11.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Conflict with existing zoning for, or cause rezoning of forestland (as defined in Public Resources Code Section 12220(g)), timberland (as defined by Public Resources Code Section 4526), or timberland zoned Timberland Production (as defined by Government Code Section 51104(g))?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives would not result in a conflict of existing zoning or cause the rezoning of forestland because they would not change existing zoning. Furthermore, under the flow requirements forests would continue to experience precipitation as they do under baseline conditions in the extended plan area and as such receive the water needed to survive. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Result in the loss of forestland or conversion of forestland to nonforest use?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives would not result in a loss of forestland or conversion of forestland to nonforest use because forestland is not irrigated with water from the three eastside tributaries or LSJR, and there are no forests present in the southern Delta. Forests located in the extended plan area would continue to receive precipitation and experience hydrologic conditions as they do under baseline conditions. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
e) Involve other changes in the existing environment which, due to their location or nature, could result in conversion of Farmland to nonagricultural use or conversion of forestland to nonforest use?	☑	☐	☐	☐

Discussion

Flow and Southern Delta Water Quality: As discussed in II(a), impacts on farmland would be potentially significant and this issue is addressed in SED Chapter 11, *Agricultural Resources*. As discussed in II(c) and II(d), there would be no impacts on forestland in the plan area or extended plan area.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
III. AIR QUALITY -- Where available, the significance criteria established by the applicable air quality management or air pollution control district may be relied upon to make the following determinations. Would the project:				
a) Conflict with or obstruct implementation of the applicable air quality plan?	☐	☐	☑	☐

Discussion

Ambient air quality is affected by the climate, topography, and type and amount of pollutants emitted. The plan area is located partially in the San Joaquin Valley Air Basin (SJVAB) and partially in the Mountain Counties Air Basin (MCAB). The extended plan area is also located in the SJVAB and MCAB, as well as in the Great Basin Valleys Air Basin (GBVAB). The following discussion describes climatic and topographic characteristics of the SJVAB, GBVAB and the MCAB, a description of criteria pollutants, relevant air quality standards, and existing air quality conditions within the basins.

Climate and Topography: The plan area and extended plan area are partially located in the SJVAB. The mountain ranges bordering the air basin the Coast Ranges to the west and Sierra Nevada to the east influence wind directions and speeds and atmospheric inversion layers in the San Joaquin Valley. These mountain ranges channel winds through the valley, affecting both the climate and dispersion of air pollutants. Because of the mountain ranges bordering the air basin, temperature inversions occur frequently in the valley. Inversions occur when the upper air is warmer than the air beneath it, thereby trapping pollutant emissions near the surface and not allowing them to disperse upward. Inversions occur frequently throughout the year in the SJVAB, though they are more prevalent and of a greater magnitude in late summer and fall. As a result, of a combination of topographical and climatic factors that result in high potential for regional and local accumulation of pollutants in this area.

The plan area and extended plan area are partially located within the MCAB, and the extended plan area is also located in the GBVAB. The general climate of the region varies based on elevation and proximity to the Sierra Nevada. Due to the complex features of the terrain within the basin, it is possible for various climate types to exist in proximity to one another; the varying patterns of mountains and hills in the basin result in a wide variation of temperature, rainfall, and localized wind. Seasonal meteorology varies substantially, and precipitation generally is light in the summer and much heavier in the winter, with temperatures dropping below freezing at night and precipitation being a mixture of light rain and snow. The meteorology and topography combine so local conditions predominate in determining the effect of emissions in the basin. Inversion layers frequently occur in small valleys and trap pollutants (e.g., carbon monoxide) close to the ground in winter and summer, when longer daylight hours, high temperatures, and stagnant air conditions are suitable for the formation of some criteria pollutants (e.g., ozone).

Criteria Pollutants: The federal and state governments have established ambient air quality standards (AAQSs) for the following criteria pollutants: ozone, carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particulate matter (both particulate matter smaller than 10 microns or less in diameter [PM10] and particulate matter smaller than 2.5 microns or less in diameter [PM2.5]), and lead. Ozone, NO_2, and particulate matter are generally considered to be regional pollutants as these pollutants or their precursors affect air quality on a regional scale. Pollutants such as CO, SO_2, and lead are considered to be local pollutants. Particulate matter is considered to be both a local and a regional pollutant. In the plan area, PM2.5, PM10, and ozone are considered pollutants of concern. Brief descriptions follow below. Toxic air contaminants (TAC) are also discussed below, although no state or federal AAQSs exist for TACs.

Ozone: Ozone is a respiratory irritant that increases susceptibility to respiratory infections and is a severe eye, nose, and throat irritant. It is also an oxidant that can cause substantial damage to vegetation and other materials. Ozone causes extensive damage to plants by discoloring leaves and damaging cells. Ozone also attacks synthetic rubber, textiles, and other materials. Ozone is primarily a summer air pollution problem. The ozone precursors, reactive organic gases (ROGs) and oxides of nitrogen (NO_X), are mainly emitted by mobile sources and stationary combustion equipment.

Carbon Monoxide: CO is a public health concern because it combines readily with hemoglobin and reduces the amount of oxygen transported in the bloodstream. CO can cause health problems such as fatigue, headache, confusion, dizziness, and even death. Motor vehicles are the dominant source of CO emissions in most areas. Data indicate that local CO concentrations do not approach the state standards; however, CO concentrations in the vicinity of congested intersections and freeways would be expected to be higher than those recorded at the monitoring station. CO concentrations are expected to continue to decline in the SJVAB, MCAB, and GBVAB because of existing controls and programs and the continued retirement of older, more polluting vehicles.

Inhalable Particulates: Inhalable particulates (e.g. PM2.5 and PM10) can damage human health and retard plant growth. Health concerns associated with suspended particulate matter focus on those particles small enough to reach the lungs when inhaled. Particulates also reduce visibility and corrode materials. Particulate emissions are generated by a wide variety of sources, including agricultural activities, industrial emissions, dust suspended by vehicle traffic and construction equipment, and secondary aerosols formed by reactions in the atmosphere.

Toxic Air Contaminants: TACs are pollutants which may be expected to result in an increase in mortality or serious illness or which may pose other present or potential hazards to human health. Health effects include cancer, birth defects, neurological damage, damage to the body's natural defense system, and diseases which lead to death. Although AAQSs exist for criteria pollutants, no standards exist for TACs. For TACs that are known or suspected carcinogens, ARB has consistently found that there are no levels or thresholds below which exposure is risk-free.

Sensitive Receptors: Air Pollution Control Districts have definitions of what a sensitive receptor is, which typically include specific population groups being exposed to certain pollutants for a period of time. Population groups that are more sensitive to air pollution than other groups include children, the elderly, and acutely ill and chronically ill persons, especially those with cardio-respiratory diseases. For example, SJVAPCD generally defines a sensitive receptor as a facility that houses or attracts children, the elderly, people with illnesses, or others who are especially sensitive to the effects of air pollutants, and where there is a reasonable expectation of continuous human exposure according to the averaging period for the AAQSs (e.g., 24-hour, 8-hour, or 1-hour). There are known sensitive receptors in the plan area and extended plan area. Sensitive receptors are primarily concentrated in urbanized areas, while scattered sensitive receptors are also located in rural areas within the plan area and extended plan area.

Air Quality Regulations: Air quality is regulated at the federal, state, and local levels. The federal government, primarily through the U.S. Environmental Protection Agency (USEPA), sets air quality standards and oversees state and local actions. The federal Clean Air Act requires states to directly regulate both stationary and mobile sources through a state implementation plan (SIP) to provide for implementation, maintenance, and enforcement of health-based national ambient air quality standards.

ARB traditionally has established state air quality standards, maintaining oversight authority in air quality planning, developing programs for reducing emissions from motor vehicles, developing air emission inventories, collecting air quality and meteorological data, and approving SIP provisions.

Responsibilities of local air districts include overseeing stationary source emissions, approving permits, maintaining emissions inventories, maintaining air quality stations, overseeing agricultural burning permits, and reviewing air quality-related sections of environmental documents required by CEQA.

Each of the 35 air pollution control districts in California has its own new source review program and issues its own new source review or prevention of significant deterioration permits to construct and operate. To do so, each district has adopted its own rules and regulations to comply with state and federal laws. These regulations usually incorporate both the California and federal regulations into one or more rules. Depending on the quantity of air pollutants that will be emitted from the source and the area designation for that pollutant, the new or modified source may be required to install best available control technology (BACT). In addition, new and/or modified sources in California may be required, depending on the type and quantity of pollutants emitted, to mitigate or offset the increases in emissions resulting from installation of BACT/lowest achievable emission rate. Conversely, if a source shuts down a permitted emission unit or decreases emissions greater than what is required by any district, state, or federal rule, it may receive emission reduction credits that it may use at a later date to offset new emissions, or that it can sell to another facility that may be increasing its emissions. The cost of these emission-reduction credits is set by the owner of the credits and varies depending on type of pollutant and the district in which they are generated.

Areas are classified as either an attainment or nonattainment area with respect to state and federal air quality standards. These classifications are made by comparing actual monitored air pollutant concentrations to state and federal standards. If a pollutant concentration is lower than the state or federal standard, the area is classified as being in attainment of the standard for that pollutant. If a pollutant violates the standard, the area is considered a nonattainment area. If data are insufficient to determine whether a pollutant is violating the standard, the area is designated unclassified. Areas that were previously designated as nonattainment areas but have recently met the standard are called maintenance areas.

PM10, PM2.5, and ozone are of particular concern in the SJVAB. USEPA has classified SJVAB as an extreme nonattainment area for the federal 8-hour ozone standard and a nonattainment area for the federal PM2.5 standard. For the federal CO standard, USEPA has classified most major population centers of the SJVAB as maintenance areas and rural areas of the SJVAB as unclassified/attainment areas. The SJVAB is classified as a serious maintenance area with regards to the federal PM10 standards.[10] ARB has classified the SJVAB as a severe nonattainment area for the state 1-hour ozone standard and a nonattainment area for the state 8-hour ozone, PM10, and PM2.5 standards. ARB has classified the SJVAB as an attainment area for the state CO standard. SJVAPCD has adopted an air quality improvement plan that addresses NO_X and ROGs, both of which are ozone precursors and contribute to the secondary formation of PM10 and PM2.5. The plan specifies that regional air quality standards for ozone and PM10 concentrations can be met through the use of additional source controls and trip reduction strategies. It also establishes emission budgets for transportation and stationary sources. Those budgets, developed through air quality modeling, reveal how much air pollution can be present in an area before national AAQSs are violated. USEPA has classified the MCAB as a nonattainment area for the federal 8-hour ozone standard in Calaveras and Mariposa Counties. The state has classified the MCAB as nonattainment for ozone and PM10 in Calaveras County and nonattainment for ozone in Mariposa and Tuolumne Counties. The state has classified the GBVAB as nonattainment for ozone and PM10 in Alpine County.

Emissions associated with typical construction activities include construction equipment exhaust, fugitive dust emissions, energy consumption emissions, and mobile source emissions associated with worker commute and material delivery activities. Emissions associated with typical operations include motor vehicle emissions and area source emissions, which often consist of the onsite combustion of natural gas for space and water heating, consumer products (cleaning supplies, kitchen aerosols, cosmetics, and toiletries), and the reapplication of architectural coatings. Approving the flow requirements and the water quality objectives, would neither result in construction activities nor result in increased operational elements (i.e., additional workers, operational and maintenance activities). Therefore, the analysis below evaluates impacts associated with approving the flow requirements or water quality objectives.

[10] The region was reclassified by the EPA from a nonattainment to attainment area for the federal PM10 standard. However, because of the region's previous nonattainment classification for PM10, it is actually a serious maintenance area for the federal PM10 standard.

Flow: The flow requirements could result in decreased hydropower generation because of the reoperation of the reservoirs. This loss in hydropower generation may necessitate increased production from other power facilities to offset the loss. The lost hydropower generation would be replaced by facilities that currently generate power, such as other renewable generating sources or non-renewable sources. The generation of additional power could result in increased criteria pollutant emissions at other power facilities. However, these power facilities are already built and permitted to emit a maximum amount of criteria pollutants. These facilities are required to offset additional power generation by using pollution credit under existing regulations. Therefore, if additional emissions are generated as a result of a loss of hydropower from the flow requirements, these emissions would be generated by facilities that are permitted to do so. The permit requirements would ensure that there would be no net increase in pollutant emissions, and would be consistent with the air quality plans because there would be no net increase due to the facility's permit requirements.

The flow requirements may also result in additional groundwater pumping to offset the reduction of surface water diversions. This groundwater pumping is anticipated to be within irrigation service areas in the counties identified in the plan area and extended plan area. Additional groundwater pumping could require additional electrical use. Electric pumps are assumed as the flow requirements would be implemented over the long term; therefore, groundwater wells would likely be used continuously in the plan area if needed to replace a reduction in surface water diversions and would be expected to be electric. It is expected that additional groundwater pumping would be powered by electric pumps because they are cheaper and more efficient than diesel pumps over a long-term basis. As discussed above, additional energy would either come from a renewable or nonrenewable energy source that is already permitted, and thus no new operational air quality emissions would be expected. However, a small portion of groundwater pumping may be powered by diesel generators. While it is currently unknown what proportion of groundwater pumping would use electric- or diesel-powered pumps, the installation of additional diesel pumps would need to comply with air pollutant rules and requirements of SJVAPCD, Calaveras County Air Pollution Control District (CCAPCD), Great Basin Unified Air Pollution Control District (GBUAPCD), Mariposa County Air Pollution Control District (MCAPCD), and Tuolumne County Air Pollution Control District (TCAPCD) as part of the permit application. CCAPCD, MCAPCD, and TCAPCD are located within the MCAB and GBUAPCD is located within the GBVAB. SJVAPCD's, CCAPCD's, GBUAPCD's, MCAPCD's, and TCAPCD's air pollutant regulations reduce and control air emissions and risks to health from a variety of emitting sources, including groundwater pumps; therefore, these regulations would preclude the possibility of significant air quality and health risk impacts.

Furthermore, a project is deemed inconsistent with air quality plans if it would result in population and/or employment growth that exceeds growth estimates included in the applicable air quality plan, which, in turn, would generate emissions not accounted for in the applicable air quality plan emissions budget. Therefore, projects are evaluated to determine whether they would generate population and employment growth and, if so, whether that growth and associated emissions would exceed those included in the relevant air plans. It is not expected that the flow requirements would result in population or employment growth that would result in a conflict with or obstruct implementation of the applicable air quality plan because they would not require activities that are associated with population growth (e.g., housing development, business centers, etc.). Consequently, impacts would be less than significant.

Southern Delta Water Quality: The existing salinity of the southern Delta would remain within the general historical range of salinity under the water quality objectives. This is because the salinity objective at Vernalis would continue to be met. Water quality objectives would not result in emissions of criteria pollutants. Furthermore, a project is deemed inconsistent with air quality plans if it would result in population and/or employment growth that exceeds growth estimates included in the applicable air quality plan, which, in turn, would generate emissions not accounted for in the applicable air quality plan emissions budget. Therefore, projects are evaluated to determine whether they would generate population and employment growth and, if so, whether that growth and associated emissions would exceed those included in the relevant air plans. It is not expected that the water quality requirements would result in population or employment growth that would result in a conflict with or obstruct implementation of the applicable air quality plan because they would not require activities that are associated with population growth (e.g., housing development, business centers, etc.). Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Violate any air quality standard or contribute substantially to an existing or projected air quality violation?	☐	☐	☑	☐

Discussion

Flow and Southern Delta Water Quality: As indicated above in Threshold III(a), impacts would be less than significant or would not occur. Air quality impacts would be similar to baseline in the SJVAB, GBVAB, and the MCAB and criteria pollutant emissions would not exceed any quantitative thresholds of significance established by applicable air pollution control districts in the plan area and extended plan area. The proposed objectives would not result in the violation of any air quality standard or contribute substantially to a project air quality violation.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Result in a cumulatively considerable net increase of any criteria pollutant for which the project region is non-attainment under an applicable federal or state ambient air quality standard (including releasing emissions which exceed quantitative thresholds for ozone precursors)?	☐	☐	☑	☐

Discussion

Flow and Southern Delta Water Quality: As discussed in Threshold III(a), the plan area and extended plan area are in non-attainment for certain criteria pollutants. However, the flow requirements or water quality objectives are not expected to result in a cumulatively considerable net increase of any criteria pollutant for which the plan area or extended plan area is non-attainment under an applicable federal or state ambient air quality standard because they would not result in new air pollutant emissions. As discussed in Threshold III(a), while generation of additional power could result in increased criteria pollutant emissions at other power facilities, these power facilities are already built and permitted to emit a maximum amount of criteria pollutants. These facilities are required to offset additional power generation by using pollution credit under existing regulations. The permit requirements would ensure that there would be no net increase in pollutant emissions, and would be consistent with the air quality plans because there would be no net increase due to the facility's permit requirements. In addition, electric or diesel pumps would also need to comply with air pollutant rules and requirements of the various air quality boards identified in Threshold III(a). As such, cumulatively considerable net increase of any criteria pollutant would not occur.

Decreased surface water diversions associated with an increase in river flow has the potential to result in decreased water available for agricultural irrigation, potentially resulting in a reduction of acres in active agricultural production. Active agricultural production is a major source of fugitive dust emissions due to soil disturbance associated with soil tillage and the harvesting of crops. The use of off-road agricultural equipment associated with agricultural activities (e.g., soil tillage, crop harvesting, and pesticide and herbicide application) would also generate large quantities of criteria pollutant exhaust emissions because the equipment is often diesel powered. The agricultural activity of controlled burning of agricultural field wastes also creates smoke emissions.

It is anticipated some croplands could experience reduced irrigation and a potential change in agricultural production primarily within the plan area. If a reduction in irrigation water resulted in a reduction of agricultural acres actively farmed, air quality would potentially benefit (i.e., reduced smoke, fugitive dust, and equipment exhaust emissions) because there would be a reduction in controlled field burning, soil tilling, crop harvesting, and herbicide/pesticide application. In addition, some land would be expected to retain crop stubble cover, ultimately experience vegetative regrowth, or both. This root material and regrowth would stabilize soils and serve to reduce the potential for fugitive dust emissions. In the event that croplands were left unvegetated, fugitive dust emissions could increase from wind-blown dust. However, any potential fugitive dust emissions would be temporary and limited in occurrence on lands that would regain vegetative growth, thereby limiting the potential for long-term fugitive dust emissions from the land surface. In contrast, the current baseline of active agricultural activities and associated emissions occur on a permanent basis, as crop burning, soil tillage, crop harvesting, and pesticide and herbicide application occur seasonally, depending on the type of crop, over the long-term lifespan of the cropland. Therefore, it is anticipated that the limited amount of potential fugitive dust emissions associated unvegetated land would be significantly outweighed by the reduction in potential long-term emissions associated with active agricultural activities. Consequently, impacts would be less than significant.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Expose sensitive receptors to substantial pollutant concentrations?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: As described above under Threshold III(a), air Pollution Control Districts have definitions of what a sensitive receptor is, which typically include specific population groups being exposed to certain pollutants for a period of time. Population groups that are more sensitive to air pollution than other groups include children, the elderly, and acutely ill and chronically ill persons, especially those with cardio-respiratory diseases. As described above under Threshold III(a), the flow requirements or water quality objectives would not result in a net increase in air pollutant emissions. Generally sensitive receptors would be exposed to air quality emissions if there was a net increase in emissions. Given that there would not be a net increase in air pollutant emissions, sensitive receptors within the plan area and extended plan area would not be exposed to substantial pollutant concentrations. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
e) Create objectionable odors affecting a substantial number of people?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: Typically odors are generated with an increase in pollutant concentrations, particularly those related to diesel (e.g., particulate matter). As discussed in Threshold III(a), there would be no net increase in pollutant emissions. As such, a creation of objectionable odors is not expected related to increased pollutant emissions. Therefore, the flow requirements or water quality objectives would not create objectionable odors affecting a substantial number of people. There would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
IV. BIOLOGICAL RESOURCES –				
Would the project:				
a) Have a substantial adverse effect, either directly or through habitat modifications, on any species identified as a candidate, sensitive, or special-status species in local or regional plans, policies, or regulations, or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☑	☐	☐	☐

Discussion

Flow: Potential impacts on aquatic biological resources and terrestrial biological resources in the plan area and extended plan area resulting from changes in river volume or rates or reservoir fluctuations associated with flow requirements are considered potentially significant and are addressed in SED Chapter 7, *Aquatic Biological Resources*, and SED Chapter 8, *Terrestrial Biological Resources*. In addition, indirect effects related to sensitive species resulting from a potential reduction in active agricultural production acreage associated with a decrease in irrigation water supply availability are addressed in SED Chapter 8.

Southern Delta Water Quality: Salinity in the southern Delta would not affect terrestrial biological resources in the plan area because salinity would be maintained relative to historic conditions. Fish species, terrestrial species, and habitats are tolerant beyond the historic levels of salinity in the southern Delta. Furthermore, salinity is expected to remain within general historical conditions because the salinity objective at Vernalis would continue to be met. As such, impacts would not occur.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Have a substantial adverse effect on any riparian habitat or other sensitive natural community identified in local or regional plans, policies, and regulations or by the California Department of Fish and Game or U.S. Fish and Wildlife Service?	☑	❒	❒	❒

Discussion

Flow: Potential impacts on terrestrial biological resources resulting from changes in river volume or rates or reservoir fluctuations in the plan area and extended plan area associated with flow requirements are considered potentially significant and are addressed in SED Chapter 8, *Terrestrial Biological Resources*.

Southern Delta Water Quality: Salinity in the southern Delta would not affect terrestrial or aquatic habitat in the plan area because salinity would be maintained relative to historic conditions. Fish species, terrestrial species, and habitats are tolerant beyond the historic levels of salinity in the southern Delta. Furthermore, salinity is expected to remain within general historical conditions because the salinity objective at Vernalis would continue to be met. As such, impacts would not occur.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Have a substantial adverse effect on federally protected wetlands as defined by Section 404 of the Clean Water Act (including, but not limited to, marsh, vernal pool, coastal, etc.) through direct removal, filling, hydrological interruption, or other means?	☑	❐	❐	❐

Discussion

Flow: Potential impacts on terrestrial biological resources in the plan area or extended plan area resulting from changes in river volume or rates or reservoir fluctuations associated with flow requirements are considered potentially significant and are addressed in SED Chapter 8, *Terrestrial Biological Resources*.

Southern Delta Water Quality: Salinity in the southern Delta would not affect wetland resources in the plan area as salinity is expected to remain within general historical conditions because the salinity objective at Vernalis would continue to be met. As such, impacts would not occur.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Interfere substantially with the movement of any native resident or migratory fish or wildlife species or with established native resident or migratory wildlife corridors, or impede the use of native wildlife nursery sites?	☑	❐	❐	❐

Discussion

Flow: In *California Wildlife: Conservation Challenges,* California's 2007 Wildlife Action Plan, the California Department of Fish and Wildlife (formerly the California Department of Fish and Game) (CDFG 2007) documents the significant habitat fragmentation and loss of terrestrial wildlife corridors caused by land conversion for agricultural, residential, and urban land uses. However, implementation of hydrologic regimes have not been implicated in this loss of habitat connectivity, and the implementation of the flow requirements are not expected to cause a significant adverse change in habitat connectivity. The flow requirements would not result in the conversion of riparian habitat or other sensitive natural communities to land uses that would interfere with the movement of native resident or migratory terrestrial species. The flow requirements would generally provide sufficient water for waterfowl in along the LSJR and the three eastside tributaries, which are stopovers on the Pacific Flyway. Impacts would be less than significant.

The migratory corridors for fish are three eastside tributaries and the LSJR and the southern Delta. As such, effects to the migratory corridors as a result of changes in flow, temperature, and floodplain habitat during migration periods for fish could be potentially significant and are addressed in SED Chapter 7, *Aquatic Biological Resources.*

Southern Delta Water Quality: As discussed above, the loss of terrestrial wildlife corridors is typically not associated with a change in water quality. As such, impacts would be less than significant. The existing salinity of the southern Delta would remain within the general historical range of salinity under the water quality objective. This is because the salinity objective at Vernalis would continue to be met. Moreover, the fish species are tolerant beyond these levels of salinity. Therefore, impacts would be less than significant.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
e) Conflict with any local policies or ordinances protecting biological resources, such as a tree preservation policy or ordinance?	☑	❒	❒	❒

Discussion

Flow: Potential impacts on terrestrial biological resources resulting from changes in river volume or rates,reservoir fluctuations, or a potential reduction in surface water associated with flow requirements are considered potentially significant and are addressed in SED Chapter 8, *Terrestrial Biological Resources*.

Southern Delta Water Quality: Salinity in the southern Delta would not affect terrestrial or aquatic habitat in the plan area because salinity would be maintained relative to historic conditions. Fish species, terrestrial species, and habitats are tolerant beyond the historic levels of salinity in the southern Delta. Furthermore, salinity is expected to remain within general historical conditions because the salinity objective at Vernalis would continue to be met. As such, conflicts with local policies or ordinances would not occur.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
f) Conflict with the provisions of an adopted habitat conservation plan, natural community conservation plan, or other approved local, regional, or state habitat conservation plan?	☑	❒	❒	❒

Discussion

Flow: Potential impacts on terrestrial biological resources resulting from changes in river volume,rates or reservoir fluctuations, or a potential reduction in surface water associated with flow requirements are considered potentially significant and are addressed in SED Chapter 8, *Terrestrial Biological Resources*.

Southern Delta Water Quality: Salinity in the southern Delta would not affect terrestrial or aquatic habitat in the plan area because salinity would be maintained relative to historic conditions. Fish species, terrestrial species, and habitats are tolerant beyond the historic levels of salinity in the southern Delta. Furthermore, salinity is expected to remain within general historical conditions because the salinity objective at Vernalis would continue to be met. As such, conflicts with habitat conservation plans or other plans would not occur.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
V. CULTURAL RESOURCES				
Would the project:				
a) Cause a substantial adverse change in the significance of a historical resource as defined in Section 15064.5?	☑	☐	☐	☐
b) Cause a substantial adverse change in the significance of an archaeological resource pursuant to Section 15064.5?	☑	☐	☐	☐
c) Directly or indirectly destroy a unique paleontological resource or site or unique geologic feature?	☑	☐	☐	☐
d) Disturb any human remains, including those interred outside of formal cemeteries?	☑	☐	☐	☐

Discussion of a, b, c, and d

Flow: The flow requirements would change the volume of water within the three eastside tributaries, the reservoirs, and the LSJR. The flow requirements would generally increase the volume of water in the rivers; changes in flow could result in surface water elevation fluctuations at the reservoirs in the plan area and extended plan area. If there is a high potential for historical or archeological resources, unique paleontological resources, or human remains to exist in the reservoirs or within or along the rivers, these resources could be affected by changes in river flow and reservoir surface water elevation fluctuations. Therefore, impacts would be potentially significant and are addressed in SED Chapter 12, *Cultural Resources*.

Southern Delta Water Quality: The salinity in the southern Delta would remain within the general historical range of salinity under the water quality objectives because the water quality objective for salinity at Vernalis would continue to be met. The effect on water quality has no potential to impact the significant historical, archaeological, or paleontological resources or human remains in the southern Delta. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
VI. GEOLOGY AND SOILS Would the project:				
a) Expose people or structures to potential substantial adverse effects, including the risk of loss, injury, or death involving:				
i) Rupture of a known earthquake fault, as delineated on the most recent Alquist-Priolo Earthquake Fault Zoning Map issued by the state geologist for the area or based on other substantial evidence of a known fault? (Refer to Division of Mines and Geology Special Publication 42.)	☐	☐	☐	☑
ii) Strong seismic ground shaking?	☐	☐	☐	☑
iii) Seismic-related ground failure, including liquefaction?	☐	☐	☐	☑
iv) Landslides?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives would either alter the volume of water within rivers or reservoirs in the plan area and extended plan area or maintain the historical range of water quality in the southern Delta. There are no impact mechanisms associated with these actions that could result in an impact on, or be affected by: Alquist-Priolo faults, strong seismic shaking, or seismic-related ground failure or landslides. Furthermore, altering the volume of water in a river would not substantially increase the number of people exposed to the risk of earthquakes or geologic hazards because it would not draw people to earthquake areas or geologic hazard locations not already frequented. Therefore, the flow requirements or water quality objectives would not have a substantial adverse effect on people or structures. There would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Result in substantial soil erosion or the loss of topsoil?	☐	☐	☑	☐

Discussion

Flow: The flow requirements could result in soil erosion along river banks in the plan area and extended plan area. For the bank erosion impacts, see Threshold IX(c). In addition, increased instream flow requirements could decrease surface water diversions and potentially reduce active agricultural acreage. Thus, indirect soil erosion could also result. The most common type of farmland in the plan area and, thus, the most likely type of farmland to be affected by changes to irrigation practices is designated farmland (i.e., Prime, Unique or Farmland of Statewide Importance). However, the fact that these lands may no longer be irrigated at present levels of water use does not mean they would necessarily be fallowed in perpetuity or potentially converted to non-agricultural uses. Implementation of water conservation measures could allow less water to service more acres. In addition, other less-intensive uses, such as dryland farming, deficit-irrigation (i.e., reduction in irrigation), and grazing could take place on lands that are no longer regularly irrigated. For example, some crops (e.g., alfalfa and pasture) are able to survive under deficit irrigation where only a portion of the crop water demands are met (Putnam et al. 2015a, 2015b). While there could be a decline in yield for these types of crops or a reduction in the full use of pasture, if the full water requirements were continually restricted, they could still potentially remain in agricultural use (Putnam et al. 2015a, 2015b). Finally, even some fallowed lands would be expected to retain crop stubble cover, ultimately experience vegetative regrowth, or both. This root material and regrowth would stabilize soils and serve to reduce the potential for erosion.

Currently, there is active agriculture in all three watersheds of the Stanislaus, Tuolumne, and Merced Rivers and along the LSJR. While the level of connectivity of any specific active agricultural acreage to local drainages (i.e., the ability of loose soil to be delivered to a stream) is unknown, soil disturbance associated with active agriculture practices and irrigation practices currently results in disturbance of topsoil and leads to soil erosion, primarily in the plan area. Active agricultural production, such as soil disturbance resulting from soil tillage, the harvesting of crops, and other activities, is a source of erosion and sedimentation associated (Grismer et al. 2006; O'Geen 2006; Singer 2003). Furthermore, even when soil is not being disturbed, agriculture practices often result in bare soil during the rainy season, which is more susceptible to erosion than soil with vegetation. In contrast, if lands are subject to less intensive use due to a reduction in surface water irrigation (e.g., dryland farming, deficit irrigation, or grazing), there would be no change or potentially less sedimentation and erosion. If active agriculture is reduced, there may be an initial period of increased sedimentation or erosion; however, ultimately, it is expected that the reduced tillage and other activities would result in less sedimentation and erosion. As such, reducing existing levels of soil disturbance associated with active agricultural practices and irrigation could reduce erosion and the loss of topsoil. Thus, the potential for soil erosion and sediment delivery to streams would be reduced overall. Consequently, impacts would be less than significant.

Southern Delta Water Quality: The water quality objectives would maintain the general historical range of salinity in the southern Delta and would not erode soil or loose topsoil. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Be located on a geologic unit or soil that is unstable, or that would become unstable as a result of the project, and potentially result in on- or off-site landslide, lateral spreading, subsidence, liquefaction or collapse?	☑	❒	❒	❒

Discussion

Flow and Southern Delta Water Quality: See Threshold VI(a) as impacts would be similar with respect to landslides, lateral spreading, liquefaction and collapse. The flow requirements or water quality objectives would not be located on a geologic unit or soil that is unstable or would become unstable, as such, there would be no impacts. However, groundwater overdraft is known to occur in the southern portion of the plan area as a result of groundwater pumping. Therefore, impacts would be potentially significant and land subsidence as it relates to groundwater is discussed in Chapter 9, *Groundwater Resources*.

Southern Delta Water Quality: See Threshold VI(a) as impacts would be similar; there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Be located on expansive soil, as defined in Table 18-1-B of the Uniform Building Code (1994), creating substantial risks to life or property?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: See Threshold VI(a), as impacts would be similar. The flow requirements or water quality objectives would not result in an impact on, or be affected by, expansive soils. Accordingly, the flow requirements or water quality objectives would not create substantial risks to life or property as a result of expansive soil. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
e) Have soils incapable of adequately supporting the use of septic tanks or alternative waste water disposal systems where sewers are not available for the disposal of waste water?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: See Threshold VI(a) as impacts would be similar. The flow requirements or water quality objectives would not involve the use of septic tanks or alternative wastewater disposal systems. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
VII. GREENHOUSE GAS EMISSIONS				
Would the project:				
a) Generate greenhouse gas emissions, either directly or indirectly, that may have a significant impact on the environment?	☑	☐	☐	☐

Discussion

Flow: The flow requirements have the potential to change flows on existing rivers that generate hydroelectric power in the plan area and extended plan area. The flow requirements may reduce surface water diversions or may increase exports. A potential change in hydroelectric power generation, change in surface water diversions, or a potential increase in exports could result in a change to existing greenhouse gas generation. As discussed above in Threshold III, existing regulations for emitting criteria pollutants requires offsetting emissions based on the permit of the emitting source. However, greenhouse gases are not managed or regulated in this manner in California. Therefore, impacts would be potentially significant and are addressed in SED Chapter 14, *Energy and Greenhouse Gases*.

Southern Delta Water Quality: The general historical range of salinity in the southern Delta would remain unchanged under the water quality objectives. It would not result in emitting greenhouse gas emissions. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Conflict with an applicable plan, policy or regulation adopted for the purpose of reducing the emissions of greenhouse gases?	☑	❐	❐	❐

Discussion

Flow: See discussion in Threshold VII(a), as impacts would be similar. Impacts would be potentially significant and are addressed in SED Chapter 14, *Energy and Greenhouse Gases*.

Southern Delta Water Quality: See discussion in Threshold VII(a), as impacts would be similar; there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
VIII. HAZARDS AND HAZARDOUS MATERIALS				
Would the project:				
a) Create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: Hazardous materials are generally the raw materials for industrial or commercial products or processes that may be classified as toxic, flammable, corrosive, or reactive. The flow requirements or water quality objectives would not involve the transport, use, or disposal of hazardous materials. The flow requirements would change the volume of water within existing rivers and reservoirs in the plan area and extended plan area. The water quality objectives for salinity would maintain the general historical range of salinity in the southern Delta. Neither of these actions involves hazardous materials. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Create a significant hazard to the public or the environment through reasonably foreseeable upset and accident conditions involving the release of hazardous materials into the environment?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: See Threshold VIII(a) as impacts would be similar; there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Emit hazardous emissions or handle hazardous or acutely hazardous materials, substances, or waste within one-quarter mile of an existing or proposed school?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: See Threshold VIII(a) as impacts would be similar; there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Be located on a site which is included on a list of hazardous materials sites compiled pursuant to Government Code Section 65962.5 and, as a result, would it create a significant hazard to the public or the environment?	❒	❒	❒	☑

Discussion

Flow: A search was conducted to identify the presence of a Cortese Site (sites compiled as being hazardous materials sites under Government Code, § 65962) for the counties within the plan area and extended plan area (CalEPA 2016). There were no sites identified for Alpine, Calaveras, Tuolumne, or Mariposa Counties on the Hazardous Waste and Substance Site List compiled into the EnviroStor online database managed by the Department of Toxic Substances Control (DTSC) (CalEPA 2016). There were a total of 19 sites identified for Madera, Merced, San Joaquin, and Stanislaus Counties. Of these sites, only two were in proximity to the rivers, rim dams, or other reservoirs in the plan area or extended plan area. These two include sites at the Port of Stockton within close proximity to the LSJR (CalEPA 2016). The flow requirements would not have the potential to modify these sites given the flows would not occur outside of the channels of the river and the Port of Stockton regulates the flows of the river. In addition to these sites identified by the EnviroStor database, CalEPA also identifies leaking underground storage tank sites, sites that have received cease and desist orders (CDOs) or clean up abatement orders (CAOs), and hazardous waste facilities where DTSC has taken corrective action (CalEPA 2016). There are no hazardous waste facility sites where DTSC has taken corrective action in the plan area or extended plan area (CalEPA 2016). As such, the flow requirements would not affect them. There are approximately 276 active open leaking underground storage tanks in the plan area and extended plan area (CalEPA 2016). There are approximately 60 facilities in the plan area and extended plan area have received CDOs/CAOs not identified as non-hazardous wastes, domestic wastewater or domestic sewage in the plan area and extended plan area (CalEPA 2016). The active and open leaking underground storage tank cases and the CDO/CAO facilities are located throughout the plan area and extended plan area. However, similar to the Hazardous Waste and Substance Sites, the flow requirements would not have the potential to modify these sites because the flows would not occur outside the channels of the river. Therefore, there would be no impacts.

Southern Delta Water Quality: The salinity of the southern Delta would remain within the general historical range of salinity under the water quality objectives because the water quality objective for salinity at Vernalis would continue to be met. Water quality does not have the potential to affect a site on the Cortese List. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within two miles of a public airport or public use airport, would the project result in a safety hazard for people residing or working in the project area?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements would result in a change in volume of water in existing reservoirs and rivers in the plan area and extended plan area. The water quality objectives would maintain the general historical range of salinity within in the southern Delta. Neither of these actions have the potential to result in an increased capacity at existing airports, a safety hazard to existing airports, or be in conflict with an airport land use plan. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
f) For a project within the vicinity of a private airstrip, would the project result in a safety hazard for people residing or working in the project area?	❐	❐	❐	☑

Discussion

Flow and Southern Delta Water Quality: As described in Threshold VIII(e), the flow requirements or water quality objectives do not involve elements that could increase air traffic volumes or cause a conflict with existing private airstrips. Therefore, neither of these plan amendments has the potential to result in a safety hazard to private airstrips. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?	❐	❐	❐	☑

Discussion

Flow: Under the National Dam Safety Program Act of 1996, dam owners are responsible for preparing and implementing emergency action plans (EAPs) for potential dam failures based on guidelines of the Federal Emergency Management Agency (FEMA) or the Federal Energy Regulatory Commission (FERC) for hydropower projects (FERC 2007) in the plan area and extended plan area. EAPs do the following: (1) specify preplanned actions to be taken by dam owners to moderate or alleviate problems at a dam, (2) contain procedures and information for issuing early warning and notification messages to responsible downstream emergency management authorities of an emergency situation, and (3) include inundation maps to show the emergency management authorities the critical areas that require action in case of an emergency. EAPs are periodically updated by dam owners based on changes, such as new contact personnel, and are required to be redistributed to all involved parties every 5 years. The flow requirements could shift the timing of reservoir operations (e.g., flows and storage levels), but the dams would continue to operate within their current design capabilities and specifications. Since the EAPs account for a wide variety of flow scenarios and are regularly updated, the flow requirements would not impair or physically interfere with these adopted emergency plans. Therefore, there would be no impacts.

Southern Delta Water Quality: The general historical salinity range in the southern Delta would be maintained under the water quality objectives because the water quality objective for the salinity objective at Vernalis would continue to be met. Because the salinity objective would continue to be met without additional flows, the salinity objective would not impair or physically interfere with adopted emergency response or evacuation plans. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?	❐	❐	❐	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements would result in a change in volume of water in existing reservoirs and rivers in the plan area and extended plan area. The general historical salinity range in the southern Delta would be maintained under the water quality objectives because the water quality objective for salinity at Vernalis would continue to be met. The flow requirements and water quality objectives would not involve the construction or operation of housing or the intermixing of residences with wildlands and would not involve increasing the number of people who may be exposed to wildland fires. Therefore, there would be no impacts.

The flow requirements may result in a change in the type of agricultural lands in the plan area as a result of potential modifications to surface water diversions, resulting in fewer acres irrigated. However, agricultural land is typically located in areas with few people or structures and areas with very little wildfire potential (i.e., flat, non-wooded lands) and therefore, it is not expected that this would result in an increase in exposure of people or structures to loss involving wildfires. Therefore, there would be no impacts.

Heavily forested or vegetated areas exist in parts of the plan area and most of the extended plan area. These areas have experienced several forest fires within the past few years. Per Public Resources Code Section 4291 it is required that communities and residences located in State Responsibility Areas (SRAs) clear defensible space around homes and buildings to avoid loss associated with wildfires and follow the requirements of this defensible space (BOF 2006). The defensible space is not irrigated or watered, but rather is a complete clearing of vegetation from around structures to reduce or prevent the risk of damage during a fire. SRAs are areas where the State of California has the primary financial responsibility for the prevention and suppression of wildland fires (BOF 2012a). SRAs are identified parts of Calaveras, San Joaquin, Stanislaus, Tuolumne, Mariposa, and Madera Counties in the plan area and extended plan area (BOF 2012a). In addition, the State of California has identified Very High Fire Hazard Severity Zones the plan area or extended plan area of following counties Calaveras, Tuolumne, Mariposa, and Madera (CALFIRE 2007). These designations allow the State to make recommendations to the local jurisdictions and the government code (Sections 51175–51982) then provides direction for the local jurisdiction to take appropriate actions to help reduce and control the potential for fire (BOF 2012b). This includes the enforcement of the defensible space requirements (BOF 2012b). The flow requirements may result in a change in reservoir storage in the extended plan area; however, these changes would not alter the requirements of the state and local agencies to enforce defensible space requirements and other requirements to reduce the potential for fire and control fires. Water would continue to be available in either reservoirs or rivers to fight potential forest fires. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
IX. HYDROLOGY AND WATER QUALITY				
Would the project:				
a) Violate any water quality standards or waste discharge requirements?	☑	❐	❐	❐

Discussion

Flow: The flow requirements would result in a change in the volume of water in existing reservoirs and rivers in the plan area and extended plan area and would not result in a violation of existing waste discharge requirements. The flow requirements could change the number of exceedances of water quality standards currently experienced at the interior southern Delta compliance stations in the plan area. Further a change in reservoir elevations could potentially result in a violation of water quality standards in the extended plan area. Potentially significant impacts are addressed in SED Chapter 5, *Surface Hydrology and Water Quality*. In addition, potential impacts on drinking water quality are discussed in SED Chapter 13, *Service Providers*.

Southern Delta Water Quality: While the water quality objectives would establish salinity levels to protect agricultural beneficial uses in the southern Delta, potential exceedances of water quality standards may be possible when combined with the flow requirements. As such, impacts would be potentially significant and are addressed in SED Chapter 5, *Surface Hydrology and Water Quality*. In addition, potential impacts on drinking water quality are discussed in SED Chapter 13, *Service Providers*.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table level (e.g., the production rate of pre-existing nearby wells would drop to a level which would not support existing land uses or planned uses for which permits have been granted)?	☑	❐	❐	❐

Discussion

Flow: The flow requirements could reduce the amount of surface water diversions on the three eastside tributaries in the plan area and extended plan area. This could result in a potential increase in groundwater use to accommodate any potential reduction in surface water diversions. Therefore, impacts would be potentially significant and are addressed in SED Chapter 9, *Groundwater Resources*.

Southern Delta Water Quality: Agricultural users in the southern Delta apply water to irrigate their crops. Some of the agricultural users apply additional water to reduce the salts in the root zone of the crops. However, this water comes primarily from surface water diversions (e.g., the southern Delta channels). Therefore, a change in groundwater pumping would not be expected because most of the irrigation water comes from surface water diversions and would continue to come from surface water diversion. There would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or offsite?	☑	❒		❒

Discussion

Flow: The potential changes in flow conditions under flow requirements could alter the existing drainage patterns of the rivers in the plan area or extended plan area, resulting in substantial erosion or siltation. Therefore, impacts would be potentially significant and are addressed in SED Chapter 6, *Flooding, Sediment and Erosion*.

Southern Delta Water Quality: The salinity of the southern Delta would remain within the general historical range of salinity under the salinity objectives because the water quality objective for salinity at Vernalis would continue to be met. Maintaining water quality would not substantially alter the existing drainage pattern of a site or area. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Substantially alter the existing drainage pattern of the site or area, including through the alteration of the course of a stream or river, or substantially increase the rate or amount of surface runoff in a manner which would result in flooding on- or offsite?	☑	❒	❒	❒

Discussion

Flow: The flow requirements could change the volume of water in existing reservoirs and rivers during different times of year, which could alter the drainage patterns of the rivers and potentially result in flooding in the plan area or extended plan area. Therefore, impacts would be potentially significant and are addressed in SED Chapter 6, *Flooding, Sediment and Erosion*.

Southern Delta Water Quality: The salinity of the southern Delta would remain within the general historical range of salinity under the water quality objectives because the water quality objective for salinity at Vernalis would continue to be met. Maintaining water quality would not substantially alter the volume of water in the southern Delta and thus would not result in an increase in flooding. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
e) Create or contribute runoff water which would exceed the capacity of existing or planned stormwater drainage systems or provide substantial additional sources of polluted runoff?	❒	❒	❒	☑

Discussion

Flow: The flow requirements could result in a change in the amount of surface water stored in the existing reservoirs or released to the rivers in the plan area and extended plan area. However, the amount of stormwater generated within the watersheds, collected, or discharged to surface waters would remain the same as baseline. Furthermore, the flow requirements would not modify the existing stormwater collection system (e.g., storm sewers or detention basins). Therefore, there would be no impacts.

Southern Delta Water Quality: The salinity of the southern Delta would remain within the general historical range of salinity under the water quality objectives because the water quality objective for salinity at Vernalis would continue to be met. Furthermore, agricultural users are expected to continue using surface water sources to irrigate agricultural crops. Thus, the water quality objectives would not create or contribute runoff that would exceed the capacity of existing or planned stormwater drainage systems or provide substantial sources of polluted runoff. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
f) Otherwise substantially degrade water quality?	☑	❒	❒	❒

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives could substantially change water quality in the southern Delta such that beneficial uses (i.e., agriculture) are impaired. In addition, the flow requirements could result in a change in contaminant concentrations in the plan area and extended plan area and, thus, substantially degrade water quality. Therefore, impacts would be potentially significant and are addressed in SED Chapter 5, *Surface Hydrology and Water Quality*.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
g) Place housing within a 100-year flood hazard area as mapped on a federal Flood Hazard Boundary or Flood Insurance Rate Map or other flood hazard delineation map?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives would not result in the development of housing. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
h) Place within a 100-year flood hazard area structures which would impede or redirect flood flows?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives would not result in the development of structures. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
i) Expose people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a levee or dam?	☑	❒	❒	❒

Discussion

Flow: As discussed in Threshold VIII(g), dams in the plan area and extended plan area would continue to operate as they currently do and within their current design capabilities and specifications. The flow requirements could shift the timing of reservoir operations (e.g., flows and storage levels) in the plan area and extended plan area, but the dams would continue to operate within their current design capabilities and specifications. EAPs, as discussed in Threshold VIII(g), are prepared to avoid potential dam failures, based on FEMA or FERC guidelines, and account for a wide variety of flow scenarios. Therefore the flow requirements would not result in flooding due to the failure of a levee or dam. However, flooding with respect to river levees and downstream river channel capacities and potentially exposing people to flooding is addressed in SED Chapter 6, *Flooding, Sediment and Erosion*, in conjunction with the discussion of Threshold IX(d).

Southern Delta Water Quality: As discussed in Threshold IX(d), the water quality objectives would not result in flooding. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
j) Inundation by seiche, tsunami, or mudflow	☐	☐	☐	☑

Discussion

Flow: The plan area and extended plan area are not located inland and not along the coast; therefore, it is not susceptible to tsunamis or inundation by tsunamis. A seiche is an oscillation of the surface of a landlocked body of water that varies in period from a few minutes to several hours that is caused by ground movement generated by meteorological effects (e.g., wind) or earthquakes. Currently, the existing reservoirs are susceptible to seiches. The flow requirements would not increase the risk of seiches at the rim reservoirs or reservoirs upstream in the extended plan area. Therefore, there would be no impacts. Mudflows generally occur in areas that have a steep relief with little vegetation and are generally caused by instances of high precipitation over short or long periods of time. Currently, the areas with steep slopes and little vegetation that experience heavy precipitation events within the watersheds of the plan area and extended plan area are already susceptible to mudflows. The flow requirements would not increase the risk of mudflows in these areas. Finally, the flow requirements would not result in bringing people to an area susceptible to seiches, tsunamis, or mudflows. In other words, people would not congregate or be located in an area exposed to these risks because of the new flow requirements. Therefore, there would be no impacts.

Southern Delta Water Quality: The salinity of the southern Delta would remain within the general historical range of salinity under the water quality objectives because the water quality objectives at Vernalis would continue to be met. Water quality does not affect the probability of or impact from of a seiche, tsunami, or mudflow. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
X. LAND USE AND PLANNING				
Would the project:				
a) Physically divide an established community?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: The new flow requirements or water quality objectives could result in a change in the volume of water within existing reservoirs or rivers or a change in the chemical properties of existing water quality. Neither of these two changes would physically divide an established community. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the project (including, but not limited to the general plan, specific plan, local coastal program, or zoning ordinance) adopted for the purpose of avoiding or mitigating an environmental effect?	☑	❒	❒	❒

Discussion

Flow and Southern Delta Water Quality: As discussed in Threshold II(a) the flow requirements could result in physical environmental effects associated with reducing surface water diversions that serve irrigated agricultural lands, primarily in the plan area. Salt-sensitive crops, such as dry beans, could be affected within the southern Delta in the plan area. Therefore there could be potentially significant impacts related to conflicts with land use plans or policies to protect or preserve agricultural lands. These issues, including potential impacts on salt-sensitive crops, are addressed in SED Chapter 11, *Agricultural Resources*.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Conflict with any applicable habitat conservation plan or natural community conservation plan?	☑	❐	❐	❐

Discussion

Flow and Southern Delta Water Quality: Similar to Threshold IV(f) the flow requirements have the potential to result in changes in water level fluctuations around the reservoirs and in the rivers, affecting existing sensitive or special status habitat, plants, or species. This impact would be potentially significant and is addressed in Chapter 8, *Terrestrial Biological Resources*.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
XI. MINERAL RESOURCES				
Would the project:				
a) Result in the loss of availability of a known mineral resource that would be of value to the region and the residents of the state?	❐	❐	❐	☑

Discussion

Flow: Mineral resource recovery sites exist on the rivers in the plan area and the extended plan area (Clinkenbeard 1999; Clinkenbeard 2012; Higgins and Dupras 1993; Rapp, Loyd, and Silva 1977; Smith and Clinkenbeard 2012). The flow requirements may affect when existing mineral resources can be accessed, though the flows would not eliminate the availability of those known mineral resources that would be of value to the region or the residents of the state. Furthermore, any mineral resource recovery site on one of the rivers already experiences high peak flows, and the peak flows under the flow requirements would be similar to existing high peak flows. Thus, a change to the timing and frequency of higher flow events would not restrict the availability of a known mineral resource. Therefore, there would be no impacts.

Southern Delta Water Quality: The water quality objectives would maintain the general historical range of salinity in the southern Delta. There would be no activities that would result in the loss of availability of a mineral resource. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Result in the loss of availability of a locally-important mineral resource recovery site delineated on a local general plan, specific plan or other land use plan?	❐	❐	❐	☑

Discussion

Flow: As discussed in Threshold XI(a) there are mineral resources sites (primarily gravel and aggregate) on the rivers within the plan area and extended plan area (Clinkenbeard 1999; Clinkenbeard 2012; Higgins and Dupras 1993; Rapp, Loyd, and Silva 1977; Smith and Clinkenbeard 2012). The California Surface Mining and Reclamation Act (SMARA) requires the State Geologist to classify land into Mineral Resource Zones, according to the known or inferred mineral potential of existing land. The primary goal of mineral land classification is to ensure that the mineral potential of land is recognized by local government decision-makers and considered before land use decisions are made that could preclude mining. Local general plans, specific plans and other local plans refer to, and use the information produced by the State Geologist to identify mineral resources because they are specialized evaluations and because the California geologic survey is the designated agency to perform these surveys under SMARA. As such, impacts would be similar to those disclosed in Threshold XI(a); there would be no impacts.

Southern Delta Water Quality: See Threshold XI(a) as impacts would be similar; there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
XII. NOISE				
Would the project result in:				
a) Exposure of persons to or generation of noise levels in excess of standards established in the local general plan or noise ordinance, or applicable standards of other agencies?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements would result in a change in volume of water in existing reservoirs and rivers in the plan area and extended plan area. The water quality objectives would maintain the general historical range of salinity in the southern Delta. Neither plan amendments would generate noise. Therefore, they do not have the potential to expose people to noise levels in excess of existing noise standards. Thus, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Exposure of persons to or generation of excessive groundborne vibration or groundborne noise levels?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements and water quality objectives would not expose people to groundborne vibrations or groundborne noise because they would adjust the amount of water in rivers and reservoirs and would maintain the general historical salinity in the southern Delta. Thus, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) A substantial permanent increase in ambient noise levels in the project vicinity above levels existing without the project?	❐	❐	❐	☑

Discussion

Flow and Southern Delta Water Quality: See Threshold XII(a) for a discussion as impacts would be similar; there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) A substantial temporary or periodic increase in ambient noise levels in the project vicinity above levels existing without the project?	❐	❐	❐	☑

Discussion

Flow and Southern Delta Water Quality: See Threshold XII(a) for a discussion as impacts would be similar; there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
e) For a project located within an airport land use plan or, where such a plan has not been adopted, within 2 miles of a public airport or public use airport, would the project expose people residing or working in the project area to excessive noise levels?	❐	❐	❐	☑

Discussion

Flow and Southern Delta Water Quality: See Thresholds VIII(e) and VIII(f) for a discussion as impacts would be similar. The flow requirements or water quality objectives do not involve elements that could affect airports and would not expose people to excessive noise levels. Thus, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
f) For a project within the vicinity of a private airstrip, would the project expose people residing or working in the project area to excessive noise levels?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: See Threshold VIII(f) for a discussion as impacts would be similar. The flow requirements or water quality objectives do not involve elements that could affect private airstrips and would not expose people to excessive noise levels. Thus, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
XIII. POPULATION AND HOUSING Would the project:				
a) Induce substantial population growth in an area, either directly (for example, by proposing new homes and businesses) or indirectly (for example, through extension of roads or other infrastructure)?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements or salinity objectives would not involve the construction of new homes or businesses that may induce substantial property growth in an area. Furthermore, the flow requirements or salinity objectives would not develop any amenities (e.g., malls, amusement parks, hotels) that would attract people to the plan area. Therefore, there would be no impacts.

However, as required by CEQA (State CEQA Guidelines § 15126.2, subd. (d)) growth-inducing effects are discussed in SED Chapter 17, *Cumulative Impacts, Growth-Inducing Effects, and Irreversible Commitment of Resources.*

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Displace substantial numbers of existing housing, necessitating the construction of replacement housing elsewhere?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives would change the volume of water or maintain the existing historical range of salinity, neither of which would involve displacement of a substantial number of housing units or disrupt or divide an established community nor necessitate the construction of replacement housing elsewhere. The percent of unimpaired flow requirement would not apply in a tributary during periods when flows from that tributary could cause or contribute to flooding or other related public safety concern. Therefore, flood releases from the three reservoirs would continue as they currently do and would not increase the flood risk that may cause housing displacement. There would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Displace substantial numbers of people, necessitating the construction of replacement housing elsewhere?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: See Thresholds XIII(a) and (b) for a discussion as impacts are similar. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
XIV. PUBLIC SERVICES				
Would the project:				
a) Result in substantial adverse physical impacts associated with the provision of new or physically altered governmental facilities, need for new or physically altered governmental facilities, the construction of which could cause significant environmental impacts, in order to maintain acceptable service ratios, response times, or other performance objectives for any of these public services:				
Fire protection?	☐	☐	☐	☑
Police protection?	☐	☐	☐	☑
Schools?	☐	☐	☐	☑
Parks?	☐	☐	☐	☑
Other public facilities?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: An increase in use of public services is generally associated with an increase in population. As a location's population increases, the need for additional or new public services and public service facilities generally increases. The flow requirements would result in a change in volume of water in existing reservoirs and rivers in the plan area and extended plan area. The salinity water quality objectives would maintain the general historical range of salinity in the southern Delta. The plan amendments would not include new structures, such as housing or businesses, or indirectly increase housing or businesses, and therefore would not result in an increase in population needing new or additional fire, police, or other public facilities. In addition, because the plan amendments do not include proposals for new housing, they would not generate students or increase demands for school services or facilities. Parks and other recreational facilities are discussed in Thresholds XV(a) and (b). The plan amendments would not generate increased demands for other public services, such as public transportation, hospitals, libraries, and waste management. There would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
XV. RECREATION Would the project:				
a) Increase the use of existing neighborhood and regional parks or other recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated?	☑	❒	❒	❒

Discussion

Flow: An increase in use of existing recreational facilities is typically associated with a substantial increase in the population to accommodate new recreationists. The flow requirements would not result in a substantial increase in population because they would not result in the development of housing or other population-inducing development (e.g., job centers) in the plan area and extended plan area. Therefore, there would be no impacts. However, the potential changes in flow conditions may result in reservoir drawdown, which may in turn result in decreased recreational opportunities on the reservoirs, such as boating, fishing, and swimming in the plan area and extended plan area. Recreationists may also experience a substantial degradation of visual character and quality associated with the three rim reservoirs in the plan area or reservoirs in the extended plan area. In addition, recreational boating, which currently takes place on existing reservoirs and rivers, may be affected such that boating activities move to other areas. Therefore, potentially significant recreational and visual impacts are discussed in SED Chapter 10, *Recreational Resources and Aesthetics*.

Southern Delta Water Quality: The water quality objectives would maintain the general historical range of salinity of the southern Delta. Any existing fluctuations of salinity that would continue under the water quality objectives would be imperceptible to recreationalists who are using the southern Delta for on-water activities, such as boating or kayaking. Water quality would not physically deteriorate existing recreational facilities. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Include recreational facilities or require the construction or expansion of recreational facilities which might have an adverse physical effect on the environment?	☐	☐	☑	☐

Discussion

Flow: The flow requirements would not include the development or operation of recreational facilities. An expansion of recreational facilities is typically associated with a substantial increase in the population to accommodate new recreationists. The flow requirements would not result in substantial increase in population because they would not result in the development of housing or other population-inducing development (e.g., job centers) in the plan area and extended plan area. Therefore, the flow requirements are not expected to increase the population such that there would be an expansion of recreational facilities. Impacts would be less than significant.

Southern Delta Water Quality: See XV(a) for discussion as impacts would be similar; there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
XVI. TRANSPORTATION/TRAFFIC Would the project:				
a) Conflict with an applicable plan, ordinance or policy establishing measures of effectiveness for the performance of the circulation system, taking into account all modes of transportation including mass transit and nonmotorized travel and relevant components of the circulation system, including, but not limited to, intersections, streets, highways and freeways, pedestrian and bicycle paths, and mass transit?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The construction or operation of facilities that require use by people, such as commercial buildings, residential housing, military facilities, and industrial facilities, can result in increased use of the transportation system and thus produce traffic. The flow requirements or water quality objectives would not require new construction or the operation of facilities that require use by people. Furthermore, a change in the volume of water or maintaining the historical range of salinity in the southern Delta would not result in additional transit trips and thus would not produce traffic. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Conflict with an applicable congestion management program, including, but not limited to, level of service standards and travel demand measures or other standards established by the county congestion management agency for designated roads or highways?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: As discussed in Threshold XVI(a), the flow requirements or water quality objectives would neither involve an increased use of the transportation system nor increase traffic conditions, and thus would not conflict with an applicable congestion management program. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Result in a change in air traffic patterns, including either an increase in traffic levels or a change in location, which results in substantial safety risks?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The construction or operation of facilities that require use by people, such as commercial buildings, residential housing, military facilities, and industrial facilities, can result in an increased need for air travel and thus affect air traffic patterns. Flow requirements and or water quality objectives would not involve new construction or operation of facilities used by people, and thus would not result in increased use of air transportation services, such as airplanes or helicopters. Furthermore, a change in the volume of water or maintaining the general historical range of salinity in the southern Delta would not result in additional plane trips and thus would not generate increased air traffic. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Substantially increase hazards due to a design feature (e.g., sharp curves or dangerous intersections) or incompatible uses (e.g., farm equipment)?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The construction or operation of infrastructure, such as roads or buildings, may result in increased hazards due to a design feature (e.g., sharp curve in the road) or incompatible use (e.g., use of roads by slow moving farm equipment). The flow requirements or water quality objectives would not involve the construction or operation of new roads and thus would not result in hazards associated with design features, nor would they create incompatible uses of existing roads. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
e) Result in inadequate emergency access?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: Typically during construction projects, roads are blocked or altered, which can impede emergency access and result in inadequate emergency access. The flow requirements or water quality objectives would not involve construction and thus would not block or alter roads or open space that would be used for emergency access. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
f) Conflict with adopted policies, plans, or programs regarding public transit, bicycle, or pedestrian facilities, or otherwise decrease the performance or safety of such facilities?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: See Threshold XVI(a) as impacts would be similar. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
XVII. UTILITIES AND SERVICE SYSTEMS				
Would the project:				
a) Exceed wastewater treatment requirements of the applicable regional water quality control board?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements and water quality objectives would not affect wastewater quality being discharged from existing wastewater treatment plants. Wastewater treatment plants would continue to discharge as they currently do. A potential change in the permit requirements of existing wastewater discharges is addressed in Threshold XVII(b). Applicable wastewater treatment requirements would not be exceeded. There would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Require or result in the construction of new water or wastewater treatment facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	☑	❐	❐	❐

Discussion

Flow: The flow requirements could result in a change in the volume of water in existing reservoirs or rivers in the plan area or extended plan area. A potential change in volume would not affect existing wastewater treatment facilities located along any of the existing rivers. However, the flow requirements could result in the need for new water facilities if surface water diversions to municipalities or irrigation districts are reduced. Therefore, the possible need to upgrade or expand water facilities and the potentially significant environmental effects of doing so are addressed in SED Chapter 13, *Service Providers*.

Southern Delta Water Quality: The Central Valley Water Board could modify National Pollution Discharge Elimination system permits they use to regulate wastewater treatment plant(s) point-source discharges to the southern Delta. A change to these permits could result in the need to upgrade or expand existing wastewater treatment plants, which could have potentially significant environmental effects. This possible permit change and its potential environmental effects are addressed in SED Chapter 13, *Service Providers*.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Require or result in the construction of new stormwater drainage facilities or expansion of existing facilities, the construction of which could cause significant environmental effects?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: See Threshold IX(e) for discussion regarding stormwater drainage facilities as impacts would be similar. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
d) Have sufficient water supplies available to serve the project from existing entitlements and resources, or are new or expanded entitlements needed?	❒	❒	❒	☑

Discussion

Flow: The flow requirements do not influence or change the demand for water in the plan area or extended plan area. Further, the flow requirements do not need new or expanded entitlements in the plan area or extended plan area. Therefore, there would be no impacts.

Impacts associated with the potential for the flow requirements to reduce the water supply in the plan area and extended plan area available to municipalities or irrigation districts in relation to Threshold IX(b) above (groundwater depletion) and to Threshold XVII(b) above (the need for new water treatment facilities if surface water diversions are reduced), are addressed in SED Chapter 13, *Service Providers*.

Southern Delta Water Quality: The water quality objectives would not require an additional reduction in diversions in order to meet the water quality objectives. Therefore, they would not involve water quantity. The requirement to comply with the Vernalis water quality objective for salinity is included in the baseline; therefore, the salinity objectives for Vernalis would have no effect on water supplies upstream of Vernalis. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
e) Result in a determination by the wastewater treatment provider, which serves or may serve the project, that it has adequate capacity to serve the project's projected demand in addition to the provider's existing commitments?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives would not generate wastewater beyond that which is currently generated under baseline. Therefore, the flow requirements or water quality objectives have no ability to affect the capacity of existing wastewater treatment facilities. There would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
f) Be served by a landfill with sufficient permitted capacity to accommodate the project's solid waste disposal needs?	☐	☐	☐	☑

Discussion

Flow and Southern Delta Water Quality: The flow requirements could change the volume of water within existing reservoirs and rivers in the plan area and extended plan area. This activity would not generate solid waste. The salinity objectives would maintain the general historical range of salinity in the southern Delta and would not generate solid waste. Therefore, there would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
g) Comply with federal, state, and local statutes and regulations related to solid waste?	❒	❒	❒	☑

Discussion

Flow and Southern Delta Water Quality: See XVII(f) for a discussion as impacts would be similar. There would be no impacts.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
XVIII. MANDATORY FINDINGS OF SIGNIFICANCE				
a) Does the project have the potential to degrade the quality of the environment, substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, reduce the number or restrict the range of a rare or endangered plant or animal, or eliminate important examples of the major periods of California history or prehistory?	☑	❒	❒	❒

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives have the potential to degrade the quality of the environment. Therefore, impacts would be potentially significant and this is addressed in SED Chapters 5 through 17.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
b) Does the project have impacts that are individually limited, but cumulatively considerable? ("Cumulatively considerable" means that the incremental effects of a project are considerable when viewed in connection with the effects of past projects, the effects of other current projects, and the effects of probable future projects)?	☑	❐	❐	❐

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives have the potential to result in cumulatively considerable effects. Therefore, cumulative effects are addressed in SED Chapter 17, *Cumulative Impacts, Growth-Inducing Effects, and Irreversible Commitment of Resources*.

	Potentially Significant Impact	Less Than Significant with Mitigation Incorporated	Less Than Significant Impact	No Impact
c) Does the project have environmental effects which will cause substantial effects on human beings, either directly or indirectly?	☑	❐	❐	❐

Discussion

Flow and Southern Delta Water Quality: The flow requirements or water quality objectives have the potential to result in some substantial effects on human beings as described above in the various resource area sections where potentially significant effects have been identified, and these are addressed in SED Chapters 5 through 17.

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Sections 21083 and 21087.

Public Resources Code Cited

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Appendix C

Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives

State Water Resources Control Board
California Environmental Protection Agency

TECHNICAL REPORT ON THE SCIENTIFIC BASIS FOR ALTERNATIVE SAN JOAQUIN RIVER FLOW AND SOUTHERN DELTA SALINITY OBJECTIVES

February 2012
(Updated June 2016)

STATE WATER RESOURCES
CONTROL BOARD
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State Water Resources Control Board
California Environmental Protection Agency

TECHNICAL REPORT ON THE SCIENTIFIC BASIS FOR ALTERNATIVE SAN JOAQUIN RIVER FLOW AND SOUTHERN DELTA SALINITY OBJECTIVES

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Acronyms and Abbreviations

2006 Bay-Delta Plan; Plan	2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary
AFRP	Anadromous Fish Restoration Program
AGR	agricultural supply
BAFF	Bio-Acoustic Fish Fence
BO	biological opinions
Bureau	U.S. Bureau of Reclamation
CALSIM II	CALSIM II San Joaquin River Water Quality Module
CDEC	California Data Exchange Center
Central Valley Water Board	Central Valley Regional Water Quality Control Board
COG	coordinated operations group
CRR	cohort return ratio
CSPA	California Sportfishing Protection Alliance
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
CWIN	California Water Impact Network
CWT	coded wire tagged
DPH	California Department of Public Health
DPS	Distinct Population Segment
dS/m	deciSiemens per meter
DSM2	Delta simulation model
DSOD	Division of Safety of Dams
DWR	California Department of Water Resources
DWSC	Stockton Deepwater Ship Channel
EC	electrical conductivity
ESA	Endangered Species Act
ESUs	Evolutionary Significant Units
FERC	Federal Energy Regulatory Commission
HOR	head of Old River
HORB	HOR barrier
IPO	Interim Plan of Operations
IRP	independent review panel
MAF	million acre-feet
MCL	Maximum Contaminant Levels
mgd	million gallons per day
MID	Modesto Irrigation District

mmhos/cm	millimhos per centimeter
MUN	Municipal and Domestic Supply
NPDES	National Pollutant Discharge Elimination System
NRDC	Natural Resources Defense Council
OMR reverse flows	Old and Middle River reverse flows
RM	river mile
RPA	Reasonable and Prudent Alternative
SED	Substitute Environmental Document
SJR	San Joaquin River
SJRA	San Joaquin River Agreement
SJRGA	San Joaquin River Group Authority
State Water Board or Board	State Water Resources Control Board
SWP	State Water Project
TBI	The Bay Institute
TDS	total dissolved solids
TNC	The Nature Conservancy
USBR	United States Bureau of Reclamation
USDOI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
VAMP	Vernalis Adaptive Management Plan
WAP	Water Acquisition Program
WSE	water supply effects
μmho/cm	micromhos per centimeter
μS/cm	microSiemens per centimeter

1 Introduction

The State Water Resources Control Board (State Water Board) is in the process of reviewing the San Joaquin River (SJR) flow objectives for the protection of fish and wildlife beneficial uses, water quality objectives for the protection of southern delta agricultural beneficial uses, and the program of implementation for those objectives contained in the 2006 Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (2006 Bay-Delta Plan). Figure 1.1 displays the project area corresponding to SJR flow objectives and program of implementation and Figure 1.2 displays the project area for the southern Delta water quality objectives and program of implementation.

The information and analytical tools described in this report (referred to hereafter as Draft Technical Report or Technical Report) are intended to provide the State Water Board with the scientific information and tools needed to consider potential changes to these objectives and their associated program of implementation. In this quasi-legislative process, State Water Board staff will propose amendments to the SJR flow objectives for the protection of fish and wildlife beneficial uses, southern Delta water quality objectives for the protection of agricultural beneficial uses, and the program of implementation contained in the 2006 Bay-Delta Plan. Also, the environmental impacts of these amendments will be evaluated in a Substitute Environmental Document (SED) in compliance with the California Environmental Quality Act. Any changes to water rights consistent with the revised program of implementation will be considered in a subsequent adjudicative proceeding.

The State Water Board released the first draft of the Technical Report on October 29, 2010. In order to receive comments and other technical information related to that draft, the State Water Board solicited public comments and held a public workshop on January 6 and 7, 2011. The purpose of the public workshop was to determine whether: 1) the information and analytical tools described in the Draft Technical Report are sufficient to inform the State Water Board's decision-making to establish SJR flow and southern Delta salinity objectives and a program of implementation to achieve these objectives; and 2) the State Water Board should consider additional information or tools to evaluate and establish SJR flow and southern Delta salinity objectives, and a program of implementation to achieve these objectives. The State Water Board received 21 comment letters on the Draft Technical Report which are available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/bay_delta_plan/water_quality_control_planning/comments120610.shtml.

The public workshop was organized into a series of panel discussions by technical experts concerning the following topics: 1) hydrologic analysis of the SJR basin; 2) scientific basis for developing alternative SJR flow objectives and a program of implementation; 3) scientific basis for developing alternative southern Delta water quality objectives and a program of implementation; and 4) water supply impacts of potential alternative SJR flow and southern Delta water quality objectives. The written comments and verbal comments made at the workshop raised a number of issues concerning the Draft Technical Report.

As a result of those comments, several edits were made and a revised draft was issued in October, 2011, which also included draft basin plan amendment language as Appendix A. That version of the Technical Report was submitted for independent scientific peer review in October of 2011. The peer review comments, in addition to other information concerning the peer review process, are available on the State Water Board's website at: http://www.waterboards.ca.gov/water_issues/programs/peer_review/sanjoaquin_river_flow.shtl

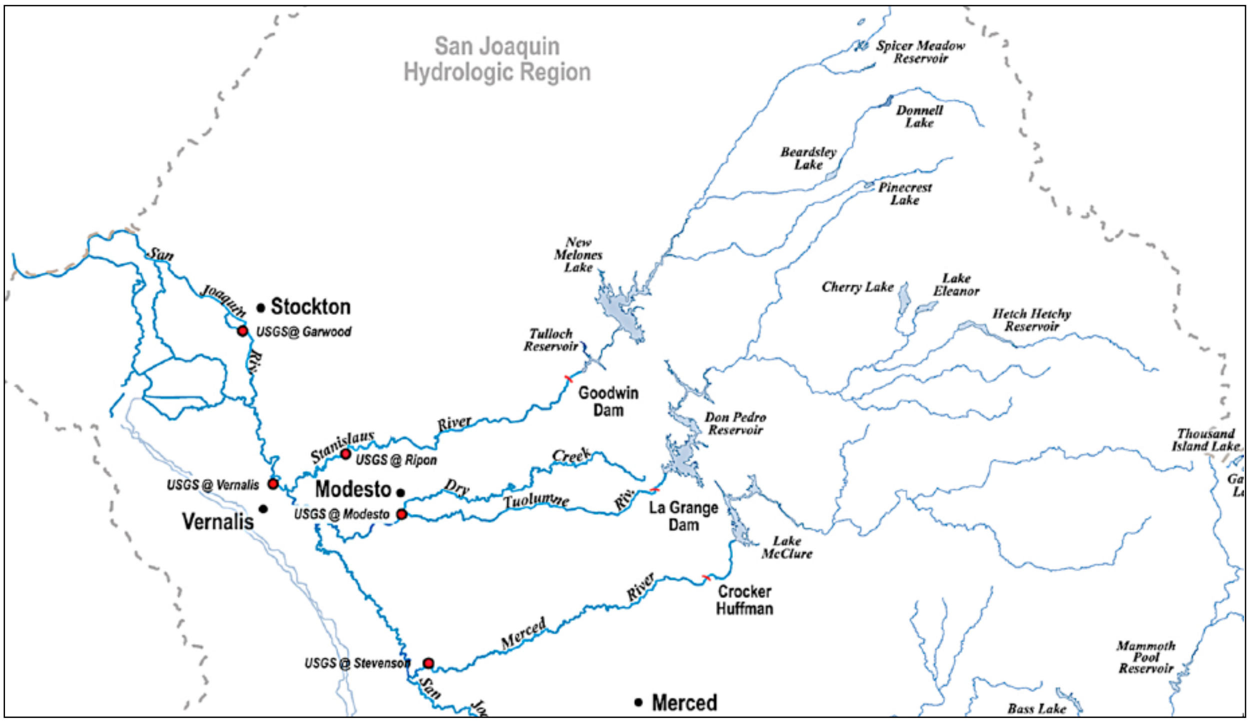


Figure 1.1. Project Area: SJR Flow Objectives

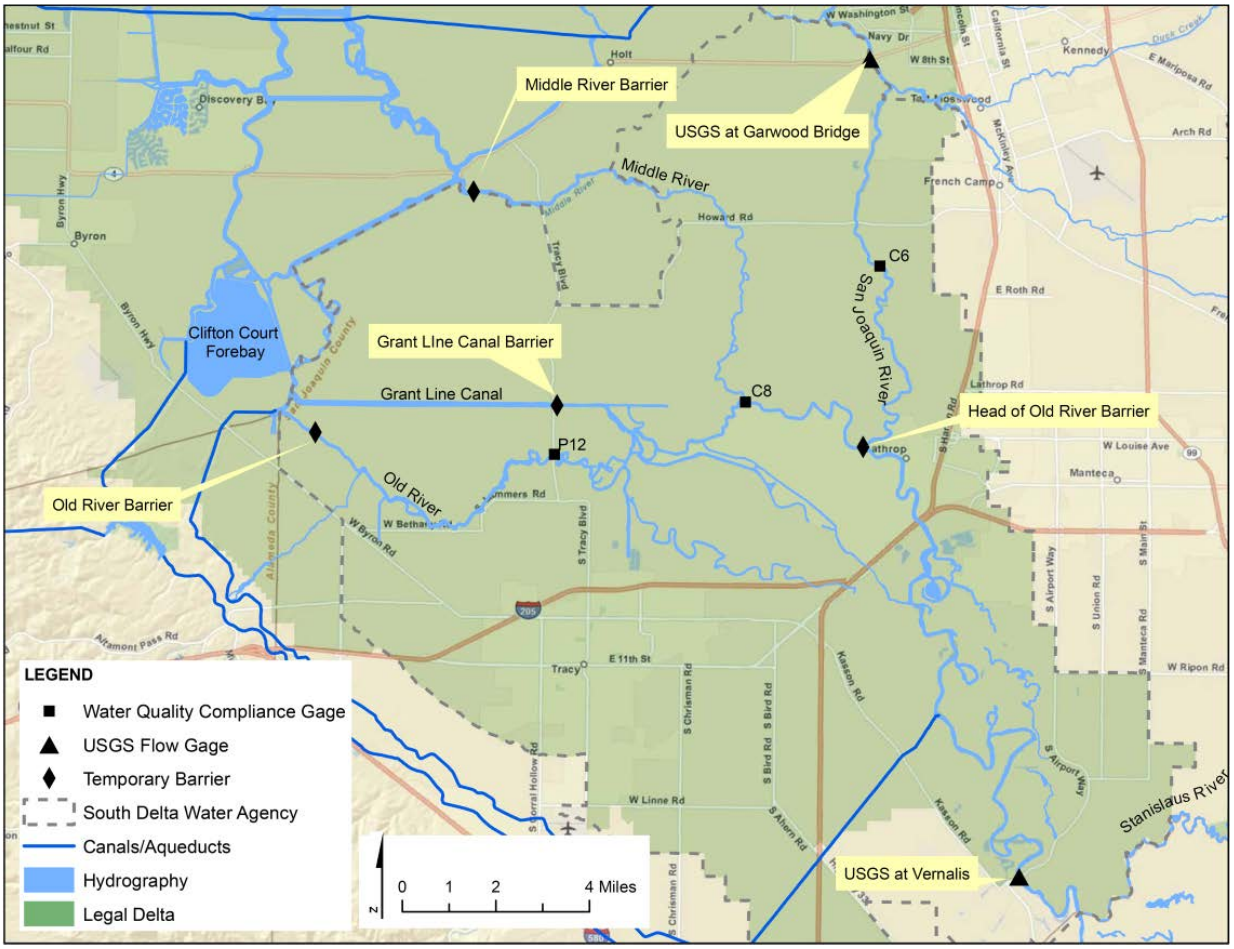


Figure 1.2. Project Area: Southern Delta Salinity Objectives, Showing Agricultural Barriers, Water Quality Compliance Stations, and Major Flow Gages

This February 2012 version of the Technical Report has been revised to address peer review comments. Not all of peer-review comments required a change in the Technical Report, but all will be addressed in a separate response to comments document. The Final Technical Report, response to comments document, and peer review findings will be included in the SED as an Appendix. Any impacts associated with the flow alternatives that are described in the Final Technical Report will be discussed in more detail in the impacts section of the appropriate resource chapter of the SED.

The following is a brief summary of the information presented in the subsequent sections of this report.

Section two provides an analysis of the flow regime within the SJR basin. The purpose of this hydrologic analysis is to describe how the magnitude, frequency, duration, timing, and rate of change of flows in the SJR and its major tributaries have been altered within the project area.

This analysis is accomplished through a comparison of observed flows against unimpaired[1] flows for each of the major tributaries in the project area (i.e., Stanislaus, Tuolumne, and Merced Rivers).

Section three provides the scientific basis for developing SJR flow objectives for the protection of fish and wildlife beneficial uses and a program of implementation to achieve those objectives. This section includes life history information and population variations for SJR fall-run Chinook salmon and Central Valley Steelhead, and flow needs for the reasonable protection of fish and wildlife beneficial uses in each of the major tributaries. Specific support for developing alternative SJR flow objectives focuses on the importance of the flow regime to aquatic ecosystem processes and species. Specifically, the Technical Report focuses on the flows needed to support and maintain the natural production of SJR fall-run Chinook salmon, identifying juvenile rearing in the tributary streams and migration through the Delta as the most critical life history stages. Flow alternatives, expressed as percentages of unimpaired flow in the juvenile rearing and migration months of February to June, represent the range of alternatives that will be further developed in the SED.

Section four provides the scientific basis for developing water quality objectives and a program of implementation to protect agricultural beneficial uses in the southern Delta, including the factors and sources that affect salinity concentrations and salt loads (mass of salt in the river), and the effects of salinity on crops. Information is provided on tools that can be used to: estimate salinity in the SJR at Vernalis and in the southern Delta; quantify the contribution of salinity from National Pollutant Discharge Elimination System (NPDES) discharges; model salinity effects on crop salt tolerance; and evaluate threshold levels for salinity impacts on the Municipal and Domestic Supply (MUN) beneficial uses.

Section five describes the tools and methods that will be used in the SED to analyze the effect of flow and southern Delta water quality alternatives on water supplies in the SJR watershed. A range of SJR and tributary flow requirement alternatives was selected to demonstrate applicability of the data, methods, and tools for analyzing the associated effects. The range of alternatives presented in this section is based on minimum flow requirements of 20%, 40%, and 60% of unimpaired flow from the SJR tributaries during the months of February through June. The range of SJR flow and southern Delta water quality alternatives will be further refined in the SED. The potential environmental, economic, water supply, and related impacts of the various alternatives will then be analyzed and disclosed prior to any determination concerning changes to the existing SJR flow and southern Delta water quality objectives and associated programs of implementation.

[1] Unimpaired flow is a modeled flow generally based on historical gage data with factors applied to primarily remove the effects of dams and diversions within the watersheds. It differs from full natural flow in that the modeled unimpaired flow does not remove changes that have occurred such as channelization and levees, loss of floodplains and wetlands, deforestation, and urbanization.

2 Hydrologic Analysis of San Joaquin River Basin

Construction of storage infrastructure (dams) and diversions have vastly altered the natural flow regime of the San Joaquin River (SJR) and its major tributaries (McBain and Trush 2000; Kondolf et al. 2001; Cain et. al 2003; Brown and Bauer 2009). The purpose of this hydrologic analysis is to describe how the magnitude, frequency, duration, timing, and rate of change of the flows in the SJR and its major tributaries have been altered within the project area. This analysis is accomplished by comparing observed flows against unimpaired flows for each of these rivers. As described in Section 2.2.2, unimpaired flows are estimated on a monthly basis for water years 1922 to 2003 by DWR, and for the purpose of this analysis, are considered to adequately portray the natural flow regime.

The SED identifies the Lower San Joaquin River (LSJR) as the portion of the SJR downstream of the Merced River confluence. The Stanislaus, Tuolumne, and Merced Rivers (LSJR tributaries), together with San Joaquin River flows into Millerton Lake (Upper SJR) are the major sources flow to the LSJR. The Chowchilla and Fresno Rivers, the Valley Floor, and Tulare Lake Basin also contribute a small portion of flow to the LSJR.

2.1 Basin Characteristics and Descriptive Studies

In the Sierra Nevada, as in other systems dependent on snow pack and snow melt, the typical components of the unimpaired flow regime generally include: fall storm flows, winter storm flows, spring snowmelt, and summer baseflows (McBain and Trush 2000; Kondolf et al. 2001; Stillwater Sciences 2001; Cain et al. 2003). These characteristics are present in the LSJR tributaries and Upper SJR in nearly all years, with wide temporal variations in magnitude throughout the year and from year to year. These characteristics are illustrated in Figure 2.1 and Figure 2.2 for a Wet water year (2005) and a Critically Dry water year (2008), respectively, for the Stanislaus River. Though the overall flow magnitudes may be different, the other characteristics of the flow regimes of the LSJR tributaries and the Upper SJR are all similar.

The mainstem of the SJR is 330 miles long from its headwaters in the Sierra Nevada Mountains to its confluence with the Sacramento River and drains an area of approximately 15,550 square miles. The SJR near Vernalis (Vernalis) is roughly the location where all non-floodplain flows from the SJR basin flow into the Delta. Vernalis is located at river mile (RM) 72, as measured from its confluence with the Sacramento River, and is upstream of tidal effects in the Delta. Table 2.1 summarizes the basin characteristics of the LSJR tributaries and Upper SJR.

The Stanislaus River flows into the mainstem SJR approximately three miles upstream of Vernalis. The Stanislaus River is 161 miles long and drains approximately 1,195 square miles of mountainous and valley terrain. Approximately 66 miles of the Stanislaus River are downstream of the New Melones Dam, 59 miles of which are downstream of Goodwin Dam, the most downstream impediment to fish passage. There are 28 Division of Safety of Dams (DSOD) dams on the Stanislaus River (and 12 additional non-DSOD dams) with a total capacity of 2.85 million acre-feet (MAF).

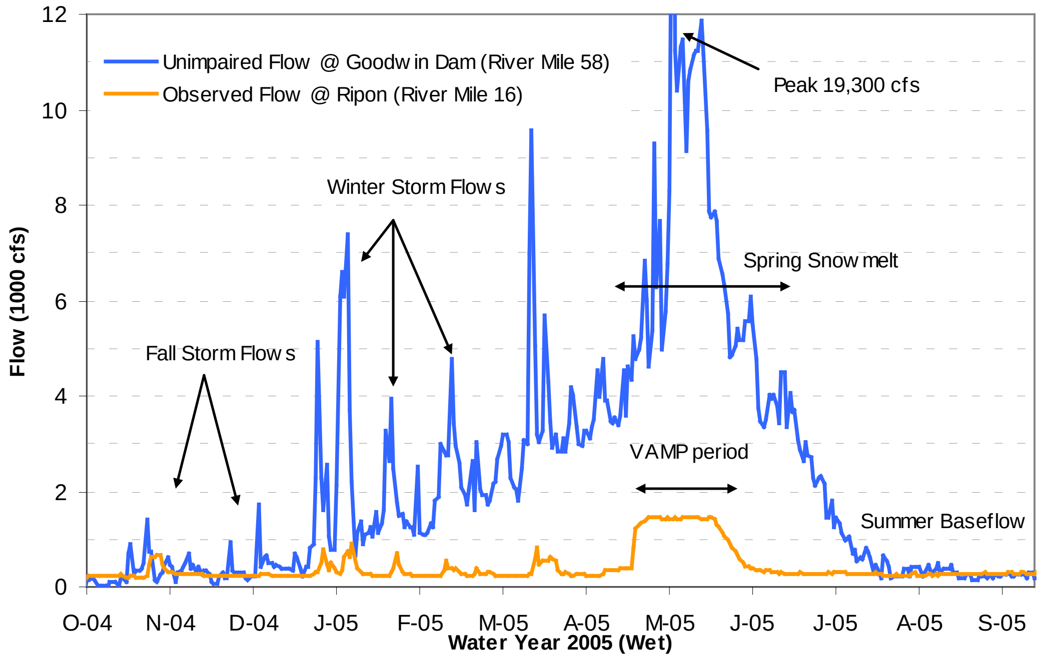


Figure 2.1. Typical Stanislaus River Annual Hydrograph of Daily Average Unimpaired and Observed Flows during a Wet Water Year (2005) Illustrating Important Hydrograph Components

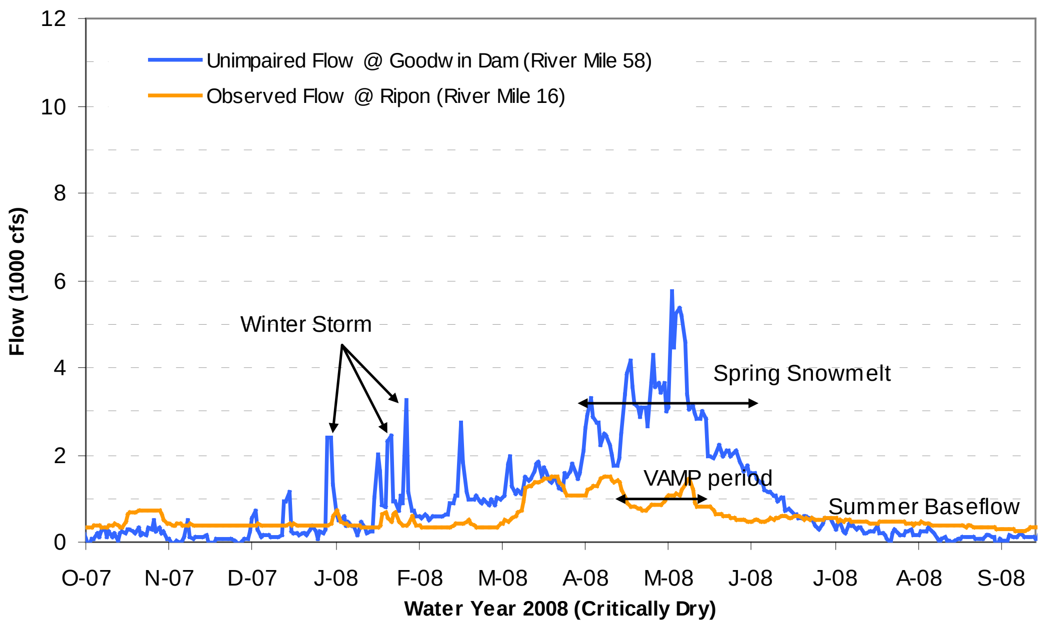


Figure 2.2. Typical Stanislaus River Annual Hydrograph of Daily Average Unimpaired and Observed Flows during a Critically Dry Water Year (2008) Illustrating Important Hydrograph Components

Table 2.1. Summary of Watershed and Dam Characteristics for each of the LSJR tributaries and Upper SJR.

Characteristic	Stanislaus River	Tuolumne River	Merced River	Upper San Joaquin River
Median Annual Unimpaired Flow (1923-2008)	1.08 MAF	1.72 MAF	0.85 MAF	1.44 MAF (upstream of Friant)
Drainage Area of Tributary at confluence with San Joaquin (and percent of tributary upstream of unimpaired flow gage)[1]	1,195 square miles (82% upstream of Goodwin)	1,870 square miles (82% upstream of La Grange)	1,270 square miles (84% upstream of Merced Falls)	5,813 square miles (28% upstream of Friant)
Total River Length and Miles Downstream of Major Dam	161 mi New Melones: 62 mi Goodwin: 59 mi	155 mi New Don Pedro: 55 mi La Grange: 52 mi	135 mi New Exchequer: 63 mi Crocker Huffman: 52 mi	330 mi Friant: 266 mi
Confluence with SJR River Miles (RM) Upstream of Sacramento River Confluence	RM 75	RM 83	RM 118	RM 118
Number of Dams[2]	28 DSOD dams[3] (12 non DSOD)	27 DSOD dams	8 DSOD dams	19 DSOD dams
Total Reservoir Storage[2]	2.85 MAF	2.94 MAF	1.04 MAF	1.15 MAF
Most Downstream Dam (with year built and capacity)[4]	Goodwin, 59 miles upstream of SJR (1912, 500 ac-ft).	LaGrange, 52 miles upstream of SJR (1894, 500 ac-ft).	Crocker-Huffman, 52 miles upstream of SJR (1910, 200 ac-ft).	Friant, 260 miles upstream of SJR (1942, 520 taf)[5]
Major Dams (with year built, reservoir capacity, and dam that it replaced if applicable)[4]	New Melones (1978, 2.4 MAF), replaced Old Melones (1926, 0.113 MAF); Tulloch, Beardsley, Donnells "Tri-dams project" (1957-8, 203 taf); New Spicer Meadows (1988, 189 taf)	New Don Pedro (1970, 2.03 MAF) replaced Old Don Pedro (1923, 290 taf); Hetch Hetchy (1923, 360 taf); Cherry Valley (1956, 273 taf)	New Exchequer (1967, 1.02 MAF), replaced Exchequer (1926, 281 taf); McSwain (1966, 9.7 taf)	Friant (1942, 520 taf); Shaver Lake (1927, 135 taf); Thomas Edison Lake (1965; 125 taf); Mammoth Pool (1960, 123 taf)

Source: Adjusted from Cain et al. 2003; [1]NRCS Watershed Boundary Dataset (2009); [2]Kondolf et. al. 1996 (adapted from Kondolf et al. 1991) as cited by Cain et al. 2003; [3]Division of Safety of Dams (DSOD) dams are those > 50 ft in height and > 50 ac-ft, [4]Cain et al. 2003; [5] No water through Gravelly Ford (RM 229) except during high runoff periods (Meade 2010).

The Tuolumne River flows into the SJR at RM 83, approximately eight miles upstream of the Stanislaus River confluence. The Tuolumne River is 155 miles long and drains an area of 1,870 square miles. Approximately 55 miles of the Tuolumne River are downstream of New Don Pedro Dam, 52 miles of which are downstream of La Grange Dam, the furthest downstream impediment to fish passage. There are 27 DSOD dams on the Tuolumne River with a total capacity of 2.94 MAF.

The Merced River flows into the SJR at RM 118, approximately 35 miles upstream of the Tuolumne River confluence. The Merced River is 135 miles long and drains a 1,270 square mile watershed. Approximately 63 miles of the Merced River are downstream of the New Exchequer Dam, 52 miles of which are downstream of Crocker Huffman Dam, the most downstream barrier to fish migration. There are eight DSOD dams on the Merced River with a total capacity of 1.04 MAF.

Additional flow enters the SJR upstream of the Merced River confluence and downstream of Friant Dam from the Chowchilla and the Fresno Rivers and the Tulare Lake Basin. These two rivers have smaller watersheds that do not extend to the crest of the Sierra Nevada Mountains and consequently, deliver a much smaller portion of flow to the SJR. In most years, no flow enters the SJR from the Tulare Lake Basin, with the exception being years with high rainfall, when the Tulare Lake Basin connects to the SJR and contributes flow to the system. Flow from these sources is discussed further in Section 2.4 of this report.

The headwaters of the SJR are on the western slope of the Sierra Nevada Mountains at elevations in excess of 10,000 feet. At the foot of the mountains, the Upper SJR is impounded by Friant Dam, forming Millerton Lake. The SJR upstream of the Merced River confluence, including the Upper SJR, and the Fresno and Chowchilla Rivers, drains a watershed area of approximately 5,800 square miles, with approximately 1,660 square miles occurring upstream of Friant Dam. There are 19 DSOD dams with a total storage capacity of 1.15 MAF in the SJR watershed upstream of the Merced River confluence.

Previous to this technical report, studies of SJR hydrology and effects on fisheries (McBain and Trush 2000; Kondolf et al. 2001; Stillwater Sciences 2001; USACE 2002; Cain et al. 2003, Brown and Bauer 2009) focused on floods and flow frequencies within the tributaries and provide less detail regarding annual, seasonal, and inter-annual trends. These studies relied primarily on historical, daily time-step gage data rather than on daily unimpaired flow for each tributary because unimpaired flow data was not readily available for all tributaries. These studies did not evaluate the possible effects of human alteration within the tributaries to flows at Vernalis.

These studies relied upon flow gage data from periods prior to major changes in the watershed as a proxy for unimpaired flows. This is often called pre-regulated flow or pre-dam flow, and generally represents flows that occurred prior to construction of a specific project or multiple projects within the water system. For example, pre-regulated flows could be the flows that existed prior to the construction of a hydroelectric or water supply reservoir. In most cases, pre-regulated flows do not fully represent unimpaired flow unless there was no development of water in the watershed for the period of time chosen by the researcher. Three potential differences or issues with using pre-regulated flow in place of unimpaired flow are: 1) each researcher may choose different periods of time to describe the alteration or pre-regulated period, 2) it is nearly impossible to obtain observed flows for time periods prior to all modifications, and 3) depending on the time period used, that time period may bias the results due to differences in climate, and/or decadal trends when comparing pre-regulated and present-day periods. In contrast, use of unimpaired flow allows for a more direct comparison with, and assessment of, the magnitude of alteration of flows relative to past conditions.

The appendices to *San Joaquin Basin Ecological Flow Analysis* by Cain et al. (2003) contain comprehensive hydrologic analyses of the hydrology of the SJR basin focusing on the LSJR tributaries and Upper SJR. The investigators used various approaches to analyze the hydrology of the SJR basin including a Hydrograph Component Analysis and an analysis using Indicators of Hydrologic Alteration. The Hydrograph Component Analysis on the LSJR tributaries and the Upper SJR (Appendix B of Cain et al. [2003]) was done by taking the unimpaired flow hydrograph and segregating various components (roughly seasonal) based on similar specific characteristics important to the natural ecosystem (Figure 2.1 and Figure 2.2). When unimpaired flow is not available, previous researchers have often separated the historical data into assorted periods that represent varying degrees of watershed modifications, such as the construction of dams and diversions. In some instances, the earlier gaged flows may represent natural flow; however, given that early settlement and diversions within the Central Valley began in the mid-19th century, historical flows may not fully represent unimpaired flow. The Hydrograph Component Analysis in Appendix B of Cain et al. (2003) was based on available unimpaired flow estimates for the Tuolumne and the Upper SJR, and observed flow from early periods representing less modified and/or pre-dam conditions for the Merced and Stanislaus Rivers.

The Nature Conservancy (TNC) developed the Indicators of Hydrologic Alteration software to calculate a set of metrics that evaluate magnitude, timing, and frequency of various events. Such metrics include annual peak daily flow, 30-day peak flow, annual minimum flow, and 30-day minimum flow among several others (Richter et al. 1996, 1997; Cain et al. 2003, TNC 2005). At the time of the Cain et al. 2003 study, daily unimpaired data was only available for the Tuolumne River, thus the Indicators of Hydrologic Alteration analysis used gage data from earlier periods to best represent pre-dam conditions in lieu of unimpaired data, and compared these to post-dam conditions. Brown and Bauer (2009) also completed an Indicators of Hydrologic Alteration analysis for the SJR basin.

2.2 Hydrologic Analysis Methods

This report presents annual, inter-annual, and seasonal components of the unimpaired annual hydrograph and compares these to present-day observed conditions. Specifically, it focuses on changes in magnitude, duration, timing, and frequency of flows to assess what alterations have occurred. To characterize present-day conditions, this analysis uses newly available information along with historical observed data from various United States Geological Survey (USGS) and California Department of Water Resources (DWR) gages, and extends portions of the analyses conducted by previous investigators. Unimpaired flow data is developed by DWR as described in more detail below.

2.2.1 Selection of Flow Data and Gages

This report uses the USGS gages located at the most downstream location for each of the LSJR tributaries, the Upper SJR, and at Vernalis to characterize historical observed flows. The most downstream gage was selected in order to account for as many diversions and return flows as possible in each of the tributaries (primarily within the Tuolumne and Merced Rivers). In general, the flows measured by the selected gages represent flows originating within the river basin; however, there are some inter-basin transfers. For example, the Highline Canal transfers drainage and urban runoff from the Tuolumne River watershed to the Merced River through the

High Line Spill. This report does not attempt to adjust for differences among river basins resulting from inter-basin transfers or return flows and other accretions from the valley floor entering downstream between the gage and the confluence with the SJR. A summary of gages used in this analysis is provided in Table 2.2.

Table 2.2. Streamflow and Gage Data used in Hydrologic Analysis and Sources of Data

Flow Data	Location/Gage No.	Source/ Reporting Agency	Dates Available and Source
Vernalis Monthly Unimpaired Flow	Flow at Vernalis	DWR	1922 to 2003[2]; 2004 to Present[1]
Vernalis Daily and Monthly Observed Flow	USGS #11303500	USGS	1923 to Present[3, 4]
Garwood Daily Observed Flow.	USGS # 11304810	USGS	1995 to Present[3]
Stanislaus Monthly Unimpaired Flow	Inflow to New Melones	DWR	1922 to 2003[2]; 2004 to Present[1]
Stanislaus Daily and Monthly Observed Flow	USGS #11303000	USGS	1940 to 2009[3]; 2009 to Present[1]
Tuolumne Monthly Unimpaired Flow	Inflow to Don Pedro	DWR	1922 to 2003[2]; 2004 to Present[1]
Tuolumne Daily and Monthly Observed Flow	USGS #11290000	USGS	1940 to Present[3]
Merced Monthly Unimpaired Flow	Inflow to Exchequer	DWR	1922 to 2003[2]: 2004 to Present[1]
Merced Daily and Monthly Observed Flow	USGS #11272500	USGS	1940 to 1995, 2001 to 2008[3]; 1995 to 1999, 2008 to Present[1]
Upper SJR Monthly Unimpaired Flow	Inflow to Millerton Lake	DWR	1922 to 2003[2]: 2004 to Present[1]
Upper SJR Daily and Monthly Observed Flow	USGS#11251000	USGS	1907 to Present[3]

[1] Source: CDEC Website: http://cdec.water.ca.gov/selectQuery.html (DWR 2010a)
[2] Source: DWR 2007a
[3] Source: USGS Website: http://wdr.water.usgs.gov/nwisgmap/ (USGS 2010)
[4] No data from October, 1924 to September, 1929.

2.2.2 Unimpaired Flow Sources and Calculation Procedures

This report uses unimpaired flow estimates for comparisons to the historical data from the LSJR tributary and Upper SJR gages. Unimpaired flow is the flow that would have occurred had the natural flow regime remained unaltered in rivers instead of being stored in reservoirs, imported, exported, or diverted. Unimpaired flow is a modeled flow generally based on historical gage data with factors applied to primarily remove the effects of dams and diversion within the watersheds. Unimpaired flow differs from full natural flow in that the modeled unimpaired flow does not remove changes that have occurred such as channelization and levees, loss of floodplain and wetlands, deforestation, and urbanization. Where no diversion, storage, or consumptive use exists in the watershed, the historical gage data is often assumed to represent unimpaired flow. Observed flow is simply the measured flow in the river.

DWR periodically updates and publishes unimpaired flow estimates for various rivers in the Central Valley. The latest edition is *California Central Valley Unimpaired Flow Data, Fourth*

Edition, Draft (UF Report; DWR 2007a). The UF Report contains monthly estimates of the volume of unimpaired flow for all sub-basins within the Central Valley divided into 24 sub-basins, identified as sub-basins UF-1 through UF-24. The individual sub-basins of the SJR (sub-basins UF-16 to UF-24) are summed in the UF Report to estimate the "San Joaquin Valley Outflow" which roughly coincides with Vernalis. For the purposes of analysis presented in this chapter, however, the "West Side Minor Streams"[2] (UF-24 in the UF Report), was subtracted from the "San Joaquin Valley Outflow" as this sub-basin enters downstream of Vernalis. The analysis in this chapter uses monthly unimpaired flow from the UF Report for each LSJR tributary, the Upper SJR, other inflows, and the flow at Vernalis as follows:

- UF-16: Stanislaus River at New Melones Reservoir;
- UF-17: San Joaquin Valley Floor;
- UF-18: Tuolumne River at New Don Pedro Reservoir;
- UF-19: Merced River at Lake McClure;
- UF-22: SJR at Millerton Lake (Upper SJR)
- UF-20, UF-21, UF-23: summed to equal unimpaired flow from Fresno River, Chowchilla River and Tulare Lake Basin Outflows
- "San Joaquin Valley Unimpaired Total Outflow" less UF-24: to represent unimpaired flow at Vernalis.

Because the UF Report does not present unimpaired flows beyond 2003, monthly unimpaired flow data was downloaded from the California Data Exchange Center (CDEC; sensor #65 "Full Natural Flow") for the LSJR tributaries and Upper SJR. To estimate monthly unimpaired flow at Vernalis for the period beyond 2003, the LSJR tributaries and Upper SJR were summed using the CDEC data and a linear correlation of tributary-to-Vernalis flow for 1984 to 2003 was developed. This linear correlation was then applied to the 2004 to 2009 LSJR tributary and the Upper SJR flows to result in the corresponding flows at Vernalis. The LSJR tributaries and Upper SJR are the only locations in the SJR basin with monthly data available from CDEC.

Unimpaired flow calculations for sub-basins 16, 18, 19, and 22 are conducted by the DWR Snow Survey Team. The methods of calculation are consistent for each sub-basin. Each begins with a flow gage downstream of the major rim dam. This is adjusted by adding or subtracting changes in storage within the major dams upstream, adding losses due to evaporation from the reservoir surfaces, and adding flow diverted upstream of the gage (Ejeta, M. and Nemeth, S., personal communication, 2010). Within DWR's calculations, the San Joaquin Valley Floor sub-basin is taken into account approximately at Vernalis, rather than within each LSJR tributary and the Upper SJR. It is possible that some portion of the flow attributed to the Valley Floor enters the tributaries themselves rather than the mainstem SJR; however, no attempt was made to do so as the valley floor component makes up only roughly 3% of the average annual unimpaired flow on the LSJR tributaries (DWR 2007a). Therefore, without Valley Floor unimpaired estimates for the LSJR tributaries and Upper SJR, it is assumed the monthly unimpaired flow estimates at the tributary rim dams provide an adequate portrayal of the natural flow regime for comparison against observed flows at the mouths of the tributaries.

[2] "West Side Minor Streams" does not include all west side streams; only those draining directly to the Delta. Other west side streams are included in the "San Joaquin Valley Floor" which is UF 17 in the UF Report (DWR 2007; personal communication, Ejeta and Nemeth 2010)

Although the UF Report is used in this analysis, there are four components of flows that are not addressed by the calculations of unimpaired flow in the UF Report. First, it is likely that ground water accretions from the very large Central Valley Floor (including both the Sacramento and San Joaquin Valleys) were considerably higher under natural conditions; however, as stated by DWR, no historical data is available for its inclusion. Valley Floor unimpaired flow uses factors to estimate flows in minor streams that drain or discharge to the Valley Floor only and does not include groundwater accretions. Second, historical consumptive use of wetland and riparian vegetation in wetlands and channels of the un-altered Central Valley could be significantly higher than current consumptive use but values are difficult to estimate. Third, during periods of high flow, Central Valley Rivers under natural conditions would overflow their banks thus contributing to interactions between groundwater and consumptive use; however, the current UF Report does not attempt to quantify these relationships. Fourth, the outflow from the Tulare Lake Basin under natural conditions is difficult to estimate, and the unimpaired flow reported for this sub-basin are only those observed from a USGS gage at Fresno Slough. It is uncertain to what degree these flows represent the natural condition.

In addition to the monthly estimates available in the UF Report, CDEC publishes real time average daily estimates of unimpaired flow just downstream of the major rim dams for the Stanislaus River at New Melones Dam starting in 1992, the Tuolumne River at New Don Pedro Dam starting in 1989, the Merced River at New Exchequer Dam starting in 1988, and the Upper SJR at Friant Dam starting in 1987. Only monthly unimpaired flow data is currently available for application at Vernalis. To assess alterations to storm flows or short term peak flows at this location, daily unimpaired flow estimates would be needed.

2.3 Hydrology of the San Joaquin River at Vernalis

The current hydrology of the SJR is highly managed through the operations of dams and diversions. As a result, the natural hydrologic variability in the SJR basin has been substantially altered over multiple spatial and temporal scales. Alterations to the unimpaired flow regime include a reduced annual discharge, reduced frequency and less intense late fall and winter storm flows, reduced spring and early summer snowmelt flows, and a general decline in hydrologic variability (McBain and Trush 2002; Cain et al. 2003; Brown and Bauer 2009; NMFS 2009a). The historical annual and inter-annual hydrologic trends at Vernalis are presented in Section 2.3.1 below, and the currently altered hydrology at Vernalis on annual, monthly, and daily temporal scales is presented in Sections 2.3.2 through Section 2.3.4, respectively, below.

2.3.1 Historical Flow Delivery, Reservoir Storage, and Inter-Annual Trends

Figure 2.3 displays the annual difference between unimpaired flow and observed flow in the SJR at Vernalis from 1930 to 2009, the overlapping range of historical gage data, and unimpaired flow data. Before 1955 the cumulative storage of reservoirs in the SJR basin was less than 2.1 MAF. However, by 1978 the cumulative storage in the SJR basin had increased to just below 8 MAF. Lake McClure (formed by New Exchequer Dam) on the Merced River and New Don Pedro Reservoir (formed by New Don Pedro Dam) on the Tuolumne River added 0.75 MAF and 1.7 MAF of storage in 1967 and 1970, respectively. New Melones Reservoir (formed by New Melones Dam) on the Stanislaus River added 2.34 MAF of storage in 1978. Prior to 1955, there was little variation in the volume stored, diverted, or consumptively used; observed flows were generally between 1.5 and 3 MAF lower than unimpaired flows. After 1955 and again after 1970, the annual difference in volume became larger and more variable from year to year, attributable mostly to large increases in storage capacity within the basin. Some of this change in variability, however, could also be attributable to changes in climate from year-to-year and decadal trends, which have not been accounted for in this analysis.

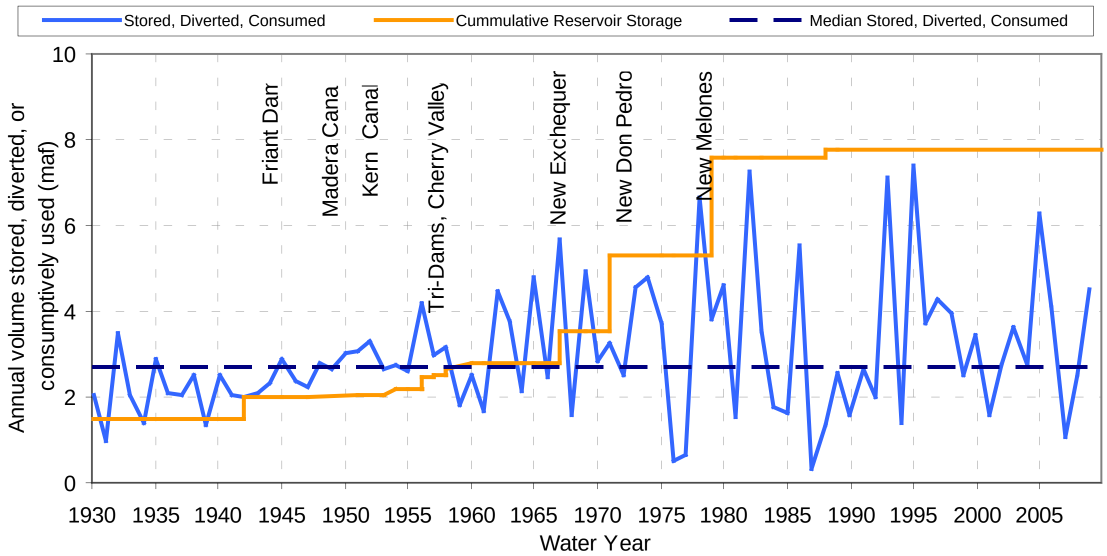


Figure 2.3. Annual Volume Stored, Diverted, or Consumptively Used Upstream of Vernalis, and Cumulative Reservoir Storage Capacity within the SJR River Basin Upstream of Vernalis

The median annual unimpaired flow in the SJR at Vernalis from water year 1930 through 2009 was 5.6 MAF. The median annual volume stored, diverted, or consumed was 2.7 MAF, while the median observed flow as a percentage of unimpaired flow was 44% over the 80 year period. This median annual reduction in flow relative to unimpaired flow is attributable to exports of water outside the basin and consumptive use of water in the basin. As shown in Table 2.3, the volume stored, diverted or used for individual years tends to be greatest in Below Normal to Critically Dry years because relatively more water is stored and consumptively used than released in such years.

The greatest volumetric reduction of annual flow has generally occurred during Wet years, and most significantly in the first year or years following a drought. Water Year 1995 experienced the greatest reduction from unimpaired flow on record when 7.4 MAF was stored or diverted in the LSJR tributaries and Upper SJR, ultimately reducing observed flow to 46% of unimpaired flow. Examples of this effect can be seen in Figure 2.4 in 1993, 1995, and again in 2005 (among others), which show large diversions to storage during wetter years that follow years of drought.

The years leading up to high storage Wet or Above Normal years were a series of Dry years forming drought conditions from 1987 to 1993 and again from 2000 to 2004, during which the quantity of water stored in the major reservoirs within the LSJR tributaries and Upper SJR (New Melones, New Don Pedro, Lake McClure, and Millerton Lake) was greatly reduced. In contrast, during the second and third Normal or wetter year following a drought, 1996 to 1997 and again in 2006, less of the inflows to these reservoirs is stored, resulting in higher percentage of flow released downstream than during the preceding wetter years.

Table 2.3. Observed and Unimpaired Annual Flow Statistics and Percent of Unimpaired Flow (1930 to 2009) in the San Joaquin River at Vernalis

	Number of Occurrences	Unimpaired Flow	Observed Flow	Volume Stored, Diverted, or Consumed	Observed Flow as a Percent of Unimpaired Flow
	# Years/ (year)	(TAF)	(TAF)	(TAF)	(%)
Average of All Years	80	6,290	3,280	3,010	48
Median of All Years[1]	80	5,640	1,850	2,660	44
Average of Wet Years	25	10,600	6,210	4,390	57
Average of AN Years	14	6,840	3,840	2,990	56
Average of BN Years	11	4,610	1,620	2,990	35
Average of Dry Years	14	3,610	1,400	2,220	40
Average of Critical Years	16	2,590	1,010	1,580	41
Wettest of Years	(1983)	18,940	15,410	3,530	81
Driest of Years	(1977)	1,060	420	640	40
Greatest % of Unimpaired Flow Stored, Diverted, Consumed	(2009)	5,390	870	4,520	16
Greatest Volume Stored, Diverted, Consumed	(1995)	13,680	6,300	7,380	46

[1] Median occurred in 2009 for unimpaired flow, 1987 for observed flow, and 1955 for volume stored, diverted, consumed.

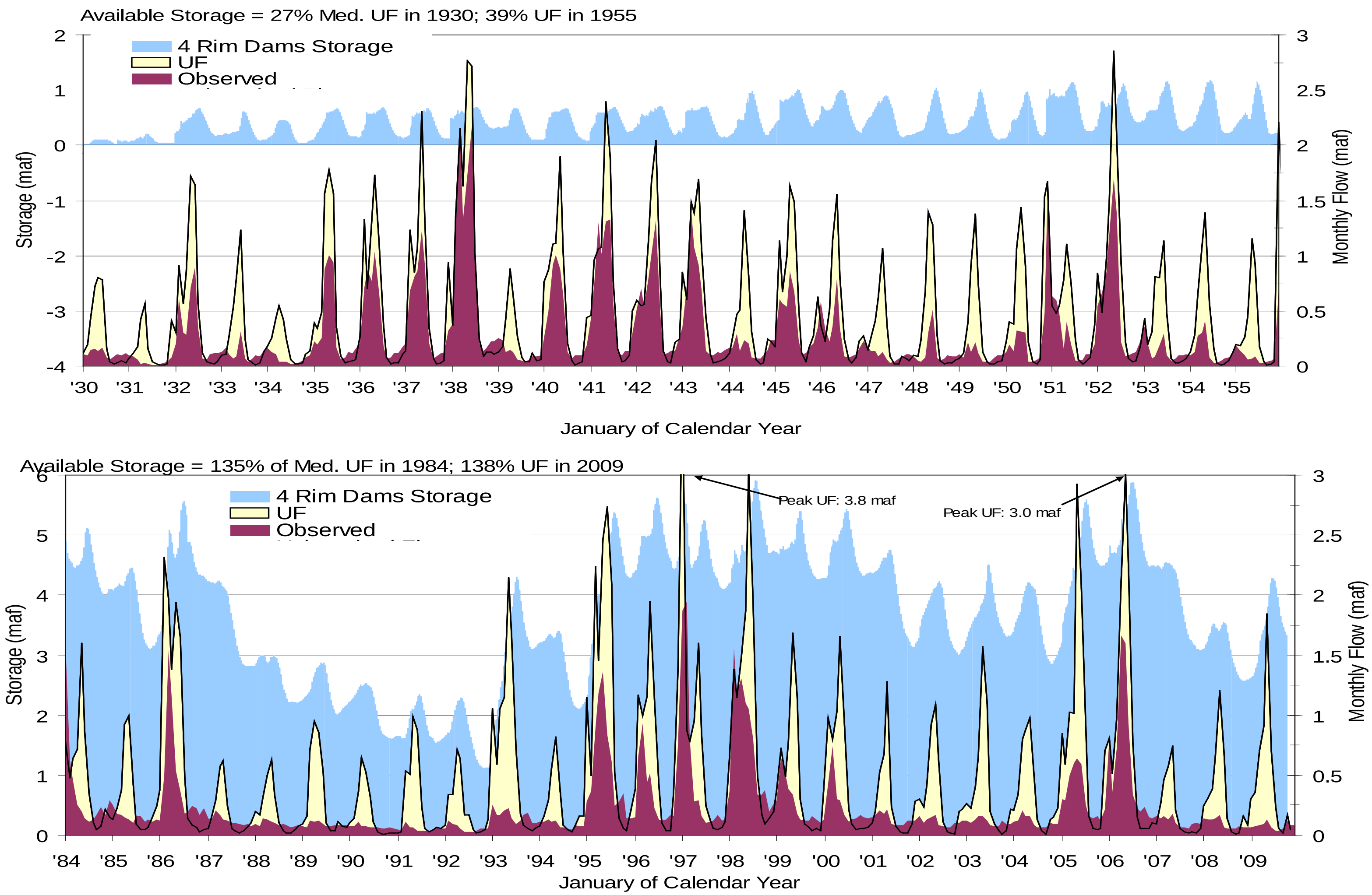


Figure 2.4. Monthly Unimpaired and Observed Flow in the San Joaquin River at Vernalis and Total Storage Behind New Melones, New Don Pedro, New Exchequer, and Friant Dams for Two Periods in Time (1930 to 1955 and 1984 to 2009)

2.3.2 Annual Flows for Pre-Dam and Post-Dam Periods

To help differentiate flow changes that have occurred as a result of changes in water storage facilities and management from changes in hydrology, the hydrologic patterns for two time periods are presented: 1930 to 1955 and 1984 to 2009. The period from 1930 to 1955 shows the time before major water storage projects were completed on the Merced, Tuolumne and Stanislaus Rivers. The period from 1984 through 2009 shows the time after completion and filling of major water storage projects on these tributaries; New Melones Reservoir was initially filled during two Wet years—1982 and 1983. Table 2.4 provides summary statistics for these two time periods which demonstrates that they had similar but not identical hydrologic conditions. Average annual unimpaired flows for these two periods were 5.9 MAF and 6.1 MAF respectively, and median annual unimpaired flows were 5.4 MAF and 4.6 MAF respectively. This shows that the later period was skewed towards lower flows, with twice as many Critically Dry and Dry years and fewer Above Normal and Below Normal years.

Table 2.4. Unimpaired and Observed Flow Statistics by Water Year Type for 1930 to 1955 and 1984 to 2009

	1930-1955			1984 - 2009			
	# Years (year)	Unimpaired Flow (TAF)	Observed Flow (TAF)	# Years (year)	Unimpaired Flow (TAF)	Observed Flow (TAF)	Observed Flow as Percentage of Unimpaired Flow
Average of All Years	26	5,900	3,520	26	6,070	2,900	45
Median of All Years	26	5,400	2,760	26	4,580	1,720	46
Average of Wet Years	6	9,490	7,160	8	10,750	5,450	50
Average of AN Years	7	7,070	4,320	3	6,820	4,240	61
Average of BN Years	6	4,350	1,670	1	4,990	1,360	27
Average of Dry Years	4	3,410	1,350	5	4,140	1,490	38
Average of Critical Years	3	2,450	960	9	2,840	1,150	42
Wettest of Years	(1938)	13,370	10,840	(1995)	13,680	8,490	84[1]
Driest of Years	(1931)	1,680	680	(1987)	2,160	660	16[2]

[1] Highest percentage of unimpaired flow
[2] Lowest percentage of unimpaired flow.

The period from 1930 to 1955 is representative of conditions where total reservoir storage volume in the SJR basin ranged from 1.5 MAF to 2.2 MAF, or 27% to 39% of the long-term median annual unimpaired flow in the basin. The period from 1984 to 2009 is representative of current conditions, with reservoir storage of 7.6 MAF to 7.8 MAF, or 135% to 138% of the long-term median annual unimpaired flow in the basin.

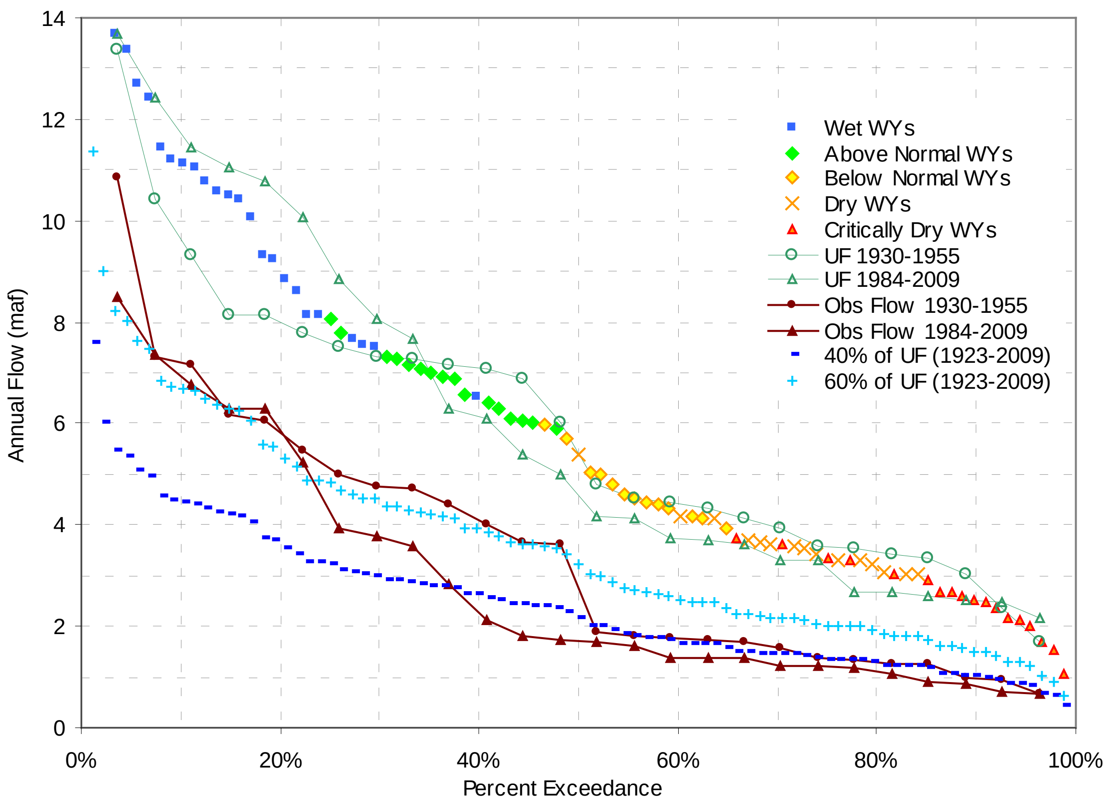


Figure 2.5. Exceedance Curves of Observed and Unimpaired Flow Hydrology in the San Joaquin River at Vernalis

Exceedance curves for unimpaired and observed flow for the two periods are superimposed on the long-term unimpaired flow for the entire unimpaired flow data set spanning 1923 to 2009 in Figure 2.5. A percent chance of exceedance was assigned to each year using the Weibull plotting positions (Viessman and Lewis 2003). This approach assigns an equal difference in percent chance exceedance per record. The period from 1930 to 1955 was slightly wetter than the period from 1984 to 2009. The earlier period had fewer extremes; that is to say there were fewer Critically Dry and Wet years, and more moderate, Below Normal and Above Normal years.

As a result of changes in storage and diversion, flow in the river has been reduced, resulting in low flow conditions more frequently than would have occurred under natural conditions. From Figure 2.5, based on the unimpaired flow data set, annual flow would have been less than approximately 2.5 MAF in only about 10% of years, roughly the 10 driest years on record. Under present-day conditions, annual flows less than approximately 2.5 MAF have been observed in 60% to 65% of years (the 35% to 40% exceedance level). From 1930 to 1955, observed annual flows less than approximately 2.5 MAF occurred in fewer than 50% of years.

Between 39% and 68% of annual unimpaired flow remained in the river for the 1930 to 1955 period, and between 34% and 58% remained in the river during the 1984 to 2009 period. The curves corresponding to 40% and 60% of unimpaired flow are overlaid for reference to the percentage of unimpaired flow ultimately remaining in the river.

In addition to inferences regarding changes over time, the long-term unimpaired flow exceedance curve in Figure 2.5 indicates that water year classification types do not always accurately describe the unimpaired flow volume within that year. For example, many of the Critically Dry water years had higher annual flow volumes than many of the Dry water years. This is in part because the water year classification depends partially on the preceding water year type. An exceedance curve of unimpaired flow is a more direct measurement of estimated flow because it is derived from hydrologic conditions and ranks them from wettest to driest. The exceedance curves for 1930 to 1955 and 1984 to 2009 are not separated by water year type as was done for the long term data, because there are too few years to accurately represent each water year classification.

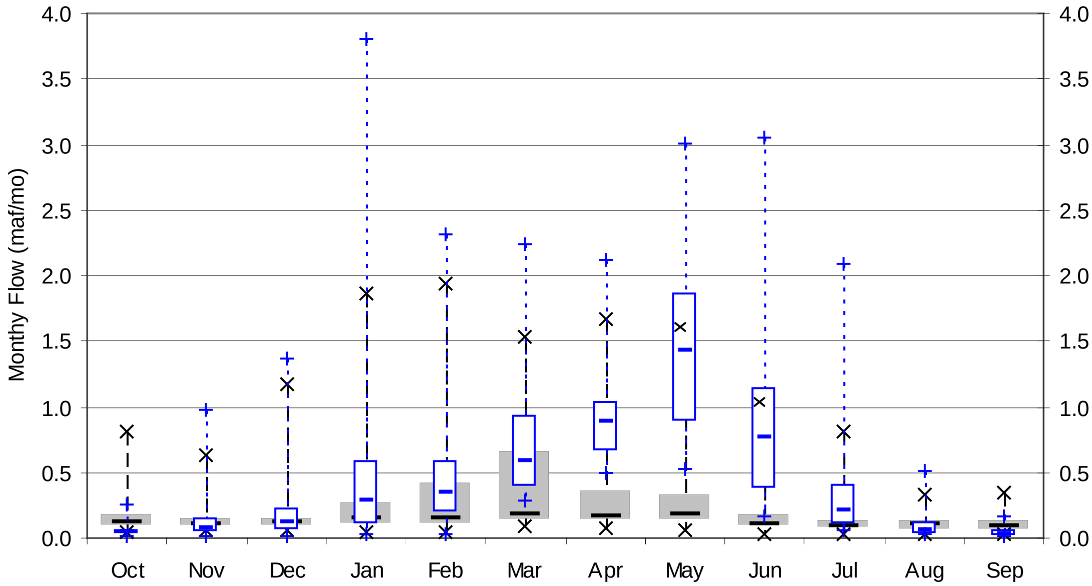
2.3.3 Monthly and Seasonal Trends

Increased storage and operational changes have resulted in flow conditions that are more static with less seasonally variable flows throughout the year (Figure 2.6). There is now a severely dampened springtime magnitude and more flow in the fall, both of which combine to create managed flows that diverge significantly from what would occur under an unimpaired condition. Tables 2.5 through 2.7 contain monthly unimpaired flow, observed monthly flow, and observed monthly flow as a percentage of monthly unimpaired flow, respectively, in the SJR at Vernalis for water years 1984 through 2009.

The percentile monthly unimpaired, observed, and percentages of unimpaired flow at Vernalis are presented in Table 2.8. The median (i.e., middle value of each data set) is given by the 50th percentile value. These statistics are presented instead of the average (or mean) in order to focus more on how often various flows occur, and to avoid a statistic that can be skewed by exceptionally high or low values. Flows presented in this table are not exceeded (i.e., flow is equal to, or less than given value) for the given percentile. For example, the 60th percentile percentage of unimpaired flow for May is 18%. This means 60% of monthly May flows between 1984 and 2009 did not exceed 18% of the corresponding monthly unimpaired flow.

Overall the annual flow volumes at Vernalis have been reduced to a median of 46% of unimpaired flow, while the February through June flow volume has been reduced to a median of 27% of unimpaired flow. In terms of median values, the greatest reduction of the monthly flows occurs during peak spring snowmelt months of April, May, and June. As presented in Table 2.8, observed flows during these months are a median of 25%, 17%, and 18% of unimpaired flow, respectively. This means that in 50% of the water years between 1984 and 2009 the observed flow as a percentage of unimpaired flow is lower than the median, with the lowest percentages of unimpaired flow (as seen from Table 2.7) reaching 4% in June of 1991, 7% in May of 1991 and 2009, and 9% in June of 2008 and 2009. These were all in water years classified as either Critically Dry or Dry. In contrast, the months of August through November have median flows higher than unimpaired: 133%, 269%, 342%, and 133% of unimpaired flow, respectively, as shown in Table 2.8.

The unimpaired flow magnitude of the snowmelt varies dramatically each year as shown in Table 2.8 by an inter-quartile range (i.e., the difference between 75th percentile and 25th percentile) of 376, 981, and 766 TAF for the months of April, May, and June, respectively, compared to observed conditions, where this range has been reduced to roughly 233, 199, and 92 TAF, respectively. By comparison, Table 2.8 shows the inter-quartile range is slightly increased for September and October. This large decrease in spring flow magnitude and variation throughout the year, as well as the augmentation of summer and fall flows is apparent in nearly all recent years. Figure 2.4 emphasizes this, especially during the later period of 1984 to 2009 where observed flows are significantly lower than unimpaired flow during the wet season and are higher than unimpaired flow during the dry season.



Key to boxplots: Median, horizontal line; box, 25th and 75th percentiles; whiskers, range for unimpaired flow ("+"sign) and observed ("x" sign).

Figure 2.6. Monthly Unimpaired Flow (Open Bars) and Observed Flow (Filled Bars) in the SJR at Vernalis from 1984 to 2009

Table 2.5. Monthly, Annual, and February through June Unimpaired Flow in the SJR at Vernalis from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	263	981	1,254	773	482	635	714	1,600	864	345	108	44	8,063	5,068
1985	D	78	220	149	134	228	380	926	997	420	95	43	45	3,715	3,085
1986	W	68	148	249	378	2,311	1,965	1,384	1,941	1,643	478	139	81	10,785	9,622
1987	C	63	30	45	52	137	287	569	624	242	60	34	17	2,160	1,911
1988	C	35	76	104	193	169	310	499	627	337	105	42	19	2,516	2,135
1989	C	21	46	75	93	158	719	947	858	523	108	34	36	3,618	3,298
1990	C	109	76	62	108	138	363	645	523	322	112	25	11	2,494	2,099
1991	C	14	17	18	23	24	538	510	987	874	231	53	28	3,317	2,956
1992	C	46	69	58	81	339	341	711	635	170	166	44	21	2,681	2,277
1993	W	31	46	135	1,052	593	1,049	1,144	2,146	1,659	719	177	83	8,834	7,643
1994	C	57	41	65	73	164	291	545	820	371	89	50	28	2,594	2,264
1995	W	75	156	160	1,152	497	2,237	1,458	2,468	2,734	2,088	515	139	13,679	10,546
1996	W	60	41	209	385	1,168	998	1,158	1,947	1,141	420	108	37	7,672	6,797
1997	W	37	352	1,374	3,810	879	782	952	1,600	845	242	122	53	11,048	8,868
1998	W	47	70	114	650	1,387	1,149	1,473	1,876	3,048	1,951	500	169	12,434	9,583
1999	AN	90	143	195	380	726	490	784	1,682	1,151	302	96	63	6,102	5,213
2000	AN	39	58	41	388	974	802	1,037	1,655	938	213	94	51	6,290	5,794
2001	D	57	55	62	103	193	531	681	1,276	234	78	24	18	3,312	3,018
2002	D	22	97	281	304	238	417	921	1,095	630	109	32	17	4,163	3,605
2003	BN	10	198	220	264	224	406	663	1,571	1,102	202	93	40	4,993	4,230
2004	D	11	40	212	208	340	802	877	976	474	127	34	12	4,113	3,676
2005	W	131	147	225	844	590	1,026	1,015	2,926	2,056	906	161	54	10,082	8,459
2006	W	51	54	702	809	515	981	2,116	3,014	2,226	760	147	61	11,436	9,661
2007	C	58	54	102	97	275	460	577	739	206	56	31	20	2,674	2,354
2008	C	25	19	53	247	312	383	654	1,207	667	145	28	13	3,753	3,470
2009	D	16	158	80	303	360	703	908	1,844	701	232	58	23	5,387	4,820

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.6. Monthly, Annual, and February through June Observed Flow in the SJR at Vernalis from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	819	635	1,176	1,576	623	461	255	199	137	117	134	174	6,306	1,675
1985	D	235	168	293	250	180	168	147	131	104	157	160	115	2,108	730
1986	W	127	115	136	127	486	1,539	1,166	539	371	178	196	249	5,227	4,100
1987	C	230	167	228	142	119	210	171	134	118	100	100	95	1,814	752
1988	C	84	92	79	91	80	138	128	110	102	83	96	86	1,168	557
1989	C	69	76	84	77	69	124	114	120	94	79	72	81	1,059	521
1990	C	86	84	85	76	76	108	78	79	66	62	64	52	916	407
1991	C	61	66	56	50	42	109	70	65	34	37	33	34	657	319
1992	C	48	65	55	59	120	90	84	55	29	27	30	38	700	379
1993	W	52	57	60	253	169	166	204	222	139	93	123	165	1,703	900
1994	C	187	105	100	109	110	136	111	121	66	70	53	52	1,220	544
1995	W	84	77	80	283	364	898	1,186	1,364	834	608	241	282	6,301	4,647
1996	W	350	144	138	149	660	927	446	518	222	136	125	129	3,945	2,773
1997	W	165	162	750	1,868	1,947	801	281	294	158	108	115	123	6,772	3,482
1998	W	166	118	130	370	1,562	1,190	1,305	1,104	1,057	811	335	343	8,491	6,217
1999	AN	378	196	266	291	650	512	383	341	179	129	121	121	3,568	2,066
2000	AN	156	128	104	131	435	744	298	296	165	117	133	139	2,846	1,938
2001	D	174	150	138	150	172	211	179	217	92	86	82	82	1,732	871
2002	D	123	125	127	164	105	131	155	168	84	75	69	70	1,396	643
2003	BN	105	102	122	118	104	135	159	161	121	81	79	78	1,365	680
2004	D	123	98	92	110	127	207	164	163	84	71	69	67	1,373	743
2005	W	108	97	97	302	295	496	599	640	594	255	161	144	3,787	2,623
2006	W	161	121	216	810	359	720	1,662	1,602	934	341	227	197	7,351	5,276
2007	C	237	151	145	159	141	157	132	178	104	70	62	60	1,596	712
2008	C	97	102	92	143	136	130	143	169	61	53	53	54	1,234	641
2009	D	76	68	69	68	79	87	90	131	65	37	37	56	866	453

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.7. Monthly, Annual, and February through June Observed Flow as a Percentage of Unimpaired Flow in the SJR at Vernalis from 1984 to 2009

Water Year	Water Year Type[1]	Oct (%)	Nov (%)	Dec (%)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Annual (%)	Feb-Jun (%)
1984	AN	311	65	94	204	129	73	36	12	16	34	124	394	78	33
1985	D	301	76	197	187	79	44	16	13	25	165	372	255	57	24
1986	W	187	78	54	34	21	78	84	28	23	37	141	307	48	43
1987	C	365	557	506	273	87	73	30	21	49	167	294	559	84	39
1988	C	241	121	76	47	47	44	26	17	30	79	228	455	46	26
1989	C	330	165	112	83	43	17	12	14	18	73	211	224	29	16
1990	C	79	110	137	71	55	30	12	15	21	55	254	474	37	19
1991	C	436	390	314	218	175	20	14	7	4	16	62	122	20	11
1992	C	105	93	95	73	35	27	12	9	17	17	67	180	26	17
1993	W	168	124	45	24	28	16	18	10	8	13	69	199	19	12
1994	C	328	255	154	149	67	47	20	15	18	78	107	185	47	24
1995	W	112	49	50	25	73	40	81	55	30	29	47	203	46	44
1996	W	583	352	66	39	57	93	39	27	19	32	116	348	51	41
1997	W	447	46	55	49	221	102	30	18	19	45	94	232	61	39
1998	W	354	168	114	57	113	104	89	59	35	42	67	203	68	65
1999	AN	420	137	137	77	89	105	49	20	16	43	126	192	58	40
2000	AN	399	221	253	34	45	93	29	18	18	55	142	272	45	33
2001	D	305	273	222	146	89	40	26	17	39	110	341	455	52	29
2002	D	560	129	45	54	44	31	17	15	13	69	214	411	34	18
2003	BN	1,048	52	56	45	47	33	24	10	11	40	85	195	27	16
2004	D	1,071	248	43	53	37	26	19	17	18	56	206	540	33	20
2005	W	82	66	43	36	50	48	59	22	29	28	100	267	38	31
2006	W	318	226	31	100	70	73	79	53	42	45	154	325	64	55
2007	C	407	280	141	164	51	34	23	24	50	126	203	309	60	30
2008	C	390	532	173	58	44	34	22	14	9	37	193	404	33	18
2009	D	462	43	86	22	22	12	10	7	9	16	65	247	16	9

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.8. Statistics of Unimpaired Flow, Observed Flow, and Observed Flows as a Percent of Unimpaired Flow in the SJR at Vernalis from 1984 to 2009

Unimpaired flow (TAF)													
Statistic	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	Feb-Jun
10%tile	15	35	49	77	148	326	557	631	238	84	29	15	2,555	2,200
20%tile	22	41	62	97	169	380	645	820	337	105	34	18	2,681	2,354
25%tile	26	46	63	104	201	389	656	887	383	108	34	19	3,313	2,972
30%tile	33	50	70	121	226	412	672	981	447	111	38	20	3,468	3,052
40%tile	39	55	102	208	275	490	714	1,095	630	145	44	28	3,753	3,470
50%tile	49	70	125	284	339	587	892	1,424	773	208	55	37	4,578	3,953
60%tile	57	76	160	378	482	719	926	1,600	874	232	94	44	6,102	5,068
70%tile	62	145	211	387	553	802	984	1,763	1,122	324	108	52	7,868	6,296
75%tile	67	148	218	585	592	936	1,032	1,868	1,149	401	119	54	8,641	7,432
80%tile	75	156	225	773	726	998	1,144	1,941	1,643	478	139	61	10,082	8,459
90%tile	100	209	491	948	1,071	1,099	1,421	2,307	2,141	833	169	82	11,242	9,603
Observed flow (TAF)														
10%tile	65	67	65	72	78	109	87	94	63	45	45	52	891	430
20%tile	84	77	80	91	104	130	114	121	66	70	62	56	1,168	544
25%tile	85	86	84	109	107	132	129	131	84	70	65	62	1,223	578
30%tile	91	95	89	114	114	135	138	133	88	73	69	68	1,300	642
40%tile	108	102	97	131	127	157	155	163	102	81	79	81	1,396	712
50%tile	125	110	113	146	155	187	167	174	111	89	98	91	1,718	747
60%tile	161	121	130	159	180	211	204	217	137	108	121	121	2,108	900
70%tile	170	136	138	252	361	504	290	295	161	123	129	134	3,678	2,002
75%tile	184	149	143	275	417	668	362	330	176	134	134	142	3,906	2,484
80%tile	230	151	216	291	486	744	446	518	222	157	160	165	5,227	2,773
90%tile	293	168	280	590	655	913	1,176	872	714	298	212	223	6,539	4,374
Observed flow as a percent of unimpaired flow (%)														
10%tile	109	50	44	29	32	19	12	9	9	16	66	189	23	14
20%tile	187	66	50	36	43	27	16	12	13	29	69	199	29	17
25%tile	256	77	54	40	44	30	17	13	16	33	87	203	33	18
30%tile	303	86	55	46	44	32	18	14	16	35	97	213	33	19
40%tile	318	121	76	53	47	34	22	15	18	40	116	247	38	24
50%tile	342	133	94	57	53	42	25	17	18	44	133	269	46	27
60%tile	390	168	114	73	67	47	29	18	21	55	154	309	48	31
70%tile	414	237	139	92	76	73	33	21	27	62	204	371	55	36
75%tile	432	253	151	134	85	73	38	22	30	72	210	401	58	39
80%tile	447	273	173	149	89	78	49	24	30	78	214	411	60	40
90%tile	572	371	238	195	121	98	80	40	41	118	274	464	66	43

Based on a review of the unimpaired flow estimates, the wettest month (i.e. the month in the water year with the greatest volume of flow) generally occurred between April and June. In 7 out of 80 years (9% of years) from 1930 to 2009, the wettest month of the year would have been April; in 57 years it would have been May and in 12 years it would have been June, one year each it would have been in January and February, and twice it was December. Six of the seven years that April was the wettest month of the year were either Dry or Critically Dry water years. To put this into perspective and show the present conditions, Table 2.9 summarizes the wettest months for the two periods discussed above.

The wettest month of the year is now less predictable as is distributed more evenly from year to year. From 1984 to 2009 the wettest month was most often March, followed by May, February, and October (Table 2.9). The early period was already severely altered with the wettest month occurring many times in either May or June and frequently in March and January. Table 2.9 summarizes the alterations to the timing of the wettest month for the two periods previously discussed using percentage of years each month was the wettest.

Table 2.9. The Wettest Months of Each Year in the SJR at Vernalis as a Percentage of Years during the Two Periods (1930 to 1955 and 1984 to 2009) for Unimpaired Flow and Observed Flow

	No. of	Percent of years by month											
Period	yrs	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Unimpaired (1930 to 1955)	26	0	0	0	8	77	12	0	0	0	0	0	4
Observed (1930 to 1955)	26	15	0	8	8	31	27	0	0	0	0	0	8
Unimpaired (1984 to 2009)	26	4	4	0	12	73	8	0	0	0	0	0	0
Observed (1984 to 2009)	26	8	15	31	4	27	0	0	0	0	12	0	4

2.3.4 Short Term Peak Flows and Flood Frequency

As shown in Figure 2.1 and Figure 2.2, short term peak or storm flows that occur several times within a given year, generally between November and March, are dramatically reduced under the present management conditions. No attempt was made to calculate the short term peak flows and flood frequencies of unimpaired flow at Vernalis in this report because daily unimpaired flow data are not readily available at Vernalis. Comparisons were made between two periods, 1930 to 1955 and 1984 to 2009 using daily gage data in place of unimpaired flow data to attempt to demonstrate and quantify how peak flows have changed between these two periods. The *Sacramento-San Joaquin Comprehensive Study* (USACE 2002) provides a flood frequency analysis at Vernalis.

Under natural conditions the, October to March storm flows are generally less intense than the peak flows that occur during the spring snowmelt. By separating the fall and winter storm peaks from the rest of the year, it is possible to see alterations to the various components of the natural flow regime as depicted in Figure 2.1 and Figure 2.2. In the 1984 to 2009 period, peak flows generally occurred between October and March, while in the 1930 to 1955 period, they occurred during the spring. Table 2.10 summarizes the exceedances of the fall and winter component. The spring component is deduced from the annual peak. If the annual peak was greater than observed between October to March, the peak flows occurred at another time during the year, specifically April to June. In order to better characterize the altered regime at Vernalis, it would be necessary to calculate these statistics using daily unimpaired flow estimates in place of the 1930 to 1955 observed flows.

Table 2.10. Percent Chance of Exceedance of October through March and Annual Maximum Daily Average Flow in the SJR at Vernalis

Percent Exceedance	Observed Flow 1930 to 1955 (cfs)		Observed Flow 1984 to 2009 (cfs)		Percent Difference from Earlier Period %	
	Oct to Mar	Annual	Oct to Mar	Annual	Oct to Mar	Annual
Exceeded 25% of years	20,400	28,200	17,400	17,400	-15	-38
Exceeded 50% of years	7,700	15,500	6,000	6,000	-22	-61
Exceeded 75% of years	4,400	6,000	4,200	4,200	-5	-30
Exceeded 90% of years	3,700	4,600	2,500	2,700	-32	-41
Greatest Peak Flow	70,000	70,000	54,300	54,300	-22	-22
Smallest Peak Flow	2,000	2,100	1,900	2,000	-5	-5

To illustrate the loss of storm flows, including those that would have occurred several times in a given year, Figure 2.7 displays daily unimpaired flow and observed flow for WY 2008, a Critically Dry water year, for each of the LSJR tributaries. Even though this was a Critically Dry water year, there were significant storm flows in response to rainfall and rain falling on snow during the later fall and early winter seasons. It is expected that a similar response would be observed at Vernalis; however, daily unimpaired flow estimates are not yet available at Vernalis.

To quantify the changes to peak flows that have occurred, exceedance curves were developed for annual peak flows using the two distinct periods previously identified, and compared to estimates by USACE (2002) shown in Table 2.11. While other studies have focused separately on the LSJR tributaries and the Upper SJR (McBain and Trush 2000; Kondolf et al. 2001; Stillwater Sciences 2001; Cain et al. 2003), the USACE 2002 analysis is the only study to have addressed the peak flow regime at Vernalis. Even though many alterations had occurred within the watershed prior to 1930, reductions in peak flows were evident between the two periods (1930 to 1955 versus 1984 to 2009). For example, reductions in the peak flows of 49%, 61%, and 23% were observed, respectively, for 1.5-year, 2-year, and 5-year return frequencies. In addition, flows of approximately 15,000 cfs, which would have occurred at least once every year or two, now occur upwards of only once every five years (Table 2.11). The difference in larger peak flows, for those that occur every 10 years on average, is, however, less pronounced, with only a 6% reduction from the early period. The USACE (2002) estimates of peak flows are somewhat higher than those estimated here because USACE used unimpaired flow data, which estimates return frequencies prior to any alterations.

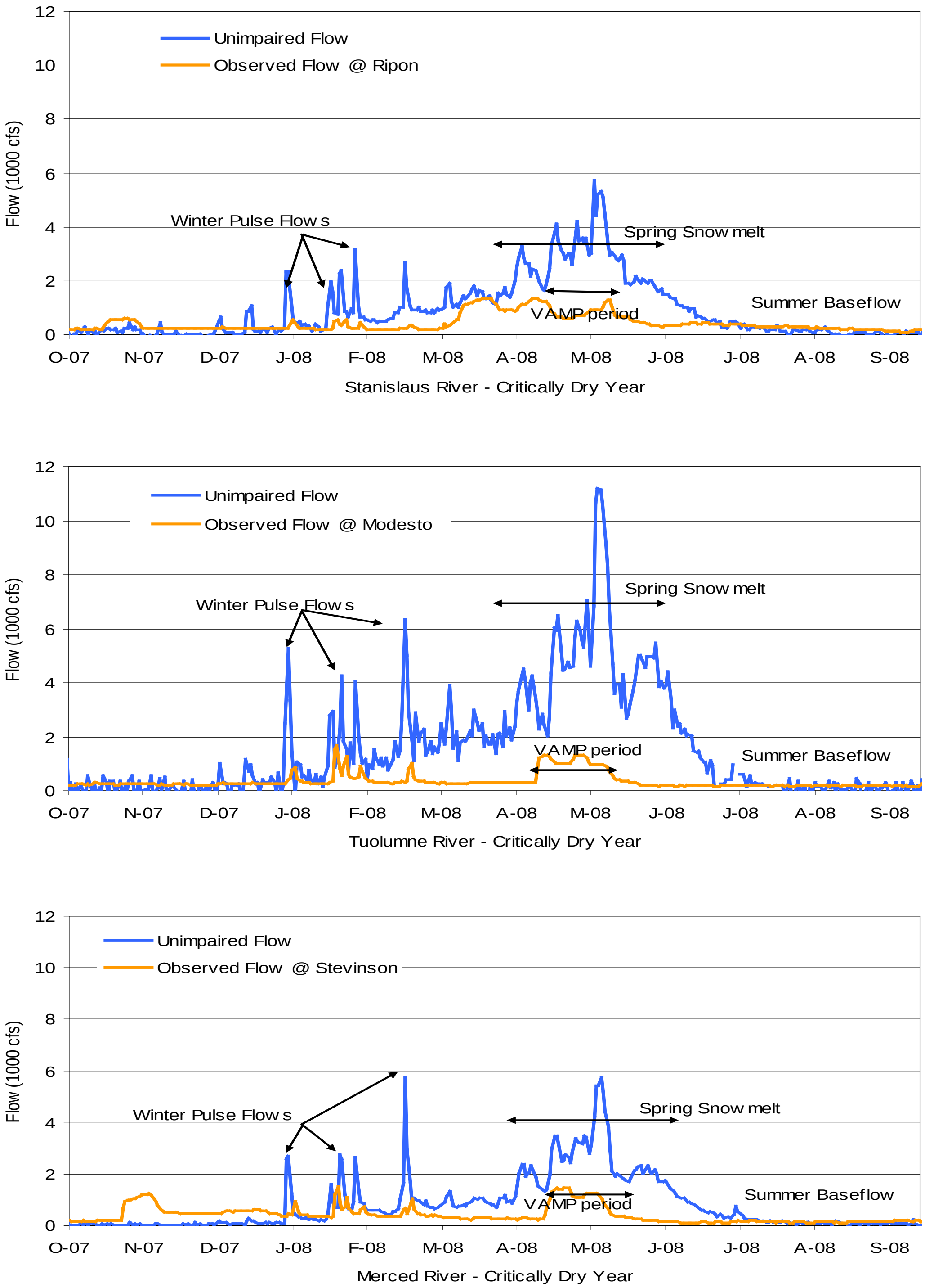


Figure 2.7. Daily Unimpaired Flow and Observed Flow for a Critically Dry Water Year (WY 2008) in the Stanislaus At Ripon (Top), Tuolumne at Modesto (Middle), and Merced at Stevinson (Bottom)

Table 2.11. Frequency Analyses of Annual Peak Flows in the SJR at Vernalis as Compared to USACE (2002)

Return Freq.	USACE "Unimpaired" 1902 to 1997[1] (cfs)	Observed Flow[2] 1930 to 1955 (cfs)	Observed Flow[2] 1984 to 2009 (cfs)	Observed Percent Difference: Late period from USACE (%)	Observed Percent Difference: Late period from early period (%)
Q1.5	~15,000	8,800	4,500	-70	-49
Q2	~25,000	15,500	6,000	-76	-61
Q5	~55,000	33,700	25,900	-53	-23
Q10	~100,000	37,100	34,800	-65	-6

[1] As interpolated from 1-Day Flood Frequency Curves in attachment B.2 page 45 in USACE (2002). Values were based on a simulated unimpaired flow.
[2] Source of data USGS Gage. # 11303500.

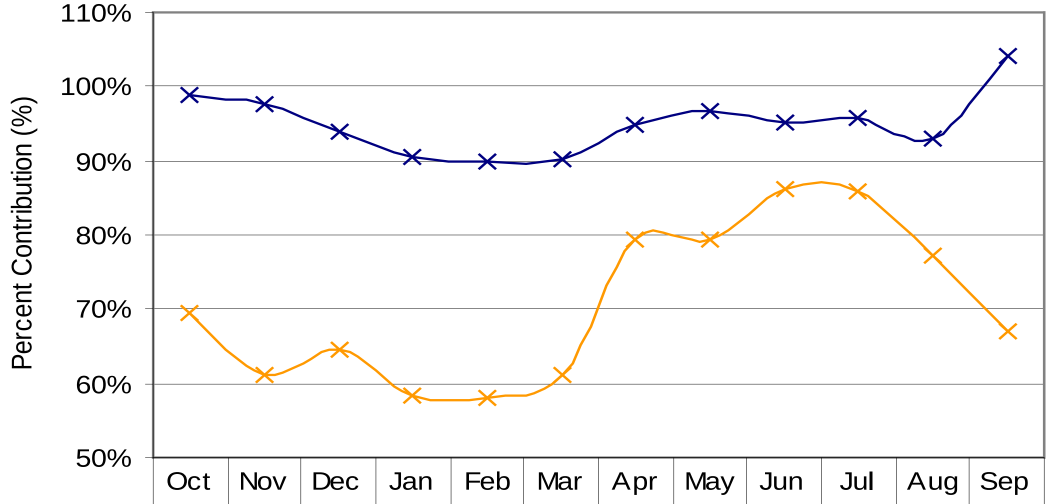
2.4 Hydrology of Tributaries to the Lower San Joaquin River

This section describes the relative contribution to SJR flow at Vernalis and the unimpaired and observed hydrology of the Stanislaus, Tuolumne, and Merced Rivers (LSJR tributaries), the Upper SJR, and the combined Chowchilla and Fresno Rivers, Valley Floor, and Tulare Lake Basin.

2.4.1 Relative Contribution from Tributaries to SJR Flow at Vernalis

SJR flow at Vernalis is largely comprised of flows from the LSJR tributaries and the Upper SJR. The combined Chowchilla and Fresno Rivers and Valley Floor also contribute flow, and in some years water from the Tulare Lake Basin also flows to the SJR via Fresno Slough. This section summarizes the contribution to flows at Vernalis from these different sources. Under unimpaired conditions, flows from the LSJR tributaries and Upper SJR account for approximately 90% to 100% of the flow at Vernalis. In contrast, these tributaries accounted for only 58% to 86% of observed flow for the 1984 to 2009 period (Figure 2.8). The remainder of flow comes from the Valley Floor, Tulare Lake Basin, Fresno River, and Chowchilla River.

Figure 2.9 displays the monthly median flow contribution by each of the LSJR tributaries and the Upper SJR as a percentage of flow at Vernalis. The LSJR tributaries and Upper SJR have been altered and now generally contribute a different percentage of the monthly flow at Vernalis as compared to unimpaired flow. Under unimpaired conditions the Stanislaus, Tuolumne, Merced, and Upper SJR would have contributed a median of 20%, 31%, 14%, and 30%, respectively, on an annual basis to the flow at Vernalis. The remaining portion, including the Fresno River, Chowchilla River, Valley Floor, and the Tulare Lake Basin, contributes 2%. The percentages presented in Figures 2.8 and 2.9 do not necessarily add up to 100% because they are median values.



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
UF	99%	98%	94%	91%	90%	90%	95%	97%	95%	96%	93%	104%
OBS	70%	61%	65%	58%	58%	61%	79%	80%	86%	86%	77%	67%

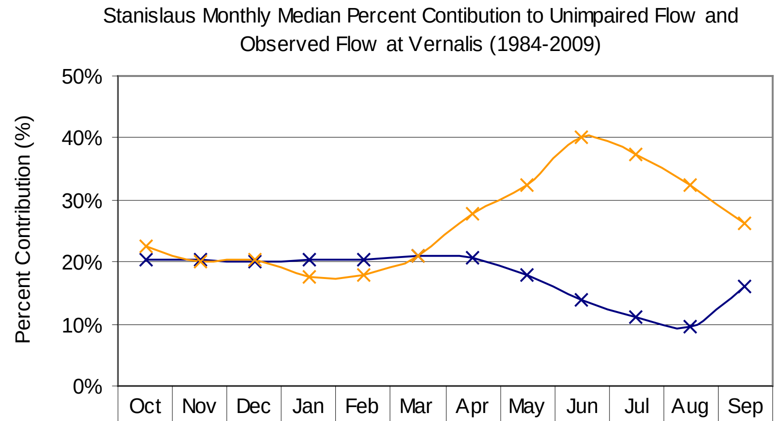
Figure 2.8. Median Observed and Unimpaired Flow Contributed by the LSJR Tributaries and Upper SJR Combined (1984 to 2009)

As shown in Table 2.12, under current conditions, the Stanislaus, Tuolumne, and Merced contribute an annual median of 24%, 21%, and 14% unimpaired flow, respectively, while the Upper SJR now contributes an annual median of 8% of flow. The difference between unimpaired and observed flow for the remainder is due primarily to the operation of the Delta Mendota Canal that adds additional flow from the Delta. Again, the percentages in this table do not necessarily add up to 100% because they are median values.

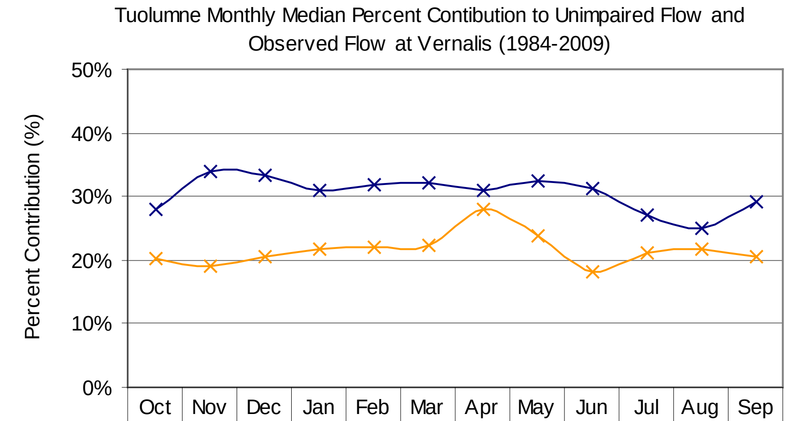
Table 2.12. Median Annual Percent Contribution of Unimpaired Flow and Observed Flow by SJR Tributary and Upper SJR to Flow at Vernalis (1984 to 2009)

	Stanislaus	Tuolumne	Merced	Upper SJR at Friant	Fresno/ Chowchilla/ Tulare/ Valley Floor
Unimpaired Flow(1984 to 2009)	20%	31%	14%	30%	2%
Observed Flow (1984 to 2009)	24%	21%	14%	8%	26%

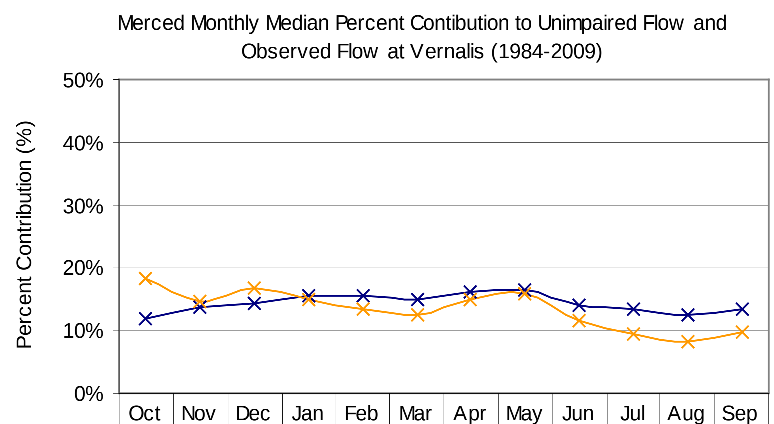
The percent of flow contributed at Vernalis by the Stanislaus River during June and July has increased dramatically, accounting for roughly 40% of flow during these months, while the contributions from the Tuolumne have been reduced to roughly 20% during these same months (Figure 2.9). The Upper SJR contributes a much lower percentage of flow compared to unimpaired conditions.



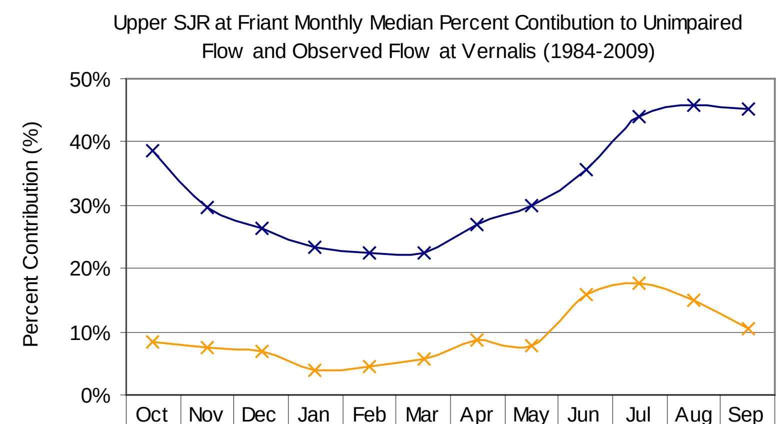
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
UF	20%	20%	20%	20%	20%	21%	21%	18%	14%	11%	10%	16%
OBS	23%	20%	20%	18%	18%	21%	28%	32%	40%	37%	32%	26%



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
UF	28%	34%	33%	31%	32%	32%	31%	33%	31%	27%	25%	29%
OBS	20%	19%	21%	22%	22%	22%	28%	24%	18%	21%	22%	21%



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
UF	12%	14%	14%	16%	15%	15%	16%	16%	14%	13%	13%	14%
OBS	18%	15%	17%	15%	13%	12%	15%	16%	12%	9%	8%	10%



	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
UF	39%	30%	26%	23%	22%	22%	27%	30%	36%	44%	46%	45%
OBS	8%	7%	7%	4%	5%	6%	9%	8%	16%	18%	15%	11%

Figure 2.9. Median Monthly Unimpaired and Observed Tributary Flow Contribution to Flow at Vernalis (1984 to 2009)

2.4.2 Monthly and Seasonal Trends

Similar to the SJR at Vernalis (as described in section 2.3.2), spring flows in each of the LSJR tributaries and Upper SJR have been significantly reduced while flows during late summer and fall (generally August to November) have increased, resulting in less variability in flow during the year. Additionally, the year to year variability in winter and spring flows has been greatly reduced. Alterations to flow characteristics at Vernalis are driven mainly by the alterations that have occurred on the main LSJR tributaries and the Upper SJR.

Boxplots of the median, 25th percentile, 75th percentile, and the wettest and driest months of water years 1984 to 2009 are presented in Figure 2.10 for the Stanislaus River, Figure 2.11 for the Tuolumne River, Figure 2.12 for the Merced River, Figure 2.13 for the Upper SJR, and Figure 2.14 for the combined Chowchilla and Fresno Rivers, Valley Floor, and Tulare Lake Basin flow contributions to the SJR. These graphical comparisons of the unimpaired flow and observed flows illustrate the magnitude of alteration in the timing, variability, and volume of flows.

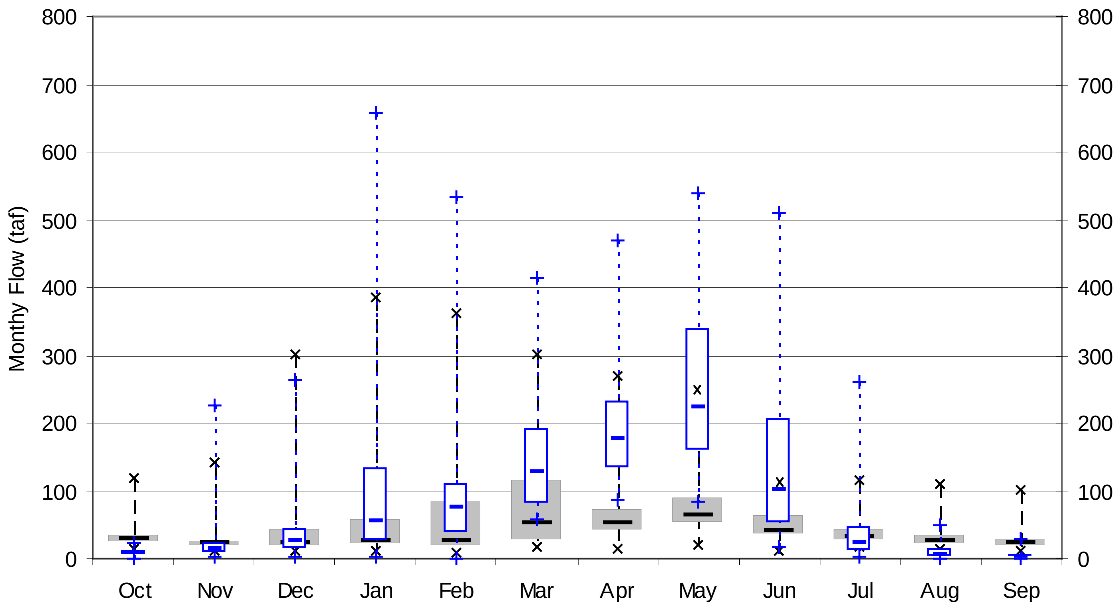
Monthly unimpaired flow, observed monthly flow, and observed monthly flow as a percentage of monthly unimpaired flow for water years 1984 through 2009 are presented in Tables 2.13 through 2.15, respectively, for the Stanislaus River. The same information is presented in Tables 2.17 through 2.19 for the Tuolumne River, Tables 2.21 through 2.23 for the Merced River, Tables 2.25 through 2.27 for the Upper SJR, and Tables 2.29 through 2.31 for the combined Chowchilla and Fresno Rivers, Valley Floor, and Tulare Lake Basin flow contributions to the SJR.

The percentile monthly unimpaired, observed, and percentages of unimpaired flow for water years 1984 through 2009 are presented in Table 2.16 for the Stanislaus River, Table 2.20 for the Tuolumne River, Table 2.24 for the Merced River, Table 2.28 for the Upper SJR, and Table 2.32 for the combined Chowchilla and Fresno Rivers, Valley Floor, and Tulare Lake Basin flow contributions to the SJR. As with the SJR at Vernalis, observed flows from these tributaries are much lower, primarily during the wet season, and with much less variation from year to year and within the year than the unimpaired flows. The inter-quartile ranges of each month are also much less than the corresponding unimpaired range. Although late summer and fall flows have been augmented, it is of lower magnitude than the spring reduction such that annual flows are greatly reduced.

Although the median February through June observed flows are 40%, 21%, 26% of unimpaired flows in the Stanislaus, Tuolumne, and Merced Rivers respectively, the April, May and June values are generally far lower, especially May and June flows on the Tuolumne and Merced Rivers (see Tables 2.16, 2.20, and 2.24). For April, May and June, the medians are 32, 26 and 40% of unimpaired flow for the Stanislaus River, 22%, 12% and 9% of unimpaired flow for the Tuolumne River, and 25%, 18% and 15% of unimpaired flow on the Merced River. Flows were as low as 2% and 1% of unimpaired flow on the Tuolumne and Merced Rivers, respectively, in June, 1991. Annual observed flows in each of the tributaries have also been reduced, and now only 58%, 40%, 46%, and 13% of annual unimpaired flow remain in the Stanislaus, Tuolumne, Merced, and Upper SJR, respectively.

The observed flow as a percentage of unimpaired flow for the Valley Floor, Fresno River, Chowchilla River, and Tulare Lake Basin outflows combined, developed by subtracting the Upper SJR, Stanislaus, Tuolumne, and Merced Rivers from the SJR at Vernalis, has a median of 150% of unimpaired flow (Table 2.16). This increase is likely due to addition of water via the DMC.

Based on the unimpaired data, the wettest month during the spring snowmelt period is generally either April or May for each of the LSJR tributaries and Upper SJR. For example in the Stanislaus River, May was the peak month for 17 of the 26 years between 1984 and 2009; April was the peak in seven years, all of which were classified Dry or Critically Dry water years. This corresponds to findings in Cain et al. (2003) using daily observed flows from 1896 to 1932, which found that the date of the median pre-dam peak was roughly May 17 for most water year types, ranging from April 21 to June 13.



Key to boxplots: Median, horizontal line; box, 25th and 75th percentiles; whiskers, range for unimpaired flow (“+”sign) and observed (“x” sign).

Figure 2.10. Monthly Unimpaired Flow (Open Bars) and Observed Flow (Filled Bars) in the Stanislaus River from 1984 to 2009

Table 2.13. Monthly, Annual, and February through June Unimpaired Flow in the Stanislaus River from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	24	225	153	144	98	137	157	297	148	41	10	1	1,435	837
1985	D	11	48	31	26	48	79	206	171	53	3	1	2	679	557
1986	W	1	40	43	99	532	353	253	300	215	57	19	25	1,937	1,653
1987	C	13	3	9	13	29	59	104	94	27	11	6	4	372	313
1988	C	3	10	14	27	35	59	86	83	40	12	6	3	378	303
1989	C	9	6	14	18	30	181	234	162	94	24	7	1	780	701
1990	C	22	17	13	25	24	83	134	87	51	12	1	1	470	379
1991	C	3	2	3	3	1	81	97	183	106	21	4	6	510	468
1992	C	12	14	13	18	72	78	136	95	17	19	6	6	486	398
1993	W	6	8	27	182	108	234	249	407	241	76	17	3	1,558	1,239
1994	C	10	10	13	15	29	61	106	159	41	4	1	6	455	396
1995	W	5	24	26	230	100	415	276	484	460	261	50	18	2,349	1,735
1996	W	11	10	42	86	276	215	255	377	175	38	4	1	1,490	1,298
1997	W	7	50	265	659	90	129	180	231	110	22	11	4	1,758	740
1998	W	12	17	20	152	250	231	245	341	511	245	40	28	2,092	1,578
1999	AN	15	31	39	101	197	124	173	370	215	49	16	17	1,347	1,079
2000	AN	9	18	12	91	189	160	222	292	128	24	7	10	1,162	991
2001	D	13	13	12	23	36	96	134	200	28	5	2	4	566	494
2002	D	6	20	57	62	55	102	213	216	97	15	5	1	849	683
2003	BN	3	31	48	58	55	96	155	325	181	22	13	7	994	812
2004	D	2	8	47	42	76	164	175	153	61	17	5	1	752	629
2005	W	17	23	41	146	111	194	211	533	292	101	15	6	1,692	1,342
2006	W	13	11	210	199	138	229	470	538	277	77	23	16	2,201	1,652
2007	C	16	13	29	27	78	112	124	124	32	5	2	1	565	471
2008	C	9	3	14	47	52	73	130	192	85	13	4	3	625	532
2009	D	5	24	15	53	73	170	190	334	100	32	13	6	1,014	867

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.14. Monthly, Annual and February through June Observed Flow in the Stanislaus River from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	109	143	303	282	101	84	52	52	29	28	32	45	1,260	318
1985	D	49	22	49	64	41	35	46	40	35	82	77	27	568	196
1986	W	26	25	27	29	91	300	116	77	73	52	73	77	967	657
1987	C	43	32	55	35	45	71	66	47	49	35	29	25	532	277
1988	C	15	19	14	13	13	67	52	54	53	47	46	42	435	239
1989	C	29	27	29	15	12	67	57	67	53	41	25	25	448	256
1990	C	20	15	13	11	10	53	33	34	36	37	33	19	314	166
1991	C	21	25	12	11	10	16	15	23	13	19	13	12	192	77
1992	C	18	22	11	10	18	16	40	21	15	16	17	18	223	110
1993	W	20	13	14	38	17	20	29	85	35	24	20	22	338	187
1994	C	34	18	19	19	17	52	32	32	28	29	25	18	324	162
1995	W	24	19	20	42	20	43	54	87	40	26	25	21	422	245
1996	W	31	19	21	25	85	214	102	92	63	45	34	28	758	555
1997	W	35	44	196	386	361	171	75	99	70	31	27	27	1,521	776
1998	W	51	24	25	71	234	150	118	127	111	115	110	101	1,237	740
1999	AN	120	57	59	107	199	126	85	94	81	45	39	33	1,046	585
2000	AN	31	25	24	26	83	135	74	97	62	25	24	24	629	451
2001	D	34	25	25	24	21	24	54	76	35	31	23	19	390	209
2002	D	29	22	26	25	27	32	59	59	33	30	20	17	379	210
2003	BN	23	19	20	20	30	31	47	51	72	32	22	19	386	232
2004	D	36	19	19	19	25	21	36	51	42	34	22	17	342	175
2005	W	21	18	19	28	18	24	22	91	35	20	19	19	333	189
2006	W	32	23	71	257	94	192	270	254	109	78	74	69	1,522	919
2007	C	96	41	56	69	48	59	49	88	47	28	22	16	619	291
2008	C	27	19	19	23	18	48	66	53	27	26	21	14	360	212
2009	D	24	17	17	13	15	18	44	54	37	22	19	28	306	167

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

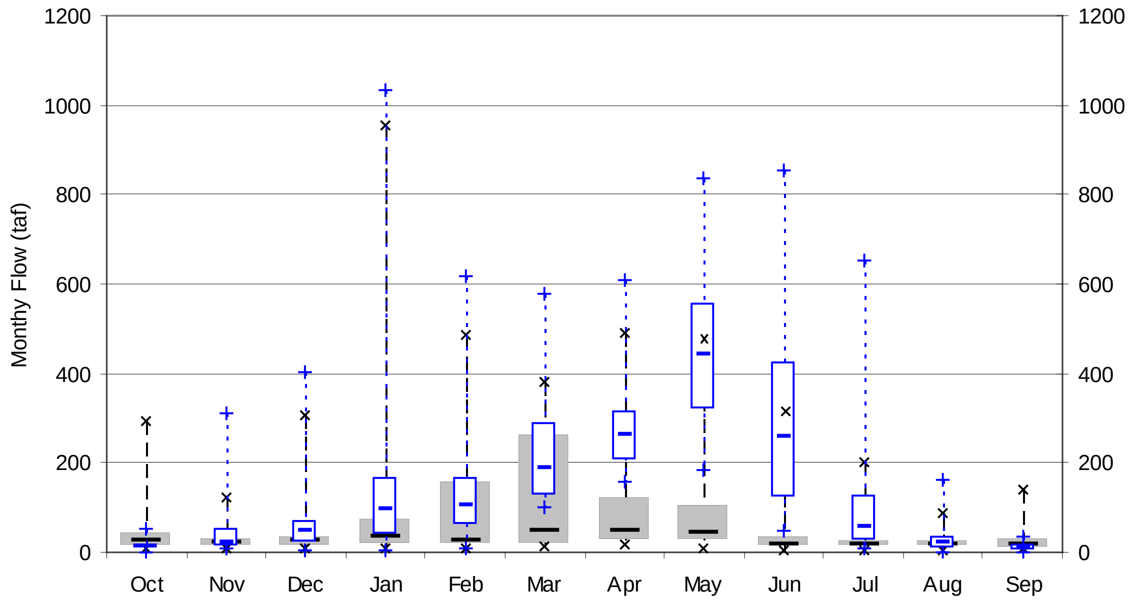
Table 2.15. Monthly, Annual, and February through June Observed Flow as a Percentage of Unimpaired Flow in the Stanislaus River from 1984 to 2009

Water Year	Water Year Type[1]	Oct (%)	Nov (%)	Dec (%)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Annual (%)	Feb-Jun (%)
1984	AN	455	63	198	196	103	61	33	17	19	69	325	4,502	88	38
1985	D	446	46	158	248	85	44	22	23	66	2,738	7,736	1,368	84	35
1986	W	2,648	61	64	29	17	85	46	26	34	91	387	309	50	40
1987	C	332	1,062	610	273	155	120	63	50	181	318	489	615	143	89
1988	C	515	188	103	47	38	113	61	65	133	388	766	1,404	115	79
1989	C	327	451	206	84	39	37	25	41	57	171	357	2,500	57	37
1990	C	90	87	102	44	43	64	24	39	70	311	3,277	1,912	67	44
1991	C	698	1,231	413	379	1,014	20	15	13	12	92	330	206	38	17
1992	C	151	158	85	57	25	21	29	23	87	85	278	305	46	28
1993	W	334	162	53	21	16	9	12	21	15	31	119	732	22	15
1994	C	338	184	144	126	60	86	30	20	68	724	2,497	305	71	41
1995	W	481	78	76	18	20	10	20	18	9	10	50	119	18	14
1996	W	278	192	50	29	31	99	40	24	36	118	853	2,828	51	43
1997	W	500	88	74	59	401	132	42	43	63	140	241	670	87	105
1998	W	427	143	123	47	93	65	48	37	22	47	275	362	59	47
1999	AN	800	185	152	106	101	102	49	25	38	93	244	193	78	54
2000	AN	340	137	199	28	44	85	33	33	49	106	348	237	54	45
2001	D	264	193	207	102	57	25	40	38	124	615	1,139	482	69	42
2002	D	490	112	46	40	49	31	28	27	34	199	391	1,745	45	31
2003	BN	771	61	42	35	55	32	31	16	40	143	168	268	39	29
2004	D	1,594	242	40	45	33	13	21	34	69	199	426	1,655	45	28
2005	W	122	79	46	19	16	12	10	17	12	20	123	302	20	14
2006	W	254	205	34	129	68	84	57	47	39	101	325	438	69	56
2007	C	590	314	190	254	61	53	40	70	147	602	993	1,135	110	62
2008	C	312	622	131	49	34	66	51	27	32	202	505	502	58	40
2009	D	526	69	112	25	21	11	23	16	37	68	147	483	30	19

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.16. Statistics of Unimpaired Flow, Observed Flow, and Observed Flow as Percent of Unimpaired Flow in the Stanislaus River from 1984 to 2009

Unimpaired flow (TAF)													
Statistic	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	Feb-Jun
10%tile	3	5	12	17	29	67	105	95	30	5	2	1	463	388
20%tile	5	8	13	23	35	79	130	153	41	12	4	1	510	468
25%tile	5	10	13	25	39	82	134	160	52	12	4	2	565	476
30%tile	6	10	14	27	50	90	135	167	57	14	5	2	595	513
40%tile	9	13	15	42	55	102	157	192	94	19	6	3	752	629
50%tile	10	16	27	55	75	127	178	224	103	22	7	4	922	721
60%tile	11	18	31	86	90	160	206	297	128	24	10	6	1,162	837
70%tile	12	24	42	100	104	176	218	329	178	40	13	6	1,463	1,035
75%tile	13	24	43	133	110	191	231	339	207	47	15	7	1,541	1,199
80%tile	13	31	47	146	138	215	245	370	215	57	16	10	1,692	1,298
90%tile	17	44	105	191	224	233	254	446	285	89	21	18	2,015	1,615
Observed flow (TAF)														
10%tile	20	17	14	12	13	19	30	33	28	21	19	16	310	164
20%tile	21	19	17	15	17	24	36	47	33	25	20	18	333	175
25%tile	23	19	19	19	17	26	41	51	35	26	21	18	339	187
30%tile	24	19	19	20	18	31	45	51	35	27	22	19	351	193
40%tile	27	19	20	24	20	43	49	54	36	29	23	19	386	210
50%tile	30	22	22	25	26	53	53	63	41	31	25	23	429	235
60%tile	32	24	25	29	41	67	57	77	49	34	27	25	532	256
70%tile	35	25	28	40	65	77	66	87	58	39	33	28	624	304
75%tile	36	25	44	59	84	116	72	90	63	44	34	28	725	417
80%tile	43	27	55	69	91	135	75	92	70	45	39	33	967	555
90%tile	74	43	65	182	150	181	109	98	77	65	74	57	1,249	698
Observed flow as a percent of unimpaired flow (%)														
10%tile	202	62	44	23	19	11	18	17	13	39	135	221	26	16
20%tile	278	78	50	29	25	20	22	18	22	69	241	302	39	28
25%tile	315	81	56	31	31	22	23	20	33	86	252	305	45	28
30%tile	330	88	69	37	33	28	24	22	34	92	277	307	46	30
40%tile	338	137	85	45	39	37	29	24	37	101	325	438	51	37
50%tile	437	160	107	48	46	57	32	26	40	129	353	493	58	40
60%tile	481	185	131	59	57	65	40	33	57	171	391	670	67	42
70%tile	508	192	155	104	65	84	41	38	67	201	497	1,251	70	45
75%tile	523	202	182	121	81	85	45	39	69	284	701	1,395	76	47
80%tile	590	242	198	129	93	86	48	41	70	318	853	1,655	84	54
90%tile	786	536	207	251	129	107	54	49	128	608	1,818	2,206	99	70



Key to boxplots: Median, horizontal line; box, 25th and 75th percentiles; whiskers, range for unimpaired flow (“+”sign) and observed (“x” sign).

Figure 2.11. Monthly Unimpaired Flow (Open Bars) and Observed Flow (Filled Bars) in the Tuolumne River from 1984 to 2009

Table 2.17. Monthly, Annual, and February through June Unimpaired Flow in the Tuolumne River from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	44	310	402	175	151	200	203	536	330	93	21	7	2,472	1,420
1985	D	26	85	48	41	69	126	302	341	135	23	15	18	1,229	973
1986	W	31	49	94	129	616	493	320	540	507	144	30	18	2,971	2,476
1987	C	18	8	13	6	37	99	194	203	65	10	8	3	664	598
1988	C	11	26	50	70	57	105	159	213	98	24	6	1	820	632
1989	C	4	21	27	37	61	285	309	321	207	28	2	10	1,312	1,183
1990	C	49	25	22	38	53	130	220	182	100	20	4	1	844	685
1991	C	1	8	5	5	8	168	180	336	295	67	19	7	1,099	987
1992	C	16	25	18	25	93	115	230	189	46	59	14	4	834	673
1993	W	10	14	46	278	161	319	335	631	524	226	54	25	2,623	1,970
1994	C	19	7	18	22	53	108	195	275	119	33	25	10	884	750
1995	W	10	64	58	348	160	579	385	659	811	652	162	35	3,923	2,594
1996	W	12	7	72	129	348	290	323	576	389	133	26	11	2,316	1,926
1997	W	8	112	387	1,033	170	232	277	542	336	57	49	21	3,224	1,557
1998	W	10	18	35	202	358	354	351	477	855	559	84	35	3,338	2,395
1999	AN	21	48	68	136	252	171	262	569	436	109	35	20	2,127	1,690
2000	AN	11	17	10	132	277	253	334	539	322	70	35	18	2,018	1,725
2001	D	17	17	22	32	60	179	227	408	55	12	2	2	1,033	929
2002	D	4	40	93	109	79	141	301	372	223	24	8	6	1,400	1,116
2003	BN	1	69	69	89	65	124	218	520	372	55	30	15	1,627	1,299
2004	D	5	13	82	70	110	257	264	318	148	33	13	7	1,321	1,097
2005	W	54	55	71	260	192	325	305	837	589	258	40	21	3,006	2,248
2006	W	15	16	248	248	154	296	610	816	649	208	37	15	3,313	2,526
2007	C	11	19	29	28	94	147	175	251	61	15	10	8	849	729
2008	C	7	7	18	78	101	124	189	360	204	32	5	4	1,129	977
2009	D	4	62	27	105	118	228	260	563	225	57	9	7	1,665	1,395

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.18. Monthly, Annual, and February through June Observed Flow in the Tuolumne River from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	293	124	263	367	268	188	56	39	19	18	19	23	1,677	569
1985	D	62	69	131	96	76	46	23	21	19	17	16	15	593	186
1986	W	29	33	38	37	140	380	305	170	103	22	21	56	1,334	1,098
1987	C	78	72	127	56	26	46	45	27	12	11	12	11	522	156
1988	C	17	18	19	18	13	15	22	9	7	6	6	7	156	65
1989	C	8	10	11	11	9	16	21	10	8	8	9	10	134	65
1990	C	15	18	16	15	15	16	16	14	7	7	8	9	157	68
1991	C	12	12	11	9	9	23	23	26	6	6	7	7	152	88
1992	C	10	12	11	12	27	16	19	22	7	6	6	7	153	90
1993	W	10	12	13	46	25	18	49	45	29	20	30	59	357	166
1994	C	46	23	27	38	23	20	31	27	9	7	8	7	266	110
1995	W	11	14	15	98	236	348	426	483	326	202	88	141	2,389	1,820
1996	W	110	26	26	41	316	328	180	252	47	21	27	31	1,406	1,123
1997	W	38	30	307	953	488	182	96	70	27	30	28	28	2,275	862
1998	W	45	29	28	167	417	348	343	224	266	184	74	97	2,223	1,599
1999	AN	71	31	80	83	288	230	129	113	28	29	27	29	1,138	788
2000	AN	36	28	26	28	149	294	109	87	35	37	60	54	942	674
2001	D	44	29	28	33	76	61	43	56	15	16	17	17	435	251
2002	D	21	16	25	28	15	19	43	38	14	15	16	14	264	129
2003	BN	21	17	20	18	15	18	48	38	20	21	23	23	284	140
2004	D	25	19	20	21	27	79	76	36	15	15	15	14	362	233
2005	W	23	15	15	53	126	275	294	299	235	133	62	32	1,560	1,229
2006	W	35	27	78	295	160	291	492	490	281	73	49	38	2,309	1,714
2007	C	39	28	29	28	29	33	38	34	15	15	15	13	316	149
2008	C	15	14	15	31	24	18	36	52	12	12	12	11	251	142
2009	D	15	13	14	14	15	18	26	49	15	14	11	12	213	122

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

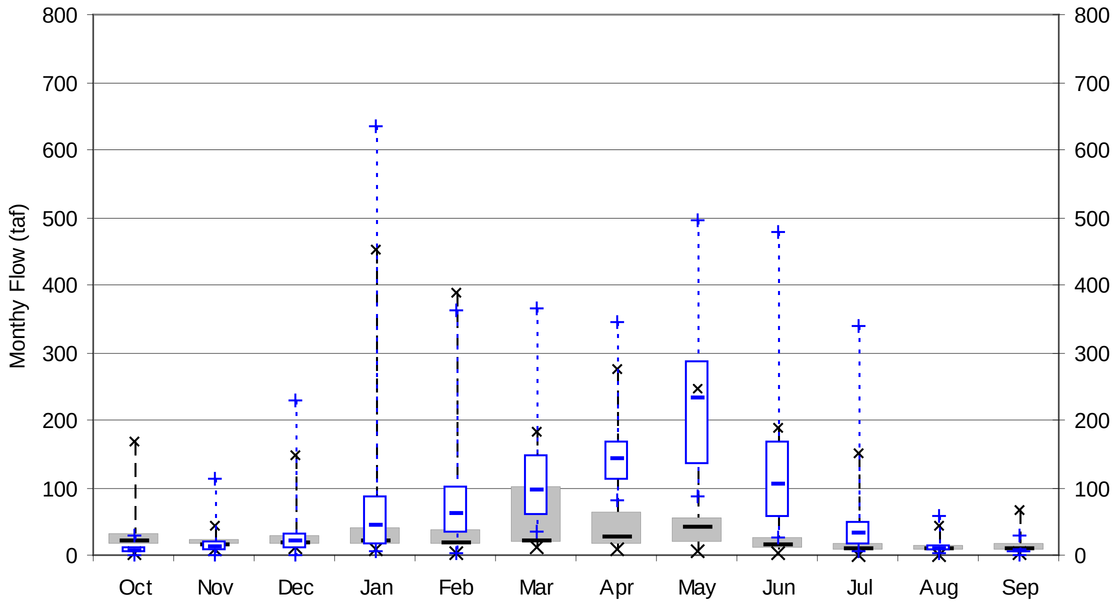
Table 2.19. Monthly, Annual, and February through June Observed Flow as a Percentage of Unimpaired Flow in the Tuolumne River from 1984 to 2009

Water Year	Water Year Type[1]	Oct (%)	Nov (%)	Dec (%)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Annual (%)	Feb-Jun (%)
1984	AN	665	40	65	210	177	94	28	7	6	20	90	330	68	40
1985	D	240	82	273	235	111	37	8	6	14	73	105	85	48	19
1986	W	92	68	40	29	23	77	95	32	20	15	71	310	45	44
1987	C	431	901	979	940	71	46	23	13	19	107	151	361	79	26
1988	C	150	70	37	26	23	14	14	4	7	25	107	660	19	10
1989	C	208	46	42	31	15	6	7	3	4	30	443	102	10	6
1990	C	31	71	74	39	28	12	7	8	7	36	209	881	19	10
1991	C	1,211	147	216	189	115	14	13	8	2	10	38	101	14	9
1992	C	60	48	62	48	29	14	8	12	14	10	43	176	18	13
1993	W	99	89	27	17	16	6	15	7	5	9	56	238	14	8
1994	C	240	335	150	174	44	18	16	10	7	21	31	74	30	15
1995	W	106	22	27	28	148	60	111	73	40	31	55	402	61	70
1996	W	919	373	35	32	91	113	56	44	12	16	105	281	61	58
1997	W	470	27	79	92	287	78	34	13	8	52	57	132	71	55
1998	W	445	162	81	83	117	98	98	47	31	33	89	278	67	67
1999	AN	338	64	118	61	114	135	49	20	6	27	77	147	54	47
2000	AN	326	162	259	22	54	116	33	16	11	52	172	298	47	39
2001	D	260	172	126	104	127	34	19	14	27	130	849	851	42	27
2002	D	513	41	27	26	18	13	14	10	6	61	203	235	19	12
2003	BN	2,084	25	29	21	23	15	22	7	6	38	76	156	17	11
2004	D	474	140	24	30	24	31	29	11	10	46	111	188	27	21
2005	W	42	27	21	20	66	85	96	36	40	51	155	153	52	55
2006	W	241	166	31	119	104	98	81	60	43	35	133	246	70	68
2007	C	356	150	97	101	31	23	21	14	25	103	143	166	37	21
2008	C	217	195	83	40	24	14	19	14	6	36	233	245	22	15
2009	D	351	21	49	13	12	8	10	9	7	24	133	178	13	9

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.20. Statistics of Unimpaired Flow, Observed Flow, and Observed Flow as Percent of Unimpaired Flow in the Tuolumne River from 1984 to 2009

Unimpaired flow (TAF)													
Statistic	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	Feb-Jun
10%tile	4	8	16	24	53	112	184	208	63	17	4	3	839	679
20%tile	5	13	18	32	60	124	195	275	100	24	8	4	884	750
25%tile	7	15	22	37	62	127	207	319	123	25	8	6	1,050	940
30%tile	9	17	25	40	67	136	219	329	141	30	9	7	1,114	975
40%tile	10	18	29	70	93	168	230	360	207	33	14	7	1,312	1,097
50%tile	11	23	47	97	105	190	263	443	260	57	20	10	1,514	1,241
60%tile	15	26	58	129	151	232	301	536	330	67	26	15	2,018	1,420
70%tile	18	49	70	134	161	271	307	541	381	101	33	18	2,394	1,708
75%tile	19	53	72	165	168	289	317	558	424	127	35	18	2,585	1,876
80%tile	21	62	82	202	192	296	323	569	507	144	37	20	2,971	1,970
90%tile	38	77	171	269	313	340	343	645	619	242	52	23	3,268	2,436
Observed flow (TAF)														
10%tile	10	12	12	13	14	16	22	17	7	7	7	7	155	78
20%tile	15	14	15	18	15	18	23	26	9	8	9	10	213	110
25%tile	15	14	15	19	17	18	27	27	12	11	11	11	254	124
30%tile	16	16	16	25	24	19	34	31	13	13	12	11	265	135
40%tile	21	18	20	28	26	23	43	38	15	15	15	14	316	149
50%tile	27	21	25	35	28	46	46	42	17	16	17	16	398	176
60%tile	36	27	27	41	76	79	56	52	20	20	21	23	593	251
70%tile	42	29	28	54	144	209	102	79	28	21	27	30	1,236	731
75%tile	44	29	35	76	158	264	124	106	33	27	28	32	1,388	844
80%tile	46	30	78	96	236	291	180	170	47	30	30	38	1,560	1,098
90%tile	74	51	129	231	302	338	324	275	251	103	61	58	2,249	1,414
Observed flow as a percent of unimpaired flow (%)														
10%tile	76	26	27	20	17	10	8	7	5	13	49	102	14	9
20%tile	106	40	29	26	23	14	13	7	6	20	57	147	18	10
25%tile	165	42	32	27	24	14	14	8	6	22	72	153	19	11
30%tile	212	47	36	28	24	14	14	8	7	24	77	161	19	12
40%tile	240	68	42	31	29	18	19	10	7	30	90	178	27	15
50%tile	293	76	64	40	49	33	22	12	9	34	106	236	40	21
60%tile	351	140	79	61	71	46	28	14	12	36	133	246	47	27
70%tile	438	156	90	97	107	78	34	15	16	49	147	289	53	42
75%tile	464	162	113	104	113	83	45	19	20	52	154	307	59	46
80%tile	474	166	126	119	115	94	56	32	25	52	172	330	61	55
90%tile	792	265	238	199	137	106	96	45	36	88	221	531	69	63



Key to boxplots: Median, horizontal line; box, 25th and 75th percentiles; whiskers, range for unimpaired flow (“+”sign) and observed (“x” sign).

Figure 2.12. Monthly Unimpaired Flow (Open Bars) and Observed Flow (Filled Bars) in the Merced River from 1984 to 2009

Table 2.21. Monthly, Annual, and February through June Unimpaired Flow in the Merced River from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	28	114	204	93	81	97	129	265	114	47	8	1	1,181	686
1985	D	8	28	21	19	33	59	147	171	57	12	5	6	566	467
1986	W	12	16	34	45	362	287	191	316	228	51	12	5	1,559	1,384
1987	C	7	3	5	6	18	36	95	95	25	6	3	1	300	269
1988	C	4	15	13	28	24	48	93	107	55	19	6	3	415	327
1989	C	1	5	10	12	23	96	160	132	73	13	5	5	535	484
1990	C	15	11	9	15	21	56	114	87	48	23	6	2	407	326
1991	C	2	1	1	5	3	96	81	184	145	36	4	2	560	509
1992	C	5	11	8	13	54	51	131	105	31	33	6	2	450	372
1993	W	2	7	22	190	100	157	181	384	280	95	21	8	1,447	1,102
1994	C	7	5	8	9	28	40	87	117	43	9	9	1	363	315
1995	W	16	22	25	200	70	364	206	388	471	340	59	13	2,174	1,499
1996	W	11	7	30	66	191	161	197	317	157	51	14	6	1,208	1,023
1997	W	2	57	230	634	102	116	169	278	114	29	13	6	1,750	779
1998	W	1	7	17	103	253	168	201	251	478	286	51	29	1,845	1,351
1999	AN	15	19	28	49	111	67	128	282	154	35	11	7	906	742
2000	AN	4	10	2	57	171	116	166	276	130	26	11	7	976	859
2001	D	4	6	10	13	31	86	108	215	33	10	3	1	520	473
2002	D	2	13	47	44	35	59	151	178	85	14	4	2	634	508
2003	BN	1	31	34	41	34	62	112	270	170	32	15	6	808	648
2004	D	2	9	26	35	60	120	139	135	54	17	7	4	608	509
2005	W	20	22	41	200	105	191	152	467	325	126	25	12	1,684	1,240
2006	W	8	7	74	129	68	171	344	496	332	85	17	9	1,741	1,411
2007	C	13	10	15	16	37	69	94	103	29	13	8	6	413	331
2008	C	5	6	7	48	64	56	104	196	93	25	7	4	617	514
2009	D	3	21	12	50	61	105	147	287	95	32	11	6	831	695

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.22. Monthly, Annual, and February through June Observed Flow in the Merced River from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	168	44	149	198	71	38	27	25	22	18	17	18	795	183
1985	D	27	32	72	42	18	19	18	18	15	13	12	13	299	87
1986	W	16	14	19	13	25	182	159	104	40	17	16	19	623	510
1987	C	28	15	14	14	13	18	11	12	10	8	8	9	159	64
1988	C	6	12	13	15	12	12	11	11	8	4	4	2	110	53
1989	C	2	8	12	12	11	19	12	10	7	2	1	3	100	58
1990	C	5	10	12	12	14	10	8	8	6	2	1	1	89	46
1991	C	2	8	10	8	4	20	8	6	1	0	1	4	74	40
1992	C	4	12	14	14	18	17	9	6	4	2	2	2	105	54
1993	W	11	15	13	36	21	21	60	56	35	22	37	36	363	194
1994	C	52	15	14	15	18	15	22	26	10	19	6	5	216	91
1995	W	21	14	13	36	17	144	194	231	190	151	34	44	1,089	776
1996	W	114	36	35	30	91	178	66	82	24	11	10	13	690	441
1997	W	32	20	124	452	388	113	41	44	11	9	9	11	1,255	598
1998	W	16	15	14	47	256	167	178	170	145	126	44	67	1,245	916
1999	AN	75	21	26	48	90	49	65	53	18	12	7	12	477	276
2000	AN	20	17	15	17	90	150	52	46	15	11	10	11	454	353
2001	D	34	35	25	21	18	24	34	43	16	8	9	8	274	135
2002	D	25	31	29	23	14	15	21	39	11	6	5	6	224	99
2003	BN	20	15	16	14	12	14	29	41	11	8	6	6	193	108
2004	D	17	16	15	16	19	17	25	41	8	6	6	7	193	111
2005	W	19	15	17	52	27	68	159	149	109	58	44	46	764	513
2006	W	25	15	41	156	43	169	275	253	153	43	42	41	1,255	892
2007	C	59	24	20	20	16	16	20	41	29	8	8	7	268	122
2008	C	19	38	30	30	25	17	27	51	7	6	5	7	261	126
2009	D	17	19	17	16	15	15	11	17	9	3	3	5	148	67

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

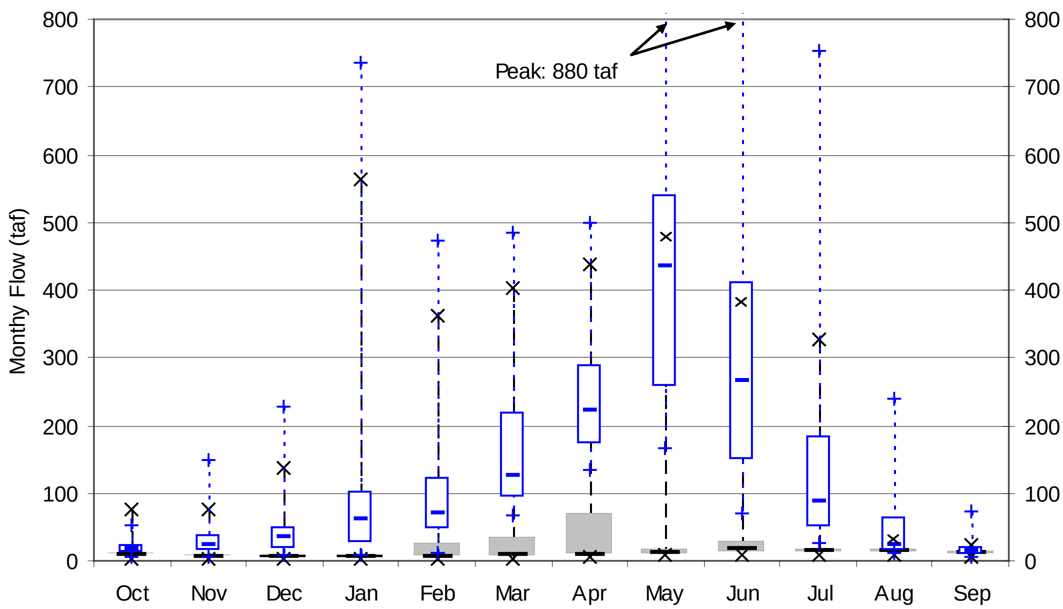
Table 2.23. Monthly, Annual, and February through June Observed Flow as a Percentage of Unimpaired Flow in the Merced River from 1984 to 2009

Water Year	Water Year Type[1]	Oct (%)	Nov (%)	Dec (%)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Annual (%)	Feb-Jun (%)
1984	AN	601	39	73	213	88	39	21	9	20	39	213	1,798	67	27
1985	D	344	116	343	220	54	33	12	10	26	109	232	223	53	19
1986	W	132	88	55	29	7	63	83	33	17	33	130	375	40	37
1987	C	397	490	281	236	73	50	11	13	40	127	256	903	53	24
1988	C	160	79	103	55	52	24	12	10	14	20	71	71	27	16
1989	C	233	162	120	103	49	20	7	7	9	16	30	61	19	12
1990	C	34	94	130	80	65	18	7	9	12	7	19	73	22	14
1991	C	97	779	1,050	159	128	21	10	3	1	1	28	219	13	8
1992	C	85	111	171	107	34	33	7	5	11	6	39	123	23	14
1993	W	532	213	58	19	21	14	33	15	13	23	175	445	25	18
1994	C	742	295	174	164	64	38	25	22	24	212	63	472	59	29
1995	W	134	64	54	18	24	40	94	60	40	44	57	337	50	52
1996	W	1,040	520	117	45	48	111	34	26	15	21	71	211	57	43
1997	W	1,592	35	54	71	381	97	24	16	10	32	73	180	72	77
1998	W	1,595	209	83	46	101	99	89	68	30	44	87	231	67	68
1999	AN	497	112	92	99	81	74	51	19	12	35	66	171	53	37
2000	AN	499	167	769	29	52	129	31	17	11	43	91	163	47	41
2001	D	857	580	245	163	59	28	32	20	49	84	284	753	53	28
2002	D	1,270	236	62	53	39	25	14	22	13	43	133	280	35	19
2003	BN	2,028	50	46	34	36	23	26	15	7	24	41	95	24	17
2004	D	768	185	56	46	32	14	18	30	15	34	93	186	32	22
2005	W	97	70	43	26	25	36	105	32	34	46	176	398	45	41
2006	W	304	212	55	120	64	99	80	51	46	50	238	468	72	63
2007	C	462	232	132	122	44	24	22	39	99	61	94	129	65	37
2008	C	396	622	424	64	39	30	26	26	7	25	65	157	42	25
2009	D	517	87	140	32	24	15	7	6	10	9	28	90	18	10

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.24. Statistics of Unimpaired Flow, Observed Flow, and Observed Flow as a Percentage of Unimpaired Flow in the Merced River from 1984 to 2009

Unimpaired flow (TAF)														
Statistic	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	Feb-Jun
10%tile	2	5	6	11	22	50	93	104	32	11	4	1	410	327
20%tile	2	6	8	13	28	56	104	117	48	13	5	2	450	372
25%tile	2	7	9	15	32	59	109	133	54	15	6	2	524	469
30%tile	3	7	10	18	34	61	113	153	56	18	6	3	548	479
40%tile	4	9	13	35	37	69	129	184	85	25	7	4	608	509
50%tile	5	11	19	45	60	96	143	233	104	31	9	5	721	581
60%tile	7	13	25	49	68	105	151	270	130	33	11	6	906	695
70%tile	10	18	29	62	91	118	163	280	156	42	13	6	1,195	819
75%tile	12	21	33	86	102	148	168	286	167	50	14	7	1387	982
80%tile	13	22	34	103	105	161	181	316	228	51	15	7	1,559	1,102
90%tile	16	30	61	195	181	181	199	386	328	110	23	10	1,746	1,368
Observed flow (TAF)														
10%tile	5	11	12	13	12	15	10	9	6	2	2	3	102	54
20%tile	11	14	13	14	14	15	11	12	8	4	4	5	148	64
25%tile	16	14	14	14	14	16	13	17	9	6	5	5	168	72
30%tile	17	15	14	15	15	17	19	21	10	6	6	6	193	89
40%tile	19	15	15	16	18	18	22	39	11	8	6	7	224	108
50%tile	20	15	16	20	18	20	27	41	13	9	8	8	271	124
60%tile	25	17	19	30	21	24	34	44	16	11	9	11	363	183
70%tile	28	21	25	36	26	59	56	52	23	15	11	13	550	314
75%tile	31	23	28	40	39	102	64	55	27	18	15	17	673	419
80%tile	34	31	30	47	71	144	66	82	35	19	17	19	764	510
90%tile	67	36	57	104	90	168	169	160	127	50	39	43	1,167	687
Observed flow as a percent of unimpaired flow (%)														
10%tile	97	57	54	28	24	16	7	7	8	8	29	82	20	13
20%tile	134	79	55	32	32	21	11	9	10	20	41	123	24	16
25%tile	179	87	56	37	35	23	12	10	11	22	59	136	25	17
30%tile	268	91	60	45	37	24	13	11	12	24	64	160	29	18
40%tile	396	112	83	53	44	28	21	15	13	32	71	180	40	22
50%tile	480	164	110	68	51	33	25	18	15	34	80	215	46	26
60%tile	517	209	130	99	54	38	26	22	17	43	93	231	53	29
70%tile	672	222	155	114	64	45	32	26	25	44	132	356	53	37
75%tile	762	235	173	121	65	60	34	29	29	45	165	392	56	40
80%tile	857	295	245	159	73	74	51	32	34	50	176	445	59	41
90%tile	1,431	550	383	189	95	99	86	45	43	96	235	613	67	57



Key to boxplots: Median, horizontal line; box, 25th and 75th percentiles; whiskers, range for unimpaired flow (“+”sign) and observed (“x” sign).

Figure 2.13. Monthly Unimpaired Flow (Open Bars) and Observed Flow (Filled Bars) in the SJR at Friant from 1984 to 2009

Table 2.25. Monthly, Annual, and February through June Unimpaired Flow in the SJR at Friant from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	53	149	227	126	107	162	203	489	266	162	67	36	2,047	1,227
1985	D	31	50	41	40	56	84	254	308	169	55	22	19	1,129	871
1986	W	24	38	68	93	472	426	361	624	593	222	76	32	3,029	2,476
1987	C	24	14	15	21	39	66	172	229	121	33	15	10	759	627
1988	C	16	24	25	59	48	91	153	220	142	49	23	12	862	654
1989	C	7	14	20	22	37	133	237	240	149	41	19	19	938	796
1990	C	23	22	17	25	34	85	173	165	122	54	14	8	742	579
1991	C	8	6	9	10	11	118	135	277	321	102	24	13	1,034	862
1992	C	12	19	18	21	68	77	209	238	76	46	17	9	810	668
1993	W	13	17	32	189	124	243	330	701	599	316	82	26	2,672	1,997
1994	C	19	17	21	23	42	75	150	258	159	36	14	12	826	684
1995	W	43	45	48	213	122	485	350	634	881	752	239	66	3,878	2,472
1996	W	24	15	50	70	229	222	333	589	412	184	55	18	2,201	1,785
1997	W	18	99	213	735	181	219	302	539	280	130	44	21	2,781	1,521
1998	W	18	24	36	102	210	232	288	446	886	686	159	72	3,159	2,062
1999	AN	36	39	50	69	111	102	182	446	337	105	32	17	1,526	1,178
2000	AN	12	12	16	80	155	164	280	530	351	91	37	15	1,743	1,480
2001	D	20	17	16	26	42	126	188	445	115	47	13	10	1,065	916
2002	D	10	22	58	64	57	94	247	323	223	53	13	8	1,172	944
2003	BN	7	62	45	62	60	109	158	436	375	89	34	12	1,449	1,138
2004	D	8	14	44	48	69	192	223	284	173	55	13	7	1,131	941
2005	W	36	41	58	165	133	226	257	818	662	343	73	17	2,830	2,096
2006	W	18	22	110	163	113	198	498	884	763	326	64	23	3,181	2,456
2007	C	20	14	26	24	47	96	137	197	71	25	14	11	684	549
2008	C	10	9	17	58	72	102	176	351	230	68	16	8	1,117	930
2009	D	10	43	26	75	82	139	231	492	223	96	28	10	1,455	1,167

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.26. Monthly, Annual, and February through June Observed Flow in the SJR at Friant from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	77	76	138	240	26	6	14	8	9	8	8	6	615	63
1985	D	5	3	2	2	2	3	6	7	8	9	8	7	64	27
1986	W	6	5	4	4	204	403	277	16	32	11	8	7	974	931
1987	C	4	4	2	2	3	2	8	8	8	10	9	8	67	28
1988	C	7	4	4	3	4	7	6	8	9	11	10	8	80	33
1989	C	8	6	4	2	4	6	7	8	9	11	12	8	84	34
1990	C	7	6	6	3	5	7	9	10	10	13	13	10	99	41
1991	C	9	7	7	6	7	6	7	10	11	13	12	10	105	40
1992	C	9	7	6	5	5	7	8	11	16	17	17	14	123	47
1993	W	12	7	6	7	5	28	69	53	63	42	16	14	322	218
1994	C	10	7	6	6	6	9	9	10	12	15	16	14	120	46
1995	W	10	7	6	6	25	258	361	470	158	327	29	11	1,668	1,272
1996	W	10	8	5	4	37	101	71	100	21	14	14	11	396	330
1997	W	10	6	71	562	362	79	12	16	17	17	19	16	1,187	486
1998	W	14	11	9	7	185	145	277	252	389	268	23	23	1,603	1,248
1999	AN	22	22	33	15	27	5	6	9	20	34	17	12	223	67
2000	AN	8	5	5	6	7	57	8	8	28	14	15	15	177	109
2001	D	12	10	11	9	6	6	7	9	16	13	15	19	132	43
2002	D	12	7	7	6	5	8	10	11	11	14	12	11	114	46
2003	BN	10	8	7	7	6	7	8	10	19	15	12	12	121	50
2004	D	11	7	6	6	6	9	11	12	13	12	12	11	117	50
2005	W	10	8	7	7	8	18	91	311	187	38	15	14	714	614
2006	W	11	9	6	26	5	34	438	409	346	48	20	18	1,370	1,233
2007	C	18	10	8	8	4	8	12	16	17	18	17	16	151	57
2008	C	10	9	6	6	6	13	16	17	17	17	14	10	142	69
2009	D	9	7	6	6	4	8	9	11	11	13	12	10	106	43

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

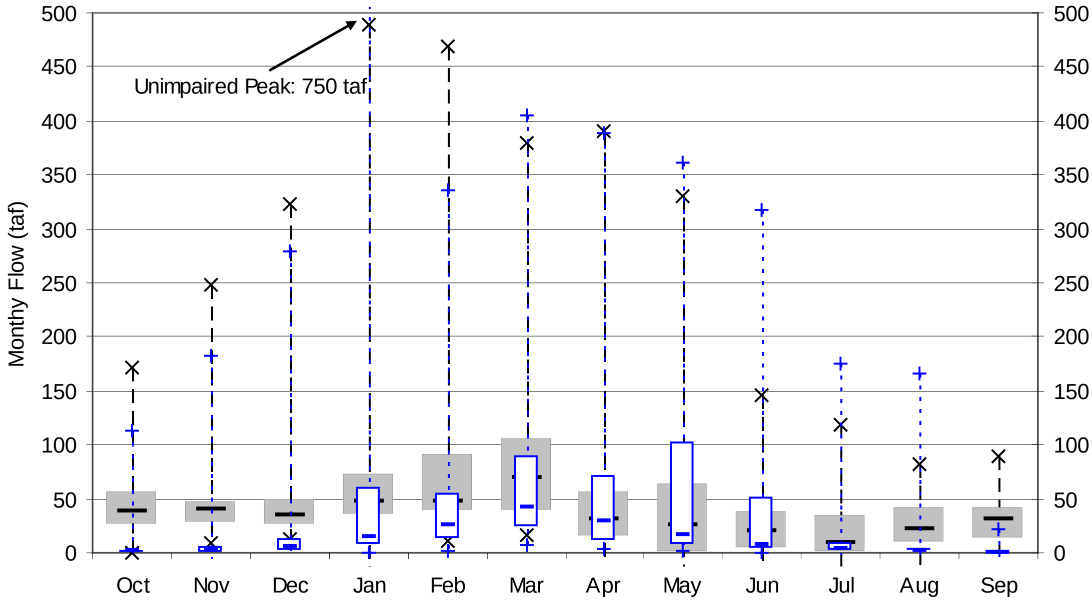
Table 2.27. Monthly, Annual, and February through June Observed Flow as a Percentage of Unimpaired Flow in the SJR at Friant from 1984 to 2009

Water Year	Water Year Type[1]	Oct (%)	Nov (%)	Dec (%)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Annual (%)	Feb-Jun (%)
1984	AN	145	51	61	190	25	4	7	2	3	5	11	17	30	5
1985	D	16	7	5	5	4	3	2	2	5	17	37	38	6	3
1986	W	26	13	5	4	43	95	77	3	5	5	10	21	32	38
1987	C	16	29	15	9	7	3	4	3	7	30	59	77	9	5
1988	C	44	17	15	5	7	8	4	3	6	22	44	68	9	5
1989	C	110	42	18	9	12	4	3	3	6	28	62	44	9	4
1990	C	32	28	35	11	14	8	5	6	8	24	93	131	13	7
1991	C	117	125	72	60	65	5	5	4	3	13	51	74	10	5
1992	C	78	37	35	24	8	9	4	5	21	36	101	157	15	7
1993	W	93	41	18	4	4	12	21	8	11	13	20	54	12	11
1994	C	51	42	27	28	14	12	6	4	8	43	111	116	15	7
1995	W	23	16	13	3	20	53	103	74	18	44	12	16	43	51
1996	W	40	52	10	6	16	46	21	17	5	8	25	61	18	18
1997	W	54	6	33	76	200	36	4	3	6	13	44	77	43	32
1998	W	78	44	26	7	88	63	96	57	44	39	15	32	51	61
1999	AN	61	58	66	22	24	5	3	2	6	33	53	72	15	6
2000	AN	68	43	32	7	5	35	3	2	8	15	41	98	10	7
2001	D	61	60	66	34	13	4	4	2	14	28	115	189	12	5
2002	D	116	32	12	9	9	9	4	4	5	26	90	138	10	5
2003	BN	142	13	16	11	9	6	5	2	5	17	37	104	8	4
2004	D	132	53	15	12	8	5	5	4	7	22	97	158	10	5
2005	W	28	19	12	4	6	8	36	38	28	11	20	82	25	29
2006	W	60	40	6	16	5	17	88	46	45	15	31	80	43	50
2007	C	90	71	29	31	9	9	9	8	23	69	119	151	22	10
2008	C	101	99	38	10	9	13	9	5	7	25	88	127	13	7
2009	D	86	16	23	8	5	5	4	2	5	13	44	102	7	4

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.28. Statistics of Unimpaired Flow, Observed Flow, and Observed Flow as a Percentage of Unimpaired Flow in the SJR at Friant from 1984 to 2009

Unimpaired flow (TAF)														
Statistic	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	Feb-Jun
10%tile	8	13	16	22	38	81	152	225	118	39	14	8	785	641
20%tile	10	14	17	24	42	91	172	240	142	47	14	10	862	684
25%tile	12	14	18	25	47	94	173	258	149	49	15	10	938	813
30%tile	12	16	21	33	52	99	179	281	164	54	17	10	1,050	867
40%tile	16	17	26	58	60	109	203	323	223	55	22	12	1,129	930
50%tile	18	22	34	63	71	130	227	441	248	90	26	14	1,311	1,041
60%tile	20	24	44	70	107	162	247	446	321	102	34	17	1,526	1,178
70%tile	24	39	49	87	118	195	269	511	363	146	50	19	2,124	1,501
75%tile	24	39	50	102	124	219	288	539	412	184	64	21	2,672	1,719
80%tile	24	43	58	126	133	222	302	589	593	222	67	23	2,781	1,997
90%tile	36	56	89	177	196	238	342	668	713	334	79	34	3,094	2,276
Observed flow (TAF)														
10%tile	7	4	4	2	4	5	6	8	9	10	9	7	82	33
20%tile	8	6	5	4	4	6	7	8	10	11	12	8	105	41
25%tile	8	6	5	4	5	6	8	9	11	12	12	10	114	43
30%tile	9	7	6	5	5	7	8	9	11	13	12	10	115	45
40%tile	10	7	6	6	5	7	9	10	13	13	12	11	121	47
50%tile	10	7	6	6	6	8	10	11	16	14	14	11	137	54
60%tile	10	7	6	6	6	9	12	12	17	15	15	12	177	67
70%tile	11	8	7	7	7	23	15	16	20	17	16	14	359	164
75%tile	12	9	7	7	25	34	69	17	28	18	17	14	615	302
80%tile	12	9	8	8	26	57	71	53	32	34	17	15	714	486
90%tile	16	11	22	20	111	123	277	281	172	45	20	17	1,279	1,082
Observed flow as a percent of unimpaired flow (%)														
10%tile	24	13	8	4	5	4	3	2	5	9	13	26	9	4
20%tile	32	16	12	5	6	5	4	2	5	13	20	44	9	5
25%tile	41	18	14	7	7	5	4	2	5	13	26	56	10	5
30%tile	47	24	15	7	8	5	4	3	6	14	34	64	10	5
40%tile	60	32	16	9	9	8	4	3	6	17	41	74	12	5
50%tile	65	40	20	10	9	8	5	4	7	22	44	79	13	7
60%tile	78	42	27	11	13	9	6	4	8	25	53	98	15	7
70%tile	91	48	33	19	15	12	9	5	10	28	75	110	20	11
75%tile	99	52	35	24	19	16	18	7	13	29	90	124	24	17
80%tile	110	53	35	28	24	35	21	8	18	33	93	131	30	29
90%tile	125	66	63	47	54	49	82	42	26	41	106	154	43	44



Key to boxplots: Median, horizontal line; box, 25th and 75th percentiles; whiskers, range for unimpaired flow (“+”sign) and observed (“x” sign).

Figure 2.14. Monthly Unimpaired Flow (Open Bars) and Observed Flow (Filled Bars) Attributed to the Chowchilla and Fresno Rivers, Valley Floor, and Tulare Lake Basin Outflows Combined from 1984 to 2009

Table 2.29. Monthly, Annual, and February through June Unimpaired Flow Attributed to the Chowchilla and Fresno Rivers, Valley Floor, and Tulare Lake Basin outflows combined from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	114	183	268	235	45	39	22	13	6	2	2	-1	928	125
1985	D	2	9	8	8	22	32	17	6	6	2	0	0	112	83
1986	W	0	5	10	12	329	406	259	161	100	4	2	1	1,289	1,255
1987	C	1	2	3	6	14	27	4	3	4	0	2	-1	65	52
1988	C	1	1	2	9	5	7	8	4	2	1	1	0	41	26
1989	C	0	0	4	4	7	24	7	3	0	2	1	1	53	41
1990	C	0	1	1	5	6	9	4	2	1	3	0	-1	31	22
1991	C	0	0	0	0	1	75	17	7	7	5	2	0	114	107
1992	C	1	0	1	4	52	20	5	8	0	9	1	0	101	85
1993	W	0	0	8	213	100	96	49	23	15	6	3	21	534	283
1994	C	2	2	5	4	12	7	7	11	9	7	1	-1	66	46
1995	W	1	1	3	161	45	394	241	303	111	83	5	7	1,355	1,094
1996	W	2	2	15	34	124	110	50	88	8	14	9	1	457	380
1997	W	2	34	279	749	336	86	24	10	5	4	5	1	1,535	461
1998	W	6	4	6	91	316	164	388	361	318	175	166	5	2,000	1,547
1999	AN	3	6	10	25	55	26	39	15	9	4	2	2	196	144
2000	AN	3	1	1	28	182	109	35	18	7	2	4	1	391	351
2001	D	3	2	2	9	24	44	24	8	3	4	4	1	128	103
2002	D	0	2	26	25	12	21	9	6	2	3	2	0	108	50
2003	BN	-2	5	24	14	10	15	20	20	4	4	1	0	115	69
2004	D	-7	-4	13	12	25	69	76	85	38	4	-4	-6	300	293
2005	W	5	6	14	73	49	90	89	272	189	79	8	-3	870	688
2006	W	-3	-3	59	70	41	86	194	280	205	65	6	-2	999	806
2007	C	-2	-3	2	2	19	36	47	63	12	-2	-5	-6	163	177
2008	C	-5	-6	-3	16	22	29	55	108	56	6	-5	-6	266	269
2009	D	-6	7	0	21	27	59	79	168	59	14	-2	-5	422	393

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.30. Monthly, Annual, and February through June Observed Flow Attributed to the Chowchilla and Fresno Rivers, Valley Floor, and Tulare Lake Basin outflows combined from 1984 to 2009

Water Year	Water Year Type[1]	Oct (TAF)	Nov (TAF)	Dec (TAF)	Jan (TAF)	Feb (TAF)	Mar (TAF)	Apr (TAF)	May (TAF)	Jun (TAF)	Jul (TAF)	Aug (TAF)	Sep (TAF)	Annual (TAF)	Feb-Jun (TAF)
1984	AN	172	248	324	489	156	145	105	77	59	44	58	81	1,958	542
1985	D	91	41	39	45	43	65	54	45	27	36	47	51	584	234
1986	W	50	38	48	44	26	274	309	172	124	77	78	90	1,329	904
1987	C	78	44	29	34	32	73	41	40	39	37	42	43	533	226
1988	C	39	39	28	42	37	38	37	28	25	16	29	27	387	166
1989	C	22	25	29	36	32	17	17	25	17	16	25	34	294	107
1990	C	39	34	38	36	32	22	12	13	7	3	8	12	256	87
1991	C	17	15	16	15	12	45	17	-1	2	-3	-1	1	135	74
1992	C	7	11	13	18	52	35	8	-5	-12	-13	-12	-4	97	78
1993	W	0	10	15	126	101	78	-4	-17	-23	-15	19	34	323	134
1994	C	46	41	35	31	46	39	17	27	7	-1	-1	7	294	136
1995	W	18	22	25	102	66	106	150	93	120	-99	66	65	733	534
1996	W	85	55	52	49	130	106	28	-8	68	45	40	46	696	324
1997	W	51	61	51	-485	348	257	57	65	33	21	32	42	534	760
1998	W	41	39	54	78	469	380	390	331	146	119	82	54	2,183	1,715
1999	AN	91	64	68	37	46	101	99	73	32	7	31	35	683	350
2000	AN	61	54	33	54	106	107	55	58	25	30	24	35	644	352
2001	D	49	51	50	63	51	96	41	32	11	18	19	19	501	232
2002	D	36	48	40	82	45	57	21	21	14	11	16	22	415	160
2003	BN	31	43	59	59	41	65	26	20	-2	6	15	17	380	150
2004	D	33	37	32	48	50	81	15	23	5	3	14	19	360	174
2005	W	36	41	39	163	116	111	33	-209	27	7	21	32	417	78
2006	W	58	48	20	77	56	33	188	196	45	100	43	31	895	518
2007	C	25	48	32	34	43	40	13	0	-4	1	0	8	241	93
2008	C	26	23	23	52	63	34	-1	-3	-2	-8	2	12	220	91
2009	D	11	13	16	19	31	29	1	0	-6	-14	-8	1	93	54

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.31. Monthly, Annual, and February through June Observed Flow as a Percentage of Unimpaired Flow Attributed to the Chowchilla and Fresno Rivers, Valley Floor, and Tulare Lake Basin outflows combined from 1984 to 2009

Water Year	Water Year Type[1]	Oct (%)	Nov (%)	Dec (%)	Jan (%)	Feb (%)	Mar (%)	Apr (%)	May (%)	Jun (%)	Jul (%)	Aug (%)	Sep (%)	Annual (%)	Feb-Jun (%)
1984	AN	151	136	121	208	348	372	477	592	979	2,191	2,900	-8,124	211	434
1985	D	4,533	451	487	565	195	204	318	758	447	1,803	0	0	522	282
1986	W	0	760	479	363	8	67	119	107	124	1,920	3,884	9,032	103	72
1987	C	7,775	2,215	981	562	226	272	1,035	1,343	985	0	2,103	-4,287	821	435
1988	C	3,882	3,929	1,425	464	748	544	459	702	1,272	1,646	2,910	0	944	638
1989	C	0	0	716	910	451	70	242	834	0	797	2,479	3,386	554	261
1990	C	0	3,448	3,761	713	541	246	303	628	727	97	0	-1,225	827	393
1991	C	0	0	0	0	1,178	59	97	-13	31	-53	-30	0	118	69
1992	C	712	0	1,287	443	100	175	156	-64	0	-148	-1,240	0	96	92
1993	W	0	0	189	59	101	81	-8	-76	-155	-247	640	162	61	48
1994	C	2,296	2,044	696	768	382	560	246	244	75	-12	-58	-744	446	295
1995	W	1,829	2,222	826	63	146	27	62	31	108	-120	1,319	929	54	49
1996	W	4,253	2,746	345	145	105	96	56	-10	854	321	446	4,598	152	85
1997	W	2,567	180	18	-65	104	298	236	647	668	537	638	4,159	35	165
1998	W	679	981	896	86	149	231	100	92	46	68	50	1,082	109	111
1999	AN	3,032	1,064	677	148	84	388	253	483	356	187	1,534	1,735	348	243
2000	AN	2,036	5,423	3,346	195	59	98	158	322	359	1,489	594	3,518	165	100
2001	D	1,629	2,556	2,503	701	213	219	173	405	358	455	463	1,919	391	225
2002	D	0	2,419	154	327	376	273	239	356	713	375	789	0	384	319
2003	BN	-1,531	850	245	420	408	434	131	101	-51	155	1,546	0	331	218
2004	D	-506	-952	257	395	203	118	20	27	12	74	-306	-290	120	59
2005	W	734	645	283	223	239	123	37	-77	14	9	280	-1,257	48	11
2006	W	-2,041	-1,896	34	111	134	39	97	70	22	154	677	-1,665	90	64
2007	C	-1,161	-1,902	1,541	2,113	235	109	28	0	-30	-49	4	-142	148	52
2008	C	-486	-394	-885	330	284	118	-3	-2	-3	-134	-40	-181	83	34
2009	D	-176	174	106,793	90	114	49	1	0	-11	-96	377	-20	22	14

Notes: [1] W, AN, BN, D, C stand for Wet, Above Normal, Below Normal, Dry, and Critically Dry classified water years, respectively.

Table 2.32. Statistics of Unimpaired Flow, Observed Flow, and Percent of Unimpaired Flow Statistics Attributed to the Chowchilla and Fresno Rivers, San Joaquin Valley Floor, and Tulare Lake Basin Outflows Combined from 1984 to 2009

Statistic	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual	Feb-Jun
Unimpaired flow (TAF)														
10%tile	-4	-3	1	4	7	12	6	4	2	2	-3	-6	59	44
20%tile	-2	0	1	5	12	21	8	6	3	2	0	-2	101	52
25%tile	0	0	2	7	13	25	11	7	4	2	1	-1	109	73
30%tile	0	1	2	9	16	27	17	8	5	3	1	-1	113	84
40%tile	0	1	3	12	22	32	22	11	6	4	1	0	128	107
50%tile	1	2	6	15	26	42	30	17	8	4	2	0	231	161
60%tile	1	2	8	25	45	69	47	23	9	5	2	0	391	283
70%tile	2	5	11	31	50	86	52	87	26	7	4	1	496	366
75%tile	2	5	13	61	54	89	71	103	51	9	4	1	786	389
80%tile	3	6	15	73	100	96	79	161	59	14	5	1	928	461
90%tile	4	8	43	187	249	137	218	276	150	72	7	4	1,322	950
Observed flow (TAF)														
10%tile	14	14	16	18	31	31	4	-7	-5	-14	-1	4	178	78
20%tile	22	23	23	34	32	35	13	-1	-2	-3	2	12	256	91
25%tile	25	28	26	35	38	38	15	0	3	0	10	14	294	96
30%tile	28	36	29	36	42	39	17	6	6	2	15	18	309	121
40%tile	36	39	32	42	45	57	21	21	11	6	19	22	380	150
50%tile	39	41	34	47	48	69	30	26	21	9	23	31	416	170
60%tile	46	43	39	52	52	81	41	32	27	16	29	34	533	232
70%tile	51	48	44	61	64	103	55	52	33	26	36	38	614	337
75%tile	56	48	50	74	92	106	56	63	38	34	42	43	673	352
80%tile	61	51	51	78	106	107	99	73	45	37	43	46	696	518
90%tile	88	58	56	114	143	201	169	132	94	61	62	60	1,112	651
Observed flow as a percent of unimpaired flow (%)														
10%tile	-1198	-897	69	72	92	54	11	-38	-24	-128	-53	-1,927	51	41
20%tile	-490	143	182	107	104	70	37	-2	6	-62	-10	-1,232	83	52
25%tile	-254	175	245	145	107	85	57	0	14	-49	38	-864	91	61
30%tile	53	262	262	157	124	97	79	13	21	-8	257	-426	100	67
40%tile	699	691	425	217	149	118	100	70	52	71	449	-158	118	85
50%tile	1,181	916	677	330	208	149	144	104	116	154	616	71	150	106
60%tile	1,912	1,652	760	405	235	219	173	322	358	241	670	990	211	218
70%tile	2,377	2,220	964	460	316	259	240	444	469	439	1,341	1,790	366	252
75%tile	2,683	2,370	1,287	562	369	273	245	565	679	537	1,537	2,285	389	277
80%tile	3,202	2,529	1,448	592	382	298	253	628	719	935	1,769	3,412	446	295
90%tile	4,281	3,378	3,009	746	496	411	389	730	941	1,740	2,774	4,203	687	414

[1] To calculate observed flow as percent unimpaired flow, months with unimpaired flow = zero were omitted. 6 Octobers, 4 Novembers, 1 December, 2 Junes, 1 July, 2 Augusts, and 6 Septembers.

2.5 Hydrodynamics Downstream of Vernalis

As previously stated, Vernalis is the location where all non-floodplain flows from the SJR basin flow into the Delta. Downstream from Vernalis, flows in the SJR and the southern and central Delta channels are affected by numerous factors including tides, in-Delta diversions, and barrier operations. This section provides a general overview of three important flow conditions associated with Central Valley Project (CVP) and State Water Project (SWP) pumping operations in the southern Delta: 1) water levels and circulation in the southern Delta; 2) the flow split at the head of Old River (HOR); and 3) reverse flows in Old and Middle Rivers.

Flow conditions downstream of Vernalis are largely affected by export operations of the two major water diverters in the Delta, the USBR and the DWR. The USBR exports water from the Delta for the CVP at the Jones Pumping Plant and the DWR exports water from the Delta for the SWP at the Banks Pumping Plant. In addition to these pumping plants, there are many smaller local agricultural diversions in the southern Delta that can affect flow conditions (State Water Board 1999.)

2.5.1 Water Levels and Circulation in the Southern Delta

The State Water Board D-1641 states that the CVP Tracy (Jones) pumping plant and SWP (Banks) pumping plant operations were having a negative effect on water levels and circulation patterns, occasionally resulting in areas of low or no circulation (i.e. null zones) (State Water Board 1999; DOI and SDWA 1980). Low water levels interfere with the ability of local agricultural diverters to access water with their pumps and siphons, and null zones can contribute to localized concentration of salts associated with agricultural return flows and municipal discharges.

As part of the South Delta Temporary Barriers Project initiated in 1991 by the DWR, three tidal flow control structures (agricultural barriers) are installed each season (from roughly April 15 to November 25) to increase water levels and circulation patterns in the southern Delta area for local agricultural diversions. These barriers are constructed of rock with culverts and flap gates designed to capture tidal flood flows and maintain higher water levels and increase circulation upstream of the barriers. The barriers are installed at Old River near Tracy, Middle River, and Grant Line Canal as shown in Figure 1.2. As will be discussed in the next section, a fourth barrier is installed in fall months at the HOR.

Based on July 1985 conditions, DWR performed modeling to quantify the effect of CVP and SWP pumping on water levels (tidal ranges) and the mitigating effects of the three agricultural barriers in the southern Delta. The output from this analysis is summarized in Table 2.33 for "no pumping/no barriers", "full pumping/no barriers", and "full pumping/temporary barriers" scenarios. Pumping operations were estimated to lower the otherwise natural lower-low tide levels by about 0.5 to 0.7 feet, and higher-high tides by about 0.9 to 2.0 feet, and installation of the agricultural barriers were demonstrated to provide significant mitigation for these effects (DWR and USDOI 2005).

A report by the DOI and SDWA (1980) stated that the effects of tidal mixing, and available downstream flow is insufficient to offset the effect of salt accumulation in these areas. Reduced flows and lower water levels have further exacerbated the occurrence of limited circulation in Middle River and portions of Old River. The channel bottom is raised in Old River just west of Tom Paine Slough and has a reduced cross sectional area and may have an effect on tidal fluctuation in Old River (DOI and SDWA 1980).

Table 2.33. Range of Tidal Fluctuation Under Various Conditions Modeled in DWR and USDOI 2005

	No Pumping/No Gates		Full Pumping[1]/ No Gates		Full Pumping[1]/ Temporary Barriers	
Barrier	Lower Low	Higher High	Lower Low	Higher High	Lower Low	Higher High
	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)	(ft msl)
Head of Old River	0.4	4.1	0.0	3.1	0.9	3.5
Grant Line Canal Barrier	-0.8	4.1	-1.4	2.1	Not Presented in Reference	
Old River Barrier	-0.8	4	-1.5	2	0.8	2.7
Middle River Barrier	-0.9	4.1	-1.3	3	0.1	3.7

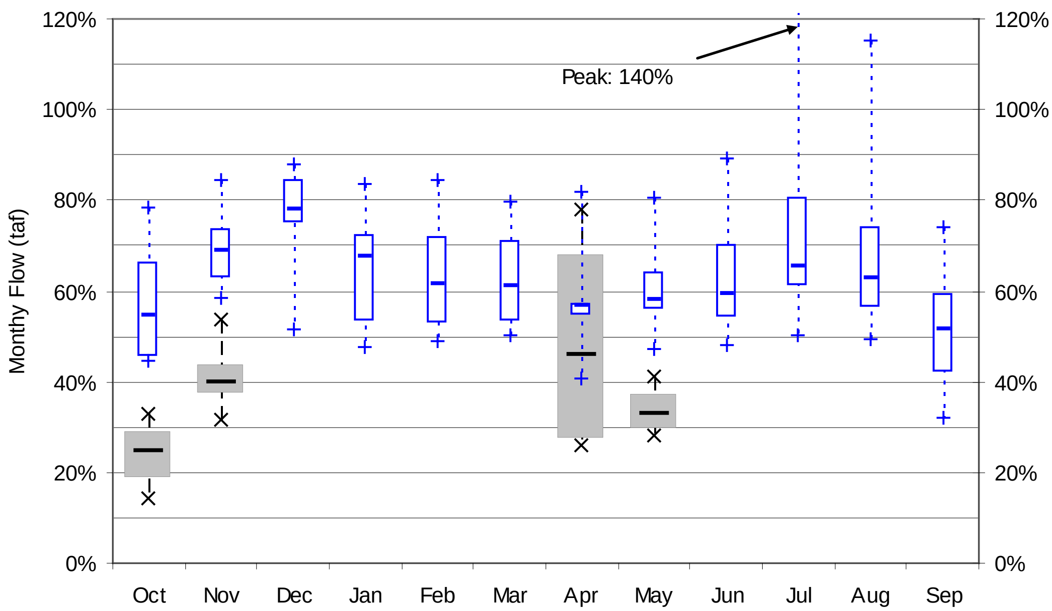
[1]Full pumping corresponds to 8,500 cfs at Clifton Court Forebay and 4,600 cfs at CVP Tracy (Jones).Source: DWR and USDOI 2005.

2.5.2 Flow Split to Old River

Downstream of Vernalis, flow from the SJR splits at the HOR and either continues downstream in the SJR toward Stockton or enters Old River, toward the CVP and SWP pumps. When Vernalis flow is greater than 16,000 cfs, a portion of the flow entering the south Delta enters through Paradise Cut, just upstream of the HOR. The amount of flow split in each direction at HOR (including flow through Paradise Cut) is affected by the agricultural and HOR barriers, and the combined pumping rates of CVP and SWP relative to SJR inflows at Vernalis. When the combined CVP and SWP pumping rates are less than the flow rate at Vernalis, the flow split to the SJR and Old River is roughly 50/50. When combined CVP and SWP pumping rates reach about five times the SJR flow at Vernalis, and without the installation of the HOR barrier, about 80% of the SJR at the HOR flows into Old River towards the pumps (Jones and Stokes 2001). Dr. Hutton (2008) also states that as south Delta diversions increase, the fraction of flow entering Old River increases.

The HOR barrier (HORB) has been installed in most years during the fall (roughly between September 30 and November 15) since 1968, and in some years during the spring (roughly between April 15 and May 30) since 1992. In general, the HORB was not installed during the spring in years with higher flows. In addition, the HORB has not been installed in the spring since 2007 due to a court order. A non-physical fish barrier was installed in its place in 2009 and 2010 (see discussion in Section 3). When the physical barrier at HOR is installed, the flow into Old River is reduced to between 20% and 50% (Jones and Stokes 2001). Data from Jones and Stokes (2001) further suggests that the agricultural barriers alone (when physical barrier at HOR was not installed), reduces flow into Old River for all pumping ranges, and reduced the effects of increased pumping on water levels and circulation. Dr. Hutton (2008) states that the increase in water levels that occur as a result of the Grant Line Canal barrier alone, decreases the flow entering Old River.

The observed amount of flow diverted to Old River using recent gage data from 1996 through 2009 is estimated by subtracting the gaged flow on the SJR at Garwood Bridge (USGS gage #11304810) from the gaged flow on the SJR at Vernalis (USGS gage #11303500) and is presented in Figure 2.15 and Table 2.34. As stated by Jones and Stokes (2001) the agricultural barriers may also affect the flow split with and without the HORB. For the months when the HORB was not installed, the percentage of flow that entered Old River was generally between 50% and 80%. For the months when all barriers were generally installed (October and November in most years, and April and May in most years prior to 2007), the percentage of flow entering Old River was roughly less than 50%. During May, both the Old and Middle River barriers were generally installed, however during April, the barriers were only in place during the second half of the month, thus May shows a reduced percentage of flow entering Old River than in April. The Grant Line Canal barrier was rarely installed during May, thus the percentage of flow entering Old River in May is greater than in October. Since 2001, all three agricultural barriers have been installed for the entire month of October, and generally the first half of November. The lowest percentage of flow entering Old River occurs in October when all barriers are installed, as shown in Figure 2.15. During July and August, the percentage of flow entering the HOR may exceed 100%; this occurs when large volumes of water are diverted from Old River in excess of SJR flows at Vernalis and water flows upstream to the HOR from the Central Delta.



Key to boxplots: median, horizontal line; box, 25th and 75th percentiles; whiskers, range barrier out ("+"sign) and barrier in ("x" sign).

Figure 2.15. Monthly Average Percentage of Flow Entering Old River from 1996 to 2009 with Barriers (Filled Bars) and without Barriers (Open Bars)

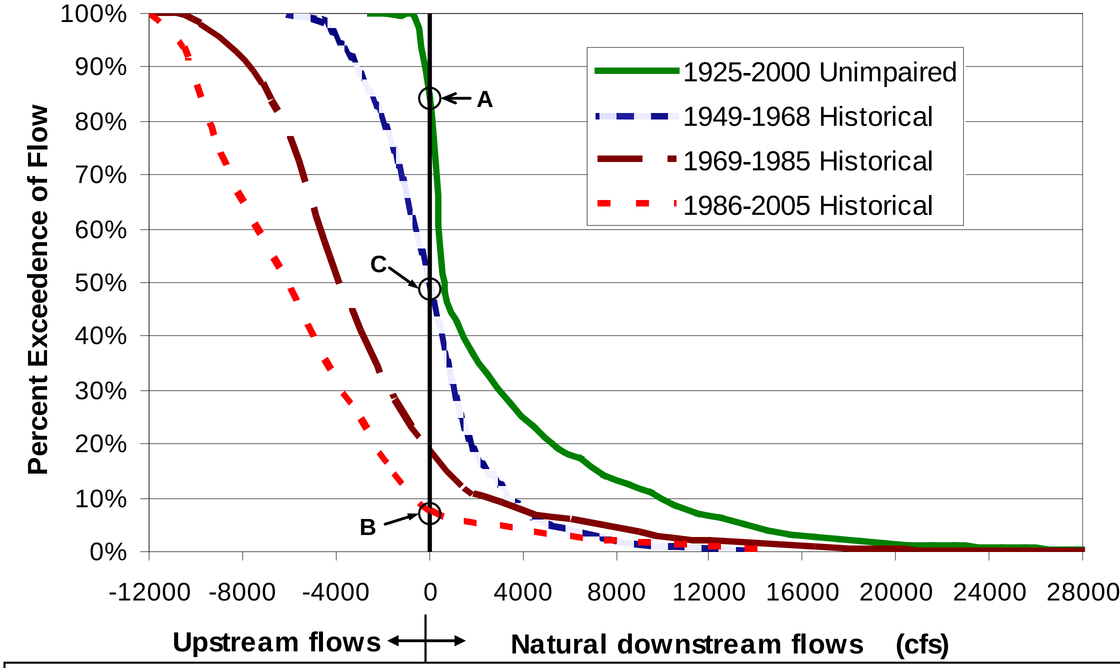
Table 2.34. Monthly Average Percentage of Flow Entering Old River from 1996 to 2009

Percent of flow entering Old River with barrier removed.												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
25%tile	45%	63%	75%	53%	53%	53%	55%	56%	54%	61%	56%	42%
Median	54%	69%	78%	68%	62%	61%	57%	58%	60%	65%	63%	52%
75%tile	66%	74%	84%	72%	72%	71%	57%	64%	70%	81%	74%	59%
Percent of flow entering Old River with barrier installed.												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
25%tile	18%	37%					27%	30%				
Median	25%	40%					46%	33%				
75%tile	29%	44%					68%	37%				

2.5.3 Reverse Old and Middle River Flows

SWP and CVP pumping operations also increase the occurrence of net Old and Middle River reverse flows (OMR) reverse flows. OMR reverse flows are now a regular occurrence in the Delta. Net OMR reverse flows occur because the major freshwater source, the Sacramento River, enters on the northern side of the Delta while the two major pumping facilities, the SWP and CVP, are located in the south. This results in a net water movement across the Delta in a north to south direction along a network of channels including Old and Middle Rivers. Net OMR is calculated as half the flow of the SJR at Vernalis minus the combined SWP and CVP pumping rate (CCWD 2010). A negative value, or a reverse flow, indicates a net water movement across the Delta along Old and Middle river channels towards the CVP and SWP pumping facilities.

Water balance models by the USGS and DWR's DSM2, are used to model OMR flows based upon CVP and SWP pumping rates and temporary barrier operations. Dr. Hutton compared the USGS and DWR models and developed a water balance regression that estimates OMR flow based on combined pumping rates and net delta channel depletions. In general the models show that increased pumping rates and lower flow entering at the HOR lead to higher OMR reverse flows (Hutton 2008). Fleenor et al. (2010) documented the change in both the magnitude and frequency of net OMR reverse flows as water development occurred in the Delta as shown in Figure 2.16. The 1925-2000 unimpaired line in this figure represents the best estimate of "quasi-natural" or net OMR values before most modern water development (Fleenor et al. 2010). The other three lines represent changes in the frequency and magnitude of net OMR flows with increasing development. Net OMR reverse flows are estimated to have occurred naturally about 15% of the time before most modern water development, including construction of the major pumping facilities in the South Delta (Point A in Figure 2.16). The magnitude of net OMR reverse flows under unimpaired conditions was seldom more negative than 2,000 cfs. In contrast, between 1986 and 2005 net OMR reverse flows occurred more than 90% of the time (Point B in Figure 2.16). The magnitude of net OMR reverse flows may now be as much as -12,000 cfs.



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

Figure 2.16. Old and Middle River Cumulative Probability Flows from Fleenor et al. 2010

2.6 Conclusions

In conclusion alterations to the unimpaired flow regime include reduced annual discharge, reduction in frequency and intensity of late fall and winter storm flows, reduced spring and early summer snowmelt flows, and a general decline in hydrologic variability. The following is a list of the findings:

A) Annual flow volumes at Vernalis have been reduced to a median of 46% of unimpaired flow, while the February through June flow volume has been reduced to a median of 27% of unimpaired flow. In terms of median values, the greatest reduction of the monthly flows occurs during peak spring snowmelt months of April, May, and June. Observed flows during these months are a median of 25%, 17%, and 18% of unimpaired flow, respectively.

B) Observed flows from February through June as percentages of unimpaired flows have fallen well below medians of 41%, 21%, and 26% in the Stanislaus, Tuolumne, and Merced Rivers respectively, with the April, May and June values generally far lower, especially May and June flows on the Tuolumne and Merced Rivers. For April, May and June, the medians are 32%, 26%, and 40% of unimpaired flow for the Stanislaus River, 22%, 12%, and 9% of unimpaired flow for the Tuolumne River, and 25%, 18% and 15% of unimpaired flow on the Merced River. This included values as low as 1% and 2% of unimpaired flow in the Merced and Tuolumne Rivers respectively in June 1991.

C) Flow conditions are more static with less seasonally variable flows throughout the year. The springtime magnitude is now severely dampened and there is more flow in the fall than would occur under an unimpaired condition. The wettest month of the year is now less predictable and is distributed over more months from year to year.

D) Short term peak or storm flows that occur several times within a given year, generally between November and March, are dramatically reduced under the present management conditions.

E) Tributary contributions are altered leading to a greater percentage of flow being delivered by the Stanislaus River, and much lower percentage of flow being delivered by the upper San Joaquin River.

3 Scientific Basis for Developing Alternate San Joaquin River Flow Objectives

3.1 Introduction

This section describes the scientific basis for developing alternative SJR flow objectives for the protection of fish and wildlife beneficial uses and the program of implementation for those objectives to be included in the Bay-Delta Plan (referred to as the LSJR flow alternatives in the SED). Draft changes to the SJR flow objectives and program of implementation are described in the conclusions section of this chapter and provided in Appendix A. Specifically, this section focuses on the Delta inflow needs from the SJR basin for SJR basin fall-run Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley steelhead (*Oncorhynchus mykiss*), as these anadromous species are among the most sensitive to inflows from the SJR basin to the Bay-Delta. The State Water Board has determined that higher and more variable inflows during the February through June time frame are needed to support existing salmon and steelhead populations in the major SJR tributaries to the southern Delta at Vernalis. This will provide greater connectivity to the Delta and will more closely mimic the flow regime to which native migratory fish are adapted. Water needed to support sustainable salmonid populations at Vernalis should be provided on a generally proportional basis from the major SJR tributaries (Stanislaus, Tuolumne, and Merced Rivers). Flow in the mainstem SJR, below Friant Dam, for anadromous fish will be increased under a different regulatory and cooperative water management program (SJRRP 2010). The draft program of implementation for the SJR flow objectives includes requirements that additional analyses be conducted to determine flow needs for other times of year and includes a commitment to evaluate potential changes to the Bay-Delta Plan to address other times of year and whether additional flows are needed from the upstream SJR below Friant Dam.

While aquatic resources in the SJR basin have been adversely impacted by numerous factors, flow remains a key factor and is the focus of the State Water Board's current review. A number of other factors (e.g., non-native species, exposure to contaminants, nutrient loading, climate change) need to be evaluated as potential contributors to the degradation of fish and wildlife beneficial uses in the SJR basin and Delta. These environmental factors or "stressors" will be addressed in the SED, and are not the focus of this review. Flow regimes needed to maintain desired conditions will change through time, as our understanding of how flow interacts with these other stressors improves and in response to changes in the geometry of waterways, global climate change, and other factors. The adaptive management approach proposed in the draft program of implementation for the SJR fish and wildlife flow objectives would provide a venue through which the flow regime could be modified in response to improved understanding of flow needs and other stressors.

3.1.1 Terminology

The following provides definitions, as used in this chapter, for observed flow, unimpaired flow, flow regime, and natural flow regime. For additional discussion regarding the methods used in the hydrologic analysis, refer to Section 2.2 of this report.

- Observed flow is the measured streamflow recorded at USGS gages located at the most downstream location for each of the major SJR tributaries and at Vernalis.

- Unimpaired flow is a modeled flow generally based on historical gage data with factors applied to primarily remove the effects of dams and diversions within the watersheds. The modeled unimpaired flow does not attempt to remove changes that have occurred such as channelization and levees, loss of floodplain and wetlands, deforestation, and urbanization.
- Flow regime describes the characteristic pattern of a river's flow, quantity, timing, and variability (Poff et al. 1997). The 'natural flow regime' represents the range of intra-and interannual variation of the hydrological regime, and associated characteristics of magnitude, frequency, duration, timing and rate of change that occurred when human perturbations to the hydrological regime were negligible (Richter et al. 1996, Richter et al. 1997, Poff et al. 1997, Bunn and Arthington 2002, Lytle and Poff 2004, Poff et al. 2010).
- For the purposes of this report, a more natural flow regime is defined as a flow regime that more closely mimics the shape of the unimpaired hydrograph.

3.1.2 Problem Statement

Scientific evidence indicates that reductions in flows and alterations to the flow regime in the SJR basin, resulting from water development over the past several decades, have the potential to negatively impact fish and wildlife beneficial uses. As outlined in the hydrology section of this report, water development in the SJR basin has resulted in: reduced annual flows; fewer peak flows; reduced and shifted spring and early summer flows; reduced frequency of peak flows from winter rainfall events; shifted fall and winter flows; and a general decline in hydrologic variability over multiple spatial and temporal scales (McBain and Trush 2002, Cain et al. 2003, Richter and Thomas 2007, Brown and Bauer 2009, NMFS 2009a). Currently, there is relatively little unregulated runoff from the SJR basin with dams regulating at least 90% of the inflow (Cain et al. 2010). Dams and diversions in the SJR basin have caused a substantial overall reduction of flows, compared to unimpaired hydrographic conditions, with a median reduction in annual flows at Vernalis of 54% and median reduction of critical spring flows of 74%, 83%, and 81% during April, May, and June, respectively.

The SJR basin once supported large spring-run and fall-run Chinook salmon populations; however, the basin now only supports a declining fall-run population. Scientific evidence indicates that in order to protect fish and wildlife beneficial uses in the SJR basin, including increasing the populations of fall-run Chinook salmon and Central Valley steelhead to sustainable levels, changes to the altered hydrology of the SJR basin are needed. Over the past several decades, various flow requirements have been established to protect fisheries resources in the SJR and its major tributaries (described below). Despite these efforts though, SJR basin fall-run Chinook salmon populations have continued to decline. In the SJR basin, it is recognized that the most critical life stage for salmonid populations is the spring juvenile rearing and migration period (DFG 2005a, Mesick and Marston 2007, Mesick et al. 2007, and Mesick 2009). Scientific evidence indicates that in order to protect fish and wildlife beneficial uses in the SJR basin, including increasing the populations of SJR basin fall-run Chinook salmon and Central Valley steelhead to sustainable levels, changes to the current flow regime of the SJR basin are needed. Specifically, a more natural flow regime from the salmon bearing tributaries (Stanislaus, Tuolumne, and Merced Rivers) is needed during the February through June time frame.

3.1.3 Existing Flow Requirements

In order to maintain and enhance fish and wildlife beneficial uses in the SJR basin several entities, through various and disparate processes, have established flow prescriptions on the mainstem SJR and its major tributaries. The existing and historical instream flow requirements for the major SJR tributaries consist of requirements set forth in water quality control plans, water right decisions, Federal Energy Regulatory Commission (FERC) proceedings, agreements and settlements, and biological opinions (BO) issued pursuant to the Federal Endangered Species Act.

Central Valley

Central Valley Project Improvement Act (CVPIA)

The Central Valley Project Improvement Act (CVPIA), which was signed into law on October 30, 1992, modified priorities for managing water resources of the CVP, a major link in California's water supply network. The intent was to make fish and wildlife protection, restoration, and enhancement as project purposes that have equal priority with agriculture, municipal and industrial, and power uses. Several environmental requirements were designed to lessen the impacts of the water projects; these include increasing instream flows, and curtailing export pumps at key times to protect fisheries. Section 3406 of the CVPIA includes actions:

> *3406(b)(1) – Special efforts to restore anadromous fish populations by 2002, including habitat restoration actions the Anadromous Fish Restoration Program (AFRP) Core Group believes necessary to at least double the production of anadromous fish in the Central Valley (see USFWS 1995)(proposed instream flow actions are described in Section 3.7 of this report).*
>
> *3406(b)(2) – Dedicate and manage annually 800,000 acre-feet of CVP yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; and to help to meet such obligations as may be legally imposed upon the CVP under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the Federal Endangered Species Act (see Table 3.1).*
>
> *3406(b)(3) – Require acquisition of water for protecting, restoring, and enhancing fish and wildlife populations (Sections 3406(b)(3) and 3406(d)). To meet water acquisition needs under CVPIA, the U.S. Department of the Interior (USDOI) has developed a Water Acquisition Program (WAP), a joint effort by the U.S. Bureau of Reclamation (Bureau) and the U.S. Fish and Wildlife Service (USFWS). The target for acquisitions is approximately 200,000 acre-feet per year, for use on the San Joaquin and Sacramento rivers and their tributaries. The USBR has yet to acquire the full 200,000 acre-feet of target flows for Section 3406(b)(3) (Table 3.2), due to a lack of willing sellers as well as the high cost of water on the open market. The actual volume of water acquired each year fluctuates based on the basin hydrology, reservoir storage and the water supplies available to WAP pursuant to the San Joaquin River Agreement (SJRA, described below).*

Table 3.1. Central Valley Project Improvement Act Environmental 3406(b)(2) Water Supplies

Allocation and Use of (b)(2) Water by Year (Approximate)					
Allocation of (b)(2) Water			Use of (b)(2) Water		
Year	Sac Valley Index Water Year Type	(b)(2) Allocated (acre-feet)	Flow (acre-feet)	Unused (acre-feet)*	Banked (acre-feet)**
2001	Dry	800,000	798,000		
2002	Dry	800,000	793,000		
2003	Above Normal	800,000	796,000		
2004	Below Normal	800,000	800,000		
2005	Above Normal	800,000	672,000		128,000
2006	Wet	800,000	422,000	183,000	195,000
2007	Dry	800,000	798,000		
2008	Critical	600,000	600,000		
2009	Dry	600,000	600,000		
2010	Below Normal	800,000	800,000		

Source: USDOI In Prep

*Section 3406 (b)(2)(D): If the quantity of water dedicated under this paragraph, or any portion thereof, is not needed for the purposes of this section, based on a finding by the Secretary, the Secretary is authorized to make such water available for other project purposes.
**In wetter precipitation years such as 2005 and 2006, a portion of the dedicated water was banked pursuant to CVPIA Section 3408(d). Banked water is reallocated back into the CVP yield in the subsequent year.

Table 3.2. Annual (b)(3) Instream Water Acquisitions

Year	Water Year Type	Annual Water Acquisitions (acre-feet)
2001	Dry	109,785
2002	Dry	68,105
2003	Above Normal	91,526
2004	Below Normal	98,211
2005	Above Normal	148,500
2006	Wet	148,500
2007	Dry	92,145
2008	Critical	106,490
2009	Dry	38,500

San Joaquin River

Bay-Delta Accord

In December 1994, State and Federal agencies, along with stakeholders, developed a proposal for water quality standards, which led to the signing of a document titled “Principles for Agreement on Bay-Delta Standards between the State of California and the Federal Government”. This agreement is known as the Bay-Delta Accord. The Bay-Delta Accord initiated a long-term planning process to improve the Delta and increase the reliability of its water supply. Among the Delta specific requirements, the Bay-Delta Accord also specified in-stream flows (Table 3.3) on the mainstem SJR below Friant (compliance point at Vernalis) for the benefit of Chinook salmon.

Table 3.3. Bay-Delta Accord Instream Flow Requirements at Vernalis

Water Year	February - June Flows (cfs)	April - May Pulse Flows (cfs)
Critical	710 - 1,140	3,110 - 3,540
Dry	1,420 - 2,280	4,020 - 4,880
Below Normal	1,420 - 2,280	4,620 - 5,480
Above Normal	2,130 - 3,420	5,730 - 7,020
Wet	2,130 - 3,420	7,330 - 8,620

.

Bay-Delta Plan and D-1641

In the 1995 Water Quality Control Plan for the Bay-Delta Plan (1995 Bay-Delta Plan), the State Water Board included objectives for the SJR flows specified in the Bay-Delta Accord and added an additional October pulse flow objective. For all water year types, the October flow objective requires flows at Vernalis of 1,000 cfs in October plus up to an additional 28,000 AF to in order to provide a monthly average flow of 2,000 cfs (with the additional flow not required in a critical year that follows a critical year). These flow objectives were primarily intended to protect fall-run Chinook salmon and provide incidental benefits to Central Valley steelhead.

During proceedings regarding implementation of the 1995 Bay-Delta Plan, as an alternate approach to deciding the responsibilities of the water right holders, the State Water Board provided the water right holders an opportunity to reach settlement agreements with other water right holders and interested parties proposing allocations of responsibly to meet the flow-dependent objectives in the 1995 Bay-Delta Plan. The result was the SJRA, which proposed an alternate method to meeting the SJR portions of the objectives included in the 1995 Bay-Delta Plan. The signatory parties, including the California Resources Agency, USDOI, San Joaquin River Group, CVP/SWP Export Interests, and two environmental groups, agreed that the San Joaquin River Group Authority (SJRGA) members would meet the experimental flows specified in the Vernalis Adaptive Management Plan (VAMP) in lieu of meeting the spring pulse flow objectives adopted in the 1995 Bay-Delta Plan. In Water Right Decision 1641 (D-1641), the State Water Board approved the conduct of the VAMP for a period of 12 years in lieu of meeting the SJR pulse flow objectives and assigned responsibility to USBR for meeting the SJR flow objectives. The State Water Board also conditioned the water rights of various SJRGA members to provide water for the VAMP and the October pulse flow objective.

The VAMP, initiated in 2000, is a large scale, 12-year experimental management program designed to protect juvenile Chinook salmon migration from the SJR through the Delta. It is also a scientific experiment to determine how juvenile fall-run Chinook salmon survival rates change in response to alterations in SJR flows and SWP and CVP exports with the installation of the HORB. The VAMP experiment (implemented for a 31-day period during April and May) is designed to assess a combination of flows, varying between 3,200 cfs and 7,000 cfs, and exports varying between 1,500 cfs and 3,000 cfs.

In addition to the SJR flow objectives, the 1995 Bay-Delta Plan (and subsequently the 2006 Bay-Delta Plan) includes a narrative objective for salmon protection that is consistent with the anadromous fish doubling goals of the CVPIA. Under the AFRP, State, Federal and local entities are continuing to implement programs within and outside the Delta geared towards achieving the CVPIA anadromous fish doubling goals. Specifically, implementation of the Bay-Delta Plan flow objectives is intended to contribute toward achieving the narrative objective.

The 1995 and 2006 Bay-Delta Plan also include salinity objectives for the protection of agriculture in the southern Delta at four compliance locations including: the SJR at Vernalis; the SJR at Brandt Bridge; Old River near Middle River; and Old River at Tracy Road Bridge. The

State Water Board set an objective of 0.7 mmhos/cm EC during the summer irrigation season (April 1 through August 31) based on the salt sensitivity and growing season of beans and an objective of 1.0 mmhos/cm EC during the winter irrigation season (September 1 through March 31) based on the growing season and salt sensitivity of alfalfa during the seedling stage. These salinity objectives were not established for the protection of fish and wildlife, but their implementation may result in releases of water from New Melones on the Stanislaus River and as a result may affect flow conditions downstream at Vernalis.

National Marine Fisheries Service Biological Opinion

In June 2009, the National Marine Fisheries Service (NMFS) issued a final biological opinion and conference opinion, based on its review of the proposed long-term operations of the CVP and SWP in the Central Valley, California, and its effects on listed anadromous fishes and marine mammal species, and designated and proposed critical habitats in accordance with section 7 of the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 *et seq.*). NMFS' final biological opinion concluded that the CVP/SWP operations are likely to jeopardize the continued existence of Federally listed endangered Sacramento River winter-run Chinook salmon (*Oncorhynchus tsawytscha*), threatened Central Valley spring-run Chinook salmon (*Oncorhynchus tsawytscha*), threatened Central Valley steelhead (*Oncorhynchus mykiss*), threatened Southern Distinct Population Segment of North American green sturgeon (*Acipenser medirostris*), and southern resident killer whales (*Orcinus orca*). As a consequence of the above jeopardy finding, NMFS (as required by the ESA) proposed several Reasonable and Prudent Alternatives (RPAs) that would enable the project to go forward in compliance with the ESA. The RPA for the SJR (RPA IV 2.1) is described below in Tables 3.4, 3.5, and 3.6 and includes interim (Phase I which applied in April and May of 2010 and 2011) and long-term flow requirements for the SJR at Vernalis and restrictions on SWP and CVP export operations in the southern Delta based on SJR inflows.

The biological opinion and associated RPAs have been the subject of ongoing litigation (Consolidated Salmonid Cases, Case No. 1:09-cf-01053-OWWV-DL). Regarding RPA IV 2.1, Judge Wanger, the court justice presiding over the case, concluded that NMFS failed to adequately justify, by generally recognized scientific principles, the precise flow prescriptions imposed by RPA action IV.2.1. Furthermore, RPA action IV.2.1 was found to be arbitrary, capricious, and scientifically unreasonable. In September 2011, the Court remanded the 2009 biological opinion back to NMFS to address flaws identified by the Court. In response to the remand, NMFS submitted a proposed schedule to the Court for re-issuance of a final biological opinion with new RPAs by September 2015. In December 2011, the Court issued an order granting the parties to the litigation the opportunity to reach agreement on the manner in which the RPA will be modified and applied during Water Year 2012. On January 12, 2012, a proposed agreement for 2012 was reached.

Table 3.4. Phase I (which applied in April and May of 2010 and 2011) of the NMFS Biological Opinion RPA action IV 2.1

1. Flows at Vernalis (7-day running average shall not be less than 7% of the target requirement) shall be based on the New Melones Index. In addition to the Goodwin flow schedule for the Stanislaus River prescribed in Action III.1.3 (described in the Stanislaus River discussion below), Reclamation shall increase its releases at Goodwin Reservoir, if necessary, in order to meet the flows required at Vernalis, as provided in the following table:

New Melones Index (TAF)	Minimum flow required at Vernalis (cfs)
0-999	No new requirements
1,000-1,399	D1641 requirements or 1,500, whichever is greater
1,400-1,999	D1641 requirements or 3,000, whichever is greater
2,000-2,499	4,500
2,500 or greater	6,000

2. Combined CVP and SWP exports shall be restricted through the following:

Flows at Vernalis (cfs)	Combined CVP and SWP Export
0-6,000	1,500 cfs
6,000-21,750	4:1 (Vernalis flow:export ratio)
21,750 or greater	Unrestricted until flood recedes below 21,750

In addition Reclamation/DWR shall seek supplemental agreement with the SJRGA, as soon as possible, to achieve minimum long term flows at Vernalis (Table 3.5) through all existing authorities.

Table 3.5. Minimum Long-Term Vernalis Flows

San Joaquin River Index (60-20-20)	Minimum long-term flow at Vernalis (cfs)
C	1,500
D	3,000
BN	4,500
AN	6,000
W	6,000

Phase II of RPA action IV.2.1 operations will begin in 2012 from April 1 to May 31 (Table 3.6).

Table 3.6. Phase II of the NMFS Biological Opinion RPA action IV 2.1

1. Reclamation shall continue to implement the Goodwin flow schedule for the Stanislaus River prescribed in Action III.1.3 (described in the Stanislaus River discussion below).

2. Reclamation and DWR shall implement the Vernalis flow-to-combined export ratios in the following table, based on a 14-day running average.

San Joaquin Valley Classification	Vernalis flow (cfs):CVP/SWP combined export ratio
C	1:1
D	2:1
BN	3:1
AN	4:1
W	4:1
Vernalis flow equal to or greater than 21,750	Unrestricted exports until flood recedes bellow 21,750

Other NMFS BO flow actions are subsequently described in the Stanislaus River discussion.

Stanislaus River

<u>1987 Agreement</u>

Reclamation and the DFG executed an agreement titled “Interim Instream Flows and Fishery Studies in the Stanislaus River Below New Melones Reservoir” on June 5, 1987 (1987 Agreement). The 1987 Agreement proposed that the signatories provide an appropriate amount of instream flows in the Stanislaus River as needed to maintain or enhance the fishery resource during an interim period in which habitat requirements are better defined. The agreement specified an Interim Plan of Operations (IPO) that would be beneficial to fishery resources and habitat downstream of New Melones dam. The IPO increased the fisheries release by changing 98,300 AF from the maximum to the minimum required, and allowed for releases as high as 302,100 AF in wetter years. The exact quantity to be released each year is determined based on a formulation involving storage, projected inflows, projected water supply and water quality demands, projected CVP contractor demands, and target carryover storage (Tables 3.7 and 3.8).

Table 3.7. Inflow Characterization for the New Melones IPO

Annual water supply catetory	March-September forecasted inflow plus end of February storage (TAF)
Low	0 - 1,400
Medium-low	1,400 - 2,000
Medium	2,000 - 2,500
Medium-high	2,500 - 3,000
High	3,000 - 6,000

Table 3.8. New Melones IPO Flow Objectives (TAF)

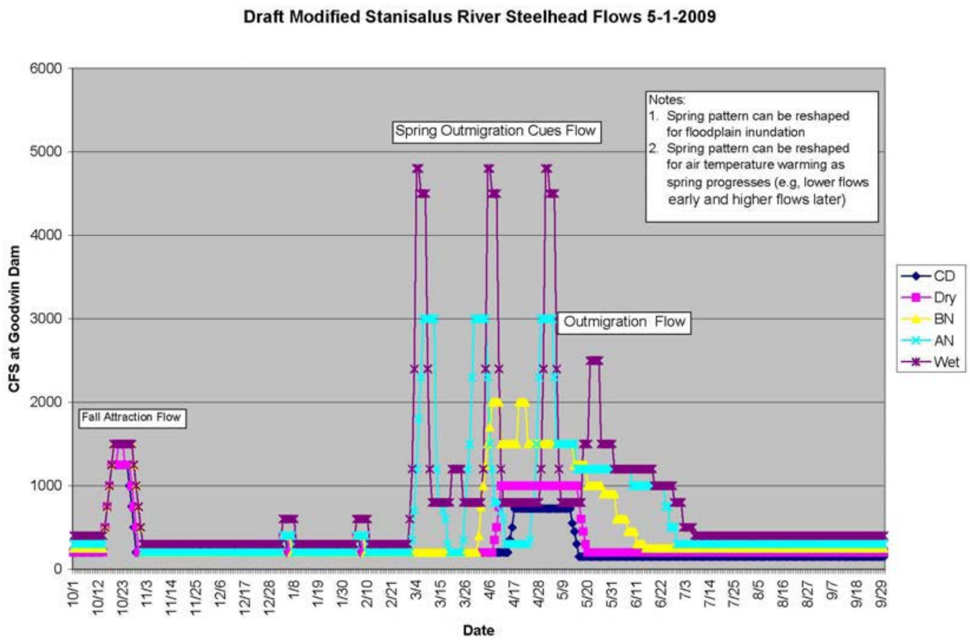
Storage plus inflow		Fishery		Vernalis Water Quality		Vernalis Flow		CVP contractors	
From	To	From	To	From	To	From	To	From	To
1,400	2,000	98	125	70	80	0	0	0	0
2,000	2,500	125	245	80	175	0	0	0	59
2,500	3,000	345	467	175	250	75	75	90	90
3,000	6,000	467	467	250	250	75	75	90	90

State Water Board Water Right Decision 1422 (D-1422)

This decision requires flow releases from New Melones Reservoir up to 70,000 AF in any one year for water quality control purposes in order to maintain a mean monthly total dissolved solids (TDS) concentration in the SJR below the mouth of the Stanislaus River at 500 ppm maximum and to maintain a dissolved oxygen level of at least five ppm in the Stanislaus River.

National Marine Fisheries Service Biological Opinion

RPA action III.1.3 (Figure 3.1) calls for maintaining minimum Stanislaus River instream flows according to a flow schedule as measured at Goodwin Dam to ensure viability of the Central Valley steelhead population on the Stanislaus River. In the Consolidated Salmonid Cases mentioned above, Judge Wanger also found that the record and best available science do not support Action III.3.1’s 5,000 cfs spring pulse flow requirement.



Source: NMFS 2009a

Figure 3.1. NMFS 2009 Biological Opinion Flow Schedule for the Stanislaus River Measured at Goodwin Dam

Tuolumne River

Federal Energy Regulatory Commission (FERC) Project Number 2299
Turlock and Modesto Irrigation Districts (TID and MID) jointly hold the initial FERC license (Project Number 2299) for the New Don Pedro Project, which was issued by the Federal Power Commission, FERC's predecessor, on March 10, 1964. The license became effective on May 1, 1966, for a term ending April 30, 2016. The FERC license for project number 2299 is conditioned to require specified releases of water from New Don Pedro for the protection of fall-run Chinook salmon which spawn in the Tuolumne River below La Grange dam (Table 3.9).

Table 3.9. FERC Project Number 2299 Instream Flow Requirements for the Tuolumne River

Period	Normal Year (cfs)	Dry Year (cfs)
October 1 - 15	200	50
October 16 – October 31	250	200
November	385	200
December 1 - 15	385	200
December 16 - 31	280	135
January	280	135
February	280	135
March	350	200
April	100	85
May - September	3	3

Table 3.10. Settlement Agreement Instream Flow Requirements for the Tuolumne River

Schedule	Days	Critical & below	Median Critical	Intermediate C-D	Median Dry	Intermediate D-BN
October 1 - October 15	15	100 cfs 2,975 ac-ft	100 cfs 2,975 ac-ft	150 cfs 4,463 ac-ft	150 cfs 4,463 ac-ft	180 cfs 5,355 ac-ft
Attraction Pulse Flow		none	none	none	none	1,676 ac-ft
October 16 - May 31	228	150 cfs 67,835 ac-ft	150 cfs 67,835 ac-ft	150 cfs 67,835 ac-ft	150 cfs 67,835 ac-ft	180 cfs 81,402 ac-ft
Outmigration Pulse Flow		11,091 ac-ft	20,091 ac-ft	32,619 ac-ft	37,060 ac-ft	35,920 ac-ft
June 1 - September 30	122	50 cfs 12,099 ac-ft	50 cfs 12,099 ac-ft	50 cfs 12,099 ac-ft	75 cfs 18,149 ac-ft	76 cfs 18,149 ac-ft
Volume	365	94,000 ac-ft	103,000 ac-ft	117,016 ac-ft	127,507 ac-ft	142,502 ac-ft
		Median Below Normal	**Intermediate BN-AN**	**Median Above Normal**	**Intermediate AN-W**	**Median Wet/Maximum**
October 1 - October 15	15	200 cfs 5,950 ac-ft	300 cfs 8,926 ac-ft	300 cfs 8,926 ac-ft	300 cfs 8,926 ac-ft	300 cfs 8,926 ac-ft
Attraction Pulse Flow		1,739 ac-ft	5,950 ac-ft	5,950 ac-ft	5,950 ac-ft	5,950 ac-ft
October 16 - May 31	228	175 cfs 79,140 ac-ft	300 cfs 135,669 ac-ft	300 cfs 135,669 ac-ft	300 cfs 135,669 ac-ft	300 cfs 135,669 ac-ft
Outmigration Pulse Flow		60,027 ac-ft	89,882 ac-ft	89,882 ac-ft	89,882 ac-ft	89,882 ac-ft
June 1 - September 30	122	75 cfs 18,149 ac-ft	250 cfs 60,496 ac-ft	250 cfs 60,496 ac-ft	250 cfs 60,496 ac-ft	250 cfs 60,496 ac-ft
Volume	365	165,002 ac-ft	300,923 ac-ft	300,923 ac-ft	300,923 ac-ft	300,923 ac-ft

1995 (Settlement Agreement)
The settlement agreement (between the Bureau and DFG) established in 1995 proposed that Article 37 of the FERC license (Project Number 2299) for the New Don Pedro Project on the Tuolumne River be amended to increase flows (Table 3.10) released from the New Don Pedro dam.

Merced River

1967 Davis-Grunsky Contract
In 1967, Merced Irrigation District (Merced ID) executed the Davis-Grunsky Contract (Number D-GGR17) with DWR. The contract provides minimum flow standards whereby flows of no less than 180-220 cfs will be maintained from November through March from Crocker-Huffman Dam to Shaffer Bridge.

Cowell Agreement
The Cowell Agreement is the result of a water rights adjudication and requires Merced ID to make specified quantities of water available below Crocker-Huffman diversion dam. This water can then be diverted from the river at a number of private ditches between Crocker-Huffman Dam and Shaffer Bridge. The minimum flow requirements are provided in Table 3.11.

Table 3.11. Cowell Agreement Instream Flow Requirements for the Merced River

Month	Flow (cfs)
October 1 - 15	50
October 16 - 31	50
November	50
December	50
January	50
February	50
March	100
April	175
May	225
June	250
July	225
August	175
September	150

Federal Energy Regulatory Commission (FERC) Project Number 2179
Merced ID owns and operates the Merced River Hydroelectric Project. Merced ID holds the initial FERC license (Project Number 2179) for the Project, which was issued on April 18, 1964. The license became effective on March 1, 1964, for a term ending February 28, 2014. The Merced River Hydroelectric Project expanded the existing Exchequer Project, a water supply/power project that was constructed in 1926–1927. FERC Project Number 2179 required the licensee to provide minimum instream flows (Table 3.12) in the Merced River downstream from the project reservoirs.

Table 3.12. FERC Project Number 2179 Instream Flow Requirements for the Tuolumne River

Period	Normal Year (cfs)	Dry Year (cfs)
June 1 – October 15	25	15
October 16 – October 31	75	60
November 1 – December 31	100	75
January 1 – MaY 31	75	60

The FERC license for Project Number 2179 also requires, insofar as possible, that between November 1 and December 31 flows be maintained downstream from the Exchequer afterbay development (McSwain Development) between 100 and 200 cfs except during dry years when the streamflow is required to be maintained between 75 and 150 cfs. Streamflow is required to be measured at Shaffer Bridge.

3.1.4 Approach

In order to develop potential change to the SJR flow objectives and their program of implementation, existing scientific literature relating to SJR flows and protection of fish and wildlife beneficial uses was evaluated. This chapter describes: life-history information and population trends of SJR basin fall-run Chinook salmon and Central Valley steelhead; flow prescriptions in the SJR basin; fall-run Chinook salmon Delta inflow needs (measured at Vernalis), including the functions supported by inflows and the relationship between flows and SJR basin fall-run Chinook salmon survival and abundance; and the importance of unaltered hydrographic conditions in supporting ecosystem processes for Chinook salmon, Central Valley steelhead, and other native species.

There is very little specific information available concerning the relationships between flow and the survival and abundance of SJR basin Central Valley steelhead. Central Valley steelhead differ distinctly from SJR basin fall-run Chinook salmon with regard to their year-round dependence on suitable habitat conditions for rearing. However, Central Valley steelhead co-occurs with fall-run Chinook salmon in the SJR basin and both species have somewhat similar environmental needs for river flows, cool water, and migratory corridors. As a result, conditions that favor fall-run Chinook salmon are assumed to provide benefits to co-occurring steelhead populations, and other native fishes (NMFS 2009a).

Information concerning flow needs of fish and wildlife beneficial uses in the SJR basin was used to develop a range of potential SJR flow alternatives to protect fish and wildlife beneficial uses. These alternatives do not necessarily represent the alternatives that will be evaluated in the SED, which is being prepared in support of potential amendments to the SJR flow objectives in the Bay-Delta Plan. Instead, these alternatives represent the range of alternatives that will be analyzed. This range may be further refined to develop alternatives for analysis in the environmental review process. The potential environmental, economic, water supply, and related impacts of the various alternatives will then be analyzed and disclosed in the SED prior to any determination concerning changes to the existing SJR flow objectives. Based on information included in the SED (including this appendix) and other information submitted to the State Water Board, the State Water Board will determine what changes to make to the SJR flow objectives in the Bay-Delta Plan to reasonably protect fish and wildlife beneficial uses and balance beneficial uses. The State Water Board may choose to adopt one of the identified alternatives or an alternative that falls within the range of the various alternatives analyzed.

3.2 Fall-Run Chinook Salmon

Within the Central Valley, three Evolutionarily Significant Units (ESUs) of Central Valley Chinook salmon have been identified. The three ESUs of Chinook salmon are winter-, spring-, and fall-/late fall–run (DFG 2010c). These separate ESU classifications are based on the timing of spawning migration, stage of sexual maturity when entering freshwater, timing of juvenile or smolt outmigration, and by the populations' reproductive isolation and contribution to the genetic diversity of the species as a whole. This section addresses fall-run Chinook salmon within the proposed project area, the SJR and its major tributaries (Stanislaus, Tuolumne, and Merced Rivers).

The SJR and its tributaries historically (prior to 1940) supported spring, fall, and possibly late fall–run Chinook salmon. However, winter-run Chinook salmon are not known to have occurred in the SJR or its tributaries. Spring-run Chinook salmon were extirpated from the SJR following the construction of impassible dams on the mainstem SJR and the major SJR tributaries. This was due, in part, to the need of spring-run Chinook to migrate to higher elevations in the watershed, where cooler water temperatures provided suitable over summering habitat. In addition, operating procedures of the dams created conditions that lead to the extirpation of any remaining populations of late fall–run Chinook salmon from the system. Fall-run Chinook salmon are the only remaining population present in the SJR basin. Winter-, spring-, fall-, and late fall–run populations still remain in the Sacramento River basin.

3.2.1 Life History

Chinook salmon are an anadromous species that are native to the North Pacific Ocean and spend most of their adult life in open ocean waters, only returning to freshwater streams to spawn a single time before they die. Chinook salmon commonly occur as one of two life-history types which are characterized by age at seaward migration. "Stream-type" Chinook reside in fresh water for a year or more before migrating seaward as age 1 or older smolts (Gilbert 1913). By contrast "ocean-type" Chinook may begin their seaward migration as recently-emerged fry and rear in freshwater for up to 5 months before entering the ocean as subyearling smolts. Environmental and genetic factors (e.g., latitude, growth-opportunity, migration distance, selection for size at migration) differing among populations may both promote variability in age at seaward migration (Taylor 1990). As a result, the seasonal patterns of adult salmon (e.g., fall and spring) do not necessarily correspond to the juvenile life history traits (ocean-type and stream-type). Fall-run Chinook salmon predominantly exhibit the ocean-type life history; meaning that they have adapted to spend most of their lives in the ocean, spawn soon after entering freshwater in summer and fall, and as juveniles, migrate to the ocean within a relatively short time (3 to 12 months; Moyle 2002). Fall-run Chinook salmon typically remain in the ocean for 2 to 4 years before returning to their natal streams to spawn (McBain and Trush 2002). However, most Central Valley salmon return to their natal streams after 2 years of ocean maturation and a small fraction (10–20%) return after 1 year of ocean maturation. These smaller 2-year old fish are called "jacks" if male and "jills" if female (PFMC 2007, Williams 2006, Moyle 2002). The SJR and its tributaries are the most southerly rivers in the Central Valley that support fall-run Chinook salmon. Table 3.13 lists the approximate monthly timing of Central Valley fall-run Chinook salmon life history stages.

Table 3.13. Generalized Life History Timing of Central Valley Fall-Run Chinook Salmon

	Upstream Migration Period	Spawning Period	Incubation	Juvenile Rearing and Outmigration	Ocean Entry
Central Valley Basin	June to December	September to December	October to March	December to June	April to June
SJR Basin	October to December	November to January	November to March	February to June	April to June
Peak SJR Basin	November	November	November to December	February to March and April to May	June

3.2.2 Adult Migration

The literature on migration timing of fall-run Chinook salmon reports a broad range of months in which upstream migration can occur, beginning as early as June and continuing through early January (DFG 2010a, BDCP 2009, DFG 1993). SJR fall-run Chinook salmon are observed to migrate into the natal streams from late October to early December, with peak migration typically occurring in November. Carcass surveys, adult fish counting weirs on the Stanislaus and Tuolumne, and daily returns to the Merced Hatchery confirm this much shorter return period for the SJR basin fall-run Chinook salmon.

The majority of Chinook begin upstream migration during the rising limb of the hydrograph, as pulse flows cue the start of the migration period (USDOI 2010). Once flow conditions and other environmental factors are suitable the mating pairs begin the construction and defense of the redd. Figure 3.2 presents an example from the Tuolumne River that highlights this chronology, with the majority of redds appearing after a pulse flow in October ends and flows stabilize.

Fall-run Chinook salmon enter freshwater at an advanced stage of maturity and move rapidly to suitable spawning areas on lower reaches of the major SJR tributaries. Migrating adults exhibit a crepuscular movement pattern, with the majority of migration activities occurring at dawn and dusk hours (NMFS 2009a). Additionally, migrating adults often forgo feeding and rely on stored energy reserves for the duration of their freshwater migration. Once adults have found a suitable spawning area, within a few days or weeks of freshwater entry, they build a redd and spawn (Healey 1991).

Adult fall-run Chinook salmon use environmental cues during upstream migration, most notably olfactory cues, as the primary method to locate and return to natal streams (Dittman and Quinn 1996, NMFS 2009a, DFG 2010a). The importance of olfactory cues and stream “odor” was established by Arthur Hasler and colleagues in the 1950s and 1960s, and the home-stream odor hypothesis is restated in Williams 2006:

> *Because of local differences in soil and vegetation of the drainage basin, each stream has a unique chemical composition and, thus, a distinctive odor; 2) before juvenile salmon go to sea they become imprinted to the distinctive odor of their home stream; and 3) adult salmon use this information as a cue for homing when they migrate through the home-stream network to the home tributary.*

If natal streams have low flows during periods of upstream migration, and salmon cannot perceive the scent of their natal stream, straying rates (i.e., proportion of returning adults that spawn in non-natal streams) are likely to increase. In addition, straying rates, on average, of hatchery Chinook salmon are also generally higher than that of naturally produced Chinook salmon (Williams 2006). Straying rates of naturally produced fish are typically low. In British Columbia straying rates averaged roughly 1.2% for naturally produced fish, 5.3% for naturally produced fish that are trucked into the estuary, and between 1% and 18% for hatchery fish (Candy and Beacham as cited in Williams 2000). In the SJR roughly 60–100% of SJR flows are diverted into the pumping facilities in the southern Delta thereby never reaching the ocean (Hallock et al. 1970). At the same time, average straying rates of SJR hatchery produced Chinook salmon is estimated to be over 70% (Grant 1997a; Williams 2006).

The upstream migration rate for Chinook salmon from the ocean, through the Bay-Delta, and to the SJR tributaries has not been measured. However, Keefer et al. (2004) found migration rates of Chinook salmon in the Columbia River ranging from 10 to 35 km per day (6–20 miles/day). These migration rates were primarily correlated with date, and secondarily with discharge and reach in the Columbia River basin (Keefer et al. 2004). Matter and Sanford (2003) documented similar migration rates of about 30 km per day (20 miles/day) for adult Chinook salmon in the Snake River. However, adult Chinook salmon in the Delta and lower Sacramento River and SJR have been observed exhibiting substantial upstream and downstream movement, for several days at a time, while migrating upstream (Hallock et al. 1970; Williams 2006).

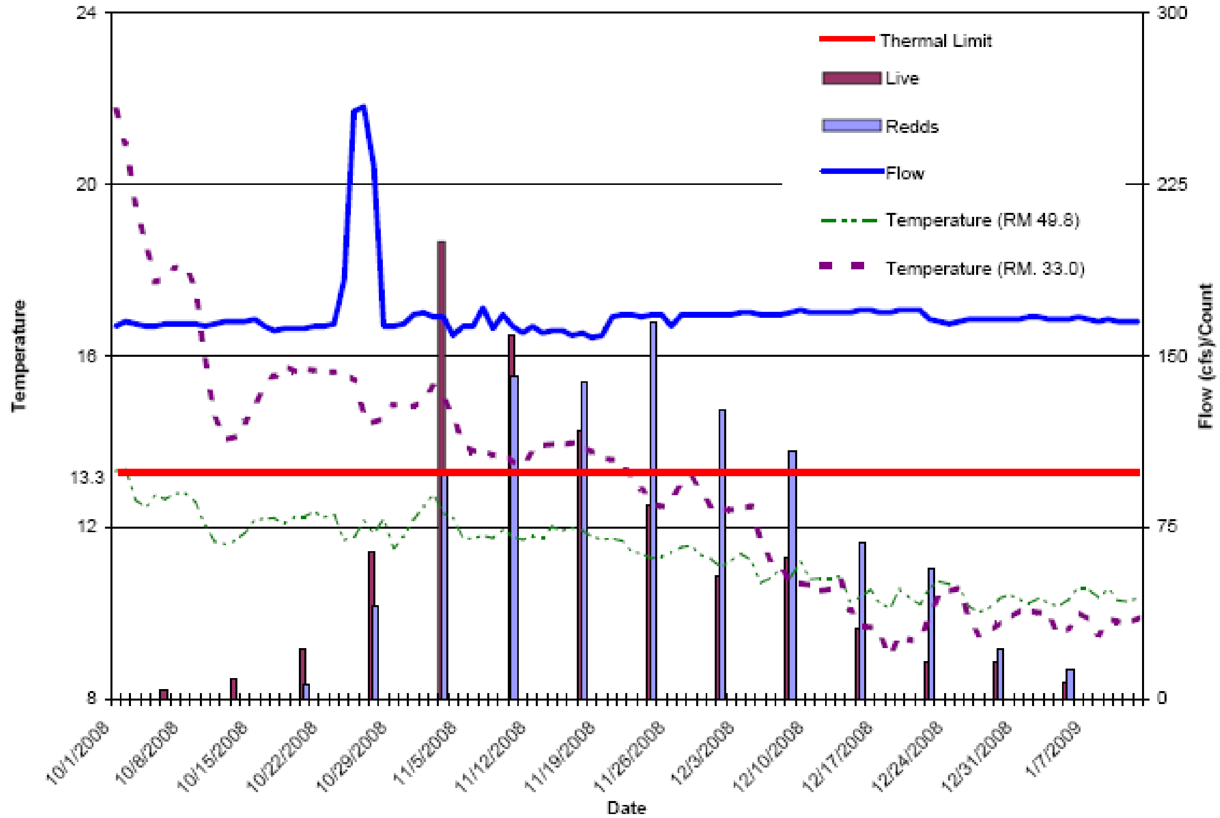
3.2.3 Spawning and Holding

Historically, adult fall-run Chinook salmon spawned in the valley floor and on lower foothill reaches of the major SJR tributaries (DFG 1993). Today, spawning takes place below the first impediment that blocks upstream migration (Crocker-Huffman, La Grange, and Goodwin dams), further limiting potential salmon spawning area. In addition, streamflow alteration, dictated by the dams on the major SJR tributaries, affect the distribution and quantity of spawning habitat.

Once fall-run Chinook salmon enter freshwater and begin migration to spawning habitat they generally do not hold in pools for long periods of time (generally 1 week or less). However, they may briefly use large resting pools during upstream migration as refuge from predators, insulation from solar heat, and to help conserve energy (Mesick 2001b; DFG 2010a).

Spawning may occur at any time between September and December; however, SJR basin Chinook salmon typically begin spawning between November and January, with peaks in November (BDCP 2010; McBain and Trush 2002; DFG 1993). This truncated spawning period is verified by the DFG’s aerial redd counts, the majority of which are observed in the months of November and December (Figure 3.2).

Redds are constructed, by female Chinook salmon, in gravel beds that are typically located at the tails of riffles or holding pools, with clean, loose gravel in swift flows that provide adequate oxygenation of incubating eggs and suitable water temperatures (NMFS 2009a). The upper preferred water temperature for spawning and egg incubation is 56ºF (Bjorn and Reiser 1991), and salmon may hold until water temperature is acceptable for spawning. The range of water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad, but generally, if a salmon can successfully swim in the spawning bed they can spawn (NMFS 2009a).



Source: DFG 2008

Figure 3.2. Live Fish and Redds Observed in the Tuolumne River in October 2008-January 2009, Overlaid with Flow and Temperature

Fall-run Chinook salmon carry an average 5,000 to 6,000 eggs per spawning female (Moyle 2002). However, the actual number of eggs carried depends on the age and size of the fish (Williams 2006). Successful spawning requires closely coordinated release of eggs and sperm by the spawning fish, which follows courtship behavior that may last for several hours (Williams 2006). Competition for the chance to fertilize redds frequently occurs. Being much smaller than a full sized adult male salmon, jack salmon often “sneak” past the fighting adults and fertilize the redd without being noticed (Moyle 2002). A redd may be fertilized by more than one male, and a male can fertilize more than one redd. This combination of large and small males ensures a high degree of egg fertilization (roughly 90%, Moyle 2002). After a male has fertilized the female’s redd, the pair may defend the redd from other spawning salmon before their death.

Spawning habitat is limited due to flow regimes, sedimentation, temperature constraints, impassible barriers, and other factors. Competition for space between spawning pairs in the tributaries also reduces the value of spawning habitat for the entire fall-run Chinook salmon population. For example, it is common, if available spawning habitat is limited, for two redds to overlap (i.e., superposition). This proves to be a significant disadvantage for the bottom redd, as the top redd has greater access to a steady flow of oxygen-containing waters (Moyle 2002).

3.2.4 Egg Development and Emergence

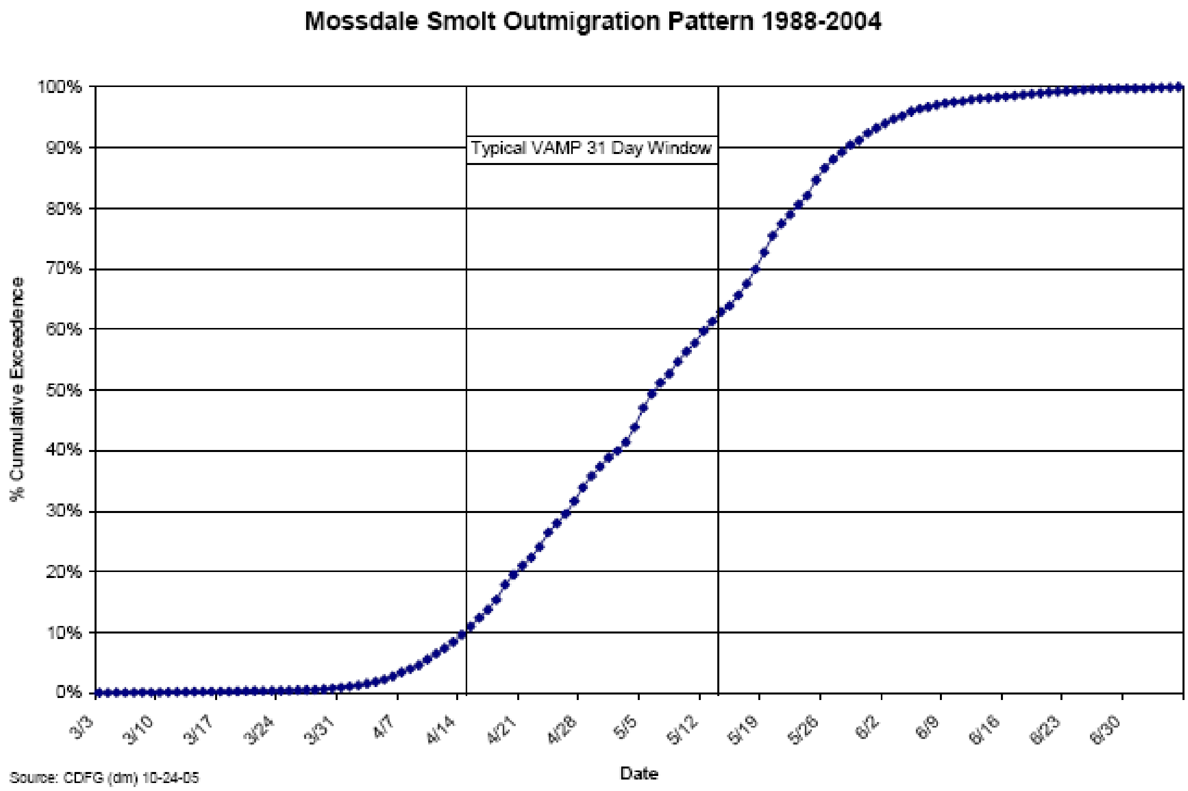
Timing of egg incubation for SJR fall-run Chinook salmon begins with spawning in late October and can extend into March, depending on water temperatures and timing of spawning (BDCP 2010). Egg incubation generally lasts between 40 to 60 days, depending on water temperatures, with optimal water temperatures for egg incubation ranging from 41ºF to 56ºF (Moyle 2002). In order to successfully hatch, incubating eggs require specific conditions such as protection from floods, siltation, desiccation, predation, poor gravel percolation, and poor water quality (NMFS 2009a).

Newly hatched salmon are called alevins, and remain in the gravel for about 4 to 6 weeks until the yolk-sac has been absorbed (NMFS 2009a). Once the yolk sack has been completely absorbed, alevins are called fry, which are roughly one inch (25 mm) long. Most fall-run Chinook salmon fry emerge from the gravel between February and March (Table 3.1; BDCP 2010; McBain and Trush 2002). Once fry grow to be roughly two inches (50 mm) in length and become camouflaged in color, exhibiting vertical stripes (i.e., parr-marks) on their body, they are called parr (Williams 2006).

3.2.5 Rearing, Smoltification, and Outmigration

Both the quantity and quality of habitat determine the productivity of a watershed, in regards to rearing and outmigration of juvenile Chinook salmon (PFMC 2000). Rearing and outmigration of fall-run Chinook salmon occurs simultaneously, and can occur in a variety of complex habitats within streams, rivers, floodplains, and estuaries (PFMC 2000). Outmigration of fry and parr occurs in response to many factors, including inherited behavior, habitat availability, flows, competition for space and food, water temperature, increasing turbidity from runoff, and changes in day length. For example, some fall-run Chinook salmon fry or parr may move immediately downstream into the lower tributary, the mainstem SJR, or the Delta for rearing. Other fry and parr may remain in the tributary to rear, eventually being flushed into downstream habitats by high tributary flows (See Table 3.7a-c Chinook Salmon Trajectory).

On average, SJR juvenile fall-run Chinook salmon rear in riverine and estuarine habitats for three to seven months before they enter the Pacific Ocean in June (DFG 2010a). Rearing and outmigration typically occurs between February and June; however, peaks in fry outmigration occur in February and March and smolt (75 mm) outmigration occurs in April and May (Rotary Screw Trap data, DFG Mossdale Trawl, Figure 3.3).



Source: DFG 2005b

Figure 3.3. Mossdale Smolt Outmigration Pattern 1988–2004, Based Upon an Updated Mossdale Smolt Outmigration Estimate by Ken Johnson (2005)

Successful rearing is associated with the magnitude, timing, and duration of flows, and connectivity with associated riparian and floodplain habitat (Mesick et al. 2007). Historically, Chinook salmon adapted to pulses in instream flows that corresponded to precipitation and snow melt events (Williams 2006, USDOI 2010). This in turn provided intermittent connectivity with riparian habitats that provided salmon with a variety of resources, including (but not limited to): increased amounts of shade, submerged and overhanging large and small woody debris, root wads, log jams, beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks (BDCP 2010).

Shallow water habitats (floodplain and riparian) provide seasonal rearing habitat for fry and parr and have been found to be more productive than main river channels (Sparks et al. 1998; Sommer et al. 2001; Opperman 2006; Williams 2006). This is due in part to favorable environmental temperatures, higher prey consumption rates, and higher densities of zooplankton, small insects, and other microcrustaceans (DFG 2010a; NMFS 2009a; Sommer et al. 2001; DFG 1993). Juveniles that use shallow water habitats typically grow faster and may survive better than fish in main river channels based on evidence of reduced exposure to predators, earlier migration to the ocean, and larger size upon ocean entry. However, increased survival has not yet been demonstrated conclusively in the field (Sommer 2005).

Smoltification usually begins when juveniles reach between three to four inches (75-100 mm).

As the juvenile salmon's body chemistry changes from freshwater tolerant to saltwater tolerant in preparation for the oceanic environment, preferred rearing is often where ambient salinity is up to 1.5 to 2.5 ppt (NMFS 2009a). Smoltification is characterized by increased levels of

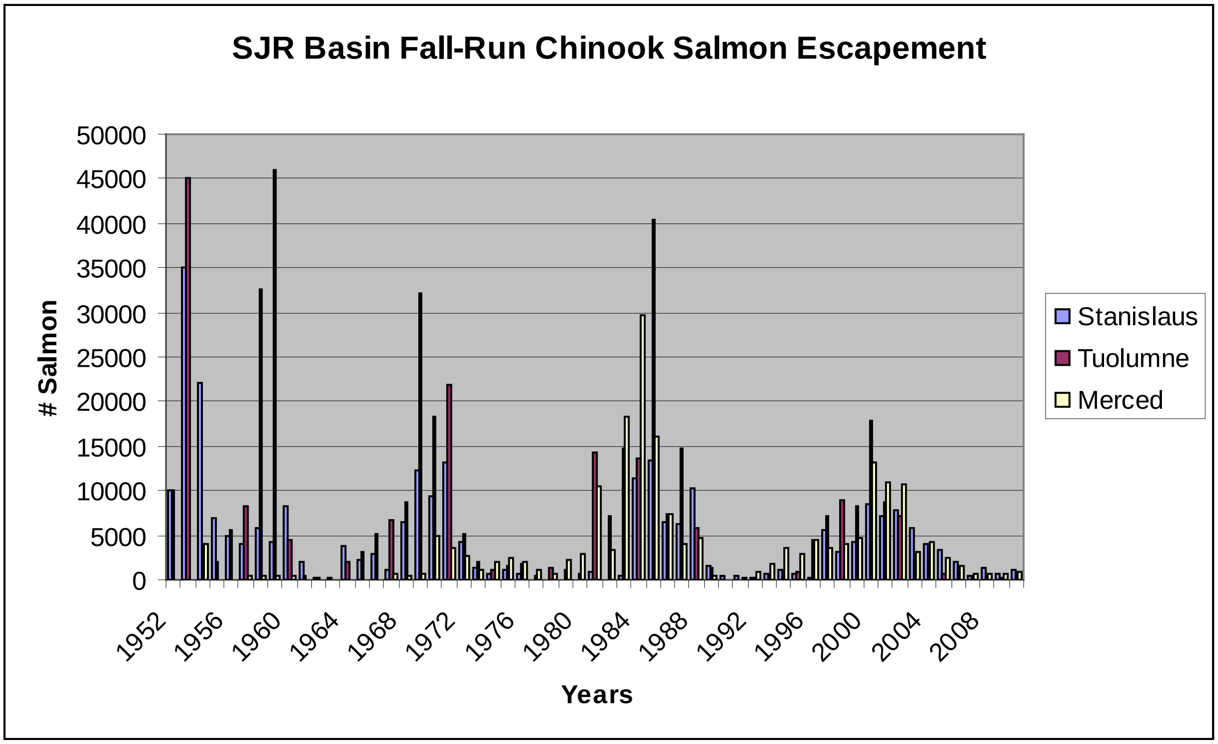
hormones, osmoregulatory changes to tolerate a more saline environment, and replacement of parr marks for a silvery body and blackened fins that are important for camouflage in an ocean environment. Although it is common to refer to juvenile Chinook that rear in river for two to three months and migrate toward the Delta between April and May as smolt migrants, most are only part way along in the smolting process, at least when they begin migrating (Williams 2006). Juvenile salmon can rear in the Delta for an additional one to three months during the smoltification process before moving into the San Francisco Bay and Pacific Ocean (Williams 2006). Juvenile Chinook salmon smolts spend, on average, one month (~40 days) migrating from Chipps Island to the Gulf of the Farallones (MacFarlane and Norton 2002).

Understanding the relationship between freshwater flows and juvenile survival during migration is complicated by the fact that flow often operates indirectly through its effects on other environmental factors that directly influence survival (DFG 2011a). In the Bay-Delta, these include (but are not limited to): water temperatures, dissolved oxygen (DO), salinity, pollutant concentrations, and predation (DFG 2011a). These environmental factors or stressors and others will be discussed in greater detail in the SED.

3.2.6 Population Trends

Spring-run Chinook salmon were probably the most abundant ESU pre-disturbance, based on the habitat and hydrology of the SJR basin (Williams 2006); however, fall-run represent the only Chinook salmon ESU that currently exist in the SJR basin. Annual returns of fall-run Chinook salmon has been estimated since 1940, but poorly documented prior to 1952. Data from 1952 to present suggest that fall-run boom and near-bust cycles have existed in the major SJR tributaries for at least the last 60 plus years.

Methods for estimating the number of returning adults (escapement) have improved over the last five decades, and have shown wide fluctuations in number of returning adult salmon (DFG 2010c). Escapement numbers for the three tributaries are generally similar in many years, suggesting that the total returning salmon may split into the three tributaries uniformly, or that the success of salmon from each tributary is similar. However, in general, the Tuolumne population has been the highest and the Merced population has been the lowest. Figure 3.4 and Appendix B show fall-run Chinook salmon escapement over the period of record for each of the major SJR tributaries.



Source: DFG 2011b

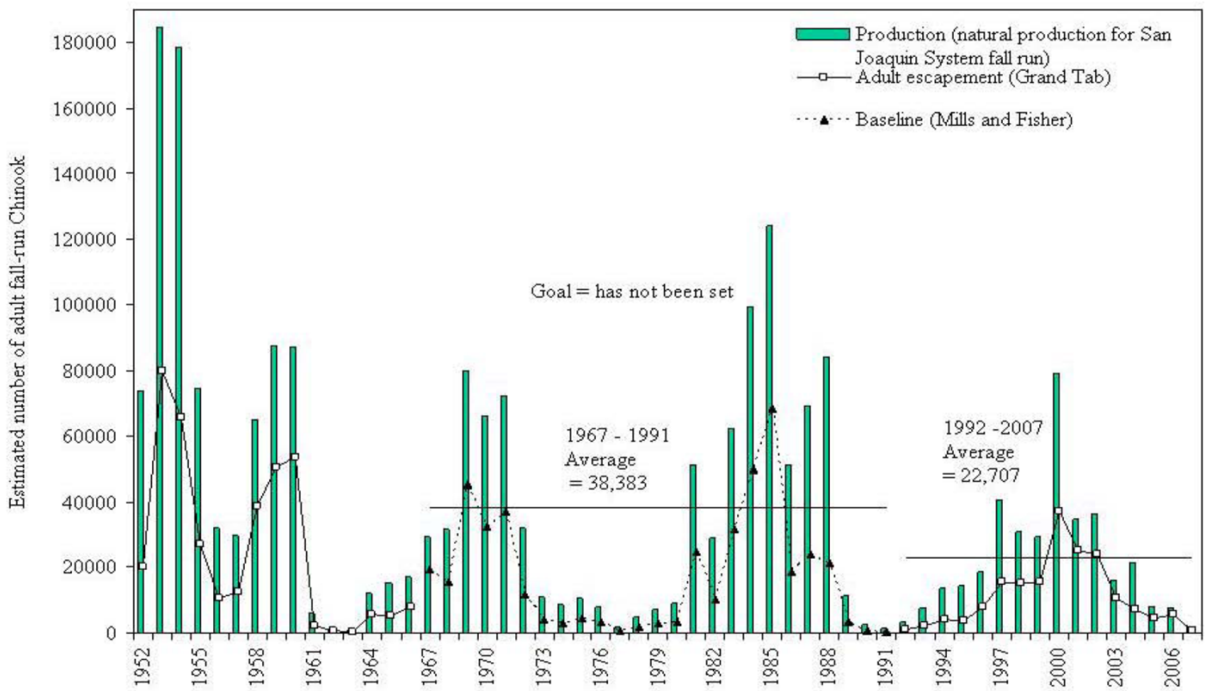
Figure 3.4. Estimated Escapement of Adult Fall-run Chinook Salmon for the Major SJR Tributaries 1952 to 2010

The annual (fall) escapement of adult fall-run Chinook salmon is really three cohort sequences, based on the typical three year return frequency (e.g., cohort “A” returning to spawn in 1952, 1955, 1958; cohort “B” returning to spawn in 1953, 1956, 1959). The success of each cohort depends on a number of factors including spawning conditions three years prior, the rearing success two years prior (dependent on river flow), and ocean conditions during the previous two years. The cohort replacement ratio for Chinook salmon provides a rough measure of the cohort return ratio and is calculated by dividing the escapement number for a given year by the escapement number from three years prior (i.e., 2010 replacement ratio = 2010 escapement/2007 escapement).

Escapement is the total number of returning Chinook salmon and does not take into account the number of salmon that could have returned to the SJR basin had they not been commercially or recreationally harvested. In order to get a more accurate estimate of total adult production, ocean harvest and recreational fishing numbers must be added to escapement. Furthermore, subtracting the number of returning adults that are of hatchery origin will give a more accurate estimate for natural production of Chinook salmon in the SJR basin.

Estimates of the fall-run Chinook salmon population have indicated a decline in both total production for the San Joaquin system and adult escapement (Figure 3.5). With regard to adult escapement, fall-run Chinook salmon escapement to the SJR basin has ranged from about 1,000 to approximately 80,000 adults, with an average escapement of about 20,000 adults. Figure 3.5 indicates that there have been periods with relatively high escapement (>25,000 adults) for several years, and periods with relatively low escapement (<10,000). Recent escapement of adult fall-run Chinook salmon to the SJR basin was estimated at approximately 2,800 fish in 2008 (DFG 2011b) and a slight increase to approximately 3,600 fish in 2009 (DFG

2010c). Declines of Central Valley Chinook salmon populations in 2008 and 2009 have been largely attributed to poor ocean conditions and have resulted in significant curtailment of westcoast commercial and recreational salmon fishing. Although ocean conditions have played a large role in the recent declines of SJR basin fall-run Chinook salmon, it is superimposed on a population that has been declining over a longer time period (Moyle et al. 2008). Looking at a longer time scale, and in the context of the CVPIA's doubling goal and State Water Board's narrative objective for salmon protection, combined escapement in the three San Joaquin tributaries since 2000 has not doubled from the average during the 1967-1991 period, but has significantly declined since the year 2000 (SJRTC 2008).



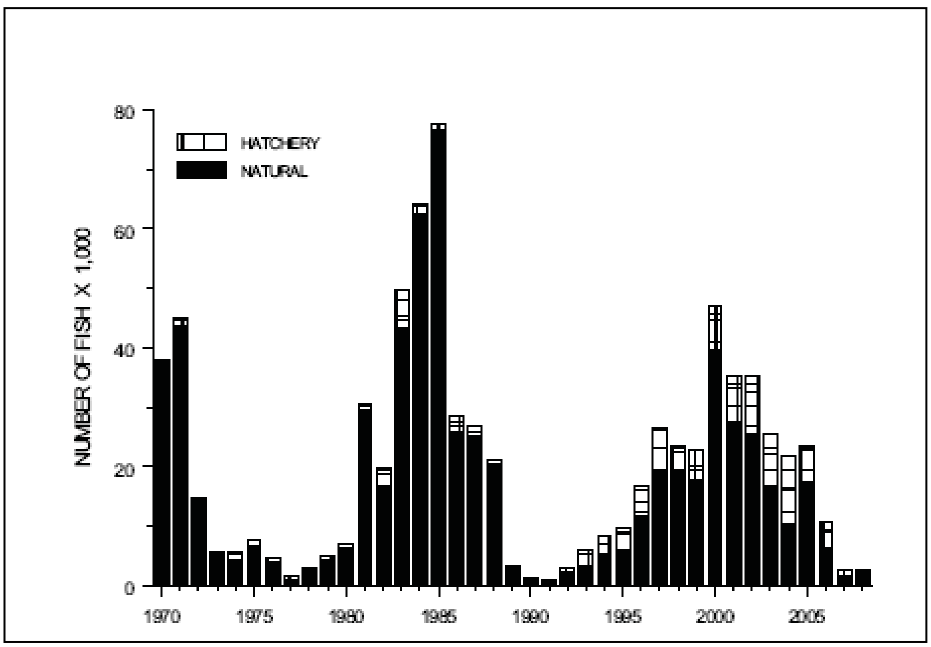
Source: SJRTC 2008

Figure 3.5. Estimated Yearly Natural Production and In-river Escapements of San Joaquin System Adult Fall-run Chinook Salmon from 1952 to 2007

The period of low escapement in the early 1990s was followed by an increase in hatchery escapements, as compared to prior years (Greene 2009, Figure 3.6). In Greene's (2009) analysis, hatchery escapement was defined as all salmon returning to the hatchery facility to spawn, and natural escapement was defined as all salmon spawning in the river. There was no separation between hatchery and natural salmon that returned to the hatchery; the same is true for hatchery and natural salmon that spawned in river. Therefore, Figure 3.6 may overestimate the escapement of natural salmon (in river spawners) and underestimate the escapement of hatchery salmon (hatchery spawners).

In the future, better information will be available concerning hatchery influences on the SJR Chinook salmon population as a result of increased marking activities. The Constant Fractional Marking Program for Central Valley fall run Chinook salmon was initiated in 2007. Through this program, a target rate of 25% of the hatchery fall-run Chinook salmon are implanted with coded-wire tags and the adipose fin is removed. In addition, at the Merced River Hatchery 100% of fish have been marked through the VAMP study and are planned to be marked in the future (Alice Low 2011 pers. comm.). Prior to these programs, relatively few of the juvenile fall-run hatchery fish produced by Central Valley hatcheries were marked and the marking rates were inconsistent.

Currently, Chinook salmon are raised at five major Central Valley hatcheries which release more than 32 million smolts each year (DFG 2010b), up from roughly 24 million in 2006 (Williams 2006). The Merced River Fish Facility is the only hatchery located in the SJR basin project area. Currently, available data indicate that hatchery-produced fish constitute a majority of the natural fall-run spawners in the Central Valley (PFMC 2007). In addition, in recent years the percentage of hatchery reared fall-run Chinook salmon returning to the SJR and its tributaries has been high proportional to wild fish (Figure 3.6, Greene 2009). These conditions may lead to increased hatchery introgression with the naturally produced fall-run Chinook salmon, which not only undermines the genetic integrity of the salmon genome, but it also leads to reduced genetic diversity between natural and hatchery salmon (Williamson and May 2005; Lindley et al. 2009; NMFS 2009a, 2009b; DFG 2011).



Source: Greene 2009

Figure 3.6. Annual Natural and Hatchery Fall-Run Chinook Escapement to the SJR Basin 1970 to 2008

Mesick (2009) evaluated the potential risk to the viability of the fall-run Chinook salmon population, and determined that the SJR basin population is at a high risk (20% risk for natural spawners within 200 years) for extinction according to some criteria and at moderate risk according to others. In making this determination Mesick (2009) used specific population viability criteria developed by Lindley el al. (2007) which identified four key factors (and associated values) that define the status of a population including: prolonged low spawner abundances (<250) over a generation; precipitous (>10%/year) declining trend in abundance;

catastrophic decline of >10% in one generation during the past 10 years; and high hatchery influence. Based on the recent population declines, reduced peak abundance of adult recruitment, and reduced population resiliency and genetic diversity through hatchery introgression, the DFG also considers the fall-run Chinook salmon run in the SJR basin to be in poor condition (DFG 2011).

SJR Basin Monitoring Programs

Comprehensive monitoring and assessment programs are critical for evaluating whether fish and wildlife beneficial uses are being protected. There are numerous agencies that participate in monitoring and assessment activities to evaluate the various life history stages of SJR basin Chinook salmon and other fish species. Sources of salmon monitoring data are identified below and are available upon request:

- Adult Chinook Salmon Escapement - DFG
- CWT Releases/Recapture - Cramer and Associates
- CVP and SWP Salvage - USFWS and DFG
- Mossdale Trawls - DFG
- Chipps Island Trawls - USFWS
- Beach Seines - USFWS
- Rotary Screw Traps on each of the major SJR tributaries - DFG, AFRP, Cramer and Associates, and TID
- Fyke Nets - DFG
- Ocean and Recreational Harvest - Pacific Fisheries Management Council

3.3 Central Valley Steelhead

Within the Central Valley, one Distinct Population Segment (DPS) of Central Valley steelhead has been identified. The steelhead DPS is defined as the portion of the population that is “markedly separated” from the resident life form, rainbow trout, due to physical, ecological, and behavioral factors. This section addresses steelhead within the proposed project area, the SJR and its major tributaries (Stanislaus, Tuolumne, and Merced Rivers).

Oncorhynchus mykiss may exhibit either anadromous (steelhead) or freshwater (resident trout) residency life history types (NMFS 2009c). Within the anadromous life history type, steelhead can be divided into two basic reproductive ecotypes, based on the state of sexual maturity at the time of river entry and duration of spawning migration. The stream-maturing type (commonly known as fall steelhead in Alaska, and summer steelhead in the Pacific Northwest and northern California) enters fresh water in a sexually immature condition and requires several months to mature and spawn. The ocean-maturing type (spring steelhead in Alaska and winter steelhead elsewhere) enters fresh water with well-developed gonads and spawns shortly thereafter (Busby et al. 1996). Summer steelhead are not found in the SJR tributaries. Remnant populations of winter steelhead are currently found in the major SJR tributaries (McEwan 2001; Good et al. 2005; Zimmerman et al. 2008). Unless noted otherwise, subsequent discussions of the anadromous form of Central Valley steelhead refers to the ocean-maturing (winter) life history type.

3.3.1 Life History

The primary differences between fall-run Chinook salmon and steelhead are that: 1) steelhead remain in the river for at least one year and as many as three years before smoltification and outmigration; 2) steelhead are capable of spawning more than once before dying; 3) steelhead can produce anadromous or non-anadromous life forms (Moyle et al. 2010); and 4) steelhead spawn in late winter and early -spring months (Table 3.14). In addition, steelhead produce smaller eggs that incubate over a shorter period during increasing winter-spring water temperatures, whereas salmon produce larger eggs that incubate over a longer period during decreasing fall-winter water temperatures (Moyle 2002; Williams 2006). Microchemistry analysis of steelhead otoliths (inner ear bone) provided evidence that there is no reproductive barrier between resident and anadromous forms, and anadromous steelhead can bear nonanadromous juveniles and vice versa (McEwan 2001; Williams 2006, Zimmerman and Reeves 1999; Zimmerman et al. 2008). Therefore, environmental conditions that become unfavorable to steelhead and favorable to resident trout may inadvertently reduce the incidence of anadromy and increase the incidence of residency in these populations. This is commonly the case on the Sacramento River below Shasta Dam (Williams 2006). This phenomenon can also be true in the opposite scenario where the anadromous life form is favored in a system over the resident life form. However, this does not appear to be the case in the SJR basin where steelhead populations are very small (i.e., remnant levels) and environmental conditions are more favorable to the resident life form. See Table 3.14 for approximate timing of steelhead life history phases.

Table 3.14. Generalized Life History Timing of Central Valley Steelhead

	Upstream Migration Period	Spawning Period	Incubation	Juvenile Rearing and Outmigration	Ocean Entry
Central Valley Basin	August to March	December to March	December to May	Year Round	Year Round
SJR Basin	July to April	December to June	December to June	Year Round	Year Round
Peak SJR Basin	October to February	January to March		March and April	April to June

3.3.2 Adult Migration

The majority of Central Valley steelhead return to their natal streams and spawn as four or five year olds (NMFS 2009c; USFWS 2001). Central Valley steelhead can begin upstream migration beginning as early as July and continue through April, with peaks in upstream migration within the SJR basin typically occurring between October and February (Table 3.2; USDOI 2008; Moyle 2002; McBain and Trush 2002). High flow events help steelhead perceive the scent of their natal stream as they begin upstream migration. Negative environmental factors (e.g., high water temperatures, low dissolved oxygen) often block or delay the migration of adult fall-run Chinook salmon into the SJR (Hallock et al. 1970; Bjornn and Reiser 1991; Mesick 2001a; Williams 2006), causing them to hold below the migration barrier for suitable environmental conditions or stray into a more suitable spawning area (DFG 2011a). Optimal immigration and holding temperatures for steelhead have been reported to range from 46°F to 52°F (NMFS 2009c).

3.3.3 Spawning and Holding

Steelhead enter fresh water with well-developed gonads and spawn downstream of impassable dams on the major SJR tributaries and the mainstem SJR, similar to fall-run Chinook salmon (NMFS 2009c). Spawning typically occurs from December through June (USDOI 2008, McBain and Trush 2002), with peaks occurring between January and March (Table 3.3; NMFS 2009a). Steelhead spawn where cool (30°F to 52°F), well oxygenated water is available year-round (McEwan and Jackson 1996).

Female steelhead select sites with good inter-gravel flow, usually in coarse gravel in the tail of a pool or in a riffle, excavates a redd with her tail, and deposit eggs while an attendant male fertilizes them. Moyle (2002) estimates that adult steelhead generally carry about 2,000 eggs per kilogram of body weight. This translates to an average fecundity of about 3,000 to 4,000 eggs for an average steelhead female (Williams 2006). However, the actual number of eggs produced is dependent on several variables including race, size, age (Leitritz and Lewis 1976), and viability of those eggs can be affected by stressful environmental factors (such as high temperatures, pesticides, and disease).

Unlike Chinook salmon, which are semelparous and spawn only once before dying, steelhead are iteroparous and are capable of spawning more than once before dying (Busby et al. 1996). However, it is rare for steelhead to spawn more than twice before dying, and those that do are typically females (Busby et al. 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby et al. 1996), and although one-time spawners are still the great majority, Shapovalov and Taft (1954) reported that repeat spawners are relatively numerous (17.2%) in California streams.

Another dissimilarity between steelhead and Chinook salmon is the duration of courtship and spawning behaviors. Briggs (1953) observed steelhead spawning from one to two days and up to as long as a week (Williams 2006). Average residence time around the redd was observed to last only a few days after fertilization. Typically, once a redd is fertilized the female steelhead attempts the journey back to the Pacific Ocean to continue maturation in preparation for another spawning year.

3.3.4 Egg Development and Emergence

Depending on water temperature, steelhead eggs may incubate in redds for four weeks to as many as four months before hatching as alevins (NMFS 2009c, McEwan 2001). Steelhead eggs that incubate at 50°F to 59°F hatch in about four weeks, and fry emerge from the gravel anywhere from four to eight weeks later (Shapovalov and Taft 1954, DFG 1993). In hatchery facilities, hatching of steelhead eggs takes about 30 days at 51°F (McEwan 2001). Incubating eggs can reportedly survive at water temperatures ranging from 35.6°F to 59°F (Myrick and Cech 2001), with the highest survival rates at water temperature ranging from 44.6°F to 50.0°F (Myrick and Cech 2001).

Incubation for steelhead eggs typically occurs between the months of December through June (Table 3.2; USDOI 2008, McBain and Trush 2002) with factors such as redd depth, gravel size, siltation, and temperature affecting emergence timing (Shapovalov and Taft 1954). Newly emerged fry usually migrate into shallow (<36 cm), protected areas associated with the stream margin (McEwan and Jackson 1996), or low gradient riffles, and begin actively feeding (USFWS 2001). With increasing size, fry move into higher-velocity, deeper, mid-channel areas, generally in the late summer and fall.

3.3.5 Rearing, Smoltification, and Outmigration

Juvenile steelhead rear in cool, clear, fast flowing permanent freshwater streams and rivers where riffles predominate over pools, for one to three years (1% spend three years; DFG 2010a). Compared to fall-run Chinook salmon, this extended amount of time needed for rearing means that juveniles are dependent on the availability of such conditions for at least a full year prior to outmigration, especially during the summer when these conditions are most restricted. Some Central Valley steelhead juveniles may use warm shallow water habitats where feeding and growth are possible throughout the winter (NMFS 2009a). These areas, such as floodplain and tidal marsh areas, allow steelhead juveniles to grow faster, which in turn requires a shorter period in freshwater before smoltification occurs (NMFS 2009a, NMFS 2009c). Diversity and richness of habitat and food sources in shallow water habitats allows juveniles to attain a larger size before ocean entry, thereby increasing their chances for survival in the marine environment (BDCP 2010).

Some Central Valley steelhead may not migrate to the Pacific Ocean (anadromous) at all and remain in rivers (fluvial) or lakes (adfluvial) as resident fish, avoiding migration through the Bay-Delta completely (Moyle 2002). Populations that have both anadromous and resident forms are likely to have an evolutionary advantage. Resident fish persist when ocean conditions cause poor survival of anadromous forms, and anadromous forms can re-colonize streams in which resident populations have been wiped out by drought or other disasters. Less is known about the migration of juvenile steelhead in the Central Valley than about juvenile fall-run Chinook salmon, but better information is becoming available from screw traps that are located in high velocity water that can catch yearlings in significant numbers (Williams 2006). However, interpretation of the data is complicated by the large proportion of the population that has adopted a resident life history pattern; making it unclear if steelhead juveniles captured in the traps are migrating to the ocean (Williams 2006).

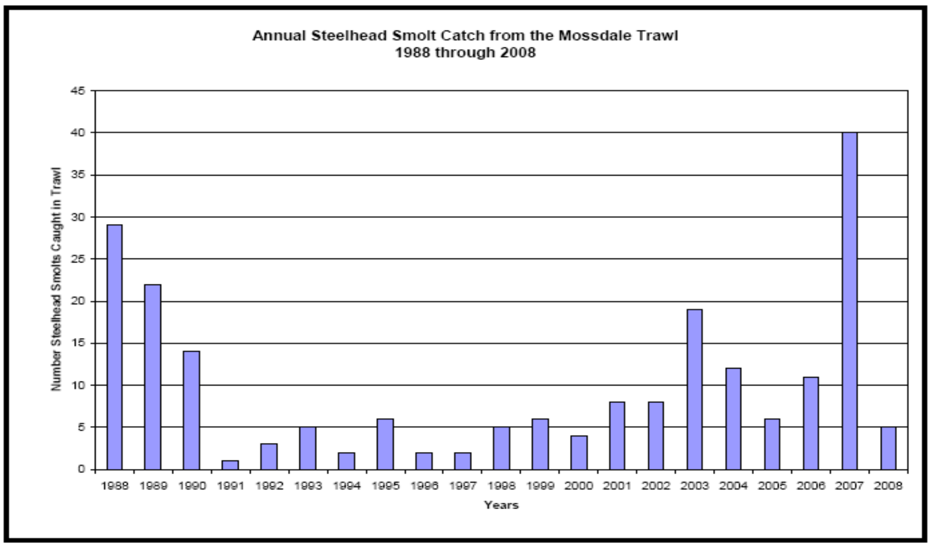
Central Valley steelhead juveniles generally begin outmigration anywhere between late December through July, with peaks occurring between March and April (Table 3.2; USDOI 2008, McBain and Trush 2002). Juvenile steelhead are considerably larger and have a greater swimming ability than Chinook salmon juveniles during outmigration. This is primarily due to a longer rearing period (1–3 years) for juvenile steelhead. During outmigration, juveniles undergo smoltification, a physiologic transformation enabling them to tolerate the ocean environment and its increased salinity. Steelhead smoltification has been reported to occur successfully at 44°F to 52°F (Myrick and Cech 2001; USDOI 2008).

3.3.6 Population Trends

There is little historical documentation regarding steelhead distribution in the SJR basin, presumably due to the lack of an established steelhead sport fishery (Yoshiyama et al. 1996). However, populations of steelhead were believed to have previously extended into the headwaters of the SJR and the major SJR tributaries (Moyle 2002). The California Fish and Wildlife Plan of 1965 estimated the combined annual steelhead run size for Central Valley and San Francisco Bay tributaries to be about 40,000 during the 1950s (McEwan and Jackson 1996). During the mid-1960s, the spawning population within the Central Valley basin was estimated at nearly 27,000 (McEwan and Jackson 1996). These numbers were comprised of both wild and hatchery populations of Central Valley steelhead. McEwan and Jackson (1996) estimated the annual run size for the Central Valley basin to be less than 10,000 adults by the early 1990s.

Until recently, steelhead were thought to be extirpated from the SJR and major SJR tributaries. DFG records contain reference to a small population characterized as emigrating smolts that are captured at the DFG Kodiak trawl survey station at Mossdale on the lower SJR each year (EA Engineering, Science, and Technology 1999). DFG staff prepared catch summaries for juvenile migrant steelhead on the SJR near Mossdale, which represents migrants from the SJR basin including the major SJR tributaries (NMFS 2009a). Based on trawl recoveries at Mossdale between 1988 and 2002, as well as rotary screw trap efforts on the major SJR tributaries, DFG found that resident rainbow trout do occur in all tributaries as migrants, and that the vast majority of them occur on the Stanislaus River (NMFS 2009a).

Currently, steelhead remain in low numbers on the major SJR tributaries below the major rim dams, as shown by DFG catches on the mainstem SJR near Mossdale (Figure 3.7) and by otolith microchemistry analyses documented by Zimmerman et al. (2008). However, due to the very limited amount of monitoring in the Central Valley, data are lacking regarding a definitive steelhead population size within each tributary. The limited data that do exist indicate that the steelhead populations in the SJR basin continue to decline (Good et al. 2005) and that none of the populations are viable at this time (Lindley et al. 2007). Recent declines are likely due to a combination of declining habitat quality, increased water exports, and land use practices that have reduced the relative capacity of existing steelhead rearing areas (NMFS 2009c; McEwan 2001).



Annual number of Central Valley steelhead smolts caught while Kodiak trawling at the Mossdale monitoring location on the SJR Marston 2004; SJRGA 2007; Speegle 2008; NMFS 2009a).

Figure 3.7. Annual Number of Central Valley Steelhead Smolts Caught in the Mossdale Trawl 1998–2008

3.4 Fall-Run Chinook Salmon Flow Needs

Flows in the SJR basin affect various life stages of fall-run Chinook salmon including: adult migration (escapement), adult spawning, egg incubation, juvenile rearing, and outmigration to the Pacific Ocean. Analyses indicate that the primary limiting factor for salmon survival and subsequent abundance is reduced flows during the late winter and spring when juveniles are completing the freshwater rearing phase of their life cycle and migrating from the SJR basin to the Delta (February through June; DFG 2005a; Mesick and Marston 2007; Mesick et al. 2007; Mesick 2009). As such, while SJR flows at other times are also important, the focus of the State Water Board's current review is on flows within the salmon-bearing tributaries and the SJR at Vernalis (inflows to the Delta) during the critical salmon rearing and outmigration period of February through June.

3.5 Functions Supported by Spring Flows

Chinook salmon migration patterns are adapted to variations in-flow conditions (Lytle and Poff 2004). Monitoring shows that both juvenile and adult salmon begin migrating during the rising limb of the hydrograph (USDOI 2010). For juveniles, pulse flows appear to be more important than for adults (USDOI 2010). Delays in precipitation producing flows may result in delayed emigration, which may result in increased susceptibility to in-river mortality from predation and poor habitat conditions (DFG 2010d).

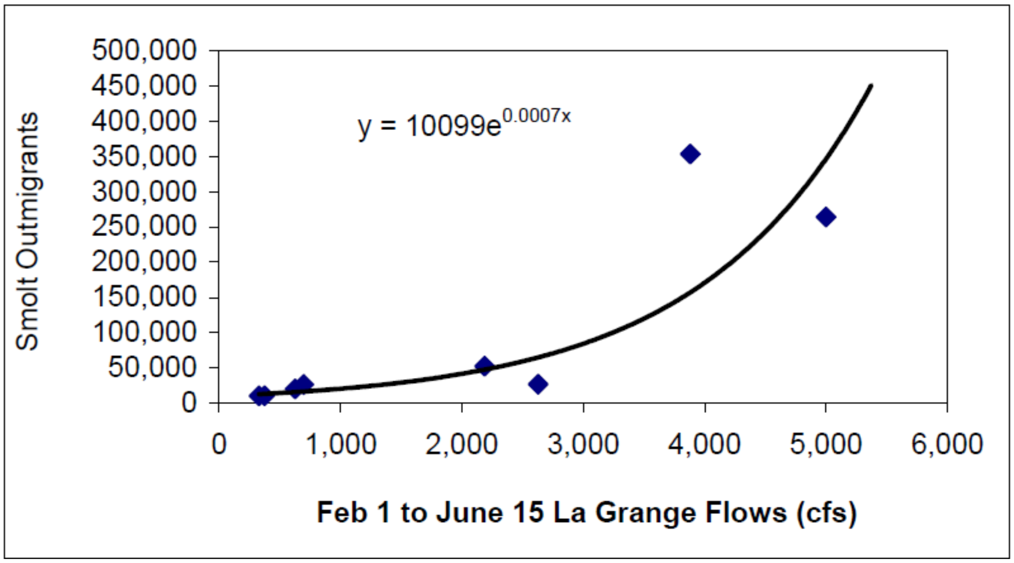
Juvenile Chinook salmon exhibit different migration and life history strategies adapted to variations in flows (Lytle and Poff 2004). Under unaltered hydrographic conditions in the SJR basin, flows on the major SJR tributaries and the mainstem SJR generally increase in response to snow-melt and precipitation during the spring period, with peak flows occurring in May. Increased flow conditions, throughout the late winter to spring period on the major SJR tributaries are important to maintain diversity in Chinook salmon populations. Increases in tributary flow, as a response to snow-melt, allow for a variety of genetic and life history strategies to develop over a variety of year types. These different life history strategies assure the continuation of the species over time and under different hydrologic and environmental conditions. Depending on several factors, some juvenile salmon can migrate as fry during early flow events and others can migrate as parr or smolts when flows increase later in the season. Fry generally begin migrating in early February and March, with peak smolt outmigration occurring during the months of April and May, as verified by monitoring data from the USFWS Mossdale Trawl (see Figure 3.2).

In late winter and spring, increased flows provide improved transport downstream and improved rearing habitat for salmon migration. These flows may also provide for increased and improved edge habitat (generally inundated areas with vegetation) in addition to increased food production for the remainder of salmon that are rearing in-river. Later in the season, higher inflows function as an environmental cue to trigger migration of smolts, facilitate transport of fish downstream, and improve migration corridor conditions (USDOI 2010). Specifically, higher inflows of various magnitudes in spring support a variety of functions including: maintenance of channel habitat and transport of sediment, biota, and nutrients (Junk et al. 1989). Increased turbidity and more rapid flows may also reduce predation of juvenile Chinook salmon (Gregory 1993; Gregory and Levings 1996, 1998). Higher inflows also provide better water quality conditions by reducing instream water temperatures, increasing dissolved oxygen levels, and reducing contaminant concentrations. NMFS has determined that each of these environmental factors are significantly impaired by current flow conditions in the SJR basin (NMFS 2009a). In addition, the USEPA recently added the portion of the SJR, extending from its confluence with the Merced River to the Delta Boundary, and each of the major SJR tributaries to the Clean Water Act Section 303(d) list for temperature impairments (USEPA 2011). In support of this decision, the USEPA evaluated whether the "Cold Freshwater Habitat (COLD)," "Migration of Aquatic Organisms (MIGR)" and "Spawning, Reproduction, and/or Early Development (SPWN)" uses are supported for Chinook salmon and steelhead trout in the respective reaches of the San Joaquin, Merced, Tuolumne, and Stanislaus rivers. As an example, based on this evaluation, USEPA believes that the frequency of exceedances of the 20° C seven day average of the daily maxima (7DADM) benchmark in the mainstem segments of the San Joaquin River provides an indication of increased risk of disease, migration blockage and delay, and overall reduction in salmonid migration fitness (USEPA 2011).

3.6 Analyses of Flow Effects on Fish Survival and Abundance

Studies that examine the relationship between fall-run Chinook salmon population abundance and flow in the SJR basin generally indicate that: 1) additional flow is needed to significantly improve production (abundance) of fall-run Chinook salmon; and 2) the primary influence on adult abundance is flow 2.5 years earlier during the juvenile rearing and outmigration life phase (AFRP 2005; DFG 2005a; Mesick 2008; DFG 2010a; USDOI 2010). These studies also report that the primary limiting factor for tributary abundances are reduced spring flow, and that populations on the tributaries are highly correlated with tributary, Vernalis, and Delta flows (Kjelson et al. 1981; Kjelson and Brandes 1989; USFWS 1995; Baker and Mohardt 2001; Brandes and McLain 2001; Mesick 2001b; Mesick and Marston 2007; Mesick 2009; Mesick 2010 a-d).

Analyses have been conducted for several decades that examine the relationship between SJR fall-run Chinook salmon survival (escapement) or abundance (e.g., adult Chinook salmon recruitment) and flow. Specifically, analyses have also been conducted to: 1) evaluate escapement (the number of adult fish returning to the basin to spawn) versus flow 2.5 years earlier when those salmon were rearing and outmigrating from the SJR basin; and 2) to estimate juvenile fall-run Chinook salmon survival at various reaches in the SJR basin and the Delta versus flow. For example, flows from March through June have been correlated to the total number of smolt outmigrants within a tributary (Mesick, et al. 2007, SJRRP 2008). Figure 3.8 suggests that prolonged late winter and spring flows in the Tuolumne River are an important factor in determining smolt survival rate (Mesick 2009). Additionally, adult Chinook salmon are thought to be highly correlated with the production of smolt outmigrants, which are highly correlated to spring flows, for each of the major SJR tributaries (Mesick and Marston 2007; Mesick et al. 2007). For a description of escapement and how it relates to production see the fall-run Chinook salmon population trends discussion (Section 3.2.6).



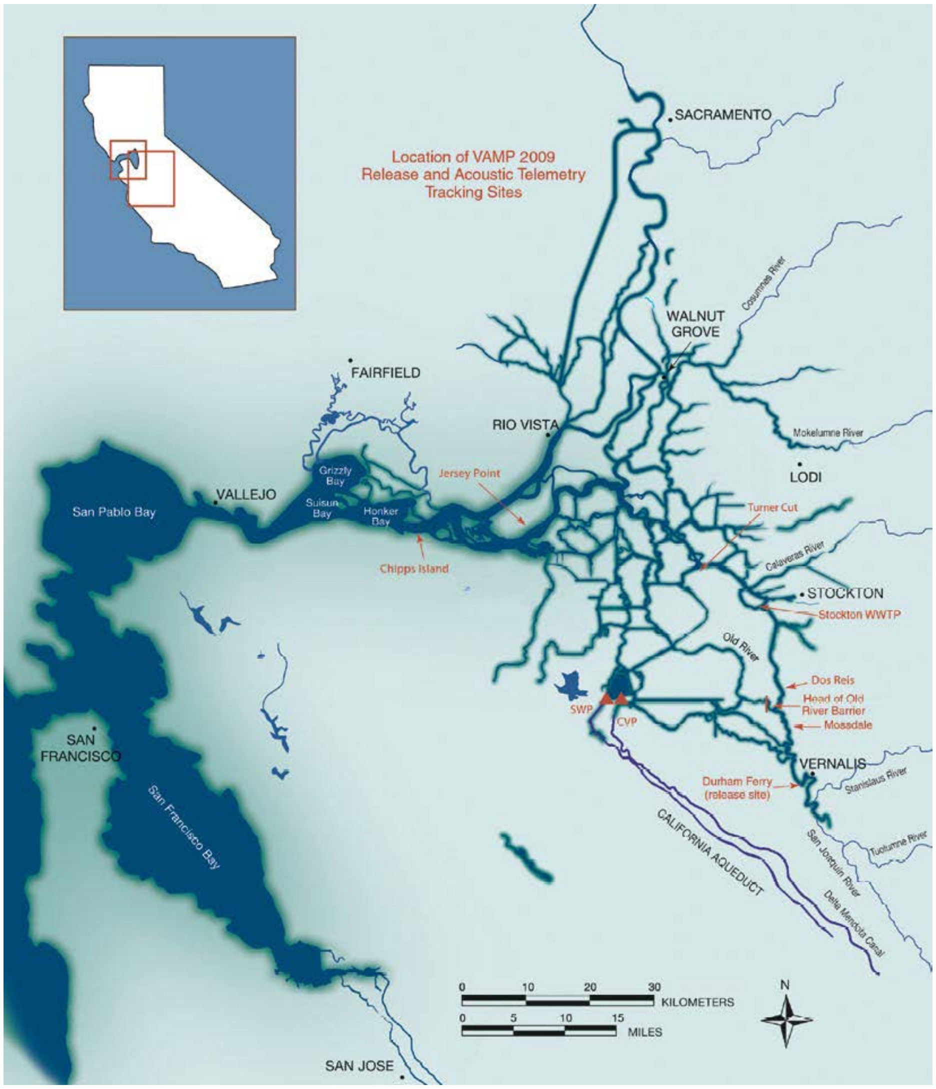
Source: Mesick 2009

Note: the spring 2006 estimates were omitted because the number of Age 3 equivalent spawners in fall of 2005 was only 447 adults, which limited smolt production unlike the other years when flows were the primary determinant.

Figure 3.8. The Number of Smolt-sized Chinook Salmon Outmigrants (>70mm) Passing the Grayson Rotary Screw Trap Site Plotted against Tuolumne River Flow from 1998-2005

3.6.1 SJR CWT Studies

Specific experiments using coded wire tagged (CWT) hatchery smolts released at various locations on the SJR and in the Delta to estimate survival of salmon smolts migrating through the Delta under various circumstances started in the early 1980's. Since 2000, CWT experiments have been conducted pursuant to the VAMP, and since 2007, VAMP survival studies have been conducted using acoustic telemetry devices. The VAMP and pre-VAMP CWT studies were similar and involved releasing hatchery fish at various locations on the SJR including Old River, Jersey Point, Durham Ferry, Mossdale, and Dos Reis (Figure 3.9), and recapturing those fish downstream in the Delta. Under the pre-VAMP studies, fish were released at unspecified flow and export conditions. The 12-year VAMP study was designed to release fish at specified flows during a 31-day period from approximately mid-April through mid-May under specified export conditions in order to evaluate the relative effects of changes in Vernalis flow and SWP and CVP export rates on the survival of SJR salmon smolts passing through the Delta. As part of the original design of VAMP, the physical HORB was also assumed to be in place, although it was recognized that in some years the barrier would not be in place. In recent years, the physical HORB has not been in place and may be precluded in the future due to concerns related to protection of Delta smelt (SJRGA 2008). The following is a summary of the evaluations conducted to date to investigate the relationship between flows and SJR fall-run Chinook salmon survival and abundance during the spring period.



Source: SJRGA 2010

Figure 3.9. Location of VAMP 2009 Release and Acoustic Telemetry Tracking Sites

In 1981, based on studies by the Ecological Study Program for the Delta, Kjelson et al. reported on the effects of freshwater inflows on the survival, abundance, and rearing of salmon in the upstream portions of the Delta. Kjelson et al. (1981) found that peak catches of salmon fry often follow flow increases associated with storm runoff, suggesting that flow surges influence the number of fry that migrate from spawning grounds into the Delta and increase the rate of migration for fry. Kjelson et al. (1981) also found that flows in the SJR and Sacramento River, during spawning and rearing periods, influence the numbers of juvenile Chinook salmon that survive to migrate to the Delta. In addition, observations made in the SJR basin between 1957 and 1973 indicate that numbers of Chinook spawners are influenced by the amount of river flow during the rearing and outmigration period (February to June) 2.5 years earlier. As a result, Kjelson et al. (1981) found that flow appears to affect juvenile survival, which in turn affects adult abundance. In testimony before the State Water Board in 1987, Kjelson again reported that data indicate that the survival of fall-run salmon smolts migrating from the SJR basin through the Delta increases with flow. Kjelson found that increased flows also appear to increase migration rates, with smolt migration rates more than doubling as inflow increased from

2,000 to 7,000 cfs (USFWS 1987). In a 1989 paper, Kjelson and Brandes once again reported a strong long term correlation (r = 0.82) between flows at Vernalis during the smolt outmigration period of April through June and resulting SJR basin fall-run Chinook salmon escapement (2.5 year lag) (Kjelson and Brandes 1989).

In 1995, the Anadromous Fish Restoration Program[1] *Working Paper on Restoration Needs: Habitat Restoration Actions to Double Natural Production of Anadromous Fish in the Central Valley of California* (Working Paper) reported that declines in adult fall-run Chinook salmon escapement to SJR basin tributaries were attributed to inadequate streamflow in the mainstem SJR and major SJR tributaries. The Working Paper reported that there is a positive relationship between smolt survival and spring flow in the Tuolumne River, and indicated that substantially higher flows are needed for salmon spawning and rearing on the lower Tuolumne River. The Working Paper also reported that escapement of adult Chinook salmon into the Stanislaus River is associated with spring outflow in both the SJR at Vernalis and the Stanislaus River at Ripon, and that the timing, amount, and quality of flow affects the migration and survival of both juvenile and adult Chinook salmon (USFWS 1995).

In 2001, Brandes and McLain reported on the findings of experiments regarding the effects of flows, exports, HORB operations and other factors on the abundance, distribution, and survival of SJR basin juvenile Chinook salmon. Brandes and McLain (2001) reported that survival appears greater for smolts that migrate down the mainstem SJR instead of through upper Old River. Brandes and McLain (2001) also found a statistically significant relationship between survival and river flow (R^2 = 0.65, *p-value* < 0.01). They found that the physical HORB may have served as a mechanism to increase the flows and that survival is improved via the barrier because of the shorter migration path, but also because it increases the flows down the mainstem SJR (Brandes and McLain 2001).

Baker and Morhardt (2001) found that fall-run Chinook salmon smolt survival through the Delta may be influenced to some extent by the magnitude of flows from the SJR, but that the relationship was not well quantified, especially in the range of flows for which such quantification would be most useful for flow management prescriptions (e.g., 5,000 cfs to 10,000 cfs). In addition, Baker and Morhardt (2001) found that there was a clear relationship when high flows were included in the analysis, but at flows below 10,000 cfs there was very little correlation between flows at Vernalis and escapement, and flows at Vernalis and smolt survival through the Delta. A 2009 NMFS Technical Memorandum regarding the SJR flows analysis for the OCAP Biological Opinion stated that inflows below approximately 5,000 cfs in April and May can produce highly variable adult escapement numbers 2.5 years later. Furthermore, factors other than flow may be responsible for the variable escapement returns. NMFS also states that for flows above approximately 5,000 cfs the relationship with escapement begins to take on a linear form, and adult escapement increases in relation to flow. NMFS explains that anomalies within the flow relationship (i.e., subsequent low adult returns during high spring flows) can be due to poor ocean conditions upon juvenile entry or low adult returns in the fall prior to the high spring flows.

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[1] Representing experts possessing specific technical and biological knowledge of Central Valley drainages and anadromous fish stocks from the DFG, Department of Water Resources, USFWS, Bureau, and NMFS (USFWS 1995).

The general relationship between flow (April and May) and escapement of adult fall-run salmon 2.5 years later is illustrated in Figure 3.10. The average observed and unimpaired April and May flows within each river are shown with the purple and blue symbols, respectively. Fall escapement for the SJR tributaries has been reported since 1952. Such an assessment relies on an assumption that each year's escapement is dominated by three year old salmon. While three year old fish generally return to spawn in the highest numbers, other aged fish may represent a significant portion of annual escapements in some years. The DFG, in consultation with Dr. Carl Mesick, prepared brood year cohort data for the SJR tributaries and compared those data with SJR spring flows at Vernalis (Mesick and Marston 2007). The results of this analysis indicate a strong relationship exists between spring flow magnitude and adult production (both ocean harvest and escapement).

In a 2001 paper, Mesick evaluated the factors that potentially limit fall-run Chinook salmon production in the Stanislaus and Tuolumne Rivers. Mesick found that recruitment to the Stanislaus River population from 1945 to 1995, and to the Tuolumne River population from 1939 to 1995, was strongly correlated with: springtime flows in the mainstem SJR and the tributaries; the ratio of Delta exports at the SWP and CVP to Vernalis flows; and to a lesser degree, the abundance of spawners (stock), ocean harvest, and anchovy landings[2]. Mesick found that correlations with herring landings, November flows during spawning, water temperature at Vernalis, and ocean climate conditions, were not significant. Mesick also found that the influence of flow and Delta exports was greatest in the Delta near Stockton, indicating that the survival of smolts migrating in the Delta downstream from Dos Reis to Jersey Point is strongly correlated with flow and to a lesser degree water temperature and Delta exports (Mesick 2001b).

In 2008, Newman published a comprehensive evaluation of data from several release-recovery experiments conducted in order to estimate the survival of outmigrating juvenile Chinook salmon and to quantify the effect of various factors on survival. This review included a Bayesian hierarchical model analysis of CWT experiments from the VAMP (2000-2006) and pre-VAMP data (1996-1999) with both the HORB in and out, SJR at Mossdale flows ranging from 1,400 cfs (1990) to 29,350 (2006) cfs, and exports ranging from 805 cfs (1998) to 10,295 cfs (1989). In this analysis, Newman found that there was a positive association between flow at Dos Reis (with at least a 97.5% probability of a positive relationship) and subsequent survival from Dos Reis to Jersey Point. If data from 2003 and later were eliminated from analysis, the strength of the association increased and a positive association between flow in Old River and survival in Old River became evident. Newman did not find any relationship for the Durham Ferry to Mossdale reach and the Mossdale to Dos Reis reach. In addition, Newman found that the expected probability of surviving to Jersey Point was consistently larger for fish staying in the SJR (passing Dos Reis) than fish entering Old River, but the magnitude of the difference varied slightly between models. Lastly, Newman found that associations between water export levels and survival probabilities were weak to negligible, however, Newman pointed out that more thorough modeling should be conducted.

[2] Landings refer to the amount of catch that is brought to land (see http://www.nmfs.noaa.gov/fishwatch/species/anchovy.htm).

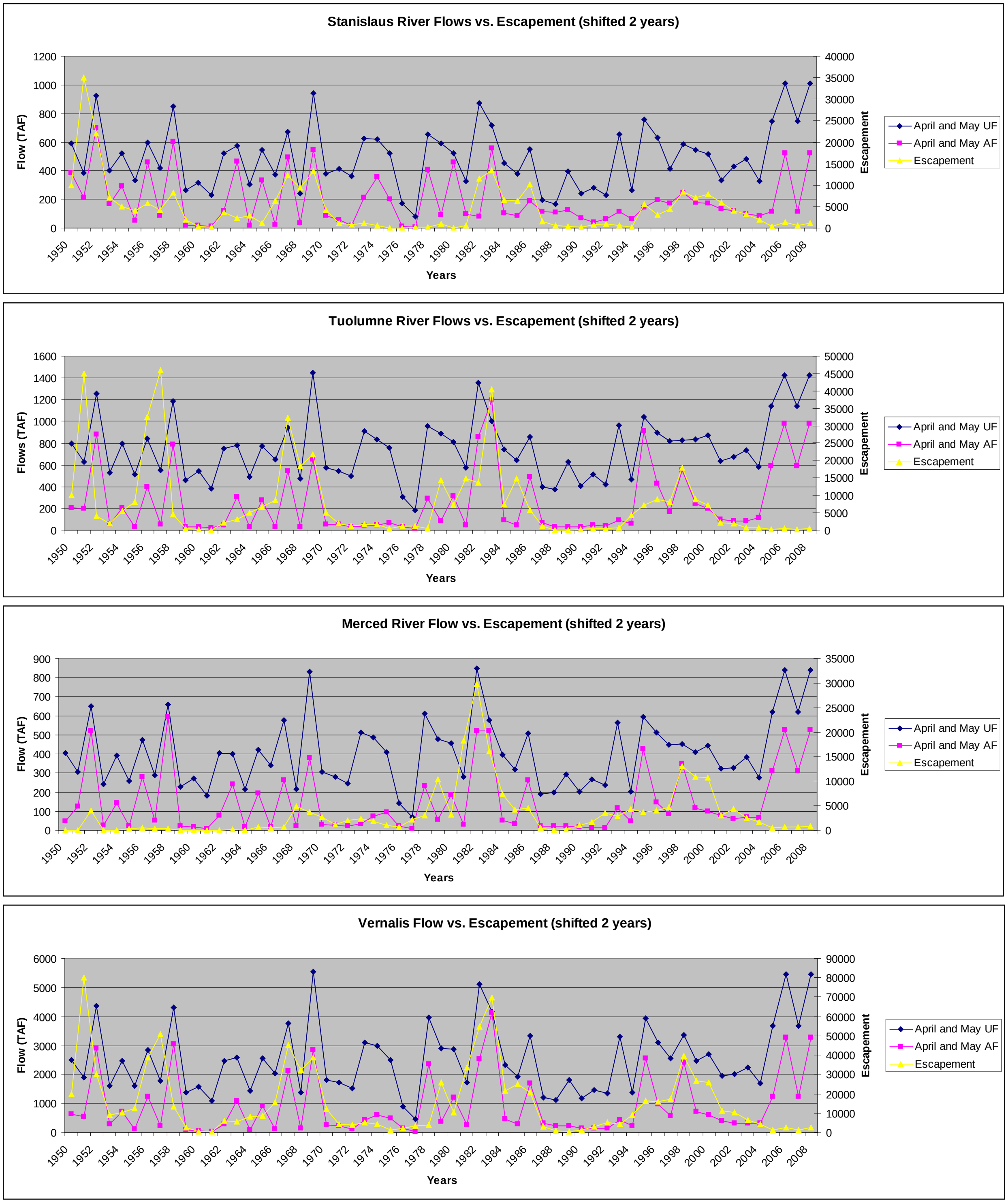


Figure 3.10. Fall-Run Chinook Salmon Escapement Compared to April and May Flows (2.5 Years Earlier) for the Stanislaus, Tuolumne, Merced Rivers, and SJR Basin Measured at Vernalis

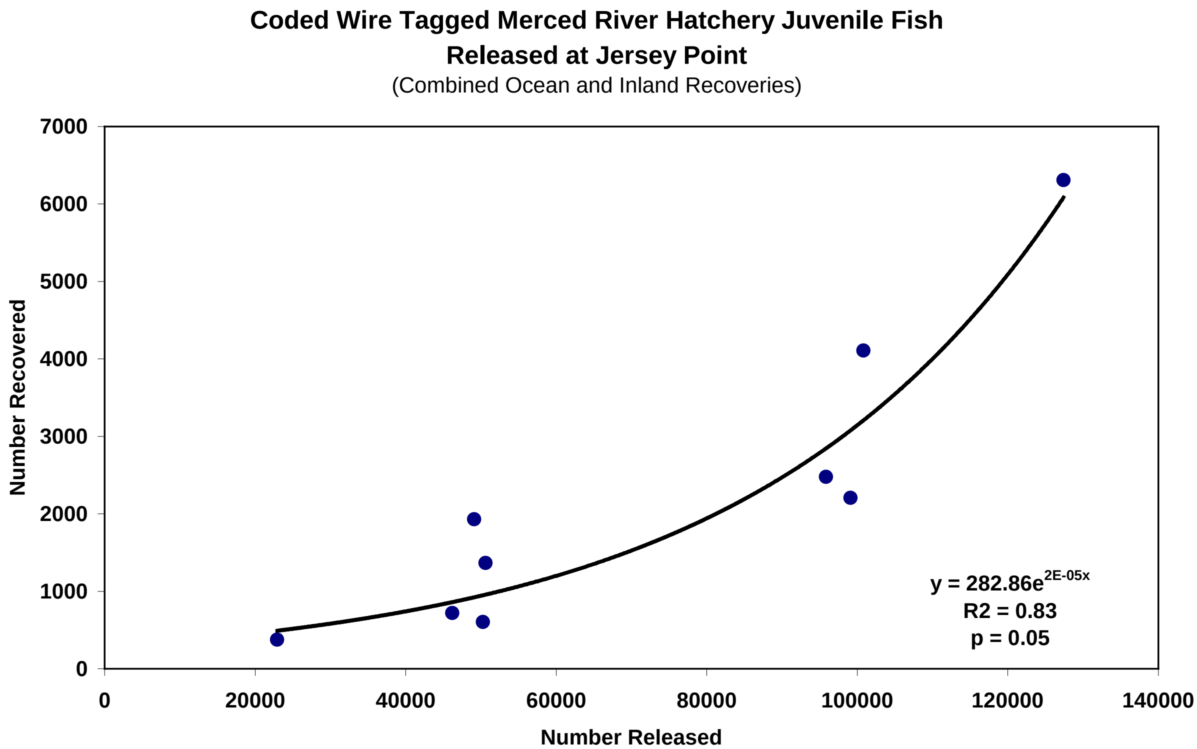
In 2007, Mesick et al. developed a Tuolumne River Management Conceptual Model that included a limiting factor analysis of Tuolumne River Chinook salmon and rainbow trout populations. The limiting factor analyses suggest that adult Chinook salmon recruitment (i.e., the total number of adults in the escapement and harvested in the sport and commercial fisheries in the ocean) is highly correlated with the production of smolt outmigrants in the Tuolumne River, and that late winter and spring flows are highly correlated with the number of smolts produced. Mesick et al. (2007) reports that other evidence from rotary screw trap studies indicate that many more fry are produced in the Tuolumne River than can be supported with the existing minimum flows; therefore, producing more fry by restoring spawning habitat is unlikely to increase adult recruitment. Mesick et al. (2007) indicates that low spawner abundances (less than 500 fish) have occurred as a result of extended periods of drought when juvenile survival is reduced as a result of low winter and spring flows and not as a result of high rates of ocean harvest. Mesick et al. (2007) also found that other factors, such as cyclic changes in ocean productivity, Delta export rates, and *Microcystis* blooms do not explain the trends in the Tuolumne River population. With all environmental factors or stressors being considered, these findings suggest that spring flows are the most important stressor to the viability of fall-run Chinook salmon and that greater magnitude, duration, and frequency of spring flows are needed to improve survival of smolts through the Tuolumne River and Delta (Mesick et al. 2007).

In 2009, Mesick published a paper on the High Risk of Extinction for the Natural Fall-Run Chinook Salmon Population in the Lower Tuolumne River due to Insufficient Instream Flow Releases which indicated that fall-run Chinook salmon escapement in the Tuolumne River, has declined from 130,000 salmon during the 1940s to less than 500 salmon during the early 1990s and 2007. Based on this low escapement, the rapid nature of the population declines, and the high mean percentage of hatchery fish in the escapement, Mesick (2009) found that the Tuolumne River's naturally produced fall-run Chinook salmon population has been at a high risk of extinction since 1990. Mesick (2009) identifies two critical flow periods for salmon smolts on the Tuolumne River: 1) winter flows which affect fry survival to the smolt stage, and 2) spring flows which affect the survival of smolts migrating from the river through the Delta. Mesick (2009) concludes that the decline in escapement is primarily due to inadequate minimum instream flow releases from La Grange Dam in late winter and spring during the non-flood years. In addition, Mesick (2009) found that since the 1940s, escapement has been correlated with mean flow at Modesto from February 1 through June 15 (2.5 years earlier), and that flows at Modesto between March 1 and June 15 explain over 90% of the escapement variation. This correlation suggests that escapement has been primarily determined by the rate of juvenile survival, which is primarily determined by the magnitude and duration of late winter and spring flows, since the 1940s. In addition, Mesick reported (as shown by other analyses) that spawner abundance, spawning habitat degradation, and the harvest of adult salmon in the ocean have not caused the decline in escapement.

In 2010, Mesick used an index of smolt survival, made by estimating the total number of CWT salmon that returned to spawn in the inland escapement and were caught in the ocean fisheries divided by the number of juvenile salmon released (Adult Recovery Rate), to compare the relationship between flow, water temperatures, exports and other factors. Mesick's analyses suggest that it is likely that without the physical HORB, flow cannot substantially reduce the impacts of the poor water quality in the Stockton Deepwater Ship Channel (DWSC). In the DWSC, high concentrations of oxygen-demanding organisms (algae from upstream, bacterial uptake of effluent from the City of Stockton Regional Wastewater Control Facility, and other unknown sources), and channel geometry causes rates of biological oxygen demand to exceed rates of gas exchange with the atmosphere and results in a sag (locally depleted concentration) in dissolved oxygen concentration (Lee and Jones-Lee 2002, Kimmerer 2004, Jassby and Van Nieuwenhuyse 2005). With the physical HORB installed, there is a positive association between

Delta flow and smolt survival and an inverse correlation between the Adult Recovery Rate and increasing water temperatures at Mossdale (Mesick 2010c). In addition to directly influencing smolt survival, increased flows reduce the travel time of smolts moving through the SJR and Delta system, thus reducing the duration of their exposure to adverse effects from predators, water diversions, and exposure to contaminants (NMFS 2009b).

In addition to the above conclusions, results of the south Delta juvenile salmon survival studies (described above) support the concept that a positive relationship exists between the number of juvenile fall-run Chinook salmon surviving to Jersey Point and the number of adults being harvested in the ocean and returning to spawn (Figure 3.11). Analyzing recovery data from CWT fish released at Jersey Point (exit point of the south Delta) and later recovered in the ocean and rivers, revealed a positive relationship between the number of juvenile fish released and the number of adults recovered. Figure 3.11 indicates that 83% of the variance in the number of adult fish recovered can be explained by the number of juvenile fish released at Jersey Point.



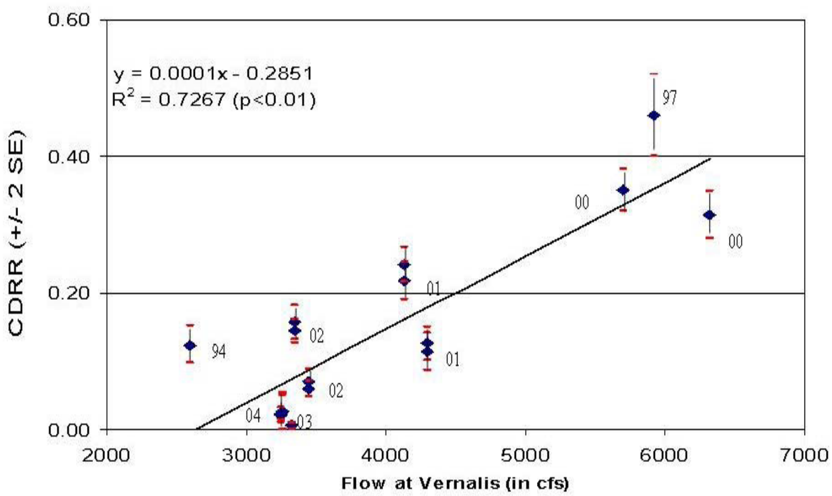
Note: Years 1995 to 2003 were used since Merced River Hatchery fish were released at Jersey Point and both adult and ocean and inland recoveries have been identified

Source: DFG 2010e

Figure 3.11. Coded Wire Tagged Adult Fall-run Chinook Salmon Recoveries as a Function of Number Juveniles Released at Jersey Point

3.6.2 VAMP Review

In 2010, an independent scientific review of the VAMP was conducted to evaluate the CWT results from the VAMP studies (2006 and prior). The independent review panel (IRP) found that two distinct statistical analyses support the conclusion that increased flows generally have a positive effect on SJR fall-run Chinook salmon survival. First, the IRP found data indicating that for flows in excess of about 2,500 to 6,500 cfs, measured at Vernalis for years when the physical HORB was in place (1994, 1997, 2000-2004), the estimated survival of outmigrating salmon between Mossdale or Durham Ferry and Jersey Point on the mainstem SJR exhibits a strong positive relationship with Vernalis flow (Figure 3.12) (see also SJRGA 2007). In addition, there was a positive, though weaker relationship between estimated survival rates from Dos Reis and Jersey Point over a broader range of flows for years with the physical HORB in place or not (see also SJRGA 2008). Second, the IRP pointed to the broader and more sophisticated Bayesian Hierarchical modeling analyses by Newman (2008) that found a positive influence of SJR flow below Old River on survival rates. The IRP also reported on its own summaries of CWT-based estimates of survival rates from Mossdale (when the physical HORB has been in place) or Dos Reis to Jersey Point that are consistent with a general increase of mean survival rates with increasing flows measured at Dos Reis.



Source: SJRGA 2007
CDRR: Point estimates of salmon survival plus or minus 2 standard errors using Chipps Island, Antioch and ocean recoveries in 1994, 1997, 2000–2004.

Figure 3.12. Survival of Outmigrating Salmon Versus Vernalis Flow

The IRP provided further information concerning the relationship between fall-run Chinook salmon survival and flows within the SJR in and near the DWSC. In a preliminary analysis of the relationships between flows, residence time, and reach specific survival in 2008 and 2009 (Holbrook et al. 2009, Vogel 2010), the review panel suggests that the DWSC could be a bottleneck for survival of salmon smolts migrating down the SJR, and that higher flows through the DWSC could benefit migrating salmon (Hankin et al. 2010).

The review panel qualified their conclusions regarding the flow versus survival relationships by noting that “only meeting certain flow objectives at Vernalis is unlikely to achieve consistent rates of smolt survival through the Delta over time. The complexities of Delta hydraulics in a strongly tidal environment, and high and likely highly variable impacts of predation, appear to affect survival rates more than the river flow, by itself, and greatly complicate the assessment of effects of flow on survival rates of smolts. And overlaying these complexities is an apparent strong trend toward reduced survival rates at all flows over the past ten years in the Delta" (Hankin et al. 2010).

In their own analysis of the VAMP data, the IRP found that survival decreased as flows decreased, and that survival has been decreasing over time within each of four flow groupings (very low, low, moderate, high). Survival estimates from Mossdale or Dos Reis to Jersey Point were just greater than 1% in 2003 and 2004 and the estimate was only about 12% in the very high flow year of 2006. This compares to survival estimates that ranged between about 30% and 80% in the years 1995 and 1997 to 2000. The IRP points out that the recent survival estimates are significantly lower than the long-term average survival estimate of about 20%, which the IRP points out is considered low when compared to the Sacramento River and other estuaries like the Columbia River. The review panel concludes that "the very low recent survival rates seem unlikely to be high enough to support a viable salmon population, even with favorable conditions for ocean survival and upstream migration and spawning success for adults" (Hankin et al. 2010).

3.6.3 Acoustic Tracking Studies (2008–2011)

Data from recent VAMP studies using acoustic tagged fish indicate survival remained low during the recent Critically Dry (2007 and 2008) and Dry (2009) water years (survival estimates for the 2010 study are not yet available). In 2007, mean flows during the VAMP period were 3,260 cfs. The lack of two key monitoring stations, receiver malfunctions, and unknown mortality (motionless tags were either in dead fish or had been defecated by a predator) near Stockton of a sizeable number of test fish reduced the ability to develop survival estimates (SJRGA 2008). The 2008 study was conducted during a period with mean flows of 3,160 cfs, and indicated that fish survival through the Delta ranged from 5% to 6% (SJRGA 2009). The most recent VAMP annual technical report for 2009 yielded similar results to 2008 during a period with mean flows of 2,260 cfs. However, VAMP was unable to install the key monitoring stations at Jersey Point and Chipps Island, which prohibited survival calculations through the Delta and data comparability with other years. Total survival for 2009 was calculated by combining survival estimates from the Old River route (survival of 8%) and the SJR route (survival of 5%). Only an estimated 6% of salmon survived through the study area. Survival in the Old River and the SJR River, and total survival through the study area would be even lower if the detection sites where no salmon were detected (Turner Cut, Middle River, and the interior of Clifton Court Forebay) were incorporated into the survival calculation. In addition, survival estimates may be even lower if data for fish survival into the holding tanks or fish salvage facilities of the SWP and CVP export facilities were incorporated into the calculation (SJRGA 2010).

In addition to the survival studies, in 2009 and 2010, the VAMP experiment included testing of a non-physical barrier at the divergence of the SJR and Old River (the Bio-Acoustic Fish Fence [BAFF]) in order to study the effectiveness of such a device in deterring juvenile fall-run Chinook salmon from migrating down Old River (referred to as the deterrence efficiency) and the effect of the device on the number of fish passing down the SJR (referred to as the protection efficiency). Testing of the BAFF in 2009 was conducted at flows averaging 2,260 cfs with a flow split averaging 75% down Old River and 25% down the mainstem SJR. When the BAFF was off, the amount of tagged salmon smolts remaining in the mainstem SJR (protection efficiency of 25.4%) was directly proportional to the amount of flow remaining in the mainstem SJR. With the BAFF on, the protection efficiency increased slightly to 30.8% and the deterrence efficiency increased substantially to 81.4%. Even though the BAFF was very efficient at deterring salmon that encountered it, the difference between the percentages of salmon remaining in the mainstem SJR was not significant between the BAFF off and BAFF on because predation near the BAFF was high (ranging from 25.2 to 61.6%) (Bowen et al. 2009).

During the BAFF study in 2010, flows averaged 5,100 cfs. Similar to 2009 (and 2008; see Holbrook et al. 2009), when the BAFF was off, the amount of tagged salmon smolts remaining in the mainstem SJR (protection efficiency = 25.9%) was directly proportional to the amount of flow remaining in the mainstem SJR. However, unlike 2009, the protection efficiency with the BAFF on (protection efficiency of 43.1%) was significantly greater than when the BAFF was off (Kruskal-Wallis X^2 = 8.2835, p=0.004; see Bowen and Bark 2010) resulting in significantly more smolts surviving and continuing down the SJR when the BAFF was on. At the same time, the deterrence efficiency of the BAFF was not nearly as effective as 2009 (23% compared to 81.4%). In addition, predation rates were much lower in 2010 than 2009, ranging from 2.8 to 20.5% for each group of smolts released upstream (Bowen and Bark 2010).

Bowen and Bark (2010) concludes that the inconsistent results between the 2009 and 2010 study may have been a consequence of higher discharges in the experimental period of 2010. These higher discharges in 2010 led to higher velocities through the BAFF, which, in turn, led to lower deterrence efficiency because the smolts had less time to avoid the BAFF. Additionally, the proportion of smolts eaten near the BAFF decreased as discharge increased. Bowen and Bark (2010) concludes that the high 2009 predation appears to be a function of the dry conditions and that smolts and predators might have been concentrated into a smaller volume of water than in 2010. Such a concentration would result in higher encounter rates between predators and smolts leading to an increased predation rate. In addition, lower velocities in drier years, such as 2009, may lead to a bio-energetically advantageous situation for large-bodied predators in the open channels near the divergence (Bowen and Bark 2010). Consequently, higher flows will generally have a positive impact on smolt survival by decreasing predation.

3.7 Importance of the Flow Regime

This section describes the importance of the flow regime in protecting aquatic fish and wildlife beneficial uses. In general, variable flow conditions provide the conditions needed to support the biological and ecosystem processes which are imperative to the protection of fish and wildlife beneficial uses. Although changes to additional ecosystem attributes, in addition to flows, are needed in order to fully restore biological and ecosystem processes on the SJR, flow remains a critical element of that restoration.

Using a river's unaltered hydrographic conditions as a foundation for determining ecosystem flow requirements is well supported by the current scientific literature (Poff et al. 1997; Tennant 1976; Orth and Maughan 1981; Marchetti and Moyle 2001; Mazvimavi et al. 2007; Moyle et al. 2011). In addition, major regulatory programs in Texas, Florida, Australia and South Africa have developed flow prescriptions based on unimpaired hydrographic conditions in order to enhance or protect aquatic ecosystems (Arthington et al. 1992; Arthington et al. 2004; NRDC 2005; Florida Administrative Code 2010), and the World Bank now uses a framework for ecosystem flows based on the unaltered quality, quantity, and timing of water flows (Hirji and Davis 2009). Major researchers involved in developing ecologically protective flow prescriptions concur that mimicking the unimpaired hydrographic conditions of a river is essential to protecting populations of native aquatic species and promoting natural ecological functions (Sparks 1995; Walker et al. 1995; Richter et al. 1996; Poff et al. 1997; Tharme and King 1998; Bunn and Arthington 2002; Richter et al. 2003; Tharme 2003; Poff et al. 2006; Poff et al. 2007; Brown and Bauer 2009). Poff et al. (1997) describes the flow regime as the "master variable" that limits the distribution and abundance of riverine species (Resh et al. 1988; Power et al. 1995) and regulates the ecological integrity of rivers. The structure and function of riverine ecosystems, and the adaptations of their constituent freshwater and riparian species, are determined by patterns of intra- and inter-annual variation in river flows (Poff et al. 1997; Naiman et al. 2008). A key foundation of the natural flow paradigm is that the long-term physical characteristics of flow variability have strong ecological consequences at local to regional scales, and at time intervals ranging from days (ecological effects) to millennia (evolutionary effects) (Lytle and Poff 2004). Nearly every other habitat factor that affects community structure; from temperature, to water chemistry to physical habitat complexity, is determined by flow to a certain extent (Moyle et al. 2011).

In a recent analysis of methods used for establishing environmental flows for the Bay-Delta, Fleenor et al. (2010) reported on two methods for determining flows needed to protect the ecosystem: 1) flows based on the unimpaired flow, and 2) flows based on the historical flow. These methods attempt to prescribe flows for the protection of the ecosystem as a whole, and use the biological concept that more variable inflows to the Delta, which mimic unaltered hydrographic conditions to which native aquatic species have adapted, will benefit native aquatic species. In a separate review of instream flow science by Petts (2009), he reports the importance of two fundamental principles that should guide the derivation of flow needs: 1) flow regime shapes the evolution of the aquatic biota and ecological process; and 2) every river has a characteristic flow regime and associated biotic community. Petts (2009) also finds that flow management should sustain flows that mimic the yearly, seasonal, and perhaps daily variability to which aquatic biota have adapted.

A more natural flow regime is anticipated to improve a number of ecosystem attributes such as (but not limited to): 1) native fish communities; 2) food web; 3) habitat; 4) geomorphic processes; 5) temperature; and 6) water quality. The effects of altered flows on each of these attributes are described below, along with the expected benefits of a more variable flow regime. These ecosystem attributes and others will be further discussed in the SED.

3.7.1 Effects on Fish Communities

Altered flow regimes have been found to negatively impact native fish communities and the aquatic ecosystem (Pringle et al. 2000, Freeman et al. 2001, Bunn and Arthington 2002, Moyle and Mount 2007). An assessment of streams across the conterminous U.S. showed that there is a strong correlation between diminished streamflow magnitudes and impaired biological communities including fish (Carlisle et al. 2011). In addition, when streams are dammed and flow regimes are simplified by dam releases, stream fish communities tend to become simplified and more predictable, usually dominated by selected species favored by fisheries, or by species that thrive in simplified and less variable habitats (Moyle et al. 2011). This has been found to be the case in the SJR basin where native fish and other aquatic organisms have been increasingly replaced by non-native species (Brown 2000; Freyer and Healey 2003; Brown and May 2006; Brown and Michniuk 2007; Brown and Bauer 2009). With respect to high flows in the spring, Moyle et al. (2011) found the proportion of the total fish community comprised of non-natives was inversely correlated to mean spring discharge, and annual 7-day maximum discharge.

Native communities of fish and other aquatic species are adapted to spatial and temporal variations in river flows under which those species evolved, including extreme events such as floods and droughts (Sparks 1995; Lytle and Poff 2004). On the other hand, permanent or more constant flows, created by damming or diverting river flows, favor introduced species (Moyle and Mount 2007; Poff et al. 2007). Long-term success (i.e., integration) of an invading species is much more likely in an aquatic system, like the SJR, that has been permanently altered by human activity than in a less disturbed system. Unlike unaltered systems, systems altered by human activity tend to resemble one another; and favor species that are desirable to humans (Gido and Brown 1999).

Establishing a more natural flow regime should better support the various life history adaptations of native fish and aquatic organisms that are synchronized with this type of flow regime (Bunn and Arthington 2002; King et al. 2003; Lytle and Poff 2004). A more natural flow regime, which includes more variation in tributary inflows, would also provide additional protection of genetically distinct sub-populations of aquatic organisms that evolved from individual rivers and their tributaries. Sub-populations are important in maintaining genetic diversity and the resilience of aquatic communities. Sub-populations exhibit important genetic variability that when preserved allows use of a wider array of environments than without it (McElhany et al. 2000; Moyle 2002; NMFS 2009c). Maintaining the diversity of sub-populations of salmonids on the major SJR tributaries has been identified as an important factor for achieving population viability (Moyle 2002).

The genetic and life-cycle diversity provided by maintaining sub-populations and varied life history timing of juvenile Chinook salmon through achieving a more natural flow regime with improved temporal and spatial variability is anticipated to help protect the population against both short-term and long-term environmental disturbances. Fish with differing characteristics between populations (i.e., greater diversity) have different likelihoods of persisting, depending on local environmental conditions. Thus, the more diverse a species is, the greater the probability that some individuals will survive and reproduce when presented with environmental variation (McElhany et al. 2000; TBI/NRDC 2010a). Genetic diversity also provides the raw material for surviving long-term environmental changes. Salmonids regularly face cyclic or directional change in their freshwater, estuarine, and ocean environments due to natural and human causes. Sustaining genetic and life-cycle diversity allows them to persist through these changes (McElhany et al. 2000; Moore et al. 2010; Carlson and Satterthwaite 2011).

Long term conditions in the region are expected to change as a result of global climate change. These long term conditions are difficult to predict, however, a more genetically diverse species will likely be better able to adapt to these new conditions. This is particularly important for salmonid species, but this also applies to the aquatic ecosystem as a whole, including the food web and other native warm and cold water fish communities. Similarly, ocean conditions constantly change, and will continue to cycle between more and less favorable conditions. As seen recently in the mid-2000’s, poor ocean conditions caused a collapse in near-shore oceanic food supplies that eventually caused a collapse of the ocean salmon fishery. While, ocean conditions have been blamed for the recent collapse of Central Valley salmon, the overall extent of the collapse was exacerbated by weak salmon runs that have lost much of their genetic variability, which normally affords them with greater resilience to poor ocean conditions over multiple years (Lindley et al. 2009).

Protecting and enhancing genetic (and life history) variability also helps to protect salmon populations from a significant loss in genetic diversity from the use of hatcheries. Fall-run Chinook salmon and other salmon hatcheries have unintentionally caused a reduction of genetic variability within the species by altering the genetic makeup of native salmon due to interbreeding with stocked strains of salmon. In addition, the greater quantity of hatchery fish within the river system has caused declines in native salmon, and further reduced the genetic viability of naturally produced strains due to predation and competition for spawning grounds, food, and space (Figure 3.6, Jones and Stokes 2010). A more natural flow regime is anticipated to maintain, and perhaps even enhance, the remaining genetic variability of natural stocks and reduce the negative effects of hatcheries on naturally produced populations.

3.7.2 Effects on Food Web

Establishing a more natural flow regime is anticipated to also benefit the food web to which native species are adapted. The diversity and abundance of beneficial algae and diatoms (the base of the food web) are higher in unregulated reference streams than in more perturbed streams (Power et al. 1996). In contrast, the benthic macroinvertebrate community (a key fish food resource) is typically characterized by species-poor communities in regulated river reaches (Munn and Brusven 1991). Carlisle et al. (2011) found that impaired macroinvertebrate communities were associated with diminished maximum flows characteristic of streams that have undergone human alteration. Additionally, loss of variability in flows, and increasingly stable regulated flows can lead to proliferation of certain nuisance insects such as larval blackflies (De Moor 1986). In regulated rivers of northern California, Wootton et al. (1996) found that seasonal shifting of scouring flows from winter to summer increased the relative abundance of predator-resistant invertebrates that diverted energy away from the natural food web and caused a shift toward predatory fish. In unregulated rivers, high winter flows reduce these predator-resistant insects and favor species that are more palatable to fish (Wooton et al. 1996, Poff et al. 1997). Additionally, reduced flows in the spring, indicative of the altered SJR system, likely negatively impact the food resources that juvenile salmon depend on. The survival of juvenile Chinook salmon to the adult stage partially depends on the ability to grow rapidly and smolt in early spring, when chances for survival and migration though the Bay-Delta and into the ocean are highest. Larger, healthier smolts are more likely to survive outmigration than smaller, poorly fed smolts (SJRRP 2008).

Reduced riparian and floodplain activation that often results from altered flows generally decreases the primary source of nutrients to river systems which support the food web (McBain and Trush 2002, SJRRP 2008). Floodplain inundation, particularly when associated with the ascending and descending limbs of the hydrograph, often provides most of the organic matter that drives aquatic food webs in rivers (Mesick 2009); Sommer et al. (2001); Opperman (2006) found floodplain habitat promotes rapid growth of juvenile salmon. Properly managed floodplains can have widespread benefits at multiple levels ranging from individual organisms to ecosystems (Junk et al. 1989; Moyle et al. 2007).

Altered flow regimes may also decrease nutrients at the base of the food web if such alterations result in a reduction of salmon that would have normally been a major nutrient source for the local food web. Salmon carcasses that remain in the stream corridor and decompose are recognized as a source of marine-derived nutrients that play an important role in the ecology of Pacific Northwest streams, and are an important nutrient source for the local food web. Salmon carcasses contain nutrients that can affect the productivity of algal and macroinvertebrate communities that are food sources for juvenile salmonids, and have been shown to be vital to the growth of juvenile salmonids (Cederholm et al. 1999; Gresh et al. 2000).

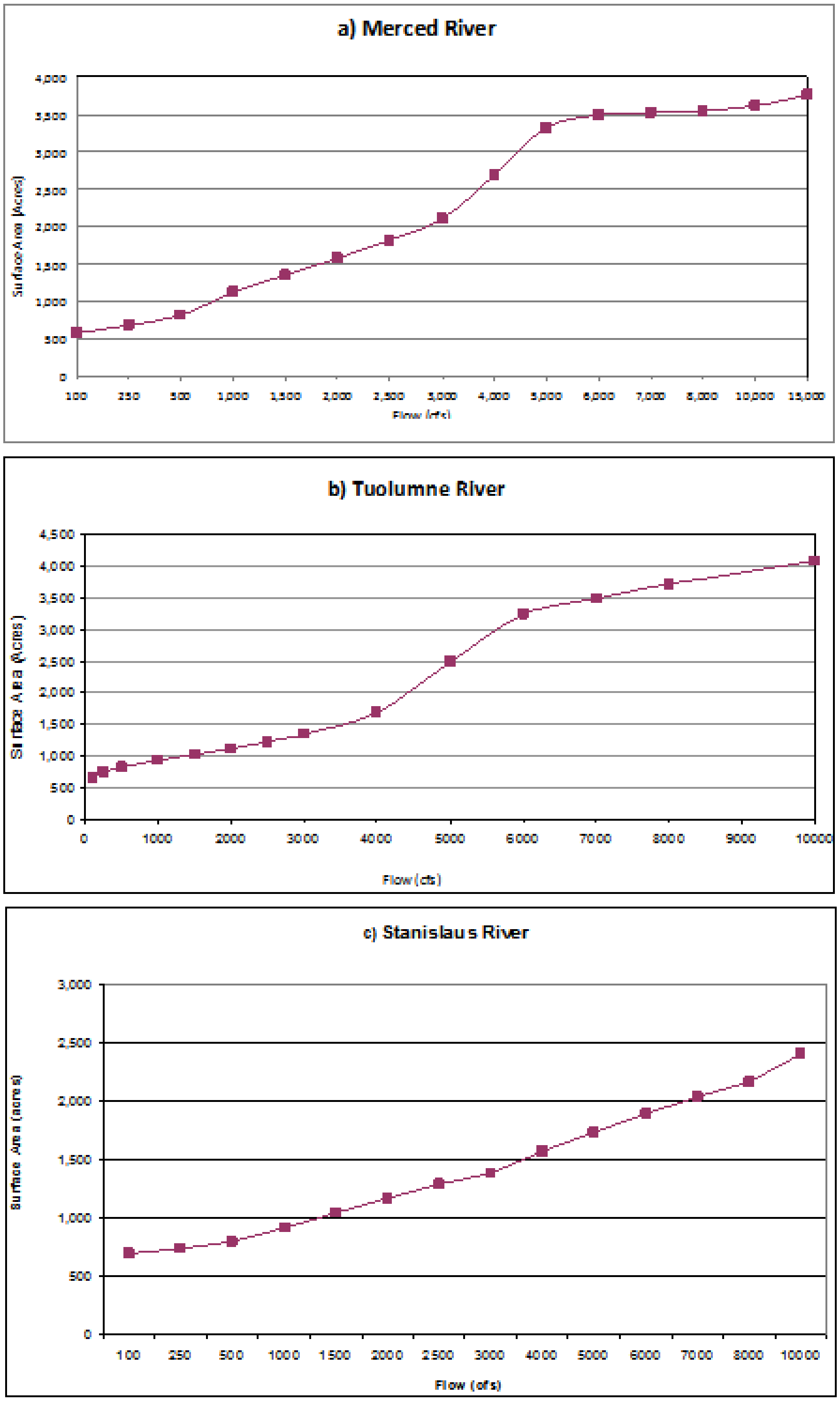
3.7.3 Effects on Aquatic Habitat

Altered flow regimes tend to decrease habitat connectivity in riverine and deltaic systems which results in a loss of lateral and longitudinal connectivity (Bunn and Arthington 2002). This loss of lateral connectivity is manifested as a loss in remnant seasonal wetlands and riparian areas, which, in turn causes a general loss of productivity and a decrease in aquatic habitat quality associated with the communities that depend on these habitats (Cain et al. 2003; McBain and Trush 2002).

Implementation of a more natural flow regime in the SJR basin is anticipated to increase longitudinal connectivity, create more beneficial migration transport, less hostile rearing conditions (protection from predators), greater net downstream flow, and connectivity with the estuary and near-shore ocean during periods that are beneficial for aquatic organisms who have adapted to this system (McBain and Trush 2002; Cain et al. 2003; Kondolf et al. 2006; Poff et al. 2007; Mesick 2009). Specifically, a more natural flow regime in the SJR basin will increase riparian and floodplain activation which in turn would increase habitat quality and quantity, allowing for energy flow between wetland areas and the river, and would provide the river and estuary with nutrients and food. Floodplain inundation provides flood peak attenuation and promotes exchange of nutrients, organic matter, organisms, sediment, and energy between the terrestrial and aquatic systems (Cain et al. 2003; Mesick 2009). It also improves juvenile fish survival by improving food availability in addition to providing refuges from predators during the critical rearing and migration time in the SJR and major SJR tributaries (Jeffres et al. 2008; Mesick 2009). Increased lateral and longitudinal connectivity also positively affects spatial distribution of organisms by facilitating the movement of organisms and creating important spawning, nursery, and foraging areas for many fish species, including salmon (Bunn and Arthington 2002; Cain et al. 2003; Jeffres et al. 2008; TBI/NRDC 2010a).

Currently, salmonids use the SJR tributaries downstream of the water diversion dams for spawning and rearing habitat including: the 24-mile reach of the Merced River between the Crocker-Huffman Dam and the town of Cressy for spawning, with rearing extending downstream to the confluence with the SJR; the 25-mile reach of the Tuolumne River between LaGrange Dam and the town of Waterford for spawning, with rearing in the entire lower river (between LaGrange Dam and the confluence with the SJR); and the 23-mile reach in the Stanislaus River between Goodwin Dam and the town of Riverbank for spawning and the entire lower river (between Goodwin Dam and the confluence with the SJR) for rearing (USFWS 1995).

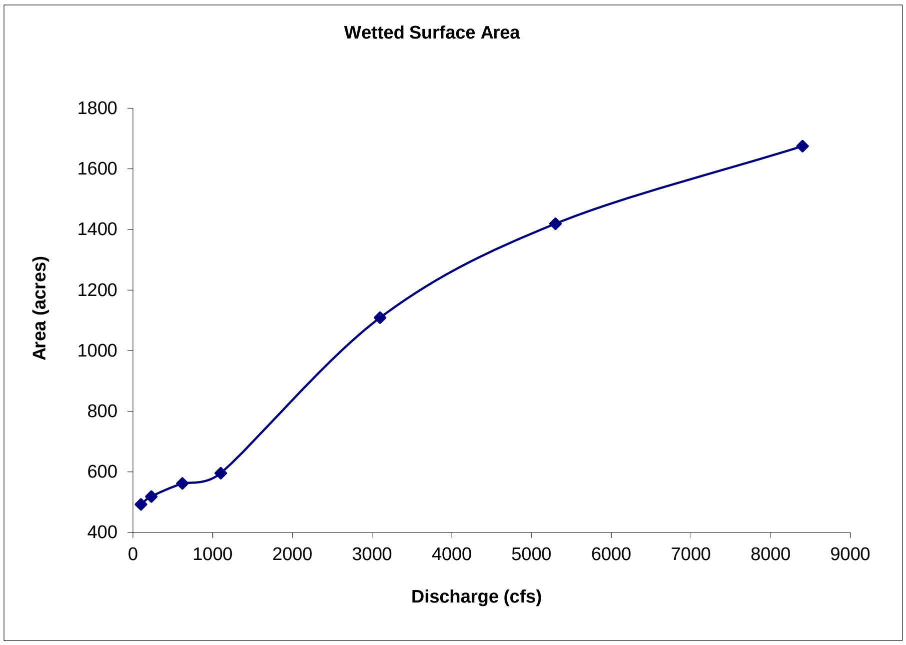
For the three major SJR tributaries (Stanislaus, Tuolumne, and Merced Rivers) DFG analyzed cross-sectional data developed by the United States Army Corps of Engineers and calculated the estimated wetted surface area from the first upstream barrier downstream to each tributary's SJR confluence (Figure 3.13). For the Merced River the wetted surface area increases more quickly from about 3,000-5,000 cfs indicating a corresponding greater increase in width within this flow range. The increase in width with flows greater than 3,000 cfs suggests the occurrence of bank overtopping or a strong likelihood for floodplain inundation. Likewise, running a similar comparison on the Tuolumne River indicates flows ranging from 4,000-6,000 cfs provide a rapid increase in width which suggests that floodplain inundation likely occurs at flows greater than 4,000 cfs. The Stanislaus River channel does not appear to have a well-defined floodplain within the 100 to 10,000 cfs flow range (DFG 2010e). Additional work is needed to confirm if flows in the ranges discussed above generate inundated floodplain conditions within the subject tributaries.



Source: DFG 2010e

Figure 3.13. Estimated Wetted Surface Areas for the three SJR tributaries. a) Merced River, b) Tuolumne River, c) Stanislaus River

In a separate analysis, the USFWS used GIS techniques to map the wetted surface area for a range of flows between 100 cfs and about 8,500 cfs (flood capacity) in order identify potential floodplain habitat on the Tuolumne River (USFWS 2008). The lower Tuolumne River was chosen for this study, as appropriate GIS data were available for the reach between La Grange Dam at RM 52 and just upstream of Santa Fe Bridge at RM 21.5 near the town of Empire. The data used for this analysis were originally developed as part of the FERC relicensing proceedings for the Don Pedro Project (Project No. 2299). The GIS layers were developed from aerial photographs taken at various flows between 1988 and 1995. The wetted area versus discharge curve for the Tuolumne River is shown in Figure 3.14 (USFWS 2008). A primary inflection is seen around 1,000 cfs which suggests that this is the minimum point where flows may begin to inundate "overbank" areas, or extend out of the channel and into the former floodplain. However, as there are no data points between 1,100 and 3,100 cfs, the actual initiation of overbank flow is not clear, but is likely to occur at a point between these two values. The wetted surface area is shown to increase with discharge from around 1,000 cfs up to the maximum studied flow of 8,400 cfs.



Source: USFWS 2008

Figure 3.14. Lower Tuolumne Inundated Area as a Function of Discharge

For comparison, the analysis conducted by DFG (2010e), suggests that floodplain inundation on the Tuolumne occurs at flows greater than 4,000 cfs. An evaluation of floodplain inundation thresholds on the tributaries by Cain et al. (2003) found that flows of 3,000-6,000 cfs (4,500 cfs on average) are necessary to inundate various low-lying floodplains below the terminal reservoirs on the upper Stanislaus, Tuolumne, Merced Rivers and SJR.

Based on the analyses discussed above, there is potential to enhance lateral connectivity on the tributaries, increasing floodplain activation and associated habitat for the benefit of salmonids and other aquatic resources. The increase in surface area and water elevation as a function of flow can be used to identify the river and potential floodplain habitat, and hydraulic models can be used to estimate water velocities in these rivers and overbank areas. Additional work is needed to verify if flows in the ranges discussed above generate inundated floodplain conditions within the subject tributaries, and if so, to better characterize the location, extent, and setting of such conditions. Substantial floodplain benefits can potentially be obtained with less than the maximum flood capacity of these tributaries. The levee flood capacity for the Tuolumne River is shown on the levee capacity map as 15,000 cfs, but the maximum regulated flow goal is 8,500 cfs. The levee capacity for the Merced River is 6,000 cfs, and the regulated flood capacity goal is 6,000 cfs. The levee capacity for the Stanislaus River is 8,000 cfs, and the regulated flood capacity goal is 6,000 cfs (DWR 2011).

3.7.4 Effects on Geomorphic Processes

The rim dams and altered flow regimes have caused a loss of geomorphic processes related to the movement of water and sediment that are important to the ecosystem (Poff et al.1997). Important benefits that these processes provide include increased complexity and diversity of the channel, riparian, and floodplain habitats, and mobilization of the streambed and upstream sediment (Grant 1997b). Floods, and their associated sediment transport, are important drivers of the river-riparian system. Small magnitude, frequent floods maintain channel size, shape, and bed texture, while larger, infrequent floods provide beneficial disturbance to both the channel and its adjacent floodplain and riparian corridor. As a result of alterations to flow regime and other factors, channel morphology within the SJR basin is now characterized by significant incision and loss of channel complexity. Of particular concern is the encroachment of vegetation into historic gravel bar habitat that has probably reduced the recruitment, availability, and quality of spawning gravel habitat for Chinook salmon (Cain et al. 2003; McBain and Trush 2002).

A more natural flow regime is anticipated to generate processes that create a less homogenous channel with structures that are important for fish habitat, such as meanders, pools, riffles, overhanging banks, and gravel substrates of appropriate sizes (Thompson and Larsen 2002, Mount and Moyle 2007). Scour and bed mobilization, associated with geomorphic processes that are driven by more variable flows, rejuvenate riparian forests and clean gravel for salmon, benthic macroinvertebrates, and benthic diatoms (McBain and Trush 2002, Cain et al. 2003, SJRRP 2008). Native fish and other aquatic species have adapted their life cycle to these processes and exploit the diversity of physical habitats these processes create (Poff et al. 1997; Thompson and Larsen 2002; Lytle and Poff 2004).

Increasing turbidity events from more variable flows and the associated geomorphic processes also is anticipated to decrease predation and provide environmental cues needed to stimulate migration (Jager and Rose 2003; Baxter et al. 2008; Mesick et al. 2007; NMFS 2009a). Juvenile salmonids emigrate during periods of increased turbidity that arise from the spring snowmelt phase of the flow regime and are afforded additional protection by the increased turbidity resulting from higher flows (Cain et al 2003). Turbidity reduces predation on young salmon by providing a form of protective cover, enabling them to evade detection or capture (Gregory 1993).

3.7.5 Effects on Temperature

Dams and reservoirs, and their associated operations, alter the temperature regime of rivers, often to the detriment of cold water species such as salmonids and other aquatic plants and animals that have adapted to colder waters and the variability associated with a more natural flow regime (Richter and Thomas 2007; DFG 2010b). Water stored in reservoirs is warmer at the surface and cooler below the thermocline in deeper waters. The temperature of water within these layers is generally different than the temperature of water entering the reservoir at any given time depending on the season, and is also dissimilar to downstream water temperatures that would occur under a natural flow regime (USACE 1987; Bartholow 2001).

Temperature control devices can control the temperature of water released from dams for the protection of downstream fisheries by varying operations of release gates. However, there are no temperature control devices to aid in water temperature management on the major SJR tributaries; therefore, temperature management can only be achieved directly through flow management (NMFS 2009a). Often, water released from reservoirs is colder in the summer and warmer in the winter compared to water temperatures that would have occurred in the absence of a dam and reservoir (Williams 2006). As a result, species experience additional temperature stress due to the river's altered flow and temperature regimes. However, where temperatures are cooler than they would be under a more natural flow regime (because of reservoir discharges of cold water through the summer), populations of *O.mykiss* (both anadromous and resident forms) are often able to persist. These areas are commonly in the reaches immediately below dams.

In addition to the changes in temperature due to reservoir storage and release, reservoirs and diversions also modify the temperature regime of downstream river reaches by diminishing the volume and thermal mass of water. A smaller quantity of water has less thermal mass, and therefore, a decreased ability to absorb temperatures from the surrounding environment (air and solar radiation) without being impacted (USACE 1987). The greatest impact occurs with less flow (less thermal mass) and warmer climate (increased solar radiation), usually in the late spring, summer, and early fall periods (BDCP 2010). The altered flow regime of the rivers in the SJR basin has largely eliminated the cold water refugia upon which salmonid populations depend (USEPA 2001). In addition to the need for cold water spawning habitat, warmer rearing temperatures (8°C to 25°C) are needed for optimal growth if food is readily available. However, temperatures that exceed these optimal levels can lead to decreased food availability, salmonid growth rates, and reduce the amount of suitable habitat for rearing (McCullough 1999, Myrick and Cech, Jr. 2001).

The combined effect of storage and dam operations have contributed to increased water temperatures and altered flow regimes that have negatively impacted salmon and other native fishes, encouraged warm-water and non-native fishes, and altered the base of the food web. In addition, undesirable and nuisance algae (e.g., *Microsystis*), and submerged aquatic vegetation (e.g., *Egeria*) have established and become widespread through the system due, in part, to the altered temperature and flow regime (Brown and May 2006; Brown and Bauer 2009; Moyle et al. 2010). A more natural flow regime; including greater flows in the spring, specifically February through June, and cooler instream water temperatures, is anticipated to benefit multiple levels of the aquatic ecosystem.

3.7.6 Effects on Water Quality

Unless otherwise indicated, the water quality information discussed in this section is taken from McBain and Trush (2002) which is derived from sampling at Newman and Vernalis. Water quality has decreased markedly in recent decades and has generally coincided with SJR flow reductions, population growth, and expanded agricultural production. There are numerous water quality constituents in the SJR basin which can negatively impact fish and wildlife beneficial uses including: dissolved oxygen, salinity and boron, nutrients, trace metals, and pesticides (Central Valley Water Board 2001; Central Valley Water Board 2004; Central Valley Water Board 2005a; Central Valley Water Board 2005b; DFG 2011a). A more natural flow regime would benefit the ecosystem in two ways: first, due to the direct relationships and interaction between flow, temperature (discussed above) and dissolved oxygen, more natural flow would ameliorate negative effects of temperature and dissolved oxygen; and second, an indirect effect of a more natural flow regime in the spring would be dilution of the other water quality constituents listed above.

Low dissolved oxygen levels can cause physiological stress to Chinook salmon and impair development of other aquatic species. In documenting passage delays and seasonal migration blockage of fall-run Chinook salmon in the lower SJR, Hallock et al. (1970) found that few adult fish migrated through water containing less than 5.0 mg/L dissolved oxygen, and the bulk of the salmon did not migrate until the DO concentration exceeded 5.0 mg/L. In addition, many invertebrates are sensitive to change in dissolved oxygen concentrations (McBain and Trush 2002), and low concentrations may alter the abundance and diversity of invertebrate and fish assemblages.

Salinity in the SJR basin is one of the largest water quality concerns, has a large influence on species diversity, and represents a major limiting factor for restoration of aquatic resources with effects on fish, invertebrates, and riparian plant establishment. Water quality data collected by the Central Valley Regional Water Quality Control Board (Central Valley Water Board) indicates that water quality objectives for salinity have been routinely exceeded at locations throughout the SJR including Vernalis and areas upstream (Central Valley Water Board 2002). Agricultural drainage water collection and disposal, including return flows discharged to the SJR through mud slough and salt slough, have been identified as a major source.

Eutrophication from the dissolution of natural minerals from soil or geologic formations (e.g., phosphates and iron), fertilizer application (e.g., ammonia and organic nitrogen), effluent from sewage-treatment plants (e.g., nitrate and organic nitrogen), and atmospheric precipitation of nitrogen oxides may cause chronic stress to fish (McBain and Trush 2002). Algae and plant growth under eutrophic (high nutrient) conditions, along with their subsequent decomposition in the water column, lead to increase oxygen consumption and decreased dissolved oxygen conditions, reduced light penetration and reduced visibility. These conditions may render areas unsuitable for salmonid species, and favor other species (e.g., sucker, blackfish, carp, and shad).

Many trace metals have been identified in the SJR basin that can cause salmonids and other fish and wildlife species serious harm, including mortality, birth defects, and behavioral and carcinogenic consequences. In particular, selenium and mercury can have deleterious interactive effects with the aquatic environment due to the compounds' ability to "bio-magnify" within the food chain. The San Joaquin Valley Drainage Program identified selenium as one of 29 inorganic compounds that are a concern for public health and maintenance of fish and aquatic life (Brown 1996). Agricultural tile drainage has been shown to cause episodic toxicity to juvenile salmonids and striped bass. In addition to the regional selenium contamination, mercury contamination of the lower SJR watershed from past mining activities (primarily gold), from the burning of fuels or garbage, and from municipal and industrial discharges may represent another limiting factor in the protection of fish and wildlife beneficial uses. Methyl mercury bio-magnification in fish can cause death, reduce reproductive success, impair growth and development, and promote behavioral abnormalities (McBain and Trush 2002).

Pesticides from urban and agricultural runoff are a source of toxicity in the SJR and Delta. Pyrethroids are of particular interest because use of these pesticides has increased as use of some of the previous generation of pesticides (e.g., organophasphates) has declined (Amweg et al. 2005; Oros and Werner 2005). Residues of pyrethroid pesticides have been found to occur at concentrations acutely toxic to some benthic macroinvertebrates (e.g., the native amphipod *Hyalella azteca*) in sediments of agricultural water bodies and urban streams (Weston and Lydy 2010). These pyrethroid compounds are introduced to the environment through their use as insecticides in agricultural pest control, and professional and homeowner applications around structures or on landscaping (Weston and Lydy 2010). Recent work has also shown that surface waters may contain pyrethroids at concentrations sufficient to cause acute toxicity (Weston and Lydy 2010). The organophosphate compounds (e.g., diazinon and chlorpyrifos), are highly soluble in water and are relatively short-lived in the environment (Brown 1998). In the early 1990s, toxic concentrations of orpanophosphate pesticides were present in the rivers and Delta channels for several days at a time (Deanovic et al. 1996). In response, the Central Valley Water Board developed and adopted TMDLs to reduce concentrations of diazinon and chlorpyrifos in the Delta and tributaries. Since then, urban uses of the organophosphates have been phased out, the overall agricultural use of diazinon and chlorpyrifos has been significantly reduced, and new label restrictions have been adopted to reduce the amount of these pesticides that enter waterways from agricultural operations.

The generation of pesticides prior to the organophosphates included organochlorine compounds such as DDT and toxaphene, which are non-polar and poorly soluble in water, and may persist in the environment for long periods. Non-polar compounds allow bio-accumulation in animal tissues over time, posing a direct threat to fishery and other aquatic resources, and human health. For salmonids, chemical interference with olfactory functions (and therefore homing), and other chronic toxic effects, are potential problems due to pesticides (and herbicides). Many of these compounds were banned several decades ago, but due to their chemical characteristics are still detected by water quality sampling programs in the SJR basin (Domagalski 1998).

3.8 Previous Flow Recommendations

The following section describes some of the previous SJR flow recommendations that have been made to improve the survival and abundance of SJR Chinook salmon based on modeling and statistical relationships between flow and survival.

3.8.1 Delta Flow Criteria – Public Informational Proceeding

In March of 2010 the State Water Board conducted a public informational proceeding to develop flow criteria for the Delta ecosystem necessary to protect public trust resources. The following are summaries of recommendations received from various entities regarding SJR inflows.

In 2005, DFG identified several statistical relationships between flow at Vernalis and Chinook salmon abundance (DFG 2005a). DFG analyses indicate that the most important parameters influencing escapement are spring flow magnitude, duration, and frequency, and that non-flow parameters have little or no relationship to escapement. DFG found that the most highly significant relationship between flow at Vernalis and juvenile production occurs at Mossdale. The relationship between flow and Delta survival to Chipps Island is less significant yet remains positive, suggesting that there are other factors also responsible for through Delta survival. Finally, the relationship between smolts at Chipps Island and returning adults to Chipps Island was not significant, suggesting that perhaps ocean conditions or other factors are responsible for mortality during the adult ocean phase. DFG combined these statistical relationships into a model allowing them to develop flow recommendations (Table 3.15) for the SJR during the March 15 through June 15 time period that will achieve doubling of salmon smolts. DFG's flow recommendations at Vernalis range from 7,000 cfs to 15,000 cfs and are recommended to be apportioned between the tributaries based on the average annual runoff for each tributary (DFG 2010a).

Table 3.15. Recommended Vernalis Flows Needed to Double Smolt Production at Chipps Island

	Water Year Type				
Flow Type	**Critical**	**Dry**	**Below Normal**	**Above Normal**	**Wet**
Base (cfs)	1,500	2,125	2,258	4,339	6,315
Pulse (cfs)	5,500	4,875	6,242	5,661	8,685
Pulse Duration (days)	30	40	50	60	70
Total Flow (cfs)	7,000	7,000	8,500	10,000	15,000
Total (acre-feet)	614,885	778,772	1,035,573	1,474,111	2,370,768

The 2005 *Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin* includes similar recommendations for achieving doubling of Chinook salmon. The AFRP recommendations are based on salmon production models for each of the three major SJR tributaries (Stanislaus, Tuolumne, and Merced Rivers) that are based on regression analyses of recruits per spawner, and April through May Vernalis flows. Adjusted R^2 values range from 0.53 to 0.65 for statistically significant positive relationships between production and flow for each tributary. These relationships suggest that increased flows during the spring outmigration period would enhance salmon production. The model combines the above individual recruitment equations to estimate the flows needed at Vernalis during the February through May period to double salmon production in the SJR basin. The flows recommended at Vernalis range from 1,744 cfs in February of Critically Dry years to a maximum of 17,369 cfs in May of Wet years and generally increase from February through May to mimic the shape of the unimpaired hydrograph (peak flow in May) (Table 3.16). Estimates of flows needed on each tributary to double salmon production range from 51% to 97% of unimpaired flow; with a greater percentage of unimpaired flow needed in drier years than wet years (AFRP 2005).

Table 3.16. Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin

Water Year Type	February	March	April	May
Stanislaus River				
Critical	500	785	1,385	1,438
Dry	500	927	1,811	1,950
Below Normal	514	1,028	1,998	2,738
Above Normal	787	1,573	2,636	3,676
Wet	1,280	2,560	3,117	4,827
Tuolumne River				
Critical	744	1,487	2,415	2,895
Dry	784	1,568	2,696	4,072
Below Normal	794	1,589	3,225	4,763
Above Normal	1,212	2,424	3,574	6,850
Wet	2,013	4,027	4,811	8,139
Merced River				
Critical	500	559	1,112	1,332
Dry	500	651	1,375	1,766
Below Normal	500	864	1,498	2,410
Above Normal	582	1,165	1,941	3,205
Wet	1,140	2,279	2,559	4,402

Water Year Type	February	March	April	May
Total (Vernalis)				
Critical	1,744	2,832	4,912	5,665
Dry	1,784	3,146	5,883	7,787
Below Normal	1,809	3,481	6,721	9,912
Above Normal	2,581	5,162	8,151	13,732
Wet	4,433	8,866	10,487	17,369

Source: AFRP 2005

To inform the State Water Board's 2010 proceeding to develop flow criteria necessary to protect public trust resources in the Delta, The Bay Institute and Natural Resources Defense Council (TBI/NRDC) conducted a logit analysis to examine the relationship between Vernalis flow and adult return ratios of SJR Chinook salmon (Cohort Return Ratio; CRR). A logit analysis describes the probability distribution of an independent variable to a dependent variable when there are two different possible results. In this case, the independent variable is Vernalis Flow (log transformed) and the dependent variable is positive or negative population growth, measured as the CRR. Where the logit regression-line crosses 0.5 on the y-axis represents the flow level at which positive and negative growth are equally "likely". Based on historical data, flows above that level are more likely to produce positive population growth and flows below that level are less likely to correspond to positive population growth. TBI/NRDC indicates that the advantage of turning CRR into a binary variable (populations increase or decrease) is that it removes any effect of initial absolute population size on the outcome. If you analyze the results with "real" population values or cohort return ratios, small populations behave erratically because small changes in the population size look very big. Conversely, when populations are large, substantial changes in population size can appear relatively small (TBI/NRDC 2010b).

In their logit analysis, TBI/NRDC found that Vernalis average March through June flows of approximately 4,600 cfs corresponded to an equal probability for positive population growth or negative population growth. TBI/NRDC found that average March through June flows of 5,000 cfs or greater resulted in positive population growth in 84% of years and flows less than 5,000 cfs resulted in population decline in 66% of years. TBI/NRDC found that flows of 6,000 cfs produced a similar response to the 5,000 cfs or greater flows, and flows of 4,000 cfs or lower resulted in significantly reduced population growth in only 37% of years. The TBI/NRDC analysis suggests that 5,000 cfs may represent an important minimum flow threshold for salmon survival on the SJR. Based on abundance to prior flow relationships, TBI/NRDC estimates that average March through June inflows of 10,000 cfs are likely to achieve the salmon doubling goal (TBI/NRDC 2010c). A summary of the SJR inflow recommendations developed by TBI/NRCD is provided in Table 3.17.

Table 3.17. San Joaquin River Inflow Recommendations

<table>
<tr><th></th><th>July - Feb</th><th colspan="2">March</th><th colspan="2">April</th><th colspan="2">May</th><th colspan="2">June</th></tr>
<tr><td>100% of years
(all yrs)</td><td>2,000</td><td colspan="2">2,000</td><td colspan="2">5,000</td><td colspan="2">5,000</td><td colspan="2">2,000</td></tr>
<tr><td>80%
(D yrs)</td><td>2,000</td><td colspan="2">2,000</td><td>5,000</td><td>10,000</td><td>7,000</td><td>5,000</td><td colspan="2">2,000</td></tr>
<tr><td>60%
(BN yrs)</td><td>2,000</td><td colspan="2">2,000</td><td>20,000</td><td>10,000</td><td>7,000</td><td>5,000</td><td colspan="2">2,000</td></tr>
<tr><td>40%
(AN yrs)</td><td>2,000</td><td>2,000</td><td>5,000</td><td colspan="2">20,000</td><td colspan="2">7,000</td><td colspan="2">2,000</td></tr>
<tr><td>20%
(W yrs)</td><td>2,000</td><td>2,000</td><td>5,000</td><td colspan="2">20,000</td><td>20,000</td><td>7,000</td><td>7,000</td><td>2,000</td></tr>
</table>

Source: TBI/NRDC 2010b

The California Sportfishing Protection Alliance (CSPA) and California Water Impact Network (CWIN) also developed recommendations for flows on the SJR and major SJR tributaries. CSPA and CWIN recommended that the State Water Board apply two general flow regimes to the Delta to protect and recover public trust resources: one regime would be based on the close linkages between riverine inflows to the Delta, the position of X2[3], and Delta outflows and the life histories of estuarine fish species; and a second regime would be based on pulse flows that match and facilitate the early life stages of salmonid larvae, juvenile rearing, and smoltification (CSPA/CWIN 2010). The recommended pulse flow regime (Table 3.16) focuses on late winter through spring flow periods along with a 10-day pulse flow in late October intended to attract adult spawning salmonids to the SJR basin. CSPA and CWIN's San Joaquin Valley outflows (Table 3.18) are derived from recommended flow releases for the Stanislaus, Tuolumne, and Merced Rivers developed by Mesick (2010a) plus flow from the SJR below Millerton Lake reflecting that river's unimpaired flow, as well as accretions and other inflows.

Table 3.18. Recommended Inflows at Vernalis with Tributary Contributions (in cfs)

Water Year	Feb		Mar	Apr		May		Jun	Oct	
C		13,400 (2 days)	4,500	6,700	8,900	1,200				5,400
D		13,400 (2 days)	4,500	6,700	8,900	1,200				5,400
BN		13,400 (16 days), 26800 (2 days)	4,500	6,700	8,900	11,200	1,200			5,400
AN		13,400 (13 days), 26800 (5 days)	4,500	6,700	8,900	11,200	1,200			5,400
W		13,400 (17 days), 26800 (5 days)	13,400				14,900			5,400

Source: CSPA/CWIN 2010

In its 2010 report on *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem (Delta Flow Criteria Report)*, the State Water Board determined that approximately 60% of unimpaired flow during the February through June period would be protective of fish and wildlife beneficial uses in the SJR. It should be noted that the State Water Board acknowledged that these flow criteria are not exact, but instead represent the general timing and magnitude of flow conditions that were found to be protective of fish and wildlife beneficial uses when considering flow alone. In addition, these flow criteria do not consider other competing uses of water or tributary specific flow needs for cold water and other purposes (State Water Board 2010).

In order to achieve the attributes of a natural hydrograph the criteria developed in the Delta Flow Criteria Report were advanced as a percentage of unimpaired flow (14-day average) to be achieved on a proportional basis from the tributaries to the SJR. The unimpaired flow estimates from which the 60% criterion is calculated are monthly estimates. To determine the percentage of unimpaired flow needed to protect Chinook salmon, the State Water Board reviewed flow exceedance information to determine what percentage of flow would be needed to achieve various flows. The State Water Board analysis indicated that if 60% of unimpaired flow at Vernalis were provided, average February through June flows would meet or exceed 5,000 cfs

[3] X2 refers to the horizontal distance in kilometers up the axis of the estuary from the Golden Gate Bridge to where the tidally averaged near-bottom salinity is 2 practical salinity units.

in over 85% of years and flows of 10,000 cfs in approximately 45% of years. The frequency of exceeding these flows would vary by month (Figures 3.15 to 3.19). Both the AFRP and DFG modeling analyses presented above seem to support the 60% recommendation of the Delta Flow Criteria Report. However, the time periods for the AFRP recommended flows is from February through May and the time period for the DFG recommended flows is from March 15 through June 15. AFRP, DFG, and TBI/NRDC provide different recommendations for how to distribute flows during the spring period in different years, with increasing flows in increasingly wet years. All are generally consistent with an approach that mimics the natural flow regime to which these fish were adapted.

3.8.2 Anadromous Fish Restoration Program (AFRP)

Several restoration actions, with regard to managing flows, were proposed by the AFRP Core Group as part of Section 3406(b)(1) for implementation in the SJR basin. These restoration actions were developed by eight technical teams that were composed of experts who possessed specific technical and biological knowledge of Central Valley drainages and anadromous fish stocks. The restoration flow targets have never been implemented. A restoration action (Table 3.19) was proposed to manage flows (in cfs) to benefit all life stages of fall-run Chinook salmon on the lower SJR (at Stevinson).

Table 3.19. AFRP Instream Flow Proposals for the SJR at Stevinson

Month	Wet	Above Normal	Below Normal	Dry	Critical
April	5,150	2,650	2,050	1,750	1,250
May	7,000	4,450	3,050	2,300	1,600
June	6,800	3,450	2,600	1,700	1,050

A second restoration action designed to increase white and green sturgeon production was proposed to provide mean monthly flows of at least 7,000 cfs (at Newman) between February and May in wet and above normal years. A third restoration action (Table 3.20) was proposed to manage flows (in cfs) to benefit all life stages of Chinook salmon, American Shad, and white and green sturgeon on the lower SJR at Vernalis.

Table 3.20. AFRP Instream Flow Proposals for the SJR at Vernalis

Month	Wet	Above Normal	Below Normal	Dry	Critical
October	1,450	950	900	700	650
November	2,000	1,500	950	900	650
December	2,850	2,250	950	950	700
January	3,950	2,550	1,100	1,000	750
February	14,000	14,000	2,150	1,450	1,050
March	14,000	14,000	2,750	2,100	1,850
April	28,400	21,800	18,900	13,500	7,800
May	28,400	21,800	18,900	13,500	7,800
June	17,300	9,750	7,650	4,600	2,950
July	4,200	1,700	1,250	650	650
August	1,150	800	600	500	450
September	1,050	750	650	500	450

A restoration action (Table 3.21) was proposed to manage flows (in cfs) to benefit all life stages of fall-run Chinook salmon on the Stanislaus River from Goodwin Dam to the confluence with the SJR.

Table 3.21. AFRP Instream Flow Proposals for the Stanislaus River

Month	Wet	Above Normal	Below Normal	Dry	Critical
October	350	350	300	250	250
November	400	350	300	300	250
December	850	650	300	300	250
January	1,150	800	300	300	250
February	1,450	1,150	700	450	300
March	1,550	1,150	850	650	550
April	5,600	4,300	3,800	2,700	1,500
May	5,600	4,300	3,800	2,700	1,500
June	2,650	1,600	1,300	700	450
July	900	400	350	200	250
August	350	300	250	200	200
September	350	300	250	200	200

A restoration action (Table 3.22) was proposed to manage flows (in cfs) to benefit all life stages of fall-run Chinook salmon on the Tuolumne River from LaGrange Dam to the confluence with the SJR.

Table 3.22. AFRP Instream Flow Proposals for the Tuolumne River

Month	Wet	Above Normal	Below Normal	Dry	Critical
October	750	300	300	200	150
November	1250	800	350	300	150
December	1,400	1,050	350	350	200
January	1,700	1,150	500	400	250
February	2,100	1,700	950	700	500
March	2,300	1,700	1,300	1,000	900
April	2,950	2,450	2,350	1,900	1,500
May	5,150	4,200	3,350	2,500	1,800
June	5,000	3,250	2,600	1,550	1,000
July	2,150	900	650	250	200
August	450	200	100	100	50
September	350	150	150	100	50

A restoration action (Table 3.23) was proposed to manage flows (in cfs) to benefit all life stages of fall-run Chinook salmon on the Merced River from Crocker-Huffman Diversion downstream to the confluence with the SJR.

Table 3.23. AFRP Instream Flow Proposals for the Merced River

Month	Wet	Above Normal	Below Normal	Dry	Critical
October	350	300	300	250	250
November	350	350	300	300	250
December	600	550	300	300	250
January	1,100	600	300	300	250
February	1,450	1,050	500	300	250
March	1,500	1,050	600	450	400
April	1,800	1,350	1,150	950	750
May	2,950	2,300	1,750	1,200	850
June	2,850	1,450	1,150	650	450
July	1,150	400	250	200	200
August	350	300	25	200	200
September	350	300	25	200	200

3.9 Conclusions

3.9.1 Description of Draft SJR Flow Objectives and Program of Implementation

Based on the information discussed above, the State Water Board developed draft changes to the SJR flow objectives and program of implementation that were included as an appendix to the October 2011 draft of the Technical Report. Those draft objectives and program of implementation are also included in Appendix A of this report. The draft objectives and program of implementation may be modified to some degree prior to release of the SED, but the draft objectives and program of implementation represent the conceptual framework the State Water Board is considering for any changes to the objectives and program of implementation. The draft changes include the following narrative flow objective:

> *Maintain flow conditions from the SJR Watershed to the Delta at Vernalis, together with other reasonably controllable measures in the SJR Watershed sufficient to support and maintain the natural production of viable native SJR watershed fish populations migrating through the Delta. Specifically, flow conditions shall be maintained, together with other reasonably controllable measures in the SJR watershed, sufficient to support a doubling of natural production of Chinook salmon from the average production of 1967–1991, consistent with the provisions of State and federal law. Flow conditions that reasonably contribute toward maintaining viable native migratory SJR fish populations include, but may not be limited to, flows that more closely mimic the hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur. Indicators of viability include abundance, spatial extent or distribution, genetic and life history diversity, migratory pathways, and productivity.*

Draft changes to the program of implementation for the narrative SJR flow objective call for the flow objective to be implemented by providing a percentage of unimpaired flow ranging from 20% to 60% from February through June from the Stanislaus, Tuolumne, and Merced Rivers, in addition to base flow requirements. To develop precise requirements for implementation, the draft program of implementation calls for establishing a workgroup consisting of parties with expertise in fisheries management, unimpaired flows, and operations on the Stanislaus, Tuolumne, and Merced Rivers to develop recommendations for consideration by the State

Water Board in the implementation proceedings for the flow objective that will follow adoption of any changes to the Bay-Delta Plan.

The draft program of implementation allows for refinement of the percent of unimpaired flow requirement by allowing for adaptive management based on specific information concerning flow needs to protect fish and wildlife beneficial uses. In addition, the draft program of implementation calls for the development of monitoring and special studies programs to develop further information concerning SJR flow needs for the protection of fish and wildlife beneficial uses in order to inform the adaptive management process, implementation actions, and future changes to the Bay-Delta Plan, including potential changes to the October pulse flow requirements and addition of flow requirements for the periods outside of the February through June and October period. The final program of implementation will also include recommendations to other agencies to take additional actions outside of the State Water Board's purview to protect SJR fish and wildlife beneficial uses. Those actions will include non-flow activities that should take place potentially including, but not limited to: habitat restoration (floodplain restoration, gravel enhancement, riparian vegetation management, passage, etc.), hatchery management, predator control, water quality measures, ocean/riverine harvest measures, recommendations for changes to flood control curves, and barrier operations.

3.9.2 Summary of Basis for Alternative SJR Flow Objectives and Program of Implementation Language

The scientific information discussed in this chapter supports the draft narrative SJR flow objective discussed above and the conclusion that a higher and more variable flow regime in salmon-bearing SJR tributaries to the Delta during the spring period (February through June) is needed to protect fish and wildlife beneficial uses (including SJR basin fall-run Chinook salmon) and other important ecosystem processes. For example, numerous studies have reported that the primary limiting factor for tributary abundances of Chinook salmon are reduced spring flow, and that populations on the tributaries are highly correlated with tributary, Vernalis, and Delta flows (Kjelson et al. 1981; Kjelson and Brandes 1989; USFWS 1995; Baker and Mohardt 2001; Brandes and McLain 2001; Mesick 2001b; Mesick and Marston 2007; Mesick 2009; Mesick 2010 a-d).

As a result of construction and operation of the rim dams, flows within the SJR basin have been substantially altered from the flow regime to which SJR basin fish and wildlife are adapted. As outlined in the hydrology section of this report, water development in the SJR basin has resulted in: reduced annual flows; fewer peak flows; reduced and shifted spring and early summer flows; reduced frequency of peak flows from winter rainfall events; shifted fall and winter flows; and a general decline in hydrologic variability over multiple spatial and temporal scales (McBain and Trush 2002; Cain et al. 2003; Richter and Thomas 2007; Brown and Bauer 2009; NMFS 2009a). At the same time, naturally produced fall-run Chinook salmon and other native SJR basin fish and wildlife have also experienced significant population declines, and as a result may be at a high risk of extinction.

While there are many other factors that contribute to impairments of fish and wildlife beneficial uses in the SJR basin, flows remain a critical component in the protection of these beneficial uses. These other factors do not obviate the need for improved SJR inflow conditions to the Delta to protect fish and wildlife beneficial uses. In fact, many of the other habitat factors that affect community structure (e.g., temperature, water chemistry, physical habitat complexity), are to some extent determined by flow (Moyle et al. 2011). There is the need to comprehensively address the various impairments to fish and wildlife beneficial uses in the SJR basin and the Delta. The flow regime has been described as the “master variable” that regulates the ecological integrity of rivers (Resh et al. 1988; Power et al. 1995; Poff et al. 1997; Poff et al. 2010). Improved flow conditions will serve to underpin restoration activities and efforts to address other stressors. As discussed above, the State Water Board will address the need for other measures needed to protect SJR basin fish and wildlife beneficial uses in the program of implementation for the revised Bay-Delta Plan.

Given the extremely flattened hydrograph of SJR flows and the various competing demands for water on the SJR, it merits noting that the State Water Board must ensure the reasonable protection of fish and wildlife beneficial uses, which may entail consideration of competing beneficial uses of water, including municipal and industrial uses, agricultural uses, and other environmental uses. Estimates of flow needs to protect fish and wildlife beneficial uses are imprecise given the various complicating factors affecting survival and abundance of Chinook salmon, steelhead, and other SJR basin fish and wildlife. Given the dynamic and variable environment to which SJR basin fish and wildlife adapted, and imperfect human understanding of these factors, developing precise flow objectives that will provide certainty with regard to protection of fish and wildlife beneficial uses is likely not possible. Nevertheless, the weight of the scientific evidence indicates that increased and more variable flows are needed to protect fish and wildlife beneficial uses. While there is uncertainty regarding specific numeric criteria and how the SJR ecosystem will respond to an alternative flow regime, scientific certainty is not the standard for agency decision making.

To assist the State Water Board in determining the amount of water that should be provided to reasonably protect fish and wildlife beneficial uses in the SJR basin, a range of alternative SJR flows will be analyzed. Based on the information discussed above, retaining the spatial and temporal attributes of the natural flow regime appears to be important in protecting a wide variety of ecosystem processes. The historic practice of developing fixed monthly flow objectives to be met from limited sources has been shown to be less than optimal in protecting fish and wildlife beneficial uses in the SJR basin. Accordingly, to preserve the attributes of the flow regime to which native SJR basin fish and wildlife have adapted, and that are believed to be generally protective of the beneficial uses, each of the alternatives is expressed as a percentage of unimpaired flow, and will consider volumes of water reflective of flow at Vernalis such that flows will come from the major salmon-bearing SJR tributaries (i.e., Stanislaus, Tuolumne, and Merced Rivers). It is important to provide flows from the major SJR tributaries to meet alternative flows at Vernalis because diminishing the water resource disproportionately (e.g., from any one tributary) would be deleterious to fish and wildlife beneficial uses within that tributary. The SJR Management Plan of 1995 recognized the importance of coordinating flows from the tributaries to facilitate migration and increase the survival of Chinook salmon. The highly coordinated fashion in which flows from all three major SJR tributaries are released to meet the VAMP flows (SJRGA 2010) also demonstrates the acknowledged importance of coordinated flows.

In a recent report describing methods for deriving flows needed to protect the Bay-Delta and watershed, Fleenor et al. (2010) suggest that while using unimpaired flows may not indicate precise, or optimum, flow requirements for fish under current conditions, it would, however, provide the general seasonality, magnitude, and duration of flows important for native species (see also Lund et al. 2008). Accordingly, as discussed above, the draft program of implementation for the narrative SJR flow objective provides for development of specific implementation provisions through a multidisciplinary workgroup and allows for adaptive management of the unimpaired flow requirement in order to respond to new information and changing circumstances.

The following water supply impacts analysis, evaluates alternative flows of 20%, 40%, and 60% of unimpaired flows from February through June (Figures 3.15 – 3.20) to demonstrate the ability of the analysis to appropriately evaluate the water supply effects of the range of potential alternative SJR flow objectives that will be analyzed in the SED. Any additional alternatives that may be included in the SED will fall within this range.

In its 2010 report on *Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem*, the State Water Board determined that approximately 60% of unimpaired flow at Vernalis from February through June would be protective of fish and wildlife beneficial uses in the SJR basin when considering flow alone. It should be noted that those criteria did not consider other competing uses of water or tributary specific needs for cold water and other purposes that will need to be considered when making changes to the Bay-Delta Plan (State Water Board 2010). The 60% recommendation is imprecise; it provides an upper end for the range of unimpaired flow alternatives that will be evaluated in the SED. The 20% alternative provides a lower end for this range and the 40% alternative provides an intermediate value for evaluation in the SED. In comparison to the alternatives, February through June flows on the Stanislaus, Tuolumne, Merced and lower SJR at Vernalis from water years 1986 through 2009 have median unimpaired flow values of 40%, 21%, 26%, and 29% respectively.

The SED will include an analysis of the 20%, 40%, and 60% of unimpaired flow alternatives and potentially other alternative flow levels within this range to determine the potential environmental, water supply, economic, and hydroelectric power production impacts of the various alternatives. The State Water Board will then use the information from the various effects analyses included in the SED, along with information included in this report, and other information presented to the State Water Board to make a decision on what changes should be made to the SJR flow objectives and program of implementation to provide for the reasonable protection of fish and wildlife beneficial uses. Flow needed for the protection of fish and wildlife beneficial uses will be balanced against flow needs for other beneficial uses of water including: agriculture and hydropower production.

As indicated above, the State Water Board's current review of SJR flow requirements is focused on the February through June time frame, as flows (magnitude, duration, frequency) during this period are a dominant factor affecting salmon abundance in the basin. The fall pulse flow objective contained in 2006 Bay-Delta Plan is not the subject of this review. However, the draft program of implementation states that the State Water Board will reevaluate the implementation of the October pulse flow and flows during other times of the year after monitoring and special studies during the water rights and FERC processes have been conducted to determine what, if any, changes should be made to these flow requirements and their implementation to achieve the narrative San Joaquin River flow objective.

Figures 3.15 through 3.19 below present exceedance plots of San Joaquin River at Vernalis monthly unimpaired flows (for 1922 to 2003) and observed flows (for 1986 to 2009), along with 20%, 40%, and 60% of unimpaired monthly flows for the months of February through June, respectively. Figure 3.20 provides the same for all February through June monthly flows together over the same time periods. These flows are presented as average monthly flow rates (in cfs), rather than total monthly volumes (in TAF), for better comparison with various flow recommendations and values in the literature. The 20%, 40%, and 60% of unimpaired flow plots in these figures are simple proportions of unimpaired flow for reference purposes only. They do not necessarily represent, but are similar to, flows that would result from implementation of the

20%, 40%, or 60% unimpaired flow alternatives (as described further in Chapter 5). For instance, releases to meet other flow requirements, flood control releases, and other inflows and accretions would increase the flows that would actually occur under the 20%, 40%, and 60% of unimpaired flow alternatives.
As described in Chapter 2, observed monthly flows are less than the median value 50% of the time, with many instances of very low percentages of unimpaired flow, particularly on the Tuolumne and Merced Rivers. Applying minimum unimpaired flow requirements, however, would eliminate the very low percentage of unimpaired flows seen in the observed flows. In the figures below, this will tend to increase the percentage of time with higher flow levels and provide a similar distribution of flows for a given overall percentage of unimpaired flow.

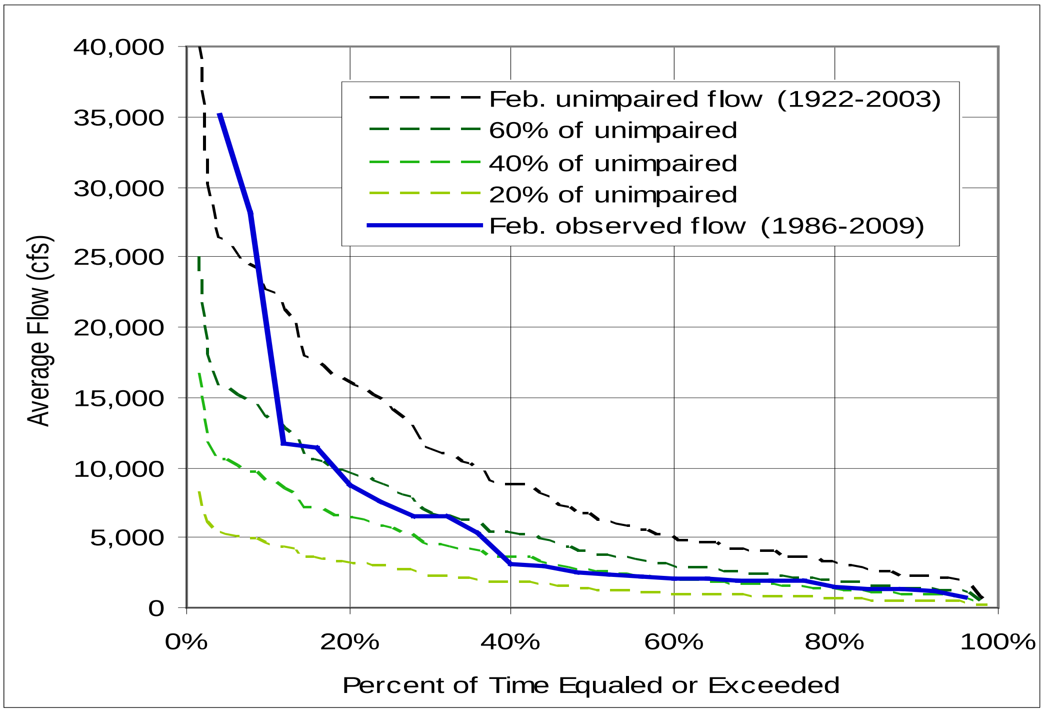


Figure 3.15. Exceedance Plot of February Monthly Average SJR Unimpaired and Observed Flows (cfs) at Vernalis

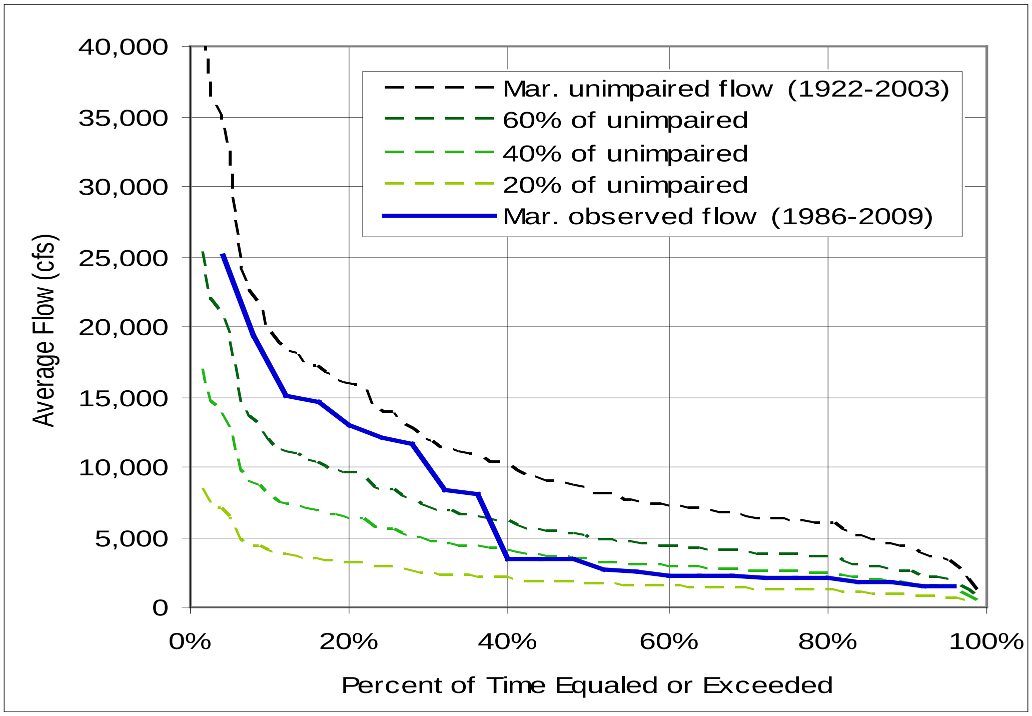


Figure 3.16. Exceedance Plot of March Monthly Average SJR Unimpaired and Observed Flows (cfs) at Vernalis

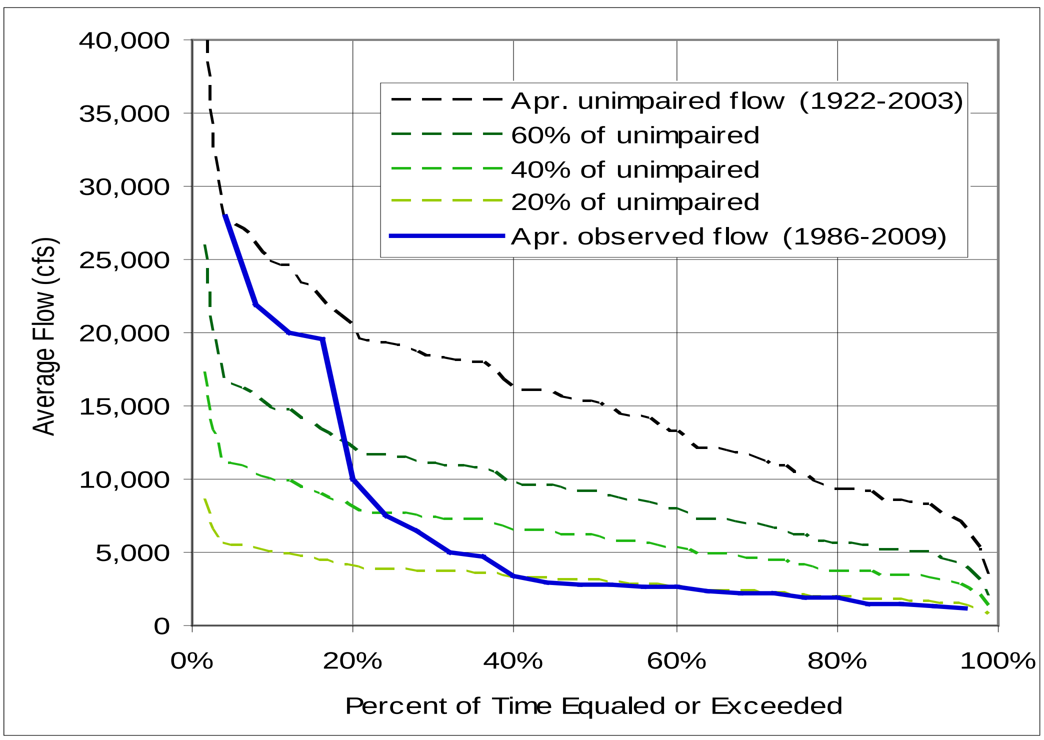


Figure 3.17. Exceedance Plot of April Monthly Average SJR Unimpaired and Observed Flows (cfs) at Vernalis

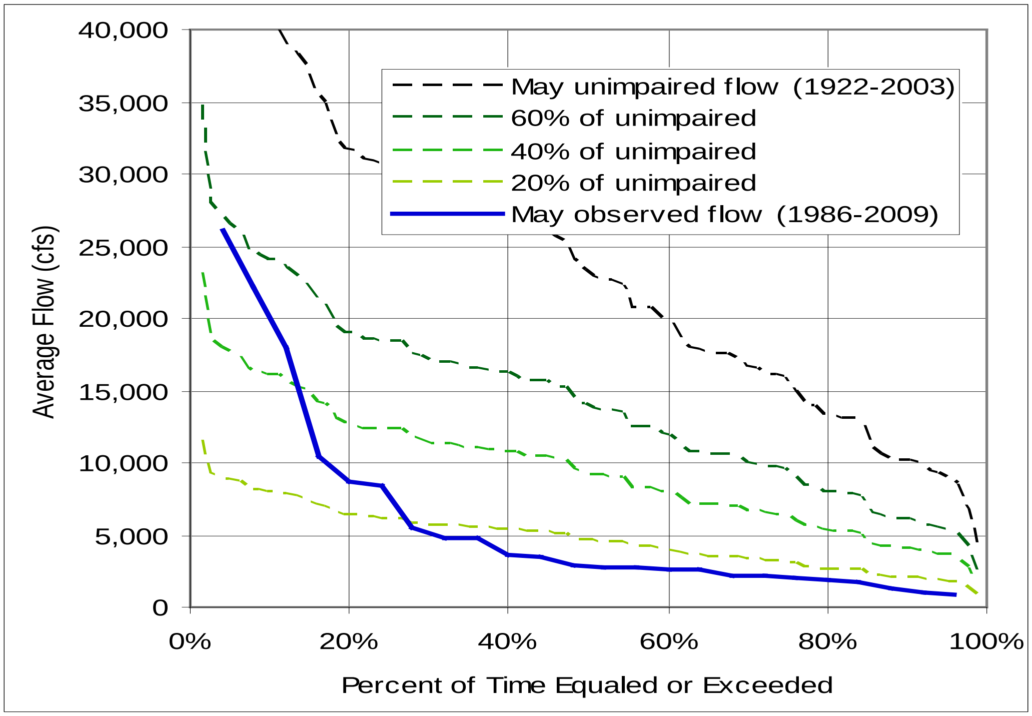


Figure 3.18. Exceedance Plot of May Monthly Average SJR Unimpaired and Observed Flows (cfs) at Vernalis

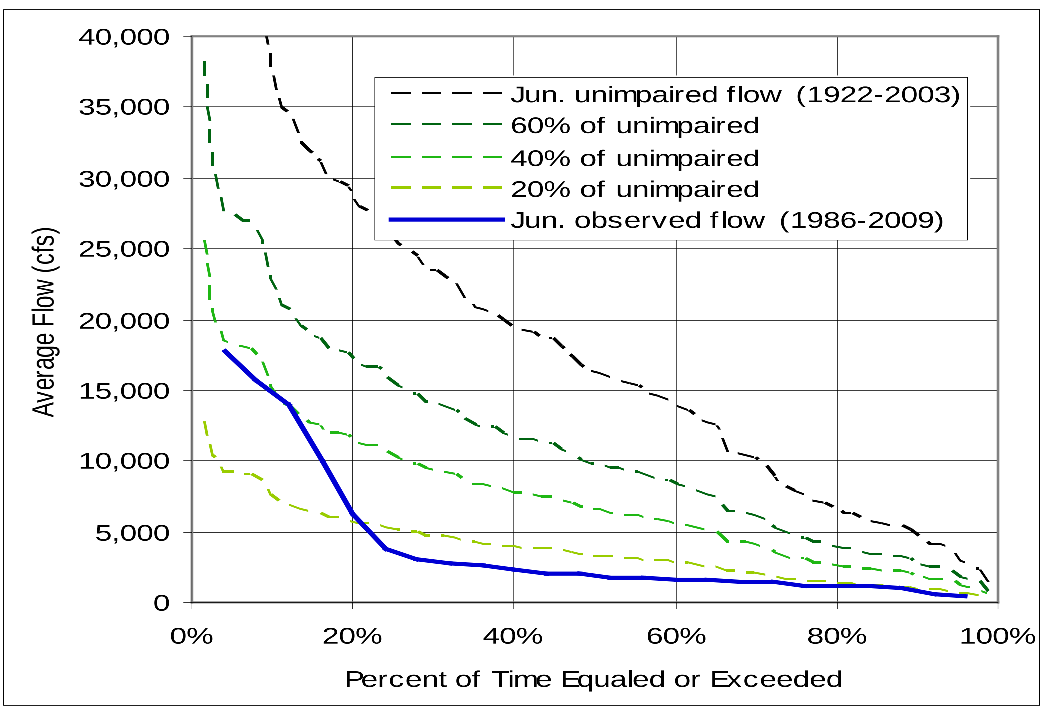


Figure 3.19. Exceedance Plot of June Monthly Average SJR Unimpaired and Observed Flows (cfs) at Vernalis

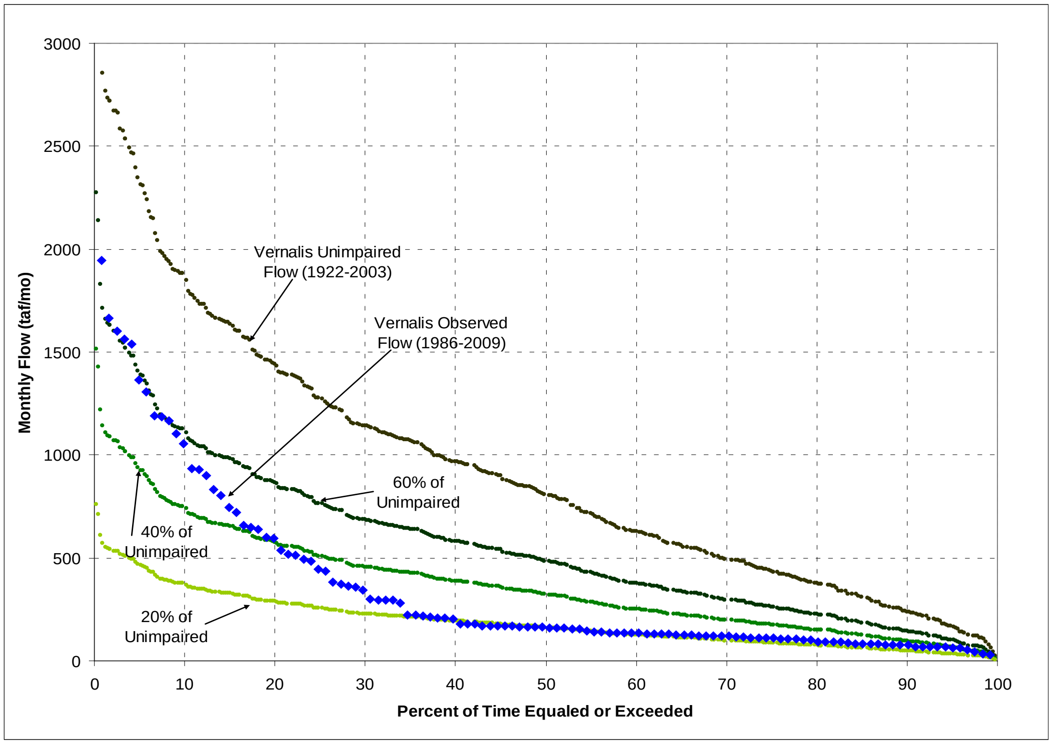


Figure 3.20. Exceedance Plot of Monthly Average SJR Unimpaired and Observed Flows (cfs) at Vernalis, February–June

4 Southern Delta Salinity

Evaluation of the LSJR flow and southern Delta water quality alternatives in the SED will consider their potential effects on various environmental resources and any associated economic impacts. This section describes the technical information and analytical methods that will be used to evaluate the potential salinity-related impacts of these objective alternatives in the SED.

4.1 Background

The State Water Board established salinity compliance stations within the south Delta at the San Joaquin River near Vernalis (station C-10) (Vernalis); the San Joaquin River at Brandt Bridge (station C-6); Old River at Middle River/Union Island (station C-8); and Old River at Tracy Road Bridge (station P-12) as shown in Figure 4.1. The salinity objective at each station is 0.7 millimhos per centimeter (mmhos/cm) electrical conductivity (EC) during the summer irrigation season (April through August) and 1.0 mmhos/cm EC during the winter irrigation season (September through March). Also shown for reference are the boundaries of the legal Delta and the South Delta Water Agency. Salinity objectives at these stations were first established in the *1978 Sacramento–San Joaquin Delta and Suisun Marsh Water Quality Control Plan* (State Water Board 1978).

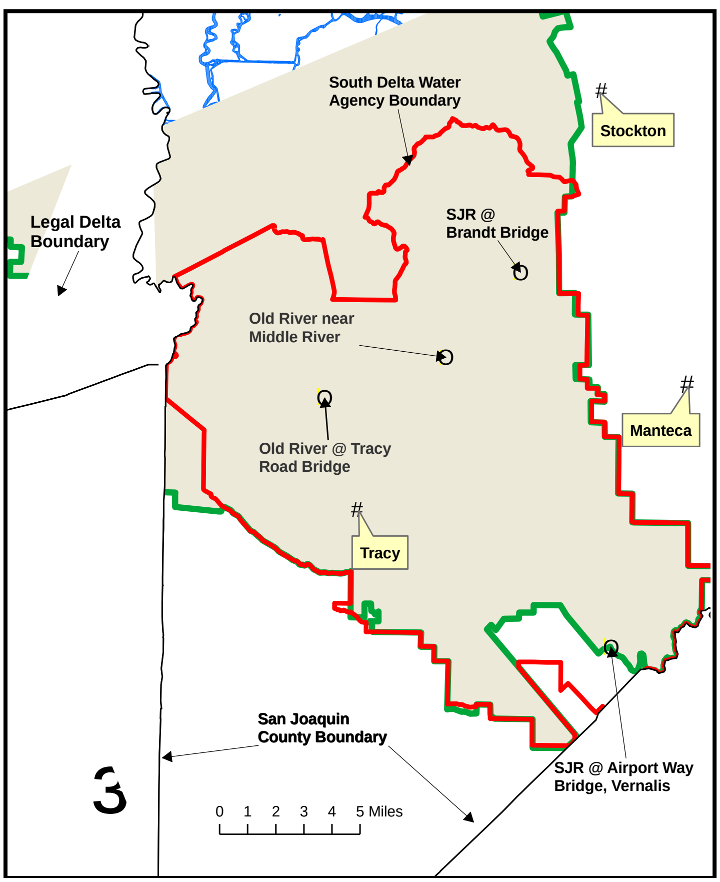


Figure 4.1. Map of Southern Delta Showing State Water Board Salinity Compliance Stations and Boundaries of the Legal Delta and South Delta Water Agency

As stated in the 2010 Hoffman Report, salt stress can damage crops in three different ways. First, and of major concern in the southern Delta, is season-long crop response to salinity. The most common whole-plant response to salt stress is a general stunting of growth. As soil salinity increases beyond a threshold level both the growth rate and ultimate size of crop plants progressively decreases. However, the threshold and the rate of growth reduction vary widely among different crop species. Second, crop sensitivity to soil salinity continually changes during the growing season. Many crops are most sensitive to soil salinity during emergence and early seedling development. Third, when crops are irrigated with sprinkler systems, foliar damage can occur when the leaves are wet with saline water. Sprinkler foliar damage is most likely to occur under hot, dry, and windy weather conditions. For more information on the effects of salinity on crops grown in the southern Delta, refer to the 2010 Hoffman Report which is included as an attachment to this Technical Report.

The approach to developing the objectives involved a determination of the water quality needs of significant crops grown in the area, the predominant soil type, and irrigation practices in the area. The State Water Board based the southern Delta EC objectives on the calculated maximum salinity of applied water which sustains 100% yields of two important salt sensitive crops grown in the southern Delta (beans and alfalfa) in conditions typical of the southern Delta.

In keeping with the literature on crop response to salinity, numerical values for EC are given in units of deciSiemens per meter (dS/m) wherever possible. This is also numerically equal to mmhos/cm, a now-outmoded unit of measure that was used for decades in agriculture to quantify salinity. EC values are sometimes also presented as microSiemens per centimeter (μS/cm) or micromhos per centimeter (μmhos/cm), which are both 1,000 times larger than numerical values in units of dS/m.

4.2 Salinity Model for the San Joaquin River Near Vernalis

An Excel spreadsheet model, created by State Water Board staff, was used to estimate how EC at Vernalis might be affected by changing flows from the Stanislaus, Tuolumne, and Merced Rivers in response to LSJR flow alternatives. The spreadsheet model uses flow and EC input from the CALSIM II model.

The ionic composition of the tributaries with headwaters in the Sierra Nevada Mountains is different from the ionic composition of the SJR as it flows through the valley floor. These different ionic compositions could lead to a combined EC that differs from a simple mass balance, but this difference is generally observed to be small in waters with the ranges of EC observed in the project area. Also, for consistency with CALSIM II, EC from each tributary is calculated as a simple mass balance.

Flow and EC downriver of the confluence of a tributary with the SJR are calculated proportional to the inflow and EC entering the confluence. Following the law of conservation of mass, the model's governing equation is described in Equation 4.1.

$$(EC * Flow)_{Downstream} = (Flow * EC)_{Tributary} + (Flow * EC)_{River} \qquad (Eqn.\ 4.1)$$

The model sums Merced River and upstream SJR flow, and calculates the flow-weighted mixed Merced River and SJR EC. The calculated flow and EC are used as the upstream inputs for the SJR at the confluence of the Tuolumne River. Inflows and salinity loads (i.e., Flow x EC) to the SJR between the Merced and the Tuolumne are held constant. This calculation is repeated through the confluence of the Stanislaus River, yielding a calculated flow and EC at Vernalis that would occur as a result of modifying flows in the major tributaries.

4.2.1 Baseline Salinity Conditions

Average monthly flow and EC estimates are extracted from CALSIM II model output files for water years 1922 through 2003. Table 4.1 shows the CALSIM II channels used in this model.

Table 4.1. CALSIM Channels Used in the Flow-Salinity Model

Location	CALSIM II ID	Description
Vernalis	C639	Flow into Vernalis from the confluence of the Stanislaus River with SJR
Confluence of Stanislaus River with SJR	C528	Flow from the Stanislaus River into the SJR
Confluence of Tuolumne River with SJR	C545	Flow from the Tuolumne River into SJR
Confluence of Merced River with SJR	C566	Flow from the Merced River into SJR

Modeled flows and corresponding salinity from the SJR (above the Merced River confluence) and other sources into the mainstem SJR are lumped together as described below.

CALSIM II has a water quality module, which provides estimates of salinity at Vernalis. This module uses a “link-node” approach that assigns salinity values to major inflows to the SJR between Lander Avenue and Vernalis and calculates the resulting salinity at Vernalis using a salt mass balance equation. Inflows from the west side of the SJR are also broken out and calculated as the return flows associated with various surface water diversions and groundwater pumping (MWH 2004).

In Figure 4.2, monthly average observed salinity data from the California Data Exchange Center (CDEC) at Vernalis (DWR 2010a) is plotted together with the CALSIM II estimates of salinity at Vernalis for water years 1994 through September 2003. This represents a period commencing shortly after temporary agricultural flow barriers in the southern Delta were regularly installed through to the end of the overlapping CALSIM II period of simulation.

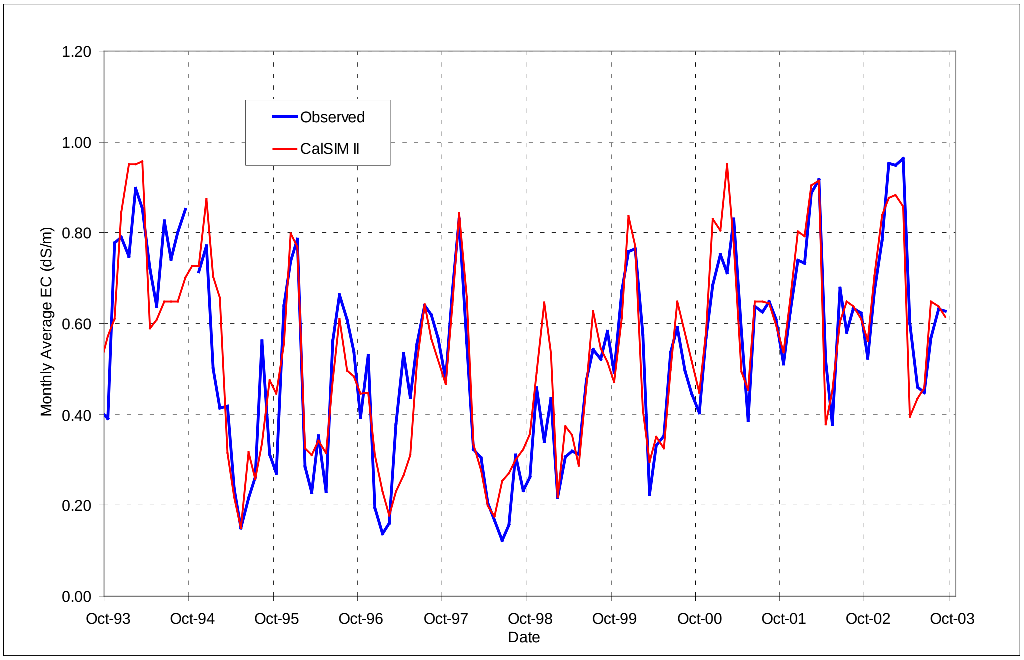


Figure 4.2. Comparison of CALSIM II Salinity (dS/m) Output at Vernalis to Monthly Average Observed Data at the Same Location for Water Years 1994 through 2003

4.2.2 Tributary EC Calculations

Output from the CALSIM II model is used to create an EC to flow relationship for each tributary at the confluence with the SJR. CALSIM II calculated EC at low flow conditions follows an exponential trend while EC at higher flow conditions approaches a constant value. The general form of the exponential equation is Equation 4.2.

$$EC = K_S * F^b \quad (Eqn.\ 4.2)$$

In Equation 4.2, EC and F represent electrical conductivity and flow respectively. Table 4.2 shows the coefficients used in Equation 4.2 to calculate EC and the coefficient of determination for each exponential equation.

Table 4.2. Coefficients Used to Approximate EC for Each Tributary

Tributary	K_S	b	R^2
Stanislaus	214.2	-0.16	0.18
Tuolumne	461.72	-0.337	0.94
Merced	448.3	-0.368	0.86

At the beginning of the exponential approximation (flows less than 6 TAF), some EC values were not valid, so an upper bound on EC was used. Invalid data were values more than 2 standard deviations from the mean EC. Toward the end of the exponential approximation equation, the EC stops decreasing as flow increases (Figure 4.3, Figure 4.4, and Figure 4.5). For this reason, a reasonable threshold value was selected to approximate EC at high flows. By inspection, these threshold values were selected to yield results similar to CALSIM II calculations. Flows below the threshold used the exponential equation, while flows above the threshold used values summarized in Table 4.3.

Table 4.3. Threshold Values for EC Approximations on Each Tributary

Tributary	Threshold Flow [TAF]	High Flow Constant [µS/cm]	Maximum EC [µS/cm]
Stanislaus	200	95	300
Tuolumne	145	85	None
Merced	100	85	500

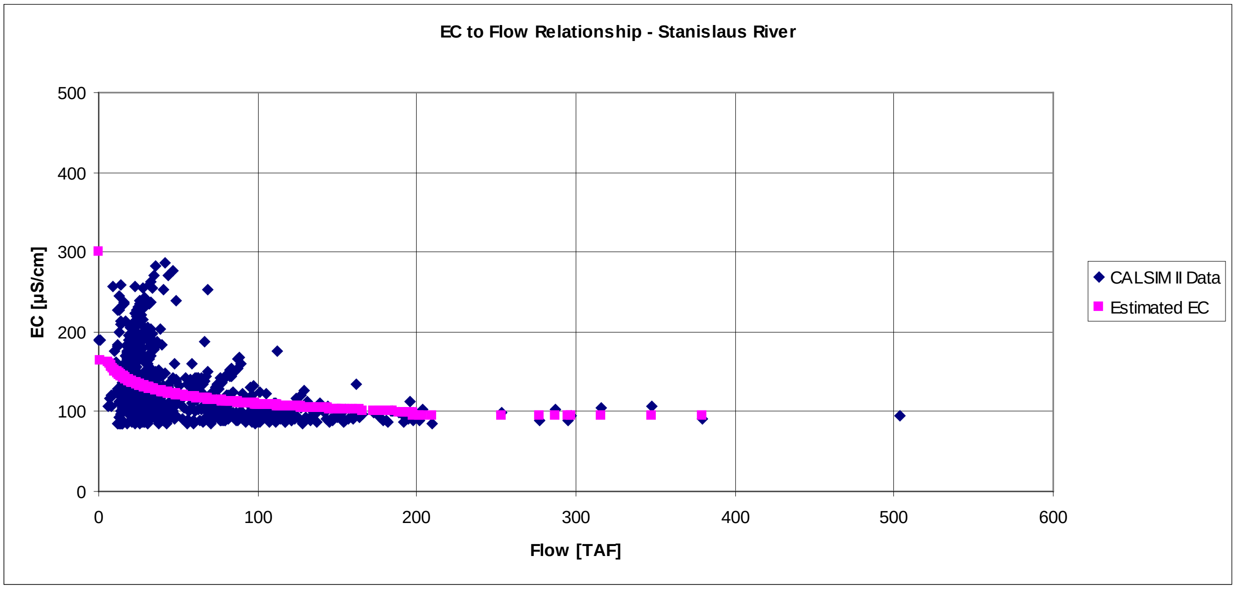


Figure 4.3. Estimated EC from CALSIM II Data on the Stanislaus River

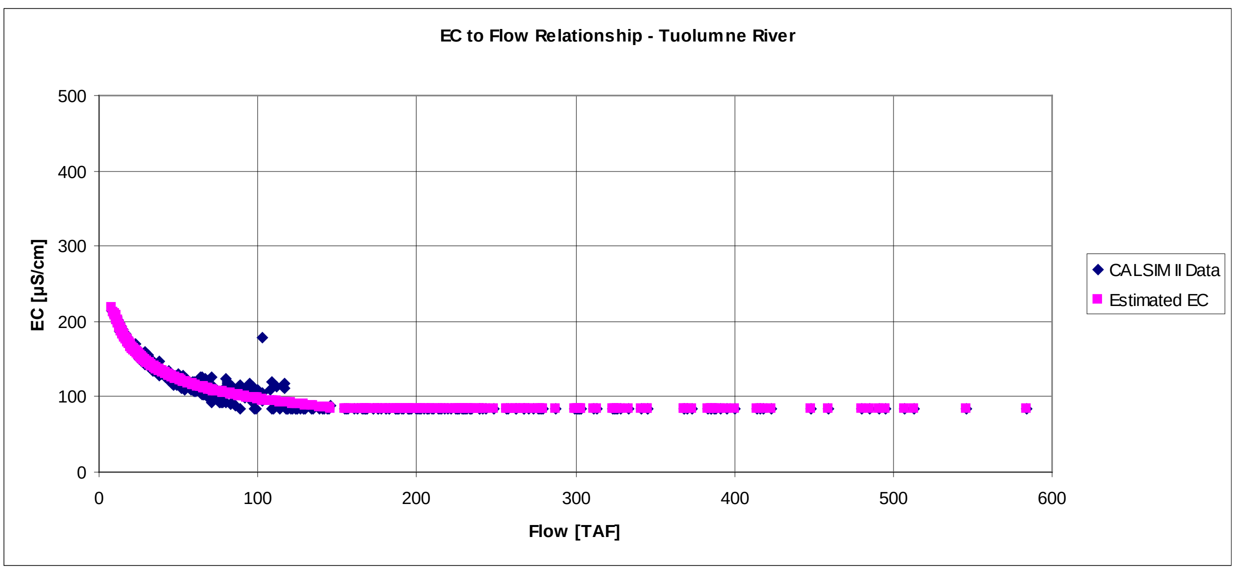


Figure 4.4. Estimated EC from CALSIM II Data on the Tuolumne River

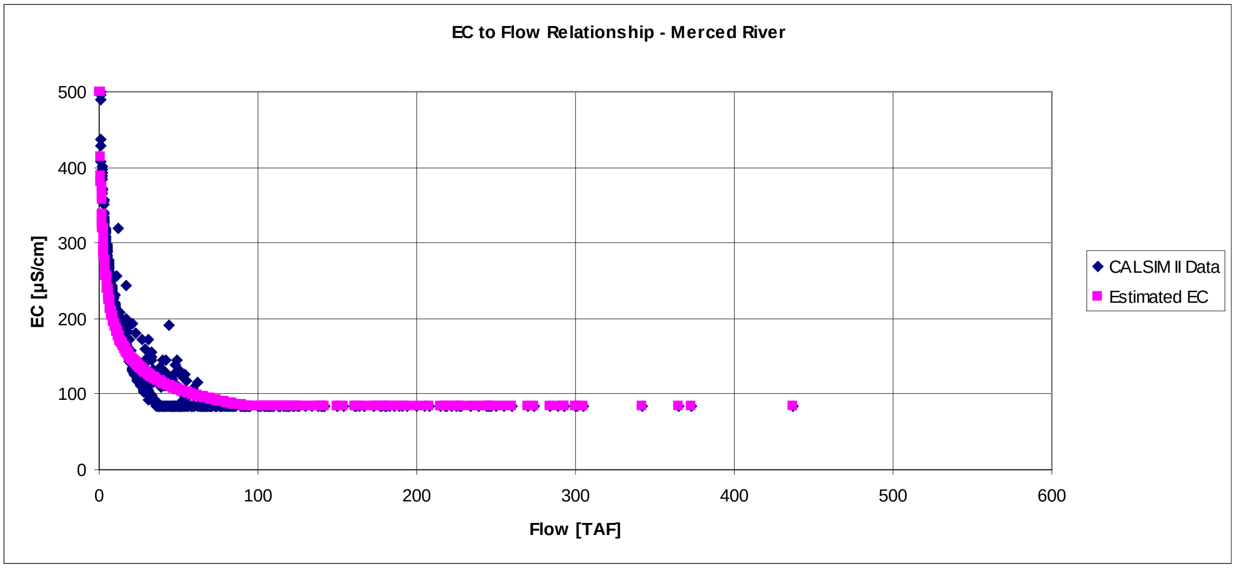


Figure 4.5. Estimated EC from CALSIM II Data on the Merced River

In June 2004 the United States Bureau of Reclamation (USBR) issued a technical memorandum entitled *Development of Water Quality Module,* which calculated EC to flow relationships for the Tuolumne and Merced Rivers (USBR 2004). USBR EC to flow relationships were compared to the EC to flow relationships generated with CALSIM II output and were determined to be approximately equal; thus the CALSIM II EC to flow relationships are used in the model for these two rivers.

4.2.3 Calculating EC at Vernalis

The modeled salt load at Vernalis must equal the sum of the salt loads of the tributaries and all other additional upstream sources. Only the flow on the tributaries varies as a result of evaluating flow alternatives, leaving all other salt load sources as a constant value. The constant value of salt loads from SJR non-tributary sources, L_{SJR}, is found by subtracting the salt loads from the tributaries from the salt load at Vernalis:

$$L_{SJR} = (Flow * EC)_{Vernalis} - (Flow * EC)_{Tributaries} \qquad (Eqn.\ 4.3)$$

Once the EC to flow relationships are established, unimpaired flow data replace the CALSIM II model flows. These new flows for the months of February through June are used with the EC to flow relationships to calculate new EC values associated with the new flows in each tributary. The new EC at Vernalis is the mass balance equation (Equation 4.1) for the salt load at Vernalis divided by the new flow balance at Vernalis, where the new flow and EC values are designated with the prime symbol (‘).

$$EC'_{Vernalis} = \frac{(Flow' * EC')_{Tributaries} + L_{SJR}}{Flow_{Vernalis} + (Flow' - Flow)_{Tributaries}} \qquad (Eqn.\ 4.4)$$

Figure 4.6 shows the calculated EC at Vernalis for water years1994–2003 at 40% and 60% of unimpaired flow.

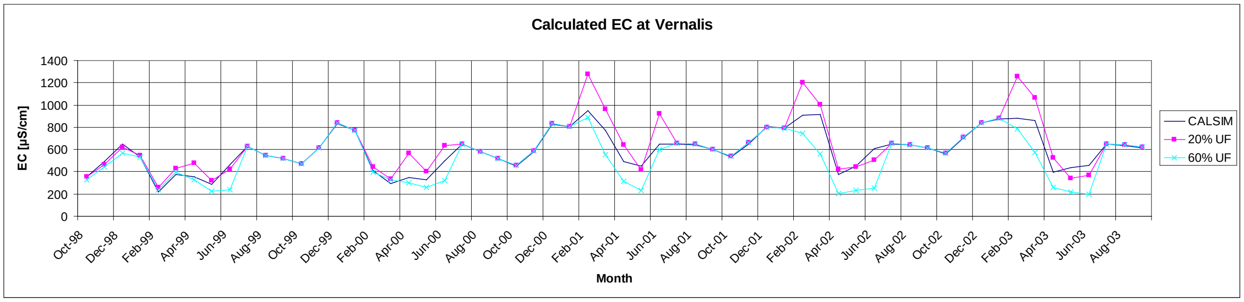


Figure 4.6. Calculated EC at Vernalis for the 40% and 60% Unimpaired Flow Example Compared to CALSIM II Results for Water Years 1994–2003

4.3 Factors Affecting Salinity in the Southern Delta

Salinity levels in the southern Delta are affected primarily by the salinity of water flowing into the southern Delta from the SJR near Vernalis and evapo-concentration of salt in water that is diverted from and discharged back into southern Delta channels for agricultural purposes. Point sources of salt in the southern Delta have a small overall salinity effect. This section discusses the methods used in the SED to evaluate the effect of these sources and processes.

4.3.1 Estimating Southern Delta Salinity Degradation

This section describes the regression analyses used to establish a relationship between salinity at the three interior southern Delta salinity stations and the upstream SJR near Vernalis station. These relationships will be used to estimate the assimilative capacity needed at Vernalis to comply with a particular salinity objective alternative in the southern Delta. This type of planning analysis provides a conservative general estimate of this relationship. This type of analysis does not provide, nor does it require, the dynamic and higher resolution modeling provided by the California DWR Delta simulation model (DSM2) or other hydrodynamic and water quality models of the south Delta. Such simulation models are appropriate for more detailed modeling studies of south Delta barrier operations or changes to CVP and SWP operating conditions. In addition, DWR has found that DSM2 underestimates salinity at Old River near Tracy (an important location for this analysis), and has recommended that regression analysis would be appropriate for this type of analysis (DWR, 2007b).

To estimate salinity degradation between Vernalis and the three southern Delta compliance stations, regression analyses were conducted using salinity data from the DWR CDEC (DWR, 2010a). Figure 4.7, Figure 4.8, and Figure 4.9 present the monthly average salinity data for all months from January 1993 to December 2009 for Old River at Tracy (CDEC station = OLD), Old River at Middle River/Union Island (CDEC station = UNI), and SJR at Brandt Bridge (CDEC station = BDT). Each station is plotted against corresponding salinity data at Vernalis (CDEC station = VER). The least squares linear regression line for each plot is shown on each plot giving the slope, y-intercept and associated correlation coefficient. The 1:1 line, where salinity at the two locations would be equal, is also shown for reference.

In general the increase in salinity downstream of Vernalis is greatest at Old River at Tracy. As such, the regression equation from this location represents a reasonable worst-case estimate of salinity degradation in the south Delta for planning purposes. Two separate regressions were further developed, one for the months of April through August in Figure 4.10 and the other for

September through March in Figure 4.11; the former period corresponding to the main growing season. Each figure shows the best-fit regression line and equation for the estimate of the EC at Old River at Tracy as a function of EC at Vernalis. Also shown is the line representing the equation that will provide an estimate of EC at Old River at Tracy which is at or above the actual EC at Old River at Tracy, 85% of the time (85% prediction line).

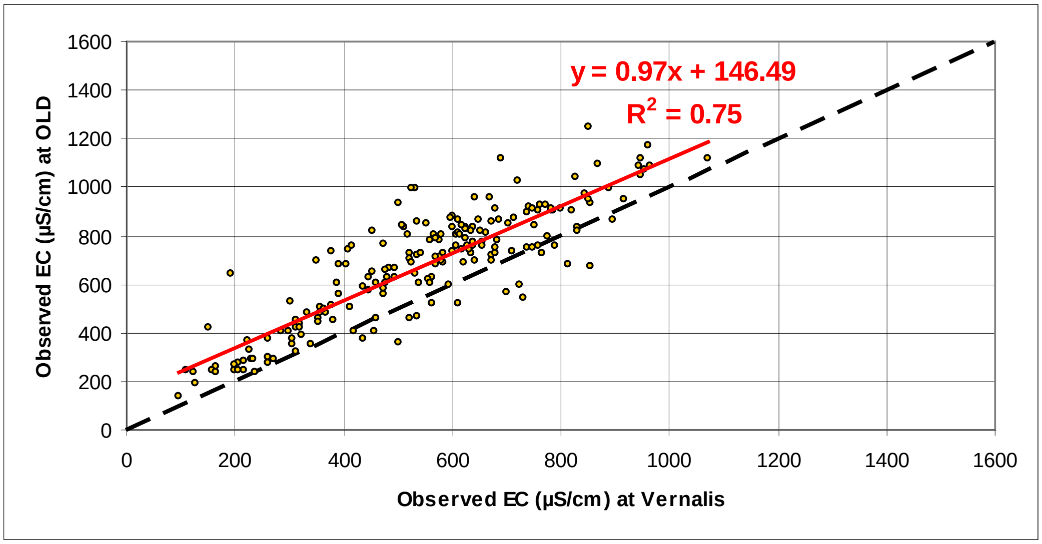


Figure 4.7. Monthly Average Salinity Data from January 1993 to December 2009 for Old River at Tracy (OLD) Plotted Against Corresponding Salinity Data at SJR Near Vernalis

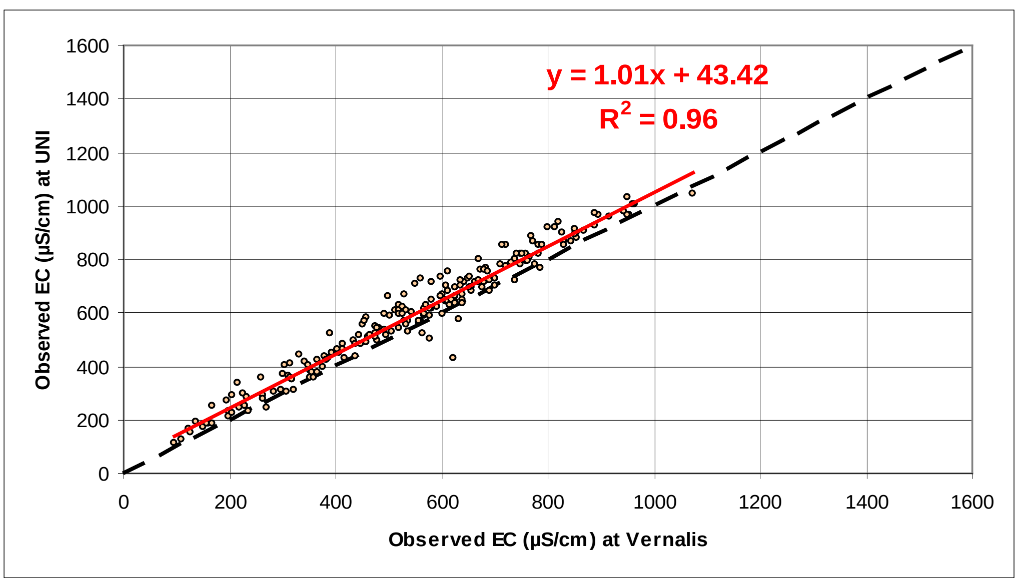


Figure 4.8. Monthly Average Salinity Data from January 1993 to December 2009 for Old River at Middle River/Union Island (UNI) Plotted Against Corresponding Salinity Data at SJR Near Vernalis

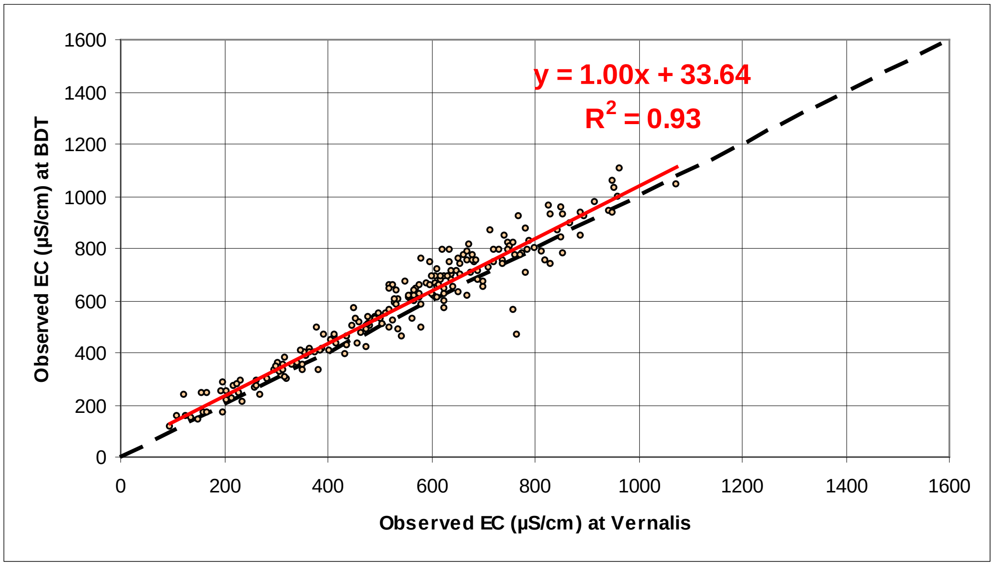


Figure 4.9. Monthly Average Salinity Data from January 1993 to December 2009 for SJR at Brandt Bridge (BDT) Plotted Against Corresponding Salinity Data at SJR Near Vernalis

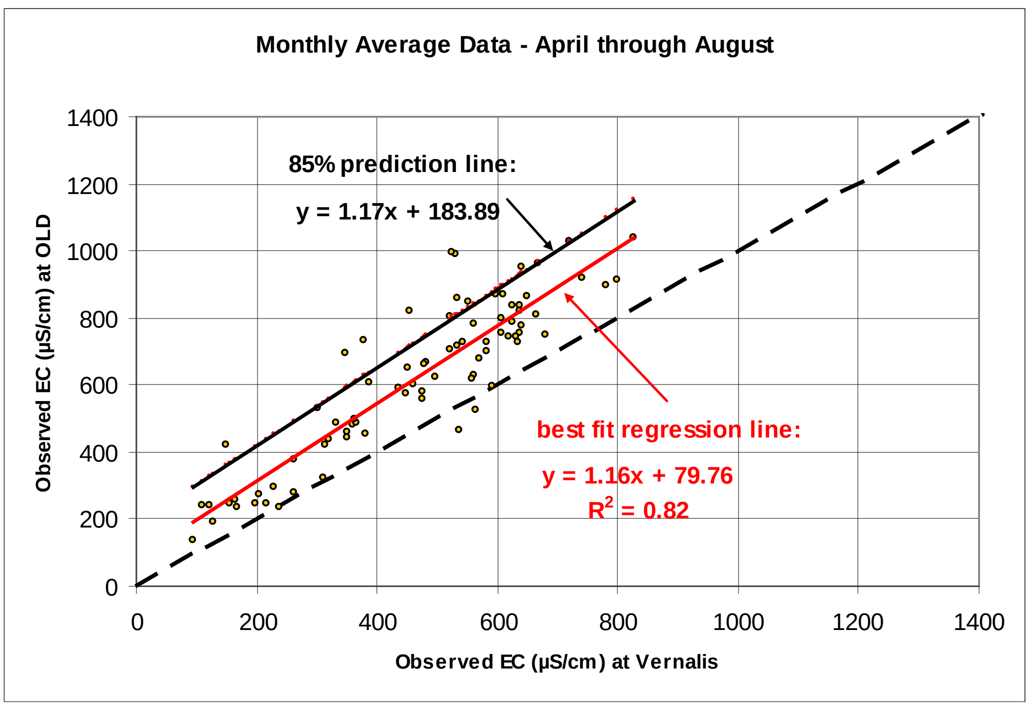


Figure 4.10. Monthly Average Salinity Data for April through August from 1993 through 2009 for Old River at Tracy (OLD) Plotted Against Corresponding Salinity Data at SJR Near Vernalis, with Best Fit Regression and 85% Prediction Lines

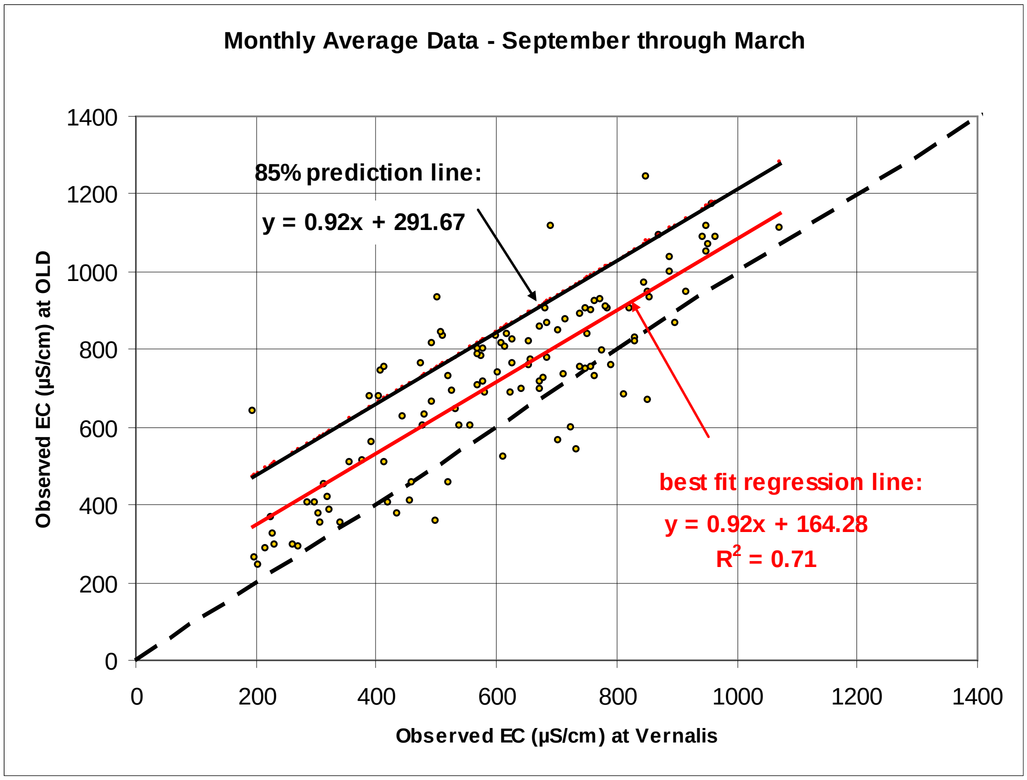


Figure 4.11. Monthly Average Salinity Data for September through March from 1993 through 2009 for Old River at Tracy (OLD) Plotted Against Corresponding Salinity Data at SJR near Vernalis, with Best Fit Regression and 85% Prediction Lines

4.3.2 Salt Loading from NPDES Discharges in Southern Delta

Two methods of analysis were used to understand the relative contribution of salt loading to the southern Delta from local NPDES point sources.

DWR Modeling Study of NPDES Discharges

DSM2 modeling was conducted by a stakeholder group including DWR in 2007 to better understand the salinity impacts of the new and expanded discharges from the City of Tracy and Mountain House Community Services District wastewater treatment plants. The model analysis concluded that the City of Tracy discharge under reasonable worst-case conditions has limited impacts on the salinity problem in the southern Delta as compared to other sources of salinity in the area defined as ambient salinity entering from the San Joaquin River, agricultural activities, and groundwater accretions. Under the assumed ambient EC of 700 µS/cm in August, the effect of the Tracy discharge at 16 million gallons per day (mgd) would increase EC by 11 and 3 µS/cm in August, under high and low export pumping scenarios respectively (Central Valley Water Board 2007).

Mass Balance Analysis

A simple mass-balance analysis was conducted to evaluate the relative effect of NPDES point sources. This analysis used a combination of observed flow and EC data, and assumptions regarding discharges from the NPDES permitted facilities. As beneficial uses are affected more by longer term salinity averages, this analysis is based on monthly averages to understand the relative importance of major contributing factors. This analysis does not account for dynamic mechanisms that affect short-term and localized fluctuations in EC concentrations.

The analysis compares the permitted maximum salinity loads from the City of Tracy, Deuel Vocational Facility, and Mountain House Community Services District wastewater treatment plants to the salinity load entering at the HOR. Figure 4.12 presents the salt load from HOR in tons/month and the total load from these three point sources as a percentage of the total HOR load for each month from January 1993 to December 2009. The results demonstrate that the salt load from point sources in this part of the southern Delta is a small percentage of the salt load entering from upstream.

Salt loads from point sources were derived using the NPDES permitted discharge rates and water quality limits. Permitted discharges for the City of Tracy, Deuel Vocational Facility, and Mountain House Community Services District wastewater treatment plants are 16.0, 0.62, and 0.54 mgd, respectively. The respective water quality limits for the permitted dischargers are 1,755, 2,604, and 1,054 µS/cm (Central Valley Regional Water Quality Control Board Order Numbers R5-2007-0036, R5-2008-0164, and R5-2007-0039). Salinity inputs at HOR were derived by assuming the same salinity concentrations as those measured at the SJR near Vernalis, and by calculating flow as the difference in the measured flow at the SJR near Vernalis and the measured flow at the HOR (as measured at USGS station #11304810 at the Garwood/Highway 4 bridge immediately upstream of the City of Stockton wastewater treatment plant).

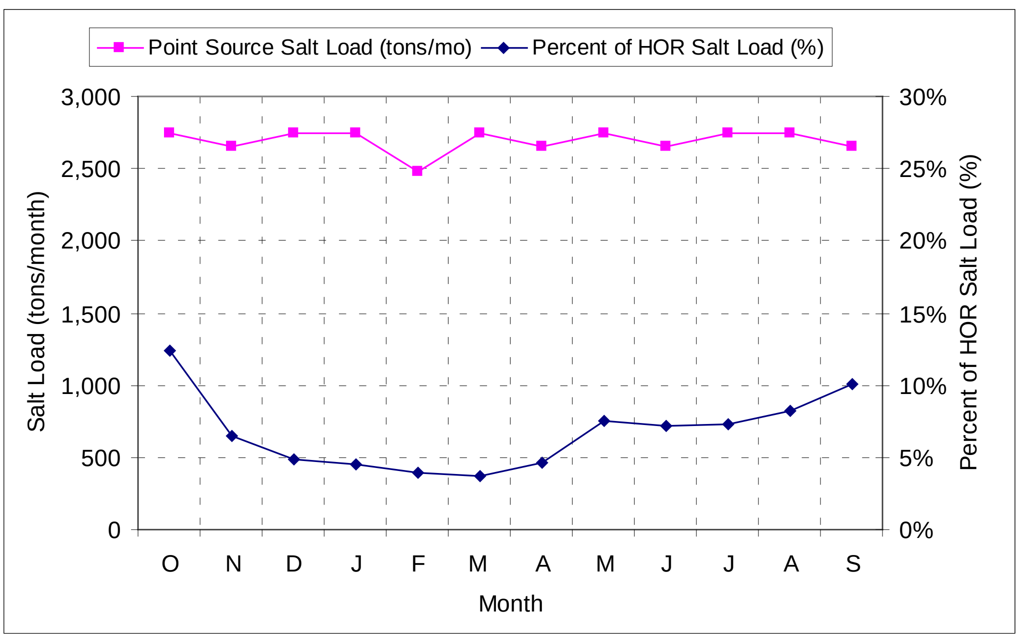


Figure 4.12. Theoretical Salinity Loading from the City of Tracy, Deuel Vocational Facility and Mountain House Wastewater Treatment Plants Stated as Total Load (tons/month) and as a Percent of the Load Entering the Head of Old River

4.4 Effects of Salinity in the Southern Delta

Salinity primarily affects agricultural supply (AGR) and MUN beneficial uses in the southern Delta. This section discusses the latest technical information and modeling methodologies relevant to evaluating potential impacts of different salinity objective alternatives on these beneficial uses in the SED.

4.4.1 Effects on Agricultural Supply Beneficial Use

The SED will need to evaluate the impact of different salinity objective alternatives on AGR beneficial uses in the southern Delta. This evaluation will rely in large part on the conclusions and the modeling methodologies presented in a January, 2010 report by Dr. Glenn Hoffman entitled *Salt Tolerance of Crops in the Southern Sacramento–San Joaquin Delta* (Hoffman 2010).

As part of the Bay-Delta Plan the State Water Board committed to re-evaluate the salinity objectives in the southern Delta. With input from stakeholders, a contract was established with Dr. Glenn Hoffman to develop the above report, which reviewed the current scientific literature regarding crop salt tolerance and to assess current conditions in the southern Delta. After presenting background and a description of soils and crops in the southern Delta, this report provides an overview of several factors affecting crop response to salinity, including a discussion of the general state of knowledge and the specific southern Delta situation. The factors considered were:

- Season-long salt tolerance
- Salt tolerance at various growth stages
- Saline-sodic soils
- Bypass flows in shrink-swell soils
- Effective rainfall
- Irrigation methods
- Sprinkling with saline water
- Irrigation efficiency and uniformity
- Crop water uptake distribution
- Climate
- Salt precipitation or dissolution
- Shallow groundwater
- Leaching fraction

In addition to these factors, the report describes and compares the different models that are currently available for estimating soil water salinity in the crop root zone. The report then uses a basic steady-state model to estimate the soil water salinity concentrations and associated effect on the relative yield for three important crops grown in the southern Delta (dry bean, alfalfa, and almond). This modeling methodology uses local historical meteorological conditions and can be applied over a range of irrigation water supply salinity concentrations (i.e., salinity objective alternatives).

This report incorporated considerable input from public and agency stakeholders. In July 2009 Dr. Hoffman issued a draft version of the subject report, which was followed by a presentation of his preliminary findings at a State Water Board public workshop in August 2009. Written comments and other input were solicited from stakeholders regarding the draft report, and Dr. Hoffman gave a follow-up presentation in November 2009 to summarize and address the comments received. Based on feedback from these presentations, Dr. Hoffman finalized the subject report, including a comment response appendix.

The main conclusions and recommendations of this report are as follows (in no particular order):

- Salt sensitive crops of significance in the southern Delta include almond, apricot, dry bean, and walnut, with dry bean being the most sensitive.
- Based on the last nine years of data, the current level of salinity in the surface waters of the southern Delta appears suitable for all agricultural crops.
- Neither sodicity nor toxicity should be a concern for irrigated crops; however, based on limited data and known crop tolerances, boron may be a concern.
- Depth to the water table in much of the southern Delta is at an acceptable depth for crop production.
- Relatively high leaching fractions are associated with an overall irrigation efficiency of 75% for furrow and border irrigation methods predominant in the southern Delta.
- Data from drains in the western part of the southern Delta suggest leaching fractions are between 0.21 and 0.27, with minimums ranged from 0.11 to 0.22 (stated as unitless fractions).
- The field study data supporting the salt tolerance of bean is sparse and over 30 years old. There is also no information on the salt sensitivity of bean and many other crops in early growth stages.
- Because the steady-state model doesn’t account for it, salt dissolution from the soil profile may cause the actual salinity in the root zone to be about 5% higher than estimated by the model.
- Steady-state modeling presented in the report, and the results from other transient model studies suggest the water quality standard could be increased up to 0.9 to 1.1 dS/m and be protective of all crops normally grown in the southern Delta under current irrigation practices. During low rainfall years, however, this might lead to yield loss of about 5% under certain conditions.
- Effective rainfall should be included in any modeling of soil water salinity in the southern Delta. Also, the exponential crop water uptake model is recommended as it better matches laboratory data. The model methodology used previously for the development of the existing objectives in the 1978 Bay-Delta Plan was more conservative and did not include consideration of rainfall, which lead to higher estimates of soil water salinity.
- In addition to the conclusions above, a number of recommendations were made for further studies in the southern Delta regarding: i) the crop salt tolerance of bean, ii) transient soil salinity modeling, iii) potential for boron toxicity to crops, and iv) leaching fractions associated with current irrigation practices.

4.4.2 Effects on Municipal and Domestic Supply Beneficial Use

The SED will also evaluate the impact of different salinity objective alternatives on other beneficial uses in the southern Delta, including MUN.

Maximum Contaminant Levels (MCL) are components of drinking water standards adopted by either the United States Environmental Protection Agency (USEPA) under the federal Safe Drinking Water Act or by the California Department of Public Health (DPH) under the California Safe Drinking Water Act. California MCLs may be found in Cal. Code Regs., tit. 22, chapter 15, division 4. Primary MCLs are derived from health-based criteria. The MCL related to salinity is specific conductance, but because specific conductance does not cause health problems, there are no Primary MCLs for specific conductance. However, Secondary MCLs are established on the basis of human welfare considerations (e.g., taste, color, and odor).

Drinking water has a Recommended Secondary MCL for specific conductance of 900 μS/cm, with an Upper MCL of 1,600 μS/cm and a Short Term MCL of 2,200 μS/cm. Specific conductance concentrations lower than the Secondary MCL are more desirable to a higher degree of consumers, however, it can be exceeded and is deemed acceptable to approach the Upper MCL if it is neither reasonable nor feasible to provide more suitable waters. In addition, concentrations ranging up to the Short Term MCL are acceptable only for existing community water systems on a temporary basis. (Note: specific conductance is electrical conductivity normalized to a temperature of 25° C).

5 Water Supply Effects Analysis

5.1 Purpose and Approach

This section describes the water supply effects (WSE) model and the approach used in the SED to quantify the potential effects that the LSJR flow alternatives could have on water supplies in the SED project area. These include the potential effects on the amount and timing of river flows, surface water diversions, and reservoir levels on the Stanislaus, Tuolumne, and Merced rivers. The output from the WSE model is used in the SED to evaluate the potential impacts of these changes on various environmental resources, agricultural revenues, hydropower generation, and the associated local economy.

Much of the input to the WSE model comes from a CALSIM II San Joaquin River Water Quality Module (CALSIM II) run representative of current hydrology and reservoir operations in the San Joaquin watershed. A description of the CALSIM II model is presented in the next section, followed by an explanation of the calculations performed by the WSE model. This model is then applied to a range of illustrative flow objective alternatives and demonstrates the applicability of the methodology across this range of flow objectives. The actual alternatives evaluated in the SED may differ from the general flow objectives described in this chapter.

The WSE model provides a general flow balance for hypothetical surface water diversion reductions and major reservoir re-operation scenarios on the Stanislaus, Tuolumne, and Merced rivers to meet different LSJR flow alternatives. These scenarios do not, however, identify specifically from where within each watershed additional flows will be provided. The model allows re-operation of the reservoirs, constrained by minimum storage and flood control levels, to minimize impacts to surface water diversions.

The methodology in this appendix has been updated and is described in Appendix F.1, *Hydrologic and Water Quality Modeling*, of this SED.

5.2 CALSIM II San Joaquin River Model

CALSIM II is a computer model developed by the USBR to simulate flow, storage, and use of water in the SJR basin. It is a planning model that imposes a specified level of water resources infrastructure development, land use, water supply contracts, and regulatory requirements over the range of historical meteorological and hydrologic conditions experienced from 1922 to 2003. Use of the model as a planning tool for future operations assumes that future meteorological and hydrologic conditions will be similar to historical. The model estimates the amount of water available for diversions, allocates this water based on various priorities, estimates demand and calculates associated return flows. The model calculates annual diversions using an index based on each year’s end-of-February storage plus perfect foresight of March to September reservoir inflow. This allows the model to calculate each year’s diversions dependent on the storage level of the major rim dams and expected inflow. The model uses regression analysis to calculate flow accretions, depletions and salinity at key locations. It also relies upon historical runoff information and standardized reservoir operating rules for determining carryover storage. Demands not met by surface water diversions can be supplemented with groundwater pumping, although CALSIM II does not model changing groundwater levels. The CALSIM II model runs on a monthly time step, with monthly average inputs and outputs (USBR 2005).

CALSIM II model output provides, among other things, monthly average estimates of diversion delivery, reservoir releases and storage, and river flows in the SJR watershed over the 82 years of simulated hydrology. All the CALSIM II model nodes and associated diversions and return flows in this portion of the SJR watershed within the SED project area are listed in Table 5.1. This list of diversions, channel flows, reservoir storage, and return flows was obtained from the flow balance equations for each of the nodes contained in the CALSIM II input files for this portion of the SJR watershed. The diversions and return flows were verified by creating a flow balance for each node, including all diversions, return flows, inflows and changes in reservoir storage.

The basis for the water supply impact analysis described in this section is the CALSIM II "Current (2009) Conditions" model run from the DWR's *State Water Project Delivery Reliability Report 2009*. A detailed description of the hydrology, facilities, regulatory, and operations assumptions are provided in Appendix A of that report (DWR, 2010b). This CALSIM II model run includes representation of both the December 2008 U.S. Fish & Wildlife Service and the June 2009 National Marine Fisheries Service biological opinions on the Central Valley Project and the State Water Project. The WSE model described in the next section can be updated if a more applicable or updated CALSIM II model run becomes available during the SED analysis.

Table 5.1. List of Diversions and Return Flows from all CALSIM II Nodes in the Portion of the SJR Basin including the Stanislaus, Tuolumne, and Merced Rivers

River	CALSIM II Node No.	CALSIM II Diversion No.	CALSIM II Flow No.	Description
Stanislaus	10	None	None	New Melones Reservoir
	76	None	None	Tulloch Reservoir
	520	D520A D520A1 D520B D2520C	None	
	528	D528	R528A R528B R528C	
Tuolumne	81	None	None	New Don Pedro Reservoir
	540	D540A D540B	None	
	545	D545	R545A R545B R545C	
Merced	20	None	None	Lake McCLure
	561	D561	None	
	562	D562	None	
	564	None	R564A R546B	
	566	D566	R566	

A simple comparison of CALSIM II calculated flows and observed monthly average flow data from the USGS gage #11303500 on the SJR at Vernalis (USGS 2010) shows that CALSIM II provides a reasonable estimate of flow for the SJR at Vernalis. Figure 5.1 shows actual flow data from water years 1984 to 2003 and output from the CALSIM II representation of current conditions assuming hydrology for the same time period. This covers a period during which actual operations in the watershed were relatively similar (correlation coefficient of 0.912) to those modeled in the CALSIM II representation of current conditions. After 1984 all major eastside dams were completed and filled and their combined effect on flows at Vernalis should be present in the actual data. CALSIM II model output ends with water year 2003.

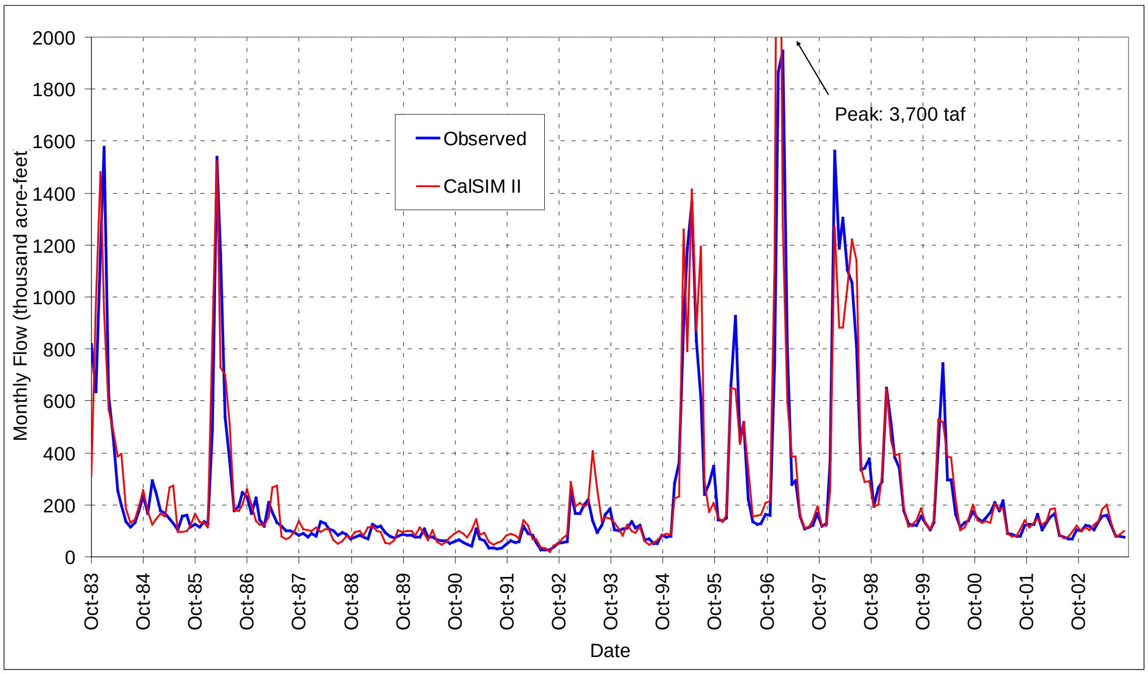


Figure 5.1. Observed Monthly Average Flow from USGS Gage #11303500 (SJR Near Vernalis) Compared to CALSIM II Model Output for SJR Flow at Vernalis

5.3 Water Supply Effects Model

This section describes the WSE model that was developed to estimate additional flows needed for, and the water supply effects of, different LSJR flow alternatives. The methods to calculate the flow targets for the flow objective alternatives and the resulting water supply effects are discussed, followed by a comparison with CALSIM II output data to validate the approach. Flow objective is the user-defined percent of unimpaired flow. Target flow is the variable monthly calculated flow that is needed to achieve the flow objective.

The WSE model is a monthly water balance spreadsheet model that calculates reductions in water supply in each tributary that would occur based upon user-defined inputs, output from CALSIM II, and flood storage rules. User defined inputs to the model include:

- Months for which flow objectives are to be set
- Monthly flow objectives as a percentage of unimpaired flow and caps for maximum or minimum monthly flows,
- Maximum annual diversion (based on CALSIM II maximum diversion)

- Diversion delivery rule curves which set annual diversions based on January storage behind rim dams (New Melones, New Don Pedro, and New Exchequer),
- Minimum annual end-of-September storage (no calculations based on this input; provides only a reference line).

Other inputs not defined by the user include:

- Baseline CALSIM II flows at the confluence with the SJR for calculating effects to river flows due to alternatives,
- Baseline CALSIM II monthly surface water diversions
- CALSIM II inflows to each rim reservoir
- CALSIM II evaporation from each rim reservoir
- CALSIM II accretions downstream from each rim reservoir
- CALSIM II monthly diversion patterns used to distribute the annual diversions
- Flood storage rule curves

Output from the WSE model, including annual and monthly diversions, river flows, and reservoir storage, are compared to CALSIM II baseline conditions to assess the effects of alternative flow objectives.

5.3.1 Calculation of Flow Targets to Meet Desired Flow Objectives

The WSE model first calculates flow targets for each tributary based on the user-defined percent of unimpaired flow. Flow objectives on the Stanislaus, Tuolumne, and Merced rivers, at their confluences with the SJR, are defined as a percentage of monthly unimpaired flow on each tributary for February through June. As described in Section 2.2.2, unimpaired flow is an estimate of the flow that would have existed in the rivers as currently configured if there were no diversions or storage. The monthly unimpaired flow for water years 1922 to 2003 available from DWR (2007a) are estimates of flow that would have entered each of the major upstream reservoirs. There are no estimates of the unimpaired flow for the tributaries at their confluence with the SJR, where the flow objectives are being established. However, the entire valley floor component of unimpaired flow is roughly three percent of the unimpaired flows of the major LSJR tributaries. The component of unimpaired flow that would otherwise be associated with accretions and other inputs downstream of the major reservoirs is therefore not expected to significantly alter the amount or timing of these flows. The unimpaired flows at the rim dams are therefore considered adequate for the purpose of establishing flow objectives.

The model user may also adjust the default minimum and maximum monthly flows. Minimum flows may be selected to limit what could be adverse fishery effects that could occur with otherwise unbounded minimum target flows. Maximum flows may be selected to limit the water supply effects that would occur to meet otherwise unbounded target flows. The default minimum monthly flows specified in the model are: 150 cfs for the Stanislaus River; 200 cfs for the Tuolumne River; and 150 cfs for the Merced River. These minimum flows generally reflect the existing regulatory requirements for minimum flows discussed in Section 3.1.3. The default maximum monthly target flows specified in the model are: 2,500 cfs for the Stanislaus River; 3,500 cfs for the Tuolumne River; and 2,000 cfs for the Merced River. These maximum flows generally reflect the median unimpaired flows in these three rivers during the February through June period (See Tables 2.10, 2.11, and 2.12). The minimum and maximum flows can be adjusted in the WSE model as needed. The model calculates and adds additional flow when required to maintain reservoirs below flood control storage requirements. Because of these adjustments, the overall percentage of unimpaired flow calculated by the WSE model might be slightly different than the user-defined percent of unimpaired flow. For months outside of the

February through June period, the target flows for the model are set to the CALSIM II monthly flow.

5.3.2 Calculation of Water Supply Effects

After the WSE model calculates target flows in each of the three rivers, it calculates the surface water diversions and the reservoir releases needed to: 1) meet these target flows; 2) satisfy surface water diversions; and 3) maintain storage levels within minimum pool and flood control limits. The rim reservoir storage level is then calculated using a flow balance equation to determine resulting changes in storage. These calculations are performed monthly using hydrologic conditions for water years 1922 to 2003. The elements of the water balance calculations are described in more detail below.

Flow Target

As described in Section 5.3.1, the flow target at the mouth of each tributary, QF_t, for a particular month is calculated as:

$$QF_t = UF_t \times Fa \begin{Bmatrix} \text{such that} & (UF_t \times Fa) \leq Qmx_t \\ \text{and} & (UF_t \times Fa) \geq Qmn_t \end{Bmatrix} \qquad \textit{(Eqn. 5.1)}$$

where:

UF_t is the DWR (2007a) unimpaired flow at time t;
Fa is the target percentage of unimpaired flow defined by the user; and
Qmx_t and Qmn_t are the user defined caps for maximum and minimum monthly flows respectively at time t.

Surface Water Diversions

The surface water diversions, D_t, for a particular month are calculated using:

$$D_t = D_{\max} \times Ka_t \times Kb \qquad \textit{(Eqn. 5.2)}$$

where:

D_{max} is the maximum annual diversion for each tributary defined by the user and based upon CALSIM II data; default values are 750 TAF on the Stanislaus; 1,100 TAF on the Tuolumne; and 625 TAF on the Merced).

Ka_t is the monthly diversion pattern used to distribute the annual diversions for each month at period t (derived from CALSIM II output using the median monthly sum of diversions).

Kb is the percent of maximum diversions for each year, set by a user-defined diversion delivery rule curve of January storage level in the rim reservoir of the associated river. The storage at time t is input to the rule curve and the corresponding percent of maximum diversions (Kb) to be delivered over the following 12 months is interpolated as a straight line between points defined by the user on the rule curve. This curve generally allows for greater percentage of diversions at higher storage levels and requires diversions to be reduced at lower storage levels. For increasing percentage of unimpaired flow objectives a more restrictive diversion delivery rule curve will be needed to meet the objectives.

Reservoir Releases

The reservoir release needed to satisfy the target flow and diversions is determined on each tributary as:

$$R_t = QF_t + D_t + RS_t - QAC_t \quad \textit{(Eqn. 5.3)}$$

where:

RS_t is the additional reservoir spill release required to stay below flood stage (as defined by the USACE flood storage curves); and

QAC_t is the sum of CALSIM II accretions (including return flows) and depletions downstream of the rim dam in month t. Accretions and return flows are assumed unchanged with respect to CALSIM II.

Reservoir Storage Levels

Storage levels behind the rim dams are initially set to CALSIM II levels at the end of December 1921. The reservoir storage at the end of the following month, and each subsequent month, S_t, is calculated with a water balance equation on each tributary using:

$$S_t = S_{t-1} + QINF_t - R_t - EV_t \quad \textit{(Eqn. 5.4)}$$

where:

S_{t-1} is the storage of the previous month;
$QINF_t$ is the CALSIM II inflow to each reservoir; and
EV_t is the CALSIM II evaporation from the rim reservoir at time t.

River Flows

The flow achieved by the WSE model at the confluence of each tributary with the SJR is determined as follows:

$$Q_t = QF_t + RS_t \quad \textit{(Eqn. 5.5)}$$

Outside of the February through June period Q_t is generally identical to the CALSIM II flow but may add additional flood spills triggered by a higher storage calculated by the WSE model relative to CALSIM II. For an example of the effects due to a 40% of unimpaired flow objective, Figure 5.2 displays a time series of CALSIM II baseline and WSE model flows and storages for WY 1997 to WY 2000 that would be needed to achieve the target flow.

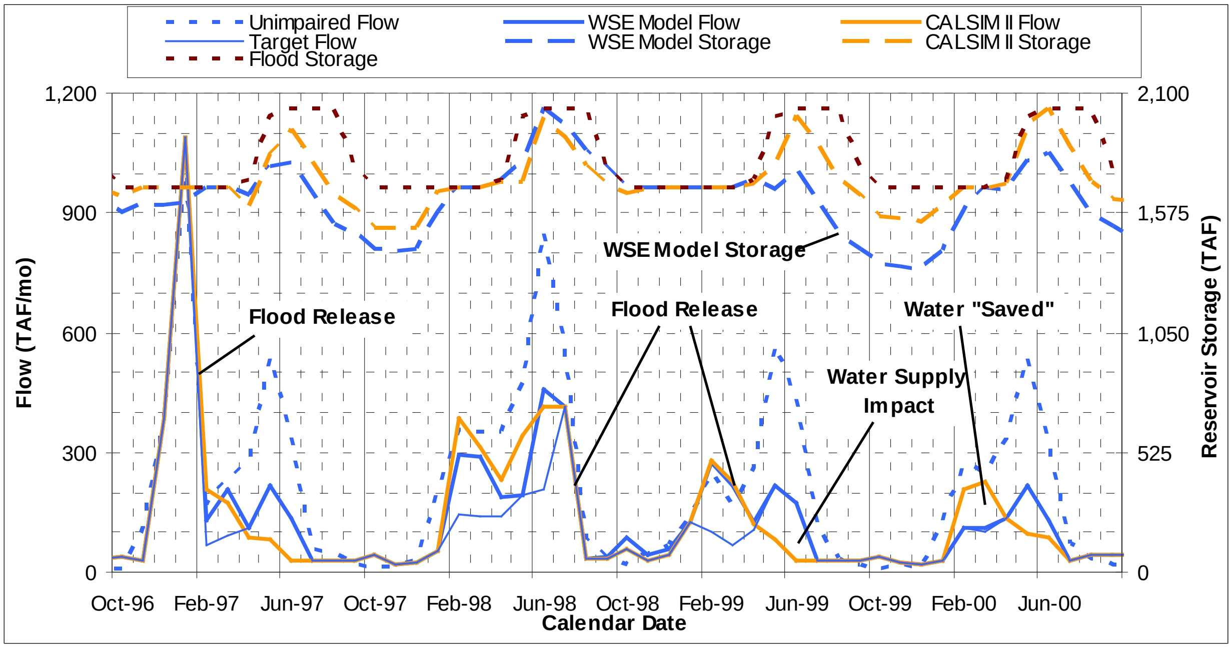


Figure 5.2. Monthly Unimpaired Flow and 40% of Unimpaired Flow Objective Alternative Compared to CALSIM II Flow on the Tuolumne River at CALSIM II Node C545

5.3.3 Comparison of Water Supply Effects Model

This section describes the steps that were taken to compare the WSE model with the CALSIM II baseline results. First, the approximate percentage of unimpaired flow that is most similar to CALSIM II river flows was determined for each of the three rivers. This was done by comparing exceedance plots for WSE and CALSIM II modeled February through June flows. The target percentage of unimpaired flow for the WSE model was adjusted until its exceedance plot matched closely with the CALSIM II plot. As seen in Figures 5.3c, 5.4c, and 5.5c the exceedance plot of CALSIM II February through June flows closely matches the WSE model exceedance plots for the 40% of unimpaired flow target on the Stanislaus River and the 20% of unimpaired flow target on both the Tuolumne and Merced rivers.

In the second step, a diversion delivery rule curve was developed that closely matched the relationship between January storage levels for the major reservoirs on each river against annual diversions as determined from CALSIM II output. The CALSIM II annual diversions were divided by the maximum annual diversion determined for each tributary, resulting in a percent of maximum annual diversion actually delivered each year. This result was then plotted against January storage in Figures 5.3d, 5.4d, and 5.5d. These results show that when storage is lower, a lower percentage of the maximum annual diversion will be delivered that year. In general, sharp cutbacks to diversions begin to occur when reservoir storage is less than roughly one half of the full capacity. Using these plots as guides, diversion delivery rule curves were developed that resulted in annual diversion exceedance curves that matched those of CALSIM II. The annual diversion exceedance curves for CALSIM II and the WSE model are shown in Figures 5.3a, 5.4a, and 5.5a.

The final step in the comparison process was to iteratively refine the diversion delivery rule curves such that end-of-September storages (carryover storage) from the WSE model matched CALSIM II end-of September storages as closely as possible. Figures 5.3b, 5.4b, and 5.5b show exceedance plots of CALSIM II and the WSE model end-of-September storage, and the target minimum end-of-September storage as a reference line. Minimum storage levels were set for each reservoir, and the number of times storages fell below this level were tabulated. The diversion delivery rule curves were further adjusted so the number of times storages dropped below the minimum level were nearly the same between the two models.

The comparison of results in Figures 5.3, 5.4, and 5.5 demonstrates that the WSE model generates similar results to CALSIM II using similar input data and operating assumptions.

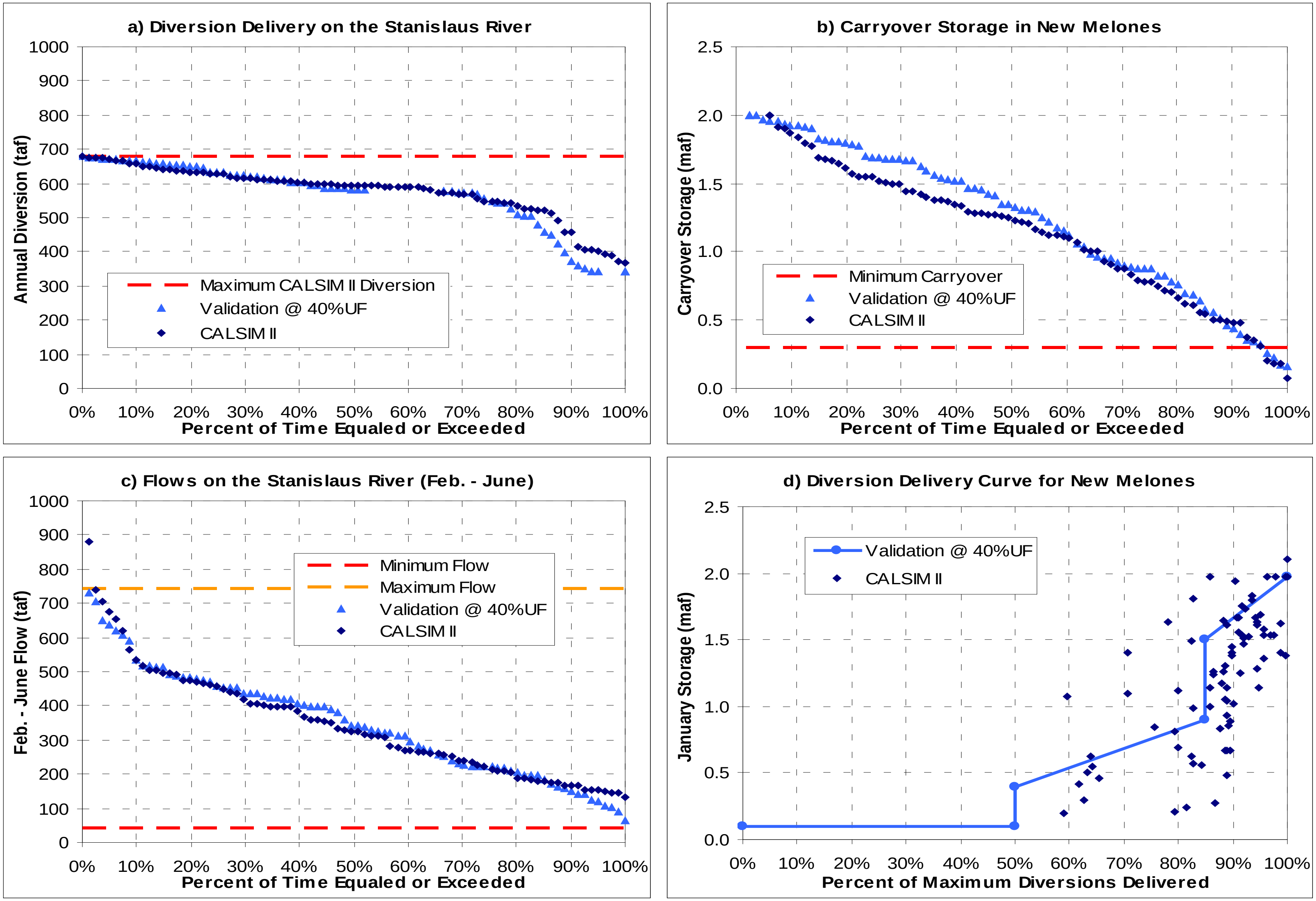


Figure 5.3. Validation of WSE Model Against CALSIM II Output on the Stanislaus River for A) Annual Diversion Delivery, B) End-of-September Storage, C) Flow at CALSIM II Node 528, D) Diversion Delivery Rule Curve Based on January Storage Level

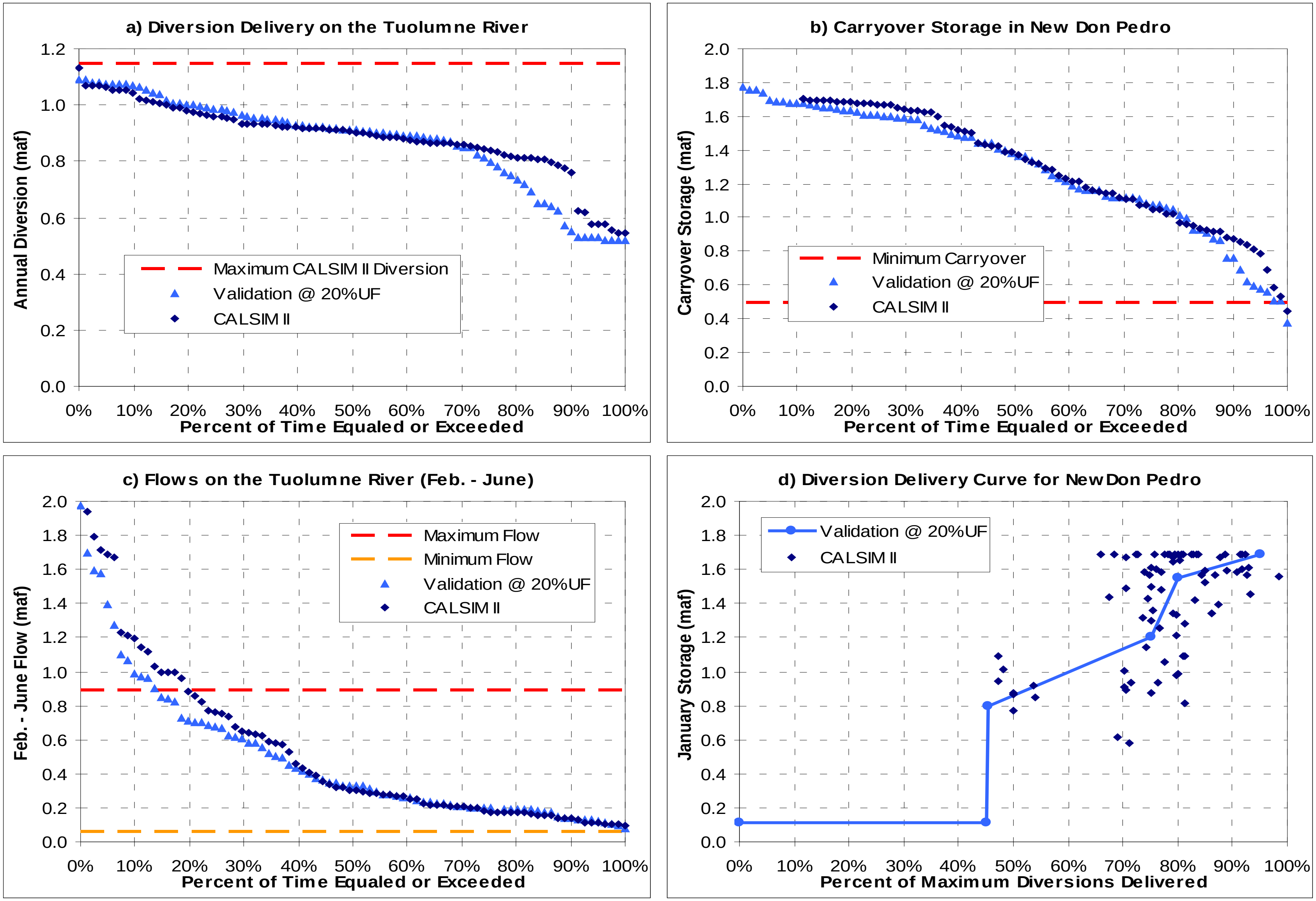


Figure 5.4. Validation Of WSE Model Against CALSIM II Output on the Tuolumne River for A) Annual Diversion Delivery, B) End-of-September Storage, C) Flow at CALSIM II Node 528, D) Diversion Delivery Rule Curve Based on January Storage Level

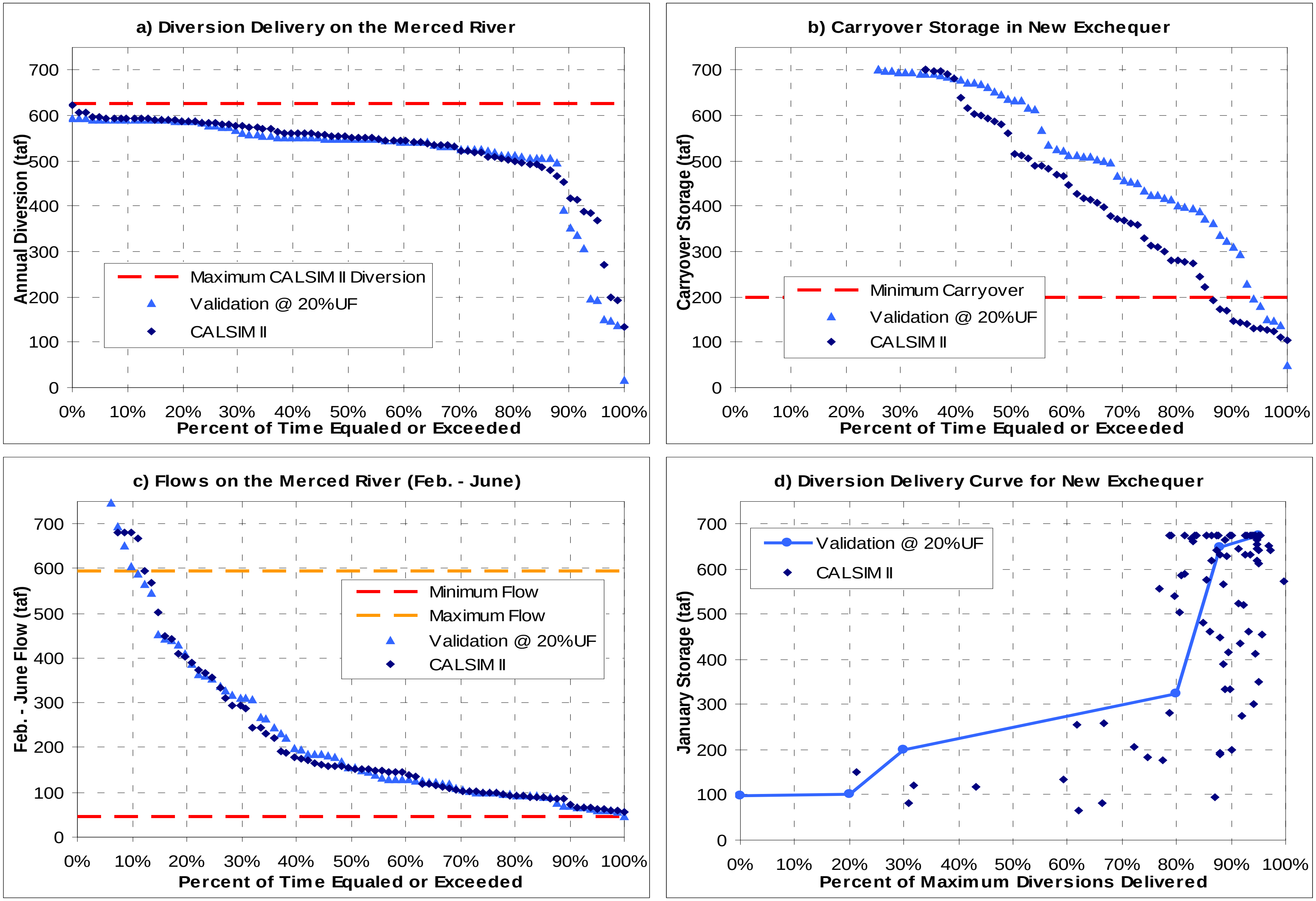


Figure 5.5. Validation of WSE Model Against CALSIM II Output on the Merced River for A) Annual Diversion Delivery, B) End-of-September Storage, C) Flow at CALSIM II Node 528, D) Diversion Delivery Rule Curve Based on January Storage Level

5.4 Summary of Annual Water Supply Effects

Tables 5.2, 5.3, and 5.4 present statistics for estimated water supply effects using the WSE model for the 20%, 40%, and 60% of unimpaired flow targets. The tables show the total annual and February through June unimpaired flow, and total annual CALSIM II diversion volumes for reference. These tables can be used to compare the effect that various flow targets would have on annual diversions and annual flow volumes relative to baseline CALSIM II diversions and flows. These tables also provide the maximum annual diversions for each tributary, as defined by the user (based upon CALSIM II data). For the Stanislaus River, the maximum annual diversion was set at 750 TAF rather than the 680 TAF maximum set in CALSIM II baseline. This additional amount includes the full Stockton East Water District diversion amount, not fully incorporated in the CALSIM II scenario. The maximum Tuolumne diversion was set to 1,100 TAF and the maximum Merced diversion was set at 625 TAF.

The results of the 20%, 40%, and 60% of unimpaired flow targets calculated using the WSE model, along with the CALSIM II representation of baseline for reference, are also presented in exceedance plots for the 82 years of CALSIM II hydrology for Figures 5.6, 5.7, and 5.8 are exceedance plots for: a) total annual diversion deliveries, b) carryover storage, and c) on total annual flow volumes for each river. These figures also show the diversion delivery rule curves (as a function of January reservoir storage) for each of the rivers. The diversion delivery rule curves are roughly linear. As expected, it can be seen that increasing LSJR flow alternatives reduces the volume of annual diversions and increases the total annual volume of flow at the confluence with the SJR in each river.

Table 5.2. Estimated Water Supply Effects (TAF) on the Stanislaus River Associated with Meeting a Range of LSJR Flow Alternatives in Comparison to CALSIM II Annual Diversion Volumes and Unimpaired February to June flow volumes

	Unimpaired Flow (TAF)		Annual Diversions by Percent Unimpaired Flow (TAF)				Feb.–Jun. Flows by Percent Unimpaired Flow (TAF)			
	Annual	Feb.–Jun.	CALSIM II Baseline	20%	40%	60%	CALSIM II Baseline	20%	40%	60%
Average	1118	874	577	672	580	461	355	228	348	465
Minimum	155	136	368	439	333	247	131	45	64	87
90%tile	456	381	455	534	407	308	167	83	152	228
80%tile	591	497	537	567	471	367	193	105	199	298
75%tile	636	550	545	619	484	389	217	113	220	330
70%tile	679	563	568	644	503	401	241	122	225	338
60%tile	891	739	589	691	563	445	270	162	302	435
50%tile	1092	817	593	719	614	486	325	188	340	490
40%tile	1260	997	603	733	636	508	377	212	404	529
30%tile	1362	1078	615	743	672	532	416	238	434	569
25%tile	1472	1130	627	745	683	544	454	254	454	576
20%tile	1560	1182	634	746	693	562	474	298	467	597
10%tile	1916	1461	656	748	716	572	531	411	523	653
Maximum	2950	2005	678	750	742	594	1196	1025	919	1057
Maximum Annual Diversion			750	750	750	750				

Table 5.3. Estimated Water Supply Effects (TAF) on the Tuolumne River Associated with Meeting a Range of LSJR Flow Alternatives in Comparison to CALSIM II Annual Diversion Volumes and unimpaired February to June flow volumes

	Unimpaired Flow (TAF)		Annual Diversions by Percent Unimpaired Flow (TAF)				Feb. – Jun Flows by Percent Unimpaired Flow (TAF)			
	Annual	Feb.–Jun.	CALSIM II Baseline	20%	40%	60%	CALSIM II Baseline	20%	40%	60%
Average	1849	1409	885	853	682	527	540	496	670	814
Minimum	384	330	542	422	317	172	93	81	139	199
90%tile	835	674	762	572	456	281	137	137	270	405
80%tile	1052	894	814	688	519	356	170	193	384	536
75%tile	1106	961	839	767	548	396	178	198	390	582
70%tile	1165	982	858	792	600	432	204	214	411	598
60%tile	1413	1186	877	844	666	496	257	245	486	672
50%tile	1776	1299	906	911	724	565	304	333	625	763
40%tile	2031	1585	920	953	763	606	449	447	678	865
30%tile	2197	1709	935	987	807	666	648	608	771	923
25%tile	2367	1756	959	992	824	680	757	686	830	970
20%tile	2486	1857	978	1001	848	698	878	749	912	1006
10%tile	3099	2194	1042	1026	868	709	1189	1011	1127	1214
Maximum	4632	2904	1132	1045	880	715	2408	1975	2115	2209
Maximum Annual Diversion			1100	1100	1100	1100				

Table 5.4. Estimated Water Supply Effects (TAF/year) on the Merced River Associated with Meeting a Range of LSJR Flow Alternatives in Comparison to CALSIM II Annual Diversion Volumes and Unimpaired February to June Flow Volumes

	Unimpaired Flow (TAF)		Annual Diversions by Percent Unimpaired Flow (TAF)				Feb.–Jun. Flows by Percent Unimpaired Flow (TAF)			
	Annual	Feb.–Jun.	CALSIM II Baseline	20%	40%	60%	CALSIM II Baseline	20%	40%	60%
Avg	956	745	527	517	440	364	270	264	344	419
Minimum	151	128	134	260	203	130	57	45	64	87
90%tile	408	326	421	368	292	209	74	69	130	196
80%tile	489	431	499	446	359	274	93	94	179	258
75%tile	524	458	511	474	374	283	99	99	184	275
70%tile	561	470	525	489	408	325	104	110	191	283
60%tile	668	568	545	539	442	354	141	127	231	335
50%tile	895	646	552	567	477	385	154	155	281	382
40%tile	1080	824	561	573	491	413	176	196	346	442
30%tile	1165	924	578	582	504	439	292	309	385	484
25%tile	1223	978	584	585	517	448	350	343	409	501
20%tile	1399	1033	588	589	523	458	402	373	459	523
10%tile	1712	1223	593	592	529	465	678	593	605	621
Maximum	2786	1837	624	594	531	469	1320	1231	1274	1305
Maximum Annual Diversion			625	625	625	625				

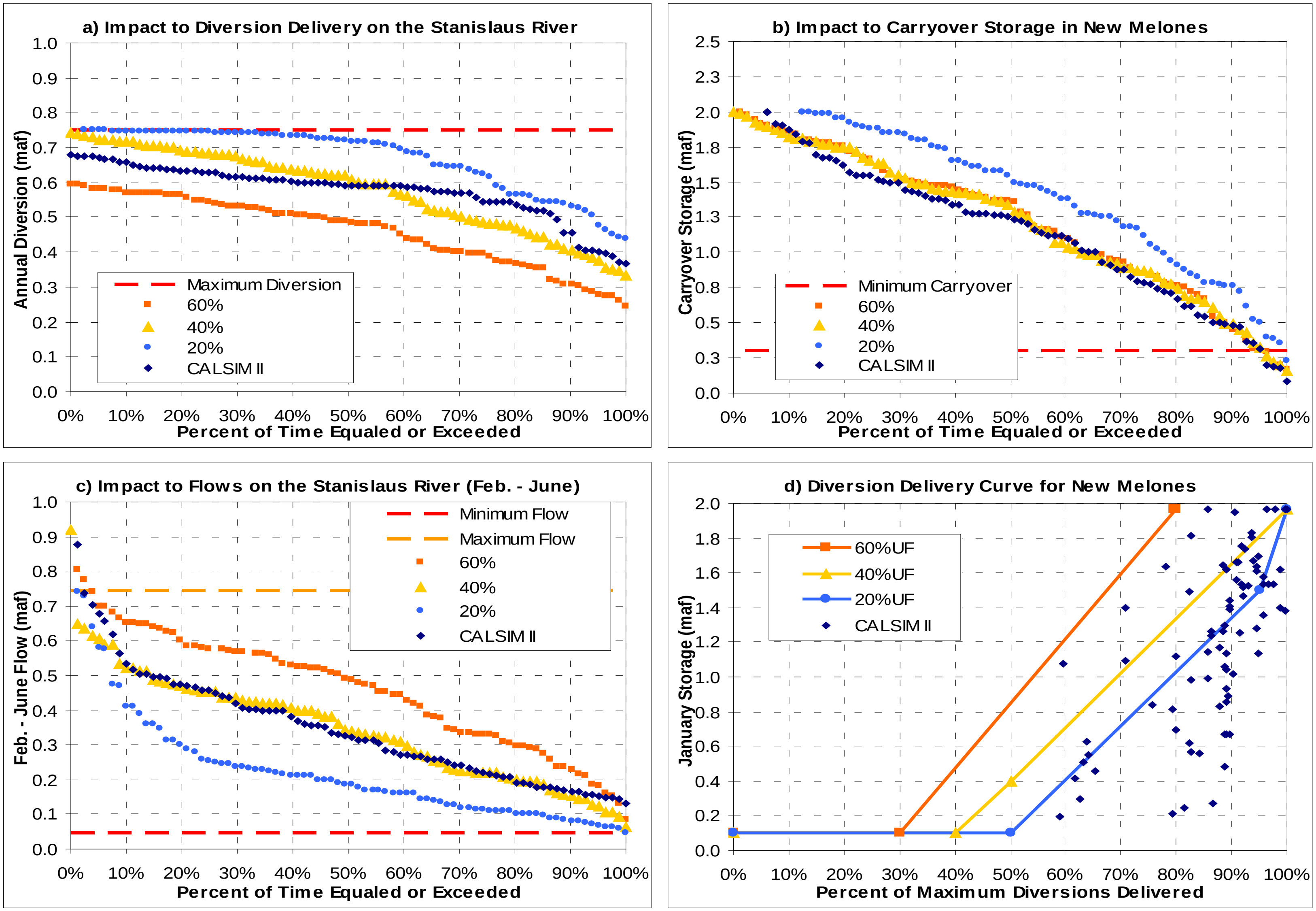


Figure 5.6. Results of Impacts for Illustrative Flow Objective Alternatives of 20%, 40% and 60% of Unimpaired Flow on the Stanislaus River

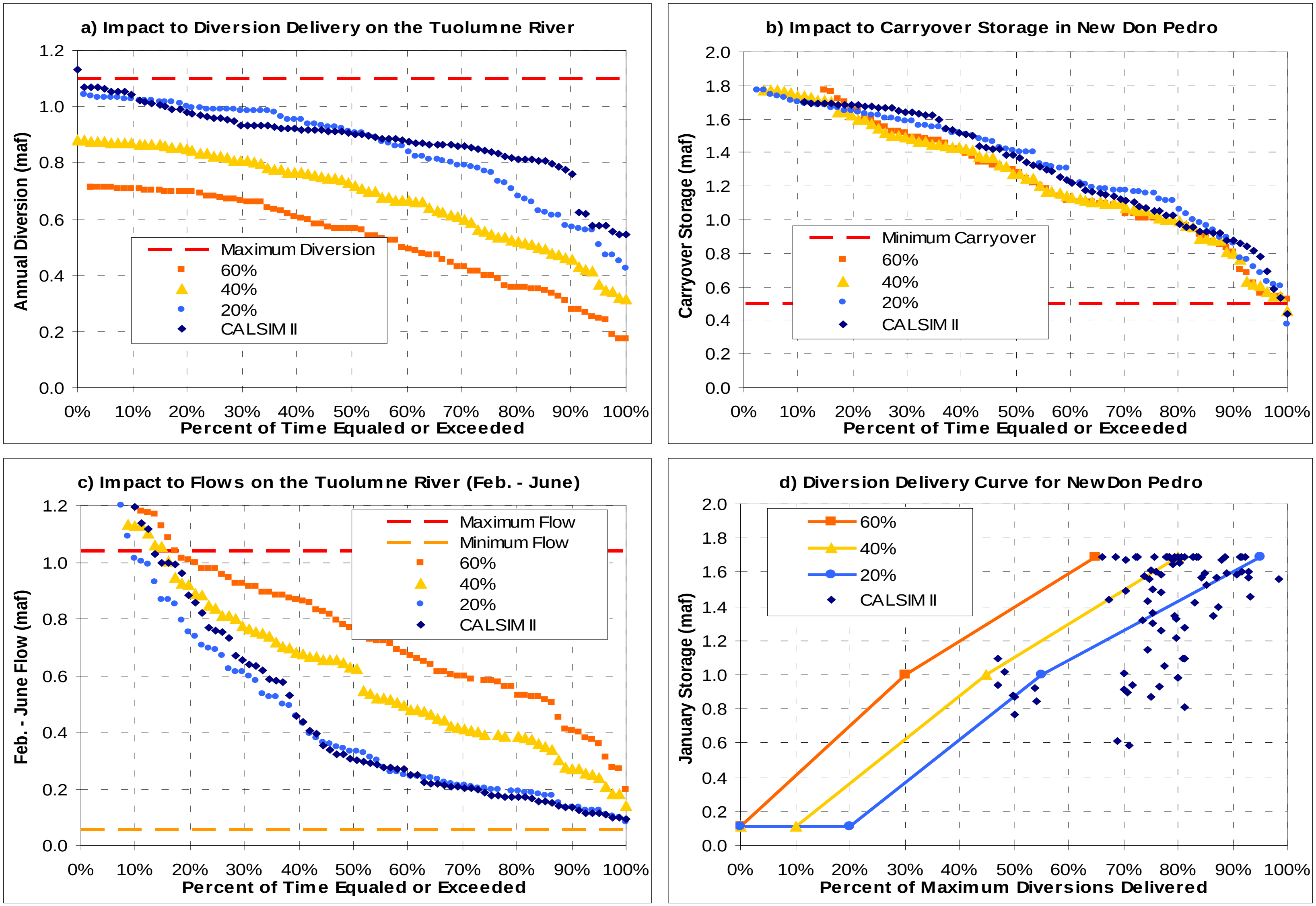


Figure 5.7. Results of Impacts for Illustrative Flow Objective Alternatives of 20%, 40% and 60% of Unimpaired Flow on the Tuolumne River

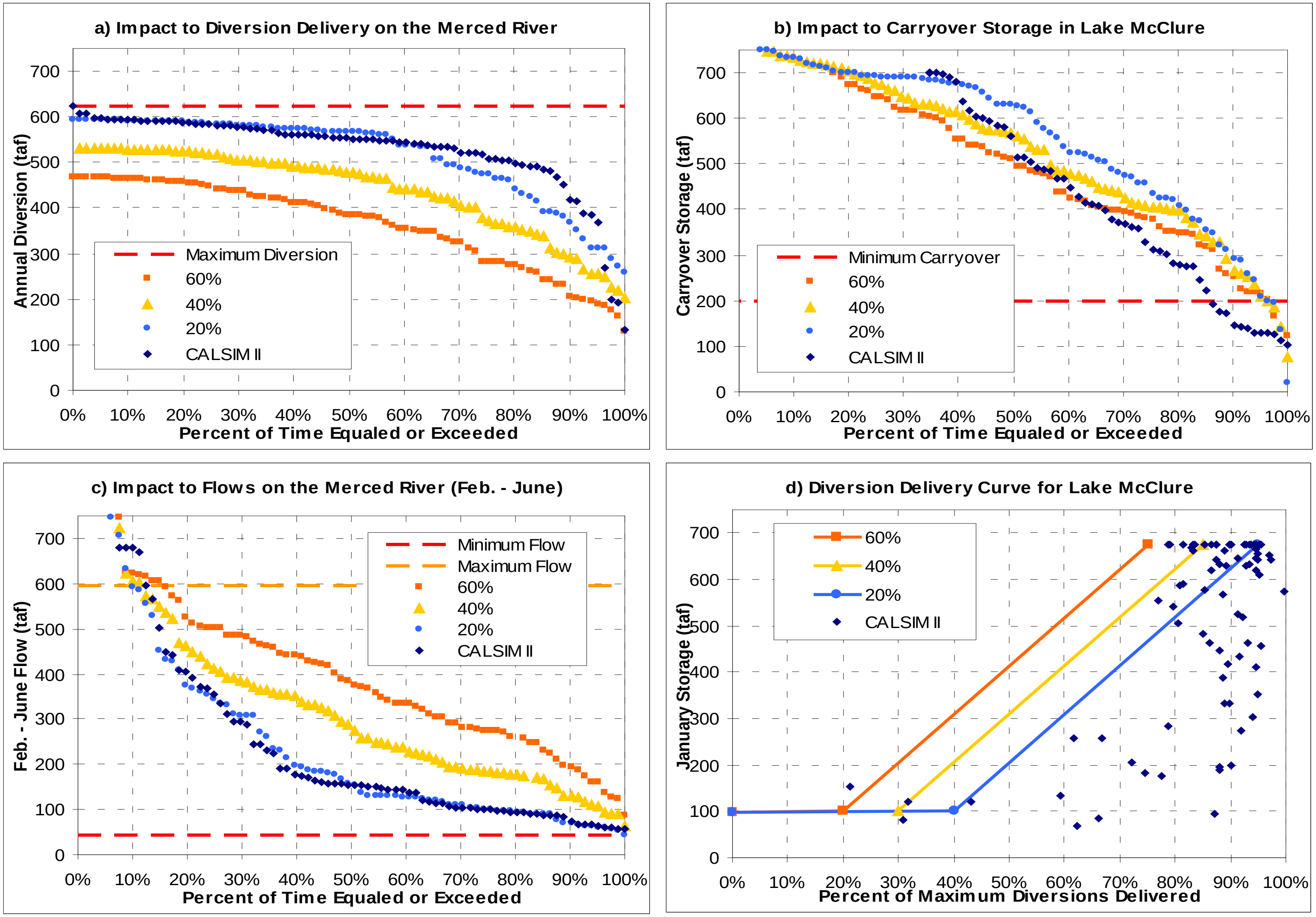


Figure 5.8. Results of Impacts for Illustrative Flow Objective Alternatives of 20%, 40% and 60% of Unimpaired Flow on the Merced River

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Appendix A. Draft Objectives and Program of Implementation

A.1. Modifications to the San Joaquin River Fish and Wildlife Flow Objectives, and the Program of Implementation

The following is a description of potential draft modifications to SJR flow objectives for the protection of fish and wildlife beneficial uses, the program of implementation for those objectives, and the monitoring and special studies program included in the 2006 Bay-Delta Plan. The exact language of alternative changes may change and will be provided in the draft Substitute Environmental Document prepared for this project.

A. San Joaquin River Fish and Wildlife Flow Objectives

The existing numeric SJR flow objectives at Vernalis during the February through June time frame contained within Table 3 of the 2006 Bay-Delta Plan would be replaced with a narrative SJR flow objective (refer to Table A-1). Draft language for the narrative SJR flow objective is included below:

> *Maintain flow conditions from the SJR Watershed to the Delta at Vernalis, together with other reasonably controllable measures in the SJR Watershed sufficient to support and maintain the natural production of viable native SJR watershed fish populations migrating through the Delta. Specifically, flow conditions shall be maintained, together with other reasonably controllable measures in the SJR watershed, sufficient to support a doubling of natural production of Chinook salmon from the average production of 1967-1991, consistent with the provisions of State and federal law. Flow conditions that reasonably contribute toward maintaining viable native migratory SJR fish populations include, but may not be limited to, flows that more closely mimic the hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur. Indicators of viability include abundance, spatial extent or distribution, genetic and life history diversity, migratory pathways, and productivity.*

A.1.1. Program of Implementation

Delete existing text in Chapter IV. Program of Implementation, A. Implementation Measures within State Water Board Authority, 3. River Flows: SJR at Airport Way Bridge, Vernalis, and add the following new text to Section B. Measures Requiring a Combination of State Water Board Authorities and Actions by Other Agencies:

River Flows: San Joaquin River at Airport Way Bridge, Vernalis

The narrative SJR flow objective is to be implemented through water right actions, water quality actions, and actions by other agencies in an adaptive management framework informed by required monitoring, special studies, and reporting. The purpose of the implementation framework is to achieve the narrative SJR flow objective by providing a flow regime that more closely mimics the shape of the unimpaired hydrograph, including more flow of a more natural spatial and temporal pattern; providing for adaptive management in order to respond to changing information on flow needs and to minimize water supply costs; and allowing for and encouraging coordination and integration of existing and future regulatory processes.

Implementation of Flows February through June

The State Water Board has determined that more flow of a more natural pattern is needed from February through June from the SJR watershed to Vernalis to achieve the narrative SJR flow objective. Specifically, more flow is needed from the existing salmon and steelhead bearing tributaries in the SJR watershed down to Vernalis in order to provide for connectivity with the Delta and more closely mimic the flow regime to which native migratory fish are adapted. Salmon bearing tributaries to the San Joaquin River currently include the Stanislaus, Tuolumne, and Merced Rivers[1].

Thus, the State Water Board has determined that approximately X percent (e.g., 20-60 percent)[2] of unimpaired flow is required from February through June from the Stanislaus, Tuolumne, and Merced Rivers on a X-day average (e.g., 14-day)[2] to a maximum of X cubic-feet per second (cfs) (e.g., 20,000 cfs)[2] at Vernalis, unless otherwise approved by the State Water Board as described below. This flow is in addition to flows in the SJR from sources other than the Stanislaus, Tuolumne, and Merced Rivers. In addition, the State Water Board has determined that base flows of X cfs (e.g., 1,000 cfs)[2] on a X-day average (e.g., 14-day)[2] is required at Vernalis at all times during the February through June period. Water needed to achieve the base flows at Vernalis should be provided on a generally proportional basis from the Stanislaus, Tuolumne, and Merced Rivers. The actions necessary to meet the above requirements are described below.

Assignment of Responsibility for Actions to Achieve the Objective

The State Water Board will require implementation of the narrative objective through water rights actions, FERC hydropower licensing processes, or other processes. In order to assure that the water rights and FERC processes are fully coordinated, implementation of the narrative flow objective may be phased, in order to achieve full compliance with the narrative objective by the completion of the FERC proceedings on the Merced and Tuolumne Rivers, or no later than 2020, whichever occurs first.

To inform the implementation process for the narrative flow objective, the State Water Board will establish a workgroup consisting of State, federal, and local agency staff, stakeholders, and other interested persons with expertise in fisheries management, unimpaired flows, and operations on the Stanislaus, Tuolumne, and Merced Rivers to develop recommendations for establishing water right, FERC, and other related requirements to implement the narrative flow objective in a manner that best achieves the narrative flow objective while minimizing water supply costs. Any recommendation developed by the workgroup shall be submitted to the State Water Board within six months (placeholder date pending additional review) from the date of the State Water Board's approval of this amendment to the Bay-Delta Plan in order to be considered in future State Water Board water right and FERC licensing proceedings.

Although the most downstream compliance location for the SJR flow objective is at Vernalis, the objective is intended to protect migratory fish in a larger area, including areas within the Delta

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[1] Currently, the San Joaquin River does not support salmon runs upstream of the Merced River confluence. However, pursuant to the San Joaquin River Restoration Program (SJRRP), spring-run Chinook salmon are planned to be reintroduced to this reach no later than December 31, 2012. Flows needed to support the reintroduction are being determined and provided through the SJRRP. During the next review of the Bay-Delta Plan, the State Water Board will consider information made available through the SJRRP process, and any other pertinent sources of information, in evaluating the need for any additional flows from the upper San Joaquin River Basin to contribute to the narrative San Joaquin River flow objective.

[2] A placeholder "X" value with examples are shown for several parameters in this draft. The final program of implementation will have a value based on subsequent analyses.

where fish that migrate to or from the SJR watershed depend on adequate flows from the SJR and its tributaries. To assure that flows required to meet the SJR narrative flow objective are not rediverted downstream for other purposes, the State Water Board may take water right and other actions to assure that those flows are used for their intended purpose. In addition, the State Water Board may take actions to assure that provision of flows to meet the narrative SJR flow objective do not result in redirected impacts to groundwater resources, potentially including requiring groundwater management plans, conducting a reasonable use proceeding, or other appropriate actions.

Adaptive Management of Flows during the February through June Period

Implementation of the narrative SJR flow objective will include the adaptive management of flows during the February through June period in order to achieve the narrative flow objective and minimize water supply impacts. Any adaptive management of flows must not result in flows of less than approximately X percent (e.g., 10 percent)[2] of unimpaired flow from each of the Stanislaus, Tuolumne, and Merced Rivers over the entire February through June period, up to a maximum of X cfs (e.g., 20,000 cfs)[2] at Vernalis. This flow is in addition to flows in the SJR from sources other than the Stanislaus, Tuolumne, and Merced Rivers.

The State Water Board or other responsible entity will establish a coordinated operations group (COG), which will be comprised of the DFG; NMFS; USFWS; representatives of water users on the Stanislaus, Tuolumne, and Merced Rivers, and any other representatives deemed appropriate by the State Water Board. The COG must agree to any adaptive management of flows, subject to final approval by the Executive Director of the State Water Board. Other interested persons may provide information to inform the COG process and the Executive Director’s approval of any adaptive management. In order to inform implementation actions, State Water Board staff will work with the COG and other interested persons to develop recommendations for an adaptive management process, to be submitted for approval by the Executive Director of the State Water Board within 12 months (placeholder date pending additional review) following the board’s approval of this amendment to the Bay-Delta Plan. By January 1 of each year, the COG also must prepare an adaptive management plan for the coming February through June season of that year for approval by the Executive Director.

In addition, based on future monitoring and evaluation to determine flow needs to achieve the narrative SJR flow objective, the State Water Board may approve modifications to the required percentage of unimpaired flows, base flows, and upper end of flows at which a percentage of unimpaired flows are no longer required. Specifically, FERC licensing proceedings on the Merced and Tuolumne Rivers are expected to yield specific information on flow needs for those tributaries. The State Water Board expects this information to inform specific measures needed to implement the narrative SJR flow objective. To obtain similar information for the Stanislaus River, the State Water Board will require the development of any additional information needed to inform specific flow needs on the Stanislaus River. The State Water Board will use the specific in-stream flow information developed for each of the tributaries to determine how to adaptively manage flows on the SJR to meet the narrative SJR flow objective and integrate Bay-Delta Plan flow requirements with FERC licensing requirements.

Any modifications to the required percentage of unimpaired flows, base flows, and upper end of flows at which a percentage of unimpaired flows are no longer required shall not result in a change of more than: X percent (e.g., 10 percent)[2] of unimpaired flow from any one tributary over the entire February through June period; more than plus or minus X cfs (e.g., 200 cfs)[2] at Vernalis for the base flow requirement; and plus or minus X cfs (e.g., 5,000 cfs)[2] for the upper end of the flow requirement at Vernalis without modification to this program of implementation in accordance with applicable water quality control planning processes. Additional specific exceptions for drought considerations or unforeseen disaster circumstances may also be approved by the State Water Board.

Implementation of Flows during October

The State Water Board will reevaluate the assignment of responsibility for meeting the October pulse flow requirement during the water right proceeding or FERC licensing proceeding following adoption of this plan amendment in order to optimize protection for fish and wildlife beneficial uses and minimize impacts to water supplies.

The State Water Board will require persons responsible for meeting the October pulse flow requirement to conduct monitoring and special studies (discussed below) to determine what, if any, changes should be made to the October pulse flow requirement and its implementation to achieve the narrative SJR flow objective. Based on this information, the State Water Board will evaluate the need to modify the October pulse flow requirement during the next review of the Bay-Delta Plan.

Implementation During Other Times of Year (July through September and November through January)

The State Water Board has not established flow requirements for the July through September and November through January time frames that are necessary to implement the narrative SJR flow objective. The State Water Board will require monitoring and special studies (discussed below) during the water rights and FERC processes to be conducted to determine what, if any, flow requirements should be established for this time period to achieve the narrative SJR flow objective. Results from the monitoring and special studies program shall be used to inform the FERC proceedings on the Merced and Tuolumne Rivers and to inform the next review of the SJR flow objectives in the Bay-Delta Plan.

Actions by Other Agencies

To be developed. This may include, but is not limited to, actions such as: habitat restoration (floodplain restoration, gravel enhancement, riparian vegetation management, passage, etc.), hatchery management, predator control, water quality measures, ocean/riverine harvest measures, recommendations for changes to flood control curves, and barrier operations.

A.1.2. New Special Studies, Monitoring, and Reporting Requirements

Add new section with the text below to the end of Chapter IV. Program of Implementation, Section D. Monitoring and Special Studies Program:

San Joaquin River Fish and Wildlife Flow Objectives

In order to inform real time adaptive management and long-term management of flows on the SJR for the protection of fish and wildlife beneficial uses, the State Water Board will require the development of a comprehensive monitoring, special studies, evaluation, and reporting program, referred to as the SJR Monitoring and Evaluation Program (SJRMEP). During the water right and FERC proceedings to implement the narrative SJR flow objective, the State Water Board will establish responsibility for development and implementation of the SJRMEP. The SJRMEP shall be developed with input from the COG and shall be subject to approval by the Executive Director of the State Water Board. The SJRMEP shall at a minimum include monitoring, special studies, and evaluations of flow related factors on the viability of native SJR watershed fish populations, including abundance, spatial extent (or distribution), diversity (both genetic and life history), and productivity. The SJRMEP shall include regular reporting and evaluation of monitoring and special studies data. Evaluations of monitoring and special studies data shall be subject to regular outside scientific review. The Executive Director of the State Water Board may direct or approve changes to the SJRMEP based on monitoring and evaluation needs. The SJRMEP shall be integrated and coordinated with existing monitoring and special studies programs on the SJR, including monitoring and special studies being conducted pursuant to federal biological opinion requirements and as part of the FERC licensing proceedings for the Merced and Tuolumne Rivers.

Specifically, the SJRMEP shall evaluate the effect of flow conditions at various times of year, including spring (February through June), fall (including October), summer, and winter months on the abundance, spatial extent, diversity, and productivity of native SJR Basin fish species in order to inform adaptive management and future changes to the SJR flow objectives and their implementation

A.2. Modifications to the Southern Delta Agricultural Water Quality Objectives, and the Program of Implementation

The following is a description of potential draft modifications to southern Delta water quality objectives for the protection of agricultural beneficial uses, the program of implementation for those objectives, and the monitoring and special studies program included in the 2006 Bay-Delta Plan. The exact language of alternative changes may change and will be provided in the draft Substitute Environmental Document prepared for this project.

A.2.1. Southern Delta Agricultural Water Quality Objectives

The existing water quality objectives for agricultural beneficial uses are contained within Table A-2 of the 2006 Bay-Delta Plan. Draft revisions to the numeric objectives and the addition of a narrative water level and circulation objective are presented in Table A-2.

A.2.2. Program of Implementation

Replace entirely Chapter IV. Program of Implementation, B. Measures Requiring a Combination of State Water Board Authorities and Actions by Other Agencies, 1. Southern Delta Agricultural Salinity Objectives with the following:

Southern Delta Agricultural Water Quality Objectives

Elevated salinity in the southern Delta is caused by various factors, including low flows; salts imported to the San Joaquin Basin in irrigation water; municipal discharges; subsurface accretions from groundwater; tidal actions; diversions of water by the SWP, CVP, and local water users; channel capacity; and discharges from land-derived salts, primarily from agricultural drainage. Salinity in the southern Delta is also affected by evapo-concentration of salts due to local agricultural operations and to a lesser extent by local municipal wastewater treatment plant discharges. Poor flow/circulation patterns in the southern Delta waterways also cause localized increases in salinity concentrations.

The numeric salinity objectives and narrative water level and circulation objectives for the southern Delta listed in Table A-2 of the Bay-Delta Plan address salinity, water levels, and circulation to provide reasonable protection of the agricultural beneficial use in the southern Delta.

State Water Board Regulatory Actions
The southern Delta water quality objectives for protection of agricultural beneficial uses listed in Table A-2 will be implemented as follows:

i. Numeric salinity objectives for the San Joaquin River at Vernalis will continue to be implemented by conditioning the water rights of USBR on compliance with this objective.

ii. Narrative water level and circulation objectives for the southern Delta will be implemented by conditioning the water rights of the USBR and DWR on compliance with this objective through the following measures:

   a. Continued operation of the agricultural barriers at Grant Line Canal, Middle River, and Old River at Tracy, or other reasonable measures, for the purpose of improving surface water levels and circulation in the southern Delta that would otherwise be impacted by operations of the CVP and SWP. This shall include modified design and/or operations as determined by the Comprehensive Operations Plan described below.

   b. Completion of the Monitoring Special Study, Modeling Improvement Plan, and Monitoring and Reporting Protocol described in Section D of the Program of Implementation: *'Monitoring and Special Studies Program'* under a new part 2: *'Southern Delta Water Quality'*.

   c. Development and implementation of a Comprehensive Operations Plan to maximize circulation (i.e. minimize null zones) in order to avoid localized concentration of salts associated with agricultural water use and municipal discharges. The plan shall also address water level issues, and once approved, will supersede the water level and quality response plans required under D-1641. This plan shall include detailed information regarding the configuration and operations of any facilities relied upon in the plan, and shall identify specific water level and circulation performance goals. The plan shall also identify a method to conduct ongoing assessment of the performance and potential improvements to the facilities or their operation. The criteria for assessing compliance with the performance goals should be coordinated with the Monitoring and Reporting Protocol. DWR and USBR shall work together with the South Delta Water Agency (SDWA), State Water Board staff, other state and federal resource agencies, and local stakeholders as appropriate to develop this plan, and hold periodic coordination meetings throughout implementation of the plan.

      The State Water Board will request DWR and USBR to submit the Comprehensive Operations Plan to the Executive Director for approval within six months from the date of State Water Board approval of this amendment to the Bay-Delta Plan. Notwithstanding voluntary compliance with this measure, at a minimum, the State Water Board will require DWR and USBR to submit the plan within six months after the water rights are amended to require compliance with this measure. Once approved, the plan shall be reviewed annually, and updated as needed, with a corresponding report to the Executive Director.

iii. Numeric salinity objectives for the three interior southern Delta waterways will be implemented through:

a. Provision of assimilative capacity by maintaining salinity objectives upstream at Vernalis.
b. Increased inflow of low salinity water into the southern Delta at Vernalis by implementing the SJR flow objectives during February through June.
c. Benefits to local salinity conditions accrued from USBR and DWR implementation of the narrative water level and circulation objectives as described above.

Compliance with the salinity objectives for the interior southern Delta waterways will be measured at stations C-6, C-8, and P-12. The monitoring requirements at these stations will be re-evaluated and possibly modified as part of the Monitoring and Reporting Protocol. Compliance with the salinity objectives for the San Joaquin River at Vernalis will be determined at station C-10. Monitoring requirements to assess compliance with the narrative water level and circulation objective will be established as part of the Monitoring and Reporting Protocol.

The interior southern Delta salinity objectives will be implemented no later than December 2020 in coordination with implementation of San Joaquin River flow objectives. The narrative water level and circulation objectives will be implemented by completion and ongoing execution of the Comprehensive Operations Plan. The salinity objectives at Vernalis will continue to be implemented by conditioning USBR water rights on compliance with this objective. To the extent necessary, the State Water Board may take other water right actions and water quality actions, in concert with actions by other agencies, to implement the objectives.

<u>Central Valley Regional Water Quality Control Board (CVRWQCB) Regulatory Actions</u>
Implementation of the Vernalis and interior southern Delta salinity objectives will also benefit from the following CVRWQCB regulatory actions:

i. <u>Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS)</u>: CV-SALTS is a stakeholder-led effort initiated by the State Water Board and the CVRWQCB in 2006 to develop a basin plan amendment and implementation actions to address salinity and nitrate problems in California’s Central Valley.
ii. <u>Discharge Regulation</u>: Using its NPDES and other permitting authorities, the CVRWQCB regulates salt discharges upstream and within the southern Delta in coordination with the ongoing CV-SALTS process. The CVRWQCB, in coordination with various Central Valley stakeholders, is also exploring a region-wide variance policy and interim program to provide variances from water quality standards for salt while CV-SALTS is in progress. This variance policy and interim program is anticipated to be considered by the CVRWQCB before the fall of 2011.
iii. <u>Upstream of Vernalis San Joaquin River Salinity Objectives</u>: CV-SALTS has established a committee to develop a Basin Plan amendment containing numerical salinity objectives and the associated control program for the lower San Joaquin River.
iv. <u>San Joaquin River at Vernalis Salt and Boron TMDL</u>: The CVRWQCB is implementing the salinity and boron TMDL at Vernalis. This effort includes a Management Agency Agreement with the US Bureau of Reclamation addressing salt imported into the San Joaquin River basin via the Delta-Mendota Canal.

<u>Actions by Other Agencies</u>
Implementation of the Vernalis and interior southern Delta salinity objectives will also benefit from the following actions being taken by other agencies:

i. Grasslands Bypass Project: Implementation of the Grasslands Bypass Project and the associated West Side Regional Drainage Plan will continue to reduce salt loads to the San Joaquin River upstream of Vernalis.

ii. San Luis Unit Feature Re-evaluation Project: The purpose of this project is to provide agricultural drainage service to the Central Valley Project San Luis Unit with the goal of long-term sustainable salt and water balance for the associated irrigated lands.

iii. Central Valley Project Improvement Act (CVPIA) Land Retirement Program: The goal of this program is to reduce agricultural drainage by retiring drainage impaired farmland and changing the land use from irrigated agriculture to restored upland habitat.

State Funding of Programs

i. Implementation of the Vernalis and interior southern Delta salinity objectives will also benefit from State Water Board funding assistance for salinity related projects through the State Revolving Fund Loan Program, the Agricultural Drainage Loan Program, the Agricultural Drainage Management Loan Program, Proposition 13, 40, 50, and grant funding through the Non-point Source Pollution Control Programs and Watershed Protection Programs.

A.2.3. New Special Studies, Monitoring, and Reporting Requirements

Add new section with the text below to the end of Chapter IV. Program of Implementation, Section D. Monitoring and Special Studies Program:

Southern Delta Agricultural Water Quality Objectives

Implementation of the numeric salinity and narrative water level and circulation objectives in the southern Delta will require information collected through the following monitoring and special studies programs:

i. Monitoring Special Study: As a condition of its water rights, DWR and USBR shall work with State Water Board staff, and solicit other stakeholder input to develop and implement a special study to characterize the spatial and temporal distribution and associated dynamics of water level, circulation, and salinity conditions in the southern Delta waterways. The extent of low/null flow conditions and any associated concentration of local salt discharges should be documented. The State Water Board will solicit participation from local agricultural water users and municipal dischargers to provide more detailed data regarding local diversions and return flows or discharges.

The State Water Board will request DWR and USBR to submit the plan for this special study to the Executive Director for approval within six months from the date of State Water Board approval of this amendment to the Bay-Delta Plan. Notwithstanding voluntary compliance with this measure, at a minimum, the State Water Board will require DWR and USBR to submit the plan within six months after the water rights are amended to require compliance with this measure. Once approved, the monitoring contained in this plan shall continue to be implemented until the Monitoring and Reporting Protocol (described below) is approved and being implemented.

ii. Modeling Improvement Plan: State Water Board Order WR 2010-0002, paragraph A.3 requires DWR and USBR to provide modeling and other technical assistance to State Water Board staff in association with reviewing and implementing the SJR flow and southern Delta salinity objectives. Plans to assess and improve hydrodynamic and water quality modeling of the southern Delta should be completed. Specific scope and deliverables are being managed as part of this ongoing process.

iii. Monitoring and Reporting Protocol: As a condition of its water rights, DWR and USBR shall work with State Water Board staff and solicit other stakeholder input to develop specific monitoring requirements to measure compliance with the narrative water level and circulation objectives, including monitoring requirements needed to assess compliance with the performance goals of the Comprehensive Operations Plan. DWR and USBR shall also use results of the monitoring special study and improved modeling capabilities described above to evaluate potential improvements to the compliance monitoring for the salinity objectives in the interior southern Delta. The State Water Board will request DWR and USBR to submit the plan to the Executive Director for approval within 18 months from the date of State Water Board approval of this amendment to the Bay-Delta Plan. Notwithstanding voluntary compliance with this measure, at a minimum, the State Water Board will require DWR and USBR to submit the plan within 18 months after the water rights are amended to require compliance with this measure.

Table A-1. Water Quality Objectives for Fish and Wildlife Beneficial Uses

RIVER FLOWS						
COMPLIANCE LOCATION	**STATION**	**PARAMETER**	**DESCRIPTION**	**WATER YEAR**	**TIME**	**VALUE**
SJR at Airport Way Bridge, Vernalis	C-10	Flow Rate	Narrative	All	February through June	*Maintain flow conditions from the SJR Watershed to the Delta at Vernalis, together with other reasonably controllable measures in the SJR Watershed sufficient to support and maintain the natural production of viable native SJR watershed fish populations migrating through the Delta. Specifically, flow conditions shall be maintained, together with other reasonably controllable measures in the SJR watershed, sufficient to support a doubling of natural production of Chinook salmon from the average production of 1967-1991, consistent with the provisions of State and federal law. Flow conditions that reasonably contribute toward maintaining viable native migratory SJR fish populations include, but may not be limited to, flows that more closely mimic the hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur. Indicators of viability include abundance, spatial extent or distribution, genetic and life history diversity, migratory pathways, and productivity.*
Confluence of Tuolumne River with the SJR	TBD					
Confluence of Merced River with the SJR	TBD					
Confluence of Stanislaus River with the SJR	TBD					
SJR at Airport Way Bridge, Vernalis	C-10	Flow Rate	Minimum Average Monthly Flow Rate (cfs)	All	Oct	1,000 [1]

[1] Plus up to an additional 28 thousand acre-feet (TAF) pulse/attraction flow shall be provided during all water year types. The amount of additional water will be limited to that amount necessary to provide a monthly average flow of 2,000 cfs. The additional 28 TAF is not required in a critical year following a critical year. The pulse flow will be scheduled in consultation with USFWS, NOAA Fisheries, and DFG.

Table A-2. Water Quality Objectives for Agricultural Beneficial Uses

COMPLIANCE LOCATIONS	STATION	PARAMETER	DESCRIPTION	WATER YEAR	TIME	VALUE
SOUTHERN DELTA SALINITY						
San Joaquin River at Airport Way Bridge, Vernalis	C-10 (RSAN112)	Electrical Conductivity (EC)	Maximum 30-day running average of mean daily EC (mmhos/cm)	All	Apr-Aug Sep-Mar	0.7 1.0
San Joaquin River from Vernalis to Brandt Bridge - and -	C-6 [1] (RSAN073)	Electrical Conductivity (EC)	Maximum 30-day running average of mean daily EC (mmhos/cm)	All	Apr-Aug (Sep-Mar)*	1.0 (1.0 to 1.4)*
Middle River from Old River to Victoria Canal - and -	C-8 [1] (ROLD69)					
Old River/Grant Line Canal from head of Old River to West Canal	P-12 [1] (ROLD59)					
SOUTHERN DELTA WATER LEVELS AND CIRCULATION						
San Joaquin River from Vernalis to Brandt Bridge - and -	[2]	Water Level & Circulation	Narrative	*Water level and circulation conditions shall be maintained sufficient to provide reasonable protection of agricultural beneficial uses.*		
Middle River from Old River to Victoria Canal - and -	[2]					
Old River/Grant Line Canal from head of Old River to West Canal	[2]					

[1] Compliance monitoring will be re-evaluated and possibly modified as part of the Monitoring and Reporting Protocol described in the implementation plan. Unless modified, compliance with these salinity objectives will be determined at the indicated locations.
[2] Monitoring requirements to assess compliance with this narrative objective will be established as part of the Monitoring and Reporting Protocol described in the implementation plan.

** Note: The salinity objective "value" parameter for September through March above is stated as a range of values that will be evaluated in the SED. Additional breakdown of applicable months for the "Time" parameter may also be evaluated in the SED.*

Appendix B. Tabular Summary of Estimated Escapement of Adult Fall-run Chinook Salmon for the Major SJR Tributaries from 1952 to 2010

Year	Stanislaus	Tuolumne	Merced (In River)	Merced (Hatchery)		
				Total	3+ years old	2 years old
1952	10000	10000				
1953	35000	45000				
1954	22000	4000	4000			
1955	7000	2000				
1956	5000	5500				
1957	4090	8170	380			
1958	5700	32500	500			
1959	4300	45900	400			
1960	8300	4500	350			
1961	1900	500	50			
1962	315	250	60			
1963	200	100	20			
1964	3700	2100	35			
1965	2231	3200	90			
1966	2872	5100	45			
1967	1185	6800	600			
1968	6385	8600	550			
1969	12327	32200	600			
1970	9297	18400	4700	100	100	0
1971	13261	21885	3451	200	200	0
1972	4298	5100	2528	120	120	0
1973	1234	1989	797	375	281	94
1974	750	1150	1000	1000	1,000	0
1975	1200	1600	1700	700	700	0
1976	600	1700	1200	700	700	0
1977	0	450	350	661	661	0
1978	50	1300	525	100	100	0
1979	110	1183	1920	227	114	114
1980	100	559	2849	157	157	0
1981	1000	14253	9491	924	616	308
1982		7126	3074	189	157	32
1983	500	14836	16453	1795	199	1,596
1984	11439	13689	27640	2109	1,888	221
1985	13473	40322	14841	1211	1,124	87
1986	6497	7404	6789	650	488	162
1987	6292	14751	3168	958	491	467
1988	10212	5779	4135	457	418	39
1989	1510	1275	345	82	66	16

Year	Stanislaus	Tuolumne	Merced (In River)	Merced (Hatchery)		
				Total	3+ years old	2 years old
1990	480	96	36	46	29	17
1991	394	77	78	41	32	9
1992	255	132	618	368	123	245
1993	677	471	1269	409	234	175
1994	1031	506	2646	943	497	446
1995	619	827	2320	602	311	291
1996	168	4362	3291	1141	395	746
1997	5588	7146	2714	946	838	108
1998	3087	8910	3292	799	347	452
1999	4349	8232	3129	1637	650	987
2000	8498	17873	11130	1946	1,615	331
2001	7033	8782	9181	1663	1,137	523
2002	7787	7173	8866	1840	1,250	588
2003	5902	2163	2530	549	392	157
2004	4015	1984	3270	1050	456	594
2005	3315	719	1942	421	346	75
2006	1923	625	1429	150	136	15
[2007]	443	224	495	79	70	9
[2008]	1305	455	389	76	39	37
[2009]	595	124	358	246	112	137
[2010]	1086	540	651	146		

Note: Data for those years in brackets (2007 – 2010) are preliminary.
Source: DFG 2011 Grandtab Report and PFMC 2011

Attachment 1

Peer Review Comments

John A. Dracup, Ph.D., P.E,
Consulting Civil Engineer & Hydrologist

November 13, 2011

Gerald Bowes, Ph.D.
Manager, Cal/EPA Scientific Peer Review Prgram
Office of Research, Planning and Performance
State Water Resources Control Board

Re: Review of the State Water Board's Technical Report

Dear Dr. Bowes:

Attached is my review of the State Water Board's Technical Report on the Scientific Basis for San Joaquin River Flow and Water Quality Objectives and Program of Implementation.

It was a pleasure working on the review.

Sincerely,

John A. Dracup

1101 Pacific Ave. # 501, San Francisco, CA. 94133
Phone: 415-409-0077, Fax: 415-409-0997, Cell: 415-519-1101
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November 13, 2011

John Dracup, Ph.D., P.E.

SCIENTIFIC PEER REVIEW OF THE TECHNICAL REPORT (TR) ON THE SCIENTIFIC BASIS FOR ALTERNATIVE SAN JOAQUIN RIVER FLOW OBJECTIVES FOR THE PROTECTION OF FISH AND WILDLIFE BENEFICIAL USES AND PROGRAM OF IMPLEMENTATION.

Issues pertaining to San Joaquin River Flows for the Protection of Fish and Wildlife Beneficial Uses

1. Adequacy of the Technical Report's hydrologic analysis of the San Joaquin River basin comparing unimpaired flow with actual observed flows in representing changes that have occurred to the hydrograph of the San Joaquin River basin in order to provide background and support for the remaining chapter of the Technical Report.

The hydrologic analysis of the San Joaquin River Basin is covered in Chapter 2, pages 2-1 to 2-38 of the TR. The first step in the hydrologic analysis is to determine the unimpaired flows using a modeling approach. The analysis was done on a monthly basis, from 1922-2003. Modeling the unimpaired flows in a developed river basin over this 82 year time period is a difficult and non-trivial task. It requires that all of the influences of the numerous dams, exports, imports and diversions within the SJR basin be reversed. The authors of this TR have relied on the work of the CA State Dept of Water Resources UF Report; DWR 2007al, and the work of academics to support their calculations.

The determination of unimpaired streamflows as modeled from observed streamflows is an crucial component of this analysis. Unimpaired flows are difficult to reconstruct from observed records and are subject to numerous judgment calls by the person or agency who is performing this analysis. However, there are many existing observed stream flows throughout the SJ Basin that are naturally unimpaired. An example of observed unimpaired streamflows are the two records on the Merced River in the Yosemite

Valley, the one at Pohona (1916 - present) and the one at Happy Isles (1915-present). It is my opinion that the modeled unimpaired streamflows, as presented in the TR, should be compared with these two streamflows and other naturally unimpaired streamflows in the SJ Basin in order to verify the accuracy of the modeled unimpaired record.

The exceedance probability curves for annual flows, shown in Figure 2.5, are as expected as the unimpaired flows are significantly higher than the observed flows.

The monthly flow results as shown in Figures 2.8 through 2.14 are as expected, that is, the unimpaired flows are higher than the observed flow. The one exception is the Stanislaus River from Apr to Sep (1984-2009) as shown in Figure 2.9 where the observed flows are higher than the unimpaired flows. The reason for this is probably the observed releases from upstream dams.

Chapter 2 would have benefited from a Conclusion section, and I recommend that it be included.

Other points are:

a. The term “the wettest month” on the first line of page 2-17, should be changed to “month of highest runoff”. The term “wettest” usually refers to rainfall not “volume of flow” as is the topic in this case.

b. I was surprised to note that nothing was said about the potential impact of global warming and climate change in this Chapter. Numerous scholarly journal articles have been written on the subject of the impact of climate change on the future hydrology of and the runoff from the Sierra Nevada Mountains. These can be summarized by stating that we can expect more runoff during early spring months when it is not needed and less runoff in the late summer and early fall months when it is needed for irrigation purposes.

2. Determination that the changes in the flow regime of the SJR basin are impairing fish and wildlife beneficial uses.

Since this is not my area of expertise, I am not going to comment on the material in Section 3, pages 3-1 to 3-56. However, I did like the fact that this section included a Conclusions section, pages 3-51 to 3-56.

3. Appropriateness of the approach used to develop SJR flow objectives for the reasonable protection of fish and wildlife beneficial uses and the associated program of implementation.

Since this is not my area of expertise, I am not going to comment on the material in Section 3, pages 3-1 to 3-56. However, I did like the fact that this section included a Conclusions section, pages 3-51 to 3-56.

4. Determination that more flow of a more natural spatial and temporal pattern is needed from the three salmon bearing tributaries to the San Joaquin River during the February through June time frame to protect San Joaquin River fish and wildlife beneficial uses.

Since this is not my area of expertise, I am not going to comment on the material in Section 3, pages 3-1 to 3-56. However, I did like the fact that this section included a Conclusions section, pages 3-51 to 3-56.

5. Appropriateness of using a percentage of unimpaired flow, ranging from 20 to 60 percent, during the February through June time frame, from the Stanislaus, Tuolumne, and Merced Rivers is an appropriate method for implementing the narrative San Joaquin River flow objective in a way that reasonably protects fish and wildlife beneficial uses, given the other factors that the State Water Board must consider when determining a reasonable level of protection for beneficial uses.

It is my opinion the that use of exceedance probabilities, as presented in Figures 3.15 to 3.20 (pages 3-53 to 3-56), is an excellent means of comparing the observed flows with the modeled unimpaired flows and with the three different percentages, 20-60, of the modeled unimpaired flows. The resulting plots are exactly as one would expect with the modeled unimpaired flow being the largest and the observed flows being a lesser amount. It is interesting that the observed flows are greater than the modeled unimpaired flows for exceedance probabilities less that 10%. This is probably due to the difficulty in modeling unimpaired large flood flows.

6. Appropriateness of proposed method for evaluating potential water supply impacts associated with the flow objective alternatives on the San Joaquin River at Vernalis, and Stanislaus, Tuolumne, and Merced Rivers.

The water supply effects analysis is covered in Chapter 5, pages 5-1 to 5-16. The analysis was done using the USBR's CALSIM II model. The CALSIM II model was developed jointly by the USBR and the CA State DWR for modeling the Central Valley water system. It has been successfully vetted by a team of seven experts led by Professor D. (Pete) Loucks of Cornell University in a report published in December 2003.

Presented in Figure 5.1, page 5-3, is a comparison of the observed monthly average flow at Vernalis as compared to the CALSIM II model output. The comparison is excellent, however, a indication of the degree of correlation between these two parameters would have been helpful, i.e. an R^2 value.

It is my opinion that the use of CALSIM II for determining the potential waiter supply impacts associated with the flow objectives alternatives is an appropriate means of doing this analysis.

<u>Issues pertaining to Water Quality Objectives for the Protection of Southern Delta Agricultural Beneficial Uses</u>

Since the water quality and salinity is not my area of interest, I am not going to comment on or answer items 7, 8 and 9 of Appendix 2.

7. Sufficiency of the statistical approach used by the State Water Board staff in the Technical Report to characterized the degradation of salinity conditions between Vernalis and the interior southern Delta.

8. Sufficiency of the mass balance analysis presented by State Water Board staff in the Technical Report for evaluating the relative effects of

National Pollutant Discharge Elimination System (NPDES) permitted point sources discharging in the southern Delta.

9. Determination by State Water Board staff that the methodology and conclusion in the January 2010 report by Dr. Glenn Hoffman, regarding acceptable levels of salinity in irrigation water, are appropriate for reasonable protection of agricultural beneficial uses n the southern Delta.

10. **Other issues.**

- The Technical Report needs an Executive Summary at its beginning.
- I did not check all of the references in the Technical Report to see if they were included in the References, pgs 6-1 to 6-15, however, the ref to Lund et al. 2010 on pa 3-52 is not in the References.

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10 November 2011

TO: Kari Kyler
Environmental Scientist
Bay-Delta Unit
State Water Resources Control Board

RE: Peer Review of Technical Reports on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives

As requested, I have reviewed the Technical Reports prepared by SWRCB staff and Dr. G. Hoffman with a focus on the science topics of concern supporting the proposed flow and water quality (WQ) objectives for the South Delta portion of the San Joaquin River system. My particular focus is on the salinity-related WQ objectives (issues #7, 8 & 9) and I provide some general comments on the other issues when able. Comments related to each issue are summarized below.

1. **Adequacy of the Technical Report's hydrologic analysis of the San Joaquin River basin comparing unimpaired flow with actual observed flows in representing changes that have occurred to the hydrograph of the san Joaquin River basin in order to provide background and support for the remaining chapters of the Technical Report.**
Generally, this is a very informative set of chapters describing the SJR basin hydrology and the effects of reservoir development on major tributary flows. Overall the methods and analysis appear adequate in setting the stage for later chapters of the Technical Report. Though perhaps included in a general heading of "consumptive use" there is little if any discussion of the decreased annual sub-basin water yields associated with reservoir evaporation after about 1940. As reservoir development continued during the next several decades, presumably evaporation losses increased thereby progressively reducing sub-basin water yields and as a result, the estimated "unimpaired flows". Some discussion of how large this effect may be on the estimated unimpaired flows is needed. Similarly, though more explicitly acknowledged in the analysis, are the effects of climate change on (a) shift of the spring snowmelt period to weeks earlier on average during the past several decades alone, and (b) possible greater rain-snow variability in the Sierras and its affect on reservoir operation and ability to contain rain-on-snow flood events.

2. **Determine that changes in the flow regime of the San Joaquin River basin are impairing fish and wildlife beneficial uses.**
   This section appears to be clear and is beyond my expertise.

3. **Appropriateness of the approach used to develop San Joaquin River flow objectives for the reasonable protection of fish and wildlife beneficial uses and associated program of implementation.**
   This section appears to be clear and is beyond my expertise.
   Overall, this subject is difficult scientifically in terms of appropriate data collection and analyses. For example, the curve in Figure 3.8 on p.3-27 is practically meaningless given the few points available; perhaps this why no R^2 value is provided. I suggest simply eliminating the curve. In Figure 3.10, there is extremely low fish "escapement" from the Merced River during 1950-1968 that would seem to "skew" results. Is there any explanation for this dearth of salmon in this period? Is it real or an artifact of sampling? In Figure 3.11, there is clearly an increase in recovered salmon as a function of the number released as might be expected, but the statistical interpretation is strained. Basically, averaging the 2-3 data points per number released indicates that approximately 2.5% salmon 'recovery' at releases of ~50,000 and 2.8% 'recovery' at releases twice as great (~100,000), leading to the possible observation that for releases up to ~100,000 fish recoveries between 2.5-3% might be expected. The single point at large value release (~128,000) suggests a greater recovery fraction (~5%), but it is only one point. Given the wide variability in the recovery numbers, I suspect that these recovery fractions are not statistically different. Perhaps a different analysis is more appropriate here.

4. **Determination that more flow of a more natural spatial and temporal pattern is needed from the three salmon bearing tributaries to the San Joaquin River during the February to the June time frame to protect San Joaquin River fish and wildlife beneficial uses.**
   This section appears to be clear and is beyond my expertise.
   I concur with the overall geomorphic summary presented in Section 3.7.4 and that the processes identified support that the more widely variable flows suggested should enhance salmon habitat.

5. **Appropriateness of using a percentage of unimpaired flow, ranging from 20 to 60%, during the February through June time frame, from the San Joaquin River basin rivers as the proposed method for implementing the narrative San Joaquin River flow objective.**
   This matter is discussed in Sections 3.8 and 3.9 of the Technical Report and summarized in several tables and figures. The Report would be strengthened by inclusion of a summary table (see beow) after Table 3.20 that is based on the previous related tables and indicates the SWRCB's conclusions, or recommended flow rates to be met or exceeded each month of the year and with what frequency (% exceedance). From such a table, the figures in section 3.9 and selection of the

20-60% of unimpaired flows can be more readily comprehended. It would be helpful to assign monthly exceedence fractions to the general designations of “critical”, “dry”, “above normal” etc. water years to flows at Vernalis (e.g. Table 3.17 or from Figure 2.5 where wet years are ~0-30%, above normal years are ~30-50%, etc.). Basically, this comparison table might take the form below from which justification for use of the 60% fraction of unimpaired flows could be supported.

Table 3.2X. Summary of Above Normal (40, or 60% exceedance) water year San Joaquin River flows (cfs) at Vernalis for doubling of fall-run Chinook population from 1967-91 average.

Month	AFRP	TBI/NDC	CSPA/CWIN	SWRCB Rec.?*
March	5162	2000-5000	13,400	6000?
April	8157	20,000	7800	10,000?
May	13732	7000	11,200 to 1200	16,000?
June		2000	1200	12,000?

*Taken from Figures 3.16-3.19 for 60% of unimpaired flows at 40% exceedance.

6. **Appropriateness of proposed method for evaluating potential water supply impacts associated with flow objective alternatives on the San Joaquin River at Vernalis and the basin rivers.**
   This matter is discussed in Chapter 5 of the Technical Report and overall the basic mass balance approach seems appropriate. A section similar to section 5.2 describing the CALSIM model applicable to the discussion in Chapter 4 would be helpful at the beginning of Chapter 4. My primary technical concern on the WSE analyses and the previous discussions also in Chapter 4 is that a monthly time-step of total flows is used. Such a time step is incongruent with daily management decisions used for reservoir operation, irrigation diversions and probably the flows and salinity encountered by the fish; a daily time-step seems to be more relevant and a justification for the monthly time-step (beyond computing resource limitations) should be provided. In addition, the objectives call for running averages of *daily* means.

7. **Sufficiency of the statistical approach used by the SWRCB staff in the Technical Report to characterize the degradation of salinity conditions between Vernalis and the interior southern Delta.**
   This matter is discussed in Section 4.3 of the Technical Report and overall the basic mass balance approach is acceptable with the caveat noted above about use of a daily time-step rather than monthly may be more appropriate. In developing the Tributary contributions to delta salinity, EC-Flow relationships observed from the recent period (1994-2003) may not represent that from the un-impaired or pre-dam flow conditions. Realizing the lack of pre-dam data, this matter should be addressed with a general discussion of what the earlier period conditions may have been relative to the present. Also for the Tributary EC calculations (p. 4-4 & Table 4.2), use of the power function is okay; however, one might expect the power function coefficients to be similar for all three tributaries unless

dramatically different hydrologic/geologic conditions can be described for the Stanislaus as compared to the Merced and Tuolomne River sub-basins. Such power functions are sensitive to the data spread, especially at low values (flows). The very small R^2 value (0.18) for the Stanislaus River is practically meaningless and I suspect that use of K_s ~ 455 and b ~ -0.35, values more consistent with those for the other two tributaries, would result in an R^2 value not that much different and certainly no less significant. Overall, observed salinities at Vernalis are generally less than 1 dS/m suggesting that the proposed WQ objective will likely be met most of the time, including during periods of greater flow releases for fisheries.

8. Sufficiency of the mass balance analysis presented by SWRCB staff in the Technical Report for evaluating the relative effects of the NPDES permitted point sources discharging in the southern Delta.

This matter is discussed in Section 4.3 of the Technical Report and overall the basic mass balance approach is acceptable with the caveat noted above about use of the daily time step and the observations below about possible typos or discrepancies between the text and figures. On p.4-11 (1st paragraph) there is the observation that was implicit throughout Chapters 4 and 5 suggesting that "beneficial uses are affected more by longer term salinity averages" such that monthly values are used. As noted above this claim should be further justified and explained so as to better support the proposed objectives and how monthly averages (flow or salinity) can, or should be reconciled with daily measurements. Preferably, such a justification would occur much earlier in the Report.

9. Determination by the SWRCB staff that the methodology and conclusions in the January 2010 report by Dr. G. Hoffman, regarding acceptable levels of salinity in irrigation water, are appropriate for reasonable protection of agricultural beneficial uses in the southern Delta.

The Salt Tolerance Report prepared by Dr. Hoffman provides an excellent summary of the state of current knowledge about soil salinity impacts on irrigated agricultural production. The focus on moderately sensitive alfalfa hay production and sensitive bean production provide a good range from which to determine possible adverse salinity effects in Delta agriculture. Overall, I support his Conclusions in Section 6 and Recommendations in Section 7 and offer general comments on his Report below.

Since boron more readily accumulates in soils (not as readily leached as salinity), I concur with Hoffman's observation (pp. 7-8) concerning boron concentrations in irrigation diversions; this subject may require more investigation and appropriate water sampling or monitoring within the South Delta so as to separate possible toxicity effects from those associated with salinity.

I also agree with Hoffman's observations on (p. 21) the limited data available for determination of bean salt tolerance. This data is relatively old, based on greenhouse pot studies and bean varieties unlikely used today commercially. Field studies in typical Delta clay soils (dominant soil type) considering salt tolerance of commercially grown beans in the Delta are needed. Nonetheless, based on salinity thresholds for other "sensitive" crops grown in the South Delta (Table 3.1), salinities of 1 dS/m appear adequate.

Salt leaching of clay soils as outlined (pp. 28-30) suggest that effective leaching fractions can be limited or are reduced through preferential flow in cracks thereby reducing alfalfa hay yields. Extensive field studies in the Imperial Valley on Holtville and Imperial silty clay soils suggested leaching fractions of ~10% under ponded or border-check irrigated conditions (Grismer, 1990 & 1992; Grismer & Tod, 1994; Grismer & Bali, 1997). Thus, a leaching fraction of 10% would likely set a conservative lower limit in the steady-state salinity modeling employed by Hoffman. Similarly, a four-year study with alfalfa hay production on Holtville silty clay found that upward flow from saline shallow groundwater (water table) at a depth of 6 ft provided nearly 20% of the crop demand in the first year decreasing to ~5% as soil salinity continued to increase into the fourth year. A single cropping of corn following the alfalfa salinity study returned soil salinities to near pre-study conditions (Bali et al., 2001a & 2001b). Under similar field conditions, more shallow rooted sudangrass hay was found to use little shallow groundwater (Grismer, 2001; Grismer & Bali, 2001). Though the water table may be shallow in parts of the South Delta, providing adequate irrigation would limit upward flow contributions to crop water use wit the exception of possibly alfalfa hay when water stressed.

The relatively large leaching fractions apparently occurring in the South Delta clay soils of ~25% suggest that current water use and irrigation is adequate to maintain soil salinity conditions within acceptable ranges (Tables 3.10 & 3.11). The very low leaching fraction values of ~10% are similar to those found for heavy clays of the Imperial Valley under alfalfa hay production and supported in the modeling efforts here. Hoffman quoting Letey (p. 67) suggests that most irrigation strategies are such that irrigations occur when soil-water contents decrease by half, thereby doubling the soil-water salinity concentration should likely be verified. My experience with deficit irrigation suggests reductions to about one-third the maximum soil-water content implying a salinity concentration by a factor of three rather than two. Of course, this affects the modeling assumptions of section 5.1.2, but at the large leaching fractions (>20%) for row or truck crop production encountered in the South Delta, such deficit irrigation is unlikely and soil-water salinity concentrations would be in the range suggested by Hoffman's modeling results (section 5.2.1). I concur that salinity affects at the proposed EC objective are not expected to adversely affect alfalfa hay production as outlined in section 5.2.2.

The ability of Delta growers to maintain high leaching fractions into the future as competition for water resources intensifies and climate change adds hydrologic uncertainties suggest that some of these issues be regularly re-visited within an Adaptive Management framework as outlined below.

10. Other issues – General remarks.

Overall the Technical Report fairly describes a workable methodology and support for assessment of the proposed water quality and flow objectives for the

San Joaquin River at Vernalis. Presumably these objectives are considered within an Adaptive Management context that not only identifies the goals of these objectives (e.g. beneficial uses for irrigated agriculture, doubling salmon populations etc.) and outlines the knowledge limitations and gaps, but also sets out the monitoring required to determine if the beneficial use goals are achieved and additional knowledge gained, as well as the possible revised management strategies (flow and water quality objectives) that should be developed and possibly implemented. Of course, Adaptive Management is a continuous process that requires regular and focused monitoring, use of management "triggers" should target goals not be met and continued knowledge acquisition (critical towards accommodating say climate change effects as they arise).

Noted Typos:

p. 3-5; 4th para. mmnos to mmhos

p. 3-17; 2nd para. last sentence appears to be missing a phrase, has extra comma

p.4-7; Figure 4.6. the text and the figure are mis-labeled – 20% not 40%

p.4-11; Figure 4.12. the figure labeling is incongruent with the text above (2nd para). The 3-point source load should be a constant based on maximum allowed WWTP discharges and salinities. Suspect that the graph should be re-labeled, or discussion above changed.

p. 4-13; item j. last line should read "which lead to higher estimates of soil water salinity"

p. 5-2; Table 5.1. mis-spelling of New Don Pedro

pp. 5-9 to 5-11; Figures 5.3-5.5, as CALSIM is also a model, perhaps the better word to use is "calibration" to CALSIM rather than "validation".

In Hoffman Report, p.65, Table 4.1, appears to be a missing value for Oat Lr for 2EC model, 0.0X?

Citations

Bali, K.M., Grismer M. E., and R. L. Snyder. 2001a. Alfalfa water use pinpointed in saline, shallow water tables of Imperial Valley. California Agriculture 55(4):38-43.

Bali K. M., M. E. Grismer and I. C. Tod. 2001b. Reduced-Runoff Irrigation of alfalfa in Imperial Valley, California. ASCE J. Irrig. & Drain. Engr. 127(3):123-130.

Grismer, M. E. 2001. Sudangrass hay uses water at rates similar to alfalfa, depending on location. California Agriculture. 55(4):44-48.

Grismer, M. E. 1990. Leaching fraction, soil salinity, and drainage efficiency. California Agriculture 44(6):24-27.

Grismer, M.E. 1992. Cracks in irrigated soil may allow some drainage. California Agriculture 46(5):9-12.

Grismer, M.E. and K.M. Bali. 1997. Continuous ponding and shallow aquifer pumping leaches salts in clay soils. California Agriculture 51(3):34-37.

Grismer M. E. and K. M. Bali. 2001. Reduced-Runoff Irrigation of Sudangrass Hay, Imperial Valley, California. ASCE J. Irrig. & Drain. Engr. 127(5):319-324.

Grismer, M. E. and I. C. Tod. 1994. Field procedure helps calculate irrigation time for cracking clay soil. California Agriculture 48(4):33-36.

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Dr. Henriette (Yetta) Jager

Oak Ridge National Laboratory

November 14, 2011

Review of the technical report on the scientific basis for alternative San Joaquin River flow objectives for the protection of fish and wildlife beneficial uses and program of implementation, for the California State Water Resources Control Board.

Below, I review the first two parts of the technical report, hereafter referred to as "the report". The relevant issues that reviewers are tasked with assessing are listed (see Table 1). I focused mainly on Part 3, which is the area best aligned with my expertise (issues #2-5), with only a brief review of Part 2, which addressed issue #1 (Table 1). In some cases, my review is of the primary studies or documents on which the report relies. My review considered the degree of support from scientific literature (were all relevant studies cited), how appropriate statistical analyses were and whether they supported conclusions drawn in the report.

Table 1. List of issues to be addressed by this review.

1.	Adequacy of the Technical Report's hydrologic analysis of the San Joaquin River basin comparing unimpaired flow with actual observed flows in representing changes that have occurred to the hydrograph of the San Joaquin River basin in order to provide background and support for the remaining chapters…
2.	Determination that changes in the flow regime of the San Joaquin River basin are impairing fish and wildlife beneficial uses.
3.	Appropriateness of the approach used to develop San Joaquin River flow objectives for the reasonable protection of fish and wildlife beneficial uses and the associated program of implementation.
4.	Determination that more flow of a more natural spatial and temporal pattern is needed from the three salmon-bearing tributaries to the San Joaquin River during the February through June time frame to protect San Joaquin River fish and wildlife beneficial uses.
5.	Appropriateness of using a percentage of unimpaired flow, ranging from 20 to 60 percent, during the February through June time frame, from the Stanislaus, Tuolumne, and Merced Rivers as the proposed method for implementing the narrative San Joaquin River flow objective.

Part 2. Hydrologic Analysis of San Joaquin River Basin

The purpose of this section is to address **issue #1 (Table 1**) by presenting evidence that a significant fraction of unimpaired flows into the San Joaquin tributaries and mainstem are stored and diverted as consumptive uses of water. These reductions in flow and alterations to flow regime are quantified. To summarize, overall annual flow have been frequently been less than half of unimpaired flows. Specifically, median annual flows were reduced to 44% of unimpaired annual flows since 1930. A physical manifestation of the magnitude of change in peak flows has been formation of a new, much lower floodplain in some tributaries (Cain et al. 2003).

In addition to documenting changes in the annual quantity of flow, the report cites seasonal shifts in timing of the remaining in-stream flows (McBain and Trush 2002; Cain et al. 2003). The reduction in spring and early summer snowmelt flows has been the most significant alteration to SJ flow regimes. Regulated flow regimes exhibit a lower frequency and intensity of late-fall and winter storm flows. Consequently, hydrologic variability is considerably lower than it would otherwise be (Cain et al. 2003). A larger proportion of regulated annual flow occurs during summer and fall, but the absolute magnitude may not differ from unimpaired flow regimes.

I concur that the Technical Report's hydrologic analysis is adequate and consistent with previous studies. The analysis demonstrated that significant changes to the San Joaquin basin flow regimes result from post-dam upstream water uses. Areas of uncertainty include the magnitude of evapotranspiration from wetland riparian species and groundwater return flows from agriculture. Nevertheless, the main result regarding the substantial differences between unimpaired and post-dam San Joaquin basin flows appears to be clear-cut and well supported.

Part 3. Scientific Basis for Developing Alternate San Joaquin River Flow Objectives

Part 3 addresses issues #2-5 (Table 1). It provides support for the argument that impaired flows have been insufficient to support the freshwater phase of fall Chinook salmon and steelhead populations and has put them at high risk of extinction. The report does a good job of presenting relevant past research carried out by California agencies to support the conclusion that water development is impairing salmon production. The flow-salmon relationship is well-documented. However, the flow-salmon relationship is dominated by indirect pathways mediated by other factors, and the remaining uncertainties involve parsing out proximate factors that link flow to salmon and steelhead status and trends. In the review below, I cited additional relevant and published research for consideration by the authors.

Assessment of extinction risk

The report provides an assessment of extinction risk based on a recent framework proposed for the Central Valley salmonids by Lindley et al. (2007). Lindley et al. (2007) set out criteria for assessing risk for salmon and steelhead based on status, trends, catastrophes, and hatchery influence, many of which build on an earlier report by McElhaney et al. (2000). Both sources are generally consistent with generally accepted scientific principles of conservation biology, but await scientific scrutiny by reviewers for a higher tier journal. They concluded that data were insufficient to assess viability of Central Valley steelhead. Mesick (2009) applied the Lindley et al. criteria in an assessment of risk for fall Chinook salmon and concluded the population is at high risk according to some criteria (high risk was defined as 20% risk of extinction [of natural spawners] within 200 y) and moderate risk according to others. Four factors that Lindley et al. used to define populations at high risk of extirpation were (1) prolonged low spawner abundances (<250) over a generation, (2) a precipitous (>10%/y) declining trend in abundance, (3) catastrophic decline of >10% in one generation during the past ten years, and (4) high hatchery influence, as summarized and commented on below.

(1) **Status**: To assess status, Mesick (2009) adjusted escapement to represent only wild spawners (rather spawners with >=1st generation wild parents). These numbered fewer than 250 for longer than one 3-y generation. Consequently, more than one brood year was affected. Without stocking or straying of adults from nearby rivers, the risk of local extirpation during these extended troughs was, and will continue to be, very high.
(2) **Declining trend**: By 2000, Tuolumne River spawner abundances had already experienced a negative 40-y trend (Jager 2000). Since that time (1999-2008), natural spawners in the SJB have declined at an average rate of 19% per year (Mesick 2009). A viable population should have a Natural Return Ratio (NRR) >=1 (McElhaney 2000). Early indications are that this year may be slightly better than last.
(3) **Catastrophe**: Mesick focused on the recent extended drought as a catastrophe. A large, order-of-magnitude decline occurred between the 2000-2002 generation and the 2003-2005 generation of spawners. In my experience with assessing future risk, past catastrophes are important mainly because of what they portend about the future. Past events can be used to quantify the frequency, magnitude, and duration of future events to aid in PVA modeling and recovery planning. I am not sure I agree with the use of a recent catastrophe as strong evidence for future risk except in the short term (see Allee effect discussion below).
(4) **Hatchery influence**: The recovery goal is a wild population and not a captive-breeding population on life support. Over 20% of Tuolumne River fall Chinook salmon is of 1st-generation hatchery origin. This exceeds a model-based threshold of 10% that McElhaney (2000) derived based on a model analysis. Ensuring that hatchery inputs are at least an order of magnitude smaller than population growth rate reduces the correlation between the hatchery and wild populations. Hatchery returns and in-river

spawner abundances are highly correlated (see figure 20 in Lindley et al. 2009) so that the hatchery inputs are highest when they are least needed and possibly, most harmful (density-dependent effects).

The report made the case that the San Joaquin Basin (SJB) fall Chinook ESU is at risk, as summarized above. In this case, the risk is fairly clear. How immediate is the risk? A population viability analysis (PVA) is needed to quantify the distribution of future times to extinction of the 'wild' population. Note that the conclusions above are consistent with my unpublished PVA for the Tuolumne River (Jager 2000).

Below are some suggestions that the report authors might consider incorporating into their framework. Population viability is usually assessed in terms of **abundance**, **productivity, spatial extent**, and **diversity** (Waples 2005). To fully assess risk of extirpation from the San Joaquin basin from a qualitative perspective, I would add additional risk factors to the ones listed in the report: (5) high volatility in abundance, (6) low carrying capacity, (7) susceptible to Allee effects, (8) high correlation among sub-populations, and (9) position at edge of geographic range. Each of these additional factors lends support to the argument made in the Report that the SJB fall Chinook salmon ESU is at high risk.

(1) Lack of Diversity and/or Spatial Extent

It is important to note that three other runs of Chinook salmon (as well as one other listed species, green sturgeon) have already been extirpated from this river basin in recent times, yet these populations have persisted in the adjacent Sacramento basin. Chinook salmon diversity in run timing has clearly been reduced as a result. Diverse migration timing increases overall population viability. Two contributing risk factors are described below.

a. **Population synchrony**: Spatial diversity is thought to reduce metapopulation exposure to catastrophic events (Hilderbrand 2003). Rescue of one tributary by its neighbors during periods of low abundance is made less likely by the tight correlation among spawner abundances in the three SJB tributaries, the nearby Mokelumne River, and hatchery sub-populations (see figure 20 in Lindley et al. 2009). Shared exposure during estuary and ocean residence also produces correlation and increase shared susceptibility to catastrophic events (Botsford and Paulsen 2000).

b. **Geographic position/range contraction**: Species are more susceptible to extinction at the edges of their geographic ranges, and this has been shown for fishes (Gotelli and Taylor 1999). Because the SJB ESU represents the southernmost population of fall Chinook salmon, range contraction is a concern. Lack of metapopulation support from the south is one mechanism. Global (or local) warming could be another. In addition to spatial range contraction, this basin has also experienced temporal contraction (fewer runs).

(2) Demographic Risks (abundance, productivity).

Population dynamics for salmon are squeezed between a lower threshold population size below which population growth is negative (due to "Allee" effects) and upper threshold sizes above which habitat is saturated and density dependent effects lead to declines. Adding fluctuations to a narrow range of feasible population sizes can contribute to a high risk of extinction.

a. **Low carrying capacity**: In PVA models of salmonids, a low carrying capacity increases extinction risk (Hilderbrand 2003, Lindley and Mohr 2003). Strong over-compensatory density limitation increases volatility and even compensatory density dependence can push numbers fluctuating around an "equilibrium" down closer to the point of no return. In the SJB data, the peak returns observed in the early 2000's were not sustained by the next t+3 generation, suggesting that habitat limitation contributes to risk for the SJB ESU.
b. **Allee effects**: Some populations are unable to increase when they reach a threshold of low abundance (Dennis et al. 1989; Dennis 2002) and such thresholds can be important in assessing risk (Staples and Taper 2006). Myers et al. (1995) demonstrated that Pacific salmon stocks were among a small group of fishes that exhibited significant depensation (i.e., a tendency to decline below a threshold population size). In the absence of an Allee effect, McElhaney et al. (2000) suggest that populations should show evidence of increase in the generation (t+3) after a generation in year t with low numbers. This has not been evaluated for the SJB ESU.
c. **Volatility**: High year-to-year variability is an important measure of extinction risk (see Staples et al. 2004). Even a population with an increasing trend can reach extinction if year-to-year fluctuations are large. Semelparous species have periodic dynamics even without any environmental drivers, and variability in Pacific salmon abundances is known to be high (Paulsen et al. 2007).

Assessment of flow-salmon relationships

Section 3 of the report establishes that changes in the flow regime of the San Joaquin River basin are impairing fish and wildlife beneficial uses (**Table 1, #2**). In particular, it defends the view that a larger proportion of unimpaired flows in the SJB are required to prevent the extirpation of fall Chinook salmon. Three aggravating factors that previously contributed to declining numbers have recently been mitigated to some extent. These include availability of spawning gravel, mortality at export facilities in the Delta, and harvest. By a process of elimination, flow remains as a leading causal factor to consider. One physical manifestation of the decrease in flow in some places is a perched remnant historical floodplain with no chance of flooding, and formation of a new, lower floodplain (report; Opperman et al. 2010). Temporally, spring is the season during which regulated flows deviate most from unimpaired flows. Spatially, a smaller proportion of Vernalis flows now come from the three salmon-bearing tributaries (Merced, Tuolumne, and Stanislaus rivers).

The crux of the argument for increasing environmental flows in the SJB put forth in the report are observed positive associations between flow and fall Chinook salmon. Observed relationships include (1) that observed between winter and spring river flows at Vernalis and adult returns 2.5 years later (TBI/NRDC 2010 Exhibit 3; Speed 1993), (2) that between flow and survival of tagged juveniles migrating through the lower SJ river and estuary to Chipps Island, and (3) that prior to migration, between juvenile growth and ephemeral inundation of floodplain habitat. Flow influences on incubation survival were not specifically addressed in the report, but a few suggestions regarding the egg and alevin life stages are also presented below for possible consideration.

Parr/fry rearing. The report cites recent studies that have demonstrated benefits of floodplain rearing for fall Chinook salmon. It has long been recognized that floodplains provide refuge from aquatic predators, and serve as important nursery areas for many fishes (Welcomme 1979; Sparks et al. 1998). Brown et al. (2002) reported that salmon smolts are larger in coastal rivers with lower gradients and larger floodplains. Several studies have now shown a growth benefit to rearing in seasonally inundated floodplains in California rivers. Sommer et al. (2001a,b; 2005) demonstrated that juvenile Chinook salmon grew faster in the floodplain (Yolo Pass, Sacramento River) than in the main channel. The availability of preferred invertebrate prey was shown to be higher, and elevated temperatures likely also contributed to faster growth. Jeffres et al. (2008) reared juveniles in enclosures and observed fastest growth in ephemeral floodplain habitats than in either permanent floodplain or river). Henery et al. (2010) replicated these results and also observed even faster growth in free-ranging juveniles with coded-wire tags. These results are consistent with the results of a study of flood-pulse effects on invertebrates in the Tuolumne River, which showed a reduction in dominance by less-preferred dipterans and an increase in EPT taxa following a flooding event (Holmquist and Schmidt-Gengenbach 2009). The presence of established riparian vegetation was an important mediator of these benefits (Jeffres et al. 2008). Although it stands to reason that faster achievement of smolt size should result in higher survival (lower predation risk, accelerated salinity tolerance, exit prior to high temperatures), increased survival has not yet been demonstrated conclusively in the field (Sommer 2005). The size-survival relationship is however, well supported by other studies and future research with more statistical power will probably demonstrate a survival advantage. Based on the research presented in the report, I concur that providing floodplain inundating pulse flows during Feb-April would be a very worthwhile experiment for this river basin. As added support, I recently incorporated the growth advantages of floodplain inundation in a simplified fall Chinook model (Jager 2011). Although preliminary, optimal flow regimes produced by this exercise suggest a higher-than-expected value of pulse flows in late-winter, allowing smolt to leave the system earlier.

SJ smolt to adult return. Positive relationships have been demonstrated between the spawner return ratio from CWT releases in the San Joaquin mainstem and flow 2.5 years previously (Speed 1993). A more recent analysis found a significant positive logistic relationship between an indicator variable (increase or decrease in the cohort return ratio) and flow at Vernalis (TBI/NRDC 2010; Exhibit 3). One important feature of both the Speed and TBI models was that they considered returns at time-t per spawner at t-3 as the dependent variable, and not just spawner returns. This is important because the number of spawners that return is biologically constrained by the original number produced in the previous generation. I did not consider other analyses presented in the report that lacked this feature. The use of logistic regression in the TBI was also a good idea because the resulting model will be robust to extrapolation beyond the range of historical flows. However, the analysis was conducted recently and has not yet undergone scientific peer review and I would encourage them to complete this step in the process. In anticipation, they might explore whether the following refinements might reduce uncertainty in the flow threshold: 1) if there is enough data/power, consider expanding the analysis to include other covariates (e.g., return cohort A, B, C; initial spawner abundance); if not, consider quantile regression as a way to reduce influence of covariates not included (see Jager et al. 2010), 2) consider residual autocorrelation, and 3) evaluate whether it is possible to solve directly for the inflection point as a parameter, which would provide confidence bounds on the flow threshold. I would not expect these refinements to alter the main conclusions of the analysis.

SJ smolt to Chipps Island. Smolt were released at Mossdale, Dos Reis, and Old River and recaptured at Chipps Island. Smolt releases in the lower river have been conducted for quite a few years, before and after use of barriers. Paired releases were used to increase the statistical power of these studies. Transit times of survivors ranged from 5 to 21 d (11 d average) (Baker and Morhardt 2001) but the total duration of estuary residence is longer, on the order of ~40 d (MacFarland and Norton 2002). Understanding the relationship between freshwater flows and survival during migration is complicated by the fact that flow often operates indirectly through its effects on intermediate factors that directly influence survival (Speed 1993). In the Bay-Delta, these include temperature, dissolved oxygen (DO), salinity, and predation. A series of sophisticated statistical analyses attempted to separate the correlated effects of river flow, release temperature, and salinity using ridge regression, hierarchical Bayesian and non-Bayesian methods (Baker et al. 1995; Baker and Morhardt 2001; Newman and Rice 2003, Newman and Brandes 2005). Inclusion of temperature and salinity as direct causal pathways reduced the predictive capability of the indirect pathway (flow) (pre-2008 analyses) or vise-versa (Newman 2008). There is little doubt that the complex of flow-related influences collectively explains the majority of variation in smolt survival. From a management standpoint, it may be important to understand the proximate mechanisms responsible for the benefits of flow so that constructive options that require lower environmental flows can be considered.

Two remaining flow-influenced factor have not been included as covariates in models of survival during outmigration cited in the report. These are predation and low DO from the Stockton Deepwater Ship Channel

(Mesick 2009, page 3-32). Studies to coordinate water quality monitoring during smolt releases might help to understand the importance of water quality. Assessing predation might be a greater challenge. Higher flows can reduce predation risk by allowing smolts to occupy a larger volume of water (Bowen et al. 2009), by increasing turbidity (pulse flows), and by decreasing temperatures (Connor et al. 2003). Predators are able to consume and process more prey when temperatures are higher (Vigg and Burley 1991). Vogel et al. (2010) recently found that a large fraction of telemetered smolts were eaten by striped bass while transiting the estuary, although these unfortunate fish might have been impaired by surgically implanted devices. One counter argument, made by MacFarlane (2010), is that growth of sub-yearling Chinook salmon during the first month following ocean entry is faster when salinity is higher, thereby reducing ocean mortality during this time. However, Lund et al. (2008) question the assumption that freshwater outflows are the main controlling factor for salinity gradients in the San Francisco Estuary and highlight the role that habitat complexity can play.

The report has little to say about the role of flow during spawning and incubation. Cain et al. recommend sufficiently high, but stable flows during winter incubation presumably to avoid dewatering or scouring of redds, and this was also the solution found by our salmon-flow optimization for the Tuolumne (Jager and Rose 2003). However, research is needed to understand flow effects on survival, which is lower in SJ tributaries than in the Columbia River (Geist et al. 2006) at similar temperatures. Siltation and low DO may account for this difference and may be mitigated by increasing flow/depth to increase exchange (downwelling) with hyporheic flow (see Tonina and Buffington 2011).

Proposed flow regimes

The report does a good job of presenting the natural flow paradigm and highlighting the inadequacy of past approaches focused on supplying minimum flows. The approach used to support flow objectives is appropriate and should protect fall Chinook salmon (**Table 1, issue #3**). The report puts forward the science supporting the need for a higher percentage (60%) of unimpaired flow with a seasonal shape similar to that of unimpaired flows. Similar efforts to restore a natural flow regime and/or reconnect rivers with their floodplains have been applied in the Missouri River (Bovee and Scott 2002) and elsewhere in the US (Opperman et al. 2010).

The report does not present one specific proposed flow regime, but rather advances guidance from other studies, and these seem to be in general agreement. The authors cite several studies in which more-specific guidance was developed for spring flows (e.g., Cain et al. 2003; TBI/NRDC 2010 Exhibit 3). The TBI/NRDC analysis recommended spring flows of 4,600 cfs (130 cms) or higher at Vernalis. If the proposed 60% of unimpaired SJR flow at Vernalis were followed for March-June, this threshold would be met or exceeded in >85% of years. The report established the basis for requiring a more natural pattern of flows in the three SJ tributaries during Feb-June to restore salmon and steelhead (**Table 1, issue #4**). Recent degradation of water quality in fall and spring in the lower SJ may in fact require high flows during critical periods than were historically observed, and it is fortunate that the storage capacity in rim dams will allow this compensation.

In the last part of Section 3, the report indicates that the SWRCB will also consider percentages of unimpaired flow as low as 20% in order to accommodate competing water demands. It is unclear to me how a percentage of even 40% would be an improvement over current median (44%) and average (48%), as I understood them from Table 2.3 in Section 2 (**Table 1, issue #5**). The basis for instituting lower percentages than are currently provided was not justified in Sections 2 and 3 of the report and seems counter-indicated by the rest of the analysis presented. However, supporting information may appear later in the Water Supply section of the report (Section 5), which I did not review.

The report was careful to emphasize that as new knowledge is gained, the management of river flows should be adjusted. The Cain et al. holistic analysis went well beyond describing the statistical flow duration curve, providing a careful assessment of how timing of flows relates to specific ecological objectives. The Cain et al. report identified flow thresholds to support channel migration, sediment mobilization, and inundation of floodplains. Their approach considered a variety of important processes through which flow influences salmon. Geo-morphological processes in low gradient rivers create slow, shallow connected floodplain habitat, which is increasingly recognized as an important component of habitat diversity for aquatic ecosystems (Trush et al. 2000; Galat et al. 1998; Galat and Lipkin 2000; Jacobson and Galat 2006). Shading by riparian vegetation help to provide refuge from high temperature (Seedang et al. 2008) and predators. The role of floodplain and shallow habitat as nursery areas for fishes (e.g., Bowen et al. 2003) was considered by including flows that inundate floodplains.

One consideration in deciding how to shape rearing and migration flows is the possibility that shorter pulses are more effective than persistent flooding. This aspect was not specifically addressed by the report. For example, studies have shown that shorter pulses stimulate juvenile outmigration (Cramer 1997; Demko & Cramer 2000). One study found floodplain inundation to be more effective when it is intermittent because vegetation growth is promoted (Jeffres et al. 2008). The presence of vegetation may reduce loss of invertebrate production when floodplains are drained. An experimental framework to examine duration effects may be needed.

Following past practice, the report describes prescribed flows developed by Cain et al. distinguish different targets by hydrologic year types. Hydrologic year types were defined by quantiles, an improvement over arbitrary past designations. To summarize recommendations, in wetter years (<20-50% exceedence), the holistic analysis provided for bed-mobilization flows, channel migration flows and flows to support riparian regeneration. Adequate fish passage flows are recommended in all but the driest years (>80%). Attraction flows and flows for salmon outmigration were included for all hydrologic year types (Cain et al. 2003). The assumption above is that wet years should be used to meet objectives that are expensive in terms of flow. Providing a higher percentage of unimpaired flows will go farther to avoid losing cohorts to extended droughts. However, from the perspective of salmon-demographics, there may be value in using a cohort-based approach (A, B, C in the report, where cohort A spawn in years t, t+3, t+6,…, [t+3]*k and cohort B spawn in years t+1, t+4, etc…).

The report listed proposed regulated schedules for flow, but did not go very far in the direction of proposing specific future flow schedules or processes for defining them. In theory, once an annual percentage is set, four options can be considered or combined to design seasonal flows to better support salmonids that can be translated into rules used in reservoir operation: 1) operate as what I would call "reduced run-of-river," 2) follow guidelines proposed by Cain et al. and/or TBI/NRDC, 3) follow regimes determined by optimizations to maximize salmon production, or 4) conduct statistically designed experiments. Run-of-river operation for the reduced percentage of water is the simplest method for tracking the natural flow regime. One advantage of this approach is that it does not require fixing the temporal resolution at which a natural flow regime is mimicked.

Optimization methods provide a more formal approach to quantify direct and indirect pathways linking flow and salmon. Ongoing research has sought to optimize flow regimes with the objective of maximizing salmon production from SJ tributaries (Bartholow and Waddle 1995; Cardwell et al. 1996; Jager and Rose 2003; Jager 2011), or salmon diversity (Jager and Rose 2003). At least one study provided guidance for designing flows to establish riparian vegetation (Stella et al. 2011). Others have included environmental objectives as part of a broader multi-objective problem in California (Draper et al 2003; Lund et al. 2008; Null and Lund 2011). If it is important to consider competing water demands, then a formal optimization with adequate provision for objectives related to restoring Chinook salmon will be needed.

One final approach to consider is statistical design of flow experiments. Treatments to consider might include pulse flows during different seasons and with different durations and magnitudes. Experimental units might be the three tributaries and the three salmon cohorts (ABC).

Areas for further research into partially-non-flow mitigation options might include mitigating for DO in Stockton Channel during both migrations, floodplain 'design' to allow for inundation at lower flows, and providing enough flow to generate habitat complexity and refuge from predators.

In summary, the report established the risk to salmon and steelhead in the Central Valley and laid out the case for increasing the percentage of unimpaired flows released to the three salmon-supporting tributaries using research conducted in the Central Valley as well as other research relevant to the situation in California. The contention that a higher percentage of unimpaired flow is needed in late winter and spring was well supported by research. In this review, I have added references and information from the scientific literature that support the general conclusions of the report with regard to issues #1 through #4, but not #5 (Table 1).

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TBI/NRDC (The Bay Institute (TBI) and Natural Resources Defense Council (NRDC)). Exhibit 2 –Written Testimony of Jonathan Rosenfield, Ph.D. and Christina Swanson, Ph.D. Regarding Flow Criteria for the Delta Necessary to Protect Public Trust Resources: Delta Outflows.

TBI/NRDC (The Bay Institute (TBI) and Natural Resources Defense Council (NRDC)). Exhibit 3. Written Testimony of Christina Swanson, Ph.D., John Cain, Jeff Opperman, Ph.D., and Mark Tompkins, Ph.D. Regarding Delta Inflows.

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November 15, 2011

Kari Kyler
Environmental Scientist
Bay-Delta Unit
State Water Resources Control Board
P.O. Box 2000 Sacramento, CA 95812

Re: External Peer Review of "Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives"

Dear Ms. Kyler,

I am pleased to submit my external peer review of the "Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives". As instructed, my evaluation focuses on the scientific validity of the topics listed in Attachment 2 of which I have sufficient scientific expertise (notably in the areas of "Aquatic Ecology and Fishery Science" and "Hydrology"). Please let me know if you have any additional questions.

Sincerely,

Julian D. Olden

Scientific Review of "Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives"

Prepared by:
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Issues pertaining to San Joaquin River Flows for the Protection of Fish and Wildlife Beneficial Uses

1. Adequacy of the Technical Report's hydrologic analysis of the San Joaquin River basin comparing unimpaired flow with actual observed flow in representing changes that have occurred to the hydrograph of the San Joaquin River basin in order to provide background and support for the remaining chapters of the Technical Report.

River discharge data may be sourced from either a streamgage (observed) or from a hydrologic model (estimated from observed data or precipitation), recorded at daily, monthly or annual time steps, spanning short or long time periods, and varying in geographic coverage. The Technical Report's hydrologic analysis (section 2.2.1) "uses the USGS gages located at the most downstream location for each of the major SJR tributaries and at Vernalis to characterize historical observed flows" (p. 2-5). According to the USGS National Streamflow Information Program a streamgage is defined as an active, continuously functioning measuring device in the field for which a mean daily streamflow is computed or estimated (from stage height) and quality assured for at least 355 days of a water year or a complete set of unit values are computed or estimated and quality assured for at least 355 days of a water year. By using observed streamgage data, data uncertainty associated with the Technical Report is limited to that derived from processing of raw stream stage and discharge data measured at the gage versus both this error and model uncertainty associated with modeling discharge from a hydrologic model (i.e., leading to error propagation). Given the high level of quality assurance performed by the USGS, the level of uncertainty in measured discharge at the streamgages is likely negligible, and thus the quality of the discharge data is high.

The length of the discharge record is critical for maximizing precision and minimizing bias in the estimation of important attributes of the hydrograph, including the quantification of annual, inter-annual and seasonal flows (Olden and Poff 2003, Kennard et al. 2010, Olden et al. 2011); the latter being the focus of the Technical Report. Here, precision is defined as the degree of variation in an estimate, and bias is defined as the difference between an estimate and the true value (Wheaton et al. 2008). Ultimately, bias and precision influences the ability to characterize and detect meaningful variation in hydrologic characteristics through space and time. Quantifying the length of discharge record required to accurately characterize temporal variability has long been important in climatology (e.g. reconstructing historical temperature and rainfall regimes and predicting future climate patterns; McMahon et al. 2007) and hydroclimatology (e.g. estimating the effects of input uncertainty on rainfall-runoff models; Kuczera et al. 2006). A recent review study by Kennard et al. (2010) found that the length of the discharge record influences our ability to accurately portray the different components of the hydrograph. This study showed that the least accurately estimated hydrologic attributes for a given record length were those describing variability in annual flows and low flow magnitude, duration and timing. This is perhaps not surprising given that variability estimates would be expected to be highly influenced by individual years with unusually high peak or total annual discharges. Maximizing the length of record used in hydrologic analyses has clear benefits because the probability of capturing extreme discharge events is enhanced with longer periods of record (Shaw 1988). Kennard et al. (2010) recommended that 15 years or more of discharge record is sufficient to estimate hydrologic attributes with comparatively low bias, high precision and high overall accuracy. Characterizing hydrographs from less than 10 years of discharge record, while occasionally recommended under specific circumstances, increases the risk of generating biased, imprecise results, especially in regions of high climatic variability. The Technical Report's hydrologic analysis (section 2.2.2) is based upon 80 years of discharge data across all years, and 11-25 years of discharge data for periods categorized as critical (wet, above normal, below normal, dry) (Table 2.2 and 2.3), therefore, in my opinion the characterization of hydrologic conditions is considered robust with respect to accuracy and precision.

Characterizing the naturally varying flow that existed in a river prior to substantial human influence is necessary to provide insight into the flow regimes to which native species and ecosystems have adapted. Comparisons of the natural flow regime with current or projected conditions can shed light on the degree of departure from natural flow conditions that has already taken place or is expected in the future. A number of approaches exist to quantifying alteration to hydrologic regimes; all of which compare present-day (altered) flows to historical (un-developed) flows (e.g., Richter et al. 1996, Mathews and Richter 2007). The Technical Report's hydrologic analysis (section 2.2.2) follows common scientific guidelines by making comparisons to unimpaired flows, which are defined as those "that would have occurred had the natural flow regime remained unaltered in rivers instead of being stored in reservoirs, imported, exported, or diverted" (p. 2-6). The Technical Report is accurate in recognizing that "unimpaired flow differs from the full natural flow in that the modeled unimpaired flow does not remove the changes that have occurred such as channelization and levees, loss of floodplain and wetlands, deforestation, and urbanization." (p. 2-6). In other words, this assumes that the historical gage data represents unimpaired flow, thus providing a conservative estimate of flow alteration by underestimating unimpaired flows. This approach has been utilized repeatedly in the scientific literature (e.g., Poff et al. 2007, Carlisle et al. 2010) and is considered robust. Furthermore, the Technical Report clearly defines four components of flow that are not addressed in the calculation of unimpaired flow (pp. 2-7 – 2.8), thus recognizing that uncertainties exist that are important to acknowledge, but do not preclude the application of the proposed methodology. I agree with this assessment, and conclude that the comparative methodology is scientifically rigorous.

The primary components of a flow regime are the magnitude, frequency, seasonal timing, predictability, duration and rate of change of flow conditions (Poff et al. 1997); these factors are the most important to the geomorphology, physical habitat, and ultimately the biota of riverine ecosystems (Bunn and Arthington 2002). Accordingly, researchers have developed and applied a number of hydrologic metrics in attempts to characterize different components of the flow regime (see Olden and Poff 2003 for a review of 171 published metrics). The Technical Report's selection of hydrologic metrics was robust for: (1) characterizing ecologically relevant flow attributes for Chinook salmon and steelhead trout in the San Joaquin River basin, (2) describing overall variability in hydrologic regimes, and (3) quantifying flow characteristics that are believed reflect human-induced changes in flow regimes across a broad range of influences including dam operations, water diversions, ground-water pumping, and landscape (catchment) modification. The hydrologic analysis included an investigation of monthly and seasonal magnitudes of flow, and the timing, duration and frequency of peak flows and floods (using summary statistics and flow frequency analysis) following standard hydrologic approaches (Gordon et al. 2004). The degree of hydrologic alteration was calculated as present-day observed flow as a percent of unimpaired flow (Table 2.5 - 2.14). This approach is appropriate, scientifically robust, and has been used repeatedly in the scientific literature (e.g., Richter et al. 1996, 1997, 1998, Poff et al. 2007).

The Technical Report concludes that "water development in the SJR basin has resulted in: reduced annual flows; fewer peak flows; reduced and shifted spring and early summer flows; reduced frequency of peak flows from winter rainfall events; shifted fall and winter flows; and a general decline in hydrologic variability over multiple spatial and temporal scales" (p. 3-2). These major findings are strongly supported by the hydrologic analysis and the previous research cited throughout the Technical Report.

2. Determination that changes in the flow regime of the San Joaquin River basin are impairing fish and wildlife beneficial uses.

The structure and function of riverine ecosystems, and the adaptations of their constituent freshwater and riparian species, are determined by patterns of intra- and inter-annual variation in river flows (Poff et al. 1997, Naiman et al. 2008). A key foundation of the natural flow paradigm (*sensu* Poff et al. 1997) is that the long-term physical characteristics of flow variability have strong ecological consequences at local to regional scales, and at time intervals ranging from days (ecological effects) to millennia (evolutionary effects) (Lytle & Poff 2004). The Technical Report provides a succinct overview of how these attributes of the flow regime interact to influence physical habitat for Chinook salmon and steelhead trout, the availability of refuges, the distribution of food resources, opportunities for movement and migration, and conditions suitable for reproduction and recruitment. The assumption is made that present-day hydrographs that aim to mimic unimpaired hydrographs represent more "natural" conditions that favor the life-histories of Chinook salmon and steelhead trout in the San Joaquin River basin. This assumption is both well defended in the Technical Report and by decades of scientific research conducted in California and elsewhere.

Life-history summaries and population trends are presented for Chinook salmon and steelhead trout in the San Joaquin River using both original analysis and existing scientific literature. Time series for fall-run Chinook salmon escapement exceed 50 years in length, highlighting steady declines since 1952 (Figure 3.5), and evidence is presented that hatchery-produced fish constitute a majority of the natural fall-run spawners in the Central Valley (Figure 3.6). The Technical Report and scientific papers discussed within collectively highlight the decadal long declines in Chinook salmon and steelhead trout (albeit limited data in the latter case) in the San Joaquin River basin. The Technical Report also correctly emphasizes that escapement numbers for the three tributaries are comparable in many years, thus suggesting the importance of coordinating flow management across the tributary systems. Indeed, discrete contributions from different tributaries may provide a portfolio effect by decreasing inter-annual variation in salmon runs across the entire system, thus stabilizing the derived ecosystem services (*sensu* Schindler et al. 2010, but within basins).

3. Appropriateness of the approach used to develop San Joaquin flow objectives for the reasonable protection of fish and wildlife beneficial uses and the associated program of implementation.

Despite notable scientific progress in the last decade for establishing flow-ecology relationships to ensure beneficial uses of fish and wildlife (Poff et al. 2010), there are still scientific uncertainties that must be recognized. The functional relationship between an ecological response and a particular flow alteration can take many forms, as noted by Arthington et al. (2006). Based on current hydroecological understanding, we expect the form of the relationship to vary depending on the selected ecological response variable (i.e., adult abundance, smolt outmigration), the specific flow metric (i.e., magnitude of spring flows, frequency of floods) and the degree of alteration under present-day conditions. These relationships could follow a number of functional forms, from monotonic to unimodal to polynomial, and different ecological response variables may increase or decrease with flow alteration.

Given these uncertainties, a key challenge in determining flow alternatives is to synthesize the knowledge and experience from previous research in a coherent and comprehensive fashion to support future management. I believe that the Technical Report was successful in this regard by collating knowledge across a number of existing scientific studies. Collectively, the Technical Report summarizes the current state of knowledge demonstrating that “additional flow is needed to significantly improve production (abundance) of fall-run Chinook salmon; and the primary limiting factor for tributary abundances are reduced spring flow” (p. 3-26). Analyses over the past several decades have established statistical linkages (supported by ecological mechanisms) between escapement versus flow 2.5 years earlier when those salmon were rearing and outmigrating, and between juvenile salmon survival and flow. These relationships were quantified using standard time series analysis and statistical tests of correlation between the timing and magnitude of discharge and estimates of salmon escapement and smolt outmigration. All time series were of sufficient length for robust statistical analyses involving cross-correlations (time lags), according to the simulation study and guidelines presented by

Olden and Neff (2001). Time lags of 2.5 years are examined (ecological mechanism discussed above), which are well with the range of lag values that ensure a low probability of spurious cross-correlations between time series.

4. Determination that more flow of a more natural spatial and temporal pattern is needed from the three salmon bearing tributaries to the San Joaquin River during the February through June time frame to protect San Joaquin River fish and wildlife beneficial uses.

The Technical Report presents both original analysis and summarized previous studies to support the conclusion that additional flow during the spring period (Feb-June) is need to protect San Joaquin River fish and wildlife beneficial uses. Given the complexity at which hydrologic factors interact at multiple spatial and temporal scales to influence Chinook salmon and steelhead trout in the San Joaquin River, the Technical Report correctly provides multiple lines of evidence in support of this recommendation. Taken together, the scientific evidence presented in the Technical Report suggests that: (1) water development in the SJR basin has resulted in reduced annual flows, fewer peak flows, and reduced and shifted spring and early summer flows (among other things), (2) reduced spring flow has led to reduced production (abundance) of fall-run Chinook salmon, and (3) given (1) and (2), greater flow magnitude during the spring period is predicted to result in greater fish and wildlife beneficial uses in the San Joaquin River basin. This argument is both logical and based on sound scientific knowledge, methods and practices.

Development of robust flow alteration–ecological response relationships will need to take into account the role that other environmental factors play in shaping ecological patterns in streams and rivers. The predicted response of Chinook salmon and steelhead is certainly known to reflect factors other than flow regime, such as water quality and habitat structure; however, a quantitative understanding of how flow interacts with these other factors is not yet well developed. The Technical Report adequately discusses potential co-founding factors that may influence the positive influence of additional flow during the spring period (Feb-June) to protect San Joaquin River fish and wildlife beneficial uses. Factors related (but not limited) to ocean climate conditions, winter flow conditions, and water temperature are discussed. Of particular importance is that human land-use (e.g., riparian habitat degradation, urbanization) and dams/diversions that alter and reduce flows can also have significant effects on riverine thermal regimes (Olden and Naiman 2010). This is discussed only briefly in the Technical Report (p. 3-44), but requires additional examination. For example, dams and diversions can cause either decreases or increases in downstream temperatures depending on their mode of operation and specific mechanism and depth of water release (Olden and Naiman 2010). Below I discuss how stream temperature can influence stream ecosystems and may affect the success of instream flow management aimed to protect fish and wildlife. This topic requires additional exploration in the Technical Report.

Dam-induced modifications to a river's thermal regime (also termed thermal pollution) can have both direct and indirect consequences for freshwater ecosystems, yet it has been relatively unappreciated in discussions of instream flow management (Olden and Naiman 2010), including the Technical Report. For example, many dams release water from above the thermocline of the reservoir (i.e. the epilimnetic layer) resulting in elevated spring–summer water temperatures (e.g. Lessard and Hayes 2003). In addition to the well-recognized ecological effects of temperature stress for salmonids, dam-induced changes in thermal regimes may also have long-term evolutionary consequences by inducing a mismatch between a species' life-history and other critical environmental conditions. For example, Angilletta et al. (2008) hypothesized that warmer temperatures during the autumn and winter below Lost Creek Dam (Rogue River, U.S.A.) may indirectly influence the fitness of Chinook salmon by accelerating the development of embryos, leading to earlier timing of emergence. Shifts to earlier emergence could lead to mortality from high flow events, elevated predation or insufficient resources. Using an age-based population model the authors predicted a decrease in mean fitness of Chinook salmon after dam construction.

The benefits of flow restoration may be enhanced if riverine thermal regimes are also considered. One example supporting this notion is in the lower Mississippi River where research has shown that growth and abundance of juvenile fishes are only linked to floodplain inundation when water temperatures are greater than a particular threshold. Schramm and Eggleton (2006) reported that the growth of catfishes (*Ictaluridae* spp.) was significantly related to the extent of floodplain inundation only when water temperature exceeded 15°C; a threshold temperature for active feeding and growth by catfishes. Under the current hydrographic conditions in the lower Mississippi River, the authors report that the duration of floodplain inundation when water temperature exceeds the threshold is only about 1 month per year) on average. Such a brief period of time is believed to be insufficient for floodplain-foraging catfishes to achieve a detectable energetic benefit (Schramm and Eggleton 2006). These results are consistent with the 'thermal coupling' hypothesis offered by Junk et al. (1989) whereby the concordance of both hydrologic and thermal cycles is required for maximum ecological benefit.

5. Appropriateness of using a percentage of unimpaired flow, ranging from 20 to 60 percent, during the February through June time frame, from the Stanislaus, Tuolumne, and Merced Rivers is an appropriate method for implementing the narrative San Joaquin River flow objective.

A variety of methods have been developed for setting instream flow schedules; each has its strengths and weaknesses and requires varying levels of effort (see review by Tharme 2003). Some of these methods employ scientific expertise from a variety of disciplines and sophisticated computational models and tools (Poff et al. 2003, Richter et al. 2003, 2006). These approaches tend to be time-consuming, but they are the most appropriate for in-depth, river-specific analysis of environmental flow needs. On the other end of the spectrum are ''desktop'' or ''standard-setting'' methods that can be readily applied. Among these are hydrologically based standard-setting approaches, such as the Tennant Method, the Aquatic Base Flow Standard, and flow duration curve methods (Tharme 2003, Annear et al. 2004). Each of these methods uses hydrologic data to establish a flow rate that should be met or exceeded, based upon statistical evaluation of historical flows. The Technical Report undertakes the second of the two approaches, specifically relying heavily on flow duration curves to schedule flow according to a percentage of unimpaired flow.

Three important points must be made in regard to the appropriateness of the proposed approach. Each should be addressed in the Technical Report.

First, methods that are designed to "protect" some portion of the overall flow in a river (e.g., 60% of mean annual flow) are useful for their ease of application, but have been criticized because they do not adequately reflect the full range of variability in flows that is essential for sustaining river-dependent species and ecosystem processes for the long term (Tharme 1996, Arthington and Zalucki 1998, Bragg and Black 1999, Railsback 2001, Annear et al. 2004). The Technical Report discusses previous hydrologic analyses presented in the San Joaquin Basin Ecological Flow Analysis (Cain et al. 2003) and by Brown and Bauer (2009), which calculated percent alteration to a set of metrics evaluating magnitude, timing, and frequency of minimum and maximum flows (see p. 2-5). Although such information can be used to inform instream flow management, this knowledge was not used in Technical Report to inform different flow objectives. Instead, the Technical Report focused solely on flow magnitude during the spring months, thus, not accounting for other critical flow events occurring during different times of the year. For example, recommendations by CSPA/CWIN highlighted the importance of high pulse flows in October to attract adult spawning salmon to the SJR basin (p. 3-49). In summary, although I agree that a fixed monthly prescription is not useful given spatial and temporal variation in runoff (p. 3-52), the Technical Report does not account for the range of ecologically-important flow events that occur over the entire year that are critical for salmon persistence and sustained productivity.

Second, the Technical Report states that "In its 2010 report on Development of Flow Criteria for the Sacramento – San Joaquin Delta Ecosystem, the State Water Board determined that approximately 60 percent of unimpaired flow during the February through June period would be protective of fish and wildlife beneficial uses in the SJR." Further, the Technical Report states "State Water Board analysis indicate that 60 percent of unimpaired SJR flow at Vernalis from March through June would achieve flows of 5,000 cfs in over 85 percent of years and flows of 10,000 cfs in approximately 45 percent of years" (p. 3-47). These results imply that flows of 5,000 cfs would be achieved for all spring months (March through June) based on 60 percent of unimpaired flow. Unfortunately, this is not the case. Table 1 below illustrates percent exceedance for March – June according to 5,000 cfs threshold identified in the 2010 report "Development of Flow Criteria for the Sacramento – San Joaquin Delta Ecosystem" (data extracted from Figure 3.16 - 3.19). This shows that according to 60% of unimpaired flow that 5,000 cfs is achieved > 85% of the years only according to April and May (supporting the statement above), whereas considerably lower percentages are apparent for March and June.

Table 1. Percent exceedance for March – June according to 5,000 cfs threshold identified in the 2010 report "Development of Flow Criteria for the Sacramento – San Joaquin Delta Ecosystem" as a minimum flow threshold for salmon survival on the SJR. Data from Figure 3.16 - 3.19.

	Unimpaired	60% unimpaired	40% unimpaired	20% unimpaired
March	85	53	30	5
April	98	90	63	10
May	99	96	85	48
June	90	75	65	28

Third, although stated for only illustrative purposes in the Technical Report, the decision to illustrate only <60% of unimpaired flows is puzzling because the 2005 report *Recommended Streamflow Schedules to Meet the AFRP Doubling Goal in the San Joaquin River Basin* indicates that "estimates of flows needed on each tributary to double salmon production range from 51 to 97 percent of unimpaired flow" (p. 3-47). Given the choice of scenarios to report (20-60% of unimpaired flow) is based on TBI/NRDC analysis suggesting 5,000 cfs threshold for salmon <u>survival</u> (p. 3-48) and that >50% is estimated to be needed to achieve doubling of salmon <u>production</u>, implies that the Technical Report is only considering potential flow schedules that <u>**may**</u> lead to salmon survival at current low levels and not salmon recovery into the future. Therefore, the rationale for examining 20-60% of unimpaired flow as the only scenarios is questionable, and it needlessly limits a full investigation of the flows required to achieve fish and wildlife beneficial use. Taken together, the use of the word "illustrative" (p. 3-53) is misleading. According to the Merriam-Webster dictionary, illustrative is defined as clarifying by use of examples or serving to demonstrate. Yet, the Technical Report states "In addition to an existing conditions scenario, these illustrative alternatives represent the likely range of alternatives the State Water Board will evaluate in the environmental document supporting any revised SJR flow objectives" (p. 3-53). Therefore, these are not illustrative scenarios, but rather the actual scenarios that will be evaluated.

6. Appropriateness of proposed method for evaluating potential water supply impacts associated with flow objective alternatives on the San Joaquin River at Vernalis, and Stanislaus, Tuolumne, and Merced Rivers.

No response is provided because the topic is outside my realm of expertise.

7. Sufficiency of the statistical approach used by the State Water Board staff in the Technical Report to characterize the degradation of salinity conditions between Vernalis and the interior southern Delta

No response is provided because the topic is outside my realm of expertise.

8. Sufficiency of the mass balance analysis presented by the State Water Board staff in the Technical Report for evaluating the relative effects of National Pollutant Discharge Elimination System (NPDES) permitted point sources discharging in the southern Delta.

No response is provided because the topic is outside my realm of expertise.

9. Determination by State Water Board staff that the methodology and conclusions in the January 2010 report by Dr. Glenn Hoffman, regarding acceptable levels of salinity in irrigation water, are appropriate for reasonable protection of agricultural beneficial uses in the southern Delta.

No response is provided because the topic is outside my realm of expertise.

10. Other issues

In conclusion, it is my opinion that although components of the Technical Report are based on sound scientific knowledge (notably, those discussed in topics 1-4), the appropriateness of using a percentage of unimpaired flow (ranging from 20 to 60 percent) as a methodology for implementing the San Joaquin River flow objective is overly simplistic and only in part accounts for the full suite of flow conditions likely required to provide a reasonable level of protection for fish and wildlife benefit uses.

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Review of:

State Water Resources Control Board
California Environmental Protection Agency

"Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives"

By:

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As a reviewer, I was asked to consider a series of questions regarding the adequacy of the Technical Report. I list them here, and make comments that directly address them. I then provide a differently structured set of comments on the report, following my natural tendency to review reports in terms of an overall assessment and then a series of points that arose as I was reading the report.

1. **Adequacy of the hydrologic analysis of the San Joaquin River (SJR) basin compared to unimpaired flows**.

Changes in flow regime of the SJR and its three major tributaries:

The report reveals that the highest flow month of the year used to be May and in some years April or June but the highest flow month is now much more variable (Table 2.6). There are now much lower mean flows from January to July but actually higher than normal flows in August to December (Table 2.5). There are fewer peak flows now than in the past (Fig. 2.1, 2.2, 2.7). The SJR's flow used to be almost entirely comprised of the three main tributaries but their contribution is smaller in recent years (Fig. 2.8).

P. 39 "Like Vernalis, spring flows in each of the major SJR tributaries have been significantly reduced while flows during late summer and fall (generally August to November) have increased, resulting in less variability in flow during the year. Additionally, the year to year variability in winter and spring flows has been greatly reduced. Boxplots for each of the tributaries (Figure 2.10 through Figure 2.14) depict the median, 25th percentile, 75th percentile, and the wettest and driest months for 1984 to 2009. These graphical comparisons of the unimpaired flow and observed flows demonstrate the magnitude of alteration in the timing, variability, and volume of flows. Flows are much lower, primarily during the wet season, and with much less variation from year to year and within the year."

Hydrodynamics downstream of Vernalis

Page 52:
"Flow conditions downstream of Vernalis are largely affected by export operations of the two major water diverters in the Delta, the USBR and the DWR. The USBR exports water from the Delta for the CVP at the Jones Pumping Plant and the DWR exports water from the Delta for the SWP at the Banks Pumping Plant. In addition to these pumping plants, there are many smaller local agricultural diversions in the southern Delta that can affect flow conditions (State Water Board 1999.)"

Page 55: Reverse flows
"SWP and CVP pumping operations also increase the occurrence of net Old and Middle River reverse flows (OMR) reverse flows. OMR reverse flows are now a regular occurrence in the Delta. Net OMR reverse flows occur because the major freshwater source, the Sacramento River, enters on the northern side of the Delta while the two major pumping facilities, the SWP and CVP, are located in the south. This results in a net water movement across the Delta in a north to south direction along a network of channels including Old and Middle Rivers. Net OMR

is calculated as half the flow of the SJR at Vernalis minus the combined SWP and CVP pumping rate (CCWD 2010). A negative value, or a reverse flow, indicates a net water movement across the Delta along Old and Middle river channels towards the CVP and SWP pumping facilities."

"Net OMR reverse flows are estimated to have occurred naturally about 15 percent of the time before most modern water development, including construction of the major pumping facilities in the South Delta (Point A in Figure 2.16). The magnitude of net OMR reverse flows under unimpaired conditions was seldom more negative than 2,000 cfs. In contrast, between 1986 and 2005 net OMR reverse flows occurred more than 90 percent of the time (Point B in Figure 2.16). The magnitude of net OMR reverse flows may now be as much as -12,000 cfs."

As Fig 2.16 reveals, the magnitude of reverse flows has increased markedly over time. I am not a hydrologist by training but I found these sections to be very helpful in establishing the overall "plumbing" of the system and revealing the major changes in water that have occurred over the years. I would characterize the section as more than adequate. A strong case is made for the significance, at least in physical terms, of the changes.

2. **Determination that changes in the flow regime of the SJR are impairing fish and wildlife beneficial uses**
3. **Appropriateness of the approach used to develop SJR flow objectives**
4. **Determination that more flow of a more natural spatial and temporal pattern is needed for fish and wildlife beneficial uses**
5. **Appropriateness of using a percentage of unimpaired flow as the proposed method for implementing the flow objective**

The bulk of my assessment dealt with these questions, and I will try to summarize my conclusions here, followed by much more detailed comments and suggestions below. As I discuss below, the report itself shows some equivocation on the issue of how important other factors (e.g., marine processes) are in determining the overall population status and trends of steelhead and Chinook salmon. On the one hand, there is no doubt that the ocean plays a very large role in survival and growth of salmon and varies greatly from year to year. However, the river's flow regime has been so radically altered that I have no hesitation whatsoever in agreeing with the report's conclusion that the changes are impairing the river from the fishes' standpoint. The approach taken is essentially to estimate, model, and otherwise reconstruct the pre-development ("unimpaired") flow regime. As noted, I am not a specialist in hydrology by any means but the approach makes sense to me and the logic can be followed. More fundamentally, the approach of comparing observed to unimpaired flows seems like the correct one if we are to understand the ways in which fish have been affected by the changes. This is not to say that all pre-development conditions are ideal for fish, wildlife and other natural resources. We are all well aware that nature can be harsh and often sub-optimal. So, we need to consider the ways in which the changes have moved the river towards a condition that is more or less favorable for the fish species. I find the report very convincing in its conclusion that, while there are other stressors to fish, a more natural flow regime is necessary if the fish are to recover. Indeed, I would further conclude that the other stressors such as contaminants and non-native fishes will be less consequential for salmon and steelhead in a more natural flow and thermal regime, so the benefits of flow enhancement will likely be both direct and indirect.

The report concludes that the shift to a more normal flow regime will be beneficial for the two fish species, as the status quo has much less water during some times of the year and somewhat more water than would be normal at others. The connections between flow and fish ecology are numerous and intricate, especially for fishes with the complex life history patterns of salmonids (e.g., obligate or facultative anadromy). Life history models that chain together a series of mortality rates in isolated stages of ontogeny without considering density dependence often miss the mark, and I am surprised to learn how many conspicuous data gaps seem to exist.

Given these complexities and uncertainties, I think the approach (percentage of unimpaired flow) is a very reasonable and defensible one, and the models showing 20%, 40% and 60% are revealing. Inevitably one can argue (or quibble) over which precise value to use. Perhaps a quantitative model could be created to evaluate the variants precisely but my examination of the plots indicates that this is very good compromise. It takes into account the fact that water years vary, and the needs of the fish vary seasonally with different life history stages.

You requested that reviewers consider several other topics, listed below (as extracted from the peer review request letter). Several of them are simply not within my ken such as those dealing explicitly with salinity, effects on crops, etc. The last one, “other issues” can be taken pretty broadly. While reviewing the document I had a number of thoughts and they appear below, along with more detailed comments on the text, references, etc. I intend all these comments to be constructive and hope they are taken in that context.

6. Appropriateness of the proposed method for evaluating potential water supply impacts associated with flow objective alternatives
7. Sufficiency of the statistical approach used to characterize the degradation of salinity conditions
8. Sufficiency of the mass-balance analysis
9. Determination that the methodology and conclusions regarding acceptable levels of salinity are appropriate for protection of agricultural beneficial uses
10. Other issues.

Overall assessment:

This report is well-written and organized, and presents a great deal of information in a readable and comprehensible manner. The graphs are largely of good quality, though a few have been copied and lost some resolution in the process. There are few typographical errors and it is generally well-produced. My expertise is strictly in the areas of fish ecology and conservation, and I therefore found it somewhat unexpected to have the heavy coverage of fish-related issues in much of the report followed by the final two sections (4 and 5, on salinity and flow) with no mention of issues related to fish. I assume that this was a design feature rather than an oversight, but the juxtaposition of fish ecology and salt tolerance of crops was a bit striking. Needless to say, both depend on water and so that is the fundamental unifying resource. I wonder if it might be possible to make this separation of these a bit more clear somehow in the organization of the report, perhaps Part 1 and Part 2, or something like that.

In general the report relies too heavily on secondary sources (e.g., Moyle 2002; NMFS 2009a, 2009b; Williams 2006). There is nothing wrong with these references *per se* but their use compels the reader to get that reference and find the relevant place in it. In cases where the secondary source is lengthy or not readily available, this is no small task. In addition, the referencing of work outside the basin and outside California is limited. I understand that the report has a sharp focus on the San Joaquin River but there are a number of places where work done elsewhere would be relevant. I have made specific suggestions below.

In terms of conclusions, the report makes a strong case that the shortages of salmon and steelhead are in large part related to the heavy modification of this river system. The mean flows and variances in flow that are normal in rivers of this region and for which the fish evolved have been radically altered (see more detailed comments below). It seems likely, however, that other processes have played a role over the years in the decline of these fishes, and will continue to hinder their recovery. Some of these processes may be synergistic with flows such as, perhaps, chemical contaminants or predation in streams, whereas other may operate independently such as fisheries management, ocean conditions, predation by marine mammals, etc. Regardless, several distinct life history stages of salmonids show some form of density dependence, making it difficult to tease apart the effects of one process or another. I understand that this report was not designed to address these other issues. It is worth noting, therefore, that my review also does not attempt to integrate these other consideration into an overall assessment of the efficacy of flow changes on the prospects for recovering salmon and steelhead in this system. Notwithstanding this limitation, there are many comments that can be made on this report and my format (below) is to identify sections or quote from passages that are especially relevant and comment on them. They are presented in the order in which they appear in the report. It is hoped that by highlighting aspects that were especially informative, their role is acknowledged. Perhaps more importantly, if I have misinterpreted the key data in some way, by linking my comment with the source of information it will make my errors more evident, and thus easier to ignore.

Scientific Basis for Developing Alternate San Joaquin River Flow Objectives

Page 57

" The State Water Board has determined that higher and more variable inflows are needed to support existing salmon and steelhead populations in the major SJR tributaries to the southern Delta at Vernalis. This will provide greater connectivity to the Delta and will more closely mimic the flow regime to which native migratory fish are adapted. Water needed to support sustainable salmonid populations at Vernalis should be provided on a generally proportional basis from the Stanislaus, Tuolumne, and Merced Rivers. Flow in the mainstem SJR, below Friant Dam, for anadromous fish will be increased under a different regulatory and cooperative water management program (SJRRP 2010). "

Page 58
" The SJR basin once supported large spring-run and fall-run Chinook salmon populations; however, the basin now only supports a steadily declining fall-run population. Scientific evidence indicates that in order to protect fish and wildlife beneficial uses in the SJR basin, including increasing the populations of fall-run Chinook salmon and Central Valley steelhead to sustainable levels, changes to the altered hydrology of the SJR basin are needed. Specifically, a more natural flow regime, including increases in flow contributions from salmon bearing tributaries (Stanislaus, Tuolumne, and Merced Rivers), is needed during the February through June time frame. "

As noted above and discussed below, there are likely many factors affecting salmonids in this system but it seems likely that the flow regime changes have contributed greatly to the decline of these fishes, and rectifying this problem is probably necessary for recovery. Whether it is sufficient for recovery is a more complex question. The text in this section is clear and the presentation of data certainly adequate.

Page 57

• Observed flow is the measured streamflow recorded at USGS gages located at the most downstream location for each of the major SJR tributaries and at Vernalis.

• Unimpaired flow is a modeled flow generally based on historical gage data with factors applied to primarily remove the effects of dams and diversions within the watersheds. The modeled unimpaired flow does not attempt to remove changes that have occurred such as channelization and levees, loss of floodplain and wetlands, deforestation, and urbanization.

• Flow regime describes the characteristic pattern of a river's flow, quantity, timing, and variability (Poff et al. 1997). The 'natural flow regime' represents the range of intra- and interannual variation of the hydrological regime, and associated characteristics of magnitude, frequency, duration, timing and rate of change that occurred when human perturbations to the hydrological regime were negligible (Richter et al. 1996, Richter et al. 1997, Poff et al. 1997, Bunn and Arthington 2002, Lytle and Poff 2004, Poff et al. 2010).

• For the purposes of this report, a more natural flow regime is defined as a flow regime that more closely mimics the shape of the unimpaired hydrograph.

Salmon and Steelhead Biology

Chinook salmon biology

The section on Life History contains some errors and needs better references. The terms "ocean-type" and "stream-type" date to Gilbert (1913) and should ideally be linked to the reviews by Taylor (1990) and Healey (1991). The seasonal return patterns of adult salmon (e.g., fall and spring) do not necessarily correspond to the juvenile life history traits (ocean-type and stream-type). This is a common misconception; in many cases they are linked but it is best to use each set of terms for the life history phase to which it refers. In addition, the juvenile life history descriptors (stream-type and ocean-type) also include quite a lot of variation driver by with both genotype and phenotypic plasticity.

The proportions of males and females by age is a very important set of data and statements about them should be backed up with tables of data indicating the sample sizes in each year, etc. I comment on this later; the importance of this basic life history information cannot be over-stated.

The use of olfaction to locate natal streams deserves better citations than (NMFS 2009a, DFG 2010a). It would be better to cite Hasler and Scholz (1983) or perhaps Dittman and Quinn (1996).

P. 70

The statement "However, if natal streams have low flows and salmon cannot perceive the scent of their natal stream, straying rates to other streams typically increases." demands more details. There should be information on this important feature of the adult phase and appropriate references. I was surprised to find that there have been no tracking studies on the movements and travel rate of salmon in this system. Can this be true, and if so, why have none been done? This is off-the-shelf technology and clearly important to inform management in many ways.

I also have some sense (though I confess to not being sure precisely where I learned it) that there are much higher straying rates from the SJR than are considered normal, and that these result from transportation of hatchery juveniles downstream, and also from the difficulties that returning adults experience in detecting odors, given the altered flow regimes. Forgive me if I am mistaken in this regard but if there is any truth to the statement that straying is more prevalent than is normal, this certainly merits more attention in the report. There should be coded wire tagging data from the main hatcheries, I would think, and the analysis of them should be simple at a first cut. The links to flow would seem to be obvious. In addition, if straying rates are above normal, then the use of fish in streams to indicate natural production and the presence of fish in hatcheries to indicate hatchery production is really questionable. Such assumptions rest strongly on the idea that all salmon return to their natal site. There are other situations (e.g., Pascual et al. 1995) where "pathologically high" straying rates have been observed, and this might be mentioned. There is also more recent work on the mid-Columbia River populations by Richard Carmichael of Oregon Dept. of Fish and Wildlife on abnormally high rates of straying, which seem to be related to transportation and also thermal regimes. For example, steelhead from the Snake River enter into the Deschutes River during their upriver migration and many are caught there by anglers or simply stay in the Deschutes and do not make it to their natal sites to spawn.

The statement that "streamflow alteration, dictated by the dams on the major SJR tributaries, affect [sic] the distribution and quantity of spawning habitat " seems to call for more information. Presumably, the dams have reduced the sediment transport patterns but some detail and references to this would be helpful, or at least an explanation of the processes. The peak flows will play a role in these kinds of sediment transport processes. Is there a loss of intermediate gravel sizes, leaving cobbles and silt? Has the gravel become embedded and so less suitable?

Figure 3.1, which seems to be copied from the NMFS BiOp, needs a proper caption; as is, it is hard to interpret.

Figure 3.2 is quite interesting. Are there similar data for other years, and if so, perhaps a summary table or figure could be produced. Are the redd counts referring to new redds, or all that were counted on each survey? Were they flagged, and so how does the total redd count relate to the number of live fish? Were there tagging studies of stream life and generation of "area-under-the-curve" estimates? In general, I find myself wanting more detail about this kind of data.

Population Trends

Chinook salmon

P. 74

" Escapement numbers for the three tributaries are generally similar in many years, suggesting that the total returning salmon may split into the three tributaries uniformly, or that the success of salmon from each tributary is similar. However, in general, the Tuolumne population has been the highest and the Merced population has been the lowest."

A table with a matrix of correlations of annual estimates would be very useful. Figure 3.4 is striking but it would still be good to see the matrix, and a plot of each population against the others.

Page 75

" The annual (fall) escapement of adult fall-run Chinook salmon is really three cohort sequences, based on the typical three year return frequency (e.g., cohort "A" returning to spawn in 1952, 1955, 1958, etc; cohort "B" returning to spawn in 1953, 1956, 1959, etc.). "

Where is the evidence for this? I have gathered that the Chinook salmon are dominated by age-3 fish but this is such an important and basic point that it cries out for tables with the data. I'd expect to see age composition data, for each of the populations, as well as a quantitative separation of wild (naturally produced) and hatchery origin fish. Surely there are long-term age data from marked fish in hatcheries and wild fish on spawning grounds?

Mention is made of the fact that the escapement does not measure productivity because the fishery is not included. This seems quite surprising to me. Where are the catch data, and why is there no formal run reconstruction and set of brood tables? I do not mean to be harsh but the data on the salmon seem to be really limited. Surely there are coded wire tagging programs at the hatcheries and reconstructions of the runs? How else can the runs to the Sacramento be separated from the SJR? This is really basic information.

" … since 1952, the average escapement of fall-run Chinook salmon has shown a steady decline."

This statement is contradicted by the figure (3.5) associated with it. There is no obvious trend downward but rather there are a series of pronounced peaks (a pair of peaks around 1954 and 1960, then discrete ones around 1970, 1985, and 2003). Each of the peaks lasted about 8 years, with distinct "troughs" in between. I think the conclusion that this was a "steady decline" is not supported. Can there be some more sophisticated analyses? What we have seems like a visual examination. What can we make of these peaks and troughs?

Page 76
"There was no separation between hatchery and natural salmon that returned to the hatchery; the same is true for hatchery and natural salmon that spawned in river."

Really? The use of the term "hatchery" to refer to fish entering the hatchery, and "natural" to those spawning in the rivers (Greene 2009; Figure 3.6) is inconsistent with the common usage of these terms. Naturally produced fish may be drawn into the hatchery, and hatchery produced fish spawn in rivers (Quinn 1993). These two processes are so common that only an assessment of marked and unmarked fish (e.g., thermal banding of otoliths, adipose fin clips, etc.) would be meaningful. Has there really been no systematic assessment of the proportions of salmon produced naturally and from hatcheries? If not, it is no criticism of the report but this important matter should be made explicit.

Page 77
A series of monitoring efforts are listed but data from them are not readily apparent. Why were the data not incorporated into the report? Are the patterns reported elsewhere in a comprehensive manner, and if so, what are the conclusions?

- Adult Chinook Salmon Escapement- DFG
- CWT Releases/Recapture- Cramer and Associates
- CVP and SWP Salvage- USFWS and DFG
- Moss dale Trawls- DFG

• Chipps Island Trawls- USFWS
• Beach Seines- USFWS
• Rotary Screw Traps on each of the major SJR tributaries- DFG, AFRP, Cramer and Associates, and TID
• Fyke Nets- DFG
• Ocean and Recreational Harvest- Pacific Fisheries Management Council

Central Valley Steelhead (P. 77)

I believe that it was Busby et al. (1996) who proposed the stream-maturing vs. ocean-maturing distinction, so that report should be referenced in this context. As far as life history differences, I would certainly add the fact that steelhead/rainbow trout are spring spawners whereas Chinook salmon are fall spawners. The former spawn much smaller eggs with a shorter incubation period, typically on the ascending temperature regime, whereas salmon spawn larger eggs with a longer period during a descending temperature regime. This is very important in the present context because it determined what period of the year (and thus flows) they will be in the gravel as embryonic stages.

The statement that “there is no reproductive barrier between resident and anadromous forms” with a citation of Zimmerman et al. (2009) needs a lot of qualification. I re-read this paper and was unable to find such a statement from the authors. I quote from the paper below:

“With such a small sample size we are unable to draw conclusions about the contribution of progeny of rainbow trout females to the emigration of smolts. Similarly, in presumed steelhead smolts collected in an estuary of a small central California coastal stream (Pilarcitos Creek at Half Moon Bay), juveniles of both steelhead and rainbow trout maternal origin were present (C. E. Zimmerman, unpublished data). Further work is needed to assess the contribution of rainbow trout progeny as smolts and the fate of these fish compared with smolts of steelhead maternal origin.” p. 288

It should be noted that work such as that by Zimmerman et al. (2009) relies on the fact that the core of the otolith reflects the environment in which the mother was rearing during the maturation process. Thus the offspring of steelhead and rainbow trout mothers can be distinguished. This says nothing about the father, and assessment of the genetic basis for anadromy and residency in a complex matter. Certainly, there are studies that indicate some exchange between rainbow and steelhead, but I think this should be approached in a careful manner and one should not go beyond the evidence.

The report states that all San Joaquin River steelhead are ocean-maturing (“winter”) fish but it then states that they enter as early as July. Surely this would be a stream-maturing or “summer” fish? Perhaps there are remnants of this life history form still in the system? I am also intrigued by the statement that “If water quality parameters and other environmental conditions are not optimal, steelhead may delay migration to another more suitable year.” Does this refer to adults or smolts? I had not been aware that there was evidence of adult steelhead returning to freshwater but then going back to sea without spawning because conditions were not favorable. It would seem that this important point (with respect to flow, temperature, etc.) should have some reference and details, regardless of whether it deals with smolts or adults. The work by the NMFS group on Scott Creek is relevant to the issue of age composition and complex smolt migration patterns (i.e., fish that do not exit the lagoon – work by Morgan Bond, Sean Hayes and others).

The description of steelhead life history is basically correct but I am surprised that there was no figure quoted for the proportion of repeat-spawning steelhead in the system. Only a very dated figure from Shapovalov and Taft (1954) is cited and, if I recall correctly, their report was for small coastal streams. Are there no contemporary or historical data for the Central Valley runs?

P. 79
The terms potadromous and limnodromous are probably unnecessary jargon, and “fluvial” and “adfluvial” are more commonly used in any case.

Page 80
“ The limited data that do exist indicate that the steelhead populations in the SJR basin continue to decline (Good et al. 2005) and that none of the populations are [sic] viable at this time (Lindley et al. 2007). ”

This latter is a very strong statement and could use some elaboration. Presumably, the implication is that only exchange with resident trout maintains the steelhead phenotype. This should be stated more explicitly, and the biological basis for this exchange merits discussion. I am surprised that the interesting recent papers on California *O. mykiss* were not cited (e.g., those by Satterthwaite, Mangel and co-authors), nor relevant papers from elsewhere (e.g., Narum and Heath). This is not merely a matter of getting some additional references but it is fundamental to the status and recovery prospects for these fish. If the anadromous life history is latent in the resident trout then changes in environmental conditions may allow it to express itself, whereas if the forms are very discrete, as is the case with sockeye salmon and kokanee (the anadromous and non-anadromous forms of *O. nerka*: e.g., Taylor et al. 1996), then the loss of one form is likely more permanent. This extent of plasticity is directly relevant to the efforts to address the chronic environmental changes to which these fishes have been subjected, and the prospects for recovery.

It is also worth noting that the migratory behavior of steelhead differs markedly from that of sub-yearling Chinook salmon. Sub-yearlings spend a lot more time in estuaries and littoral areas whereas steelhead seem to migrate more rapidly (as individuals), exit estuaries quicker (as a population), and occupy offshore waters to a much greater extent. There was extensive sampling in the Columbia River system by Dawley, McCabe and co-workers showing this, and many references to the use of estuaries.

The summary of the importance of spring flows for Chinook salmon seems very reasonable but it would be good to actually see more of the data on which these statements are based. What relationship might there be to pre-spawning mortality or incomplete spawning of adults, or egg-fry survival?

Figure 3.8 would be better expressed after adjustment for the size of the parent escapement and some density-dependence. Plotting numbers of smolts vs. flow suggests a connection but I would think that multi-variate relationships should be explored.

Page 84-85.
" In a 1989 paper, Kjelson and Brandes once again reported a strong long term correlation (R^2 of 0.82) between flows at Vernalis during the smolt outmigration period of April through June and resulting SJR basin fall-run Chinook salmon escapement (2.5 year lag) (Kjelson and Brandes 1989).

This relationship should be easy to update and I would like to see the recent data. Frankly, I find this correlation implausibly high. There are so many factors affecting marine survival that even a perfect estimate of the number of smolts migrating to sea will not have an R^2 of 0.82 with total adult return, much less with escapement (including both process and measurement error). I do not doubt that higher flows make for speedier passage and higher survival, but to link them so closely with adult escapement is stretching it. Indeed, it would seem that NMFS (2009) came to a similar conclusion. After acknowledging the shortcomings in this approach, it seems odd to see Figure 3.10, which is a time-series with flow during the smolt period and lagged escapement. If we much have escapement as the metric rather than smolt survival, can we not at least plot flow on the x-axis rather than date, and some form of density-adjusted recruit per spawner metric on the y-axis? I find it very difficult to see the relationship when plotted as time series.

Figure 3.12. This figure is a poor quality reproduction, and the y-axis is not defined. What is CDRR? (It is not in the list of acronyms). This report is pretty dense in terms of jargon and acronyms and abbreviation, so any effort to state things in plain English will be appreciated.

The text on the Importance of Flow Regime (3.7) is very sensible. It would be helpful to know what sources of the salmon mortality are most directly affected by flow reduction but, given the obvious data gaps, this seems unlikely. Thus overall correlations with survival and basic ecological principles have to carry the day. The text on fish communities, however, is rather confusing. I expected to see information of species composition, comparative tolerances to warm and cool water by various native and non-native fishes, ecological roles with respect to salmon, etc. However, there was a shift to population structure and importance of genetic and life history diversity for the success of salmon. This text (which would benefit from basic references such as Hilborn et al. 2003 for sockeye salmon, and the more recent papers by Moore and by Carlson on salmon in areas more extensively affected by humans) is fine but the reference to variable ocean conditions and marine survival seems to contradict the earlier statements that only smolt number going to sea really matter. Overall, I think this holistic view is more tenable than one only emphasizing the link between flow and smolt production. There is no question that marine survival varies from year to year but all you can ask from a river is that it produce juvenile salmon.

With respect to water temperature, the relationships between physical factors (local air temperature, water depth, solar radiation, groundwater, and heat loss, etc.) are quite well understood so it should be possible to hind-cast the thermal regime that would have occurred in the SJR and its tributaries had the dams and diversions not taken place. An approach such as the one described by Holtby and Scrivener (1989) might be very useful and more precise than just saying that releasing more water would cool things down.

The section on water quality (3.7.6) should be better integrated into the arguments related to flow. As it is, we have a list of effects and possible connections to salmon but no way to link to the rest of the report. For example, salinity seems very likely to be a function of discharge but we are not given the relationship, much less the connection to salmon. Pesticides are probably prevalent but what will their interaction be with flow? Will more water reduce their effects, and will the patterns be linear or not?

Delta Flow Criteria

"Finally, the relationship between smolts at Chipps Island and returning adults to Chipps Island was not significant, suggesting that perhaps ocean conditions or other factors are responsible for mortality during the adult ocean phase."

This statement, referring to DFG data, also seems to contradict the earlier statements that marine conditions do not matter and that flow is all that matters. It would seem more correct to state that flow is the most important, among the things under our control.

On Table 3.15, it would be very helpful to present the status quo, so we can see the difference between the flows that DFG concluded are needed to double smolt production from present levels.

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"State Water Board determined that approximately 60 percent of unimpaired flow during the February through June period would be protective of fish and wildlife beneficial uses in the SJR. It should be noted that the State Water Board acknowledged that these flow criteria are not exact, but instead represent the general timing and magnitude of flow conditions that were found to be protective of fish and wildlife beneficial uses when considering flow alone."

This would seem to be a critical, overall conclusion: Higher and more variable flows are needed, and can be ca. 60% of unimpaired flows. This is logical and well supported by basic ecological principles, as these flows would provide benefits specific to salmon at several life history stages, and broader ecosystem benefits a well. The various exceedance plots (Figures 3.15 to 3.20) indicate that there is substantial improvement from flow at the 60% level whereas 20% and 40% achieve much less in the important late winter and early spring periods. As the report correctly notes, this is inevitably a bit arbitrary (why 60% - might 59% not do just as well?). Just as with agriculture and wildlife, fish production depends on complex interactions among a number of factors, of which flow is very important but not the only one. Extrapolation from lab studies to the field, where so many things go on at once and where history cannot be played back in a different scenario. So, one can pick at this value, just as one might pick at any specific value, and ask whether the fish can get by with a little less overall, or at some time of the year. Likewise, how much water do crops really need? Can we give the farmers less without hurting production? Obviously, that would depend on soil, temperature, distribution of the water, insects (beneficial and otherwise), and many other factors too. I think that this value (60%) is well-supported, given these kinds of uncertainties. The fish would probably benefit from even more water, but they will be more than glad to get this amount, as it will be a big improvement over the status quo.

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"Given the dynamic and variable environment to which SJR basin fish and wildlife adapted, and imperfect human understanding of these factors, developing precise flow objectives that will provide certainty with regard to protection of fish and wildlife beneficial uses is likely not possible. Nevertheless, the weight of the scientific evidence indicates that increased and more variable flows are needed to protect fish and wildlife beneficial uses. "

I agree completely – this is very well-stated.

4. Salinity (pages 113-126)
The report has so much effort devoted to salmon and steelhead that the absence of reference to these fishes in the section on salinity is stark. Are there no issues related to estuarine dynamics or salinity related to salmon?

5. Flows
Same as above for salinity.

Suggested additional references, or references mentioned in the above comments

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Attachment 2

Responses to Peer Review Comments

Attachment 2

The State Water Resources Control Board (State Water Board) submitted the October 2011 Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives, (Technical Report) to five independent scientific peer reviewers on October 14, 2011. This peer review was conducted according to California EPA's peer review standards, and was overseen by Cal EPA Peer Review Manager; Dr. Gerald Bowes.

The five peer reviewers chosen to perform an independent scientific peer review of the Technical Report are listed in Table A below. State Water Board Staff (Staff) extends our sincerest thanks to the peer reviewers for their time and efforts in this process. The peer reviewer's comments indicated that they understood the intent of their review, were qualified to conduct the review, and that their reviews were adequately supported by the materials were provided to them.

In general, the peer reviewer comments indicated an overall agreement with the scientific basis and methodology presented in the Technical Report. Peer reviewers agreed that the Technical Report was well written and based on sound scientific knowledge, methods, and practices. Peer reviewers also agreed with the Staffs' underlying statement, "flow of a more natural spatial and temporal pattern is needed from the three salmon bearing tributaries to the San Joaquin River during the February through June time frame to protect San Joaquin River fish and wildlife beneficial uses".

Each peer reviewer commented about sections relevant to their expertise differently, and in some cases there are clear differences in opinions between reviewers. Staff did not agree with all the peer reviewers' comments, and notes that while some comments seem to reflect minor misunderstandings of the method, other comments clearly reflect a technical understanding of the topic and constructive criticism for improving the Technical Report. However, Staff agreed with most of the suggestions and comments provided by the peer reviewers and will use this constructive criticism to guide revisions to the Technical Report.

Table A. Peer Reviewers for the Technical Report

Reviewer	Reviewers Affiliation
John A. Dracup, Ph.D., P.E.	Professor, Civil & Environmental Engineering University of California Berkeley
Henriette (Yetta) Jager, Ph.D.	Adjunct Faculty, Ecology & Evolutionary Biology University of Tennessee
	Research Scientist, Environmental Sciences Division Oak Ridge National Laboratory
Mark E. Grismer, Ph.D., P.E.	Professor, Hydrology and Agricultural Engineering University of California Davis
Julian D. Olden, Ph.D.	Associate Professor, Aquatic & Fishery Sciences University of Washington
	Assistant Professor, Aquatic & Fishery Sciences University of Washington
Thomas P. Quinn, Ph.D.	Professor, Aquatic & Fishery Sciences University of Washington

Below are the issue statements asked to all peer reviewers in Attachment 2 of the August 12, 2011 Request for Scientific Peer Review Letter. Peer reviewer comments and Staff responses have been provided under each issue statement.

Issues pertaining to San Joaquin River Flows for the Protection of Fish and Wildlife Beneficial Uses

1. **Adequacy of the Technical Report's hydrologic analysis of the San Joaquin River basin comparing unimpaired flow with actual observed flows in representing changes that have occurred to the hydrograph of the San Joaquin River basin in order to provide background and support for the remaining chapters of the Technical Report.**

Dracup Comment #1: The modeled unimpaired stream flows, as presented in the TR, should be compared with locations that represent natural unimpaired stream flows, such as the Merced River in the Yosemite Valley at Pohono (1916-present) and at Happy Isles (1915-present), in order to verify the accuracy of the modeled unimpaired record.

Dracup Response #1: Comment noted. At the January 6-7, 2011 Workshop that presented and discussed the Draft Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives, Staff asked the Panel of experts the following question: "Does the current Department of Water Resources methodology provide an adequate representation of unimpaired flow?". The overall responses given by the experts were that the unimpaired flow was adequately represented by the calculations by Department of Water Resources. It was also suggested that given the timeframe of the project, and the fact that it is a programmatic project, that additional precision from further analysis would not be necessary. It was also stated that the flows at the reservoirs, or just below the rim dams, are accurate and easy to calculate, however the unimpaired flow at locations on the Valley floor and further downstream is more difficult to calculate. It was also agreed that nearly all of the flow volume comes from upstream of the reservoirs, while little additional flow is added from the Valley floor.

Action: No changes were made to the Technical Report.

Dracup Comment #2: The monthly flow results as shown in Figures 2.8 through 2.14 are as expected, that is, the unimpaired flows are higher than the observed flow. The one exception is the Stanislaus River from April to September (1984-2009) as shown in Figure 2.9 where the observed flows are higher than the unimpaired flows. The reason for this is probably the observed releases from upstream dams.

Dracup Response #2: Comment noted. Figure 2.9 shows that occasionally the observed flow from the Stanislaus River has a higher monthly median percentage contribution to flow at Vernalis compared to the unimpaired flow contribution. The figure does not indicate that the observed flow is greater than the unimpaired flow, since it depicts the proportion of flow at Vernalis and not the observed flow. However, as shown in Figure 2.10, during later summer and fall, median monthly flows are higher than unimpaired flows in the Stanislaus River as a result of reservoir releases of stored water.

Action: No changes were made to the Technical Report.

Dracup Comment #3: The term “the wettest month” on the first line of page 2-17, should be changed to “month of highest runoff”. The term “wettest” usually refers to rainfall not “volume of flow” as is the topic in this case.

Dracup Response #3: Comment noted. The term is clarified within the parentheses that follow this text “(i.e. the month in the water year with the greatest volume of flow)”, however, to eliminate any future comments on this topic; the term “wettest month’ will be clarified to the “month of highest runoff”.

Action: The appropriate changes were made to the Technical Report.

Dracup Comment #4: I was surprised to note that nothing was said about the potential impact of global warming and climate change in this Chapter. Numerous scholarly journal articles have been written on the subject of the impact of climate change on the future hydrology of and the runoff from the Sierra Nevada Mountains. These can be summarized by stating that we can expect more runoff during early spring months when it is not needed and less runoff in the late summer and early fall months when it is needed for irrigation purposes.

Dracup Response #4: Comment noted. The potential impacts of global climate change were discussed briefly in Section 3.5.1 of the Technical Report. A more detailed discussion of the potential impacts of global climate change was included in the Substitute Environmental Document (SED) that was prepared in response to the proposed Bay-Delta Plan amendments.

Action: No changes were made to the Technical Report.

Grismer Comment #1: Under the “consumptive use” there is little if any discussion of the decreased annual sub-basin water yields associated with reservoir evaporation after about 1940. As reservoir development continued during the next several decades, presumably evaporation losses increased thereby progressively reducing sub-basin water yields and as a result, the estimated “unimpaired flows”. Some discussion of how large this effect may be on the estimated unimpaired flows is needed.

Grismer Response #1: Comment noted. Section 2.2.2 of the Technical Report described unimpaired flow data obtained from the Department of Water Resources (Department) reports, how the Department considered and adjusted for reservoir evaporation in the calculation of unimpaired flow, and how this data was used in the Technical Report. In addition, reservoir evaporation was included as a variable in the Water Supply Effects Model (WSE Model) that was described in Section 5.3 of the Technical Report. Appendix F1 of the SED provides additional details regarding how reservoir evaporation was incorporated into the final WSE model.

Action: No changes were made to the Technical Report.

Grismer Comment #2: The effects of climate change on (a) shift of the spring snowmelt period to weeks earlier on average during the past several decades alone, and (b) possible greater rain-snow variability in the Sierras and its effect on reservoir operation and ability to contain rain-on-snow flood events should also have a discussion.

Grismer Response #2: Comment noted. Please refer to Dracup Response #4.

Action: No changes were made to the Technical Report.

Jager Comment #1: I concur that the Technical Report’s hydrologic analysis is adequate and consistent with previous studies. The analysis demonstrated that significant changes to the San Joaquin basin flow regimes result from post-dam upstream water uses. Areas of uncertainty include the magnitude of evapotranspiration from wetland riparian species and groundwater return flows from agriculture. Nevertheless, the main result regarding the substantial differences between unimpaired and post-dam San Joaquin basin flows appears to be clear-cut and well supported.

Jager Response #1: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #1: The Technical Report’s hydrologic analysis (section 2.2.2) is based upon 80 years of discharge data across all years, and 11-25 years of discharge data for periods categorized as critical (wet, above normal, below normal, dry) (Table 2.2 and 2.3), therefore, in my opinion the characterization of hydrologic conditions is considered robust with respect to accuracy and precision.

Olden Response #1: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #2: The Technical Report is accurate in recognizing that “unimpaired flow differs from the full natural flow in that the modeled unimpaired flow does not remove the changes that have occurred such as channelization and levees, loss of floodplain and wetlands, deforestation, and urbanization.” (p. 2-6). In other words, this assumes that the historical gage data represents unimpaired flow, thus providing a conservative estimate of flow alteration by underestimating unimpaired flows. This approach has been utilized repeatedly in the scientific literature (e.g., Poff et al. 2007, Carlisle et al. 2010) and is considered robust.

Olden Response #2: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #3: Furthermore, the Technical Report clearly defines four components of flow that are not addressed in the calculation of unimpaired flow (pp. 2-7 – 2.8), thus recognizing that uncertainties exist that are important to acknowledge, but do not preclude the application of the proposed methodology. I agree with this assessment, and conclude that the comparative methodology is scientifically rigorous.

Olden Response #3: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #4: The Technical Report's selection of hydrologic metrics was robust for: (1) characterizing ecologically relevant flow attributes for Chinook salmon and steelhead trout in the San Joaquin River basin, (2) describing overall variability in hydrologic regimes, and (3) quantifying flow characteristics that are believed reflect human-induced changes in flow regimes across a broad range of influences including dam operations, water diversions, ground-water pumping, and landscape (catchment) modification.

Olden Response #4: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #5: The hydrologic analysis included an investigation of monthly and seasonal magnitudes of flow, and the timing, duration and frequency of peak flows and floods (using summary statistics and flow frequency analysis) following standard hydrologic approaches (Gordon et al. 2004). The degree of hydrologic alteration was calculated as present-day observed flow as a percent of unimpaired flow (Table 2.5 - 2.14). This approach is appropriate, scientifically robust, and has been used repeatedly in the scientific literature (e.g., Richter et al. 1996, 1997, 1998, Poff et al. 2007).

Olden Response #5: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #6: The Technical Report concludes that "water development in the SJR basin has resulted in: reduced annual flows; fewer peak flows; reduced and shifted spring and early summer flows; reduced frequency of peak flows from winter rainfall events; shifted fall and winter flows; and a general decline in hydrologic variability over multiple spatial and temporal scales" (p. 3-2). These major findings are strongly supported by the hydrologic analysis and the previous research cited throughout the Technical Report.

Olden Response #6: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #1: As Fig 2.16 reveals, the magnitude of reverse flows has increased markedly over time. I am not a hydrologist by training but I found these sections to be very helpful in establishing the overall "plumbing" of the system and revealing the major changes in water that have occurred over the years. I would characterize the section as more than adequate. A strong case is made for the significance, at least in physical terms, of the changes.

Quinn Response #1: Comment noted.

Action: No changes were made to the Technical Report.

2. Determination that changes in the flow regime of the San Joaquin River basin are impairing fish and wildlife beneficial uses.

Jager Comment #2: The report does a good job of presenting relevant past research carried out by California agencies to support the conclusion that water development is impairing salmon production.

Jager Response #2: Comment noted.

Action: No changes were made to the Technical Report.

Jager Comment #3: The flow-salmon relationship is well-documented. However, the flow-salmon relationship is dominated by indirect pathways mediated by other factors, and the remaining uncertainties involve parsing out proximate factors that link flow to salmon and steelhead status and trends.

Jager Response #3: Comment noted. Poff et al. (1997) describes the flow regime as the "master variable" that limits the distribution and abundance of riverine species (Resh et al. 1988; Power et al. 1995), and regulates the ecological integrity of rivers. Therefore, the lack of spring flow continuity between SJR tributaries and the south Delta, with the addition of elevated water temperature in the tributaries and lower reach of the SJR, has been identified as the critical element needed for restoration, and the focus of the Technical Report.

In the SJR basin, it is recognized that the most critical life stage for salmonid populations is the spring juvenile rearing and migration period (DFG 2005a, Mesick and Marston 2007, Mesick et al. 2007, and Mesick 2009). Scientific evidence presented in the technical report indicates that in order to protect fish and wildlife beneficial uses in the SJR basin, including increasing the populations of SJR basin fall-run Chinook salmon and Central Valley steelhead to sustainable levels, changes to the current flow regime of the SJR basin are needed. Specifically, a more natural flow regime from the salmon bearing tributaries (Stanislaus, Tuolumne, and Merced Rivers) is needed during the February through June time frame. As such, while SJR flows at other times are also important, the focus of the current review is on flows within the salmon-bearing tributaries and the SJR at Vernalis (inflows to the Delta) during the critical salmon rearing and outmigration period of February through June.

Some additional discussion has been added to the Technical Report regarding environmental factors associated with flow that affect salmon survival. Not all factors related to flow (e.g., bed mobilization, habitat connectivity etc.) have a well described or established relationship to salmon survival compared to the flow and salmon survival relationship. Thus it is hard to quantify how flow interacts with these factors to improve salmon survival. However, future monitoring and studies will be performed as required in the draft Program of Implementation, identified in Appendix K in the SED, and the results of the monitoring and studies will provide a better understanding of how flow influences the factors that affect salmon survival, which will help to inform implementation of the proposed LSJR flow objectives. Additionally, adaptive implementation measures are included that provide the ability to optimize the required flows to improve habitat conditions in the tributaries and the lower SJR.

Action: The appropriate changes were made and references added to the Technical Report.

Jager Comment #4: Lindley et al. (2007) set out criteria for assessing risk for salmon and steelhead based on status, trends, catastrophes, and hatchery influence, many of which build on an earlier report by McElhaney et al. (2000). Both sources are generally consistent with generally accepted scientific principles of conservation biology, but await scientific scrutiny by reviewers for a higher tier journal. Mesick (2009) applied the Lindley et al. (2007) criteria in an assessment of risk for fall Chinook salmon and concluded the population is at high risk according to some criteria (high risk was defined as 20% risk of extinction [of natural spawners] within 200 years) and moderate risk according to others.

Jager Response #4: Comment noted.

Action: No changes were made to the Technical Report.

Jager Comment #5: The report made the case that the San Joaquin Basin (SJB) fall Chinook ESU is at risk, as summarized above. In this case, the risk is fairly clear. How immediate is the risk? A population viability analysis (PVA) is needed to quantify the distribution of future times to extinction of the 'wild' population. Population viability is usually assessed in terms of abundance, productivity, spatial extent, and diversity (Waples 2005). To fully assess risk of extirpation from the San Joaquin basin from a qualitative perspective, I would add additional risk factors to the ones listed in the report: (5) high volatility in abundance, (6) low carrying capacity, (7) susceptible to Allee effects, (8) high correlation among sub-populations, and (9) position at edge of geographic range. Each of these additional factors lends support to the argument made in the Report that the SJB fall Chinook salmon ESU is at high risk.

Jager Response #5: Comment noted. A PVA is a process of identifying the threats (i.e., environmental factors or stressors) faced by a species (i.e., Chinook salmon and steelhead) and evaluating the likelihood that said species will persist for a given amount of time into the future. A PVA was not conducted in the Technical Report because stressors, other than flow, that affect Chinook salmon and steelhead will be addressed in greater detail in the Draft SED, and were not the focus of the Technical Report. A formal PVA is also not included in the Draft SED, which is a programmatic document that focuses on the qualitative impacts associated with implementation of the proposed LSJR flow objectives to identified resources in the program area. In some cases, however, a quantitative analysis of impacts to salmonids, such as changes in available spawning and rearing habitat, is discussed in the SED.

Action: No changes were made to the Technical Report

Jager Comment #6: Flow influences on incubation survival were not specifically addressed in the report.

Jager Response #6: Comment noted. Some additional discussion regarding how water temperature influences and larval survival incubation survival was added to the Technical

Report. However, Staff focused primarily on flow influences on survival to the spring juvenile rearing and migration life stages, because, in the SJR basin, it is recognized that this is the most critical life stage for salmonid populations (DFG 2005a, Mesick and Marston 2007, Mesick et al. 2007, and Mesick 2009). Analyses indicated that the primary limiting factor for salmon survival and abundance is reduced flows during the late winter and spring when juveniles are completing the freshwater rearing phase of their life cycle and migrating from the SJR basin to the Delta (February through June; DFG 2005a; Mesick and Marston 2007; Mesick et al. 2007; Mesick 2009). As such, while SJR flows at other times are also important, the focus of the State Water Board's current review was on flows within the salmon-bearing tributaries and the SJR at Vernalis (inflows to the Delta) during the critical salmon rearing and outmigration period of February through June.

Action: The appropriate changes were made and references added to the Technical Report.

Jager Comment #7: The use of logistic regression in the TBI was also a good idea because the resulting model will be robust to extrapolation beyond the range of historical flows. However, the analysis was conducted recently and has not yet undergone scientific peer review and I would encourage them to complete this step in the process. In anticipation, they might explore whether the following refinements might reduce uncertainty in the flow threshold: 1) if there is enough data/power, consider expanding the analysis to include other covariates (e.g., return cohort A, B, C; initial spawner abundance); if not, consider quantile regression as a way to reduce influence of covariates not included (see Jager et al. 2010), 2) consider residual autocorrelation, and 3) evaluate whether it is possible to solve directly for the inflection point as a parameter, which would provide confidence bounds on the flow threshold. I would not expect these refinements to alter the main conclusions of the analysis.

Jager Response #7: Comment noted. The logistic regression was performed by TBI/NRDC to inform the State Water Board's 2010 proceeding to develop flow criteria necessary to protect public trust resources in the Delta. Altering the analysis performed by TBI/NRDC was outside our purview. Additionally, Jager also states that the additional refinements (mentioned above) to the logistic regression analysis would not likely alter the main conclusions of the analysis.

Action: No changes were made to the Technical Report.

Jager Comment #8: Understanding the relationship between freshwater flows and survival during migration is complicated by the fact that flow often operates indirectly through its effects on intermediate factors that directly influence survival (Speed 1993). In the Bay-Delta, these include temperature, dissolved oxygen (DO), salinity, and predation. From a management standpoint, it may be important to understand the proximate mechanisms responsible for the benefits of flow so that constructive options that require lower environmental flows can be considered.

Jager Response #8: Comment noted. Additional information regarding the interaction between flow and water temperature is provided in the SED, Chapter 9 (Aquatic Resources) and additional discussion of predation and the impact of nonnative species on salmonids has been added to the Technical Report in Section 3.5.1. Please refer to Jager Response #3.

Action: The appropriate changes were made and references added to the Technical Report.

Jager Comment #9: Two remaining flow-influenced factors have not been included as covariates in models of survival during outmigration cited in the report. These are predation and low DO from the Stockton Deepwater Ship Channel (Mesick 2009, page 3-32). Studies to coordinate water quality monitoring during smolt releases might help to understand the importance of water quality. Assessing predation might be a greater challenge.

Jager Response #9: Comment noted. Additional information regarding studies that assess the impact of predation on salmonids has been added to Section 3.5.1. Please refer to Jager Response #3.

Action: The appropriate changes were made and references added to the Technical Report.

Jager Comment #10: The report has little to say about the role of flow during spawning and incubation. Cain et al. recommend sufficiently high, but stable flows during winter incubation presumably to avoid dewatering or scouring of redds, and this was also the solution found by our salmon-flow optimization for the Tuolumne (Jager and Rose 2003). However, research is needed to understand flow effects on survival, which is lower in SJ tributaries than in the Columbia River (Geist et al. 2006) at similar temperatures. Siltation and low DO may account for this difference and may be mitigated by increasing flow/depth to increase exchange (downwelling) with hyporheic flow (see Tonina and Buffington 2011).

Jager Response #10: Comment noted. Additional discussion regarding water velocity and depth requirements for successful Chinook salmon spawning was added to the Technical Report. Please refer to Jager Response #6.

Action: The appropriate changes were made and references added to the Technical Report.

Olden Comment #7: The Technical Report provides a succinct overview of how attributes of the flow regime interact to influence physical habitat for Chinook salmon and steelhead trout, the availability of refuges, the distribution of food resources, opportunities for movement and migration, and conditions suitable for reproduction and recruitment. The assumption is made that present-day hydrographs that aim to mimic unimpaired hydrographs represent more "natural" conditions that favor the life-histories of Chinook salmon and steelhead trout in the San Joaquin River basin. This assumption is both well defended in the Technical Report and by decades of scientific research conducted in California and elsewhere.

Olden Response #7: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #8: The Technical Report and scientific papers discussed within collectively highlight the decadal long declines in Chinook salmon and steelhead trout (albeit limited data in the latter case) in the San Joaquin River basin. The Technical Report also correctly emphasizes that escapement numbers for the three tributaries are comparable in many years, thus suggesting the importance of coordinating flow management across the tributary systems. Indeed, discrete contributions from different tributaries may provide a portfolio effect by decreasing inter-annual variation in salmon runs across the entire system, thus stabilizing the derived ecosystem services (*sensu* Schindler et al. 2010, but within basins).

Olden Response #8: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #9: There are likely many factors affecting salmonids in this system but it seems likely that the flow regime changes have contributed greatly to the decline of these fishes, and rectifying this problem is probably necessary for recovery. Whether it is sufficient for recovery is a more complex question. The text in this section is clear and the presentation of data certainly adequate.

Quinn Response #9: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #2: The river's flow regime has been so radically altered that I have no hesitation whatsoever in agreeing with the report's conclusion that the changes are impairing the river from the fishes' standpoint. The approach taken is essentially to estimate, model, and otherwise reconstruct the predevelopment ("unimpaired") flow regime. As noted, I am not a specialist in hydrology by any means but the approach makes sense to me and the logic can be followed. More fundamentally, the approach of comparing observed to unimpaired flows seems like the correct one if we are to understand the ways in which fish have been affected by the changes.

Quinn Response #2: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #3: I find the report very convincing in its conclusion that, while there are other stressors to fish, a more natural flow regime is necessary if the fish are to recover. Indeed, I would further conclude that the other stressors such as contaminants and non-native fishes will be less consequential for salmon and steelhead in a more natural flow and thermal regime, so the benefits of flow enhancement will likely be both direct and indirect.

Quinn Response #3: Comment noted.

Action: No changes were made to the Technical Report.

3. Appropriateness of the approach used to develop San Joaquin River flow objectives for the reasonable protection of fish and wildlife beneficial uses and the associated program of implementation.

Grismer Comment #3: The curve in Figure 3.8 on p.3-27 is practically meaningless given the few points available; perhaps this is why no R^2 value is provided. I suggest simply eliminating the curve.

Grismer Response #3: Comment noted. Figure 3.8 has been replaced with additional discussion and data on coded wire tag studies in Section 3.4.1.

Action: The appropriate changes were made and references added to the Technical Report.

Grismer Comment #4: In Figure 3.10, there is extremely low fish "escapement" from the Merced River during 1950-1968 that would seem to "skew" results. Is there any explanation for this dearth of salmon in this period? Is it real or an artifact of sampling?

Grismer Response #4: Comment noted. Figure 3.10 (Figure 3.9 in revised Technical Report) and 3.4 were produced from DFW Grand Tab data, which estimates adult fall-run Chinook salmon escapement for the major SJR tributaries. Figure 3.4 has been replaced by figures depicting fish escapement data for each tributary. The estimation methods used to calculate escapement is the same for all tributaries. Low fish escapement between 1950 and 1968 is likely representative of the natural fall-run population that was present in the Merced River. The Merced River Hatchery was built and began operation in 1970 which likely accounts for the elevated escapement numbers, as compared to the 1950-1968 period.

Action: No changes were made to the Technical Report.

Grismer Comment #5: In Figure 3.11, there is clearly an increase in recovered salmon as a function of the number released as might be expected, but the statistical interpretation is strained. Basically, averaging the 2-3 data points per number released indicates that approximately 2.5% salmon ‘recovery’ at releases of ~50,000 and 2.8% ‘recovery’ at releases twice as great (~100,000), leading to the possible observation that for releases up to ~100,000 fish recoveries between 2.5-3% might be expected. The single point at large value release (~128,000) suggests a greater recovery fraction (~5%), but it is only one point. Given the wide variability in the recovery numbers, I suspect that these recovery fractions are not statistically different. Perhaps a different analysis is more appropriate here.

Grismer Response #5: Comment noted. Staff did not perform the analysis used to produce Figure 3.11 (Figure 3.10 in revised Technical Report), but used the figure to support the discussion in the Technical Report. Again it was outside our purview to alter existing analyses performed in scientific papers that were referenced. Staff utilized the best available scientific information to support its discussion, and in this instance, the analysis performed to generate Figure 3.11 was a product of the best available scientific information.

Action: No changes were made to the Technical Report.

Jager Comment #11: The report does a good job of presenting the natural flow paradigm and highlighting the inadequacy of past approaches focused on supplying minimum flows. The approach used to support flow objectives is appropriate and should protect fall Chinook salmon.

Jager Response #11: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #9: Despite notable scientific progress in the last decade for establishing flow-ecology relationships to ensure beneficial uses of fish and wildlife (Poff et al. 2010), there are still scientific uncertainties that must be recognized. Given these uncertainties, a key challenge in determining flow alternatives is to synthesize the knowledge and experience from previous research in a coherent and comprehensive fashion to support future management. I believe that the Technical Report was successful in this regard by collating knowledge across a number of existing scientific studies. Collectively, the Technical Report summarizes the current state of knowledge demonstrating that “additional flow is needed to significantly improve production (abundance) of fall-run Chinook salmon; and the primary limiting factor for tributary abundances are reduced spring flow” (p. 3-26).

Olden Response #9: Comment noted.

Action: No changes were made to the Technical Report.

4. Determination that more flow of a more natural spatial and temporal pattern is needed from the three salmon bearing tributaries to the San Joaquin River during the February through June time frame to protect San Joaquin River fish and wildlife beneficial uses.

Grismer Comment #6: I concur with the overall geomorphic summary presented in Section 3.7.4 and that the processes identified support that the more widely variable flows suggested should enhance salmon habitat.

Grismer Response #6: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #10: The Technical Report adequately discusses potential co-founding factors that may influence the positive influence of additional flow during the spring period (Feb-June) to protect San Joaquin River fish and wildlife beneficial uses. Factors related (but not limited) to ocean climate conditions, winter flow conditions, and water temperature are discussed.

Olden Response #10: Comment noted.

Action: No changes were made to the Technical Report.

Olden Comment #11: Of particular importance is that human land-use (e.g., riparian habitat degradation, urbanization) and dams/diversions that alter and reduce flows can also have significant effects on riverine thermal regimes (Olden and Naiman 2010). This is discussed only briefly in the Technical Report (p. 3-44), but requires additional examination. For example, dams and diversions can cause either decreases or increases in downstream temperatures depending on their mode of operation and specific mechanism and depth of water release (Olden and Naiman 2010). Below I discuss how stream temperature can influence stream ecosystems and may affect the success of instream flow management aimed to protect fish and wildlife. This topic requires additional exploration in the Technical Report.

Olden Response #11: Comment noted. Human land-use (e.g., riparian habitat degradation, urbanization) and specific dams/diversions that alter and reduce flows were not the focus of the Technical Report. The Technical Report specifically focused on information that supports the scientific basis for flow objectives for the protection of fish and wildlife beneficial uses and southern delta salinity objectives for the protection of agricultural beneficial uses and their program of implementation. Detailed discussion of issues related to land-use and the impact of dams/diversions is provided in the SED. In particular, the SED contains an examination of water temperature and includes modeling results that depict how water temperature conditions are expected to improve as a result of the proposed LSJR flow objectives.

Action: No changes were made to the Technical Report.

5. **Appropriateness of using a percentage of unimpaired flow, ranging from 20 to 60 percent, during the February through June time frame, from the Stanislaus, Tuolumne, and Merced Rivers as the proposed method for implementing the narrative San Joaquin River flow objective.**

Dracup Comment #5: It is my opinion the that use of exceedance probabilities, as presented in Figures 3.15 to 3.20 (pages 3-53 to 3-56), is an excellent means of comparing the observed flows with the modeled unimpaired flows and with the three different percentages, 20 to 60 percent, of the modeled unimpaired flows. The resulting plots are exactly as one would expect with the modeled unimpaired flow being the largest and the observed flows being a lesser amount. It is interesting that the observed flows are greater than the modeled unimpaired flows for exceedance probabilities less than 10%. This is probably due to the difficulty in modeling unimpaired large flood flows.

Dracup Response #5: Comment noted. Staff did not speculate why some observed flows were greater than modeled unimpaired flows. However, this phenomenon only occurs in February, and is likely the result of high flows in 1997, 1998, and 1999. In addition, observed flow data is based on fewer data points causing the return frequency (Percent Exceedance) to be exaggerated.

Action: No changes were made to the Technical Report.

Grismer Comment #7: The Report would be strengthened by inclusion of a summary table (see below) after Table 3.20 that is based on the previous related tables and indicates the conclusions, or recommended flow rates to be met or exceeded each month of the year and with what frequency (% exceedance). From such a table, the figures in section 3.9 and selection of the 20-60% of unimpaired flows can be more readily comprehended. It would be helpful to assign monthly exceedance fractions to the general designations of “critical”, “dry”, “above normal” etc. water years to flows at Vernalis (e.g. Table 3.17 or from Figure 2.5 where wet years are ~0-30%, above normal years are ~30-50%, etc.). Basically, this comparison table might take the form below from which justification for use of the 60% fraction of unimpaired flows could be supported.

Table 3.2X. Summary of Above Normal (40, or 60% exceedance) water year San Joaquin River flows (cfs) at Vernalis for doubling of fall-run Chinook population from 1967-1991 average.

Month	AFRP	TBI/NDC	CSPA/CWIN	Rec.?*
March	5162	2000-5000	13400	6000?
April	8157	20000	7800	10000?
May	13732	7000	11200 to 1200	16000?
June		2000	1200	12000?

*Taken from Figures 3.16-3.19 for 60% of unimpaired flows at 40% exceedance.

Grismer Response #7: Comment noted. Staff did not include a summary table of the previous flow recommendations in the Technical Report because the Staff recommendation, which is based on the percent UF, is not directly comparable to a specific volume of flow/month. There is, however, an evaluation of these other flow recommendations that addresses this comment in the Alternatives Description (Chapter 3) of the SED. Additionally, shaping of rearing and migration flows is discussed in greater detail in the SED and measures to provide flexibility to optimize the flows are included in the adaptive implementation program described in Appendix K to the SED.

The Staff analysis indicated that if 60 percent of unimpaired flow at Vernalis were provided, average February through June flows would meet or exceed 5,000 cfs during some months in over 85 percent of years and flows of 10,000 cfs in approximately 45 percent of years. The frequency of exceeding these flows would vary by month (Figures 3.32 to 3.36 in the Technical Report). Both the AFRP and DFW modeling analyses presented above seem to support the 60 percent recommendation of the Delta Flow Criteria Report. However, the time periods for the AFRP recommended flows is from February through May and the time period for the DFW recommended flows is from March 15 through June 15. AFRP, DFW, and TBI/NRDC provided different recommendations for how to distribute flows during the spring period in different years, with increasing flows in increasingly wet years. All are generally consistent with an approach that uses the percent UF to mimic the natural flow regime to which these fish were adapted.

Action: No changes were made to the Technical Report.

Jager Comment #12: In the last part of Section 3, the report indicates that the State Water Board will also consider percentages of unimpaired flow as low as 20% in order to accommodate competing water demands. It is unclear to me how a percentage of even 40% would be an improvement over current median (44%) and average (48%), as I understood them from Table 2.3 in Section 2. The basis for instituting lower percentages than are currently provided was not justified in Sections 2 and 3 of the report and seems counter-indicated by the rest of the analysis presented.

Jager Response #12: Comment noted. It is not appropriate to compare the observed annual flow at Vernalis to the February through June proposed flow objective. The median of 44% and average of 48% of unimpaired flow shown in Table 2.3 is an annual value for the 1930-2009 time period. The proposed 20% and 40% of unimpaired flow would only apply during the February through June time frame, and therefore should not be compared to the annual median flow value. As shown in Table 2.8, the observed February through June flow at Vernalis is a median of 27% of unimpaired flow (based on flow data from 1984-2009). This is the flow statistic that should be directly compared to the proposed 20-60% unimpaired flow objective for the February through June time frame. A flow prescription of 30% of unimpaired flow would have the potential to increase the flow in all months in the February through June period in all years that fall below this percentage to meet the 30% requirement. For example, flow at Vernalis would have been increased in May during 80% of years during the 1984-2009 period, according to Table 2.8. Moreover, the required percentage of unimpaired flow will be applied to each tributary, which will improve conditions since the observed tributary flows are sometimes much less than 30% unimpaired flow. For example, in some years the Tuolumne River has been as low as 2% and 3% of unimpaired flow in June and May respectively (see Table 2.19).

Action: No changes were made to the Technical Report.

Jager Comment #13: One consideration in deciding how to shape rearing and migration flows is the possibility that shorter pulses are more effective than persistent flooding. This aspect was not specifically addressed by the report. For example, studies have shown that shorter pulses stimulate juvenile outmigration (Cramer 1997; Demko & Cramer 2000). One study found floodplain inundation to be more effective when it is intermittent because vegetation growth is promoted (Jeffres et al. 2008). The presence of vegetation may reduce loss of invertebrate production when floodplains are drained. An experimental framework to examine duration effects may be needed.

Jager Response #13: Comment noted. Additional discussion of floodplain habitat was added to the Technical Report. The proposed February through June flow objectives are designed to provide a flow regime that mimics the natural unimpaired flow and would lead to greater temporal and spatial variability in flow, which would potentially lead to intermittent floodplain inundation. Further discussion of floodplain inundation and the importance of shaping of rearing and migration flows is provided in the Draft SED in Chapter 7 (Aquatic Resources) and in Chapter 18 (Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30). Additionally, the draft Program of Implementation in Appendix K requires monitoring and special studies, the results of which, will inform the adaptive implementation process that is intended to optimize the flow requirements for the benefit of anadromous fish.

Action: The appropriate changes were made and references added to the Technical Report.

Jager Comment #14: Providing a higher percentage of unimpaired flows will go farther to avoid losing cohorts to extended droughts. However, from the perspective of salmon-demographics, there may be value in using a cohort based approach (A, B, C in the report, where cohort A spawn in year's t, t+3, t+6, *t+3+*k and cohort B spawn in year's t+1, t+4, etc…).

Jager Response #14: Comment noted.

Action: No changes were made to the Technical Report.

Jager Comment #15: The report listed proposed regulated schedules for flow, but did not go very far in the direction of proposing specific future flow schedules or processes for defining them. Run-of-river operation for the reduced percentage of water is the simplest method for tracking the natural flow regime. One advantage of this approach is that it does not require fixing the temporal resolution at which a natural flow regime is mimicked. Optimization methods provide a more formal approach to quantify direct and indirect pathways linking flow and salmon. If it is important to consider competing water demands, then a formal optimization with adequate provision for objectives related to restoring Chinook salmon will be needed. One final approach to consider is statistical design of flow experiments. Treatments to consider might include pulse flows during different seasons and with different durations and magnitudes. Experimental units might be the three tributaries and the three salmon cohorts (ABC).

Jager Response #15: Comment noted. The Draft SED includes an analysis of the 20, 40, and 60 percent of unimpaired flow alternatives together with adaptive implementation actions that would allow the flow to vary within a specified range. The draft SED examines the potential environmental, water supply, economic, and hydroelectric power production impacts associated with the various alternatives. The State Water Board will then use the information from the various effects analyses included in the Draft SED, along with information included in this Technical Report, and other information presented to the State Water Board to make a decision on what changes should be made to the SJR flow objectives and program of implementation to provide for the reasonable protection of fish and wildlife beneficial uses. Flow needed for the protection of fish and wildlife beneficial uses will be balanced against flow needs for other beneficial uses of water including: agriculture and hydropower production.

The draft objectives and program of implementation may be modified to some degree, but the draft objectives and program of implementation accompanying this report represent the conceptual framework the State Water Board was considering at the time the report was produced for any changes to the objectives and program of implementation. The current version of the draft objectives includes the following narrative flow objective:

Maintain inflow conditions from the San Joaquin River Watershed to the Delta at Vernalis, sufficient to support and maintain the natural production of viable native San Joaquin River watershed fish populations migrating through the Delta. Inflow conditions that reasonably contribute toward maintaining viable native migratory San Joaquin River fish populations include, but may not be limited to, flows that mimic the natural hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur. Indicators of viability include population abundance, spatial extent, distribution, structure, genetic and life history diversity, and productivity.

The draft Program of Implementation or the draft narrative SJR flow objective call for the flow objective to be implemented by providing a percentage of unimpaired flow ranging from 20 to 60 percent from February through June from the Stanislaus, Tuolumne, and Merced Rivers, in addition to base flow requirements. Additionally, the draft Program of Implementation describes adaptive implementation measures that provide flexibility to optimize the proposed percent UF objectives and requires studies and monitoring to provide information needed to inform future implementation actions. The draft Program of Implementation also calls for establishing a workgroup consisting of parties with expertise in fisheries management, unimpaired flows, and operations on the Stanislaus, Tuolumne, and Merced Rivers to develop flow management recommendations for consideration by the State Water Board in the implementation proceedings for the flow objective that will follow adoption of any changes to the Bay-Delta Plan.

Action: No changes were made to the Technical Report.

Jager Comment #16: Areas for further research into partially-non-flow mitigation options might include mitigating for DO in Stockton Ship Channel during both migrations, floodplain ‘design’ to allow for inundation at lower flows, and providing enough flow to generate habitat complexity and refuge from predators.

Jager Response #16: Comment noted. It is not within the State Water Board’s authority to perform non-flow related mitigation options, however the Central Valley Regional Water Quality Control Board adopted a Total Maximum Daily Load (TMDL) for DO in the Stockton Ship Channel that led to the implementation of non-flow measures to address low DO condition, including the installation of aerators at the Port of Stockton. Additionally, the draft Program of Implementation allows for adaptive implementation of the required percent of unimpaired flow based on specific information concerning flow needs to protect fish and wildlife beneficial uses. It also calls for the development of monitoring and special studies programs to develop further information concerning SJR flow needs for the protection of fish and wildlife beneficial uses to inform implementation actions, and future changes to the Bay-Delta Plan, including potential changes to the October pulse flow requirements and addition of flow requirements for the periods outside of the February through June and October period. The final Program of Implementation will include recommendations to other agencies to take additional actions outside of the State Water Board’s purview to protect SJR fish and wildlife beneficial uses. Those actions will include non-flow activities including, but not limited to: habitat restoration (floodplain restoration, gravel enhancement, riparian vegetation management, passage, etc.), hatchery management, predator control, water quality measures, ocean/riverine harvest measures, recommendations for changes to flood control curves, and barrier operations.

Action: No changes were made to the Technical Report.

Olden Comment #12: Although I agree that a fixed monthly prescription is not useful given spatial and temporal variation in runoff (p. 3-52), the Technical Report does not account for the range of ecologically important flow events that occur over the entire year that are critical for salmon persistence and sustained productivity.

Olden Response #12: Comment noted. Please refer to Jager Response #6. Additionally, the flow objective alternatives currently being evaluated are focused on the February through June time frame, as flows (magnitude, duration, frequency) during this period are a dominant factor affecting salmon abundance in the basin. Adaptive implementation measures included in the draft Program of Implementation would allow for some adjustments to be made to optimize flow outside of the February through June period. The fall pulse flow objective (all water year types) contained in 2006 Bay-Delta Plan is not the subject of this review. However, the draft Program of Implementation states that the State Water Board will reevaluate the implementation of the October pulse flow and flows during other times of the year as part of future updates to the Bay-Delta Plan and after monitoring and special studies have been conducted to determine what, if any, changes should be made to these flow requirements and their implementation to achieve the narrative San Joaquin River flow objective.

Action: No changes were made to the Technical Report.

Olden Comment #13: The Technical Report states “State Water Board analysis indicate that 60 percent of unimpaired SJR flow at Vernalis from March through June would achieve flows of 5,000 cfs in over 85 percent of years and flows of 10,000 cfs in approximately 45 percent of years” (p. 3-47). These results imply that flows of 5,000 cfs would be achieved for all spring months (March through June) based on 60 percent of unimpaired flow. Unfortunately, this is not the case.

Olden Response #13: Comment noted. The text was modified to clarify that the projected flows specified in the comment would not occur during all spring months.

Action: The appropriate changes were made to the Technical Report.

Olden Comment #14: The rationale for examining 20-60% of unimpaired flow as the only scenarios is questionable, and it needlessly limits a full investigation of the flows required to achieve fish and wildlife beneficial use.

Olden Response #14: Comment noted. Please refer to Olden Response #12.

Action: No changes were made to the Technical Report.

Quinn Comment #4: Given these complexities and uncertainties, I think the approach (percentage of unimpaired flow) is a very reasonable and defensible one, and the models showing 20%, 40% and 60% are revealing. Inevitably one can argue (or quibble) over which precise value to use. Perhaps a quantitative model could be created to evaluate the variants precisely but my examination of the plots indicates that this is very good compromise. It takes into account the fact that water years vary, and the needs of the fish vary seasonally with different life history stages.

Quinn Response #4: Comment noted.

Action: No changes were made to the Technical Report.

6. Appropriateness of proposed method for evaluating potential water supply impacts associated with flow objective alternatives on the San Joaquin River at Vernalis, and the Stanislaus, Tuolumne, and Merced Rivers.

Dracup Comment #6: Presented in Figure 5.1, page 5-3, is a comparison of the observed monthly average flow at Vernalis as compared to the CALSIM II model output. The comparison is excellent, however, an indication of the degree of correlation between these two parameters would have been helpful, i.e. an R^2 value. It is my opinion that the use of CALSIM II for determining the potential water supply impacts associated with the flow objectives alternatives is an appropriate means of doing this analysis.

Dracup Response #6: Comment noted. The correlation coefficient (R^2), 0.912, has been added to Figure 5.1.

Action: The appropriate changes were made to the Technical Report.

Grismer Comment #8: A section similar to section 5.2 describing the CALSIM model applicable to the discussion in Chapter 4 would be helpful at the beginning of Chapter 4.

Grismer Response #8: Comment noted. The Technical Report was modified to better describe the methods that Staff used to estimate EC values at Vernalis. Specifically, an Excel spreadsheet model, created by Staff, was used to estimate how EC at Vernalis might be affected by changing flows from the Stanislaus, Tuolumne, and Merced Rivers in response to LSJR flow alternatives. The spreadsheet model uses tributary flow and EC input from the CALSIM II model to calculate new EC values at Vernalis. The final WSE model does not use the approach described in the Technical Report for estimating the tributary salt load, but instead relies upon CALSIM baseline model results for salt loads at Vernalis and the projected change in flow at Vernalis under the proposed flow objectives. These values are then used in a spreadsheet model to calculate the expected salinity values at Vernalis under the proposed LSJR flow alternatives. More details about the calculations used to estimate EC at Vernalis are provided in Chapter 5 (Hydrology and Water Quality) and in Appendix F1 of the draft SED.

Action: The appropriate changes were made to the Technical Report.

Grismer Comment #9: My primary technical concern on the WSE analyses and the previous discussions also in Chapter 4 is that a monthly time step of total flows is used. Such a time step is incongruent with daily management decisions used for reservoir operation, irrigation diversions and probably the flows and salinity encountered by the fish; a daily time-step seems to be more relevant and a justification for the monthly time-step (beyond computing resource limitations) should be provided. In addition, the objectives call for running averages of daily means.

Grismer Response #9: Comment noted. The CALSIM II model runs on a monthly time step, with monthly average inputs and outputs (USBR 2005). National Pollutant and Discharge Elimination System (NPDES) and stream gauge data are available on a daily basis, but these data cannot be analyzed without taking into consideration other southern Delta factors that are included in CALSIM II (east-side tributaries, pumping, Sacramento River flows, etc.). Also, some daily data may cover only 20 years, whereas CALSIM covers an 83 year time period and thus allows an examination of water supply effects over a wide range of hydrological conditions. CALSIM, a peer reviewed water resources model, is the best fit for our analysis, despite the use of a monthly time-step.

Action: No changes were made to the Technical Report.

Issues Pertaining to Water Quality Objectives for the Protection of Southern Delta Agricultural Beneficial Uses

7. **Sufficiency of the statistical approach used by State Water Board staff in the Technical Report to characterize the degradation of salinity conditions between Vernalis and the interior southern Delta.**

Grismer Comment #10: This matter is discussed in Section 4.3 of the Technical Report and overall the basic mass balance approach is acceptable with the caveat noted above about use of a daily time-step rather than monthly may be more appropriate.

Grismer Response #10: Comment noted. Please refer to Grismer Response #9.

Action: No changes were made to the Technical Report.

Grismer Comment #11: In developing the Tributary contributions to delta salinity, EC-Flow relationships observed from the recent period (1994-2003) may not represent that from the un-impaired or pre-dam flow conditions. Realizing the lack of pre-dam data, this matter should be addressed with a general discussion of what the earlier period conditions may have been relative to the present.

Grismer Response #11: Comment noted. The commenter is correct that there is limited historical EC data for the tributaries. Current EC values in the tributaries are low, with a maximum value of between 100-300 µS/cm, except for the Merced River where EC may approach 500 µS/cm during low flow conditions (Figures 4.3 – 4.5). Pre-dam EC values in the tributaries would have likely been lower than or similar to current EC values due to higher flows and lower salt inputs associated with less irrigated agriculture. Higher flows of low EC water from the tributaries coupled with a reduction in salt inputs due to less irrigated agriculture would have led to lower EC values in the Southern Delta compared to current conditions.

Action: No changes were made to the Technical Report.

Grismer Comment #12: Also for the Tributary EC calculations (p. 4-4 & Table 4.2), use of the power function is okay; however, one might expect the power function coefficients to be similar for all three tributaries unless dramatically different hydrologic/geologic conditions can be described for the Stanislaus as compared to the Merced and Tuolumne River sub-basins. Such power functions are sensitive to the data spread, especially at low values (flows). The very small R^2 value (0.18) for the Stanislaus River is practically meaningless and I suspect that the use of Ks ~ 455 and b ~ -0.35, values more consistent with those for the other two tributaries, would result in an R^2 value not that much different and certainly no less significant.

Grismer Response #12: Comment noted. The equation for the Stanislaus is of similar format as the other tributaries, with slightly different magnitude and, as monitoring data suggests, results in lower EC concentrations than the other tributaries. The power functions were developed using the flow and EC as modeled by CALSIM II. The relationship between flow and EC in the Stanislaus data from CALSIM II is poor due to the scatter in the data. More importantly, the approach described in the Technical Report that relies on estimating the relationship between EC and flow in the tributaries was not used in the final WSE model. Instead, EC at Vernalis is calculated using the salt loads estimated for Vernalis obtained from CALSIM together with the new tributary flows under the proposed flow objectives. More details regarding the approach used to calculate EC at Vernalis in the final WSE model can be found in Appendix F1 and Chapter 5 of the draft SED.

Action: No changes were made to the Technical Report.

8. Sufficiency of the mass balance analysis presented by State Water Board staff in the Technical Report for evaluating the relative effects of National Pollutant Discharge Elimination System (NPDES) permitted point sources discharging in the southern Delta.

Grismer Comment #13: This matter is discussed in Section 4.3 of the Technical Report and overall the basic mass balance approach is acceptable with the caveat noted above about use of the daily time step and the observations about possible typos or discrepancies between the text and figures.

Grismer Response #13: Comment noted. Please refer to Grismer Response #9.

Action: No changes were made to the Technical Report.

Grismer Comment #14: On p.4-11 (1st paragraph) there is the observation that was implicit throughout Chapters 4 and 5 suggesting that "beneficial uses are affected more by longer term salinity averages" such that monthly values are used. As noted above this claim should be further justified and explained so as to better support the proposed objectives and how monthly averages (flow or salinity) can, or should be reconciled with daily measurements. Preferably, such a justification would occur much earlier in the Report.

Grismer Response #14: Comment noted. Salinity in the SJR basin is one of the largest water quality concerns, has a large influence on species diversity, and represents a major limiting factor for restoration of aquatic resources with effects on fish, invertebrates, and riparian plant establishment. Nevertheless, the impact that salinity has on agriculture is the focus of Chapter 4 of the Technical Report since agriculture is the most sensitive beneficial use at the range of salinities observed in the geographic area affected by the plan alternatives. Section four provides the scientific basis for developing water quality objectives for salinity and a program of implementation to protect agricultural beneficial uses in the southern Delta, including the factors and sources that affect salinity concentrations and salt loads (mass of salt in the river), and the effects of salinity on crops grown in the region. In general, crops respond to the average root zone salinity rather than to daily variation in irrigation water salinity, therefore it is appropriate to examine the changes in monthly average salinity to assess impacts to agricultural beneficial uses.

Action: No changes were made to the Technical Report.

9. Determination by State Water Board staff that the methodology and conclusions in the January 2010 report by Dr. Glenn Hoffman, regarding acceptable levels of salinity in irrigation water, are appropriate for reasonable protection of agricultural beneficial uses in the southern Delta.

Grismer Comment #15: The Salt Tolerance Report prepared by Dr. Hoffman provides an excellent summary of the state of current knowledge about soil salinity impacts on irrigated agricultural production. The focus on moderately sensitive alfalfa hay production and sensitive bean production provide a good range from which to determine possible adverse salinity effects in Delta agriculture. Overall, I support his Conclusions in Section 6 and Recommendations in Section 7.

Grismer Response #15: Comment noted.

Action: No changes were made to the Technical Report.

Grismer Comment #16: Since boron more readily accumulates in soils (not as readily leached as salinity), I concur with Hoffman's observation (pp. 7-8) concerning boron concentrations in irrigation diversions; this subject may require more investigation and appropriate water sampling or monitoring within the South Delta so as to separate possible toxicity effects from those associated with salinity.

Grismer Response #16: Comment noted.

Action: No changes were made to the Technical Report.

Grismer Comment #17: I also agree with Hoffman's observations on (p. 21) the limited data available for determination of bean salt tolerance. This data is relatively old, based on greenhouse pot studies and bean varieties unlikely used today commercially. Field studies in typical Delta clay soils (dominant soil type) considering salt tolerance of commercially grown beans in the Delta are needed. Nonetheless, based on salinity thresholds for other "sensitive" crops grown in the South Delta (Table 3.1), salinities of 1 dS/m appear adequate.

Grismer Response #17: Comment noted.

Action: No changes were made to the Technical Report.

Grismer Comment #18: Thus, a leaching fraction of 10% would likely set a conservative lower limit in the steady-state salinity modeling employed by Hoffman.

Grismer Response #18: Comment noted.

Action: No changes were made to the Technical Report.

Grismer Comment #19: Though the water table may be shallow in parts of the South Delta, providing adequate irrigation would limit upward flow contributions to crop water use with the exception of possibly alfalfa hay when water stressed. The relatively large leaching fractions apparently occurring in the South Delta clay soils of ~25% suggest that current water use and irrigation is adequate to maintain soil salinity conditions within acceptable ranges (Tables 3.10 & 3.11).

Grismer Response #19: Comment noted.

Action: No changes were made to the Technical Report.

Grismer Comment #20: I concur that salinity affects at the proposed EC objective are not expected to adversely affect alfalfa hay production as outlined in section 5.2.2.

Grismer Response #20: Comment noted.

Action: No changes were made to the Technical Report.

Grismer Comment #21: The ability of Delta growers to maintain high leaching fractions into the future as competition for water resources intensifies and climate change adds hydrologic uncertainties suggest that some of these issues be regularly re-visited within an Adaptive Management framework.

Grismer Response #21: Comment noted.

Action: No changes were made to the Technical Report.

10. Other Issues

Dracup Comment #7: The Technical Report needs an Executive Summary at its beginning.

Dracup Response #7: Comment noted. Staff chose not to include an Executive Summary to the Technical Report. However, the introduction to the Technical Report was updated to include a description of the most current changes made pursuant to the comments received from the Peer Reviewers.

Action: The appropriate changes were made to the Technical Report.

Grismer Comment #22: Overall the Technical Report fairly describes a workable methodology and support for assessment of the proposed water quality and flow objectives for the San Joaquin River at Vernalis.

Grismer Response #22: Comment noted.

Action: No changes were made to the Technical Report.

Grismer Comment #23: There is a typo on pages 5-9 to 5-11; Figures 5.3-5.5, as CALSIM is also a model, perhaps the better word to use is “calibration” to CALSIM rather than “validation”.

Grismer Response #23: Comment noted. As the WSE model was not calibrated to CALSIM, this too would be an improper wording. The intent was to attempt to compare to the CALSIM outputs as a validation that the WSE model can produce results similar to CALSIM. Perhaps the proper wording would be to replace "validation" with "comparison."

Action: The appropriate changes were made to the Technical Report.

Olden Comment #15: The use of the word “illustrative” (p. 3-53) is misleading. According to the Merriam-Webster dictionary, illustrative is defined as clarifying by use of examples or serving to demonstrate. Yet, the Technical Report states “In addition to an existing conditions scenario, these illustrative alternatives represent the likely range of alternatives the State Water Board will evaluate in the environmental document supporting any revised SJR flow objectives” (p. 3-53). Therefore, these are not illustrative scenarios, but rather the actual scenarios that will be evaluated.

Olden Response #15: Comment noted.

Action: The appropriate changes were made to the Technical Report.

Olden Comment #16: In conclusion, it is my opinion that although components of the Technical Report are based on sound scientific knowledge (notably, those discussed in topics 1-4), the appropriateness of using a percentage of unimpaired flow (ranging from 20 to 60 percent) as a methodology for implementing the San Joaquin River flow objective is overly simplistic and only in part accounts for the full suite of flow conditions likely required to provide a reasonable level of protection for fish and wildlife benefit uses.

Olden Response #16: Comment noted. The decision to use a percentage of unimpaired flow as the primary metric for the new flow objectives was based on the need to provide a higher and more variable flow regime in salmon-bearing SJR tributaries to the Delta during the spring period. As discussed in Section 3.9.2 of the Technical Report, developing precise flow objectives that will provide certainty with regard to protection of fish and wildlife beneficial uses is likely not possible. The percentage of unimpaired flow approach is expected to provide the general seasonality, magnitude, and duration of flows important for native species and is considered to be an improvement over fixed monthly flow objectives that have been used in the past. Moreover, the draft Program of Implementation includes measures that provide flexibility to optimize the flows so that implementation may not necessarily be done strictly based on the proposed percentage of unimpaired flow. Also included are requirements for studies and monitoring that will provide information to assess how well the flow requirements are providing protection for the beneficial uses and to better manage flows in the future.

Action: No changes were made to the Technical Report.

Quinn Comment #5: This report is well-written and organized, and presents a great deal of information in a readable and comprehensible manner. The graphs are largely of good quality, though a few have been copied and lost some resolution in the process. There are few typographical errors and it is generally well-produced.

Quinn Response #5: Comment noted.

Action: No changes (other than fixing typographical errors) were made to the Technical Report.

Quinn Comment #6: My expertise is strictly in the areas of fish ecology and conservation, and I therefore found it somewhat unexpected to have the heavy coverage of fish-related issues in much of the report followed by the final two sections (4 and 5, on salinity and flow) with no mention of issues related to fish. I assume that this was a design feature rather than an oversight, but the juxtaposition of fish ecology and salt tolerance of crops was a bit striking. Needless to say, both depend on water and so that is the fundamental unifying resource. I wonder if it might be possible to make this separation of these a bit more clear somehow in the organization of the report, perhaps Part 1 and Part 2, or something like that.

Quinn Response #6: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #7: In general the report relies too heavily on secondary sources (e.g., Moyle 2002; NMFS 2009a, 2009b; Williams 2006). There is nothing wrong with these references per se but their use compels the reader to get that reference and find the relevant place in it.

Quinn Response #7: Comment noted. Additional primary literature sources have been incorporated into the Technical Report.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #8: The referencing of work outside the basin and outside California is limited. I understand that the report has a sharp focus on the San Joaquin River but there are a number of places where work done elsewhere would be relevant.

Quinn Response #8: Comment noted. It is true that this report has a sharp focus on the SJR basin; a few additional references where work was performed outside the San Joaquin River Basin were added and changes made to the Technical Report.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #10: The terms “ocean-type” and “stream-type” date to Gilbert (1913) and should ideally be linked to the reviews by Taylor (1990) and Healey (1991). The seasonal return patterns of adult salmon (e.g., fall and spring) do not necessarily correspond to the juvenile life history traits (ocean-type and stream-type). This is a common misconception; in many cases they are linked but it is best to use each set of terms for the life history phase to which it refers. In addition, the juvenile life history descriptors (stream-type and ocean-type) also include quite a lot of variation driven by with both genotype and phenotypic plasticity.

Quinn Response #10: Comment noted. Additional text was incorporated regarding the distinction between “ocean-type” and “stream-type” Chinook salmon.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #11: The proportions of males and females by age is a very important set of data and statements about them should be backed up with tables of data indicating the sample sizes in each year, etc. I comment on this later; the importance of this basic life history information cannot be over-stated.

Quinn Response #11: Comment noted. SJR Basin Monitoring Programs (listed at the end of Section 3.2) partially address Quinn’s 11th question. Specifically, Appendix B shows the Adult Chinook Salmon Escapement for the major SJR tributaries and subgroups escapement, to the Merced River, into jack (2 year-old) and adult (3+ year-old) returns. Specific data that identifies escapement numbers and has sex and age information is limited or unavailable. Other SJR basin monitoring data listed at the end of Section 3.2 is available upon request.

Action: No changes were made to the Technical Report.

Quinn Comment #12: The use of olfaction to locate natal streams deserves better citations than (NMFS 2009a, DFG 2010a). It would be better to cite Hasler and Scholz (1983) or perhaps Dittman and Quinn (1996).

Quinn Response #12: Comment noted. Additional discussion of the role of olfaction in salmonid migratory behavior has been added to the Technical Report.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #13: I also have some sense (though I confess to not being sure precisely where I learned it) that there are much higher straying rates from the SJR than are considered normal, and that these result from transportation of hatchery juveniles downstream, and also from the difficulties that returning adults experience in detecting odors, given the altered flow regimes.

Quinn Response #13: Comment noted. Additional text was incorporated describing straying rates for Chinook salmon.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #14: Figure 3.1, which seems to be copied from the NMFS BiOp, needs a proper caption; as is, it is hard to interpret.

Quinn Response #14: Comment noted. The caption for Figure 3.1 has been modified.

Action: The appropriate changes were made to the Technical Report.

Quinn Comment #15: Figure 3.2 is quite interesting. Are there similar data for other years, and if so, perhaps a summary table or figure could be produced. Are the redd counts referring to new redds, or all that were counted on each survey? Were they flagged, and so how does the total redd count relate to the number of live fish? Were there tagging studies of stream life and generation of “area-under-the-curve” estimates? In general, I find myself wanting more detail about this kind of data.

Quinn Response #15: Comment noted. Figure 3.2 was provided as an example to show the typical timing of fall-run Chinook salmon spawning in the San Joaquin River basin. Details regarding the redd survey methods can be found in the DFW’s annual spawning report.

Action: No changes were made to the Technical Report.

Quinn Comment #16: A table with a matrix of correlations of annual estimates would be very useful. Figure 3.4 is striking but it would still be good to see the matrix, and a plot of each population against the others.

Quinn Response #16: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #17: In reference to the statement: "The annual (fall) escapement of adult fall-run Chinook salmon is really three cohort sequences, based on the typical three year return frequency (e.g., cohort "A" returning to spawn in 1952, 1955, 1958, etc.; cohort "B" returning to spawn in 1953, 1956, 1959, etc.)."

Where is the evidence for this? I have gathered that the Chinook salmon are dominated by age-3 fish but this is such an important and basic point that it cries out for tables with the data. I'd expect to see age composition data, for each of the populations, as well as a quantitative separation of wild (naturally produced) and hatchery origin fish. Surely there are long-term age data from marked fish in hatcheries and wild fish on spawning grounds?

Quinn Response #17: Comment noted. The appropriate changes were made and references added to the Technical Report. Additionally, other SJR basin monitoring data listed at the end of Section 3.2 is available upon request and may be used in analyses in the Draft SED. Specific SJR basin monitoring data that addresses this comment has been added to the Technical Report as an appendix.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #18: Mention is made of the fact that the escapement does not measure productivity because the fishery is not included. This seems quite surprising to me. Where are the catch data, and why is there no formal run reconstruction and set of brood tables? I do not mean to be harsh but the data on the salmon seem to be really limited. Surely there are coded wire tagging programs at the hatcheries and reconstructions of the runs? How else can the runs to the Sacramento be separated from the SJR?

Quinn Response #18: Comment noted. The Technical Report relied on the best available scientific information on salmon population dynamics in the SJR basin which may not be sufficient to fully reconstruct historic salmon runs for the entire watershed. Run reconstruction information for the Tuolumne River with data for brood years 1979-1990 was added on page 3-31, table 3-15. Section 3.6.1 provides a discussion of coded wire tagging studies conducted in the SJR basin that includes an analysis of coded wire tag recoveries from Merced River Hatchery fish (see Figure 3.10). Additionally, other SJR basin monitoring data listed at the end of Section 3.2 is available upon request and may be used in analyses in the Draft SED. Specific SJR basin monitoring data that addresses this comment has been added to the Technical Report as an appendix.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #19: In reference to the statement: "… since 1952, the average escapement of fall-run Chinook salmon has shown a steady decline."

This statement is contradicted by the figure (3.5) associated with it. There is no obvious trend downward but rather there are a series of pronounced peaks (a pair of peaks around 1954 and 1960, then discrete ones around 1970, 1985, and 2003). Each of the peaks lasted about 8 years, with distinct "troughs" in between. I think the conclusion that this was a "steady decline" is not supported. Can there be some more sophisticated analyses? What we have seems like a visual examination. What can we make of these peaks and troughs?

Quinn Response #19: Comment noted. The previous figure 3.5 has been replaced with figures 3.4, 3.5 and 3.6 illustrating the large cyclic fluctuations in escapement in the major SJR tributaries. The peaks and troughs observed in the fall-run Chinook salmon escapement data shown in these figures are likely a reflection of the variable hydrological conditions that occur in the SJR basin. The periods of low escapement generally correspond with dry conditions such as the droughts that occurred in 1976-1977 and in the late 1980's/early 1990's, which exemplify the important role that flow plays for salmonid populations.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #20: The use of the term “hatchery” to refer to fish entering the hatchery, and “natural” to those spawning in the rivers (Greene 2009; Figure 3.6) is inconsistent with the common usage of these terms. Naturally produced fish may be drawn into the hatchery, and hatchery produced fish spawn in rivers (Quinn 1993). These two processes are so common that only an assessment of marked and unmarked fish (e.g., thermal banding of otoliths, adipose fin clips, etc.) would be meaningful. Has there really been no systematic assessment of the proportions of salmon produced naturally and from hatcheries? If not, it is no criticism of the report but this important matter should be made explicit.

Quinn Response #20: Comment noted. Staff was not the principal authors of the Greene 2009 paper, and therefore not responsible for terms identified within. No changes were made to the Technical Report or the Greene 2009 paper. Additionally, this terminology was defined in Greene 2009 and in the section of the Technical Report that incorporates the discussion mentioned in the comment. The Greene 2009 terminology is not used throughout the Technical Report. Additional text was incorporated regarding the Constant Fractional Marking Program for fall-run Chinook salmon facilitating the distinction between hatchery and naturally produced fish.

Action: The appropriate changes were made to the Technical Report.

Quinn Comment #21: A series of monitoring efforts are listed but data from them are not readily apparent. Why were the data not incorporated into the report? Are the patterns reported elsewhere in a comprehensive manner, and if so, what are the conclusions?

Quinn Response #21: Comment noted. The purpose of the SJR Basin Monitoring Programs list was to inform the reader of the variety of monitoring data that is collected in the SJR basin. This monitoring data is available upon request and may be used in further evaluation in the Draft SED.

Action: No changes were made to the Technical Report.

Quinn Comment #22: I believe that it was Busby et al. (1996) who proposed the stream-maturing vs. ocean-maturing distinction, so that report should be referenced in this context. As far as life history differences, I would certainly add the fact that steelhead/rainbow trout are spring spawners whereas Chinook salmon are fall spawners. The former spawn much smaller eggs with a shorter incubation period, typically on the ascending temperature regime, whereas salmon spawn larger eggs with a longer period during a descending temperature regime. This is very important in the present context because it determined what period of the year (and thus flows) they will be in the gravel as embryonic stages.

Quinn Response #22: Comment noted. Additional text has been incorporated into the Technical Report regarding stream-maturing and ocean-maturing life history strategies for steelhead, and life history distinctions between steelhead and fall-run Chinook salmon.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #23: The statement that “there is no reproductive barrier between resident and anadromous forms” with a citation of Zimmerman et al. (2009) needs a lot of qualification.

Quinn Response #23: Comment noted. Additional clarification and references were added to the discussion of reproductive barriers between resident and anadromous forms of steelhead.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #24: The report states that all San Joaquin River steelhead are ocean-maturing (“winter”) fish but it then states that they enter as early as July. Surely this would be a stream-maturing or “summer” fish? Perhaps there are remnants of this life history form still in the system?

Quinn Response #24: Comment noted. The text was modified in Section 3.3 to clarify that though there may have been stream-maturing steelhead present in the SJR basin in the past prior to the construction of the rim dams, only ocean-maturing type Central Valley steelhead are currently found.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #25: I am also intrigued by the statement that “If water quality parameters and other environmental conditions are not optimal, steelhead may delay migration to another more suitable year.” Does this refer to adults or smolts? I had not been aware that there was evidence of adult steelhead returning to freshwater but then going back to sea without spawning because conditions were not favorable. It would seem that this important point (with respect to flow, temperature, etc.) should have some reference and details, regardless of whether it deals with smolts or adults.

Quinn Response #25: Comment noted. The text was modified to clarify how environmental factors may alter or delay steelhead migration, which can ultimately lead to changes in the relative incidence of anadromous versus resident life histories.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #26: The description of steelhead life history is basically correct but I am surprised that there was no figure quoted for the proportion of repeat-spawning steelhead in the system. Only a very dated figure from Shapovalov and Taft (1954) is cited and, if I recall correctly, their report was for small coastal streams. Are there no contemporary or historical data for the Central Valley runs?

Quinn Response #26: Comment noted. The small size of the Central Valley steelhead population and the lack of historical monitoring data have made it difficult to accurately document steelhead life history in the SJR basin.

Action: No changes were made to the Technical Report.

Quinn Comment #27: The terms potadromous and limnodromous are probably unnecessary jargon, and “fluvial” and “adfluvial” are more commonly used in any case.

Quinn Response #27: Comment noted. The Technical Report was modified to use the terminology suggested above.

Action: The appropriate changes were made to the Technical Report.

Quinn Comment #28: In reference to the statement: “The limited data that do exist indicate that the steelhead populations in the SJR basin continue to decline (Good et al. 2005) and that none of the populations are [sic] viable at this time (Lindley et al. 2007).”

This latter is a very strong statement and could use some elaboration. Presumably, the implication is that only exchange with resident trout maintains the steelhead phenotype. This should be stated more explicitly, and the biological basis for this exchange merits discussion. I am surprised that the interesting recent papers on California O. mykiss were not cited (e.g., those by Satterthwaite, Mangel and co-authors), nor relevant papers from elsewhere (e.g., Narum and Heath). This is not merely a matter of getting some additional references but it is fundamental to the status and recovery prospects for these fish. If the anadromous life history is latent in the resident trout then changes in environmental conditions may allow it to express itself, whereas if the forms are very discrete, as is the case with sockeye salmon and kokanee (the anadromous and non-anadromous forms of O. nerka: e.g., Taylor et al. 1996), then the loss of one form is likely more permanent. This extent of plasticity is directly relevant to the efforts to address the chronic environmental changes to which these fishes have been subjected, and the prospects for recovery.

Quinn Response #28: Comment noted. Additional discussion and references regarding the trends in the steelhead population in the SJR and the relationship between resident and anadromous life history strategies were added to the Technical Report.

Action: The appropriate changes were made to the Technical Report.

Quinn Comment #29: It is also worth noting that the migratory behavior of steelhead differs markedly from that of sub-yearling Chinook salmon. Sub-yearlings spend a lot more time in estuaries and littoral areas whereas steelhead seem to migrate more rapidly (as individuals), exit estuaries quicker (as a population), and occupy offshore waters to a much greater extent.

Quinn Response #29: Comment noted. With regard to migratory behavior, the distinction is made that steelhead are much larger at outmigration, and have a greater swimming ability than Chinook salmon.

Action: The appropriate changes were made to the Technical Report.

Quinn Comment #30: The summary of the importance of spring flows for Chinook salmon seems very reasonable but it would be good to actually see more of the data on which these statements are based. What relationship might there be to pre-spawning mortality or incomplete spawning of adults, or egg fry survival?

Quinn Response #30: Comment noted. Please refer to Jager Response #6. Additionally, other SJR basin monitoring data listed at the end of Section 3.2 is available upon request and may be used in analyses in the Draft SED.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #31: Figure 3.8 would be better expressed after adjustment for the size of the parent escapement and some density-dependence. Plotting numbers of smolts vs. flow suggests a connection but I would think that multi-variate relationships should be explored.

Quinn Response #31: Comment noted. Figure 3.8 is an original figure from Mesick 2009; Staff chose not to alter it in the Technical Report. No changes were made to the Technical Report. Additionally, other SJR basin monitoring data listed at the end of Section 3.2 is available upon request and may be used in analyses in the Draft SED.

Action: No changes were made to the Technical Report.

Quinn Comment #32: In response to the statement: "In a 1989 paper, Kjelson and Brandes once again reported a strong long term correlation (R^2 of 0.82) between flows at Vernalis during the smolt outmigration period of April through June and resulting SJR basin fall-run Chinook salmon escapement (2.5 year lag) (Kjelson and Brandes 1989).

This relationship should be easy to update and I would like to see the recent data. Frankly, I find this correlation implausibly high. There are so many factors affecting marine survival that even a perfect estimate of the number of smolts migrating to sea will not have an R^2 of 0.82 with total adult return, much less with escapement (including both process and measurement error). I do not doubt that higher flows make for speedier passage and higher survival, but to link them so closely with adult escapement is stretching it. Indeed, it would seem that NMFS (2009) came to a similar conclusion. After acknowledging the shortcomings in this approach, it seems odd to see Figure 3.10, which is a time-series with flow during the smolt period and lagged escapement. If we must have escapement as the metric rather than smolt survival, can we not at least plot flow on the x-axis rather than date, and some form of density-adjusted recruit per spawner metric on the y-axis? I find it very difficult to see the relationship when plotted as time series.

Quinn Response #32: Comment noted. The State Water Board did not perform the analysis in the 1989 Kjelson and Brandes paper, but used the R^2 value to support the discussion in the Technical Report. Again, it is outside our purview to alter existing analyses performed in scientific papers that we reference. The State Water Board utilizes the best available scientific information to support its discussion, and the general relationship between flow (April and May) and escapement of adult fall-run salmon two and a half years later, a recognized relationship, is illustrated in Figure 3.10 (Figure 3.9 in the revised version of the Technical Report). Additionally, other SJR basin monitoring data listed at the end of Section 3.2 is available upon request and may be used in analyses in the Draft SED.

Action: No changes were made to the Technical Report.

Quinn Comment #33: Figure 3.12. This figure is a poor quality reproduction, and the y-axis is not defined. What is CDRR? (It is not in the list of acronyms). This report is pretty dense in terms of jargon and acronyms and abbreviation, so any effort to state things in plain English will be appreciated.

Quinn Response #33: Comment noted. Figure 3.12 (Figure 3.11 in the revised Technical Report) is an original figure from SJRGA 2007, however the figure legend was modified to define CDRR.

Action: The appropriate changes were made to the Technical Report.

Quinn Comment #34: The text on the Importance of Flow Regime (3.7) is very sensible. It would be helpful to know what sources of the salmon mortality are most directly affected by flow reduction but, given the obvious data gaps, this seems unlikely. Thus overall correlations with survival and basic ecological principles have to carry the day.

Quinn Response #34: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #35: The text on fish communities is rather confusing. I expected to see information of species composition, comparative tolerances to warm and cool water by various native and non-native fishes, ecological roles with respect to salmon, etc.

Quinn Response #35: Comment noted. Please refer to Jager Response #3.

Quinn Comment #36: The text regarding population structure and importance of genetic and life history diversity for the success of salmon would benefit from basic references such as Hilborn et al. 2003 for sockeye salmon, and the more recent papers by Moore and by Carlson on salmon in areas more extensively affected by humans.

Quinn Response #36: Comment noted.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #37: The reference to variable ocean conditions and marine survival seems to contradict the earlier statements that only smolt going to sea really matter. There is no question that marine survival varies from year to year but all you can ask from a river is that it produces juvenile salmon.

Quinn Response #37: Comment noted. Ocean conditions, marine survival, and the effect on Chinook salmon and steelhead populations in the SJR basin, are not the focus of the Technical Report. However, stressors other than flow are identified in the Technical Report and are briefly discussed. The Draft SED will address these stressors in greater detail.

Action: No changes were made to the Technical Report.

Quinn Comment #38: With respect to water temperature, the relationships between physical factors (local air temperature, water depth, solar radiation, groundwater, and heat loss, etc.) are quite well understood so it should be possible to hind-cast the thermal regime that would have occurred in the SJR and its tributaries had the dams and diversions not taken place. An approach such as the one described by Holtby and Scrivener (1989) might be very useful and more precise than just saying that releasing more water would cool things down.

Quinn Response #38: Comment noted. A more thorough analysis of expected changes in tributary water temperature associated with the proposed flow objectives, including water temperature modeling results, is included in the draft SED.

Action: No changes were made to the Technical Report.

Quinn Comment #39: The section on water quality (3.7.6) should be better integrated into the arguments related to flow. As it is, we have a list of effects and possible connections to salmon but no way to link to the rest of the report. For example, salinity seems very likely to be a function of discharge but we are not given the relationship, much less the connection to salmon. Pesticides are probably prevalent but what will their interaction be with flow? Will more water reduce their effects, and will the patterns be linear or not?

Quinn Response #39: Comment noted. Additional discussion was added regarding the interaction between flow and water quality. Please refer to Jager Response #3.

Action: The appropriate changes were made and references added to the Technical Report.

Quinn Comment #40: In regards to the statement: “Finally, the relationship between smolts at Chipps Island and returning adults to Chipps Island was not significant, suggesting that perhaps ocean conditions or other factors are responsible for mortality during the adult ocean phase. ”

This statement, referring to DFW data, also seems to contradict the earlier statements that marine conditions do not matter and that flow is all that matters. It would seem more correct to state that flow is the most important, among the things under our control.

Quinn Response #40: Comment noted. Please refer to Jager Response #3.

Action: No changes were made to the Technical Report.

Quinn Comment #41: On Table 3.15, it would be very helpful to present the status quo, so we can see the difference between the flows that DFW concluded are needed to double smolt production from present levels.

Quinn Response #41: Comment noted. Table 2.6 provides information on the monthly observed flows at Vernalis between1984-2009 that also contains water year type designations for each year that can be used to compare with the DFW flow recommendations contained in Table 3.15.

Action: No changes were made to the Technical Report.

Quinn Comment #42: In regards to the statement: “State Water Board determined that approximately 60 percent of unimpaired flow during the February through June period would be protective of fish and wildlife beneficial uses in the SJR. It should be noted that the State Water Board acknowledged that these flow criteria are not exact, but instead represent the general timing and magnitude of flow conditions that were found to be protective of fish and wildlife beneficial uses when considering flow alone.”

This would seem to be a critical, overall conclusion: Higher and more variable flows are needed, and can be 60% of unimpaired flows. This is logical and well supported by basic ecological principles, as these flows would provide benefits specific to salmon at several life history stages, and broader ecosystem benefits a well.

Quinn Response #42: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #43: The various exceedance plots (Figures 3.15 to 3.20) indicate that there is substantial improvement from flow at the 60% level whereas 20% and 40% achieve much less in the important late winter and early spring periods. As the report correctly notes, this is inevitably a bit arbitrary (why 60% - might 59% not do just as well?).

Quinn Response #43: Comment noted. Draft changes to the Program of Implementation for the narrative SJR flow objective call for the flow objective to be implemented by providing a percentage of unimpaired flow ranging from 20 to 60 percent from February through June from the Stanislaus, Tuolumne, and Merced Rivers, in addition to base flow requirements. The 60 percent recommendation provides an upper end for the range of unimpaired flow alternatives that will be evaluated in the Draft SED. The 20 percent alternative provides a lower end for this range and the 40 percent alternative provides an intermediate value for evaluation in the Draft SED. The draft program of implementation allows for refinement of the percent of unimpaired flow requirement by allowing for adaptive implementation based on specific information concerning flow needs to protect fish and wildlife beneficial uses. Figures 3.15 through 3.19 (now Figure 3.32 through 3.36 in the revised Technical Report) present exceedance plots of San Joaquin River at Vernalis monthly unimpaired flows (for 1922 to 2003) and observed flows (for 1986 to 2009), along with 20, 40, and 60 percent of unimpaired monthly flows for the months of February through June, respectively.

Action: No changes were made to the Technical Report.

Quinn Comment #44: Just as with agriculture and wildlife, fish production depends on complex interactions among a number of factors, of which flow is very important but not the only one. Extrapolation from lab studies to the field, where so many things go on at once and where history cannot be played back in a different scenario. So, one can pick at this value, just as one might pick at any specific value, and ask whether the fish can get by with a little less overall, or at some time of the year. Likewise, how much water do crops really need? Can we give the farmers less without hurting production? Obviously, that would depend on soil, temperature, distribution of the water, insects (beneficial and otherwise), and many other factors too. I think that this value (60%) is well supported, given these kinds of uncertainties. The fish would probably benefit from even more water, but they will be more than glad to get this amount, as it will be a big improvement over the status quo.

Quinn Response #44: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #45: In response to the statement: “Given the dynamic and variable environment to which SJR basin fish and wildlife adapted, and imperfect human understanding of these factors, developing precise flow objectives that will provide certainty with regard to protection of fish and wildlife beneficial uses is likely not possible. Nevertheless, the weight of the scientific evidence indicates that increased and more variable flows are needed to protect fish and wildlife beneficial uses. ”

I agree completely – this is very well-stated.

Quinn Response #45: Comment noted.

Action: No changes were made to the Technical Report.

Quinn Comment #46: The report has so much effort devoted to salmon and steelhead that the absence of reference to these fishes in the section on salinity is stark. Are there no issues related to estuarine dynamics or salinity related to salmon?

Quinn Response #46: Comment noted. The primary focus for the discussion of salinity was on agricultural beneficial uses in the southern Delta since that is the most sensitive beneficial use associated with the range of salinity values observed in the project area.

Action: No changes were made to the Technical Report.

Appendix D

Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1)

Appendix D

Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1)

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Acronyms and Abbreviations

BO	biological opinion
CEQA	California Environmental Quality Act
cfs	cubic feet per second
CSJWCD	Central San Joaquin Water Conservation District
DWR	California Department of Water Resources
FERC	Federal Energy Regulatory Commission
LSJR	Lower San Joaquin River
NMFS	National Marine Fisheries Service
NMI	New Melones Reservoir Index
OID	Oakdale Irrigation District
OMR	Old River at Middle River
ppt	parts per thousand
SDWQ	southern Delta water quality
SED	substitute environmental document
SEWD	Stockton East Water District
SJR	San Joaquin River
SJRA	San Joaquin River Agreement
SSJID	South San Joaquin Irrigation District
State Water Board	State Water Resources Control Board's
TAF/y	thousand acre-feet per year
USBR	U.S. Bureau of Reclamation
VAMP	Vernalis Adaptive Management Plan
WSE	Water Supply Effects model

D.1 Introduction

The California Environmental Quality Act (CEQA) Guidelines require that the potential impacts of not approving a proposed project be evaluated under a No Project Alternative. "The purpose of describing and analyzing a No Project Alternative is to allow decision makers to compare the impacts of approving the proposed project with the impacts of not approving the proposed project." (14 Cal. Code Regs., § 15126.6(e)(1).) When the project is the revision of an existing regulatory plan, such as the 2006 *Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary* (2006 Bay-Delta Plan), the No Project Alternative will be the continuation of the existing plan and its implementation into the future. (14 Cal. Code Regs., § 15126.6(e)(3)(A).) Thus, in general, the existing plan and the projects initiated under the existing plan would continue until the new plan amendments[1] are approved. The No Project Alternative analysis must discuss the existing conditions "as well as what would be reasonably expected to occur in the foreseeable future if the project were not approved, based on current plans and consistent with available infrastructure and community services." (14 Cal. Code Regs., § 15126.6(e)(2).)

For the purposes of this analysis, the No Project Alternative is the continuation of the State Water Resources Control Board's (State Water Board) 2006 Bay-Delta Plan, as implemented through Water Right Decision 1641 (D-1641), including implementation of the San Joaquin River (SJR) at Vernalis flow objectives (also referred to as the SJR flow objectives) and the southern Delta salinity (EC[2]) objectives (including the salinity objective on the SJR at Vernalis). Lower San Joaquin River (LSJR) Alternative 1 and southern Delta water quality (SDWQ) Alternative 1 are referred to as the No Project Alternative in this appendix and in Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1)*, which evaluates the potential impacts of the no project alternative.

This appendix describes the assumptions in the State Water Board's Water Supply Effects (WSE) model, which was used to model the baseline and estimate the changes in flows needed to fully comply with the 2006 Bay-Delta Plan as implemented through D-1641.

[1] These plan amendments are the *project* as defined in State CEQA Guidelines, Section 15378.

[2] EC is electrical conductivity, which is generally expressed in deciSiemens per meter (dS/m) in this document. Measurement of EC is a widely accepted indirect method to determine the salinity of water, which is the concentration of dissolved salts (often expressed in parts per thousand or parts per million). EC and salinity are therefore used interchangeably in this appendix.

D.2 Description of the No Project Alternative

The No Project Alternative assumes continued implementation of, and full compliance with, the 2006 Bay-Delta Plan, as implemented through D-1641. The No Project Alternative focuses on effects related to the implementation of Vernalis flow and southern Delta salinity objectives because these objectives are the ones proposed to be amended. The Vernalis flow objectives were first established in the 1995 Bay-Delta Plan to protect fish and wildlife beneficial uses. These objectives include the minimum monthly flow rates for fish and wildlife beneficial uses during specific times of the year, as presented in Table 3 of the 2006 Bay-Delta Plan and implemented through D-1641. In D-1641, the State Water Board assigned compliance with these minimum flows on the SJR at Vernalis to the U.S. Bureau of Reclamation (USBR). When the State Water Board subsequently amended the Bay-Delta Plan in 2006, it approved an interim flow regime through the Vernalis Adaptive Management Plan (VAMP) experiment, as proposed in the San Joaquin River Agreement (SJRA), in lieu of meeting the April-May pulse flow objective (as presented in Table 3 of the 2006 Bay-Delta Plan).

No Project Alternative conditions differ from baseline conditions because the Vernalis flow objectives in Table 3 of the 2006 Bay-Delta Plan have not been fully implemented and are not part of the baseline because of the implementation of the SJRA and VAMP. The VAMP flows, which are generally lower than the Table 3 flows in the 2006 Bay-Delta Plan, are thus included in the baseline. During VAMP, a portion of the flows needed to comply with VAMP came from the three eastside tributaries[3] even though the 2006 Bay-Delta Plan and D-1641 do not contain numeric or narrative flow requirements specific to those rivers. However, the No Project Alternative does not include VAMP flows because that experimental flow regime concluded in 2011. The No Project Alternative and the baseline both include the 2009 National Marine Fisheries Service (NMFS) Biological Opinion (BO) flow requirements on the Stanislaus River, Federal Energy Regulatory Commission (FERC) requirements on the Tuolumne and Merced Rivers, and the Davis-Grunsky requirements on the Merced River.

The No Project Alternative assumes the flows would continue to be the responsibility of USBR and that the objectives would be met with additional releases from New Melones Reservoir on the Stanislaus River. The analytical approach used here evaluates increased releases from New Melones Reservoir to meet the objectives, because such releases could be the primary method by which the Vernalis flow objectives and southern Delta salinity objectives would be achieved. Focusing the evaluation on New Melones Reservoir releases affords an evaluation of maximum potential water supply impacts compared to assuming that increases in Vernalis flow would be distributed among the tributaries.

The No Project Alternative also assumes continuation of the southern Delta salinity objectives for agricultural beneficial uses identified in Table 2 of the 2006 Bay-Delta Plan and full compliance with these objectives as implemented through D-1641. Under D-1641, compliance with the numeric salinity objectives on the SJR at Vernalis (station C-10) is the obligation of USBR. Compliance with the numeric salinity objectives at the three interior southern Delta compliance stations – SJR at Brandt Bridge (station C-6), Old River near Middle River (station C-8), and Old River at Tracy Road

[3] In this document, the term *three eastside tributaries* refers to the Stanislaus, Tuolumne, and Merced Rivers.

Bridge (station P-12) – are the combined obligation of USBR and the California Department of Water Resources (DWR).

D.3 Evaluating the No Project Alternative

D.3.1 Modeling

For water-related projects in California, it is standard practice to evaluate the difference between baseline conditions and the alternatives using a sequence of historical hydrology (often monthly) that includes the effects from seasonal and year-to-year variations in rainfall, runoff, and reservoir operations. It is important to evaluate changes that would result from revised reservoir operations using a full range of runoff conditions. Baseline conditions for water resources (e.g., runoff, reservoir storage, river flows, salinity, and temperature) can often be described using the most recent 10-25 years of historical measurements. However, because new facilities may be added or operating rules may change (i.e., VAMP, Old River at Middle River [OMR] limits), a long-term planning-model comparison approach is often used to evaluate the differences between a baseline case with certain operating rules and facilities, and a project (alternative) case.

The State Water Board's WSE model was used to simulate baseline and modified hydrologic responses to the LSJR and SDWQ alternatives. The WSE model is a monthly water balance spreadsheet model that calculates the changes in river flows, water supply diversions, and reservoir operations that would occur in each of the three eastside tributaries based upon user-defined inputs, inputs to CALSIM, and flood storage rules. The WSE model allows the release flow targets for each tributary to be a specified fraction of the monthly unimpaired runoff or any other minimum flow requirement.

The WSE model is discussed in further detail in Appendix F.1, *Hydrologic and Water Quality Modeling*.

D.3.2 Assumptions

The monthly sequence of river flows, water supply diversions, reservoir storage, and Vernalis salinity for the No Project Alternative differs from the recent historical measurements and from baseline because of differences in assumptions used to calculate the baseline and the No Project Alternative.

The No Project Alternative differs from the baseline condition for the following reasons.

1. For baseline, the Vernalis flow objectives for a 30-day period April-May are based on the VAMP that was in effect during the 12-year period (2000-2011). VAMP has ended, and in the absence of VAMP, the original D-1641 flow objectives that are dependent only on the SJR water year type and Delta outflow are assumed for the No Project Alternative.
2. Under baseline conditions, the Vernalis flow objectives for February-June, which are dependent on the SJR water year type and the daily location of the 2-parts per thousand (ppt) salinity (i.e., Delta outflow), were not always fully implemented during the 1996-2011 period. This occurred when the SJRA cap of 110 thousand acre-feet per year (TAF/y) for meeting the Vernalis flow requirements was met. The No-Project Alternative assumes full compliance with D-1641 flow requirements.

3. The No Project Alternative would meet the southern Delta salinity objectives by requiring additional New Melones Reservoir releases. An assumed EC increment from Vernalis to Tracy Boulevard reduced by higher Vernalis flow (i.e., EC increment [µS/cm] = 300,000 / Vernalis flow [cubic feet per second (cfs)]) was calculated for each month to estimate the maximum allowed Vernalis EC and the corresponding additional flow releases from New Melones Reservoir to meet the EC objectives at Tracy Boulevard. In some years, this assumption resulted in much higher flows relative to baseline.
4. Baseline allows water to be purchased from the Merced and Tuolumne Rivers to satisfy VAMP flow objectives. The No Project Alternative would not include the purchased water for the purposes of satisfying Vernalis flow objectives, so flows on the Merced and Tuolumne Rivers would be lower when compared to baseline in April and May of some years. The No Project Alternative would satisfy the D-1641 flows with releases from New Melones Reservoir alone.

The No Project Alternative would be different than the recently observed historical flow and salinity conditions for the reasons described above and for the following additional reasons:

1. The required flows on the Stanislaus River at Goodwin Dam have been recently revised by the NMFS BO, requiring generally higher fish flows for Chinook salmon and Central Valley steelhead (NMFS 2009). These higher flows are included in baseline and the No Project Alternative.
2. The full CVP contract for Stanislaus River water (155 TAF/y) has recently been required by a 2014 federal court judgment (*Stockton East Water District v. United States)*; USBR has fulfilled demands by Oakdale Irrigation District (OID) and South San Joaquin Irrigation District (SSJID) up to 600 TAF/y under the 1988 Agreement, but has rarely delivered the full 155 TAF/y contract with Stockton East Water District (SEWD) and Central San Joaquin Water Conservation District (CSJWCD), subject to availability based on the New Melones Index condition. Both baseline and the No Project Alternative assume the full diversion objective of 755 TAF/y subject to district demands and water availability.

The assumptions made for the No Project Alternative include reasonably foreseeable and feasible future actions, and therefore provide a sufficient degree of analysis to evaluate the environmental effects being considered. (State CEQA Guidelines, § 15204(a)) The baseline is the same baseline used for impact analysis in Chapters 5–14 of this recirculated substitute environmental document (SED).

D.3.3 Estimating Flows for the No Project Alternative

This section describes the methods used to estimate the additional flows needed to comply with the No Project Alternative (i.e., continuation of the 2006 Bay-Delta Plan objectives as implemented through D-1641) and compares the additional flows against the baseline results for 1922–2003. The analysis assumes that additional Vernalis flows would come entirely from New Melones Reservoir on the Stanislaus River.

Stanislaus River Flow Requirements

The State Water Board's WSE model was used to evaluate all of the alternatives and includes the Stanislaus River flows at Goodwin Dam, as required by the NMFS BO (NMFS 2009). The NMFS BO requires specified daily flows be released from New Melones Reservoir at certain times of the year related to the lifecycle of steelhead and Chinook species. The daily flow patterns depend on runoff and reservoir storage conditions each year. Specifically, pulse flows are required during the fall for adult attraction, and during the spring for outmigration cues and juvenile outmigration. Flows generally range from approximately 200–1,500 cfs in the fall and approximately 200–5,000 cfs in the spring.

The NMFS flow requirements are based on five different daily flow schedules based on the New Melones Reservoir Index (NMI) value of each year, as described in Appendix 2E of the NMFS BO. These requirements are incorporated in the WSE model using the monthly totals of the daily flow values, resulting in an equivalent monthly average flow, as shown in Table D-1. The NMI is calculated as the end of February storage plus the (forecasted) Stanislaus River runoff volume for March-September. The monthly flows are allocated based on the NMI value each year. Because these flow requirements are based in part on New Melones Reservoir storage, this may result in a change in the NMFS BO flow requirement in the No Project Alternative relative to baseline, due to changes in storage.

Table D-1. Stanislaus River Monthly Flows at Goodwin Dam Required by NMFS Biological Opinion Appendix 2E (NMFS 2009) as a Function of New Melones Index [NMI]) as Incorporated in the WSE Model

NMI WY Type	NMI Value[a] (TAF)	Oct (cfs)	Nov (cfs)	Dec (cfs)	Jan (cfs)	Feb (cfs)	Mar (cfs)	Apr (cfs)	May (cfs)	Jun (cfs)	Jul (cfs)	Aug (cfs)	Sep (cfs)	Annual (TAF)
C	<1,400	583	200	200	220	214	200	459	400	150	150	150	150	185
D	<2,000	567	200	200	226	221	200	765	630	200	200	200	200	230
BN	<2,500	773	200	200	233	235	200	1,551	1,240	363	250	250	250	347
AN	<3,000	795	200	200	240	235	1,518	1,398	1,552	938	300	300	300	483
W	>3,000	840	300	300	369	364	1,645	1,630	1,955	1,098	428	400	400	589

cfs = cubic feet per second
WY = water year
TAF = thousand acre-feet
C = critical
D = dry
BN = below normal
AN = above normal
W = wet
[a] Stanislaus flows are currently implemented under year types defined by the New Melones Interim Plan of Operation (USBR 2007) although these NMI water year type ranges are not specifically defined in the NMFS Biological Opinion.

Vernalis Flow Objectives

The No Project Alternative assumes full D-1641 Vernalis flow objectives,[4] whereas baseline incorporates VAMP. The D-1641 flow objectives at Vernalis are higher when the X2 location[5] is

[4] Vernalis flow objectives specified for February-June are based on the SJR 60-20-20 water year index and the end-of month X2 values (i.e., Delta outflow).

[5] X2 is the location of the 2 parts per thousand salinity contour (isohaline), 1 meter off the bottom of the estuary measured in kilometers upstream from the Golden Gate Bridge. The abundance of several estuarine species has been correlated with X2. In the 2006 Bay-Delta Plan, a salinity value--or electrical conductivity (EC) value--of 2.64 millimhos/centimeter (mmhos/cm) is used to represent the X2 location. Note, in this document, EC is generally expressed in deciSiemens per meter (dS/m). The conversion is 1 mmhos/cm = 1 dS/cm.

downstream of Chipps Island (i.e., higher outflow). Table D-2 shows the monthly D-1641 flow objectives for the two cases: X2 upstream or X2 downstream of Chipps Island (75 kilometers [km]). Because the 30-day pulse flow spans half of April and May, the required flows in these 2 months were calculated as the average of the base flow and the pulse flow. There were several years when the baseline model flows did not meet the Vernalis flow objectives because the SJRA cap of 110 TAF

Table D-2. D-1641 Vernalis Monthly Flow Objectives (cfs) for X2 Upstream or Downstream of Chipps Island (km 75) Based on SJR 60-20-20 Water-Year Type

D-1641 with X2 >75 km[a]	Feb	Mar	Apr[b]	May[b]	Jun
C	710	710	2,265	2,265	710
D	1,420	1,420	3,430	3,430	1,420
BN	1,420	1,420	3,730	3,730	1,420
AN	2,130	2,130	4,995	4,995	2,130
W	2,130	2,130	5,795	5,795	2,130
D-1641 with X2 <75 km[a]	**Feb**	**Mar**	**Apr[b]**	**May[b]**	**Jun**
C	1,140	1,140	2,340	2,340	1,140
D	2,280	2,280	3,580	3,580	2,280
BN	2,280	2,280	3,880	3,880	2,280
AN	3,420	3,420	5,220	5,220	3,420
W	3,420	3,420	6,020	6,020	3,420

km = kilometers
cfs = cubic feet per second
C = critical
D = dry
BN = below normal
AN = above normal
W = wet
[a] The WSE model utilized X2 position from CALSIM II in order to determine Vernalis flow requirements.
[b] April and May flows are the average of base flow and pulse flow.

per year on the additional releases needed to meet the Vernalis flow requirements was met. Full compliance with the Vernalis flow objectives would have a substantial effect on water supply diversions from the Stanislaus River because of the additional water needed to satisfy the objectives.

Southern Delta Salinity Objectives

The No Project Alternative would include full compliance with the southern Delta salinity objectives. This includes compliance at SJR at Vernalis and the three interior southern Delta compliance locations. The baseline meets the Vernalis salinity objectives but may not have enough of an EC buffer (i.e., Vernalis salinity objective minus Vernalis salinity) to meet the southern Delta EC objectives. Though this was not always the case for the historically observed EC at Vernalis, the Vernalis salinity objectives were always met in the baseline results.

The historical EC measurements have generally been highest at the Old River at Tracy Boulevard station, as described in Appendix F.2, *Evaluation of Historical Flow and Salinity Measurements of the*

Lower San Joaquin River and Southern Delta. Therefore, the Tracy Boulevard station was selected to determine compliance with the southern Delta salinity objectives. The Vernalis EC required to meet the Old River at Tracy Boulevard salinity objectives was calculated based on the observed EC increments between Vernalis and Tracy Boulevard that were dependent on Vernalis flow. Based on historical EC data, the EC increment at Tracy Boulevard was estimated as:

$$\text{EC Increment } (\mu S/cm) = 300{,}000 \,/\, \text{Vernalis flow (cfs)} \qquad \text{(Eqn. D-1)}$$

For example, the EC increment from Vernalis to Tracy Boulevard would be 300 μS/cm when the Vernalis flow was 1,000 cfs, 150 μS/cm when the Vernalis flow was 2,000 cfs, and 100 μS/cm when the Vernalis flow was 3,000 cfs. The measured EC increments at Brandt Bridge and Union Island were generally much less (approximately 33 percent of the Tracy Boulevard EC increment).

To achieve full compliance with the salinity objectives at Tracy Boulevard, the Vernalis EC must be reduced to the EC objective minus the EC increment. For example, if the Vernalis flow was 4,000 cfs in April, the assumed EC increment from Vernalis to Tracy Boulevard would be 75 μS/cm and the Vernalis EC would need to be less than 625 μS/cm in order to also meet the EC objective of 700 μS/cm at Tracy Boulevard. The Vernalis EC can be reduced, if necessary, by increasing the Vernalis flow with additional New Melones Reservoir releases. If the Stanislaus EC was 0 μS/cm, then the Vernalis EC would change as the inverse of the Vernalis flow change (ratio).

D.3.4 No Project Alternative Results

The baseline flows at Vernalis were compared to No Project Alternative flows at Vernalis to determine the volume of additional Stanislaus water needed to fully comply with the assumptions of the No Project Alternative. Table D-3 summarizes the annual baseline New Melones Reservoir releases and the additional releases that would be required under the No Project Alternative. The first column gives the baseline New Melones Reservoir annual water year releases (excluding releases for diversions), which ranged from 186 to 2,219 TAF, with an average release volume of 404 TAF. The second column gives the No Project Alternative New Melones Reservoir annual water year releases (excluding releases for diversions), which would range from 195 to 2,219 TAF, with an average release volume of 474 TAF, an increase of 70 TAF per year.

The third and fourth columns of Table D-3 give the flows needed to fully satisfy the Vernalis flow objectives for baseline and the No Project Alternative, respectively. There would be a considerable amount of water needed in a few years when the SJR water year index was wet; the required baseline releases ranged from 0 to 186 TAF, with an average of 31 TAF. The required releases under the No Project Alternative ranged from 0 to 460 TAF, with an average of 82 TAF.

The fifth column of Table D-3 gives the additional flow released under baseline to meet the EC objective at Vernalis, which ranged from 0 to 70 TAF. The sixth column gives the additional releases needed for the No Project Alternative to meet the EC objective at both Vernalis and Old River at Tracy Boulevard. Because the EC increment was conservatively estimated, the total additional releases from New Melones Reservoir to meet the No Project Alternative conditions ranged from 0 to 267 TAF, with an average of 60 TAF; there were 3 years when there was not enough water in New Melones Reservoir to meet the Tracy Boulevard objective in all months. About half of the total additional water was required to meet the Tracy Boulevard EC objectives.

The last column of Table D-3 gives the annual VAMP releases (in April and May) on the Tuolumne and Merced Rivers that were assumed in the baseline. These VAMP releases ranged from 0 to

77 TAF, with an average of 26 TAF. The majority of these VAMP purchases were on the Merced River, so, in the absence of VAMP, Merced River flows would be lower in some years in the No Project Alternative relative to baseline. Under the No Project Alternative, it is assumed that these VAMP flows would be replaced by Stanislaus River flows required to meet D-1641 Vernalis flow requirements (as shown in column 4 of Table D-3).

Table D-3. Estimated Annual Baseline and No Project Alternative New Melones Reservoir Releases (thousand acre-feet [TAF]) for Vernalis Flow Objectives and Southern Delta Salinity Objectives (Vernalis and Tracy Boulevard EC Objectives), and Baseline VAMP Releases from the Tuolumne and Merced Rivers

Year[a]	Total Releases[b] (Baseline)	Total Releases[b] (No-Project)	Stanislaus Releases for Vernalis Flow[c] (Baseline)	Stanislaus Releases for Vernalis Flow[d] (No-Project)	Stanislaus Releases for Salinity[e] (Baseline)	Stanislaus Releases for Salinity[f,g] (No-Project)	Tuolumne and Merced VAMP (Baseline)
1922	308	308	0	0	0	0	0
1923	365	376	47	50	0	8	9
1924	266	452	0	24	18	180	0
1925	210	258	0	0	0	48	0
1926	285	375	56	107	0	84	25
1927	310	412	105	203	0	7	25
1928	240	316	26	47	0	54	69
1929	190	366	0	5	1	173	13
1930	191	377	12	54	0	143	25
1931	261	491	0	109	70	191	0
1932	256	474	92	266	0	43	26
1933	222	405	35	106	1	112	25
1934	218	482	15	110	21	190	31
1935	348	394	186	211	0	22	31
1936	274	268	70	52	0	12	62
1937	225	234	27	27	0	9	0
1938	419	419	0	0	0	0	0
1939	362	398	12	0	0	48	25
1940	325	339	15	9	0	20	27
1941	446	446	0	0	0	0	0
1942	449	449	0	0	0	0	7
1943	870	771	0	0	0	4	0
1944	406	420	36	26	0	24	77
1945	331	321	10	0	0	0	37
1946	479	522	15	46	0	13	59
1947	288	460	45	141	0	75	25
1948	299	450	75	179	0	47	48
1949	233	456	8	198	0	78	25

Year[a]	Total Releases[b] (Baseline)	Total Releases[b] (No-Project)	Stanislaus Releases for Vernalis Flow[c] (Baseline)	Stanislaus Releases for Vernalis Flow[d] (No-Project)	Stanislaus Releases for Salinity[e] (Baseline)	Stanislaus Releases for Salinity[f,g] (No-Project)	Tuolumne and Merced VAMP (Baseline)
1950	251	402	35	185	0	50	58
1951	368	433	86	240	0	18	77
1952	499	280	0	0	0	0	0
1953	545	399	39	50	0	14	77
1954	358	398	17	20	0	39	0
1955	231	372	0	34	0	107	0
1956	443	325	10	26	0	0	44
1957	390	394	49	28	0	26	77
1958	413	413	0	0	0	0	0
1959	372	437	27	43	0	49	71
1960	245	402	0	30	2	129	13
1961	210	473	8	88	7	190	0
1962	247	376	78	136	0	71	77
1963	386	469	182	288	0	22	77
1964	197	363	12	83	0	100	25
1965	392	459	95	224	0	40	41
1966	272	458	35	202	0	73	75
1967	472	333	58	58	0	0	0
1968	344	409	0	112	0	58	17
1969	506	422	0	0	0	0	0
1970	959	818	66	137	0	13	77
1971	392	391	64	43	0	20	73
1972	380	489	39	180	0	72	0
1973	367	399	61	190	4	18	42
1974	457	356	15	57	0	0	57
1975	485	459	27	137	0	0	73
1976	250	374	0	0	0	126	0
1977	219	537	5	74	18	267	9
1978	186	195	0	0	0	9	0
1979	408	317	103	98	0	18	77
1980	441	298	0	0	0	0	0
1981	347	401	4	17	0	43	5
1982	610	542	0	0	0	0	0
1983	2219	2219	0	0	0	0	0
1984	1166	1185	0	15	0	5	21
1985	340	387	0	9	0	37	0
1986	604	471	0	0	0	0	0

Year[a]	Total Releases[b] (Baseline)	Total Releases[b] (No-Project)	Stanislaus Releases for Vernalis Flow[c] (Baseline)	Stanislaus Releases for Vernalis Flow[d] (No-Project)	Stanislaus Releases for Salinity[e] (Baseline)	Stanislaus Releases for Salinity[f,g] (No-Project)	Tuolumne and Merced VAMP (Baseline)
1987	379	439	0	0	0	89	0
1988	229	471	0	39	26	228	0
1989	201	481	0	110	14	184	0
1990	202	489	0	64	16	238	0
1991	196	536	0	93	13	260	0
1992	193	454	11	130	7	150	0
1993	293	630	141	460	0	17	0
1994	214	464	0	42	26	234	2
1995	315	326	28	28	0	11	0
1996	447	468	1	0	0	21	25
1997	1243	1289	22	171	0	11	59
1998	766	612	0	0	0	0	0
1999	844	869	62	71	0	16	51
2000	477	496	22	19	0	22	73
2001	319	370	0	79	0	75	0
2002	354	558	116	254	0	75	41
2003	387	598	164	357	0	62	25
Minimum	186	195	0	0	0	0	0
Average	404	474	31	82	3	60	26
Maximum	2219	2219	186	460	70	267	77

VAMP = Vernalis Adaptive Management Program

[a] All releases except VAMP are releases from New Melones Reservoir only.

[b] Includes all flow and salinity releases and excludes releases for diversions. Includes the flows required by the National Marine Fisheries Services (NMFS) Biological Opinion Stanislaus River reasonably prudent alternative, including Action 3.1.3.

[c] Includes VAMP pulse flow releases from New Melones Reservoir only and D-1641 base flow releases, and excludes releases for EC objective.

[d] Includes D-1641 pulse and base flow releases from New Melones Reservoir only, and excludes releases for EC objective.

[e] Additional release to meet EC objective at Vernalis.

[f] Additional release to meet EC objective at Vernalis and Tracy Boulevard.

[g] No Project Alternative EC objective was unachievable for 1931, 1991, and 1992. The shortfall was 5 TAF in 1931, 6 TAF in 1991, and 1060 TAF in 1992.

Under the No Project Alternative, the average annual extra flow needed relative to baseline in order to attain the Vernalis flow objectives (50 TAF) and the EC objectives (57 TAF) is greater than the increase in the average annual releases for Stanislaus River flow (70 TAF). This occurs because occasionally some Stanislaus River flow requirements are lower under the No Project Alternative than under baseline; spills (which are rare on the Stanislaus River even under baseline conditions) and NMFS BO flows tend to be a little lower under the No Project Alternative because New Melones storage tends to be lower. Still, the overall average Stanislaus River releases required by the No Project Alternative are substantially greater than the releases required by the baseline alternative.

The WSE model was used to evaluate effects of the No Project Alternative. Table D-4 and Figures D-1 through D-6 present WSE model results for river flows, reservoir carryover storage, and water supply diversions on the three eastside tributaries and the SJR at Vernalis under the No Project Alternative and baseline conditions.

Under the No Project Alternative, flow in the Stanislaus River would generally be equal to or greater than baseline (Table D-4 and Figures D-2a and D-6a). Because the Stanislaus River water supply diversions were reduced to meet the required Stanislaus flows and continue the 2006 Bay-Delta Plan as implemented through D-1641, generally the No Project Alternative annual diversions would be equal to or less than baseline (Figures D-1a and D-2c) and New Melones Reservoir storage would either be equal to or less than baseline (Figures D-1b and D-2b). The baseline average diversions of 637 TAF/y would be potentially reduced to an average of 578 TAF/y. This reduction in the Stanislaus River water supply diversions would be closest to the reductions needed for LSJR Alternative 3 (i.e., 40 percent unimpaired flow; which would result in an average diversion of 558 TAF/y). Although most of the additional flows would come from reduced diversions, without additional constraints on withdrawals from storage, a large portion of the additional flow could be taken from storage and in some years would completely drain the reservoir (Figure D-1b). Although the average diversion is still relatively high for the No Project Alternative, in some years, Stanislaus River diversions could be near zero (Figures D-1a and D-2c).

Conditions on the Tuolumne River would generally be similar under the No Project Alternative and the baseline, as the baseline does not release much water for VAMP (Table D-4, Figures D-3a, D-3b, D-3c, and D-3d, and Figure D-6b). Under the No Project Alternative, Lake McClure on the Merced River would retain some additional water in storage due to the reduction in flows otherwise released for VAMP under baseline (Figure D-4b). Under the No Project Alternative, February–June flows on the Merced River would be reduced compared to baseline in over half of the years (Figure D-4a), with all the reductions occurring during the VAMP months of April and May, as a result of no VAMP implementation (Table D-4). This reduction in flow on the Merced River is opposite to the increases in Merced River flows that were associated with the LSJR alternatives.

SJR February-June flows at Vernalis under the No Project Alternative are similar to the baseline conditions (Figure D-5a); as were the combined diversion on the Stanislaus, Tuolumne, and Merced Rivers in most years, with baseline diversions being lower in about 20 percent of the years (Figure D-5b). Under the No Project Alternative, the SJR flows at Vernalis as a percentage of unimpaired flow were very similar to baseline flows (Figure D-5c).

Table D-4. Monthly Cumulative Distributions of Baseline Flow and Differences from Baseline for the No Project Alternative for the 82-Year WSE Modeling Period

Percentile	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Stanislaus Flow at Ripon – Baseline												
10	729	248	224	270	230	308	573	525	292	293	302	311
50	889	319	288	337	385	486	1,556	1,422	629	437	416	419
90	1,116	454	421	576	1,285	1,911	1,997	2,107	1,655	705	632	667
No Project – Percent difference from Baseline												
10	-3%	0%	1%	9%	5%	1%	82%	66%	121%	98%	47%	-8%
50	-4%	0%	7%	3%	32%	31%	10%	12%	49%	73%	47%	0%
90	-1%	-1%	-3%	-1%	0%	0%	14%	11%	-8%	44%	43%	-6%
Tuolumne Flow at Modesto (cfs) – Baseline												
10	290	246	257	316	312	349	546	546	270	262	277	256
50	550	464	470	570	647	1,568	1,414	1,238	499	448	426	422
90	813	756	1,152	3,424	5,084	5,097	4,591	4,810	4,387	3,331	652	691
No Project – Percent difference from Baseline												
10	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
50	0%	0%	1%	2%	11%	0%	-6%	-12%	0%	0%	0%	0%
90	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Merced Flow at Stevinson (cfs) – Baseline												
10	325	266	277	280	312	283	150	117	88	55	32	55
50	423	338	348	385	450	384	508	473	225	155	163	170
90	548	419	991	1,621	2,556	1,728	973	2,478	2,981	2,113	1,150	544
No Project – Percent difference from Baseline												
10	0%	2%	0%	0%	0%	0%	-29%	-76%	0%	0%	0%	0%
50	0%	1%	0%	0%	0%	0%	-54%	-52%	4%	0%	6%	2%
90	3%	6%	2%	0%	14%	0%	-5%	0%	0%	0%	0%	0%
San Joaquin River Flow at Vernalis (cfs) – Baseline												
10	2,000	1,566	1,513	1,481	1,856	1,614	1,616	1,543	1,009	959	1,055	1,488
50	2,598	1,981	1,941	2,200	3,489	3,502	4,640	4,600	2,280	1,620	1,544	2,024
90	3,331	2,724	4,264	10,926	15,228	13,821	12,538	13,327	11,586	6,902	2,983	2,940
No Project – Percent difference from Baseline												
10	0%	0%	8%	5%	17%	21%	42%	22%	64%	71%	50%	0%
50	-1%	0%	1%	1%	1%	1%	0%	-3%	0%	18%	10%	-1%
90	-1%	2%	0%	0%	1%	0%	0%	1%	-1%	-1%	-2%	-2%

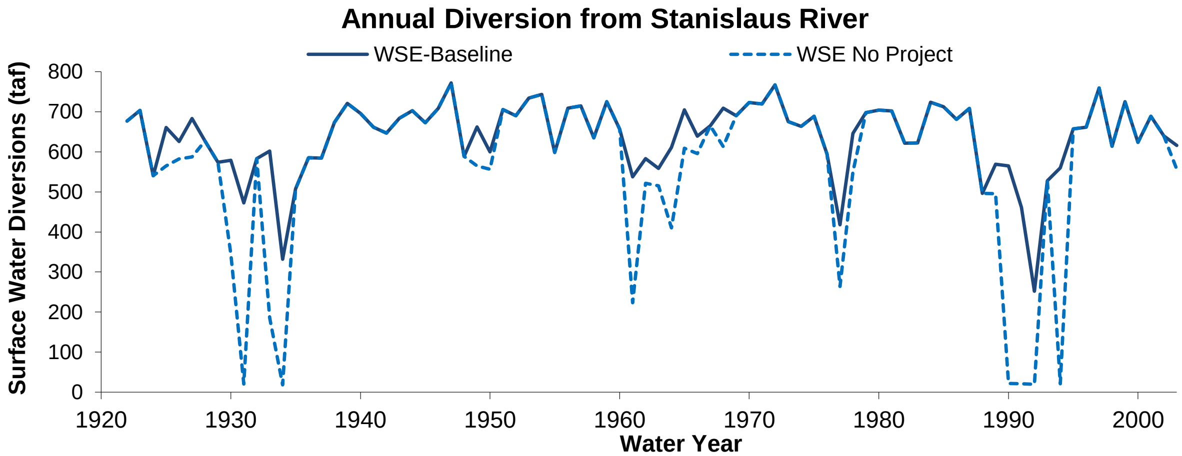

Figure D-1a. Stanislaus River Baseline and No Project Alternative Annual Diversions (TAF = thousand acre-feet)

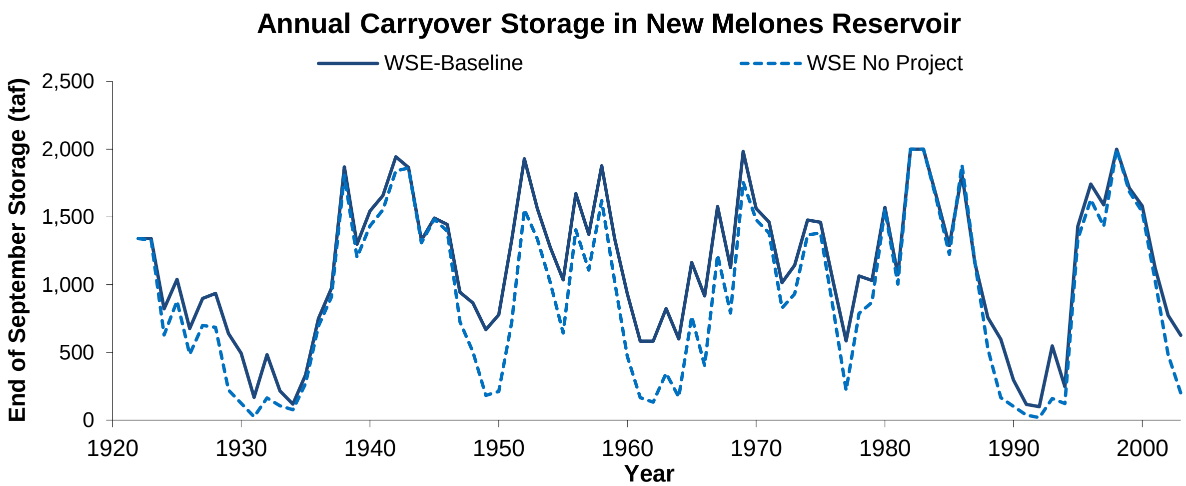

Figure D-1b. New Melones Baseline and No Project Alternative Carryover Storage (TAF = thousand acre-feet)

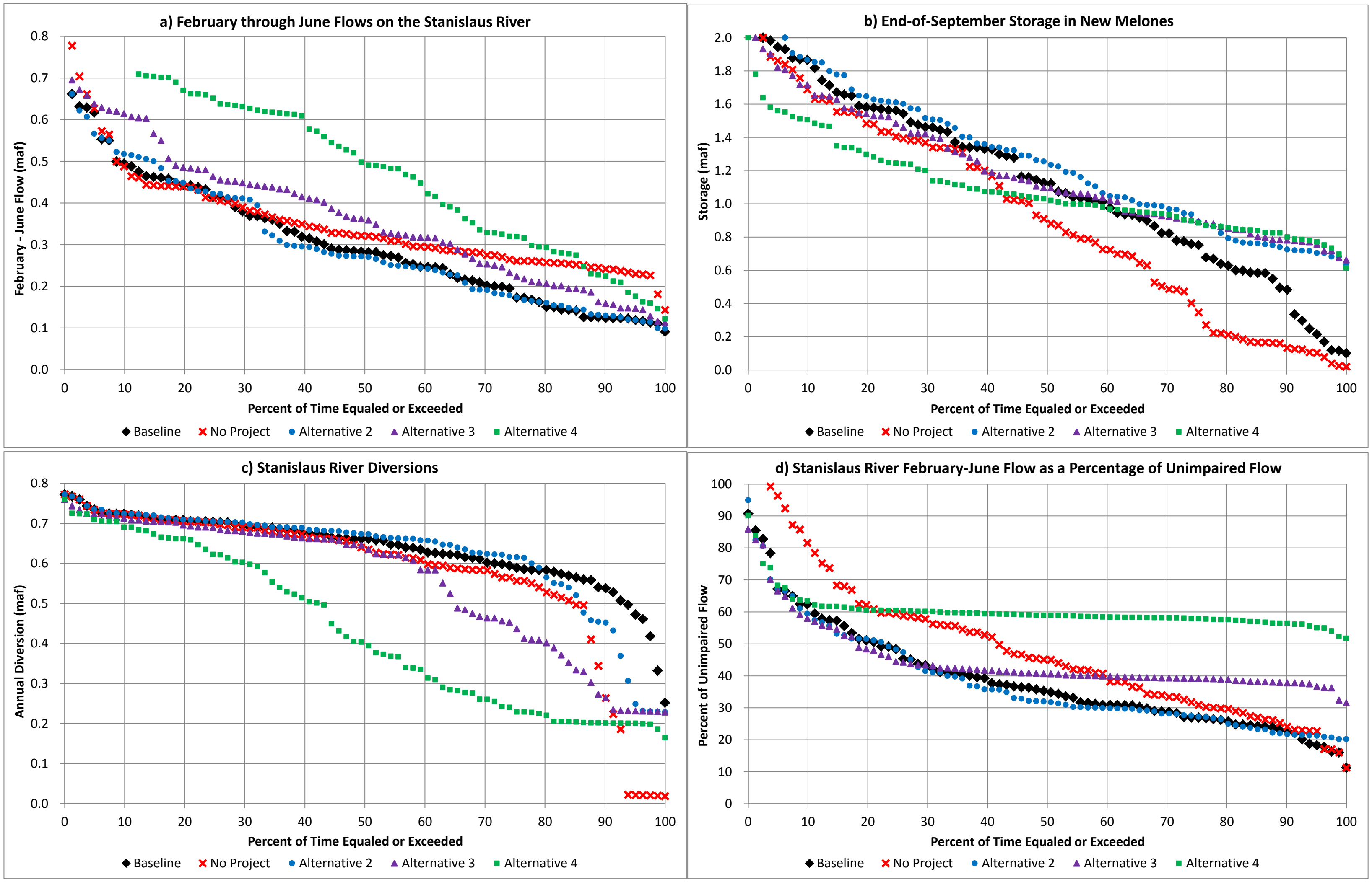

Figure D-2. Stanislaus River a) February-June Flow at Ripon, b) End-of-September (i.e., Carryover) Storage in New Melones Reservoir, c) Diversions, and d) February-June Flow as a Percentage of Unimpaired Flow

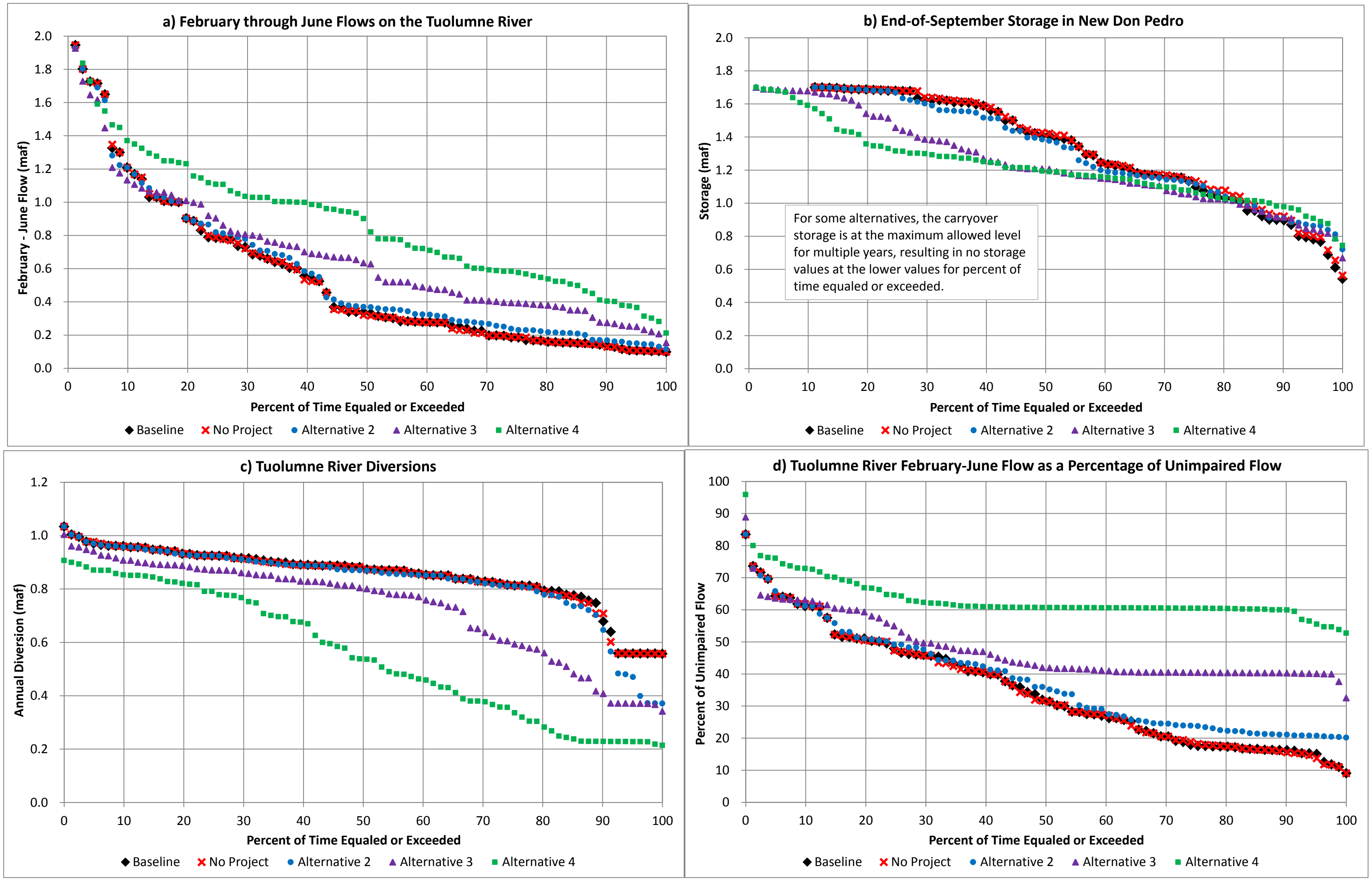

Figure D-3. Tuolumne River a) February-June Flow at Modesto, b) End-of-September (i.e., Carryover) Storage in New Don Pedro Reservoir, c) Diversions, and d) February-June Flow as a Percentage of Unimpaired Flow

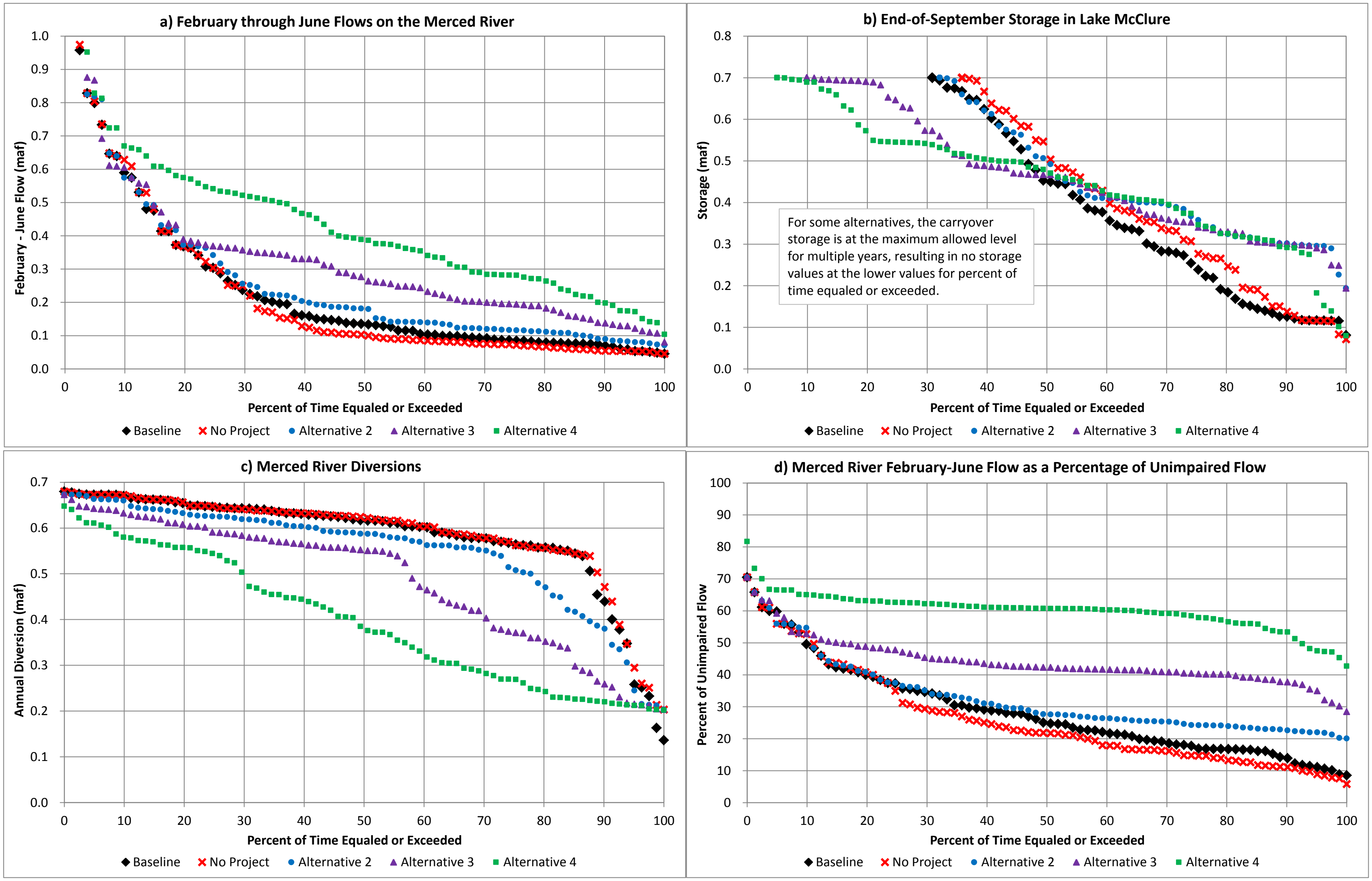

Figure D-4. Merced River a) February-to-June Flow at Stevinson, b) End-of-September (i.e., Carryover) Storage in Lake McClure, c) Diversions, and d) February-June Flow as a Percentage of Unimpaired Flow

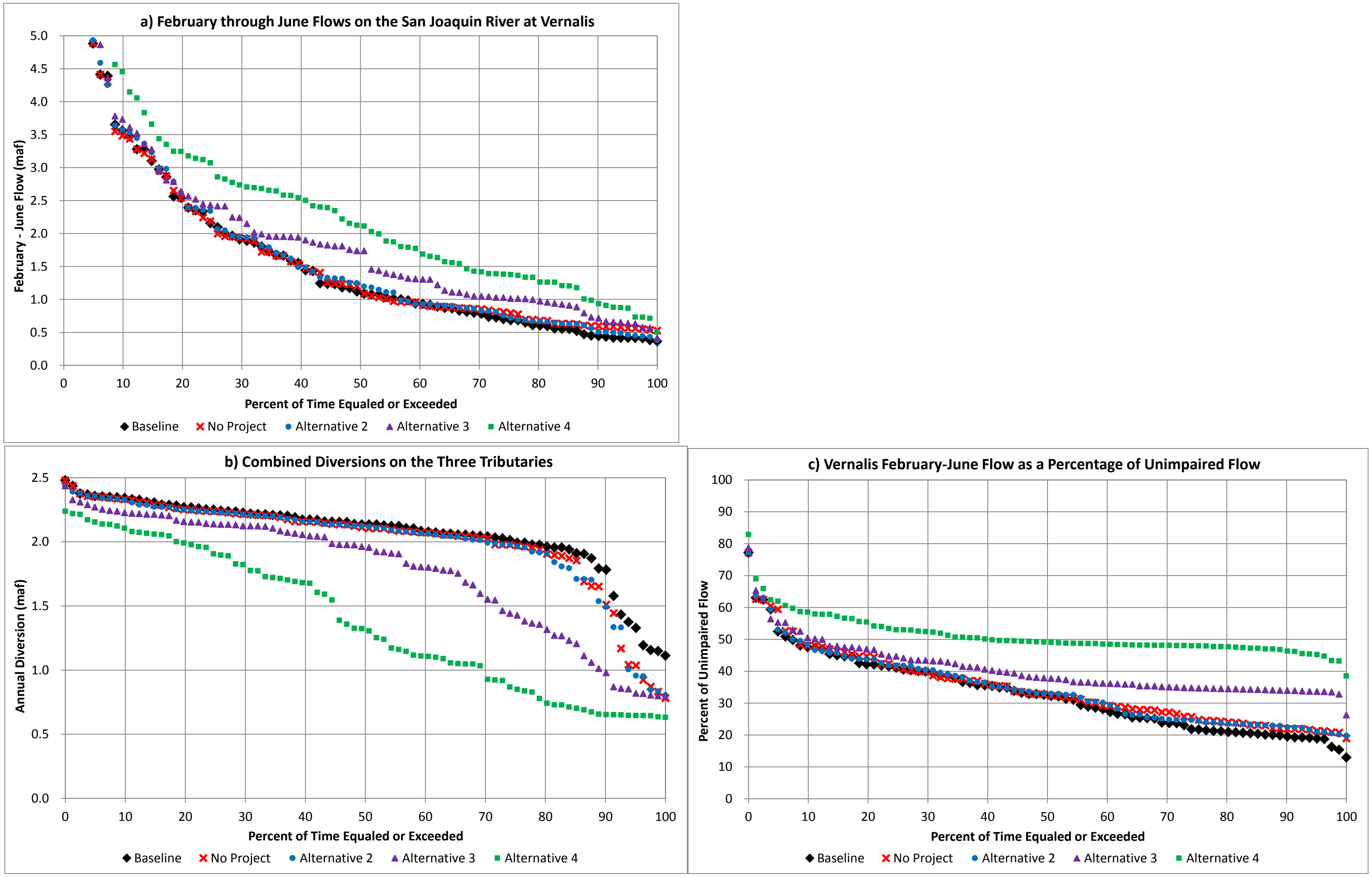

Figure D-5. San Joaquin River a) February-June Flow at Vernalis, b) Combined Diversions from the Three Tributaries (Stanislaus, Tuolumne, and Merced Rivers), and c) February-June Flow as a Percentage of Unimpaired Flow

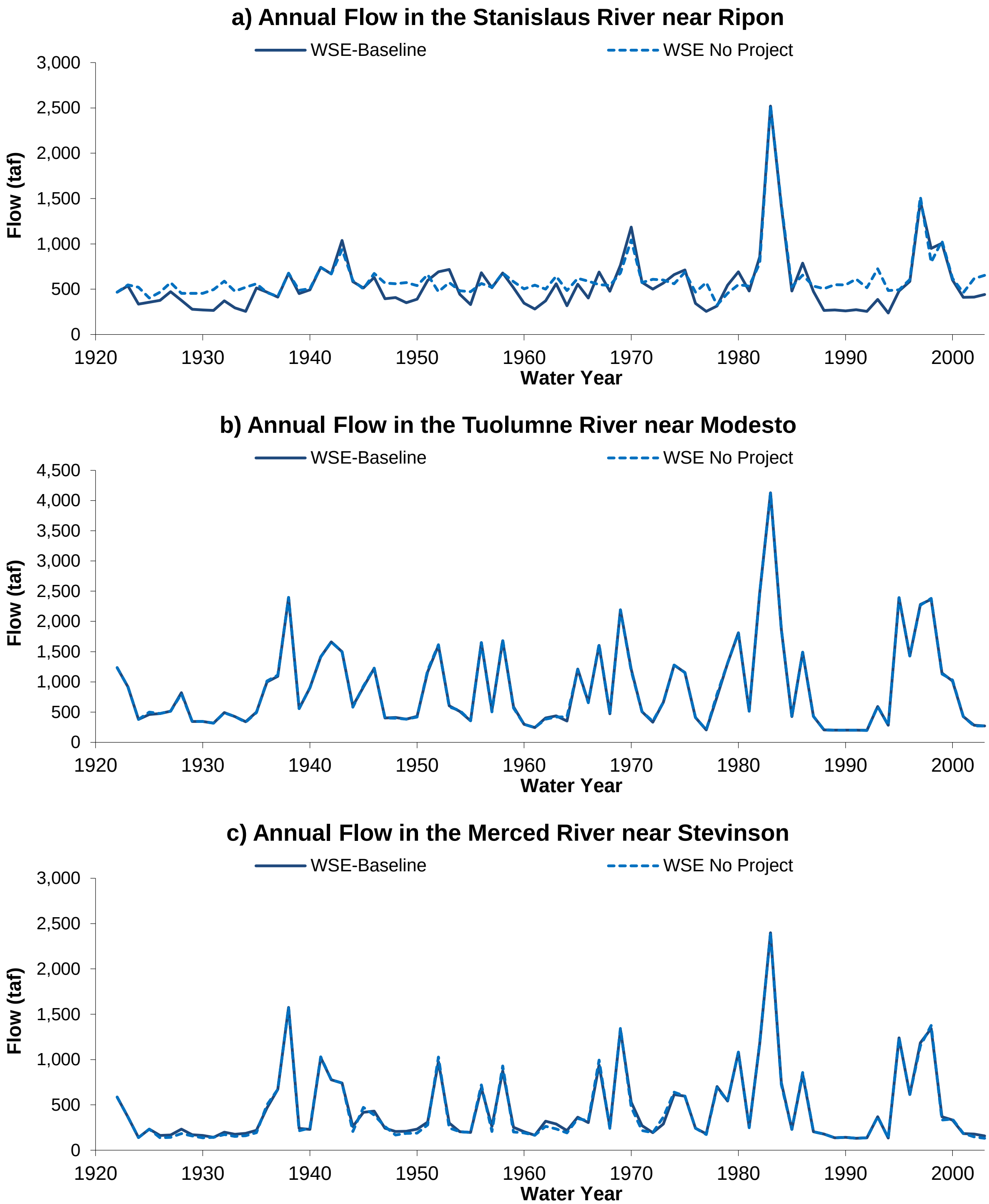

Figure D-6. Comparison of Baseline and No Project Alternative Annual Flow Volume (TAF = thousand acre-feet) for the a) Stanislaus, b) Tuolumne, and c) Merced Rivers near their Confluences with the San Joaquin River from 1922–2003

Appendix E

Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta

Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta

Final Report
January 5, 2010

By
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For
California Environmental Protection Agency
State Water Resources Control Board
Division of Water Rights

Salt Tolerance of Crops in the Southern Sacramento-San Joaquin Delta

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Acknowledgments

I would like to acknowledge Mark Gowdy of the State Water Resources Control Board for assistance with information and data acquisition, steady-state model programming, geographic information system (GIS) and other analyses, and report production (all under my direction). Mark was extremely helpful in accomplishing all of the objectives for this report. His abilities in preparing publishable figures were invaluable.

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1. Introduction

1.1. Location

The southern Delta, in general, encompasses lands and water channels of the Sacramento-San Joaquin Delta southwest of Stockton, California. The bulk of the lands in the southern Delta are included within the South Delta Water Agency (SDWA), and frequently referred to as the South Delta. Figure 1.1 shows the outline of the South Delta Water Agency relative to the San Joaquin County line and the legal boundary of the Delta. This report will focus on the area included within the SDWA as being representative of the southern Delta. Of the nearly 150,000 acres within the South Delta, the total irrigated area has declined from over 120,000 acres in the last three decades of the 20^{th} century to about 100,000 acres in recent years. The non-irrigated area includes urban lands, water courses, levees, farm homesteads, islands within channels, and levees.

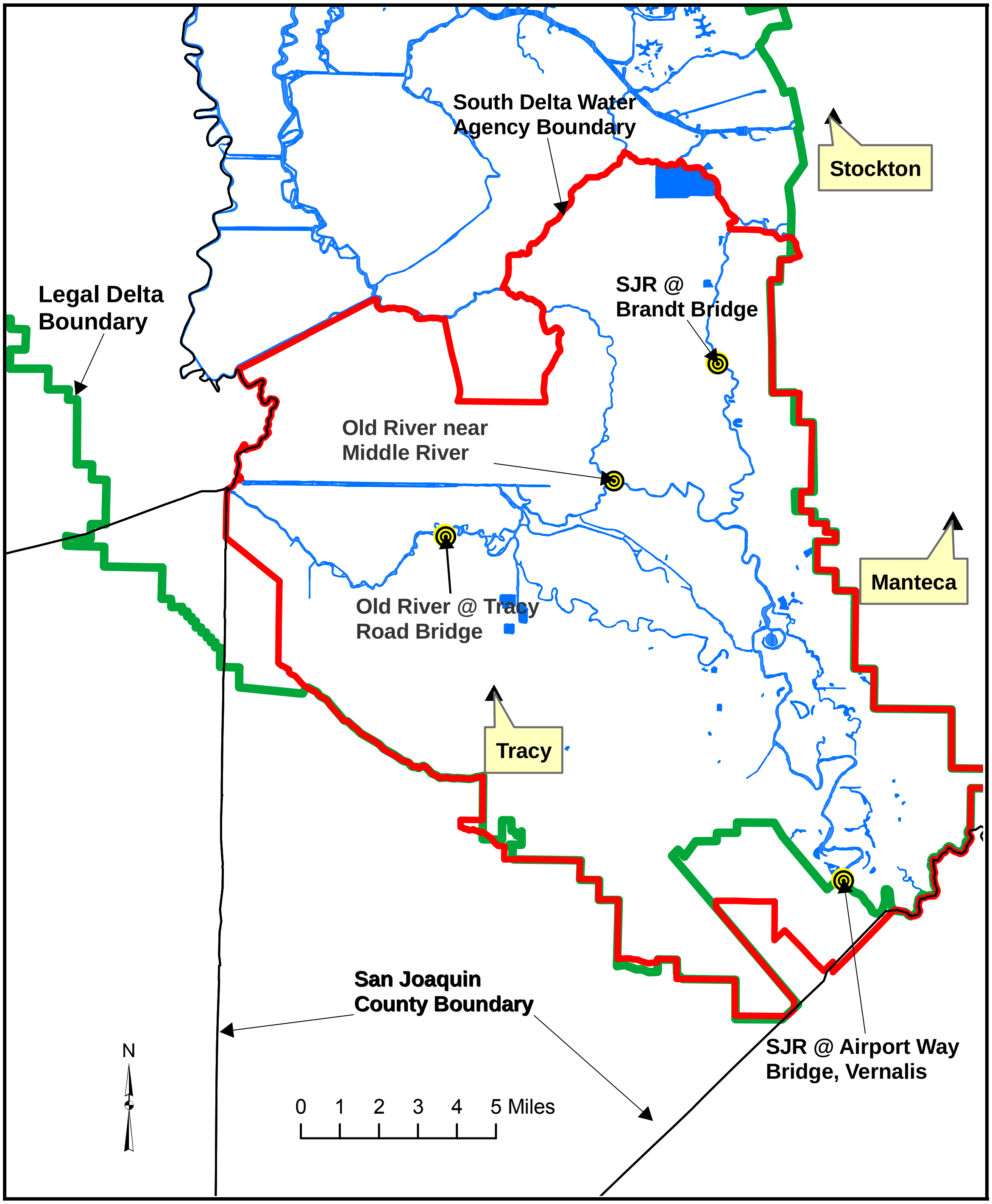
1.2. Regulations

The California State Water Resources Control Board (State Water Board) established the current southern Delta salinity objectives in the 1978 Sacramento-San Joaquin Delta and Suisun Marsh Water Quality Control Plan (1978 Delta Plan). The approach used in developing the objectives involved an initial determination of the water quality needs of significant crops grown in the area, the predominant soil type, and irrigation practices in the area. The State Water Board based the southern Delta electrical conductivity (EC) objectives on the calculated maximum salinity of applied water which sustains 100 percent yields of two important salt sensitive crops grown in the southern Delta (beans and alfalfa) in conditions typical of the southern Delta. These calculations were based on guidelines from the University of California's Cooperative Extension and Irrigation and Drainage Paper 29 of the Food and Agriculture Organization of the United Nations (Ayers and Westcot, 1976).

The State Water Board set an objective of 0.7 millimhos per centimeter (mmhos/cm) EC during the summer irrigation season (April through August) based on the salt sensitivity and growing season of beans and an objective of 1.0 mmhos/cm EC during the winter irrigation season (September through March) based on the growing season and salt sensitivity of alfalfa during the seedling stage. Salinity compliance stations within the south Delta are shown in Figure 1.1: San Joaquin River at Vernalis, CA; San Joaquin River at Brandt Bridge; Old River at Middle River; and Old River at Tracy Road Bridge.

In December of 2006, the State Water Board adopted the 2006 Bay-Delta Plan. The southern Delta salinity objectives originally adopted in 1978 were not substantively changed in the 2006 Bay-Delta Plan due to the fact that adequate scientific information was not available on which to base changes. However, the application of these objectives was modified to apply throughout the southern Delta and to additional discharge sources. The State Water Board, however, identified Delta and Central Valley salinity as an emerging issue and cited its pending effort to evaluate the southern Delta salinity objectives and their implementation as part of its larger salinity planning endeavor.

Figure 1.1. Map of southern Delta showing boundary of the South Delta Water Agency and salinity compliance stations.



1.3. Purpose and Objectives

The purpose of this report is to research the scientific literature and provide the state of knowledge on subjects that impact crop productivity with saline irrigation water and analyze the existing information from the South Delta and quantify how the various factors influencing the use of saline water applies to conditions in the South Delta. There are five objectives for this study. One of the objectives of this study is the review of existing literature relating to the effect of salinity on a variety of irrigated crops under South Delta conditions, preparation of a comprehensive list of references, and a synopsis of findings from key references. A second objective is the review of the relative strengths and limitations of steady-state and transient models that have been used to determine the suitability of saline water for crop production. As part of this second objective, the strengths, limitations, and assumptions of each model when applied to field conditions are to be presented. The third objective involves the use of soil information to determine and describe the approximate area and nature of saline and drainage-impaired soils; an estimate of the effectiveness of local rainfall in reducing the irrigation requirement; and compiling and evaluating historical crop types, acreages, and evapotranspiration information. The fourth objective is to provide conclusions and recommendations to the State Water Resources Control Board based upon the literature, modeling, and data evaluation. Among the conclusions and recommendations to be reported the following are considered paramount. (1) Identify significant gaps or uncertainties in the literature and recommend future studies to fill the gaps. (2) Using a steady-state model and appropriate data for the South Delta, estimate the leaching fraction required for salinity control for crops regularly grown on the drainage- and salinity-impaired soils of the South Delta. (3) Using the approach as in (2), recommend a salinity guideline that could provide full protection of the most salt sensitive crop currently grown or suitable to be grown on the drainage- and salinity- impaired soils. The final objective is to present the findings and recommendations in Sacramento to interested stakeholders and representatives of California state agencies.

2. Background Information

2.1. General Salinity Information

Soluble salts are present in all natural waters, and it is their concentration and composition that determine the suitability of soils and waters for crop production. Water quality for crop production is normally based on three criteria: (1) salinity, (2) sodicity, and (3) toxicity. Salinity is the osmotic stress caused by the concentration of dissolved salts in the root zone on crop growth. To overcome osmotic stress, plants must expend more energy to take up nearly pure water from the saline soil; thereby leaving less energy for plant growth. When the proportion of sodium compared to calcium and magnesium becomes excessive, soil structure deteriorates and the soil is said to be sodic. This deterioration of the soil structure, particularly near the soil surface, reduces infiltration and penetration of water into the soil; thereby, making it difficult for plants to take up sufficient water to satisfy evapotranspiration (ET) needs. Toxicity encompasses the effects of specific solutes that damage plant tissue or cause an imbalance in plant nutrition. The impact of salinity on plants is well summarized by Maas and Grattan (1999). Much of what follows in this section is taken from that reference.

The most common whole-plant response to salt stress is a reduction in the rate of plant growth. The hypothesis that seems to fit observations best asserts that excess salt reduces plant growth, primarily because it increases the energy that the plant must expend to acquire water from the soil and make the biochemical adjustments necessary to survive. Thus, energy is diverted from the processes that lead to growth and yield, including cell enlargement and the synthesis of metabolites and structural compounds (Rhoades, 1990). Although salinity affects plants in many ways physiologically, overt injury symptoms seldom appear except under extreme conditions of salt stress. Salt-affected plants usually appear normal, except they are stunted and may have darker green leaves which, on some plant species, are thicker and more succulent. Growth suppression seems to be a nonspecific salt effect that is directly related to the total salt concentration of soluble salts or the osmotic potential of the soil water. Within limits, the same osmotic concentration of different combinations of salts cause nearly equal reductions in growth. On the other hand, single salts or extreme ion ratios are likely to cause specific ion effects, such as ion toxicities or nutritional imbalances which cause even further yield reductions. For a discussion of the mechanisms of osmotic and specific ion effects, see Lauchli and Epstein (1990) and Bernstein (1975).

With most crops, including tree species, yield losses from osmotic stress can be significant before foliar injury is apparent. However, salts tend to accumulate in woody tissues, like trees, over time and toxic symptoms may not appear for several years; but, leaf injury can be dramatic when salts accumulate in the leaves (Hoffman, et al., 1989).

While crop salt tolerance values are based solely on desired yield, salinity adversely affects the quality of some crops while improving others. By decreasing the size and/or quality of fruits, tubers, or other edible organs, salinity reduces the market value of many vegetable crops, e.g., carrot, celery, cucumber, pepper, potato, cabbage, lettuce, and yam. Beneficial effects include increased sugar content of carrot and asparagus, increased soluble solids in tomato and cantaloupe, and improved grain quality of durum wheat. Generally, however, beneficial effects of salinity are offset by decreases in yield.

Soils and waters have no inherent quality independent of the site-specific conditions in question. Thus, soils and waters can only be evaluated fully in the context of a specified set of conditions. There are a number of factors that must be considered when evaluating a salinity standard for water quality in irrigated agriculture. These factors include: plant response to soil salinity, effective rainfall, irrigation management and method, uniformity of water applications, crop root water uptake distribution, climate, preferential (bypass) flow of applied water through the soil profile, leaching fraction, salt precipitation/dissolution in the crop root zone, and extraction of water by crops from shallow groundwater. The current state of knowledge for each of these factors, based upon published literature, is discussed in Section 3. Following the discussion of each factor, the importance of that factor is evaluated using data and information from the South Delta. Factors that appear to be insignificant will be identified and the reason the factor is insignificant will be noted. Factors that are important will be described in detail and their potential impact on a salinity water quality standard will be quantified. In Section 4 a number of steady-state and transient models are presented and discussed.

In Section 5 two steady-state models will be used to estimate the impact on South Delta agriculture over a range of possible salinity standards and leaching fractions.

2.2. Sources & Quality of Irrigation Water in the South Delta

Water conditions in the South Delta are influenced by San Joaquin River inflow; tidal action; water export facilities (primarily water levels and circulation); local pump diversions; agricultural and municipal return flows; channel capacity; and upstream development. The area is irrigated primarily with surface water through numerous local agricultural diversions. A small percentage of the land is irrigated with groundwater.

2.2.1. Salinity

The salinity of the water used for irrigation, reported as electrical conductivity in units of microSiemens per centimeter (μS/cm), is monitored at several locations in the South Delta. The numerical values in units of μS/cm are 1000 times larger than the numerical values in units of deciSiemens per meter (dS/m). In keeping with the literature on crop response to salinity the units of dS/m will be used in this report. Another important reason for using dS/m is that it is numerically equal to millimho per centimeter (mmho/cm), an outmoded unit of measure for electrical conductivity that was used for decades in agriculture to quantify salinity.

For information only, the monthly average electrical conductivity (EC) values from the California Data Exchange Center (CDEC) for the water in the San Joaquin River at Vernalis and for Old River at the Tracy Bridge from January, 2000 until January, 2009 are given in Figure 2.1 (DWR 2009a). Only data from these two southern Delta compliance stations are shown as they tend (but not always) to represent the lowest and highest EC concentrations respectively of the four compliance stations (locations as shown in Figure 1.1). As one would expect there are continuous variations in the measured values. With very few exceptions, the EC remains below 1.0 dS/m (1000 μS/cm) at both sampling locations. Figure 2.2 shows the median and the high and low values of the electrical conductivity by month for Old River at Tracy Bridge from the data in Figure 2.1. Note that during the months of April through August, the growing season for bean, the median EC is below 0.7 dS/m.

2.2.2. Sodicity

An important consideration in evaluating irrigation water quality is the potential for an excess concentration of sodium to occur in the soil leading to a deterioration of soil structure and reduction of permeability. When calcium and magnesium are the predominant cations adsorbed on the soil exchange complex, the soil tends to have a granular structure that is easily tilled and readily permeable. High levels of salinity reduce swelling and aggregate breakdown (dispersion) and promote water penetration, whereas high proportions of sodium produce the opposite effect. Excess sodium becomes a concern when the rate of infiltration is reduced to the point that the crop cannot be adequately supplied with water or when the hydraulic conductivity of the soil profile is too low to provide adequate drainage. The sodium-adsorption-ratio (SAR), is defined as:

$$SAR = C_{Na} / (C_{Ca} + C_{Mg})^{1/2} \qquad \text{(Eqn. 2.1)}$$

Figure 2.1. 30-day running average of electrical conductivity (dS/m) for Old River at Tracy (in red) and San Joaquin River at Vernalis (in blue) from Jan. 2000 through Jan. 2009 (CDEC Stations OLD and VER).

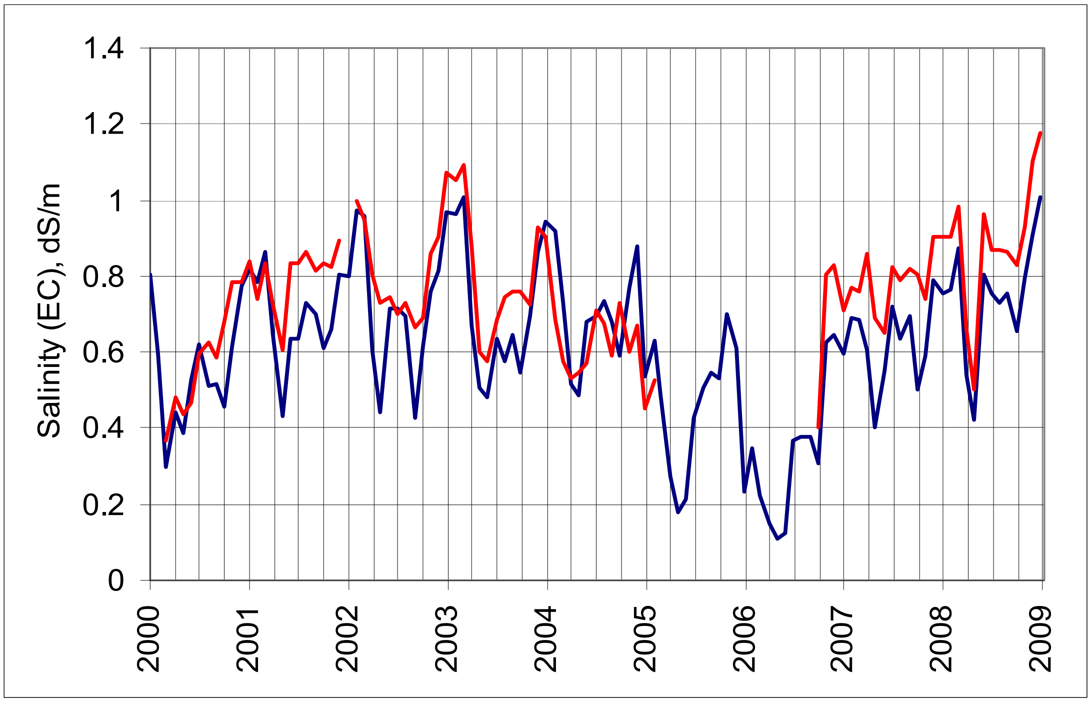
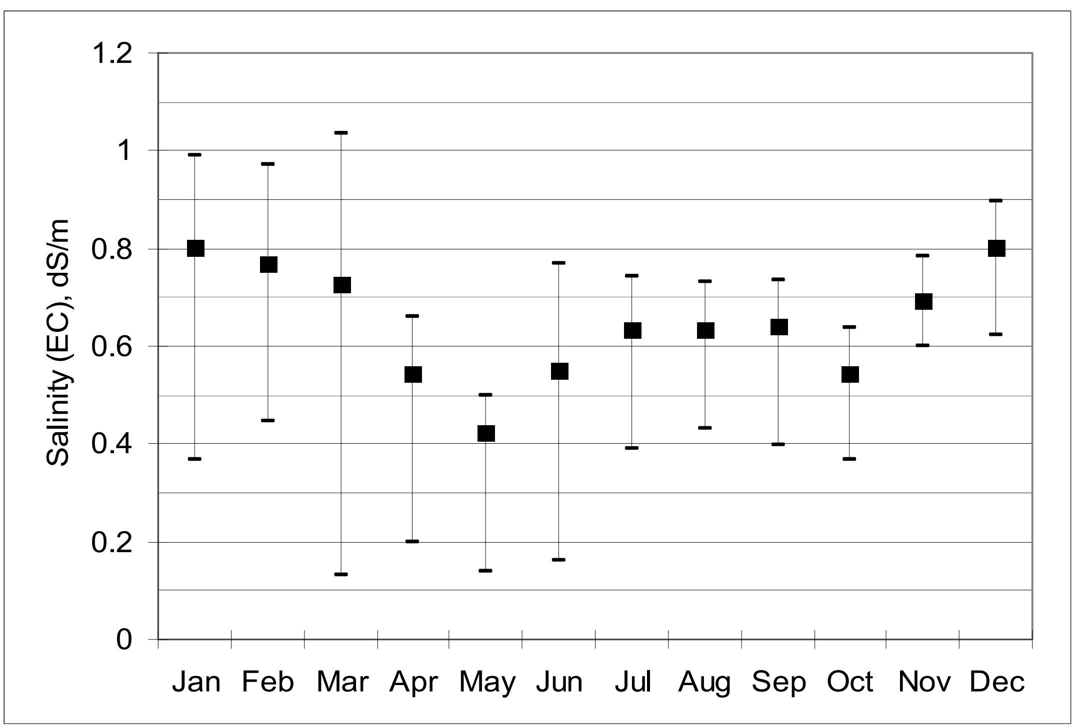


Figure 2.2. Median, high, and low electrical conductivity (dS/m) values averaged by month as measured for Old River at Tracy (CDEC Station OLD) from Jan. 2000 through Jan. 2009.



with all ion concentrations (C) being in units of mol/m^3. This equation is used to assess the sodium hazard of irrigation water. Both the salinity and the SAR of the applied water must be considered simultaneously when assessing the potential effects of water quality on soil water penetration.

From the water quality data for the San Joaquin River at Mossdale from 2000 to 2007 (154 analyses), average ion concentrations were: Na = 3.2 mol/m^3; Ca = 0.94 mol/m^3; and Mg = 0.77 mol/m^3 (Dahlgren, 2008). Inserting these values into Equation 2.1 gives an SAR of 2.4. This SAR is well below a value that would cause a sodicity problem (Maas and Grattan, 1999).

2.2.3. Toxicity

The potentially toxic effects of certain specific solutes, such as boron, sodium, and chloride, are normally associated with their uptake by crop roots and accumulation in the leaves. Some ions, like chloride, can also be absorbed directly into the leaves when moistened during sprinkler irrigation. Many trace elements are also toxic to plants at very low concentrations. Suggested maximum concentrations for these trace elements are given by Pratt and Suarez (1990). Fortunately, most irrigation waters contain insignificant concentrations of these potentially toxic trace elements and are generally not a problem. No information was found indicating that toxicity may occur from sodium, chloride, and most trace elements in the irrigation water used in the South Delta.

Boron, however, may be a concern. The boron tolerance of bean, for example, is a threshold value of 0.75 to 1.0 mg/l in the soil water within the crop root zone (Maas and Grattan, 1999). The data in Figure 2.3 from two surface water sources in the South Delta over the past two decades is quite variable with values ranging from 0.1 to over 1.0 mg/l (DWR 2009b). In addition, the boron concentration of effluent from subsurface drains in the New Jerusalem Drainage District over the past three decades averaged 2.6 mg/l with a range of 0.8 to 4.2 mg/l (Belden et al., 1989 and Westcot, unpublished report, 2009). Boron toxicity is outside the scope of this report but it warrants study.

2.3. South Delta Soils & Crops

2.3.1. Soils

The soils in the South Delta have been identified by a Soil Survey conducted by the Soil Conservation Service (SCS) for San Joaquin County in 1992 (SCS, 1992). Figure 2.4 was developed using the geographic information system (GIS) representation of this survey information from the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) Database (NRCS, 2009). The soils are shown in Figure 2.4 by different colors based on surface soil texture. The associated SCS soil units and some key soil properties are listed in Table 2.1 and grouped by the same general soil texture types.

Based on Montoya (2007), much of the surface geology of the Diablo Range immediately west and up-gradient from the South Delta is generally classified as marine sedimentary rock. Soils in the South Delta originated, to varying degrees, from these marine sedimentary rocks. Based on detailed logs of over 1,500 20-foot deep drill holes by DWR in the 1950's and 1960's, the San Joaquin Valley was partitioned into several general physiographic classifications. Three classifications overlapping the immediate South Delta included alluvial fan material from the Diablo Range, the basin trough, and the basin rim (Montoya, 2007). Land surrounding the City of Tracy (south, west, east, and just north) was characterized as water-laid sediment forming a slightly sloped alluvial fan. This alluvial fan was formed with eroded material from the Diablo Range. The boundary of the distal end of the alluvial fan (basin rim) generally extends in an east-to-west fashion just north of Tracy. The basin rim is a relatively slim band of sedimentary deposits from the Diablo Range with a flat or very slightly sloping topography. From the rim, the basin trough extends to Old River. Soils making up the basin trough are a mixture of sedimentary material from the Diablo Range and granitic material from the Sierra Nevada range carried into the floodplain during high flows. Therefore, land in the South Delta is bisected with soils of different types and origins. The alluvial fan material in the southernmost portion of the South Delta originated from the Diablo Range. Further north, the soils transition to a lesser-mineralized mixture of organic deposits, eroded Diablo Range material, and sediment from the Sierra Nevada carried down into the floodplain during periods of high runoff (Montoya, 2007).

Figure 2.3. Boron concentrations in two South Delta surface water bodies with the range of bean boron tolerance thresholds.

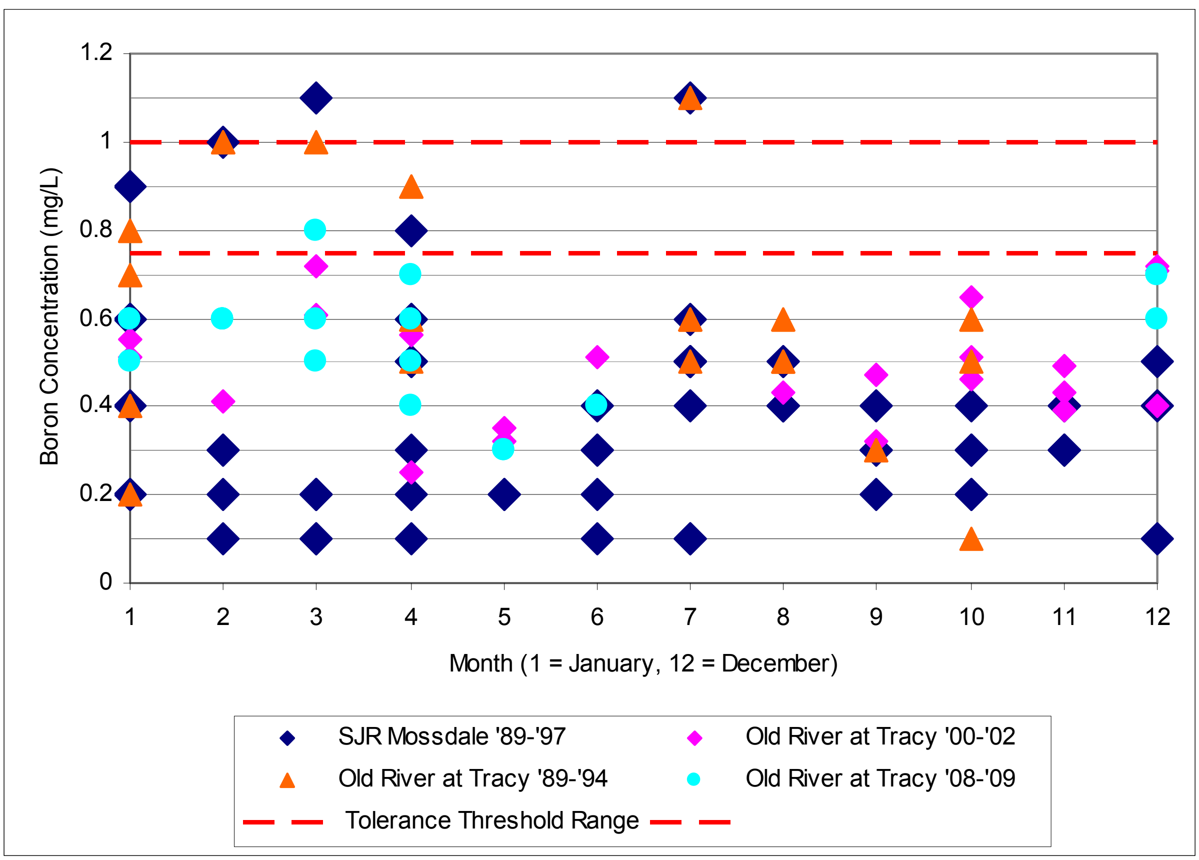


Figure 2.4. Map of soil textures in the southern Delta using GIS data from the NRCS-SSURGO Database.

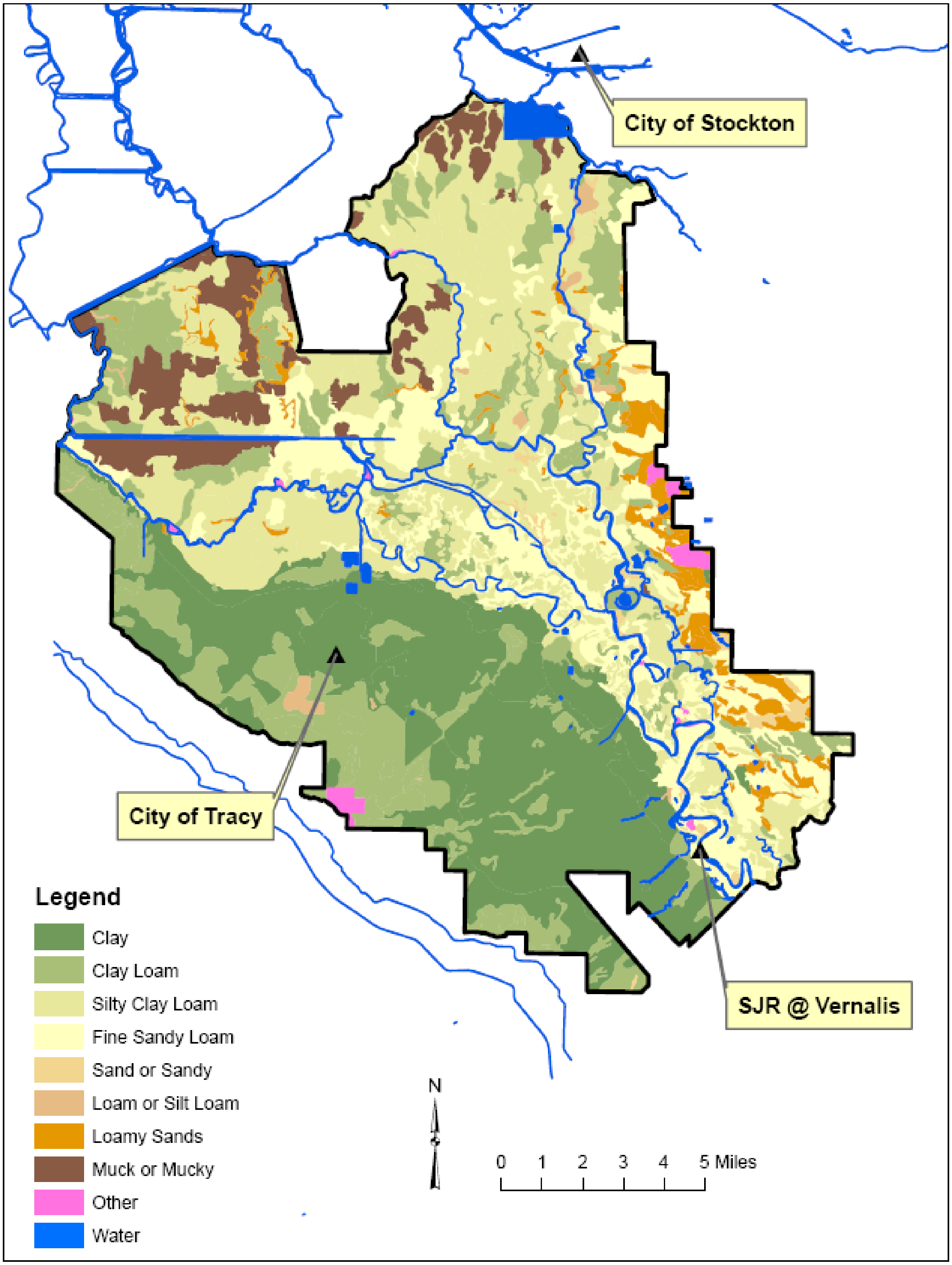


Table 2.1. Properties of the surface layer for soil units within the SDWA from the NRCS-SSURGO database, including key soil properties and sorted by soil texture (with corresponding colors in Figure 2.4).

Texture Category	Soil Unit No.	Soil Unit Name	Ksat (in/hr)	Water Holding Capacity (in./in.)	Depth to Groundwater (feet)	Hydrologic Group	Total Acres	Corresponding color in Figure 2.3
Clay	118	Capay	0.13	0.14 to 0.16	6.6	D	14,910	
	120	Capay	0.13	0.10 to 0.15	5.0	D	943	
	121	Capay	0.13	0.13 to 0.16	5.0	D	12,672	
	122	Capay	0.13	0.14 to 0.16	6.6	D	2,538	
	160	Galt	0.07	0.12 to 0.15	6.6	D	41	
	180	Jacktone	0.13	0.14 to 0.16	5.0	D	102	
	274	Willows	0.03	0.10 to 0.12	5.0	D	3,911	
						Subtotal:	**35,117**	
Clay Loam	110	Boggiano	0.68	0.17 to 0.20	6.6	B	5	
	148	Dello	10.54	0.17 to 0.18	5.0	A	1,220	
	156	El Solyo	0.17	0.17 to 0.20	6.6	C	1,926	
	158	Finrod	0.14	0.18 to 0.20	6.6	C	23	
	167	Grangeville	3.00	0.17 to 0.18	5.0	B	2,861	
	169	Guard	0.18	0.17 to 0.19	5.0	C	1,541	
	211	Pescadero	0.12	0.14 to 0.16	4.5	D	1,082	
	230	Ryde	0.94	0.17 to 0.20	3.5	C	3,691	
	232	Ryde	5.15	0.18 to 0.20	3.5	C	1,754	
	233	Ryde-Peltier	0.94	0.17 to 0.20	3.5	C	491	
	243	Scribner	0.38	0.19 to 0.21	4.0	C	1,287	
	244	Scribner	3.71	0.19 to 0.21	4.0	C	264	
	252	Stomar	0.26	0.16 to 0.18	6.6	C	7,521	
	253	Stomar	0.26	0.17 to 0.19	5.0	C	814	
	258	Trahern	0.16	0.16 to 0.18	5.0	D	798	
	268	Vernalis	1.14	0.17 to 0.18	6.6	B	1,254	
	269	Vernalis	1.14	0.17 to 0.18	5.0	B	1,225	
	281	Zacharias	0.38	0.15 to 0.19	6.6	B	581	
	282	Zacharias	0.83	0.10 to 0.15	6.6	B	456	
						Subtotal:	**28,795**	
Silty Clay Loam	139	Cosumnes	0.16	0.17 to 0.19	6.6	C	33	
	153	Egbert	0.16	0.17 to 0.19	5.0	C	8,574	
	154	Egbert	4.44	0.18 to 0.20	3.5	C	5,849	
	197	Merritt	0.55	0.17 to 0.19	5.0	B	24,580	
	198	Merritt	0.65	0.17 to 0.19	5.0	B	501	
	231	Ryde	5.15	0.18 to 0.20	3.5	C	52	
	267	Veritas	1.92	0.17 to 0.19	6.6	B	404	
						Subtotal:	**39,994**	
Fine Sandy Loam	130	Columbia	3.97	0.10 to 0.12	6.6	B	4,068	
	131	Columbia	3.97	0.10 to 0.12	4.0	C	1,081	
	132	Columbia	3.97	0.10 to 0.12	4.0	C	1,270	
	133	Columbia	3.21	0.10 to 0.12	4.0	C	2,050	
	166	Grangeville	3.97	0.12 to 0.14	5.0	B	7,780	
	196	Manteca	1.84	0.13 to 0.15	6.6	C	3,263	
	266	Veritas	3.05	0.12 to 0.15	6.6	B	2,202	
						Subtotal:	**21,714**	
Sand or Sandy	137	Cortina	3.97	0.07 to 0.14	6.6	B	17	
	144	Dello	13.04	0.06 to 0.08	3.5	C	385	
	147	Dello	6.94	0.10 to 0.13	5.0	B	314	
	175	Honcut	3.97	0.10 to 0.12	6.6	B	207	
	265	Veritas	2.92	0.10 to 0.13	4.5	B	346	
						Subtotal:	**1,269**	
Loam or Silt Loam	140	Coyotecreek		0.18 to 0.20	6.6		28	
	201	Nord		0.13 to 0.15	6.6		32	
	223	Reiff		0.13 to 0.16	6.6		355	
	261	Valdez		0.15 to 0.17	3.5		583	
						Subtotal:	**998**	
Loamy Sands	109	Bisgani	13.04	0.06 to 0.08	4.3	B	715	
	142	Delhi	13.04	0.06 to 0.10	6.6	A	91	
	145	Dello	13.04	0.07 to 0.10	6.6	A	706	
	146	Dello	13.04	0.07 to 0.10	3.5	C	854	
	254	Timor	12.18	0.06 to 0.08	6.6	A	571	
	255	Tinnin	13.04	0.06 to 0.08	6.6	A	2,224	
						Subtotal:	**5,162**	
Muck or Mucky	152	Egbert	0.16	0.18 to 0.20	5.0	C	378	
	190	Kingile	3.71	0.26 to 0.30	3.5	C	332	
	191	Kingile-Ryde	3.71	0.26 to 0.30	3.5	C	114	
	204	Peltier	0.95	0.18 to 0.20	3.5	C	7,777	
	224	Rindge	13.04	0.16 to 0.18	3.5	C	22	
	225	Rindge	13.04	0.26 to 0.30	3.5	C	50	
						Subtotal:	**8,673**	
Other	108	Arents, Saline/Sodi	0.47	n/a	n/a	D	307	
	159	Fluvaquents	0.56	n/a	n/a	D	312	
	214	Pits, Gravel	n/a	n/a	n/a	A	356	
	260	Urban land	n/a	n/a	n/a	n/a	229	
						Subtotal:	**1,204**	
Water	284	Water	n/a	n/a	n/a	n/a	4,402	
						Subtotal:	**4,402**	
Grand Total							**147,327**	

2.3.2. Crops

Based upon crop surveys conducted by the California Department of Water Resources (DWR) about every decade during the past 30 years (DWR, 2008 and Woods, 2008), changes in the cropping pattern have been documented (data summarized in Table 2.2). When looking at the total irrigated area and the non-irrigated land for 1976, 1988, and 1996 the values are relatively constant. Due to economics and farmer preference, the types and amounts of the individual crops changed over time. A number of changes occurred between the 1996 and 2007 surveys. For example, the total irrigated area in the South Delta remained at about 120,000 acres from 1976 to 1996 but dropped to just over 100,000 acres in the 2007 survey and the non-irrigated area ranged from about 15,000 acres to 20,000 acres earlier but increased to almost 40,000 acres in 2007. For comparison, the 2007 crop survey conducted by the San Joaquin County Agricultural Commissioner (SJCAC) is also presented in Table 2.2 (SJCAC, 2008). The irrigated area reported by the SJCAC is about midway between the earlier surveys and the 2007 survey at about 110,000 acres.

Jean Woods of DWR provided the following explanations for the differences between the 2007 survey and the earlier surveys (Woods, 2008). Planned and partially constructed housing developments near Lathrop and Clifton Court Forebay and an expansion of urban land in the northeastern part of the South Delta have resulted in a loss of about 7,000 acres of irrigated land over the last decade. Another difference between surveys was the delineation of field borders. Before 2007, field borders were assumed to be the centers of farm roads and often included canals and ditches. The irrigated acreage was then corrected by multiplying by 0.95. For 2007, the field borders, in most cases, represent just the irrigated crop area. This change in the method of calculating irrigated acreage would result in an additional reduction of almost 6,000 acres. In addition, the values in Table 2.2 were adjusted to include double cropped acres for various crops. With all of these changes, the total irrigated area is closer to what would be expected. However, because of these differences it is probably more appropriate to compare percentages for each crop or group of crops of interest. Table 2.3 gives the percentage of the general crop types in the irrigated area of the South Delta. These tables are provided for general reference only and depending on the use, more detailed analysis might be appropriate. Such analysis may be useful for establishing changes in crop acreage based on economics, farmer preference, salt tolerance, crop water use, and the type of irrigation system.

Table 2.2. Summary of irrigated crop acreage in SDWA for 1976, 1988, 1996, & 2007 from DWR land use surveys (including input received from Jean Woods at DWR on October 6, 2009), and for 2007 from San Joaquin County Agricultural Commissioner survey.

Crop	Salt Tolerance [1]	DWR Land Use Surveys (acres) 1976	1988	1996	2007	San Joaquin County Ag Commisioner (acres) 2007	Remarks
Fruits & Nuts							
Apples	S	30	5	119	18	15	
Apricots	S	0	1,246	980	204	128	
Olives	T	0	0	0	77	132	
Peaches & Nectarines	S	0	0	94	0	0	
Pears	S	0	59	0	0	0	
Plums	MS	0	0	45	5	0	
Almonds	S	0	3,122	2,472	3,107	2,860	
Walnuts	S	76	3,973	3,693	2,051	1,699	
Pistachios	MS	0	40	30	18	18	
Fruit or Nut - Misc. or <10 acres	Other	7,207	231	95	56	35	Pecan, Cherry, Pomegranite
Subtotal:		7,313	8,676	7,528	5,536	4,886	
Field Crops							
Cotton	T	0	0	0	34	0	
Safflower	MT	588	4,738	9,183	2,684	2,768	
Sugar Beets	T	14,066	11,594	1,761	135	449	
Corn	MS	13,407	7,632	15,014	15,481	14,242	Corn, human & fodder
Grain Sorghum	MT	1,072	8	0	0	86	
Sudan	MT	3,727	581	626	1,286	302	
Castor Beans	S	51	0	0	0	0	
Dry Beans	S	6,016	7,471	8,673	4,417	2,998	
Sunflowers	MT	0	517	275	0	0	
Hybrid sorghum/sudan	MT	0	0	0	71	0	
Field Crops - Misc. or <10 acres	Other	0	8	0	0	1,720	Lima, Beans, Unspecified
Subtotal:		38,927	32,549	35,532	24,108	22,564	
Grain & Hay Crops							
Wheat	MT	0	0	0	0	5,806	Wheat, human & fodder
Oats	T	0	0	0	0	4,616	Oats, human & fodder
Grain & Hay - Misc.	Other	24,128	9,776	16,109	7,297	1,568	Forage hay, barley, rye for fodder
Subtotal:		24,128	9,776	16,109	7,297	11,990	
Pasture							
Alfalfa	MS	26,841	36,581	30,911	31,342	33,021	
Clover	MS	0	31	0	0	0	
Turf Farm	MT	0	232	347	324	0	
Pasture - Misc.	Other	3,938	2,630	2,476	3,148	956	
Subtotal:		30,779	39,474	33,734	34,814	33,977	
Truck & Berry Crops							
Asparagus	T	5,069	7,393	6,794	3,651	4,137	
Green Beans	S	58	164	39	24	458	
Cole Crops	MS	385	557	19	257	1,097	Brocolli, Cabbage
Carrots	S	0	0	219	197	247	
Celery	S	0	0	0	105	436	
Melons, Squash, Cucumbers	MS	750	2,210	4,874	2,628	2,757	Melon, Pumpkin, Squash, Cucumber
Onions (Garlic)	S	109	326	277	165	906	Dry & green onions
Tomatoes	MS	16,991	15,863	14,069	16,444	18,635	Tomatoes & processing tomatoes
Strawberries	S	0	0	41	4	0	
Peppers	MS	166	77	46	253	531	
Truck Crops - Misc. or <10 acres	Other	117	89	100	555	4,932	Various [3]
Subtotal:		23,645	26,679	26,478	24,282	34,137	
Vineyards							
Unspecified Varieties	MS	755	521	2,095	2,902	2,940	
Other							
Idle Fields	Other	527	2,266	373	2,114	0	
Other	Other		0	0	0	0	
Subtotal Irrigated Crops:		**126,074**	**119,942**	**121,849**	**101,053**	**110,494**	
Breakdown by Salt Tolerance:	S	6,340	16,366	16,607	10,291	9,747	
	MS	59,295	63,512	67,103	69,330	73,241	
	MT	5,387	6,076	10,431	4,364	8,962	
	T	19,135	18,987	8,555	3,898	9,334	
	Other	35,917	15,000	19,153	13,170	9,210	
Non-Irrigated Land:		14,805	20,937	19,030	39,826	n/a	
Total for SDWA[2]:		140,879	140,879	140,879	140,879	n/a	

[1] Salt tolerance categories as follows:
S = Sensitive; MS = Moderately Sensitive; MT = Moderately Tolerant; T = Tolerant

[2] Actual area of SDWA within legal Delta (as used in this survey) is 140,879 acres. The total area of SDWA is 147,328 acres.

[3] Includes blueberry, bok choy, celeriac, christmas tree, cilantro, collard, fruit berries, herbs, kale, leek, leaf lettuce, mustard, outdoor plants, spinach, swiss chard

Table 2.3. Percentage of total irrigated land in SDWA for each crop grown in 1976, 1988, 1996, & 2007 from DWR land use surveys (including input received from Jean Woods at DWR on October 6, 2009), and for 2007 from San Joaquin County Agricultural Commissioner survey.

Crop	Salt Tolerance [1]	DWR Land Use Surveys (%) 1976	1988	1996	2007	San Joaquin County Ag Commisioner (%) 2007	Remarks
Fruits & Nuts							
Apples	S	0.02	0.00	0.10	0.02	0.01	
Apricots	S	0.00	1.04	0.80	0.20	0.12	
Olives	T	0.00	0.00	0.00	0.08	0.12	
Peaches & Nectarines	S	0.00	0.00	0.08	0.00	0.00	
Pears	S	0.00	0.05	0.00	0.00	0.00	
Plums	MS	0.00	0.00	0.04	0.00	0.00	
Almonds	S	0.00	2.60	2.03	3.07	2.59	
Walnuts	S	0.06	3.31	3.03	2.03	1.54	
Pistachios	MS	0.00	0.03	0.02	0.02	0.02	
Fruit or Nut - Misc. or <10 acres	Other	5.72	0.19	0.08	0.06	0.03	Pecan, Cherry, Pomegranite
Subtotal:		5.80	7.23	6.18	5.48	4.42	
Field Crops							
Cotton	T	0.00	0.00	0.00	0.03	0.00	
Safflower	MT	0.47	3.95	7.54	2.66	2.51	
Sugar Beets	T	11.16	9.67	1.45	0.13	0.41	
Corn	MS	10.63	6.36	12.32	15.32	12.89	Corn, human & fodder
Grain Sorghum	MT	0.85	0.01	0.00	0.00	0.08	
Sudan	MT	2.96	0.48	0.51	1.27	0.27	
Castor Beans	S	0.04	0.00	0.00	0.00	0.00	
Dry Beans	S	4.77	6.23	7.12	4.37	2.71	
Sunflowers	MT	0.00	0.43	0.23	0.00	0.00	
Hybrid sorghum/sudan	MT	0.00	0.00	0.00	0.07	0.00	
Field Crops - Misc. or <10 acres	Other	0.00	0.01	0.00	0.00	1.56	Lima, Beans, Unspecified
Subtotal:		30.88	27.14	29.16	23.86	20.42	
Grain & Hay Crops							
Wheat	MT	0.00	0.00	0.00	0.00	5.25	Wheat, human & fodder
Oats	T	0.00	0.00	0.00	0.00	4.18	Oats, human & fodder
Grain & Hay - Misc.	Other	19.14	8.15	13.22	7.22	1.42	Forage hay, barley, rye for fodder
Subtotal:		19.14	8.15	13.22	7.22	10.85	
Pasture							
Alfalfa	MS	21.29	30.50	25.37	31.02	29.88	
Clover	MS	0.00	0.03	0.00	0.00	0.00	
Turf Farm	MT	0.00	0.19	0.28	0.32	0.00	
Pasture - Misc.	Other	3.12	2.19	2.03	3.12	0.87	
Subtotal:		24.41	32.91	27.69	34.45	30.75	
Truck & Berry Crops							
Asparagus	T	4.02	6.16	5.58	3.61	3.74	
Green Beans	S	0.05	0.14	0.03	0.02	0.41	
Cole Crops	MS	0.31	0.46	0.02	0.25	0.99	Brocolli, Cabbage
Carrots	S	0.00	0.00	0.18	0.19	0.22	
Celery	S	0.00	0.00	0.00	0.10	0.39	
Melons, Squash, Cucumbers	MS	0.59	1.84	4.00	2.60	2.49	Melon, Pumpkin, Squash, Cucumber
Onions (Garlic)	S	0.09	0.27	0.23	0.16	0.82	Dry & green onions
Tomatoes	MS	13.48	13.23	11.55	16.27	16.87	Tomatoes & processing tomatoes
Strawberries	S	0.00	0.00	0.03	0.00	0.00	
Peppers	MS	0.13	0.06	0.04	0.25	0.48	
Truck Crops - Misc. or <10 acres	Other	0.09	0.07	0.08	0.55	4.46	Various [(2)]
Subtotal:		18.75	22.24	21.73	24.03	30.89	
Vineyards							
Unspecified Varieties	MS	0.60	0.43	1.72	2.87	2.66	
Other							
Idle Fields	Other	0.42	1.89	0.31	2.09	0.00	
Other	Other	0.00	0.00	0.00	0.00	0.00	
Subtotal Irrigated Crops:		**100.00**	**100.00**	**100.00**	**100.00**	**100.00**	
Breakdown by Salt Tolerance:	S	5.03	13.65	13.63	10.18	8.82	
	MS	47.03	52.95	55.07	68.61	66.29	
	MT	4.27	5.07	8.56	4.32	8.11	
	T	15.18	15.83	7.02	3.86	8.45	
	Other	28.49	12.51	15.72	13.03	8.34	

[1] Salt tolerance categories as follows:
S = Sensitive; MS = Moderately Sensitive; MT = Moderately Tolerant; T = Tolerant

[2] Includes blueberry, bok choy, celeriac, christmas tree, cilantro, collard, fruit berries, herbs, kale, leek, leaf lettuce, mustard, outdoor plants, spinach, swiss chard

3. Factors Affecting Crop Response to Salinity

3.1. Season-Long Crop Salt Tolerance

3.1.1. State of Knowledge

Salinity, salt stress, can damage crops in three different ways. First, and of major concern in the South Delta, is season-long crop response to salinity. The most common whole-plant response to salt stress is a general stunting of growth. As soil salinity increases beyond a threshold level both the growth rate and ultimate size of crop plants progressively decreases. However, the threshold and the rate of growth reduction vary widely among different crop species. Second, crop sensitivity to soil salinity continually changes during the growing season. Many crops are most sensitive to soil salinity during emergence and early seedling development. Third, when crops are irrigated with sprinkler systems, foliar damage can occur when the leaves are wet with saline water. Sprinkler foliar damage is most likely to occur under hot, dry, and windy weather conditions. Crop salt tolerance at various growth stages is discussed in the following section. The impact of sprinkling crops with saline water is described within the section on irrigation methods. Here, the impact of soil salinity over the cropping season is presented.

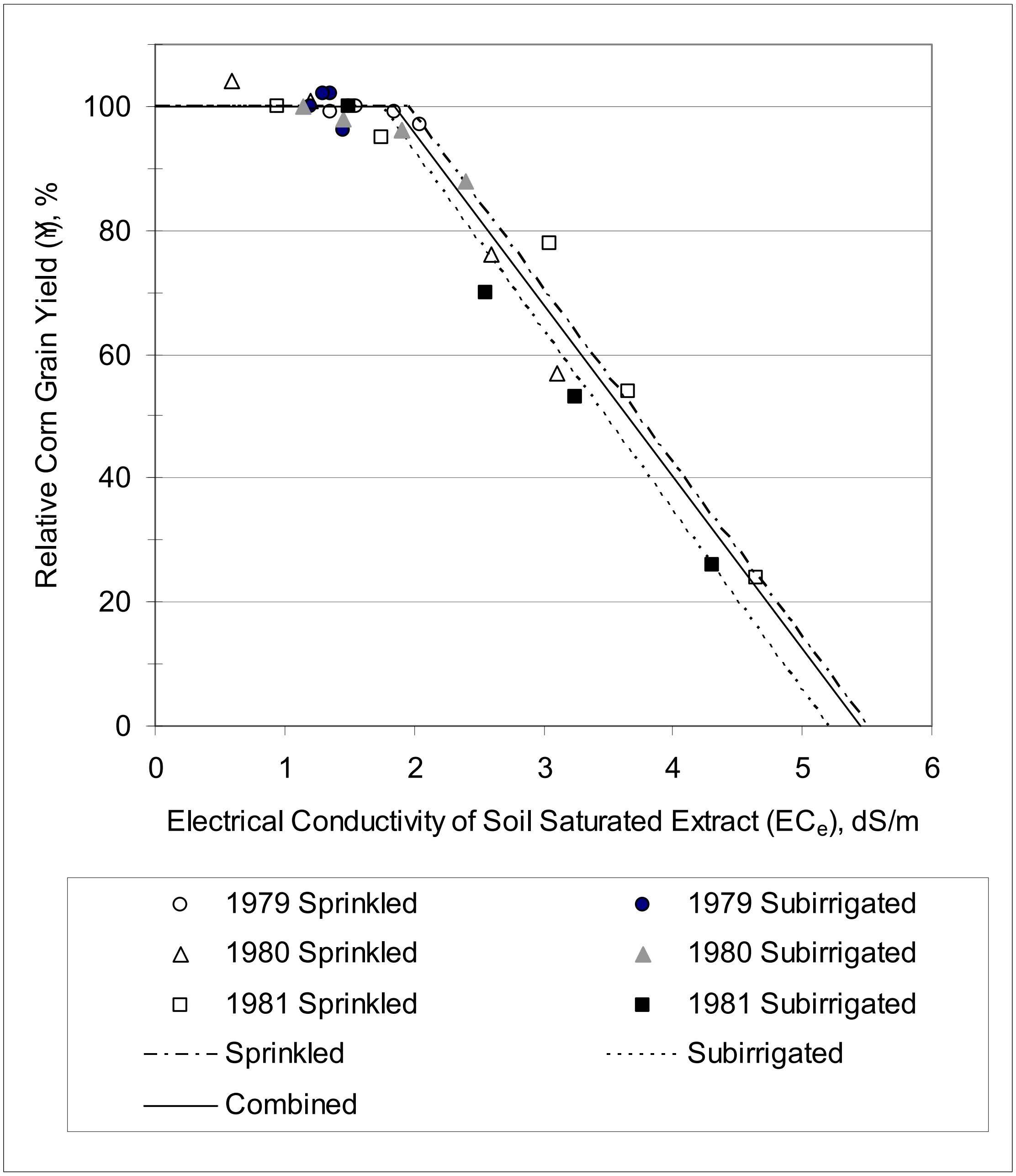
Maas and Hoffman (1977) proposed that the yield response of crops to soil salinity for the growing season could be represented by two line segments: one, a tolerance plateau with a zero slope; and the second, a salt concentration-dependent line whose slope indicates the yield reduction per unit increase in salinity. The point at which the two lines intersect designates the “threshold”, i.e., the maximum soil salinity that does not reduce yield below that obtained under non-saline conditions. This two-piece linear response function provides a reasonably good fit for commercially acceptable yields plotted against the electrical conductivity of the saturated-soil extract (EC_e). Electrical conductivity of the saturated-soil extract is the traditional soil salinity measurement with units of deciSiemens (dS) per meter (1 dS/m = 1 mmho/cm, the traditional units for reporting electricity conductivity; or 1 dS/m = 1000 μS/cm, units frequently used by DWR). One deciSiemen per meter is approximately equal to 640 mg/l or 640 parts per million total dissolved solids. For soil salinities exceeding the threshold of any given crop, relative yield (Y_r) can be estimated by:

$$Y_r = 100 - b\,(EC_e - a) \qquad \text{(Eqn. 3.1)}$$

with a = the salinity threshold expressed in deciSiemens per meter; b = the slope expressed in percentage per deciSiemens per meter; EC_e = the mean electrical conductivity of a saturated-soil extract taken from the root zone. An example of how this piecewise linear response function fits data can be seen in Figure 3.1 for data taken from a field experiment on corn in the Sacramento-San Joaquin River Delta near Terminus, CA (Hoffman et al., 1983).

Crop salt tolerance has been established for a large number of crops in experimental plots, greenhouse studies, and field trials (Maas and Hoffman, 1977 and Maas and

Figure 3.1. Relative grain yield of corn grown in the Sacramento - San Joaquin River Delta as a function of soil salinity by sprinkled and sub-irrigated methods (Hoffman et al., 1983).



Grattan, 1999). The salt tolerance coefficients, threshold (a) and slope (b), presented in these publications and applied to Equation 3.1 are used throughout the world and are used in steady-state and transient models dealing with salinity control. Most of the data used to determine these two coefficients were obtained where crops were grown under conditions simulating recommended cultural and management practices for commercial production. Consequently, the coefficients indicate the relative tolerances of different crops grown under different conditions and not under some standardized set of conditions. Furthermore, the coefficients apply only where crops are exposed to fairly uniform salinities from the late seedling stage to maturity.

3.1.2. South Delta Situation

The crop salt tolerance threshold and slope values for the 18 crops important in the South Delta are given in Table 3.1. The relative salt tolerance rating of a given crop compared to other agricultural crops is also given in Table 3.1 and the definition of these relative ratings is given Figure 3.2. Bean is the most salt sensitive crop grown on significant acreage in the South Delta. Tree crops are also salt sensitive but not to the same degree as bean.

Unfortunately, some of the crops in the DWR crop surveys (DWR, 2008 and Woods, 2008) are reported as pasture, grain and hay, fruit and nut, citrus, field crops, and truck crops. A salt tolerance can not be assigned to these general categories. However, there is a sufficient number of crops identified that the range of crop salt tolerance in the South Delta is known (see Tables 2.2 and 2.3).

Of particular interest is the amount and location of crops based upon their salt tolerance. Figure 3.3 shows the percentage of crops grown in the South Delta based upon relative crop salt tolerance. The data are from the crop surveys taken about every decade since 1976. Of note are the increase in the percentage of sensitive and moderately salt sensitive crops and a decrease in the salt tolerant percentage. This may indicate that the farmers have become more confident in the economics of growing more salt sensitive crops and the near elimination of sugar beet, a salt tolerant crop, in recent years. In Figure 3.4, the locations where crops are grown based upon salt tolerance are illustrated for the four DWR crop surveys. The area where salt sensitive and moderately salt sensitive crops are grown has increased with time. Although salt sensitive crops are grown throughout, the majority are grown in the southwest corner of the South Delta. It should be noted that Figure 3.4 maps crop acreage for the first crop only (Class1 and Subclass1 attributes from the DWR GIS databases), while Figure 3.3 (based on Table 2.2) also includes second crop acreages (i.e. Class2 and Subclass2 attributes from the DWR GIS databases).

Bean is the most salt sensitive crop with any significant acreage in the south Delta. If bean is to be the crop upon which the water quality standard is to be based then it is instructive to see how the acreage and location of bean has changed over the past three decades. Figure 3.5 presents the location of bean fields from the 1976, 1988, 1996 and 2007 DWR crop surveys, differentiating between those which had bean as a first crops versus those with bean as a second crop. Although beans are predominately

Table 3.1. Crop salt tolerance coefficients for important crops in the South Delta (Maas and Grattan, 1999).

Common Name	Botanical Name	Tolerance based on	Threshold* ECe, dS/m	Slope* % per dS/m	Relative Tolerance **
Alfalfa	Medicago sativa	Shoot DW	2.0	7.3	MS
Almond	Prunus duclis	Shoot growth	1.5	19	S
Apricot	Prunus armeniaca	Shoot growth	1.6	24	S
Asparagus	Asparagus officinalis	Spear yield	4.1	2.0	T
Barley	Hordeum vulgare	Grain yield Shoot DW	8.0 6.0	5.5 7.1	T MT
Bean	Phaseolus vulgaris	Seed yield	1.0	19	S
Corn	Zea mays	Ear FW Shoot DW	1.7 1.8	12 7.4	MS MS
Cucumber	Cucumis sativus	Fruit yield	2.5	13	MS
Grape	Vitus vinifera	Shoot growth	1.5	9.6	MS
Muskmelon	Cucumis melo	Fruit yield	1.0	8.4	MS
Oat	Avena sativa	Grain yield Straw DW	--- ---	--- ---	T T
Safflower	Carthamus tinctorius	Seed yield	---	---	MT
Squash	Curcubita-pepo Scallop Zucchini	 Fruit yield Fruit yield	 3.2 4.9	 16 10.5	 MS MT
Sugar beet	Beta vulgaris	Storage root	7.0	5.9	T
Tomato	Lycopersicon lycopersicum	Fruit yield	2.5	9.9	MS
Walnut	Juglans	foliar injury	---	---	S
Watermelon	Citrullus lanatus	Fruit yield	---	---	MS
Wheat	Triticum aestivum	Grain yield	6.0	7.1	MT

* Values of threshold = (a) and slope = (b) for Equation 3.1.

** Relative salt tolerance ratings noted as (S) sensitive, (MS) moderately sensitive, (MT) moderately tolerant, and (T) tolerant, see Fig. 3.2.

Figure 3.2. Classification of crop tolerance to salinity based on relative crop yield against electrical conductivity of saturated soil extract (EC_e), dS/m.

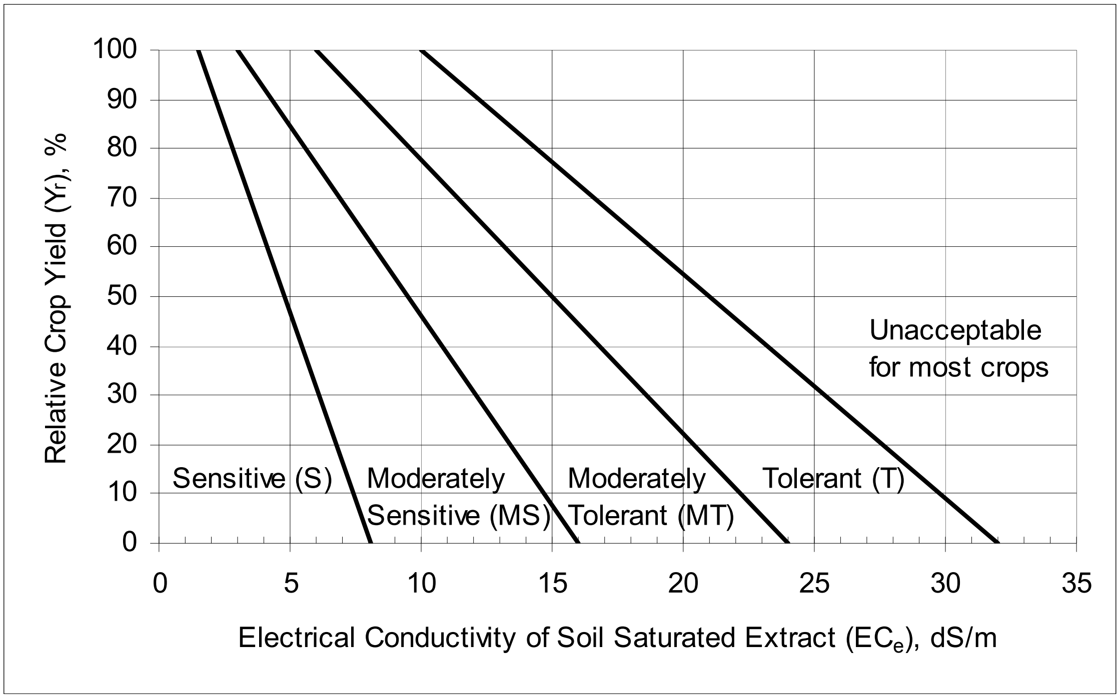
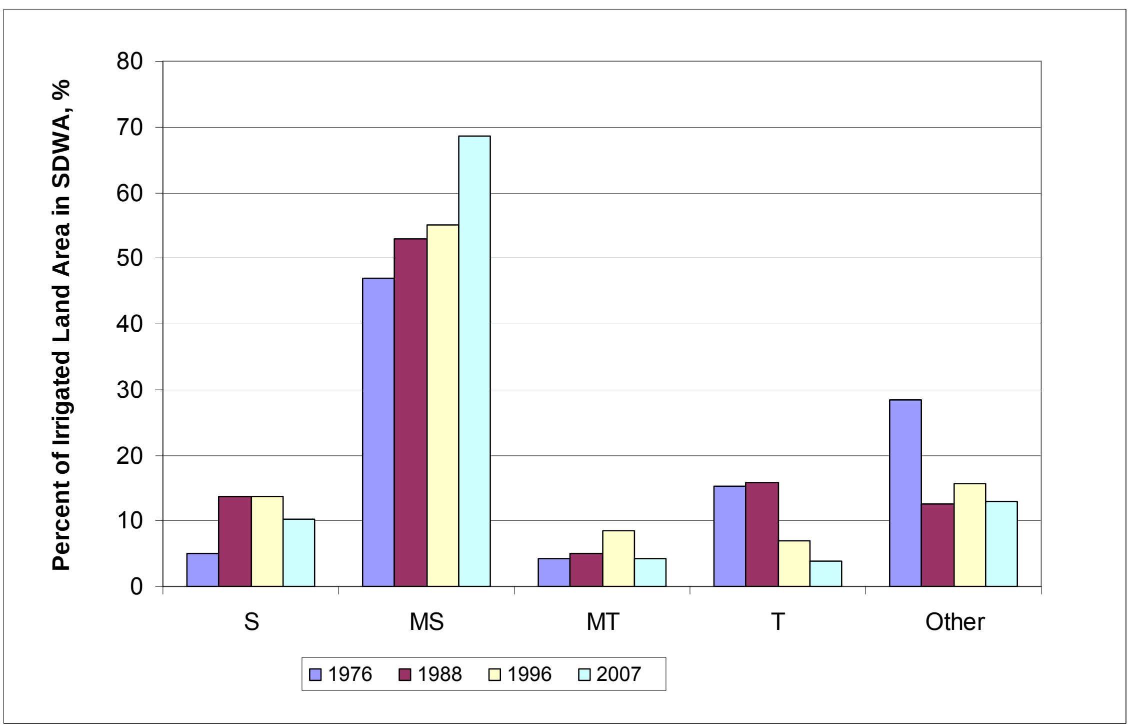


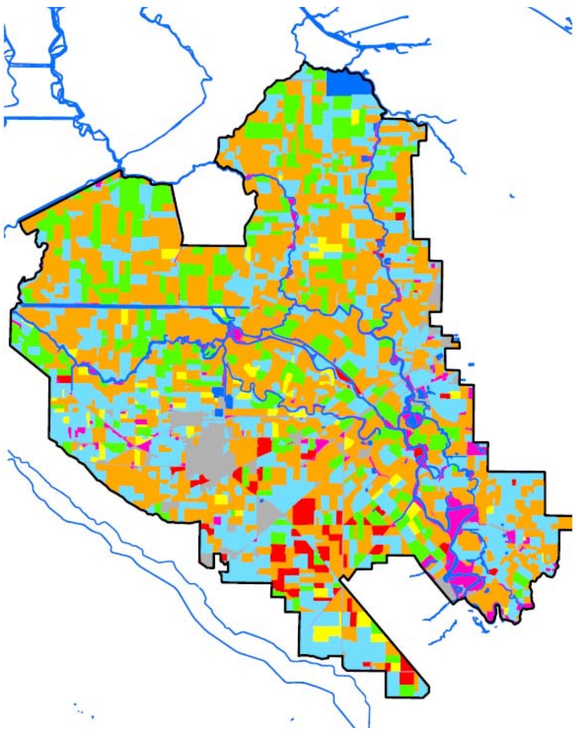
Figure 3.3. Distribution of crops based on salt tolerance relative (as a percent) to total irrigated acres in the SDWA in 1976, 1988, 1996 and 2007 (based on DWR land use surveys).



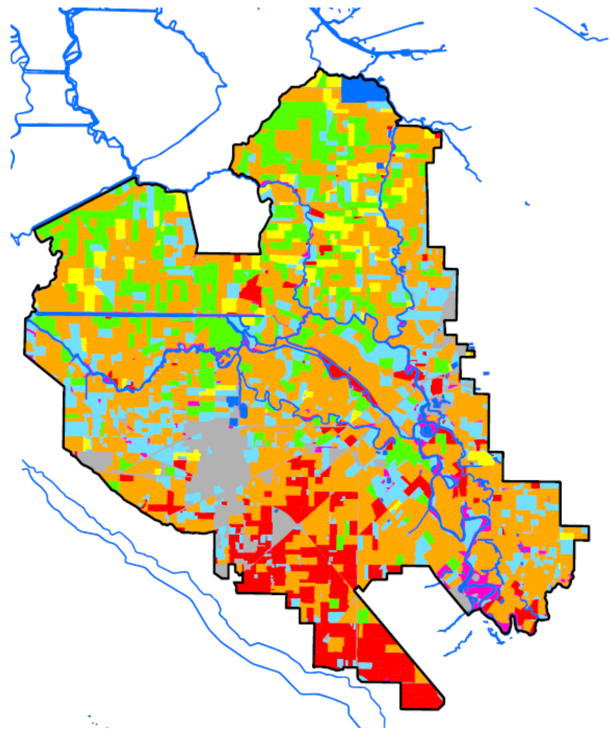
S = Sensitive; MS = Moderately Sensitive; MT = Moderately Tolerant; T = Tolerant

Figure 3.4. Distribution of crops in the southern Delta for 1976, 1988, 1996, and 2007 based on salt tolerance (from DWR land use surveys).

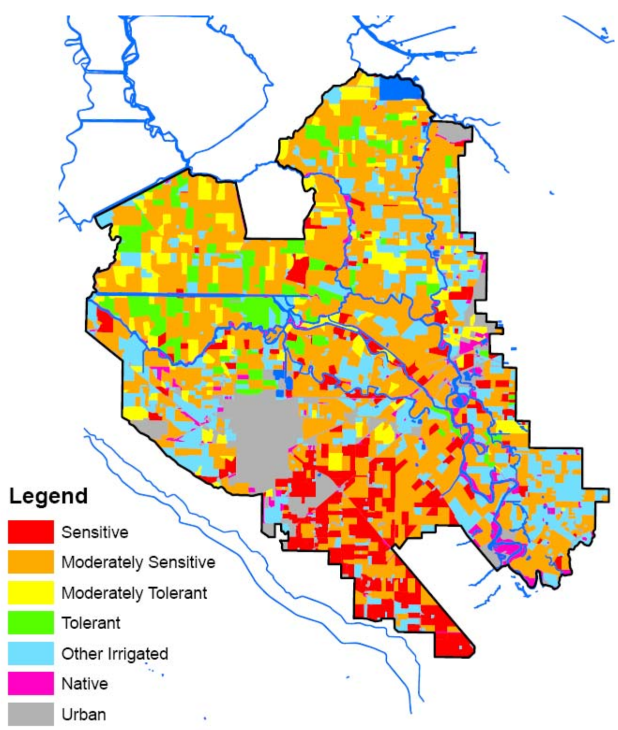
a) 1976



b) 1988



c) 1996



d) 2007

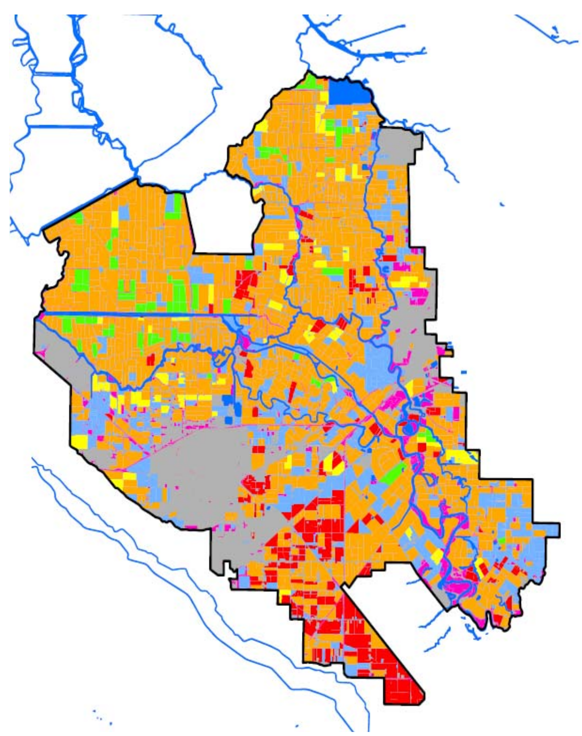
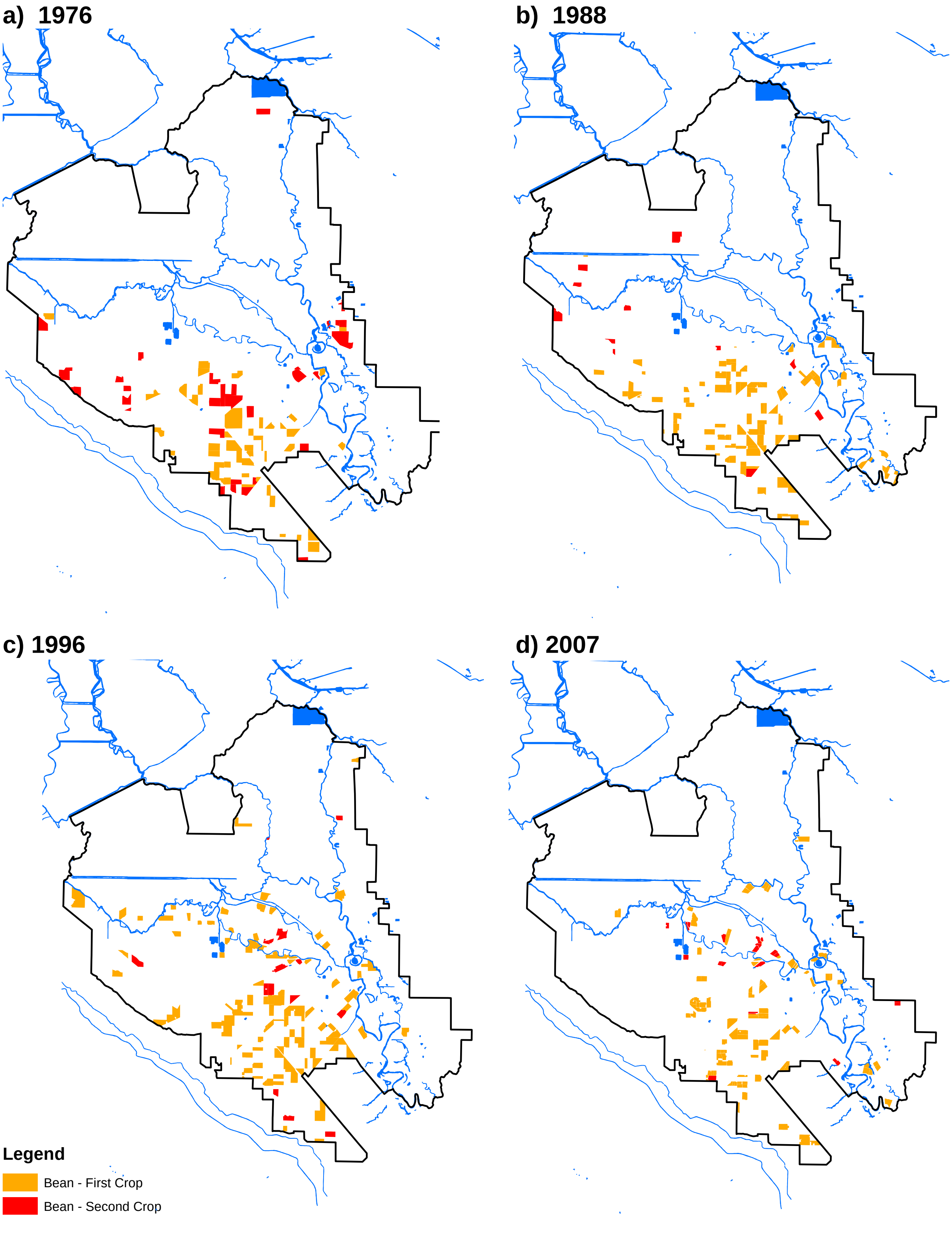


Figure 3.5. Distribution of dry beans grown in the southern Delta for 1976, 1988, 1996, and 2007 (from DWR land use surveys).

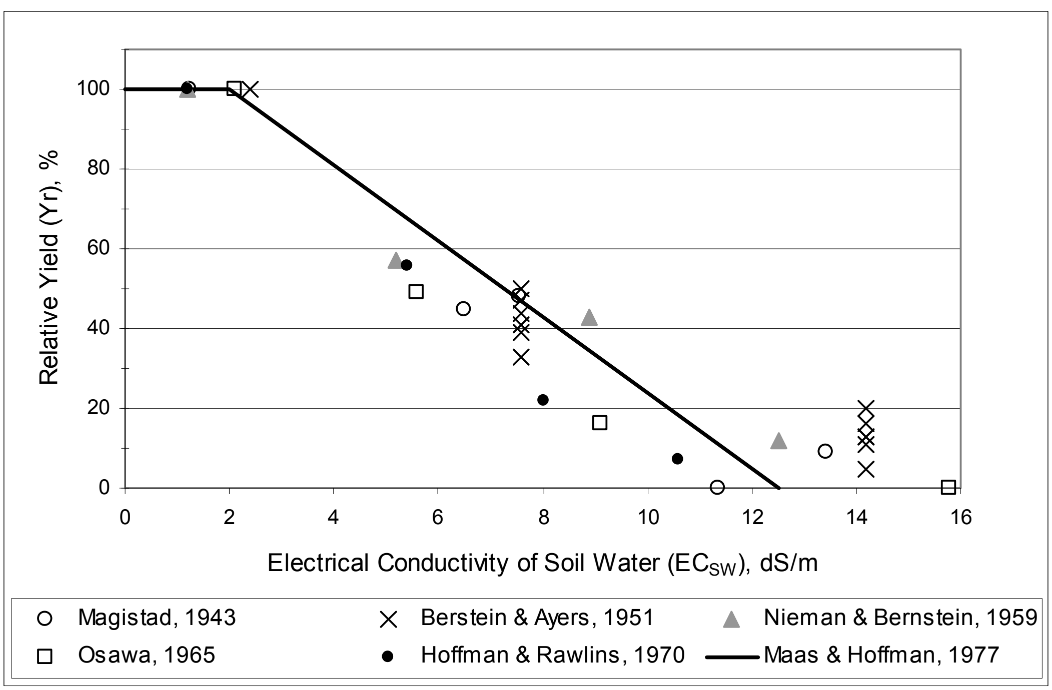


grown in the southern portion of the South Delta, the location of bean fields has spread into the central portion of the area in recent years. If the 2007 data for dry and green beans for the two surveys are combined the total acreage is not too different (4,447 acres from the DWR survey and 3,456 acres from the SJCAC report). The acreage for lima beans reported in the SJCAC survey is not added with the other bean acreages because lima bean is more salt tolerant than dry and green beans.

If bean is chosen as the crop to protect all irrigated crops in the South Delta from salinity, it is unfortunate that the salt tolerance of bean is only based on five published reports of laboratory studies with only one experiment being conducted in soil. Furthermore, these experiments were all conducted more than 30 years ago and there are probably new and improved varieties now being grown.

I reviewed the original analysis performed by Maas and Hoffman (1977) to establish the salt tolerance of bean. Everyone who has published the salt tolerance of bean based upon Equation 3.1 has used their results. A total of nine experiments were analyzed. Of these nine, Maas and Hoffman (1977) used five. Results from the remaining four were not considered because the control (non-saline) treatment exceeded the salt tolerance threshold determined from the other five experiments or only pod weights were measured. The bean varieties were red kidney or wax. All of the experimental data used to establish the salt tolerance of bean are shown in Figure 3.6. The relationship for the salt tolerance of bean published by Maas and Hoffman (1977) is also shown in Figure 3.6 for comparison with the experimental results. If such an important decision as the water quality standard is to be based on the salt tolerance of bean, it is recommended that a field experiment be conducted in the South Delta similar to the corn experiment near Terminus, CA (Hoffman et al., 1983).

Figure 3.6. Original data from five experiments establishing bean salt tolerance.



3.2. Crop Salt Tolerance at Various Growth Stages

3.2.1. State of Knowledge

Sensitivity of plants to soil salinity continually changes during the growing season. Most crops are tolerant during germination but the young developing seedlings are susceptible to salt injury during emergence from the soil and during early development. Once established, most crops generally become increasingly tolerant during later stages of growth. One of the effects of salt stress is that it delays germination and emergence. Furthermore, because of evaporation at the soil surface, the salt concentration in the seed bed is often greater than at deeper soil depths. Consequently, the juvenile roots of emerging seedlings are exposed to greater salt stress than indicated by salinity values averaged over deeper soil depths. The loss of plants during this critical growth phase may reduce the plant population density to suboptimal levels which would significantly reduce yields.

Salt tolerance during emergence does not correlate well with salt tolerance expressed in terms of yield and varies considerably among crops. Unfortunately, different criteria must be used to evaluate plant response to salinity during different stages of growth. Tolerance at emergence is based on survival, whereas tolerance after emergence is based on decreases in growth or yield. Maas and Grieve (1994) summarized the scientific literature on the relative salt tolerance for seedling emergence for 31 crops.

Most published data indicate that plants are more sensitive to salinity during the seedling stage than germination, e.g. barley, corn, cotton, peanut, rice, tomato, and wheat (Maas and Grattan, 1999). Seedlings are also more sensitive than older plants. Greenhouse experiments on corn and wheat indicated that dry matter yields of 3-week-old plants were reduced by salt concentrations that were lower than the salinity thresholds for grain production. In sand culture experiments designed to test the relative effects of salt stress at different stages of growth on grain production, sorghum (Maas et al., 1986), wheat (Maas and Poss, 1989a) and cowpea (Maas and Poss, 1989b) were most sensitive during the vegetative and early reproductive stages, less sensitive during flowering, and least sensitive during the grain-filling stage. Increased tolerance with age also has been observed in asparagus, a perennial that was more tolerant after the first year’s growth (Francois, 1987).

There are several cultural/management practices that are beneficial to prevent or reduce the impact of soil salinity on crops during emergence and early growth stages. The most common is an irrigation before planting. Pre-plant irrigation is practiced in many irrigated areas where salinity is a hazard and winter rainfall has been insufficient to dilute and leach salts shallow in the soil profile. It is typical for the application of 6 to 12 inches as a pre-plant irrigation. Another practice is to plant more seeds than where salinity is not a concern with the expectation that some seeds will not germinate or survive the early growth stage. A less common practice is to plant the seeds on the sloping portion of the bed for furrow irrigation. This places the seeds in an area lower in salinity than if the seeds were planted on top of the bed. Refer to Figure 3.12 to note the distribution of soil salinity using furrow irrigation.

3.2.2. South Delta Situation

Of the 18 crops important in the South Delta, seedling emergence data have been reported for nine. The soil salinity level that reduced emergence by 10 % is reported in Table 3.2. Where more than one reference was reported for the same crop, the range of soil salinity that reduced emergence by 10 % is given.

Except for the relatively salt tolerant crops of barley, sugar beet, and wheat, all of the crops reported that are important in the South Delta have a higher salt tolerance at emergence than for yield. Only one reference for barley (Ayers and Hayward, 1948) had a low tolerance at emergence compared to four other references that reported a higher tolerance. There was only one published reference for sugar beet and it reported a low tolerance, also Ayers and Hayward (1948). Two of the four references for wheat (as report by Maas and Grieve, 1994) found a low tolerance for some cultivars while other cultivars had a very high salt tolerance at emergence. Thus, it appears that salt tolerance at emergence may not be a concern if more tolerant cultivars are chosen.

Table 3.2. The level of soil salinity required to reduce emergence by 10 % for crops important in the South Delta (Maas and Grieve, 1994).

Common Name	Botanical Name	Electrical Conductivity of Soil Salinity (EC_e) that Reduced Emergence by 10 %
Alfalfa	Medicago sativa	2.5 to 9.5
Barley	Hordeum vulgare	6 to 18
Bean	Phaseolus vulgaris	5.5
Corn	Zea mays	5 to 16
Oat	Avena sativa	16
Safflower	Carthamus tinctorius	8
Sugar beet	Beta vulgarus	4.5
Tomato	Lycopersicon Lycopersicum	3 to 7.5
Wheat	Triticum aestivum	1 to 11

Table 3.3 summarizes the salinity effects at various stages of growth for several crops. Unfortunately, only a few crops important in the South Delta have been studied. The data given in Table 3.3 are not very helpful for many of the crops in the South Delta. Of particular importance is the sensitivity of bean and other salt sensitive crops at various growth stages. Also the apparent sensitivity of asparagus in the first year of growth is another concern. Thus, it is recommended that laboratory and/or field trials be conducted to establish the change in sensitivity to salt with growth stage on crops like bean, asparagus, and perhaps other crops that are salt sensitive and important in the South Delta.

Table 3.3. Salinity effects on crops at various stages of plant growth.

Crop	Salt Tolerance Threshold, EC_e (dS/m)				Reference
Asparagus	Germination 4.7	1st Growth 0.8	Fern 1.6	Spears 4.1	Francois, 1987
Corn, sweet	Germination 5.0	Emergence 4.6	Seedling 0.5	Yield 2.9	Maas et al., 1983
Corn, field	No salt affect on seedling density up to EC_e=8 dS/m				Hoffman et al., 1983
Corn (16 cultivars)	Germination 3.1 to 10	Seedling 0.2 to 1.2			Maas et al., 1983
Cowpea	Vegetation 0.8	Flowering 0.8	Pod-Filling 3.3		Maas & Poss, 1989b
Sorghum NK 265 DTX	Vegetation 3.3 3.3	Reproduction 10 7.8	Maturity 10 10		Maas et al., 1986
Wheat	Vegetation 6.7	Reproduction 12	Maturity 12		Maas & Poss, 1989a
Wheat, Durum	Vegetation 3.6	Reproduction 5.0	Maturity 22		Maas & Poss, 1989a

3.3. Saline/Sodic Soils

3.3.1. State of Knowledge

Saline Soils

A soil is said to be saline if salts have accumulated in the crop root zone to a concentration that causes a loss in crop yield. In irrigated agriculture, saline soils often originate from salts in the irrigation water or from shallow, saline groundwater. Yield reductions occur when salts accumulate in the root zone to an extent that the crop is unable to extract sufficient water from the salty soil solution, resulting in an osmotic (salt) stress. If water uptake is appreciably reduced, the plant slows its rate of growth and yield loss occurs. Salts that contribute to a salinity problem are water soluble and readily transported by water. A portion of the salts that accumulate from prior irrigations can be drained (leached) below the rooting depth if more irrigation or precipitation infiltrates the soil than is used by the crop or evaporates from the soil surface and barriers to drainage do not occur in the soil profile.

Sodic Soils

An important property of a soil is its friability (tilth). In sodic soils, physicochemical reactions cause the slaking of soil aggregates and the swelling and dispersion of clay minerals, leading to reduced permeability and poor tilth. The loss of permeability causes a reduction in the infiltration of applied water and water remains on the soil surface too long or infiltrates too slowly to supply the crop with sufficient water to obtain acceptable yields. The two most common water quality factors influencing infiltration are the salinity of the applied water and its sodium content relative to the calcium and magnesium content. Water high in salinity will increase infiltration while a water low in salinity or with a high ratio of sodium to calcium plus magnesium will decrease infiltration.

3.3.2. South Delta Situation

The Soil Survey published by the Soil Conservation Service in 1992 (SCS, 1992) shows saline soils in the South Delta to be in two general areas. The largest area traverses the South Delta from the northwest to the southeast in what may be a previous water channel and generally follows the area described by Montoya (2007) as the basin rim. It begins just south of Clifton Court Forebay, follows along the south side of Old River passing just north of Tracy, then southwest of the junction of interstate highways 5 and 205, and continuing southeast passing beyond the Banta-Carbona Canal and ending just before meeting the San Joaquin River. The soils in this area are Capay clay, Pescadero clay loam and Willow clay. The other soils noted as saline are on the eastern boundary of the South Delta. These soils are designated as Arents sandy loam or loam and Trahern clay loam. Table 3.4 gives each soil that was mapped as saline in 1992 in the South Delta. Note in Table 3.4 that the total area mapped as saline by the SCS was 5 % of the total irrigated area. Figure 3.7 shows the location of these soils in the South Delta.

Based on the DWR crop surveys and the saline soils identified by the SCS (1992), the distribution of crops between the South Delta as a whole and just the saline soils is presented in Figure 3.8. As with Figure 3.3 above, Figure 3.8 also includes second crop acreages. Very few salt sensitive crops are on the saline soils. Moderately salt sensitive and more tolerant crops are grown on the saline areas with the same or higher percentage as elsewhere in the South Delta.

No sodic soils were identified in the 1992 Soil Survey. This is not unexpected based on the calculation of the SAR for waters from the San Joaquin River (see Section 2.2.2).

Table 3.4. Saline soils according to the Soil Survey of San Joaquin County, California (Soil Conservation Service, 1992).

Soil Map Unit	Soil Series	Range of Soil Salinity (dS/m)	Area (acres)	% of South Delta irrigated lands
108	Arents sandy loam or loam	not given	307	0.2
120	Capay clay	4-8	943	0.7
211	Pescadero clay loam	4-16	1082	0.8
258	Trahern clay loam	4-8	798	0.6
274	Willows clay	2-8	3911	2.7
		TOTAL:	7041	5.0

Figure 3.7. Location of saline soils in the SDWA using GIS data from the NRCS-SSURGO database (legend shows soil map units from Table 3.4).

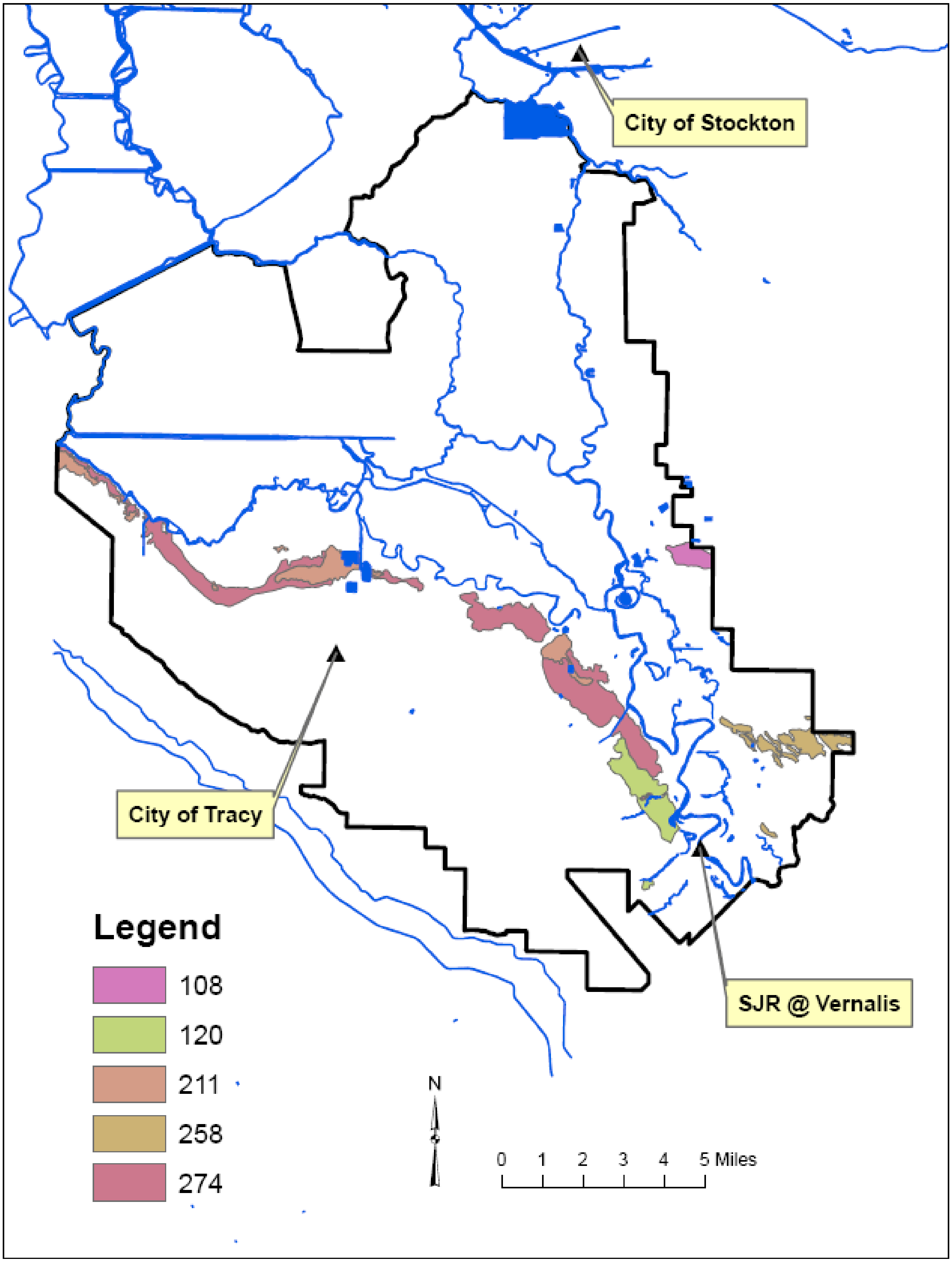
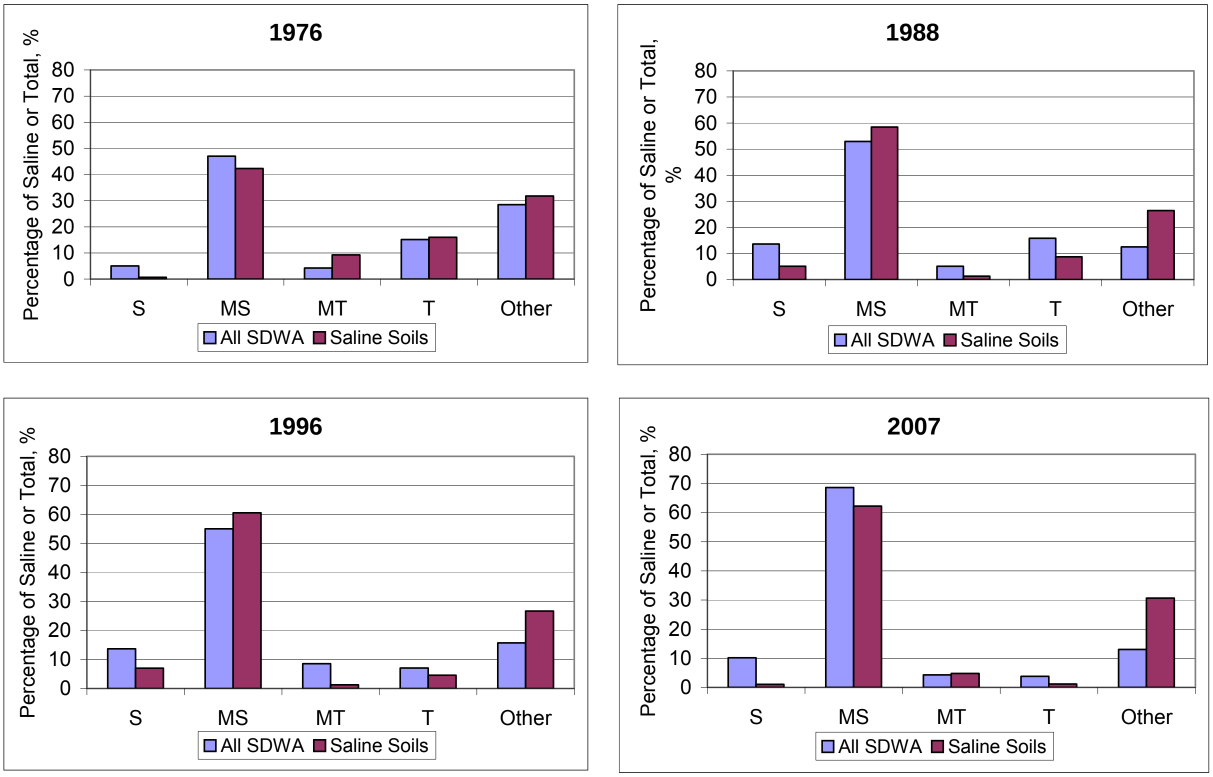


Figure 3.8. Distribution of crops based on salt tolerance relative (as a percent) to: a) total irrigated crops grown on saline/sodic soils and b) total irrigated crops grown in SDWA for 1976, 1988, 1996, 2007 (based on DWR land use surveys).



S = Sensitive **MS = Moderately Sensitive** **MT = Moderately Tolerant** **T = Tolerant**

3.4. Bypass Flow in Shrink-Swell Soils

3.4.1. State of Knowledge

Over the past few decades the impact of applied water bypassing the upper reaches of the soil profile has been studied and modeled (i.e., Corwin et al., 1991). The phenomenon in which infiltrating water passes a portion or all of the upper soil profile via large pores or cracks without contacting or displacing water present within finer pores or soil aggregates is referred to as bypass (preferential) flow. It is most likely to occur in aggregated soils or soils high in clay content. These types of soils tend to form channels beginning at the soil surface as the soil starts to dry. This may be of particular importance in soils high in clay content when water is applied infrequently. Bypass flow is more prevalent during the summer when high temperatures and low humidity produce a noticeably drier soil surface which results in more cracks than are noticed in the winter.

An example of bypass flow is the Imperial Valley of California where many soils are high in clay and crops like alfalfa are irrigated about twice monthly in the summer and less frequently during the winter. In a recent publication, Corwin et al., 2007 evaluated the impact of bypass flow for California's Imperial Valley. The study assumed a rotation of 4 years of alfalfa and one crop of wheat followed by one crop of lettuce. They simulated soil properties of Imperial and Holtville silty-clay soils. These soils account for almost 60% of the irrigated portion of the Imperial Valley and are characterized by low infiltration rates. The shrink-swell properties of the Imperial soil are high while the Holtville varies from high to low. In their lysimeter study, bypass flow occurred through surface cracks during irrigations until the cracks were swollen closed, after which preferential flow was substantially reduced and subsequently dominated by flow through pores scattered throughout the profile. The simulations revealed that when less than 40% of the applied water bypassed the surface soils, salinity was less than the crop salt tolerance threshold for each crop in the rotation even though the irrigation water simulated was Colorado River water (EC_i =1.23 dS/m). At most, the yield of alfalfa was reduced by 1.5% only during the first season. They concluded that the levels and distribution of soil salinity would not be affected significantly by bypass flow up to at least 40%. Although the extent of bypass flow in the Imperial Valley has not been established, it has been concluded that it is doubtful that crop yields would be reduced by bypass flow (Corwin et al., in press).

3.4.2. South Delta Situation

According to the SCS Soil Survey (1992) there are 15 soil series that have the potential to shrink and swell as the soil dries and is then rewet. These soil series are listed in Table 3.5 along with the per cent of the South Delta area they represent. Figure 3.9 shows the location of these soils within the South Delta. The color reference to identify each soil series is given in Table 3.5.

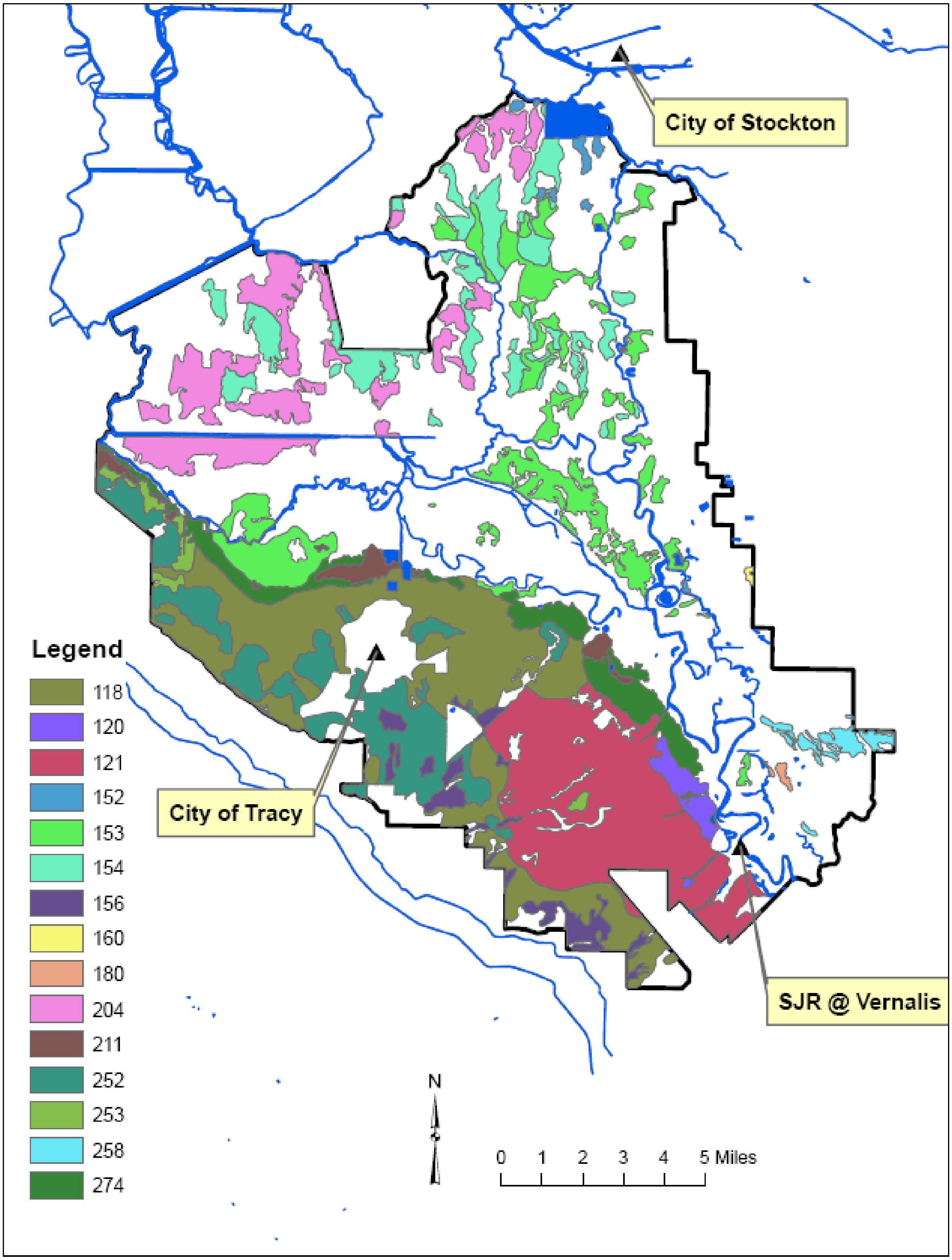
The percent of the South Delta with soils that have the potential to shrink and swell is somewhat less then reported by Corwin et al. (2007) for the Imperial Valley but the severity of the shrink/swell potential is probably similar. As stated above, Corwin and co-workers concluded that shrink/swell should not be a problem in the Imperial Valley.

Without any evidence to the contrary for the South Delta, it is probably safe to assume that shrink/swell should not cause bypass flow in the South Delta to the extent that it would cause a salt management problem.

Table 3.5. Soil series in the South Delta that have the potential to shrink and swell (SCS Soil Survey, 1992), with color identification used in Figure 3.9.

Soil Map Unit	Soil Unit Name	% of South Delta Area	Color on Fig. 3.9
118	Capay clay	10.4	
120	Capay clay, saline-sodic	0.6	
121	Capay clay, wet	8.9	
152	Egbert mucky clay loam	0.3	
153	Egbert silty clay loam	6.0	
154	Egbert silty clay loam, sandy substratum	4.1	
156	El Solyo clay loam	1.3	
160	Galt clay	0.02	
180	Jacktone clay	0.07	
204	Peltier mucky clay loam	5.4	
211	Pescadero clay loam	0.8	
252	Stomar clay loam	5.3	
253	Stomar clay loam, wet	0.6	
258	Trahern clay loam	0.6	
274	Willows clay	2.7	
	% of Total Area	47.1	

Figure 3.9. Location of NRCS SURRGO soil map units with shrink-swell potential in the SDWA (as listed in Table 3.5).



3.5. Effective Rainfall

3.5.1. State of Knowledge

Rainfall can be an important source of water for crops in California. Depending on location and crop, rain provides from very little to all of the water available to a crop. The amount of rain actually used by crops, called effective rainfall or effective precipitation, is largely influenced by climate and plant and soil characteristics.

Rainfall has several benefits in mediating soil salinity. First, rain can substitute for irrigation water to satisfy crop evapotranspiration; thereby reducing the amount of salt applied in the irrigation water. Second, rain falling in the off-season can be stored in the soil profile, providing moisture for the subsequent crop. Third, rain water dilutes the salinity of the soil water in the upper reaches of the crop root zone and if the rainfall is sufficient it can leach salts from the root zone. An important aspect of off-season rains is the availability of stored soil water from rains to satisfy evaporation from the soil surface.

Methods to estimate the effectiveness of rain falling during the growing season are available (i.e., Patwardnan et al., 1990; NRCS, 1993). Patwardnan and co-workers reported that using a daily soil water balance equation to estimate effective rainfall was significantly more accurate than more simple and vague procedures such as the SCS monthly effective precipitation method (NRCS, 1993). The daily soil water balance approach requires a computer program and these methods are not presented here because in most of California and particularly in the South Delta, rain falls primarily during the winter – the non-growing season for many crops. However, winter rain can help meet part of the water requirement of summer crops, because rainwater can infiltrate the soil and be carried into the following growing season as stored soil water. Of course, if a winter crop is being grown, rainfall can be treated like irrigation in determining effectiveness.

Relatively involved techniques have been developed to account for winter rains being stored in the soil profile when determining crop evapotranspiration (ETc) (Allen et al., 2007). However, a field measurement program was conducted by the California Department of Water Resources (MacGillivray and Jones, 1989) to validate the techniques of estimating the effectiveness of winter rains. The study was designed to determine the broad relationships between monthly amounts of winter rain and the portion stored in the soil and available for crop use during the following growing season. Total monthly rainfall and the corresponding change in soil water content were measured during winter at about 10 sites in the Central Valley of California. The 4-year study, started in 1983, drew several important conclusions. First, the relationship between total rainfall and change in soil water content is remarkably similar for November, December, January, and February. The relationship is:

$$\text{Change in stored soil water} = -0.54 + 0.94 \times (\text{rainfall amount}). \qquad \text{(Eqn. 3.2)}$$

The second conclusion was that soil water content increases linearly with increased monthly rainfall for each of the four months. Third, soil surface evaporation is relatively constant, at 0.6 to 0.8 inches per month. The DWR report also concluded that in October, when the soil is initially dry, both the amount of stored soil water and the amount of evaporation from the soil surface increase with increasing amounts of total monthly rain. The relationship for October is:

Change in stored soil water = -0.06 + 0.635 x (rainfall amount). (Eqn. 3.3)

In contrast, for March, when initial soil water content is generally high and evaporative demand is also high, surface evaporation rates are twice those for the four winter months, and the amount of rain going to stored soil water is correspondingly low. The relationship for March is:

Change in stored soil water = -1.07 + 0.837 x (rainfall amount). (Eqn. 3.4)

3.5.2. South Delta Situation

The average annual rainfall for locations along the 400-mile axis of the Central Valley of California is shown in Figure 3.10 (MacGillivray and Jones, 1989). The rainfall gradient along the axis of the Valley is remarkably uniform. During any given year, however, rainfall can vary significantly from these long-term averages.

Table 3.6 from MacGillivray and Jones (1989) summarizes the disposition of average annual rainfall for two zones in the Central Valley of California. The eight zones depicted in their table cover the distance from Red Bluff to Bakersfield. Zone 4 is north of Stockton and zone 5 is south of Modesto. Values for these two zones and the average of the two (noted as representing the South Delta) are presented in Table 3.6. The South Delta values in Table 3.6 are the best estimate of effective rainfall that was found in the literature based on field measurements.

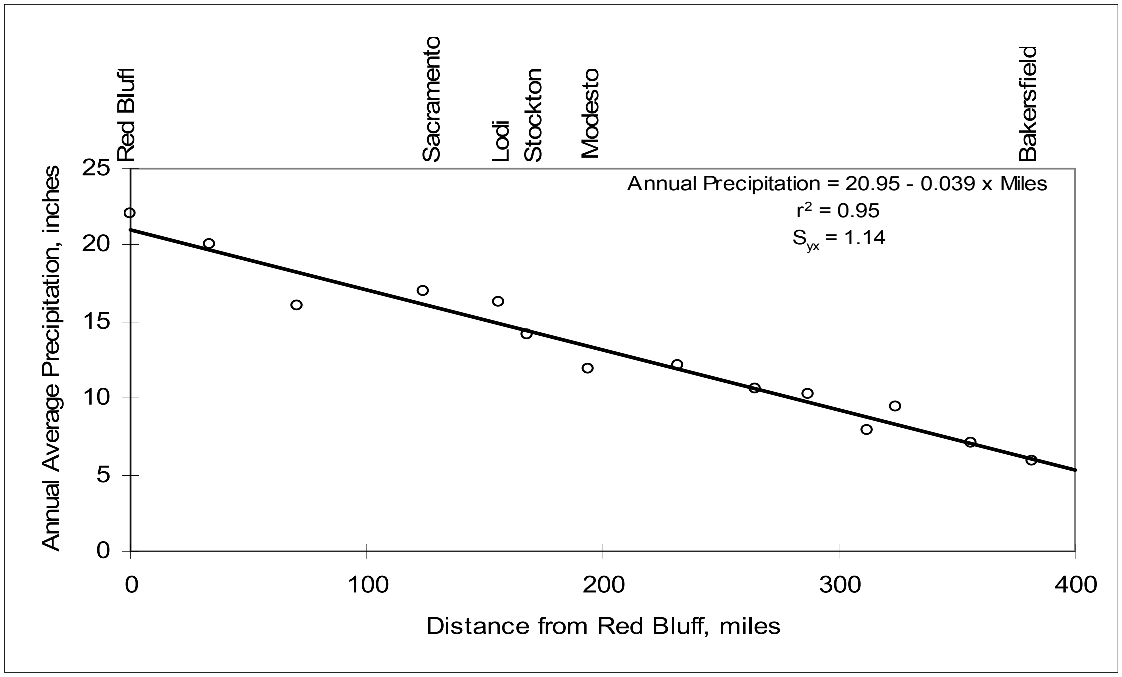
Table 3.6. Disposition of average rainfall for two zones, one just north and one just south of the South Delta, along with the average of these two zones to represent the South Delta. (MacGillivray and Jones, 1989).

		Effective Rainfall				
Zone	**Average Annual Rainfall (in.)**	**Growing Season (in.)**	**Non-Growing Season (in.)**	**Total(in.)**	**Surface Evaporation (in.)**	**Deep Percolation (in.)**
4	15.0	1.3	7.5	8.8	5.5	0.7
5	12.5	1.1	6.3	7.4	5.1	0.0
South Delta	13.8	1.2	6.9	8.1	5.3	0.4

Assumptions to develop Table 3.6 were average rainfall amounts, frequency, and intensity; no surface runoff; deep, medium-textured soil with water storage capacity of 1.5 inches/foot; bare soil surface during winter; crop planted in early April and harvested in late September; and 5-foot rooting depth. The average annual rainfall calculated by averaging zones 4 and 5 is higher than the 10.5 inches reported over a 57-year period of record from the South Delta but the relative values among the partitioned values of the rainfall is sufficiently accurate for modeling efforts.

As noted in section 3.5.1, an average evaporation rate from the soil surface can be taken as 0.7 inches per month. This value is used in the steady-state models reported in Section 5 for the South Delta.

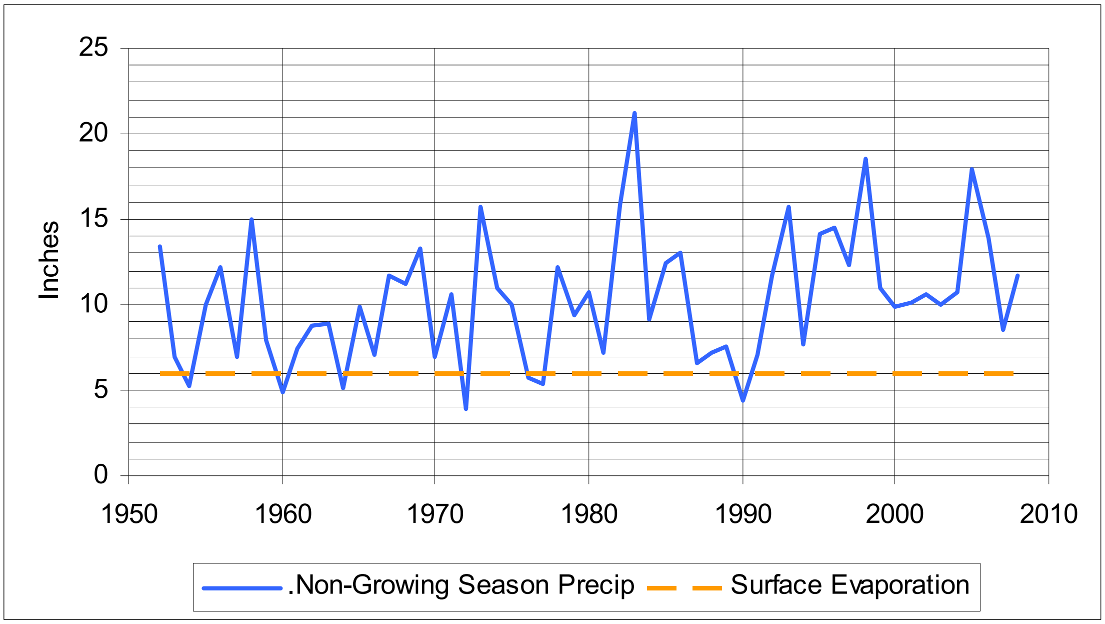
Figure 3.10. Annual precipitation totals along a longitudinal transect of the Central Valley of California (MacGillivray and Jones, 1989).



Precipitation during the non-growing season (P_{NG}) can be beneficial in the overall soil-water balance by contributing water for evaporation from the soil surface (E_S) during the non-growing season, adding to the amount of water stored in the crop root zone, or leaching if precipitation is in excess of these two amounts. Non-beneficial aspects are surface runoff if P_{NG} is excessive and a depletion of stored soil water if precipitation is minimal. For bean with a May 1st planting date, the surface evaporation during the non-growing season is 6.0 in. (0.7 in./month during the roughly 8.5 month non-growing season), so P_{NG} of at least 6.0 in. would be consumed by surface evaporation (E_S). If P_{NG} were below 6.0 in. then water would be taken from stored water or surface evaporation would be reduced. Figure 3.11 shows P_{NG} for the 57 years of record plus surface evaporation, E_S. In only 7 years is P_{NG} not large enough to satisfy the E_S of 6.0 in. For the other 50 years, P_{NG} can reduce the irrigation requirement each year more than 3 in.

A potential factor in reducing effective rainfall is surface runoff. Surface runoff from rain in the South Delta is probably low. First, rainfall in the South Delta is normally of low to moderate intensity. Unfortunately, rainfall records only consist of daily amounts and do not report intensity to verify this statement. Second, irrigated fields in the South Delta have been leveled with a slope typically of about 0.2 % to enhance irrigation management. This low slope is not conducive to runoff. Third, crop residue after harvest, cultivations throughout the year, and harvesting equipment traffic are all deterrents to surface runoff. Thus, without definitive measurements to the contrary, surface runoff is assumed to not be a significant factor in reducing effective rainfall in the South Delta.

Figure 3.11. Comparison of bean non-growing season precipitation (P_{NG}) with estimate of surface evaporation (E_S); for May 1st planting and precipitation data from NCDC station no. 8999, Tracy-Carbona for water years 1952 through 2008.



3.6. Irrigation Methods

3.6.1. State of Knowledge

The method of irrigation can affect salinity management and the crop's response to salinity. The irrigation method: (1) influences the distribution of salts in the soil profile, (2) determines whether crop leaves will be subjected to wetting, and (3) provides different efficiencies and uniformities of water application. These impacts of the irrigation method are described in the following discussions.

Salt Distribution in Soils

The pattern of salt distribution within a given field varies with location in the field and with soil depth. The distribution pattern also changes with differences in soil properties, variances in water management, and the design of the irrigation system. The soil salinity profile that develops as water is transpired or evaporated depends, in part, on the water distribution pattern inherent with the irrigation method. Distinctly different salinity profiles develop for different irrigation methods. Each irrigation method has specific advantages and disadvantages for salinity management. The basic irrigation methods are flood, furrow, sprinkler, micro-irrigation (trickle), and sub-irrigation.

The major types of flood irrigation are borders and basins. Border methods commonly have excessive water penetration (low salinity levels) near the levees, at the edge of the border where water is applied, and at the low end of the borders if surface drainage is prevented. Inadequate water penetration midway down the border may result in detrimental salt accumulations. If insufficient amounts of water are applied, the far end of the borders may have excessive salt accumulations. The basin method of flooding has the potential for more uniform water applications than other flooding methods provided the basins are leveled, sized properly, and have uniform soils.

With furrow irrigation, salts tend to accumulate in the seed beds because leaching occurs primarily below the furrows. If the surface soil is mixed between crops and the irrigation water is not too saline, the increase in salt in the seed bed over several growing seasons may not be serious. In furrow and flood methods, the length of run, irrigation application rate, soil characteristics, slope of the land, and time of application are factors that govern the severity of salinity concerns.

Flooding and sprinkler irrigation methods that wet the entire soil surface create a profile of salt that increases with soil depth to the bottom of the crop root zone, provided that moderate leaching occurs, irrigation application is uniform, and no shallow, saline groundwater is present.

Micro-irrigation (trickle or drip) systems, where water is applied from point or line sources, have the advantage of high leaching near the emitters and high soil water contents can be maintained in the root zone near the emitters by frequent but small water applications. Plant roots tend to proliferate in the leached zone of high soil water content near the water sources. This allows water of relatively high salt content to be used successfully in many cases. Possible emitter clogging, the redistribution of water required to germinate seeds, and the accumulation of salts at the soil surface between emitters are management concerns.

The salinity profile under line sources of irrigation, such as furrow and either porous or multi-emitter micro-irrigation systems, has lateral and downward components. The typical cross-sectional profile has an isolated pocket of accumulated salts at the soil surface midway between the line sources of water and a second, deep zone of accumulation, with the concentration depending on the amount of leaching. A leached zone occurs directly beneath the line source of irrigation. Size of the leached zone depends on the irrigation rate, the amount and frequency of irrigation, and the crop water uptake pattern.

Whereas the salt distribution from line sources increases laterally and downward, the distribution from point irrigation sources, such as micro-basins and drip systems with widely spaced emitters, increases radially from the water source in all directions below the soil surface. As the rate of water application changes, the shape of the salinity distribution changes. For tree crops irrigated with several emitters per tree, the wetting patterns may overlap, thereby reducing the level of salt accumulation midway between the emitters under a tree.

The continuous upward water movement from a sub-irrigation system results in salt accumulation near the soil surface as water is lost by evapotranspiration. Subsurface systems provide no means of leaching these shallow salt accumulations. The soil must be leached periodically by rainfall or surface irrigation to displace these shallow accumulations down out of the crop root zone.

Figure 3.12 presents illustrations of the salt distribution under different irrigation methods with non-saline and saline irrigation water. Note the concentration of salts near the top of the seedbed for furrow irrigation. The sketches in this figure are idealized and many soil, plant, and management factors will distort the soil salinity pattern.

3.6.2. South Delta Situation

During the 2007 crop survey conducted by the California Department of Water Resources (DWR, 2008) the irrigation method was identified wherever possible. Except for the crop type of Grain and Hay (see Table 3.7) where the irrigation method was unknown on 70% of the area, the irrigation method was noted for every crop. For brevity, the crops have been grouped into the five major types in Table 3.7. Nearly half of the area where fruit and nut trees and grape vines are grown are irrigated by micro-irrigation. Micro-irrigation includes surface and subsurface drip irrigation and micro-sprinklers. For both truck and field crops 90% of the irrigated area is by furrow. Nearly all of the remaining truck crops are irrigated by sprinkler or micro-irrigation. No sprinkler or micro-irrigation systems were reported for field crops. For the 70% of the irrigation systems for grain and hay not reported, it is probably reasonable to assume that almost all of the area is irrigated by border or basin. This assumption is supported by the crop survey indicating that almost all of the land planted to alfalfa, pasture, and grass is irrigated by border with about 10% being irrigated by basin.

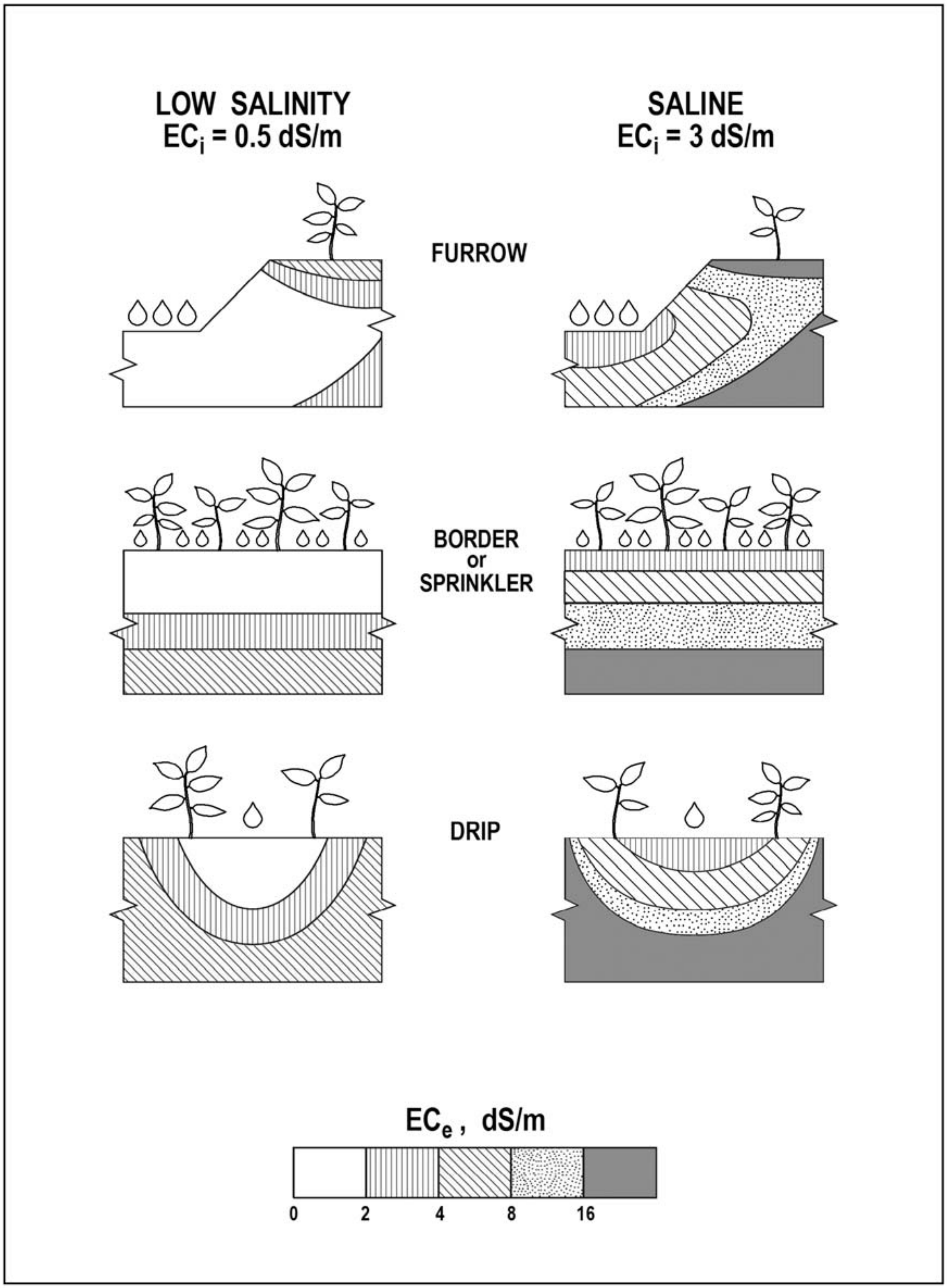
Table 3.7. Irrigation methods by crop type in the South Delta based upon the 2007 DWR crop survey (DWR, 2008).

Crop Type	Crop Area (acres)	Crop Area (%)	Irrigation Method					
			Furrow (%)	Border (%)	Basin (%)	Sprinkler (%)	Micro-irrigation* (%)	Unknown (%)
Trees & Vines	8,438	9	22	10	3	17	48	0
Truck Crops	24,283	25	90	0	0	3	6	1
Field Crops	23,258	24	90	3	3	0	0	4
Grain & Hay	7,297	7	6	19	5	0	0	70
Alfalfa, Pasture, Grass	34,814	35	0	86	11	1	0	2
Totals:	98,090	100	46	34	5	2	6	7

* *Micro-irrigation includes surface and subsurface drip irrigation and mini-sprinklers.*

Based upon the values reported in Table 3.7 and the assumption that the unknown irrigation systems for grain and hay are approximately the same as for alfalfa, grass, and pasture, it is reasonable to assume that 46% of the South Delta is irrigated by furrow, 34% by border, 5% by basin, 2% by sprinkler, and 6% by micro-irrigation. These percentages are used in Section 3.8 for determining the average irrigation efficiency for the South Delta.

Figure 3.12. Influence of irrigation water quality and the irrigation method on the pattern of soil salinity (Hoffman et al., 1990).



3.7. Sprinkling with Saline Water

3.7.1. State of Knowledge

In addition to yield loss from soil salinity, crops irrigated by sprinkler systems are subject to salt injury when the foliage is wetted with saline water. Additional yield reduction can be expected for those crops that are susceptible to foliar damage caused by salts absorbed directly through the leaves. Tomatoes sprinkled with 3.6 dS/m water produced only 38% as much fruit as plants that were drip irrigated with the same water (Gornat et al., 1973). Bernstein and Francois (1973a) found that pepper yields were decreased 16% when furrow irrigated with 4.5 dS/m water as compared with 0.6 dS/m water; but were decreased 54% when irrigated by sprinkler. Sprinkling barley with 9.6 dS/m water reduced grain yield by 58% compared to non-sprinkled plants (Benes et al., 1996).

Obviously, saline irrigation water is best applied through surface distribution systems. If sprinkling with marginally saline water can not be avoided, several precautions should be considered. If possible, susceptible crops should be irrigated below the plant canopy to eliminate or reduce wetting of the foliage. Intermittent wetting by slowly rotating sprinklers that allow drying between cycles should be avoided. Perhaps the best strategy to minimize foliar injury is to irrigate at night when evaporation is lower because of lower temperatures and higher humidity and salt absorption is lower because leaf stomata are closed. If daytime sprinkling is necessary, hot, dry, windy days should be avoided.

Except for the few studies described above, there are no data available to predict crop yield losses as a function of the salt concentration of sprinkler irrigation water. There are, however, sufficient data for some crops to allow estimates of the threshold concentrations of Cl and Na of the irrigation water based on sprinkling induced foliar injury (Table 3.8). These thresholds can be compared with EC_i thresholds based on yield attributed to soil salinity. Those crops that have foliar injury thresholds below the soil salinity threshold have a high likelihood of foliar injury when sprinkled with waters that have salt concentrations equal to or above the soil salinity threshold. At concentrations above both thresholds, both foliar injury and yield reductions can be expected.

3.7.2. South Delta Situation

With a few exceptions, the only crops that may be irrigated by sprinklers apparently are tree crops and vines. From April, 2003 until December, 2007, the concentration of chloride in the San Joaquin River at Mossdale (Dahlgren, 2008) never exceeded 5 mol/m^3 and averaged about 2.5 mol/m^3. Over the same time period, the concentration of sodium averaged about 3 mol/m^3. However, during the winter months of January to April from 2001 to 2003 average concentrations were between 5 and 6 mol/m^3. Of course, trees and vines are not irrigated during the winter. Based upon the estimates of the types of irrigation methods and the chloride and sodium concentrations reported for the San Joaquin River, it is not likely that yield loss from sprinkling is a concern.

Table 3.8. Relative susceptibility of crops to foliar injury from saline sprinkling waters (Maas and Grattan, 1999).

Na or Cl concentration causing foliar injury, mol/m^3*			
<5	5-10	10-20	>20
Almond	Grape	Alfalfa	Cauliflower
Apricot	Pepper	Barley	Cotton
Citrus	Potato	Corn	Sugar beet
Plum	Tomato	Cucumber	Sunflower
		Safflower	
		Sesame	
		Sorghum	

To convert mol/m^3 to mg/l or ppm divide Cl concentration by 0.02821 and Na concentration by 0.04350. The conversion from mg/l to EC is EC = mg/l / 640.

Note: These data are to be used as general guidelines for daytime sprinkling. Foliar injury is also influenced by cultural and environmental conditions.

3.8. Irrigation Efficiency and Uniformity

3.8.1. State of Knowledge

Irrigation efficiency is defined as the ratio of the amount of water which is beneficially used to the amount of water applied. Beneficial uses include crop water use, salt leaching, frost protection, crop cooling, and pesticide and fertilizer applications. Excessive deep percolation, surface runoff, water use by weeds, wind drift, and spray evaporation are not beneficial uses and thus decrease irrigation efficiency. The non-uniformity of water applications by an irrigation system within a given field can be a major contributor to low irrigation efficiency. An irrigation system that does not apply water uniformly must apply excess water in some areas to provide enough water in other areas, such that water stress over the entire field is minimized. The excess water may cause surface runoff and/or deep percolation below the crop root zone.

The various definitions of irrigation efficiency do not account for the non-uniformity of irrigation water applications within a given field. The volume of water infiltrating into the soil is affected by the uniformity of an irrigation, but it is difficult to measure. For sprinkler systems, irrigation uniformity is evaluated by measuring the application depths with catch cans. For micro-irrigation systems, emitter discharge is measured while the intake opportunity time is used to evaluate uniformity for surface irrigation systems.

Relatively high irrigation efficiencies are possible with surface irrigation methods, but it is much easier to obtain these potential high efficiencies with the basin method on relatively uniform soil types within the basin. The following range of irrigation efficiencies are taken from Heermann and Solomon (2007). Irrigation efficiencies for basin systems can be as high as 80 to 90%. Reasonable efficiencies for border systems are from 70 to 85%, and from 65 to 75% for furrow irrigation. There are many types of sprinkler systems. The efficiency of solid set or permanent sprinkler systems ranges from 70 to 80%. Center pivot and linear move systems have attainable efficiencies of 75 to 90%.

Properly designed and managed micro-irrigation systems are capable of efficiencies from 80 to 95%. The irrigation efficiency for all of these irrigation methods can be much lower than the values quoted here if the system is poorly designed or mismanaged.

Crop productivity throughout the entire irrigated area is important and is generally considered in conjunction with the economic returns versus the costs to upgrade an irrigation system to achieve a higher uniformity. The crop and economic models are complex and are generally evaluated based on physical measurements of uniformity. The complexity of crop and economic models results from interactions with crop, soil differences, management, and fertility.

The non-uniformity of irrigation applications and the efficiency inherent with each irrigation system leads to excess water being applied to the field to minimize the portions of the field receiving insufficient water to satisfy crop ET. This typically results in relatively high leaching fractions, particularly where salinity is a hazard.

3.8.2. South Delta Situation

From the estimates reported in Table 3.7 and average values for irrigation efficiency (78 % for border, 70 % for furrow, 75 % for sprinkler, and 87% for micro-irrigation), it is reasonable to assume that the irrigation efficiency for the South Delta is about 75 %. Because bean is the most salt sensitive crop and is furrow irrigated, an irrigation efficiency of 70% is reasonable. If desired, a range of irrigation efficiencies could be assumed to determine the impact on a water quality standard.

The uniformity of irrigation applications is probably relatively low because of the variability of soil types within a given field and the inherent problems of applying water uniformly with surface irrigation systems. No attempt is made here to quantify non-uniformity in the South Delta but because the irrigation efficiency of the systems used in the South Delta averages 75%, this figure is probably close to an upper limit for the combined impact of irrigation efficiency and uniformity.

3.9. Crop Water Uptake Distribution

3.9.1. State of Knowledge

Different crops have different water uptake patterns, but all take water from wherever it is most readily available within the rooting depth (Ayers and Westcot, 1985). Many field and laboratory experiments have been conducted over the years to determine the actual root water extraction pattern and models have also been proposed to predict crop water uptake (Feddes, 1981). Unfortunately, the water uptake distribution is very hard to quantify and there are numerous factors that impact the uptake pattern. Among the soil factors are: texture, hydraulic conductivity, water-holding capacity, aeration, temperature, and fertility. Among the plant factors are: plant age, rooting depth, root distribution, and distribution of root hairs that take up water. Needless to say, the water uptake distribution is very complex and varies with crop, soil, and environmental conditions. For lack of a better scheme, Ayers and Westcot (1985) assumed that about 40 % of the soil water is taken up in the upper quarter of the crop root zone, 30 % from the second quarter, 20 % from the third quarter, and 10 % from the lowest quarter. This water uptake distribution has been assumed in some models to determine the leaching requirement to control salinity. As will be seen in Section 4.3, an exponential water uptake distribution fits field and plot experiments to determine leaching requirement under saline conditions better than the 40-30-20-10 pattern (Hoffman, 1985).

3.9.2. South Delta Situation

There are no measurements or estimates of crop water uptake patterns for the South Delta. Thus, both the exponential and the 40-30-20-10 distribution patterns are used in the steady-state models developed for the South Delta in Section 5.

3.10. Climate

3.10.1. State of Knowledge

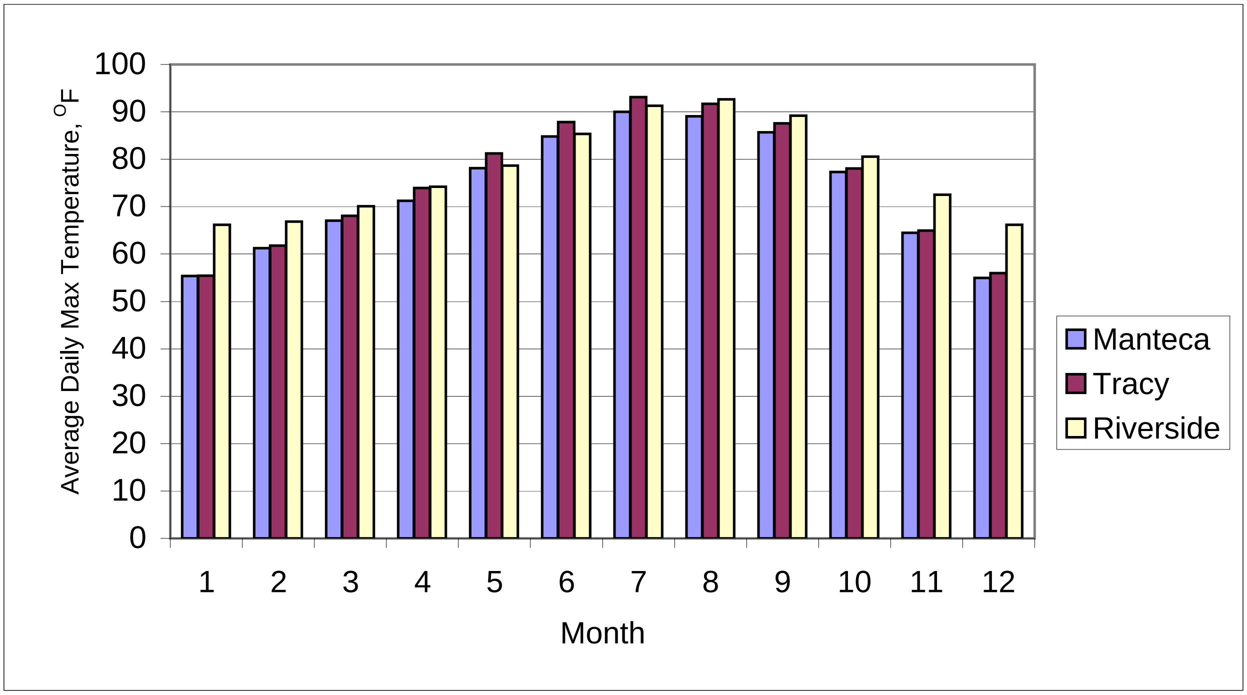
Climatic conditions can influence plant response to salinity. Most crops can tolerate greater salt stress if the weather is cool and humid than if it is hot and dry. The combined effects of salinity and conditions of high evaporative demand, whether caused by temperature, low humidity, wind, or drought, are more stressful than salinity under low evaporative demand conditions. Studies on several crops including alfalfa, bean, beet, carrot, cotton, onion, squash, strawberry clover, saltgrass, and tomato have shown that salinity decreased yields more when these crops were grown at high temperatures (Ahi and Powers, 1938; Magistad et al., 1943; Hoffman and Rawlins, 1970). Yields of many crops also are decreased more by salinity when atmospheric humidity is decreased. Experiments indicate that barley, bean, corn, cotton, onion, and radish were more sensitive to salt at low than high humidity; however, the tolerances of beet and wheat were not markedly affected by humidity (Hoffman and Rawlins, 1970, 1971; Hoffman et al., 1971; Nieman and Poulsen, 1967).

3.10.2. South Delta Situation

The vast majority of experiments to establish crop salt tolerance have been conducted in Riverside, California at the U. S. Salinity Laboratory. The average monthly temperature and relative humidity in Riverside, California are compared with average monthly values at Tracy and/or Manteca, California, which are located in the South Delta. Maximum and minimum daily temperatures and maximum and minimum relative humidity values reported in Figures 3.13 and 3.14 are from November 1987 through September 2008. As seen in Figure 3.13, the average daily maximum temperature by month is slightly higher in Riverside for all months except May, June, and July when the maximum is slightly higher in the South Delta. The average daily minimum temperature is higher in Riverside than the South Delta for every month. Figure 3.14 shows the comparison between average daily minimum and maximum relative humidity for Manteca and Riverside. A record was not available for Tracy over the same time period. The relative humidity was always lower in Riverside than in Manteca. Thus, on average, plants experience higher evaporative demands in Riverside than in the South Delta and, under otherwise identical conditions, plants in Riverside would experience slightly more salt stress than plants in the South Delta. These slight differences in climate would result in a slightly smaller reduction in crop yields than the published salt tolerance responses. Thus, using the crop salt tolerance values above should be slightly conservative with respect to climatic conditions.

Figure 3.13. Average over the month of a) daily maximum temperature and b) daily minimum temperature as measured at Manteca (CIMIS #70), Riverside (CIMIS #44), and Tracy (NCDC #8999) between November 1987 and September 2008 (Month 1 = January; 12 = December).

a) Average over the month of daily maximum temperature.



b) Average over the month of daily minimum temperature.

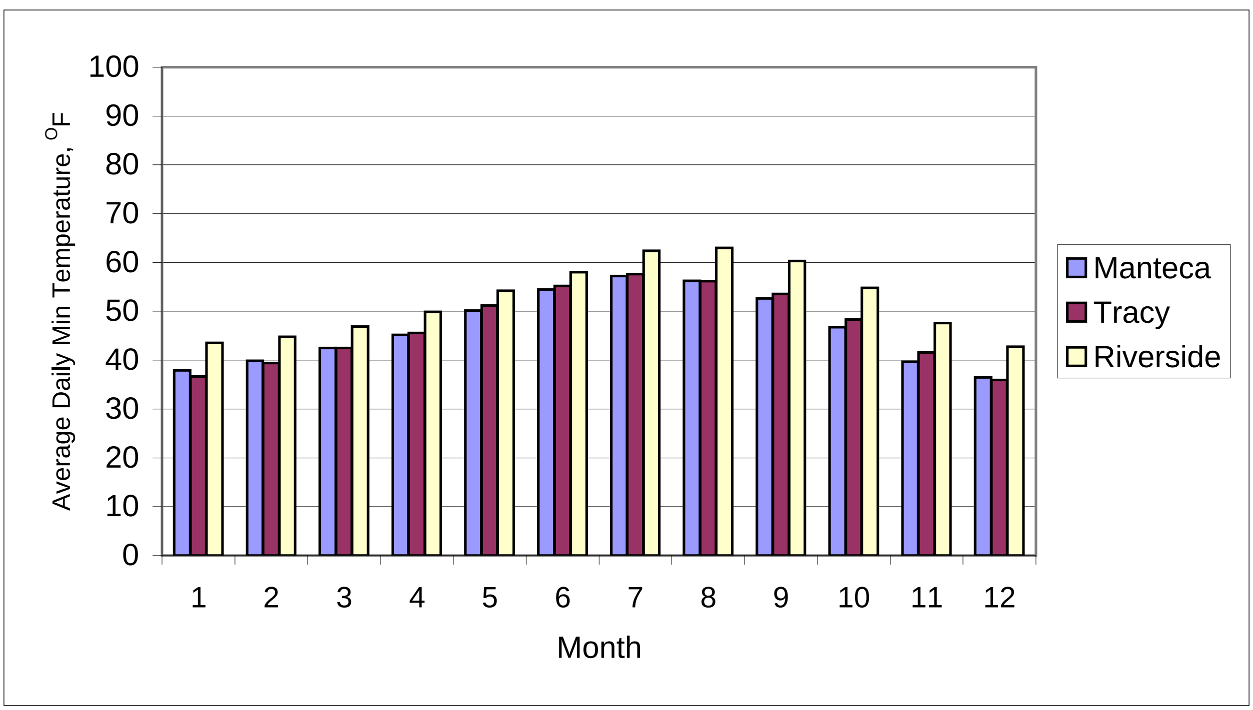
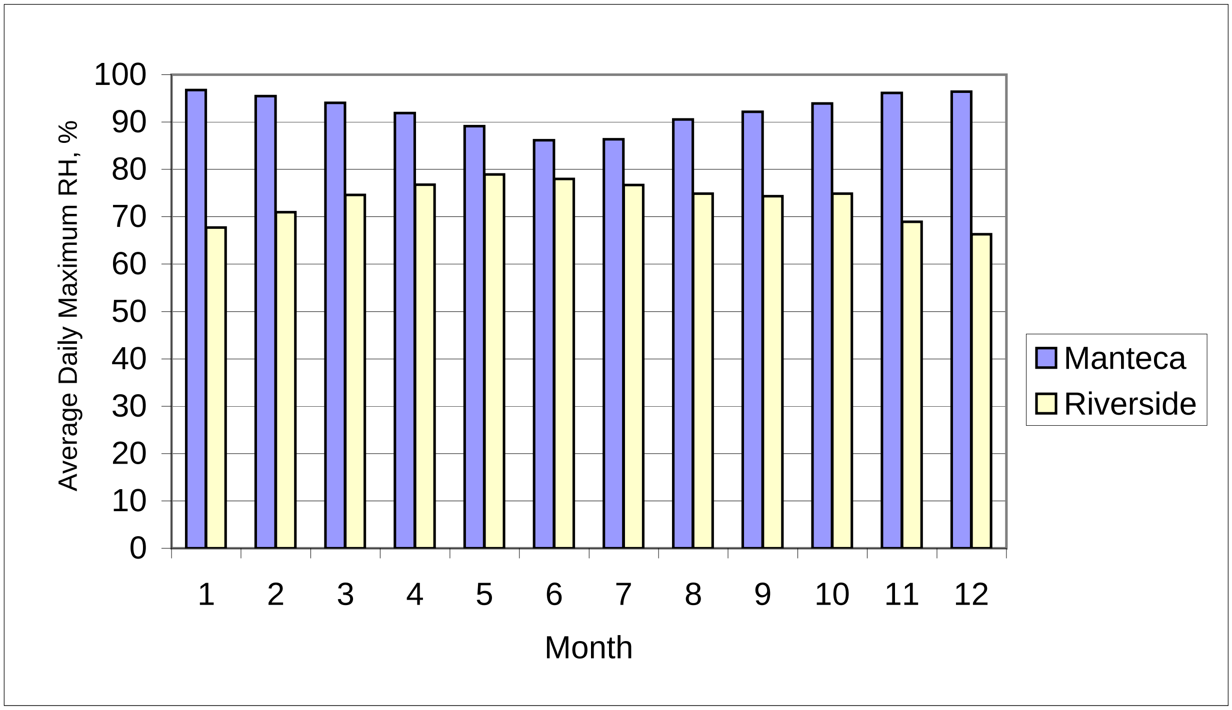
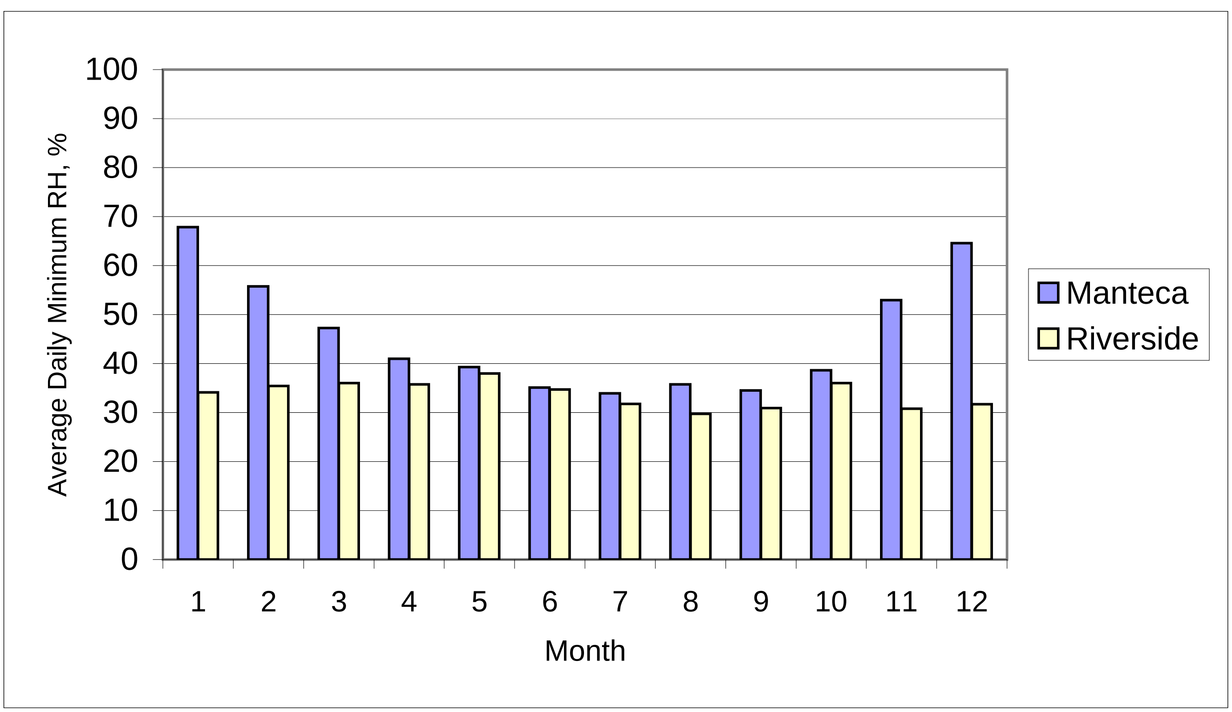


Figure 3.14. Average over the month of a) daily maximum relative humidity and b) daily minimum relative humidity as measured at Manteca (CIMIS #70) and Riverside (CIMIS #44) between November 1987 and September 2008 (Month 1 = January; 12 = December).

a) Average over the month of daily maximum relative humidity (RH).



b) Average over the month of daily minimum relative humidity (RH).



3.11. Salt Precipitation or Dissolution

3.11.1. State of Knowledge

Depending upon the constituents of the irrigation water and their concentrations, salts may precipitate out of the soil solution or salts in the soil may be dissolved by irrigation waters as it passes through the soil. The salt balance in the soil profile is affected by chemical reactions involving slightly soluble salts, such as gypsum, carbonates, or silicate minerals. Consequently, the amount of salt leached below the crop root zone may be less or more than that applied over a long time period depending on whether salts precipitate or dissolve in the crop root zone.

Soils in arid and semi-arid regions, like the South Delta, are relatively un-weathered. Un-weathered minerals provide plant nutrients, but are also a source of salinity. In studies using simulated irrigation waters from the western U.S., Rhoades and colleagues (Rhoades et al., 1973, 1974) showed that the dissolution of primary minerals is most important when the irrigation water's salt content is low – less than 100 to 200 mg/l (EC_i = 0.15 to 0.3 dS/m) and when the leaching fraction is at least 0.25. For example, irrigation with water from California's Feather River, which has a salt content of 60 mg/l, results in more salt in the drain water due to dissolution (weathering) than due solely to the salt content of the irrigation water at high leaching fractions (Rhoades et al., 1974).

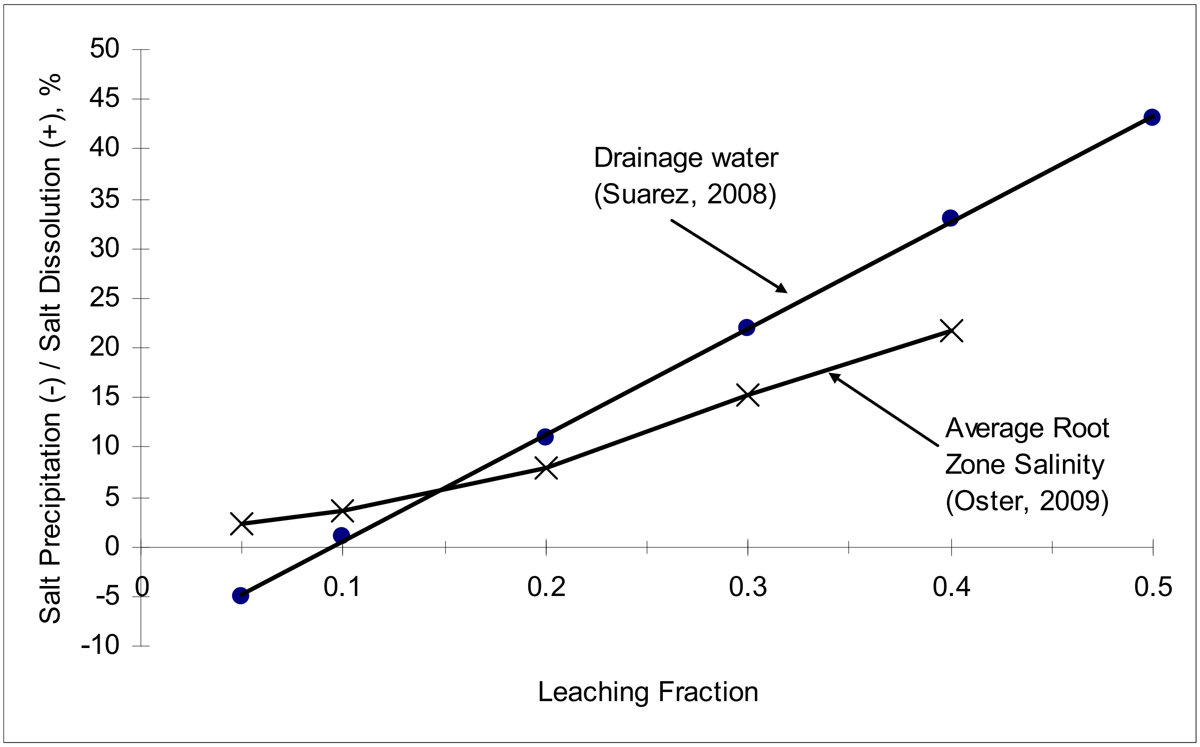
3.11.2. South Delta Situation

Based upon the salt constituents of the water from the San Joaquin River at Mossdale, CA from 2000 to 2003 and from 2005 to 2007 (Dahlgren, 2008), the relationship between the leaching fraction and whether salt would precipitate or be dissolved was calculated (Figure 3.15). The salt constituent data were analyzed by Dr. Don Suarez, Director of the U. S. Salinity Laboratory in Riverside, CA, and he determined the relationship shown in Figure 3.15 using the WATSUIT model for drainage water salinity. The results show that because the water is low in gypsum, carbonates, and silicate minerals at leaching fractions higher than 0.10 the water draining from the root zone would contain salt dissolved from the soil profile and at leaching fractions lower than 0.10 salt would precipitate in the soil. This means that if the leaching fraction for the South Delta is based upon the ratio EC_i/EC_d the leaching fraction would be slightly lower than it really is because some of the salts in the drainage water would be from dissolution of salts in the soil.

I also asked Dr. Jim Oster, emeritus professor from the University of California, Riverside, to analyze the same data set. He also used the WATSUIT model but based his analysis on the average root zone salinity rather than drainage water salinity. The results are also shown in Figure 3.15. The results by Oster predict that salts would tend to dissolve from the soil profile at all leaching fractions.

Both analyses indicate that at a leaching fraction of 0.15, salinity would be increased about 5%. Considering all of the other factors that influence crop response to salinity, the effect of salt precipitation/dissolution would be minimal at leaching fractions near 0.15.

Figure 3.15. The relationship between leaching fraction and salt precipitation or dissolution in the soil when using water from the San Joaquin River (Don Suarez, 2008, personal communication and Jim Oster, 2009, personal communication).



3.12. Shallow Groundwater

3.12.1. State of Knowledge

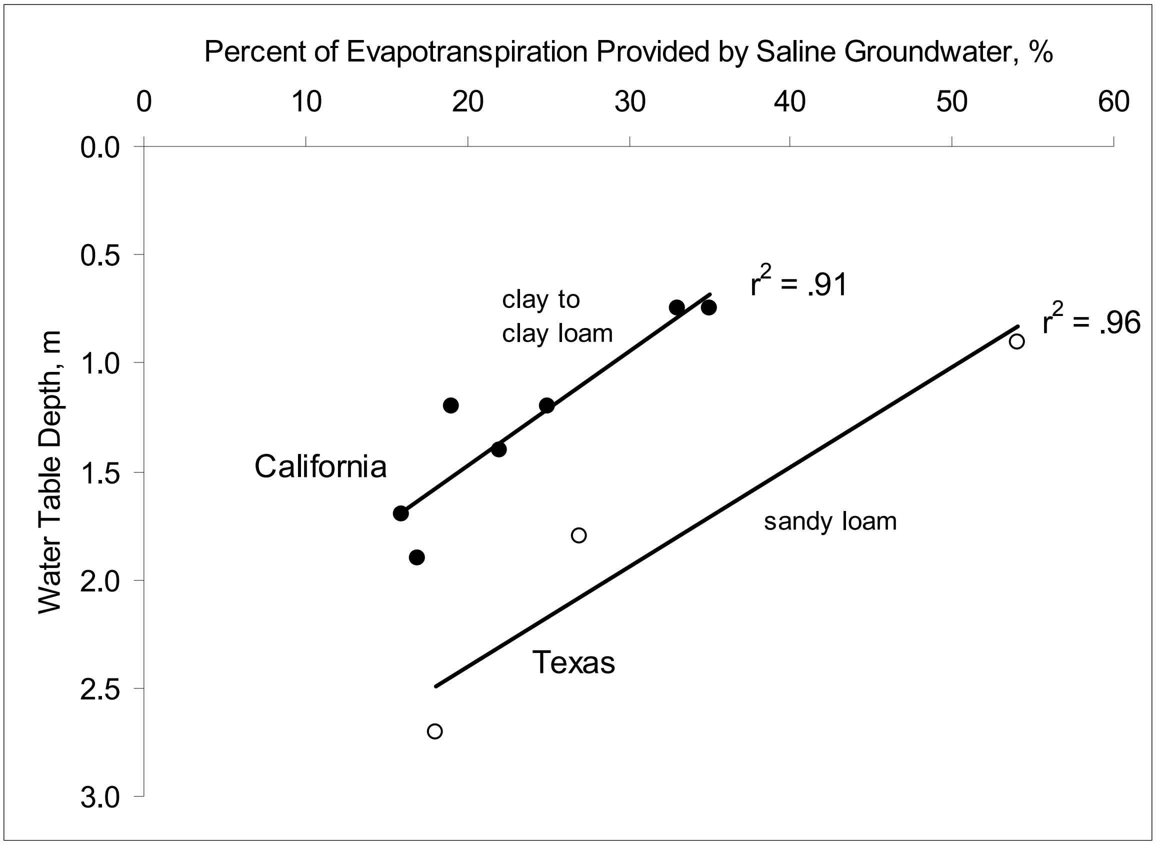
An important mechanism leading to salination of soils is the upward movement of saline groundwater into the crop root zone. To minimize upward movement and thus reduce the salinity hazard, attempts are usually made to lower the water table by drainage. The impact of the water table depth and soil properties on the rate of upward movement must be known to evaluate what water table depth should be maintained. This information is also desirable when estimating the amount of water available to plants due to upward movement of groundwater, thereby reducing the irrigation requirement.

The depth at which a water table should be maintained to minimize upward flow can be determined from an analysis like that published by Gardner (1958). Lowering the water table from the soil surface to a depth of about 3 feet would be of little value in most irrigated soils in a semi-arid or arid climate where groundwater is saline. Upward flow at these shallow depths could be in excess of 0.1 in. per day for clay soils and greater for coarser textured soils (Gardner and Fireman, 1958). As the water table is lowered below 3 ft. the upward flow becomes limited by the hydraulic properties of the soil and decreases markedly with increasing soil depth. Lowering the water table from 4 to 10 ft. in Pachappa sandy loam would decrease upward flow by a factor of 10 (Gardner and Fireman, 1958). When the water table is at 8 ft., further lowering reduces upward flow only slightly. Upward movement and evaporation of water from the soil surface is possible even with the water table at a depth of 13 ft., and, although the rate will be slow, accumulation of harmful amounts of soluble salts is possible if the groundwater is sufficiently saline, if sufficient time is allowed, and if rainfall and irrigation amounts are low. These results, verified by field observations, and the increased cost of drain installation at deeper soil depths have lead to most subsurface drainage systems being installed at depths of 5 to 8 ft. where salinity is a hazard.

Water supplied to a crop by capillary rise from shallow groundwater can be an important resource. Benefits of using shallow groundwater include reduced irrigation, lower production costs, moderation of groundwater moving to deeper aquifers, and minimization of groundwater requiring disposal through subsurface drainage systems. As an example, cotton, grown on a loam soil in the San Joaquin Valley of California with a water table 6 to 8 ft. below the soil surface, obtained 60 % or more of its water requirements from the shallow groundwater that had an EC of 6 dS/m (Wallender et al., 1979). As less water was applied by irrigation, the groundwater contribution to ET increased, but lint yields were reduced.

The relationships between crop water use and the depth and salt content of groundwater are not well understood. Several experiments have been conducted, but generalizations are difficult to make based upon these results. Some of the most consistent data have been obtained with cotton (see Figure 3.16). The relationship between cotton water use from the groundwater and water table depth for soils ranging from clay to clay loam is from field experiments on the west side of the San Joaquin Valley. The data points presented are from three independent studies (Grimes et al., 1984; Hanson and Kite, 1984; and Ayars and Schoneman, 1986). The relationship in Figure 3.16 for sandy loam soil is from a lysimeter study in Texas (Namken et al., 1969). Results indicate uptake of groundwater by cotton is not reduced measurably until the EC of the groundwater exceeds at least 12 dS/m. Groundwater use by alfalfa and corn varies from 15 to 60 % of the total seasonal water use, but the data are not consistent enough to establish a relationship. As an example, groundwater use by alfalfa from a water table 0.6 m deep relative to the total seasonal use in the Grand Valley of Colorado (Kruse et al., 1986) varied among years by more than double; 46 % vs. 94 % in two separate years when the salinity of the groundwater was 0.7 dS/m and 23 % vs. 91 % when the groundwater EC was 6 dS/m.

Figure 3.16. Contribution of shallow, saline groundwater to the evapo-transpiration of cotton as a function of depth to the water table and soil type.



3.12.2. South Delta Situation

Three sources of information on the depth of the water table in the South Delta were located. One source is the NRCS-SSURGO database (NRCS, 2009); a second source is data from ten wells throughout the South Delta as monitored by Department of Water Resources (DWR, 2009c); and the third source is the salinity status report of Meyer et al. (1976).

The depths to ground water for each soil series in the south Delta were determined using the NRCS-SSURGO database and are mapped in Figure 3.17 (see also Table 2.1). The depth to the water table is at least 3 feet for all soils (with the exception of miscellaneous areas totaling about 300 acres along the San Joaquin and Old Rivers). The shallowest depths tend to be along the northern boundaries of the South Delta. About 32% of the SDWA has a water table greater than 5 feet deep.

The locations of 10 shallow wells are also shown in Figure 3.17. The depth to the water table measured in the wells over the past 30 years varies with time of year but the average depth is 5 feet or more as shown in Table 3.9. A depth of 5 feet will minimize upward flow of water from the water table and except for deep rooted crops like alfalfa and cotton the crops are probably not taking up significant amounts of water from the groundwater. Furthermore, the more salt sensitive crops in the South Delta are shallow rooted. In a few areas the water table is on the order of 3 to 4 feet deep. On these soils, crops could extract water from the groundwater but if irrigation management prevents crop water stress, insignificant amounts of water will be taken up from the groundwater.

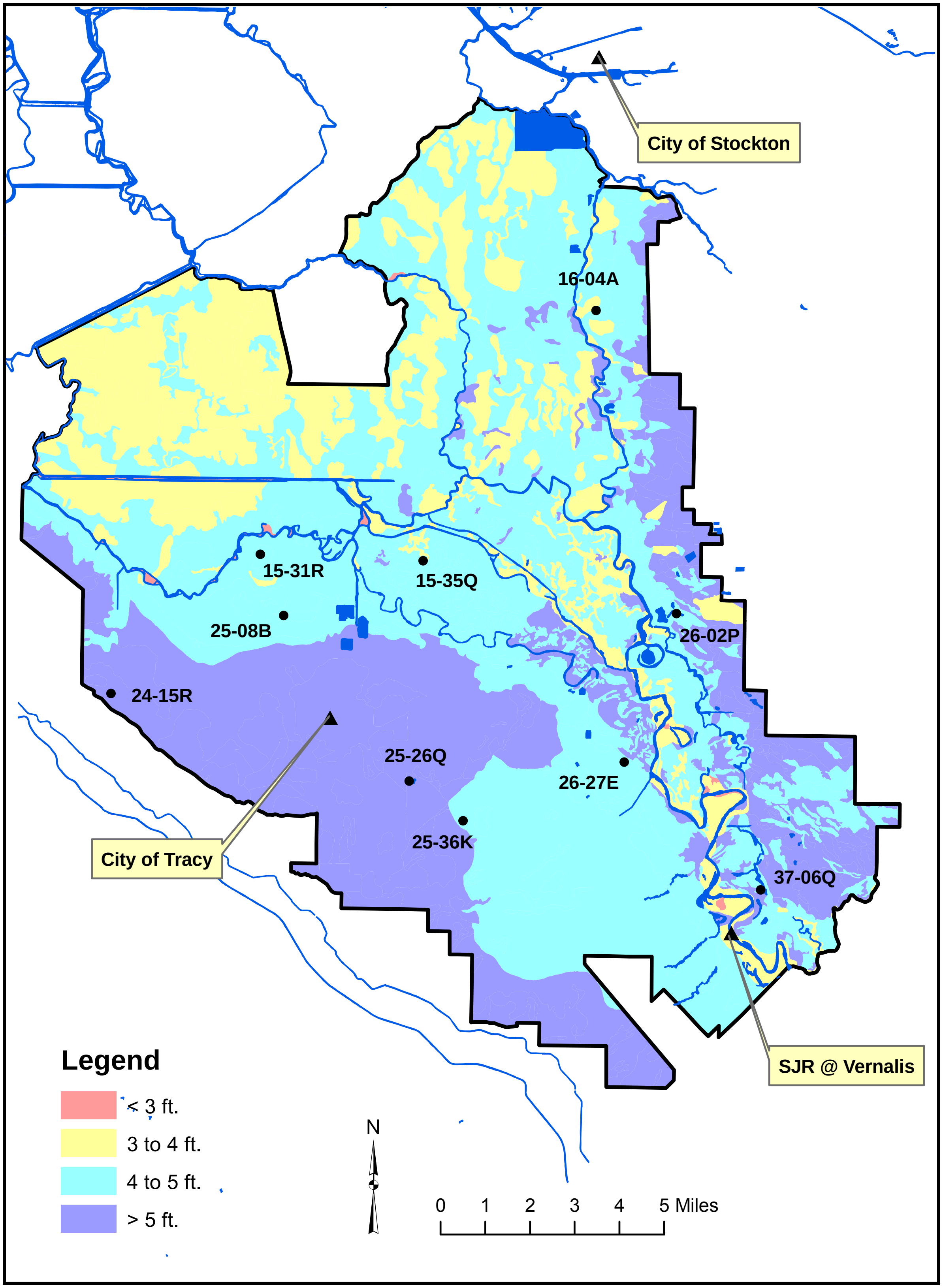
Table 3.9. Depth to groundwater at 10 wells located within the SDWA per Department of Water Resources monitoring network (DWR, 2009c).

State Well No.	Identifier on Figure 3.17	Years of Data	Average Depth (ft.)	Depth per NRCS-SURRGO
02S05E26Q001M	25-26Q	1960 to 1995	14.5	6.6
02S06E02P001M	26-02P	1973 to 2005	10.6	5.0
02S06E27E001M	26-27E	1960 to 2008	9.9	5.0
01S05E31R002M	15-31R	1962 to 2008	3.4	5.0
02S05E08B001M	25-08B	1960 to 2008	6.6	5.0
01S05E35Q002M	15-35Q	1963 to 2002	6.8	4.0
03S07E06Q001M	37-06Q	1966 to 2008	7.8	6.6
01S06E04A002M	16-04A	1963 to 2003	6.7	5.0
02S05E36K001M	25-36K	1960 to 1993	7.7	5.0
02S04E15R002M	24-15R	1958 to 2008	3.3	6.6

In 1976, Meyer and colleagues (Meyer et al., 1976) studied the salinity status at nine locations in the South Delta. The depth of the water table was found to be from 4-5 feet to as deep as 12 feet. Unfortunately, this study only included nine locations and thus no generalizations can be inferred.

Although there are relatively few observations of water table depth at various times over the past thirty years, the depth of the water table appears to be at least 3 to 4 feet throughout the South Delta. The installation of subsurface tile drains in the central, southern, and western potions of the South Delta (see discussion of agricultural drains in section 3.13.2) would indicate that any problems of shallow groundwater have been rectified by subsurface tile drains.

Figure 3.17. Depth to the water table in the south Delta from the NRCS SURRGO database, and locations of 10 groundwater wells listed in Table 3.9.



3.13. Leaching Fraction

3.13.1. State of Knowledge

The amount of applied water needed to satisfy the crop's water requirement can be estimated from water and salt balances within the crop root zone. The major flows of water into the root zone are irrigation, rainfall, and upward flow from the groundwater. Water flows out by evaporation, transpiration, and drainage. Under steady-state conditions, the change in the amount of water and salt stored in the root zone is essentially zero. If the total water inflow is less than evaporation plus transpiration, water is extracted from soil storage and drainage is reduced, with time, the difference between inflows and outflows becomes zero. In the absence of net downward flow beyond the root zone, salt will accumulate, crop growth will be suppressed, and transpiration will be reduced.

In the presence of a shallow water table, deficiencies in the irrigation and rainfall amounts may be offset by upward flow from the groundwater. Upward flow will carry salts into the root zone. If upward flow continues and sufficient leaching does not occur, soil salinity will ultimately reduce crop growth and water consumption. Over the long term, a net downward flow of water is required to control salination and sustain crop productivity.

Conditions controlling the water that flows into and out of the root zone do not prevail long enough for a true steady state to exist except perhaps at the bottom of the root zone when crop and irrigation management remain constant. However, it is instructive to consider a simple form of the steady-state equation to understand the relationship between drainage and salinity. If it is assumed that the upward movement of salt is negligible, the quantities of salt dissolved from the soil minerals plus salt added as fertilizer or amendments is essentially equal to the sum of precipitated salts plus salt removed in the harvested crop, and the change in salt storage is zero under steady-state conditions, the leaching fraction (L) can be written as:

$$L = D_d / D_a = C_a / C_d = EC_a / EC_d \qquad \text{(Eqn. 3.5)}$$

where D refers to depth of water, C is salt concentration, and EC is the electrical conductivity and the subscripts d and a designate drainage and applied water (irrigation plus rainfall). This equation applies only to salt constituents that remained dissolved.

The minimum leaching fraction that a crop can endure without yield reduction is termed the leaching requirement, L_r, which can be expressed as follows:

$$L_r = D_d{}^* / D_a = C_a / C_d{}^* = EC_a / EC_d{}^*. \qquad \text{(Eqn. 3.6)}$$

The notation in Equation 3.6 is the same as in Equation 3.5 except the superscript (*) distinguishes required from actual values.

3.13.2. South Delta Situation

The leaching fraction in the South Delta is difficult to estimate because measurements of soil salinity or salt concentration of drainage water are not measured routinely. However, there are several areas where subsurface drains have been installed and the electrical conductivity of the drainage water measured for various periods of time. In addition, the study by Meyer and colleagues (Meyer et al., 1976) on soil salinity through the crop root zone in nine locations in the South Delta on different soils and crops was used to estimate the leaching fraction.

Chilcott and co-workers (1988) sampled tile drain discharge in the San Joaquin River Basin and Delta from Contra Costa County in the north to Fresno County in the south. Only the drains in Zone C from their report are discussed here. The subsurface drains in Zone C are located in the western portion of San Joaquin County principally from the Delta Mendota pumping plant to just east of the City of Tracy (see Figure 3.18). The majority of the drains lie along a line approximately 1 to 3 miles upslope of the San Joaquin River. Twenty four of the discharge sites within this zone were only from subsurface tile drains. The drains were sampled in June, 1986 and again in June, 1987. The drain waters were analyzed for many properties including minerals and trace elements; only the electrical conductivity measurements are reported in Table 3.10 along with the calculated leaching fraction based upon the average EC measurement.

It has been suggested that the irrigation water for some of the drained areas listed in Table 3.10 may come from the Delta Mendota Canal. The EC of water in the Delta Mendota Canal averages 0.5 dS/m (DWR 2009a) compared to 0.7 dS/m for the San Joaquin River. Thus the leaching fractions for both water qualities are given in Table 3.10. It has not, however, been confirmed which areas receive water from the Delta Mendota Canal.

The data in Table 3.10 are relatively consistent from one year to the next with values from different drains ranging from 1.6 to 6.2 dS/m with an overall average of 3.0 dS/m. The drains are located in a variety of soil types and are in or near the soils mapped as saline (compare Figures 3.7 and 3.18). If the applied water (irrigation and rainfall) averaged 0.7 dS/m then the average leaching fraction for the fields drained by the systems reported in Table 3.10 was $L = 0.7 / 3.0 = 0.23$. If the applied water quality was 0.5 dS/m then the average L would be 0.18 with a minimum of 0.08 and a maximum of 0.31. If the applied water was 1.0 dS/m then the L would be $1.0/3.0 = 0.33$. Regardless of the applied water quality, the leaching fractions are relatively high and indicative of surface irrigation systems managed to prevent crop water stress and avoid excess salinity.

Montoya (2007) summarized the sources of salinity in the South Sacramento-San Joaquin Delta. Of the approximately 74 discharge sites to waterways in the South Delta, he reported that the vast majority of the discharge sites were agricultural. The report gives the electrical conductivity of 26 agricultural drains in the South Delta taken from several DWR reports. The drain discharges monitored included 8 drains discharging into the Grant Line Canal, 7 into Paradise Cut, 9 into South Old River, and 2 into Tom

Paine Slough. The average electrical conductivity of the 26 outlets was 1.5 dS/m. If the salinity of the applied water was 0.7 dS/m then the leaching fraction would be 0.7/1.5 = 0.47. This is a very high leaching fraction and based on these data one would surmise that the irrigation efficiency, on average, is low and/or a great deal of low salinity water was entering the drains without passing through the crop root zone. If the main drains were open surface drains then it is possible that much of the discharge from these drains was irrigation return flow rather than subsurface drainage.

Table 3.10. Electrical conductivity (EC) and calculated leaching fraction (L), assuming EC of applied water is 0.7 dS/m for subsurface tile drains during 1986 and 1987. (Chilcott et al., 1988.).

Drain Location	No. of Samples	EC (dS/m)	L assuming EC_i=0.5 dS/m	L assuming EC_i=0.7 dS/m
3, Grant Line Rd. Sump	3	2.7	0.19	.26
4, Bethany / Lammers	3	2.1	0.24	.33
5, Patterson Pass Rd.	6	2.5	0.20	.28
6, Moitose	3	1.6	0.31	.44
7, Krohn Rd.	4	2.1	0.24	.33
8, Pimentel	2	2.2	0.23	.32
9, Lammers / Corral Hollow	4	4.4	0.11	.16
11, Delta Ave.	6	2.4	0.21	.29
13, Costa Brothers East	2	4.1	0.12	.17
14, Costa Brothers West	4	3.6	0.14	.19
15, Castro	3	2.4	0.21	.29
16, Earp	4	2.8	0.18	.25
17, Freeman	4	3.9	0.13	.18
18, Costa	5	3.4	0.15	.21
19, Moitoso and Castro	4	2.0	0.25	.35
24, Corral Hollow / Bethany	5	6.2	0.08	.11
26, Chrisman Rd.	3	2.0	0.25	.35
36, Kelso Rd. / Byron Hwy.	6	2.4	0.21	.29
37, Spirow Nicholaw	4	3.1	0.16	.23
38, JM Laurence Jr. East	4	3.5	0.14	.20
39, JM Laurence Jr. West	4	2.4	0.21	.29
40, Sequeira	3	3.6	0.14	.19
41, Reeve Rd.	3	3.8	0.13	.18
44, Larch Rd.	4	2.8	0.18	.25
Number of Drains Sampled: 24				
	Average:	3.0	0.18	0.23
	Median:	2.8	0.18	0.25
	Minimum:	1.6	0.08	0.11
	Maximum:	6.2	0.31	0.44

An example of the average leaching fraction for a large area is the New Jerusalem Drainage District. The location of the 12,300 acre District is shown in Figure 3.19. The soils drained are clay and clay loam. The electrical conductivity and the calculated leaching fraction assuming an EC_i of 0.7 dS/m are summarized in Table 3.11. From 1 to 13 samples were analyzed annually from 1977 to 2005. The average EC of the drainage water was 2.6 dS/m with the minimum annual value being 2.4 dS/m and the maximum being 3.2 dS/m. If the EC of the applied water is taken as 0.7 dS/m, the average annual leaching fraction is 0.27 with the minimum and maximum being 0.22 and 0.29, respectively. The measurements over the 17 years of measurements are relatively stable.

Table 3.11. Electrical conductivity (EC) and calculated leaching fraction (L) for applied water of 0.7 dS/m for the New Jerusalem Drainage District (Belden et al., 1989 and D. Westcot, personal communication, 2009)

Year Sampled	No. of Samples	EC of Effluent (dS/m)	L w/ ECi = 0.7 dS/m
1977	1	2.6	0.27
1978	1	3.2	0.22
1979	1	3.0	0.23
1980	1	2.6	0.27
1982	5	2.5	0.28
1983	11	3.0	0.23
1984	13	2.6	0.27
1985	11	2.5	0.28
1986	5	2.5	0.28
1987	2	2.4	0.29
1988	4	2.5	0.28
2000	3	2.4	0.29
2001	12	2.5	0.28
2002	13	2.4	0.29
2003	9	2.4	0.29
2004	6	2.4	0.29
2005	11	2.4	0.29
Number of Years Sampled: 17			
Number of Samples: 109			
	Average:	2.6	0.27
	Median:	2.5	0.28
	Minimum:	2.4	0.22
	Maximum:	3.2	0.29

Another drainage system monitored from 1982 until 1987 is the Tracy Boulevard Tile Drain Sump. This system is labeled in Figure 3.19. As shown in Figure 3.12, the 44 samples taken over the 6-year period had an average EC of 3.4 dS/m with minimum and maximum annual values of 3.1 and 3.6 dS/m. Again, if the EC of the applied water is taken as 0.7 dS/m, the leaching fraction averaged 0.21.

Table 3.12. Electrical conductivity (EC) and calculated leaching fraction (L) for an applied water of 0.7 dS/m for the Tracy Boulevard Tile Drain Sump (Belden et al., 1989).

Year Sampled	No. of Samples	EC of Effluent (dS/m)	L w/ ECi = 0.7 dS/m
1982	3	3.5	0.20
1983	10	3.6	0.19
1984	10	3.4	0.21
1985	12	3.4	0.21
1986	7	3.1	0.23
1987	2	3.1	0.23
Number of Years Sampled: 6			
Number of Samples: 44			
	Average:	3.4	0.21
	Median:	3.4	0.21
	Minimum:	3.1	0.19
	Maximum:	3.6	0.23

The other source of information located for the South Delta is the study by Meyer and colleagues (1976). They measured soil salinity at nine locations in April or May, 1976 and again in August or September, 1976. The locations represented a variety of crops, soil types, and irrigation water sources. They estimated the leaching fraction based upon the irrigation water quality in 1976 and the maximum soil salinity in the lower reaches of the crop root zone. Of the nine locations studied, five had leaching fractions of 0.25 or greater. At three locations the leaching fraction was estimated at 0.15 or greater; one location had an apparent leaching fraction of less than 0.10. The highest soil salinities and lowest apparent leaching fractions occurred at locations where water quality was the best in this study, seasonal average of about 0.7 dS/m. High leaching and low salt accumulations were found at the locations where more saline irrigation water was available, 1.1 dS/m or more.

Figure 3.18. Location of subsurface tile drains sampled on the west side of the SDWA (Chilcott, et al., 1988).

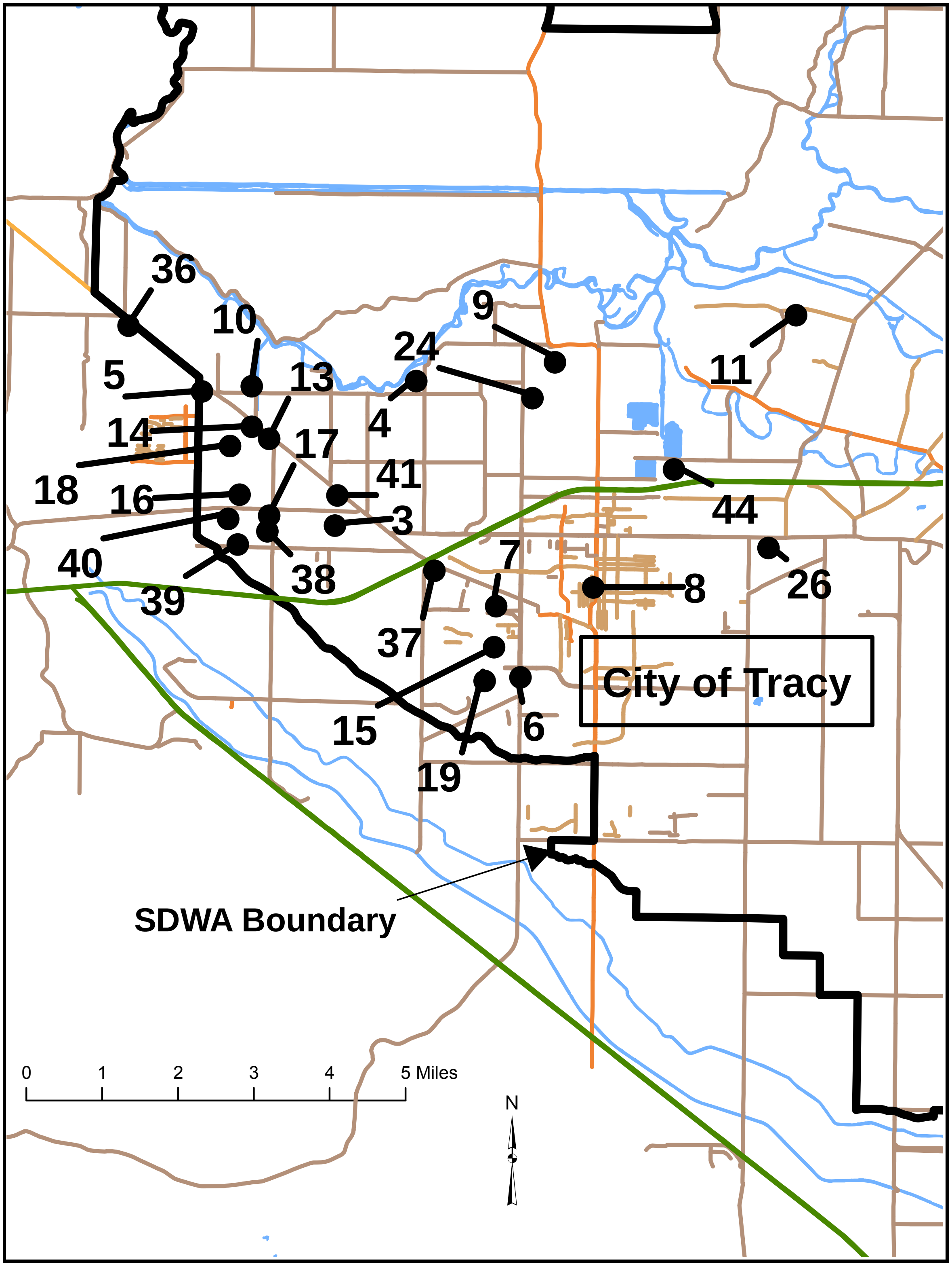
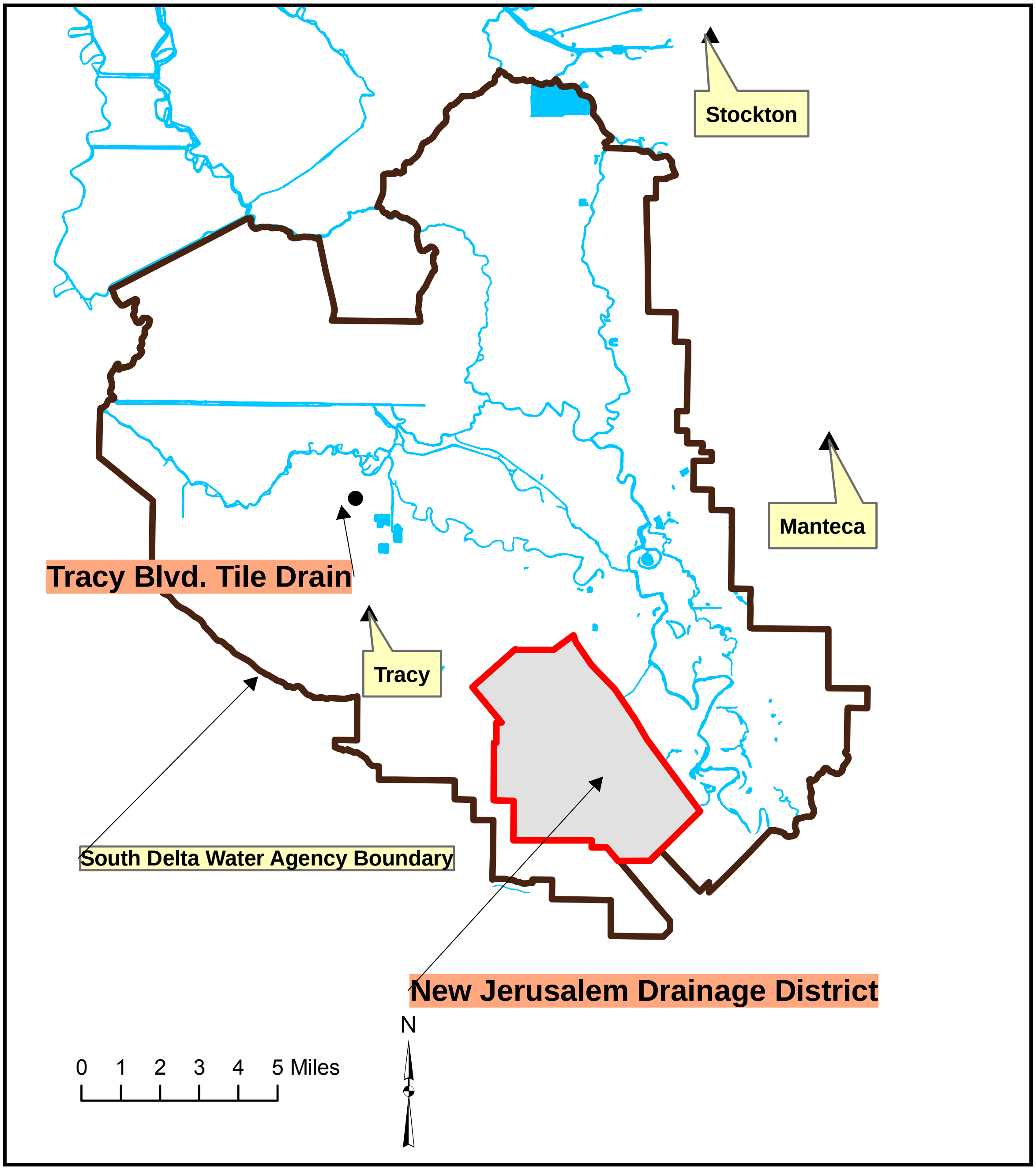


Figure 3.19. Location of the New Jerusalem Drainage District in the South Delta (shaded area southeast of Tracy).



4. Steady State vs. Transient Models for Soil Salinity

4.1. Steady-State Models

Steady-state analyses are simpler than transient-state analyses. The common assumption is that with time, a transient system will converge into a steady-state case and provide justification for steady-state analyses if crop, weather, and irrigation management remain unchanged over long periods of time. This assumption is true primarily at the bottom of the root zone. Shallow in the root zone, irrigations are applied as a pulse that creates a "wave" action as the applied water moves down the soil profile. The amplitude of the wave decreases with increased soil depth. Ultimately it dissipates and soil water content is relatively constant at the bottom of the root zone. Because of the dissipation of the irrigation wave, investigators have found that steady-state analyses are excellent first approximations and over long time periods, if rainfall is taken into account, provide acceptable results and do not require the vast amount of information on irrigation amount and frequency, soil physical and chemical properties, and crop evapotranspiration that are typically required for transient models.

At least five different steady-state models have been developed and published over the past half century. These models are typically applied over a period of a year or a number of years, assuming the storage of soil water and salt does not change over the period of time in question; thus, steady-state is assumed. All of the steady-state models considered here have been directed at solving for the leaching requirement. The leaching requirement (L_r) is the smallest fraction of applied water (irrigation plus rainfall) that must drain below the crop root zone to prevent any loss in crop productivity from an excess of soluble salts. The amount of leaching necessary to satisfy the L_r depends primarily upon the salinity of the applied water and the salt tolerance of the crop. As the leaching fraction decreases, the salt concentration of the soil solution increases as crop roots extract nearly pure soil water leaving most of the salts behind. If the salt concentration in the soil exceeds the crop's salt tolerance threshold level (refer to Table 3.1), leaching is required to restore full crop productivity. Depending on the degree of salinity control required, leaching may occur continuously or intermittently at intervals of a few months to a few years. If leaching is insufficient, losses will become severe and reclamation will be required before crops can be grown economically.

All steady-state and transient models are based upon mass balance of water and salt. Thus for a unit surface area of a soil profile over a given time interval, inflow depths of irrigation (D_i) and effective precipitation (P_e) minus outflows of crop evapotranspiration (ET_c) and drainage (D_d) must equal changes in soil water storage (ΔD_s). For steady-state conditions:

$$\Delta D_s = D_i + P_e - ET_c - D_d = 0. \qquad \text{(Eqn. 4.1)}$$

The amount of salt leaving the soil by evapotranspiration and that applied in precipitation are negligible. Thus, the change in mass of salt stored per unit area within the root zone (ΔM_s) for steady-state is given by

$$\Delta M_s = (C_i \times D_i) - (C_d \times D_d) = 0. \qquad \text{(Eqn. 4.2)}$$

The salt concentration in the irrigation water is noted as C_i and the salt concentration in the drain water is represented by C_d. Under steady-state conditions ΔD_s and ΔM_s are zero. Therefore, the leaching fraction (L) at steady-state, defined as the ratio of water leaving the root zone as drainage to that applied, $D_a = D_i + P_e$, or the ratio of salt applied to salt drained, can be expressed as was given in Equation 3.5. The leaching requirement (L_r) can be expressed as presented in Equation 3.6.

Steady-state models have been proposed to relate EC_d^* to some readily available value of soil salinity that is indicative of the crop's leaching requirement. Bernstein (1964) assumed EC_d^* to be the electrical conductivity of the soil saturation extract (EC_e) at which yield in salt tolerance experiments was reduced by 50 % (EC_{e50} in Figure 4.1). Bernstein and Francois (1973b) and van Schilfgaarde et al. (1974) contended that the value of EC_d^* could be increased to the EC of soil water at which roots can no longer extract water. Assuming the soil water content in the field to be half of the water content of a saturated soil sample, the value of EC_d^* was proposed to be twice EC_e extrapolated to zero yield from salt tolerance data ($2EC_{e0}$ in Figure 4.1). Concurrently, Rhoades (1974) proposed that EC_d^* could be estimated from $EC_d^* = 5EC_{et} – EC_i$ in which EC_{et} is the salt tolerance threshold ($5EC_{et} – EC_i$ in Table 4.1). A fourth model, proposed by Rhoades and Merrill (1976) and Rhoades (1982), differentiates between infrequent and high-frequency irrigations. The model calculates soil salinity based upon a 40-30-20-10 soil water extraction pattern by successively deeper quarter-fractions of the root zone. The average soil salinity for conventional (infrequent) irrigations is taken as the linear-average of the quarter-fraction values. This is the model utilized by Ayers and Westcot (1976 and 1985). For high frequency irrigation, Rhoades assumed soil salinity is weighted by crop water-uptake.

Hoffman and van Genuchten (1983) determined the crop water-uptake weighted salinity by solving the continuity equation for one dimensional vertical flow of water through the soil assuming an exponential soil water uptake function (Exponential in Table 4.1). Their equation given as the crop water-uptake weighted salt concentration of the saturated extract (C) is given by:

$$C/C_a = 1/L + [\delta/(Z \times L)] \times \ln [L + (1 – L) \times \exp^{(-Z/\delta)}]. \qquad \text{(Eqn. 4.3)}$$

C_a is the salt concentration of the applied water, L is the leaching fraction, Z is the depth of the crop root zone, and δ is an empirical constant set to 0.2xZ.

The resultant mean root zone salinity (C) for any given L was reduced by the mean root zone salinity at an L of 0.5 because salt tolerance experiments were conducted at leaching fractions near to 0.5. The amount of soil salinity at a crop's salt tolerance threshold does not have to be leached. This correction results in a reasonable relationship between any given crop's salt tolerance threshold, determined at an L of about 0.5, and the salinity of the applied water as a function of L_r. The L_r based on the Hoffman and van Genuchten model can be determined from Figure 4.2 for any given EC of the applied water and the crop's salt tolerance threshold.

Figure 4.1. Three of the salt tolerance variables used in various steady-state models illustrated for tomatoes.

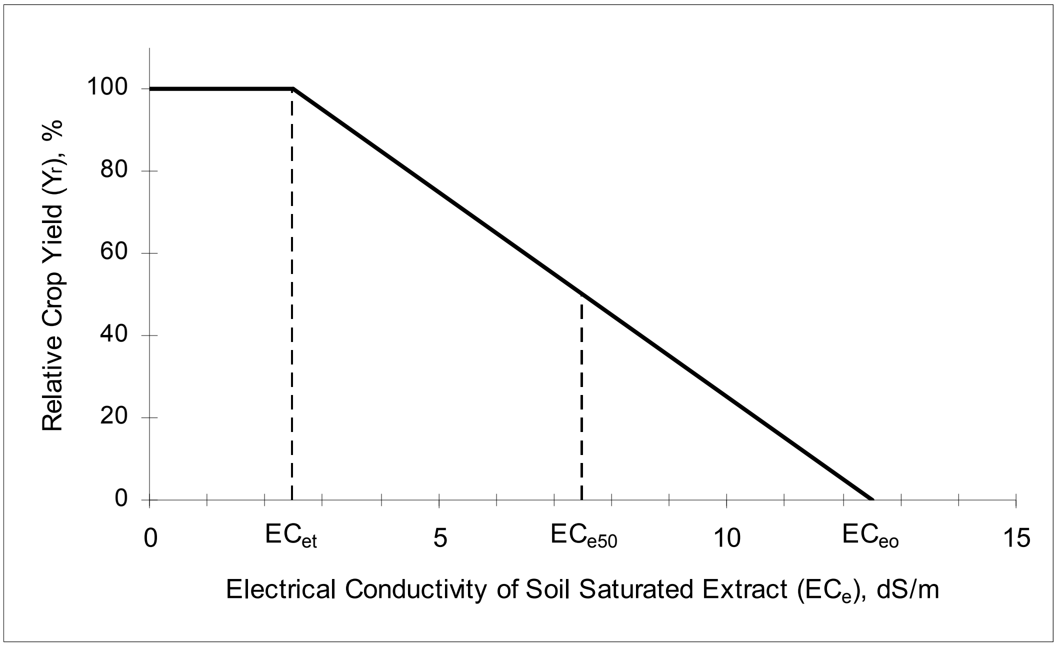
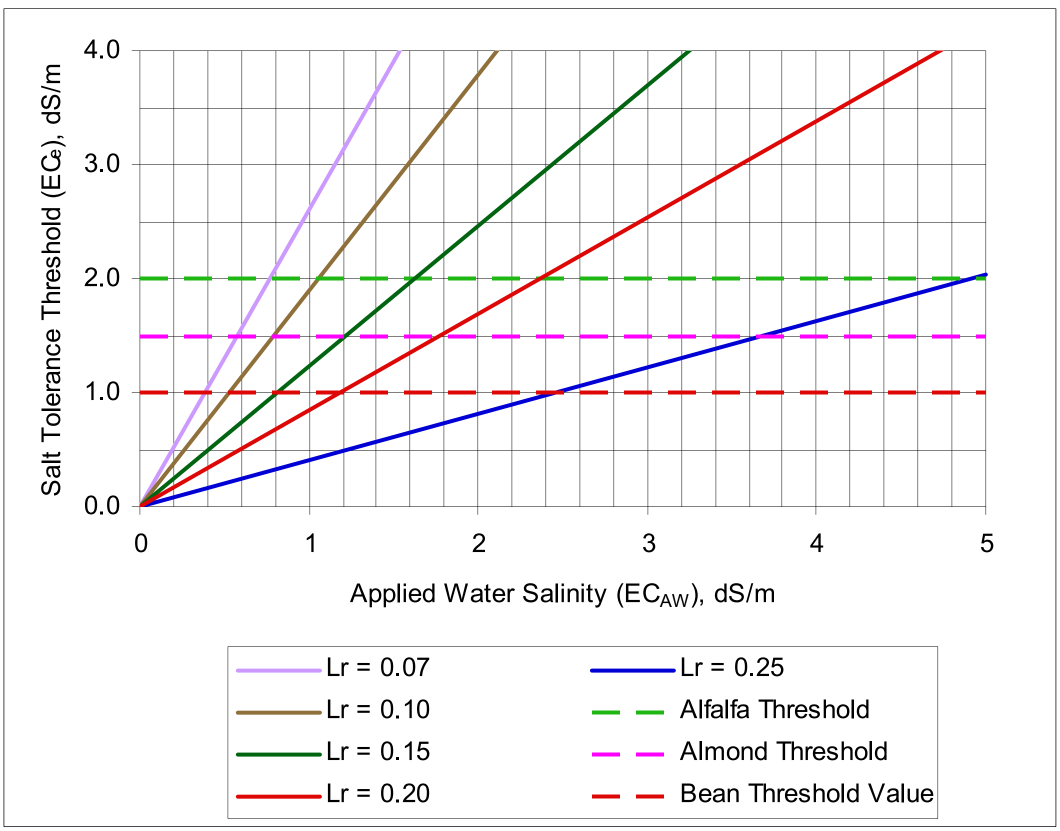


Figure 4.2. Graphical solution (using exponential plant water uptake model) for crop salt tolerance threshold (EC_e) as a function of applied water salinity (EC_{AW}) for different leaching requirements (Hoffman and Van Genuchten, 1983).



4.2. Transient Models

Transient models are designed to account for the time dependent variables encountered in the field. These variables include switching crops with different salt tolerances, variable irrigation water salinity, rainfall, multiple years of drought, timing and amount of irrigation, multiple soil layers, crop ET, initial soil salinity conditions, and other time dependent variables. Some basic concepts concerning transient models are as follows. The water flow and salt transport equations are the basic concepts of transient models (Equations 4.1 and 4.2 without ΔD_s and ΔM_s being set to zero). Water flow, which takes into account water uptake by roots, is quantified by the Darcy-Richards equation. Salt transport is calculated using the convection-dispersion equation for a non-reactive, non-interacting solute. Solving the nonlinearity of these two equations is typically accomplished by numerical methods that require high-speed computers. Beyond these two basic equations, differences among models exist to account for soil-water-plant-salinity interactions, such as water stress, bypass flow, salt precipitation/dissolution, water uptake distribution, and evapotranspiration as a function of plant size and soil salinity.

Letey and Feng (2007) listed the following factors that need to be considered when evaluating transient models for managing irrigation under saline conditions. (1) Is the appropriate water-uptake function for crops utilized? (2) Is there a feedback mechanism between the soil-water status, plant growth, and transpiration? (3) Does the model allow for extra water uptake from the non-stressed portion of the root zone to compensate for reduced water uptake from the stressed portion of the root zone? (4) Does the model account for possible salt precipitation or dissolution? (5) Have model simulations been compared to field experimental results? The inclusion of these factors in each transient model is given in the following discussion of each model.

In recent years, a number of transient models have been developed using complex computer programs for managing irrigation where salinity is a hazard. These models do not assume steady-state and frequently use daily values of applied water, drainage, and crop evapotranspiration. Four of these models, called the Grattan, Corwin, Simunek, and Letey models for short, will be discussed in terms of the principles employed, the assumptions made, the factors considered, and the conclusions drawn. Other transient models that have been proposed recently include: SALTMED (Ragab et al., 2005a,b), SWAGMAN (Khan et al., 2003), and SDB (Sahni et al., 2007). These models are not considered in this report.

Grattan Model

Isidoro-Ramirez et al. (2004), Grattan and Isidoro-Ramirez (2006), and Isidoro and Grattan (in press) developed a model based upon the steady-state approach used by Ayers and Westcot (1976 and 1985) and it relates EC_i to the seasonal average root zone salinity. The model proposed by Grattan and co-workers considers the timing and quantity of applied irrigation water, the quantity and distribution of rainfall, and various soil water factors based on soil texture. Like Ayers and Westcot (1976 and 1985), they assumed a water uptake pattern of 40-30-20-10 % by quarter fractions down through the crop root zone and that the average root zone salinity could be calculated by averaging the soil-water salinity at the soil surface and at the bottom of each quarter of the root zone. A daily mass balance (water and salt) is calculated for each layer. The inputs for the first layer are applied irrigation and rainfall and the outputs are the drainage from layer 1 to layer 2 and evapotranspiration (ET) from the layer. For the underlying layers, the only input is drainage from the overlying layer and the outputs are the drainage to the underlying layer and ET from the layer. For the fourth and deepest layer, the drainage represents the total drainage from the crop root zone. Important soil properties in the model are the wilting point (WP), field capacity (FC), and total available water (TAW) for the crop (TAW = FC – WP). The evapotranspiration of the crop (ET_c) is calculated for each soil layer using appropriate crop coefficient values (K_c) and historical reference evapotranspiration (ET_o) data from Goldhamer and Snyder (1989). The achievable ET_c is calculated as $ET_c = K_c \times ET_o$. Between cropping seasons all ET (or evaporation (E) since there is no crop) is assumed to take place from the upper soil layer and bare soil surface evaporation (E_S) is assumed to be relatively constant at 0.024 in./day or 0.7 in./month(MacGillivray and Jones, 1989). The latest version of this model (Isidoro and Grattan, in press) provides a feedback mechanism to account for different amounts of water stress between the soil layers and adjusts water uptake among soil layers in response to water stress in each layer.

The model can be used to either quantify the extent by which an irrigation supply with a given salinity would decrease the crop yield potential under site-specific conditions or determine the maximum EC of an irrigation supply, which if used as the sole source of irrigation water over the long term, is fully protective of crop production. This model was used to evaluate site-specific conditions near Davis, CA. The specific goal was to determine the maximum EC value for Putah Creek that would protect downstream agricultural uses of the water. Bean was chosen for the analysis because it is potentially grown in the downstream area and bean is salt sensitive, having a salt tolerance threshold of EC_e = 1.0 dS/m. They concluded that protecting bean would, in turn, protect all other crops commonly grown in the area.

Isidoro-Rameriz and co-workers (2004) considered three scenarios:

1. No rainfall and an irrigation water having an EC_i of 0.7 dS/m. Without rainfall, the situation considered is similar to that of Ayers and Westcot (1985), no off-season ET was assumed.
2. Calculate the maximum EC_i to maintain EC_e less than or equal to 1 dS/m using daily rainfall for periods of record representing a five year period of low rainfall and a five year period of average rainfall.
3. Irrigation water with an EC_i of 1.1 dS/m and 1.2 dS/m over an entire 53-year record of rainfall.

The purpose of the first scenario was to compare their model with results obtained using the approach of Ayers and Westcot by assuming no rainfall. The Grattan model predicted that an EC_i of 0.7 dS/m would result in an average seasonal soil salinity (EC_e) of 0.95 dS/m compared to 1.0 dS/m by Ayers and Westcot.

The second scenario introduced rainfall while keeping all other factors and assumptions the same as for scenario 1. The dry period (1953-1957) and an average rainfall period (1963-1967) gave essentially the same results; namely that an EC_i of 1.2 dS/m gave an average seasonal soil salinity of 1.0 dS/m. They concluded that the results suggest rainfall distribution plays a significant role in determining seasonal soil salinity.

In the third scenario when an EC_i of 1.1 dS/m is considered over 53 years of rainfall record (1951 to 2003), the Grattan model predicts a seasonal mean EC_e of 0.94 dS/m. Over the 53 years of record, bean yield is predicted to be reduced during only 3 years with an EC_i of 1.1 dS/m. Yield reductions would be 2, 4, and 6 % for the 3 years. These predicted yield reductions are probably less than the error associated with the yield threshold itself. With an EC_i of 1.2 dS/m, the seasonal mean soil salinity was 1.02 dS/m, while the range in seasonal EC_e for individual years varied from 0.88 to 1.42 dS/m. For the year with an average EC_e of 1.42 dS/m, the yield reduction for bean would be 8 %. Given these results, Grattan and co-workers concluded that an EC_i of 1.1 dS/m would be protective for bean, and thus would be protective for all other crops in the Davis area.

When considering if the Grattan model satisfies the five factors given above from Letey and Feng (2007) for transient models, the latest version of the model has a water uptake function, provides for a feedback mechanism in response to water stress, and adjusts the water uptake depending on stress. The model does not account for salt precipitation or dissolution and no field verification of the model results has been published.

Corwin Model

The TETrans model proposed by Corwin and colleagues (Corwin et al., 1991) is a functional, transient, layer-equilibrium model that predicts incremental changes over time in amounts of solute and water content occurring within the crop root zone. Transport through the root zone is modeled as a series of events or processes within a finite collection of discrete depth intervals. The sequential events or processes include infiltration of water, drainage to field capacity, plant water uptake resulting from transpiration, and/or evaporative losses from the soil surface. Each process is assumed to occur in sequence within a given depth interval as opposed to reality where transport is an integration of simultaneous processes. Other assumptions include: (1) the soil is composed of a finite series of discrete depth intervals with each depth interval having homogeneous properties, (2) drainage occurs through the profile to a depth-variable field capacity water content, (3) the depletion of stored water by evapotranspiration within each depth increment does not go below a minimum water content that will stress the plant, (4) dispersion is either negligible or part of the phenomenon of bypass flow, and (5) upward or lateral water flow does not occur.

Included within the Corwin model is a simple mechanism to account for bypass (preferential) flow of applied water. Bypass is approximated using a simple mass-balance approach by assuming that any deviation from piston flow for the transport of a conservative solute is due to bypass flow (Corwin et al., 1991).

With respect to satisfying the five factors proposed by Letey and Feng (2007), this model performs well. The soil profile is divided into many depth intervals so ET can be considered for many soil depth intervals. There is a feedback mechanism to prevent transpiration to go below a water content that would stress the plant. The model does not account for salt precipitation/dissolution but it does consider bypass flow. The model was tested using data from the Imperial Valley of California.

Simunek Model

Simunek and co-workers developed a sophisticated mechanistic, numerical model called UNSATCHEM. This model simulates the flow of water in unsaturated soils, along with transport and chemical reactions of solutes, and crop response to salinity (Simunek and Suarez, 1994). The model has submodels accounting for major ion chemistry, crop response to salinity, carbon dioxide (CO_2) production and transport, time-varying concentration in irrigated root zones, and the presence of shallow groundwater. The variably-saturated water flow is described using the Richard's equation and the transport of solutes and CO_2 is described using the convection-dispersion equation. Root growth is estimated by using the logistic growth function and root distribution can be made user-specific. Precipitation, evapotranspiration, and irrigation fluxes can be specified at any user-defined time interval.

While the model was not developed to determine the L_r, it can be altered to do so by determining the minimum L that can be used under a specified set of soil, crop, and management conditions while preventing losses in crop yield. The UNSATCHEM model does not account for bypass flow but the complex transient chemical processes included are salt precipitation and/or dissolution, cation exchange, and complexation reactions as influenced by the CO_2 composition of the soil air, which largely controls the soil pH, as well as sulfate ion association, which affects the solubility of gypsum.

The Simunek model satisfies the first and fourth factor listed by Letey and Feng (2007), but it does not adjust the potential ET to account for reduced plant growth in response to water stress, nor does it provide increased water uptake from non-stressed portions of the root zone to compensate for decreased water uptake from stressed portions. Comparisons between model-simulated crop yield and experimentally measured crop yield has been reported for California's Imperial Valley.

Letey Model

Letey and co-worker developed a transient model called ENVIRO-GRO (Pang and Letey, 1998). The Letey model uses the Darcy-Richards equation to account for water flow. This equation has a term to quantify water uptake by roots. In comparing water uptake functions, Cardon and Letey (1992) concluded that the equation

$$S = S_{max} / 1 + [(ah + \pi) / \pi 50]^3 \qquad \text{(Eqn. 4.4)}$$

was the best water uptake function to use in their model. The factors in equation 4.4 are: S is the root water uptake, S_{max} is the maximum water uptake by a plant that is not stressed (potential transpiration), a accounts for the differential response of the crop to matrix and osmotic pressure head influences and is equal to the ratio of π50 and h50 where 50 represents the values at which S_{max} is reduced by 50 %, h is the soil-water pressure head, and π is the osmotic pressure head. This model satisfies all of the factors listed by Letey and Feng (2007) except it does not account for salt precipitation/dissolution. Model simulations on corn yield agreed well with experimental data from an extensive field experiment conducted in Israel (Feng et al., 2003). The model has recently been converted from a combination of several computer programs to the C++ program.

4.3. Comparison of Leaching Requirement Models

Hoffman (1985) compared the five steady-state models described above with results from seven independent experiments conducted to measure the leaching requirement of 14 crops with irrigation waters of different salt concentrations. Bower, Ogata, and Tucker (1969 and 1970) studied alfalfa, tall fescue, and sudan grass. Hoffman and colleagues experimented on barley, cowpea, and celery (Hoffman and Jobes, 1983); oat, tomato, and cauliflower (Jobes, Hoffman, and Wood, 1981); and wheat, sorghum, and lettuce (Hoffman, et al., 1979). Bernstein and Francois (1973b) studied alfalfa and Lonkerd, Donovan, and Williams (1976, unpublished report) experimented on wheat and lettuce. Comparisons between measured and predicted leaching requirements by these five steady-state models are given in Table 4.1.

The EC_{e50} model consistently over estimated the L_r while the $2EC_{e0}$ model consistently under estimated. The $5EC_{et}$-EC_i model gave reasonable estimates at low leaching requirements, but over estimated severely at high leaching requirements. The exponential model correlated best with measured values of L_r but under estimated high measured values of the L_r.

One of the main conclusions of Letey and Feng (2007) was that steady-state analyses generally over predict the negative consequences of irrigating with saline waters. In other words, the L_r is lower than that predicted by steady-state models. Letey (2007) made a comparison among steady-state models and concluded that the highest L_r was calculated with linear averaged soil salt concentrations, intermediate L_r values occurred with the $5EC_{et}$-EC_i model, and the lowest L_r was found with the water-uptake weighted soil salt concentrations, the exponential model. This is confirmation that if a steady model is to be used to evaluate a water quality standard, the exponential model is the closest to the results from a transient model like the ENVIRO-GRO transient model proposed by Letey (2007).

Table 4.1. Comparisons of leaching requirement (L_r) predicted by five steady-state models with experimentally measured leaching requirements for 14 crops with various saline irrigation waters (Hoffman, 1985).

	Data		L_r Prediction Using				
Crop	L_r	EC_i	EC_{e50}	$2EC_{e0}$	$5EC_{et}$-EC_i	40-30-20-10	Exp.
CEREALS							
Barley	0.10	2.2	0.12	0.04	0.06	0.01	0.05
Oat	0.10	2.2	0.18	0.06	0.11	0.04	0.09
Sorghum	0.08	2.2	0.22	0.08	0.07	0.01	0.06
Wheat	0.07	1.4	0.11	0.03	0.05	0.03	0.04
Wheat	0.08	2.2	0.17	0.05	0.08	0.01	0.07
VEGETABLES							
Cauliflower	0.17	2.2	0.31	0.09	0.25	0.22	0.18
Celery	0.14	2.2	0.22	0.06	0.32	0.34	0.20
Cowpea	0.16	2.2	0.24	0.08	0.10	0.03	0.09
Lettuce	0.26	2.2	0.43	0.12	0.51	0.72	0.24
Lettuce	0.22	1.4	0.27	0.08	0.27	0.36	0.18
Tomato	0.21	2.2	0.29	0.09	0.21	0.16	0.16
FORAGES							
Alfalfa	0.20	2.0	0.18	0.05	0.15	0.16	0.13
Alfalfa	0.32	4.0	0.36	0.11	0.36	0.52	0.22
Alfalfa	0.06	1.0	0.11	0.03	0.11	0.09	0.09
Alfalfa	0.15	2.0	0.23	0.06	0.25	0.31	0.17
Barley	0.13	2.2	0.17	0.05	0.08	0.02	0.07
Cowpea	0.17	2.2	0.31	0.09	0.38	0.45	0.22
Fescue	0.10	2.0	0.17	0.05	0.17	0.17	0.13
Fescue	0.25	4.0	0.25	0.07	0.40	0.58	0.23
Oat	0.17	2.2	0.31	0.0	0.25	0.22	0.18
Sudan Grass	0.16	2.0	0.14	0.04	0.19	0.17	0.13
Sudan Grass	0.31	4.0	0.28	0.08	0.49	0.58	0.23

Corwin and coworkers compared the Corwin and Simunek transient models along with the $5EC_{et}$-EC_i and the WATSUIT steady-state computer models (Corwin et al., in press). For their comparative analysis they selected a set of realistic conditions representative of California's Imperial Valley. Details describing the development of the data set from available data sources can be found in Corwin et al. (2007). To estimate the L_r for the entire Imperial Valley they choose a single crop rotation that would be representative of the Valley. From available records, it was found that the dominant crops grown in the Valley during the period 1989-1996 were field crops with alfalfa as the most dominant followed by wheat. Lettuce was the most dominant truck crop. Thus, they choose a 6-year crop rotation of four years of alfalfa, followed by one year of wheat and one year of lettuce. The EC of the irrigation water was taken as 1.23 dS/m (Colorado River water). ET_c values for alfalfa, wheat, and lettuce were assumed to be 5273 (4-year total), 668, and 233 mm, respectively. Additional irrigation water was added to compensate for E during the fallow periods and for the depletion of soil water that occurred during cropping. Table 4.2 summarizes the L_r predicted by the four methods.

Table 4.2. Summary of leaching requirements (L_r) for California's Imperial Valley as estimated by two steady-state and two transient models. (Corwin et al., in press).

Model	Leaching Requirement Crop or Cropping Period Alfalfa	Wheat	Lettuce	Crop Growth*	Overall Rotation*
Steady-State					
$5EC_{et}$ – ECi	0.14	0.04	0.23	0.14	0.13
WATSUIT	0.09	0.03	0.13	0.09	0.08
Transient					
TETrans	<0.14	<0.04	<0.17		<0.13
UNSATCHEM	<0.10	0.00	<0.13		<0.08

**Crop Growth refers to period included in crop simulation and Overall Rotation includes entire rotation with fallow periods.*

Using the area of every crop and an estimate of the L_r for each crop by the $5EC_{et}$-EC_i model to obtain a valley-wide L_r based on the weighted average of the crop areas and the leaching requirements, Jensen and Walter (1998) obtained a L_r value of 0.14 for the Imperial Valley. In comparison, field studies by Oster et al. (1986) showed a similar steady-state estimate of L_r of 0.12. The L_r value obtained from Corwin et al. (2007) as described above was 0.13. The three results are essentially the same.

The conclusions drawn by Corwin et al. (2007) are summarized in this paragraph. Based on the results presented in Table 4.2, they noted that steady-state models over-estimated L_r compared to transient models, but only to a minor extent. The estimates of L_r were significantly reduced when the effect of salt precipitation with Colorado River water was included in the salt-balance calculations, regardless of whether the model was steady-state (WATSUIT) or transient (UNSATCHEM). The small differences in the estimated L_r between WATSUIT and UNSATCHEM shows that accounting for salt precipitation under the conditions of the Imperial Valley was more important than whether the model was a steady-state or transient model. This comparison suggests that there are instances where steady-state models can be used as long as the steady-state model accounts for all the dominant mechanisms such as bypass flow, salt precipitation/dissolution reactions, plant water uptake, and perhaps other factors that are affecting the leaching of salts and that few or no perturbations have occurred over a long time period that would prevent essentially steady-state conditions. For instance, in situations where salt precipitation/dissolution reactions are dominant and temporal dynamic effects are minimal, L_r could be adequately estimated using WATSUIT. Or, in situations where irrigation water quality and amount minimizes the temporal dynamic effects of plant water uptake, L_r could be adequately estimated by the exponential model.

Letey and Feng (2007) compared the $5EC_{et}$-EC_i steady-state model and the ENVIRO-GRO model using inputs from an Israeli field experiment on corn (Feng et al., 2003) for yields of 85, 90, 95, and 100%. Only the results for 100 % yield are given in Table 4.3.

The transient model estimates a lower L_r than the steady-state model. The primary reason for the over estimate of the L_r is that the $5EC_{et}$-EC_i model assumes that the plants response to the linear average root zone salinity.

Table 4.3. Comparison of the calculated leaching requirement for a steady-state model and the ENVIRO-GRO model based on the Israeli field experiment on corn (Letey and Feng, 2007).

Irrigation Salinity dS/m	Leaching Requirement	
	$5EC_{et} – EC_i$ steady-state model	ENVIRO-GRO transient-state model
1.0	0.14	<0.05
2.0	0.32	0.15

Strong evidence that the water quality standard could be raised was presented by Letey (2007) based upon his comparisons between steady-state and transient models. The following is nearly a direct quote from his publication. The reasons that the transient-state analysis simulated a much lower irrigation amount than the steady-state approach for a given yield (see Table 4.3) are as follows: The steady-state approach assumed that the plant responded to the average root zone salinity that increased greatly as the L decreased. However the major amount of water is extracted by plant roots from the upper part of the root zone. Furthermore, the salt concentration at a given depth in the field does not remain constant with time, but is continually changing. The salts become concentrated by water extraction, but the irrigation water “flushes” the salts downward thus reducing the concentration to a lower value at a given depth after irrigation. The concentration immediately after irrigation near the soil surface would be close to the concentration in the irrigation water. For most soils, the volumetric soil-water content would be reduced by less than half between irrigations. (The practice of irrigating when half of the soil water available to the plant has been extracted is a very typical irrigation practice.) Thus the salts would concentrate by less than two between irrigations. Therefore as a general guideline, a water with a salt concentration equal to the Maas and Hoffman threshold value (see Table 3.1) can be used and irrigated with a relatively low L. This conclusion is based on the fact that the Maas and Hoffman coefficients are on the basis of EC_e which is about $EC_{sw}/2$. The soil-water can therefore be concentrated by a factor of two without exceeding the threshold value.

Based upon Letey’s reasoning, the water quality standard could be raised to 1.0 dS/m. This is predicated on the salt tolerance of bean being selected to protect all crops in the South Delta. Since the salt tolerance threshold for bean is 1.0 dS/m the water quality standard could be 1.0 dS/m.

5. Steady-State Modeling for South Delta

5.1. Model Description

5.1.1. Steady-State Assumptions

The models, developed specifically for the South Delta, begin with the equations presented in Section 4.1. At steady state the inputs of irrigation (I) and precipitation (P) must equal crop evapotranspiration (ET_c) plus drainage (D) (see Equation 4.1 presented as depths of water). Furthermore, the amount of salt entering the crop root zone must equal the amount leaving (refer to Equation 4.2). The time frame chosen for the model is yearly and the inputs and outputs are annual (water year, October 1st through September 30th) amounts. Being steady-state models, change in soil water storage and salt mass are assumed to not change from one year to the next. In addition, the steady-state models are one-dimensional, vertical direction only, and do not account for soil permeability. The steady-state models assume no crop water stress and that fertility is adequate and insects and diseases are avoided. The dissolution of salts from the root zone (5 to 10% of the salts leaving the bottom of the root zone from Section 3.11) is not considered in the steady-state model. Also the model is not capable of determining intra-seasonal salinity or double or inter-row cropping. These modeling deficiencies, however, can be addressed by using transient models.

5.1.2. Cropping Assumptions

Three crops were modeled: bean because it is the most salt sensitive crop in the South Delta with any significant acreage; alfalfa, a perennial crop, was used to set the current salinity objective for the time of the year not governed by bean; and almond because it is a salt sensitive, perennial tree crop. The salt tolerance threshold for bean is an EC_e of 1.0 dS/m (refer to Table 3.1). In the model the salinity of the soil water (EC_{sw}) is used. Thus, for ease in comparison, the threshold value for bean is an EC_{sw} of 2.0 dS/m. This assumes the relationship $EC_{sw} = 2 \times EC_e$. The salt tolerance threshold for alfalfa is an EC_e of 2.0 dS/m or an EC_{sw} of 4.0 dS/m. For almond the threshold is an EC_e of 1.5 dS/m or an EC_{sw} of 3.0 dS/m.

Based upon the publication of Goldhamer and Snyder (1989), beans in the San Joaquin Valley are planted from April 1 until as late as mid-June and harvested as early as the end of July until the end of September. Bean was modeled for the three planting shown in the Goldhamer and Snyder report: April 1, May 1, and June 16. For ease in calculations in the model it is assumed that there is no double cropping and that the soil surface is bare from harvest until planting. The model could be used to evaluate bean followed by a second crop or a multi-year crop rotation if desired.

The model was also run for a mature crop of alfalfa assuming seven cuttings per year. Seven is probably the most harvests possible, depending upon weather and possible management decisions only six cuttings may be made. Assuming seven harvests, requires more irrigation water to satisfy crop ET and leaching than six cuttings so a lower salinity objective might be required than for six cuttings.

A mature almond orchard was also modeled. With almond being more salt sensitive than alfalfa, the salinity objective might be lower for almond than alfalfa when bean is not the controlling crop.

5.1.3. Crop Evapotranspiration

Crop water requirements are normally expressed as the rate of evapotranspiration (ET_c). The level of ET_c is related to the evaporative demand of the air above the crop canopy. The evaporative demand can be expressed as the reference evapotranspiration (ET_o) which predicts the effect of climate on the level of crop evapotranspiration of an extended surface of a 4 to 6 inch-tall cool season grass, actively growing, completely shading the ground, and not short of water.

One of the more simple and accurate equations to estimate ET_o is the Hargreaves equation (Hargreaves and Allen, 2003). The equation can be written as

$$ET_o = 0.0023 \times R_a \times (TC + 17.8) \times TR^{0.50} \qquad \text{(Eqn. 5.1)}$$

where R_a is the extraterrestrial radiation, TR is the difference between the mean maximum and minimum daily temperatures in degrees Celsius, and TC is the average of the maximum and minimum daily temperature in degrees Celsius.

Values of ET_o are calculated with the Hargreaves equation using temperature data from the National Climate Data Center (NCDC) station #8999 (Tracy-Carbona) and then compared with ET_o calculated by the Penman-Monteith equation based upon data collected at the California Irrigation Management Information System (CIMIS) station #70 near Manteca in Figure 5.1. The Penman-Monteith equation is generally considered the most comprehensive and accurate equation to estimate ET_o. However, the CIMIS station has a short historical record compared to the 57 years of temperature and precipitation data at the NCDC Tracy-Carbona station. The longer historical record is used in our steady-state analysis; thus, the Hargreaves equation was employed in the model for the years 1952 to 2008. The data in Figure 5.1 shows excellent agreement between the Hargreaves and the Penman-Monteith equations. This excellent comparison validates the use of the Hargreaves equation. Figure 5.2 shows the location of the NCDC #8999, Tracy-Carbona and CIMIS #70 Manteca stations.

The evapotranspiration of a crop (ET_c) can be estimated by multiplying the ET_o value by a crop coefficient (K_c) that accounts for the difference between the crop and cool-season grass. A crop coefficient actually varies from day to day depending on many factors, but it is mainly a function of crop growth and development. Thus, K_c values change as foliage develops and as the crop ages. Crop growth and development rates change somewhat from year to year, but the crop coefficient corresponding to a particular growth stage is assumed to be constant from season to season. Daily variations in ET_c reflect changes in ET_o in response to evaporative demand. The equation to calculate crop evapotranspiration is

$$ET_c = K_c \times ET_o. \qquad \text{(Eqn. 5.2)}$$

Figure 5.1. Monthly reference evapotranspiration (ET_O) calculated with the Hargreaves equation plotted against CIMIS ET_O calculations with the Penman-Monteith equation; using Manteca CIMIS #70 climate data from January 1988 through September 2008.

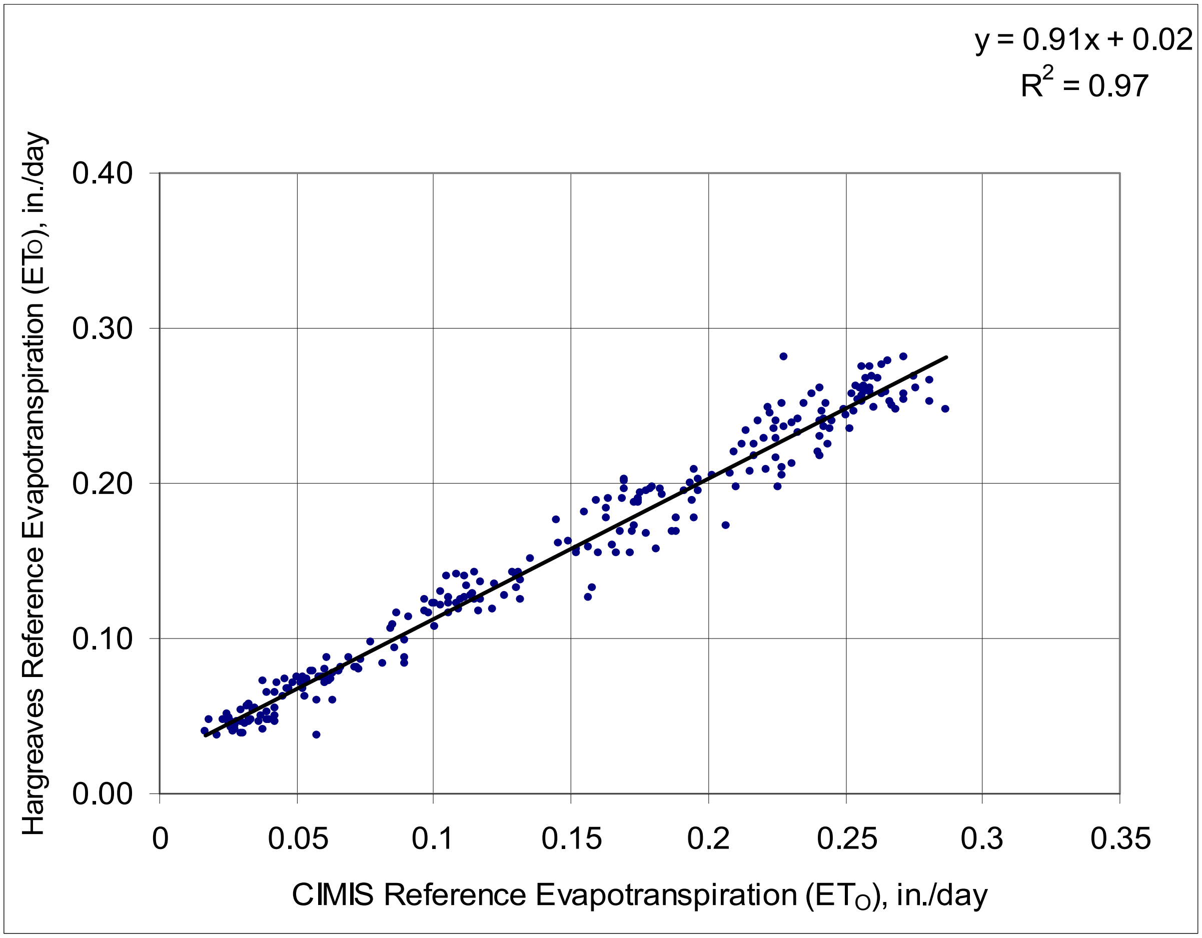
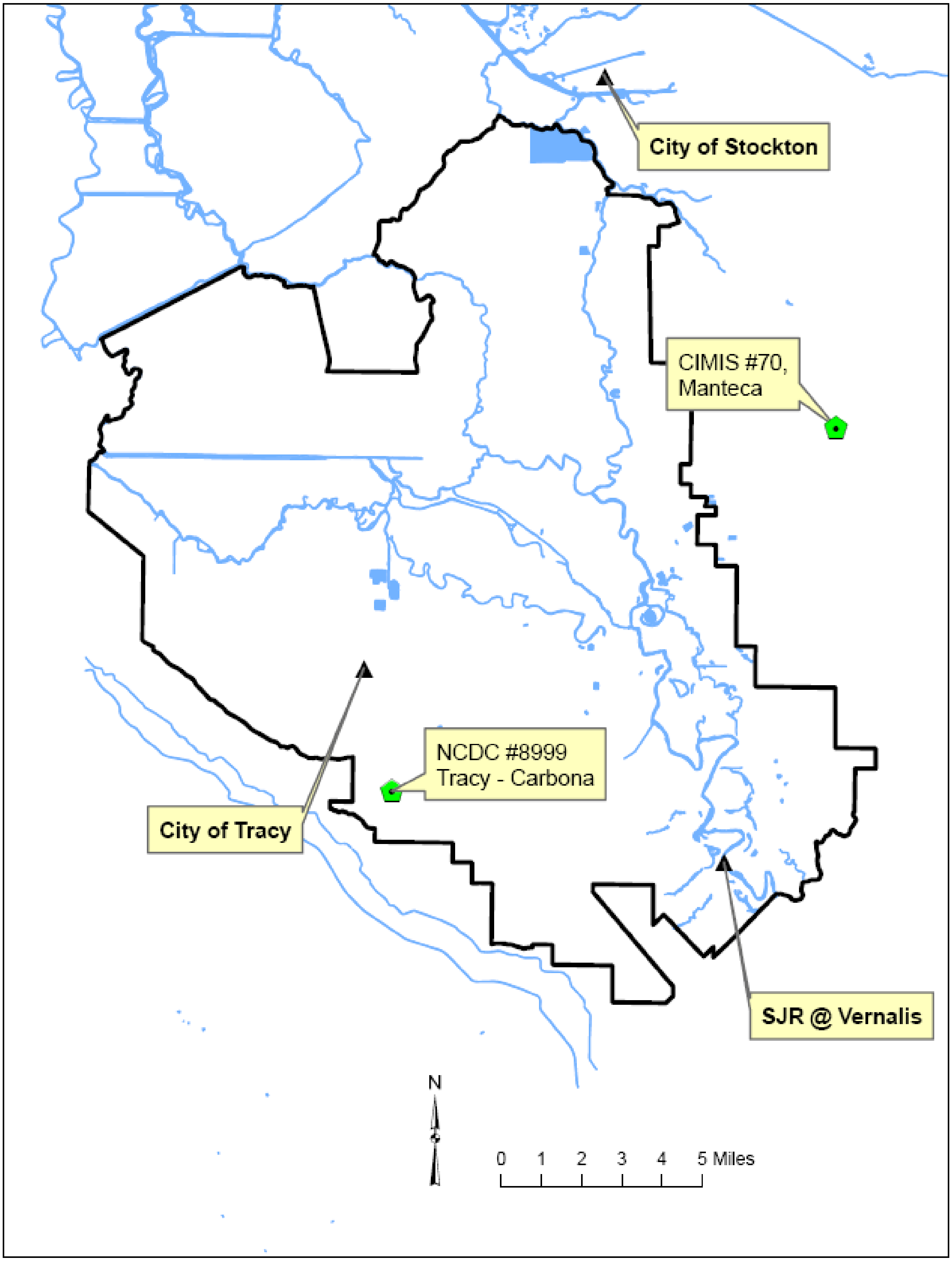
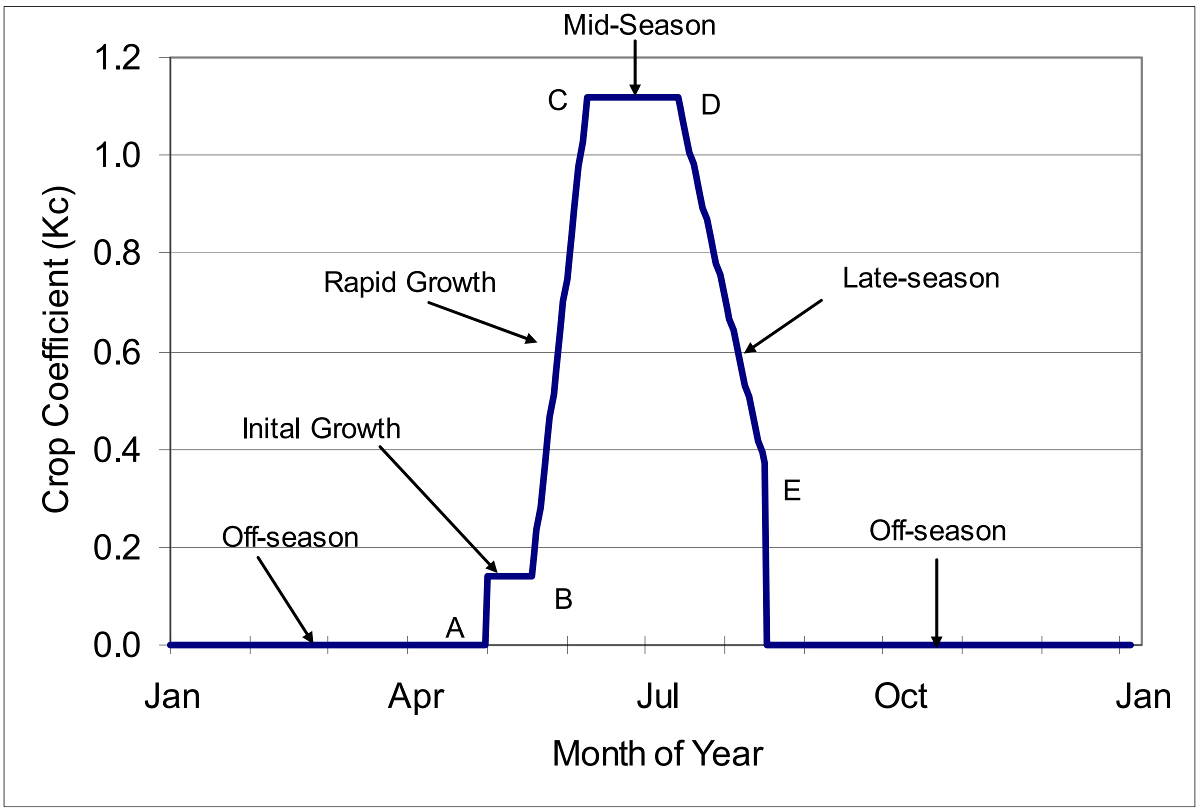


Figure 5.2. Location map for NCDC #8999, Tracy-Carbona and CIMIS #70 Manteca weather stations.



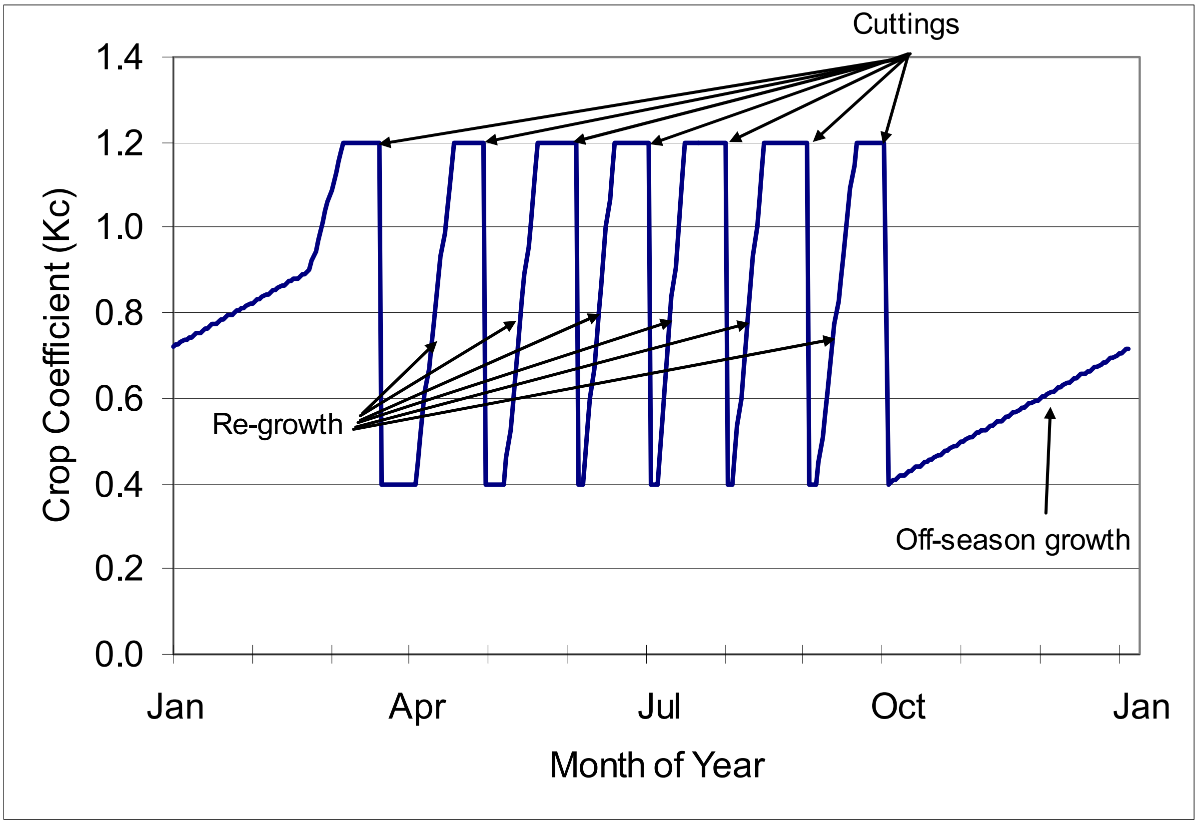
The crop coefficient for annual crops is typically divided into four growth periods as shown in Figure 5.3 for bean (Goldhamer and Snyder, 1989). The four growth periods for annual crops are initial growth, rapid growth, midseason, and late season. Growth is reflected by the percentage of the ground surface shaded by the crop at midday. For annual crops, the K_c dates correspond to: A, planting; B, 10 % ground shading; C, 75 % or peak ground shading; D, leaf aging effects on transpiration; and E, end of season. Figure 5.3 shows the K_c values for bean with a planting date of May 1and the dates when each growth stage changes.

Figure 5.3. Crop coefficients (Kc) for different growth and development periods of bean with May 1st planting date (Goldhamer and Snyder, 1989) used in steady-state modeling.



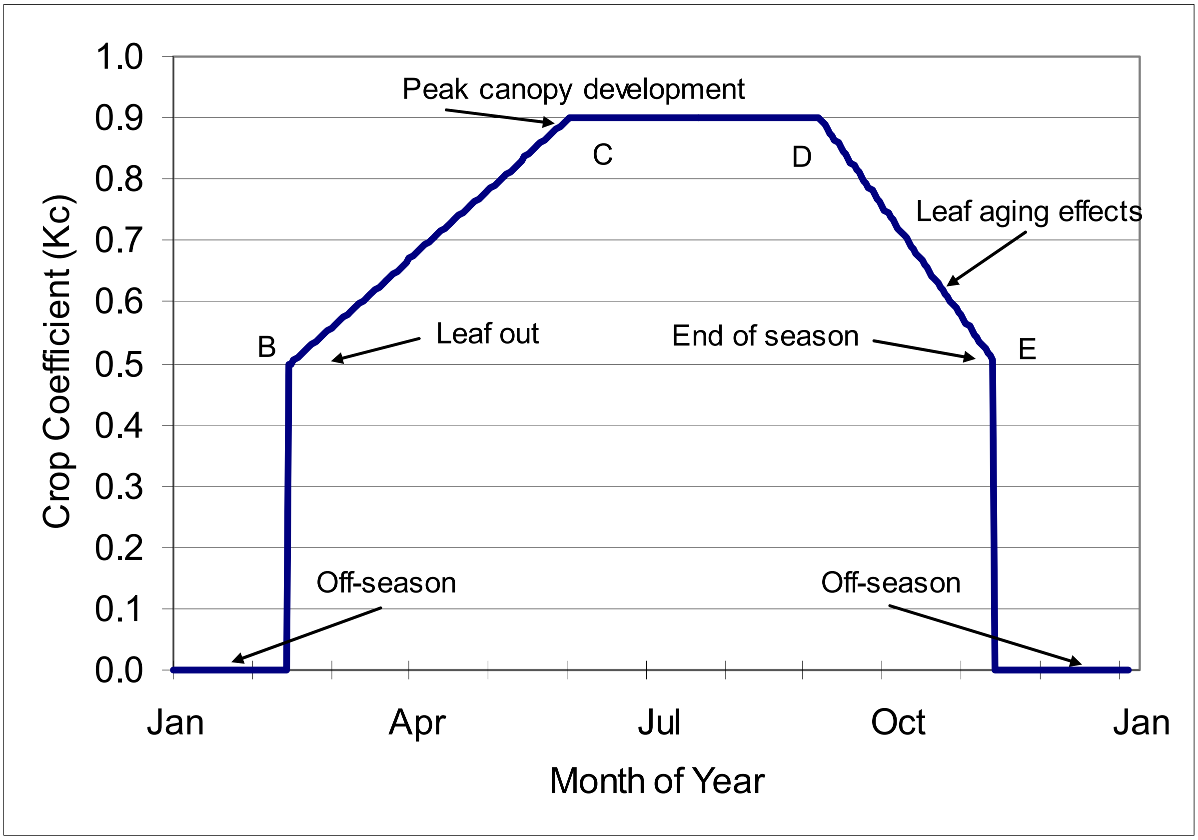
The crop coefficients for alfalfa are presented in Figure 5.4 assuming seven harvests. Note in Figure 5.4 that on the day that alfalfa is cut K_c drops from 1.2 to 0.4 and after a few days increases rapidly to 1.2 as the crop grows. Cuttings are typically made every 28 to 30 days after the first spring cutting.

Figure 5.4. Crop coefficients (Kc) for different growth and development periods assuming 7 cuttings per year of alfalfa (adapted from Goldhamer and Snyder, 1989 and SDWA input) used in steady-state modeling.



The crop coefficients are plotted in Figure 5.5 for almond. The non-growing season for almond was taken as November 10 until February 15 as reported by Goldhamer and Snyder (1989). It was assumed that there was no cover crop. If a cover crop was grown in the almond orchard, ET_c for the cover crop would have to be added to ET_c for almond to determine the irrigation requirements in the models.

Figure 5.5. Crop coefficients (Kc) for the different growth and development periods of almond (Goldhamer and Snyder, 1989) used in steady-state modeling.



5.1.4. Precipitation

To maximize the time period for the model, precipitation records were taken from the NDCD at the Tracy-Carbona Station. Rainfall records are presented by water years (October of previous year through September of the stated water year) from 1952 through 2008.

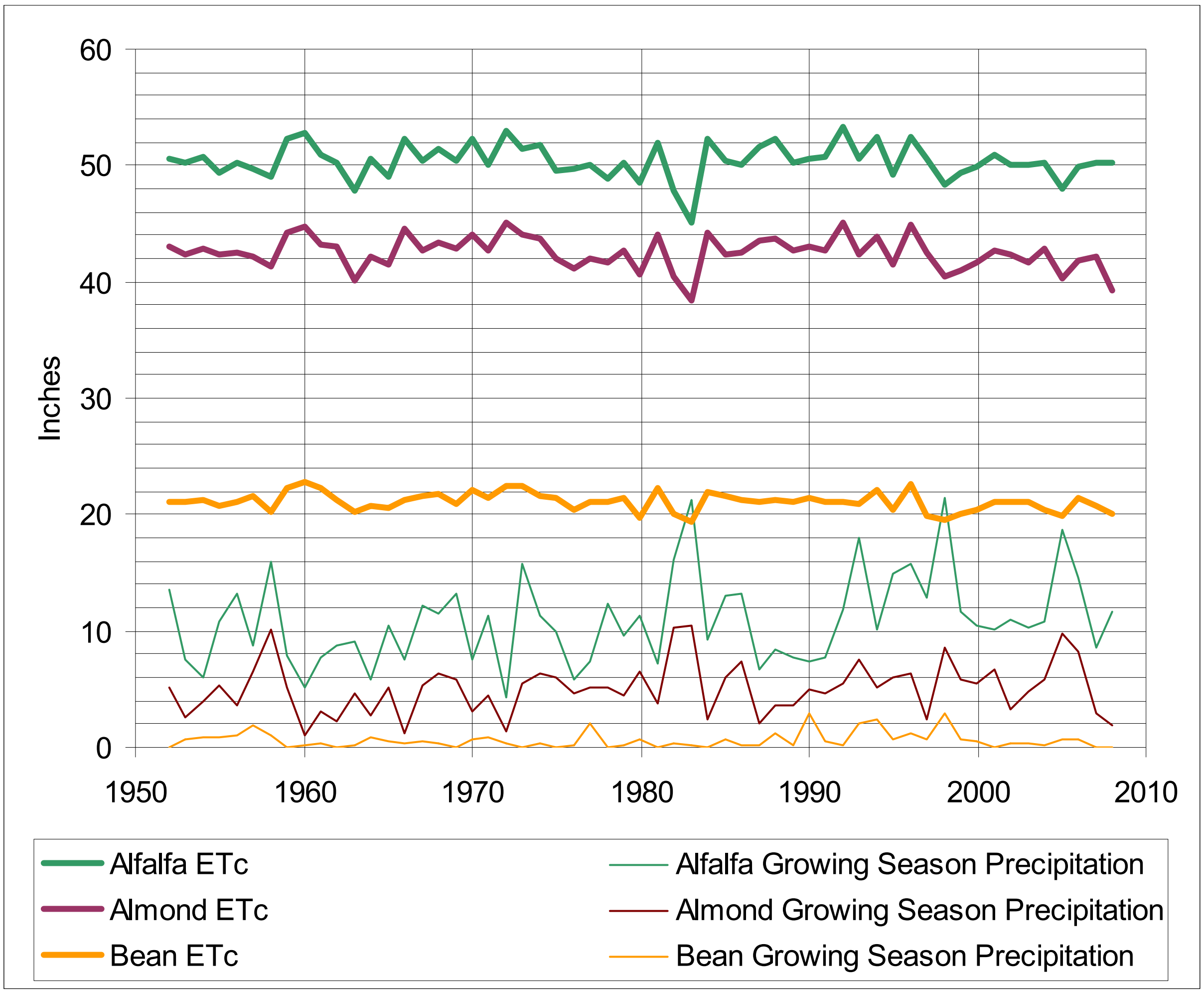
For bean, the rainfall amounts were divided between the amount during the growing season from planting to harvest (P_{GS}) and the remainder of the year (P_{NG}). For alfalfa, all precipitation was assumed to be effective because there was always a crop present. The non-growing season for almond was November 10 until February 15.

It was also assumed that all rainfall occurring during the growing season was consumed by evapotranspiration for all three crops. The reasons for this assumption are given in Section 3.5.2. The amount of rainfall during the growing season (P_{GS}) for bean never exceeded 4.1 inches and the median was only 1.2 inches over the 57 years of rainfall record. For almond the median amount of rainfall during the growing season (Pgs) was 5.1 inches with the maximum being 10.5 inches and the minimum being 1.0 inch. Thus, if some runoff occurred it would generally be insignificant.

During the non-growing season the rate of surface evaporation (E_s) was taken as 0.7 inches per month as discussed in Section 3.5.2. This value was also used in the Grattan model for the watershed near Davis, CA. For bean with a 3.5-month growing season, surface evaporation (E_S) would total 6.0 inches for the 8.5 months of the year without a crop. On a yearly basis, the evapotranspiration for bean was added to the 6.0 inches of E_s to obtain one of the outputs from the root zone. The values for ET_C, and P_{GS}, for bean planted on May 1 are plotted in Figure 5.6 and listed in Table 5.1 for water years 1952 to 2008. P_{EFF} is P_{GS} + (P_{NG} - E_S) and is also listed in Table 5.1. P_{GS} is taken as contributing to ET_C and P_{NG} is reduced annually by E_S or 6.0 inches per year. As reported in Table 5.1 for bean, in only 4 years of the 57 years of record was P_{EFF} negative (1960, 1964, 1972 and 1976) which means that stored water had to be used to satisfy E_S. This result is similar to Figure 3.11 which shows that non-growing season precipitation (P_{NG}) is less than surface evaporation for 7 of the 57 years. Surface runoff was assumed to be zero for the reasons stated in Section 3.5.2. Thus, all of the precipitation and irrigation is assumed to infiltrate the soil surface and be available for surface evaporation, crop evapotranspiration, or leaching.

The annual evapotranspiration (ET_C) for alfalfa and almond from 1952 until 2008 is also shown in Figure 5.6 along with the annual growing season precipitation for both alfalfa and almond. Note as alfalfa is growing at some level all year, the associated annual growing season precipitation is equal to the total measured annual precipitation (P_T).

Figure 5.6. Comparison of crop evapotranspiration (ET_C) estimate for bean, alfalfa, and almond against total precipitation during the corresponding growing season (P_{GS}) with precipitation data from NCDC station no. 8999, Tracy-Carbona for water years 1952 through 2008. Note that P_{GS} for alfalfa is equal to total precipitation for the year.



5.1.5. Steady-State Models

As discussed in Sections 3.9 and 4.1, there are two crop water uptake distribution models that appear to be appropriate to calculate the average soil salinity. One distribution assumes a 40-30-20-10 uptake distribution by quarter fractions of the root zone and the other assumes an exponential uptake distribution. These patterns are described in detail in Section 3.9. Although the exponential pattern agrees the best with experimental results (see Section 4.1), both are used in this modeling effort because the 40-30-20-10 pattern is used in several models.

The equations used in the model to calculate the average EC_{SW} for both water uptake distributions are given in Table 5.2. Both equations use EC_i when precipitation is ignored and EC_{AW} when rainfall is considered.

Table 5.1. Output from the steady-state models both 1) without precipitation and 2) including precipitation (all equations defined in Table 5.2) with precipitation data from NCDC Tracy-Carbona Station #8999 and crop evapotranspiration coefficients from Goldhamer & Snyder (1989) for beans with May 1st planting date.

Input Variables							Model Output						
	EC_i = 1.0			L = 0.15			1) without precipitation			2) with precipitation			
Water Year	P_T (in.)	P_{NG} (in.)	E_S (in.)	P_{GS} (in.)	P_{EFF} (in.)	ET_C (in.)	I_1 (in.)	EC_{SWa-1} (dS/m)	EC_{SWb-1} (dS/m)	I_2 (in.)	EC_{AW-2} (dS/m)	EC_{SWa-2} (dS/m)	EC_{SWb-2} (dS/m)
1952	13.5	13.5	6.0	0.1	7.5	21.0	24.7	3.18	2.46	17.2	0.69	2.21	1.71
1953	7.6	7.0	6.0	0.6	1.6	21.1	24.8	3.18	2.46	23.2	0.93	2.97	2.30
1954	6.1	5.3	6.0	0.8	0.1	21.3	25.0	3.18	2.46	24.9	1.00	3.17	2.45
1955	10.9	10.0	6.0	0.8	4.9	20.7	24.3	3.18	2.46	19.4	0.80	2.54	1.97
1956	13.2	12.1	6.0	1.0	7.2	21.0	24.7	3.18	2.46	17.6	0.71	2.26	1.75
1957	8.8	7.0	6.0	1.9	2.8	21.6	25.4	3.18	2.46	22.6	0.89	2.82	2.19
1958	16.0	15.0	6.0	1.0	10.0	20.2	23.7	3.18	2.46	13.7	0.58	1.83	1.42
1959	7.9	7.9	6.0	0.0	1.9	22.3	26.3	3.18	2.46	24.4	0.93	2.95	2.28
1960	5.1	4.9	6.0	0.1	-0.9	22.8	26.8	3.18	2.46	27.7	1.03	3.29	2.55
1961	7.8	7.5	6.0	0.3	1.8	22.3	26.3	3.18	2.46	24.5	0.93	2.96	2.29
1962	8.7	8.7	6.0	0.0	2.8	21.3	25.1	3.18	2.46	22.3	0.89	2.83	2.19
1963	9.1	9.0	6.0	0.1	3.1	20.2	23.8	3.18	2.46	20.7	0.87	2.76	2.14
1964	5.9	5.1	6.0	0.8	-0.1	20.7	24.4	3.18	2.46	24.5	1.00	3.19	2.47
1965	10.5	9.9	6.0	0.5	4.5	20.6	24.2	3.18	2.46	19.7	0.81	2.59	2.00
1966	7.5	7.1	6.0	0.4	1.5	21.3	25.1	3.18	2.46	23.6	0.94	2.99	2.31
1967	12.2	11.7	6.0	0.5	6.2	21.6	25.5	3.18	2.46	19.3	0.76	2.41	1.86
1968	11.5	11.2	6.0	0.3	5.5	21.7	25.6	3.18	2.46	20.1	0.78	2.50	1.93
1969	13.2	13.2	6.0	0.0	7.3	20.8	24.5	3.18	2.46	17.2	0.70	2.24	1.73
1970	7.6	7.0	6.0	0.7	1.6	22.1	25.9	3.18	2.46	24.3	0.94	2.98	2.31
1971	11.4	10.6	6.0	0.8	5.4	21.5	25.3	3.18	2.46	19.8	0.78	2.50	1.93
1972	4.2	3.9	6.0	0.3	-1.8	22.5	26.4	3.18	2.46	28.2	1.07	3.39	2.63
1973	15.7	15.7	6.0	0.0	9.8	22.5	26.5	3.18	2.46	16.7	0.63	2.01	1.55
1974	11.4	11.0	6.0	0.4	5.4	21.6	25.5	3.18	2.46	20.0	0.79	2.50	1.94
1975	10.0	9.9	6.0	0.1	4.0	21.4	25.1	3.18	2.46	21.1	0.84	2.67	2.07
1976	5.8	5.7	6.0	0.1	-0.1	20.5	24.1	3.18	2.46	24.2	1.01	3.20	2.48
1977	7.4	5.4	6.0	2.0	1.4	21.1	24.8	3.18	2.46	23.4	0.94	3.00	2.32
1978	12.3	12.3	6.0	0.1	6.3	21.1	24.8	3.18	2.46	18.5	0.74	2.37	1.83
1979	9.6	9.4	6.0	0.2	3.6	21.4	25.2	3.18	2.46	21.6	0.86	2.73	2.11
1980	11.4	10.8	6.0	0.6	5.4	19.8	23.2	3.18	2.46	17.9	0.77	2.44	1.89
1981	7.2	7.1	6.0	0.1	1.2	22.4	26.3	3.18	2.46	25.1	0.95	3.03	2.34
1982	16.2	15.9	6.0	0.3	10.2	20.1	23.6	3.18	2.46	13.4	0.57	1.81	1.40
1983	21.3	21.2	6.0	0.1	15.3	19.3	22.7	3.18	2.46	7.4	0.32	1.03	0.80
1984	9.2	9.2	6.0	0.0	3.2	22.0	25.8	3.18	2.46	22.6	0.88	2.79	2.16
1985	13.1	12.4	6.0	0.7	7.1	21.6	25.5	3.18	2.46	18.4	0.72	2.29	1.78
1986	13.3	13.0	6.0	0.3	7.3	21.3	25.0	3.18	2.46	17.8	0.71	2.26	1.75
1987	6.7	6.6	6.0	0.1	0.7	21.1	24.8	3.18	2.46	24.1	0.97	3.09	2.39
1988	8.4	7.2	6.0	1.2	2.4	21.3	25.0	3.18	2.46	22.6	0.90	2.87	2.22
1989	7.7	7.5	6.0	0.2	1.7	21.1	24.8	3.18	2.46	23.1	0.93	2.96	2.29
1990	7.3	4.4	6.0	3.0	1.4	21.5	25.3	3.18	2.46	23.9	0.95	3.01	2.33
1991	7.7	7.1	6.0	0.6	1.7	21.0	24.7	3.18	2.46	23.0	0.93	2.96	2.29
1992	11.8	11.7	6.0	0.1	5.8	21.1	24.8	3.18	2.46	19.0	0.77	2.44	1.89
1993	17.9	15.8	6.0	2.1	12.0	20.8	24.5	3.18	2.46	12.5	0.51	1.63	1.26
1994	10.1	7.7	6.0	2.4	4.2	22.1	25.9	3.18	2.46	21.8	0.84	2.67	2.07
1995	14.9	14.2	6.0	0.7	8.9	20.4	24.0	3.18	2.46	15.1	0.63	2.00	1.55
1996	15.7	14.5	6.0	1.2	9.7	22.6	26.5	3.18	2.46	16.8	0.63	2.02	1.56
1997	12.9	12.3	6.0	0.7	7.0	19.9	23.4	3.18	2.46	16.4	0.70	2.23	1.73
1998	21.4	18.5	6.0	2.9	15.4	19.6	23.1	3.18	2.46	7.7	0.33	1.05	0.82
1999	11.7	10.9	6.0	0.8	5.7	20.1	23.7	3.18	2.46	18.0	0.76	2.41	1.87
2000	10.4	9.9	6.0	0.5	4.4	20.4	24.0	3.18	2.46	19.5	0.82	2.60	2.01
2001	10.1	10.1	6.0	0.0	4.2	21.1	24.8	3.18	2.46	20.6	0.83	2.65	2.05
2002	11.0	10.7	6.0	0.3	5.0	21.1	24.8	3.18	2.46	19.8	0.80	2.54	1.97
2003	10.3	10.0	6.0	0.3	4.4	21.0	24.7	3.18	2.46	20.3	0.82	2.62	2.03
2004	10.9	10.7	6.0	0.2	4.9	20.4	24.0	3.18	2.46	19.1	0.80	2.53	1.96
2005	18.6	17.9	6.0	0.8	12.7	19.9	23.5	3.18	2.46	10.8	0.46	1.46	1.13
2006	14.6	13.9	6.0	0.7	8.6	21.5	25.3	3.18	2.46	16.7	0.66	2.10	1.62
2007	8.6	8.6	6.0	0.0	2.6	20.8	24.5	3.18	2.46	21.9	0.89	2.84	2.20
2008	11.7	11.7	6.0	0.0	5.7	20.0	23.5	3.18	2.46	17.8	0.76	2.41	1.87
Median:	10.5	10.0	6.0	0.4	4.5	21.1	24.8	3.18	2.46	20.0	0.81	2.59	2.00
Max:	21.4	21.2	6.0	3.0	15.4	22.8	26.8	3.18	2.46	28.2	1.1	3.39	2.63
Min:	4.2	3.9	6.0	0.0	-1.8	19.3	22.7	3.18	2.46	7.4	0.32	1.03	0.80

Table 5.2. Definition of input variables and equations for the steady-state models.

Input Variables

L = leaching fraction (input assumption)

EC_i = irrigation water salinity (input assumption)

P_T = total annual precipitation

P_{NG} = total precipitation during the non-growing season (dates determined by Goldhamer & Snyder, 1989)

E_S = total off-season surface evaporation (0.7 in/mo. from end of previous to beginning of stated water year's growing season)

P_{GS} = total precipitation during the growing season (dates determined by Goldhamer & Snyder, 1989)

P_{EFF} = total effective precipitation where: $P_{EFF} = P_{GS} + (P_{NG} - E_S)$

ET_C = total crop evapotranspiration as calculated per Goldhamer & Snyder 1989 (total for growing season of stated water year)

Steady-State Equations (without consideration of precipitation)

For a particular water year:

I_1 = irrigation required to satisfy assumed L given total ET_C (excluding precipitation): $I_1 = ET_C / (1\text{-}L)$

$$EC_{SWa\text{-}1} = \left[ECi + \frac{EC_i * I_1}{I_1 - (0.4 * ET_C)} + \frac{EC_i * I_1}{I_1 - (0.7 * ET_C)} + \frac{EC_i * I_1}{I_1 - (0.9 * ET_C)} + \frac{EC_i * I_1}{I_1 - ET_C} \right] \div 5$$

$$EC_{SWb\text{-}1} = \left[\left(\frac{1}{L}\right) + \left(\frac{0.2}{L}\right) * \ln\left[L + (1 - L) * \exp(-5)\right] - 1.7254 \right] * EC_i$$

Steady-State Equations (including consideration of precipitation)

For a particular water year:

I_2 = amount of irrigation required to maintain L (accounting for precipitation): $I_2 = [ET_C / (1\text{-}L)] - P_{EFF}$

EC_{AW} = salinity of applied water (combined $P_{EFF} + I_2$): $EC_{AW} = I_2 \times EC_i / (P_{EFF} + I_2)$.

$$EC_{SWa\text{-}2} = \left[EC_{AW} + \frac{EC_{AW} * (I_2 + P_{EFF})}{(I_2 + P_{EFF}) - (0.4 * ET_C)} + \frac{EC_{AW} * (I_2 + P_{EFF})}{(I_2 + P_{EFF}) - (0.7 * ET_C)} + \frac{EC_{AW} * (I_2 + P_{EFF})}{(I_2 + P_{EFF}) - (0.9 * ET_C)} + \frac{EC_{AW} * (I_2 + P_{EFF})}{(I_2 + P_{EFF}) - ET_C} \right] \div 5$$

$$EC_{SWb\text{-}2} = \left[\left(\frac{1}{L}\right) + \left(\frac{0.2}{L}\right) * \ln\left[L + (1 - L) * \exp(-5)\right] - 1.7254 \right] * EC_{AW}$$

5.2. Model Results

5.2.1. Bean

An example of the calculated irrigation amounts and the soil water salinity values for 57 water years is given for the May 1 planting date in Table 5.1. Values are presented for both water uptake distributions with and without precipitation. The example is for model input variables of EC_i = 1.0 dS/m and L = 0.15. The input values for total, growing season, and non-growing season precipitation, off season evaporation, and crop evapotranspiration for the 57 water years are also given in Table 5.1. The model was run over a range of EC_i values from 0.5 to 2.0 dS/m, with L = 0.15, 0.20, and 0.25.

Results from the exponential model are summarized in Table 5.3 for the three planting dates and corresponding crop coefficients given by Goldhamer and Snyder (1989) for the San Joaquin Valley. Also shown in Table 5.3 are the median values for soil salinity to compare with the salt tolerance threshold for bean. Note that the planting date has no impact on the soil salinity values for either an EC_i of 0.7 or 1.0 dS/m. Soil salinity values are given for three leaching fractions (0.15, 0.20, and 0.25). As expected, the higher the leaching fraction, the lower the soil salinity. Based upon the leaching fractions calculated from the effluent from subsurface drainage systems, Section 3.13.2, no leaching fractions below 0.15 were modeled for bean. No median values reported in Table 5.3 exceeded the salt tolerance threshold for bean.

The results given in Table 5.3 are the median values for the median annual rainfall of 10.5 inches. If the rainfall is below 10.5 inches the soil salinity may exceed the salt tolerance threshold. Figure 5.7 shows the impact of rainfall on the average soil salinity for an EC_i of 0.7 dS/m for both the 40-30-20-10 model and the exponential model for leaching fractions of 0.15, 0.20, and 0.25. For the 40-30-20-10 model, regardless of the amount of annual rainfall the bean threshold is not exceeded if the leaching fraction is higher than 0.20. However, as the rainfall drops below 7 inches the threshold is exceeded and some yield loss would occur for a L of 0.15. For the exponential model no yield loss would occur even if the annual rainfall total is 4 inches if the leaching fraction is higher than 0.15. Thus, there is basically no risk for a loss in bean yield if EC_i is 0.7 dS/m.

Figure 5.8 shows the modeling results when EC_i is 1.0 dS/m. In this scenario, bean yield losses occur even at the median rainfall for the 40-30-20-10 model except at a leaching fraction of 0.25. At the five percentile for rainfall, about 6 inches, the yield loss would be 11, 7, and 3% for leaching fractions of 0.15, 0.20, and 0.25, respectively, using equation 3.1. In contrast, the exponential model would predict no yield loss for leaching fractions above 0.20. For 15% leaching and at the five percentile for rainfall, yield loss would be 5% using the exponential model. Thus, there is some risk of bean yield loss when annual rainfall is low but the worse case would be a yield loss of 11% at a leaching fraction of 0.15 and using the 40-30-20-10 model. Almost no risk is predicted with the exponential model.

Table 5.3. Comparison of growth stage coefficients and dates for the three plantings of dry beans presented in Goldhamer and Snyder (1989) and corresponding exponential model output (median EC_{SWb-2}) at L = 0.15, 0.20, and 0.25 with ECi = 0.7 and 1.0 dS/m.

April 1st Planting Date

Growth Stage	Kc	Dates
Initial Growth	0.14	April 1 thru 30th
Rapid Growth	0.14 to 1.15	April 30 to May 25
Mid-Season	1.15	May 25 to June 29
Late Season	1.15 to 0.30	June 29 to July 31
		121 Days Total

Median EC_{SWb-2}

	L = 0.15	L = 0.20	L = 0.25
EC_i = 0.7 dS/m	1.38	0.97	0.68
EC_i =1.0 dS/m	1.98	1.38	0.98

May 1st Planting Date

Growth Stage	Kc	Dates
Initial Growth	0.14	May 1 to 18th
Rapid Growth	0.14 to 1.12	May 18 to June 8
Mid-Season	1.12	June 8 to July 12
Late Season	1.12 to 0.35	July 12 to August 15
		106 Days Total

Median EC_{SWb-2}

	L = 0.15	L = 0.20	L = 0.25
EC_i = 0.7 dS/m	1.40	0.98	0.69
EC_i =1.0 dS/m	2.00	1.40	0.99

June 16th Planting Date

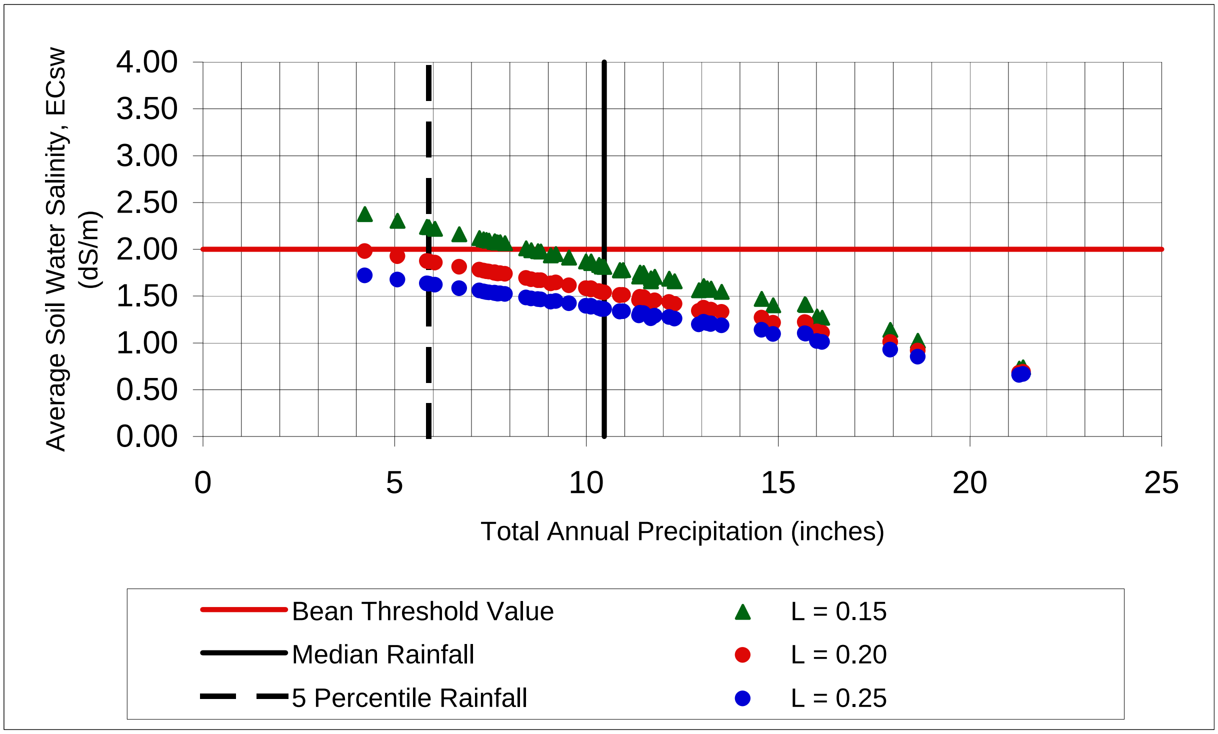
Growth Stage	Kc	Dates
Initial Growth	0.13	June 16 to July 1
Rapid Growth	0.13 to 1.07	July 1 to July 26
Mid-Season	1.07	July 26 to Sept. 2
Late Season	1.07 to 0.20	Sept. 2 to Sept. 30
		106 Days Total

Median EC_{SWb-2}

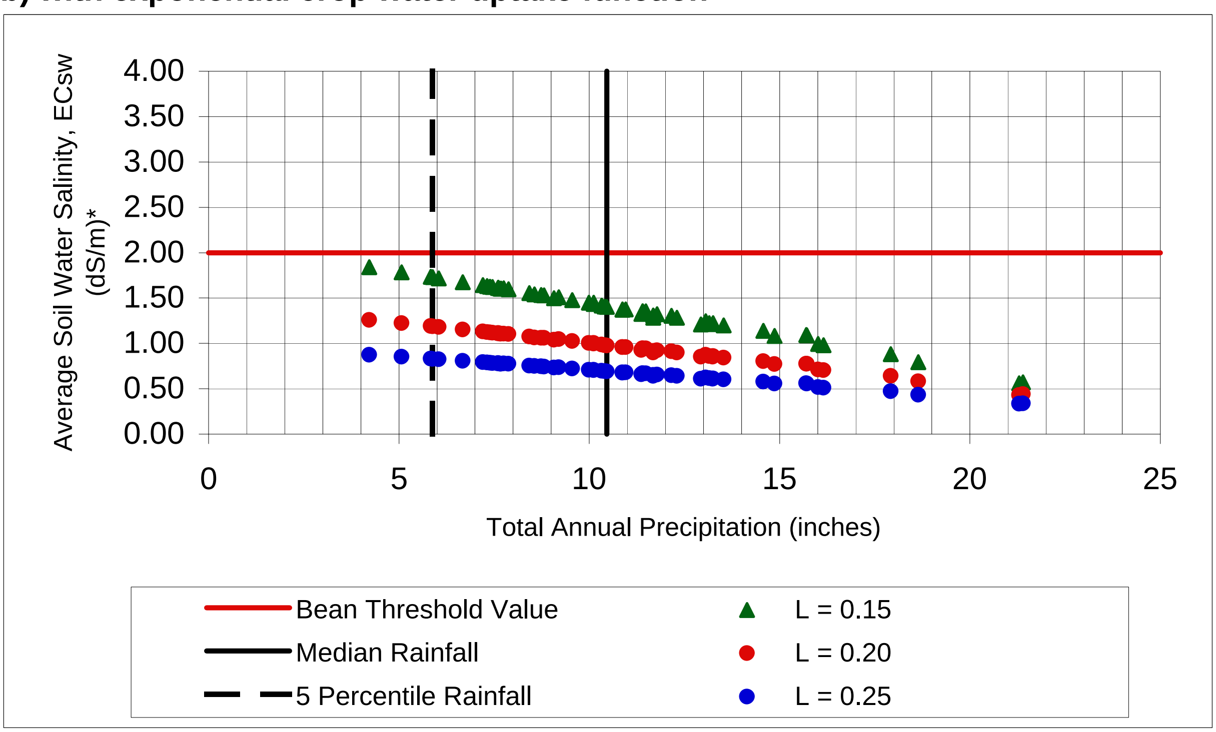
	L = 0.15	L = 0.20	L = 0.25
EC_i = 0.7 dS/m	1.36	0.95	0.67
EC_i =1.0 dS/m	1.95	1.36	0.96

Figure 5.7. Average soil water salinity (ECsw) vs. total annual rainfall for bean with leaching fractions ranging from 0.15 to 0.25 and irrigation water (EC_i) = 0.7 dS/m using both 40-30-20-10 and exponential crop water uptake functions (precipitation from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008) .

a) with 40-30-20-10 crop water uptake function



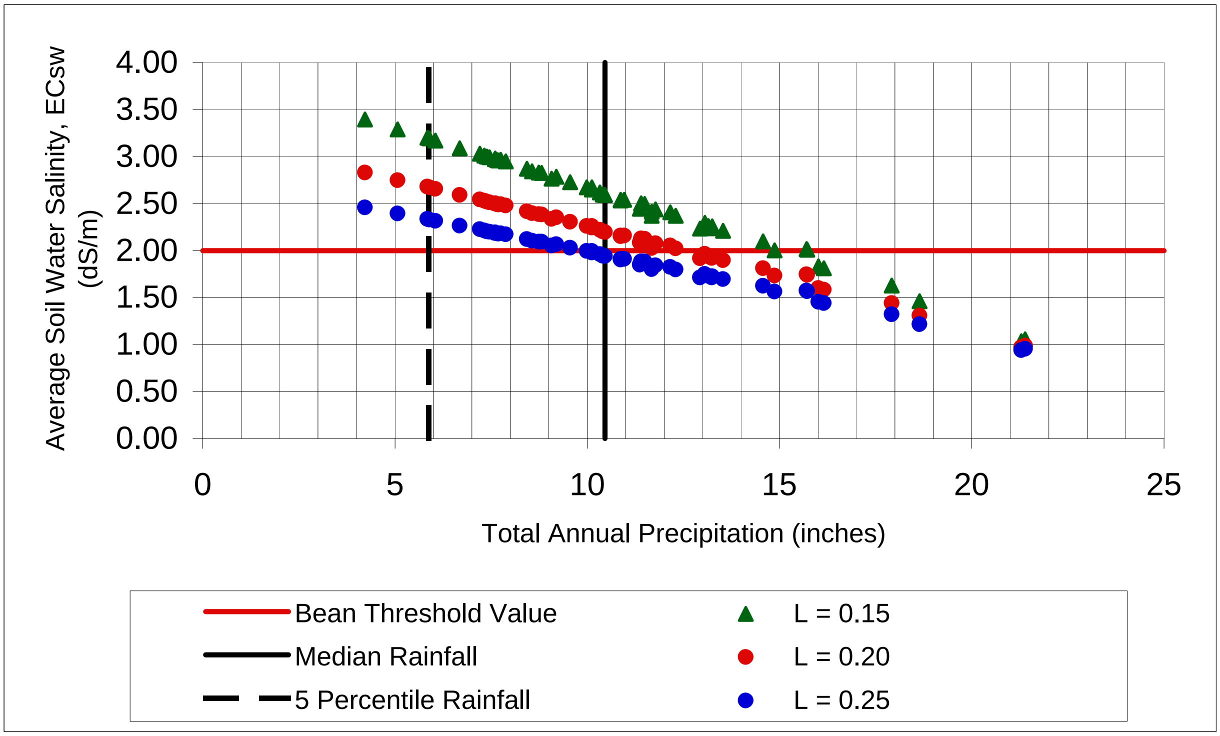
b) with exponential crop water uptake function*



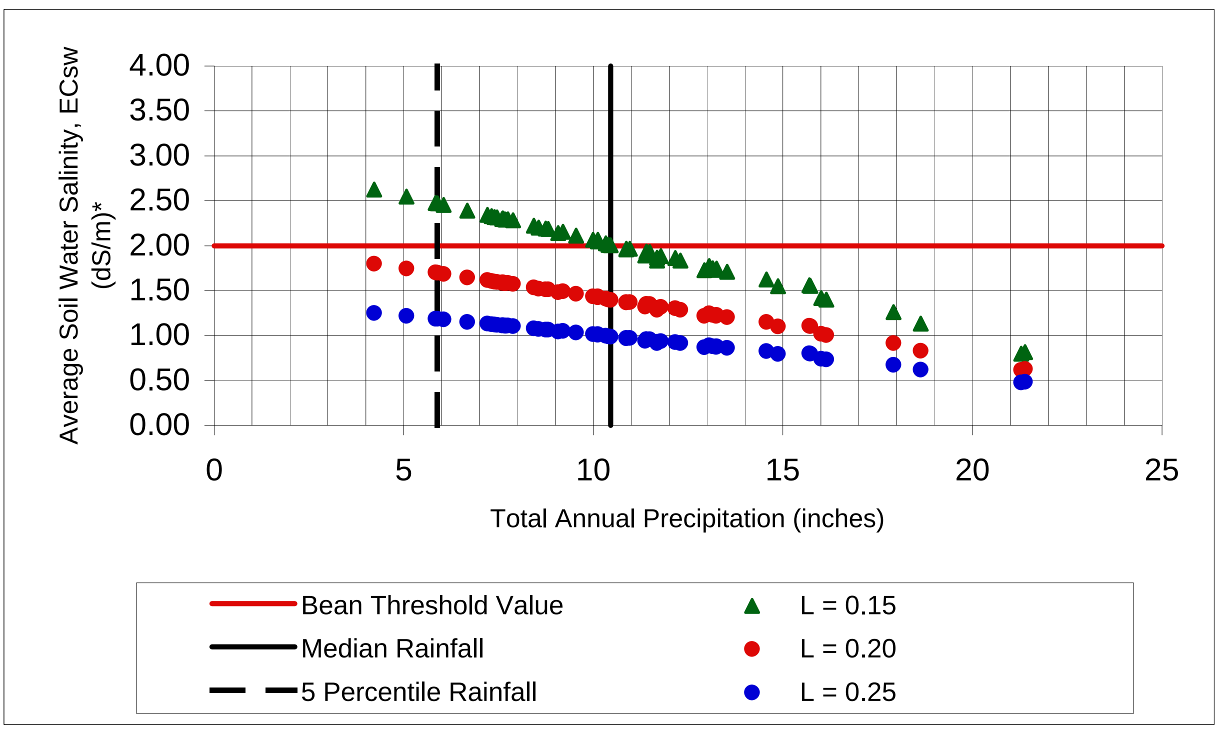
** As discussed in Section 4.1, the average soil water salinity was reduced by the soil salinity at 50% leaching for the exponential model.*

Figure 5.8. Average soil water salinity (ECsw) vs. total annual rainfall for bean with leaching fractions ranging from 0.15 to 0.25 and irrigation water (EC_i) = 1.0 dS/m using both 40-30-20-10 and exponential crop water uptake functions (precipitation from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008) .

a) with 40-30-20-10 crop water uptake function



b) with exponential crop water uptake function*



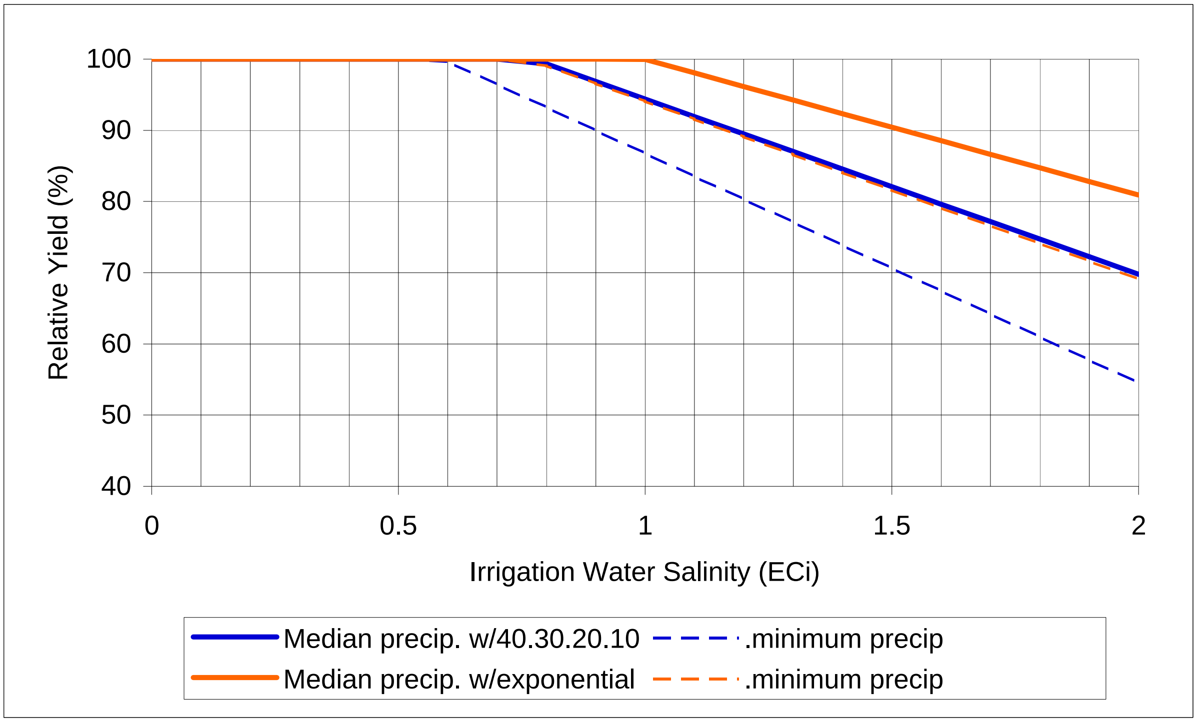
** As discussed in Section 4.1, the average soil water salinity was reduced by the soil salinity at 50% leaching for the exponential model.*

The results for median and minimum precipitation values are shown in Figure 5.9 with relative bean yield shown as a function of irrigation water salinity. The dashed lines assume minimum precipitation from the NCDC Tracy- Carbona station and the solid lines are for median precipitation. First, the average of the threshold point for L=0.15 and 0.20 with the 40-30-20-10 approach and minimum precipitation shows that an ECi of about 0.7 dS/m could be used without bean yield loss. This is in general agreement with the analysis of Ayers and Westcott (1976), which assumed no precipitation. When considering median precipitation with the 40-30-20-10 approach, EC_i increases to 0.77 dS/m at L=0.15 and 0.92 dS/m for a L of 0.2 as the threshold. The model results for the exponential water uptake distribution gives a permissible EC_i of 0.80 dS/m at a L of 0.15 with minimum precipitation without bean yield loss. Considering median precipitation at a L of 0.15, EC_i at the bean threshold is 1.0 dS/m. EC_i using the exponential model could be increased even further if the leaching fraction is increased above 0.15.

Figure 5.10 presents the relative crop yield for bean with L = 0.15 at ECi = 0.7 and 1.0 dS/m against total annual rainfall using both 40-30-20-10 and exponential crop water uptake functions. This is useful for visualizing how the relative yield is distributed around the median value as a function of annual precipitation. As shown in Figure 5.10 the exponential model shows no reduction in bean yield regardless of precipitation for an EC_i = 0.7 dS/m and a yield reduction of 6 % with the lowest recorded precipitation at an EC_i = 1.0 dS/m.

Figure 5.9. Relative bean yield (percent) as a function of irrigation water salinity (ECi) with a) L = 0.15 and b) L = 0.20 assuming median precipitation (solid lines) and minimum precipitation (dashed lines) from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008.

a) L = 0.15



b) L = 0.20

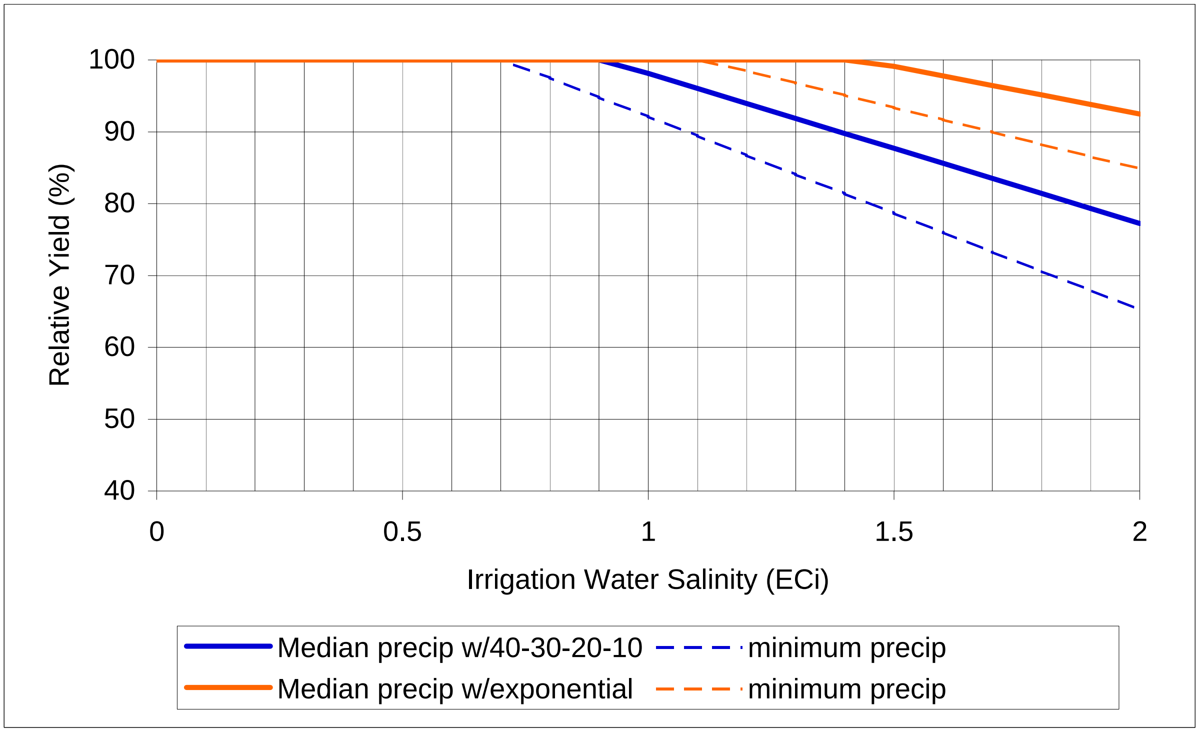
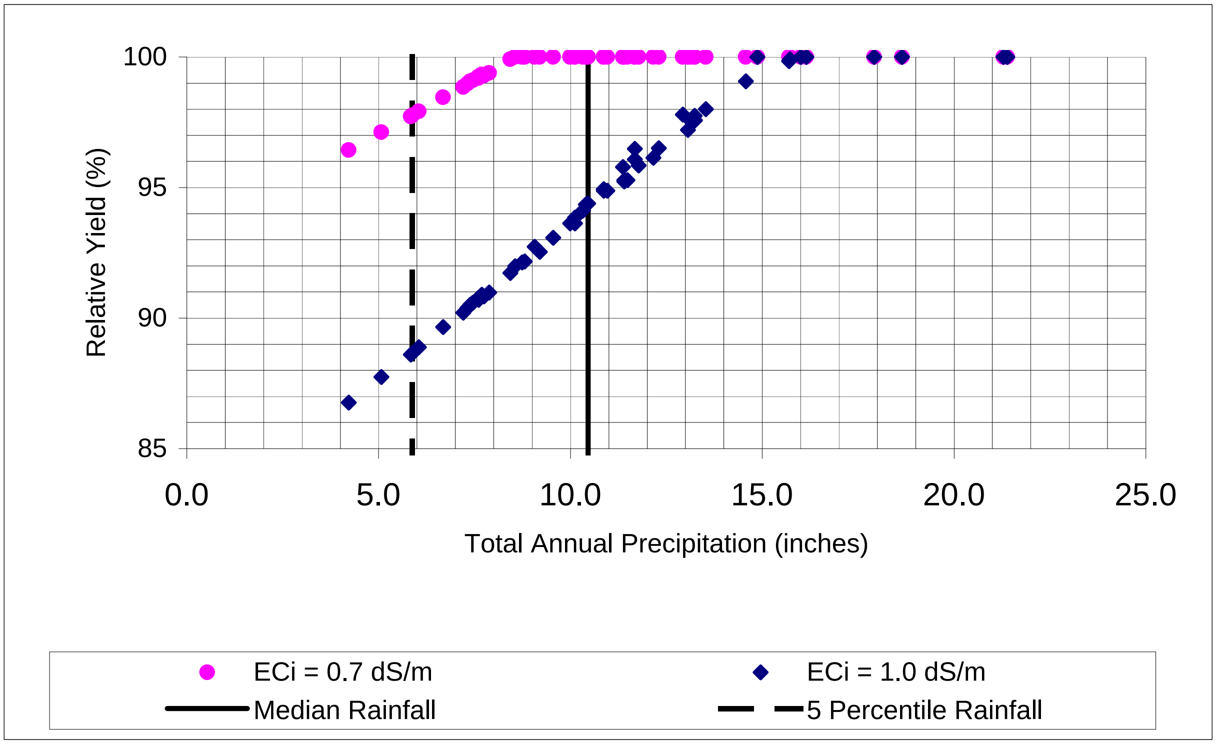
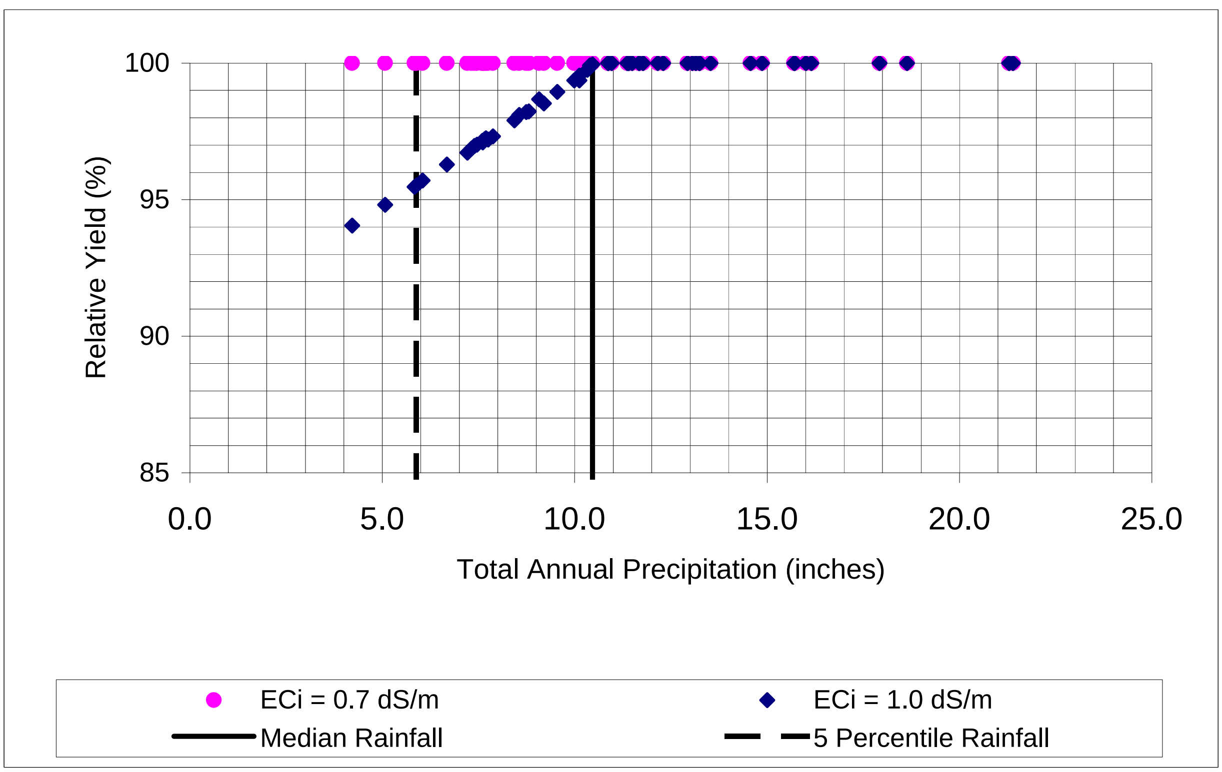


Figure 5.10. Relative crop yield (%) for bean with L = 0.15 at EC_i = 0.7 and 1.0 dS/m vs. total annual rainfall using both 40-30-20-10 and exponential crop water uptake functions (precipitation from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008).

a) with 40-30-20-10 crop water uptake function



b) with exponential crop water uptake function



5.2.2. Alfalfa

Bean is only a 3.5 to 4-month long crop, so the question arises as to what the salinity objective might be for the remainder of the year. Alfalfa is currently used for the salinity objective for the time of the year when bean is not used so it was modeled using the two water uptake distributions used for bean. Alfalfa is more salt tolerant than bean (EC_e of 2.0 versus 1.0 dS/m). In Table 5.4, the total precipitation is taken as effective rainfall and ET_c is calculated using the crop coefficients shown in Figure 5.4.

Alfalfa is frequently grown on clay soils which have a low infiltration rate; less than 0.2 inches/hour. In addition, alfalfa has a high water requirement with an annual evapotranspiration of 50 inches (see Table 5.4). Thus, it can be difficult to meet the high demand for evapotranspiration plus additional water for leaching. To investigate this scenario, leaching fractions of 0.07 and 0.10 were modeled in addition to leaching fractions of 0.15 and 0.20 that were tested for bean. Example results shown in Table 5.4 are for an EC_i of 1.0 dS/m and a leaching fraction of 0.10 is probably a worst-case scenario. A L of 0.10 is a worst-case scenario because the lowest L calculated from subsurface drainage systems in Section 3.13.2 was 0.11. Also at leaching fractions below 0.10 both models predict high values of soil salinity, which if experienced for significant periods of time, would result in large yield losses for alfalfa.

Similar to Figures 5.7 and 5.8 for bean, Figures 5.11 and 5.12 shows the impact of annual rainfall on soil salinity. Figure 5.11 shows the impact of leaching fraction from 0.07 to 0.20 on soil salinity as a function of annual rainfall for both models assuming an EC_i of 1.0 dS/m. Soil salinity remains below the threshold for alfalfa for both models except at a L of 0.07 when annual rainfall is below the median. Figure 5.12 is the same as Figure 5.11 except an EC_i of 1.2 dS/m is used. At an EC_i of 1.2 dS/m both models predict alfalfa yield loss at a L of 0.07 for all but the wettest years. Some yield loss is also predicted at a L of 0.10 for the drier years. Since a L of 0.11 was the lowest L calculated from subsurface drainage systems, an EC_i of 1.2 dS/m would protect alfalfa production except in the very dry years where a yield loss of 2 % would be predicted.

Similar to Figures 5.9 and 5.10 for bean, Figures 5.13 and 5.14 below show the relative yield of alfalfa as a function of irrigation water salinity (EC_i) and total annual precipitation (P_T), respectively. Note that the yield impact curve calculated using the 40-30-20-10 and exponential water uptake functions are nearly identical at L = 0.10. In general the two uptake functions generate similar results at lower leaching fractions, and gradually divergent results as L increases. Model results shown in Figure 5.13 for median rainfall indicates that at a L of 0.10 both models predict a loss in alfalfa yield beginning at an EC_i of 1.0 dS/m but at a L of 0.15 no yield loss occurs until EC_i surpasses 1.3 dS/m for the exponential model.

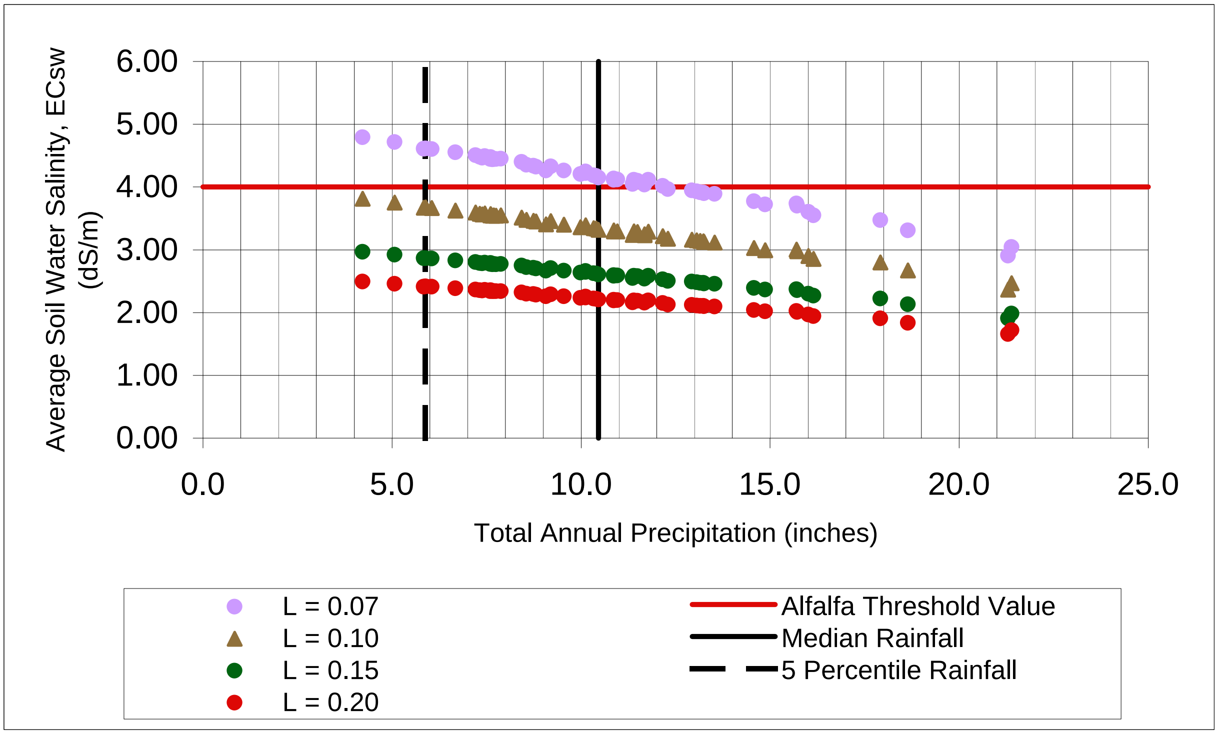
As a result of these model predictions, no yield loss would occur for alfalfa if the L is 0.10 or higher regardless of annual rainfall amounts for an EC_i of 1.0 dS/m. If an EC_i of 1.2 dS/m is assumed with a L of 0.10 no yield loss would occur for rainfall above the median and the yield for the driest year would be about 98% using the 40-30-20-10 model and 99% using the exponential model.

Table 5.4. Output from the steady-state models both 1) without precipitation and 2) including precipitation (all equations defined in Table 5.2) with precipitation data from NCDC Tracy-Carbona Station #8999 and alfalfa crop evapotranspiration coefficients (modified Goldhamer & Snyder, 1989).

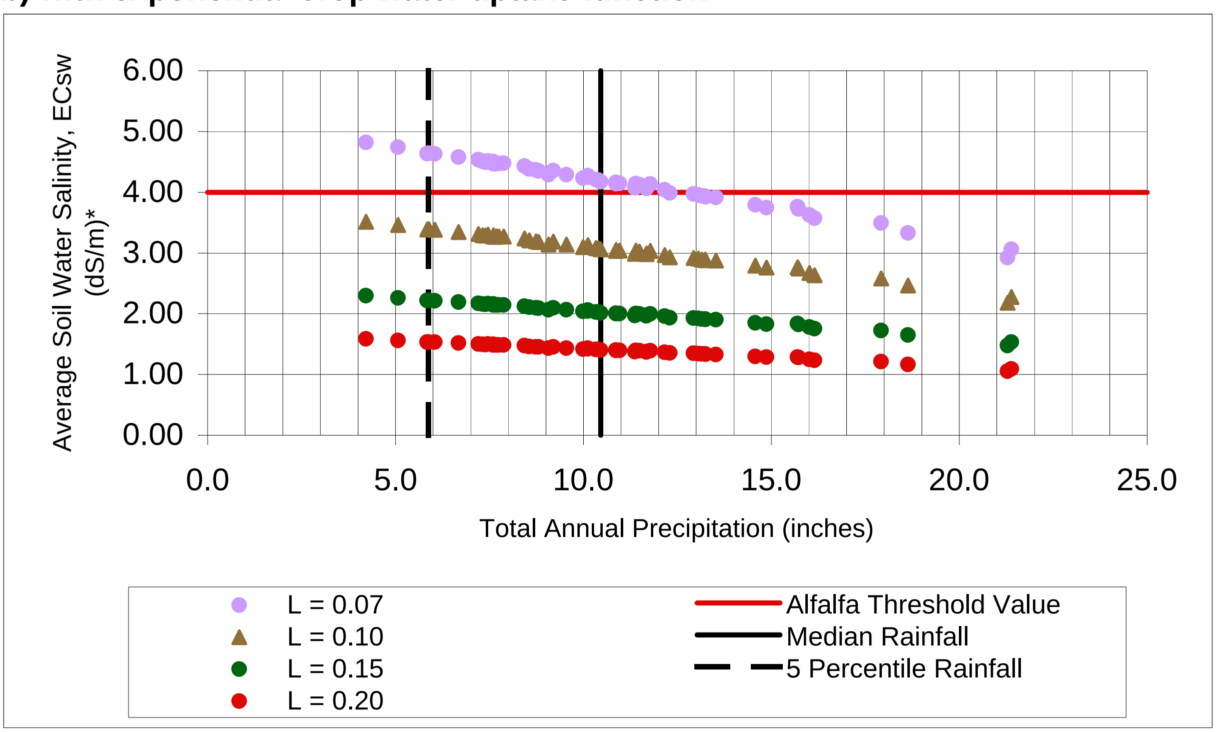
	Input Variables EC_i = 1.0			L = 0.10			Model Output						
							1) without precipitation			2) with precipitation			
Water Year	P_T (in.)	P_{NG} (in.)	E_S (in.)	P_{GS} (in.)	P_{EFF} (in.)	ET_C (in.)	I_1 (in.)	EC_{SWa-1} (dS/m)	EC_{SWb-1} (dS/m)	I_2 (in.)	EC_{AW-2} (dS/m)	EC_{SWa-2} (dS/m)	EC_{SWb-2} (dS/m)
1952	13.5	0.0	0.0	13.5	13.5	50.6	56.2	4.11	3.79	42.7	0.76	3.12	2.88
1953	7.6	0.0	0.0	7.6	7.6	50.2	55.7	4.11	3.79	48.1	0.86	3.55	3.27
1954	6.1	0.0	0.0	6.1	6.1	50.8	56.4	4.11	3.79	50.4	0.89	3.67	3.38
1955	10.9	0.0	0.0	10.9	10.9	49.4	54.9	4.11	3.79	44.0	0.80	3.29	3.04
1956	13.2	0.0	0.0	13.2	13.2	50.2	55.8	4.11	3.79	42.6	0.76	3.14	2.89
1957	8.8	0.0	0.0	8.8	8.8	49.7	55.2	4.11	3.79	46.4	0.84	3.45	3.18
1958	16.0	0.0	0.0	16.0	16.0	49.0	54.4	4.11	3.79	38.4	0.71	2.90	2.67
1959	7.9	0.0	0.0	7.9	7.9	52.3	58.1	4.11	3.79	50.2	0.86	3.55	3.27
1960	5.1	0.0	0.0	5.1	5.1	52.8	58.7	4.11	3.79	53.6	0.91	3.75	3.46
1961	7.8	0.0	0.0	7.8	7.8	51.0	56.6	4.11	3.79	48.9	0.86	3.54	3.27
1962	8.7	0.0	0.0	8.7	8.7	50.2	55.8	4.11	3.79	47.1	0.84	3.46	3.19
1963	9.1	0.0	0.0	9.1	9.1	47.8	53.1	4.11	3.79	44.0	0.83	3.40	3.14
1964	5.9	0.0	0.0	5.9	5.9	50.5	56.2	4.11	3.79	50.3	0.90	3.68	3.39
1965	10.5	0.0	0.0	10.5	10.5	49.0	54.4	4.11	3.79	44.0	0.81	3.32	3.06
1966	7.5	0.0	0.0	7.5	7.5	52.3	58.1	4.11	3.79	50.7	0.87	3.58	3.30
1967	12.2	0.0	0.0	12.2	12.2	50.4	56.0	4.11	3.79	43.9	0.78	3.21	2.97
1968	11.5	0.0	0.0	11.5	11.5	51.5	57.2	4.11	3.79	45.7	0.80	3.28	3.03
1969	13.2	0.0	0.0	13.2	13.2	50.4	56.0	4.11	3.79	42.7	0.76	3.13	2.89
1970	7.6	0.0	0.0	7.6	7.6	52.3	58.1	4.11	3.79	50.5	0.87	3.57	3.29
1971	11.4	0.0	0.0	11.4	11.4	50.1	55.6	4.11	3.79	44.2	0.80	3.26	3.01
1972	4.2	0.0	0.0	4.2	4.2	53.0	58.8	4.11	3.79	54.6	0.93	3.81	3.52
1973	15.7	0.0	0.0	15.7	15.7	51.4	57.1	4.11	3.79	41.4	0.72	2.97	2.74
1974	11.4	0.0	0.0	11.4	11.4	51.8	57.5	4.11	3.79	46.1	0.80	3.29	3.04
1975	10.0	0.0	0.0	10.0	10.0	49.5	55.0	4.11	3.79	45.1	0.82	3.36	3.10
1976	5.8	0.0	0.0	5.8	5.8	49.6	55.2	4.11	3.79	49.3	0.89	3.67	3.39
1977	7.4	0.0	0.0	7.4	7.4	50.1	55.7	4.11	3.79	48.3	0.87	3.56	3.28
1978	12.3	0.0	0.0	12.3	12.3	48.9	54.3	4.11	3.79	42.0	0.77	3.18	2.93
1979	9.6	0.0	0.0	9.6	9.6	50.2	55.7	4.11	3.79	46.2	0.83	3.40	3.14
1980	11.4	0.0	0.0	11.4	11.4	48.5	53.8	4.11	3.79	42.5	0.79	3.24	2.99
1981	7.2	0.0	0.0	7.2	7.2	51.9	57.7	4.11	3.79	50.5	0.88	3.59	3.31
1982	16.2	0.0	0.0	16.2	16.2	47.8	53.1	4.11	3.79	36.9	0.70	2.86	2.63
1983	21.3	0.0	0.0	21.3	21.3	45.2	50.2	4.11	3.79	28.9	0.58	2.36	2.18
1984	9.2	0.0	0.0	9.2	9.2	52.4	58.2	4.11	3.79	49.0	0.84	3.46	3.19
1985	13.1	0.0	0.0	13.1	13.1	50.5	56.1	4.11	3.79	43.0	0.77	3.15	2.91
1986	13.3	0.0	0.0	13.3	13.3	50.0	55.6	4.11	3.79	42.3	0.76	3.13	2.88
1987	6.7	0.0	0.0	6.7	6.7	51.5	57.2	4.11	3.79	50.6	0.88	3.63	3.35
1988	8.4	0.0	0.0	8.4	8.4	52.4	58.2	4.11	3.79	49.7	0.86	3.51	3.24
1989	7.7	0.0	0.0	7.7	7.7	50.2	55.7	4.11	3.79	48.1	0.86	3.54	3.27
1990	7.3	0.0	0.0	7.3	7.3	50.6	56.2	4.11	3.79	48.9	0.87	3.57	3.29
1991	7.7	0.0	0.0	7.7	7.7	50.8	56.4	4.11	3.79	48.7	0.86	3.55	3.27
1992	11.8	0.0	0.0	11.8	11.8	53.3	59.2	4.11	3.79	47.4	0.80	3.29	3.03
1993	17.9	0.0	0.0	17.9	17.9	50.6	56.2	4.11	3.79	38.3	0.68	2.80	2.58
1994	10.1	0.0	0.0	10.1	10.1	52.4	58.2	4.11	3.79	48.1	0.83	3.39	3.13
1995	14.9	0.0	0.0	14.9	14.9	49.2	54.7	4.11	3.79	39.8	0.73	2.99	2.76
1996	15.7	0.0	0.0	15.7	15.7	52.5	58.3	4.11	3.79	42.6	0.73	3.00	2.77
1997	12.9	0.0	0.0	12.9	12.9	50.6	56.3	4.11	3.79	43.3	0.77	3.16	2.92
1998	21.4	0.0	0.0	21.4	21.4	48.3	53.6	4.11	3.79	32.2	0.60	2.47	2.28
1999	11.7	0.0	0.0	11.7	11.7	49.3	54.8	4.11	3.79	43.1	0.79	3.23	2.98
2000	10.4	0.0	0.0	10.4	10.4	50.0	55.5	4.11	3.79	45.1	0.81	3.34	3.08
2001	10.1	0.0	0.0	10.1	10.1	50.9	56.6	4.11	3.79	46.4	0.82	3.37	3.11
2002	11.0	0.0	0.0	11.0	11.0	50.0	55.5	4.11	3.79	44.6	0.80	3.30	3.04
2003	10.3	0.0	0.0	10.3	10.3	50.1	55.6	4.11	3.79	45.3	0.81	3.34	3.08
2004	10.9	0.0	0.0	10.9	10.9	50.3	55.8	4.11	3.79	45.0	0.81	3.31	3.05
2005	18.6	0.0	0.0	18.6	18.6	48.1	53.4	4.11	3.79	34.7	0.65	2.67	2.46
2006	14.6	0.0	0.0	14.6	14.6	49.9	55.4	4.11	3.79	40.9	0.74	3.03	2.79
2007	8.6	0.0	0.0	8.6	8.6	50.2	55.7	4.11	3.79	47.2	0.85	3.48	3.21
2008	11.7	0.0	0.0	11.7	11.7	50.2	55.7	4.11	3.79	44.0	0.79	3.25	2.99
Median:	10.5	0.0	0.0	10.5	10.5	50.2	55.8	4.11	3.79	45.1	0.81	3.32	3.06
Max:	21.4	0.0	0.0	21.4	21.4	53.3	59.2	4.11	3.79	54.6	0.93	3.81	3.52
Min:	4.2	0.0	0.0	4.2	4.2	45.2	50.2	4.11	3.79	28.9	0.58	2.36	2.18

Figure 5.11. Average soil water salinity (ECsw) vs. total annual rainfall for alfalfa with leaching fractions ranging from 0.07 to 0.20 and irrigation water (EC_i) = 1.0 dS/m using both 40-30-20-10 and exponential crop water uptake functions (precipitation from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008).

a) with 40-30-20-10 crop water uptake function



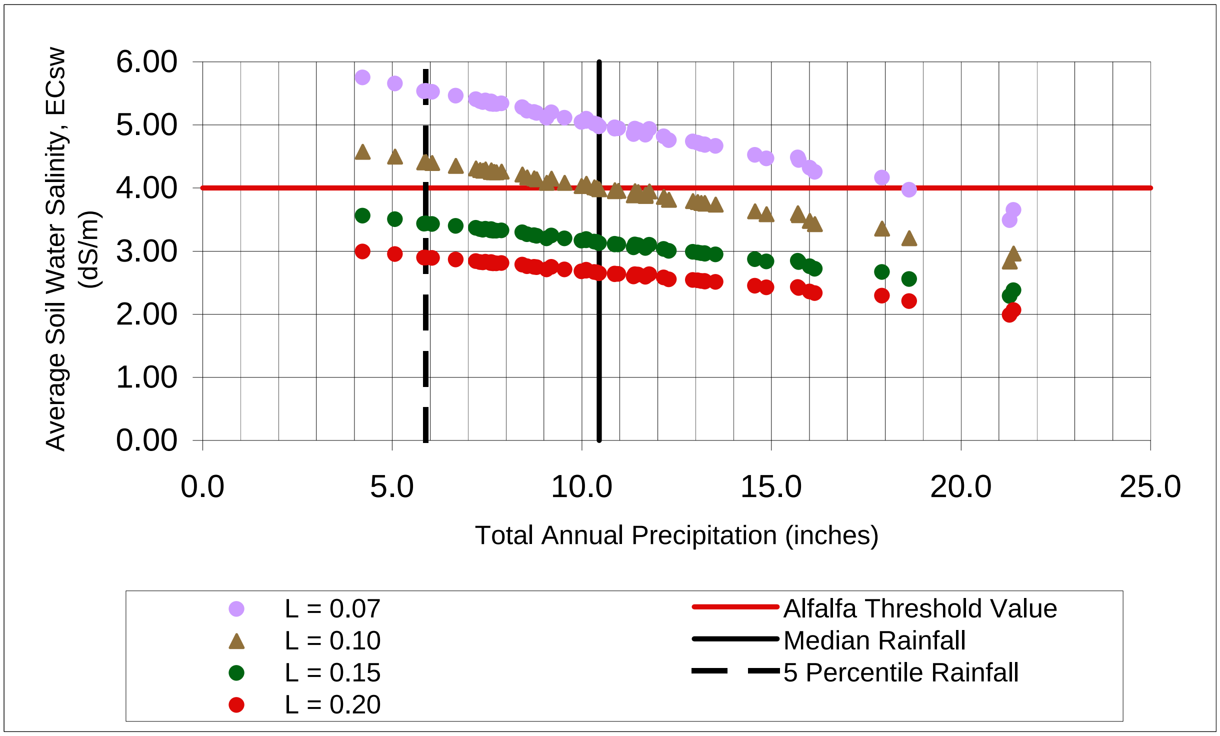
b) with exponential crop water uptake function*



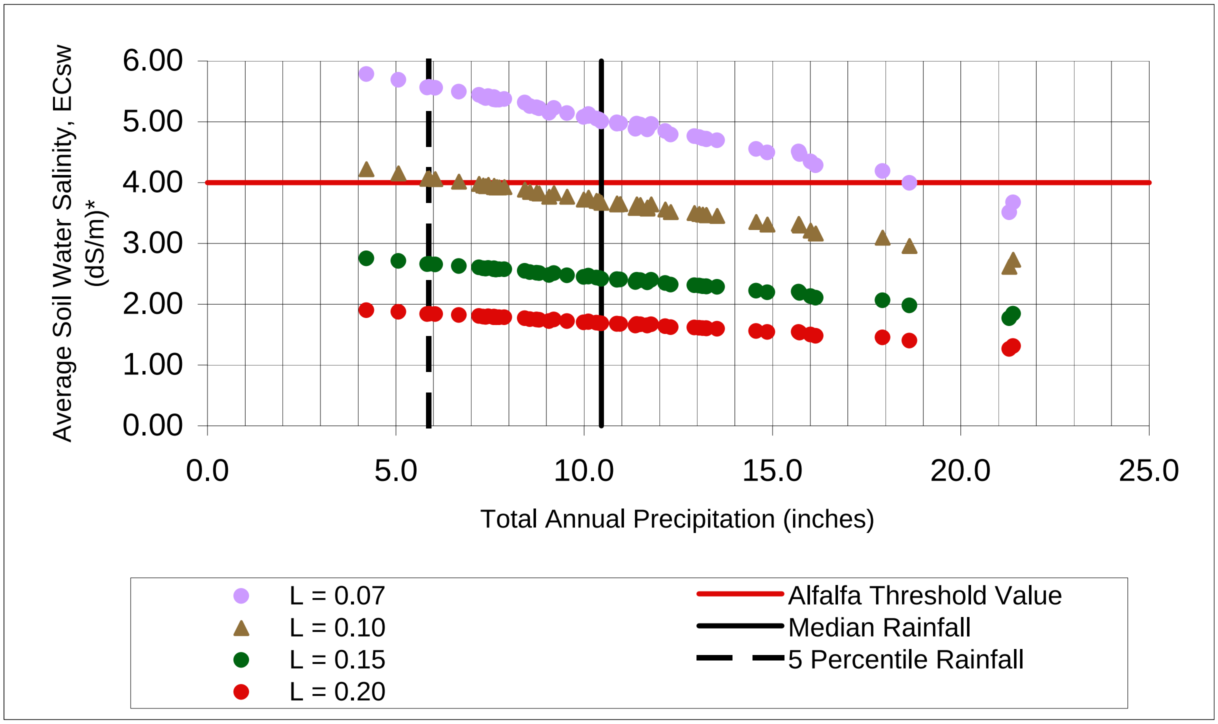
** As discussed in Section 4.1, the average soil water salinity was reduced by the soil salinity at 50% leaching for the exponential model.*

Figure 5.12. Average soil water salinity (ECsw) vs. total annual rainfall for alfalfa with leaching fractions ranging from 0.07 to 0.20 and irrigation water (EC_i) = 1.2 dS/m using both 40-30-20-10 and exponential crop water uptake functions (precipitation from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008).

a) with 40-30-20-10 crop water uptake function



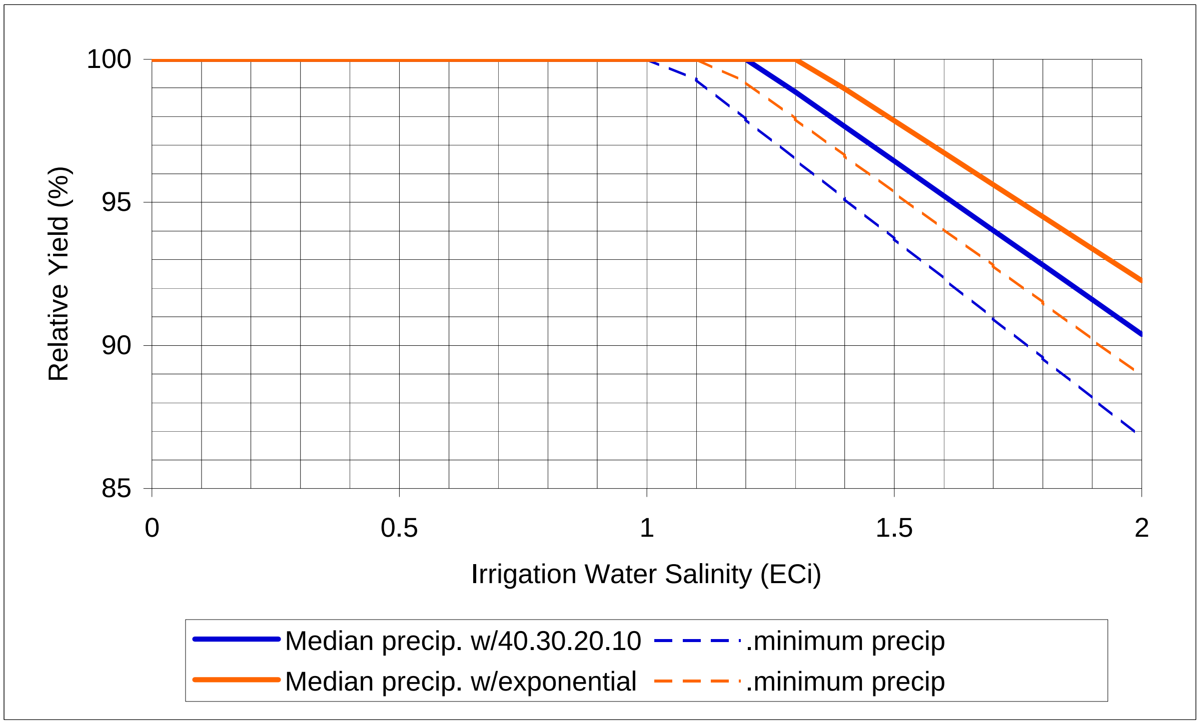
b) with exponential crop water uptake function*



** As discussed in Section 4.1, the average soil water salinity was reduced by the soil salinity at 50% leaching for the exponential model.*

Figure 5.13. Relative alfalfa yield (percent) as a function of irrigation water salinity (ECi) with a) L = 0.10 and b) L = 0.15 assuming median precipitation (solid lines) and minimum precipitation (dashed lines) from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008.

a) L = 0.10



b) L = 0.15

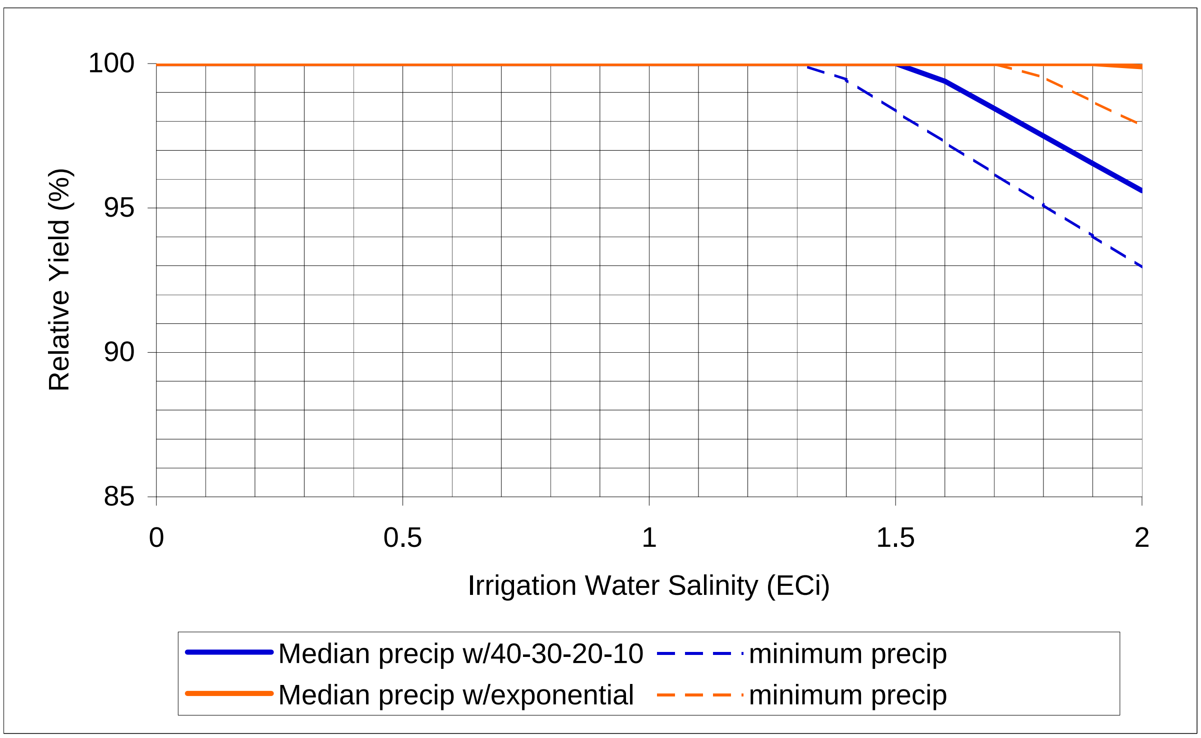
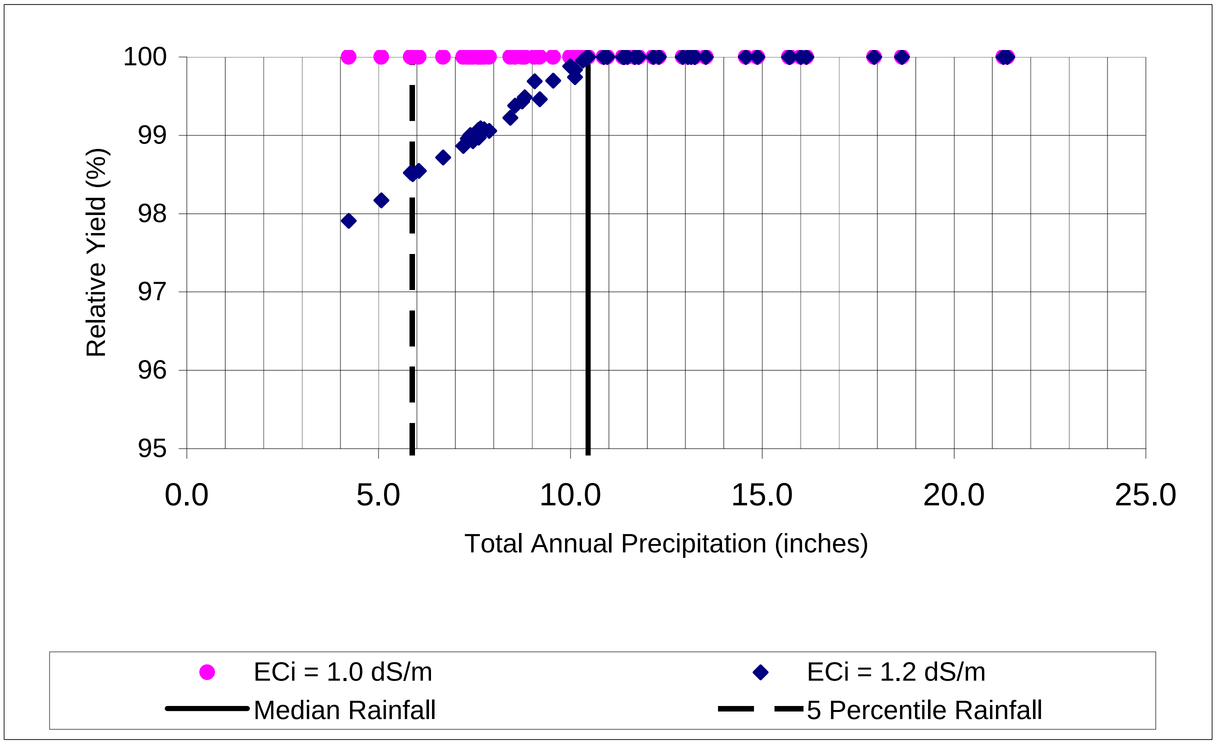
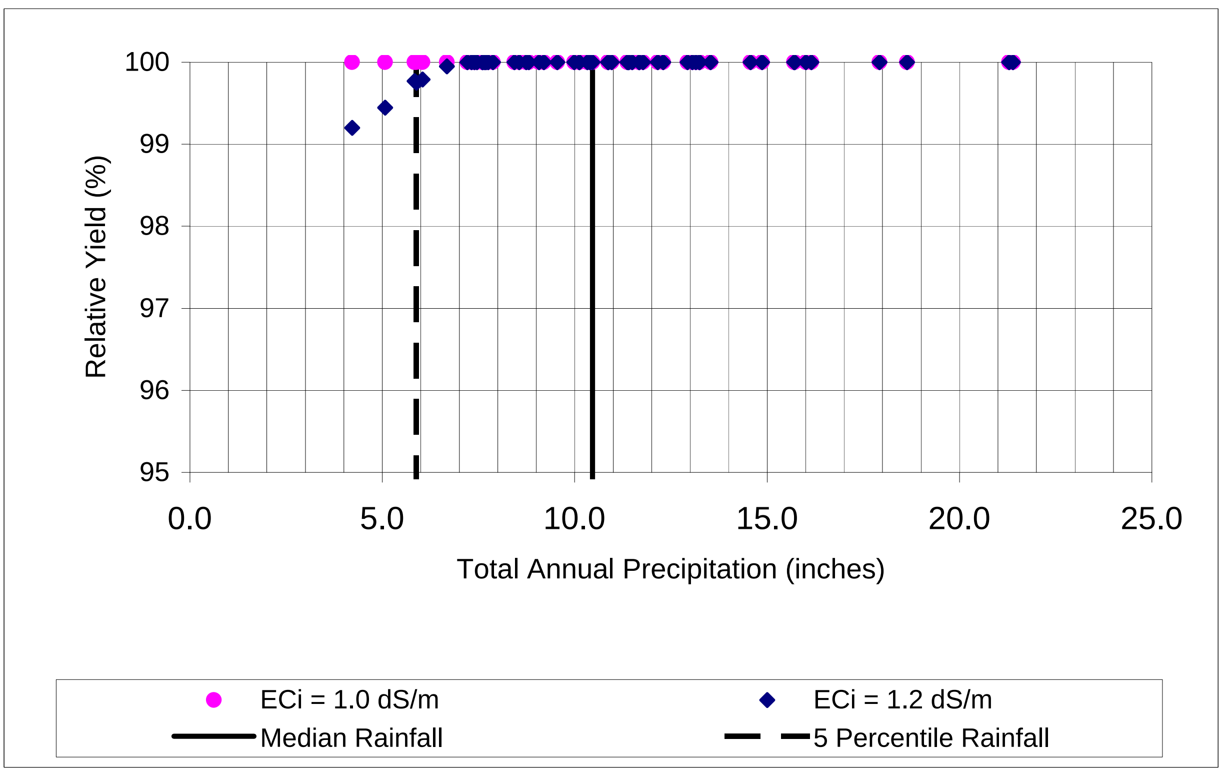


Figure 5.14. Relative crop yield (%) for alfalfa with L = 0.10 at EC_i = 1.0 and 1.2 dS/m vs. total annual rainfall using both 40-30-20-10 and exponential crop water uptake functions (precipitation from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008).

a) with 40-30-20-10 crop water uptake function



b) with exponential crop water uptake function



5.2.3. Almond

To test a more salt sensitive, perennial crop than alfalfa, almond was chosen. The crop coefficients shown in Figure 5.5 were used to calculate ET_c. The non-growing season for almond was taken as November 10 to February 15 as reported by Goldhamer and Snyder (1989). It was assumed that there was no cover crop. The input variables for almond are given in Table 5.5. This table also gives the soil salinity values for both models with and without rainfall for the case where EC_i is 1.0 dS/m and the leaching fraction is 0.10.

As shown in Figure 5.15, soil salinity is below the salt tolerance threshold for almond for leaching fractions as low as 0.10 assuming an EC_i of 0.7 dS/m regardless of the amount of annual precipitation for both models. As shown in Figure 5.16, for an EC_i of 1.0 dS/m losses of almond yield occurs at a L of 0.10 when rainfall totals are below the median value. For median and minimum amounts of annual rainfall, almond yield as a function of irrigation water salinity is presented in Figure 5.17. For the exponential model, the yield threshold is predicted at an EC_i of 0.9 dS/m for a L of 0.10 and an EC_i of 1.4 dS/m for a L of 0.15. Yield losses for almond as a function of annual precipitation for both models is given in Figure 5.18 with L = 0.10. As an example, a yield loss of 6% is predicted for the driest year by the exponential model assuming an EC_i of 1.0 dS/m.

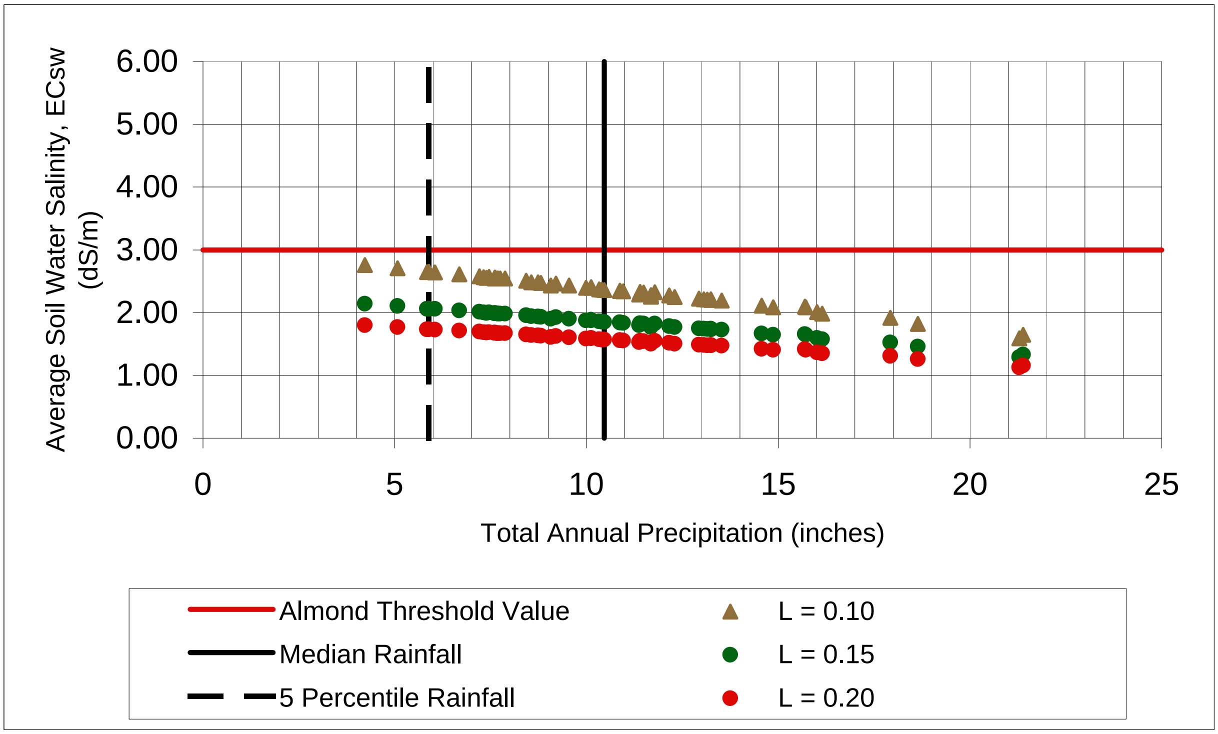
Thus, employing the exponential model, an EC_i of 1.0 dS/m would protect almond from yield loss if the L is 0.10 for all annual rainfall above the median but the yield loss would be 6% for the driest year. A L of 0.15 would prevent yield loss for an EC_i of 1.0 dS/m regardless of rainfall amount.

Table 5.5. Output from the steady-state models both 1) without precipitation and 2) including precipitation (all equations defined in Table 5.2) with precipitation data from NCDC Tracy-Carbona Station #8999 and almond crop evapotranspiration coefficients from Goldhamer & Snyder (1989).

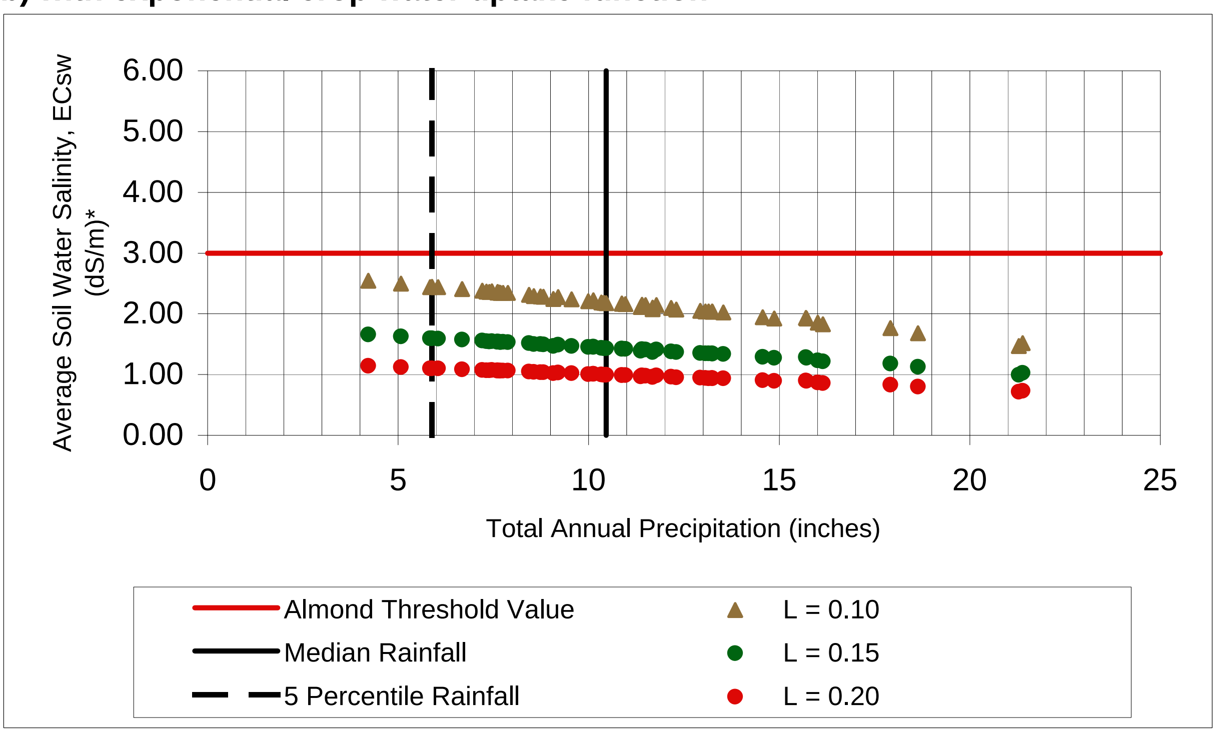
Input Variables: EC_i = 1.0; L = 0.10							Model Output: 1) without precipitation			2) with precipitation			
Water Year	P_T (in.)	P_{NG} (in.)	E_S (in.)	P_{GS} (in.)	P_{EFF} (in.)	ET_C (in.)	I_1 (in.)	EC_{SWa-1} (dS/m)	EC_{SWb-1} (dS/m)	I_2 (in.)	EC_{AW-2} (dS/m)	EC_{SWa-2} (dS/m)	EC_{SWb-2} (dS/m)
1952	13.5	8.4	2.2	5.2	11.3	43.1	47.9	4.11	3.79	36.6	0.76	3.13	2.89
1953	7.6	5.0	2.2	2.6	5.4	42.3	47.0	4.11	3.79	41.6	0.89	3.64	3.35
1954	6.1	2.1	2.2	4.0	3.8	42.9	47.6	4.11	3.79	43.8	0.92	3.77	3.48
1955	10.9	5.6	2.2	5.2	8.7	42.4	47.1	4.11	3.79	38.5	0.82	3.35	3.09
1956	13.2	9.6	2.2	3.6	10.9	42.5	47.2	4.11	3.79	36.3	0.77	3.15	2.91
1957	8.8	2.4	2.2	6.5	6.6	42.1	46.8	4.11	3.79	40.2	0.86	3.53	3.26
1958	16.0	5.9	2.2	10.1	13.8	41.3	45.9	4.11	3.79	32.1	0.70	2.87	2.65
1959	7.9	2.8	2.2	5.1	5.7	44.2	49.1	4.11	3.79	43.4	0.88	3.63	3.35
1960	5.1	4.0	2.2	1.0	2.9	44.7	49.7	4.11	3.79	46.8	0.94	3.87	3.57
1961	7.8	4.6	2.2	3.1	5.5	43.2	48.0	4.11	3.79	42.5	0.89	3.63	3.35
1962	8.7	6.4	2.2	2.3	6.5	43.0	47.7	4.11	3.79	41.2	0.86	3.54	3.27
1963	9.1	4.4	2.2	4.6	6.9	40.0	44.5	4.11	3.79	37.6	0.85	3.47	3.20
1964	5.9	3.1	2.2	2.8	3.7	42.2	46.9	4.11	3.79	43.2	0.92	3.78	3.49
1965	10.5	5.3	2.2	5.1	8.2	41.5	46.1	4.11	3.79	37.8	0.82	3.37	3.11
1966	7.5	6.2	2.2	1.3	5.3	44.5	49.5	4.11	3.79	44.2	0.89	3.67	3.39
1967	12.2	6.8	2.2	5.4	10.0	42.7	47.5	4.11	3.79	37.5	0.79	3.24	2.99
1968	11.5	5.2	2.2	6.3	9.3	43.5	48.3	4.11	3.79	39.0	0.81	3.32	3.06
1969	13.2	7.4	2.2	5.9	11.0	42.9	47.7	4.11	3.79	36.7	0.77	3.16	2.91
1970	7.6	4.5	2.2	3.1	5.4	44.1	49.0	4.11	3.79	43.6	0.89	3.65	3.37
1971	11.4	7.0	2.2	4.4	9.2	42.7	47.4	4.11	3.79	38.2	0.81	3.31	3.05
1972	4.2	2.9	2.2	1.4	2.0	45.1	50.1	4.11	3.79	48.1	0.96	3.94	3.64
1973	15.7	10.2	2.2	5.5	13.5	44.1	49.0	4.11	3.79	35.5	0.72	2.98	2.75
1974	11.4	5.1	2.2	6.3	9.2	43.8	48.7	4.11	3.79	39.5	0.81	3.33	3.07
1975	10.0	4.0	2.2	6.0	7.8	42.0	46.6	4.11	3.79	38.9	0.83	3.42	3.16
1976	5.8	1.3	2.2	4.6	3.6	41.2	45.7	4.11	3.79	42.1	0.92	3.78	3.49
1977	7.4	2.2	2.2	5.2	5.2	42.0	46.6	4.11	3.79	41.5	0.89	3.65	3.37
1978	12.3	7.2	2.2	5.1	10.1	41.6	46.2	4.11	3.79	36.1	0.78	3.21	2.96
1979	9.6	5.1	2.2	4.5	7.3	42.7	47.4	4.11	3.79	40.1	0.85	3.47	3.20
1980	11.4	4.8	2.2	6.6	9.2	40.7	45.2	4.11	3.79	36.0	0.80	3.27	3.02
1981	7.2	3.4	2.2	3.8	5.0	44.0	48.9	4.11	3.79	43.9	0.90	3.69	3.40
1982	16.2	5.8	2.2	10.3	13.9	40.4	44.9	4.11	3.79	31.0	0.69	2.83	2.61
1983	21.3	10.8	2.2	10.5	19.1	38.5	42.7	4.11	3.79	23.7	0.55	2.27	2.10
1984	9.2	6.7	2.2	2.5	7.0	44.2	49.1	4.11	3.79	42.1	0.86	3.52	3.25
1985	13.1	7.1	2.2	6.0	10.8	42.3	47.0	4.11	3.79	36.2	0.77	3.16	2.92
1986	13.3	5.8	2.2	7.5	11.0	42.5	47.2	4.11	3.79	36.2	0.77	3.15	2.90
1987	6.7	4.6	2.2	2.1	4.5	43.6	48.4	4.11	3.79	44.0	0.91	3.73	3.44
1988	8.4	4.8	2.2	3.6	6.2	43.7	48.5	4.11	3.79	42.3	0.87	3.58	3.30
1989	7.7	4.0	2.2	3.6	5.4	42.6	47.4	4.11	3.79	41.9	0.89	3.64	3.35
1990	7.3	2.4	2.2	5.0	5.1	43.0	47.8	4.11	3.79	42.7	0.89	3.67	3.38
1991	7.7	3.1	2.2	4.6	5.5	42.6	47.4	4.11	3.79	41.9	0.88	3.63	3.35
1992	11.8	6.3	2.2	5.5	9.6	45.1	50.1	4.11	3.79	40.5	0.81	3.32	3.06
1993	17.9	10.3	2.2	7.6	15.7	42.3	47.1	4.11	3.79	31.4	0.67	2.74	2.52
1994	10.1	5.0	2.2	5.2	7.9	43.9	48.8	4.11	3.79	40.9	0.84	3.44	3.17
1995	14.9	8.8	2.2	6.1	12.7	41.5	46.1	4.11	3.79	33.4	0.73	2.98	2.75
1996	15.7	9.3	2.2	6.4	13.5	44.9	49.9	4.11	3.79	36.4	0.73	3.00	2.76
1997	12.9	10.6	2.2	2.4	10.7	42.5	47.2	4.11	3.79	36.5	0.77	3.18	2.93
1998	21.4	12.9	2.2	8.5	19.2	40.4	44.9	4.11	3.79	25.7	0.57	2.35	2.17
1999	11.7	5.8	2.2	5.8	9.5	41.0	45.6	4.11	3.79	36.1	0.79	3.25	3.00
2000	10.4	4.9	2.2	5.5	8.2	41.6	46.3	4.11	3.79	38.1	0.82	3.38	3.12
2001	10.1	3.4	2.2	6.7	7.9	42.8	47.5	4.11	3.79	39.6	0.83	3.42	3.16
2002	11.0	7.6	2.2	3.3	8.8	42.4	47.1	4.11	3.79	38.3	0.81	3.34	3.08
2003	10.3	5.6	2.2	4.7	8.1	41.7	46.4	4.11	3.79	38.2	0.82	3.39	3.12
2004	10.9	5.1	2.2	5.8	8.7	42.8	47.5	4.11	3.79	38.9	0.82	3.36	3.10
2005	18.6	8.9	2.2	9.7	16.4	40.3	44.8	4.11	3.79	28.4	0.63	2.60	2.40
2006	14.6	6.3	2.2	8.3	12.4	41.8	46.5	4.11	3.79	34.1	0.73	3.01	2.78
2007	8.6	5.7	2.2	2.9	6.4	42.1	46.8	4.11	3.79	40.4	0.86	3.55	3.27
2008	11.7	9.8	2.2	1.9	9.5	39.3	43.7	4.11	3.79	34.2	0.78	3.22	2.97
Median:	10.5	5.6	2.2	5.1	8.2	42.5	47.2	4.11	3.79	38.9	0.82	3.37	3.11
Max:	21.4	12.9	2.2	10.5	19.2	45.1	50.1	4.11	3.79	48.1	0.96	3.94	3.64
Min:	4.2	1.3	2.2	1.0	2.0	38.5	42.7	4.11	3.79	23.7	0.55	2.27	2.10

Figure 5.15. Average soil water salinity (ECsw) vs. total annual rainfall for almond with leaching fractions ranging from 0.10 to 0.20 and irrigation water (EC_i) = 0.7 dS/m using both 40-30-20-10 and exponential crop water uptake functions (precipitation from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008) .

a) with 40-30-20-10 crop water uptake function



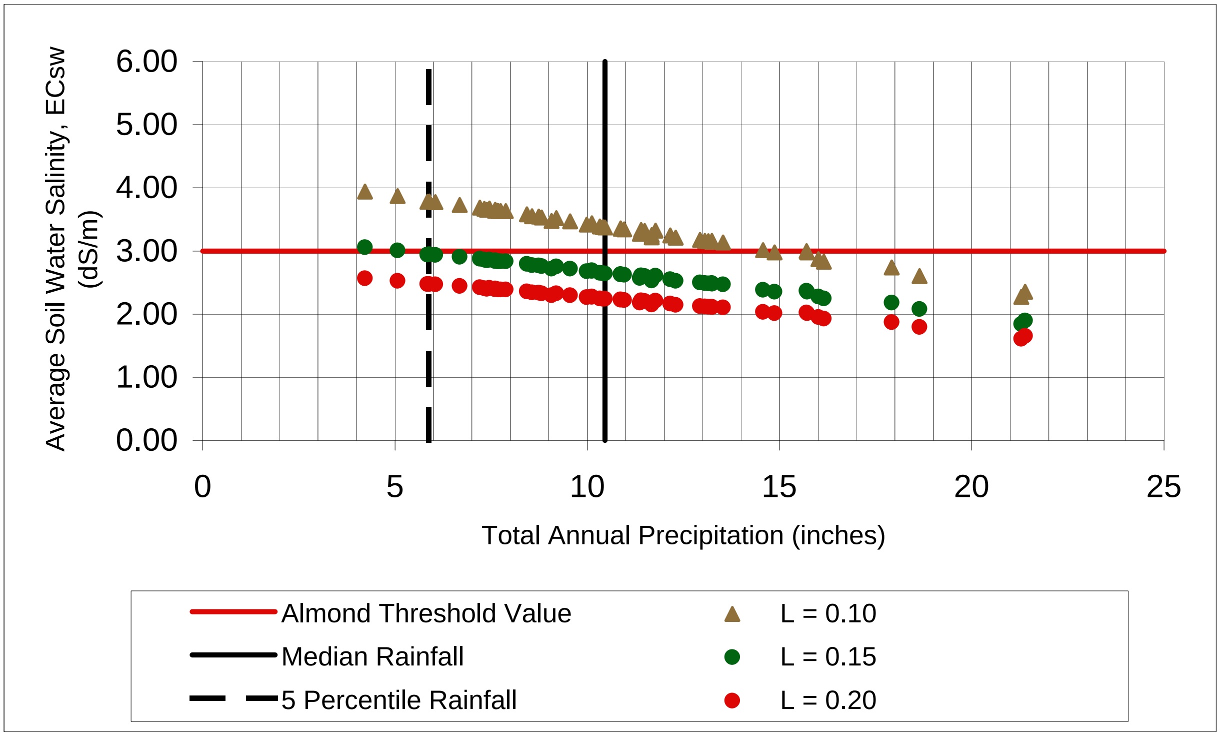
b) with exponential crop water uptake function*



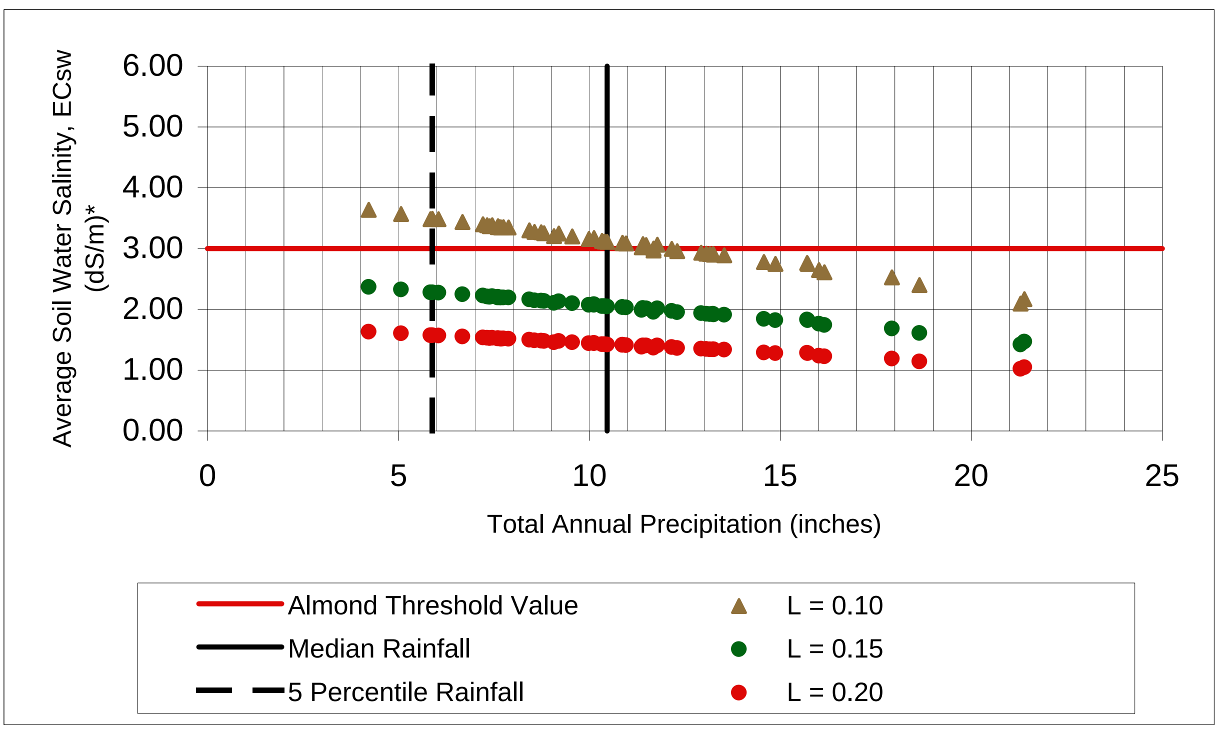
** As discussed in Section 4.1, the average soil water salinity was reduced by the soil salinity at 50% leaching for the exponential model.*

Figure 5.16. Average soil water salinity (ECsw) vs. total annual rainfall for almond with leaching fractions ranging from 0.10 to 0.20 and irrigation water (EC_i) = 1.0 dS/m using both 40-30-20-10 and exponential crop water uptake functions (precipitation from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008) .

a) with 40-30-20-10 crop water uptake function



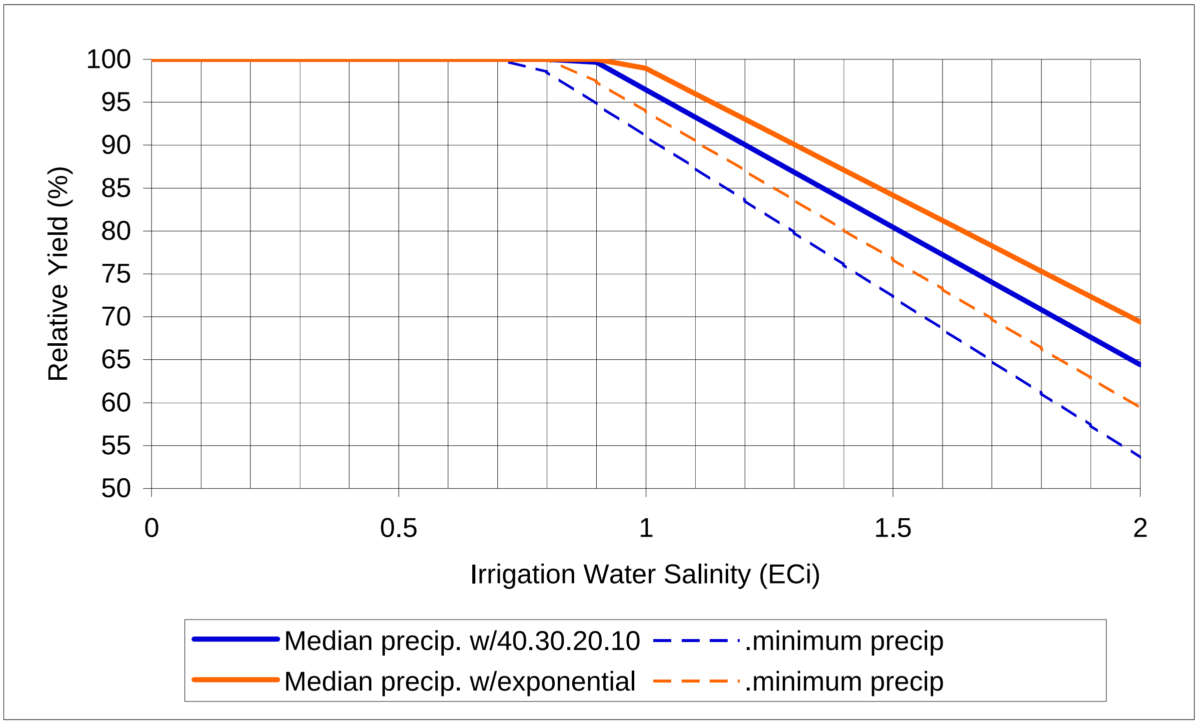
b) with exponential crop water uptake function*



** As discussed in Section 4.1, the average soil water salinity was reduced by the soil salinity at 50% leaching for the exponential model.*

Figure 5.17. Relative almond yield (percent) as a function of irrigation water salinity (ECi) with a) L = 0.10 and b) L = 0.15 assuming median precipitation (solid lines) and minimum precipitation (dashed lines) from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008.

a) L = 0.10



b) L = 0.15

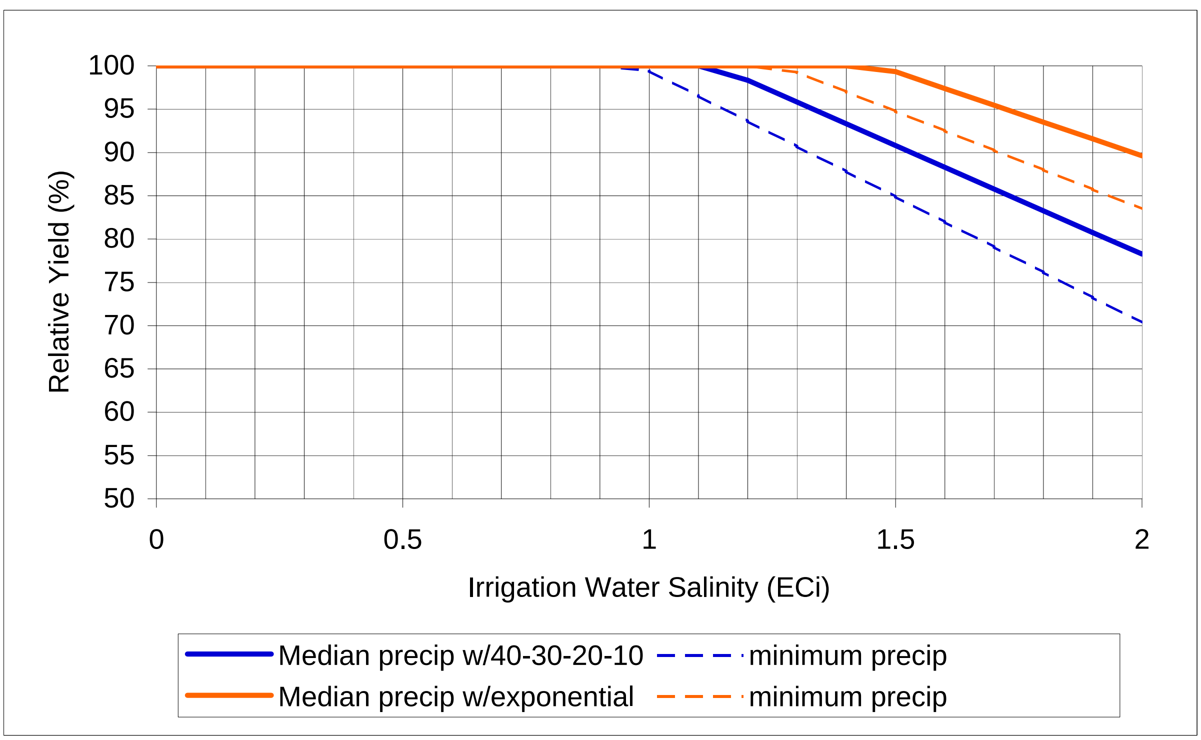
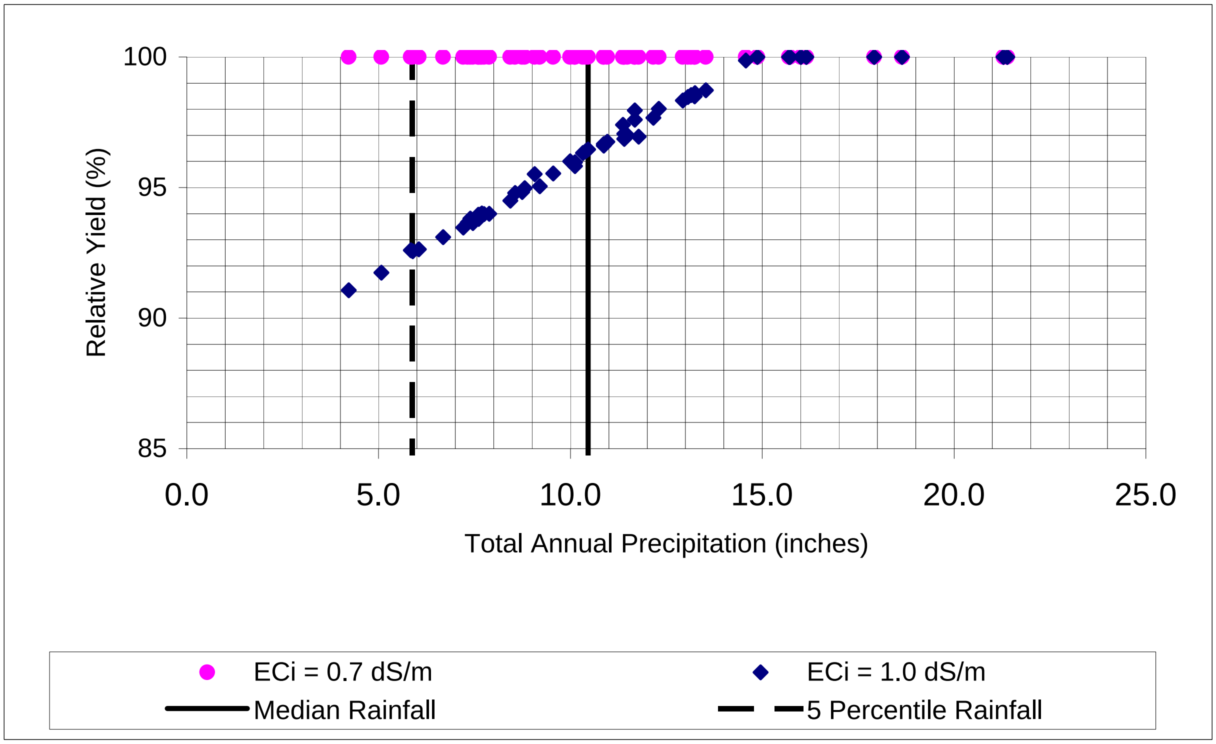
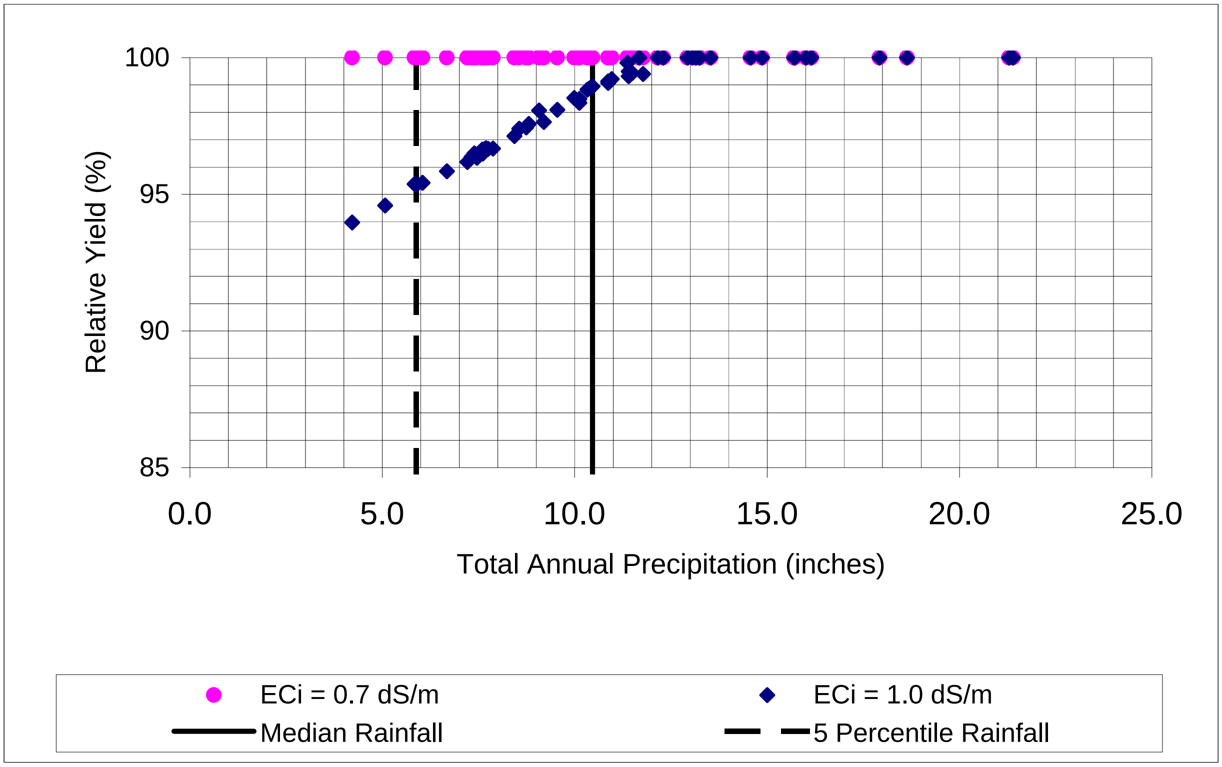


Figure 5.18. Relative crop yield (%) for almond with L = 0.10 at EC_i = 0.7 and 1.0 dS/m vs. total annual rainfall using both 40-30-20-10 and exponential crop water uptake functions (precipitation from NCDC station no. 8999, Tracy-Carbona - water years 1952 through 2008).

a) with 40-30-20-10 crop water uptake function



b) with exponential crop water uptake function



6. Summary & Conclusions

This portion of the report is divided into two sections. The first section summarizes the information on irrigation water quality, soil types and location of saline and shrink/swell soils, crop surveys, salt tolerance of crops, effective rainfall, irrigation methods and their efficiency and uniformity, crop water uptake distribution, climate, salt precipitation / dissolution in soil, shallow groundwater, and leaching fraction. The second section draws conclusions on published steady-state and transient models, compares model results with experimental or field results, and draws conclusions from the results of the steady-state models developed in Section 5 using data applicable to the South Delta.

6.1. Factors Influencing a Water Quality Standard

The quality of water in the San Joaquin River from 1990 to 2006 as measured at Vernalis and the quality in South Old River at Tracy Bridge over the same time period averages about 0.7 dS/m and ranges from 0.1 to 1.4 dS/m. The average level of salinity in the irrigation water is suitable for all agricultural crops. Based on analyses of these waters for various salt constituents, neither sodicity nor toxicity should be a concern for irrigated agriculture except for the possible concern of boron exceeding the threshold for bean and possibly other crops.

Review of the 1992 SCS Soil Survey indicates that clay and clay loam soils are predominant in the southwestern portion of the South Delta, organic soils are minimal in area and are restricted to the northern section, and loam soils are dominate in the remainder of the South Delta. Saline soils were identified in 1992 on about 5 % of the irrigated land. Sodic soils were not reported. The Soil Survey also identified a number of soils that have a high potential to shrink and swell. These shrink/swell soils occupy nearly 50 % of the irrigated area. However, based on a study of soils in the Imperial Valley of similar texture, it does not appear that bypass flow of applied water in these shrink/swell soils should cause a salinity management problem.

Data taken from Crop Surveys over the past three decades indicate that tree and vine crops have ranged from 6% up to 8% of the irrigated land in the South Delta, field crops from 31% down to 24%, truck crops from 19% up to 24%, grain and hay from 19% down to 7%, and pasture from 24% up to 34%. Of the predominant crops identified in the Crop Surveys the salt sensitive crops are almond, apricot, bean, and walnut with bean being the most sensitive with a salt tolerance threshold of EC_e =1.0 dS/m. Thus, to protect the productivity of all crops, bean yield must be protected against loss from excess salinity. It is unfortunate that the published results on the salt tolerance of bean are taken from five laboratory experiments conducted more than 30 years ago. In addition, there are no data to indicate how the salt tolerance of bean changes with growth stage. With such an important decision as the water quality standard to protect all crops in the South Delta, it is unfortunate that a definitive answer can not be based on a field trial with modern bean varieties.

One of the shortcomings of some leaching requirement models is the failure to account for effective rainfall to satisfy a portion of a crop's evapotranspiration. The DWR study in the Central Valley makes it possible to estimate effective rainfall from winter rains. This information is used in the steady-state model prepared for the South Delta in Section 5.

Based upon the 2007 DWR crop survey it appears that about 39% of the South Delta is irrigated by borders or basins which have an average irrigation efficiency of about 78%, 46% is irrigated by furrows with an average efficiency of 70%, and 8% is irrigated by sprinklers (75 % efficiency) and/or micro-irrigation (87 % efficiency). The irrigation method on about 7% of the irrigated land was not identified. Thus, on average, the overall irrigation efficiency in the South Delta is about 75 %. With so little irrigation by sprinkling it is reasonable to assume that foliar damage is not a concern.

One of the important inputs to most steady-state and transient models is the crop water uptake distribution through the root zone. The distribution used in some models is the 40-30-20-10 uptake distribution but the exponential distribution has also been used. In comparisons of steady-state model outputs with experimentally measured leaching requirements, both distributions worked satisfactorily but the exponential distribution agreed a little better with the experimental results. In the model developed for the South Delta (see Section 5) both distributions were used. However, the exponential model is recommended because it agrees more closely with transient model results than the 40-30-20-10 model.

It has been shown experimentally that hot, dry conditions cause more salt stress in plants than cool, humid conditions. A comparison of temperature and humidity between the South Delta and Riverside, CA, where most salt tolerance experiments have been conducted, showed the South Delta to be slightly cooler and more humid than Riverside. Thus, the tolerance of crops to salinity may be slightly higher in the South Delta than many published results.

Two analyses of the waters reported in Section 2.2 would result in an additional 5 % being added to the salt load from salts being weathered out of the soil profile at leaching fractions of about 0.15. Therefore, the salt load in the soil profile and in the drains would be higher than expected from the irrigation water alone. This may cause L estimates to be a little lower than might be expected in the absence of salt dissolution from the soil profile.

The depth to the water table in the South Delta appears to be at least 3 feet with much of the area having a groundwater depth of at least 5 feet. Subsurface tile drains have been installed in the western portion of the South Delta to maintain the water table at an acceptable depth for crop production. With the water table at these depths, any significant water uptake by crop roots would be restricted to deep-rooted and more salt tolerant crops like cotton and alfalfa.

Estimates of leaching fraction were made based upon the salinity of tile drain discharge from a large number of drainage systems and a few soil samples taken at various locations in the South Delta. Combining all of these calculated leaching fractions it appears that the leaching fractions in the South Delta, with perhaps a few exceptions, average between 0.21 and 0.27. Minimum leaching fractions ranged from 0.11 to 0.22.

6.2. Using Models to Determine Water Quality Standards

A number of steady-state and transient models have been developed to calculate the leaching requirement which can also be used to estimate a water quality standard. At least five different steady-state models have been published. When the steady-state models are compared with experimentally measured leaching requirements for 14 crops, the exponential model agreed most closely with the measured values. This conclusion is supported by the comparisons made between steady-state and transient models by Letey (2007) and Corwin et al. (in press).

If the steady-state model based on an exponential crop water uptake pattern is applied considering rainfall, the water quality standard, based on median annual rainfall, could be 1.0 dS/m at a leaching fraction of 0.15 and 1.4 dS/m at a leaching fraction of 0.20. Considering the variability of rainfall, no loss in bean yield would occur even at the lowest annual rainfall amounts from 1952 to 2008 if the leaching fraction was higher than 0.20 with an EC_i of 1.0 dS/m. At a leaching fraction of 0.15, yield losses would be predicted at rainfall below the median value of 10.5 inches. At the 5 percentile for rain, yield loss would be 5%.

Using the steady-state model with the 40-30-20-10 crop water uptake distribution and taking the median rainfall of 10.5 inches into account, the water quality standard could be 0.8 dS/m at a leaching fraction of 0.15 and 0.9 dS/m at a leaching fraction of 0.20.

The leaching fraction in the South Delta based upon drain discharge and soil sampling averages between 0.21 and 0.27, with perhaps a few exceptions. Anecdotal evidence of relatively high leaching fractions are the irrigation efficiencies estimated to be 70% for furrow irrigated beans and an overall irrigation efficiency of 75% for the South Delta.

Four transient models were reviewed. The Grattan model which uses a 40-30-20-10 water uptake distribution was applied to a watershed near Davis, CA. No verification of this model has been attempted. The Corwin model, called TETrans, is a functional, layer-equilibrium model. The model was tested using data from the Imperial Valley, CA. The Simunek model, called UNSATCHEM, is a sophisticated, mechanistic, numerical model. Although not developed to determine the LR, it can be altered to do so. This model was also tested on data from the Imperial Valley. Letey and co-workers developed the ENVIRO-GRO model. This model contains a sophisticated equation to compute crop water uptake. Letey's model was tested on a corn experiment conducted in Israel.

Results from the Grattan model indicated that the water quality standard could be 1.1 dS/m for the watershed near Davis, CA. Using information from the Imperial Valley, Corwin and co-workers noted that steady-state models over-estimated the L_r compared to transient models, but only to a minor extent. Based upon the conclusion of Letey comparing steady-state and transient models, the water quality standard could be raised to 1.0 dS/m. This assumes that the salt tolerance of bean is to be used to protect irrigated agriculture.

All of the models presented in this report predict that the water quality standard could be increased to as high as 0.9 to 1.1 dS/m and all of the crops normally grown in the South Delta would be protected. This finding is substantiated by the observation that bean is furrow irrigated with an irrigation efficiency of about 70 % which results in a high leaching fraction.

7. Recommendations

1. If the salt tolerance of bean is to be used to set the water quality standard for the South Delta, it is recommended that a field experiment be conducted to ensure that the salt tolerance of bean is established for local conditions. The published data for bean are based on five laboratory experiments; one in soil, three in sand, and one water-culture. All five laboratory experiments were conducted more than 30 years ago. There may well be new varieties grown that under local conditions might have a different salt tolerance than the one published.

2. If the water quality standard is to be changed throughout the year then the salt tolerance of bean at different growth stages (time of year) needs to be determined. No published results were found on the effect of salinity on bean at different stages of growth. This type of experiment can best be conducted at the U. S. Salinity Laboratory at Riverside, CA where the experimental apparatus and previous experience on studying salt tolerance at different stages resides.

3. If a steady-state model is to be used to determine the water quality standard, it is recommended that either the exponential or the 40-30-20-10 model be used with the inclusion of effective rainfall as part of the applied water. As reported in Section 5, the 40-30-20-10 model gives a more conservative water quality standard than the exponential model (1.0 dS/m for the exponential versus 0.8 dS/m for the 40-30-20-10 model at a leaching fraction of 0.15 for bean as an example.)

4. Transient models have a number of advantages over steady-state models. Of course the major advantage is that transient models account for time dependent variables. These variables include considering crop rotations, double cropping, and intercropping; changes in irrigation water quality and quantity and rainfall. The major disadvantage is that far more data are required. Transient models are currently under development but very few checks of their validity against field data have been accomplished. It is recommended that support be given to the testing of one or more of these models using data from the South Delta.

5. To estimate the leaching fraction in the South Delta, data from agricultural subsurface drains were used. It was not clear for some of the reported drains whether the drain discharge was a combination of irrigation return flow and subsurface drainage or subsurface drainage alone. To make the collected data useful for calculating leaching fraction, it is recommended that the source of the drain discharge be identified. It would also be helpful to know the area drained by the various systems.

6. The concentration of boron in surface water and in the subsurface drain discharge is a possible concern because the boron threshold tolerance for bean is 0.75 to 1.0 mg/l. It is recommended that this concern be studied to determine if there needs to be a boron objective for the surface waters in the South Delta.

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Appendix A: Summary of Public Comments Received by September 14, 2009 and Written Responses

Eight comments letters regarding the July 14, 2009 draft of this report were received from the public by September 14, 2009. The following is a summary of the comments received followed by a response to each.

Comment Letter #1: Central Valley Clean Water Association
September 14, 2009

Comment #1.1
CVCWA encourages the State Board to coordinate this process for the development of South Delta objectives with the Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS) process

Response:
I agree that the State Board should coordinate the development of South Delta objectives with the Central Valley Salinity Alternatives for Long-Term Sustainability but it is not within the purview of this report to make the recommendation. It is for the State Board to decide.

Comment #1.2
The final report should clearly separate the two major recommendations, the first being the recommended model for use in the State Water Board's current revaluation of salinity objectives, and the second being the additional study and investigation required to address uncertainty of evaluating salinity objectives.

Response**:**
In Section 7, Recommendations, the two major recommendations are separate. With respect to the recommended steady-state model to use (see Recommendation 3), the exponential or the 40-30-20-10 model with inclusion of rainfall is recommended. If one is to be chosen, then the exponential model is less conservative. With respect to the transient model to be used (see Recommendation 4), no one or two models has been developed and tested at this time to show that it is superior to the exponential steady-state model for modeling large irrigated areas over a long time period. There are two groups of scientists currently comparing a number of transient models to ascertain which one is best for long-term evaluations for a given irrigated area. The additional studies recommended to clarify the salt tolerance of salt sensitive crops are given in Recommendations 1 and 2.

Comment #1.3
CVCWA is concerned the report is too conservative and recommends adding a list of the conservative assumptions made in selecting model parameters, so there will be confidence that the modeled result will be protective of the irrigation use without being needlessly stringent.

Response:
It is true that the climate in the South Delta is slightly less stressful than Riverside, CA where many of the salt tolerance experiments were conducted. However, no experiments have ever quantified the impact of a slightly different climate on crop salt tolerance. With all of the differences in cultural and irrigation practices the small climate differences are insignificant. With respect to leaching fraction, there is a fairly large impact on the water quality objective depending on the appropriate leaching fraction being chosen. With the additional subsurface drainage information from the New Jerusalem Drainage District now included in Section 3.13 and the realization that the soil samples reported on by Meyers and colleagues in 1976 were taken during a severe drought period, the leaching fractions appear to be between 0.20 and 0.30. These values are consistent with the irrigation efficiencies in the South Delta averaging 75%. Thus, the modeling results reported in Section 5 now include values for leaching fractions of 0.15, 0.20, and 0.25 for all three crops modeled and 0.07 and 0.10 for alfalfa. It would appear that a leaching fraction of 0.25 may be a very good estimate of the degree of leaching that has been occurring in the South Delta over the past few decades and a leaching of 0.15, used previously is too low except perhaps for alfalfa. Other assumptions in the modeling efforts are best management practices that include prevention of crop water stress, adequate fertility, and avoidance of insects and diseases. The dissolution of salts from the root zone (5 to 10% of total amount of salinity leaving the root zone) was ignored which would increase the leaching fraction if taken into account.

Comment #1.4
The endpoint selected for the model is not reasonable. Consideration should be given to determination of a reasonable yield target that reflects some level of risk. The historical yield generated by the model for conditions where the irrigation water quality is not a factor should be the benchmark for the year.

Response:
No farmer strives to receive a crop yield less than 100%. There are numerous management and weather uncertainties, in addition to salinity, that may reduce yields below 100%. To consider a water quality standard that would result in yields below 100%, please refer to Figures 5.9 and 5.10 for bean and Figures 5.13 and 5.14 for alfalfa and Figures 5.17 and 5.18 for almond.

Comment #1.5
The report should also consider the reasonable water quality objectives for winter irrigation of alfalfa.

Response:
As several have suggested, the water quality standard for the irrigation of alfalfa outside of the growing season for bean has been added to Section 5. The water quality standard for almond, a perennial crop more salt sensitive than alfalfa, has also been added to Section 5.

Comment #1.6
The steady state models calculate more conservative salinity requirements due to the fact that they cannot account for the natural variations that occur in the growing cycle. Therefore, in the event the State Board determines the use of a steady state model is appropriate for the current salinity objective evaluation, the specific model should be carefully selected.

Response:
It is true that steady-state models, like the recommended exponential model, are more conservative than transient models appear to be. However, if bean is more salt sensitive during the early growing season than the cropping season average used in the model then the exponential model may not be conservative and may in fact put the crop at risk.

Comment Letter #2: Eric Soderlund, Staff Counsel, DWR
September 14, 2009

General Comments:
For the most part, DWR supports the Study Report's conclusions and recommendations. The Study Report provides strong evidence that existing soil and irrigation water conditions in the southern Delta are favorable for growing agricultural crops, including beans, and that the current salinity objectives are overly protective.

Comment #2.1
Regarding a field experiment to determine the salt tolerance of bean for local conditions, DWR does not believe that such an experiment should delay the current review and potential modification process. The current state of knowledge demonstrates that a 0.7 EC objective is not necessary to protect agriculture in the southern Delta. The SWB could address results of the experiment as part of a future periodic review.

Response:
I am not aware of how quickly the State Board will decide on a revised water quality objective. I agree that the results of this report give adequate justification for the State Board to change the water quality objective. A field study like the one I am recommending will take 3 to 5 years to conduct. If the results of the field experiment are significantly different than the conclusions of this report the State Board could certainly change the water quality objective based on the field results.

Comment #2.2
In the Study Report, the table of crop acreages based upon DWR's land use surveys does not accurately reflect the acreages of crops that were mapped. The corrected crop acreages are provided in four tables, one for each land use survey.

Acreage discrepancies shown in Table 2.2 of the report from crop acreage data acquired from the San Joaquin County Agricultural Commissioner may have resulted from a situation where multiple polygons represent a single field. The digital maps developed by the Ag. Commissioners are used to track pesticide application permits and more than 10 polygons may be stacked at a single location, which can generate errors if the polygons are used to calculate crop acreages.

DWR recommends reprocessing the land and soil data to provide a more accurate summary of the relationships between soil characteristics and crops since some field beans and other crops were not represented in this analysis.

Response:
The revised crop acreages based upon DWR's survey have now been inserted into Tables 2.2 and 2.3 and the correct values are now used throughout the report. Providing the irrigation method used for the various crops in the 2007 crop survey is now used to improve the estimates of the irrigation methods in Section 3.6.

Comment #2.3
In section 2.21, the relationship between the two electrical conductivity units is not clear. The numbers representing a given salinity value are 1000 times larger when you use microSiemens per centimeter because the unit is smaller (units of microSiemens per centimeter are 1000 times smaller than deciSiemens per meter).

Response:
Thank you for pointing out this error in grammar. The sentence in Section 2.21 now reads "The numerical values in units of microSiemens per cm are 1000 times larger than the numerical values in units of deciSiemens per meter.

Comment #2.4
In section 3.5.2, Table 3.6, a value of 13.8 for mean annual precipitation is probably high for the South Delta since the area is in the rain shadow of Mount Diablo. Refer to the Soil Survey of San Joaquin County, California, published by the USDA Natural Resources Conservation Service for a more detailed map of average annual precipitation for this area.

Response:
The value of 13.8 inches averaged from data published by MacGillivray and Jones (1989) is too high for the South Delta. However, in Section 5 the precipitation measured at the Tracy-Carbona Station #8999 was used to model the South Delta crops. The median annual precipitation was 10.5 inches (see Table 5.1).

Comment #2.5
In section 3.12.1, Figure 3.16, please label the two lines representing different soil textures.

Response:
Thanks for finding this omission. The upper line in Figure 3.16 is for the California results and the lower line is for Texas. The correlation coefficient of 0.96 for the Texas data was also omitted.

Comment #2.6
In section 5.2, Table 5.1, while one might expect the required irrigation water to be the same when no precipitation is included in the model, but not more when precipitation is taken into account.

Response:
In Table 5.1, the irrigation amount each year is always more when precipitation is assumed to be zero than when precipitation is taken into account (compare column I_1 with column I_2).

Comment Letter #3: Melissa A. Thorme, Special Counsel, City of Tracy
September 14, 2009

Comment #3.1
The City of Tracy (City) disagrees with the statement on page 1 of the report that the southern Delta salinity objectives "were not substantively changed in the 2006 Bay-Delta Plan." The Bay-Delta Plan modifications made in 2006 changed the application of the electrical conductivity ("EC") objectives to all regions of the southern Delta, rather than just to the previous four compliance points specified in earlier versions of the Plan. In addition, the Bay-Delta Plan in 2006 imposed compliance with the EC objectives on municipal dischargers for the first time without having undertaken the mandatory analysis required by Water Code section 13241. To make the report more accurate, the City suggests including the following at the end of the first sentence in the third paragraph at section 1.2 on page 1: "…was not available on which to base changes. <u>However, the application of these objectives was modified to apply throughout the southern Delta and to additional discharge sources."</u>

<u>Response:</u>
The underlined sentence in Comment #3.1 was added to Section 1.2.

Comment #3.2
The State Water Board should measure EC objectives in microSiemens per centimeter (μS/cm) or deciSiemens per meter (dS/m), which are more updated units of measurement.

<u>Response:</u>
I agree with Comment #3.2 and personally prefer deciSiemens per meter (dS/m).

Comment #3.3
Report should incorporate historic data showing salinity levels prior to water supply improvements to the Delta shown in Figure 2.1 to get a more accurate picture of the salinity in the Delta over time.

<u>Response:</u>
The Report focuses on what the salinity objective should be in the future. Figure 2.1 is presented only to indicate what the salinity of surface water has been in recent years. There are many references that provide historical data.

Comment #3.4
State Water Board should take note that southern Delta waters are not impaired for EC over the long term, and should consider revising EC objectives to be long term averages that would still be protective.

<u>Response:</u>
I agree with this comment but the State Water Board may wish to change the EC objective during the year in a fashion similar to what is currently being done.

Comment #3.5
Federal law allows once in three year exceedance of all objectives, and criteria set to protect aquatic life are set at the 95th percentile and are not generally based on the most sensitive species, therefore, Dr. Hoffman should incorporate the 95th percentile values in the analysis due to the fact that 100% protection is not required by law.

Response:
No farmer wishes to achieve less than 100% crop yields. Thus, the emphasis in this report is the requirements to obtain full crop production. If one wanted to note the EC objective to obtain less than 100% yield the values can be determined from the graphs in Figure 5.9 for bean, Figure 5.13 for alfalfa, and Figure 5.17 for almond. For example, the EC objective to achieve 95% yield of beans at a leaching fraction of 0.15 would be 1.25 dS/m assuming median rainfall and using the exponential model.

Comment #3.6
Due to the fact that Dr. Hoffman found no evidence of sodicity, the State Water Board should consider the use of the Sodium Absorption Ration ("SAR") as a better objective.

Response:
I do not understand comment #3.6. The Sodium Adsorption Ratio (SAR) is an estimate of the severity of excess sodium compared to calcium and magnesium in irrigation or soil water. The larger the SAR the higher the resultant loss of water penetration into and through the soil profile. SAR has no meaning in establishing a salinity objective.

Comment #3.7
Dr. Hoffman should opine on whether total dissolved solids ("TDS"), sodium, or other ions should be used as the proper objective since EC is not a pollutant, just a measurement of salinity.

Response:
The objective of this report is to evaluate an objective for salinity, the total dissolved solids content in the San Joaquin River. Electrical conductivity is an accurate and easily measured indicator of the amount of total dissolved solids present in water. As stated in Section 2.2, in excess, salinity, sodicity, and toxicity can all reduce crop yields. However, the objective of this report was to evaluate salinity. Obviously, if excess sodium or toxic constituents were present in the water, standards would need to be determined to protect irrigated agriculture.

Comment #3.8
The proposed 1.0 dS/m EC objective is only needed to protect the most salt sensitive bean crop that is grown on less than 4,000 acres in the Delta. This 1.0 dS/m level is rarely exceeded and it would be cheaper for the State Water Board to purchase the land or buy out the farmers' right to grow salt sensitive crops than it would be to install expensive and energy intensive treatment facilities to meet this objective.

Response:
The objective of this report is to determine a salinity standard that would be protective of all irrigated agricultural crops in the South Delta. It is a matter for the State Water Board to decide upon the prudent steps to be undertaken.

Comment #3.9
Dr. Hoffman should identify the source of the water used on the acreage where the most salt sensitive crops are being grown as the irrigation water used could be groundwater and not river water. Further, Dr. Hoffman should include the projected cost of the updated bean study suggested on page 20.

Response:
Without exception, groundwater taken from beneath an irrigated area will be more saline than the irrigation water because crops extract nearly pure water from the soil thereby causing the salinity of the remaining soil water, which eventually becomes groundwater, to increase. Furthermore, I have no information indicating that groundwater is being used in the South Delta to irrigate salt sensitive crops. The field study I propose will not be cheap if it is conducted over at least three years and has sufficient numbers of treatments and replications to establish the salt tolerance of bean and perhaps other crops like asparagus during its first year of growth. If a field experiment is considered by the State Water Board, I will be glad to work with their staff to determine a budget.

Comments #3.10
Dr. Hoffman should identify any other available water management techniques that could be utilized to improve leaching to allow higher EC water to be equally protective of crop yield.

Response:
The objective should not be to increase leaching but to improve water management so leaching can be reduced. The improvement of irrigation systems and their management to increase irrigation efficiency and to improve the uniform distribution of irrigation water are the top means to use less water for irrigation and thereby reduce leaching. Micro-irrigation and sprinklers are irrigation systems that are presently available that can increase irrigation efficiency and improve the uniform distribution of irrigation water compared to furrow and border irrigation methods.

Comments #3.11
If EC objectives are not adjusted, perhaps waste discharge requirements (“WDRs”) need to be placed on agricultural drains as the average EC from these discharges was cited as being 1.5 dS/m.

Response:
The question of waste discharge requirements is not within the objectives of this report.

Comment Letter #4: John Letey
September 9, 2009

Comment #4.1
Although irrigation uniformity affects irrigation efficiency, they are distinctly different and must be discussed separately. Irrigation efficiency is important in designing irrigation projects, but irrigation uniformity has significant consequences on irrigation management.

Response:
I agree that irrigation uniformity and irrigation efficiency are different. I have changed Section 3.8 of the report to discuss the two terms separately.

Comment #4.2
Equation 3.6 is meaningless because there is no way to accurately relate the salinity at the bottom of the root zone with crop response to the salinity in the root zone where all of the action is.

Response:
I agree that equation 3.6 is not a useful equation to prediction the leaching requirement but it shows how thinking progressed from equation 3.5 to the various steady-state equations proposed by different scientists as discussed in Section 4.1. The term EC_d^* in equation 3.5 was replaced by EC_{e50}, $2EC_{e0}$, and $5EC_{et}$-EC_i in three of the steady-state equations presented in Section 4.1.

Comment #4.3
Linear averages give equal weight to the very high concentrations at the bottom of the root zone as to the much lower concentrations where the greatest mass of roots exists. This averaging procedure provides results that the salinity impact is the least detrimental of all the steady-state approaches.

Response:
The linear averaging technique is used by the 40-30-20-10 steady-state model but the other steady-state models do not average salinity values through the root zone. This, along with comparisons with experimentally determined leaching requirements, is why I recommend the exponential model over the 40-30-20-10 model.

Comment #4.4
The Grattan transient state model is actually a hybrid that includes steady-state and transient aspects.

Response:
The Grattan model has been refined recently and has been submitted for publication. It now is much closer to a transient than a steady-state model.

Comment #4.5
The 3 relationships presented with the Grattan model in Section 4.2 require clarification. EC_{sw} and EC_e vary with time and depth. At what time and positions are they related to EC_i as presented in the first 2 equations? $EC_{sw} = 2 \times EC_e$ is only true when the soil-water content equals the amount of distilled water added to create the saturated extract.

Response:
The three relationships were eliminated because they are not used in the discussion.

Comment #4.6
The numbers in Table 4.2 can be used to conclude that the transient models prescribed a lower L_r than the steady state models. No judgment as to the quantitative difference can be made because <0.13 could be 0.12, 0.05 or any other number less than 0.13.

Response:
I agree that the differences between steady-state and transient model results reported in Table 4.2 can't be quantified. I merely reported the statements made by Corwin et al. (2007) about the differences between results.

Comment #4.7
Equations 4.1 and 4.2 are mass balance equations and not necessarily steady-state assumptions.

Response:
Thanks for reminding me of this fact. I changed the text to state that both steady-state and transient models are based upon equations 4.1 and 4.2.

Comment Letter #5: DeeAnne Gillick, Attorney at Law, County of San Joaquin September 8, 2009

Comment #5.1
The County of San Joaquin believes that adequate water quality standards apply within the Southern Delta and that those standards are already met. More analysis than what has been given in the report is necessary to accurately evaluate the water quality needs of agriculture in the south Delta.

Response:
I have now added more analyses in Section 5 pertaining to alfalfa, almond, and different planting dates for bean. Along with the other analyses already in the report, all of the results indicate that the water quality standard could be raised in the South Delta.

Comment Letter #6: Linda Dorn, Environmental Program Manager, SRCSD in addition to comments submitted by CVCWA
September 14, 2009

Comment #6.1
In the Report, the threshold salinity discussed for all cases is the salinity corresponding to 100% yield of crops. Specification of 100% yield as the threshold may not be necessary to provide reasonable protection for the irrigation use. Salinity in the southern Delta is strongly related to water year and the actual yield of a crop may be lower than 100% for reasons other than the irrigation water. To account for the condition where the crop yield is lowered for reasons other than salinity, the model should be run at a yield less than 100%.

The Report should be clarified to link the irrigation practice utilized for the target crop to the selected leaching fraction used in the modeling. Underestimating the leaching fraction will result in overly stringent irrigation water quality requirements.

The Report could be enhanced by bolstering the discussion on selecting the appropriate value for both parameters (threshold salinity and leaching fraction) based on the conditions in the southern Delta and the specific crop under consideration.

Response:
To evaluate the impact of the salinity of the irrigation water on crop yield please refer to Figures 5.9 and 5.10 for bean, Figures 5.13 and 5.14 for alfalfa, and Figures 5.17 and 5.18 for almond. You may select any crop yield below 100% and note the salinity of the irrigation that causes a specific yield reduction and the impact of annual rainfall. None of the steady state models can predict crop yield reductions caused by factors other than salinity. Transient models can also predict yield reductions caused by water stress but they are not able to predict crop yield reductions by other factors. The report has been rewritten to explain how crop yields below 100% can be determined.

Linking the irrigation method with the target crop is an excellent idea. I have tried to do this by providing the relationship between irrigation water salinity and crop yield for several leaching fractions in Figures 5.7, 5.8, 5.11, 5.12, 5.15, and 5.16 in the revised report. With additional information on the actual leaching fractions being achieved over the past several decades based upon measurements of salinity from subsurface drainage systems, I have added a leaching fraction of 0.25 to my analyses. It appears clear that the leaching fractions occurring in the South Delta is probably between 0.20 and 0.30 for large areas of the South Delta where salt sensitive crops are being grown. I also added results for leaching fractions of 0.07 and 0.10 for alfalfa. As the leaching fraction increases the water quality standard can be increased.

Comment #6.2
The southern Delta is a complex system and the irrigation requirements may not be the appropriate water quality objectives for the entire southern Delta.

Response:
The objective of this report was to ascertain the water quality standard for irrigation in the South Delta. Acknowledging that the South Delta is a complex system, factors other than irrigation were not considered.

Comment #6.3
The Report recommends the use of a steady state model due to issues with each of the considered transient models. The recommendations should be expanded to link the additional study necessary for consideration of the different models, as the transient models are the desired method for determining irrigation requirements.

Response:
Transient models are more accurate than steady-state models, particularly on a seasonal basis and if significant changes in cropping patterns, water quality, and other factors occur over time. The steady-state models as proposed here are reasonably accurate over periods of decades if significant changes are not occurring. The steady-state model appears to be very reasonable at leaching fractions above 0.15. At least two groups of scientists and engineers are currently working on comparing the transient models described here and several others and attempting to resolve which model(s) should be used. One must keep in mind that transient models require a large amount of input data which are not always available. It is hoped that within a few years transient models will have been developed and field tested so that they may be used with confidence. In the meantime, with the high leaching fractions reported in the South Delta and the relatively stable cropping pattern and irrigation water quality, the steady-state model recommended should prove adequate.

Comment Letter #7: San Joaquin River Group Authority and State Water Contractors
September 14, 2009

Comment #7.1
The background information on timing and cultural practices of dry beans in the South Delta needs to be changed to reflect present day practices and that information utilized in the analysis.

Response:
The analysis has been expanded to include planting dates of April 1, May 1, and June 16. The planting date had no impact on the water quality standard (see the results in Table 5.3). If pre-plant irrigation is practiced for bean then germination and seedling emergence could still be a problem if the water quality objective is higher than the salt tolerance of bean at early growth stages. Thus, the recommendation to determine the salt tolerance of bean at different stages is appropriate. The crop survey is for the entire South Delta and it would require some time for DWR personnel to separate the bean acreage served by the Central Valley Project from the remainder of the South Delta. With that being acknowledged, some beans are grown using water from the San Joaquin River. The total acreage is probably not important if the objective is to protect the most salt sensitive crop.

Comment #7.2
Salinity is likely not the only factor limiting dry-bead yield. Another factor which may be greater than salinity in the South Delta is boron.

Response:
I have included data on boron concentrations in surface waters in the revised report and the concentrations are sufficiently high to be a concern. I have added a recommendation that boron levels in the South Delta be studied.

Comment #7.3
The utilization of a 100% yield potential based on the 1977 Mass and Hoffman analysis that established crop tolerance curves for major crops is not based on a strong data set and is likely over conservative. It is recommended that the report strongly advise against the continued use of this data and recommend that a new curve be established for dry beans.

Response:
I agree with this comment. My number one recommendation is to conduct a field experiment to establish the salt tolerance of bean using current cultivars and under the field conditions representative of where beans are grown in the South Delta. I also agree that the salt tolerance values for bean may be conservative, but in the meantime, these values will protect South Delta irrigated agriculture until the experimental results are known.

Comment #7.4
A review needs to be conducted of cultural practices presently being used to limit the potential for salt sensitivity of dry beans at germination such as major pre-irrigations.

Response:
You stated earlier in your comments that pre-plant irrigation is a common practice to leach the soil profile of salts and to minimize water stress during germination and seedling emergence. I am not aware of any other cultural practices being employed to limit salt sensitivity of bean.

Comment #7.5
There is a need to clarify the salt leaching potential of rainfall in the “applied water” definition.

Response:
This need for clarification was pointed out by another reviewer and the text has been changed in Section 3.5 to address this comment.

Comment #7.6
There is a need to expand the discussion of actual leaching fraction by using presently available field data. The Study Report needs to take a closer look at actual leaching fractions (L) in the Delta

Response:
I agree with this comment and based upon documents provided by this reviewer I have added a great deal of data on leaching fractions that can be inferred from subsurface tile drain effluent. Section 3.13.2 has been expanded to provide the inclusion of the results from analyze of the documents provided.

Comment #7.7
It is unlikely that there will be a reduction in the high leaching fractions being found on dry bean production today. If a water conservation modeling effort is undertaken similar high leaching fractions on dry bean production should be assumed.

Response:
I agree with this comment and have therefore added results when higher leaching fractions are achieved. The current leaching fraction calculations from Section 3.13.2 indicate that leaching fractions above 0.15 are common and generally the leaching fraction is between 0.2 and 0.3. Thus, leaching fractions of 0.15, 0.20, and 0.25 are modeled in Section 5.2 for bean, 0.07, 0.10, 0.15, and 0.20 for alfalfa, and 0.10, 0.15, and 0.20 for almond.

Comment #7.8
The analysis to show the basis for the winter irrigation season objective and the role of effective rainfall during the winter irrigation season has been left out of the report. This analysis needs to be conducted and the impact of winter rains on leaching and salt control needs to be fully evaluated.

Response:
This is an excellent observation and this comment has been addressed by modeling a year-long alfalfa crop and almond trees in Section 5.2. Comments regarding the modeling results are added in Sections 5.2 and 6.2.

Comment #7.9
We support the development of a transient model for South Delta conditions but in its absence the Study Report should recommend the use of the exponential model over the 40-30-20-10 model.

Response:
The decision on whether the exponential or the 40-30-20-10 model is used is at the prerogative of the CA State Water Resources Control Board. However, I recommend that the exponential model be used. I also support the development of a transient model for the South Delta as stated in my recommendations, Section 7.

Comment Letter #8 John Herrick, Counsel, South Delta Water Agency September 14, 2009

Comment #8.1
Protecting for the "most salt sensitive" crop (bean) by reviewing impacts on crop productivity by the use of saline water might not necessarily be protective for other crops if other factors affect crop salt tolerance or if the protection of the "most salt sensitive" crop differs significantly from the protections of other crops under varying conditions.

Response:
I have added the impact of various water quality objectives on alfalfa, the crop considered previously for the time of the year when beans are not grown, and almond trees, a perennial salt sensitive crop grown in the South Delta. The results of this investigation are given in Section 5.2.

Comment #8.2
The applied water quantity and salinity and timing for each of the varieties of southern Delta crops must first be determined before you can determine if the same salinity standard can protect full yield of more than one crop at all times of the year.

Response:
This comment is a follow-up to Comment #8.1 and is addressed in Sections 5.2 and 6.2 for bean, alfalfa, and almond trees.

Comment #8.3
There are a few problems that are largely ignored in the draft Report that include:
1. The achievable leach fraction through and out of the root zone in alfalfa and tree crops depends on the percolation capacity throughout the deep root zone, and on the soaking time which is both available and non-damaging to the crop.

2. The existence of stagnant channel reaches occur whenever the flow into south Delta channels is less than the consumptive use of water in the south Delta. No standard can be met in stagnant reaches.

3. The lack of adequate allowance for the fact that seedlings and young crop plants are more salt sensitive than established plants, and that it is typically very difficult to maintain soil moisture of low salinity in the seedling root zone.

4. Allowance for the assumption that farmers should accept a reduced percentage of seedling emergence caused by soil moisture salinity. The report makes no analysis of possible abnormal distribution and/or reduced vigor of seedlings that then do emerge. There should be some allowance for the uncertainty this imposes on ultimate crop yield.

Response:

1. The average leaching fractions achievable have been calculated from subsurface tile drainage systems over a large portion of the South Delta. The lowest leaching fraction calculated for one year from all of the drains monitored was 0.11 with the average being between 0.21 and 0.27 depending on the drainage system (see Section 3.13.2). This is not to say that some fields or portions of a field do not have a low leaching fraction. Meyer et al. (1976) soil sampling nine different locations reported only one alfalfa crop on a clay soil with a leaching fraction below 0.1. I have no information on "soaking" time for problematic soils. However, it is well known that the rate of water penetration into and through a soil is increased as the salt content of the water increases. Thus, increasing the water quality objective will decrease the soaking time.
2. The objective of this report was the water quality objective for the San Joaquin River and did include stagnant channel reaches.
3. Based upon recent information that a pre-plant irrigation is applied before planting beans negates the need to establish the salt sensitive during germination and seedling growth for bean if bean is not more sensitive than the salinity objective early in the growth period. I recommend that an experiment be conducted to determine the salt sensitive of bean during germination and for early seedling growth. I do not know if pre-plant irrigations are applied for other salt sensitive crops.
4. The report does not assert that a farmer should accept a reduced percentage of seedling emergence. The report does provide salinity levels that resulted in a 10% loss of germinating seeds for comparisons among crops. It is true that the report does not account for abnormal distribution and/or reduced vigor of seedlings. With pre-plant irrigation the problems of poor emergence should be minimized.

Comment #8.4

A paper by Dr. Gerald Orlob shows that 40% of the lands in the southern Delta are classified as "slow" permeability. This means that when water is applied, it soaks into and through the soil at a very slow rate; <0.2 inches per hour. Such extremely slow rates hamper the ability to achieve the leaching fractions discussed and assumed in the draft Report.

Response:

As state above, all of the analyses from subsurface drainage systems indicate relatively high leaching fractions. However, recognizing that alfalfa has a high water requirement (about 50 inches annually) and is frequently grown on slowly permeable soils, results have been added to Section 5.2 for leaching fractions of 0.07 and 0.10. Also, as the salinity of the applied water increases, the infiltration and water penetration rate increases which should benefit soils of "slow" permeability.

Comment #8.5

Groundwater levels vary greatly depending on the distance to the neighboring channels, and the relationship to sea level and tidal flows. In certain portions of the Delta, the land is at or below sea level; hence, without an ongoing drainage system at work, the ground water will rise to or above the land surface. This results in salts that collect and are repeatedly reintroduced into the very zone that needs to be flushed. Therefore, “normal” irrigation practices will not result in the leaching of the salts.

Response:
If no leaching occurs the soil will become saline and no crops can be grown. If “normal” irrigation practices will not result in leaching then other methods must be found or the land will have to be abandoned. As pointed out, a drainage system may need to be utilized to maintain crop productivity.

Comment #8.6
Should the lowest permeability in the profile be used, especially for deep-rooted crops like alfalfa or trees? (Referring to table 2.1 in report)

Response:
Table 2.1 was intended to show some of the physical properties of the soils in the South Delta. The Table was not developed to show soil properties below the surface layer.

Comment #8.7
Generalizations on groundwater cannot be made due to the fact that groundwater levels exhibit regular and significant fluctuations due to tidal effects.

Response:
I have no information on the impact of tides on groundwater depths. However, the data in Table 2.1 and Section 3.12.2 would include the normal influence of the tides at the location of the measurements.

Comment #8.8
There is a lack of confidence in the Chilcott, Montoya and Meyer data. The Montoya 2007 report attempts to identify agricultural discharges as “sources” of salt load and concentration, when in fact virtually all of the salt originated from the activities of the CVP in upstream areas. The report is a synthesis of old information and is not current or reliable.

Response:
I have updated the drainage effluent information and the resultant leaching fractions and added information from the New Jerusalem Drainage District and the drainage sump at Tracy Boulevard in Section 3.13.2. All of the drainage effluent and the resultant leaching fractions are relatively consistent. The data for New Jerusalem goes from 1977 to 2005. In addition, only data from drains that were only for subsurface tile drains are included in Table 3.10.

Appendix F.1

Hydrologic and Water Quality Modeling

Appendix F.1
Hydrologic and Water Quality Modeling

Tables

Figures

Attachments

Acronyms and Abbreviations

AF	acre-feet
AF/y	acre feet per year
AN	above normal
AWMPs	Agricultural Water Management Plans
BN	below normal
BO	biological opinion
C	critically dry
CAD	Cowell Agreement Diversion
CCSF	City and County of San Francisco
CDFW	California Department of Fish and Wildlife
cfs	cubic feet per second
CSJWCD	Central San Joaquin Water Conservation District
CUAW	Consumptive Use of Applied Water
CVP	Central Valley Project
D	dry
DWR	Department of Water Resources
FERC	Federal Energy Regulatory Commission
HEC	Hydrologic Engineering Center
HOR	Head of Old River
HWMS	Hydrologic Water Quality Modeling System
LSJR	Lower San Joaquin River
M&I	municipal and industrial
Merced ID	Merced Irrigation District
mmhos/cm	millimhos per centimeter
MID	Modesto Irrigation District
MSL	mean sea level
NMFS	National Marine Fisheries Service
NMI	New Melones Index
NWR	National Wildlife Refuge
OCAP	Operations Criteria and Plan
OID	Oakdale Irrigation District
OMR	Old and Middle River
ppt	parts per thousand
RPAs	Reasonable and Prudent Alternatives
SED	substitute environmental document
SEWD	Stockton East Water District
SJR	San Joaquin River

SJRA	San Joaquin River Agreement
SJRRP	San Joaquin River Restoration Program
SOI	Sphere of Influence
SSJID	South San Joaquin Irrigation District
State Water Board or SWRCB	State Water Resources Control Board
SWP	State Water Project
TAF	thousand acre feet
TAF/y	thousand acre-feet per year
TID	Turlock Irrigation District
USACE	U.S. Army Corps of Engineers
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
VAMP	Vernalis Adaptive Management Plan
W	wet
WSE	Water Supply Effects
WTP	Water Treatment Plant

F.1.1 Introduction

This appendix includes a description of the hydrologic, water supply, and water quality modeling methods and assumptions used to evaluate the Lower San Joaquin River (LSJR) alternatives in this recirculated substitute environmental document (SED). The primary models used were the Water Supply Effects (WSE) spreadsheet model and the San Joaquin River Basin-Wide Water Temperature Model (CALFED 2009; CDFW 2013). The State Water Resources Control Board (State Water Board or SWRCB) developed the WSE model, based on the CALSIM II framework, in order to evaluate, under baseline conditions and each of the LSJR alternatives, effects on reservoir operations, water supply diversions, and river flow for each of the eastside tributaries (Stanislaus, Tuolumne, and Merced Rivers) and flow and salinity at Vernalis on the San Joaquin River (SJR). The San Joaquin River Basin-Wide Water Temperature Model, developed using the U.S. Army Corps of Engineers (USACE) Hydrologic Engineering Center's HEC-5Q water quality model, was used in coordination with the WSE model results to evaluate temperature effects caused by the LSJR alternatives. Both the modeling methods and results for baseline conditions and the three LSJR alternatives are described in this appendix. This appendix includes some assumptions regarding minimum levels of groundwater pumping that offset surface water demands but does not describe effects on groundwater resources, which are described in Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results*.

The monthly and annual results from the WSE model and San Joaquin River Basin-Wide Water Temperature Model were used to assess the potential impacts of the LSJR alternatives on resource areas discussed in the SED that are affected by reservoir operations and streamflows. These resource areas are: flooding, sediment, and erosion (Chapter 6); aquatic biological resources (Chapter 7); terrestrial biological resources (Chapter 8); recreational resources and aesthetics (Chapter 10); cultural resources (Chapter 12), and energy and greenhouse gases (Chapter 14). Results showing the annual changes in water supply deliveries from the three eastside tributaries were used to analyze impacts related to groundwater resources (Chapter 9), agricultural resources (Chapter 11), service providers (Chapter 13), and economic analyses (Chapter 20).

As described in more detail in Chapter 3, *Alternatives Description*, LSJR Alternatives 2, 3, and 4 would also include adaptive implementation intended to optimize flows to achieve the narrative objective while allowing for consideration of other beneficial uses, provided that these other beneficial uses do not reduce intended benefits to fish and wildlife. There are four methods of adaptive implementation, detailed in Chapter 3, *Alternatives Description*, that allow for an adjustment of the volume of water required under LSJR Alternatives 2, 3, and 4. In general, the methods are as follows: method 1, increasing or decreasing the percent of unimpaired flow required by 10 percent, depending on the LSJR alternative selected; method 2, adjusting the percent of unimpaired flow either within or between the months of February–June; method 3, adjusting the percent of unimpaired flow outside of February–June, depending on the LSJR alternative selected; and method 4, maintaining a minimum base flow in the SJR at Vernalis at all times during the February–June period. The operational changes made using the adaptive implementation methods above may take place on either a short-term (e.g., monthly or annually) or a longer-term basis.

The Stanislaus, Tuolumne, and Merced Working Group (STM Working Group), composed of State Water Board staff, fishery agencies, and water users, will assist with implementation, monitoring, and assessment activities for the unimpaired flow objectives and with developing biological goals to help evaluate the effectiveness of the unimpaired flow objectives and adaptive implementation actions.

The quantitative results in the figures, tables, and text of Sections F.1.2.5 through F.1.2.7 of this appendix present primarily WSE modeling of the specified minimum unimpaired flow requirement of each LSJR alternative (i.e., 20, 40, or 60 percent of unimpaired flow). As such, any reference in this appendix to 20, 40, and 60 percent unimpaired flow is the same as LSJR Alternative 2, 3, and 4, respectively. Unimpaired flow represents the water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. It differs from natural flow because unimpaired flow is the flow that occurs at a specific location under the current configuration of channels, levees, floodplain, wetlands, deforestation and urbanization.

Modeling was also performed to provide data at 30 percent and 50 percent of unimpaired flow to evaluate the three adaptive implementation approaches. For example, figures, tables, and text in Sections F.1.2.2 and F.1.2.3, and the summary tables throughout the appendix, present WSE modeling of the 30 and 50 percent unimpaired flow to show the effect of the adaptive implementation approach 1. In addition, modeling at 40, 50, and 60 percent unimpaired flow allowed for retention of water to maintain carryover storage in the reservoirs to show the effect of adaptive implementation approaches 2 and 3.

Table F.1.1-1 summarizes the different unimpaired flows that could be required under each LSJR alternative as part of the minimum unimpaired flow that is part of the Program of Implementation or as a possible minimum or maximum range as part of the three adaptive implementation approaches. As mentioned previously, any reference in this appendix to 20, 40, and 60 percent unimpaired flow is the same as LSJR Alternative 2, 3, and 4, respectively.

Table F.1.1-1. Introduction: Percent Unimpaired Flows by LSJR Alternative

Percent Unimpaired Flow	LSJR Alternative 1 (No Project)	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
20%	NA	X	NA	NA
30%	NA	X	X	NA
40%	NA	NA	X	NA
50%	NA	NA	X	X
60%	NA	NA	NA	X

The No-Project Alternative is discussed in Chapter 15, *No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1)*, and Appendix D, *Evaluation of the No Project Alternative (LSJR Alternative 1 and SDWQ Alternative 1)*.

F.1.2 Water Supply Effects Modeling—Methods

This section describes the development of the WSE spreadsheet model, the assumptions used to model baseline and LSJR alternative conditions, and results of the modeling. The initial scientific basis and methodologies for the WSE model are described in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*. The additions and refinements to the WSE methodologies are described in this appendix. WSE modeling results highlight the changes in reservoir operations, river flow, and surface water diversions that would result from the LSJR alternatives as compared to baseline. These results are also referenced in other chapters in the SED, as stated in Section F.1.1, *Introduction*.

The WSE model was developed rather than using CALSIM/CALSIM II[1] because CALSIM, a widely-accepted planning-level modeling tool for Central Valley water managers, 1) does not easily allow setting of monthly downstream flow targets as a fraction of the unimpaired flows, 2) it is difficult to change operations and assess those changes rapidly, and 3) it is not readily understood by a wide variety of users. By using a spreadsheet as the platform for the WSE model, it can be easily understood by a wide variety of users, can rapidly assess alternatives for reservoir operations, and can rapidly assess effects of alternatives for flow requirements. Because the WSE model uses the same node framework, hydrologic input, and similar mechanics and assumptions as CALSIM II, it can produce similar results to CALSIM II given similar operational inputs. The WSE model is considered an equivalent tool to CALSIM II for the purposes of this comparative water balance analysis and is sufficiently representative of baseline and potential future conditions for the programmatic-level planning needed to assess the plan amendments described in Chapter 3, *Alternatives Description*.

As is with many programmatic level operations models, the WSE model is not designed to precisely re-create historical conditions, nor can it precisely predict the potential future operations of the system. Real-time operational decisions made by directors and water planners do not always follow logic that can be input to a model, and thus would differ from a modeled result. As similarly stated (OTA 1982),

> Human behavior cannot be analyzed in the same sense as interactions that take place in the physical sciences. Human interactions may be extremely complex, and involve many factors not readily subject to quantification. At best, social scientists can estimate statistical variations in human behaviors under a set of assumed conditions.

Furthermore, planning level models are not meant to model precise conditions, but rather aid in planning by presenting a set, or sets of conditions that represent the likelihood of future conditions based on actual hydrologic events that span both drought and flood sequences. Other modeling efforts have stated similarly, as in the Federal Energy Regulatory Commission (FERC) report for hydrology modeling related to the Tuolumne River (SFPUC 2007), that

> While the modeling tool uses information on actual historical hydrology, it does not "predict" or necessarily precisely depict the past, historical operation of the system. The historical operation of the system in an actual year will differ from the operations simulated by the model for that year as a result of day-to-day adjustments made by the system operators, who constantly modify operations throughout the year to respond to changing conditions related to weather, demand, water quality, or facilities conditions (e.g., maintenance or unplanned facilities outages)…The objective of using the modeling tool is to assess the effect of system changes on future operations over a broad range of realistic hydrologic conditions.

The primary utility of a planning-level model is in comparative analysis, where the physical system is represented at a sufficient level of precision in order to accurately represent the most important effects of perturbations in the system. In this case, the WSE model is configured to determine, first and foremost, the change from baseline of water supply stored and available to meet diversion demands as a result of alternatives incorporating streamflow requirements.

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[1] CALSIM is a generalized water resource simulation model for evaluating operational alternatives of the State Water Project/Central Valley Project system (USBR 2005). CALSIM II is the latest application of the generic CALSIM model to simulate SWP/CVP operations. CALSIM and CALSIM II are products of joint development between the Department of Water Resources and the U.S. Bureau of Reclamation. This appendix uses CALSIM and CALSIM II interchangeably.

The WSE model is a monthly spreadsheet model that calculates the monthly flows, reservoir storage levels, and water supply diversions for each eastside tributary based upon user-specified target flows, other user defined inputs, input from CALSIM II, and flood storage rules. The general approach is to calculate available water for diversion in each water year based on inflows, net available water from storage after carryover guidelines, and after streamflow targets are met. User-defined inputs to the model include the following.

- Months for which flow targets are to be set.
- Monthly flow targets as a percentage of unimpaired monthly flow for each eastside tributary.
- Monthly minimum flows for each eastside tributary.
- Minimum annual surface water diversion (can supersede storage guidelines).
- Annual end-of-September storage guidelines.
- Maximum annual allowable draw[2] from reservoirs as a fraction of the available storage.

Other inputs not defined by the user included the following:

- CALSIM II inflows to each major reservoir (New Melones, New Don Pedro, and Lake McClure), and SJR inflow from upstream of the Merced River confluence near Newman.
- CALSIM II evaporation rates from each major reservoir
- CALSIM II accretions/depletions downstream from each major reservoir including diversions.
- CALSIM II Consumptive Use of Applied Water (CUAW) monthly values. Translation from CUAW to diversion demand was based on updated estimates of district water balance components.
- CALSIM II flood storage rule curves at each major reservoir.

The sections below describe the calculation methodologies for flow targets, surface water demands, diversion deliveries, and the river and reservoir water balances; the development process for the WSE-CALSIM baseline scenario; and the development of inputs and assumptions for the WSE CEQA baseline and LSJR alternative simulations. Output data from the WSE model LSJR alternative simulations, including annual diversions, monthly river flows, and monthly reservoir storage, are compared to baseline conditions to assess the effects of the LSJR alternatives and intermediate simulations (i.e., 30 percent and 50 percent unimpaired flow) in Section F.1.2.2, *Water Supply Effects Model Results*.

F.1.2.1 U.S. Bureau of Reclamation CALSIM II SJR Module

The WSE model had its origin in the CALSIM II SJR module node framework. The U.S. Bureau of Reclamation (USBR) developed the CALSIM II SJR module to simulate monthly flows, reservoir storages, and water supply deliveries in the SJR Basin subject to specific requirements. The module is part of the larger CALSIM II planning model for the entire Central Valley Project (CVP) and State Water Project (SWP) that calculates reservoir operations and Delta operations for a specified set of water resources and level of development (i.e., demands) and regulatory requirements using the

[2] *Allowable draw* in this case refers to a reservoir modeling parameter that determines the available water allocation. This is not intended in a regulatory sense but, rather, to provide an example of reservoir operations to meet both streamflow requirements and carryover storage guidelines and preserve a portion for the following year's supply as well as maintaining cold pool.

historical sequence of hydrologic conditions 1922–2003. The CALSIM II SJR module encompasses the SJR Basin from the Upper SJR at Millerton Reservoir to Vernalis, including all tributaries to the LSJR.

The watershed inflows to Millerton Reservoir, the Fresno and Chowchilla Rivers, and the inflows to Lake McClure on the Merced River, New Don Pedro Reservoir on the Tuolumne River, and New Melones Reservoir on the Stanislaus River are the primary boundary conditions of the SJR module. In the module, these inflows have been modified from the unimpaired runoff by upstream reservoir operations. The New Melones inflows, developed by USBR, are a combination of planning study inflows and actual recorded inflows for recent years. The New Don Pedro inflows, provided by CCSF are a result of a long-term simulation of current project operations for the period prior to 1996 and actual computed inflow since 1996. The Lake McClure inflows were estimated using the Lake McClure outflows adjusted for change in storage and evaporation in Lake McClure (USBR 2005).

Subject to the calculated inflows, the CALSIM II SJR module estimates the reservoir operations, diversions and river flows on each tributary to the LSJR, considering flow requirements, municipal and agricultural demands, and other operational constraints like flood control. It calculates annual available river diversions using the end-of-February storage plus actual March–September reservoir inflow (perfect foresight) on the Stanislaus and Merced Rivers, and March storage plus April–July reservoir inflows on the Tuolumne River. Flow requirements also factor in to the available diversions by reducing the amount of surface water available by the volume required to be released. On the Stanislaus River, the USBR also delivers water to CVP contractors, primarily based on a lookup table that determines the availability of water as related to the New Melones Index (NMI) and allows up to a maximum of 155 thousand acre feet (TAF) to be delivered annually.

The State Water Board used the SJR module (USBR 2013a, 2013b) and made minor adjustments to operations on the Stanislaus River and Vernalis pulse flow requirements. The first Stanislaus operations adjustment included an updated representation of the National Marine Fisheries Service (NMFS) Biological Opinion Stanislaus River Reasonable and Prudent Alternative (RPA), including Action 3.1.3 (NMFS BO) Table 2E flow requirements (i.e., lookup table), which are based on the NMI (NMFS 2009). The second adjustment was to allow full CVP/SWP diversions (Stockton East Water District and Central San Joaquin Water Control District) up to 155 TAF/y, if available, by using a diversion delivery schedule based on the NMI (Table F.1.2-1). The third adjustment (conducted by USBR) fixed a bug related to the Vernalis pulse flow calculation where, in the DWR 2009 Delivery Reliability Report, flows had overestimated the pulse volumes in April and May. The last adjustment to the Stanislaus operations was to begin the model with a New Melones Reservoir starting storage of 1,000,000 acre-feet (AF) on October 1, 1922, instead of 1,700,000 AF.

Table F.1.2-1. Stanislaus River Combined CVP Contractor (Stockton East Water District [SEWD] and Central San Joaquin Water Conservation District [CSJWCD]) Diversion Delivery Curves Based on New Melones Index Used in the WSE Model

New Melones Index (TAF)	SEWD Delivery (TAF)	CSJWCD Delivery (TAF)	Total (TAF)
> 1,800	75	80	155
1,400–1,800	10	49	59
0–1,400	10	0	10

The State Water Board CALSIM case includes the D-1641 base flow and salinity objective at Vernalis to be released from New Melones Reservoir. The VAMP April 15–May 15 Vernalis pulse flows are released based on the San Joaquin River Agreement (SJRA) distribution schedule from either New Melones Reservoir, New Don Pedro Reservoir, or Lake McClure. In the State Water Board CALSIM case, other than VAMP pulse flows, the minimum flows on the Tuolumne and Merced River were based on the current requirements by FERC, the Davis-Grunsky Agreement, CDFW Settlement Agreement for the Tuolumne River, and the Cowell Agreement. This model version did not include San Joaquin River Restoration Program (SJRRP) flow releases.

Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*, contains an analysis of historical SJR flow and salinity. It compares measured monthly average SJR flows at Vernalis with the CALSIM results for water years 1984–2003. This covers a period during which actual operations in the watershed were relatively similar to those modeled in the CALSIM representation of current conditions. All major eastside dams were completed and filled, and their combined effect on flows at Vernalis is present in the actual data. CALSIM model output ends with water year 2003. The comparison of CALSIM results with recent historical flow and EC (salinity) data demonstrates that it provides a reasonable (accurate) representation of the baseline SJR flow and EC conditions.

F.1.2.2 Development of the WSE Model Baseline and Alternative Assumptions

This section contains the assumptions and methods used to develop the WSE model baseline and Alternative scenarios. In addition, this section also describes the static inputs to the calculations above.

The WSE model baseline conditions were developed such that they would corroborate with CALSIM II SJR module results, both subject to a similar set of assumptions and rules and, thus, demonstrating the efficacy of the WSE model. The State Water Board conducted CALSIM II modeling using the CALSIM II SJR module supplied by USBR (USBR 2013a, 2013b). This version of the model contained many of the same assumptions and inputs as the CALSIM II “Current Conditions” case used in the DWR 2009 Delivery Reliability Report (DWR 2010), a version of CALSIM II which closely represents the baseline conditions over 82 years of historical climate. Differences between CALSIM II and the WSE model are described below.

CALSIM was used for corroboration because it is a widely accepted and rigorously reviewed planning model for the Central Valley, and contains a longer available dataset for comparison than historical data alone. Furthermore, as the observed historical conditions become increasingly different than current conditions reaching farther back in history, corroboration with a baseline conditions model becomes more appropriate than calibration to historical data.

The WSE CALSIM-baseline results set is the baseline WSE model run that best matches CALSIM II levels of demand and water balance parameters, while the WSE CEQA-baseline incorporates adjusted levels of demand and water balance parameters based on the best available information, including recent published data from Agricultural Water Management Plans.

The WSE CEQA-baseline version was developed to better model baseline conditions representative of the 2009 existing environment, and most consistent with the definition of baseline conditions. The primary changes from WSE CALSIM-baseline to WSE CEQA-baseline were related to estimates of demand as described in Tables F.1.2-12, F.1.2-13, and F.1.2-15. In addition, the level of Merced Cowell Agreement diversions is changed from CALSIM levels to full diversion according to Table F.1.2-7. The only other difference is that under CALSIM mode the Stanislaus minimum monthly flow requirement given in Table F.1.2-4 is chosen based on NMI calculated from the CALSIM Storage levels, while under CEQA-baseline the storage is calculated from equation F.1-8. Figure F.1.2-1 illustrates the relationship between SWRCB-CALSIM II, WSE model with CALSIM parameters for corroboration purposes, and WSE model CEQA-baseline used for alternatives analysis.

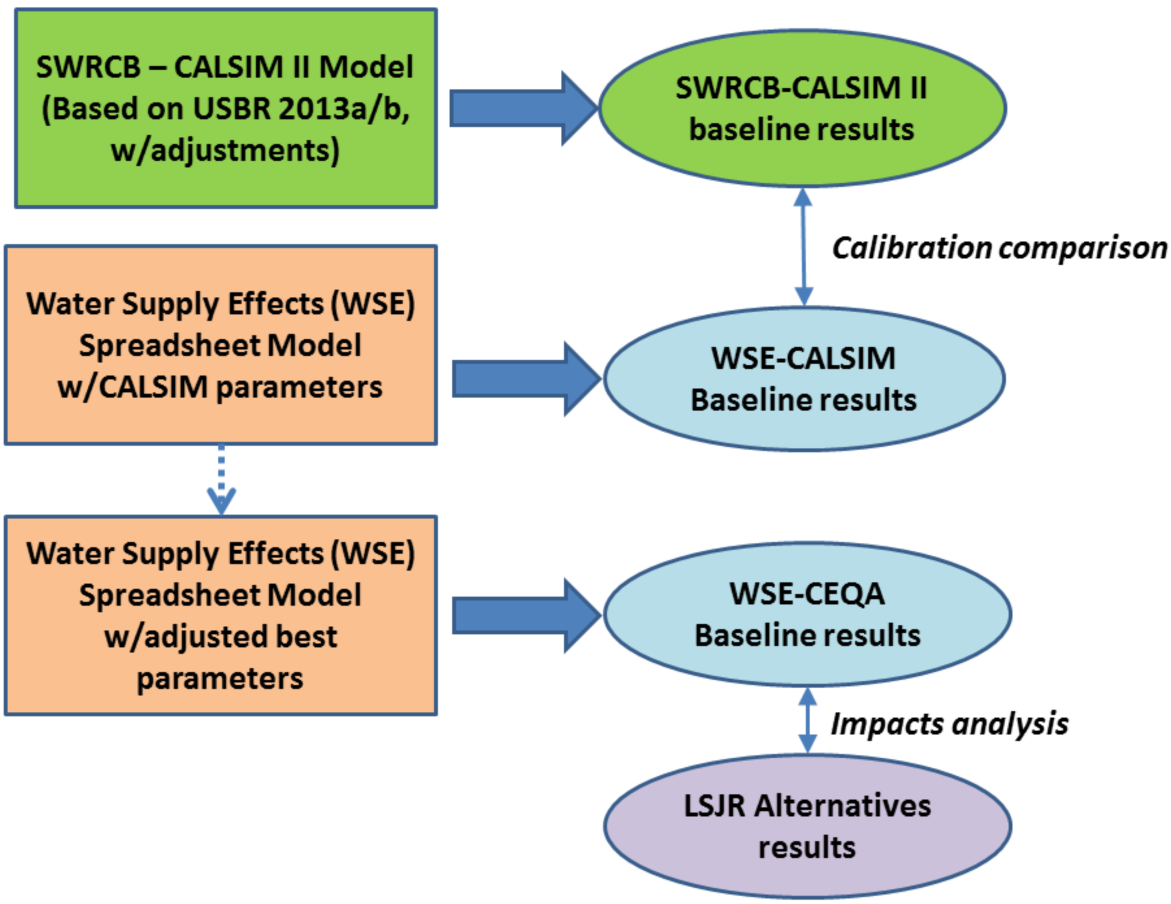


Figure F.1.2-1. Illustration of Differing Model Configurations Described in This Appendix

Table F.1.2-2, below, describes the differences in baseline assumptions for DWR DRR 2009 CALSIM II, USBR CALSIM II, the adapted version referred to herein as *SWRCB-CALSIM II*, and WSE baseline (used in this recirculated SED analysis). Based on comments received on the 2012 Draft SED and further study, the 2012 Draft SED WSE model has been revised, as described in Table F.1.2-3.

Table F.1.2-2. DWR DRR CALSIM II, USBR CALSIM II, SWRCB CALSIM II, and WSE Baseline Model Assumptions

CALSIM II and Baseline Model Assumptions	DWR DRR CALSIM II (used for 2012 Draft SED baseline)	USBR CALSIM II	SWRCB CALSIM II	WSE – Baseline[a]
Diversion Delivery Method	Stan: Feb storage plus Mar–Sep inflow Tuol: Mar storage plus Apr–Jul inflow Mer: Mar storage plus Apr–Sep inflow	Unchanged	Unchanged	Index of March 1 storage plus Apr–Sep inflow with WSE allocation scheme
SJRRP	Not Included	Included	Not included	Not included
VAMP and VAMP Base	Included – double step with split responsibility based on schedule	Included – single step, Merced fully responsible	Included – double step with split responsibility based on schedule	Included – double step with split responsibility(uses CALSIM VAMP pulse flow values)
D-1641 Base Flow (including X2) Feb–Jun	Included	Included	Included	Included
D-1641 Pulse Flow (including X2) Apr–May	Not Included	Not Included	Not included (VAMP instead)	Not included (VAMP instead)
D-1641 Vernalis EC (12 months)	Included	Included	Included	Included
New Melones Starting Storage	1,000 TAF	1,700 TAF	1,000 TAF	1,000 TAF
Stanislaus Minimum Flows Stanislaus RPA	Included – although has errors	Included – errors fixed (contains off-ramp in drought sequence)	Included – errors fixed (no off-ramp)[b]	Included – errors fixed (no off-ramp)[b]
Tuolumne Minimum Flows 1995 FERC	Included	Included	Included	Included
Merced Minimum Flows	Davis-Grunsky/FERC/Cowell	Davis-Grunsky/ FERC/Cowell	Davis-Grunsky/FERC/Cowell	Davis-Grunsky/ FERC/Cowell

CALSIM II and Baseline Model Assumptions	DWR DRR CALSIM II (used for 2012 Draft SED baseline)	USBR CALSIM II	SWRCB CALSIM II	WSE – Baseline[a]
Stanislaus Annual Irrigation Year (Mar–Feb) Diversions from 1922 to 2003	2005 level of development Max ~560 TAF SSJID/OID + Max ~117 TAF SEWD/CSJWCD + ~20 TAF Riparian	2020 level of development Max ~590 TAF SSJID/OID + Max ~155 TAF SEWD/CSJWCD + ~20 TAF Riparian	2020 level of development Max ~590 TAF SSJID/OID + Max ~155 TAF SEWD/CSJWCD + ~20 TAF Riparian	CALSIM LOD2020/modified Max ~594 TAF SSJID/OID + Max ~155 TAF SEWD/CSJWCD + ~20 TAF Riparian
Tuolumne Annual Irrigation Year (Mar–Feb) Diversions from 1922 to 2003	2005 level of development Max ~1,094 TAF MID/TID + ~8 TAF Riparian	2020 level of development Max ~1,107 TAF MID/TID + ~7 TAF Riparian	2020 level of development Max ~1,107 TAF MID/TID + ~7 TAF Riparian	CALSIM LOD2020/modified Max ~1,025 TAF MID/TID + ~7 TAF Riparian
Merced Annual Irrigation Year (Mar–Feb) Diversions from 1922 to 2003	2005 level of development Max ~543 TAF Merced ID + ~26 TAF Cowell + ~41 TAF Riparian	2020 level of development Max ~528 TAF Merced ID + ~25 TAF Cowell + ~41 TAF Riparian	2020level of development Max ~528 TAF Merced ID + ~25 TAF Cowell + ~41 TAF Riparian	CALSIM LOD2020/modified Max ~542 TAF Merced ID + ~94 TAF Cowell + ~41 TAF Riparian
Operational Maximum Flow[c]	1,500 cubic feet per second (cfs) in Stanislaus River	Stan max flow removed	Stan max flow removed	9,999 cfs on all three tributaries

[a.] All of these parameters are equivalent in WSE versions described as “WSE-CALSIM baseline” and “WSE-CEQA baseline,” with the exception of the adjustment factors for CUAW demand.

[b.] The RPA used in modeling is based on the NMI, and thus, as the cumulative distribution of storage changes, so would the RPA required flow (can potentially be different within the alternatives).

[c.] Flow maximum may be exceeded in spill events for flood control.

Table F.1.2-3. WSE Modeling Assumptions

WSE Modeling Assumptions	Old Version WSE (2012 Draft SED version for comparison)	WSE – Baseline	WSE – Alternatives
Diversion Delivery Method	End-of-January storage sets diversion for Feb–Jan	Index of storage plus inflow with minimum allocation, and maximum of available water	Index of storage plus inflow with minimum allocation, and maximum of available water
SJRRP	Not Included	Not Included	Not Included
VAMP	Not Included	Included – double step with split responsibility based on schedule (uses CALSIM determined VAMP flow)	VAMP not included (expired)
D-1641 Base Flow (including X2) Feb–JunS	Not Included	Included – responsibility assigned to New Melones Res.	Included – responsibility assigned to New Melones Res.
D-1641 Pulse Flow (including X2) Apr–May	Not Included	Superseded by VAMP	D-1641 in effect
D-1641 Vernalis WQ (12 months)	Included – responsibility assigned to New Melones Res.	Included – Responsibility assigned to New Melones Res.	Included – responsibility assigned to New Melones Res.
New Melones Starting Storage	1,000 TAF	1,000 TAF	1,000 TAF
Stanislaus Minimum Flows Stanislaus RPA	Included with errors – %UF Feb–Jun (CALSIM other months)	Included year-round – errors fixed (no off-ramp)[a]	Greater of %UF or RPA during objective months; RPA other months[1]
Tuolumne Minimum Flows 1995 FERC	Not Included – %UF Feb–Jun (CALSIM other months)	FERC year-round	Greater of %UF or FERC during objective months; FERC other months
Merced Minimum Flows	Not Included – %UF Feb–Jun (CALSIM other months)	Included year-round using generalized minimum flow similar to Davis-Grunsky/FERC/Cowell	%UF or generalized minimum flow based on Davis-Grunsky/FERC/Cowell during objective months; baseline minimum flow in other months
Stanislaus Annual Irrigation Year (Mar–Feb) Diversions	Max 750 TAF	Max ~594 TAF SSJID/OID + Max ~155 TAF SEWD/CSJWCD + ~20 TAF Riparian	Max ~589 TAF SSJID/OID + Max ~155 TAF SEWD/CSJWCD + ~20 TAF Riparian
Tuolumne Annual Irrigation Year (Mar–Feb) Diversions	Max 1,100 TAF	Max ~1025 TAF MID/TID + ~7 TAF Riparian	Max ~995 TAF MID/TID + ~7 TAF Riparian

WSE Modeling Assumptions	Old Version WSE (2012 Draft SED version for comparison)	WSE – Baseline	WSE – Alternatives
Merced Annual Irrigation Year (Mar–Feb) Diversions	Max 625 TAF (only 2 years CALSIM diverted up to 625)	Max ~542 TAF Merced ID + ~94 TAF Cowell + ~41 TAF Riparian	Max ~532 TAF Merced ID + ~94 TAF Cowell + ~41 TAF Riparian
Flood Storage Curve	Stanislaus: same as CALSIM; Tuolumne: does not factor in conditional storage; Merced: greater storage capacity in July–September than CALSIM)	Stanislaus: same as CALSIM Tuolumne: Same as CALSIM (conditional time series) Merced: Same as CALSIM	Stanislaus: same as CALSIM Tuolumne: Same as CALSIM (conditional time series) Merced: Same as CALSIM
Channel Maximum Flows	2,500 cubic feet per second (cfs); 3,500 cfs; 2,000 cfs	9,999 cfs; 9,999 cfs; 9,999 cfs	9,999 cfs; 9,999 cfs; 9,999 cfs

[a] The RPA used in modeling is based on the NMI, and thus, as the cumulative distribution of storage changes, so would the RPA required flow (could be quite different for the alternatives).

Modifications were incorporated into the original WSE modeling based on public comments received on the 2012 Draft SED. These modifications can be summarized as follows:

- CALSIM representation of baseline is no longer used directly in the SED. The WSE model was modified to provide a representation of baseline conditions, and is now used to model both the baseline and the LSJR alternatives for the purpose of impacts analysis in the SED. The WSE model representation of baseline includes the assumptions listed below, and except for the VAMP minimum flow requirements (first item below), all the other assumptions apply to the WSE modeling of the LSJR alternatives as well.
    - Vernalis Adaptive Management Plan (VAMP) minimum flow requirements per the San Joaquin River Agreement (USBR and SJRGA 1999 [EIS/EIR for SJRA]).
    - Stanislaus RPA 3.1.3 minimum streamflows at Goodwin Dam required by Biological Opinion Table 2E as a function of NMI (NMFS 2009)
    - Stanislaus River maximum diversions based on a 155 TAF total for SEWD and CSJWCD (USBR 2013a; USBR 2013b) and 600 TAF for SSJID and OID per the 1988 Stipulated Agreement with USBR (USBR and OID 1988).
    - The model no longer waives the minimum February–June percentage of unimpaired flow requirements during high flow events.
    - Future anticipated San Joaquin River Restoration Program flows are not included.
- The WSE model now also calculates flow in each tributary for the months of July–January, as opposed to relying on CALSIM output for those months as was done in the 2012 Draft SED, in addition to the February–June period. These flows are based on the minimum flow requirements applicable to each tributary and Vernalis, plus any reservoir releases needed to maintain compliance with flood storage curves. The model still, however, uses estimates of reservoir inflows, downstream accretions and depletions, demands, and other inputs as developed by USBR for the CALSIM model.
- WSE modeling of the LSJR alternatives in the 2012 Draft SED was configured to closely match the baseline condition of end-of-September storage levels in the main reservoirs on each tributary. To better simulate diversion priorities and reservoir operations, the modified WSE model now calculates the amount of water available for diversion each year based on the sum of available end-of-February storage plus March–September inflows (using foresight), less the sum of March–September river flow requirements and end-of-September minimum storage guidelines (the latter subject to annual diversion minimum constraints that supersede the guidelines in times of major shortage). Available water is then compared against estimates of demand (primarily agricultural irrigation) for the year, with the lesser determining the amount diverted.
- Minimum end-of- September storage guidelines storage conditions that maintain coldwater reserves adequate to ensure there are no temperature-related impacts on fisheries resulting from lower reservoir levels due to project alternatives. These minimum storage guidelines were modeled to be waived if certain minimum levels of diversion could not be met, as described in the below section, Calculation of Available Water for Diversion. Diversion demands for major irrigation districts are derived from annually- and monthly-varying CUAW demands from CALSIM, with operational efficiency estimates derived from Agricultural Water Management Plans (AWMPs), and total diversion and use adjusted for best match to AWMP surface water use data and district operations models. For smaller diversions, CALSIM values for diversions are used directly.

- With all of the above revisions, and by adjusting the overall demands for each river, the WSE model was calibrated for best match to SWRCB CALSIM baseline diversions, streamflows, and reservoir levels. This exercise demonstrated the WSE model's effectiveness in representing system dynamics similarly to the CALSIM model.
- Next, some water budget quantities in the WSE model were improved based on published estimates of reservoir losses, municipal and industrial water use, and other factors described in Appendix F.1. The final WSE baseline used in alternatives analysis includes all of the above changes, but with additional revisions to improved parameters. This is denoted as "CEQA Mode," and differs slightly from the original CALSIM baseline.
- In some water year types, a portion of LSJR alternative instream flow requirement was "shifted" outside of the February–June period to summer or fall months in order to reduce further any temperature impacts in those months caused by lower reservoir levels.
- Maximum streamflows (aka "flow caps") in downstream reaches were removed from the WSE model.

F.1.2.3 Calculation of Flow Targets

Generally, the WSE model calculates monthly flow targets for each eastside tributary based on the existing regulatory minimum flow schedules or user-specified percent of unimpaired monthly flow. The percentage of unimpaired flow could be variable between tributaries and months, although uniform values (20, 40, and 60 percent unimpaired flow) were used for each of the tributaries and for each month for the LSJR alternatives. Monthly unimpaired flows for water years 1922–2003 available from the Department of Water Resources (DWR 2007) are estimates of unimpaired flows upstream of the major reservoirs. These DWR estimates of unimpaired flows were used as unimpaired flow indices for the entirety of each eastside tributary because there are no estimates of unimpaired inflow to the tributaries between the major reservoirs and the LSJR, where the flow objectives are being established. Furthermore, based on information from DWR (DWR 2007), the entire Central Valley floor component of unimpaired flow (i.e., downstream of the major reservoirs) is roughly 3 percent of the unimpaired flows of the three eastside tributaries; thus, the component of unimpaired flow that would otherwise be associated with accretions and other inputs downstream of the major reservoirs is not expected to significantly alter the amount or timing of these flows. The unimpaired flows at the major reservoirs are therefore considered adequate for the purpose of establishing flow objectives. Proposed percentages of unimpaired flow are considered an additional requirement, and thus the greater of either the baseline flow requirements or the unimpaired flow requirement was selected for each month.

The February–June minimum instream flow requirement is calculated as a percentage of that month's unimpaired flow, for each month in February–June. For example, the unimpaired flow volume in the Stanislaus River in February 2003 was 55 TAF. An unimpaired flow of 40 percent would be 22 TAF (a monthly average of 396 cfs) for the month of February. Each month is calculated individually. Higher flows such as flood spills would meet the requirement during the month of the spills, but the surplus would not apply to successive months that would still need to meet the minimum flow.

The model allows for specifying maximum and minimum monthly flows for each eastside tributary and at Vernalis. Maximum flows could be selected to limit flooding effects and reduce water supply effects from extremely high target flows. However, for baseline and the alternatives, there were no maximum flow levels specified in the WSE model. The minimum monthly flows for each alternative and the baseline have been set to the existing (baseline) regulatory minimum flow requirements within each tributary. These existing flow requirements generally apply to the release of flows at the re-regulating or diversion dams on the Stanislaus, Tuolumne, and the Merced Rivers (Goodwin Dam, La Grange Dam, and Crocker Huffman Dam, respectively), while the WSE model sets flow requirements at the confluences with the LSJR. Minimum flow requirements at the confluences were determined by translating the existing upstream requirements using CALSIM accretions and depletions of flow between the dams and downstream. This allows for meeting existing requirements upstream while also allowing the unimpaired flow requirements to be specified near the confluences.

On the Stanislaus River, the existing minimum flow requirement is from the 2009 National Marine Fisheries Service (NMFS) biological opinion (BO) Stanislaus River Reasonable and Prudent Alternatives (RPAs), including Action 3.1.3 (NMFS 2009). These flows have been interpreted as monthly flow totals by the WSE model as shown in Table F.1.2-4, preserving the total volumes and including pulse flows. The schedule was based on the NMI, (a value set each year as the March 1 storage plus projected inflows to the New Melones Reservoir through September). The WSE model calculates the NMI each year as the end-of-February storage in New Melones plus the total of anticipated New Melones inflow March–September (available water supply through the end of the water year). New Melones inflows, an input to CALSIM II, are a combination of planning study inflows and actual recorded inflows for recent years (USBR 2004). As this flow schedule is dependent on storage, changes in storage relative to baseline result in changes to the flow requirement relative to baseline.

Table F.1.2-4. Minimum Monthly Flow Requirements at Goodwin Dam on the Stanislaus River per NMFS BO Table 2E

New Melones Index	Minimum Monthly Flow (TAF) by New Melones Index				
	> 3,000	> 2,500	> 2,000	> 1,400	> 0
Calendar Month					
1	22	14.3	13.9	13.5	13.1
2	20.2	13.1	13.1	12.3	11.9
3	101.2	93.4	12.3	12.3	12.3
4	97	83.2	92.3	45.5	27.3
5	120.2	95.4	76.2	38.7	24.6
6	65.3	55.8	21.6	11.9	8.9
7	26.3	18.4	15.3	12.3	9.2
8	24.6	18.4	15.3	12.3	9.2
9	23.8	17.8	14.9	11.9	8.9
10	51.7	48.9	47.5	34.8	35.8
11	17.8	11.9	11.9	11.9	11.9
12	18.4	12.3	12.3	12.3	12.3
Annual	588.5	482.8	346.5	229.6	185.3

Notes:

Sum of daily values in Appendix 2E of NMFS BO (NMFS 2009).

New Melones Index is the sum of March 1st Storage in New Melones plus projected inflow through September.

TAF = thousand acre feet per month

On the Tuolumne River, the existing minimum flow requirement is the 1995 FERC minimum flow requirement at La Grange Dam established in 1995 by Article 37 of the FERC license (Project Number 2299) in the settlement agreement between USBR and the California Department of Fish and Wildlife (CDFW). Table F.1.2-5 contains the monthly flow schedule as interpreted by the WSE model by water year type. As this is a total monthly flow, the pulse flows are retained in the monthly volumes. The schedule uses the SJR 60-20-20 water year type index, as defined by Water Rights Decision D-1641 (SWRCB 2000). The WSE model uses the historical water year type Water Supply Indices to determine the required flows in any given year over the 82-year model sequence.

Table F.1.2-5. Minimum Monthly Flow Requirements at La Grange Dam on the Tuolumne River per 1995 FERC Settlement Agreement

	Minimum Monthly Flow (TAF) by San Joaquin Basin (60-20-20) Water Year Type Index						
Index	> 3,100	> 2,700	> 2,400	> 2,200	> 2,000	> 1,500	> 0
Calendar Month							
1	18.4	10.8	11.1	9.2	9.2	9.2	9.2
2	16.7	9.7	10.0	8.3	8.3	8.3	8.3
3	18.4	10.8	11.1	9.2	9.2	9.2	9.2
4	63.1	40.6	28.8	27.6	25.4	19.1	14.6
5	63.1	40.6	28.8	27.6	25.4	19.1	14.6
6	14.9	4.5	4.5	4.5	3.0	3.0	3.0
7	15.4	4.6	4.6	4.6	3.1	3.1	3.1
8	15.4	4.6	4.6	4.6	3.1	3.1	3.1
9	14.9	4.5	4.5	4.5	3.0	3.0	3.0
10	24.4	13.2	12.7	9.2	9.2	7.7	7.7
11	17.9	10.4	10.7	8.9	8.9	8.9	8.9
12	18.4	10.8	11.1	9.2	9.2	9.2	9.2
Annual	300.9	165.0	142.5	127.5	117.0	103.0	94.0

Notes:
Monthly interpretation of 1995 FERC Settlement Agreement including pulse flows (FERC 1995).
San Joaquin Valley water year type index (60-20-20) as defined by D-1641 (SWRCB 2000).
TAF = thousand acre-feet per month

On the Merced River, the existing minimum flow requirement is a combination of the FERC (Project Number 2179) requirements and the 1967 Davis-Grunsky Contract (DWR 1967). Table F.1.2-6 contains the WSE model interpretation of the minimum flow requirement. To develop Merced River minimum flows in the WSE model, the highest of the FERC or Davis-Grunsky flows in a given month is selected and assumed to be the same in all years. The "normal year" FERC schedule is used to simplify the requirement between Normal and Dry. An additional release of 12,500 AF in October was also required on top of the FERC minimum flow requirement to satisfy the CDFW fall fishery pulse flow requirement. The Cowell Agreement Diversion (CAD) release requirements, presented in Table F.1.2-7, are not factored into the flow target, but they are included in release and diversion requirements discussed below. CAD releases are released from Crocker-Huffman Dam, but are entirely diverted, and do not contribute to minimum flows at the confluence with the LSJR.

Table F.1.2-6. Minimum Monthly Flow Requirements and Modeled Flow Requirement at Shaffer Bridge on the Merced River per FERC 2179 License, Article 40 and 41

	FERC (cfs)	FERC (cfs)	Davis-Grunsky (cfs)	Davis-Grunsky (cfs)	Modeled (cfs)
Calendar Month	Normal Year	Dry Year	Normal Year	Dry Year	All Years[1]
1	75	60	220	180	220
2	75	60	220	180	220
3	75	60	220	180	220
4	75	60	Not Applicable	Not Applicable	75
5	75	60			75
6	25	15			25
7	25	15			25
8	25	15			25
9	25	15			25
10	50	38			280[1]
11	100	75	220	180	220
12	100	75	220	180	220

Notes:

For simplification, and due to inconsistencies with CALSIM II, Normal Year minimum flows on the Merced River were assumed for all years.

[1] Includes additional CDFW fall fishery release of 12,500 acre-feet in October.

cfs = cubic feet per second (monthly average)

Table F.1.2-7. Monthly Cowell Agreement Diversions on the Merced River between Crocker-Huffman Dam and Shaffer Bridge

Calendar Month	Modeled Cowell Agreement Release (cfs)
1	50
2	50
3	100
4	175
5	225
6	250
7	225
8	175
9	150
10	50
11	50
12	50
Annual (TAF)	94

Notes:

Cowell Agreement release assumed to be fully released by Merced Irrigation District at Crocker-Huffman Dam and fully diverted before Shaffer Bridge.

TAF = thousand acre-feet per month; cfs = cubic feet per second

Two factors result in releases that may be different from the unimpaired flow objectives. The first is that the model calculates and releases additional flow, as described below, when required to maintain reservoirs below CALSIM flood control storage requirements, also known by the general term "spill." The second, as described in Appendix K, *Revised Water Quality Control Plan*, is that as part of adaptive implementation, flows can be shifted outside of the February–June period and into the summer and fall to provide for temperature control, to reduce likelihood of negative effects, and to increase the overall potential benefit. This flow shift, described in further detail later in this appendix, is not part of the unimpaired flow objective. However, the calculation in the modeling attenuates the target volume by the amount to be shifted and increases July–November flows by increasing the minimum flow target. Because of these adjustments, the WSE model calculates flows that can be lower or higher than the specified percent of unimpaired flow or minimum flow.

As described above, the flow target at the mouth of each eastside tributary, $\mathbf{QF_t}$, for a particular month, **t**, is calculated as:

$$QF_t = Min(Max(UF_t * Fa_t, Qmn_t), Qmx_t)$$ (Eqn. F.1-1)

Where:

$\mathbf{UF_t}$ is the DWR monthly unimpaired flow for month **t** (DWR 2007);

$\mathbf{Fa_t}$ is the monthly target percentage of unimpaired flow defined by the user; and

$\mathbf{Qmx_t}$ and $\mathbf{Qmn_t}$ are the user defined maximum and minimum regulatory defined monthly flows, for month **t**. In any given month, the flow target is the highest target set for that month (e.g., if percent of unimpaired flow was lower than the minimum, the minimum would be the target).

If flows are to be shifted outside of the February–June period, $\mathbf{QF_t}$ is adjusted accordingly.

With the flow target defined, WSE then performs an initial flow routing on each tributary prior to making any releases from the rim dams. This routing takes into account any accretions/depletion, stream inflows, non-district and non-riparian diversions, and return flows that occur before the confluence with the San Joaquin River. These inflow timeseries are taken directly from CALSIM II. Since this routing is intended to identify how each tributary is affected by the CALSIM II inflow timeseries, the flow may be negative. If any negative flows are found, the tributary's rim dam must release enough water to eliminate them. Depending on the location of the negative flow along the tributary this release may count towards any flow requirements upstream. From here WSE operates the rim dams to meet the flow target defined above. First, WSE releases enough water to meet the unimpaired flow requirement at the confluence for the February–June period. Second, WSE releases water to meet each tributaries minimum flow requirement at the downstream regulating reservoirs (Crocker-Huffman, La Grange, and Goodwin) in all months, unless it was already satisfied with one of the previous releases. Finally, WSE makes any flow shifting releases. On the Merced River there is also an additional release on top of the others to meet the Cowell Agreement flow requirement at Crocker Huffman.

The WSE model also contains a user-defined flow target for the SJR at Vernalis that, if not met by the tributary releases, requires additional releases to meet the Vernalis minimum. The user may select among D-1641 pulse and base flow and salinity at Vernalis, VAMP pulse flows, and/or a user defined minimum to be met at Vernalis. Tables F.1.2-8 and F.1.2-9 contain the D-1641 and VAMP Vernalis flow schedules as interpreted by the WSE model. When activated in the model, the D-1641 pulse and base flows and salinity only require additional releases from the Stanislaus River. Additional pulse flows to meet VAMP, if activated, were distributed to each tributary according to Table F.1.2-10. The user-defined minimum at Vernalis distributes any additional flow, if needed, to each of the three eastside tributaries based on their unimpaired flow contribution as 29, 47, and 24 percent from the Stanislaus, Tuolumne, and Merced Rivers respectively. The Vernalis flow and water quality requirements are discussed in more detail in Appendix C, *Technical Report on the Scientific Basis for Alternative San Joaquin River Flow and Southern Delta Salinity Objectives*.

Table F.1.2-8. D-1641 Minimum Monthly Flow Requirements and Maximum Salinity Concentration in the SJR at Airport Way Bridge Near Vernalis

Calendar Month	Minimum Monthly Flow (TAF) by San Joaquin River Basin (60-20-20) Water Year Type			Maximum Salinity Concentration	
60-20-20 Water Year Type[2]	Feb 1–April 14 and May 16–June 30[1] (cfs)	April 15–May 15[1] (cfs)	October (cfs)	April–Aug (mmhos/cm)	Sep–March (mmhos/cm)
W	2,130/3,420	7,330/8,620	2,000	0.7	1.0
AN	2,130/3,420	5,730/7,020	2,000	0.7	1.0
BN	1,420/2,280	4,620/5,480	2,000	0.7	1.0
D	1,420/2,280	4,020/4,880	2,000	0.7	1.0
C	710/1,140	3,110/3,540	2,000	0.7	1.0

Notes:

[1] Greater flow used when required X2 position is at or west of Chipps Island (km 75). The required X2 position was determined by CALSIM and used in the WSE for each alternative and the baseline. The X2 standard, introduced in the 1995 Bay-Delta Plan, refers to the position at which 2 parts per thousand (ppt) salinity occurs in the Delta estuary and is designed to improve shallow-water fish habitat in the spring of each year and can limit export pumping.

[2] San Joaquin Valley Water Year Type Index (60-20-20) as defined by D-1641 (SWRCB 2000).

cfs = cubic feet per second

mmhos/cm = millimhos per centimeter

W = wet

AN = above normal

BN = below normal

D = dry

C = critically dry

Table F.1.2-9. VAMP Minimum Pulse Flow Requirements in the SJR at Airport Way Bridge near Vernalis

60-20-20 Water Year Type[2]	Minimum Monthly Flow (TAF) by San Joaquin Basin (60-20-20) Water Year Type		
	60-20-20 Index Indicator Value (cfs)	Existing Flow (cfs)	VAMP Pulse Target Flow (April 15–May 15)[1] (cfs)
C	1	0–1,999	2000
D	2	2,000–3,199	3,200
BN	3	3,200–4,449	4,450
AN	4	4,450–5,699	5,700
W	5	5,700–7,000	7,000

Notes:

[1] According to San Joaquin River Agreement, if the sum of current year's index and previous year's index is 7 or greater, a double step is required (next highest target level); if less than 4, no target is required (USBR and SJRGA 1999).

[2] San Joaquin Valley water year type index (60-20-20) as defined by D-1641 (SWRCB 2000).

cfs = cubic feet per second

Table F.1.2-10. Division of VAMP Additional Flow per Tributary According to the SJR Agreement

	Division of VAMP Pulse Flow Water (AF)				
	First 50,000 AF	Next 23,000 AF	Next 17,000 AF	Next 20,000 AF	Totals
Merced	25,000	11,500	8,500	10,000	55,000
OID/SSJID	10,000	4,600	3,400	4,000	22,000
Exchange Contractors	5,000	2,300	1,700	2,000	11,000
MID/TID	10,000	4,600	3,400	4,000	22,000

AF = acre-feet

OID = Oakdale Irrigation District

SSJID = South San Joaquin Irrigation District

MID = Modesto Irrigation District

TID = Turlock Irrigation District

Source: USBR and SJRGA 1999

F.1.2.4 Calculation of Monthly Surface Water Demand

Monthly surface water demand is a set time series based on CALSIM II CUAW. It varies monthly and from year to year dependent on climatic factors and is unchanged among simulations. CUAW was calculated by USBR for various regions throughout the plan area using the DWR consumptive use model (USBR 2005) and is an input to CALSIM II. USBR developed these estimates based on land use data, crop surveys, information from irrigation districts, and from river gages. In CALSIM this value is then expanded by various factors representing components of the overall water balance, including evaporation, seepage, and operational spills to determine the ultimate volume of water diverted from surface water.

Because CUAW represents the portion of applied water consumed by crops, it excludes losses that occur on the field and in the distribution system and excludes operational spills required to meet all delivery turnouts throughout the districts and contractor canals. Therefore, the total district surface water demand along each tributary is determined as the sum of CUAW demand, deep percolation losses, distribution losses, operational spills and returns, any municipal and industrial (M&I) surface water demands, and regulating reservoir seepage. For Merced Irrigation District (Merced ID) Sphere of Influence (SOI) deliveries to Stevinson and other areas are also included in the total diversion demand estimate. In addition, as the irrigation districts fulfill a portion of their applied water demand by maintaining a certain minimum level of groundwater pumping in all years, these minimum pumping levels are subtracted from CUAW demand. Figure F.1.2-2 shows a schematic representation of the components of the WSE generalized irrigation district water balance and a summary of annual average components under the baseline condition.

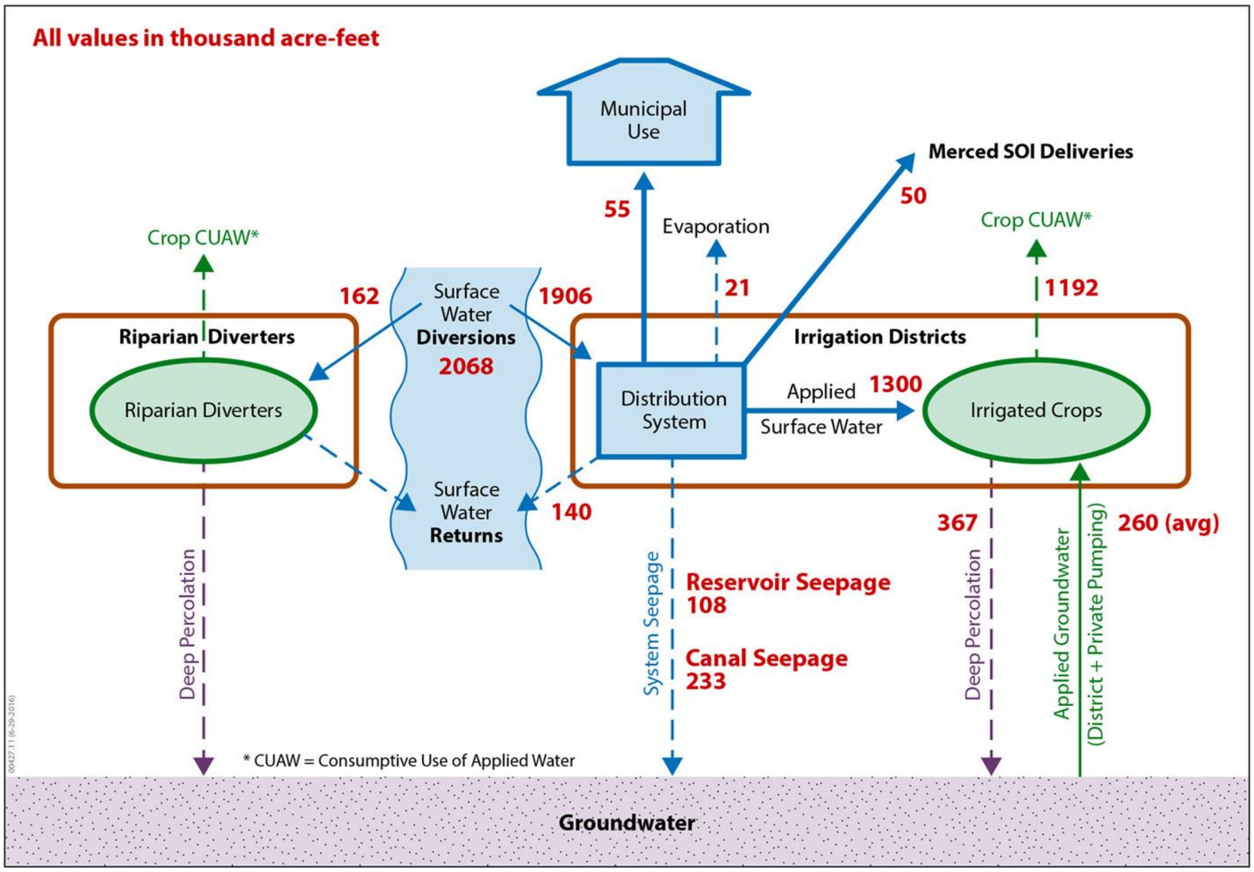


Figure F.1.2-2. Average Annual Baseline Water Balance for the Combined Stanislaus, Tuolumne, and Merced Rivers below the Major Rim Dams

Deep Percolation and Distribution Losses

Deep percolation represents a fraction of applied water that is not consumptively used, and instead seeps into groundwater. In WSE, deep percolation factors represent the proportion of deep percolation to CUAW, in other words, how much water percolates compared to how much is consumed by the crops. Estimates of district CUAW and deep percolation have been obtained from irrigation district Agricultural Water Management Plans (AWMPs) and used to calculate the deep percolation factors, shown in Table F.1.2-11. Deep percolation demand is calculated by multiplying each districts CUAW demand by its associated deep percolation factor.

Distribution losses represent the portion of water that is lost from the district distribution system, either as leakage or evaporation. In WSE the distribution loss factors represent the proportion of distribution losses to other surface water demands, not including municipal and industrial (M&I) demands or demands associated with losses from regulating reservoirs. Derivation of the distribution loss factors is based on information obtained from the AWMPs summarized in Table F.1.2-11. Distribution Loss demand is calculated for each district by taking the sum of CUAW, deep percolation, operational spills, and SOI demands; subtracting minimum groundwater pumping; and multiplying the total by its associated distribution loss factor.

Table F.1.2-11. Calculation of Deep Percolation Factors and Distribution Loss Factors

		Irrigation Districts				
		SSJID[a,b]	OID[c]	MID[d,e]	TID	Merced ID
Sources		Table 5-1, SSJID AWMP	Table 5-13 through 5-16, OID AWMP	Table 44, 47, and 48, MID AWMP	Table 4.6, 4.8, and 4.9, TID AWMP	Table 5.20, 5.21, and 5.22, Merced ID AWMP
Consumptive Use of Applied Water (CUAW)	AF/y	152,454	128,884	153,067	349,690	237,838
Deep Percolation of Applied Water (DP)	AF/y	42,321	24,496	58,132	159,111	60,116
Operational Spills/Returns (OS)	AF/y	19,847	48,884	29,768	60,019	33,116
GW pumping (GWP)	AF/y	45,260	26,372	28,017	99,769	63,021
Sphere of Influence Deliveries (SOI)	AF/y	NA	NA	NA	NA	74,712
Conveyance Evaporation (CEV)	AF/y	542	3,682	2,100	1,503	9,846
Conveyance Seepage (CES)	AF/y	28,317	47,203	8,000	36,209	98,526
Deep Percolation Factor	(DP)/(CUAW)	0.28	0.19	0.38	0.46	0.25

Sources		SSJID[a,b]	OID[c]	MID[d,e]	TID	Merced ID
		Irrigation Districts				
		Table 5-1, SSJID AWMP	Table 5-13 through 5-16, OID AWMP	Table 44, 47, and 48, MID AWMP	Table 4.6, 4.8, and 4.9, TID AWMP	Table 5.20, 5.21, and 5.22, Merced ID AWMP
Distribution Loss Factor	(CEV+CES)/ (CUAW+DP+ OS+SOI-GWP)	0.17	0.29	0.05	0.08	0.32

Notes:

a. South San Joaquin ID operational spill/returns are the sum of lateral spills (17,029 AF, Table 5-1), Lateral Seepage (8,165 AF, Table 5-1), and Tailwater (2,541 AF, Table 5-1).

b. South San Joaquin ID conveyance seepage is the sum of main canal seepage (20,152 AF, Table 5-1) and lateral seepage (8,165 AF, Table 5-1).

c. Oakdale ID GW pumping is the sum of district GW pumping (7,084 AF, Table 5-13) and private GW pumping (19,288 AF, Table 5-15).

d. Modesto ID consumptive use of applied water was determined using the Crop ET (173,179 AF, Table 44) and subtracting annual effective precipitation (20,112 AF, Table 47).

e. Modesto ID GW pumping is the sum of district GW pumping (20,057 AF, Table 47) and private GW pumping (7,960 AF, Table 48)

AF/y = acre feet per year

Operational Spills and Returns

Operational spills and returns represent water diverted by the districts that returns to the river. Excess flow often is used to maintain constant pressure head in the distribution system and maintain delivery. This water is eventually spilled or released from the distribution system and returned to the river. Operational spills and returns are modeled as a constant timeseries of monthly demands identical to CALSIM II return flow timeseries. In CALSIM II each district may have several return flow timeseries, so for incorporation into the WSE total demand calculation, these return flows have been aggregated into a single timeseries for each district. These flows return to the flow node framework in the same location as in CALSIM (i.e., not aggregated).

Other Surface Water Demands

Other surface water demands accounted for in WSE include Woodward, Modesto, and Turlock Reservoir Seepage; Modesto City M&I demands; and Merced ID Sphere of Influence (SOI) demands. CALSIM II represents these demands as constant annual volumes distributed in the same monthly patterns every year. After some analysis, it has been determined that CALSIM II estimates for these annual demands can be refined to represent baseline conditions. Effort was made to acquire more accurate and up-to-date estimates for these parameters, which are shown in Table F.1.2-12. On the left of the table are shown the original CALSIM II estimates, and on the right are estimates derived from more recent sources such as irrigation district AWMPs, information request response letters from the irrigation districts, and the Merced Operations model released as part of Merced ID's FERC relicensing process (FERC 2015). In addition, another M&I demand was added for SSJID to represent Degroot Water Treatment Plant (WTP) based on information in the SSJID AWMP (SSJID 2012). With these new parameters, WSE diverges slightly from the CALSIM calibration and representation of baseline; therefore, separate modes were created, one, CALSIM mode, to try and replicate CALSIM II operations using all the CALSIM II parameters and another, CEQA mode, to model the LSJR alternatives with more up-to-date information, representing the most appropriate baseline determined by SWRCB.

Woodward Reservoir, Modesto Reservoir, and Turlock Reservoir are regulating reservoirs used by the districts to provide off stream storage for diversions and regulate irrigation water deliveries. Woodward Res. serves South San Joaquin Irrigation District (SSJID), Modesto Res. serves Modesto Irrigation District (MID), and Turlock Res. serves Turlock Irrigation District (TID). To keep these reservoirs in operation, water losses to seepage must be replaced. These terms also include any seepage losses from the upstream conveyance systems. In WSE these, annual demands are of the same quantity and distributed in the same monthly pattern as in CALSIM.

The City of Modesto has an agreement with MID to purchase Tuolumne River water from the district to reduce the city's reliance on groundwater. In WSE, this annual demand is distributed in the same monthly pattern as it is distributed in CALSIM. Operation of the Degroot WTP began in 2005, and it serves the cities of Manteca, Lathrop, and Tracy with Stanislaus river water delivered from SSJID. This demand was not included in CALSIM II because it came online after the model was constructed. In WSE, this demand is represented as a constant annual volume distributed equally over all months. In WSE, M&I surface water demands are assumed to be diverted directly from the district's regulating reservoir and do not pass through the district's distribution system, so they are not considered in the calculation of distribution losses shown above.

Table F.1.2-12. Other Annual Demands for Each Irrigation District

		WSE CALSIM Mode		WSE CEQA Mode	
Parameters	Irrigation District	Annual Total (TAF/y)	Source	Annual Total (TAF/y)	Source
Woodward Reservoir Losses	SSJID	62	CALSIM	29.5	SSJID AWMP
Modesto Reservoir Losses	MID	55	CALSIM	31.2	MID AWMP
Turlock Reservoir Losses	TID	92	CALSIM	46.8	TID Info Request
Modesto M&I Demand	MID	65	CALSIM	30.0	MID AWMP
Degroot WTP M&I Demand	SSJID	15.7	SSJID AWMP	15.7	SSJID AWMP
Merced Sphere of Influence (SOI) Demands[a]	Merced ID	81.4	CALSIM	68	Merced Operations Model

Notes:

[a.] Merced SOI demands include Merced National Wildlife Refuge (15 TAF/y, both modes), Stevinson (26.4 TAF/y CALSIM, 24 TAF/y CEQA), El Nido (40 TAF/y CALSIM, 13 TAF/y CEQA), and other SOI demand (0 TAF/y CALSIM, 16 TAF/y CEQA).

TAF/y = thousand acre-feet per year

Merced ID SOI demands occur outside of the district, but share the districts distribution system. The SOI demands include the Stevinson Entitlement, required deliveries to Bear Creek in the Merced National Wildlife Refuge (NWR) as part of the districts FERC license, deliveries to El Nido, and water sales by Merced ID to other nearby entities (Merced ID 2013). Because these demands share the district's distribution system, they are included in calculations of distribution loss demand. El Nido was actually incorporated into the district in 2005 (Merced ID 2013); however, CALSIM II represents them separately from the district. Since the demands are aggregated into a single total demand for the district in WSE, it is unnecessary to separate El Nido from the other SOI demands. In WSE, the surface water demand for Merced NWR is modeled using the CALSIM II monthly demand timeseries, while the rest of the annual SOI demand is distributed over the water year in the same monthly proportions as Merced ID CUAW demand.

Minimum Groundwater Pumping

In each irrigation district there is a minimum amount of groundwater pumping that is assumed to occur every year regardless of surface water availability, either because the surface water distribution system doesn't reach some areas, or because the timing of diversions does not meet the growers needs. In WSE, Merced ID minimum groundwater pumping is a constant annual volume distributed over each water year based on the districts CUAW demand. For SSJID, Oakdale Irrigation District (OID), MID, and TID the minimum groundwater pumping is a constant annual volume distributed based on CALSIM II's repeating monthly pattern for minimum groundwater pumping in each corresponding district. After analysis, it was determined to use updated information to represent minimum groundwater pumping for baseline conditions. Table F.1.2-13 shows the annual volume of minimum groundwater pumping used in CALSIM II and estimates based on more recent information, from the AWMPs and the information request response letters from the irrigation districts.

Table F.1.2-13. Annual Minimum Groundwater Pumping Estimates for Each Irrigation District

		CALSIM Mode		CEQA Mode	
Parameter	Irrigation District	Annual Total (TAF/y)	Source	Annual Total (TAF/y)	Source
Minimum Groundwater Pumping	SSJID	52.0[a]	CALSIM	25.6	SSJID Info Request
	OID	20.0[a]	CALSIM	18.3	OID Info Request
	MID	38.5	CALSIM	12.0	MID Info Request
	TID	157.5	CALSIM	80.6	TID AWMP
	Merced ID	54.0	CALSIM	37.0	Merced ID AWMP

Notes:

[a.] SSJID minimum GW pumping to CALSIM district node 522 includes minimum GW pumping for the portion of OID on the north side of the Stanislaus, and OID CALSIM represents only OID south. Minimum GW pumping to CALSIM district node 530 on the south side of the Stanislaus.

TAF/y = thousand acre-feet per year

Irrigation District Diversion Data

For the modern era, irrigation districts report some of their diversion data in their AWMPs. Table F.1.2-14, below, shows a sample of the historical diversions of the irrigation districts published in the 2012 AWMPs and 2015 updates. Diversions are a result of total surface water demands, as described above, and water availability as a function of the available inflows and storage.

Table F.1.2-14. Sample of Irrigation District Diversion Data Reported in AWMPs

Water Year	WY Type	SSJID	OID	MID	TID[a]	Merced ID
2000	AN	229,632				483,391
2001	D	217,940				465,222
2002	D	249,271				470,156
2003	BN	228,117				431,926
2004	D	262,500				463,744
2005	W	204,501	223,706			468,724
2006	W	222,390	225,614			484,759
2007	C	249,569	261,896	296,000	499,137	430,739
2008	C	252,483	244,606	288,000	441,466	312,072
2009	BN	244,059	234,424	267,300	466,063	
2010	AN	223,202	217,143	264,633[b]	531,107	
2011	W	219,289	218,147	315,912[b]	537,685	
Average		233,579	232,219	286,369	495,092	445,637

a. In the 2012 AWMP, TID reports diversions measured below Turlock Reservoir, not from the river.
b. Modesto ID in the 2015 update AWMP reports 2010 and 2011 diversion totals as 261,728 AF and 282,640 AF, respectively.
Sources:
SSJID AWMP 2015; OID AWMP 2012; MID AWMP 2012; TID AWMP 2012; Merced ID AWMP 2012

Comparison of Surface Water Demands

Under WSE-CALSIM mode, an adjustment factor was applied to each river's CUAW demand to align the resulting annual diversions to the magnitude and distribution of total annual diversions calculated by SWRCB-CALSIM II. Similarly, under WSE-CEQA mode, a factor was applied to the CUAW demand on each river so that the total annual diversions would be consistent with the diversion levels represented in the Merced, Tuolumne, and Stanislaus operations models (MID 2015; MID and TID 2013; SJTA 2012).[3] Table F.1.2-15 contains the final adjustment factors applied to CUAW demand for each irrigation district to determine the total surface water demand time series from each river.

[3] Stanislaus, Tuolumne, and Merced Operations Models may differ from CALSIM and WSE in their system representation of inflows, allocations, assumptions, and dynamics, but Operations Models diversions are t sufficiently representative of baseline irrigation district diversions (meeting full demands when possible, otherwise limited by water availability), as represented by the districts themselves. They are more up to date than available CALSIM CUAW representations. CALSIM CUAW is utilized within WSE, adjusted as described above, because the time series of CALSIM CUAW is essential to representing the inter-annual pattern of demand that varies as a function of weather conditions. Primarily, the most important aspect is characterization of maximum demand. Stanislaus Operations Model and CALSIM maximum demands are in excess of recent irrigation diversions, but are considered to account for some exercise of OID/SSJID entitlements under the 1988 Agreement that would take the form of water transfers or sales not considered in the model. Tuolumne maximum demands in the FERC Tuolumne Operations model are lower than either CALSIM or long-term historical diversions, but match more closely with recent AWMP reported diversions, so WSE-CEQA diversions have been adjusted downward accordingly. Merced ID maximum diversions in the Merced Operations Model are similar to CALSIM, but these levels of demand can be met less often in the CALSIM and WSE allocation schemes. The recent drought has illustrated that zero allocations do occur for Merced ID based on low available storage in New Exchequer Reservoir.

Table F.1.2-15. Adjustment Factors Applied to CUAW Demands

CUAW Multiplier	Irrigation District				
	SSJID	OID	MID	TID	Merced ID
WSE-CALSIM Mode Adjustment Factor[a]	1.09	1.09	1.15	1.15	1.17
WSE-CEQA Mode Adjustment Factor[b]	1.09	1.09	1.08	1.08	1.19

[a.] Adjustment factors were developed during corroboration with SWRCB-CALSIM II as a final adjustment to best match SWRCB-CALSIM II deliveries for baseline conditions.

[b.] Adjustment factors were developed to match WSE annual diversions under WSE-CEQA baseline conditions to the annual diversions as seen in the baseline runs for the operations models.

TAF/y = thousand acre-feet per year

Once again, these factors are applied to CUAW demand at the field scale, which then are expanded by the addition of percolation, distribution losses, and operational spills/returns, so that total surface demand is determined. Total surface demand fluctuates based on the climactic factors that affect CUAW demand, but diversion to meet this demand is subject to allocation of available water. These adjustments to global demand for each tributary, combined with the best available efficiency data as described in prior sections, were required to best match the diversion time-series and distributions in CALSIM, and likewise in WSE-CEQA mode to match diversions from the Operation Models. Although AWMP data are far from complete, they offer a snapshot for comparison of recent conditions to the modeled baseline assumptions over 82 years. These comparisons are shown in Table F.1.2-16 and Figure F.1.2-3 for district diversions from the Stanislaus River, in Table F.1.2-17 and Figure F.1.2-4 for district diversions from the Tuolumne River, and Table F.1.2-18 and Figure F.1.2-5 for district diversions from the Merced River. Additional tables of annual components of reservoir release, streamflow and diversions are shown in Attachment 1 to this appendix.

Table F.1.2-16. Annual Irrigation Year (Mar–Feb) Diversions from the Stanislaus River by OID/SSJID, as Represented by USGS Observed, CALSIM, Stanislaus Operations Model, WSE-CALSIM Baseline, WSE-CEQA Baseline, and AWMP Data

Diversion Statistics Results Set	Max (TAF)	75th (TAF)	Median (TAF)	25th (TAF)	Min (TAF)
USGS Observed (1988–2003)	564	512	482	458	373
SWRCB-CALSIM Baseline (1971–2003)	588	533	505	481	256
Stanislaus Operations RPA (1971–2003)[a]	600	529	508	469	381
WSE w/CALSIM parameters (1971–2003)	587	531	511	474	244
WSE – CEQA Baseline (1971–2003)	589	531	511	474	232
AWMP Data (2005–2011)	511	488	448	439	428

[a] Stanislaus operations model annual diversions are totaled by water year.

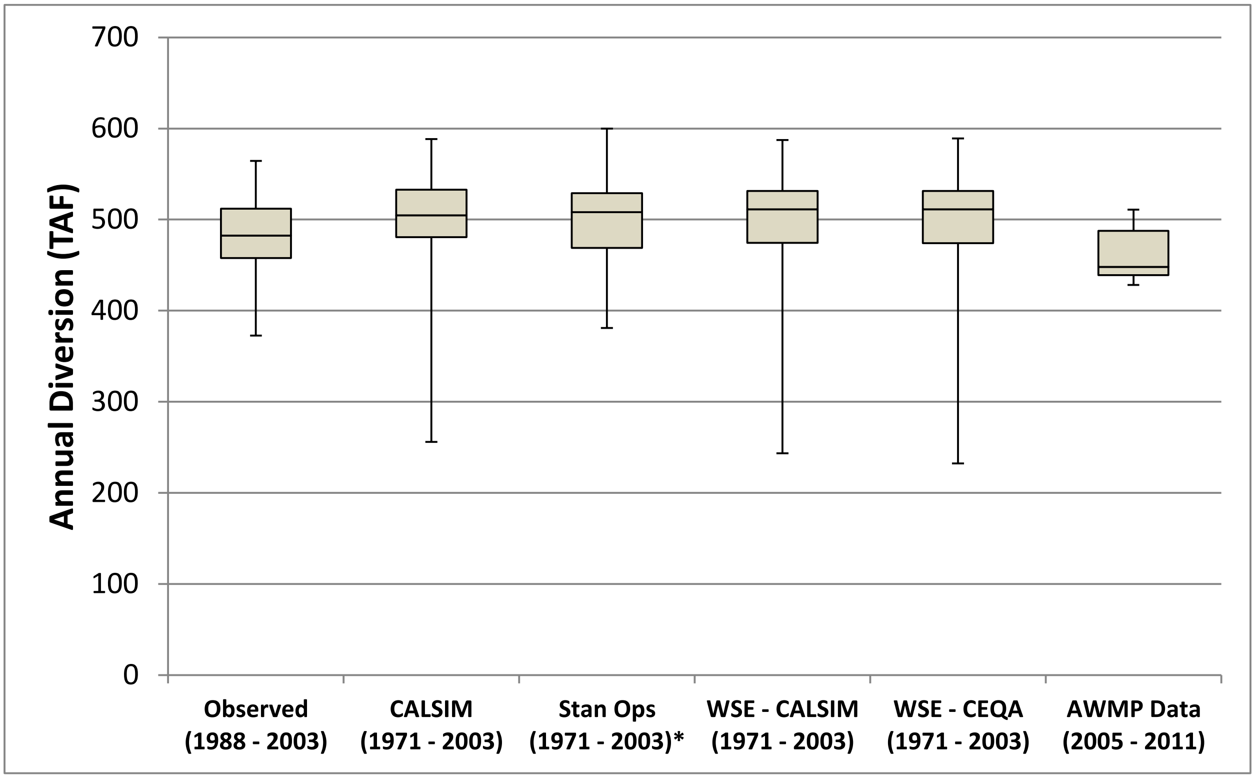


Figure F.1.2-3. Annual Irrigation Year (Mar–Feb) Diversions from the Stanislaus River by OID/SSJID, as represented by USGS Observed, SWRCB-CALSIM, Stanislaus Operations Model (*Statistics are for Annual Water Year Diverions), WSE-CALSIM Baseline, WSE-CEQA Baseline, and AWMP Data

Table F.1.2-17. Annual Irrigation Year (Mar–Feb) Diversions from the Tuolumne River by MID/TID, as Represented by USGS Observed, SWRCB-CALSIM, Tuolumne Operations Model, WSE-CALSIM Baseline, WSE-CEQA Baseline, and AWMP Data

Diversion Statistics Results Set	Max (TAF)	75th (TAF)	Median (TAF)	25th (TAF)	Min (TAF)
USGS Observed (1971–2003)	1,201	997	933	800	396
SWRCB-CALSIM Baseline (1971–2003)	1,107	957	873	808	511
WSE w/CALSIM parameters (1971–2003)	1,050	931	889	810	550
WSE CEQA Baseline (1971–2003)	1,025	886	844	771	550
Tuolumne Ops Model (1971–2003) FERC Baseline	960	893	838	782	640
AWMP Data (2007–2011)[a]	900	843	842	780	776

[a] Because TID does not report reservoir losses in AWMP, 46.8 TAF added for estimate for additional diversion

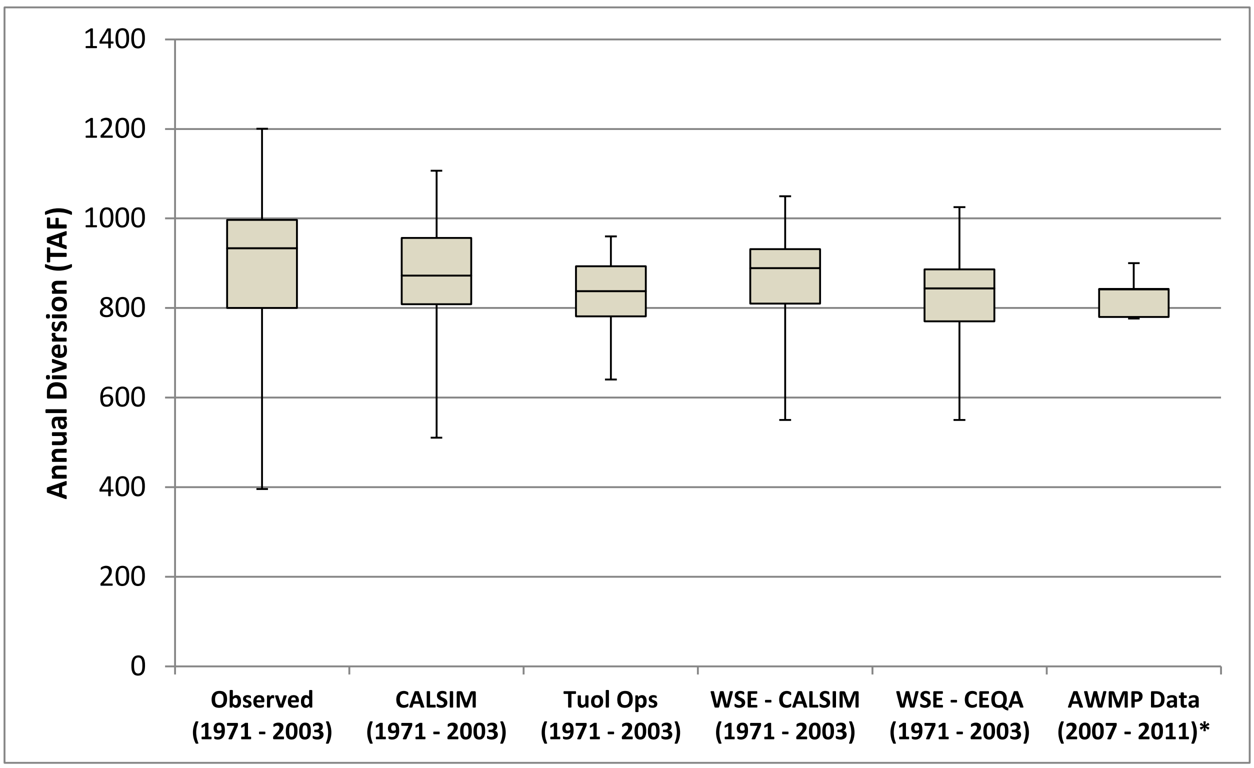


Figure F.1.2-4. Annual Irrigation Year (Mar–Feb) Diversions from the Tuolumne River by MID/TID , as represented by USGS Observed, CALSIM, Stanislaus Operations Model, WSE w/CALSIM parameters, WSE-CEQA Baseline, and AWMP Data (*w/46.8 TAF added for Turlock Res. losses)

Table F.1.2-18. Annual Irrigation Year (Mar-Feb) Diversions from the Merced River by Merced ID, as Represented by Observed, CALSIM, Merced Operations Model, WSE w/CALSIM parameters, WSE-CEQA Baseline, and AWMP Data

Diversion Statistics Results Set	Max (TAF)	75th (TAF)	Median (TAF)	25th (TAF)	Min (TAF)
SWRCB CALSIM Baseline D561 (1971–2003)	528	493	462	432	42
WSE w/CALSIM parameters D561 (1971–2003)	542	501	456	414	14
WSE CEQA Baseline D561 (1971–2003)	542	503	467	424	3
Merced Ops Model/Observed (1970–2003)	535	498	477	456	60
AWMP Data (2000–2008)	485	470	465	432	312

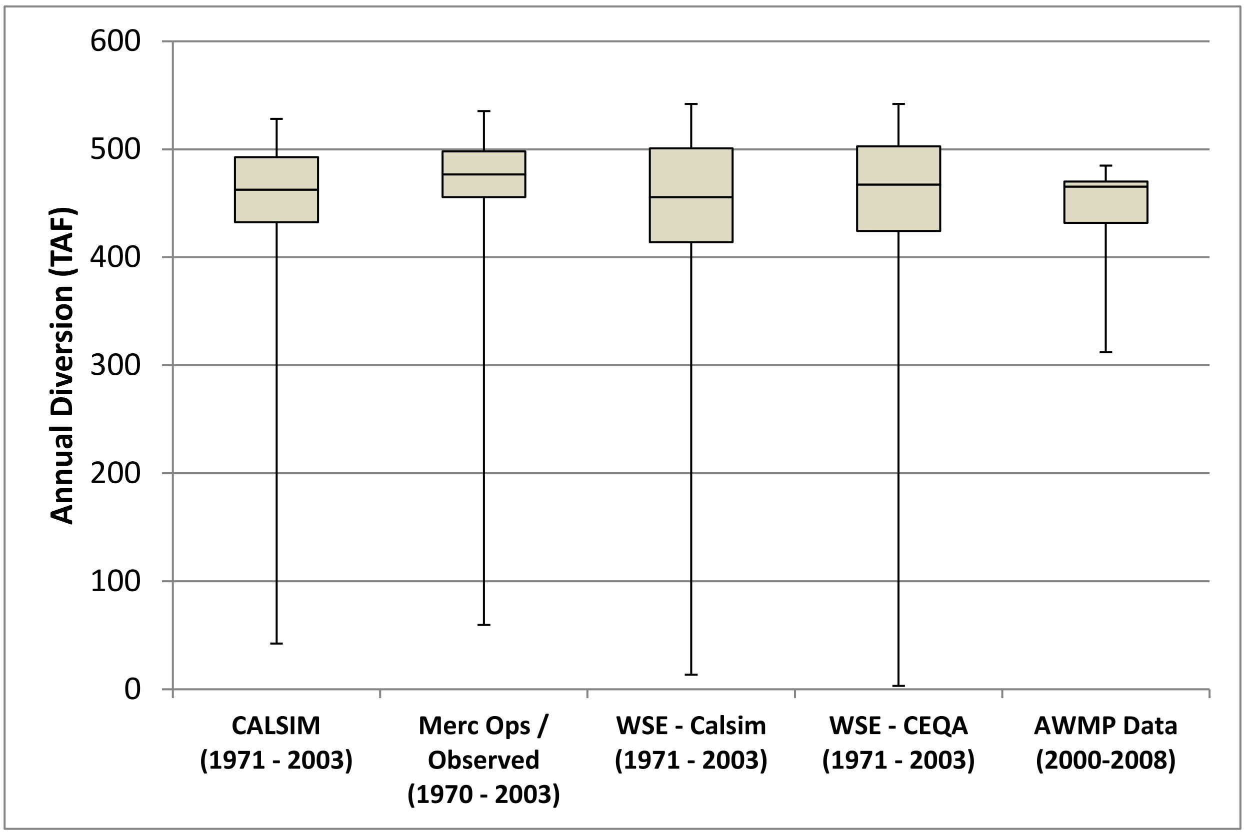


Figure F.1.2-5. Annual Irrigation Year (Mar–Feb) Diversions from the Merced River by Merced ID, as Represented by SWRCB-CALSIM Baseline, Merced Operations Model, WSE-CALSIM Baseline, WSE-CEQA Baseline, and AWMP Data

CVP Contractor Demands

The CVP contractors, Stockton East Water District (SEWD) and Central San Joaquin Water Conservation District (CSJWCD) are treated differently compared to the other districts. Their demands are represented as a constant annual volume of 155 thousand acre-feet per year (TAF/y) (with 80 TAF/y for CSJWCD and 75 TAF/y for SEWD) based on information from USBR (USBR 2013a, 2013b). This demand is distributed over the year in a monthly pattern, as shown in Table F.1.2-19.

Table F.1.2-19. CVP Contractor Monthly Diversion Schedule

	SEWD/CSJWCD	
Month	Monthly Demand Pattern (% of Annual)	Modeled Demand (TAF)
January	3%	5
February	3%	5
March	4%	6
April	4%	6
May	11%	17
June	18%	27
July	20%	31
August	15%	24
September	9%	13
October	5%	8
November	4%	7
December	4%	6
Total	100%	155

Minor, Riparian, and Cowell Agreement Diversion Demands

Finally, minor and riparian demands represent diverters with riparian rights or smaller diversions along each tributary. In WSE, these demands are modeled using the monthly timeseries of diversions taken from CALSIM II (D528 and D545) and are kept separate from the district demands. The CAD demands are also treated as minor and riparian demands in WSE. However, the SWRCB-CALSIM II timeseries of CAD diversions (D528) does not fully divert the Cowell Agreement Flow described in Table F.1.2-7. Under CEQA mode in WSE the monthly CAD demands were increased so that they would equal that month's Cowell Agreement Flow Release.

F.1.2.5 Calculation of Available Water for Diversion

As a part of the modeling analysis, it has been necessary to utilize certain reservoir constraints and parameters that determine allocation of available water for diversions, both in baseline and alternatives scenarios. These parameters are central to the model's determination of when there is available water to meet full irrigation demands and, at other times, when there is not adequate water supply from inflow and reservoir storage, which, in turn, requires diminished allocations of water to diversions while preserving a reserve of storage supply for future years.

The analysis contained in this SED provides LSJR alternatives that represent examples of system operation to determine the significance of impacts, pursuant to CEQA. Selection of appropriate parameters has first been made to represent baseline conditions most closely in terms of diversion allocations and reservoir operations, similar to those in the CALSIM baseline scenario. Under additional streamflow requirements of the LSJR alternatives, changes in water availability require adjustment of parameters to ensure feasibility for the 82-year simulation so that the reservoirs are not drained entirely in the worst droughts of record. In addition, carryover storage guidelines have been increased for New Melones Reservoir and New Exchequer Reservoir to minimize impacts on instream temperature that would be caused by lower reservoir levels and a limited coldwater pool. These operational constraints, as components of modeling simulations, do not by themselves comprise a plan of implementation or otherwise carry the weight of regulatory requirements. Rather, they are included as elements of the modeling simulation to evaluate the feasibility of the LSJR alternatives. An implementation plan developed in a future proceeding would need to identify and evaluate supply, storage, and temperature conditions and appropriate operational objectives, to best protect beneficial uses and avoid adverse effects where feasible.

In WSE, the following operational parameters are used to govern reservoir operations and determination[4] of the available water for diversion and use:

- Maximum Storage Levels (Flood Curves): The maximum level allowable in the reservoir is set equal to the CALSIM flood control levels in New Melones and New Don Pedro Reservoirs (including conditional storage, when applicable) and Lake McClure. The model assumes projected filling above these levels will be evacuated within that month to maintain at or below these maximum operating levels. These flood curves are based on USACE requirements, but with some differences (USBR 2005).
- Minimum End-of-September Storage: A minimum end-of-September storage guideline was developed by iteration in order to determine levels protective of coldwater pool and river temperatures in the summer and fall. Projected end-of-September storage for a given year is reduced by this value to determine the amount of storage supply available for diversion for that year.
- Minimum Diversion Level (Minimum End-of-September Relaxation): Diversions can override the end-of September storage guideline and draw additional water from storage in the event the available surface water for diversion is less than a specified minimum level. This in effect is a relaxation in certain years to the end-of-September storage guideline. The minimum level constraint was set after trial and error to ensure there were no significant temperature impacts.
- Maximum Allowable Draw from Storage: The model constrains the percentage of the available storage (after holding back for minimum end-of-September storage) that is available for diversion over the irrigation season. This limits the amount of storage that can be withdrawn to reduce potential effects on river temperatures by protecting carryover storage and the

[4] Determination of available water to supply demand is a modeling necessity to represent baseline conditions and operational envelopes for LSJR alternatives; however, these parameters, including "Maximum Allowable Draw from Storage," *do not* represent regulatory requirements of how the reservoir storage and use system must be operated—rather, alternatives are examples of system operation that illustrate most likely water availability as a function of additional constraints of instream flow requirements. To some extent, carryover storage guidelines have been increased over baseline to reduce indirect temperature effects that would otherwise occur because of lower storage levels. Implementation most likely will require further optimization of these parameters with balanced consideration of desired temperatures and tradeoffs with other resource values.

coldwater pool in the reservoirs leading into a drought sequence. Baseline "allowable draw" was determined empirically to match CALSIM patterns of allocations, similar to how a "delivery versus carryover risk curve" might be used.

- End-of-Drought Storage Refill Requirement (only needed in alternatives with 40+ percent of unimpaired flow, not in baseline): When reservoir levels are very low (typically after a drought sequence), the model limits the amount of inflow that can be allocated for diversion in a subsequent wet year(s). By reducing the amount of inflow that can be diverted in such years, reservoirs and associated coldwater pools recover more quickly after a drought. Without such a requirement, reservoirs otherwise would remain lower for longer after a drought, causing associated temperature impacts.

Calculation of available water proceeds as follows:

After the instream flow and other environmental release requirements are satisfied, the available water for diversions is calculated for each year's growing season. Available water for diversion is the amount of projected inflow plus carryover storage adjusted downward by the amount of required flow releases, the first estimate of reservoir evaporation, and the end-of-September storage guidelines.

Equation F.1-2 shows the calculation to determine available water for diversion, $W_{avail,GS}$:

$$W_{avail,GS} = \overbrace{K_{Stor} * \left(S_a - EOS_{req}\right)}^{Available\ \ Storage} + \overbrace{\sum_{n=a+1}^{b} \left(QINF_n - ER_n - EV_n\right)}^{Available\ \ Inflow}$$

(Eqn. F.1-2)

Where:

K_{Stor} is the percentage of the available storage at the tributary's major reservoir that would be available for diversion over the growing season. In general, this value limits the amount of storage that can be withdrawn, reducing potential impacts on river temperatures by protecting the reservoir's coldwater pool.

S_a is the ending storage at the tributary's major reservoir for month **a.** Month **a** is selected by the user and represents the last month prior to the start of the growing season; **a** = 2 (February) for the baseline and alternative simulations.

EOS_{req} is the minimum end-of-September carryover storage guideline at the tributary's major reservoir that would protect coldwater pool and river temperatures in the summer and fall.

QINF is the forecast CALSIM II inflow to the tributary's major reservoir over the growing season, from month **a**+1 to month **b**. Month **b** is also selected by the user and represents the final month of the growing season; **b** = 9 (September) for the baseline and alternative simulations. The inflow time series for each reservoir was developed by DWR and USBR outside of CALSIM II as an input to CALSIM II. The New Melones Reservoir inflows, developed by USBR, are a combination of planning study inflows and actual recorded inflows for recent years; the New Don Pedro Reservoir inflows, provided by the City and County of San Francisco (CCSF), are a result of a long-term simulation of current project operations for the period prior to 1996 and actual computed inflow since 1996. The Lake McClure inflows were estimated using the Lake McClure outflows adjusted for change in storage and evaporation in Lake McClure (USBR 2005).

ER is the sum of monthly reservoir releases over the growing season to meet all instream flow and environmental requirements for the tributary. This includes reservoir releases to meet the depletions along the river, the unimpaired flow requirement, the tributary minimum flows, the flow shifting requirements, the CAD flow requirement on the Merced, VAMP, D1641, and Vernalis minimum flow and EC.

EV is forecast total evaporation from the tributary's major reservoir over the growing season. For this available water calculation, the monthly evaporation timeseries is taken directly from CALSIM values.[5]

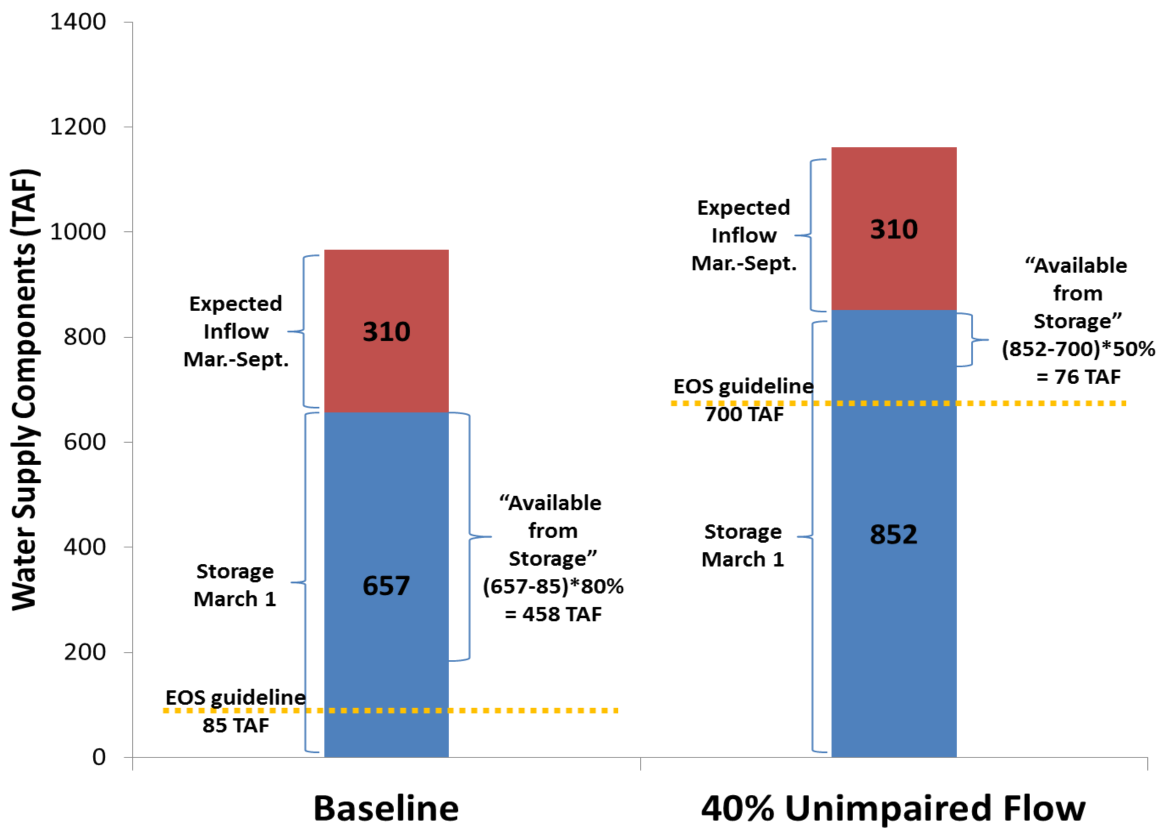


Figure F.1.2-6. Illustration of Available Storage Calculation for the Example Year 1991

[5] CALSIM seasonal evaporation quantities (based on CALSIM baseline reservoir volumes and rates) are sufficient for a first-order estimate of available water for diversion. After the allocation of available water is performed, the final water balance is calculated, with the monthly evaporation calculation based on the actual reservoir volume and surface area, using the CALSIM rates. This approach was a method to avoid circular references in Excel.

Table F.1.2-20. Baseline End-of-September Storage Guidelines, Maximum Draw from Storage, and Minimum Diversion Variables for the Eastside Tributaries

Variable	Stanislaus River	Tuolumne River	Merced River
End-of-September Storage Guideline (TAF)	85	800	115
Maximum Draw from Storage (% of available storage)	80%	65%	80%
Minimum Diversion (TAF)	0	550	0

Evaporation

For the three major reservoirs, evaporation is a function of the evaporation rate and the surface area of the reservoirs. CALSIM rates are used for each month of the simulation, and the area of each reservoir is recalculated by WSE using a volume/area relationship. Note that in order to prevent circular references, the available water allocation is made using CALSIM estimates of evaporation (based on SWRCB-CALSIM baseline, the evaporation from reservoirs based on levels in that scenario), while the final water balance is performed with evaporation recalculated more precisely by WSE, based on the volume-area relationships contained in Tables F.1.2-21a, F.1.2-b, and F.1.2-c.

Table F.1.2-21a. Area/Volume Relationship for New Melones Reservoir for Calculating Evaporation

Elevation (ft. MSL)	Storage (TAF)	Area (acres)
500.00	0.98	2
700.00	53.90	1,217
760.00	160.55	2,374
808.00	299.52	3,446
920.00	846.52	6,485
992.00	1,398.83	8,901
1,049.50	1,969.50	10,962
1,088.00	2,419.52	12,442
1,100.00	2,571.83	12,949
1,123.40	2,871.00	14,011

Table F.1.2-21b. Area/Volume Relationship for New Don Pedro Reservoir for Calculating Evaporation

Elevation (ft. MSL)	Storage (TAF)	Area (acres)
300.00	2.00	2
524.00	100.00	1,752
628.00	400.00	4,116
683.00	700.00	5,983
725.00	1,000.00	7,675
760.00	1,300.00	9,270
791.00	1,600.00	10,800
820.00	1,900.00	12,283
847.00	2,200.00	13,732
872.00	2,500.00	15,151

Table F.1.2-21c. Area/Volume Relationship for New Exchequer Reservoir for Calculating Evaporation

Elevation (ft. MSL)	Storage (TAF)	Area (acres)
400.00	2.00	2
618.00	100.00	1,368
674.00	200.00	2,156
713.00	300.00	2,852
758.00	450.00	3,813
793.00	600.00	4,718
823.00	750.00	5,589
848.00	900.00	6,434
871.00	1,050.00	7,261
891.00	1,200.00	8,073

Table F.1.2-22. Annual Average Evaporation for New Melones, New Don Pedro, and New Exchequer Reservoirs for Baseline and LSJR Alternatives

Scenario	Parameter	New Melones	New Don Pedro	New Exchequer
ALL	Avg. annual inflow (TAF)	1,087	1,586	965
BASELINE	Avg. annual evap (TAF)	50	61	21
20%UF	Avg. annual evap (TAF)	54	61	22
30%UF	Avg. annual evap (TAF)	53	60	22
40%UF	Avg. annual evap (TAF)	52	58	21
50%UF	Avg. annual evap (TAF)	50	57	21
60%UF	Avg. annual evap (TAF)	49	56	20

WSE Model Operational Parameters for the LSJR Alternatives

After a baseline WSE model was developed, it was modified to estimate the resulting flows, diversions, and reservoir operations of the LSJR alternatives by adjusting the parameters in Tables F.1.2-23a, F.1.2-23b, and F.1.2-23c to incorporate the alternative flow requirements. The following sets of inputs were used in the WSE model for the alternatives and intermediate simulations, ranging from 20 percent of unimpaired flow to 60 percent of unimpaired flow.

Table F.1.2-23a. Minimum Diversion, Minimum September Carryover Guideline, Maximum Draw from Storage, and Flow Shifting for the Stanislaus River

	Baseline	20% Unimpaired Flow	30% Unimpaired Flow	40% Unimpaired Flow	50% Unimpaired Flow	60% Unimpaired Flow
Minimum District Diversion (TAF, % of District Max)	0 TAF	210 TAF (35%)	210 TAF (35%)	210 TAF (35%)	180 TAF (30%)	180 TAF (30%)
Minimum September Carryover Guideline (TAF)	85	700	700	700	700	700
Maximum Storage Draw (% of Mar 1 minus Sep guideline)	80%	80%	70%	50%	45%	35%
Flow Shifting to Fall[a]	NA	None	None	Yes	Yes	Yes
End-of-Drought Storage Refill	NA	100%	100%	70%	50%	50%
Vernalis Minimum[b] Feb–Jun (cfs)	D-1641/ VAMP	1,000	1,000	1,000	1,000	1,000

TAF = thousand acre feet

cfs = cubic feet per second

[a] In the alternatives, the shifting of a portion of unimpaired flow requirement was completed during wet years, designed to allow only a percentage of diversions in the qualifying years (if storage was within 10% of the guideline September storage and inflow was projected to be higher than average).

[b] For unimpaired flow alternatives, the Stanislaus River is assumed to provide 29 percent of additional releases necessary to meet the Vernalis minimum flow requirement based on its long-term fraction of unimpaired flow among the three eastside tributaries.

Table F.1.2-23b. Minimum Diversion, Minimum September Carryover Guideline, Maximum Draw from Storage, and Adaptive Implementation for the Tuolumne River

	Baseline	20% Unimpaired Flow	30% Unimpaired Flow	40% Unimpaire d Flow	50% Unimpaired Flow	60% Unimpaired Flow
Minimum District Diversion (TAF, % of District Max)	550 TAF (50%)	363 TAF (33%)	363 TAF (33%)	363 TAF (33%)	275 TAF (20%)	275 TAF (20%)
Minimum September Carryover Guideline (TAF)	800	800	800	800	800	800
Maximum Storage Draw (% of Mar 1 minus Sep guideline)	65%	60%	55%	50%	45%	35%
Flow Shifting to Fall[a]	NA	None	None	Yes	Yes	Yes
Drought End Storage Refill	NA	100%	100%	70%	50%	50%
Vernalis Minimum[b] Feb–Jun (cfs)	D-1641/ VAMP	1,000	1,000	1,000	1,000	1,000

TAF = thousand acre feet; cfs = cubic feet per second

[a] In the alternatives, the shifting of a portion of unimpaired flow requirement was completed during wet years, designed to allow only a percentage of diversions in the qualifying years (if storage was within 10% of the guideline September storage and inflow was projected to be higher than average).

[b] For unimpaired flow alternatives, the Tuolumne River is assumed to provide 47 percent of additional releases necessary to meet the Vernalis minimum flow requirement based on its long-term fraction of unimpaired flow among the three eastside tributaries.

Table F.1.2-23c. Minimum Diversion, Minimum September Carryover Guideline, Maximum Draw from Storage, and Flow Shifting for the Merced River

	Baseline	20% Unimpaired Flow	30% Unimpaired Flow	40% Unimpaired Flow	50% Unimpaired Flow	60% Unimpaired Flow
Minimum District Diversion (TAF, % of District Max)	0 TAF	78 TAF (15%)	78 TAF (15%)	78 TAF (15%)	78 TAF (15%)	78 TAF (15%)
Minimum September Carryover Guideline (TAF)	115 TAF	300	300	300	300	300
Maximum Storage Draw (% of Mar 1 minus Sep guideline)	80%	70%	60%	50%	45%	35%
Shifting to Fall[a]	NA	None	None	Yes	Yes	Yes
Drought End Storage Refill	NA	100%	100%	100%	50%	50%
Vernalis Minimum[b] Feb–Jun (cfs)	D-1641/ VAMP	1000	1000	1000	1000	1000

TAF = thousand acre feet

cfs = cubic feet per second

[a] In the alternatives, the shifting of a portion of unimpaired flow requirement was completed during wet years, designed to allow only a percentage of diversions in the qualifying years (if storage was within 10% of the guideline September storage and inflow was projected to be higher than average).

[b]For unimpaired flow alternatives, the Merced River is assumed to provide 24 percent of additional releases necessary to meet the Vernalis minimum flow requirement based on its long-term fraction of unimpaired flow among the three eastside tributaries.

F.1.2.6 Calculation of Surface Water Diversion Allocation

In WSE, for each tributary and irrigation year (March–February) monthly diversions are calculated in four steps:

1. During the initial flow routing mentioned above, if the flow available from inflows at any reach with a diversion demand is greater than the flow requirement at that reach, the excess can be used to satisfy the diversion demand. This prevents water already in the river that is not contributing to any flow requirements from being wasted.
2. Riparian and minor demands are fully met, because these diverters are considered senior[6] to appropriative ones. The water available for the districts during the growing season, $\mathbf{DW_{avail,GS}}$, is calculated by subtracting Riparian growing season diversion from $\mathbf{W_{avail,GS}}$.
3. The district diversion during the growing season, $\mathbf{Div_{GS}}$, is calculated as the minimum of annual district demand, maximum annual district diversion, and available water for the districts, as shown in equation F.1-3:

[6] For the purposes of WSE modeling, CALSIM diversions D528 and D545 are considered to be riparian and senior in priority and given full allocation. The bases of right for these diversions have not yet been confirmed. In any case, these diversions are small in comparison to overall system diversions.

$$Div_{GS} = Min\left(Dmx_{GS},\ DW_{avail\,,GS},\ Dem_{GS}\right) \quad \text{(Eqn. F.1-3)}$$

Where:

Dmx_{GS} is the maximum allowable diversion over the growing season. For the Stanislaus the annual maximum district diversion is distributed over the irrigation year based on the monthly demands and then summed over the growing season. For the Tuolumne and Merced the annual maximum district diversion was distributed monthly based on a repeating yearly pattern based on typical monthly fractions in CALSIM over the growing season.

Dem_{GS} is the total growing season diversion demand. In general, demand is the limiting volume during wet years, while available surface water is the limiting factor during dryer years.

On the Stanislaus there is an additional constraint to represent the growing season allowable diversion under the 1988 Agreement, **D_{1988}**. This agreement stipulates that SSJID and OID will receive the first 600 TAF/y of inflow to New Melones or if the inflow is less than 600 TAF/y they will receive the Inflow plus 1/3 x (600 minus inflow) (SSJID 2012). In WSE this annual total is distributed over the irrigation year based on the monthly demands and then summed over the growing season to determine **D_{1988}**.

4. Finally, the total growing season diversion is distributed monthly to determine **Div_t**, the diversion in month **t**. It is assumed that the same proportion of demand met in the growing season as a whole will be met in all months over the irrigation year. Equation F.1-4A shows the calculation:

$$Div_t = \overbrace{Div_{GS} / Dem_{GS}}^{delivery\ \ proportion} * Dem_t * K_{Refill} \quad \text{(Eqn. F.1-4A)}$$

Where:

Dem_t is the district demand in month **t**.

K_{Refill} is a reservoir refill user specified parameter between 0 and 1 that reduces diversion in an effort to help refill the major reservoirs at the end of a drought. This parameter is activated if: 1) storage in the major reservoir at the end of the previous October was less than **EOS_{req}** plus 10 percent and 2) inflow to the major reservoir over the growing season will be greater than an inflow trigger set by the user. This diversion cut will continue over the entire irrigation year (March–February) unless the reservoir reaches the flood curve at which point the cut will end for the rest of the year. However, if the calculated growing season diversion is less than the user defined minimum annual diversion, monthly diversion will be determined using Eqn. F.1-4B:

$$Div_t = \overbrace{Dmn\% * Dmx_{IY}}^{min\ \ annual\ \ diversion} * \frac{Dem_t}{Dem_{IY}} \quad \text{(Eqn. F.1-4B)}$$

Where:

Dmn% is the minimum annual district diversion as a percent of maximum annual diversion. This variable allows the diversion to override the end-of September storage guideline and draw additional water from storage in the event the available surface water for diversion is less than the minimum diversion level. Because this allows additional diversion, this variable could also be considered a relaxation in some years to the end-of-September storage guideline. The minimum diversion rates were set for the baseline such that resulting diversion and storage were similar to the results of CALSIM. As the unimpaired flow requirement increased, the minimum diversion level was lowered to help balance the reservoir, reduce potential temperature impacts, and ultimately maximize diversions.

$\mathbf{Dmx_{IY}}$ is the maximum annual district diversion over the irrigation year. The maximum district diversion on each tributary is 600 TAF/y for the Stanislaus River, 1,100 TAF/y for the Tuolumne River, and 542 TAF/y for the Merced River. These values did not change among simulations and were held constant for each year.

$\mathbf{Dem_{IY}}$ is the total district demand over the irrigation year.

CVP Contractor Diversion

On the Stanislaus, diversion to the CVP contractors (SEWD and CSJWCD) is calculated differently than for the other irrigation districts. The contractors receive diversion only after the senior district has received its allocation of water based on the above calculations. The water available to the contractors during the growing season would be $\mathbf{DW_{avail,GS}}$, minus any diversion to the senior districts. Growing season water allocation to the contractors, $\mathbf{CDiv_{GS}}$, is shown in equation F.1-5, which is then distributed monthly, $\mathbf{CDiv_t}$, in equation F.1-6:

$$CDiv_{GS} = Min\left(DW_{avail,GS} - Div_{GS}, CDem_{GS}\right) \qquad \text{(Eqn. F.1-5)}$$

$$CDiv_t = Min\left(CK_{cut}, \frac{CDiv_{GS} * K_{Refill}}{CDem_{GS}}\right) * CDem_t \qquad \text{(Eqn. F.1-6)}$$

Where:

$\mathbf{CDem_{GS}}$ and $\mathbf{CDem_t}$ are the total contractor water demand on the Stanislaus River over the growing season and in month **t**, respectively.

$\mathbf{CK_{cut}}$ is a user defined allocation factor based on the NMI (Table F.1.2-1 in the prior section). This factor supersedes the calculated allocation based on water availability and demand unless the calculated allocation is smaller**.**

F.1.2.7 Calculation of River and Reservoir Water Balance

Once the annual diversion is calculated, WSE begins a final flow routing through the rivers to Vernalis including deliveries from the reservoirs to diversions. Because there are requirements at Vernalis that depend on the flows from the tributaries, the model conducts multiple routing cycles to determine the required release from the three major reservoirs. The first cycle determines the flow that would occur at Vernalis assuming there were no requirements at Vernalis and no flood releases. During the first cycle the resulting Vernalis flow is checked against the minimum flow requirement at Vernalis and additional flow requirements are distributed among the tributaries if needed, as described earlier under Calculations of Flow Targets. The second cycle determines the resulting flow at Vernalis while including the Vernalis minimum flow requirement, VAMP requirements, and flood control flows from the Merced and Tuolumne. During the Second cycle Vernalis flow is checked against D1641 and then salinity requirements. If either D1641 or Vernalis Salinity is not met, any additional flow needed is taken from the Stanislaus River. The final cycle re-calculates the tributary and SJR flows through to Vernalis, including all required releases, diversions, and flood spills. The equations below describe the reservoir and river flow calculations.

Required Reservoir Releases

The required reservoir release needed to satisfy the target flows and diversions is determined monthly on each eastside tributary as the sum of flow requirement, diversion, and flood control release:

$$R_t = ER_t + Div_t + CDiv_t + RipD_t + F_t \qquad \text{(Eqn. F.1-7)}$$

Where:

$\mathbf{ER_t}$ is the environmental flow release.

$\mathbf{Div_t}$ is the irrigation district diversion, $\mathbf{Cdiv_t}$ is the CVP contractor diversion (only on the Stanislaus), and $\mathbf{RipD_t}$ is the riparian diversion (does not includes CAD diversions on the Merced as those are accounted for in $\mathbf{ER_t}$).

$\mathbf{F_t}$ is the additional reservoir spill release required to stay below flood stage in New Melones and New Don Pedro Reservoirs (as defined by the CALSIM flood storage curves in Table F.1.2-24) and the discretionary hydropower operations level in Lake McClure. Spills are only necessary in months when storage would otherwise exceed flood control limits.

Table F.1.2-24. CALSIM End-of-Month Flood Control Storage Limitations Applied to New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure in the WSE Model

Calendar Month	New Melones[a] (TAF)	New Don Pedro[b] (TAF)	Lake McClure[c] (TAF)
1	1,970	---[b]	674.6
2	1,970	---[b]	674.6
3	2,030	---[b]	735
4	2,220	---[b]	845
5	2,420	---[b]	970
6	2,420	---[b]	1,024
7	2,300	---[b]	910
8	2,130	---[b]	770
9	2,000	---[b]	700
10	1,970	---[b]	674.6
11	1,970	---[b]	674.6
12	1,970	---[b]	674.6

Notes:

[a]. Maximum storage volume (to spillway) in New Melones Reservoir is 2,420 TAF.

[b] "New Don Pedro Reservoir flood control constraints (reserved storage) are included in CALSIM II as a time series. The time series reflects end-of-month rain-flood reservation space and conditional reservation space during the snowmelt season per COE requirements" (USBR 2005). This 82-year monthly CALSIM time series is referenced by the WSE model for each month. Maximum storage in New Don Pedro Reservoir is 2,030 TAF.

[c] Maximum storage volume in Lake McClure is 1,024 TAF.

Reservoir Storage Levels

Storage levels behind the major dams are initially set the same as CALSIM II levels at the end of September, 1921 (951TAF in New Melones, 1,313 TAF in New Don Pedro, and 469 TAF in Lake McClure). As with CALSIM II, the maximum level allowable in the reservoir is set equal to the flood control levels in New Melones and New Don Pedro Reservoirs (including conditional storage, when applicable) and Lake McClure, (Table F.1.2-24). The model assumes projected filling above these levels will be evacuated within that month to maintain at or below these maximum operating levels. The reservoir storage at the end of each subsequent month, $\mathbf{S_t}$, is calculated with a water balance equation on each tributary using:

$$S_t = S_{t-1} + QINF_t - R_t - EV_t \qquad \text{(Eqn. F.1-8)}$$

Where:

$\mathbf{S_{t-1}}$ is the ending storage of the previous month.

$\mathbf{QINF_t}$ is the CALSIM II inflow to each major reservoir described above in Equation F.1-2; and

$\mathbf{EV_t}$ is the evaporation from the major reservoir at time **t**. WSE evaporation is calculated using the CALSIM II evaporation rates multiplied by the reservoir surface area at time t.

River Flows

The resulting flow achieved by the WSE model at the confluence of each of the three eastside tributaries with the SJR is determined as follows:

$$Q_t = R_t - Div_t - CDiv_t - RipD_t + QAC_t \qquad \text{(Eqn. F.1-9)}$$

The flow resulting at Vernalis, QVt, is calculated as follows:

$$QV_t = QN_t + \sum (Q_t \; 3 \; tributaries) - Dv_t + QACv_t \qquad \text{(Eqn. F.1-10)}$$

Where:

$\mathbf{QAC_t}$ is the sum of CALSIM II accretions (including natural and return inflows) and depletions between the major dam and the mouth of the river in month **t**. Accretions/depletions and return flows are unchanged for each alternative and the baseline.

$\mathbf{QN_t}$ is the SJR inflow from upstream of the Merced River near Newman. The flow is set equal to CALSIM II estimates and is assumed unchanged for the alternatives and baseline.

$\mathbf{Dv_t}$ is the sum of diversions along the LSJR from the Merced River to Vernalis. The values are assumed equal to CALSIM II and assumed not affected by changes due to the project and the alternatives, with the following exception: In some months under WSE baseline conditions the CALSIM II diversions on the San Joaquin between the Merced and Tuolumne are reduced, because the flow released from the Merced is not enough to meet it all.[7]
To protect the assumption that these diversions are not affected by changes due to the

[7] CALSIM D620B has a maximum diversion quantity of 267 TAF/month. For WSE CEQA baseline, D620B is attenuated when water is not available from the Merced River and Upper SJR combined. This adjustment averages -3.2 percent over the 82-year study period, up to a maximum of -33 percent. This attenuation is identical in the alternative scenarios.

project and the alternatives, these baseline reductions are maintained in each of the alternatives.

$QACv_t$ is the sum of accretions and depletions along the LSJR from the Merced River to Vernalis. Accretions and depletions are equal to those of CALSIM II and assumed unchanged for each alternative and the baseline.

Shifting of Flow Requirement

As a result of instream flow requirements in the February–June period, reservoir levels in modeling scenarios are generally lower than baseline, which can cause a reduced magnitude and frequency of reservoir spill in wet years. In addition, reservoir levels generally lower than baseline can result in elevated temperatures in summer and fall when rivers are at FERC or RPA minimum flows. The combined effects of smaller, less-frequent spills and lower reservoir levels would cause an undesirable result of elevated temperatures when compared to baseline, in the absence of additional flow measures, for alternatives of 40 percent unimpaired flow or greater. Therefore, it was determined, as a part of adaptive implementation, to shift a quantity of flow from the February–June period to the July–November period in certain year types so that LSJR alternative scenarios would have a negligible impact on instream temperatures.

All modeling scenarios described in this Recirculated SED for alternatives of 40 percent or greater of unimpaired flow incorporate some shifting of the flow requirement in certain water year types from the February–June period to the July–November period, not to exceed 25 percent of the quantity determined by the percent of unimpaired flow (e.g., in the 40 percent of unimpaired flow alternative, flow shifting would not exceed 10 percent of the overall unimpaired flow). The generalized concept of shifting a portion of the unimpaired flow requirement is shown in Figure F.1.2-7, below.

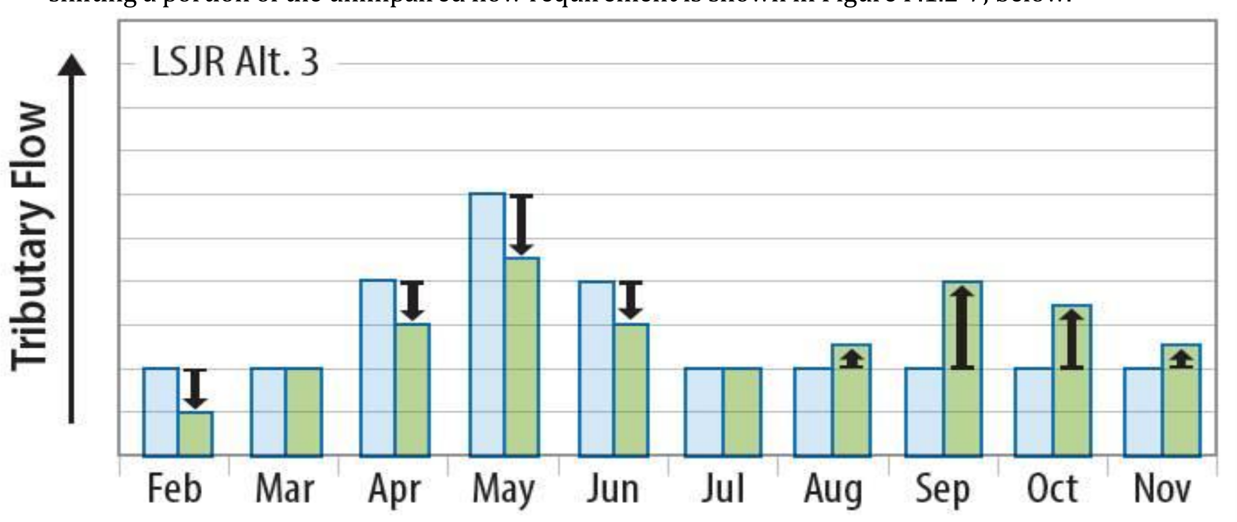


Figure F.1.2-7. Generalized Illustration of Shifting of Flow Requirement to Summer and Fall

The amount of shifted flow was determined by iteration to find appropriate quantities of flow in the summer and fall months that would mitigate increases of temperature under LSJR alternatives. Shifting up to 25 percent of the flow requirement was found to minimize these increases while preserving the benefits of the February–June flows. Generally, these flow quantities were found to reduce temperature impacts to less than 10 percent change from the number of days that exceed the EPA 7DADM temperature criteria for anadromous fish life stages (see fish temperature discussion in Chapter 7, *Aquatic Biological Resources*) and, in most months, completely ameliorate the impact compared to baseline in the three tributaries.

The shifted flow targets in July–September are in the form of additional flow to meet a target flow, in cubic feet per second, in the confluence reach of each of the three tributaries, as described in Table F.1.2-25, below.

Table F.1.2-25. Instream Flow Targets July–November that Determine Necessary Volume of Flow Shifting from the February–June Period for the (a) Stanislaus, (b) Tuolumne, and (c) Merced Rivers for Each Water Year Type

A. Stanislaus Minimum Flow by Water Year Type and Month					
WYT	July (cfs)	August (cfs)	September (cfs)	October (cfs)	November (cfs)
W	800	500	800	1,400	—
AN	—	—	—	1,200	—
BN	—	—	—	1,000	—
D	—	—	—	1,000	—
C	—	—	—	1,000	—
B. Tuolumne Minimum Flow by Water Year Type and Month					
WYT	July (cfs)	August (cfs)	September (cfs)	October (cfs)	November (cfs)
W	1,200	600	1,000	1,000	1,000
AN	—	—	—	—	—
BN	—	—	—	—	—
D	—	—	—	—	—
C	—	—	—	—	—
C. Merced Minimum Flow by Water Year Type and Month					
WYT	July (cfs)	August (cfs)	September (cfs)	October (cfs)	November (cfs)
W	600	600	600	800	800
AN	200	200	200	—	—
BN	—	—	—	—	—
C	—	—	—	—	—
D	—	—	—	—	—

Shifted flow quantities, determined as the amount of additional flow release necessary to meet minimum instream flow shifting targets, in addition to the flow already present in these months, have been deducted from the percent unimpaired flow requirements in the February–June period. These deductions are in proportion to each month's contribution to the total unimpaired flow requirement for February–June. Total quantities shifted in each water year type for 40 percent, 50 percent, and 60 percent of unimpaired flow alternatives are shown for each tributary in Table F.1.2-26, below

Table F.1.2-26. Average Quantity of Flow Shifted to Fall for the Stanislaus, Tuolumne, and Merced Rivers for Each Water Year Type

Water Year Type	Stanislaus Annual Flow Shifting (TAF)			Tuolumne Annual Flow Shifting (TAF)			Merced Annual Flow Shifting (TAF)		
	40% alt	50% alt	60% alt	40% alt	50% alt	60% alt	40% alt	50% alt	60% alt
W	51	51	52	102	102	102	105	116	120
AN	17	17	18	0	0	0	11	11	11
BN	8	9	9	0	0	0	0	0	0
D	10	11	13	0	0	0	0	0	0
C	4	5	5	0	0	0	0	0	0
Average	21	22	23	29	29	29	32	35	36

WSE Model CALSIM-Baseline Comparison to CALSIM II

Described below are the steps taken to compare the WSE model with SWRCB-CALSIM II model run and develop the WSE CALSIM-baseline simulation. By using some CALSIM II inputs and a similar approach for estimating water supply diversions in the WSE model, the WSE model CALSIM-baseline results are similar to CALSIM II and considered sufficient to demonstrate that the model is adequate to determine water supply effects comparable with CALSIM II, but with the additional flexibility of the spreadsheet approach.

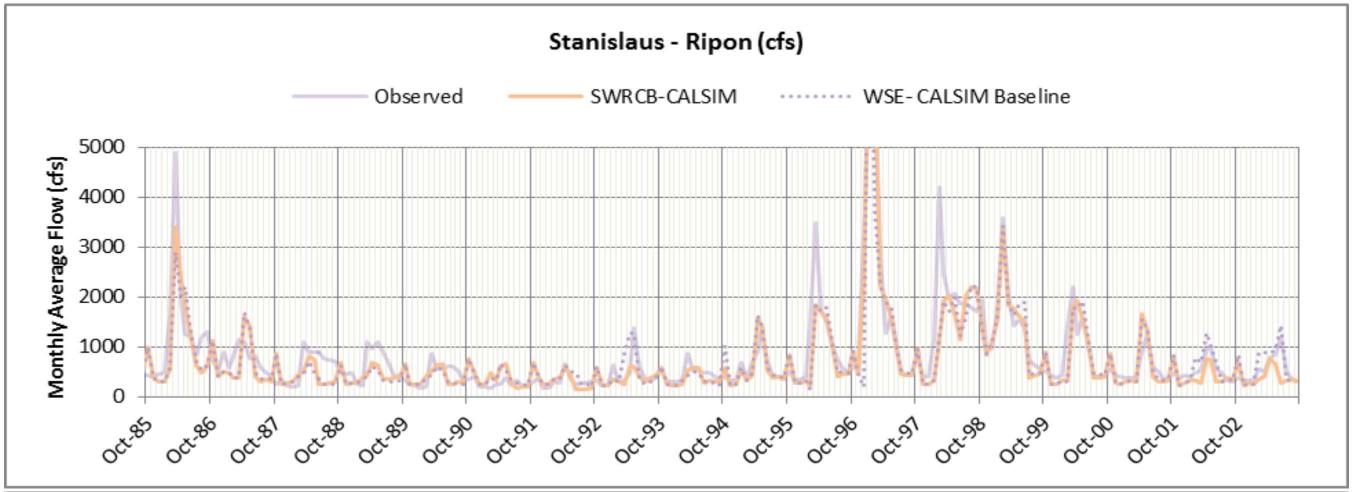
Three variables were used to calibrate the WSE model baseline with the CALSIM II representation of baseline: (1) demand adjustment factors that globally scale the monthly-variable CUAW demand for each tributary, (2) end-of-September storage guidelines, and (3) maximum draw from storage. After numerous iterations, these variables were set such that the baseline storage and diversion results were most similar to CALSIM II results. First, the maximum draw from storage in any given year (as a percentage of the March 1 storage minus end-of-September storage) was limited (down from 100 percent) to a level causing reservoir dynamics comparable to those seen in CALSIM II (similar to the application of a delivery versus carryover-risk curve). After iterating, the maximum draw from storage was set at 80, 65, and 80 percent on the Stanislaus, Tuolumne, and Merced Rivers respectively.

Second, the baseline end-of-September storage guidelines were set to be 85,000 AF, 800,000 AF, and 115,000 AF in New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure respectively. These values effectively work so that WSE closely matches the storages for each of the reservoirs in the CALSIM II results.

Lastly, adjustment factors were applied through iteration to the calculated surface water demand values as described above, until the resulting WSE model storage and annual diversions matched the CALSIM II model results. During the iteration process, results were judged based on how well the maximum, minimum, and quartiles of the resulting WSE monthly diversion timeseries matched with the same parameters from the CALSIM II diversion results. The resulting factors are listed in Table F.1.2-15. These factors are similar to the “turnout factor” used in CALSIM to calibrate to river gage and delivery data during development. Additionally, under WSE CALSIM-baseline a minimum annual diversion of 550,000 AF (or ~50 percent of the annual maximum diversion), was needed on the Tuolumne River to bring diversion and storage results into alignment with CALSIM. Table F.1.2-20 contains the end-of-September storage targets, maximum draw from storage, and minimum diversion levels set in the WSE CALSIM-baseline that resulted in a close match of the CALSIM model results.

Because flows are largely dictated by minimum requirements on each river and only differ if flood control evacuation is necessary, this variable did not need to be adjusted through iterations; however, they were checked on a monthly time step to verify corroboration with historical and CALSIM II modeled flows (Figures F.1.2-8a, F.1.2-8b, F.1.2-8c). Flows match CALSIM closely for all three tributaries.

The WSE CALSIM-baseline simulation and CALSIM II results are compared using several graphs that show annual values for the 1922–2003 period. The annual values were sorted to show the distribution of annual values as the maximum to the minimum values (i.e., exceedance plots). Figures F.1.2-9a, F.1.2-9b, F.1.2-9c, and F.1.2-9d show the annual WSE results for the Stanislaus River and New Melones Reservoir compared to the CALSIM II baseline values. Figure F.1.2-9a shows the February–June flow volume at the confluence; Figure F.1.2-9b shows the carryover (i.e., end-of-September) storage in New Melones Reservoir; Figure F.1.2-9c shows the annual water supply diversions; and Figure F.1.2-9d shows February–June flow volume at the confluence as a percentage of unimpaired flow volume. Figures F.1.2-10a, F.1.2-10b, F.1.2-10c, and F.1.2-10d show the same annual WSE results for the Tuolumne River and New Don Pedro Reservoir compared to the CALSIM values. Figures F.1.2-11a, F.1.2-11b, F.1.2-11c, and F.1.2-11d show the same annual WSE results for the Merced River and Lake McClure compared to the CALSIM values. Figure F.1.2-12a shows the annual WSE results for total diversions from the three tributaries compared to CALSIM II results, while Figures F.1.2-12b and F.1.2-12c show annual WSE results for February–June flow at Vernalis compared to CALSIM II results. Figures F.1.2-13, F.1.2-14, and F.1.2-15 show the same comparisons of diversion, flow, and storage as annual time series for the Stanislaus, Tuolumne, Merced, and San Joaquin Rivers respectively.



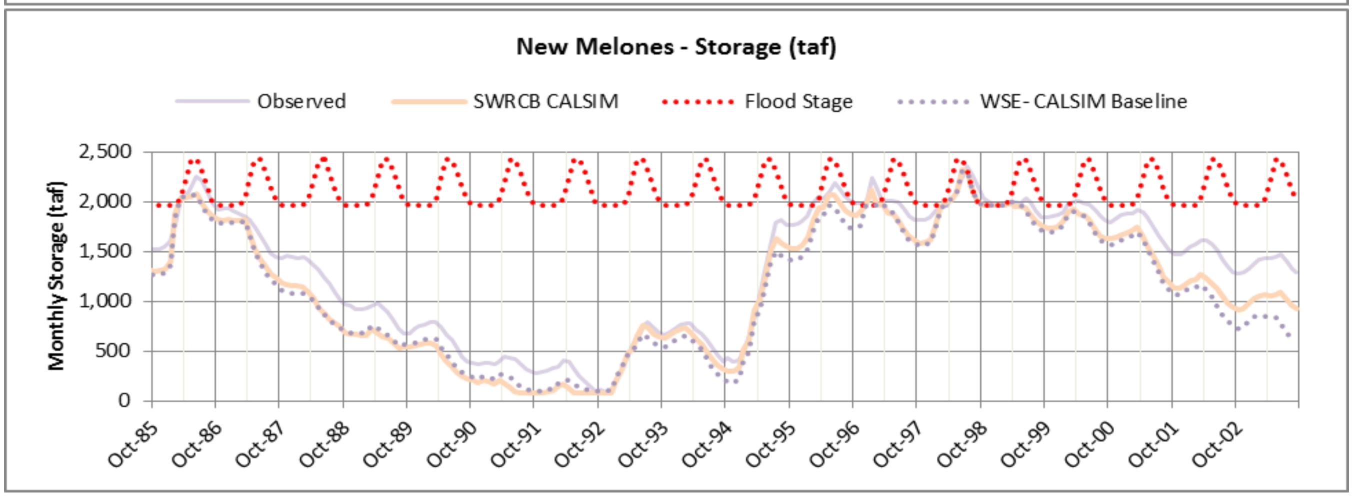


Figure F.1.2-8a. Monthly Comparison of WSE CALSIM-Baseline Flow and Storage Results to Historical Gage Data and SWRCB-CALSIM Model Results on the Stanislaus River

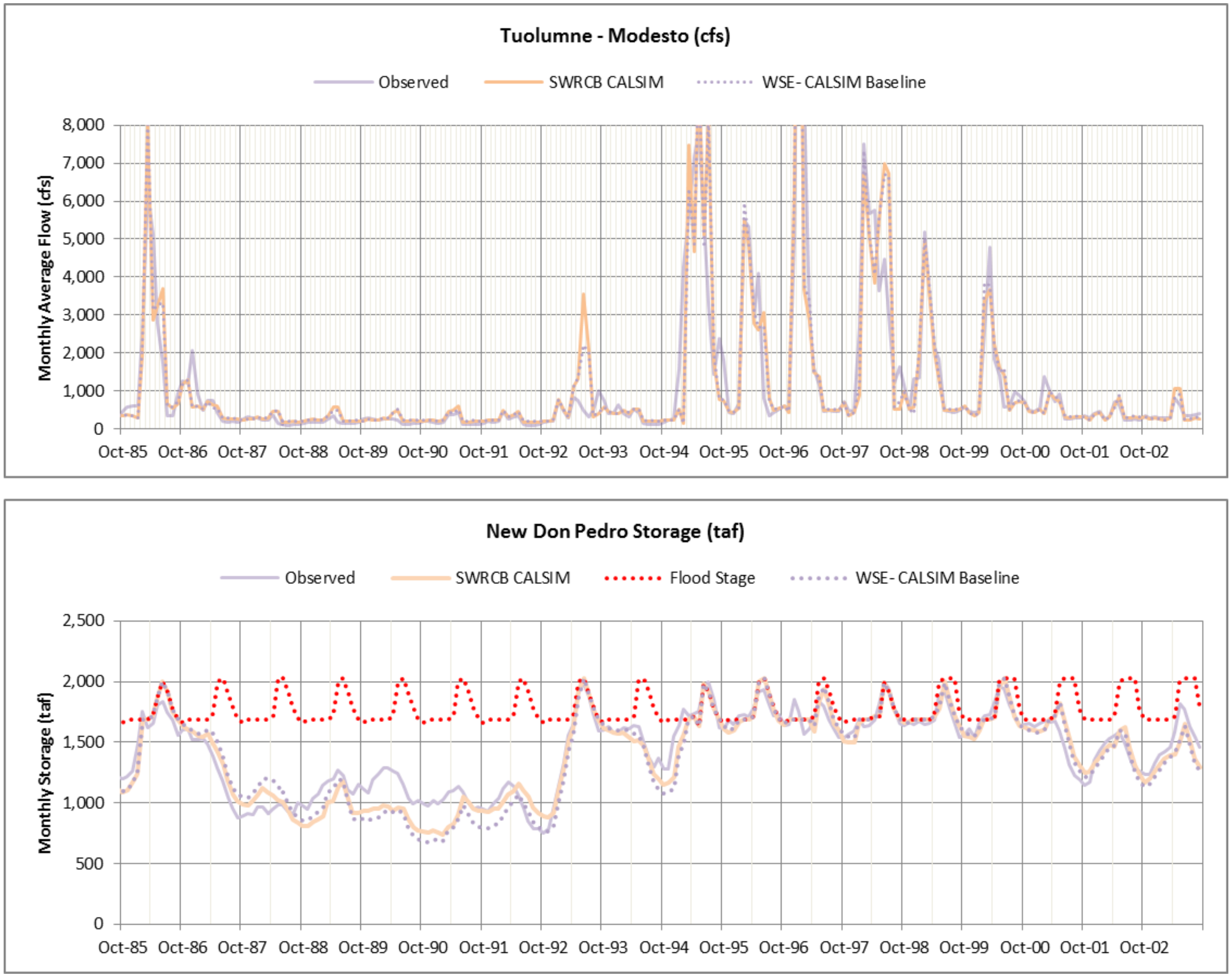
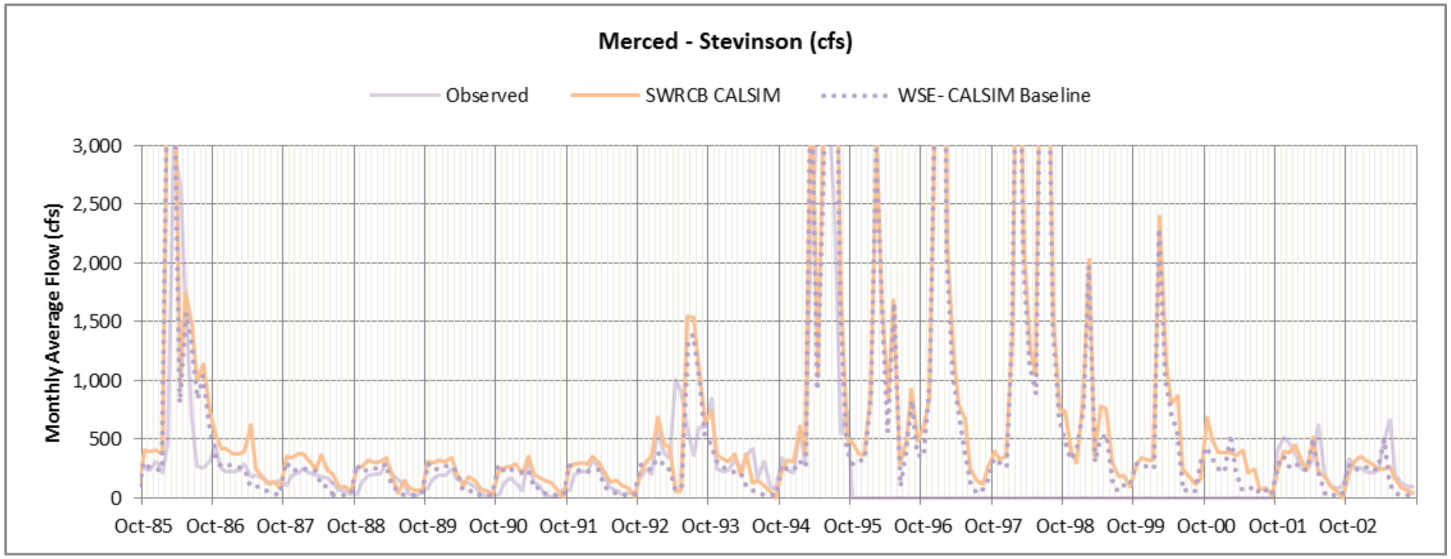


Figure F.1.2-8b. Monthly Comparison of WSE CALSIM-Baseline Flow and Storage Results to Historical Gage Data and SWRCB-CALSIM Model Results on the Tuolumne River



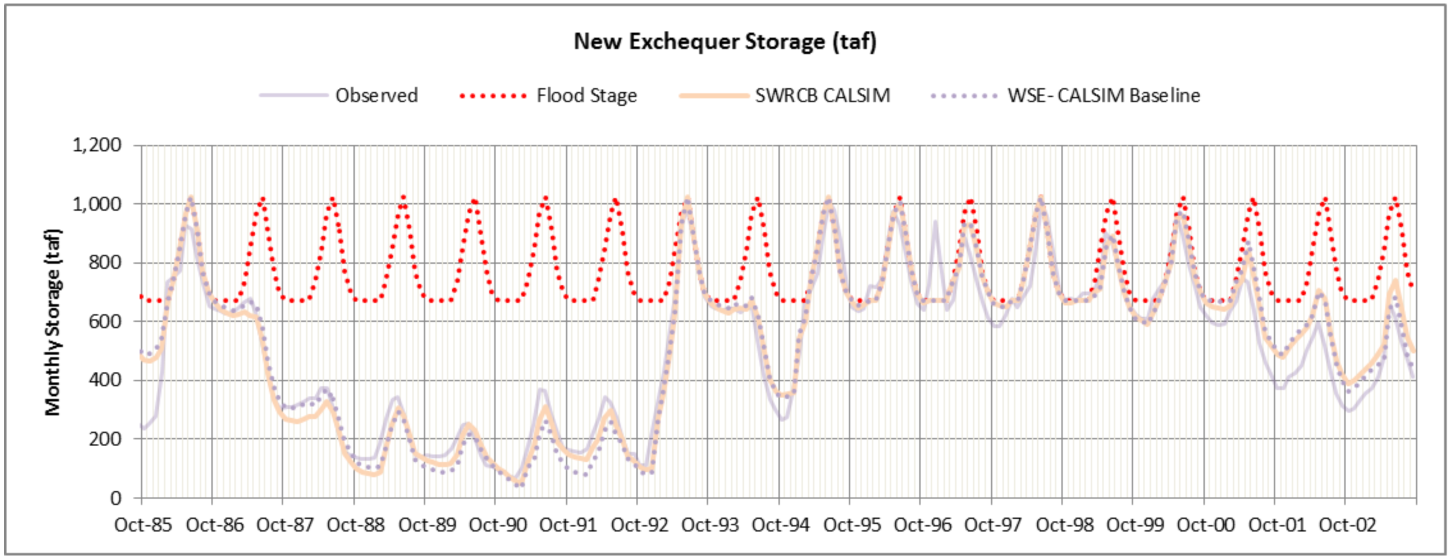


Figure F.1.2-8c. Monthly Comparison of WSE CALSIM-Baseline Flow and Storage Results to Historical Gage Data and SWRCB-CALSIM Model Results on the Merced River

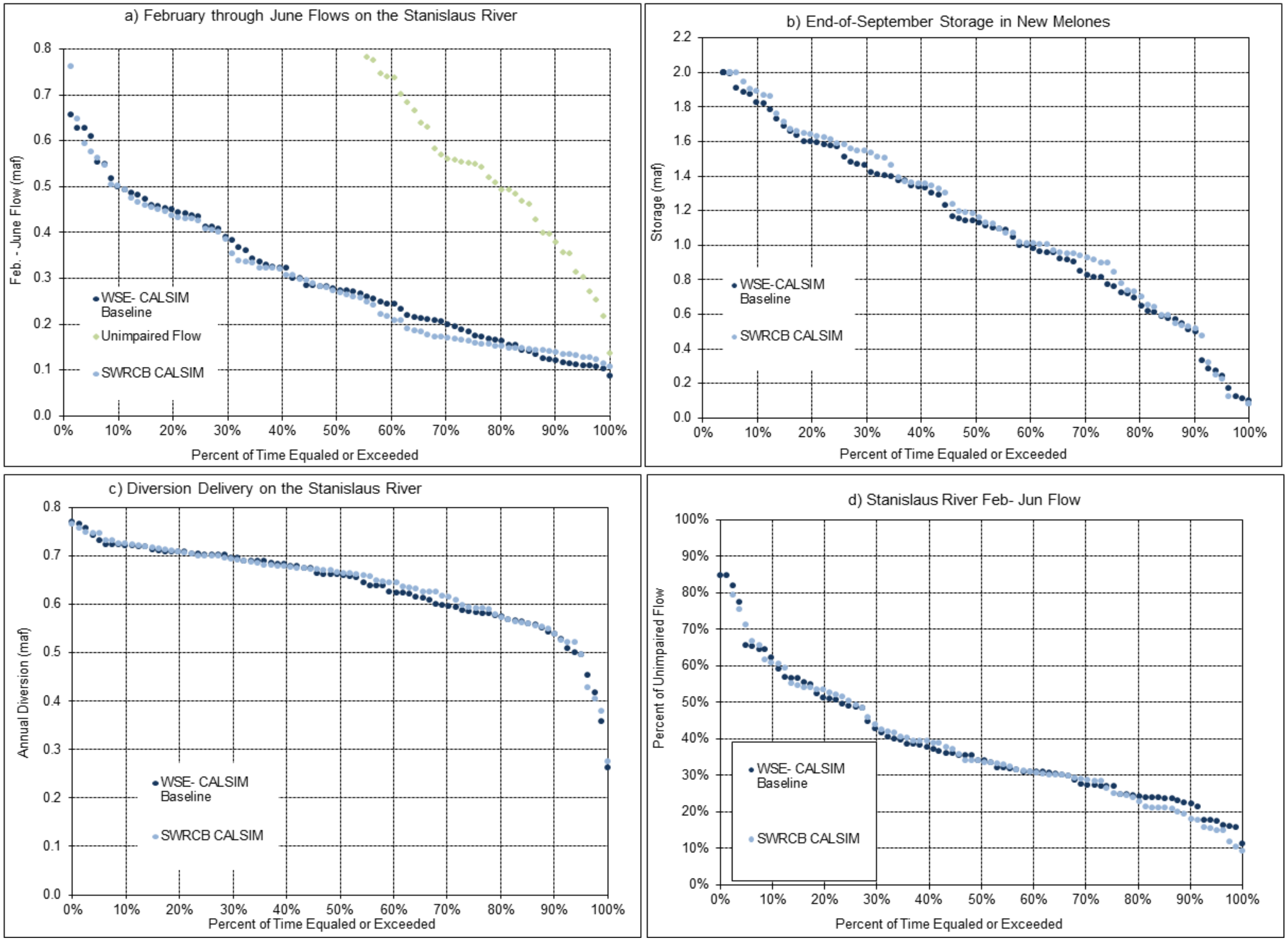


Figure F.1.2-9. Comparison of WSE CALSIM-Baseline with SWRCB-CALSIM output on the Stanislaus River for (a) February–June Flow at Ripon, (b) End-of-September Storage, (c) Annual Diversion Delivery, (d) February–June at Ripon as a Percentage of Unimpaired Flow

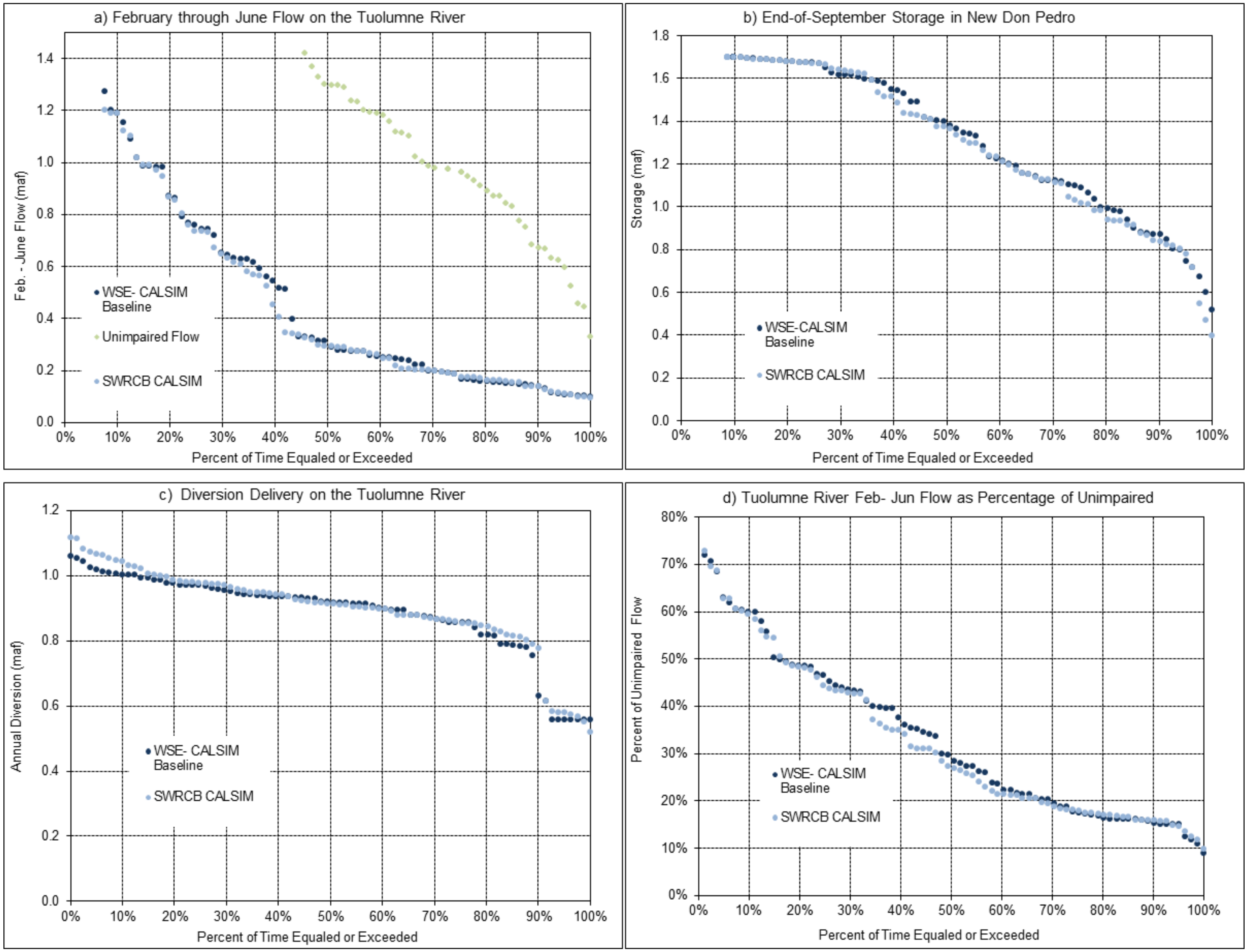


Figure F.1.2-10. Comparison of WSE CALSIM-Baseline with SWRCB-CALSIM Output on the Tuolumne River for (a) February–June Flow at Modesto, (b) End-of-September Storage, (c) Annual Diversion Delivery, (d) February–June at Modesto as a Percentage of Unimpaired Flow

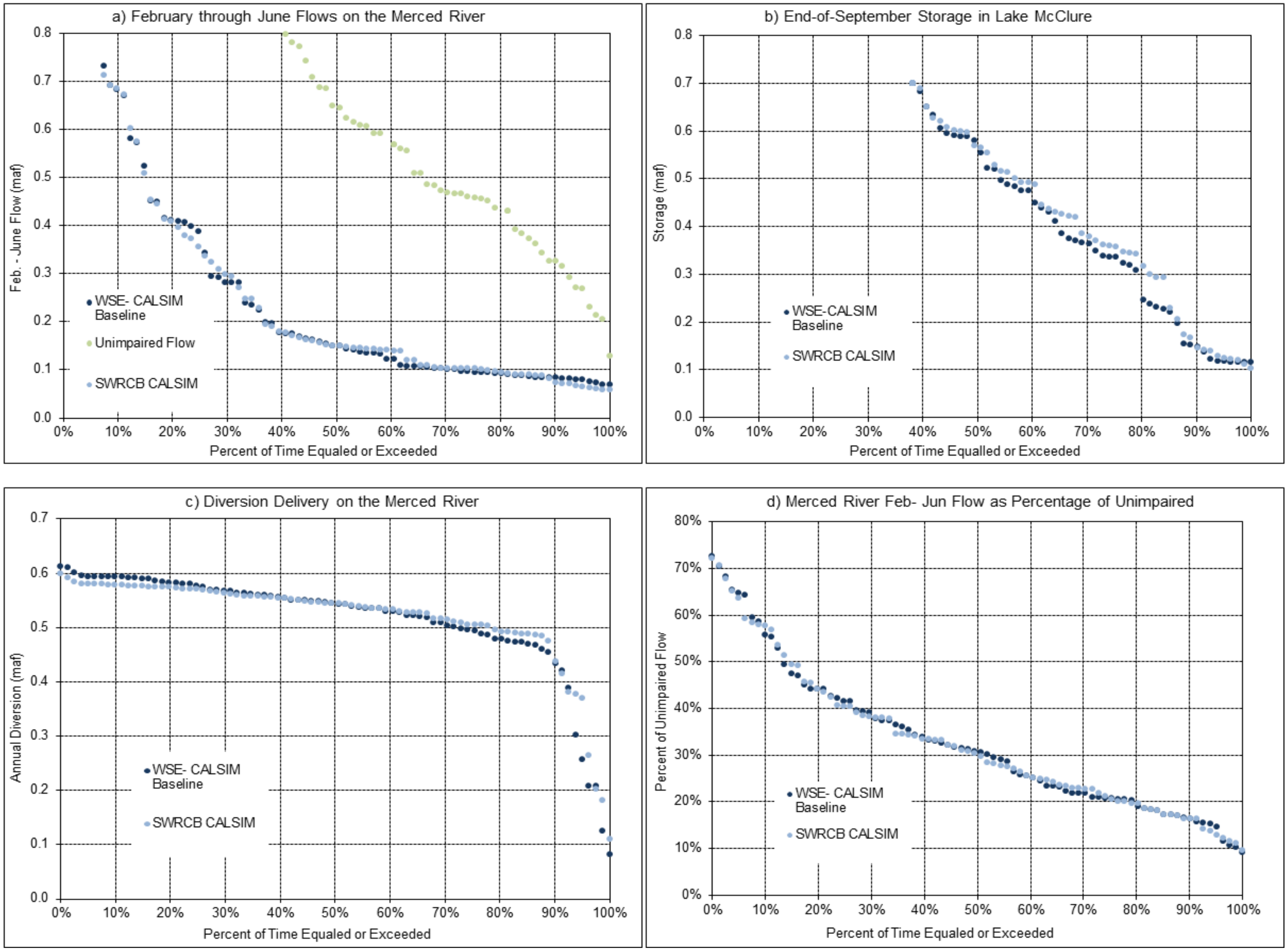


Figure F.1.2-11. Comparison of WSE CALSIM-Baseline with SWRCB CALSIM Output on the Merced River for (a) February–June Flow at Stevinson, (b) End-of-September Storage, (c) Annual Diversion Delivery, (d) February–June Flow at Stevinson as a Percentage of Unimpaired Flow

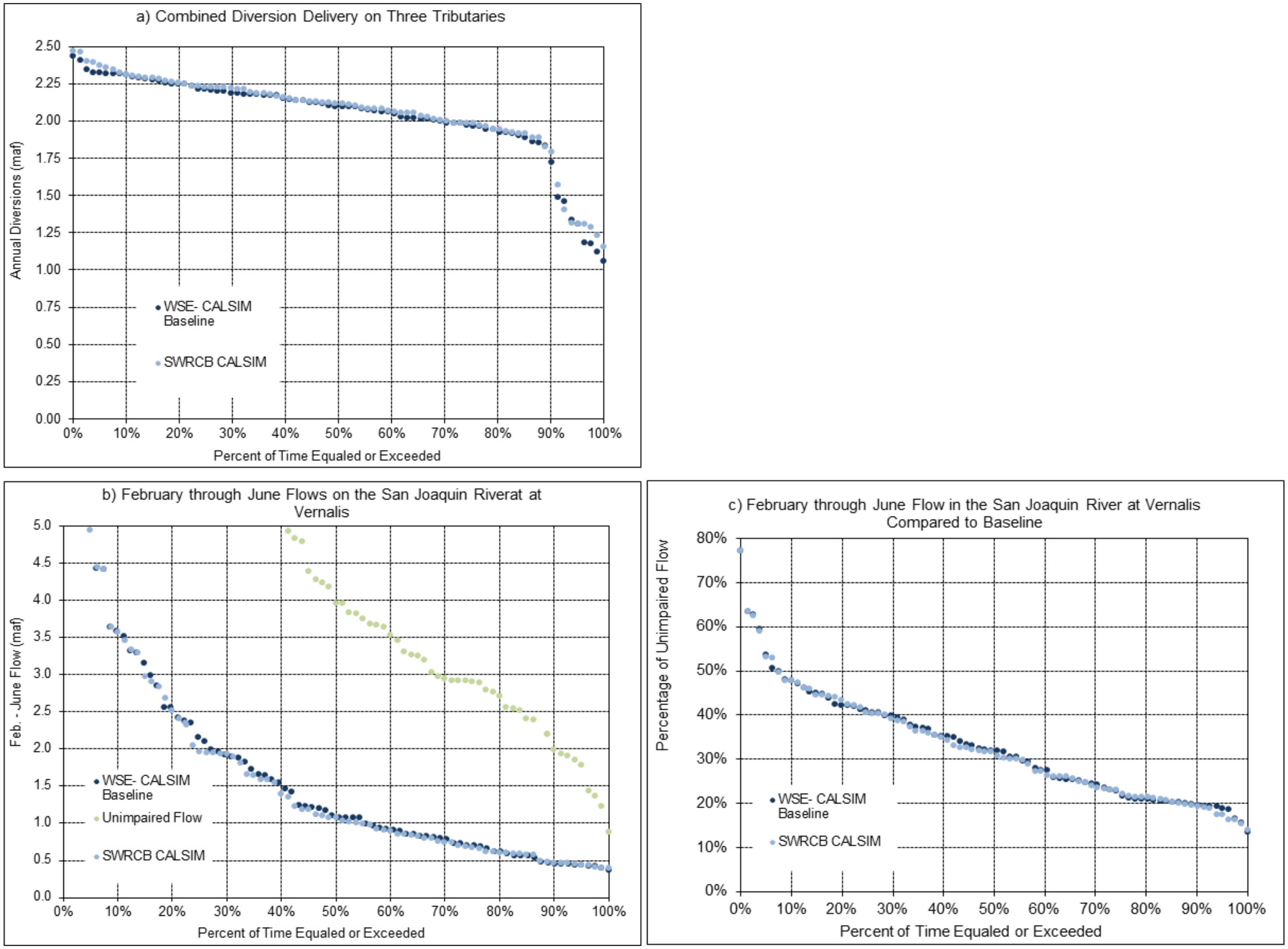


Figure F.1.2-12. Comparison of WSE CALSIM-Baseline with SWRCB-CALSIM Output for (a) Annual Diversion Delivery from All Three Major Tributaries, (b) Flow at Vernalis, (c) February–June Flow at Vernalis as a Percentage of Unimpaired Flow

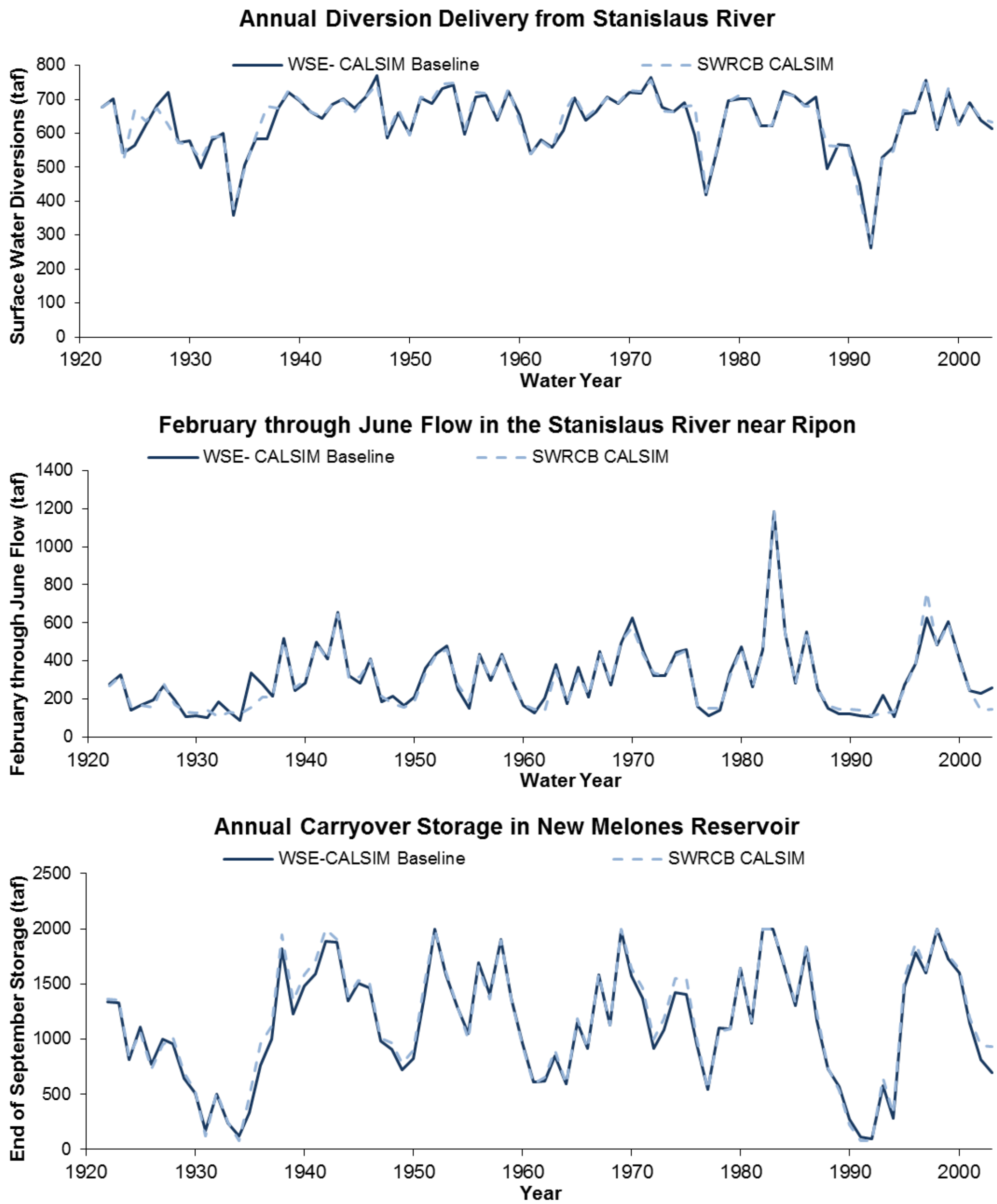


Figure F.1.2-13. Annual WSE CALSIM-Baseline Results for Stanislaus River Diversions, Flow, and Reservoir Operations Compared to SWRCB-CALSIM Results

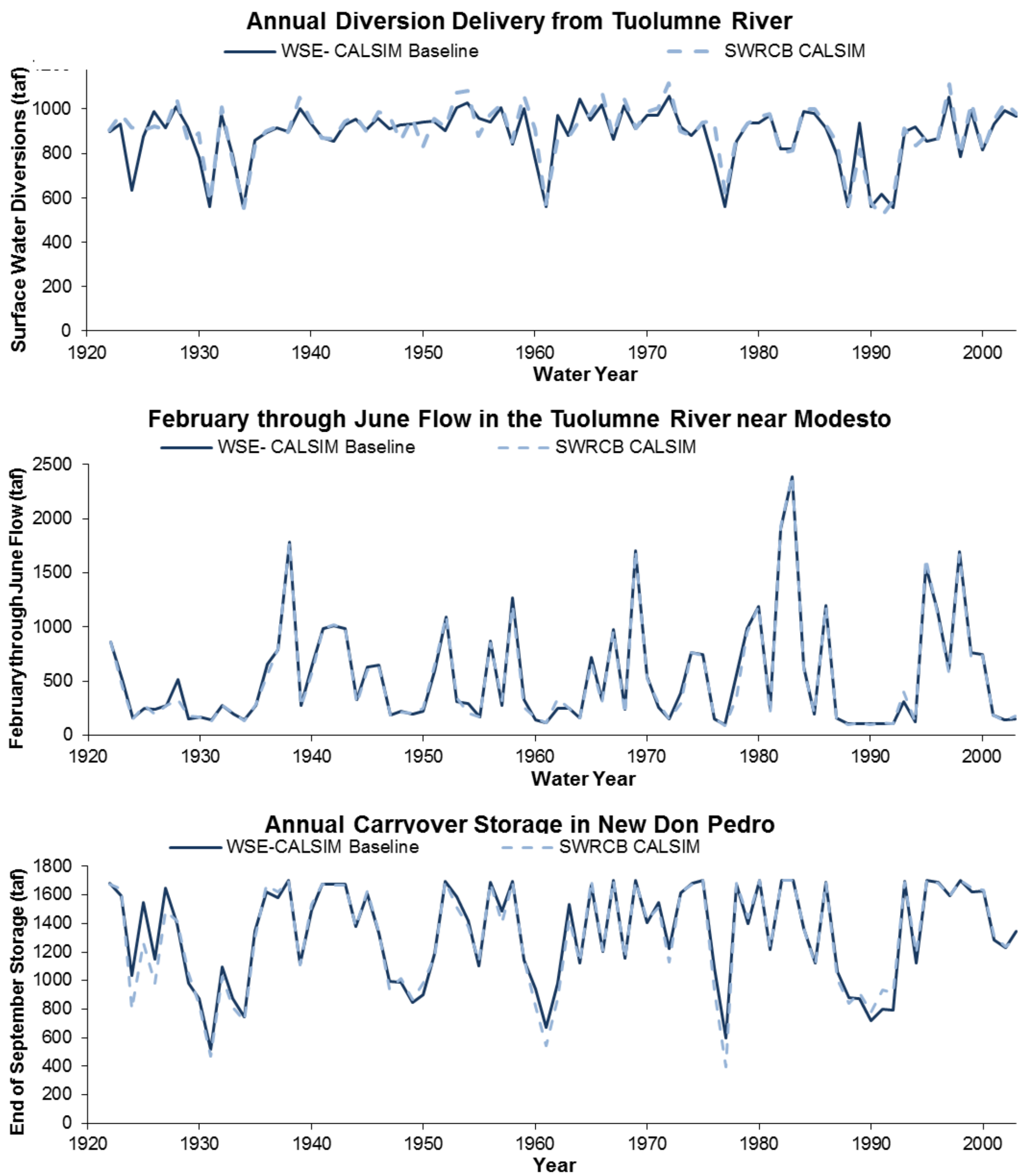


Figure F.1.2-14. Annual WSE CALSIM-Baseline Results for Tuolumne River Diversions, Flow, and Reservoir Operations Compared to SWRCB CALSIM Results

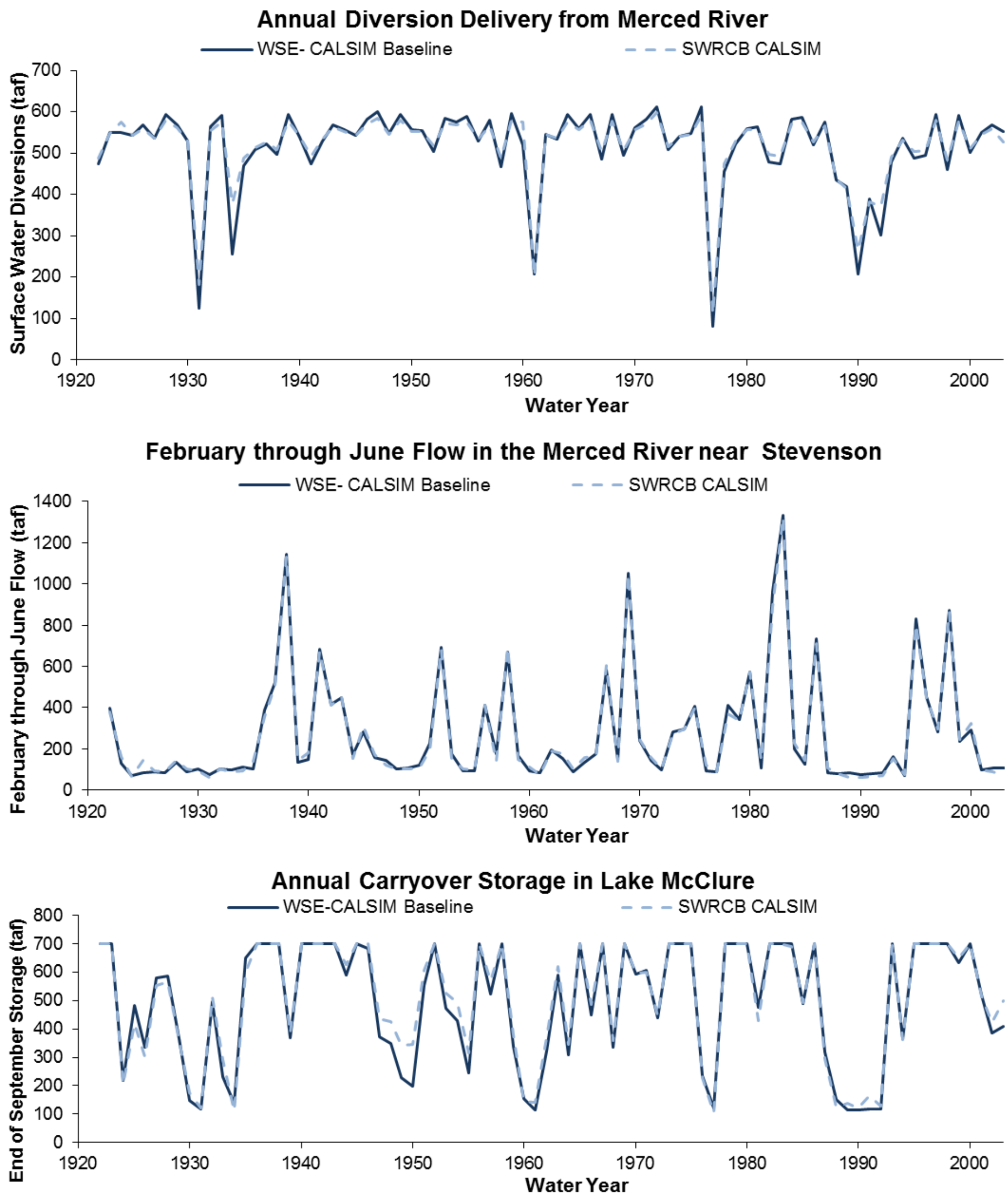


Figure F.1.2-15. Annual WSE CALSIM-Baseline Results for Merced River Diversions, Flow, and Reservoir Operations Compared to SWRCB CALSIM Results

F.1.3 Water Supply Effects Modeling—Results

This section summarizes the modeled results for reservoir operations, surface water diversions, and river flows. It also contains detailed results for baseline conditions and each LSJR alternative by geographic area (e.g., three eastside tributaries, LSJR).

In many cases, hydrologic conditions are described using cumulative distribution tables. The cumulative distribution of a particular variable (e.g., flow or storage) provides a basic summary of the distribution (range) of values. The percentile (percent cumulative distribution) associated with each value indicates the percent of time that the values were less than the specified value. For example, a 10th percentile value of 2 indicates that 10 percent of the time the values were less than 2. The 0th percentile is the minimum value, the 50th percentile is the median value, and the 100th percentile is the maximum value. In many cases, the 10th and 90th percentiles have been selected to represent relatively low and high values rather than the minimum and maximum because they are representative of multiple years rather than the one year with the highest value and the one year with the lowest value.

For additional detail, Attachment 1 of this appendix contains the monthly model outputs for reservoir storage and streamflow for the baseline conditions and LSJR Alternatives 2, 3, and 4 over the 1922–2003 period. Attachment 1 is presented by month for each water year.

F.1.3.1 Summary of Water Supply Effects Model Results

Summarized below are the resulting effects of monthly storage, carryover storage (end-of-September), annual water diversions, and river flows for LSJR Alternatives 2, 3, and 4 compared to baseline in the three eastside tributaries. Detailed results are discussed after this section for the baseline conditions and LSJR Alternatives 2, 3, and 4 (20, 40, and 60 percent unimpaired flow). Summary results also include the adaptive implementation approaches for the various LSJR alternatives (e.g., 30 and 50 percent unimpaired flow). Results on the tributaries were as calculated near the LSJR confluence, specifically at Ripon, Modesto, and Stevinson for the Stanislaus, Tuolumne, and Merced Rivers, respectively.

Reservoir Storage

Reservoir storage and release is used for calculation of hydropower generation effects, recreation, and is used as input to temperature modeling. The end-of-September storage is generally an indicator of potential effects to stream temperature. Falling below a certain level of storage may result in increased temperatures at a time when fish are vulnerable (e.g., during the fall spawning season). Average carryover storage is presented in Table F.1.3-1a for the entire 82-year modeling period and in Table F.1.3-1b for the critically dry years only.

Figures F.1.3-1a, F.1.3-1b, and F.1.3-1c display the baseline and WSE monthly storage results for the LSJR alternatives (20, 40, and 60 percent unimpaired flows) for the three tributary reservoirs for water years 1922–2003. The monthly flood control storage levels and the monthly unimpaired flows are shown for reference. The ranges of estimated storage for the LSJR alternatives were similar to the baseline storage values, although storage was allowed to be drained further in wetter years as the unimpaired flow requirement increased. The inclusion of carryover storage guidelines tended to raise storage in dryer years compared to baseline.

Table F.1.3-1a. Average Carryover Storage within the Three Major Reservoirs over the 82-Year Modeling Period (TAF)

Percent Unimpaired Flow	New Melones	New Don Pedro	Lake McClure
Baseline	1,125	1,348	453
20%	1,261	1,342	511
30%	1,211	1,291	498
40%	1,188	1,248	480
50%	1,131	1,216	476
60%	1,087	1,223	462

Table F.1.3-1b. Average Carryover Storage during Critically Dry Years within the Three Major Reservoirs over the 82-Year Modeling Period (TAF)

Percent Unimpaired Flow	New Melones	New Don Pedro	Lake McClure
Baseline	540	880	154
20%	793	945	315
30%	784	956	324
40%	830	939	329
50%	822	982	312
60%	846	968	267

Note:

Sixteen years were classified as critically dry from 1922–2003.

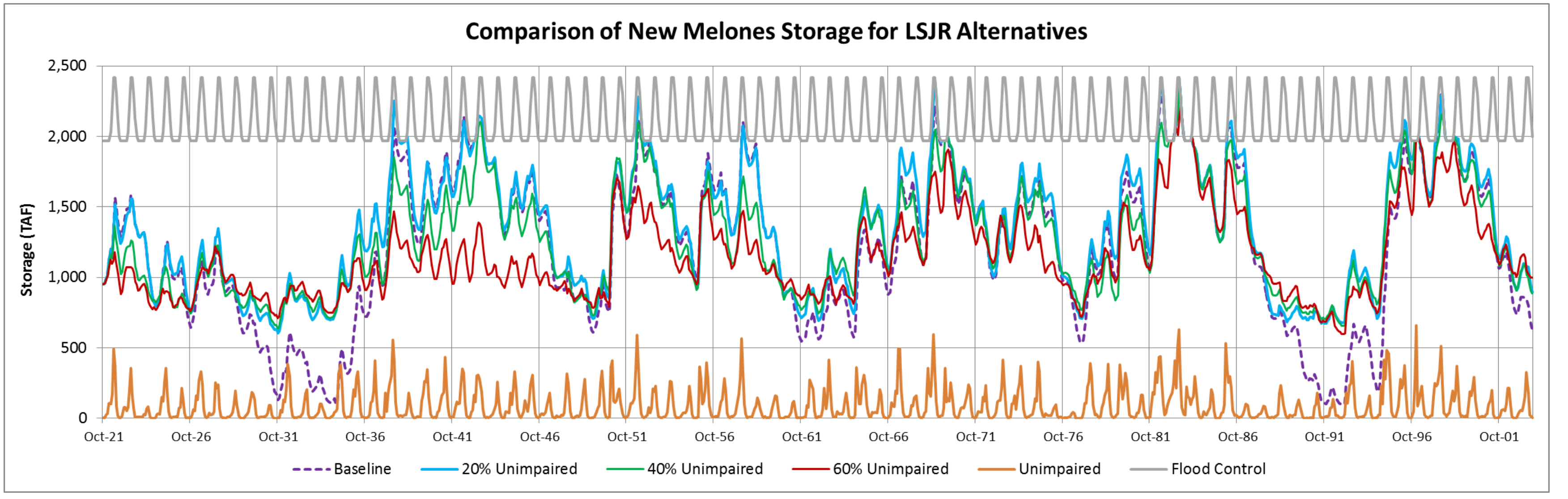


Figure F.1.3-1a. Comparison of Baseline Conditions and WSE Model Results for 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4): New Melones Reservoir Storage and Stanislaus River Unimpaired Flows for 1922–2003

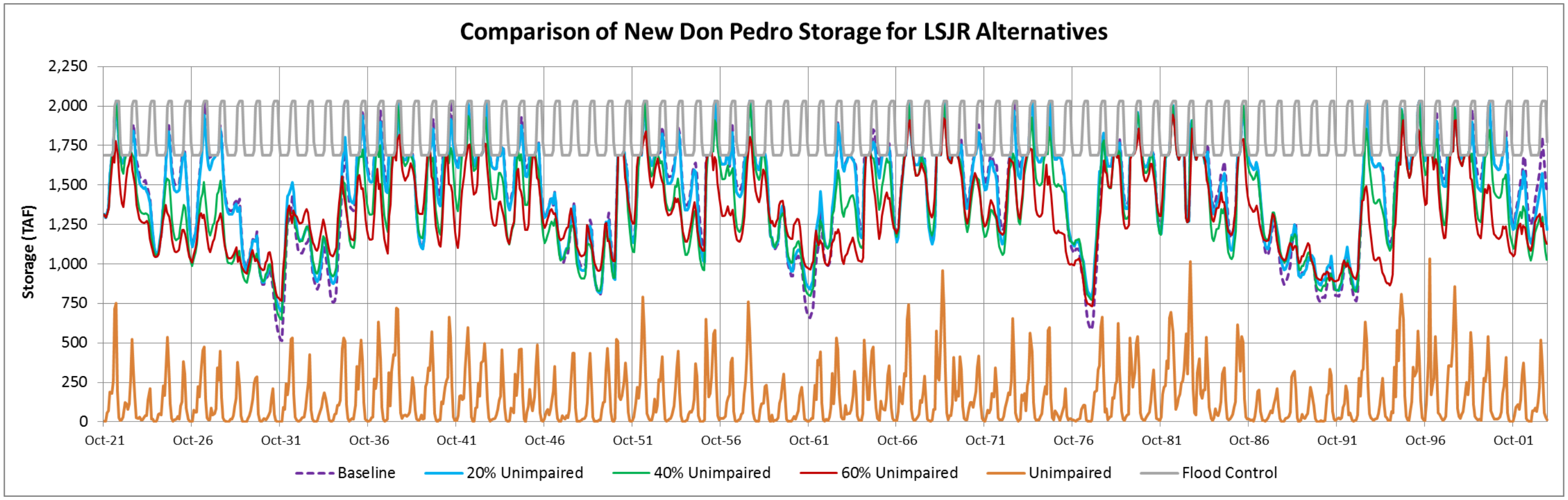


Figure F.1.3-1b. Comparison of Baseline Conditions and WSE Model Results for 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4): New Don Pedro Reservoir Storage and Tuolumne River Unimpaired Flows for 1922–2003

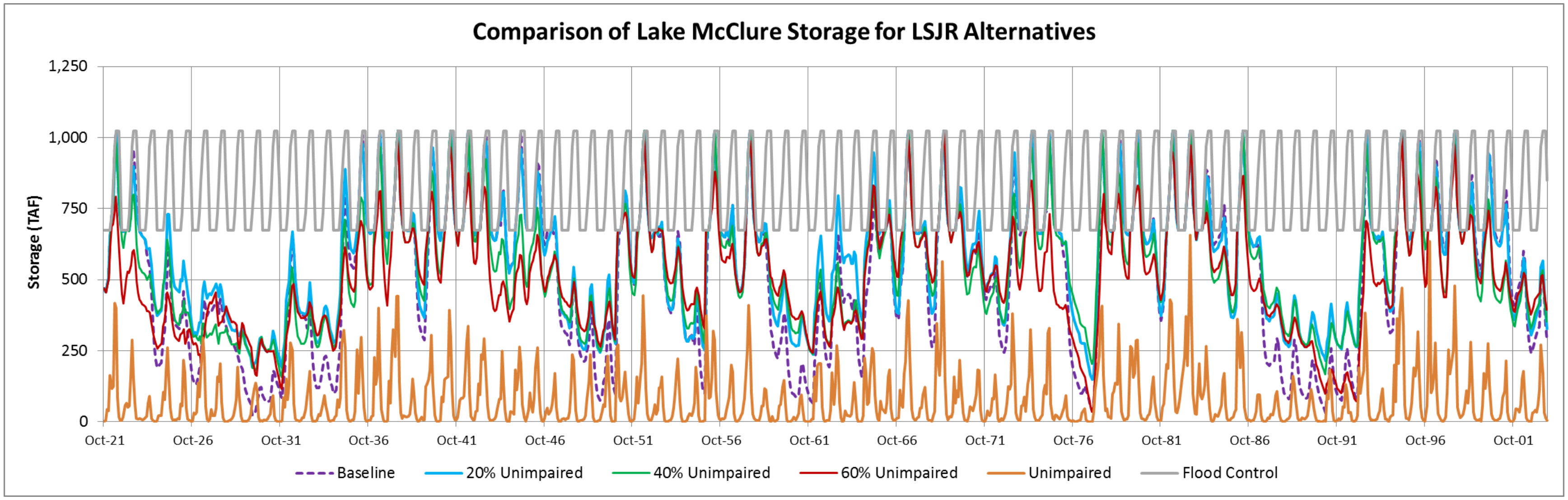


Figure F.1.3-1c. Comparison of Baseline Conditions and WSE Model Results for 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4): Lake McClure Storage and Merced River Unimpaired Flows for 1922–2003

River Flows

Table F.1.3-2a contains a summary of the average effects of the LSJR alternatives on river flows (flow volumes, TAF) from February–June and annually as compared to the baseline flows for each eastside tributary and near Vernalis on the SJR. Most of the change in flow volume associated with implementation of the unimpaired flow objectives (in terms of TAF) occurred during the unimpaired flow objective months (February–June). During the other months, the LSJR alternative flows were similar to the baseline flows. Table F.1.3-2b summarizes the mean annual February–June instream flow totals under Alternative 3 for each tributary in the plan area by water year type.

Figures F.1.3-2a, F.1.3-2b, F.1.3-2c, and F.1.3-2d show the simulated monthly flows in the Stanislaus, Tuolumne, and Merced Rivers near the confluence with the LSJR and the SJR at Vernalis for water years 1984–2003. The unimpaired flows are shown for comparison. The baseline flows were generally low in many months each year until runoff was high enough to increase reservoir storage and cause flood control releases (in wet years). From February–June, in general, as the percentage of unimpaired flow increases, the resulting river flow increased. The simulated river flows are described in more detail in Sections F.1.2.4 through F.1.2.7.

Table F.1.3-2a. Average Baseline Streamflow and Differences from Baseline Conditions on the Eastside Tributaries and near Vernalis

Percent Unimpaired Flow	Stanislaus River near Ripon (TAF)/(%)	Tuolumne River near Modesto (TAF)/(%)	Merced River near Stevinson (TAF)/(%)	Total three tributaries (TAF)/(%)	SJR near Vernalis (TAF)/(%)
February–June Average					
Baseline	312/100	562/100	245/100	1,116/100	1,742/100
20%	-3/-1	32/6	27/11	56/5	56/3
25%	11/4	53/10	42/17	106/10	106/6
30%	27/9	85/15	62/26	174/16	174/10
35%	30/9	98/17	70/29	197/18	197/11
40%	62/20	135/24	91/38	288/26	288/17
45%	91/29	171/30	111/46	373/33	373/21
50%	128/41	220/39	137/57	485/43	485/28
55%	164/53	271/48	163/67	598/54	598/34
60%	203/65	332/59	193/80	728/65	728/42
Annual Average					
Baseline	549/100	895/100	454/100	1,897/100	2,965/100
20%	5/1	23/3	31/7	59/3	59/2
25%	15/1	37/4	42/9	94/5	94/3
30%	28/5	63/7	58/13	149/8	149/5
35%	42/8	90/10	74/16	206/11	206/7
40%	74/13	127/14	93/21	294/15	294/10

Percent Unimpaired Flow	Stanislaus River near Ripon (TAF)/(%)	Tuolumne River near Modesto (TAF)/(%)	Merced River near Stevinson (TAF)/(%)	Total three tributaries (TAF)/(%)	SJR near Vernalis (TAF)/(%)
45%	94/17	159/18	110/24	363/19	363/12
50%	132/24	202/23	135/30	469/25	469/16
55%	163/30	249/28	158/35	571/30	571/19
60%	202/37	307/34	184/41	693/37	693/23

Notes:

Resulting flow effects on the tributaries were as calculated near the LSJR confluence, specifically at Ripon, Modesto, and Stevinson for the Stanislaus, Tuolumne, and Merced Rivers, respectively.

Table F.1.3-2b. Mean Annual February–June Instream Flow in the Plan Area by Water Year Type

		Year Type				
		Wet	Above Normal	Below Normal	Dry	Critically Dry
Stanislaus	Baseline (TAF)	455	380	261	232	134
	LSJR Alt 3 (30% UF)* (TAF)	519	382	288	231	155
	Change (TAF)	64	2	27	-1	21
	Change (%)	14%	1%	10%	-1%	15%
	LSJR Alt 3 (40% UF) (TAF)	555	440	343	234	175
	Change (TAF)	100	60	82	2	41
	Change (%)	22%	16%	31%	1%	31%
	LSJR Alt 3 (50% UF)* (TAF)	661	523	398	265	201
	Change (TAF)	206	143	137	33	67
	Change (%)	45%	38%	52%	14%	50%
Tuolumne	Baseline (TAF)	1165	575	297	231	132
	LSJR Alt 3 (30% UF)* (TAF)	1196	695	415	320	231
	Change (TAF)	31	120	118	89	99
	Change (%)	3%	21%	40%	39%	75%
	LSJR Alt 3 (40% UF) (TAF)	1177	780	514	387	296
	Change (TAF)	12	205	217	156	164
	Change (%)	1%	36%	73%	68%	124%
	LSJR Alt 3 (50% UF)* (TAF)	1226	903	637	473	365
	Change (TAF)	61	328	340	242	233
	Change (%)	5%	57%	115%	105%	176%
Merced	Baseline (TAF)	541	178	129	98	68
	LSJR Alt 3 (30% UF)* (TAF)	583	282	202	150	118
	Change (TAF)	42	104	73	52	50
	Change (%)	8%	58%	56%	53%	73%
	LSJR Alt 3 (40% UF) (TAF)	575	342	256	186	146
	Change (TAF)	34	164	127	88	78
	Change (%)	6%	92%	98%	90%	115%
	LSJR Alt 3 (50% UF)* (TAF)	606	421	315	226	176
	Change (TAF)	65	243	186	128	108
	Change (%)	12%	136%	144%	131%	158%
Total Three Tributaries	Baseline (TAF)	2161	1133	687	561	334
	LSJR Alt 3 (30% UF)* (TAF)	2298	1359	905	701	503
	Change (TAF)	137	226	218	140	169
	Change (%)	6%	20%	32%	25%	51%
	LSJR Alt 3 (40% UF) (TAF)	2307	1562	1113	807	617
	Change (TAF)	146	429	426	246	283
	Change (%)	7%	38%	62%	44%	85%
	LSJR Alt 3 (50% UF)* (TAF)	2493	1847	1350	965	741
	Change (TAF)	332	714	663	404	407
	Change (%)	15%	63%	97%	72%	122%

UF = unimpaired flow

TAF = thousand acre-feet

*LSJR Alt 3 (30% UF) and LSJR Alt 3 (50% UF) both refer to LSJR alternative 3 with adaptive implementation.

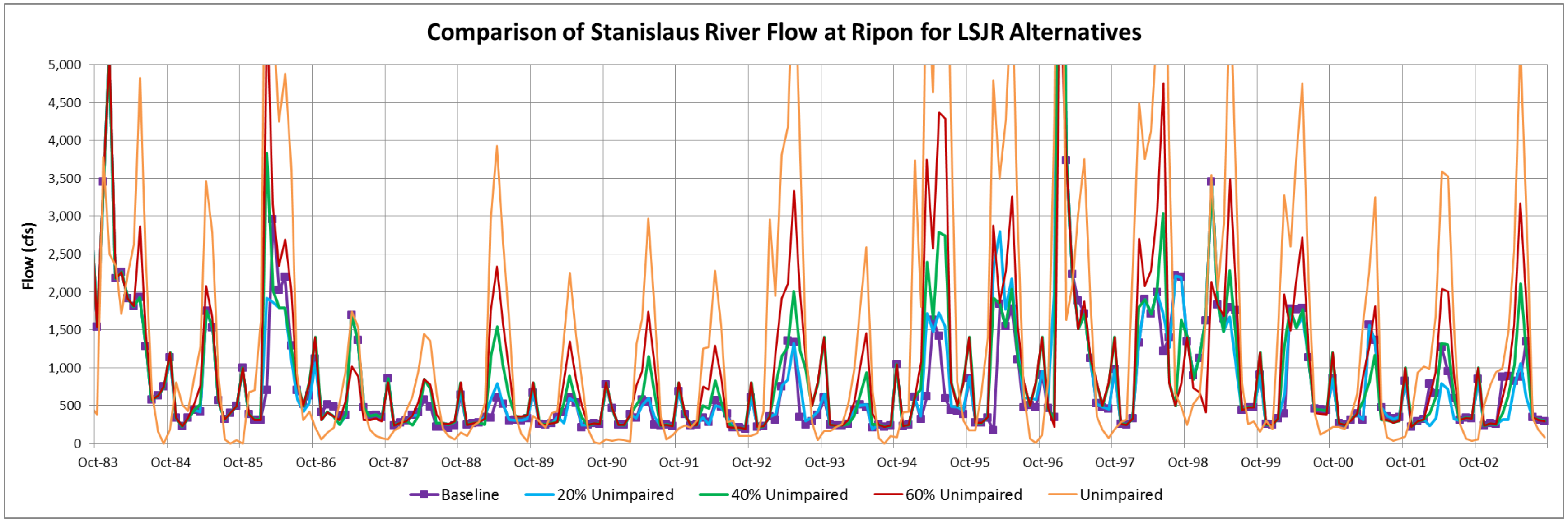


Figure F.1.3-2a. Comparison of Monthly Stanislaus River Flows for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for Water Years 1984–2003

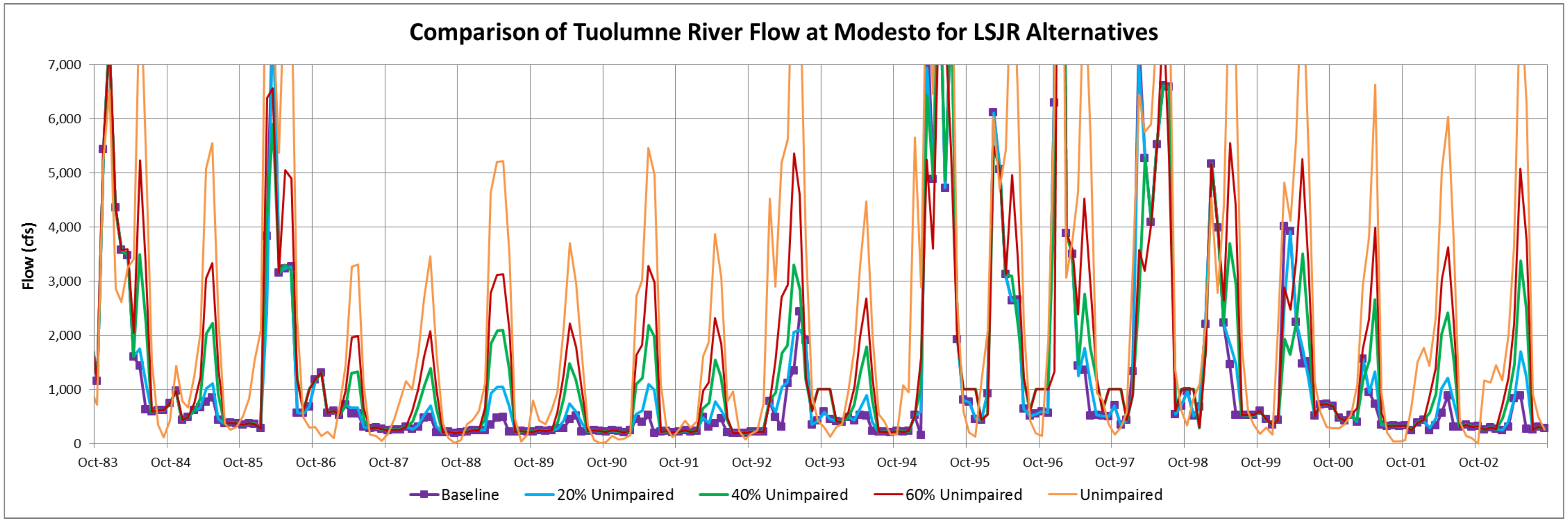


Figure F.1.3-2b. Comparison of Monthly Tuolumne River Flows for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for Water Years 1984–2003

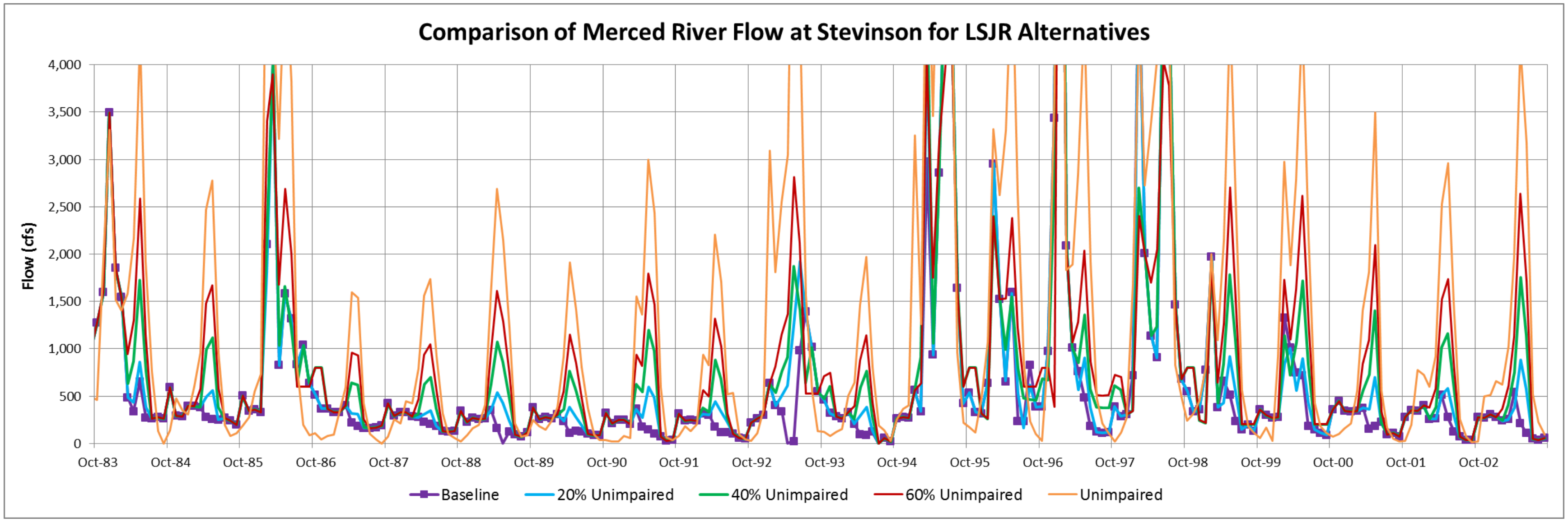


Figure F.1.3-2c. Comparison of Monthly Merced River Flows for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for Water Years 1984–2003

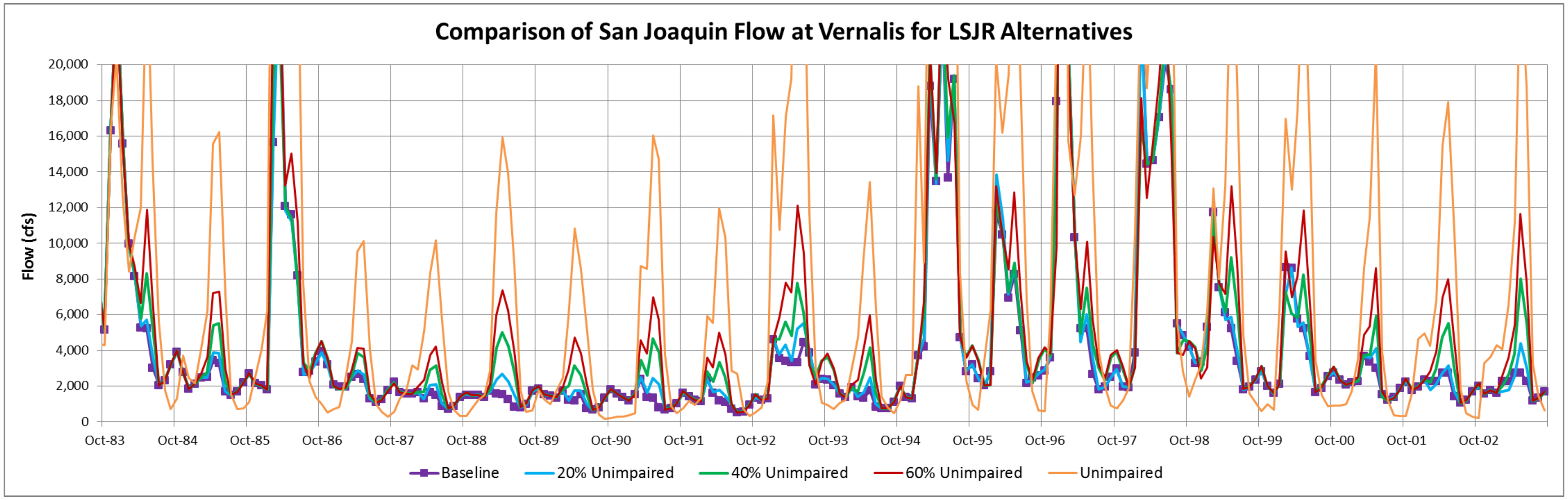


Figure F.1.3-2d. Comparison of Monthly SJR at Vernalis Flows for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for Water Years 1984–2003

Surface Water Diversions

Table F.1.3-3 contains a summary of the effects on diversions for each eastside tributary and for the plan area of the LSJR alternatives as compared to the baseline for the 82-year modeling period. Tables F.1.3-4a, F.1.3-4b, and F.1.3-4c show the annual cumulative distributions of water supply diversions under the LSJR alternatives as compared to the baseline water supply diversions and deficits indicators for each tributary. The deficit indicator was calculated as maximum demand minus delivery, where the maximum demand equals the maximum annual diversion under baseline conditions. It should be noted, however, that in some years (particularly wet years), the demand is lower than in other years, so the deficit indicator could be an overprediction of the actual deficit. The annual values are summarized with the minimum and maximum and average, as well as the 10 percent increments of the distribution of values. The range of annual unimpaired flow for each tributary is shown for comparison. Additional details are discussed in Sections F.1.2.4 through F.1.2.7 for baseline and LSJR Alternatives 2, 3, and 4.

Table F.1.3-3. Average Annual Baseline Water Supply and Difference from Baseline Conditions on the Eastside Tributaries and Plan Area Totals over the 82-year Modeling Period

Percent Unimpaired Flow Requirement	Stanislaus Diversion (TAF)/(% of Baseline)	Tuolumne Diversion (TAF)/(% of Baseline)	Merced Diversion (TAF)/(% of Baseline)	Total Three Tributaries (TAF)/(% of Baseline)
Baseline	637/100	851/100	580/100	2,068/100
20%	-12/-2	-20/-2	-33/-6	-65/-3
25%	-20/-3	-32/-4	-44/-8	-96/-5
30%	-33/-5	-56/-7	-60/-10	-149/-7
35%	-45/-7	-82/-10	-75/-13	-202/-10
40%	-79/-12	-119/-14	-95/-16	-293/-14
45%	-97/-15	-149/-18	-111/-19	-357/-17
50%	-136/-21	-193/-23	-136/-23	-465/-23
55%	-167/-26	-240/-28	-159/-27	-566/-27
60%	-206/-32	-298/-35	-185/-32	-689/-33

Annual Summary of Results

Baseline and the LSJR alternatives for each tributary are summarized with the distribution of the annual carryover storage (end-of-September), the distribution of annual water supply deliveries, and the distribution of annual or February–June river flows (volume and percentage of unimpaired flow). Tables F.1.3-4a, F.1.3-4b, and F.1.3-4c present the cumulative distributions for annual diversions and annual diversion deficits on the Stanislaus, Tuolumne, and Merced Rivers, respectively. Table F.1.3-4d illustrates the variation of diversion by water year type under LSJR Alternative 3.

Table F.1.3-4a. Annual Water Supply Diversions for Baseline Conditions and Percent of Unimpaired Flow on the Stanislaus

	Unimpaired Flow	Stanislaus Diversions (TAF)						Stanislaus Deficit Indicator (TAF)					
		Baseline	20%	30%	40%	50%	60%	Baseline	20%	30%	40%	50%	60%
Minimum	155	252	228	228	228	198	164	520	544	544	544	574	607
10%	456	538	452	320	265	222	201	234	320	452	507	550	571
20%	592	583	570	508	403	288	221	189	202	264	369	484	551
30%	680	605	624	616	464	333	260	167	148	156	307	439	511
40%	891	630	657	640	584	461	322	142	115	132	188	311	450
50%	1,095	661	673	664	640	575	399	111	99	108	132	196	373
60%	1,264	676	687	681	663	630	510	96	85	91	109	142	262
70%	1,368	694	701	697	679	663	601	78	71	75	93	109	171
80%	1,563	708	709	708	695	681	661	64	63	63	77	91	111
90%	1,910	723	724	724	712	705	690	49	48	48	60	67	82
Maximum	2,954	772	772	772	759	759	759	0	0	0	13	13	13
Average	1,118	637	624	604	558	500	431	135	147	168	214	271	341

Table F.1.3-4b. Annual Water Supply Diversions for Baseline Conditions and Percent of Unimpaired Flow on the Tuolumne

	Unimpaired Flow	Tuolumne Diversions (TAF)						Tuolumne Deficit Indicator (TAF)					
		Baseline	20%	30%	40%	50%	60%	Baseline	20%	30%	40%	50%	60%
Minimum	384	557	371	371	341	215	214	477	663	663	693	819	820
10%	836	685	652	543	408	322	229	349	382	491	625	712	805
20%	1,055	796	781	715	563	395	287	237	253	319	471	639	747
30%	1,166	828	822	777	641	511	378	205	211	257	393	523	656
40%	1,413	855	852	823	763	652	460	179	182	211	271	382	574
50%	1,783	878	869	851	802	751	538	156	165	183	232	283	496
60%	2,036	891	889	871	828	802	673	143	145	163	206	231	361
70%	2,198	915	910	890	859	828	763	119	124	144	175	206	271
80%	2,490	932	930	911	887	857	820	102	104	123	147	177	214
90%	3,090	960	957	938	908	890	853	74	77	96	126	144	181
Maximum	4,630	1,034	1,034	1,004	1,004	1,004	907	0	0	30	30	30	127
Average	1,851	851	831	795	732	657	553	183	203	239	302	376	481

Table F.1.3-4c. Annual Water Supply Diversions for Baseline Conditions and Percent of Unimpaired Flow on the Merced

	Unimpaired Flow	Merced Diversions (TAF)						Merced Deficit Indicator (TAF)					
		Baseline	20%	30%	40%	50%	60%	Baseline	20%	30%	40%	50%	60%
Minimum	151	136	203	203	203	202	202	543	476	476	476	478	478
10%	408	441	380	308	259	231	220	239	299	372	420	448	459
20%	489	558	472	407	353	300	243	122	208	273	326	380	437
30%	560	578	551	495	408	330	284	102	129	185	272	350	396
40%	669	602	565	537	467	387	323	78	114	143	212	293	357
50%	895	617	587	560	551	482	380	63	92	120	128	198	299
60%	1,086	630	603	582	564	522	442	50	77	98	116	158	238
70%	1,169	643	619	611	582	558	494	37	61	69	97	122	186
80%	1,399	653	632	627	607	579	557	26	48	53	73	100	122
90%	1,706	669	659	642	632	610	580	10	21	37	48	70	100
Maximum	2,790	680	673	673	673	668	648	0	7	7	7	12	32
Average	958	580	547	520	485	444	395	100	133	160	194	235	284

Table F.1.3-4d. Mean Annual Diversions Under 40 Percent Unimpaired Flow Proposal by Water Year Type

		Year Type				
		Wet	Above Normal	Below Normal	Dry	Critically Dry
Stanislaus	Baseline (TAF)	661	661	661	683	520
	LSJR Alt 3 (40% UF) (TAF)	662	630	613	536	303
	Change (TAF)	1	-31	-48	-147	-217
	Change (%)	0%	-5%	-7%	-22%	-42%
Tuolumne	Baseline (TAF)	848	882	931	938	689
	LSJR Alt 3 (40%UF) (TAF)	845	855	800	681	426
	Change (TAF)	-3	-27	-131	-257	-263
	Change (%)	0%	-3%	-14%	-27%	-38%
Merced	Baseline (TAF)	591	622	642	650	416
	LSJR Alt 3 (40% UF) (TAF)	591	607	508	381	272
	Change (TAF)	0	-15	-134	-268	-144
	Change (%)	0%	-2%	-21%	-41%	-35%
Total Three Tributaries	Baseline (TAF)	2,099	2,164	2,233	2,271	1,625
	LSJR Alt 3 (40% UF) (TAF)	2,097	2,091	1,921	1,598	1,001
	Change (TAF)	-2	-73	-313	-673	-624
	Change (%)	0%	-3%	-14%	-30%	-38%

UF = percent of unimpaired flow

TAF = thousand acre-feet

Figures F.1.3-3a, F.1.3-3b, F.1.3-3c, and, F.1.3-3d show the summary of annual results on the Stanislaus River. This compares the distribution of annual (a) February–June flow volume, (b) end-of-September storage, (c) diversion volume from the river, and (d) February–June flow as a percentage of unimpaired flow. The Stanislaus River February–June flow volumes were slightly reduced from baseline flows for LSJR Alternative 2 (20 percent unimpaired flow), were higher for LSJR Alternative 3 (40 percent unimpaired flow), and were much increased for LSJR Alternative 4 (60 percent unimpaired flow). As seen in Figure F.1.3-3d, the percentage of unimpaired flow does not always meet the percentage specified by the alternatives (LSJR Alternatives 3 and 4, specifically). This is because a portion of the flow from February–June in wet years was shifted to later in the year as part of adaptive implementation for controlling potential temperature effects during that time of year. End-of-September storage generally tended to be reduced slightly as a result of the LSJR alternatives, primarily during the wetter years (with the reduction increasing with the amount of unimpaired flow released), except in the driest years, when the carryover storage guidelines resulted in higher carryover storage for the LSJR alternatives compared with baseline conditions. The distribution of annual deliveries was decreased slightly for LSJR Alternative 2, reduced for LSJR Alternative 3, and reduced substantially for LSJR Alternative 4 in the majority of years compared with baseline conditions.

Figures F.1.3-4a, F.1.3-4b, F.1.3-4c, and F.1.3-4d show the summary of annual results on the Tuolumne River. This compares the distribution of (a) annual February–June flow, (b) end-of-September storage, (c) annual water supply diversions from the three tributaries, and (d) flow as a percentage of unimpaired flow. The Tuolumne River February–June flow volumes were generally slightly greater than the baseline flows for LSJR Alternative 2 (20 percent unimpaired flow), were increased for LSJR Alternative 3 (40 percent unimpaired flow), and were increased more for LSJR Alternative 4 (60 percent unimpaired flow). As can be seen in Figure F.1-20d, the percentage of unimpaired flow does not always meet the percentage specified by the alternatives (LSJR Alternatives 3 and 4 specifically). This is because there is a portion of the flow from February–June in wet years that shifts to later in the year as part of adaptive implementation for controlling potential temperature effects during that time of year. End-of-September storage generally tended to be reduced slightly as a result of the LSJR alternatives primarily during the wetter years (with the reduction increasing with the amount of unimpaired flow released), except in the driest years when the carryover storage guidelines resulted in higher carryover storage for the LSJR alternatives than baseline. The distribution of annual deliveries was decreased slightly for LSJR Alternative 2, was reduced for LSJR Alternative 3, and was reduced substantially for LSJR Alternative 4 in the majority of years compared to the baseline conditions.

Figures F.1.3-5a, F.1.3-5b, F.1.3-5c, and F.1.3-5d show the summary of annual results on the Merced River. This compares the distribution of (a) annual February–June flow, (b) end-of-September storage, (c) annual water supply diversions from the three tributaries, and (d) flow as a percentage of unimpaired flow. The Merced River February–June flow volumes were slightly increased from the baseline flows for LSJR Alternative 2 (20 percent unimpaired flow), were increased for LSJR Alternative 3 (40 percent unimpaired flow), and were increased more for LSJR Alternative 4 (60 percent unimpaired flow). As can be seen in Figure F.1-21d, the percentage of unimpaired flow does not always meet the percentage specified by the alternatives (LSJR Alternatives 3 and 4 specifically). This is because there is a portion of the flow from February–June in wet and above-normal years that shifts as part of adaptive implementation to later in the year for controlling potential temperature effects during that time of year. End-of-September storage generally tended to be reduced slightly as a result of the LSJR alternatives primarily during the wetter years (with the reduction increasing with the amount of unimpaired flow released), except in the driest years when the carryover storage guidelines resulted in higher carryover storage for the LSJR alternatives than baseline. The distribution of annual deliveries was decreased slightly for LSJR Alternative 2, was reduced for LSJR Alternative 3, and was reduced substantially for LSJR Alternative 4 in the majority of years compared to the baseline conditions.

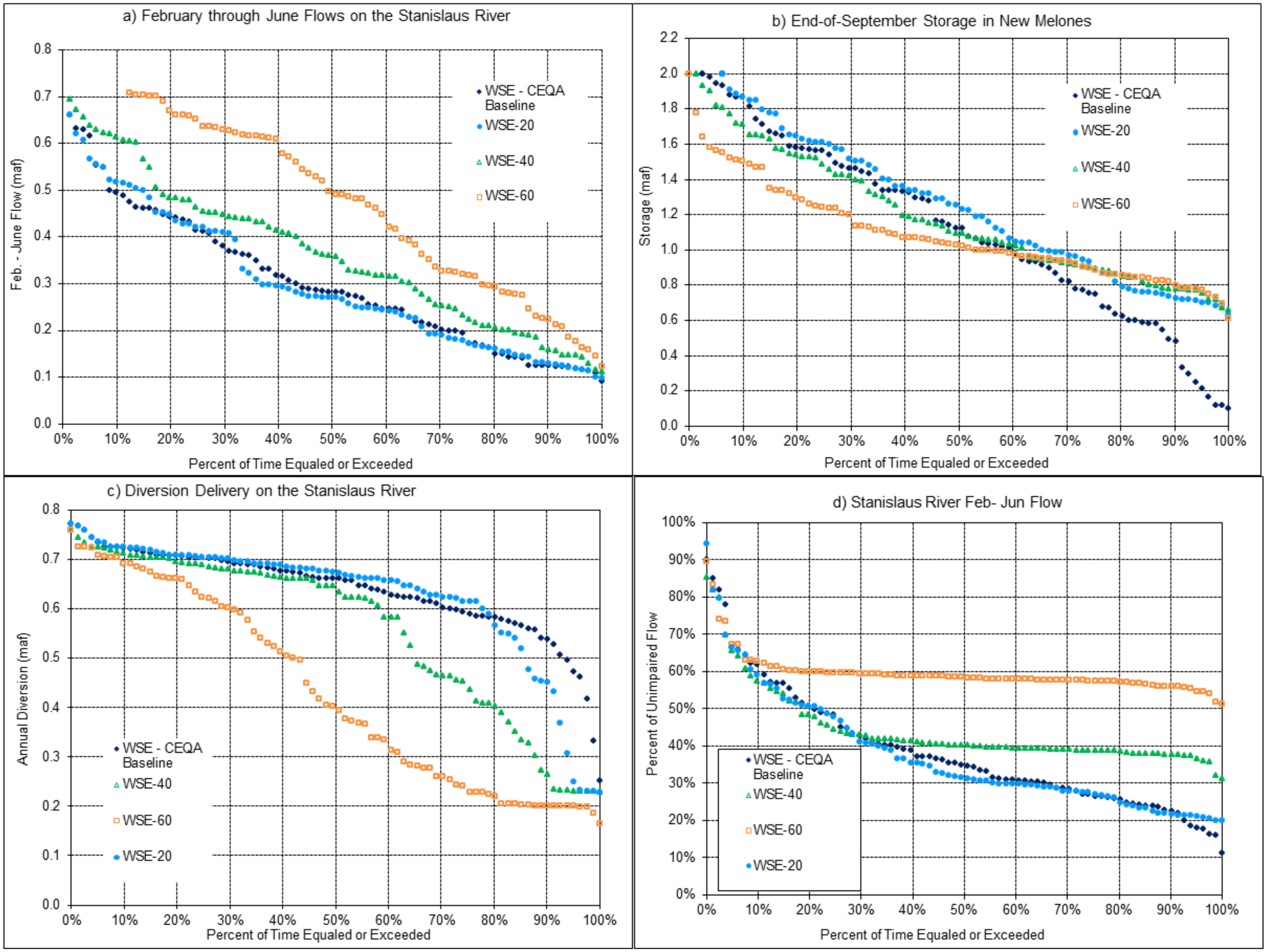


Figure F.1.3-3. Stanislaus River Annual Distributions from 1922–2003 of (a) February–June Flow Volume, (b) End-of-September Storage, (c) Annual Diversion Delivery, and (d) February–June Flow Volume as a Percentage of Unimpaired Flow

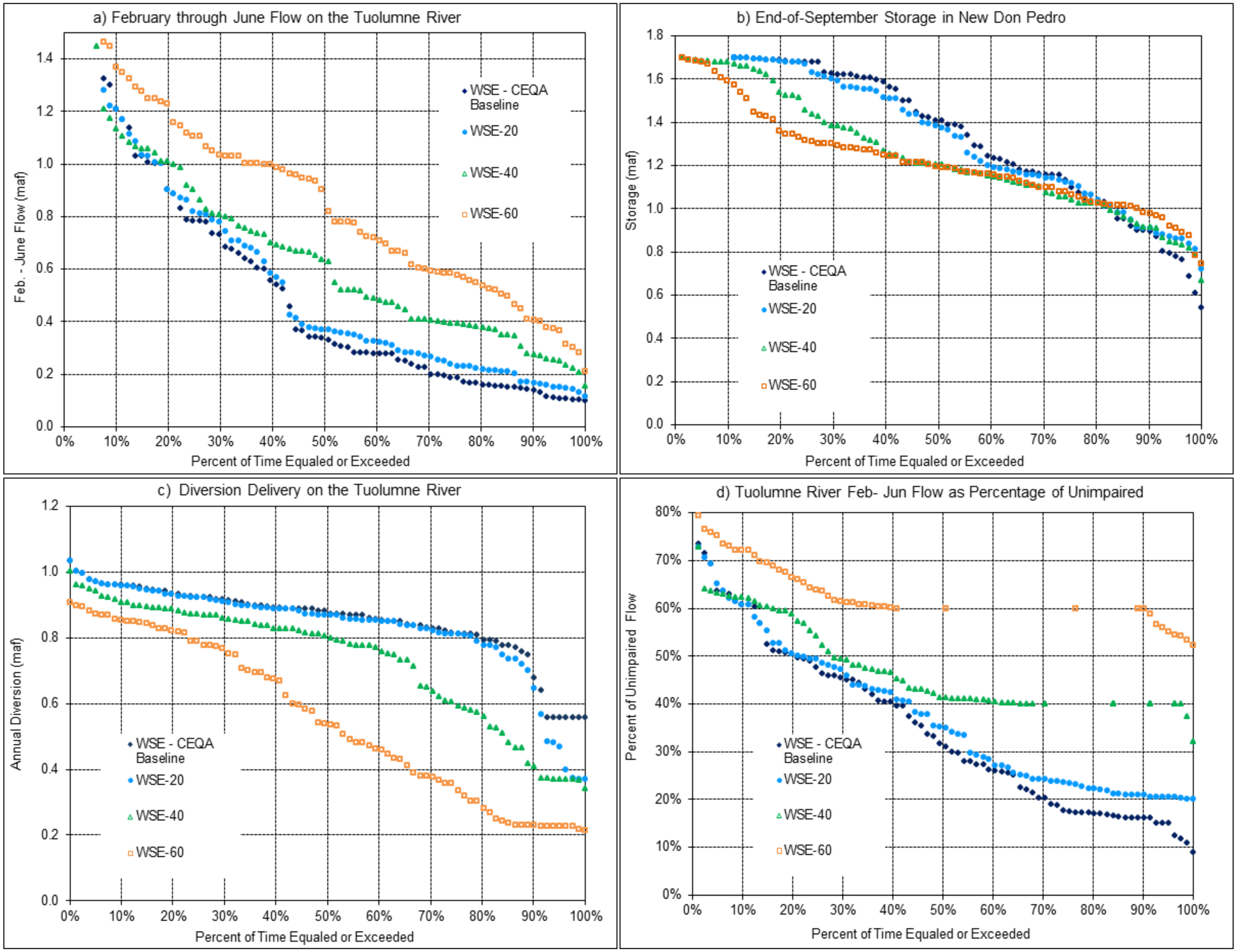


Figure F.1.3-4. Tuolumne River Annual Distributions from 1922–2003 of (a) February–June Flow Volume, (b) End-of-September Storage, (c) Annual Diversion Delivery, and (d) February–June Flow Volume as a Percentage of Unimpaired Flow

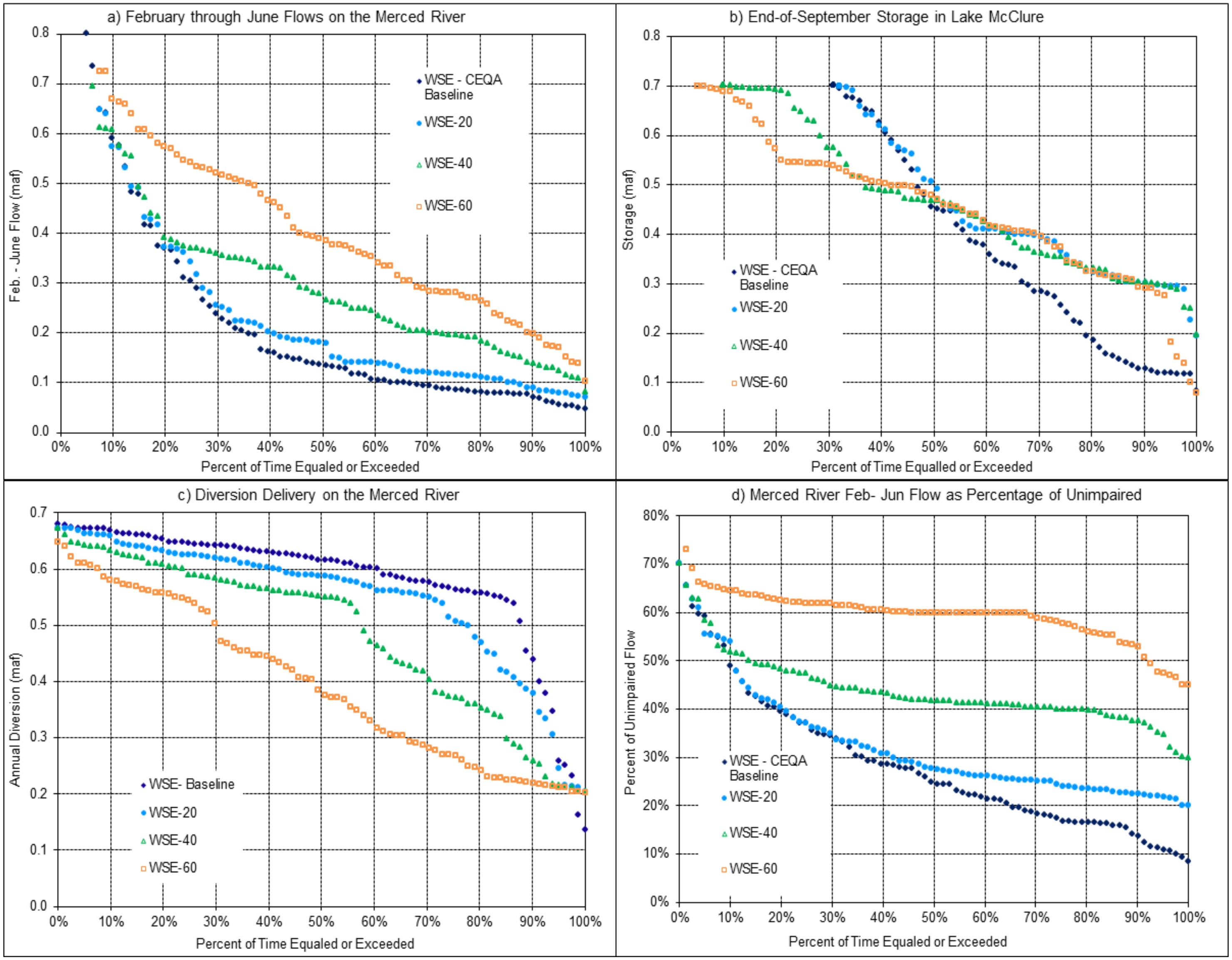


Figure F.1.3-5. Merced River Annual Distributions from 1922–2003 of (a) February–June Flow Volume, (b) End-of-September Storage, (c) Annual Diversion Delivery, and (d) February–June Flow Volume as a Percentage of Unimpaired Flow

Figures F.1.3-6a, F.1.3-6b, and F.1.3-6c show the summary of annual results on the SJR at Vernalis. This compares the distribution of (a) annual February–June Flow, (b) annual water supply diversions from the plan area, and (c) flow as a percentage of unimpaired flow. The SJR at Vernalis February–June flow volumes were generally similar to the baseline flows for LSJR Alternative 2, were increased for LSJR Alternative 3, and were increased more for LSJR Alternative 4. Because the flow at Vernalis is also dependent on flow from the Upper SJR, the resulting flow at Vernalis did not reach the full percentage set out by LSJR Alternatives 3 and 4 as well as it was reached in the three tributaries.

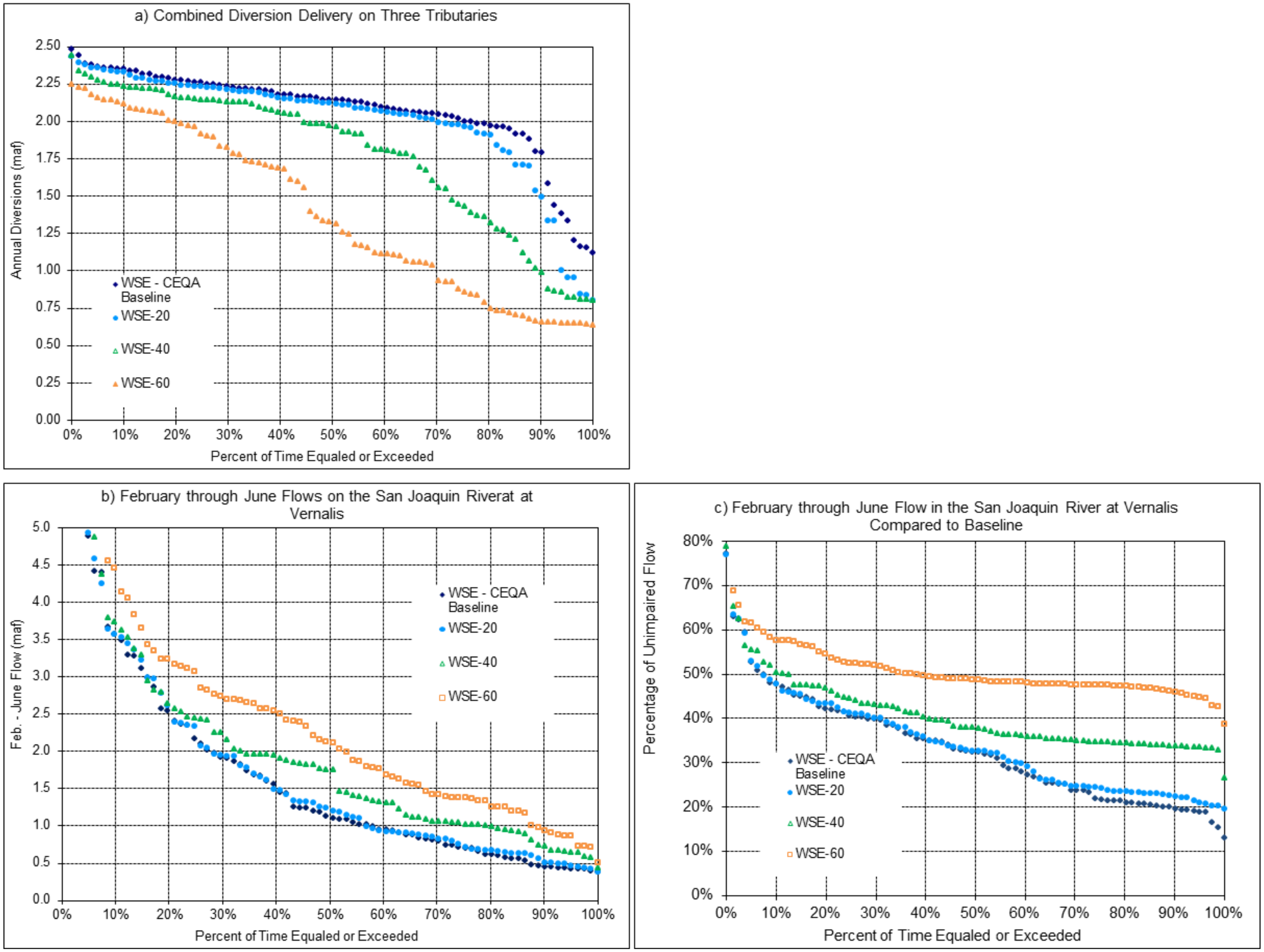


Figure F.1.3-6. SJR Annual Distributions from 1922–2003 of (a) Annual Three Tributary Diversion Delivery, (b) February–June Flow Volume near Vernalis, and (c) February–June Flow Volume near Vernalis as a Percentage of Unimpaired Flow

F.1.3.2 Characterization of Baseline Conditions

Baseline conditions were simulated with the WSE model, as previously described, using historical hydrology from 1922–2003 assuming regulatory conditions described in Section F.1.2.2, *Development of WSE Baseline and LSJR Alternative Conditions*. This section compares baseline to the three LSJR alternatives. The SJR upstream of the Merced River confluence was assumed to remain unchanged and equal to the baseline conditions for LSJR Alternatives 2, 3, and 4.

Upper and Middle SJR

For baseline conditions and all alternatives, flows in the SJR upstream of the Merced River were assumed to be equal to those simulated by the CALSIM case discussed in Section F.1.2.1, *Water Supply Effects Methods*. Table F.1.3-5a shows the monthly and annual cumulative distributions for the CALSIM simulated SJR flows upstream of the Merced River. This flow originates from upstream releases at Friant Dam or from the Fresno and Chowchilla Rivers, local runoff from the Bear River in the vicinity of Merced, wetlands releases from the Grasslands Wildlife Management Area refuges, and agricultural drainage from irrigated lands in this upstream portion of the SJR watershed. The CALSIM model estimated monthly flows that were nearly identical in more than 50 percent of the years (clearly assumed values) with median monthly flows that were less than 500 cubic feet per second (cfs) in most months and less than 1,000 cfs in all months.

Table F.1.3-5a. Baseline Monthly Cumulative Distributions of SJR above the Merced Flow (cfs) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
SJR above Merced Flow (cfs)													
Minimum	184	341	297	230	511	275	148	220	219	196	179	470	215
10%	193	396	378	285	565	447	247	284	296	248	198	485	259
20%	234	460	379	301	619	495	325	354	312	248	225	614	291
30%	234	460	396	334	655	528	369	443	329	264	225	614	304
40%	234	476	412	366	738	632	414	481	346	264	225	614	323
50%	237	477	428	423	864	702	555	510	380	264	225	614	367
60%	251	521	461	513	1,026	934	703	554	407	274	225	614	488
70%	251	595	516	800	1,477	1,213	843	633	452	296	241	614	552
80%	251	651	630	1,533	2,751	1,750	1,442	826	514	313	241	631	977
90%	266	765	1,096	2,353	6,149	4,604	4,696	4,660	1,889	360	256	631	1,583
Maximum	713	3,531	8,657	22,173	15,188	16,113	12,031	10,642	10,639	5,312	290	648	5,604
Average	246	612	885	1,355	2,136	1,759	1,511	1,356	948	472	228	604	726

Note:

This is the same for all LSJR alternatives as these alternatives are not modifying the flow above the confluence of the LSJR and the Merced River and this is outside the plan area. Please see Chapter 3, *Alternatives Description*, for more information.

Merced River

Figure F.1-7a illustrates the basic water supply need for seasonal storage in Lake McClure to increase the water supply delivery in the summer months when the unimpaired runoff is less than the monthly demands for irrigation water. The water delivery target was compared to the distribution of unimpaired flow values, which are shown as 10th, 30th, 50th, 70th, and 90th percentiles. Because agricultural use requires a specified monthly pattern of water deliveries to satisfy crop needs (transpiration), seasonal storage is needed to extend the period when unimpaired runoff could be (directly) diverted for irrigation. For the Merced River, the average monthly demands were less than or equal to the 10 percent cumulative monthly runoff from November through May. The average June demand was between 30 and 50 percent cumulative runoff, and the average monthly demands for July through October were greater than the 90 percent cumulative runoff. This indicates that reservoir storage is needed to satisfy the June demand in about 30 to 50 percent of the years, and reservoir storage is needed in more than 90 percent of the years to satisfy the July–October demands.

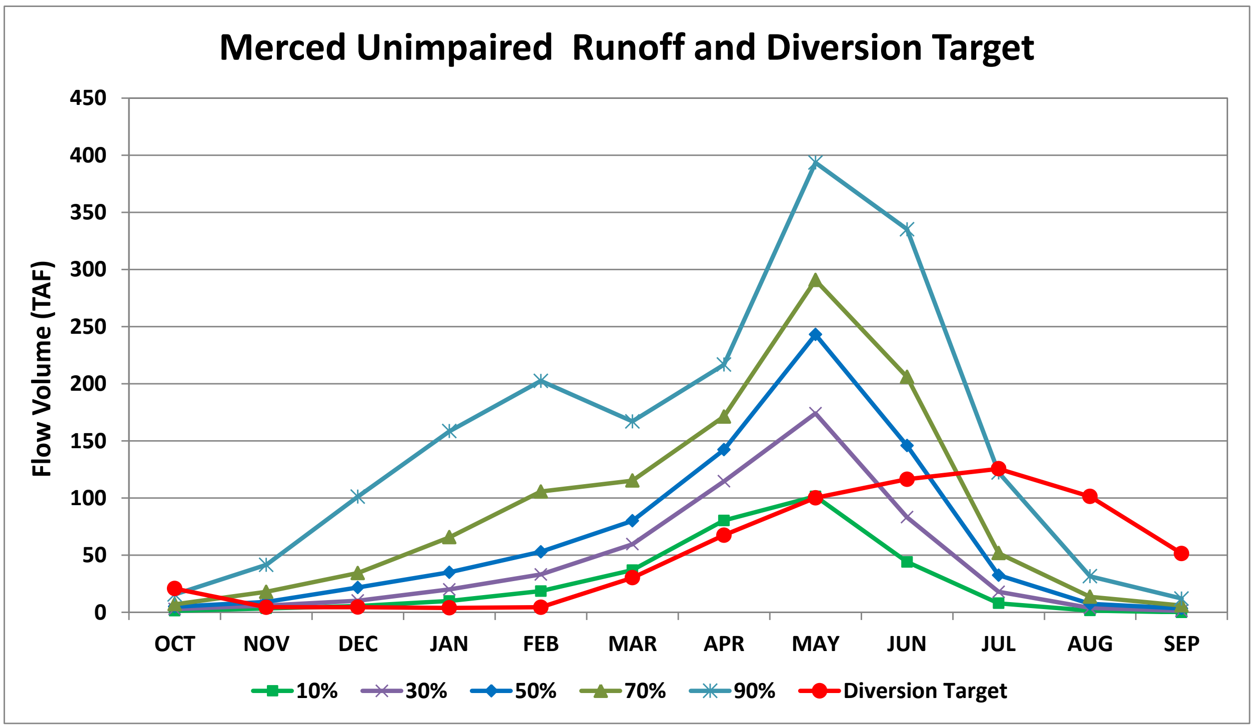


Figure F.1.3-7a. Monthly Merced River Unimpaired Runoff Compared to Average Monthly Water Supply Demands

Because there are no significant reservoirs or diversions in the Merced River watershed upstream of Lake McClure, the inflow to Lake McClure is the Merced unimpaired runoff. Table F.1.3-5b shows the monthly cumulative distributions for the baseline simulated Lake McClure storage (TAF). These monthly storage patterns are similar to the historical storage observed since the New Exchequer Dam was completed in 1965. The maximum storage of 1,024 TAF was simulated in about 30 percent of the years in June. Storage was limited for flood control in the other months. The maximum storage was 675 TAF from October–February. The median monthly storage levels were more than 400 TAF in all months and more than 600 TAF February–July. The minimum carryover storage (end-of-September) was 81 TAF (12 percent of capacity), the 10 percent cumulative carryover storage was 126 TAF (18 percent of capacity) and the 20 percent cumulative carryover storage was 186 TAF (27 percent of capacity). The 50 percent cumulative (or median) carryover storage was above 451 TAF (64 percent of capacity).

Table F.1.3-5b. Simulated Baseline Monthly Cumulative Distributions of Lake McClure Storage for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Lake McClure Storage (TAF)												
Minimum	56	39	56	46	31	24	23	39	67	94	97	81
10%	98	91	87	100	144	157	227	261	260	197	149	126
20%	155	163	193	208	276	273	329	401	412	319	235	186
30%	253	259	287	311	372	398	439	546	518	420	334	283
40%	350	348	389	440	484	506	584	650	617	516	407	365
50%	430	436	465	552	638	654	663	710	703	606	503	451
60%	573	588	611	635	674	680	721	831	854	755	667	616
70%	656	643	650	669	675	723	773	940	983	889	770	700
80%	666	662	665	675	675	735	818	970	1,024	910	770	700
90%	674	675	675	675	675	735	845	970	1,024	910	770	700
Maximum	675	675	675	675	675	735	845	970	1,024	910	770	700
Average	424	423	437	462	494	529	583	680	697	605	505	453

Figure F.1.3-7b shows the Lake McClure carryover storage for the baseline conditions compared to carryover storage for the simulated 20, 40, and 60 percent unimpaired flow. The baseline results reflect the historical periods of low runoff (reduced storage) and the periods of high runoff (with maximum carryover storage of 700 TAF). Many of the carryover storage values are at the maximum allowed storage for flood control.

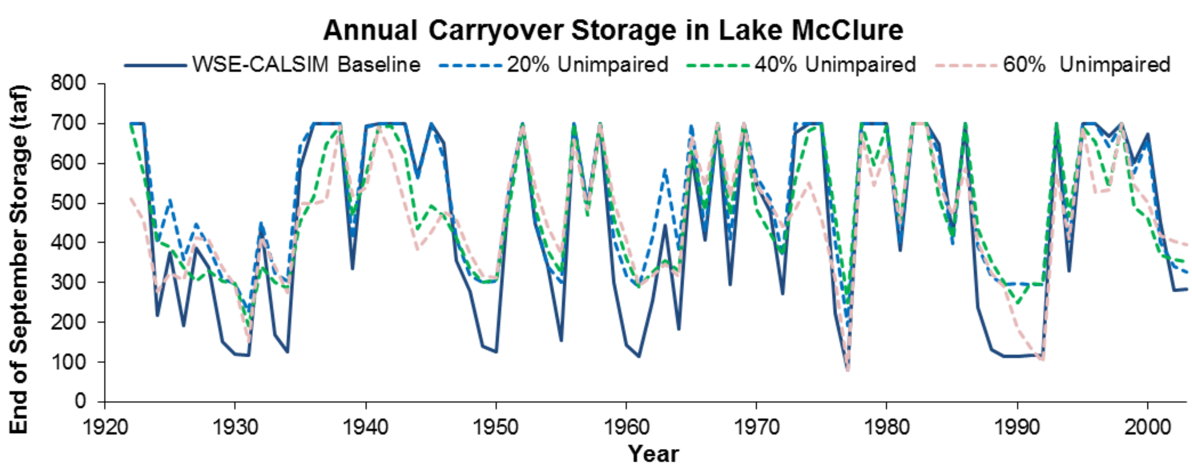


Figure F.1.3-7b. Lake McClure Carryover Storage (TAF) for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

The Lake McClure storage values correspond to surface elevations that can be calculated with a simple stage-storage equation of the form:

Lake McClure Elevation = (Storage/Ks) ^ (1/b) (Eqn. F.1-11)

Where:

Elevation = feet above mean sea level (MSL)

Storage = reservoir storage in TAF

Ks = 1.665E-15 for storage ≥ 240 TAF and 3.068E-20 for storage < 240 TAF

b = 6.055 for storage ≥ 240 TAF and 7.709 for storage < 240 TAF

The equation coefficients Ks and b were based on the reservoir geometry (i.e., elevation, surface area, volume).

The surface elevation is an important variable for evaluating hydroelectric energy generation at the dam, boat dock access and recreation uses, reservoir fish habitat, and exposure of cultural resources during extreme drawdown periods. Using this equation, the storages can be converted to surface elevations for these resource evaluations. The surface elevation is about 617 feet for a storage volume of 100 TAF (10 percent of maximum storage), 676 feet for a storage volume of 200 TAF (20 percent of maximum storage), and about 770 feet for a storage volume of 500 TAF (50 percent of maximum storage). The elevation is about 867 feet for a maximum storage of 1,024 TAF. Table F.1.3-5c shows the monthly cumulative distributions of Lake McClure water surface elevations (feet MSL) for the baseline.

Table F.1.3-5c. Simulated Baseline Monthly Cumulative Distributions of Lake McClure Water Surface Elevations (feet MSL) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Lake McClure Elevation (feet mean sea level)												
Minimum	573	547	573	558	530	513	511	546	587	612	615	601
10%	616	610	606	617	647	654	686	692	692	674	650	636
20%	653	658	672	679	698	697	719	743	746	715	685	669
30%	688	691	703	712	733	742	754	782	775	748	720	701
40%	726	725	739	754	766	772	790	804	798	774	744	731
50%	751	753	761	783	802	805	807	816	815	795	771	757
60%	788	791	796	801	809	810	818	838	842	825	808	797
70%	806	803	804	808	809	819	828	855	861	847	827	814
80%	808	807	807	809	809	821	835	859	867	850	827	814
90%	809	809	809	809	809	821	840	859	867	850	827	814
Maximum	809	809	809	809	809	821	840	859	867	850	827	814
Average	735	734	739	747	756	765	778	799	802	782	759	745

Table F.1.3-5d shows the monthly cumulative distributions for the WSE-calculated Merced River target flows at Stevinson for baseline conditions. These target flows include all releases from Lake McClure to meet instream flow requirements, plus any inflows along the river below Lake McClure. Table F.1.3-5e shows the monthly and annual cumulative distributions for the baseline simulated Merced River flows at Stevinson. A need for flood control releases was indicated by values in the cumulative distributions of monthly flows that were higher than the values in the cumulative distribution of the targets flows (because target flows are specified at the downstream ends of the rivers in the absence of flood control releases). Under baseline conditions, flood control releases from Lake McClure were frequently necessary. Flood control releases were needed occasionally in all months but occurred primarily in late winter and spring. In February, for example, the average flow was more than 500 cfs greater than the average target flow. Based on month-by-month comparisons of the Merced River flows at Stevinson to the target flows, about 50 percent of the 82 years modeled required flood control releases under baseline conditions.

The median monthly flows were lowest (less than 250 cfs) June–September and were highest October–May. In some cases, average flows were much higher than median flows (e.g., average of 1,058 cfs in February). This phenomenon generally was caused by high flood control releases in a few years. The range of annual Merced River flows was 161 TAF (10 percent cumulative distribution) to 1,017 TAF (90 percent cumulative distribution), with a median flow of 261 TAF and an average flow of 454 TAF. Figure F.1.3-7c shows the annual sequence of February–June flows on the Merced River at Stevinson for baseline conditions and the LSJR alternatives.

The baseline Merced River annual diversions (water supply deliveries) ranged from 441 TAF (10 percent cumulative distribution) to 669 TAF (90 percent cumulative distribution), with a median annual diversion of 617 TAF and an average annual diversion of 580 TAF (Table F.1.3-4c). Figure F.1.3-7d shows the WSE simulated sequence of annual Merced River diversions for baseline conditions and the LSJR alternatives.

Table F.1.3-5d. Baseline Monthly Cumulative Distributions of Target Flows (cfs) for the Merced River at Stevinson for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Merced at Stevinson Target Flow (cfs)													
Minimum	(0)	152	33	99	139	67	(0)	(0)	(0)	(0)	(0)	(0)	106
10%	300	255	263	260	283	275	121	55	57	47	19	36	157
20%	350	290	287	318	330	307	176	150	110	82	56	67	176
30%	372	312	309	332	340	343	271	184	126	101	84	87	196
40%	393	325	332	345	364	358	296	212	160	132	110	118	210
50%	414	336	338	360	388	378	353	277	211	147	122	131	227
60%	430	346	352	386	405	399	481	356	226	174	144	146	238
70%	450	353	363	424	452	480	563	474	251	223	171	167	250
80%	462	369	381	482	556	533	647	554	276	240	196	192	266
90%	502	396	409	560	730	658	757	706	387	276	220	222	299
Maximum	1,276	847	1,075	1,730	2,059	2,037	1,284	1,017	923	1,133	536	629	763
Average	415	338	344	416	465	441	428	341	214	175	128	135	231

Table F.1.3-5e. Baseline Monthly Cumulative Distributions of Merced River at Stevinson Flow (cfs) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
						Merced at Stevinson Flow (cfs)							
Minimum	219	152	33	144	207	204	(0)	(0)	(0)	(0)	(0)	(0)	130
10%	325	266	277	280	312	283	150	117	88	55	32	55	161
20%	356	296	304	327	337	328	220	196	121	92	76	90	181
30%	380	317	325	343	363	351	293	229	144	117	109	122	204
40%	399	330	336	360	393	363	354	312	181	139	124	140	232
50%	423	338	348	385	450	384	508	473	225	155	163	170	261
60%	440	348	358	431	671	475	592	548	250	226	205	193	326
70%	456	360	372	552	926	533	661	714	365	258	483	332	510
80%	470	374	395	837	1,661	969	756	929	1,251	993	964	420	699
90%	548	419	991	1,621	2,556	1,728	973	2,478	2,981	2,113	1,150	544	1,017
Maximum	1,276	1,910	3,495	9,859	5,151	5,959	4,845	5,379	7,273	5,863	2,392	1,275	2,398
Average	439	384	513	780	1,058	787	588	788	861	659	420	261	454

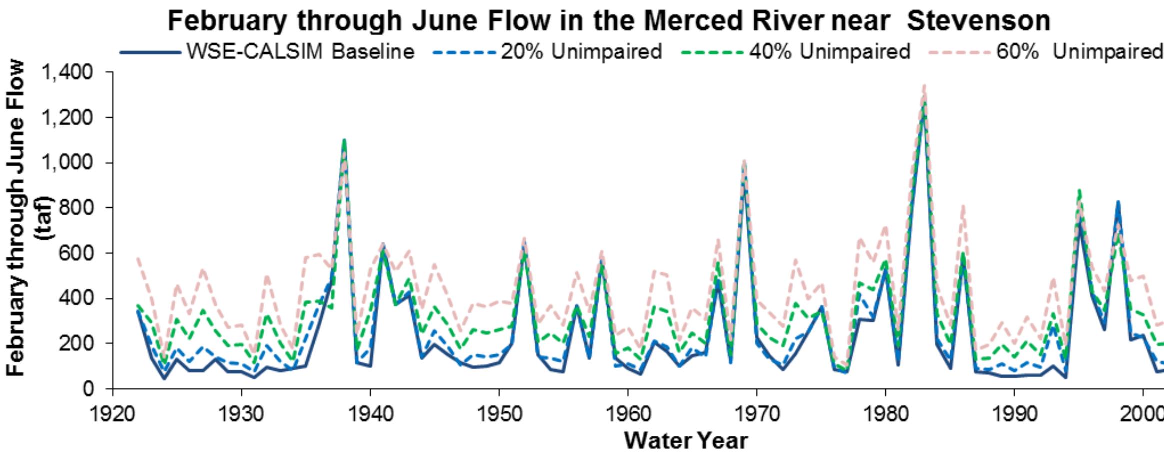


Figure F.1.3-7c. Merced River near Stevinson February–June Flow Volumes (TAF) Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

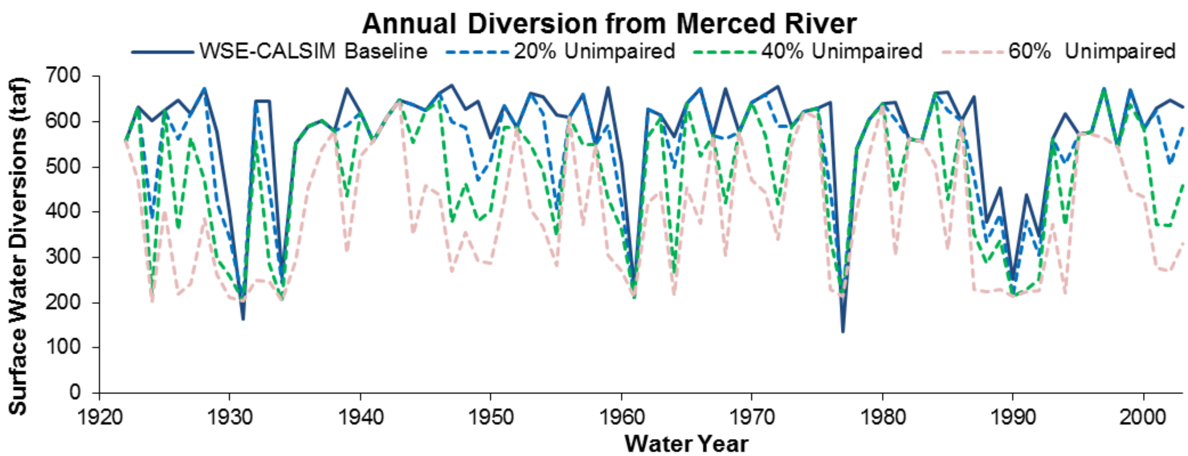


Figure F.1.3-7d. Merced River Annual Water Supply Diversions for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

Tuolumne River

Figure F.1.3-8a illustrates the basic water supply need for seasonal storage in New Don Pedro Reservoir to increase the water supply delivery in the summer months when the unimpaired runoff is less than the monthly demands for irrigation water. The water delivery target is compared to the distribution of unimpaired flow values, which are shown as 10th, 30th, 50th, 70th, and 90th percentiles. Because agricultural use requires a specified monthly pattern of water deliveries to satisfy crop needs (transpiration), storage is needed to extend the period when water can be diverted for irrigation. For the Tuolumne River, the average monthly demands were less than or equal to the 10 percent cumulative monthly runoff from November through May. The average June demand was between 10 and 30 percent cumulative runoff, while the demand for July was between 70 and 90 percent cumulative runoff. The average monthly demands for the remaining months, from August through October, were equal to or greater than the 90 percent cumulative monthly runoff. In other words, reservoir storage was needed to satisfy the July demand in about 70 to 90 percent of the years and the August–October demand in more than 90 percent of the years.

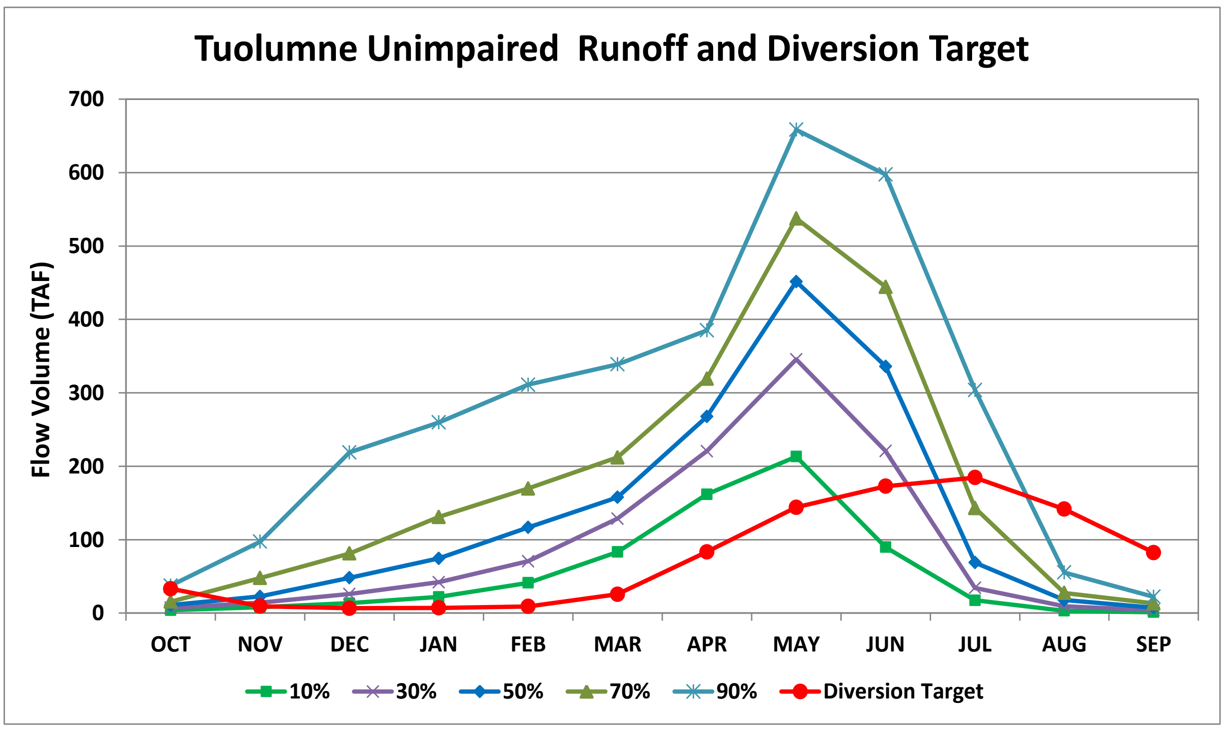


Figure F.1.3-8a. Monthly Tuolumne River Unimpaired Runoff Compared to Average Monthly Water Supply Demands

Under baseline conditions, the upstream operations of the CCSF seasonally shift and reduce the inflow to New Don Pedro Reservoir. Table F.1.3-5f gives the monthly and annual cumulative distributions for the CALSIM inflow to New Don Pedro Reservoir (TAF). The median annual inflow was 1,496 TAF and the average annual inflow was 1,586 TAF. Table F.1.3-5g gives the monthly and annual cumulative distributions of the differences between the Tuolumne unimpaired runoff and the New Don Pedro Reservoir inflow, which represent the upstream CCSF diversions and reservoir filling (in TAF). The changes from the unimpaired runoff were relatively small in most months, with maximum reductions caused by diversions to storage in the spring months of April–June. The median monthly upstream diversions were 73 TAF in April, 123 TAF in May, and 44 TAF in June. The negative diversions represent flood control storage reductions in the upstream reservoirs. The median and average annual upstream diversions were both 263 TAF, indicating that the annual CCSF diversions were evenly distributed. The 10 percent annual diversion was 201 TAF, and the 90 percent annual diversion was 307 TAF.

Table F.1.3-5f. CALSIM-Simulated Baseline Monthly Cumulative Distributions of New Don Pedro Reservoir Inflow (TAF) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual
New Don Pedro Reservoir Inflow (TAF)													
Minimum	5	5	7	6	9	11	20	31	9	9	12	10	223
10%	9	9	18	23	44	73	99	105	40	18	16	21	601
20%	11	11	23	30	64	101	126	169	76	21	18	22	829
30%	13	13	38	39	79	116	154	215	156	26	21	23	902
40%	14	15	43	55	100	140	173	261	210	35	24	25	1,146
50%	16	17	54	67	141	163	191	286	279	52	28	28	1,496
60%	17	26	63	96	172	198	224	315	325	80	29	31	1,742
70%	19	29	82	134	205	230	247	354	371	119	32	33	1,931
80%	23	48	106	188	243	248	270	448	452	166	36	34	2,255
90%	29	66	191	262	313	306	290	528	555	278	41	38	2,804
Maximum	162	430	578	978	547	559	576	852	965	615	184	94	4,438
Average	20	37	90	123	160	186	200	308	294	107	31	29	1,586

Table F.1.3-5g. CALSIM-Simulated Baseline Monthly Cumulative Distributions of CCSF Upstream Diversions and Reservoir Operations (TAF) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual
CCSF Tuolumne River Diversions (TAF)													
Minimum	-18	-5	-99	-96	-97	-91	-64	11	-1	-14	-24	-35	130
10%	-7	-2	-32	-25	-59	-49	16	52	25	-2	-14	-21	201
20%	-7	-1	-20	-13	-32	-20	38	73	28	1	-13	-21	226
30%	-6	1	-12	-5	-25	-11	55	89	31	6	-13	-20	243
40%	-6	2	-2	0	-14	2	61	102	38	19	-11	-20	256
50%	-5	5	2	4	-8	6	73	123	44	22	-9	-19	263
60%	-4	10	3	6	-2	12	85	152	54	25	-6	-18	273
70%	-3	16	8	11	3	23	97	168	65	25	-3	-17	284
80%	0	21	13	19	7	35	108	206	75	26	2	-16	293
90%	3	30	23	29	19	43	125	246	92	26	15	-11	307
Maximum	15	92	74	88	69	118	194	341	231	44	34	10	435
Average	-3	11	-1	1	-13	4	73	139	58	17	-4	-17	263

Table F.1.3-5h shows the monthly cumulative distributions for the baseline New Don Pedro Reservoir storage (TAF). The maximum storage was simulated in only about 10 percent of the years in June. Storage was limited for flood control in the other months. The maximum storage was 1,690 TAF October–March. The median monthly storage levels were relatively high, with more than 1,500 TAF January–July, and with more than 1,350 TAF August–December. The minimum carryover storage (September) was about 543 TAF (27 percent of capacity) and the 20 percent cumulative carryover storage values were above 1000 TAF (near 50 percent of capacity). Figure F.1.3-8b shows the New Don Pedro carryover storage for baseline conditions and the LSJR alternatives (simulated by the WSE model). The baseline results reflect the historical periods of low runoff (reduced storage) and the periods of high runoff (with maximum carryover storage of 1,700 TAF). Many of the carryover storage values are at the maximum allowed storage for flood control.

Table F.1.3-5h. Baseline Monthly Cumulative Distributions of New Don Pedro Reservoir Storage (TAF) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Don Pedro Reservoir Storage (TAF)												
Minimum	520	514	644	705	787	870	892	854	759	651	575	543
10%	856	843	866	953	1,020	1,123	1,134	1,146	1,192	1,064	940	896
20%	1,002	1,018	1,053	1,067	1,139	1,257	1,292	1,338	1,350	1,210	1,104	1,031
30%	1,113	1,154	1,217	1,337	1,445	1,491	1,551	1,603	1,525	1,370	1,232	1,158
40%	1,216	1,269	1,338	1,445	1,590	1,638	1,627	1,656	1,621	1,443	1,309	1,239
50%	1,362	1,376	1,480	1,541	1,665	1,690	1,684	1,706	1,775	1,629	1,488	1,409
60%	1,527	1,522	1,553	1,630	1,690	1,690	1,694	1,737	1,873	1,787	1,650	1,578
70%	1,606	1,607	1,618	1,687	1,690	1,690	1,713	1,800	1,958	1,846	1,705	1,625
80%	1,635	1,626	1,665	1,690	1,690	1,690	1,713	1,857	2,019	1,910	1,767	1,687
90%	1,653	1,662	1,690	1,690	1,690	1,690	1,713	1,895	2,030	1,910	1,779	1,700
Maximum	1,662	1,690	1,690	1,690	1,690	1,690	1,718	2,002	2,030	1,910	1,790	1,700
Average	1,310	1,319	1,368	1,422	1,489	1,523	1,542	1,614	1,673	1,544	1,417	1,348

The New Don Pedro Reservoir storage values correspond to surface elevations that can be calculated with a simple equation of the form:

$$New\ Don\ Pedro\ Elevation = (Storage/Ks)\ ^\wedge\ (1/b) \qquad \text{(Eqn. F.1-12)}$$

Where:

Elevation = feet above MSL

Storage = reservoir storage in TAF

Ks = 7.071E-12 for storage ≥ 700 TAF and 7.954E-19 for storage < 700 TAF

B = 4.950 for storage ≥ 700 TAF and 7.393 for storage < 700 TAF

The equation coefficients Ks and b were based on values from CALSIM, which were based on the reservoir geometry (i.e., elevation, surface area, volume).

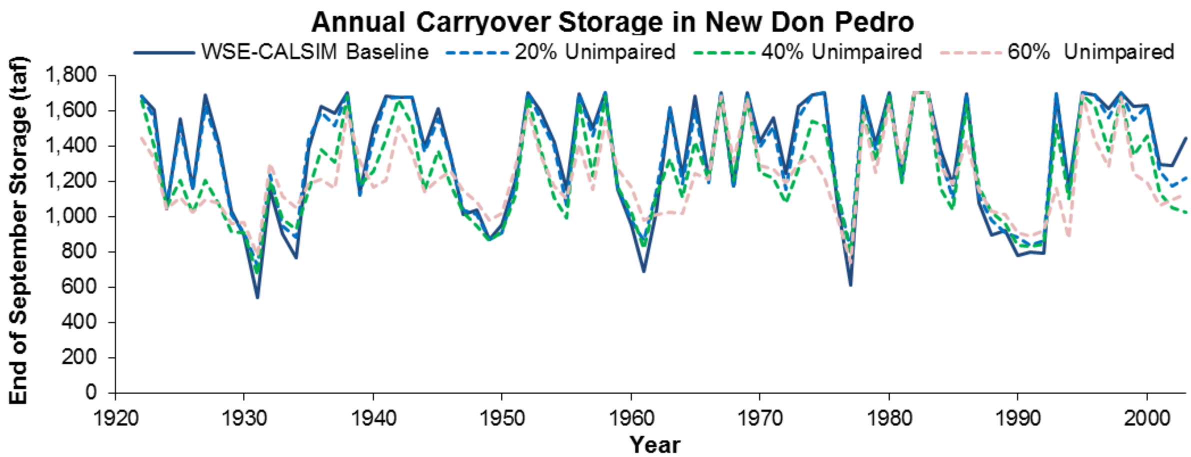


Figure F.1.3-8b. New Don Pedro Reservoir Carryover Storage (TAF) for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

The surface elevation is an important variable for evaluating hydroelectric energy generation at the dam, boat dock access and recreation uses, reservoir fish habitat, and exposure of cultural resources during extreme drawdown periods. Using this equation, the storages can be converted to surface elevations for these resource evaluations. The surface elevation is about 575 feet for a storage volume of 200 TAF (10 percent of maximum storage), 651 feet for a storage volume of 500 TAF (25 percent of maximum storage), and about 722 feet for a storage volume of 1,000 TAF (50 percent of maximum storage). The elevation is about 833 feet for a maximum storage of 2,030 TAF. Table F.1.3-5i shows the monthly cumulative distributions for the baseline New Don Pedro Reservoir water surface elevations (feet MSL).

Table F.1.3-5i. Baseline Monthly Cumulative Distributions of New Don Pedro Water Surface Elevations (feet MSL) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Don Pedro Reservoir Elevation (feet mean sea level)												
Minimum	654	653	673	673	688	702	706	700	683	674	663	658
10%	700	698	702	715	725	739	741	742	748	731	713	706
20%	723	725	730	732	742	756	761	766	767	751	737	727
30%	738	743	752	766	778	783	789	795	787	770	753	744
40%	751	758	766	778	793	798	797	800	796	778	763	754
50%	769	770	782	788	801	803	802	805	811	797	783	774
60%	787	786	789	797	803	803	803	808	820	812	799	792
70%	795	795	796	803	803	803	805	813	827	817	804	797
80%	798	797	801	803	803	803	805	818	832	823	810	803
90%	799	800	803	803	803	803	805	822	833	823	811	804
Maximum	800	803	803	803	803	803	806	831	833	823	812	804
Average	759	760	766	772	780	785	786	793	798	785	771	763

Table F.1.3-5j shows the monthly cumulative distributions for the baseline Tuolumne River target flows at Modesto. Table F.1.3-5k shows the monthly and annual cumulative distributions for the baseline Tuolumne River Flows at Modesto. A need for flood control releases is indicated by values for the cumulative distributions of monthly flows that are higher than the values for the cumulative distributions of the target flows. Under baseline conditions, flood control releases from New Don Pedro Reservoir were required in many years, primarily during the late winter and spring. For example, in April, the average flow was more than 900 cfs greater than the average target flow. Based on month-by-month comparisons of the Tuolumne River flows at Modesto to the target flows, about 66 percent of the 82 years modeled required some flood control releases under baseline conditions.

The median monthly flows were between 422 and 647 cfs in all months, except for March through May, when median flows were well over 1,000 cfs. The range of annual Tuolumne River flows was 280 TAF (10 percent cumulative) to 1,799 TAF (90 percent cumulative), with a median annual flow of 572 TAF and an average annual flow of 895 TAF. Figure F.1.3-8c shows the annual sequence of February–June flows on the Tuolumne River for baseline conditions compared to values for the 20, 40, and 60 percent unimpaired flow simulations.

The baseline Tuolumne River annual diversions (water supply deliveries) ranged from 685 TAF (10 percent cumulative) to 960 TAF (90 percent cumulative) with a median annual diversion of 878 TAF and an average annual diversion of 851 TAF (Table F.1.3-4b). Figure F.1.3-8d shows the WSE-simulated sequence of annual Tuolumne River diversions for baseline conditions and the LSJR alternatives.

Table F.1.3-5j. Baseline Monthly Cumulative Distributions of Target Flows (cfs) for the Tuolumne River at Modesto for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Tuolumne Target Flow at Modesto (cfs)													
Minimum	199	206	71	208	117	—	373	418	193	194	187	166	198
10%	290	246	251	316	276	328	546	540	270	262	277	256	280
20%	395	324	319	417	376	435	665	676	310	319	346	334	343
30%	447	382	399	434	466	476	800	798	368	364	365	366	383
40%	488	443	430	479	487	516	887	1,051	395	403	399	381	415
50%	550	454	445	524	514	573	1,203	1,133	455	448	426	421	431
60%	608	479	496	572	549	606	1,368	1,352	516	519	515	497	465
70%	689	525	581	602	610	652	1,449	1,422	592	568	581	544	518
80%	735	608	602	648	663	702	1,473	1,488	685	601	588	593	546
90%	757	756	655	757	795	782	1,531	1,590	766	681	638	611	594
Maximum	1,171	1,530	1,405	2,411	1,550	1,324	2,108	1,782	1,360	1,067	760	809	815
Average	556	502	479	560	547	573	1,106	1,106	504	471	458	447	441

Table F.1.3-5k. Baseline Monthly Cumulative Distributions of Tuolumne River at Modesto Flow (cfs) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
						Tuolumne at Modesto Flow (cfs)							
Minimum	199	206	217	208	152	248	373	418	193	194	187	166	198
10%	290	246	257	316	312	349	546	546	270	262	277	256	280
20%	395	324	327	427	458	458	737	699	323	319	346	334	351
30%	447	382	409	443	486	518	812	808	369	364	365	366	426
40%	488	449	434	518	519	647	1,111	1,088	410	403	399	381	482
50%	550	464	470	570	647	1,568	1,414	1,238	499	448	426	422	572
60%	632	498	523	610	992	2,220	1,633	1,427	606	559	515	522	870
70%	692	536	597	757	2,201	3,492	2,472	1,501	756	601	581	585	1,161
80%	737	608	675	1,483	3,597	4,058	3,462	1,771	2,407	915	588	599	1,425
90%	813	756	1,152	3,424	5,084	5,097	4,591	4,810	4,387	3,331	652	691	1,799
Maximum	3,090	5,440	7,479	17,925	7,440	16,297	9,332	9,474	8,159	8,190	2,996	2,296	4,129
Average	606	572	818	1,362	1,837	2,409	2,016	1,789	1,367	1,090	502	499	895

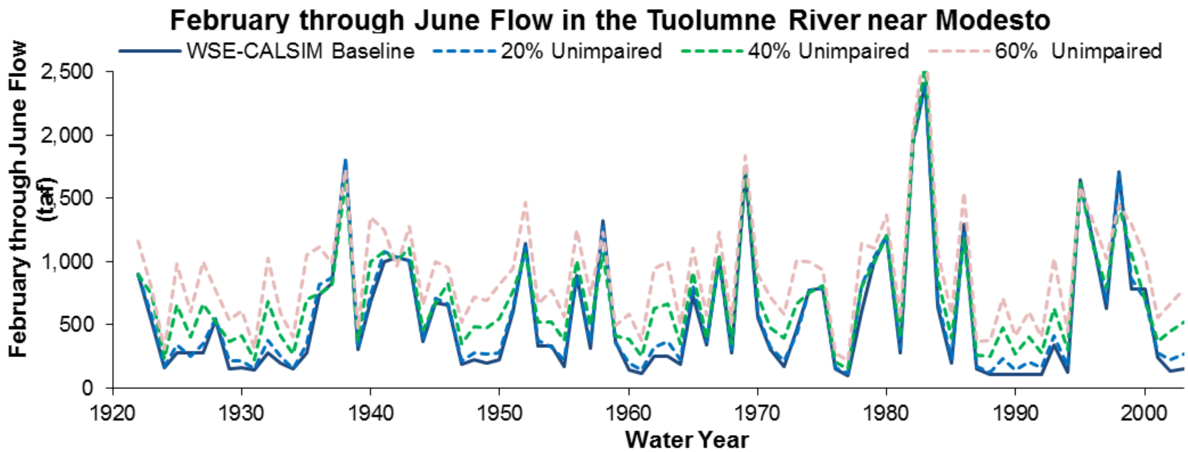


Figure F.1.3-8c. Tuolumne River February–June Flow Volumes (TAF) for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

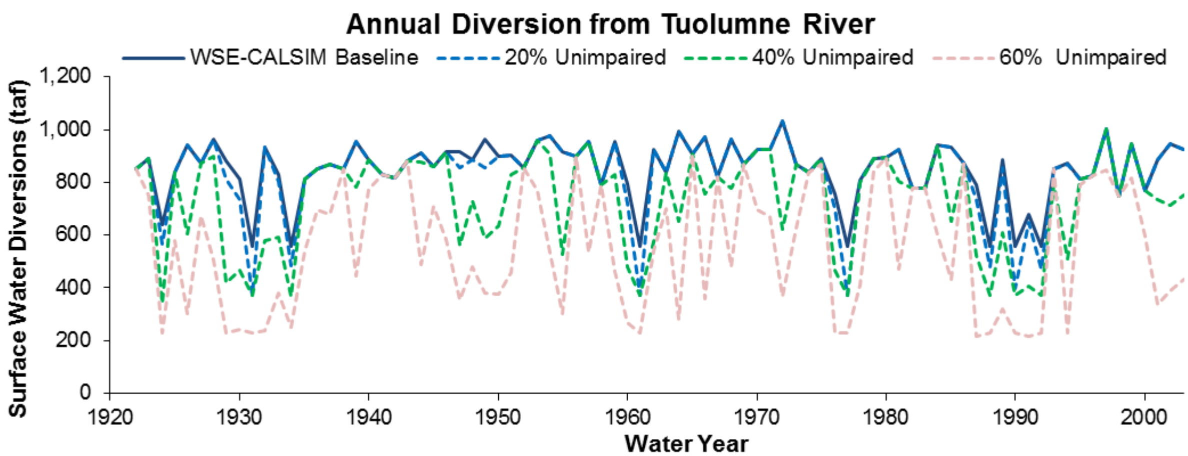


Figure F.1.3-8d. Tuolumne River Annual Water Supply Diversions for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

Stanislaus River

Figure F.1.3-9a illustrates the basic water supply need for seasonal storage in New Melones Reservoir to increase the water supply delivery in the summer months when the unimpaired runoff is less than the monthly demands for irrigation water. Water delivery target was compared to the distribution of unimpaired flow values, which were shown as 10th, 30th, 50th, 70th, and 90th percentiles. Because agricultural use requires a specified monthly pattern of water deliveries to satisfy crop needs (transpiration), storage is needed to extend the period when unimpaired runoff could be (directly) diverted for irrigation. For the Stanislaus River, the average monthly demands were less than or equal to the 10 percent cumulative monthly runoff from December through May. The average June demand was between 30 and 50 percent cumulative runoff, and the average monthly demands from July through October were greater than the 90 percent cumulative runoff. In other words, reservoir storage was needed to satisfy the June demand in about 30 to 50 percent of the years and was needed to satisfy the July–October demands in about 90 percent of the years.

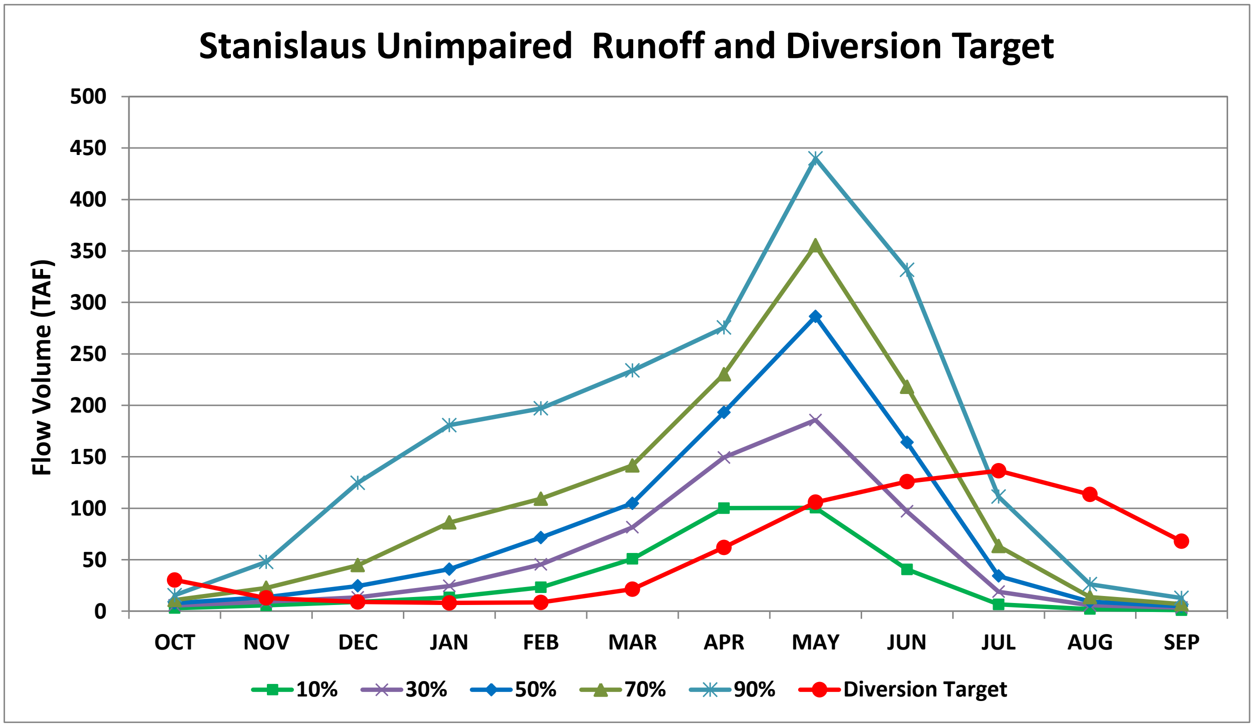


Figure F.1.3-9a. Monthly Stanislaus River Unimpaired Runoff Compared to Average Monthly Water Supply Demands

Upstream reservoir operations for seasonal storage and hydroelectric energy generation shift the monthly inflows to New Melones Reservoir but do not change the annual inflow. Table F.1.3-5l shows the monthly cumulative distributions for the baseline New Melones storage (TAF). The maximum storage of 2,420 TAF was simulated in just a few years in June. Storage was limited to less than 2,000 TAF October–February. The median monthly storage levels were all higher than 1,050 TAF (approximately 44 percent of capacity). The minimum carryover storage (end of September) was 100 TAF (4 percent of capacity), but the 10 percent cumulative carryover storage was 484 TAF (approximately 20 percent of capacity). The 50 percent cumulative carryover storage was 1,124 TAF (46 percent of capacity). Figure F.1.3-9b shows the New Melones carryover storage for baseline conditions and 20, 40, and 60 percent unimpaired flow. The baseline results reflect the historical periods of low runoff (reduced storage) and the periods of high runoff (with maximum carryover storage of 2,000 TAF).

Table F.1.3-5l. Baseline Monthly Cumulative Distributions of New Melones Storage (TAF) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Melones Storage (TAF)												
Minimum	97	99	101	130	102	111	216	175	144	122	105	100
10%	455	455	474	485	525	627	573	524	616	579	520	484
20%	611	612	651	676	737	831	850	854	807	727	662	630
30%	815	854	868	910	937	944	995	1,013	990	918	848	823
40%	961	984	1,004	1,081	1,130	1,186	1,175	1,227	1,193	1,101	1,030	989
50%	1,079	1,094	1,205	1,302	1,325	1,415	1,365	1,384	1,361	1,281	1,186	1,124
60%	1,287	1,284	1,314	1,429	1,524	1,607	1,586	1,580	1,555	1,470	1,372	1,329
70%	1,424	1,438	1,471	1,528	1,632	1,678	1,686	1,657	1,696	1,609	1,517	1,462
80%	1,553	1,568	1,611	1,650	1,736	1,809	1,745	1,844	1,814	1,720	1,623	1,580
90%	1,809	1,802	1,836	1,853	1,912	1,945	1,912	1,976	2,062	2,000	1,909	1,861
Maximum	1,970	1,970	1,970	1,970	1,970	2,030	2,151	2,250	2,420	2,300	2,130	2,000
Average	1,094	1,108	1,145	1,197	1,263	1,309	1,304	1,328	1,331	1,253	1,169	1,125

The New Melones storage values correspond to surface elevations that can be calculated with a simple equation of the form:

New Melones Elevation = (Storage/Ks) ^ (1/b) (Eqn. F.1-13)

Where:

Elevation = feet above MSL

Storage = reservoir storage in TAF

Ks = 6.237E-16 for storage ≥ 300 TAF and 3.393E-33 for storage < 300 TAF

B = 6.121 for storage ≥ 300 TAF and 12.026 for storage < 300 TAF

The equation coefficients Ks and b were based on values from CALSIM, which were based on the reservoir geometry (i.e., elevation, surface area, volume).

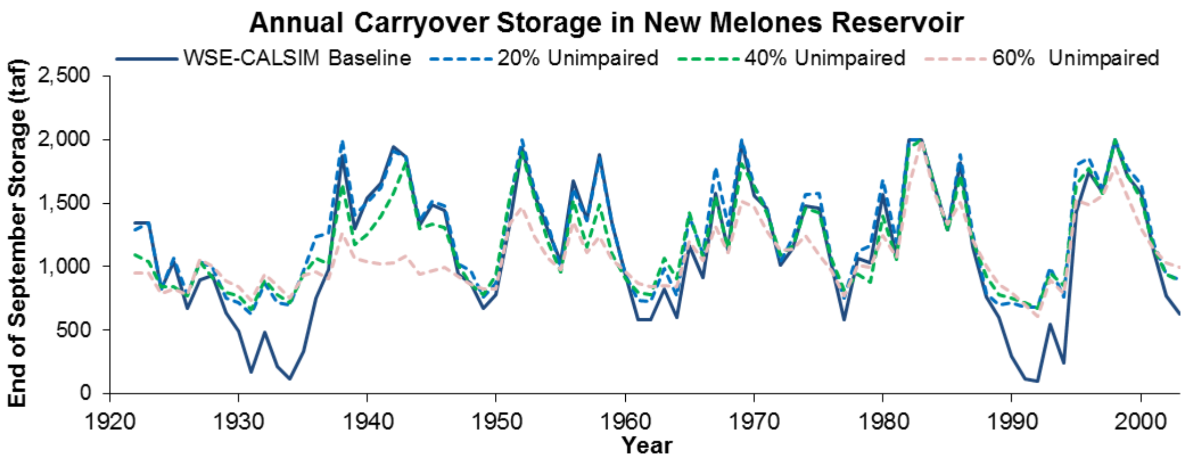


Figure F.1.3-9b. New Melones Reservoir Carryover Storage (TAF) for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

The surface elevation is an important variable for evaluating hydroelectric energy generation at the dam, boat dock access and recreation uses, reservoir fish habitat, and exposure of cultural resources during extreme drawdown periods. Using this equation, the storages can be converted to surface elevations for these resource evaluations. The surface elevation was about 793 feet for a storage volume of 250 TAF (10 percent of maximum storage), 841 feet for a storage volume of 500 TAF (20 percent of maximum storage), and about 971 feet for a storage volume of 1,200 TAF (50 percent of maximum storage). The elevation is about 1,089 feet for a maximum storage of 2,420 TAF. Table F.1.3-5m shows the monthly cumulative distributions for the baseline New Melones Reservoir water surface elevations (feet).

Table F.1.3-5m. Baseline Monthly Cumulative Distributions of New Melones Water Surface Elevations (feet MSL) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Melones Elevation (feet mean sea level)												
Minimum	733	735	736	751	736	742	784	770	758	747	738	735
10%	828	828	834	837	848	873	860	848	870	862	847	837
20%	869	870	878	884	897	914	918	918	910	894	881	874
30%	911	918	921	928	932	934	941	944	941	929	917	913
40%	936	940	943	954	961	969	967	974	970	957	947	941
50%	954	956	971	984	987	997	991	994	991	981	969	961
60%	982	982	985	999	1,009	1,018	1,016	1,015	1,013	1,003	992	987
70%	998	1,000	1,004	1,010	1,021	1,025	1,026	1,023	1,027	1,018	1,009	1,003
80%	1,013	1,014	1,019	1,023	1,031	1,038	1,032	1,041	1,039	1,030	1,020	1,015
90%	1,038	1,037	1,041	1,042	1,048	1,051	1,048	1,053	1,061	1,055	1,047	1,043
Maximum	1,053	1,053	1,053	1,053	1,053	1,058	1,068	1,076	1,089	1,080	1,066	1,055
Average	941	943	949	957	965	971	971	974	974	963	952	946

Table F.1.3-5n shows the monthly and annual cumulative distributions for the baseline Stanislaus River target flows at Ripon, and Table F.1.3-5o shows the monthly and annual cumulative distributions for the baseline simulated Stanislaus River flows at Ripon. A need for flood control releases is indicated by values for the cumulative distributions of monthly flows that are higher than the values for the cumulative distributions of the target flows. Under baseline conditions, flood control releases from New Melones Reservoir were required less often than were needed on the Merced or Tuolumne Rivers. Flood control releases were needed more during January and February. Based on month-by-month comparisons of the Stanislaus River flows at Ripon to the target flows, about 12 percent of the 82 years modeled required some flood control releases under baseline conditions.

The median monthly flows were less than 500 cfs July–March, except for October, when required pulse flows increased the median flow to about 890 cfs. The high April and May flows were the result of the NMFS BO flow requirements that extend the VAMP flows to a 2-month pulse flow. The range of annual Stanislaus River flows was 271 TAF (10 percent cumulative) to 786 TAF (90 percent cumulative), with a median annual flow of 478 TAF and an average annual flow of 549 TAF. Figure F.1.3-9c shows the annual sequence of February–June flows on the Stanislaus River for baseline conditions and 20, 40, and 60 percent unimpaired flow.

The baseline Stanislaus River annual diversions (water supply deliveries) ranged from 538 TAF (10 percent cumulative) to 723 TAF (90 percent cumulative) with a median annual diversion of 661 TAF and an average annual diversion of 637 TAF (Table F.1.3-4a). Figure F.1.3-9d shows the WSE simulated sequence of annual Stanislaus River diversions for baseline conditions and the LSJR alternatives.

Table F.1.3-5n. Baseline Monthly Cumulative Distributions of Target Flows (cfs) for the Stanislaus River at Ripon for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Stanislaus Target Flow at Ripon (cfs)													
Minimum	599	213	—	129	168	58	409	281	210	205	201	174	236
10%	729	248	223	261	230	308	573	525	292	293	302	311	271
20%	772	260	239	294	268	348	765	695	375	324	337	345	336
30%	806	267	262	309	326	372	918	828	444	358	365	369	380
40%	833	292	272	322	368	411	1,177	1,055	536	389	406	397	425
50%	889	319	287	335	384	486	1,556	1,422	629	437	416	419	478
60%	959	337	303	346	401	716	1,674	1,559	1,115	484	455	463	517
70%	979	348	311	366	464	1,265	1,754	1,707	1,276	523	478	490	584
80%	1,041	382	338	407	590	1,672	1,848	1,898	1,427	591	526	520	679
90%	1,110	449	403	506	741	1,842	1,997	2,107	1,625	688	624	666	706
Maximum	1,409	732	674	884	1,465	2,234	2,155	2,603	1,964	1,021	732	887	770
Average	905	328	299	361	453	869	1,347	1,328	872	466	435	448	490

Table F.1.3-5o. Baseline Monthly Cumulative Distributions of Stanislaus River at Ripon Flow (cfs) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
						Stanislaus at Ripon Flow (cfs)							
Minimum	599	213	—	198	168	58	409	281	210	205	201	174	236
10%	729	248	224	270	230	308	573	525	292	293	302	311	271
20%	772	260	241	295	268	348	765	695	375	324	337	345	336
30%	806	267	262	312	326	372	918	828	444	358	365	369	380
40%	833	292	280	324	368	411	1,177	1,055	536	389	406	397	425
50%	889	319	288	337	385	486	1,556	1,422	629	437	416	419	478
60%	959	337	304	349	415	716	1,674	1,559	1,115	484	463	463	517
70%	979	348	316	375	507	1,265	1,754	1,707	1,281	531	483	490	584
80%	1,042	382	348	449	654	1,717	1,848	1,898	1,456	616	529	528	681
90%	1,116	454	421	576	1,285	1,911	1,997	2,107	1,655	705	632	667	786
Maximum	1,810	3,453	5,126	10,555	5,177	6,223	2,155	2,603	4,653	4,340	2,664	3,050	2,520
Average	919	394	398	644	655	960	1,347	1,328	913	522	483	521	549

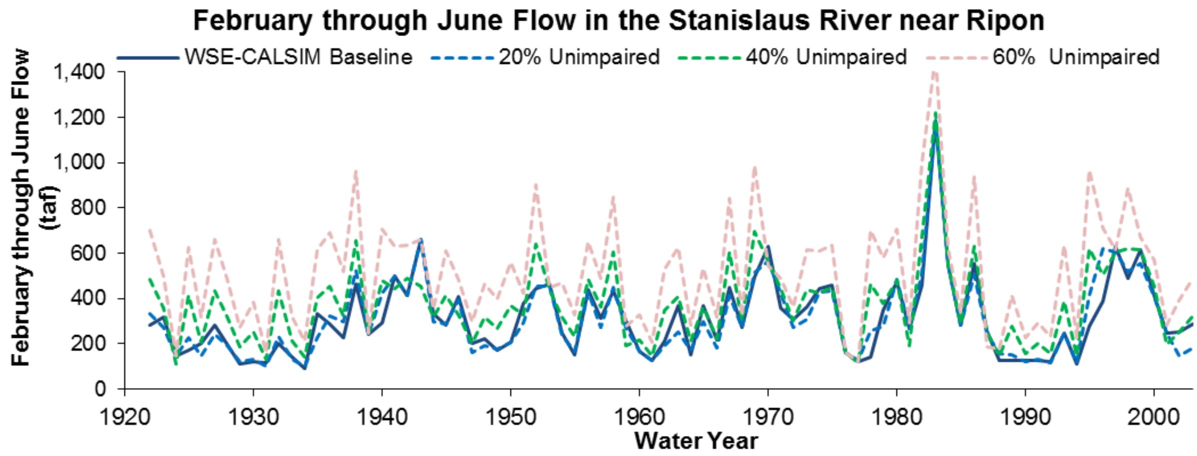


Figure F.1.3-9c. Stanislaus River February–June Flow Volumes (TAF) for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

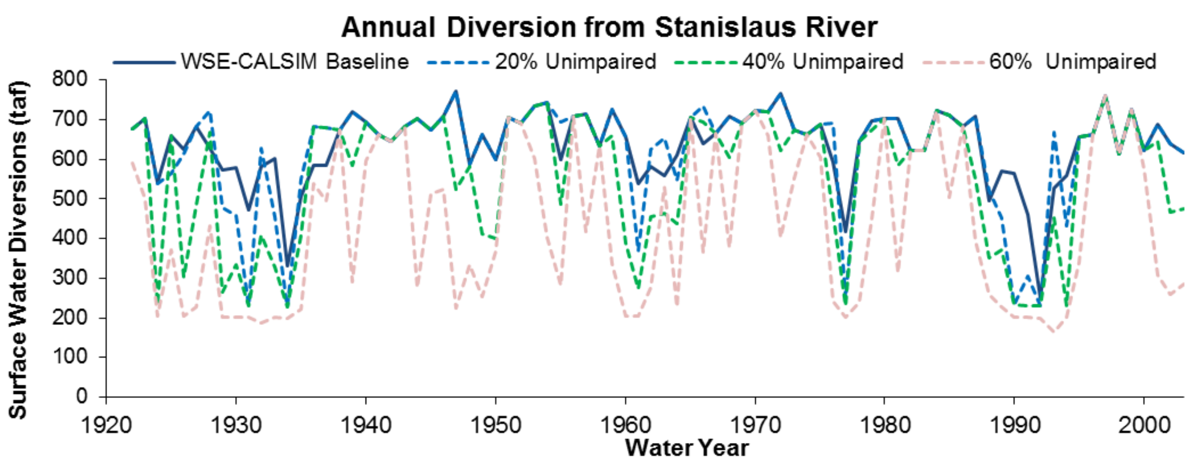


Figure F.1.3-9d. Stanislaus River Annual Water Supply Diversions for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

SJR at Vernalis

Table F.1.3-5p shows the monthly and annual cumulative distributions for the baseline SJR flows at Vernalis, downstream of the Stanislaus River. The median monthly baseline flows were between 1,500 and 2,600 cfs from June to January and 3,400 and 4,700 cfs from February to May. The higher median flows in April and May were caused by the Vernalis pulse flows. High flows, greater than 10,000 cfs from January to June (i.e., reservoir flood control releases), were simulated in only about 10 percent of the years. The range of annual SJR flows was 1,077 TAF (10 percent cumulative) to 5,542 TAF (90 percent cumulative), with a median annual flow of 2,041 TAF and an average annual flow of 2,965 TAF. Figure F.1.3-10 shows the annual sequence of February to June flows on the SJR at Vernalis for baseline conditions and 20, 40, and 60 percent unimpaired flows.

Table F.1.3-5p. Baseline Monthly Cumulative Distributions of SJR at Vernalis Flow (cfs) for 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
							SJR at Vernalis Flow (cfs)						
Minimum	1,343	1,233	1,238	1,146	1,526	1,124	1,171	1,096	710	525	579	955	875
10%	2,000	1,566	1,513	1,481	1,856	1,614	1,616	1,543	1,009	959	1,055	1,488	1,077
20%	2,132	1,696	1,657	1,699	2,029	2,280	2,347	2,310	1,420	1,134	1,249	1,685	1,386
30%	2,319	1,807	1,789	1,905	2,280	2,370	3,325	3,081	1,540	1,251	1,379	1,796	1,585
40%	2,385	1,918	1,884	2,121	2,707	3,405	3,925	3,443	1,843	1,418	1,437	1,894	1,778
50%	2,598	1,981	1,941	2,200	3,489	3,502	4,640	4,600	2,280	1,620	1,544	2,024	2,041
60%	2,727	2,132	2,044	2,479	4,456	5,570	5,239	5,210	3,097	1,831	1,703	2,165	2,690
70%	2,854	2,239	2,261	3,289	6,207	7,733	6,225	5,211	3,420	2,051	2,142	2,411	3,266
80%	2,971	2,512	2,679	4,785	9,314	8,562	7,901	7,075	6,229	3,284	2,665	2,610	4,197
90%	3,331	2,724	4,264	10,926	15,228	13,821	12,538	13,327	11,586	6,902	2,983	2,940	5,542
Maximum	6,753	16,297	24,021	62,587	34,271	48,485	26,465	25,624	27,086	23,865	9,143	7,677	15,907
Average	2,663	2,352	3,060	4,719	6,210	6,640	5,985	5,978	4,408	3,065	1,935	2,247	2,965

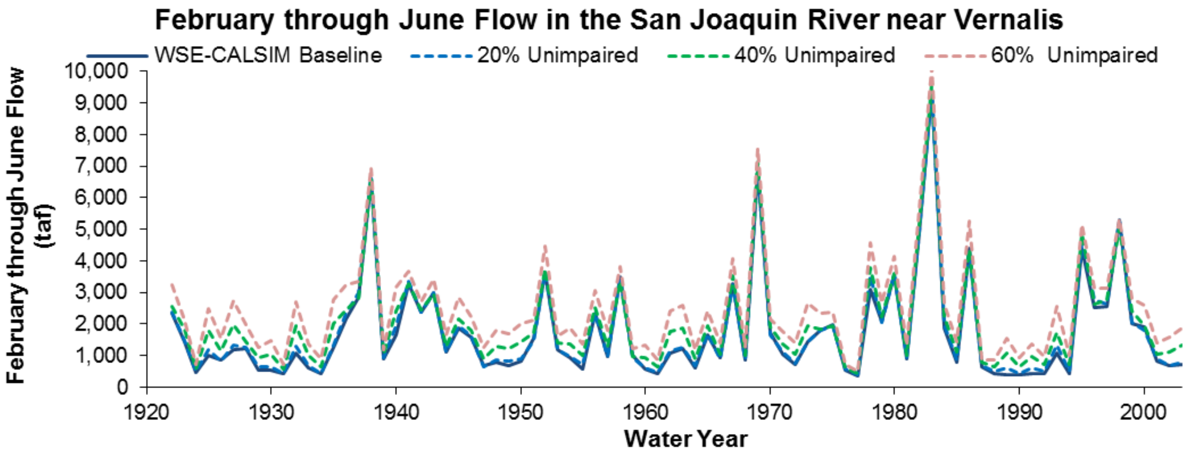


Figure F.1.3-10. SJR at Vernalis February–June Flow Volumes for Baseline Conditions and 20%, 40%, and 60% Unimpaired Flow (LSJR Alternatives 2–4) for 1922–2003

F.1.3.3 20 Percent Unimpaired Flow (LSJR Alternative 2)

The WSE model was used to simulate 20 percent unimpaired flow, which represents typical conditions for LSJR Alternative 2. For this simulation, LSJR tributary flows were greater than or equal to 20 percent of the unimpaired flow for February–June. In some years February–June flows were higher than the 20 percent unimpaired flow objective because of flood control releases or other flow requirements. The reservoir storage and water supply diversions were adjusted to satisfy these monthly flow objectives for each of the eastside tributaries. Flood control releases were reduced or eliminated in some years because more water was released to satisfy the flow objectives. Water supply diversions were reduced in some years to account for the 20 percent unimpaired flow requirement and maintain storage in the reservoirs.

Merced River

Table F.1.3-6a shows the monthly cumulative distributions for the WSE-calculated Lake McClure storage (TAF) for LSJR Alternative 2. These monthly storage patterns differ from baseline storage patterns because the timing and magnitude of releases for instream flow requirements and diversions are different. The median carryover storage was 499 TAF, slightly higher than the baseline median carryover storage of 451 TAF. Table F.1.3-6b shows the monthly cumulative distributions for the WSE-calculated Lake McClure water surface elevations (feet MSL) for LSJR Alternative 2. The median September reservoir elevation was 770 TAF, slightly higher than the baseline median September elevation of 757 TAF.

Table F.1.3-6a. WSE Results for Lake McClure Storage (TAF) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Lake McClure Storage (TAF)												
Min	165	148	165	229	214	193	204	211	225	245	216	194
10%	274	264	261	265	302	319	351	413	416	367	326	302
20%	293	289	319	329	375	382	415	486	493	439	371	325
30%	366	361	367	392	445	488	558	599	577	494	429	395
40%	385	390	425	478	553	619	647	699	657	547	451	411
50%	471	465	519	587	637	659	686	729	737	652	554	499
60%	593	596	616	636	674	687	742	851	858	766	670	618
70%	657	644	650	669	675	723	774	922	963	883	770	700
80%	668	662	668	675	675	735	818	966	1,024	910	770	700
90%	675	675	675	675	675	735	845	970	1,024	910	770	700
Max	675	675	675	675	675	735	845	970	1,024	910	770	700
Avg	482	480	493	515	546	581	639	727	741	655	561	511

Table F.1.3-6b. WSE Results for Lake McClure Water Surface Elevations (feet MSL) for 20% Unimpaired Flow (20% Unimpaired Flow)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Lake McClure Elevation (feet mean sea level)												
Minimum	659	650	659	685	682	672	677	680	686	685	682	673
10%	698	693	692	694	709	715	727	746	747	732	718	709
20%	705	704	715	719	735	737	747	767	769	754	733	717
30%	732	730	732	740	756	767	784	794	789	769	751	741
40%	738	739	750	765	783	798	804	814	806	782	757	746
50%	763	761	775	791	802	806	812	820	821	805	784	770
60%	792	793	797	802	809	812	822	841	842	826	809	798
70%	806	803	804	808	809	819	828	852	858	846	827	814
80%	808	807	808	809	809	821	836	859	867	850	827	814
90%	809	809	809	809	809	821	840	859	867	850	827	814
Maximum	809	809	809	809	809	821	840	859	867	850	827	814
Average	759	759	762	768	776	784	796	813	815	799	779	767

Table F.1.3-6c shows the monthly cumulative distributions for the WSE-calculated Merced River target flows at Stevinson for 20 percent unimpaired flow. Target flows are the flows specified for the downstream ends of the river in the absence of flood control releases. Comparison to the baseline indicates that the average monthly target flows for LSJR Alternative 2 increased from February–June and remained unchanged from July–January. The greatest increase came in May when the average target flow increased from 341 cfs under baseline to 785 cfs under the alternative.

Table F.1.3-6c. Merced River Target Flows (cfs) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Merced Target Flow (cfs)												
Minimum	(0)	152	33	99	207	205	186	182	44	(0)	(0)	(0)
10%	300	255	263	260	306	297	283	330	171	47	19	36
20%	350	290	287	318	336	335	317	435	229	82	56	67
30%	372	312	309	332	353	355	378	566	276	101	84	87
40%	393	325	332	345	385	372	432	658	383	132	110	118
50%	414	336	338	360	397	398	477	792	491	147	122	131
60%	430	346	352	386	449	475	533	876	562	174	144	146
70%	450	353	363	424	545	504	576	946	691	223	171	167
80%	462	369	381	482	660	575	647	1,045	881	240	196	192
90%	502	396	409	560	828	672	735	1,261	1,127	276	220	222
Maximum	1,276	847	1,075	1,730	2,059	2,037	1,442	1,838	2,205	1,133	536	629
Average	415	338	344	416	513	478	510	785	583	175	128	135

Table F.1.3-6d shows the monthly cumulative distributions for the WSE-calculated Merced River flows at Stevinson for LSJR Alternative 2. The Merced River flows were changed mostly in the February–June period. The monthly flows were higher than the target flows for the higher cumulative distribution values, indicating that flood control releases were required for LSJR Alternative 2 in many years, particularly during February. Based on month-by-month comparisons of the Merced River flows at Stevinson to the target flows, about 51 percent of the 82 years modeled required some flood control releases.

Table F.1.3-6d. Merced River Flows at Stevinson (cfs) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Merced at Stevinson Flow (cfs)													
Minimum	219	208	83	144	207	205	186	182	44	(0)	(0)	(0)	165
10%	325	271	281	280	312	297	283	330	171	55	30	53	187
20%	356	300	306	327	337	335	317	435	229	90	72	89	216
30%	380	318	325	342	372	355	378	566	276	113	104	120	241
40%	399	332	337	358	396	372	432	658	383	138	122	137	261
50%	423	340	349	378	470	399	477	792	491	153	155	166	293
60%	440	350	359	422	662	485	536	890	562	202	199	196	366
70%	457	361	374	528	843	550	578	946	698	232	401	332	536
80%	473	376	409	1,012	1,653	969	665	1,175	1,596	993	971	420	765
90%	563	437	1,037	1,725	2,874	1,728	914	2,445	2,658	2,113	1,159	545	1,016
Maximum	1,276	1,910	3,495	9,859	5,092	5,959	4,845	5,379	7,273	5,863	2,392	1,275	2,398
Average	440	395	540	835	1,074	813	603	1,020	1,011	644	414	260	485

Tuolumne River

Table F.1.3-6e shows the monthly cumulative distributions for the WSE-calculated New Don Pedro Reservoir storage (TAF) for LSJR Alternative 2. These monthly storage patterns differ from baseline storage patterns because the timing and magnitude of releases for instream flow requirements and diversions are different. The median carryover storage under the alternative was 1,381 TAF, slightly less than the baseline median carryover storage of 1,409 TAF. Table F.1.3-6f shows the monthly cumulative distributions for the WSE-calculated New Don Pedro Reservoir water surface elevations (feet MSL) for LSJR Alternative 2. The median September reservoir elevation was 771 TAF, about the same as the baseline median September elevation of 774 TAF.

Table F.1.3-6e. WSE Results for New Don Pedro Storage (TAF) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Don Pedro Reservoir Storage (TAF)												
Minimum	705	700	818	860	897	975	961	924	861	787	738	721
10%	885	887	924	1,015	1,080	1,161	1,187	1,220	1,183	1,052	936	910
20%	1,023	1,048	1,120	1,141	1,262	1,329	1,368	1,339	1,360	1,219	1,101	1,044
30%	1,112	1,123	1,183	1,303	1,408	1,466	1,539	1,574	1,495	1,326	1,201	1,145
40%	1,171	1,203	1,324	1,416	1,549	1,638	1,632	1,640	1,573	1,405	1,270	1,194
50%	1,341	1,347	1,444	1,506	1,636	1,690	1,680	1,712	1,761	1,600	1,459	1,381
60%	1,467	1,464	1,516	1,613	1,690	1,690	1,690	1,737	1,832	1,737	1,595	1,514
70%	1,550	1,605	1,615	1,669	1,690	1,690	1,713	1,768	1,899	1,815	1,675	1,599
80%	1,631	1,624	1,648	1,690	1,690	1,690	1,713	1,834	1,987	1,910	1,767	1,684
90%	1,649	1,643	1,690	1,690	1,690	1,690	1,713	1,895	2,030	1,910	1,779	1,700
Maximum	1,662	1,690	1,690	1,690	1,690	1,690	1,718	2,002	2,030	1,910	1,790	1,700
Average	1,307	1,317	1,370	1,428	1,497	1,534	1,553	1,613	1,657	1,533	1,409	1,342

Table F.1.3-6f. WSE Results for New Don Pedro Water Surface Elevations (feet MSL) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Don Pedro Reservoir Elevation (feet mean sea level)												
Minimum	673	672	694	701	707	719	716	711	701	688	679	676
10%	705	705	711	724	734	744	748	752	747	730	713	709
20%	726	729	739	742	757	765	770	766	769	752	736	729
30%	738	739	747	762	774	780	788	792	783	765	749	742
40%	746	750	764	775	789	798	797	798	792	774	758	749
50%	766	767	778	785	798	803	802	805	810	794	780	771
60%	780	780	786	796	803	803	803	807	816	807	794	785
70%	789	795	796	801	803	803	805	810	822	815	802	794
80%	797	797	799	803	803	803	805	816	830	823	810	802
90%	799	798	803	803	803	803	805	822	833	823	811	804
Maximum	800	803	803	803	803	803	806	831	833	823	812	804
Average	759	760	767	774	782	786	788	794	797	784	771	763

Table F.1.3-6g shows the monthly cumulative distributions for the WSE-calculated Tuolumne River target flows at Modesto for LSJR Alternative 2. Target flows are the flows specified for the downstream ends of the river in the absence of flood control releases. Comparison to the baseline indicates that the average monthly target flows for LSJR Alternative 2 increased from February–June and remain unchanged from July–January. The greatest increase came in June when the average target flow increased from 504 cfs under baseline to 1,203 cfs under the alternative.

Table F.1.3-6g. Tuolumne River Target Flows (cfs) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Tuolumne Target Flow (cfs)												
Minimum	199	206	71	208	235	338	411	418	283	194	187	166
10%	290	246	251	316	348	434	633	695	374	262	277	256
20%	395	324	319	417	466	486	783	977	457	319	346	334
30%	447	382	399	434	487	538	852	1,124	742	364	365	366
40%	488	443	430	479	524	595	1,042	1,232	969	403	399	381
50%	550	454	445	524	580	628	1,207	1,469	1,129	448	426	421
60%	608	479	496	572	617	686	1,353	1,666	1,343	519	515	497
70%	689	525	581	602	795	738	1,417	1,752	1,495	568	581	544
80%	735	608	602	648	934	853	1,469	1,870	1,785	601	588	593
90%	757	756	655	757	1,158	1,115	1,525	2,142	2,009	681	638	611
Maximum	1,171	1,530	1,405	2,411	2,218	1,883	2,218	3,123	3,415	1,067	760	809
Average	556	502	479	560	680	711	1,158	1,460	1,203	471	458	447

Table F.1.3-6h shows the monthly cumulative distributions for the WSE-calculated Tuolumne River flows at Modesto for LSJR Alternative 2. The Tuolumne River flows were generally changed only in the February–June period. The cumulative distributions of monthly flows were often higher than the cumulative distributions of the target flows, indicating that flood control releases were required in many years, particularly in February through April. Based on month-by-month comparisons of the Tuolumne River flows at Modesto to the target flows, about 63 percent of the 82 years modeled required some flood control releases.

Table F.1.3-6h. Tuolumne River Flows at Modesto (cfs) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
						Tuolumne at Modesto Flow(cfs)							
Minimum	199	206	217	208	235	338	411	418	283	194	187	166	222
10%	290	246	257	316	348	434	633	695	374	262	277	256	334
20%	395	324	327	427	466	488	795	977	457	319	346	334	396
30%	447	382	409	443	501	569	956	1,124	742	364	365	366	460
40%	488	447	434	518	609	815	1,075	1,232	969	403	399	381	525
50%	550	458	470	552	800	1,451	1,328	1,469	1,149	448	426	422	583
60%	632	489	523	599	1,044	1,945	1,633	1,700	1,379	559	515	522	940
70%	692	536	597	691	2,185	3,492	2,374	1,824	1,555	597	581	585	1,166
80%	737	608	624	1,483	3,377	4,058	3,462	2,117	2,174	864	588	599	1,403
90%	813	756	926	3,424	4,583	5,026	4,591	5,036	4,387	3,331	652	691	1,766
Maximum	3,090	5,440	7,479	17,925	7,280	16,297	9,332	9,474	7,396	8,190	2,996	2,296	4,129
Average	606	571	749	1,308	1,808	2,378	2,042	2,035	1,682	1,067	502	499	918

Stanislaus River

Table F.1.3-6i shows the monthly cumulative distributions for the WSE model calculated New Melones Reservoir storage (TAF) for LSJR Alternative 2. These monthly storage patterns differ from baseline storage patterns because the timing and magnitude of releases for instream flow requirements and diversions are different. The median carryover storage under the alternative was about 1,244 TAF, compared to the baseline median carryover storage of 1,124 TAF. Table F.1.3-6j shows the monthly cumulative distributions for the WSE model calculated New Melones Reservoir water surface elevations (feet MSL) for LSJR Alternative 2. The median September reservoir elevation was 977 TAF, slightly higher than the baseline median September elevation of 961 TAF.

Table F.1.3-6i. WSE Results for New Melones Storage (TAF) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Melones Reservoir												
Minimum	606	618	674	703	710	742	717	671	659	647	630	630
10%	710	710	732	759	806	866	865	856	843	794	756	727
20%	757	776	827	870	960	1,008	985	990	991	904	832	798
30%	947	960	1,002	1,032	1,063	1,105	1,120	1,168	1,174	1,096	1,015	974
40%	1,021	1,059	1,126	1,189	1,292	1,317	1,335	1,350	1,272	1,186	1,097	1,054
50%	1,199	1,221	1,294	1,364	1,439	1,485	1,437	1,515	1,485	1,378	1,289	1,244
60%	1,297	1,309	1,349	1,463	1,567	1,640	1,653	1,630	1,595	1,499	1,406	1,352
70%	1,478	1,502	1,557	1,597	1,720	1,749	1,727	1,723	1,777	1,663	1,564	1,513
80%	1,617	1,642	1,677	1,721	1,801	1,871	1,819	1,823	1,864	1,776	1,681	1,643
90%	1,836	1,850	1,867	1,897	1,967	1,992	1,948	2,054	2,106	2,010	1,917	1,865
Maximum	1,970	1,970	1,970	1,970	1,970	2,030	2,219	2,317	2,420	2,300	2,130	2,000
Average	1,226	1,239	1,275	1,327	1,390	1,437	1,437	1,463	1,469	1,391	1,307	1,261

Table F.1.3-6j. WSE Results for New Melones Water Surface Elevations (feet MSL) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Melones Elevation (feet mean sea level)												
Minimum	868	871	883	890	891	897	892	883	880	877	874	874
10%	891	891	895	901	910	920	920	919	916	908	900	894
20%	900	904	914	921	936	944	940	941	941	927	914	908
30%	934	936	943	947	952	958	960	966	967	957	945	938
40%	946	951	961	969	983	986	988	990	980	969	957	950
50%	971	974	983	991	1,000	1,005	1,000	1,008	1,005	993	982	977
60%	983	985	989	1,003	1,014	1,022	1,023	1,021	1,017	1,007	996	990
70%	1,004	1,007	1,013	1,017	1,030	1,032	1,030	1,030	1,035	1,024	1,014	1,008
80%	1,019	1,022	1,025	1,030	1,037	1,044	1,039	1,039	1,043	1,035	1,026	1,022
90%	1,041	1,042	1,043	1,046	1,052	1,055	1,051	1,060	1,064	1,056	1,048	1,043
Maximum	1,053	1,053	1,053	1,053	1,053	1,058	1,073	1,081	1,089	1,080	1,066	1,055
Average	967	968	973	980	988	994	994	996	996	987	977	971

Table F.1.3-6k shows the monthly cumulative distributions for the WSE-calculated Stanislaus River target flows at Ripon for LSJR Alternative 2. Target flows are the flows specified for the downstream ends of the river in the absence of flood control releases. The average monthly target flows under LSJR Alternative 2 were similar to the flows under baseline conditions, with slight differences because of changes in the NMI under the alternative. From March to June, the average monthly target flows were generally lower than the baseline targets. These target flows were reduced as a result of removing the Vernalis D1641 minimum flow requirements and the VAMP requirements.

Table F.1.3-6k. Stanislaus River Target Flows (cfs) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Stanislaus Target Flow (cfs)												
Minimum	599	213	94	129	216	238	393	299	188	205	208	174
10%	760	248	223	261	239	313	600	553	316	297	312	312
20%	774	260	241	294	308	340	798	726	363	325	352	358
30%	827	267	262	312	355	370	908	942	500	364	381	387
40%	850	292	273	325	373	384	1,122	1,263	587	395	413	419
50%	902	318	288	339	389	415	1,495	1,373	778	437	424	429
60%	970	336	304	349	422	497	1,650	1,478	836	500	463	469
70%	979	348	316	366	482	1,604	1,744	1,670	1,135	538	478	497
80%	1,041	382	347	407	600	1,719	1,775	1,743	1,281	618	538	537
90%	1,109	453	403	506	823	1,897	1,858	2,036	1,544	688	625	666
Maximum	1,409	732	674	884	1,916	2,234	2,088	2,425	2,124	1,021	732	887
Average	913	330	303	361	479	860	1,314	1,318	848	475	443	456

Table F.1.3-6l shows the monthly cumulative distributions for the Stanislaus River flows at Ripon for LSJR Alternative 2. The Stanislaus River flows were generally changed only in the February–June period. The cumulative distributions of the monthly flows were occasionally higher than the target flows, indicating that flood control releases were sometimes required. Based on month-by-month comparisons of the Stanislaus River flows at Ripon to the target flows, about 18 percent of the 82 years modeled required some flood control releases (less often than was needed on the Merced or Tuolumne Rivers).

Table F.1.3-6l. Stanislaus River Flows at Ripon (cfs) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Stanislaus at Ripon Flow (cfs)													
Minimum	599	213	94	198	216	238	393	299	188	205	208	174	241
10%	760	248	225	270	239	313	600	553	316	297	312	312	284
20%	774	260	242	295	308	340	798	726	363	325	352	358	339
30%	827	267	262	317	355	370	908	942	500	364	381	387	369
40%	850	292	280	327	376	384	1,122	1,263	587	395	413	419	422
50%	902	318	291	343	389	415	1,495	1,373	778	437	424	429	474
60%	970	336	305	352	437	497	1,650	1,478	836	510	463	469	505
70%	979	348	320	375	546	1,639	1,744	1,670	1,135	540	483	501	624
80%	1,042	382	368	446	657	1,776	1,775	1,743	1,281	627	541	564	694
90%	1,128	456	423	606	1,315	1,911	1,858	2,036	1,544	726	632	689	929
Maximum	1,810	3,453	5,126	10,555	5,177	6,223	2,088	2,425	4,653	4,340	2,664	3,050	2,520
Average	928	395	426	645	696	949	1,314	1,318	878	537	521	564	554

SJR at Vernalis

Table F.1.3-6m shows the monthly cumulative distributions for the WSE-calculated SJR at Vernalis flows for LSJR Alternative 2. The SJR at Vernalis flows changed most during May and June. LSJR Alternative 2 provided a more natural distribution of flows from February–June. The average annual flow was about 59 TAF more (2 percent) than the average baseline flow.

Table F.1.3-6m. SJR Flows at Vernalis (cfs) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
						SJR at Vernalis Flow (cfs)							
Minimum	1,343	1,233	1,238	1,146	1,526	1,124	1,349	1,267	1,000	525	579	955	915
10%	2,000	1,566	1,513	1,481	1,775	1,617	1,867	2,202	1,114	959	1,055	1,488	1,136
20%	2,147	1,696	1,657	1,699	1,937	1,810	2,499	2,930	1,540	1,139	1,249	1,685	1,451
30%	2,335	1,807	1,789	1,886	2,223	2,467	3,125	3,361	1,894	1,251	1,379	1,796	1,594
40%	2,395	1,918	1,884	2,121	2,445	2,979	3,603	4,203	2,583	1,447	1,449	1,913	1,825
50%	2,611	1,981	1,941	2,225	3,623	3,606	4,280	4,522	3,334	1,639	1,565	2,024	2,102
60%	2,755	2,132	2,035	2,373	4,575	5,295	5,074	5,522	3,719	1,819	1,682	2,173	2,740
70%	2,889	2,266	2,240	3,153	6,321	7,748	6,032	6,071	3,993	2,034	2,112	2,416	3,269
80%	2,992	2,525	2,622	4,849	9,115	9,231	8,229	8,106	6,093	3,284	2,718	2,616	4,507
90%	3,331	2,777	3,885	11,153	14,905	13,821	13,179	14,366	11,700	6,902	3,029	3,216	5,505
Maximum	6,753	16,297	24,021	62,587	34,271	48,485	26,465	25,624	27,086	23,865	9,143	7,677	15,907
Average	2,673	2,363	3,041	4,721	6,237	6,624	5,992	6,446	4,840	3,041	1,967	2,289	3,024

F.1.3.4 40 Percent Unimpaired Flow (LSJR Alternative 3)

The WSE model was used to simulate 40 percent unimpaired flow, which represents typical conditions for LSJR Alternative 3. For this simulation, LSJR tributary flows were generally greater than or equal to 40 percent of the unimpaired flow from February–June. Some of the February–June flow was reserved for controlling potential temperature effects later in the year; thus, resulting flows decreased to slightly below 40 percent of unimpaired flow during some years. In some years, February–June flows were higher than the 40 percent unimpaired flow objective because of flood control releases or other flow requirements. The reservoir storage and water supply diversions were managed to satisfy these monthly flow objectives for each tributary river. Flood releases in many years were reduced or eliminated because higher flows were released from February–June to satisfy the flow objectives. Water supply diversions were reduced in some years to account for the 40 percent unimpaired flow requirement and maintain storage in the reservoirs.

Merced River

Table F.1.3-7a shows the monthly cumulative distributions for the WSE-calculated Lake McClure storage (TAF) for LSJR Alternative 3. These monthly storage patterns differ from baseline storage patterns because the timing and magnitude of releases for instream flow requirements and diversions are different. The median carryover storage was 467 TAF, slightly higher than the baseline median carryover storage of 451 TAF. Table F.1.3-7b shows the monthly cumulative distributions for the WSE-calculated Lake McClure water surface elevations (feet MSL) for LSJR Alternative 3. The median September reservoir elevation was 762 TAF, slightly higher than the baseline median September elevation of 757 TAF.

Table F.1.3-7a. WSE Results for Lake McClure Storage (TAF) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
					Lake McClure Storage (TAF)							
Minimum	168	157	195	181	166	189	188	182	189	238	213	194
10%	276	266	265	272	303	313	341	348	358	338	314	301
20%	303	296	305	320	359	351	390	440	455	411	359	330
30%	334	343	366	393	413	429	469	522	527	458	394	360
40%	394	408	404	426	515	540	568	618	591	523	456	418
50%	442	437	460	502	569	624	644	671	648	572	503	467
60%	454	457	499	579	632	652	699	764	738	642	543	488
70%	543	536	584	618	667	707	744	841	832	741	633	573
80%	634	598	619	651	675	735	795	914	980	909	770	690
90%	645	627	653	675	675	735	837	968	1,024	910	770	700
Maximum	675	675	675	675	675	735	845	970	1,024	910	770	700
Average	448	442	460	487	522	556	601	669	681	609	526	480

Table F.1.3-7b. WSE Results for Lake McClure Water Surface Elevation (feet MSL) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Lake McClure Elevation (feet mean sea level)											
Minimum	661	655	673	667	660	671	670	667	671	683	681	673
10%	698	694	693	696	709	713	723	725	729	722	713	708
20%	709	706	710	715	729	727	739	754	758	746	729	719
30%	721	724	731	740	746	751	762	776	777	759	741	730
40%	741	745	744	750	774	780	787	798	792	776	759	748
50%	755	753	760	771	787	799	803	809	804	788	771	762
60%	758	759	770	789	801	805	814	826	822	803	781	767
70%	781	779	790	798	808	816	822	839	838	822	801	788
80%	801	793	798	805	809	821	832	851	861	850	827	812
90%	803	800	805	809	809	821	839	859	867	850	827	814
Maximum	809	809	809	809	809	821	840	859	867	850	827	814
Average	751	750	755	761	771	778	788	801	803	789	771	760

Table F.1.3-7c shows the monthly cumulative distributions for the Merced River target flows at Stevinson for LSJR Alternative 3. Target flows are the flows specified for the downstream ends of the river in the absence of flood control releases. Comparison to the baseline indicates that the average monthly target flows for LSJR Alternative 3 increased from July–November (as a result of adaptive implementation flow shifting) and remained unchanged during December and January. From February through June, the average monthly target flows were higher under the alternative compared to baseline because of the unimpaired flow requirement, particularly from March to June. The greatest increase came in May when the average target flow increased from 341 cfs under baseline to 1,405 cfs under the alternative.

Table F.1.3-7c. Merced River Target Flows (cfs) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Merced Target Flow (cfs)											
Minimum	219	166	33	99	207	260	208	254	87	(0)	(0)	(0)
10%	342	271	263	260	325	335	538	660	290	55	35	55
20%	358	304	287	318	340	363	620	870	348	94	84	101
30%	387	324	309	332	376	399	734	1,121	553	134	121	133
40%	405	336	332	345	392	475	814	1,263	758	163	163	172
50%	429	350	338	360	446	515	860	1,421	912	200	200	200
60%	457	368	352	386	537	603	946	1,552	1,029	223	200	200
70%	513	444	363	424	716	659	1,028	1,695	1,313	266	263	251
80%	727	709	381	482	900	782	1,128	1,841	1,486	521	506	503
90%	800	800	409	560	1,296	923	1,242	2,033	1,692	600	600	600
Maximum	1,276	847	1,075	1,730	2,103	2,364	2,614	2,882	4,330	1,133	600	629
Average	503	445	344	416	635	616	897	1,405	1,010	267	252	258

Table F.1.3-7d shows the monthly cumulative distributions for the Merced River flows at Stevinson for LSJR Alternative 3. The cumulative distributions of monthly flows were often higher than the target flows indicating that flood control releases were sometimes required. However, only about 37 percent of the years simulated required flood control releases, much less than under baseline conditions, during which flood control releases occurred in about 50 percent of the years.

Table F.1.3-7d. Merced River Flows at Stevinson (cfs) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Merced at Stevinson Flow (cfs)													
Minimum	219	166	83	144	207	260	208	254	87	(0)	(0)	(0)	185
10%	342	271	268	266	325	335	538	660	290	55	35	55	247
20%	358	304	300	325	340	363	620	870	348	94	84	101	294
30%	387	324	317	338	380	399	734	1,121	553	134	121	133	323
40%	405	336	333	354	404	475	814	1,263	758	163	163	172	367
50%	429	350	342	376	453	515	860	1,421	912	200	200	200	417
60%	457	368	357	398	810	603	946	1,552	1,029	223	200	200	496
70%	513	444	368	433	1,089	760	1,034	1,695	1,313	266	263	251	548
80%	727	709	390	622	1,584	969	1,142	1,841	1,509	618	876	513	802
90%	800	800	434	1,726	2,158	1,728	1,328	2,519	2,625	1,844	1,150	600	982
Maximum	1,276	1,910	3,495	9,859	4,875	5,959	4,845	5,379	7,273	5,863	2,392	1,275	2,398
Average	507	468	448	762	995	884	945	1,522	1,233	636	396	282	547

Tuolumne River

Table F.1.3-7e shows the monthly cumulative distributions for the WSE-calculated New Don Pedro Reservoir storage (TAF) for 40 percent unimpaired flow (LSJR Alternative 3). These monthly storage patterns differ from baseline storage patterns because the timing and magnitude of releases for instream flow requirements and diversions are different. The median carryover storage was 1,207 TAF, 202 TAF less than the baseline median carryover storage of 1,409 TAF. Table F.1.3-7f shows the monthly cumulative distributions for the WSE-calculated New Don Pedro Reservoir water elevations (feet MSL) for LSJR Alternative 3. The median September reservoir elevation was 750 TAF, slightly less than the baseline median September elevation of 774 TAF.

Table F.1.3-7e. WSE Results for New Don Pedro Reservoir Storage (TAF) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Don Pedro Storage (TAF)												
Minimum	653	648	827	846	859	906	913	871	808	735	686	669
10%	896	896	927	994	1,070	1,124	1,120	1,120	1,084	1,000	948	914
20%	1,007	1,018	1,075	1,122	1,178	1,269	1,268	1,248	1,214	1,123	1,051	1,024
30%	1,066	1,083	1,144	1,176	1,273	1,327	1,335	1,342	1,287	1,196	1,136	1,084
40%	1,126	1,143	1,194	1,257	1,363	1,411	1,463	1,514	1,458	1,317	1,202	1,148
50%	1,173	1,195	1,255	1,359	1,472	1,581	1,557	1,569	1,522	1,385	1,265	1,207
60%	1,245	1,282	1,339	1,424	1,547	1,672	1,663	1,628	1,634	1,492	1,349	1,264
70%	1,341	1,339	1,433	1,533	1,638	1,690	1,690	1,669	1,701	1,608	1,463	1,384
80%	1,496	1,486	1,534	1,639	1,690	1,690	1,713	1,716	1,865	1,787	1,641	1,537
90%	1,600	1,572	1,633	1,690	1,690	1,690	1,713	1,842	2,000	1,910	1,774	1,677
Maximum	1,660	1,690	1,690	1,690	1,690	1,690	1,718	1,974	2,030	1,910	1,790	1,700
Average	1,217	1,221	1,280	1,348	1,425	1,477	1,487	1,504	1,525	1,422	1,313	1,248

Table F.1.3-7f. WSE Results for New Don Pedro Reservoir Water Surface Elevation (feet MSL) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Don Pedro Elevation (feet mean sea level)												
Minimum	674	674	695	698	700	708	709	702	692	679	679	677
10%	706	706	711	721	732	740	739	739	734	722	715	709
20%	723	725	733	739	747	758	758	755	751	739	730	726
30%	732	734	742	746	758	765	766	767	760	749	741	734
40%	740	742	749	756	769	774	780	785	779	764	750	743
50%	746	749	756	768	781	792	790	791	786	771	757	750
60%	755	759	766	776	789	801	800	797	798	783	767	757
70%	766	766	777	787	798	803	803	801	804	795	780	771
80%	783	782	787	798	803	803	805	806	819	812	798	788
90%	794	791	797	803	803	803	805	817	831	823	811	802
Maximum	800	803	803	803	803	803	806	829	833	823	812	804
Average	749	750	757	765	774	780	781	782	783	772	760	753

Table F.1.3-7g shows the monthly cumulative distributions for the WSE-calculated Tuolumne River target flows at Modesto for LSJR Alternative 3. Target flows are the flows specified for the downstream ends of the river in the absence of flood control releases. Comparison to the baseline indicates that the average monthly target flows for LSJR Alternative 3 increased slightly from July–November (as a result of adaptive implementation flow shifting) and remained unchanged during December and January. From February through June, the average monthly target flows were higher under the alternative compared to baseline because of the unimpaired flow requirement, particularly in May and June. The greatest increase came in June when the average target flow increased from 504 cfs under baseline to 2,231 cfs under the alternative.

Table F.1.3-7g. Tuolumne River Target Flows (cfs) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
						Tuolumne Target Flow (cfs)						
Minimum	199	206	71	208	235	338	531	690	283	194	187	166
10%	290	246	251	316	442	608	1,112	1,388	602	262	277	256
20%	395	324	319	417	505	738	1,293	1,894	913	319	346	334
30%	463	389	399	434	604	833	1,481	2,248	1,485	364	369	366
40%	499	452	430	479	647	925	1,632	2,439	1,846	403	403	381
50%	552	472	445	524	814	1,008	1,709	2,823	2,160	483	428	425
60%	681	562	496	572	940	1,116	1,804	3,013	2,583	582	586	574
70%	742	926	581	602	1,118	1,275	2,016	3,302	2,901	698	600	697
80%	1,000	1,000	602	648	1,662	1,545	2,183	3,497	3,232	1,200	600	1,000
90%	1,000	1,000	655	757	2,101	2,008	2,548	4,048	3,670	1,200	638	1,000
Maximum	1,171	1,530	1,405	2,411	4,164	3,484	4,063	5,693	6,531	1,200	760	1,000
Average	633	609	479	560	1,041	1,179	1,769	2,757	2,231	637	471	573

Table F.1.3-7h shows the monthly cumulative distributions for the WSE-calculated Tuolumne River flows at Modesto for LSJR Alternative 3. The cumulative distributions of monthly flows were higher than the target flows, indicating that flood control releases were sometimes required. However, only about 44 percent of the years simulated required flood control releases, much less than under baseline conditions, during which flood control releases occurred in about 66 percent of the years.

Table F.1.3-7h. Tuolumne River Flows at Modesto (cfs) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
						Tuolumne at Modesto Flow(cfs)							
Minimum	199	206	217	208	235	338	531	690	283	194	187	166	261
10%	290	246	257	316	442	608	1,112	1,388	602	262	277	256	459
20%	395	324	322	427	511	801	1,293	1,894	913	319	346	334	560
30%	463	389	402	443	609	895	1,492	2,248	1,485	364	369	366	617
40%	499	452	431	518	722	1,014	1,659	2,439	1,846	403	403	381	678
50%	552	472	450	542	902	1,174	1,998	2,867	2,173	483	428	425	816
60%	681	562	518	593	1,188	1,661	2,236	3,117	2,583	582	586	574	918
70%	742	926	589	639	1,691	2,665	2,601	3,387	2,901	698	600	697	1,209
80%	1,000	1,000	611	836	2,583	3,463	3,183	3,538	3,334	1,200	600	1,000	1,425
90%	1,000	1,000	679	2,404	4,065	5,027	4,591	4,810	4,422	3,135	652	1,000	1,720
Maximum	3,090	5,440	7,479	17,925	6,927	16,297	9,332	9,474	7,110	8,047	2,996	2,296	4,129
Average	661	677	679	1,148	1,660	2,217	2,378	3,013	2,370	1,046	515	601	1,022

Stanislaus River

Table F.1.3-7i shows the monthly cumulative distributions for the WSE-calculated New Melones Reservoir storage (TAF) for LSJR Alternative 3. These monthly storage patterns differ from baseline storage patterns because the timing and magnitude of releases for instream flow requirements and diversions are different. The median carryover storage was 1,096 TAF, about 28 TAF less than the baseline median carryover storage of 1,124 TAF. Table F.1.3-7j shows the monthly cumulative distributions for the WSE-calculated New Melones Reservoir water surface elevations (feet MSL) for LSJR Alternative 3. The median September reservoir elevation was 957 TAF under the alternative, about the same as the baseline median September elevation of 961 TAF.

Table F.1.3-7i. WSE Results for New Melones Reservoir Storage (TAF) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Melones Reservoir Storage (TAF)												
Minimum	636	648	661	737	748	784	767	704	691	679	662	662
10%	754	766	788	809	852	902	877	864	849	825	795	781
20%	824	830	858	872	906	968	949	929	964	949	891	854
30%	884	901	932	1,009	1,031	1,058	1,077	1,069	1,062	1,011	948	924
40%	988	1,001	1,045	1,094	1,128	1,208	1,214	1,211	1,178	1,123	1,067	1,028
50%	1,042	1,081	1,127	1,202	1,296	1,363	1,402	1,357	1,323	1,215	1,132	1,096
60%	1,141	1,178	1,235	1,361	1,418	1,476	1,477	1,493	1,447	1,332	1,235	1,193
70%	1,344	1,364	1,394	1,450	1,533	1,552	1,553	1,594	1,648	1,568	1,479	1,415
80%	1,489	1,494	1,546	1,607	1,649	1,734	1,717	1,705	1,753	1,690	1,596	1,539
90%	1,658	1,668	1,695	1,725	1,811	1,901	1,936	1,949	1,924	1,827	1,749	1,710
Maximum	1,970	1,970	1,970	1,970	1,970	2,030	2,090	2,137	2,385	2,300	2,130	2,000
Average	1,145	1,160	1,198	1,254	1,308	1,354	1,352	1,360	1,363	1,297	1,227	1,188

Table F.1.3-7j. WSE Results for New Melones Reservoir Water Surface Elevation (feet MSL) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Melones Elevation (feet mean sea level)												
Minimum	875	878	881	896	899	906	902	890	887	884	881	881
10%	900	902	906	910	918	926	922	920	917	913	908	905
20%	913	914	919	922	927	937	934	931	937	934	925	918
30%	924	926	932	944	947	951	954	953	952	944	934	930
40%	940	942	949	956	961	972	973	972	968	960	952	947
50%	949	954	961	971	983	991	996	991	986	973	962	957
60%	963	968	975	991	998	1,004	1,004	1,006	1,001	987	975	970
70%	989	991	995	1,001	1,010	1,012	1,013	1,017	1,022	1,014	1,005	997
80%	1,006	1,006	1,012	1,018	1,022	1,031	1,029	1,028	1,033	1,027	1,017	1,011
90%	1,023	1,024	1,027	1,030	1,038	1,047	1,050	1,051	1,049	1,040	1,032	1,029
Maximum	1,053	1,053	1,053	1,053	1,053	1,058	1,063	1,067	1,086	1,080	1,066	1,055
Average	957	960	965	972	979	985	984	985	985	977	968	963

Table F.1.3-7k shows the monthly cumulative distributions for the WSE-calculated Stanislaus River target flows at Ripon for LSJR Alternative 3. Target flows are the flows specified for the downstream ends of the river in the absence of flood control releases. Comparison to the baseline indicates that the average monthly target flows under LSJR Alternative 3 remained mostly unchanged from July to February (except in October), with some differences because of changes in the NMI under the alternative. October targets were higher as a result of adaptive implementation flow shifting in order to control potential temperature effects during summer and fall. From February to June, the average monthly target flows were generally higher than under baseline. The greatest increase came in May when the average target flow increased from 1,328 cfs under baseline to 1,771 cfs under the alternative.

Table F.1.3-7k. Stanislaus River Target Flows (cfs) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Stanislaus Target Flow (cfs)											
Minimum	763	213	94	129	225	238	460	443	205	205	208	174
10%	800	248	225	267	268	371	693	756	315	307	312	299
20%	1,000	260	243	294	340	462	955	1,084	442	325	352	358
30%	1,000	267	263	310	389	516	1,230	1,346	608	357	370	377
40%	1,000	292	280	323	445	599	1,395	1,610	864	395	410	397
50%	1,122	318	288	335	519	692	1,539	1,782	1,114	437	425	421
60%	1,200	336	305	347	705	813	1,687	2,003	1,261	534	471	476
70%	1,204	348	320	360	778	1,162	1,744	2,109	1,365	682	500	700
80%	1,400	379	368	397	921	1,711	1,822	2,265	1,590	800	512	800
90%	1,400	445	423	502	1,409	1,897	1,928	2,711	2,050	800	554	800
Maximum	1,409	732	1,071	884	3,832	2,636	2,766	3,752	4,189	1,021	732	887
Average	1,121	326	323	358	730	967	1,440	1,771	1,139	524	439	515

Table F.1.3-7l shows the monthly cumulative distributions for the WSE-calculated Stanislaus River flows at Ripon for LSJR Alternative 3. The monthly flows were higher than the target flows for some of the higher cumulative distribution values, indicating that flood control releases were sometimes required. However, only about 7 percent of the years required some flood control releases.

Table F.1.3-7l. Stanislaus River Flows at Ripon (cfs) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
						Stanislaus at Ripon Flow (cfs)							
Minimum	763	213	94	129	225	238	460	443	205	205	208	174	253
10%	800	248	225	267	268	371	693	756	315	307	312	299	325
20%	1,000	260	247	295	340	462	955	1,084	442	325	352	358	406
30%	1,000	267	267	312	389	516	1,230	1,346	608	357	370	377	457
40%	1,000	292	280	324	445	599	1,395	1,610	864	395	410	397	519
50%	1,122	318	291	336	519	692	1,539	1,782	1,114	437	425	421	591
60%	1,200	336	306	349	730	813	1,687	2,003	1,261	534	471	476	619
70%	1,204	348	320	362	788	1,162	1,744	2,109	1,365	682	500	700	686
80%	1,400	379	368	414	1,196	1,711	1,822	2,265	1,590	800	512	800	760
90%	1,400	445	423	541	1,799	1,897	1,928	2,711	2,050	800	554	800	930
Maximum	1,538	3,453	5,126	10,555	5,177	6,223	2,766	3,752	4,189	3,770	2,664	3,050	2,453
Average	1,123	382	417	582	878	1,011	1,440	1,771	1,139	560	462	551	622

SJR at Vernalis

Table F.1.3-7m shows the monthly cumulative distributions for the WSE-calculated SJR at Vernalis flows for LSJR Alternative 3. The average Vernalis flows were similar to the baseline flows in February and March but were 810–2,400 cfs higher from April–June. LSJR Alternative 3 provided a more natural distribution of flows from February–June, and the average annual flow volume was 294 TAF more than the average baseline flow volume at Vernalis (10 percent higher).

Table F.1.3-7m. SJR Flows at Vernalis (cfs) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
SJR at Vernalis Flow (cfs)													
Minimum	1,539	1,233	1,238	1,146	1,526	1,124	1,349	1,724	1,000	525	579	955	956
10%	2,000	1,566	1,513	1,480	1,852	1,742	2,788	3,220	1,537	955	1,054	1,459	1,465
20%	2,263	1,696	1,657	1,699	2,033	2,453	3,747	4,456	2,199	1,139	1,248	1,685	1,773
30%	2,451	1,795	1,789	1,886	2,316	2,775	4,219	5,349	3,083	1,226	1,341	1,796	1,924
40%	2,571	1,906	1,884	2,113	2,636	3,310	4,796	6,154	4,169	1,439	1,449	1,913	2,098
50%	2,832	1,998	1,941	2,167	3,073	3,949	5,394	7,330	5,061	1,633	1,568	2,030	2,504
60%	3,066	2,170	2,035	2,352	5,426	5,367	5,986	8,009	5,604	1,865	1,767	2,180	2,922
70%	3,473	2,706	2,157	3,024	6,679	6,733	6,926	9,125	6,197	2,289	2,081	2,971	3,412
80%	3,876	3,121	2,555	4,020	8,828	8,674	8,553	9,992	7,796	3,305	2,539	3,331	4,524
90%	3,987	3,344	3,029	9,349	12,232	13,701	13,460	15,878	11,927	6,345	2,984	3,543	5,492
Maximum	6,343	16,297	24,021	62,587	34,271	48,485	27,192	27,339	29,234	20,781	9,143	7,677	15,840
Average	2,990	2,528	2,869	4,425	6,194	6,596	6,795	8,378	6,011	3,036	1,904	2,401	3,259

F.1.3.5 60 Percent Unimpaired Flow (LSJR Alternative 4)

The WSE model was used to simulate 60 percent unimpaired flow, which represents typical conditions for LSJR Alternative 4. For this simulation, LSJR tributary flows were greater than or equal to 60 percent of the unimpaired reservoir inflow from February–June. Some of the February–June flow was reserved for controlling potential temperature effects later in the year; thus, resulting flows may decrease slightly below 60 percent of unimpaired flow during some years. In some years, February–June flows were higher than the 60 percent unimpaired flow objective because of flood control releases or other flow requirements. The reservoir storage and water supply diversions were adjusted to satisfy these monthly flow objectives for each of the eastside tributaries. Flood control releases in many years were reduced or eliminated because higher flows were released from February–June to satisfy the flow objectives. Water supply diversions were reduced in many years to account for the 60 percent unimpaired flow requirement and maintain storage in the reservoirs.

Merced River

Table F.1.3-8a shows the monthly cumulative distributions for the WSE-calculated Lake McClure storage (TAF) for LSJR Alternative 4. These monthly storage patterns differ from baseline storage patterns because the timing and magnitude of releases for instream flow requirements and diversions are different. The median carryover storage was 475 TAF, about 24 TAF more than the baseline median carryover storage of 451 TAF. Table F.1.3-8b shows the monthly cumulative distributions for the WSE-calculated Lake McClure water surface elevations (feet MSL) for LSJR Alternative 4. The median September reservoir elevation was 764 TAF, slightly higher than the baseline median September elevation of 757 TAF.

Table F.1.3-8a. WSE Results for Lake McClure Storage (TAF) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Lake McClure Storage (TAF)												
Minimum	52	35	52	102	99	132	141	167	147	128	101	80
10%	269	264	264	264	288	318	339	291	303	321	305	292
20%	299	295	292	319	350	364	375	407	405	377	350	325
30%	376	374	389	394	402	394	420	461	482	456	410	397
40%	416	411	426	444	467	476	495	554	537	493	450	422
50%	446	442	460	483	534	550	571	611	615	575	515	475
60%	472	465	485	522	600	630	655	671	689	630	546	503
70%	501	495	522	587	637	681	698	737	728	677	588	541
80%	529	528	574	645	675	720	759	811	828	740	627	568
90%	631	597	637	675	675	735	797	875	964	910	770	689
Maximum	675	675	675	675	675	735	845	970	1,024	910	770	700
Average	431	424	444	473	503	530	559	602	612	568	502	462

Table F.1.3-8b. WSE Results for Lake McClure Water Surface Elevations (feet MSL) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Lake McClure Elevation (feet mean sea level)												
Minimum	567	538	567	619	617	640	646	660	649	638	618	599
10%	695	693	693	693	703	715	722	704	709	716	710	705
20%	708	706	705	715	726	731	735	745	744	735	726	717
30%	735	734	739	741	743	741	748	760	766	759	745	742
40%	747	746	750	755	762	764	769	783	779	768	757	749
50%	756	755	760	766	779	783	787	796	797	788	774	764
60%	763	761	766	776	794	800	805	809	812	800	782	771
70%	771	769	776	791	802	811	814	821	820	810	791	780
80%	777	777	788	803	809	818	825	834	837	822	800	787
90%	800	793	802	809	809	821	832	845	858	850	827	812
Maximum	809	809	809	809	809	821	840	859	867	850	827	814
Average	746	743	749	757	765	772	778	787	788	779	765	755

Table F.1.3-8c shows the monthly cumulative distributions for the WSE-calculated Merced River target flows at Stevinson for LSJR Alternative 4. Target flows are the flows specified for the downstream ends of the river in the absence of flood control releases. Comparison to the baseline indicates that the average monthly target flows for LSJR Alternative 4 increased from July–November (as a result of adaptive implementation flow shifting) and remained unchanged during December and January. From February through June, the average monthly target flows were higher in the alternative compared to baseline because of the unimpaired flow requirement, particularly from April–June. The greatest increase came in May when the average target flow increased from 341 cfs under baseline to 2,164 cfs under the alternative.

Table F.1.3-8c. Merced River Target Flows (cfs) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Merced Target Flow (cfs)												
Minimum	219	166	33	99	207	281	313	381	131	(0)	(0)	(0)
10%	342	271	263	260	332	391	807	989	435	55	35	55
20%	358	304	287	318	360	505	930	1,306	522	94	84	101
30%	387	324	309	332	397	576	1,101	1,681	829	134	121	133
40%	405	336	332	345	488	637	1,245	1,918	1,137	163	163	172
50%	429	350	338	360	557	769	1,308	2,192	1,377	200	200	200
60%	457	368	352	386	706	877	1,462	2,431	1,574	223	200	200
70%	569	444	363	424	903	1,002	1,589	2,604	2,016	266	263	251
80%	800	800	381	482	1,379	1,235	1,735	2,808	2,386	600	600	600
90%	800	800	409	560	1,961	1,442	1,961	3,191	2,703	600	600	600
Maximum	1,276	847	1,075	1,730	3,406	3,567	4,055	4,719	6,535	1,133	600	629
Average	517	461	344	416	873	911	1,379	2,164	1,563	281	267	274

Table F.1.3-8d shows the monthly cumulative distributions for the WSE-calculated Merced River flows at Stevinson for LSJR Alternative 4. The monthly flows were greater than the target flows for some of the higher cumulative distribution values, but this occurred less often than under baseline conditions. This indicates that flood control releases were required in fewer years than under baseline. Under LSJR Alternative 4, about 28 percent of years required flood control releases compared to about 50 percent of years under baseline.

Table F.1.3-8d. Merced River Flows at Stevinson (cfs) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Merced at Stevinson Flow (cfs)													
Minimum	219	166	196	144	207	281	313	381	131	(0)	(0)	(0)	209
10%	342	271	273	261	332	391	807	989	435	55	35	55	316
20%	358	304	301	323	360	505	930	1,306	522	94	84	101	379
30%	387	324	317	334	410	576	1,101	1,681	829	134	121	133	401
40%	405	336	333	352	497	637	1,245	1,918	1,137	163	163	172	474
50%	429	350	342	370	581	769	1,308	2,192	1,377	200	200	200	560
60%	457	368	357	395	881	913	1,462	2,431	1,574	223	200	200	640
70%	569	444	368	432	1,411	1,010	1,589	2,604	2,016	266	263	251	708
80%	800	800	389	521	1,844	1,350	1,735	2,808	2,386	600	600	600	860
90%	800	800	427	1,522	2,368	1,731	1,961	3,191	2,703	908	1,073	600	1,015
Maximum	1,276	1,910	3,495	9,859	4,474	5,959	4,845	5,120	6,535	5,048	2,392	1,073	2,398
Average	521	484	424	728	1,097	1,045	1,388	2,169	1,571	508	362	287	637

Tuolumne River

Table F.1.3-8e shows the monthly cumulative distributions for the WSE-calculated New Don Pedro Reservoir storage (TAF) for LSJR Alternative 4. These monthly storage patterns differ from baseline storage patterns because the timing and magnitude of releases for instream flow requirements and diversions are different. The median carryover storage was 1,192 TAF, lower than the baseline median carryover storage of 1,409 TAF. Table F.1.3-8f shows the monthly cumulative distributions for the WSE-calculated New Don Pedro Reservoir water surface elevations (feet MSL) for LSJR Alternative 4. The median September reservoir elevation was 748 TAF, slightly less than the baseline median September elevation of 774 TAF.

Table F.1.3-8e. WSE Results for New Don Pedro Reservoir Storage (TAF) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	New Don Pedro Reservoir Storage (TAF)											
Minimum	735	733	793	937	935	951	945	893	815	774	750	745
10%	962	964	997	1,027	1,087	1,130	1,110	1,082	1,043	1,009	986	979
20%	1,026	1,048	1,069	1,117	1,189	1,247	1,226	1,169	1,146	1,091	1,048	1,027
30%	1,081	1,076	1,144	1,198	1,256	1,304	1,287	1,277	1,233	1,185	1,124	1,098
40%	1,137	1,143	1,183	1,256	1,309	1,355	1,365	1,326	1,302	1,253	1,185	1,157
50%	1,175	1,176	1,247	1,297	1,379	1,453	1,410	1,435	1,434	1,344	1,247	1,192
60%	1,221	1,242	1,300	1,353	1,451	1,555	1,598	1,510	1,493	1,409	1,314	1,249
70%	1,282	1,297	1,366	1,457	1,571	1,638	1,646	1,556	1,532	1,444	1,343	1,297
80%	1,316	1,360	1,461	1,593	1,688	1,690	1,690	1,640	1,631	1,618	1,472	1,356
90%	1,524	1,482	1,565	1,690	1,690	1,690	1,705	1,729	1,792	1,814	1,683	1,590
Maximum	1,660	1,690	1,690	1,690	1,690	1,690	1,713	1,874	1,943	1,910	1,790	1,700
Average	1,196	1,202	1,263	1,333	1,395	1,439	1,440	1,408	1,402	1,352	1,271	1,223

Table F.1.3-8f. WSE Results for New Don Pedro Reservoir Water Surface Elevations (feet MSL) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	New Don Pedro Reservoir Elevation (feet mean sea level)											
Minimum	679	678	689	713	712	715	714	706	693	686	681	680
10%	717	717	722	726	735	740	738	734	728	724	720	719
20%	726	729	732	739	748	755	753	745	742	735	729	726
30%	734	733	742	749	756	762	760	759	753	747	739	736
40%	741	742	747	756	763	768	769	765	762	756	747	744
50%	746	746	755	761	771	779	774	777	777	767	755	748
60%	752	755	762	768	779	790	794	785	783	774	763	755
70%	759	761	769	779	791	798	799	790	787	778	767	761
80%	763	769	780	793	803	803	803	798	797	796	781	768
90%	786	782	791	803	803	803	805	807	813	815	802	793
Maximum	800	803	803	803	803	803	805	820	826	823	812	804
Average	747	748	755	764	771	776	776	772	771	765	756	750

Table F.1.3-8g shows the monthly cumulative distributions for the Tuolumne River target flows at Modesto for LSJR Alternative 4. Target flows are the flows specified for the downstream ends of the river in the absence of flood control releases. Comparison to the baseline indicates that the average monthly target flows for LSJR Alternative 4 increased slightly from July–November (as a result of adaptive implementation flow shifting) and remained unchanged during December and January. From February through June, the average monthly target flows were higher under the alternative compared to baseline because of the unimpaired flow requirement. The greatest increase came in May when the average target flow increased from 1,106 cfs under baseline to 4,209 cfs under the alternative.

Table F.1.3-8g. Tuolumne River Target Flows (cfs) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Tuolumne Target Flow (cfs)											
Minimum	199	206	71	208	235	338	797	1,034	366	194	187	166
10%	290	246	251	316	525	826	1,605	2,081	903	262	277	256
20%	395	324	319	417	650	1,130	1,877	2,842	1,369	319	346	334
30%	463	389	399	434	756	1,249	2,221	3,371	2,227	364	369	366
40%	499	452	430	479	907	1,388	2,458	3,696	2,889	403	403	381
50%	552	472	445	524	1,247	1,542	2,617	4,332	3,287	483	428	425
60%	681	562	496	572	1,448	1,674	2,836	4,550	3,993	582	586	574
70%	742	926	581	602	1,623	1,968	3,042	5,091	4,390	698	600	697
80%	1,000	1,000	602	648	2,493	2,338	3,309	5,258	5,031	1,200	600	1,000
90%	1,000	1,000	655	757	3,269	3,106	3,827	6,095	5,673	1,200	638	1,000
Maximum	1,171	1,530	1,405	2,411	6,382	5,305	6,281	8,816	9,946	1,200	760	1,000
Average	633	609	479	560	1,535	1,791	2,677	4,209	3,410	637	471	573

Table F.1.3-8h shows the monthly cumulative distributions for the WSE-calculated Tuolumne River flows at Modesto for LSJR Alternative 4. The cumulative distributions of monthly flows were higher than the target flows in some months, indicating that flood control releases were sometimes required. However, only about 29 percent of years had flood control releases under LSJR Alternative 4 compared to 66 percent of years under baseline.

Table F.1.3-8h. Tuolumne River Flows at Modesto (cfs) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
							Tuolumne at Modesto Flow (cfs)						
Minimum	199	206	217	208	235	338	797	1,034	366	194	187	166	319
10%	290	246	257	316	525	826	1,605	2,081	903	262	277	256	594
20%	395	324	322	427	650	1,130	1,877	2,842	1,369	319	346	334	739
30%	463	389	402	443	772	1,255	2,221	3,371	2,227	364	369	366	805
40%	499	452	431	518	971	1,413	2,458	3,696	2,889	403	403	381	913
50%	552	472	450	549	1,296	1,615	2,652	4,359	3,287	483	428	425	1,088
60%	681	562	518	595	1,712	1,928	2,937	4,684	3,993	582	586	574	1,256
70%	742	926	589	639	2,488	2,846	3,197	5,107	4,390	698	600	697	1,384
80%	1,000	1,000	611	748	3,291	3,544	3,545	5,338	5,031	1,200	600	1,000	1,588
90%	1,000	1,000	679	2,200	3,963	4,421	4,105	6,355	5,673	1,200	652	1,000	1,916
Maximum	3,090	5,440	7,479	17,925	6,917	16,297	9,332	8,816	9,946	5,424	2,123	2,296	4,131
Average	661	677	664	1,142	1,963	2,420	2,861	4,268	3,410	795	504	601	1,202

Stanislaus River

Table F.1.3-8i shows the monthly cumulative distributions for the WSE-calculated New Melones Reservoir storage (TAF) for LSJR Alternative 4. These monthly storage patterns differ from baseline storage patterns because the timing and magnitude of releases for instream flow requirements and diversions are different. The median carryover storage was 1,026 TAF, about 98 TAF lower than the baseline median carryover storage of 1,124 TAF. Table F.1.3-8j shows the monthly cumulative distributions for the WSE-calculated New Melones Reservoir water surface elevations (feet MSL) for LSJR Alternative 4. The median September reservoir elevation was 946 TAF under the alternative, slightly lower than the baseline median September elevation of 961 TAF.

Table F.1.3-8i. WSE Results for New Melones Reservoir Storage (TAF) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Melones Reservoir Storage (TAF)												
Minimum	599	601	603	719	744	757	714	656	642	627	615	613
10%	782	783	803	850	888	909	862	843	833	808	795	802
20%	834	853	872	916	940	951	919	880	898	883	858	857
30%	900	912	937	960	988	999	1,001	972	999	966	946	936
40%	944	962	997	1,037	1,087	1,121	1,097	1,062	1,065	1,031	996	974
50%	968	994	1,036	1,101	1,145	1,190	1,185	1,158	1,139	1,078	1,039	1,026
60%	1,034	1,064	1,109	1,202	1,241	1,265	1,242	1,250	1,232	1,181	1,098	1,072
70%	1,117	1,157	1,211	1,277	1,330	1,357	1,358	1,351	1,350	1,254	1,202	1,182
80%	1,250	1,263	1,299	1,444	1,509	1,526	1,524	1,512	1,486	1,415	1,328	1,294
90%	1,449	1,469	1,518	1,591	1,646	1,720	1,764	1,776	1,749	1,630	1,545	1,503
Maximum	1,970	1,970	1,970	1,970	1,970	2,030	2,065	2,011	2,133	2,232	2,130	2,000
Average	1,048	1,067	1,110	1,174	1,216	1,250	1,233	1,208	1,201	1,161	1,113	1,087

Table F.1.3-8j. WSE Results for New Melones Reservoir Water Surface Elevations (feet MSL) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
New Melones Reservoir Elevation (feet mean sea level)												
Minimum	867	867	867	893	898	900	892	880	877	873	870	870
10%	905	905	909	918	924	928	920	916	915	910	908	909
20%	915	918	921	929	933	935	929	923	926	923	919	919
30%	926	928	932	936	940	942	942	938	942	937	934	932
40%	933	936	942	948	955	960	957	952	952	947	942	938
50%	937	941	948	957	963	969	969	965	963	954	948	946
60%	947	952	958	971	976	979	976	977	975	968	957	953
70%	959	965	972	981	987	990	991	990	990	978	971	968
80%	977	979	983	1,001	1,008	1,010	1,009	1,008	1,005	997	987	983
90%	1,001	1,003	1,009	1,017	1,022	1,030	1,034	1,035	1,032	1,021	1,012	1,007
Maximum	1,053	1,053	1,053	1,053	1,053	1,058	1,061	1,056	1,066	1,074	1,066	1,055
Average	946	949	955	963	969	973	971	967	966	961	955	952

Table F.1.3-8k shows the monthly cumulative distributions for the WSE-calculated Stanislaus River target flows at Ripon for LSJR Alternative 4. Comparison to the baseline indicates that the average monthly target flows under LSJR Alternative 3 remained mostly unchanged from July to February (except in October), with some differences because of changes in the NMI under the alternative. October targets were higher as a result of adaptive implementation flow shifting in order to control potential temperature effects during summer and fall. From February to June, the average monthly target flows were generally higher than under baseline. The greatest increase came in May when the average target flow increased from 1,328 cfs under baseline to 2,617 cfs under the alternative.

Table F.1.3-8k. Stanislaus River Target Flows (cfs) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Stanislaus Target Flow (cfs)												
Minimum	763	213	94	122	230	358	516	464	221	205	208	174
10%	800	248	225	267	325	463	1,001	922	389	298	279	293
20%	1,000	260	243	294	391	664	1,263	1,545	572	324	348	343
30%	1,000	267	263	312	479	770	1,540	1,764	931	356	365	372
40%	1,000	292	280	324	594	902	1,735	2,232	1,214	385	403	394
50%	1,113	318	288	336	767	1,000	1,902	2,631	1,548	423	413	419
60%	1,200	335	305	345	1,049	1,187	2,032	3,041	1,899	526	462	463
70%	1,200	347	320	362	1,167	1,492	2,130	3,295	2,103	657	500	700
80%	1,400	378	357	396	1,382	1,854	2,341	3,525	2,422	800	500	800
90%	1,400	442	411	503	2,113	2,215	2,659	4,141	3,139	827	578	800
Maximum	1,409	732	1,071	884	5,747	3,973	4,222	5,687	6,313	1,867	732	887
Average	1,121	325	321	359	1,047	1,249	1,880	2,617	1,690	547	430	507

Table F.1.3-8l shows the monthly cumulative distributions for the WSE-calculated Stanislaus River flows at Ripon for LSJR Alternative 4. Under LSJR Alternative 4, only about 4 percent of the years required flood control releases from New Melones Reservoir.

Table F.1.3-8l. Stanislaus River Flows at Ripon (cfs) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Stanislaus at Ripon Flow (cfs)													
Minimum	763	213	94	122	230	358	516	464	221	205	208	174	258
10%	800	248	225	267	325	463	1,001	922	389	298	279	293	392
20%	1,000	260	243	295	391	664	1,263	1,545	572	324	348	343	496
30%	1,000	267	263	314	479	770	1,540	1,764	931	356	365	372	540
40%	1,000	292	280	325	594	902	1,735	2,232	1,214	385	403	394	652
50%	1,113	318	288	339	767	1,000	1,902	2,631	1,548	423	413	419	725
60%	1,200	335	305	347	1,096	1,187	2,032	3,041	1,899	526	462	463	806
70%	1,200	347	320	364	1,182	1,492	2,130	3,295	2,103	657	500	700	896
80%	1,400	378	357	405	1,731	1,854	2,341	3,525	2,422	800	500	800	947
90%	1,400	442	411	526	2,250	2,215	2,659	4,141	3,139	827	578	800	1,166
Maximum	1,538	3,453	5,126	6,009	5,747	6,223	4,222	5,687	6,313	1,867	1,560	3,050	2,162
Average	1,122	361	377	482	1,127	1,277	1,880	2,617	1,690	547	440	534	750

SJR at Vernalis

Table F.1.3-8m shows the monthly cumulative distributions for the WSE-calculated SJR at Vernalis flows for LSJR Alternative 4. The average Vernalis flows for LSJR Alternative 4 were much higher than the baseline flows from February–June. LSJR Alternative 4 provided a more natural distribution of flows from February–June. The average annual flow volume was 693 TAF more than the average annual baseline flow volume at Vernalis (19 percent higher).

Table F.1.3-8m. SJR Flows at Vernalis (cfs) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
SJR at Vernalis Flow (cfs)													
Minimum	1,539	1,233	1,238	1,146	1,526	1,124	1,716	2,195	1,000	525	579	955	1,043
10%	2,000	1,566	1,513	1,480	1,941	2,284	3,838	4,338	2,057	955	1,054	1,459	1,659
20%	2,220	1,696	1,657	1,698	2,335	3,162	4,736	6,294	2,953	1,111	1,248	1,688	2,131
30%	2,451	1,795	1,789	1,886	2,714	3,570	5,468	7,424	4,389	1,235	1,335	1,796	2,263
40%	2,571	1,906	1,884	2,113	3,141	3,901	6,456	8,671	5,814	1,439	1,414	1,872	2,600
50%	2,832	1,998	1,941	2,163	3,725	4,824	7,174	10,188	7,036	1,615	1,537	2,013	3,153
60%	3,066	2,170	2,035	2,352	6,588	6,296	7,755	11,785	8,244	1,853	1,758	2,180	3,591
70%	3,543	2,706	2,140	2,985	8,203	7,804	8,633	12,841	9,134	2,274	2,040	2,969	3,999
80%	3,925	3,173	2,447	3,531	9,884	9,802	9,864	13,664	11,222	3,278	2,337	3,393	4,851
90%	4,020	3,434	3,024	7,772	14,782	13,521	13,926	19,299	14,257	4,450	2,958	3,543	6,312
Maximum	6,343	16,297	24,021	58,041	34,271	48,485	28,647	31,045	34,035	16,706	7,165	7,677	15,552
Average	3,003	2,523	2,791	4,285	6,847	7,225	8,162	11,127	7,940	2,644	1,837	2,388	3,658

F.1.4 Comparison of the Cumulative Distributions of Monthly Flows

The WSE model has been used to estimate the monthly flow in the three eastside tributary rivers and at SJR at Vernalis under baseline conditions and 20, 40, and 60 percent unimpaired flow, which represent typical conditions for LSJR Alternatives 2, 3, and 4. As described above, the calculated monthly flows for the 82-year period (water years 1922–2003) are summarized in tables showing monthly cumulative distributions of flows in 10^{th} percentile increments. These monthly cumulative distributions for LSJR Alternatives 2, 3, and 4 can be graphed and compared to the monthly cumulative distributions of baseline flows. This allows the overall effects of the LSJR alternatives to be summarized and compared for each month. The monthly cumulative distributions of flows provide a good summary of the range of flows that would be observed over a number of years. These graphs summarize the probability of future monthly flow conditions under LSJR Alternatives 2, 3, and 4.

The differences between the monthly cumulative distributions of flows for the LSJR alternatives and baseline conditions provide a summary of the general monthly flow changes. Although the WSE model simulates some relatively large increases or decreases in the monthly river flows, these individual monthly changes would generally balance one another over the 82-year sequence, resulting in smaller shifts in the cumulative distributions of flows for each month or for the seasonal flow volume distribution. The comparison of monthly cumulative distributions of flows, rather than the individual monthly changes in flow, provides an appropriate measure of hydrologic changes resulting from the LSJR alternatives.

F.1.4.1 Merced River Flows

The monthly cumulative distributions for February–June flow (TAF) for LSJR Alternatives 2, 3, and 4 provide an overall summary of the February–June changes in flow compared to baseline conditions. Table F.1.4-1 gives the cumulative distribution values for the February–June flow volumes (TAF) on the Merced River. A flow volume of 60 TAF corresponds to a 5-month average flow of about 200 cfs; a flow volume of 150 TAF corresponds to an average flow of 500 cfs; a flow volume of 300 TAF corresponds to an average flow of 1,000 cfs.

Figure F.1.4-1a shows the Merced River cumulative distributions of the February–June flow volume (TAF) for baseline conditions and the LSJR alternatives for the 82-year period 1922–2003At most flow levels, the unimpaired flow simulations resulted in higher Merced River flows at Stevinson, with flows increasing incrementally as the percent of unimpaired flow increased. Above the 90^{th} percentile (high-flow years with flood control releases), there was very little difference between baseline conditions and the unimpaired flow simulations. Flow distributions for the 30 percent and 50 percent unimpaired flow simulations, which are not shown in this graph, were intermediate between the 20 percent and 40 percent unimpaired flow simulations and the 40 percent and 60 percent unimpaired flow simulations, respectively (Table F.1.4-1).

Table F.1.4-1. Cumulative Distributions of February–June River Flow Volumes (TAF) in the Merced River at Stevinson for Baseline Conditions and the Percent Unimpaired Flow Simulations (20%–60%)

		Percent Unimpaired Flow				
Percentile	Baseline	20%	30%	40%	50%	60%
0	46	71	72	81	92	104
10	70	90	110	138	168	198
20	79	112	147	184	226	265
30	92	120	158	200	243	286
40	104	140	187	237	290	346
50	135	181	239	270	325	388
60	160	202	269	331	390	465
70	234	255	311	356	431	520
80	367	373	394	388	483	574
90	588	574	587	602	625	669
100	1,290	1,290	1,290	1,290	1,290	1,341

Figures F.1.4-1b, F.1.4-1c, F.1.4-1d, F.1.4-1e, and F.1.4-1f show the cumulative distributions of Merced River flow at Stevinson for February–June. During February, the Merced River flows were not as greatly modified by the LSJR alternatives as from March–June. This is in part because, under baseline conditions, Lake McClure is often near the maximum storage allowed for this month and much of the runoff must be released. The March and April Merced River flows were generally higher for 40 percent and 60 percent unimpaired flow than under baseline conditions. In May and June, the flows with all unimpaired flow objectives were substantially higher than under baseline conditions.

From July–January, LSJR alternatives had slightly different flows than under baseline conditions. Some of the reasons why flows may differ from baseline are listed below.

- Flood releases may be altered due to differences in reservoir storage, resulting in more or less release for flood control.
- A portion of the February–June unimpaired flow requirement for the 40, 50, and 60 percent unimpaired flow simulations can be retained for release in July–November.

Figures F.1.4-1g, F.1.4-1h, F.1.4-1i, F.1.4-1j, F.1.4-1k, F.1.4-1l, and F.1.4-1m show the cumulative distributions of Merced River flow at Stevinson from July–January. Flow differences between alternatives during these months occurred only at flow levels higher than the median flows.

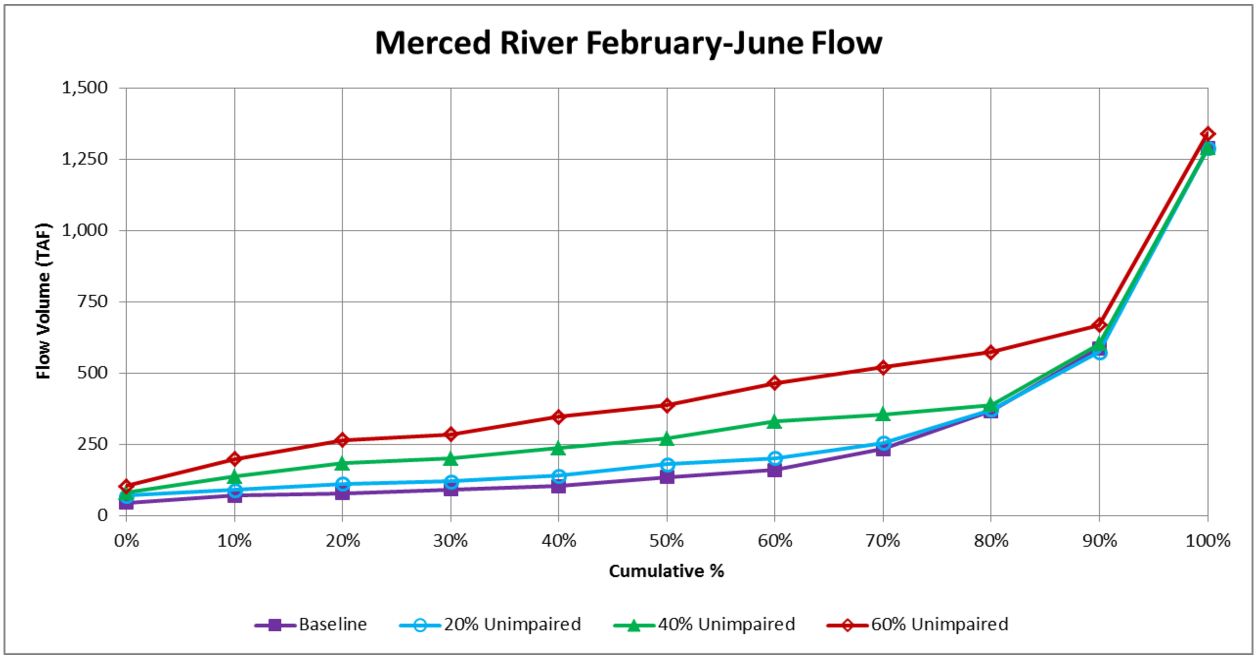


Figure F.1.4-1a. WSE-Simulated Cumulative Distributions of Merced River February–June Flow Volumes (TAF) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

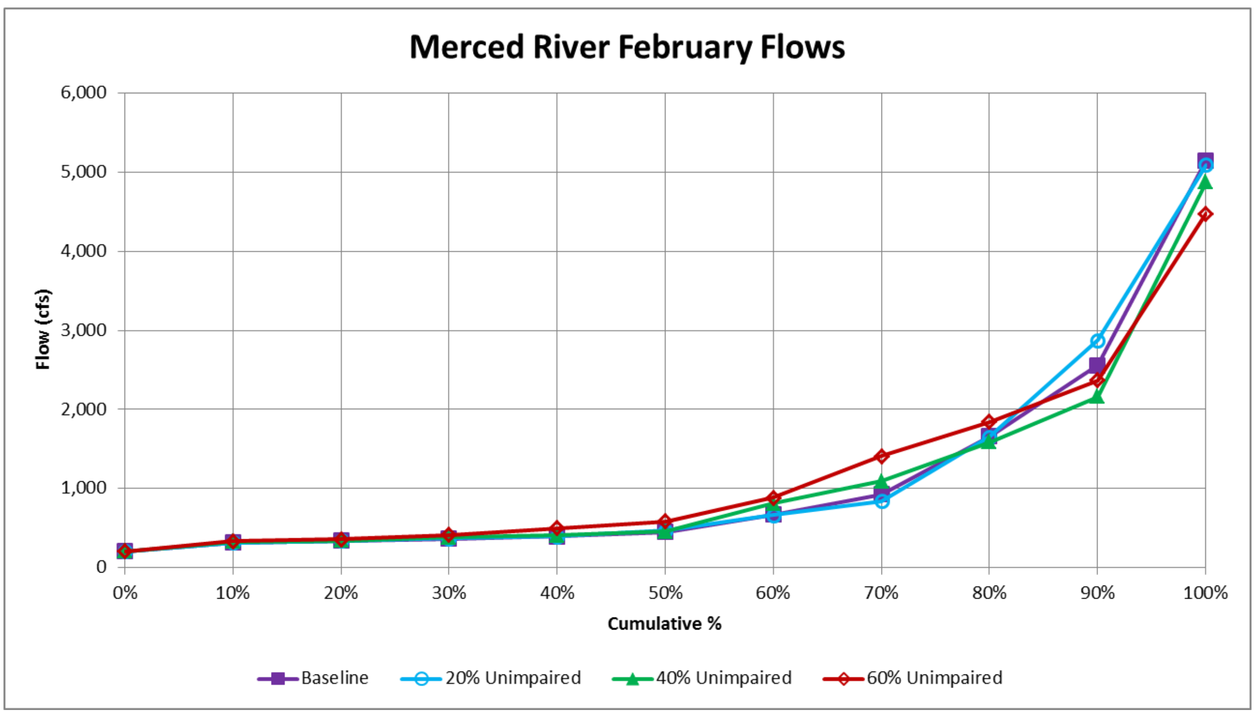


Figure F.1.4-1b. WSE-Simulated Cumulative Distributions of Merced River February Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

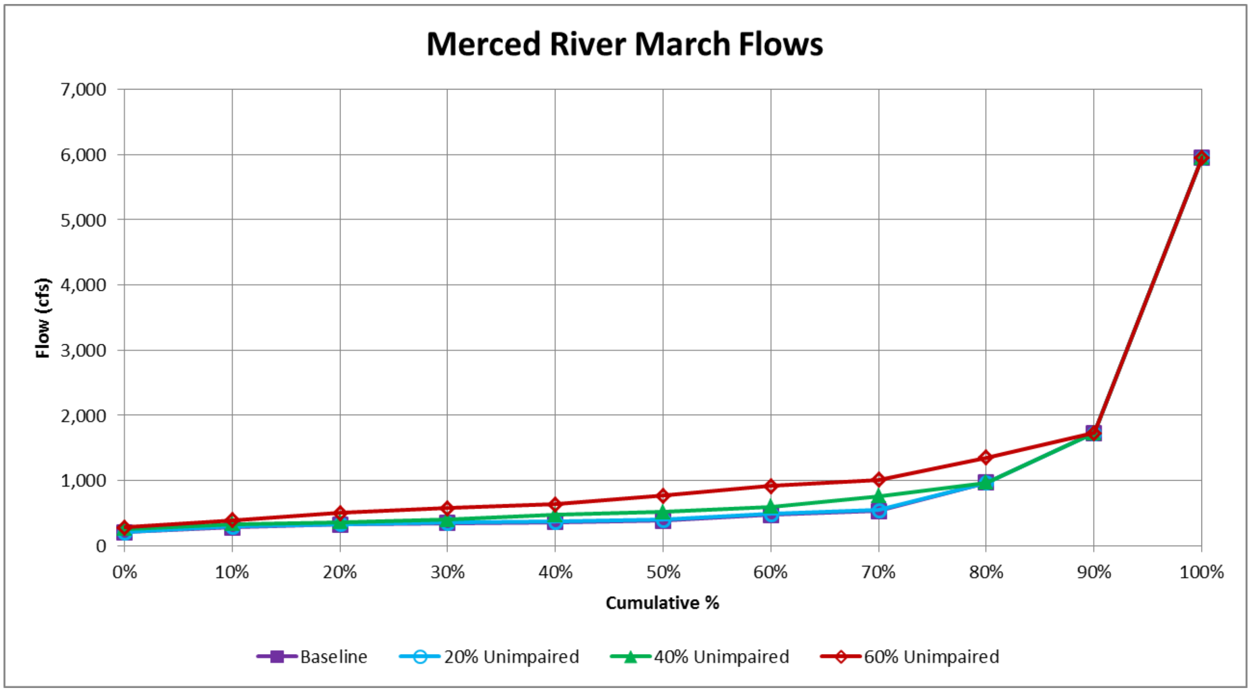


Figure F.1.4-1c. WSE-Simulated Cumulative Distributions of Merced River March Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

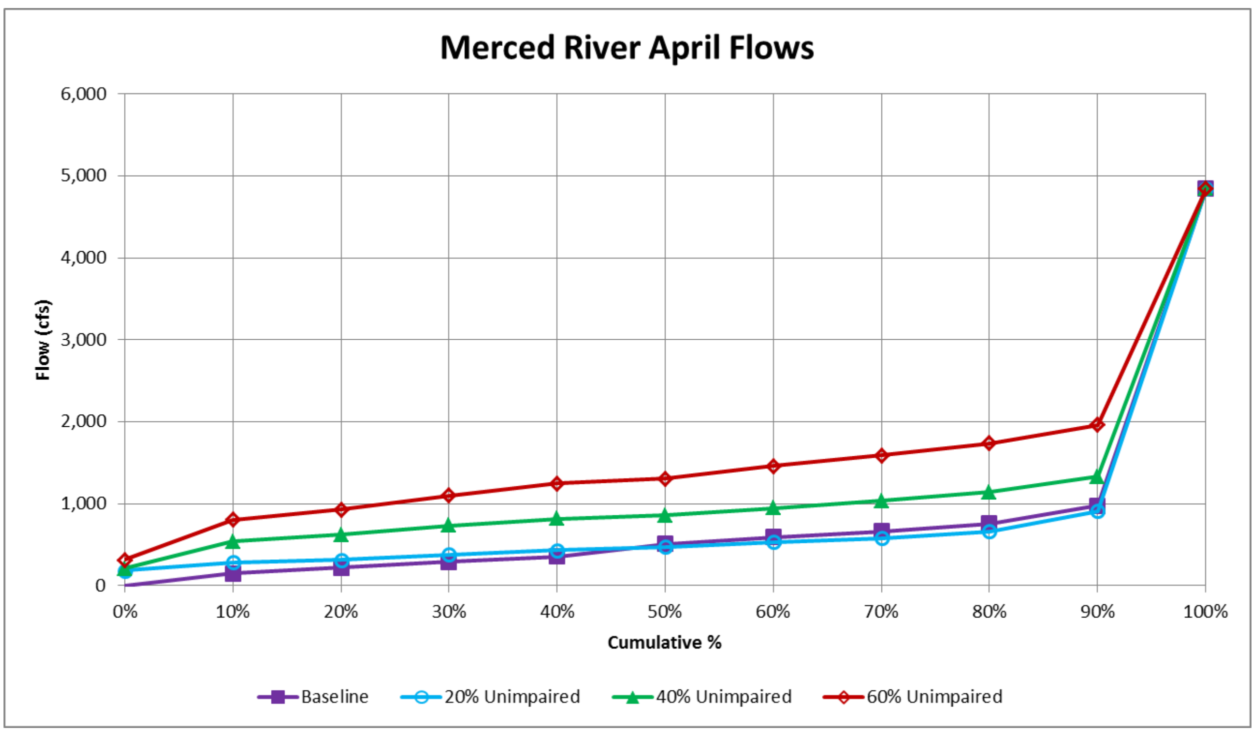


Figure F.1.4-1d. WSE-Simulated Cumulative Distributions of Merced River April Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

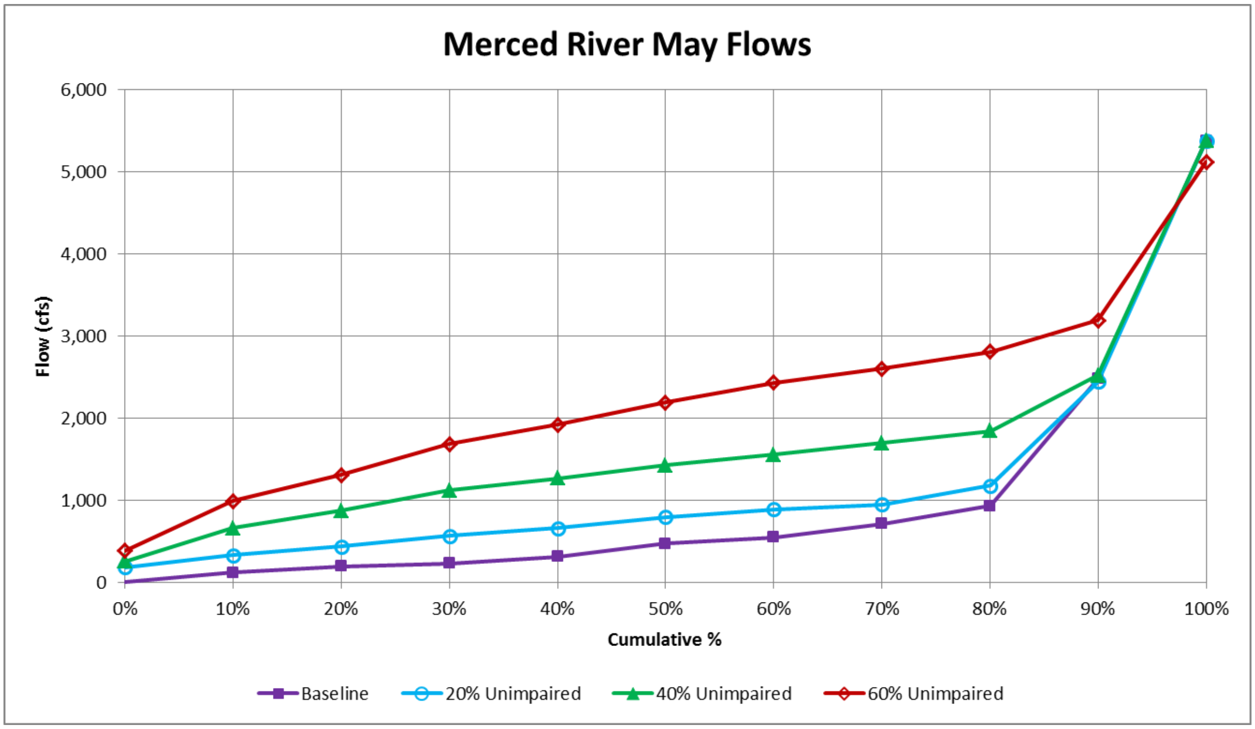


Figure F.1.4-1e. WSE-Simulated Cumulative Distributions of Merced River May Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

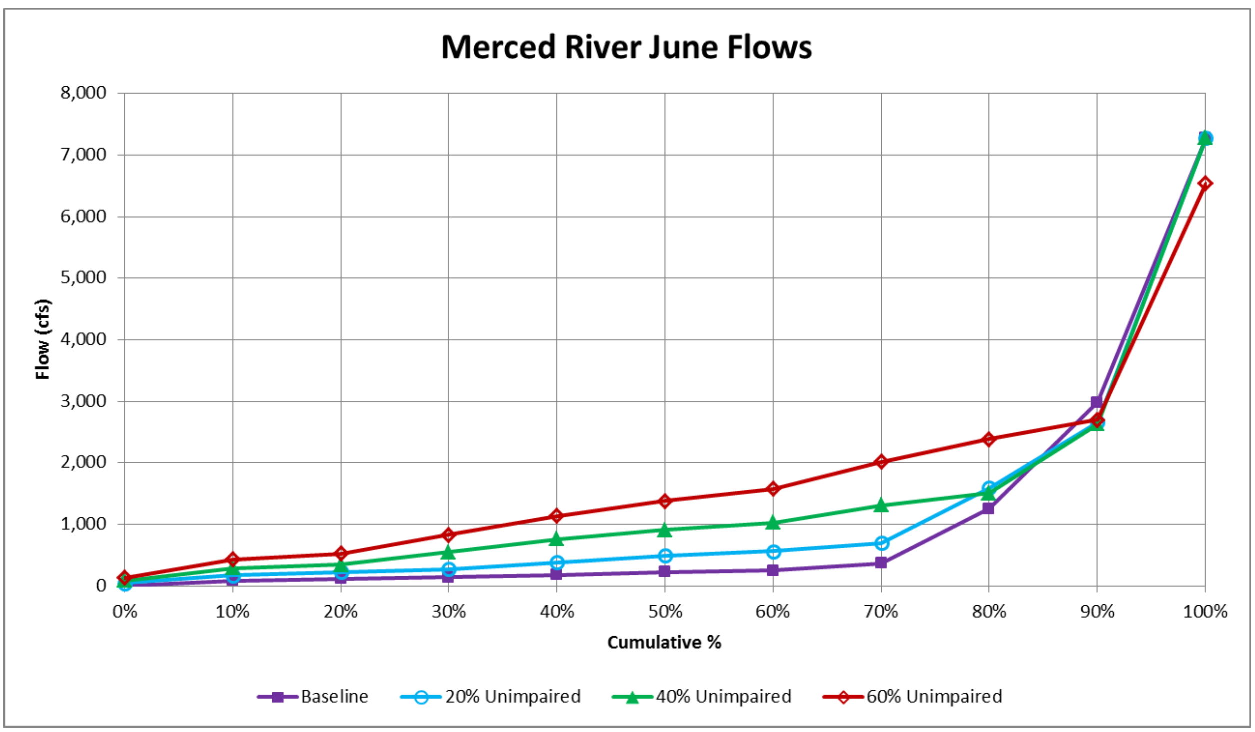


Figure F.1.4-1f. WSE-Simulated Cumulative Distributions of Merced River June Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

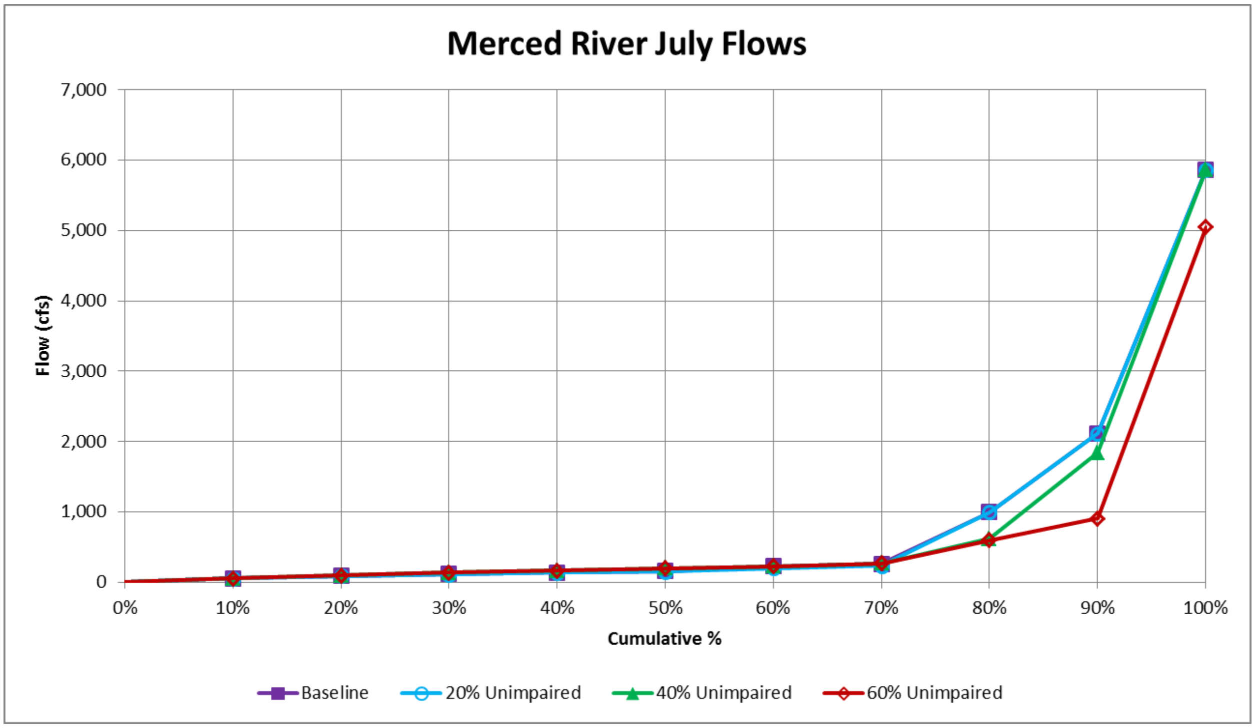


Figure F.1.4-1g. WSE-Simulated Cumulative Distributions of Merced River July Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

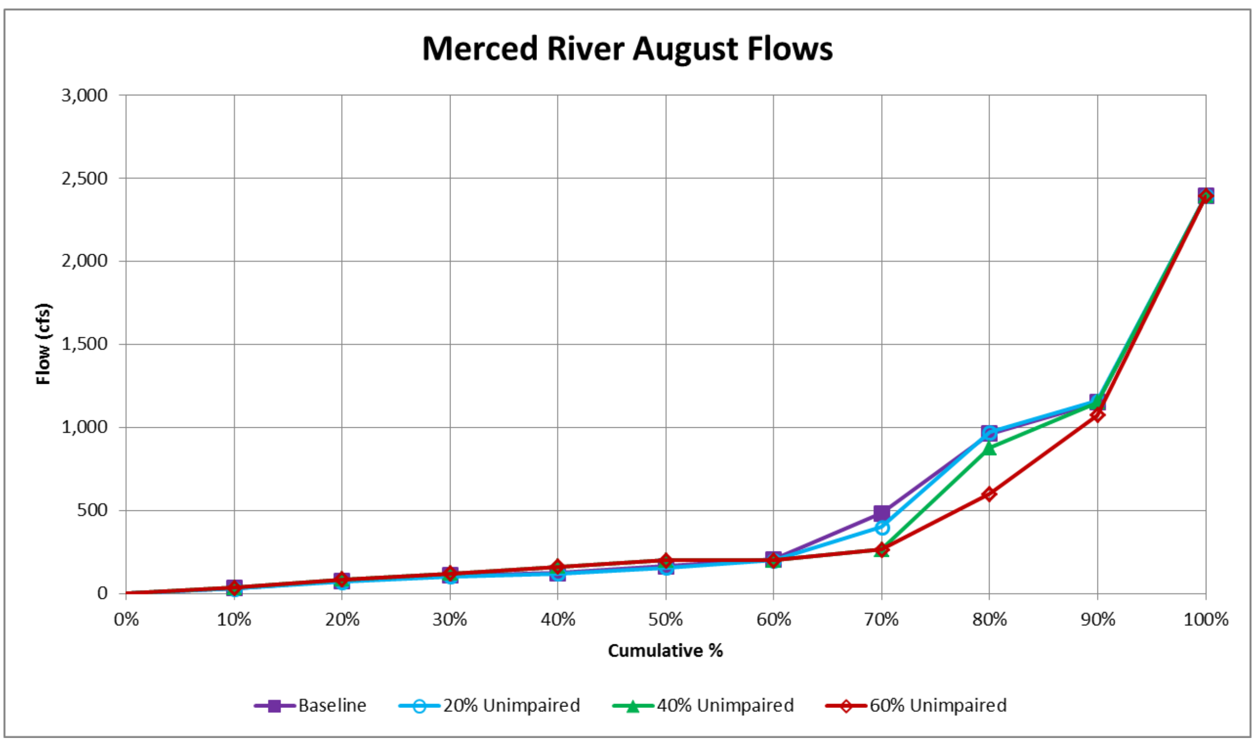


Figure F.1.4-1h. WSE-Simulated Cumulative Distributions of Merced River August Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

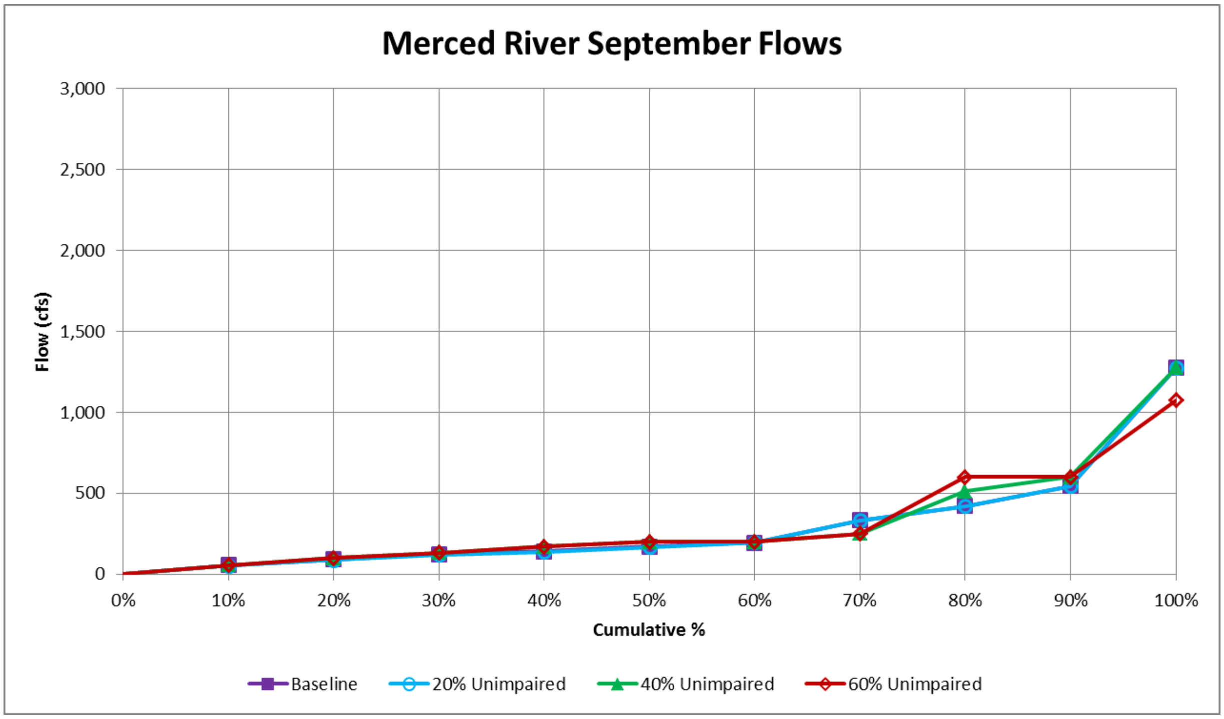


Figure F.1.4-1i. WSE-Simulated Cumulative Distributions of Merced River September Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

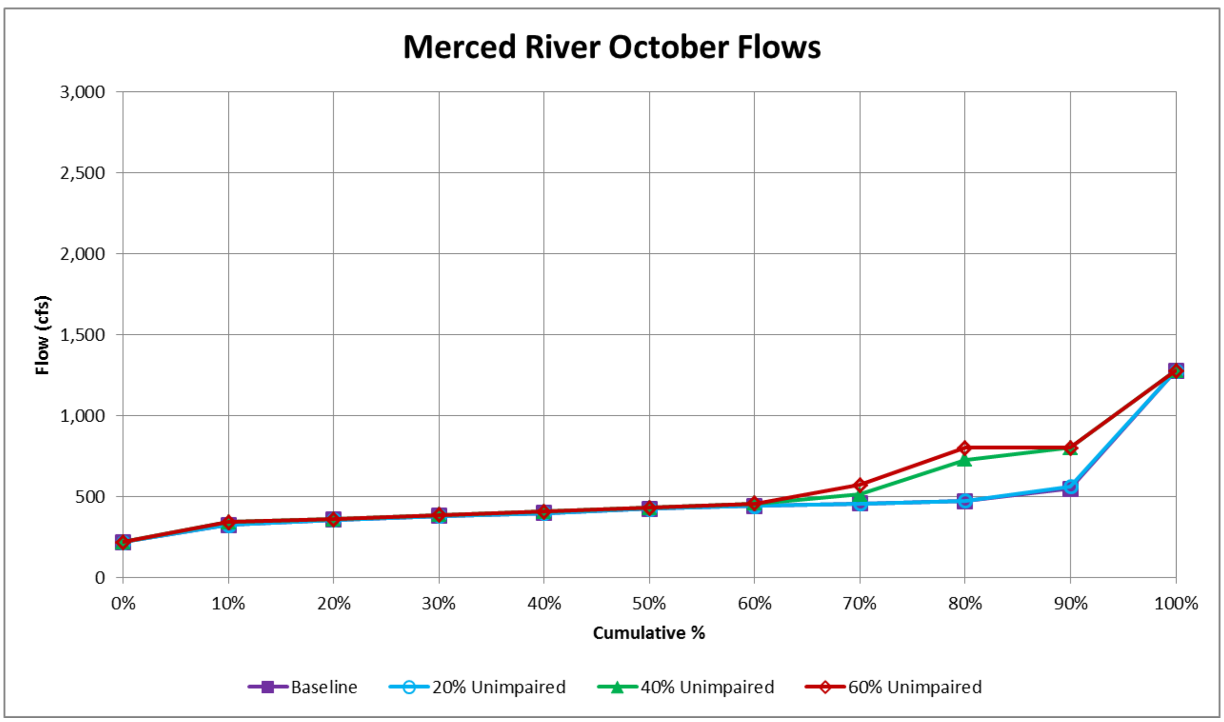


Figure F.1.4-1j. WSE-Simulated Cumulative Distributions of Merced River October Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

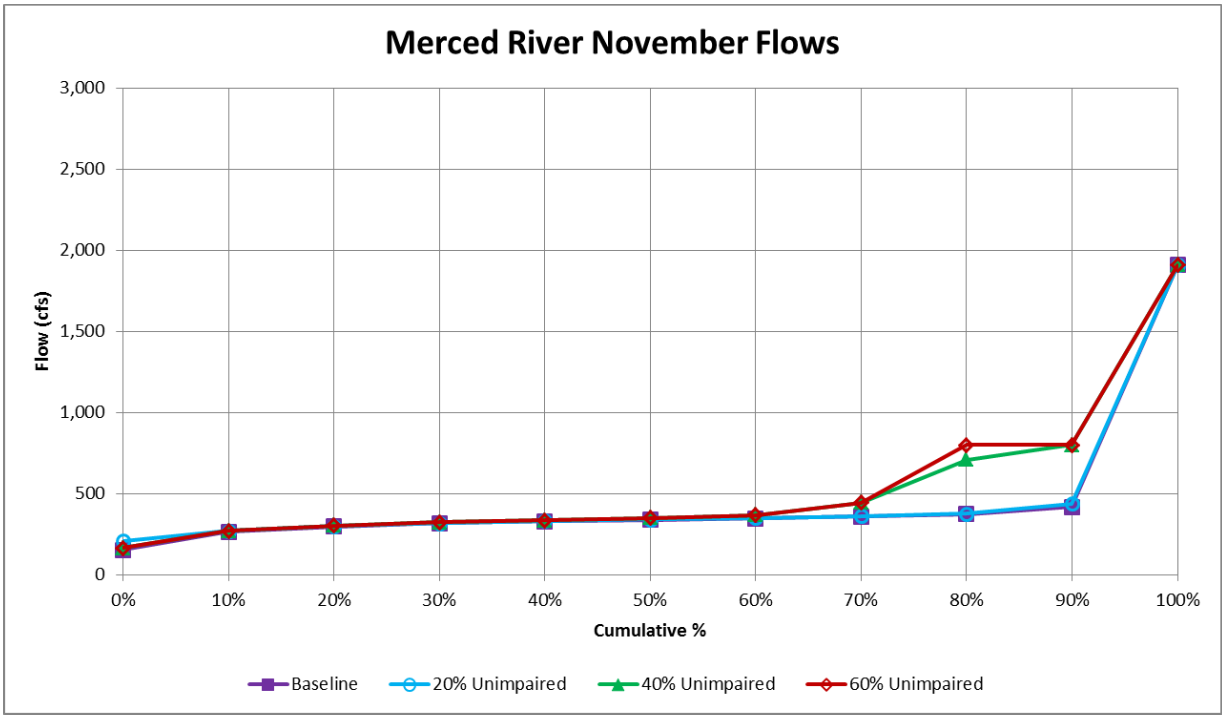


Figure F.1.4-1k. WSE-Simulated Cumulative Distributions of Merced River November Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

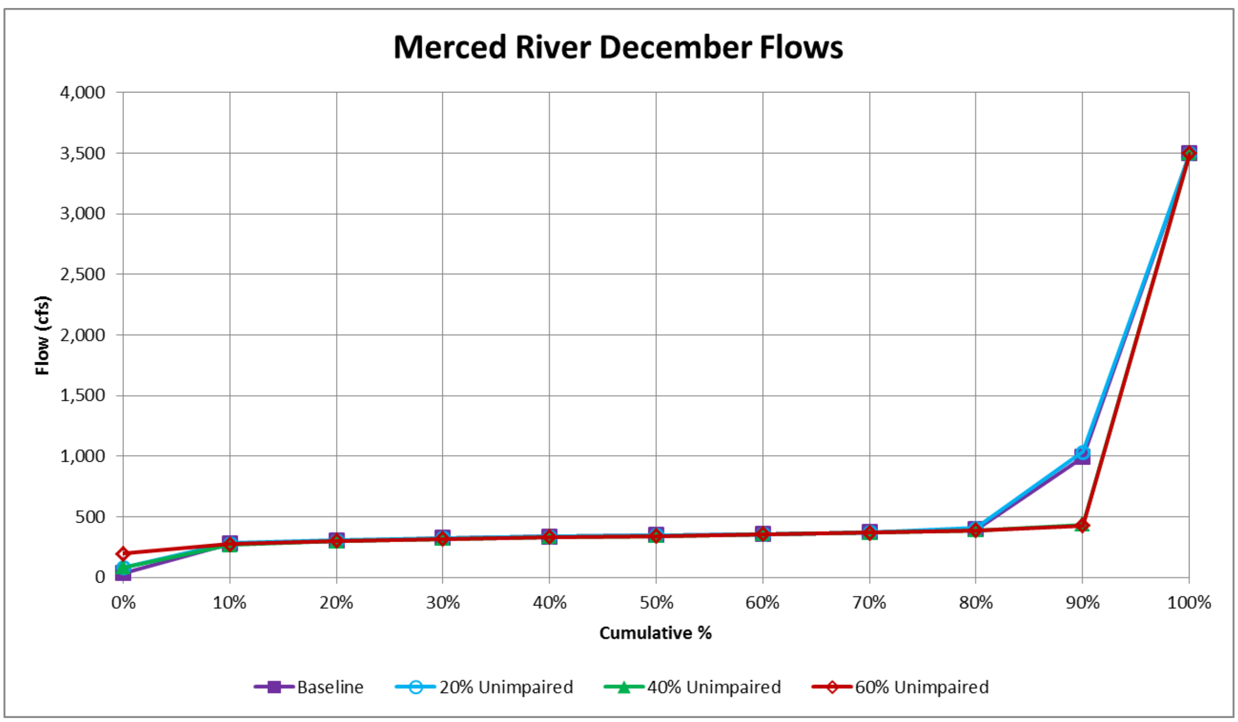


Figure F.1.4-1l. WSE-Simulated Cumulative Distributions of Merced River December Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

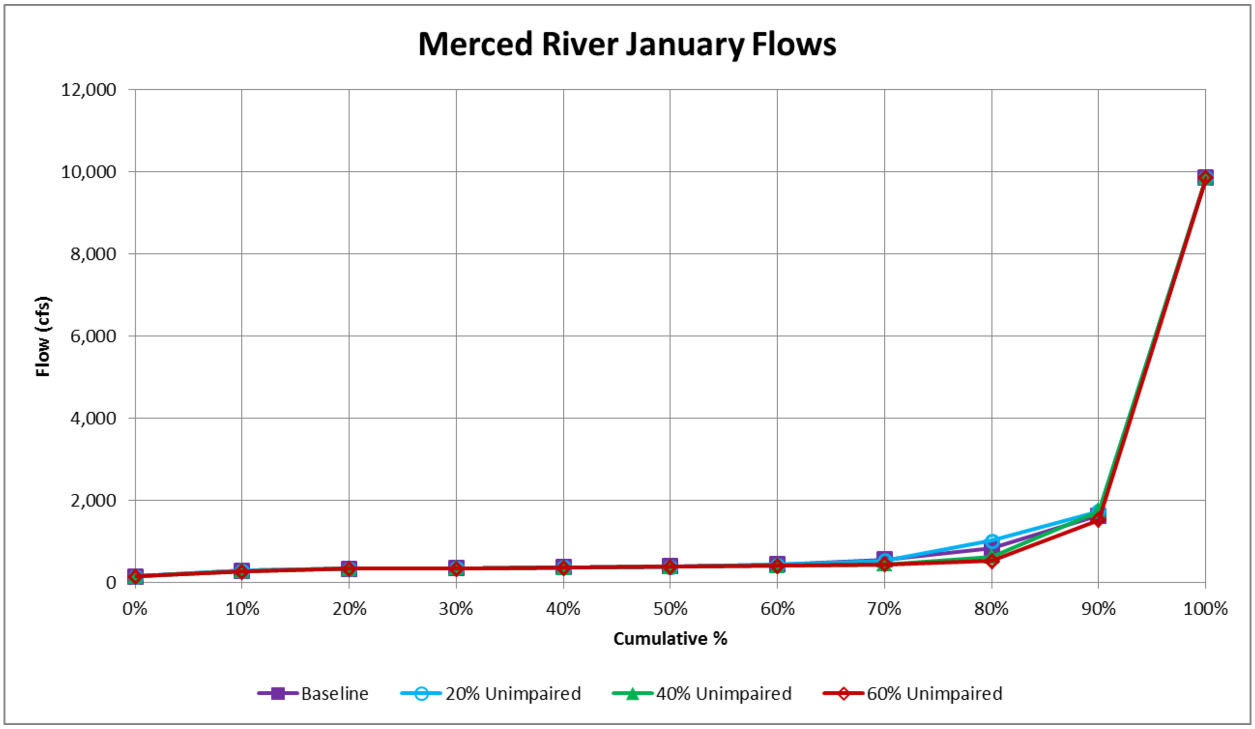


Figure F.1.4-1m. WSE-Simulated Cumulative Distributions of Merced River January Flows (cfs) at Stevinson for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

F.1.4.2 Tuolumne River Flows

The monthly cumulative distributions for February–June flow (TAF) for the Tuolumne River provide an overall summary of the February–June changes compared to baseline conditions. Table F.1.4-2 gives the cumulative distributions for the February–June flow volumes (TAF) on the Tuolumne River at Modesto.

Figure F.1.4-2a shows the cumulative distributions of the February–June Tuolumne River flow volumes (TAF) at Modesto for the 82-year simulation period 1922–2003. The LSJR Alternative 2 flows were slightly greater than the baseline flows, with a median flow volume of 334 TAF for baseline and 369 TAF for LSJR Alternative 2. The cumulative distributions of the LSJR Alternatives 3 and 4 flow volumes for February–June were progressively higher than baseline. The February–June flow volumes were dominated by flood control releases in the highest runoff years (90 to 100 percent cumulative distribution). Flow distributions for the 30 percent and 50 percent unimpaired flow simulations (which are not shown in this graph) were intermediate between the 20 percent and 40 percent unimpaired flow simulations and the 40 percent and 60 percent unimpaired flow simulations, respectively (Table F.1.4-2).

Table F.1.4-2. Cumulative Distributions of February–June River Flow Volumes (TAF) in the Tuolumne River at Modesto for Baseline Conditions and the Unimpaired Flow Simulations (20%–60%)

		Percent of Unimpaired Flow				
Percentile	Baseline	20%	30%	40%	50%	60%
0	99	115	126	154	183	212
10	139	168	212	274	341	405
20	161	218	294	379	465	539
30	206	268	346	406	500	595
40	279	324	393	484	603	714
50	334	369	480	631	770	861
60	549	578	656	696	833	994
70	717	768	810	805	898	1,033
80	900	900	962	1,007	1,041	1,216
90	1,204	1,204	1,175	1,131	1,226	1,368
100	2,410	2,410	2,481	2,565	2,667	2,768

Figures F.1.4-2b, F.1.4-2c, F.1.4-2d, F.1.4-2e, and F.1.4-2f show the cumulative distributions of Tuolumne River flow at Modesto from February–June. From February–April, the baseline and LSJR Alternative 2 flows were only slightly different. During these months, the flows for LSJR Alternatives 3 and 4 were incrementally higher than flows for baseline and LSJR Alternative 2 under most flow conditions except during higher runoff years. During higher runoff years, the flows for LSJR Alternatives 3 and 4 tended to be lower than flows for baseline conditions and LSJR Alternative 2 because more reservoir capacity was available.

Because unimpaired flow is particularly high during May and June due to snowmelt, the LSJR alternatives often resulted in particularly high flows during these months (e.g., a median May flow of 4,359 cfs for LSJR Alternative 4). During May and June, flows resulted in incrementally higher Tuolumne River flows at Modesto as the unimpaired flow objective increased under each alternative (LSJR Alternatives 2, 3, and 4).

In the modeling, from July–January, river and reservoir operations generally were the same under the LSJR alternatives as under baseline conditions. However, there were some differences. Figures F.1.4-2g, F.1.4-2h, F.1.4-2i, F.1.4-2j, F.1.4-2k, F.1.4-2l, and F.1.4-2m show the cumulative distributions of Tuolumne River flow at Modesto from July–January. All of the flow differences between the LSJR alternatives during these months occurred only at flow levels higher than the median flows. In July and January, LSJR Alternative 3 (January) and LSJR Alternative 4 (July and January), were not as affected by reservoir limits (due to lower reservoir storage), resulting in lower values for the highest flows (e.g., the 80^{th} to 100^{th} percentiles). In a few years during October and particularly November, some extra releases were made under LSJR Alternatives 3 and 4 using water reserved for temperature control purposes.

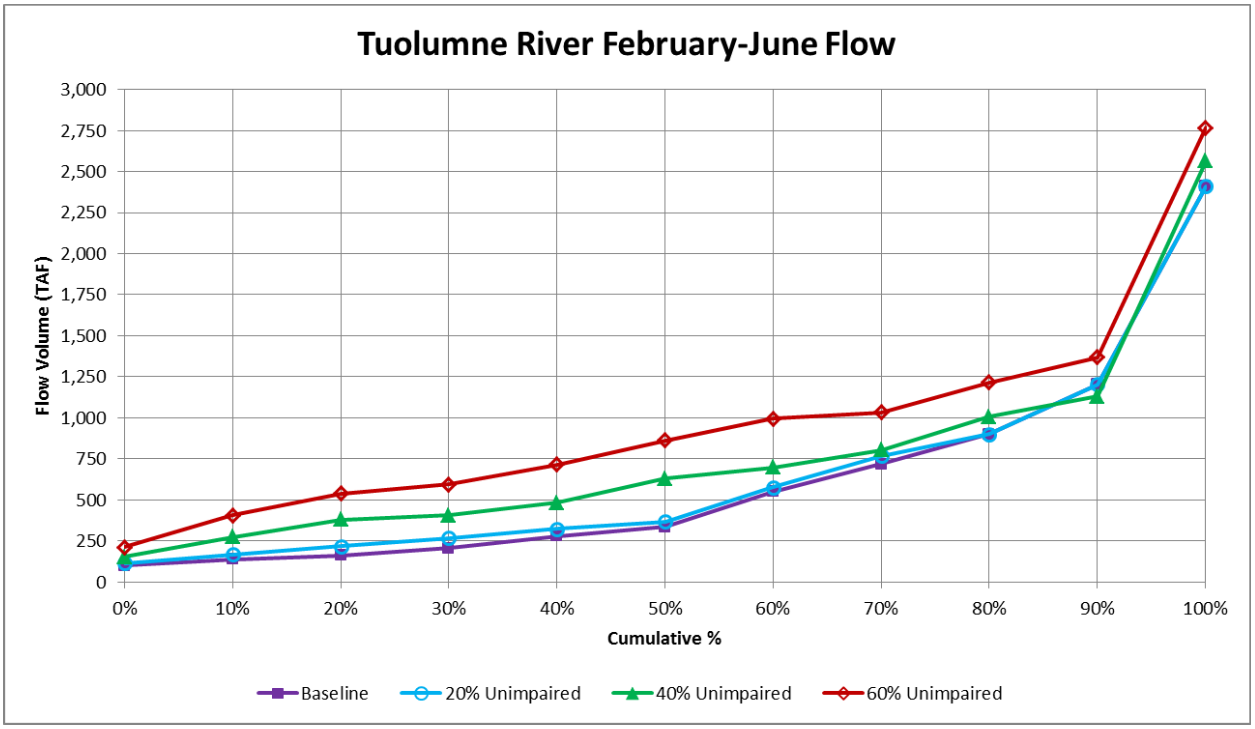


Figure F.1.4-2a. WSE-Simulated Cumulative Distributions of Tuolumne River February–June Flow Volumes (TAF) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

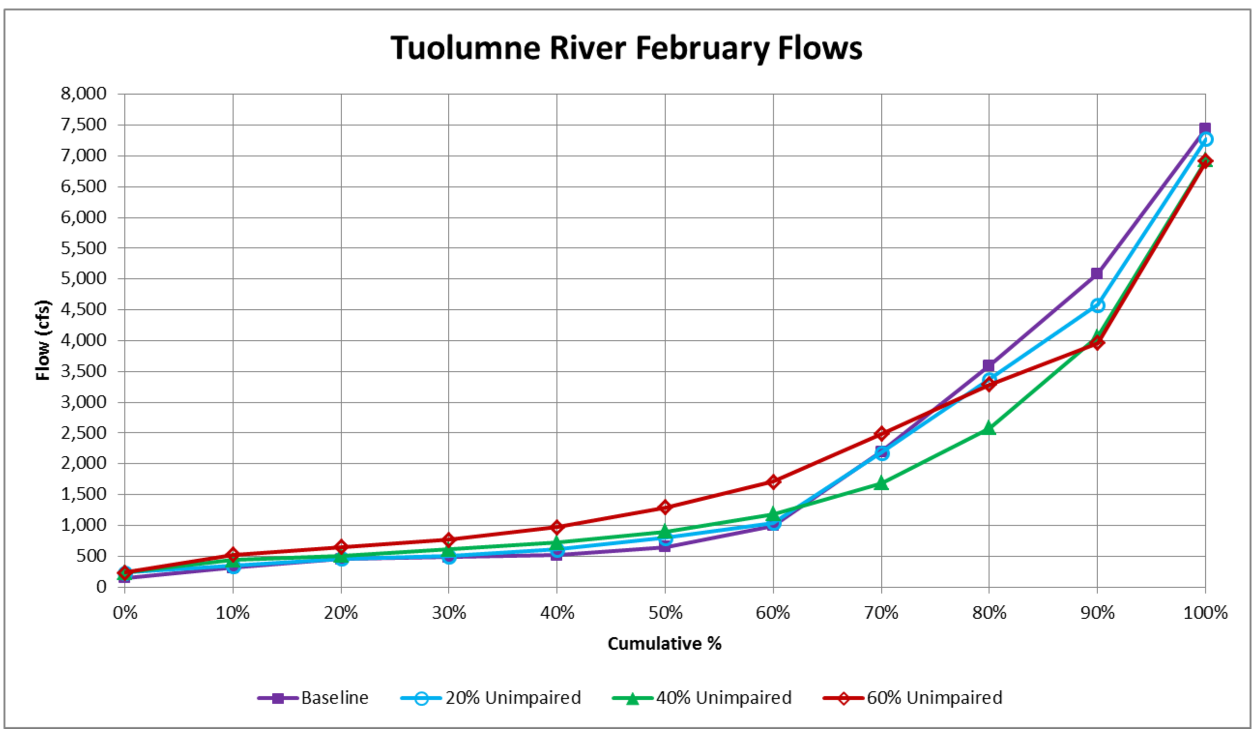


Figure F.1.4-2b. WSE-Simulated Cumulative Distributions of Tuolumne River February Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

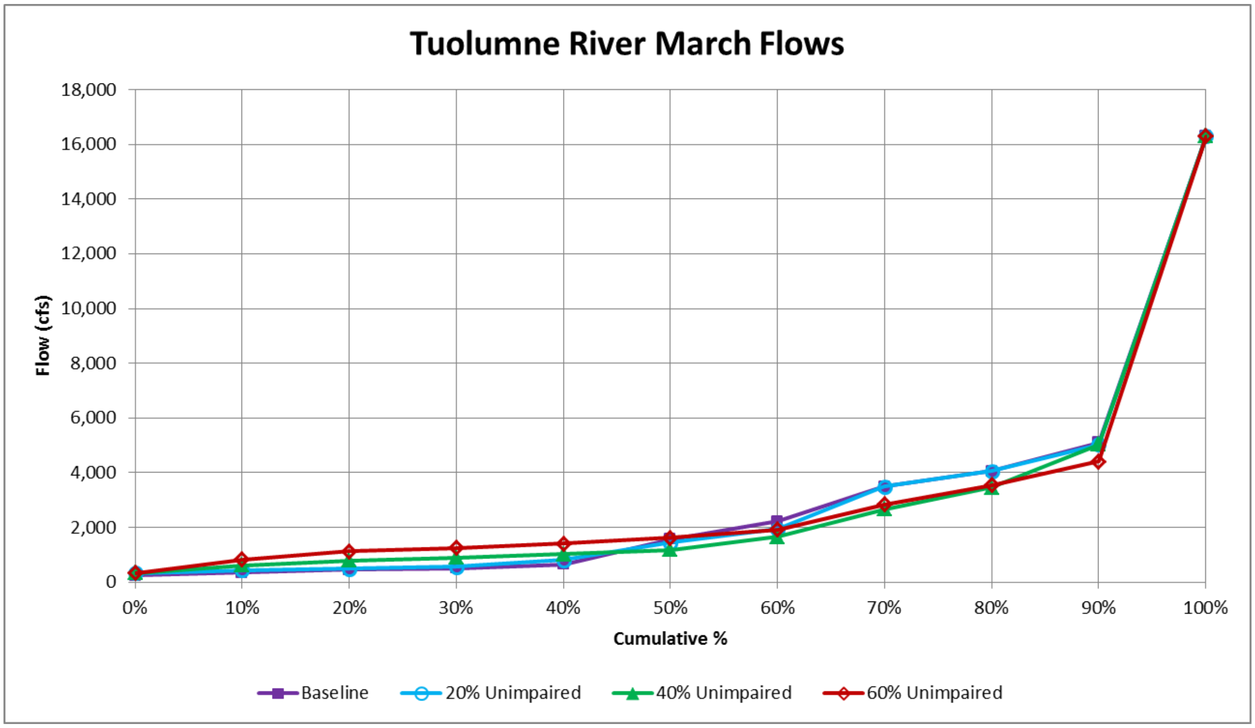


Figure F.1.4-2c. WSE-Simulated Cumulative Distributions of Tuolumne River March Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

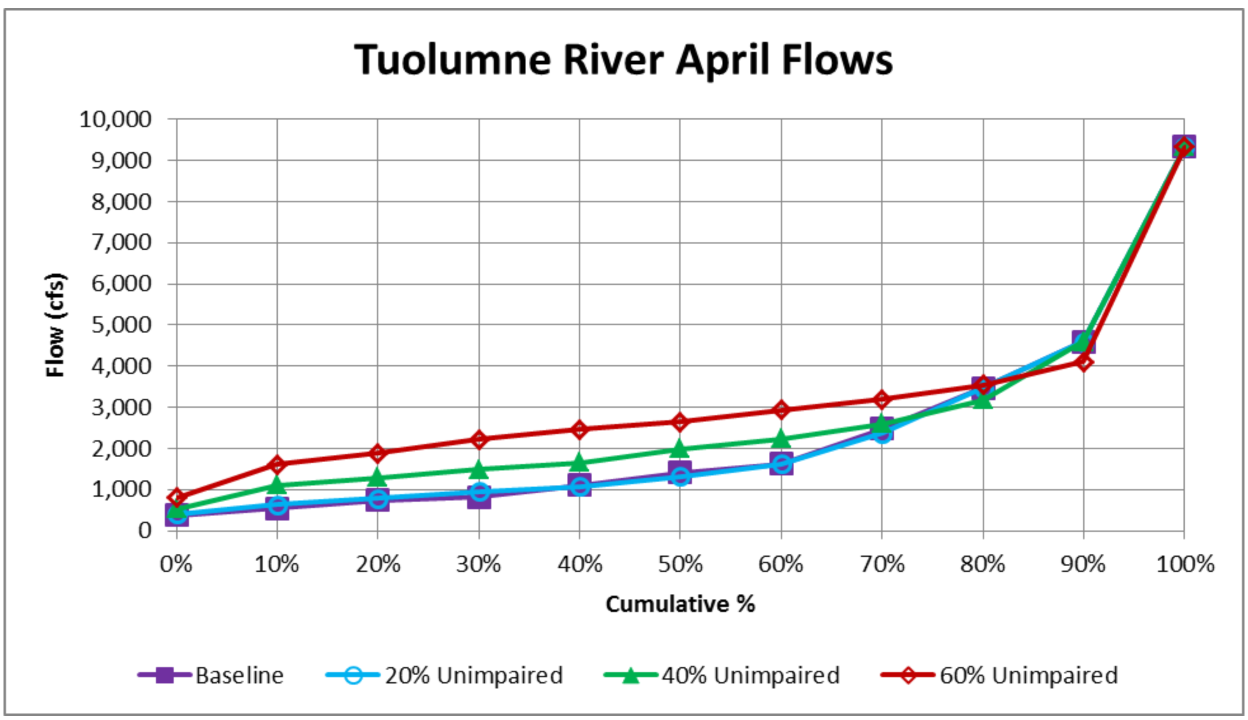


Figure F.1.4-2d. WSE-Simulated Cumulative Distributions of Tuolumne River April Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

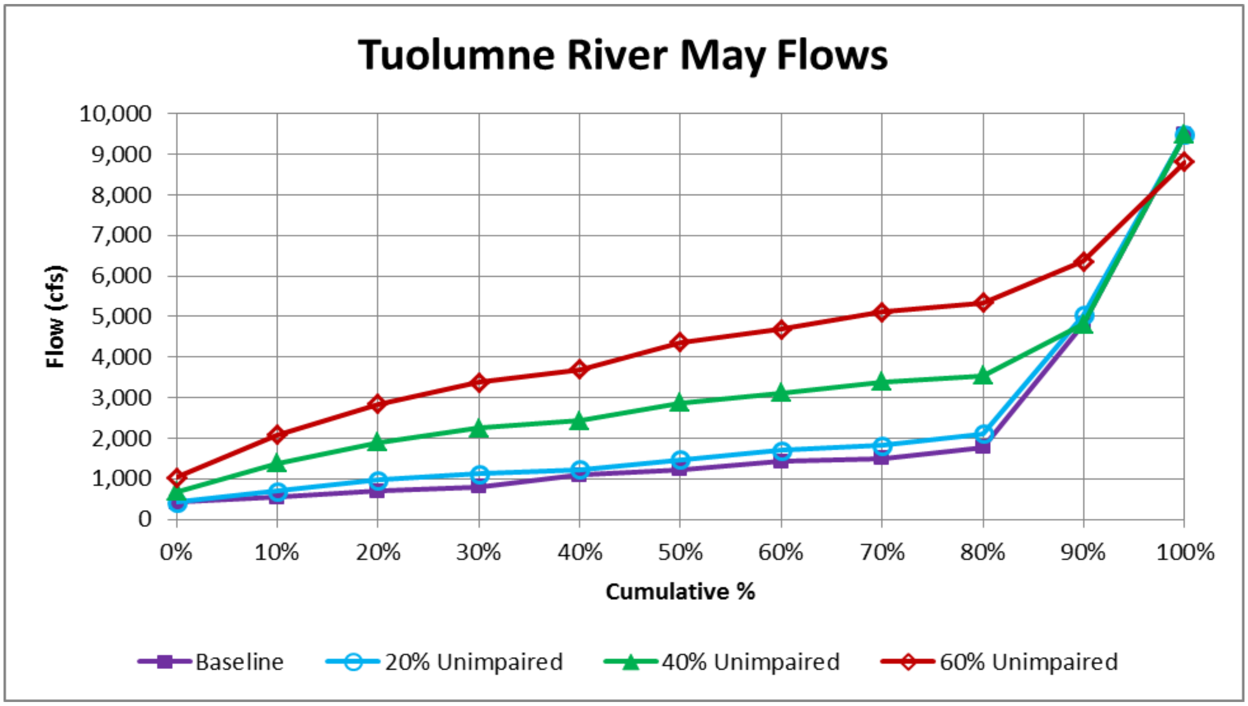


Figure F.1.4-2e. WSE-Simulated Cumulative Distributions of Tuolumne River May Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

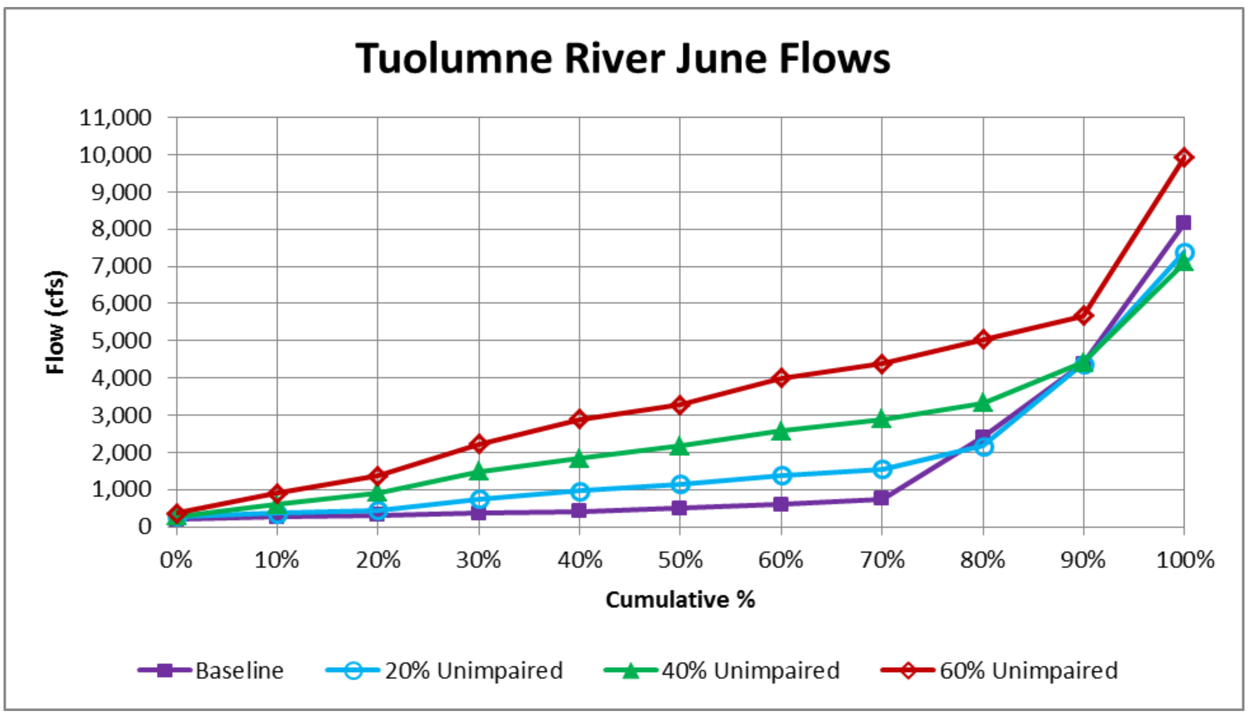


Figure F.1.4-2f. WSE-Simulated Cumulative Distributions of Tuolumne River June Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

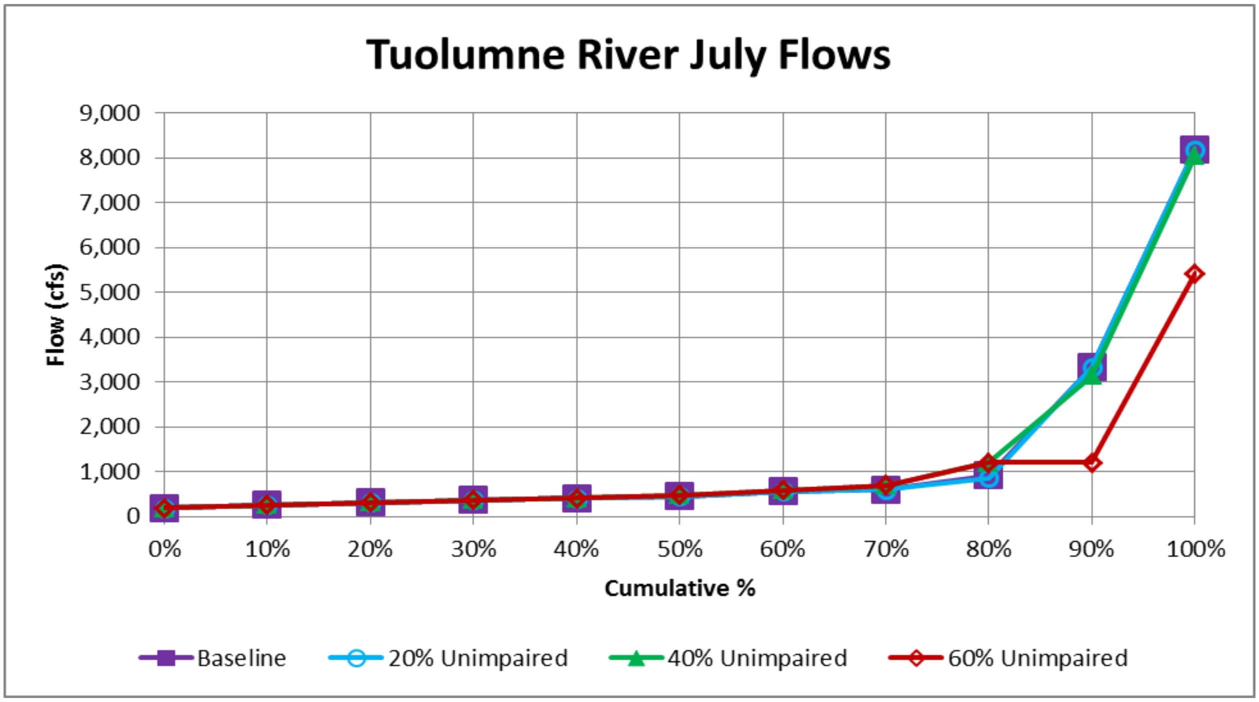


Figure F.1.4-2g. WSE-Simulated Cumulative Distributions of Tuolumne River July Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

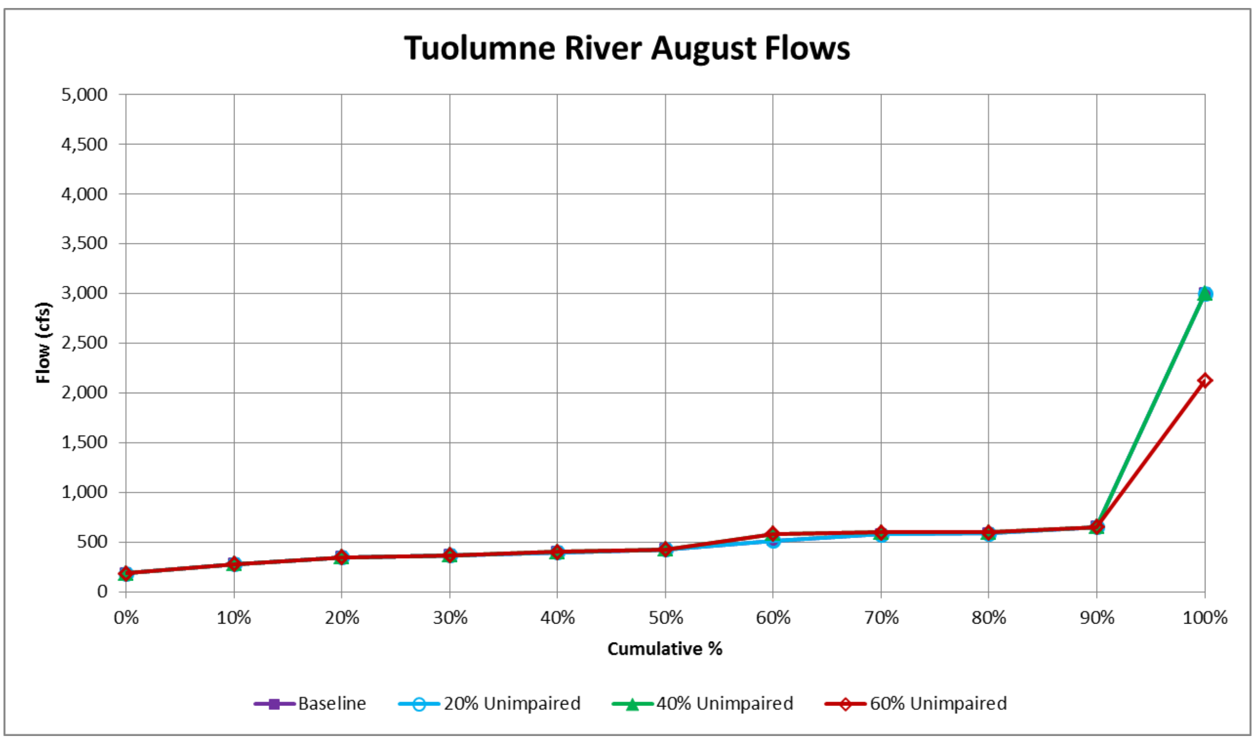


Figure F.1.4-2h. WSE-Simulated Cumulative Distributions of Tuolumne River August Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

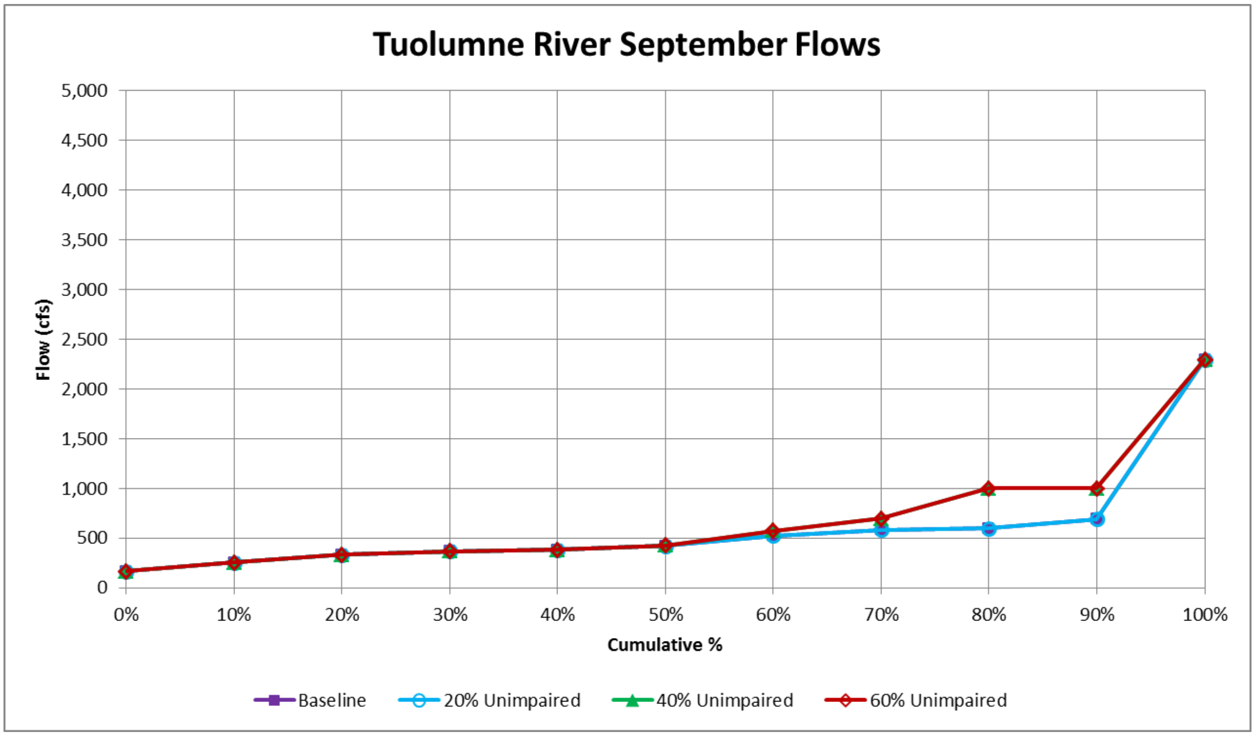


Figure F.1.4-2i. WSE-Simulated Cumulative Distributions of Tuolumne River September Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

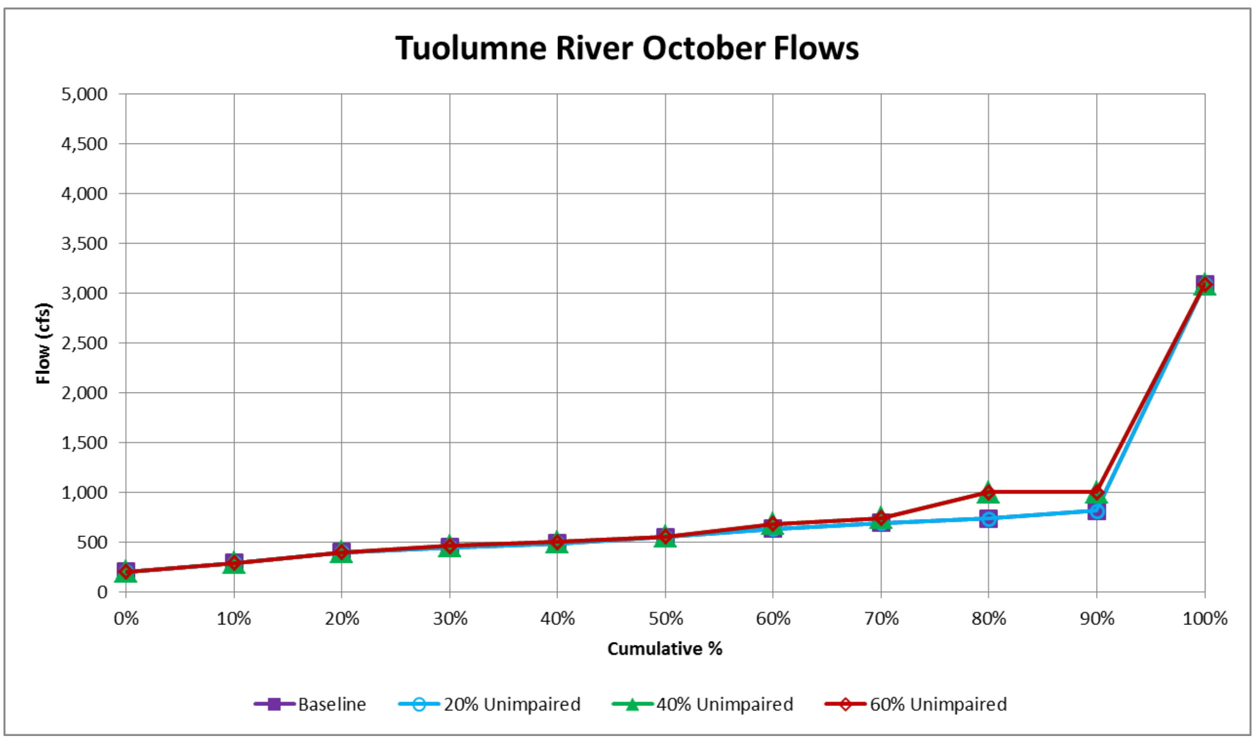


Figure F.1.4-2j. WSE-Simulated Cumulative Distributions of Tuolumne River October Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

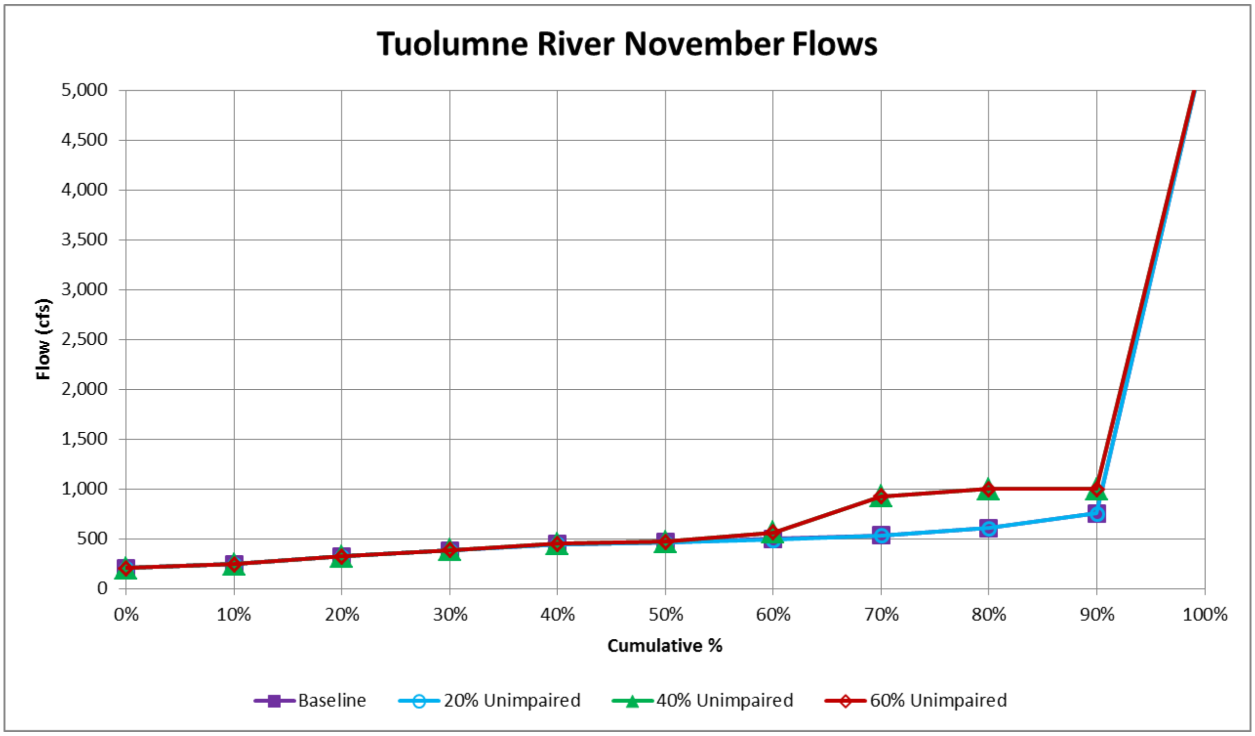


Figure F.1.4-2k. WSE-Simulated Cumulative Distributions of Tuolumne River November Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

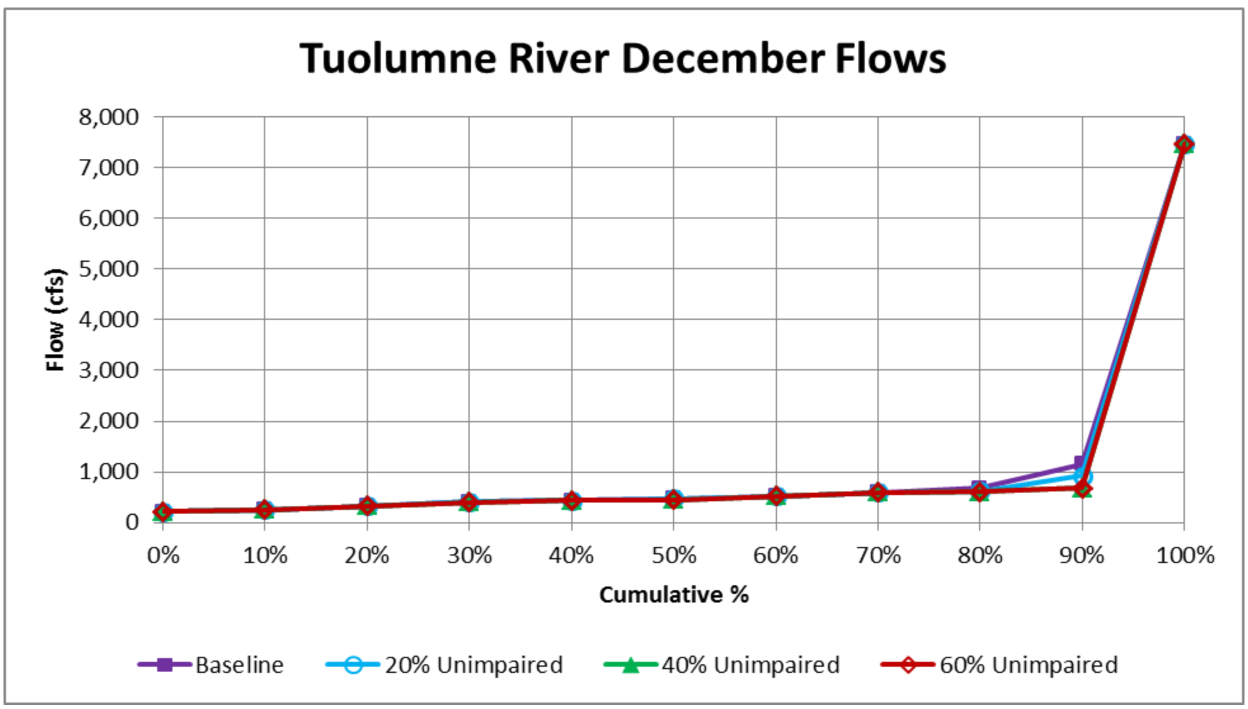


Figure F.1.4-2l. WSE-Simulated Cumulative Distributions of Tuolumne River December Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

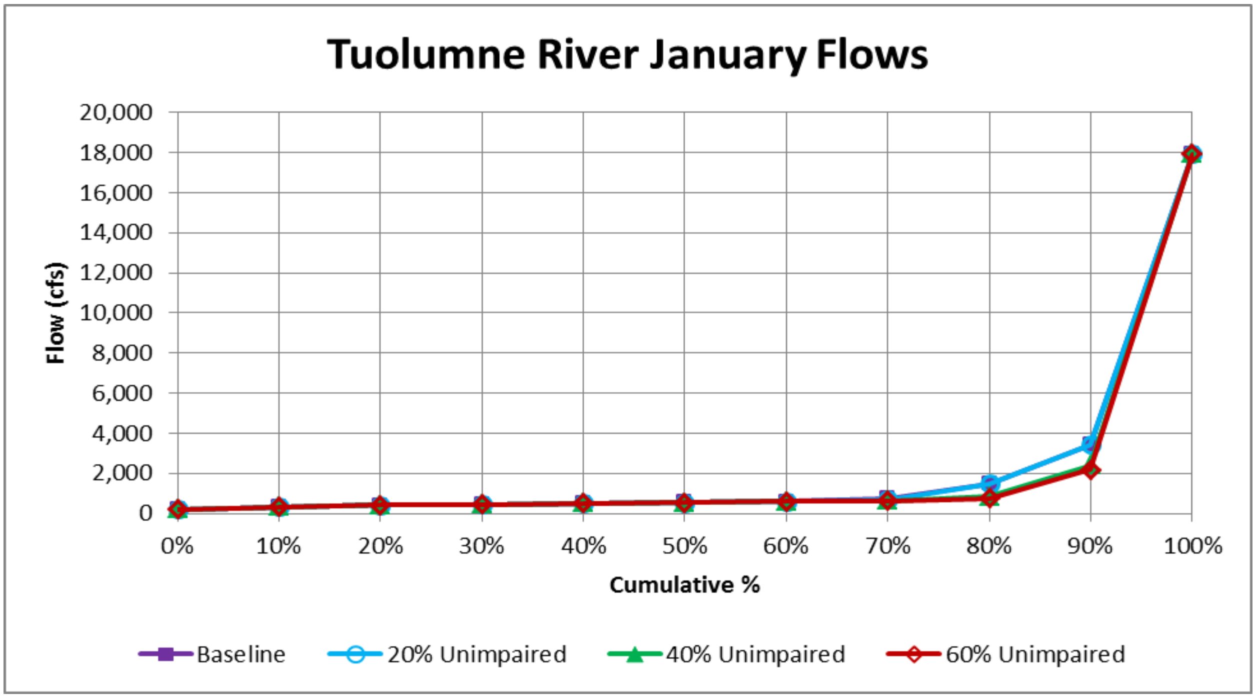


Figure F.1.4-2m. WSE-Simulated Cumulative Distributions of Tuolumne River January Flows (cfs) at Modesto for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

F.1.4.3 Stanislaus River Flows

The monthly cumulative distributions for February–June flow (TAF) for the Stanislaus River for LSJR Alternatives 2, 3, and 4 provide an overall summary of the February–June changes in flow compared to baseline. Table F.1.4-3 gives the cumulative distribution values for the February–June flow volumes (TAF) on the Stanislaus River at Ripon.

Figure F.1.4-3a shows the cumulative distributions of the February–June Stanislaus River flow volumes (TAF) at Ripon for the 82-year simulation period 1922–2003. The baseline and LSJR Alternative 2 flows were very similar, with a median baseline flow volume of 283 TAF for baseline and 271 TAF for LSJR Alternative 2. The cumulative distributions of LSJR Alternatives 3 and 4 flow volumes for February–June were progressively higher than LSJR Alternative 2. The February–June flows were dominated by flood control releases in a few of the highest runoff years (i.e., greater than 90 percent cumulative distribution). Flow distributions for the 30 percent and 50 percent unimpaired flow simulations (which are not shown in this graph) were intermediate between the 20 percent and 40 percent unimpaired flow simulations and the 40 percent and 60 percent unimpaired flow simulations, respectively (Table F.1.4-3).

Table F.1.4-3. Cumulative Distributions of February–June River Flow Volumes (TAF) in the Stanislaus River at Ripon for Baseline Conditions and the Percent Unimpaired Flow Simulations (20%–60%)

		Percent of Unimpaired Flow				
Percentile	Baseline	20%	30%	40%	50%	60%
0	91	98	112	113	118	122
10	124	130	147	159	185	225
20	153	161	190	207	243	294
30	204	191	245	254	283	330
40	246	243	277	317	391	432
50	283	271	302	360	426	494
60	317	295	341	413	507	596
70	377	410	425	447	541	630
80	443	446	500	484	577	668
90	494	517	554	613	718	848
100	1,185	1,185	1,185	1,220	1,337	1,472

Figures F.1.4-4b, F.1.4-4c, F.1.4-4d, F.1.4-4e, and F.1.4-4f show the cumulative distributions of Stanislaus River flow at Ripon from February–June. During these months, the flows for LSJR Alternative 2 were similar to the baseline flows. The flows for LSJR Alternatives 3 and 4 were incrementally higher than flows for baseline conditions and LSJR Alternative 2 under most flow conditions. However, at low to moderate flow levels, the percentages of increase from April–June were generally less than the percentages of increase on the Merced and Tuolumne Rivers because the baseline releases were already relatively high.

Baseline and LSJR alternative flows are usually similar from July–January. Figures F.1.4-4g, F.1.4-4h, F.1.4-4i, F.1.4-4j, F.1.4-4k, F.1.4-4l, and F.1.4-4m show the cumulative distributions of Stanislaus River flow at Ripon from July–January. All of the flow differences between alternatives during these months occur only at flow levels higher than the median flows. Decreases in the highest flows (e.g., 100th percentile in July, August, and January) were most likely caused as a result of LSJR Alternative 4 and sometimes LSJR Alternative 3 having more reservoir capacity, thereby reducing releases for flood control. During July, September, and October, the 70th and 80th percentile flows for LSJR Alternatives 3 and 4 were slightly higher than the flows for baseline conditions and LSJR Alternative 2, potentially resulting from the release of water reserved for temperature control purposes (i.e., adaptive implementation flow shifting). On the Stanislaus River, flow may also be affected by releases for salinity control in the Delta and changes in NMFS BO flows associated with changes in reservoir storage (NMI).

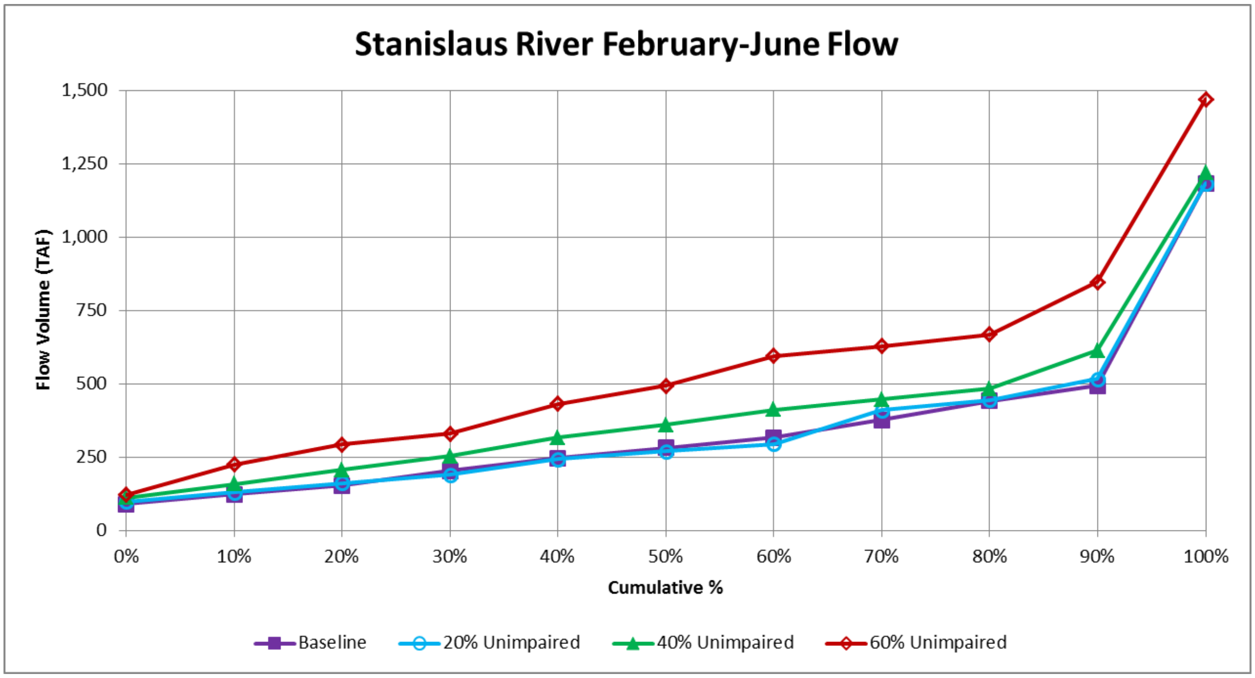


Figure F.1.4-3a. WSE-Simulated Cumulative Distributions of Stanislaus River February–June Flow Volumes (TAF) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

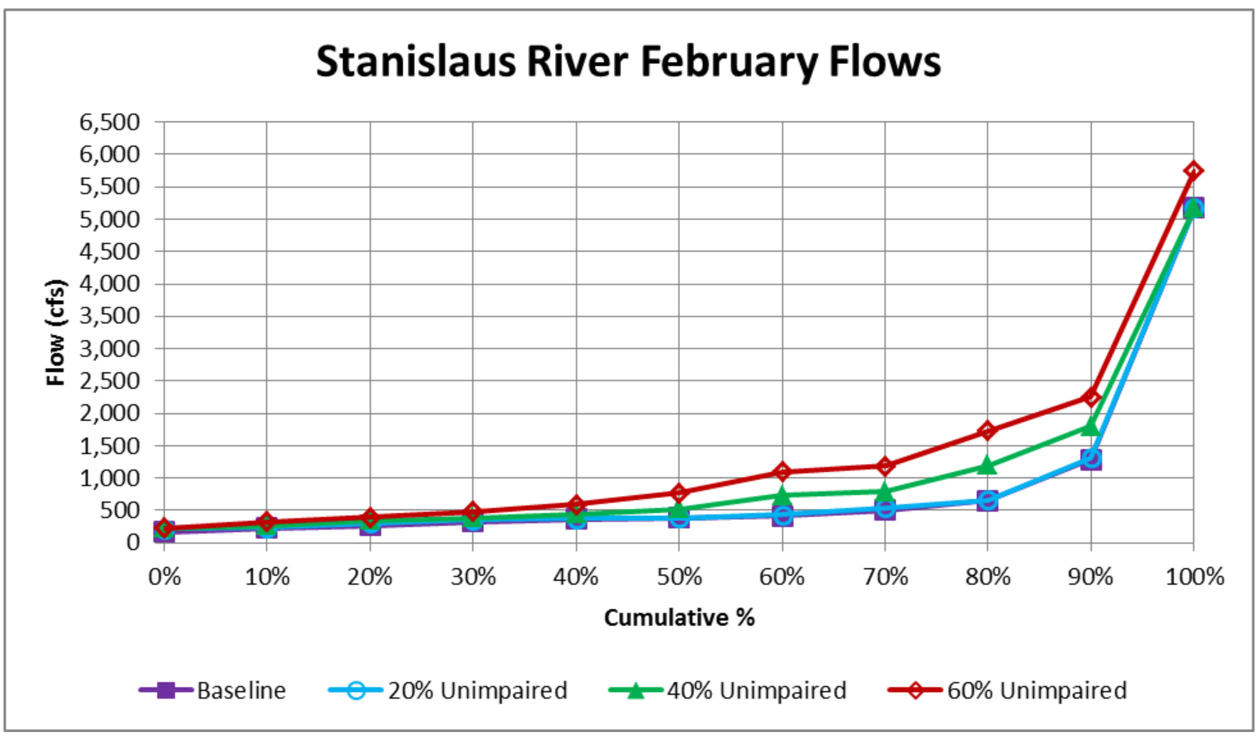


Figure F.1.4-3b. WSE-Simulated Cumulative Distributions of Stanislaus River February Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

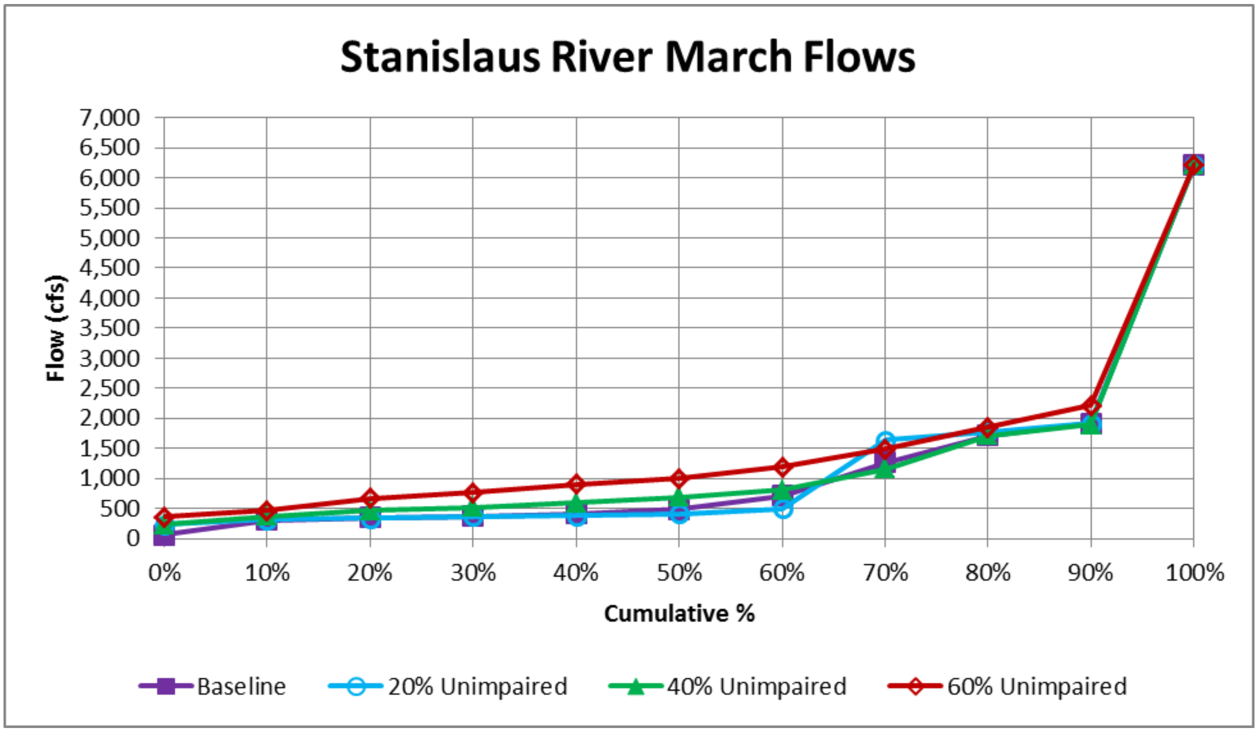


Figure F.1.4-3c. WSE-Simulated Cumulative Distributions of Stanislaus River March Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

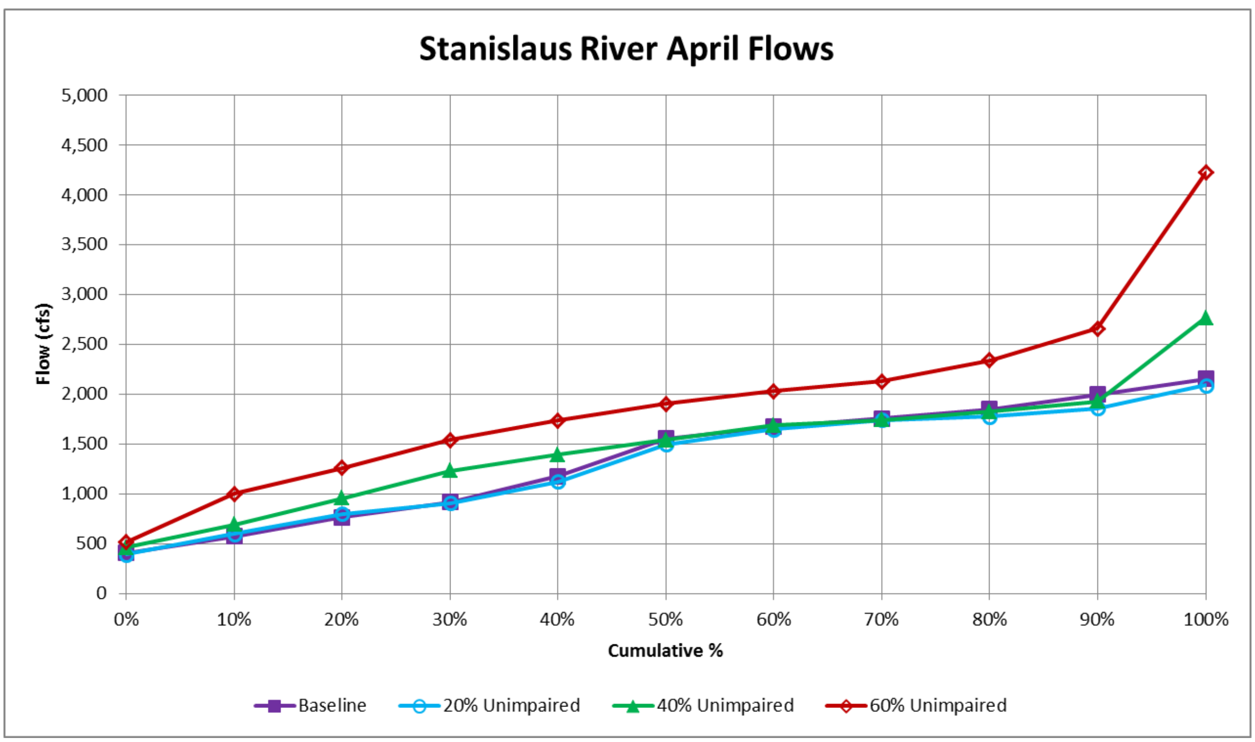


Figure F.1.4-3d. WSE-Simulated Cumulative Distributions of Stanislaus River April Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

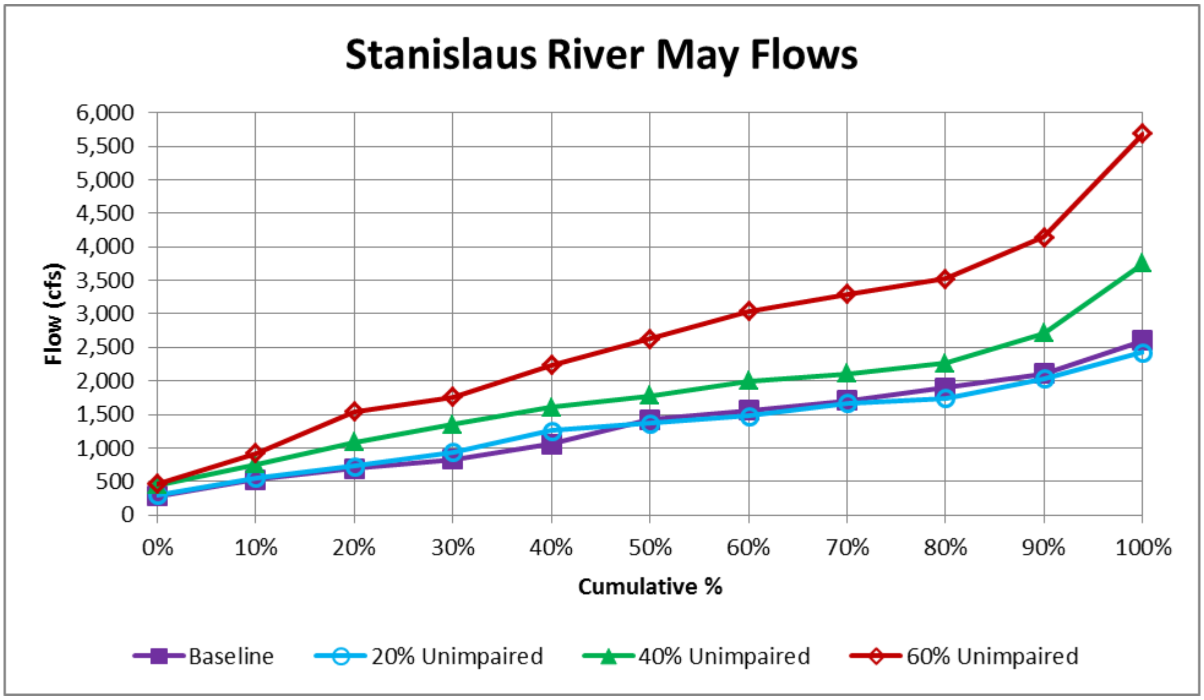


Figure F.1.4-3e. WSE-Simulated Cumulative Distributions of Stanislaus River May Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

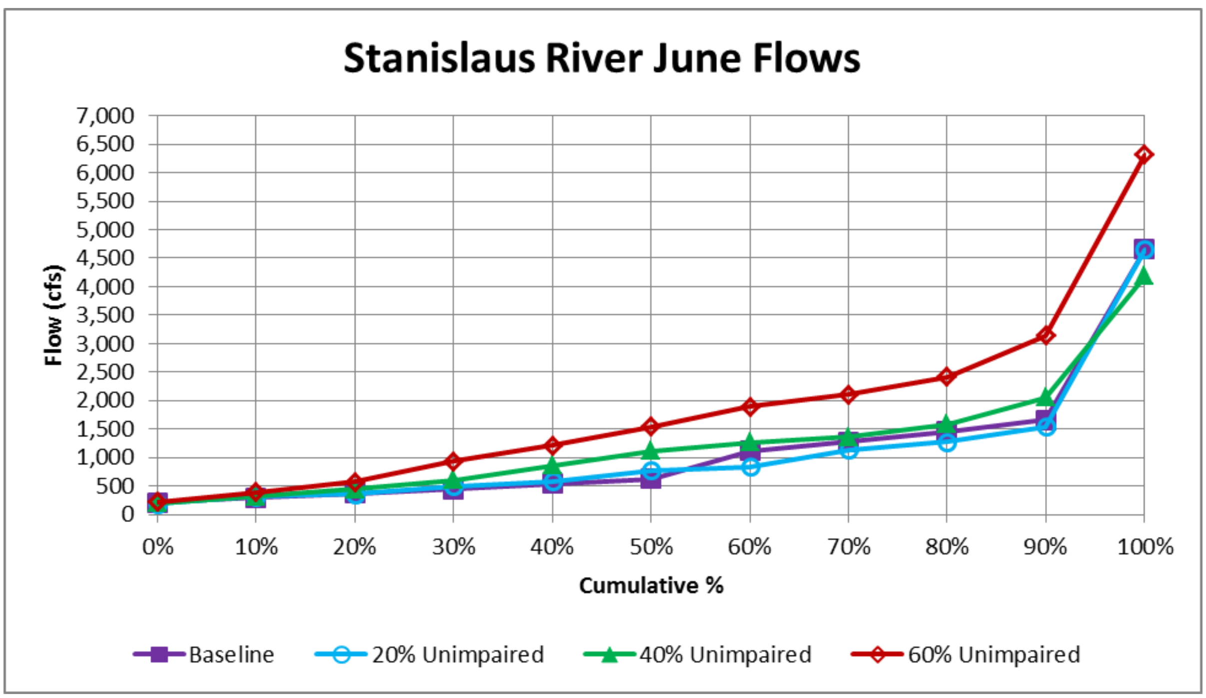


Figure F.1.4-3f. WSE-Simulated Cumulative Distributions of Stanislaus River June Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

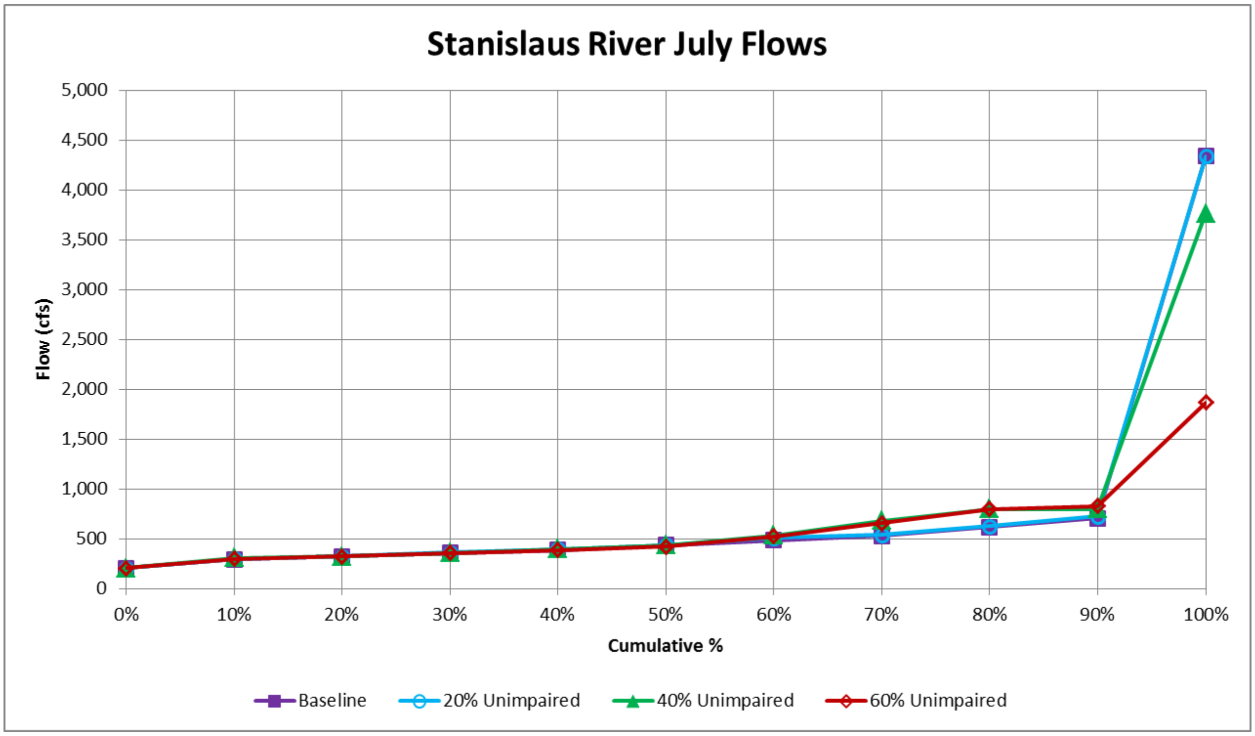


Figure F.1.4-3g. WSE-Simulated Cumulative Distributions of Stanislaus River July Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

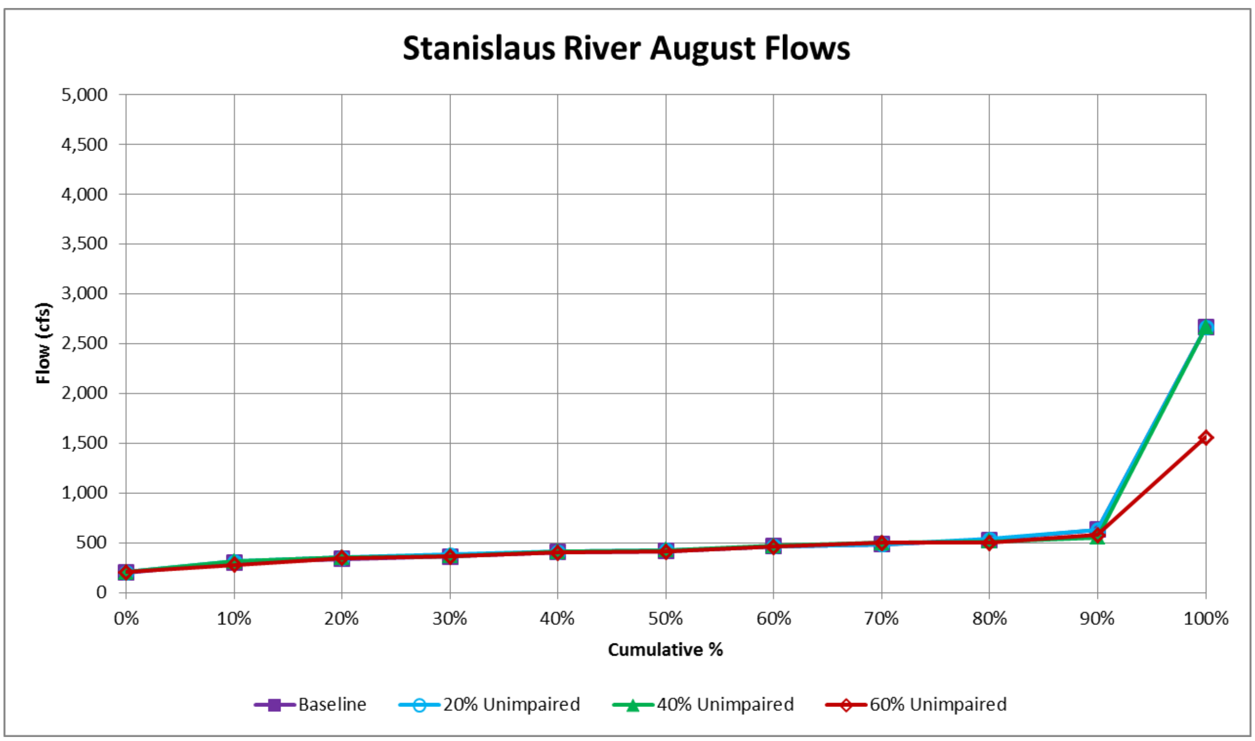


Figure F.1.4-3h. WSE-Simulated Cumulative Distributions of Stanislaus River August Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

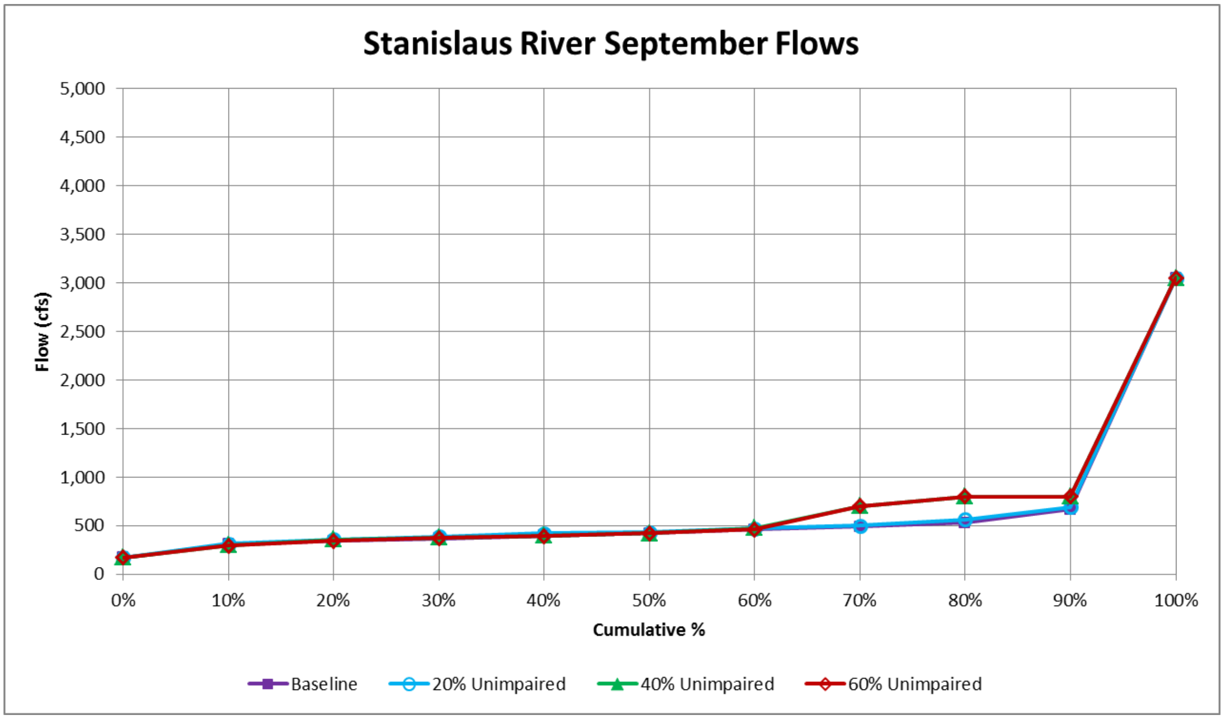


Figure F.1.4-3i. WSE-Simulated Cumulative Distributions of Stanislaus River September Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

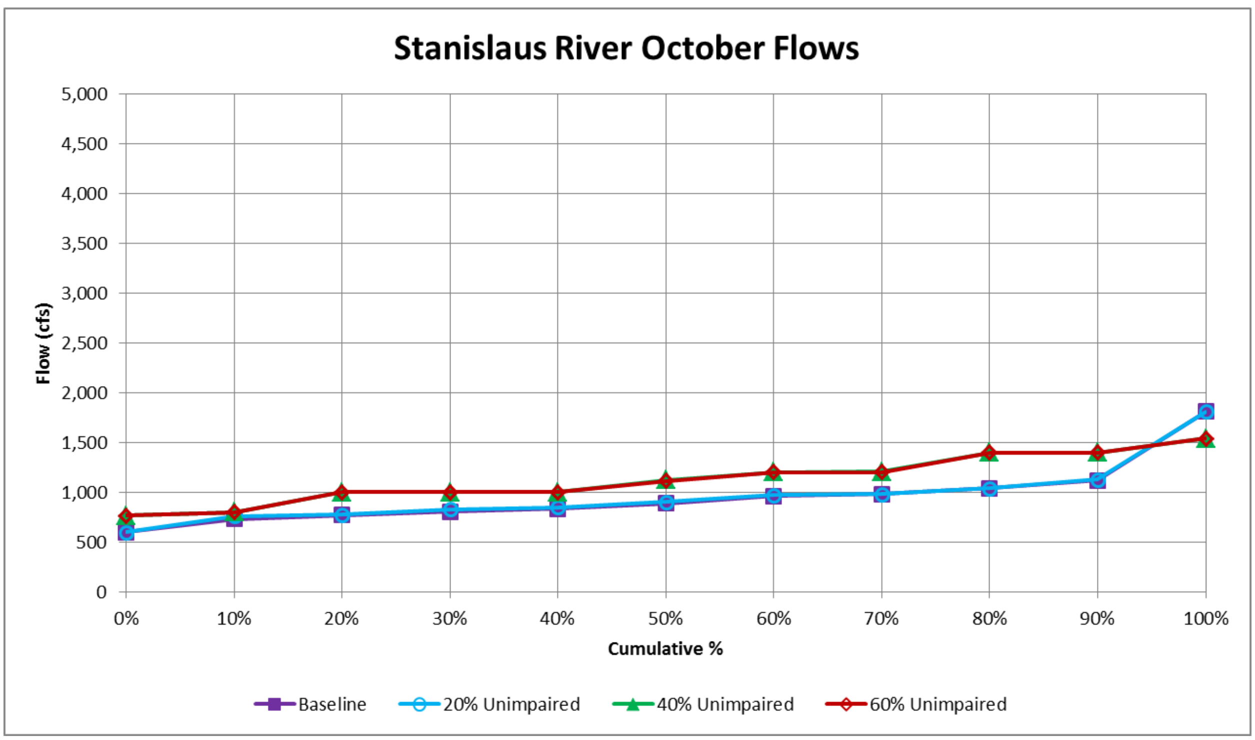


Figure F.1.4-3j. WSE-Simulated Cumulative Distributions of Stanislaus River October Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

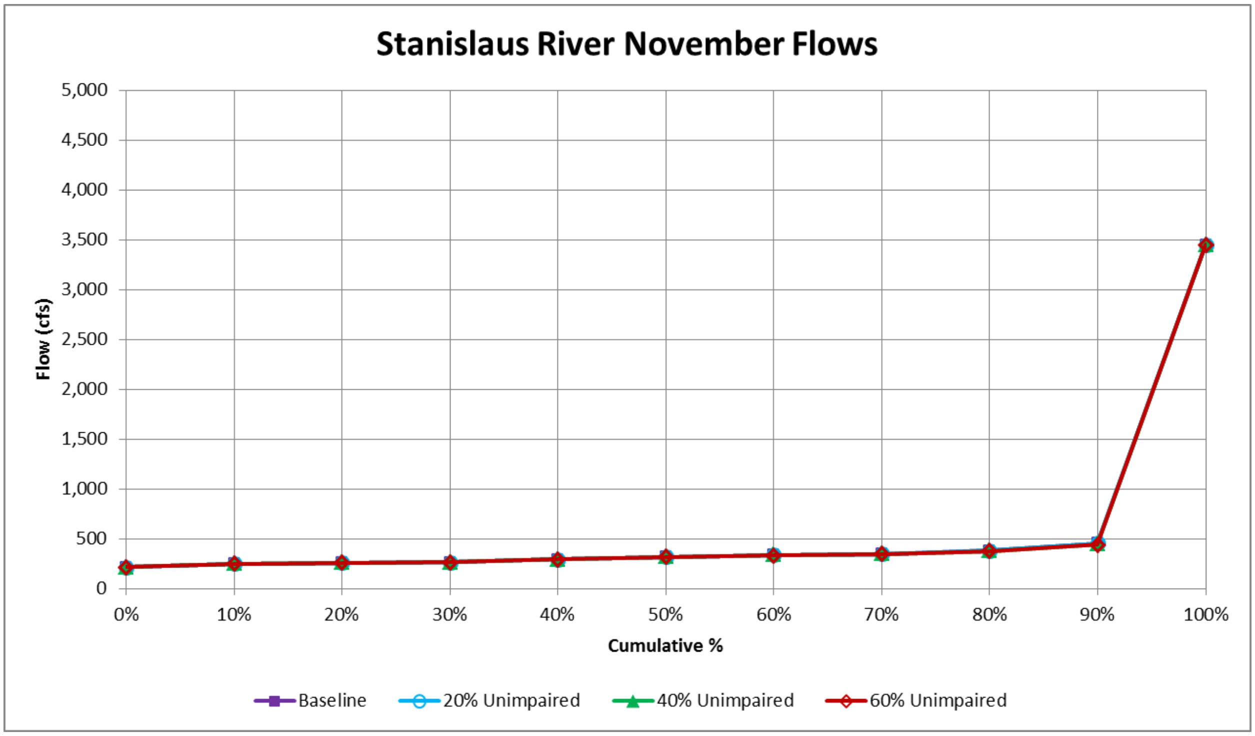


Figure F.1.4-3k. WSE-Simulated Cumulative Distributions of Stanislaus River November Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

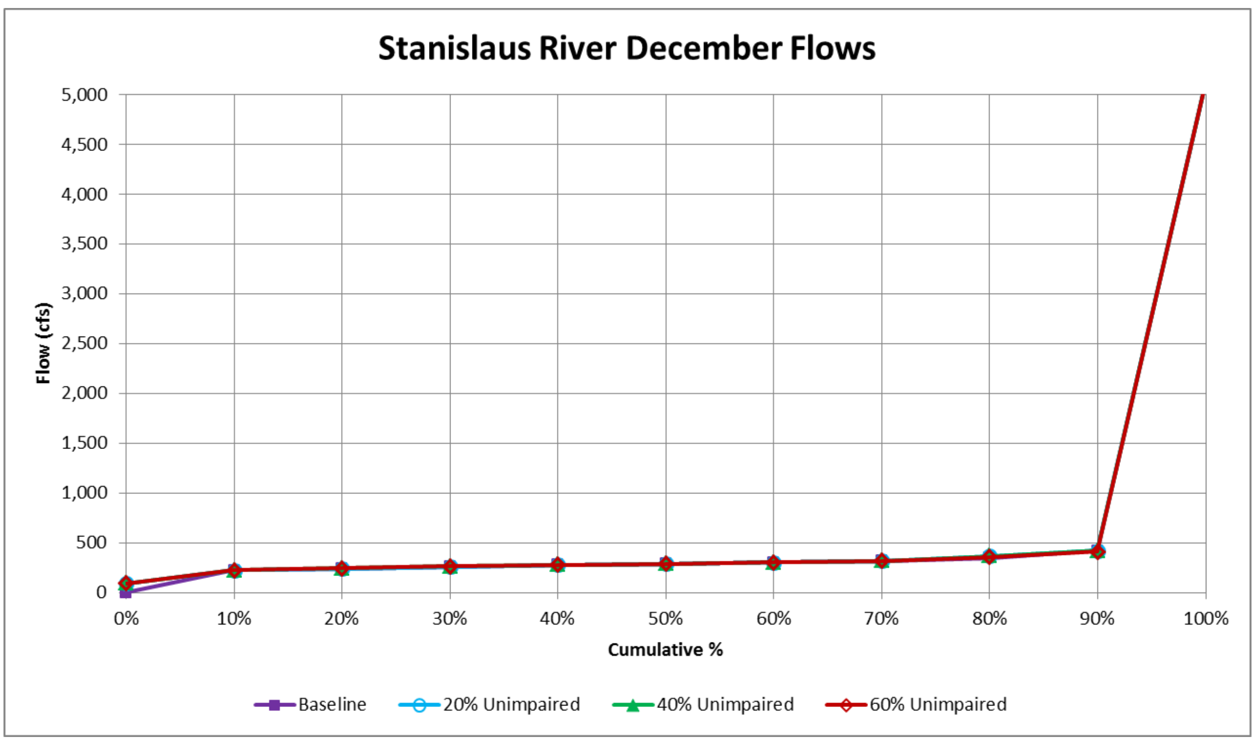


Figure F.1.4-3l. WSE-Simulated Cumulative Distributions of Stanislaus River December Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

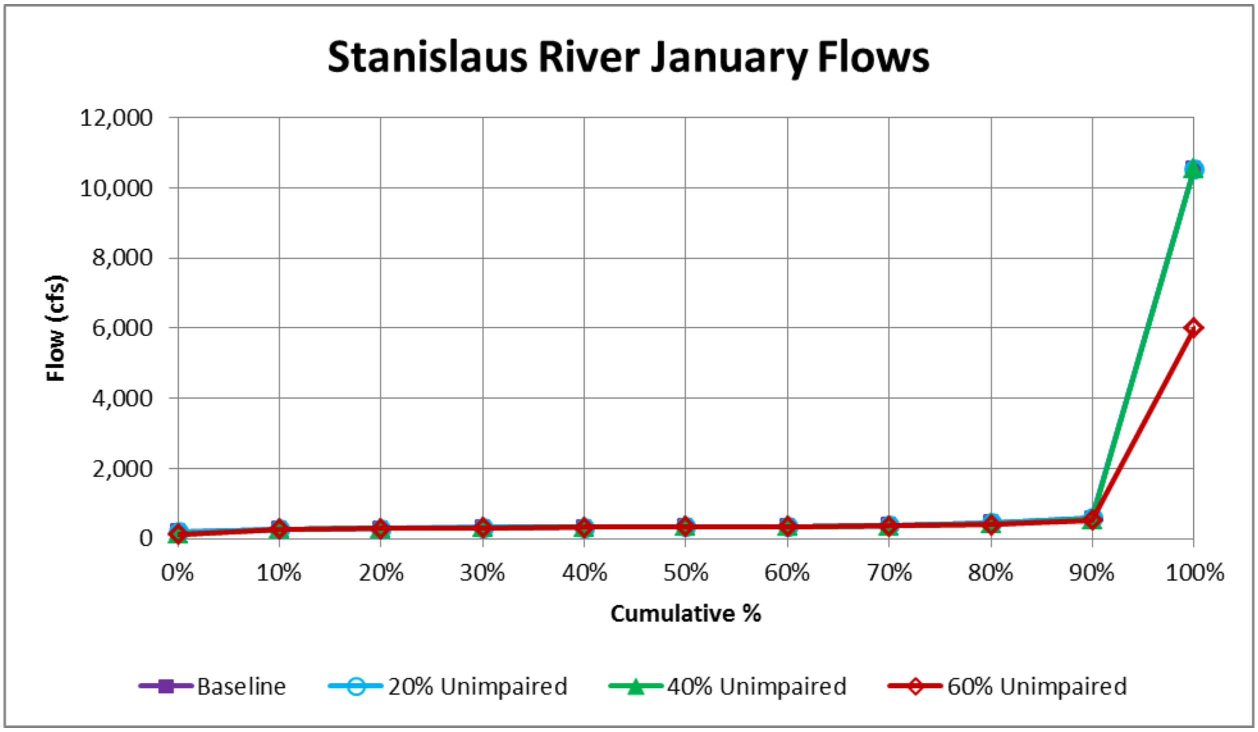


Figure F.1.4-3m. WSE-Simulated Cumulative Distributions of Stanislaus River January Flows (cfs) at Ripon for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

F.1.4.4 SJR at Vernalis Flows

The monthly cumulative distributions for February–June flow (TAF) for the SJR at Vernalis for LSJR Alternatives 2, 3, and 4 provide an overall summary of the February–June changes compared to baseline. Table F.1.4-4 gives the cumulative distribution values for the February–June flow volumes (TAF).

The SJR at Vernalis flows are the sum of the three eastside tributary flows; the flow from upstream of the Merced River; and flows from groundwater seepage, creeks, and other drainages that enter the SJR downstream of the Merced River. The SJR at Vernalis flows are influenced by the baseline water quality objectives (i.e., EC and flow).

Figure F.1.4-4a shows the cumulative distributions of the February–June SJR at Vernalis flow volumes. The LSJR Alternative 2 flows were similar to baseline flows, but were generally a little higher (increase in February–June median flow volume of about 118 TAF). The cumulative distributions for LSJR Alternatives 3 and 4 for February–June were progressively higher than baseline and LSJR Alternative 2. Compared to baseline conditions, LSJR Alternative 3 would increase the February–June Vernalis median flow volume by about 633 TAF; LSJR Alternative 4 would increase the February–June SJR at Vernalis median flow volume by about 1,016 TAF. Average increases in flow from February–June would be less than the increases in median flows, about 288 TAF for LSJR Alternative 3 and 728 TAF for LSJR Alternative 4. For baseline and LSJR Alternatives 2 and 3, the February–June flow volumes were dominated by flood control releases in about 10 percent of the years. Flow distributions for the 30 percent and 50 percent unimpaired flow simulations (which are not shown in this graph) were intermediate between the 20 percent and 40 percent unimpaired flow simulations and the 40 percent and 60 percent unimpaired flow simulations, respectively (Table F.1.4-4).

Table F.1.4-4. Cumulative Distributions of February–June River Flow Volumes (TAF) of SJR at Vernalis for Baseline Conditions and the Unimpaired Flow Simulations (20%–60%)

		Percent of Unimpaired Flow				
Percentile	Baseline	20%	30%	40%	50%	60%
0	364	381	389	417	460	504
10	444	513	598	716	805	940
20	604	668	847	977	1,110	1,277
30	785	835	962	1,048	1,239	1,420
40	935	930	1,093	1,307	1,505	1,721
50	1,103	1,221	1,460	1,736	1,948	2,119
60	1,509	1,487	1,671	1,926	2,163	2,526
70	1,904	1,949	2,096	2,213	2,429	2,727
80	2,508	2,573	2,635	2,623	2,883	3,230
90	3,554	3,568	3,629	3,718	4,025	4,425
100	9,415	9,415	9,487	9,606	9,825	10,112
Average	1,742	1,797	1,916	2,030	2,227	2,470

Figures F.1.4-4b, F.1.4-4c, F.1.4-4d, F.1.4-4e, and F.1.4-4f show the cumulative distributions of SJR flow at Vernalis from February–June. The baseline February flows were similar to most of the LSJR alternative flows. Between March and May, the Vernalis flows associated with LSJR Alternatives 3 and 4 increased relative to baseline flow, such that by May, the median flows under LSJR Alternative 4 were over 10,000 cfs. However, by May, the Vernalis flows for LSJR Alternative 2 were only slightly greater than the baseline flows. The June pattern of flows was similar to May, although flows were slightly reduced.

In general, from July–January, river and reservoir operations were similar under the LSJR alternatives as under baseline conditions. Figures F.1.4-4g, F.1.4-4h, F.1.4-4i, F.1.4-4j, F.1.4-4k, F.1.4-4l, and F.1.4-4m show the cumulative distributions of SJR flow at Vernalis from July–January. The flow differences between alternatives during these months were relatively small and occurred only at flow levels higher than the median flows. There are several possible reasons why LSJR alternative flows may sometimes differ from baseline flows and each other during these months. Where there were differences in the highest flows, the differences were often caused by LSJR Alternatives 3 and 4 having more reservoir capacity, thereby reducing releases for flood control. Most other differences were generally caused by the release of retained water under LSJR Alternatives 3 and 4 for temperature control purposes. However, some differences were also caused by other factors such as variable releases for salinity control at Vernalis and changes in NMFS BO flows for the Stanislaus River associated with changes in reservoir storage.

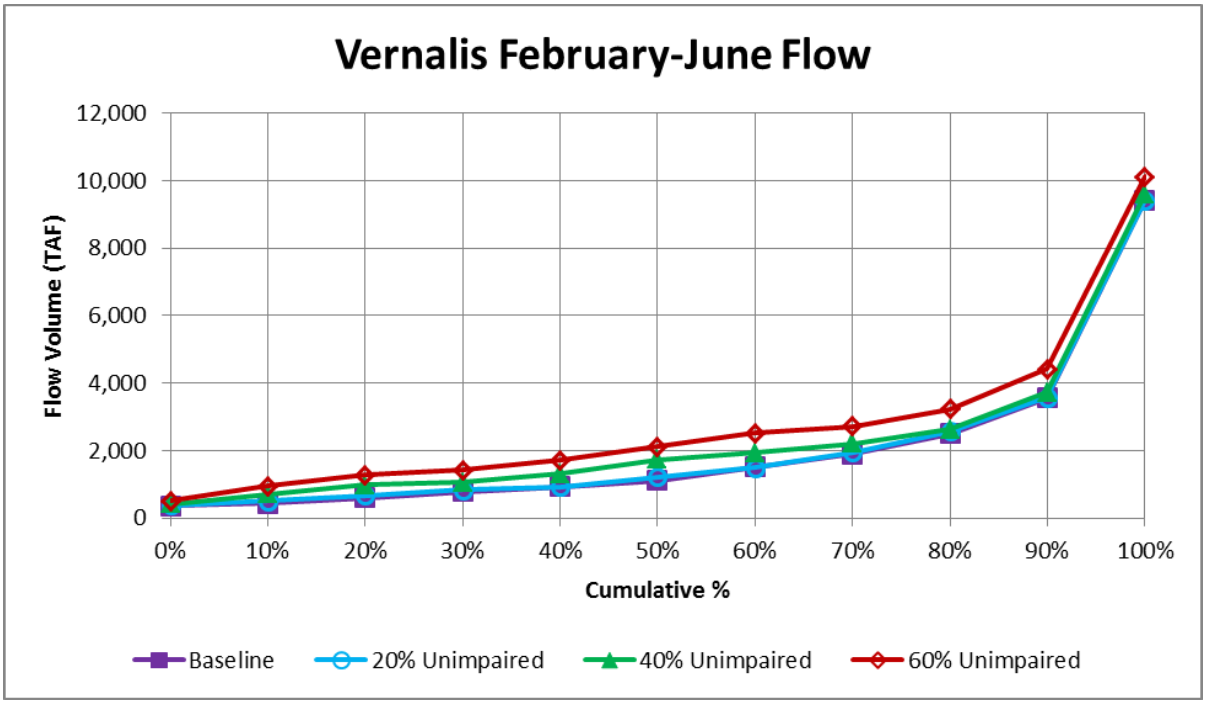


Figure F.1.4-4a. WSE-Simulated Cumulative Distributions of SJR at Vernalis February–June Flow Volumes (TAF) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

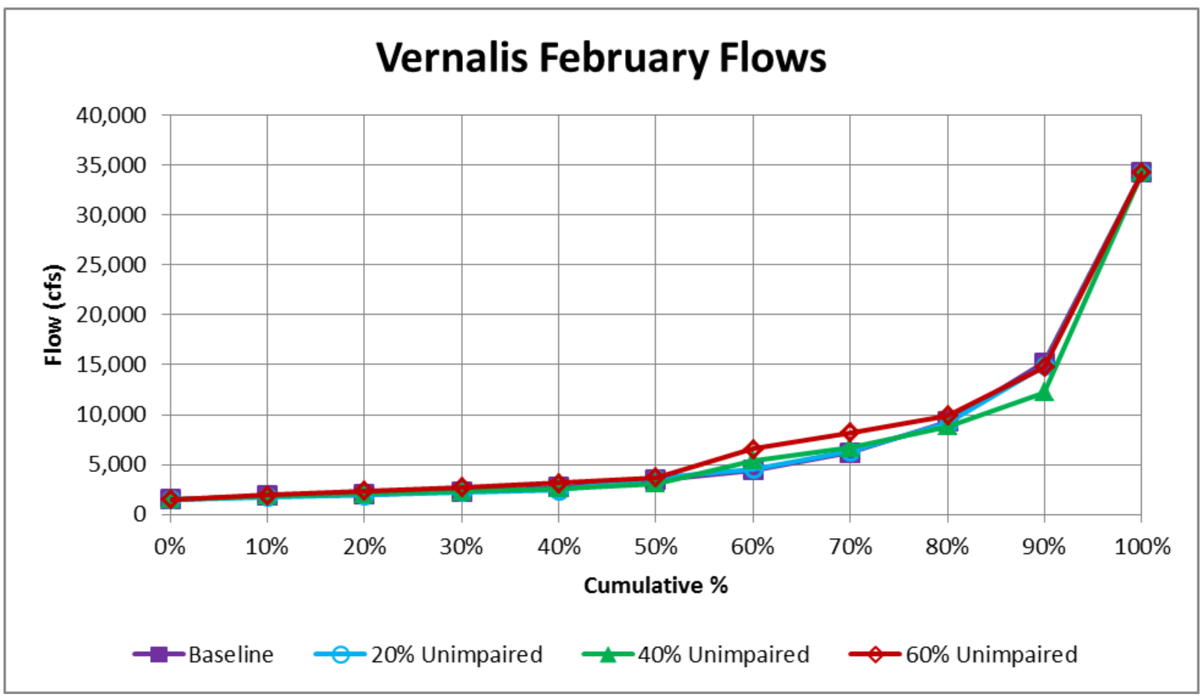


Figure F.1.4-4b. WSE-Simulated Cumulative Distributions of SJR at Vernalis February Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

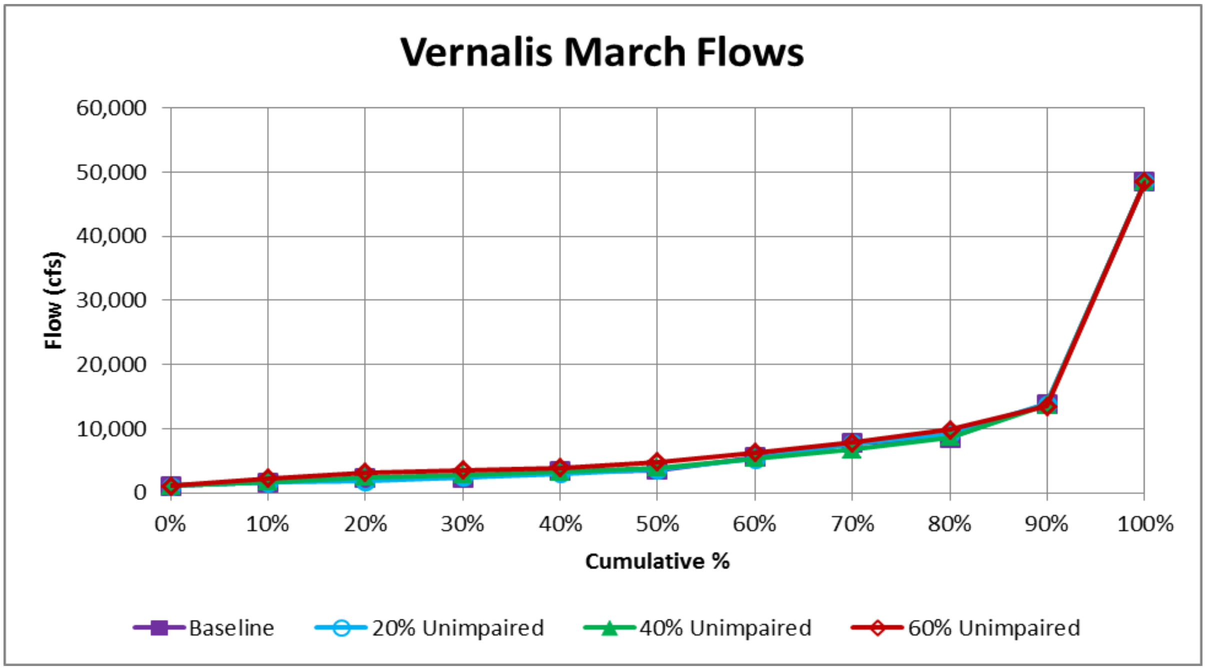


Figure F.1.4-4c. WSE-Simulated Cumulative Distributions of SJR at Vernalis March Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

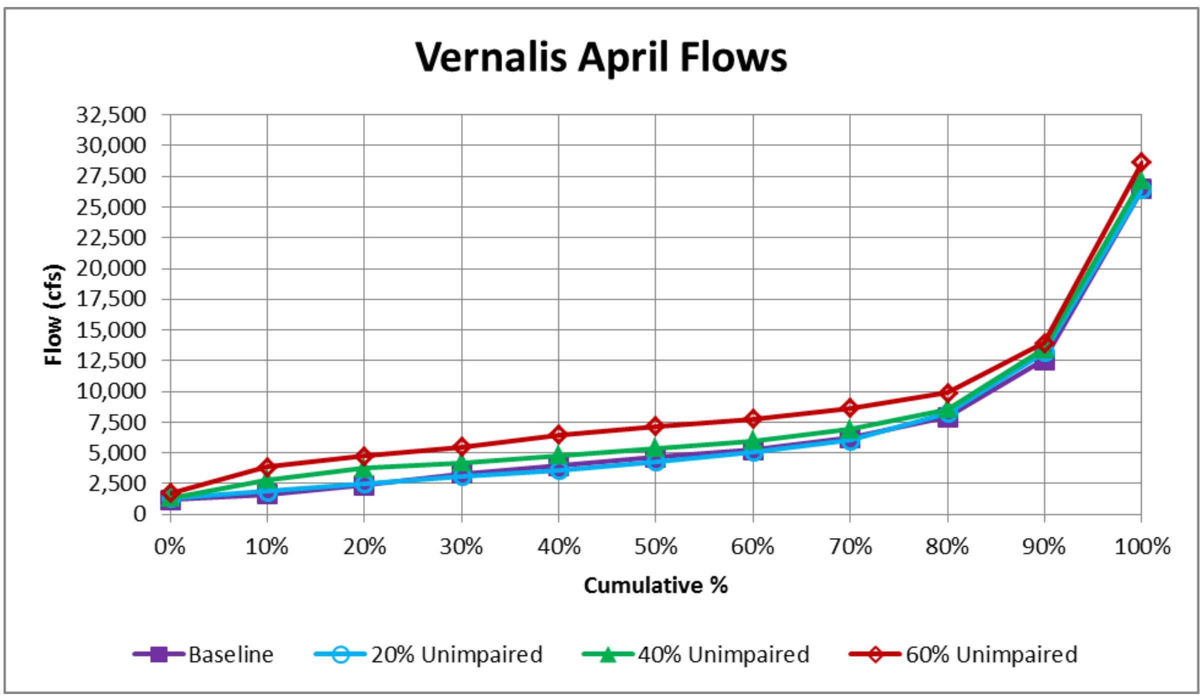


Figure F.1.4-4d. WSE-Simulated Cumulative Distributions of SJR at Vernalis April Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

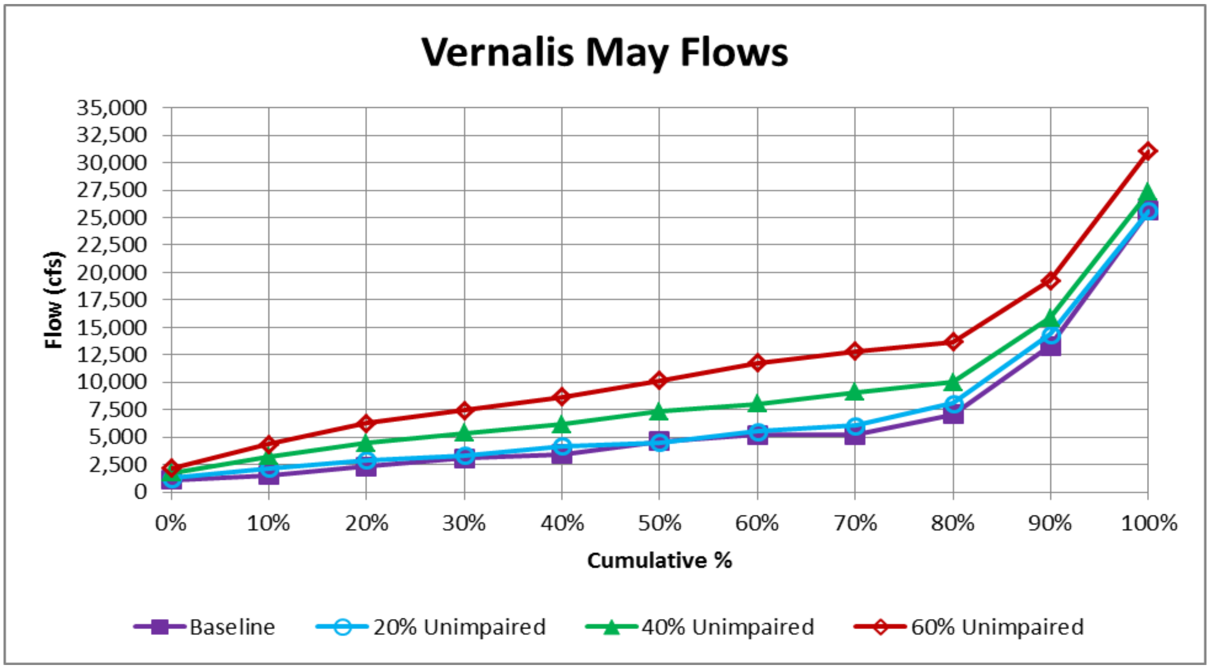


Figure F.1.4-4e. WSE-Simulated Cumulative Distributions of SJR at Vernalis May Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

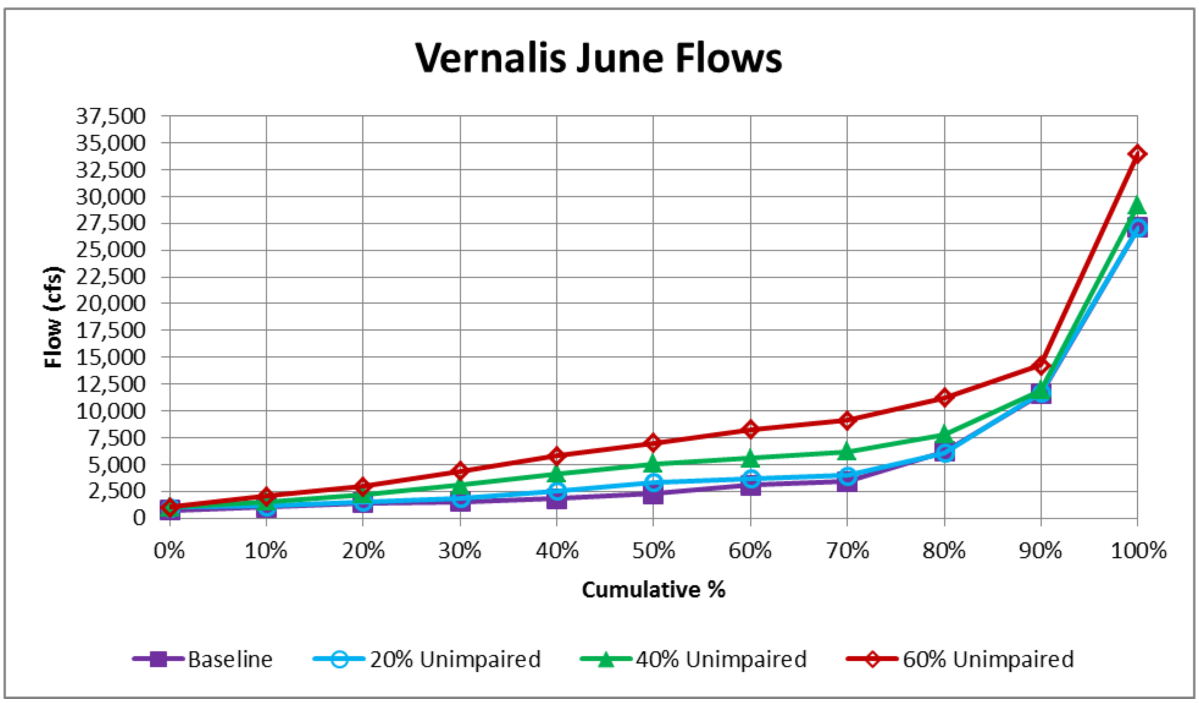


Figure F.1.4-4f. WSE-Simulated Cumulative Distributions of SJR at Vernalis June Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

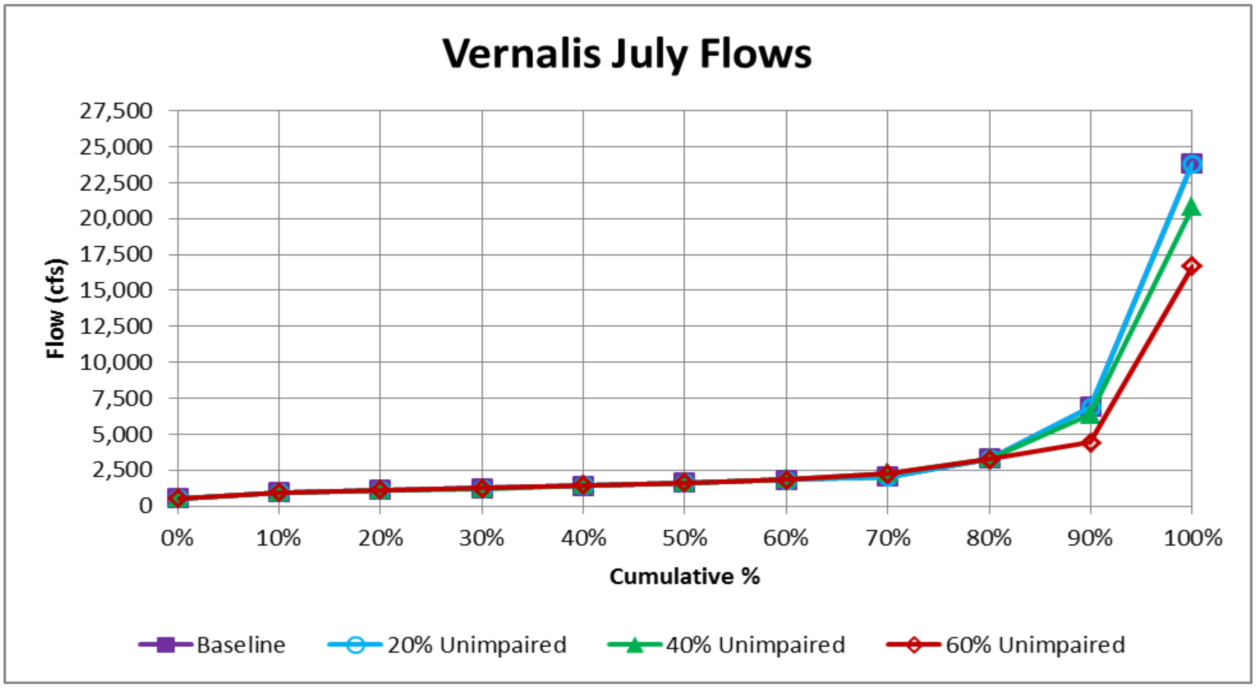


Figure F.1.4-4g. WSE-Simulated Cumulative Distributions of SJR at Vernalis July Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

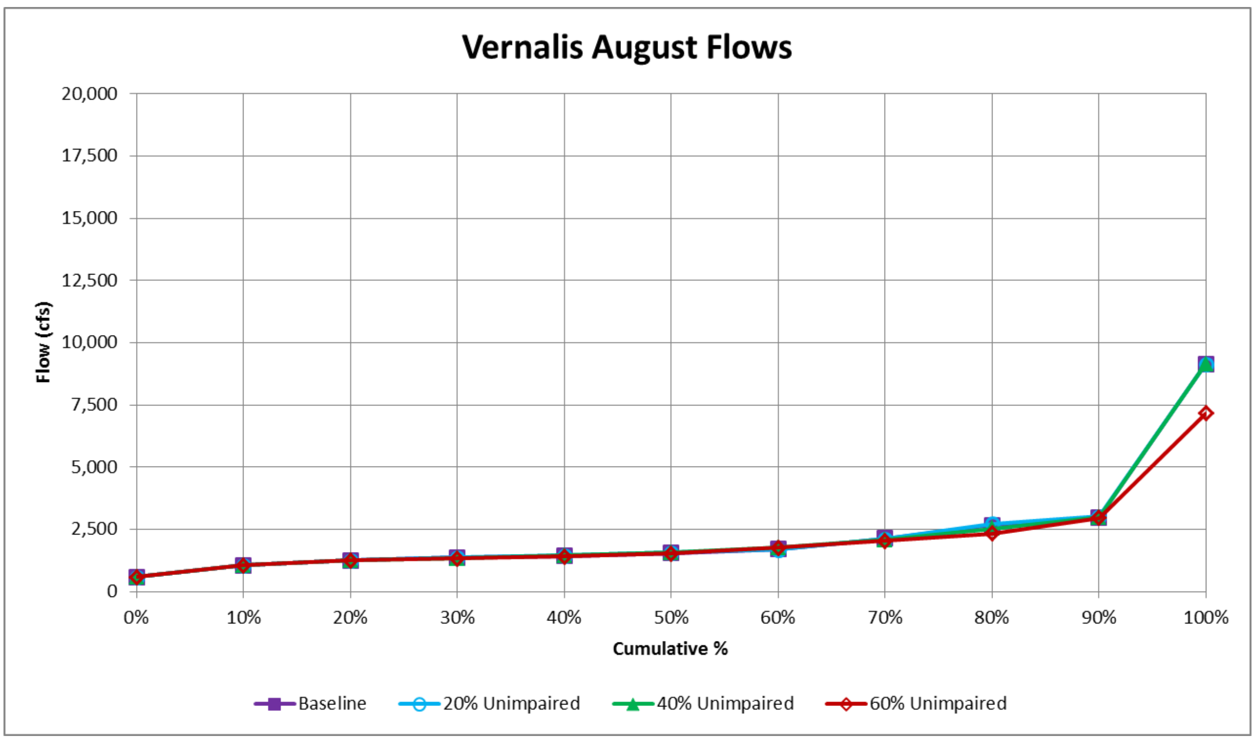


Figure F.1.4-4h. WSE-Simulated Cumulative Distributions of SJR at Vernalis August Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

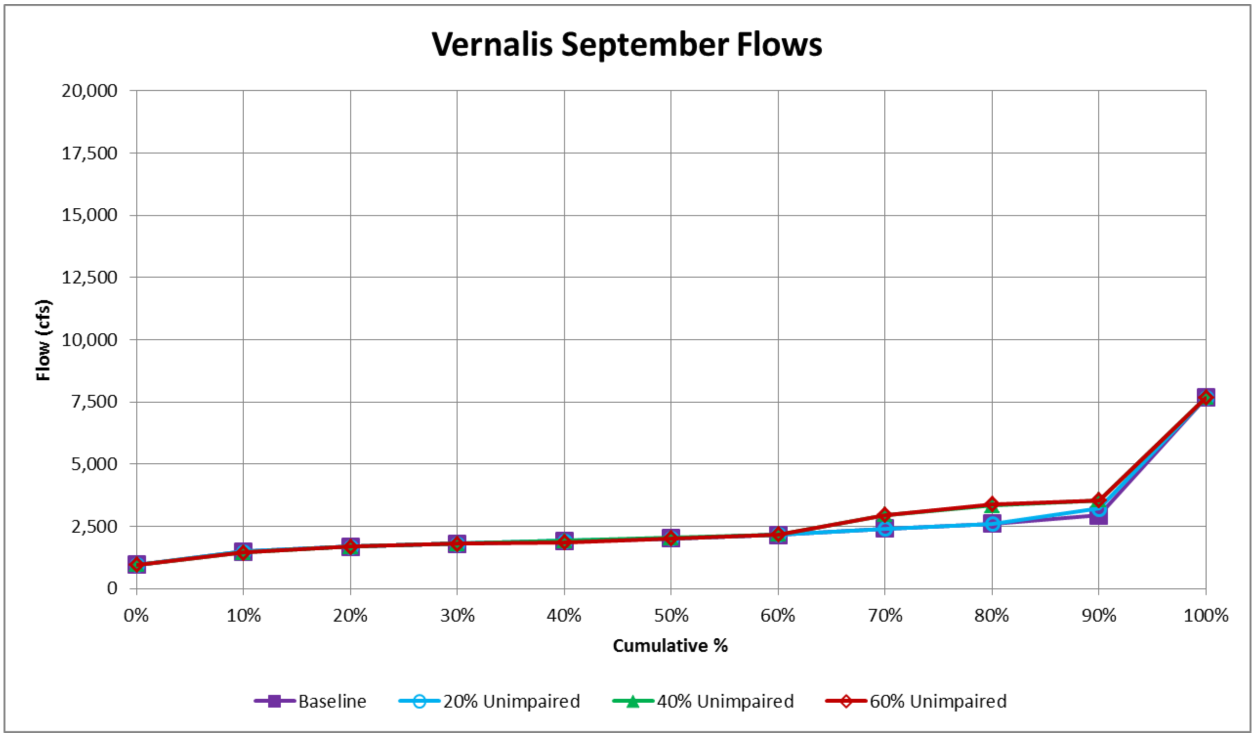


Figure F.1.4-4i. WSE-Simulated Cumulative Distributions of SJR at Vernalis September Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

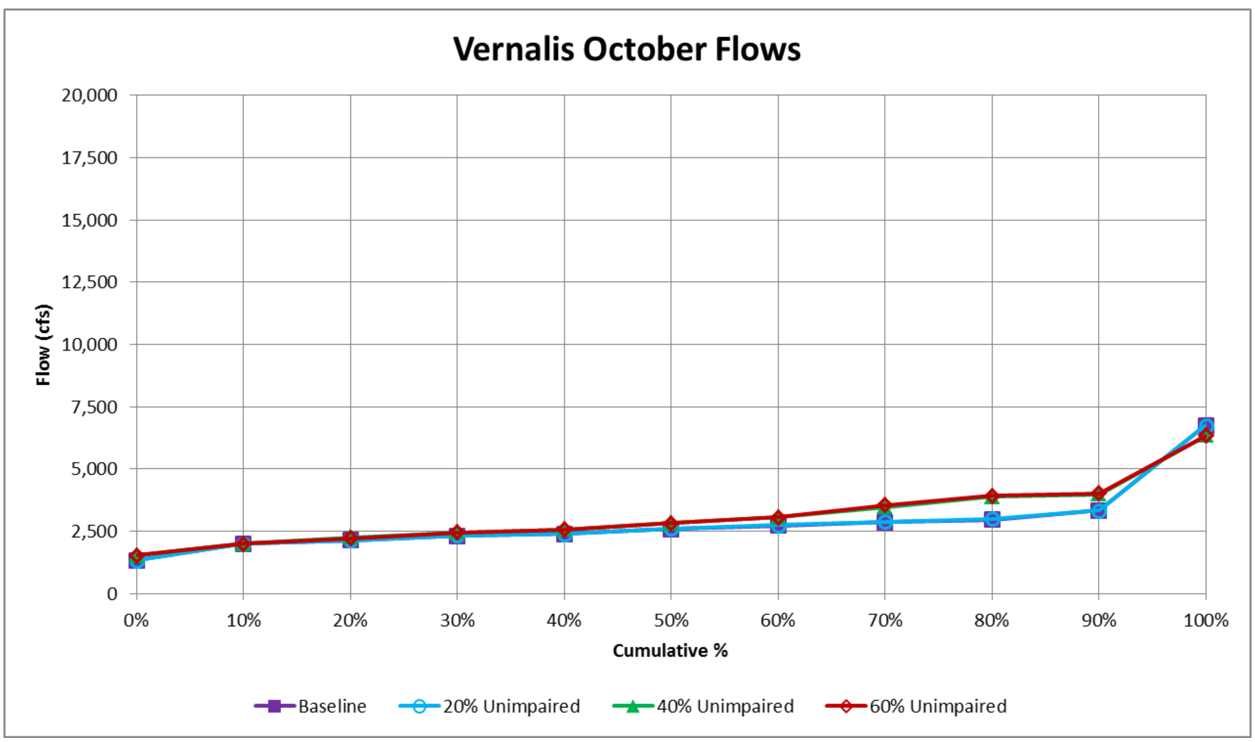


Figure F.1.4-4j. WSE-Simulated Cumulative Distributions of SJR at Vernalis October Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

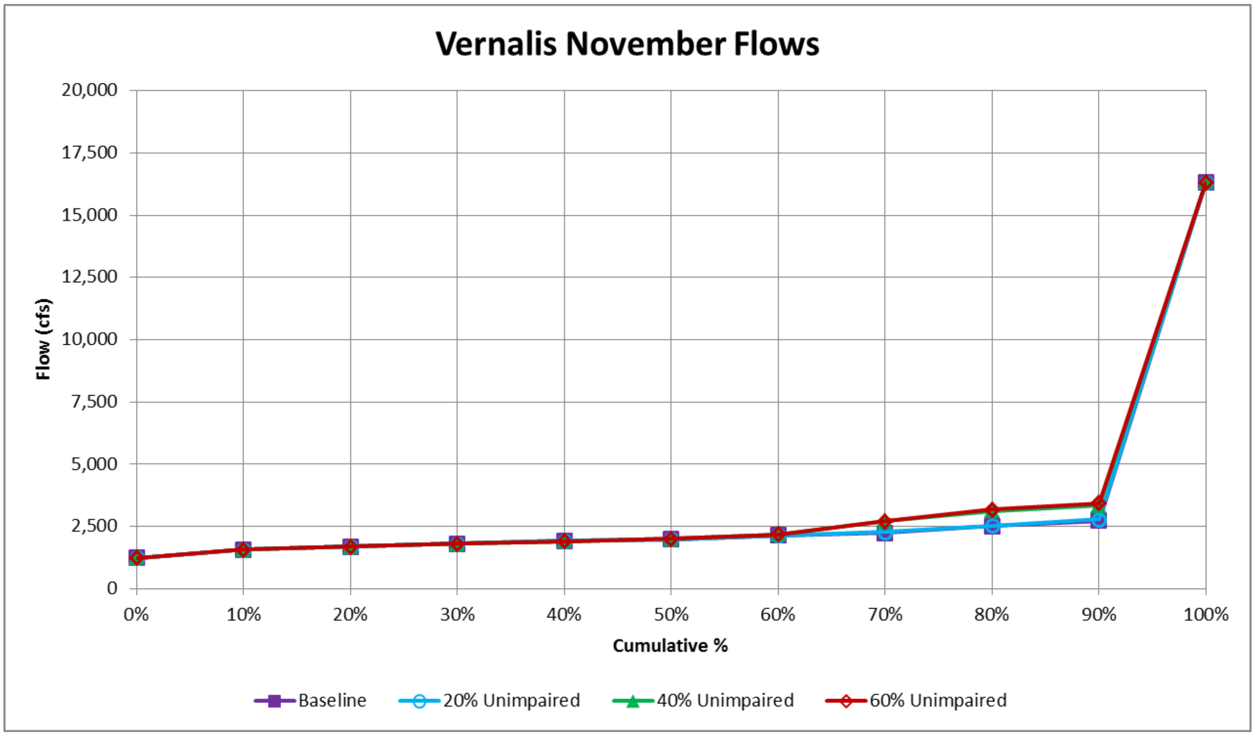


Figure F.1.4-4k. WSE-Simulated Cumulative Distributions of SJR at Vernalis November Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

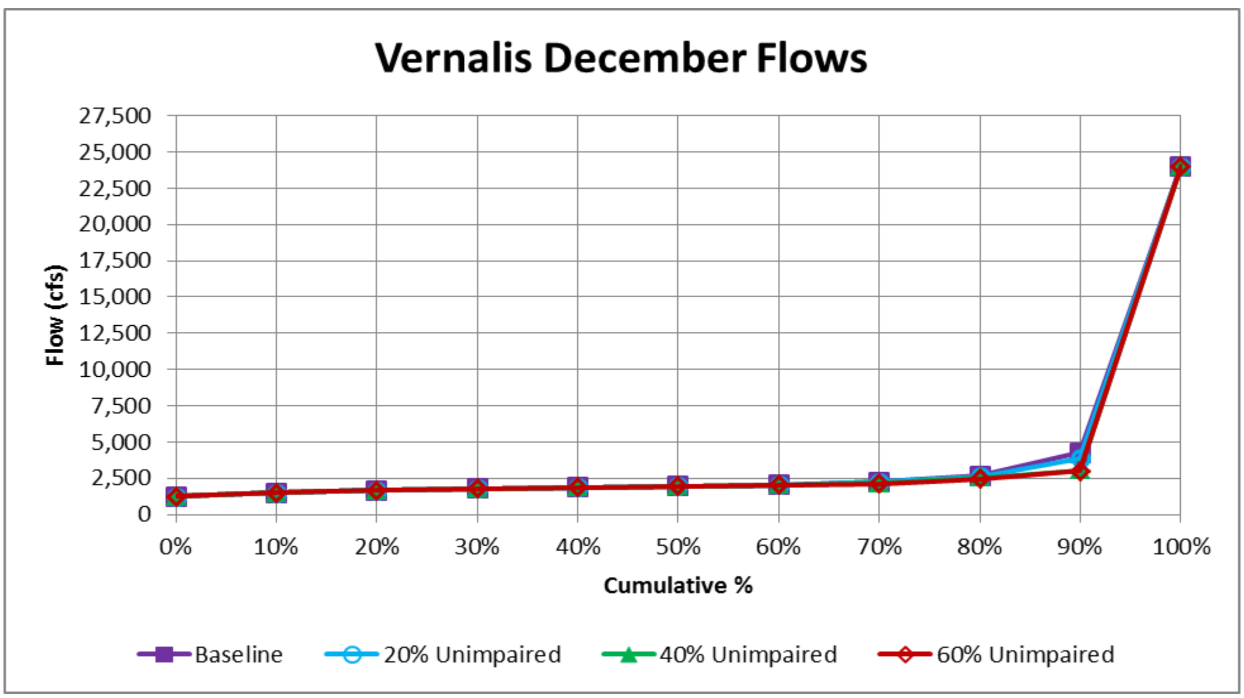


Figure F.1.4-4l. WSE-Simulated Cumulative Distributions of SJR at Vernalis December Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

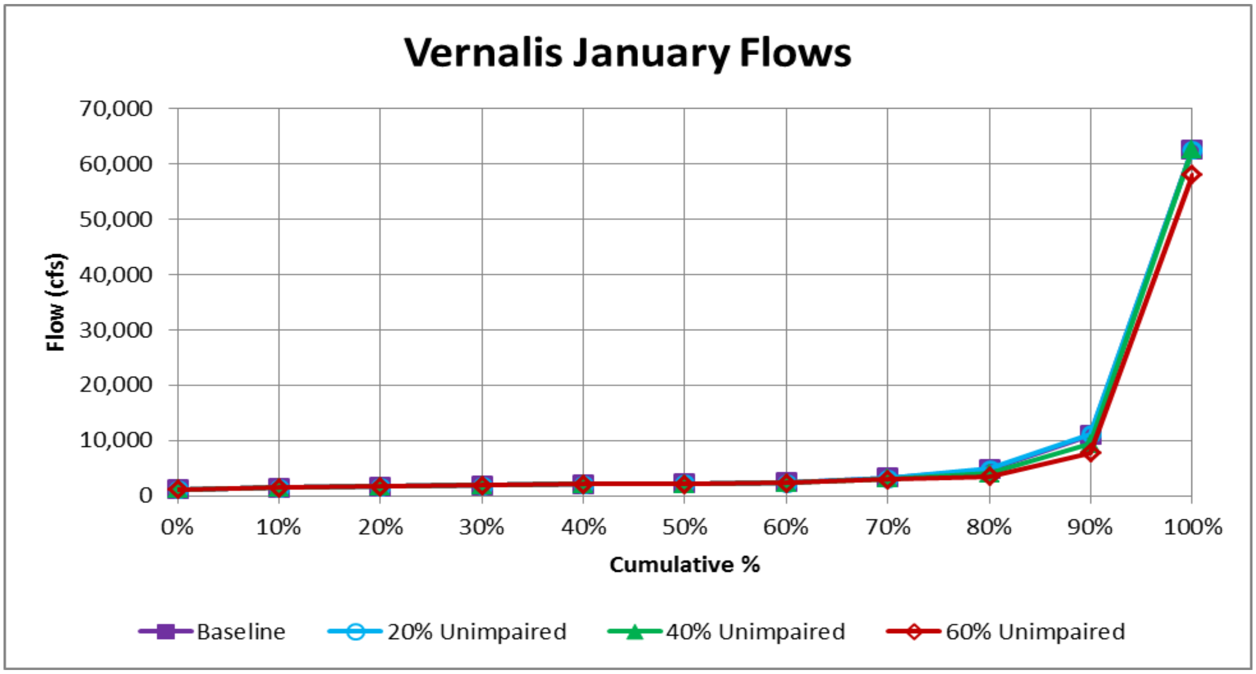


Figure F.1.4-4m. WSE-Simulated Cumulative Distributions of SJR at Vernalis January Flows (cfs) for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

F.1.5 Salinity Modeling

This section contains the modeling methods and results of estimating the effects of the LSJR alternatives on salinity (EC) at Vernalis and in the southern Delta. EC at Vernalis was simulated with the WSE model using a ratio based on CALSIM results. The CALSIM model is discussed in more detail in Section F.1.2.1, *Water Supply Effects Methods*. Vernalis EC objectives were met in the WSE model by ensuring that enough flow was maintained at Vernalis to meet the EC objectives. Southern Delta EC values were estimated using empirically derived relationships with Vernalis EC. Alternative effects were determined by comparing the LSJR alternatives to baseline conditions.

F.1.5.1 Salinity Modeling Methods

The salinity calculations are based on salinity estimates calculated by the CALSIM model used in the development of the WSE baseline discussed above. CALSIM flow and salinity at Vernalis were used to develop the alternative salinity at Vernalis subject to the LSJR alternative flow. The WSE model roughly estimates the salinity at Vernalis for the entire 82 year period of modeling. The CALSIM EC was adjusted to approximate the inverse of the flow change ratio. The WSE model estimates the adjusted EC at Vernalis as:

*Adjusted Vernalis EC = CALSIM EC * (CALSIM Flow/Adjusted Flow)* (Eqn. F.1-14)

For example, a Vernalis flow increase of 10 percent will reduce the Vernalis EC by almost 10 percent. A flow reduction of 10 percent will increase the EC by almost 10 percent. Reservoir releases for the Stanislaus River sometimes had to be increased in the WSE in order to meet the Vernalis EC objective, generally when the Vernalis flow was relatively low.

CALSIM values were used as a starting point because the CALSIM results include the 82-year period of estimated salinity and because CALSIM closely matches recent historical salinity at Vernalis (Figure F.1.5-1). A discussion of improvements to the CALSIM SJR EC calculations and evaluation of the performance of the model for calculating EC at Vernalis is available in the USBR (2004) document, Technical Memorandum, Development of Water Quality Module. CALSIM II has a water quality module, which provides estimates of salinity at Vernalis. This module uses a “link-node” approach that assigns salinity values to major inflows to the SJR between Lander Avenue and Vernalis and calculates the resulting salinity at Vernalis using a salt mass balance equation. Inflows from the west side of the SJR are also broken out and calculated as the return flows associated with various surface water diversions and groundwater pumping (USBR 2004). The CALSIM model assumes constant flow to EC relationships (i.e., EC = a x flow-b) for the SJR above the Merced, Tuolumne, and Stanislaus Rivers to estimate the salinity at Vernalis.

In Figure F.1.5-1, monthly average observed salinity data from the California Data Exchange Center (CDEC) at Vernalis (DWR 2010a) are plotted together with the CALSIM II estimates of salinity at Vernalis for water years 1994 through September 2003. This represents a period commencing shortly after temporary agricultural flow barriers in the southern Delta were regularly installed through to the end of the overlapping CALSIM II simulation period.

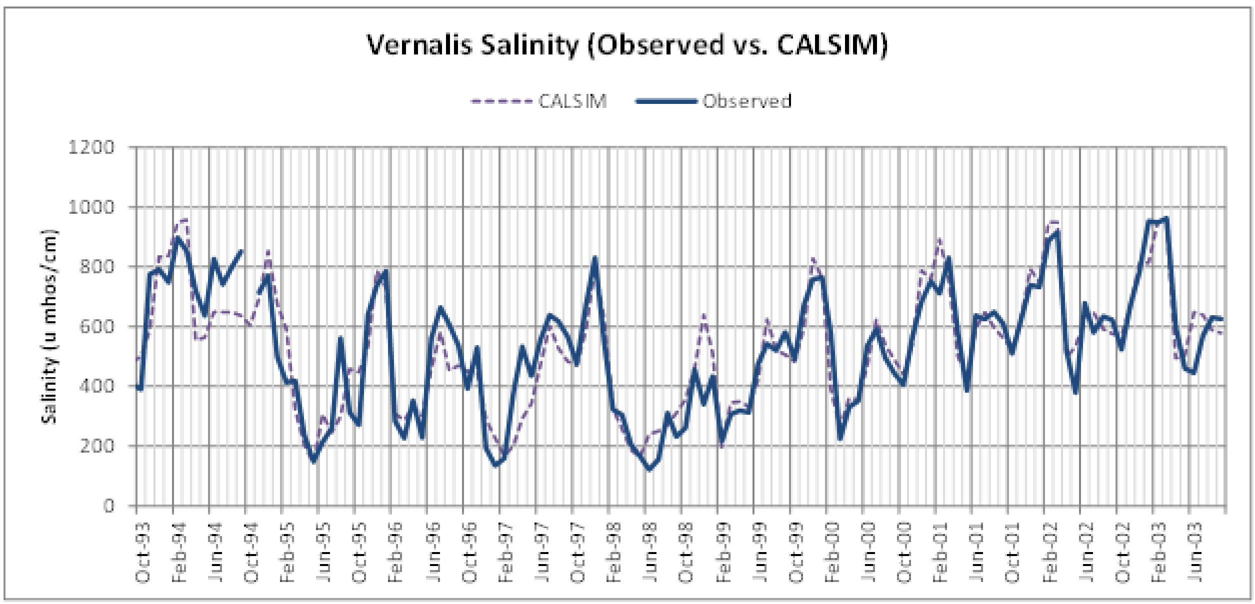


Figure F.1.5-1. Comparison of CALSIM II Salinity Output at Vernalis to Monthly Average Observed Data at the Same Location for Water Years 1994–2003)

Southern Delta EC Increments

In order to estimate the resulting EC at the interior Delta stations, a simplified approach was taken using historical data. Simple calculations of the southern Delta EC values were made based on the historical EC increases between Vernalis and the southern Delta stations for 1985–2010 (described in detail in Appendix F.2, *Evaluation of Historical Flow and Salinity Measurements of the Lower San Joaquin River and Southern Delta*). The EC increment can be described as the increase in salinity from the Vernalis station to the next station due to additional salt introduced downstream from Vernalis. These calculated EC increases between Vernalis and the southern Delta compliance stations (Brandt Bridge, Union Island, and Tracy Boulevard) were assumed to be reasonable approximations for purposes of salinity impact assessment.

Figure F.1.5-2a shows the measured EC increments between Vernalis and Brandt Bridge or between Vernalis and Old River at Union Island as a function of the Vernalis flow. The measured EC increments generally are reduced when the Vernalis flow is higher. An example flow-dilution relationship is shown on the graph for 100,000/flow (cfs) and for 200,000/flow (cfs). Some EC increments are higher and some are lower, but this appears to be a reasonable approach for estimating the southern Delta EC based on the Vernalis EC and Vernalis flow. The review of the historical EC data suggested that the EC increment from Vernalis to Brandt Bridge or Old River at Middle River (Union Island) can be approximated with a flow-dilution relationship:

EC increase from Vernalis (µS/cm) = 100,000/SJR flow at Vernalis (cfs) (Eqn. F.1-15)

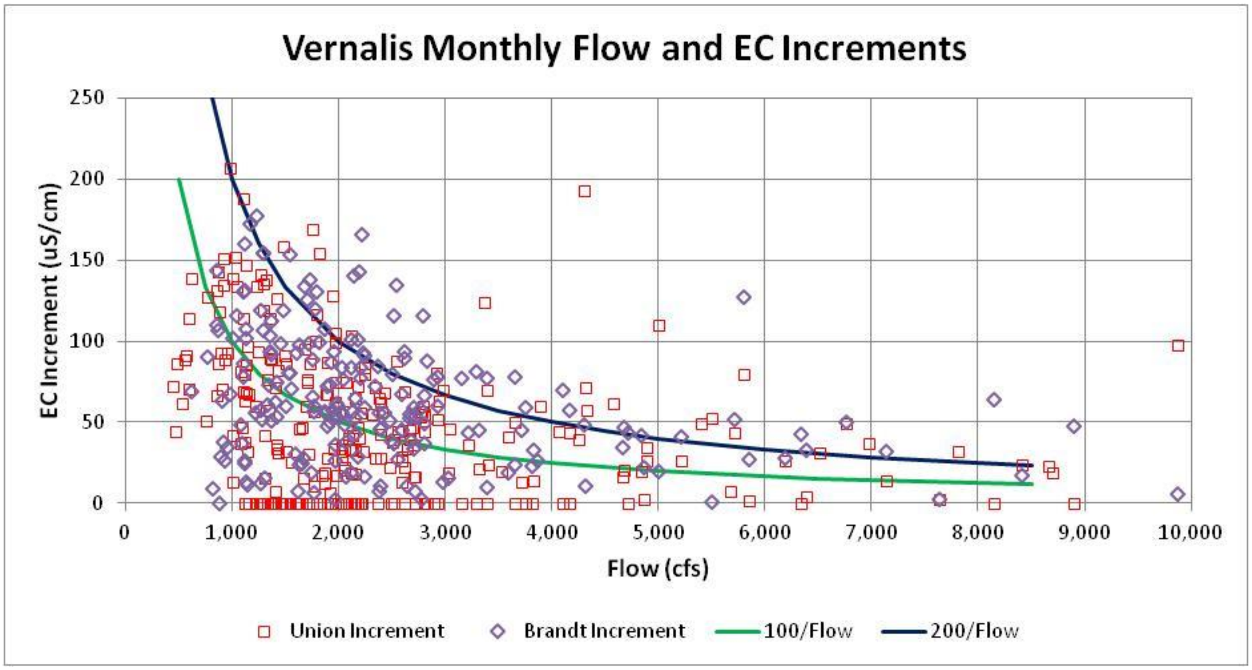


Figure F.1.5-2a. Historical Monthly EC Increments from Vernalis to Brandt Bridge and Union Island as a Function of Vernalis Flow (cfs) for Water Years 1985–2010)

Therefore, for a flow of 1,000 cfs, the EC increase (EC increment) would be 100 µS/cm. For a flow of 2,000 cfs, the EC increase would be 50 µS/cm, and for a flow of 5,000 cfs, the EC increase would be 20 µS/cm. Figure F.1.5-2b shows the measured EC increments between Vernalis and Old River at Tracy Boulevard as a function of the Vernalis Flow. The measured EC increments generally are reduced when the Vernalis flow is higher. An example flow-dilution relationship is shown on the graph for 200,000/flow (cfs) and for 400,000/flow (cfs). The EC increase at Old River at Tracy Boulevard was assumed to be three times the EC increase at Brandt Bridge:

EC increase from Vernalis (μS/cm) = 300,000/SJR flow at Vernalis (cfs) (Eqn. F.1-16)

The Tracy Boulevard station is most affected by salt sources within the Delta and limited tidal circulation in Old River between Doughty Cut and the CVP Jones Pumping plant. These calculated EC increases were assumed for purposes of salinity impact assessment and could be modified if more accurate descriptions of the southern Delta salinity relationships are determined.

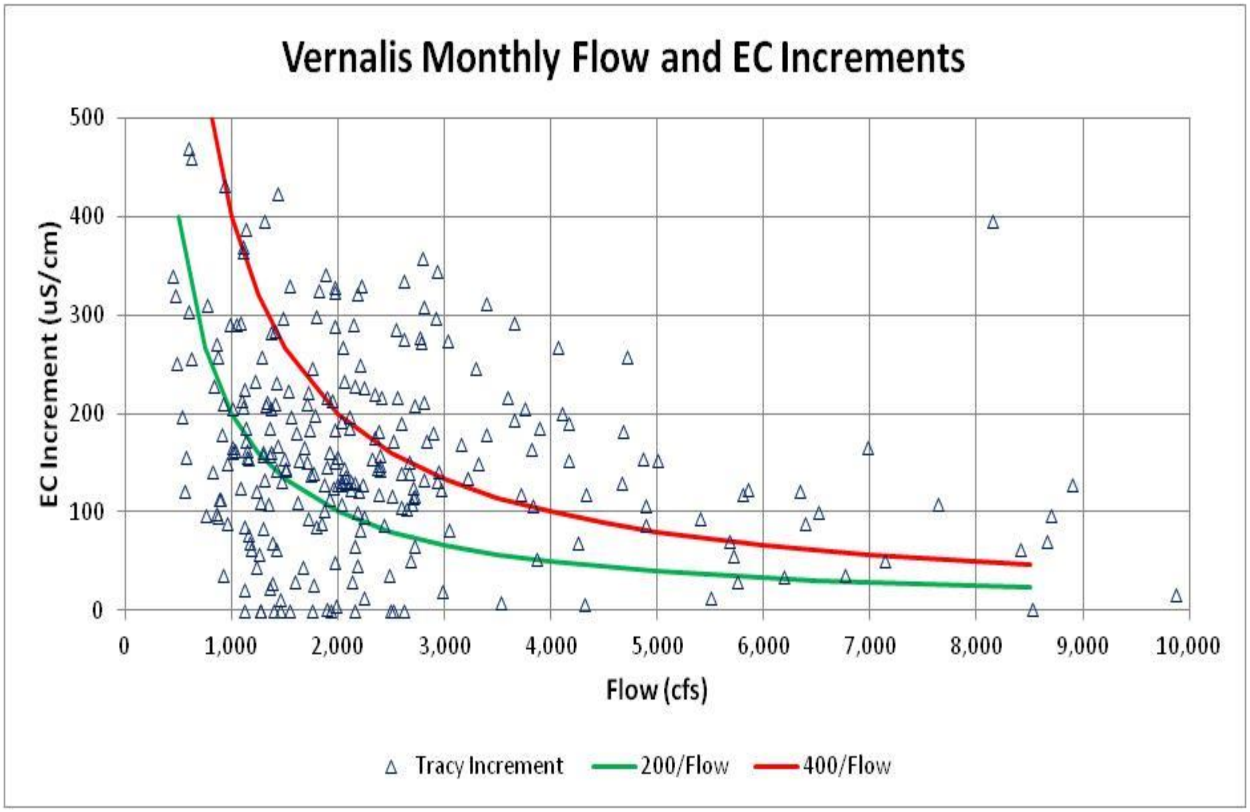


Figure F.1.5-2b. Historical Monthly EC Increments from Vernalis to Tracy Boulevard as a Function of Vernalis Flow (cfs) for Water Years 1985–2010)

F.1.5.2 Salinity Modeling Results

Baseline conditions for salinity are discussed below. The calculated changes under 20, 40, and 60 percent minimum unimpaired flow (LSJR Alternatives 2, 3, and 4) are presented and discussed below. Results for the 30 percent and 50 percent unimpaired flow simulation would be intermediate between the 20 percent and 40 percent and 40 percent and 60 percent unimpaired flow simulations respectively.

Baseline Conditions

The flow, EC, and salt load of the SJR upstream of the Merced River are assumed to remain the same for all of the LSJR alternatives. The CALSIM salt load upstream of the Merced River contributes to the CALSIM salt load at Vernalis, which is used in the Vernalis EC calculation by the WSE model.

Table F.1.5-1a shows the CALSIM-estimated SJR EC values upstream of the Merced River. This is an important location because the combination of the flow and the salinity represents the simulated upstream salt load for baseline conditions, which was assumed to remain the same for LSJR Alternatives 2, 3, and 4. The median (50 percent) monthly EC ranged from about 1,000 µS/cm to about 1,400 µS/cm (in July). The maximum monthly EC values of 1,200 µS/cm to 2,200 µS/cm correspond to the lowest flows; the lowest monthly EC values, which were less than 500 µS/cm for most months, correspond to the highest flows. The last column in Table F.1.5-1a shows the annual salt load cumulative distributions for the SJR above the Merced River (1,000 tons). A factor of 0.65 was used to convert EC in units of µS/cm to total dissolved solids (TDS) in units of mg/l. The annual salt load above the Merced River ranged from about 304,000 tons (10 percent cumulative distribution) to 663,000 tons (90 percent cumulative distribution) with an average of about 447,000 tons. This upstream salt load accounts for about 40 percent of the annual salt load for the SJR at Vernalis (average of about 1,100,000 tons). Much of the remainder of the salt load originates from tile drainage and shallow groundwater seepage to the SJR from below irrigated lands.

The baseline results for the SJR at Vernalis are summarized here using the monthly and annual cumulative distribution format tables for the period 1922–2003. Table F.1.5-1b shows the monthly and annual cumulative distributions for the baseline SJR EC at Vernalis. These baseline condition EC values were assumed to always satisfy the Vernalis EC objectives, although the historical record has occasionally shown otherwise since this EC objective was implemented in 1995 by the Bay-Delta Plan.

Table F.1.5-1a. CALSIM-Simulated Baseline Monthly Cumulative Distributions of SJR above the Merced EC (µS/cm) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Salt Load (1000 tons)
SJR Above Merced EC (µS/cm)													
Minimum	494	331	333	290	296	317	194	201	204	239	1,085	1,135	253
10%	1,159	964	905	467	463	548	289	277	496	1,242	1,135	1,150	304
20%	1,172	1,022	1,104	791	716	791	608	790	1,048	1,309	1,143	1,156	326
30%	1,173	1,095	1,184	955	905	947	846	968	1,120	1,331	1,165	1,163	334
40%	1,174	1,185	1,245	1,117	1,010	1,040	929	1,051	1,174	1,363	1,196	1,167	340
50%	1,182	1,215	1,282	1,197	1,093	1,156	1,030	1,109	1,210	1,385	1,196	1,167	371
60%	1,200	1,227	1,303	1,255	1,173	1,232	1,171	1,125	1,252	1,411	1,196	1,168	414
70%	1,200	1,231	1,322	1,307	1,223	1,423	1,233	1,195	1,271	1,415	1,196	1,169	460
80%	1,201	1,241	1,325	1,365	1,282	1,556	1,283	1,285	1,300	1,430	1,196	1,172	532
90%	1,201	1,261	1,349	1,366	1,351	1,616	1,382	1,359	1,322	1,456	1,197	1,187	663
Maximum	1,304	1,318	1,375	1,433	1,529	2,157	1,801	1,447	1,717	1,559	1,227	1,204	1,460
Average	1,176	1,136	1,181	1,062	1,012	1,154	966	1,000	1,100	1,319	1,178	1,166	447

Note: these results are the same for all LSJR alternatives.

Table F.1.5-1b. Baseline Monthly Cumulative Distributions of SJR at Vernalis EC (µS/cm) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Vernalis EC (µS/cm)												
Minimum	193	155	222	218	186	193	180	144	205	222	163	227
10%	440	507	606	386	296	264	245	192	334	451	420	448
20%	468	542	749	568	344	306	305	299	406	544	442	481
30%	484	584	784	672	466	337	347	341	432	573	497	495
40%	489	596	807	752	600	458	374	362	467	586	528	510
50%	496	612	813	769	684	631	413	375	528	597	547	521
60%	506	629	824	785	780	658	442	421	564	610	569	539
70%	515	645	831	798	870	791	517	461	588	629	590	552
80%	529	664	844	824	936	859	594	567	628	643	613	567
90%	547	686	867	838	1,000	1,000	676	644	682	660	655	590
Maximum	589	759	926	882	1,000	1,000	700	700	700	700	700	669
Average	492	598	770	697	655	592	435	407	508	577	535	518

Table F.1.5-1c shows the monthly and annual cumulative distributions for the baseline salt loads for the SJR at Vernalis. The monthly salt loads (proportional to the flow multiplied by the EC values) ranged from about 20,000 tons during summer months with low flow to more than 250,000 tons in some high-flow winter and spring months. These salt loads are relatively uniform throughout the year, increasing most dramatically with higher flows. The annual salt load at Vernalis ranged from 707,000 tons (10 percent cumulative distribution) to 1,693,000 tons (90 percent cumulative distribution) with a median salt load of 971,000 tons and an average of 1,118,000 tons.

The Vernalis EC results reveal an important assumption in the operations of New Melones Reservoir. In addition to the required environmental releases, New Melones releases additional water to reduce the Vernalis EC to below the objective. The baseline condition results indicate that the 1,000 µS/cm EC objective is controlling the Vernalis flow (and the New Melones release) in February and March for more than 10 percent of the years, and the 700 µS/cm EC objective is controlling flows in June and July for more than 10 percent of the years. The available EC data at Vernalis and at the southern Delta monitoring stations are described in Appendix F.2.

Table F.1.5-1c. Baseline Monthly Cumulative Distributions of SJR at Vernalis Salt Load (1,000 tons) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual
	SJR at Vernalis Salt Load (1,000 tons)												
Minimum	43	49	60	55	75	61	39	41	18	18	22	34	589
10%	55	56	72	68	87	87	59	53	36	32	37	46	707
20%	61	59	78	75	93	94	70	69	42	39	40	50	809
30%	64	61	81	82	98	104	82	74	47	42	42	52	859
40%	67	63	84	90	103	111	91	81	55	46	44	53	913
50%	70	64	86	92	109	118	100	89	63	52	45	55	971
60%	73	66	89	98	118	123	108	95	71	58	52	60	1,095
70%	75	68	93	122	124	130	121	108	80	69	60	64	1,196
80%	77	71	109	161	162	138	128	126	158	102	65	66	1,449
90%	80	74	147	220	258	234	145	143	209	169	68	69	1,693
Maximum	93	133	314	741	459	579	250	262	291	287	81	92	3,130
Average	69	66	103	125	139	141	104	98	90	76	50	57	1,118

Table F.1.5-1d shows the calculated monthly cumulative distributions of the EC increments between Vernalis and Brandt Bridge (and at Old River at Middle River) for the baseline flow conditions.

Table F.1.5-1d. Calculated Baseline Monthly Cumulative Distributions of the EC Increment (µS/cm) from Vernalis to Brandt Bridge and Vernalis to Old River at Middle River 1922–2003 (Overall Average of µS/cm)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Brandt Bridge and Old River at Middle River EC Increment (µS/cm)											
Minimum	15	6	4	2	3	2	4	4	4	4	11	13
10%	30	37	23	9	7	7	8	8	9	14	34	34
20%	34	40	37	21	11	12	13	14	16	30	38	38
30%	35	45	44	30	16	13	16	19	29	49	47	41
40%	37	47	49	40	22	18	19	19	32	55	59	46
50%	38	50	52	45	29	29	22	22	44	62	65	49
60%	42	52	53	47	37	29	25	29	54	71	70	53
70%	43	55	56	52	44	42	30	33	65	80	73	56
80%	47	59	60	59	49	44	43	43	70	88	80	59
90%	50	64	66	68	54	62	62	65	99	104	95	67
Maximum	74	81	81	87	66	89	85	91	141	190	173	105
Average	40	50	48	41	30	31	28	29	50	65	65	50

Table F.1.5-1e shows the monthly cumulative distributions for the calculated SJR at Brandt Bridge and Old River at Middle River EC for baseline conditions. This EC is the calculated Vernalis EC plus the estimated EC increment from Vernalis to Brandt Bridge. The calculated EC at Brandt Bridge was greater than the baseline EC objectives in many months (110 of 984) because the estimated EC increase was sometimes large. The calculated EC at Brandt Bridge was greater than the EC objectives in 68 months (out of 410) during the February–June period.

Table F.1.5-1e. Calculated Baseline Monthly Cumulative Distributions of SJR at Brandt Bridge and Old River at Middle River EC (μS/cm) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Brandt Bridge and Old River at Middle River EC (μS/cm)												
Minimum	208	162	226	220	191	203	183	148	208	226	174	241
10%	471	543	630	395	304	272	252	198	342	466	453	482
20%	502	580	786	590	353	311	323	312	425	598	480	519
30%	521	629	829	698	479	348	365	362	457	623	555	541
40%	525	645	856	793	624	477	394	381	497	649	589	558
50%	534	658	866	814	709	659	436	393	584	657	612	572
60%	550	681	878	831	819	690	465	450	621	685	639	592
70%	558	700	887	851	912	835	551	499	642	710	660	606
80%	573	723	903	881	985	902	637	612	706	741	690	628
90%	597	750	935	901	1,054	1,062	730	698	757	762	761	652
Maximum	663	840	993	969	1,066	1,089	784	786	827	868	870	773
Average	532	647	818	739	686	622	463	437	558	642	600	568

Table F.1.5-1f shows the calculated monthly cumulative distributions of the assumed EC increments between Vernalis and Tracy Boulevard for baseline conditions, and Table F.1.5-1g shows the resulting monthly cumulative distributions for the calculated Old River at Tracy Boulevard EC for baseline conditions. The calculated EC at Tracy Boulevard was greater than the (baseline) EC objectives in many months (267 of 984) because the assumed EC increase was often large. The calculated EC at Tracy Boulevard was greater than the EC objectives in 114 months (out of 410) during the February–June period. Because the baseline EC objectives are the same at the southern Delta stations, these baseline EC increments will cause many EC values at the southern Delta stations to be greater than the EC objectives.

Table F.1.5-1f. Calculated Baseline Monthly Cumulative Distributions of the EC Increment (µS/cm) from Vernalis to Old River at Tracy Boulevard 1922–2003 (Overall Average of 132 µS/cm)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Old River at Tracy Boulevard EC Increment (µS/cm)											
Minimum	44	18	12	5	9	6	11	12	11	13	33	39
10%	90	110	70	27	20	22	24	23	26	43	101	102
20%	101	119	112	63	32	35	38	42	48	91	113	115
30%	105	134	133	91	48	39	48	58	88	146	140	124
40%	110	141	147	121	67	54	57	58	97	164	176	139
50%	115	151	155	136	86	86	65	65	132	185	194	148
60%	126	156	159	141	111	88	76	87	163	212	209	158
70%	129	166	168	157	132	127	90	98	195	240	218	167
80%	141	177	181	177	148	132	128	130	211	265	240	178
90%	150	192	198	203	162	186	186	195	297	313	284	202
Maximum	223	243	242	262	197	267	256	274	423	571	519	314
Average	120	149	144	124	91	92	85	88	151	194	195	151

Table F.1.5-1g. Calculated Baseline Monthly Cumulative Distributions of Old River at Tracy Boulevard EC (µS/cm) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Old River at Tracy Boulevard Bridge EC (µS/cm)											
Minimum	237	174	234	223	201	222	191	157	216	234	196	267
10%	533	615	678	414	321	295	267	210	358	495	521	550
20%	571	659	861	635	362	327	359	339	473	662	555	592
30%	590	719	915	752	506	371	400	403	512	732	653	626
40%	601	736	953	873	676	515	434	418	558	755	710	649
50%	609	757	972	907	760	715	483	435	675	785	749	673
60%	626	785	983	924	900	748	524	506	736	827	778	699
70%	645	812	999	955	997	922	611	563	767	859	803	713
80%	665	841	1,024	999	1,085	986	723	703	847	910	853	745
90%	697	878	1,072	1,036	1,161	1,186	865	826	984	980	948	786
Maximum	812	1,003	1,133	1,143	1,197	1,267	952	969	1,088	1,210	1,215	983
Average	612	746	914	821	746	684	519	495	658	772	730	669

20 Percent Unimpaired Flow (LSJR Alternative 2)

Table F.1.5-2a shows the WSE-calculated monthly cumulative distributions for the SJR at Vernalis EC for LSJR Alternative 2. These SJR at Vernalis EC values are calculated from the monthly flow changes on the three eastside tributaries and the CALSIM simulated EC values for the SJR at Vernalis. The EC values were higher than the baseline EC values whenever the Vernalis flow was increased and lower than the baseline EC values whenever the Vernalis flow was reduced. The EC changes were smallest when the baseline flow was high and the baseline EC was low. The median calculated SJR at Vernalis EC values were higher than the median baseline EC values in April but lower in May and June. On average, Vernalis EC was very slightly less with LSJR Alternative 2 (20 percent unimpaired flow) than with baseline conditions. Under LSJR Alternative 2, monthly EC values at Vernalis were sometimes lower and sometimes higher than baseline values, with the overall annual average EC values being almost the same (10 µS/cm less for LSJR Alternative 2 than baseline).

Table F.1.5-2a. SJR at Vernalis EC (µS/cm) for 20% Unimpaired Flow (LSJR Alternative 2)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	SJR at Vernalis EC (µS/cm)											
Minimum	193	155	222	218	186	193	180	142	205	222	163	227
10%	437	501	623	380	281	263	242	187	276	451	412	428
20%	467	536	755	546	335	301	300	269	318	552	440	477
30%	480	579	794	695	489	330	357	307	345	581	498	496
40%	486	596	810	754	573	473	397	326	375	588	534	507
50%	492	612	818	777	651	631	431	342	419	601	547	519
60%	504	629	825	789	853	703	465	372	443	620	567	536
70%	514	645	832	806	912	836	497	407	464	631	580	548
80%	529	664	848	825	976	969	536	438	524	649	607	567
90%	544	686	867	848	1,000	1,000	596	502	583	663	654	585
Maximum	589	759	926	882	1,000	1,000	700	700	700	700	700	669
Average	490	595	778	700	667	608	426	355	422	581	531	512

Table F.1.5-2b shows the monthly cumulative distributions for the WSE-calculated EC for the SJR at Brandt Bridge and Old River at Middle River for LSJR Alternative 2. Table F.1.5-2c shows the monthly cumulative distributions for the WSE-calculated EC for Old River at Tracy Boulevard for LSJR Alternative 2. The EC increment at Tracy Boulevard was assumed to be three times the EC increment at Brandt Bridge. The calculated EC in the southern Delta would change primarily during the February–June period when the specified percent unimpaired flow requirement is being met. Because the monthly flows at Vernalis did not change by very much, the calculated EC values in the southern Delta did not change substantially for LSJR Alternative 2. However, whenever there was an increase in the monthly Vernalis flow, there was an reduction in the Vernalis EC and a further reduction in the southern Delta EC estimates (more dilution of agricultural drainage and wastewater discharges). There were 93 months (51 in the February–June period) with calculated EC greater than the baseline EC objectives at Brandt Bridge and 248 months (91 in the February–June period) at Tracy Boulevard (i.e., fewer exceedances than with baseline).

Table F.1.5-2b. Calculated Monthly Cumulative Distributions of SJR at Brandt Bridge and Old River at Middle River EC (µS/cm) for 20% Unimpaired Flow (LSJR Alternative 2) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Brandt Bridge EC (µS/cm)												
Minimum	208	162	226	220	191	203	183	146	208	226	174	241
10%	468	538	636	390	288	271	250	191	302	466	445	459
20%	501	575	798	564	343	306	312	283	338	600	477	514
30%	514	624	840	725	508	343	378	324	373	633	555	541
40%	523	645	859	794	595	488	420	342	408	653	589	552
50%	528	658	868	824	682	659	462	361	452	674	616	569
60%	547	681	878	837	894	736	498	396	481	692	635	584
70%	558	700	887	857	957	876	525	433	504	713	655	603
80%	573	723	903	882	1,028	1,028	572	473	584	738	688	628
90%	595	750	935	901	1,056	1,062	641	548	661	761	757	650
Maximum	663	840	993	969	1,066	1,089	774	779	799	868	870	773
Average	530	645	826	742	698	639	453	380	462	646	596	562

Table F.1.5-2c. Calculated Monthly Cumulative Distributions of Old River at Tracy Boulevard Bridge EC (µS/cm) for 20% Unimpaired Flow (LSJR Alternative 2) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Old River at Tracy Boulevard Bridge EC (µS/cm)												
Minimum	237	174	234	223	201	222	191	155	216	234	196	267
10%	529	611	690	410	303	288	264	200	347	495	511	520
20%	571	655	878	600	358	318	336	315	383	689	551	590
30%	586	715	925	788	542	370	421	363	422	733	658	626
40%	595	736	953	875	640	516	462	379	465	770	713	646
50%	604	757	972	916	733	715	509	395	512	793	742	666
60%	626	785	983	933	977	801	554	442	556	831	772	684
70%	644	812	999	960	1,047	956	586	500	591	859	802	713
80%	665	841	1,024	999	1,131	1,139	650	546	721	904	853	744
90%	697	878	1,072	1,036	1,169	1,185	757	630	819	980	948	786
Maximum	812	1,003	1,133	1,143	1,197	1,267	922	937	998	1,210	1,215	983
Average	610	744	923	825	760	702	506	430	543	776	725	661

40 Percent Unimpaired Flow (LSJR Alternative 3)

Table F.1.5-3a shows the monthly cumulative distribution for the WSE-calculated EC for the SJR at Vernalis for LSJR Alternative 3. The median calculated SJR at Vernalis EC values were 90 to 229 µS/cm less from March–June compared to the median baseline EC values. Table F.1.5-3b shows the monthly cumulative distributions for the calculated SJR at Brandt Bridge and Old River at Middle River EC for LSJR Alternative 3. Table F.1.5-3c shows the monthly cumulative distributions for the calculated Old River at Tracy Boulevard EC for LSJR Alternative 3. Because the monthly flows at Vernalis generally increased for LSJR Alternative 3, the southern Delta EC values were usually reduced from baseline, especially in March–June, and there were fewer months with EC greater than the EC objectives. There were 74 months (28 in the February–June period) with calculated EC greater than the baseline EC objectives at Brandt Bridge and 202 months (43 in the February–June period) at Tracy Boulevard (i.e., fewer exceedances than with baseline).

Table F.1.5-3a. SJR at Vernalis EC (μS/cm) for 40% Unimpaired Flow (LSJR Alternative 3)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Vernalis EC (μS/cm)												
Minimum	205	155	222	218	186	193	175	136	141	246	163	227
10%	355	409	750	414	282	288	216	168	184	428	416	361
20%	368	424	792	674	379	313	252	186	210	506	436	382
30%	404	510	807	757	448	374	285	202	242	571	511	436
40%	444	590	813	776	498	438	312	217	273	585	525	502
50%	467	612	824	785	714	541	339	234	299	589	555	524
60%	473	631	830	799	797	610	356	247	340	608	574	540
70%	479	646	841	817	863	672	389	271	372	627	592	551
80%	488	664	859	833	945	763	415	291	418	642	617	567
90%	515	688	895	855	988	925	462	316	489	663	654	585
Maximum	540	759	1,000	936	1,000	1,000	700	557	673	700	700	669
Average	443	567	807	734	649	554	341	244	323	570	538	493

Table F.1.5-3b. Calculated Monthly Cumulative Distributions of SJR at Brandt Bridge and Old River at Middle River EC (μS/cm) for 40% Unimpaired Flow (LSJR Alternative 3) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Brandt Bridge EC (μS/cm)												
Minimum	221	162	226	220	191	203	179	140	167	252	174	241
10%	381	439	791	425	290	294	223	181	196	451	452	389
20%	394	455	837	700	395	325	274	197	228	537	473	411
30%	433	547	856	794	462	394	301	215	264	614	561	471
40%	477	636	865	819	518	456	329	230	293	641	585	551
50%	506	658	875	831	750	565	358	248	322	657	625	574
60%	514	683	885	849	834	645	376	262	371	685	642	590
70%	518	702	900	872	907	705	412	285	424	710	668	605
80%	528	724	922	890	994	799	447	313	447	734	688	626
90%	573	752	963	921	1,041	978	486	346	538	762	750	653
Maximum	594	840	1,037	985	1,066	1,089	774	615	765	868	870	773
Average	479	614	856	776	679	582	362	261	352	634	603	541

Table F.1.5-3c. Calculated Monthly Cumulative Distributions of Old River at Tracy Boulevard Bridge EC (µS/cm) for 40% Unimpaired Flow (LSJR Alternative 3) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
	Old River at Tracy Boulevard Bridge EC (µS/cm)											
Minimum	253	174	234	223	201	222	186	149	196	262	196	267
10%	432	499	874	447	307	305	243	191	225	479	519	448
20%	447	518	926	746	426	351	306	221	258	589	557	467
30%	492	621	952	873	487	430	340	241	286	711	655	537
40%	542	729	967	909	559	492	358	259	336	747	713	644
50%	577	757	980	924	822	621	396	274	360	790	754	673
60%	592	788	993	946	904	708	419	295	409	826	784	694
70%	599	813	1,007	971	997	778	457	323	484	865	802	715
80%	612	842	1,043	1,004	1,087	875	496	357	538	910	853	744
90%	676	881	1,088	1,059	1,149	1,085	547	421	653	980	938	790
Maximum	709	1,003	1,133	1,143	1,197	1,267	922	731	951	1,210	1,215	983
Average	552	709	954	862	739	638	403	294	411	761	733	638

60 Percent Unimpaired Flow (LSJR Alternative 4)

Table F.1.5-4a shows the monthly cumulative distributions for the WSE-calculated EC for the SJR at Vernalis for LSJR Alternative 4. The median calculated SJR at Vernalis EC values were considerably less than the median baseline EC values. The median calculated SJR at Vernalis EC values were 109 to 305 µS/cm less from February–June compared to the median baseline EC values.

Table F.1.5-4b shows the monthly cumulative distributions for the calculated SJR at Brandt Bridge and Old River at Middle River EC for LSJR Alternative 4. Table F.1.5-4c shows the monthly cumulative distributions for the calculated Old River at Tracy Boulevard EC for LSJR Alternative 4. Because the monthly flows at Vernalis were substantially increased in the February–June period for LSJR Alternative 4, the southern Delta EC values were reduced from baseline, and there were fewer months with EC greater than the EC objectives. There were 68 months (12 in the February–June period) with calculated EC greater than the baseline EC objectives at Brandt Bridge and 196 months (26 in the February–June period) at Tracy Boulevard.

Table F.1.5-4a. SJR at Vernalis EC (μS/cm) for 60% Unimpaired Flow (LSJR Alternative 4)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Vernalis EC (μS/cm)												
Minimum	205	155	222	235	186	162	137	113	96	286	208	227
10%	347	401	760	481	265	266	174	130	128	482	419	361
20%	365	413	798	713	334	295	201	138	146	567	497	382
30%	403	510	808	766	377	330	222	149	177	588	509	436
40%	444	590	816	780	414	381	237	155	205	605	533	507
50%	468	612	825	791	575	431	258	165	223	614	564	526
60%	473	631	832	808	638	472	288	176	255	629	576	542
70%	479	646	841	829	792	551	300	192	283	638	593	552
80%	488	664	859	847	836	610	331	203	303	659	620	565
90%	520	688	895	873	950	757	370	232	346	700	654	589
Maximum	540	759	1,000	1,000	1,000	1,000	550	438	647	700	700	669
Average	442	566	811	748	581	471	272	178	243	597	548	495

Table F.1.5-4b. Calculated Monthly Cumulative Distributions of SJR at Brandt Bridge and Old River at Middle River EC (μS/cm) for 60% Unimpaired Flow (LSJR Alternative 4) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
SJR at Brandt Bridge EC (μS/cm)												
Minimum	221	162	226	237	191	170	151	121	113	292	222	241
10%	371	429	799	494	276	277	183	136	137	513	453	389
20%	391	445	842	745	348	305	214	145	159	619	539	411
30%	432	547	857	810	392	339	232	156	197	645	560	472
40%	477	636	867	826	428	397	254	164	219	664	592	556
50%	506	658	875	839	602	453	277	175	236	689	632	578
60%	514	683	885	861	672	496	304	186	274	707	648	596
70%	518	702	900	882	830	586	319	204	299	722	671	608
80%	528	724	922	901	882	641	347	219	322	734	689	621
90%	572	752	963	932	1,000	800	391	256	416	762	750	653
Maximum	594	840	1,037	1,031	1,066	1,089	609	483	736	868	870	773
Average	478	613	860	791	607	494	288	190	266	662	613	544

Table F.1.5-4c. Calculated Monthly Cumulative Distributions of Old River at Tracy Boulevard Bridge EC (µS/cm) for 60% Unimpaired Flow (LSJR Alternative 4) 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Old River at Tracy Boulevard Bridge EC (µS/cm)												
Minimum	253	174	234	240	201	185	176	134	134	304	250	267
10%	422	490	877	519	285	303	205	145	157	560	526	445
20%	441	508	936	808	369	327	236	160	181	711	626	471
30%	490	621	952	896	414	361	255	171	227	746	659	540
40%	542	729	967	920	459	431	288	184	246	771	710	652
50%	577	757	980	933	655	502	304	195	267	794	769	677
60%	592	788	996	955	741	552	332	208	303	834	791	701
70%	599	813	1,012	989	900	642	359	228	341	874	813	716
80%	612	842	1,043	1,011	979	697	385	250	386	910	852	736
90%	676	881	1,088	1,076	1,105	887	435	300	501	980	938	790
Maximum	709	1,003	1,133	1,143	1,197	1,267	725	574	914	1,210	1,215	983
Average	550	707	959	878	661	541	319	214	311	792	745	641

F.1.6 Temperature Modeling

This section includes an in-depth description of the temperature model used by the State Water Board to model river temperatures and the effects due to the LSJR alternatives. The State Water Board used the June 2013 release (CDFW 2013) of the temperature model to conduct a comparative analysis of resulting river temperatures as the June 2013 release is the most recent and well documented model of river temperatures within the San Joaquin system. The following sections only present the temperature model methods and resulting river temperatures. This section does not go in to detail regarding the specific changes in temperature and how they would affect other resources. The effects on other resources are discussed within other chapters of the SED.

The LSJR alternatives could affect water temperature by altering river flows and reservoir storage, both of which influence the monthly release temperature. To model effects on temperature in the LSJR and three eastside tributaries, the State Water Board modified the San Joaquin River Basin-Wide Water Temperature and EC Model (named here as SJR HEC-5Q model, or temperature model) developed by a group of consultants between 2003 and 2008 through a series of CALFED contracts that included peer review and refinement (CALFED 2009). The model was most recently updated by CDFW and released in June of 2013 (CDFW 2013). The temperature model uses the Hydrologic Water Quality Modeling System (HWMS-HEC5Q), a graphical user interface that employs the USACE Hydrologic Engineering Center (HEC) flow and water quality simulation model, HEC-5Q.

The temperature model was designed to provide a SJR basin-wide evaluation of temperature response at 6-hour intervals for alternative conditions, such as operational changes, physical changes, and combinations of the two. The extent of the model includes the Merced, Tuolumne, and Stanislaus River systems from their LSJR confluences to the upstream end of the major reservoirs (i.e., McClure, New Don Pedro, and New Melones, respectively). On the SJR, the upstream extent of the model is the Merced River confluence. The downstream extent of the model is the SJR at Mossdale. The model simulates the reservoir stratification, release temperatures, and downstream river temperatures as a function of the inflow temperatures, reservoir geometry and outlets, flow, meteorology, and river geometry. Calibration data was used to accurately simulate temperatures for a range of reservoir operations, river flows, and meteorology.

F.1.6.1 Temperature Model Methods

This section includes a discussion of the temperature model used to calculate river temperatures in the plan area. One of the important features in the June 2013 release of the temperature model is the interface with CALSIM II or monthly data formatted similarly to CALSIM II output (i.e., CALSIM to HEC-5Q). A pre-processing routine converts the monthly output to a format compatible with the SJR HEC-5Q model. This routine serves two purposes: 1) to allow the temperature model to perform a long-term simulation compatible with the period used in CALSIM II and 2) to disaggregate monthly output to daily values used in the temperature model.

Using the monthly output from the WSE model, the June 2013 CALSIM to HEC-5Q temperature model pre-processor was used, and the temperature model was run to determine the river temperature effects of the LSJR alternatives within the Merced, Tuolumne, and Stanislaus Rivers, and the LSJR. The WSE model was developed such that it would output flows at each location corresponding to the CALSIM II nodes. This allowed for a nearly seamless replacement of CALSIM flow values used in the HEC5Q modeling process by the WSE alternative results. The other CALSIM values needed by the temperature model are for portions of the model not affecting the temperature results along the three eastside rivers and the LSJR. Thus, data pertaining to the Upper SJR for example, was unchanged with respect to each LSJR alternative and was unchanged from the HEC-5Q download package. Given the large quantity of data produced by the temperature model, the temperature model was only run from 1970–2003. This retains a period with sufficient length and climatic variation to determine the effects of the LSJR alternatives on river temperatures.

Figure F.1.6-1 is a schematic representation of the SJR HEC-5Q model for the SJR and three eastside tributaries, including Lake McClure, New Don Pedro Reservoir, and New Melones Reservoir. The model computes the vertical distribution of temperature in the reservoirs and the longitudinal temperature distributions in the river reaches based on daily average flows and meteorology. Reservoirs represented in the model include Lake McClure, Lake McSwain, Merced Falls Reservoir, and Crocker Huffman Reservoir on the Merced River; New Don Pedro and La Grange Reservoirs on the Tuolumne River; and New Melones, Tulloch, and Goodwin Reservoirs on the Stanislaus River.

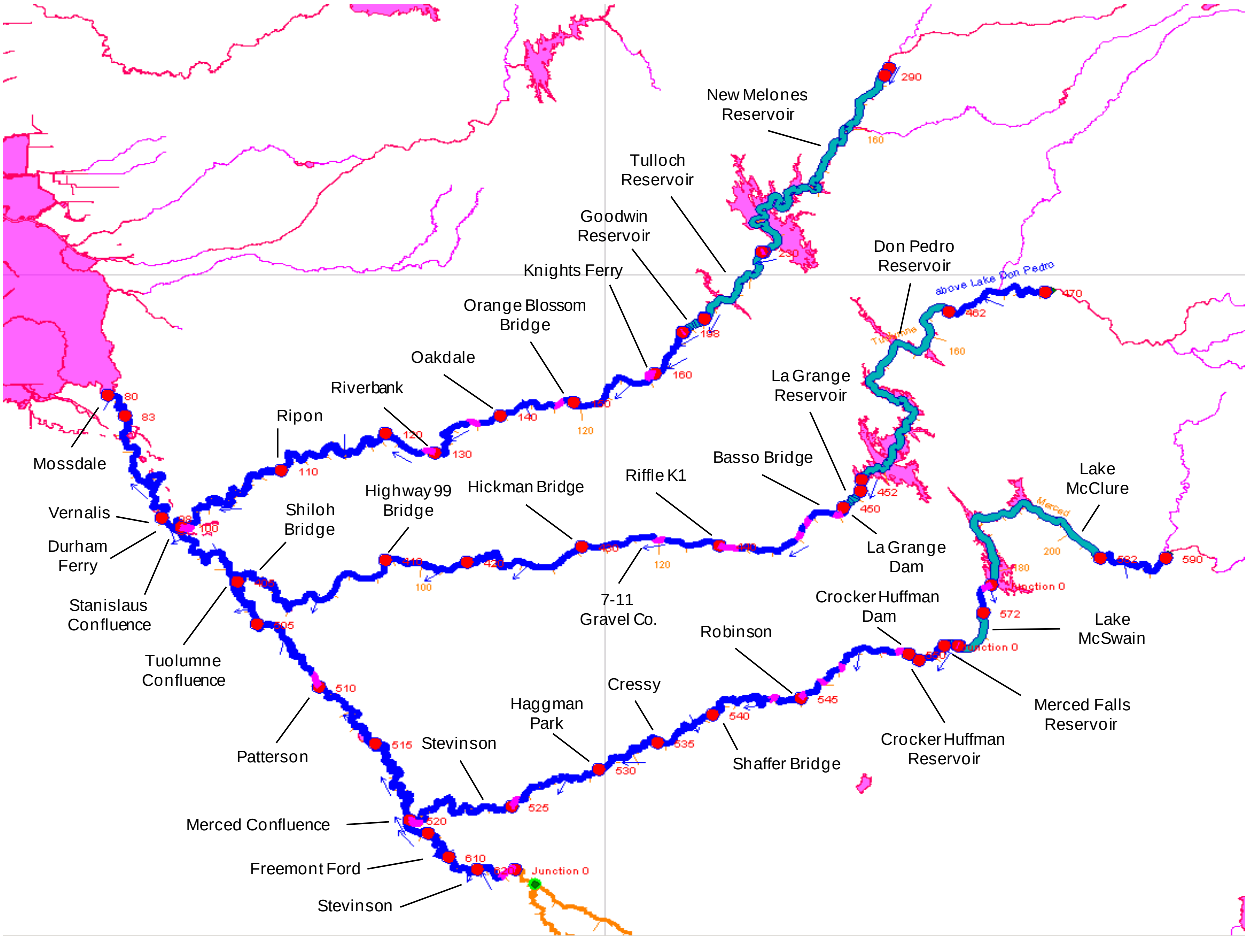


Figure F.1.6-1. The SJR Basin, Including the Stanislaus, Tuolumne, and Merced River Systems, as Represented in the HEC-5Q Model

Water Temperature Model Geometry

The river geometry is specified from measured cross-section data for each 1-mile segment. The river reaches are represented as a series of volume elements. The width, cross-sectional area, and depth vary with the flow using specified relationships developed from appropriate hydraulic computations using the measured river cross-sections. The reservoirs are simulated as a series of vertically stratified layers. The reservoir inflow distribution (vertical spread) and outlet distribution are calculated from the water temperatures (density) and specified coefficients. Vertical advection of water and heat is simulated as a mass balance once the inflow and outflow from each layer is calculated. The balance between solar heating and wind or convective (i.e., cooling at surface) mixing control the surface layer mixed depth.

The river hydraulic model uses the standard one-dimensional river backwater calculations that solve the Manning Equation from the downstream end upriver. These calculations require river cross-sections to describe the local river channel geometry. The HEC-5Q river geometry is simplified as the width at specified elevations for a range of elevations that should allow the maximum flow to be simulated. The hydraulic model can be used to determine the water elevations, with corresponding width and cross sectional area, for a range of flows. Because these sections are specified for various locations along the river, the full river geometry can be described for a range of flows. The sections can be summarized in geometry tables for the river; the river surface area (section width times river distance) and the river volume (cross-sectional area times river distance) can be determined for each section of the river or for the entire length.

Table F.1.6-1a gives the river geometry (surface area, volume, and depth) for the Stanislaus River for a range of flows from 250–10,000 cfs. The average velocity and the travel time from upstream to downstream can be calculated (from the volume, length, and flow). The travel time has been included in the table. For example, the Stanislaus River length is about 58 miles and has a surface area of 736 acres, which is equivalent to an average width of 105 feet at a flow of 250 cfs. The volume is 2,252 AF, so the average depth is 3.1 feet. The travel time for water at the low flow of 250 cfs would be about 4.5 days (109 hours). At this flow, warming would be rapid in the upstream portion of the river (during the first 1–2 days), because the difference between the equilibrium temperature and the release temperature would be greatest.

Table F.1.6-1a. Stanislaus River Geometry Calculated in the HEC-5Q Temperature Model (58-mile Length

Flow (cfs)	Surface Area (acres)	Volume (AF)	Average Depth (feet)	Travel Time (hours)
250	736	2,252	3.1	109
500	799	2,938	3.7	71
1,000	913	4,199	4.6	51
1,500	1,040	5,702	5.5	46
2,000	1,166	7,225	6.2	44
2,500	1,284	8,703	6.8	42
3,000	1,387	10,096	7.3	41
4,000	1,567	12,793	8.2	39
5,000	1,731	15,391	8.9	37
10,000	2,394	27,020	11.3	33

Table F.1.6-1b gives the river geometry (surface area, volume, and depth) for the Tuolumne River for a range of flows from 250–10,000 cfs. The travel time has been included in the table. For example, the Tuolumne River length is about 53 miles and has a surface area of 745 acres, which is equivalent to an average width of 116 feet at a flow of 250 cfs. The volume is 2,623 AF, so the average depth is 3.5 feet. The travel time for water at the low flow of 250 cfs would be about 5.3 days (127 hours). Warming would be rapid in the upstream portion of the river (during the first 1–2 days), because the difference between the equilibrium temperature and the release temperature would be greatest. At a flow of 1,000 cfs, the Tuolumne River area is 933 acres (145 feet width) and the volume is 4,519 AF, so the average depth is 4.8 feet and the travel time is 55 hours (2.3 days).

Table F.1.6-1b. Tuolumne River Geometry Calculated in the HEC-5Q Temperature Model (53-mile Length

Flow (cfs)	Surface Area (acres)	Volume (AF)	Average Depth (feet)	Travel Time (hours)
250	745	2,623	3.5	127
500	829	3,347	4.0	81
1,000	933	4,519	4.8	55
1,500	1,025	5,573	5.4	45
2,000	1,120	6,575	5.9	40
2,500	1,217	7,536	6.2	36
3,000	1,351	8,457	6.3	34
4,000	1,679	10,327	6.2	31
5,000	2,491	12,869	5.2	31
10,000	4,082	24,304	6.0	29

Table F.1.6-1c gives the river geometry (surface area, volume, and depth) for the Merced River for a range of flows from 250–10,000 cfs. The travel time has been included in the table. For example, the Merced River length is about 52 miles and has a surface area of 684 acres, which is equivalent to an average width of 109 feet at a flow of 250 cfs. The volume is 2,158 AF, so the average depth is 3.2 feet. At low flow there may be considerable volume of water in the pools upstream of riffles and runs. At a flow of 1,000 cfs, the Merced River area is 913 acres (145 feet width) and the volume is 4,696 AF, so the average depth is 4.6 feet and the travel time is 51 hours (about 2 days). The Merced River continues to spread out at higher flows, indicating limited levees or channel incision compared to the Stanislaus River.

Table F.1.6-1c. Merced River Geometry Calculated in the HEC-5Q Temperature Model (52-mile Length

Flow (cfs)	Surface Area (acres)	Volume (AF)	Average Depth (feet)	Travel Time (hours)
250	684	2,158	3.2	104
500	815	3,099	3.8	75
1,000	1,114	4,696	4.2	57
1,500	1,341	6,156	4.6	50
2,000	1,570	7,598	4.8	46
2,500	1,818	9,036	5.0	44
3,000	2,102	10,473	5.0	42
4,000	2,698	13,266	4.9	40
5,000	3,320	15,983	4.8	39
10,000	3,610	17,283	4.8	21

New Melones Reservoir on the Stanislaus River has a crest elevation of 1,135 feet and a spillway crest of 1,088 feet. There are two elevations from which to withdraw water, in addition to the spillway. The power intakes are located at an elevation of 775 feet MSL (top of the penstock) corresponding to a reservoir storage of about 200 TAF. The low-level outlet (two pipes) operates at lake elevations less than 785 feet. The old dam may affect the reservoir release temperatures at low elevations. The old dam has a crest elevation of 735 feet and a spillway elevation of 723 feet. The original outlet works are located at approximately 610 feet. When water surface elevations are above 785 feet, the power intake is used to generate hydropower. Below that elevation, the lower-elevation outlet must be used. For water levels from 785–728 feet (5 feet above the old dam spillway invert), all water is assumed to pass over the crest and/or the spillway of the old dam. Below 728 feet, all flows must pass through the old dam's low elevation outlet. The outlet elevation affects the release temperature. New Melones spillway has never been used; it would be needed if releases greater than 7,700 cfs were required. Tulloch Reservoir downstream has a low-level power outlet with a capacity of 2,060 cfs; higher outflows pass through the gated spillway.

New Don Pedro Reservoir on the Tuolumne River has a maximum storage elevation of approximately 830 feet MSL. The power intakes are located at an elevation of 535 feet (storage of about 75 TAF). The original Don Pedro Dam was inundated when the newer dam was completed. The old dam had a crest elevation of 607 feet and the spillway was located at 590 feet. Because the power outlet for the new dam is below the elevation of the old dam, all power releases must pass over the old dam, which is represented in the model as a submerged weir.

Lake McClure on the Merced River has a single outlet located in the old dam that has been incorporated into the new dam (New Exchequer). The power intakes are located at an elevation of 500 feet MSL (storage of about 25 TAF). Lake McSwain, just downstream of Lake McClure, has approximately 10 TAF of storage. The outlet is located near the bottom at approximately 370 feet MSL, 25 feet below the surface. The Lake McClure outlet temperature may be warmed in the three downstream regulating reservoirs before being released to the river at the Crocker-Huffman diversion dam (and Merced River Fish Hatchery).

Water Temperature Calibration Results

Equilibrium temperature and surface heat exchange coefficients were used to evaluate the net rate of heat transfer. Equilibrium temperature is defined as the water temperature at which the net rate of heat exchange between the water surface and the overlying atmosphere is zero. The coefficient of surface heat exchange is the rate at which heat is transferred to the water. All heat transfer mechanisms, except short-wave solar radiation, were applied at the water surface. Short-wave radiation penetrates the water surface and may affect water temperatures below the air-water interface. The heat exchange with the river bottom is a function of conductance and the heat capacity of the bottom sediment and has only a slight effect on diurnal temperature variation (i.e., behaves as slightly deeper water).

The model was calibrated using observed data within the period 1999–2007. The model used hourly meteorological data from three meteorological stations at Modesto, Merced, and Kesterson. Calibration was based on temperature profiles in the main reservoirs and time series of temperatures recorded in streams at several locations. Calibration of the reservoir temperatures was accomplished by comparing computed and observed vertical reservoirs temperature profiles both graphically and statistically. Some adjustments of the meteorological coefficients (e.g., wind speed function and solar radiation reflection) were necessary to match the seasonal surface temperatures in the reservoirs. Calibration of the river temperatures was accomplished by comparing computed and observed stream temperatures both graphically and statistically. Some adjustments of the meteorological coefficients (e.g., shading and river hydraulic parameters for width and depth) provided a close match with daily temperatures along the three eastside tributaries and the LSJR. The model bias, defined as the difference between the average computed and observed temperatures, was 0.3°F, 0.7°F, 0.3°F, and 0.3°F for the Stanislaus, Tuolumne, and Merced Rivers and LSJR, respectively. The seasonal temperature ranges were very accurately simulated at each of the river stations.

In October 2006, the initial temperature model and calibration results were favorably approved through a CALFED-sponsored peer review process. The model was refined and enhanced to provide a planning and analysis tool for the SJR stakeholders. The completed model was presented to the SJR stakeholders and became available for public use (CALFED 2009). Figure F.1.6-2a shows the comparison of measured and simulated temperatures for the Stanislaus River at Goodwin Dam (River Mile [RM] 58) for calendar years 1999–2007. This generally demonstrates the accuracy of the reservoir stratification and withdrawal simulations. The release temperatures varied from about 50°F in the winter months to about 55°F–57°F in the fall months.

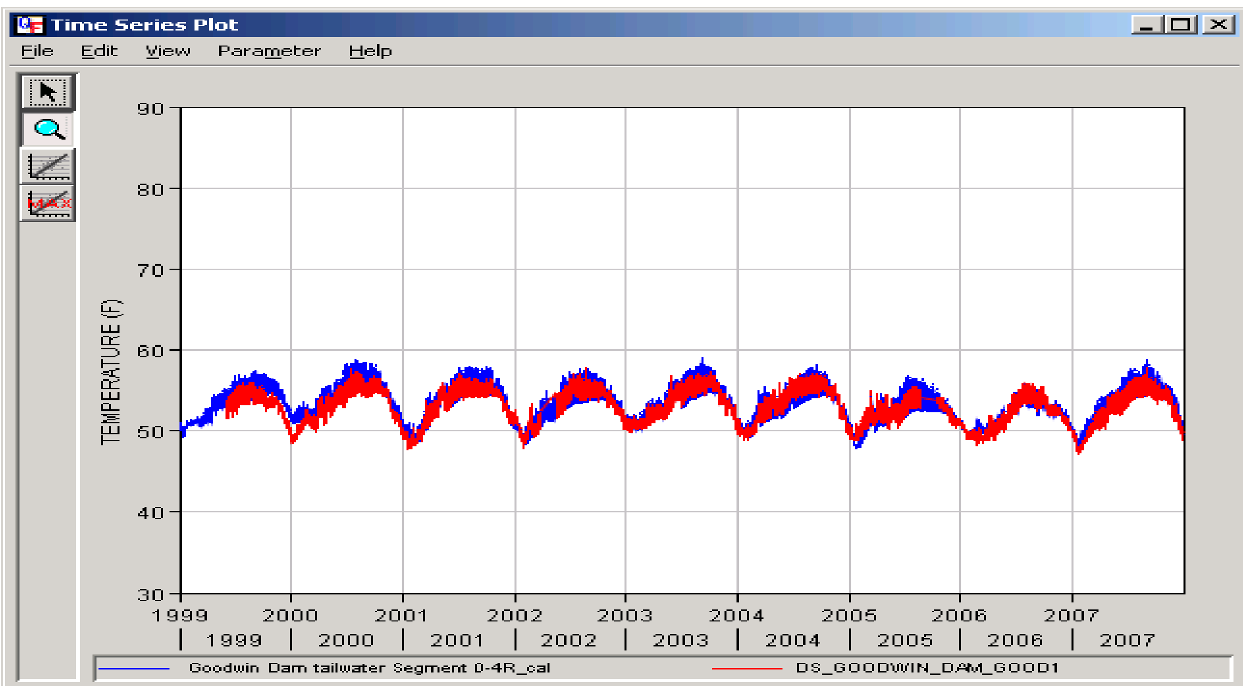


Figure F.1.6-2a. Comparison of Computed (Blue) and Observed (Red) Water Temperatures on the Stanislaus River Below Goodwin Dam (RM 58) for 1999–2007

Figure F.1.6-2b shows the comparison of measured and simulated temperatures at the mouth of the Stanislaus River downstream of Ripon. This demonstrates the general accuracy of the combination of river hydraulic calculations (i.e., depth and surface area) and the meteorological heating and solar radiation shading estimates. The river temperatures varied from about 45°F–50°F in the winter months to about 75°F–80°F in the summer months. There was considerable variation in the peak summer temperatures between years, with the lowest temperatures of about 75°F in the higher flow years of 1999 and 2006. Several of the years showed a distinct decrease in temperatures associated with the VAMP pulse flow release in mid-April to mid-May. The river temperatures were simulated to increase more rapidly during low flow conditions and to increase less during higher flows, such as during the VAMP period, with releases of about 1,500 cfs in several years. The effects of river flows on downstream warming will be described in more detail below in the evaluation of baseline temperatures. The Stanislaus River temperatures were very accurately simulated for 1999–2007.

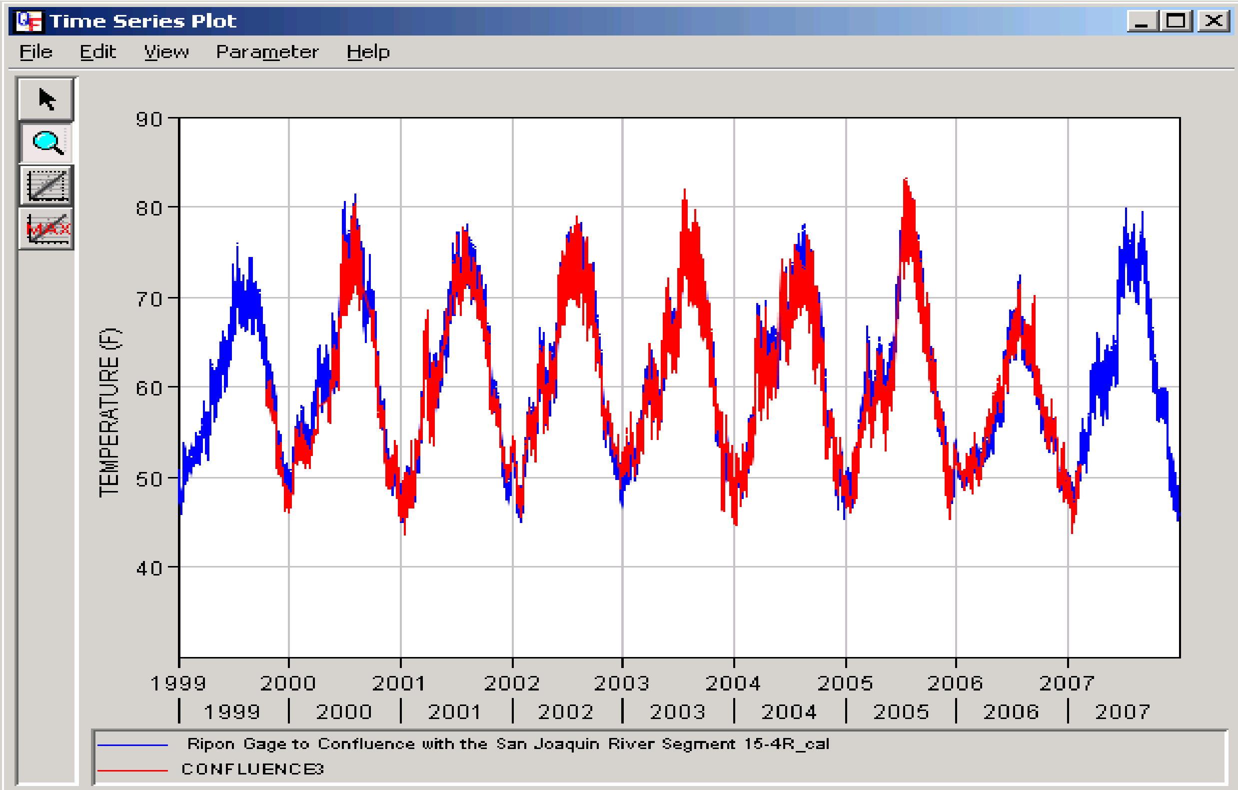


Figure F.1.6-2b.Comparison of Computed (Blue) and Observed (Red) Water Temperatures on the Stanislaus River above the SJR Confluence (RM 0) for 1999–2007

Figure F.1.6-3a shows the comparison of measured and simulated temperatures for the Tuolumne River at La Grange Dam (RM 52) for 1999–2007. The releases temperatures varied from about 50°F in the winter months to about 53°F–55°F in the fall months. The Tuolumne River temperatures were even less variable than release temperatures on the Stanislaus because the New Don Pedro Reservoir carryover storage generally remains high and because the La Grange regulating reservoir is small compared to the Tulloch and Goodwin regulating reservoirs on the Tuolumne River. Figure F.1.6-3b shows the comparison of measured and simulated temperatures at the mouth of the Tuolumne River at Shiloh Bridge (RM 3.4). The Tuolumne River temperatures varied from about 45°F–50°F in the winter months to about 80°F–85°F in the summer months. The Tuolumne River summer temperatures were slightly higher than the Stanislaus River summer temperatures, perhaps because of lower flows (longer travel time) or less shading along the Tuolumne River. The two river mouths are less than 5 miles apart and experience the same meteorology. The coolest summer temperatures were measured and simulated for 2005 and 2006. The Tuolumne River temperatures were very accurately simulated for 1999–2007.

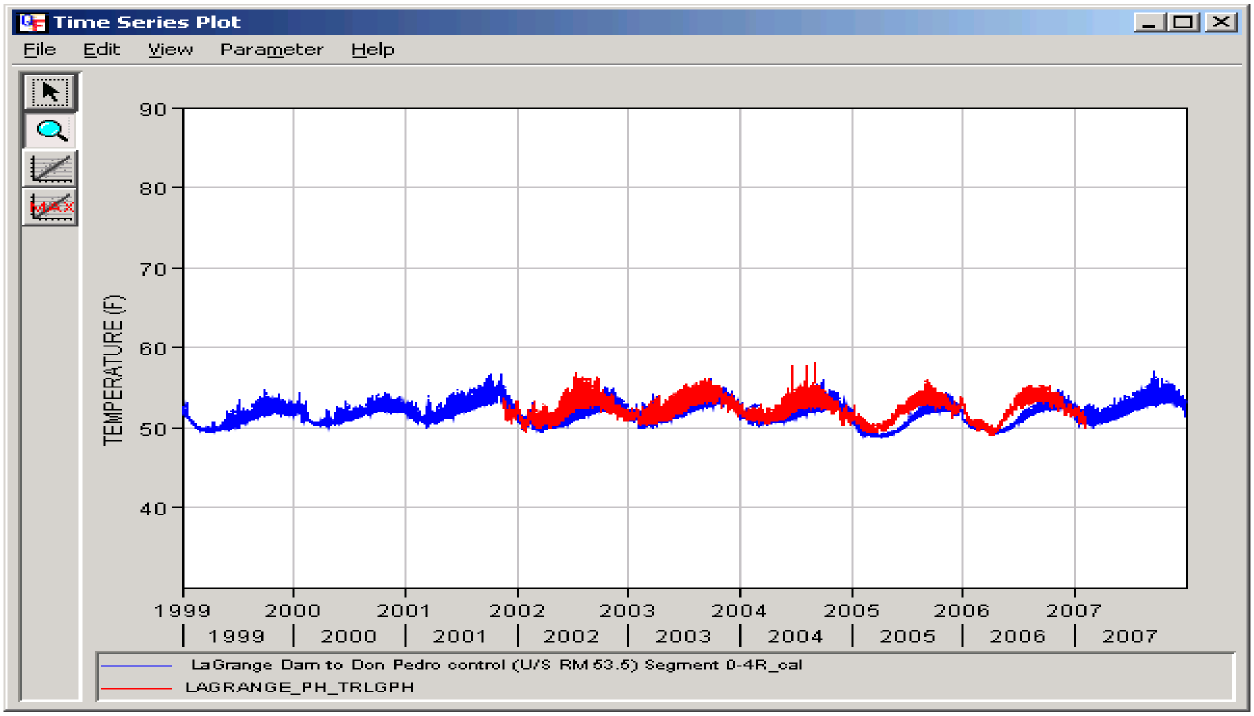


Figure F.1.6-3a. Comparison of Computed (Blue) and Observed (Red) Water Temperatures on the Tuolumne River below La Grange Dam (RM 52)

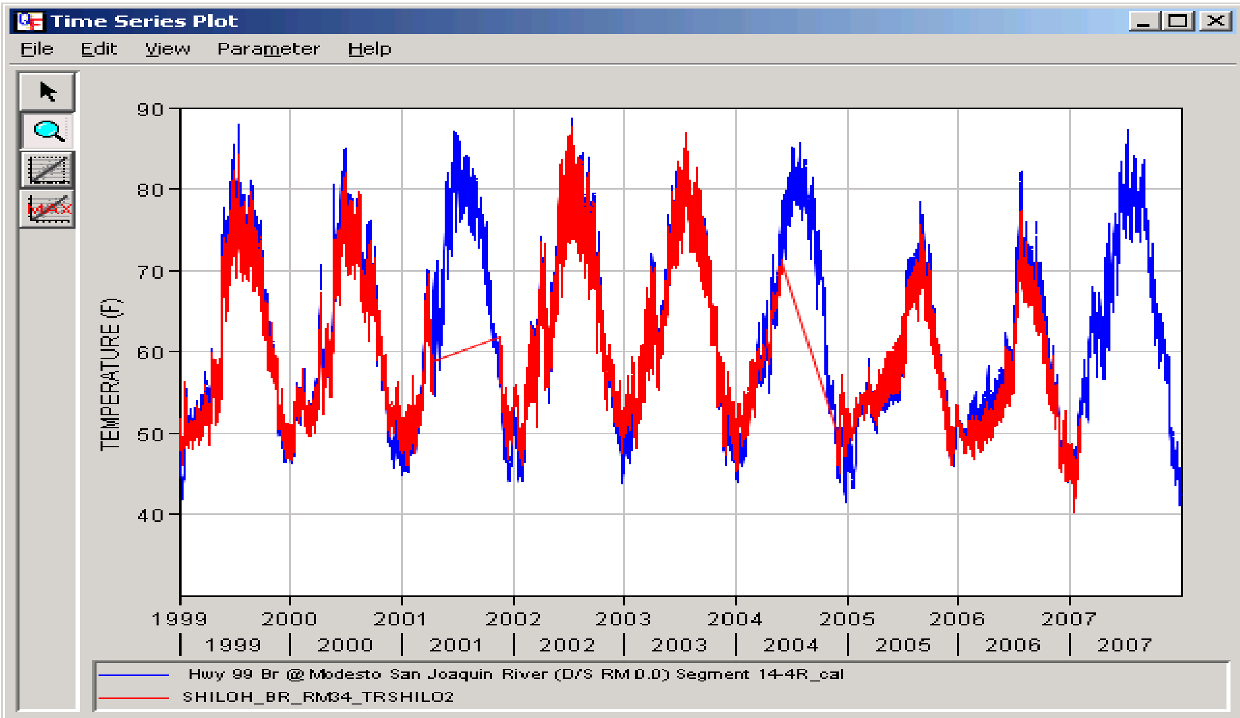


Figure F.1.6-3b. Comparison of Computed (Blue) and Observed (Red) Water Temperatures on the Tuolumne River at Shiloh Bridge (RM 3.4)

Figure F.1.6-4a shows the comparison of measured and simulated temperatures for the Merced River below McSwain Dam (RM 56) for 1999–2007. McSwain Dam is located about 6.5 miles below New Exchequer Dam. The release temperatures varied from about 50°F in the winter months to about 57°F–60°F in the fall months. The Merced River release temperatures were more variable than on the Stanislaus or Tuolumne Rivers because Lake McClure carryover storage can be very low in dry years and because McSwain Reservoir is relatively shallow, with a volume of about 8 TAF. The travel time for a flow of 2,000 cfs (to the canals and river) would be about 2 days. The release temperature remained cooler in 2005 and 2006 when the runoff was higher and the reservoir storage remained higher in the fall. There may be additional warming in the reservoirs of Merced Falls (RM 55) and Crocker-Huffman (RM 52) diversion dams. Figure F.1.6-4b shows the comparison of measured and simulated temperatures at the mouth of the Merced River for 1999–2007. The Merced River temperatures varied from about 45°F–50°F in the winter months to about 80°F–85°F in the summer months. The Merced River temperatures were very similar to the Tuolumne River temperatures. The coolest temperatures were measured and simulated in 2005 and 2006. The Merced River temperatures were very accurately simulated for 1999–2007.

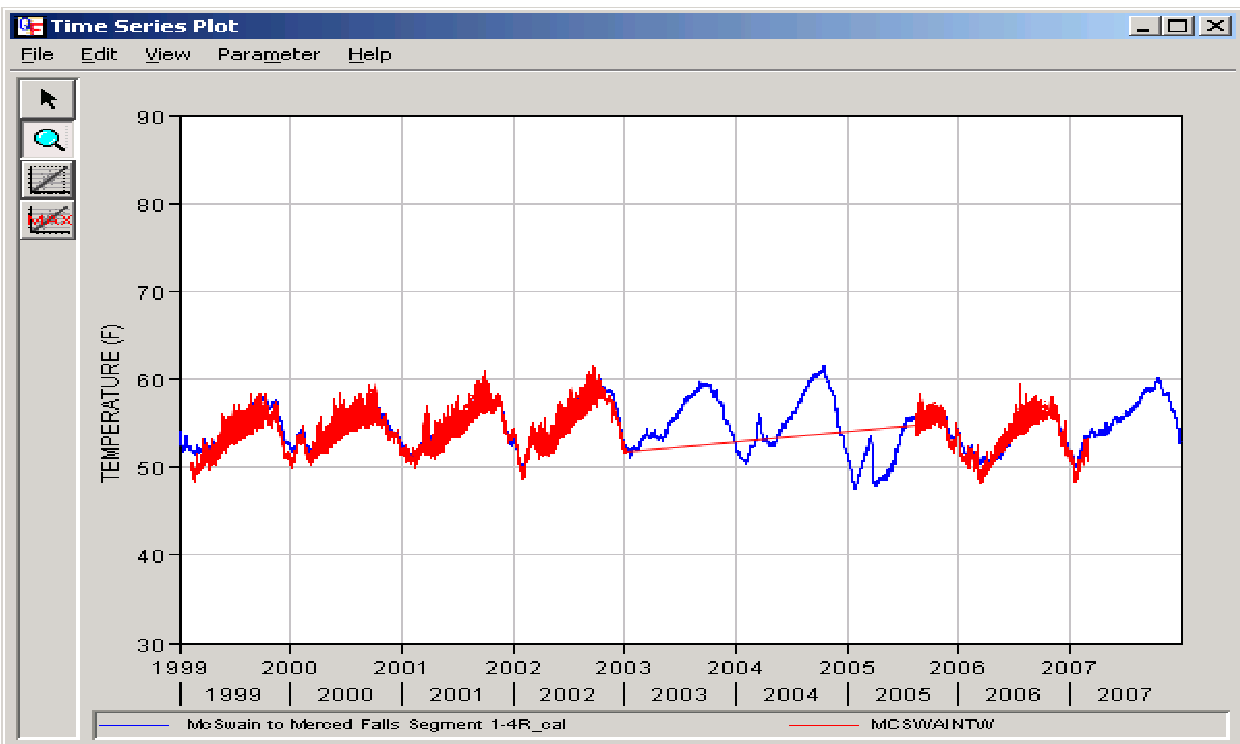


Figure F.1.6-4a. Comparison of Computed (Blue) and Observed (Red) Temperatures in the Merced River below McSwain Dam (RM 56)

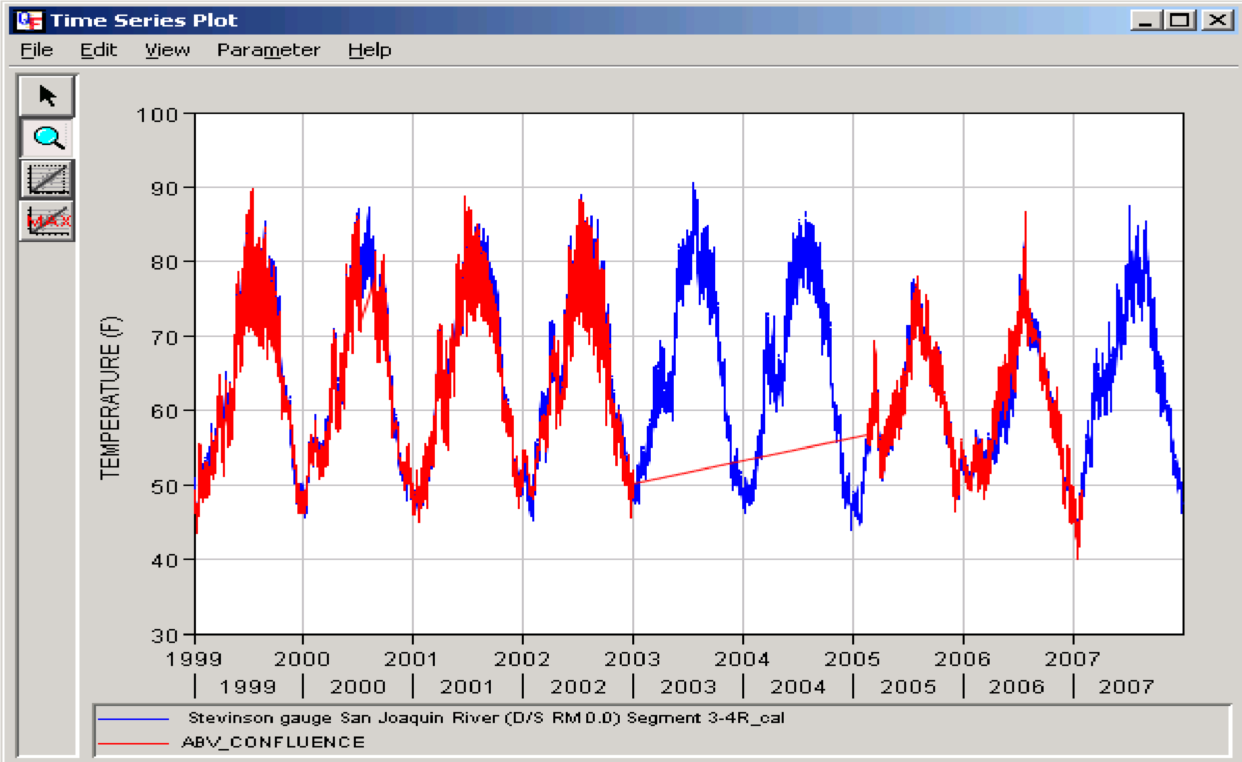


Figure F.1.6-4b. Comparison of Computed (Blue) and Observed (Red) Temperatures in the Merced River above the SJR Confluence (RM 0)

F.1.6.2 Temperature Model Results

Baseline Conditions Temperature Results

Stanislaus River Temperatures

Figure F.1.6-5a shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir and below Goodwin Dam in September–December for 1970–2003. The reservoir release temperatures for September and October generally had about the same response to changes in reservoir storage; temperatures at New Melones Reservoir were less than 55°F when New Melones storage was more than 750 TAF and were usually more than 60°F when New Melones storage was less than about 400 TAF. The September and October Goodwin temperatures were less than 55°F when New Melones storage was more than 1,000 TAF and increased to above 65°F when New Melones storage was 250 TAF or less. The November temperatures were similar to the September and October temperatures, except at lower storage when temperatures were more likely to be affected by meteorological conditions. The December temperatures at New Melones and Goodwin were 50°F–55°F regardless of storage, because the reservoir was fully mixed, and the release temperatures were controlled by the meteorology and not the reservoir storage. Based on these results, the New Melones carryover storage target of at least 700 TAF would provide a Goodwin Dam release temperature of less than 60°F from September–December.

Figure F.1.6-5b shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir, below Goodwin Dam, at RM 28.2 (approximately half way between Goodwin Dam and the confluence) and at the confluence in January–March for 1970–2003 as a function of the river flow (at the confluence). In January, temperatures were controlled by the meteorology; water temperatures were 45°F–55°F in all years, and there was no downstream warming. In February, temperatures were controlled by meteorology, and all temperatures were 45°F–55°F; there was slightly more warming when flows were less than 500 cfs. In March, temperatures were still largely controlled by meteorology; all downstream temperatures (i.e., at RM 28.2 and the confluence) were between about 47°F and 60°F. In general, the downstream warming (between Goodwin and the confluence) was less than 5°F when flows were greater than 1,500 cfs and were about 7°F when flows were less than 500 cfs.

Figure F.1.6-5c shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir, below Goodwin Dam, at RM 28.2 and at the confluence in April–June for 1970–2003 as a function of the river flow (at the confluence). In April, temperatures were controlled by the meteorology and the flow. Goodwin temperatures were about 50°F–55°F. At flows greater than 1,000 cfs, confluence temperatures were 53°F–59°F (warming of 3°F–9°F), and when flows were less than 750 cfs, confluence temperatures were 60°F–65°F (warming of 10°F). In May, temperatures at RM 28.2 and the confluence were controlled by meteorology and flow. At flows of more than 1,500 cfs, RM 28.2 temperatures were about 55°F and confluence temperatures were about 60°F. At a flow of 500 cfs, RM 28.2 temperatures were 62°F–65°F, and mouth temperatures were 64°F–70°F. In June, temperatures at RM 28.2 and the confluence were controlled by meteorology and flow. When flow was about 1,500 cfs, the average warming from Goodwin to RM 28.2 was about 5°F (55°F–60°F), and when flow was about 500 cfs, this warming was about 10°F–12°F (60°F–70°F). The confluence temperatures were about 62°F when flow was greater than 1,500 cfs and were about 70°F when flow was less than 500 cfs. Because of the relatively high spring flows on the Stanislaus (required by the NMFS BO), flows in April and May were almost always greater than 500 cfs for baseline conditions.

Figure F.1.6-5d shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir, below Goodwin Dam, at RM 28.2 and at the confluence in July–September for 1970–2003 as a function of the river flow (at the confluence). In July, as flow fell from 750 cfs to 250 cfs, Goodwin temperatures climbed from 50°F to 55°F. At flows of about 250 cfs, the Goodwin temperatures ranged from 55°F–60°F. At RM 28.2, there was a similar increase in temperature with falling flow. As flow fell from 750 cfs to 250 cfs, Goodwin temperatures climbed from 65°F to 75°F. The confluence temperatures in July were consistently about 4°F warmer than the RM 28.2 temperatures regardless of flow. In August, temperature effects were similar to those in July. Flows generally ranged from 250–650 cfs at the confluence, with Goodwin temperatures of 50°F–65°F, RM 28.2 temperatures of 65°F–75°F, and confluence temperatures of 70°F–77°F. The increase in temperature as flow was reduced from 750 to 250 cfs was greater at Goodwin than at the locations farther downstream. The September temperature patterns were similar to the August temperature patterns, but the temperatures at RM 28.2 and the confluence were slightly less than in August.
Figure F.1.6-5e shows the simulated monthly average Stanislaus River temperatures below New Melones Reservoir, below Goodwin Dam, at RM 28.2 and at the confluence in October–December for 1970–2003 as a function of the river flow (at the confluence). In October, the wide range of river flows was dependent primarily on reservoir storage (higher flood control releases when storage was high). Goodwin temperatures were usually less than 55°F when the flow at the confluence was greater than 1,000 cfs, but at flows lower than 750 cfs, the Goodwin temperatures could reach as high as 65°F. The meteorological warming from Goodwin to the confluence was about 5°F regardless

of the flow, except when the Goodwin temperatures were exceptionally high (more than 60°F) because the temperatures were already approaching equilibrium and there was less warming as the water moved downstream. November and December temperatures showed very little meteorological warming. In November, confluence flows were almost always less than 500 cfs, and temperatures were usually less than 55°F at all locations. However, at low flows of about 250 cfs, temperatures could be a bit higher, ranging from 55°F–60°F at RM 28.2 at the confluence. December temperatures at all locations were between about 47°F and 55°F. In some instances, particularly in December, equilibrium water temperatures were less than the New Melones release temperatures, resulting in a small amount of cooling as the water moved downstream. These temperature results illustrate the combination of factors controlling Stanislaus River temperatures. The factors affecting temperature along the river include New Melones and Goodwin release temperatures, which are indirectly proportional to New Melones storage; air temperature and meteorological warming effects as water moves downstream, especially from March–October; and the amount of flow in the river.

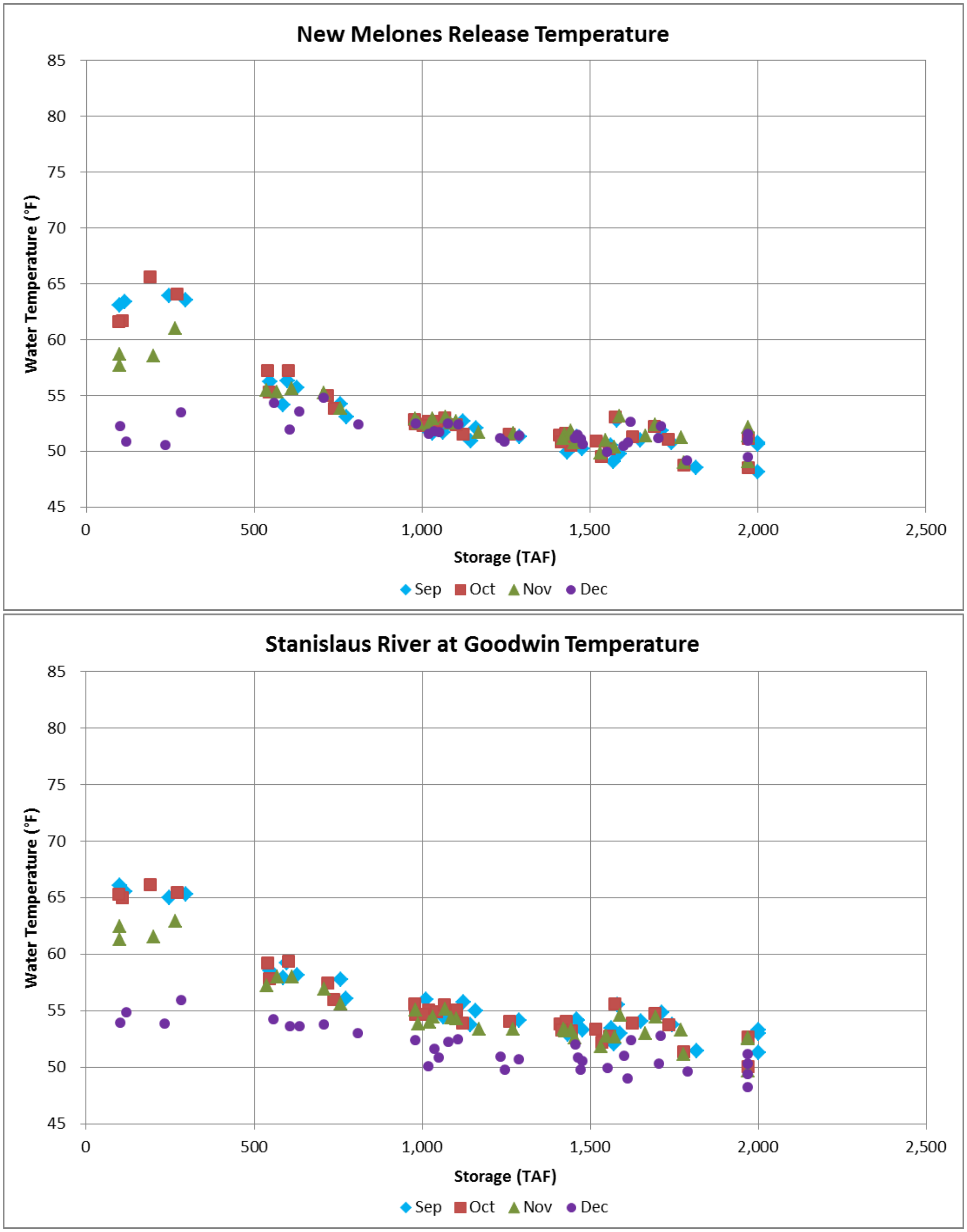


Figure F.1.6-5a. Stanislaus River Water Temperatures as a Function of New Melones Storage September–December at New Melones Dam and Goodwin Dam for Baseline Conditions 1970–2003

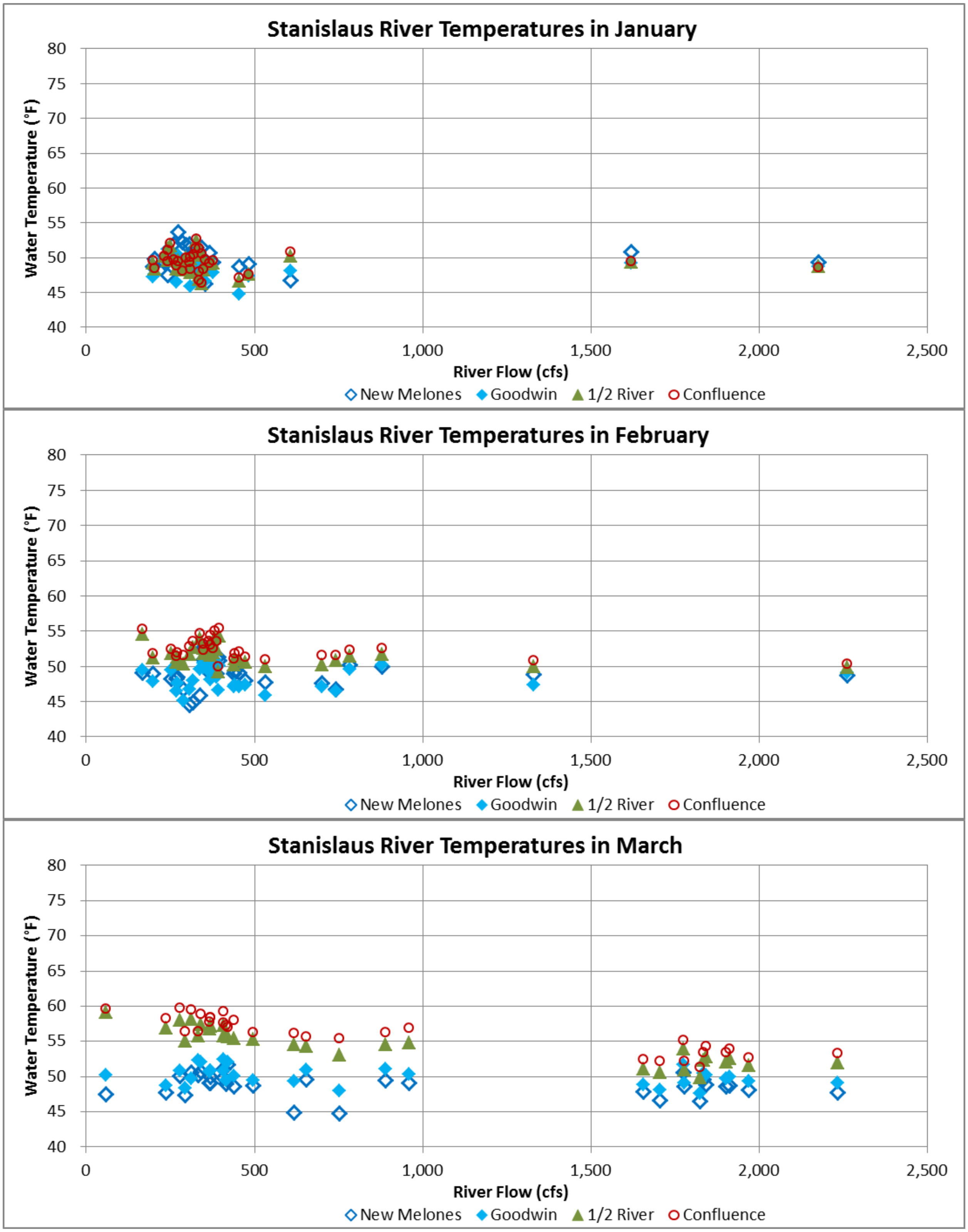


Figure F.1.6-5b. Effects of Stanislaus River Flow on Stanislaus River Water Temperatures January–March for Baseline Conditions 1970–2003

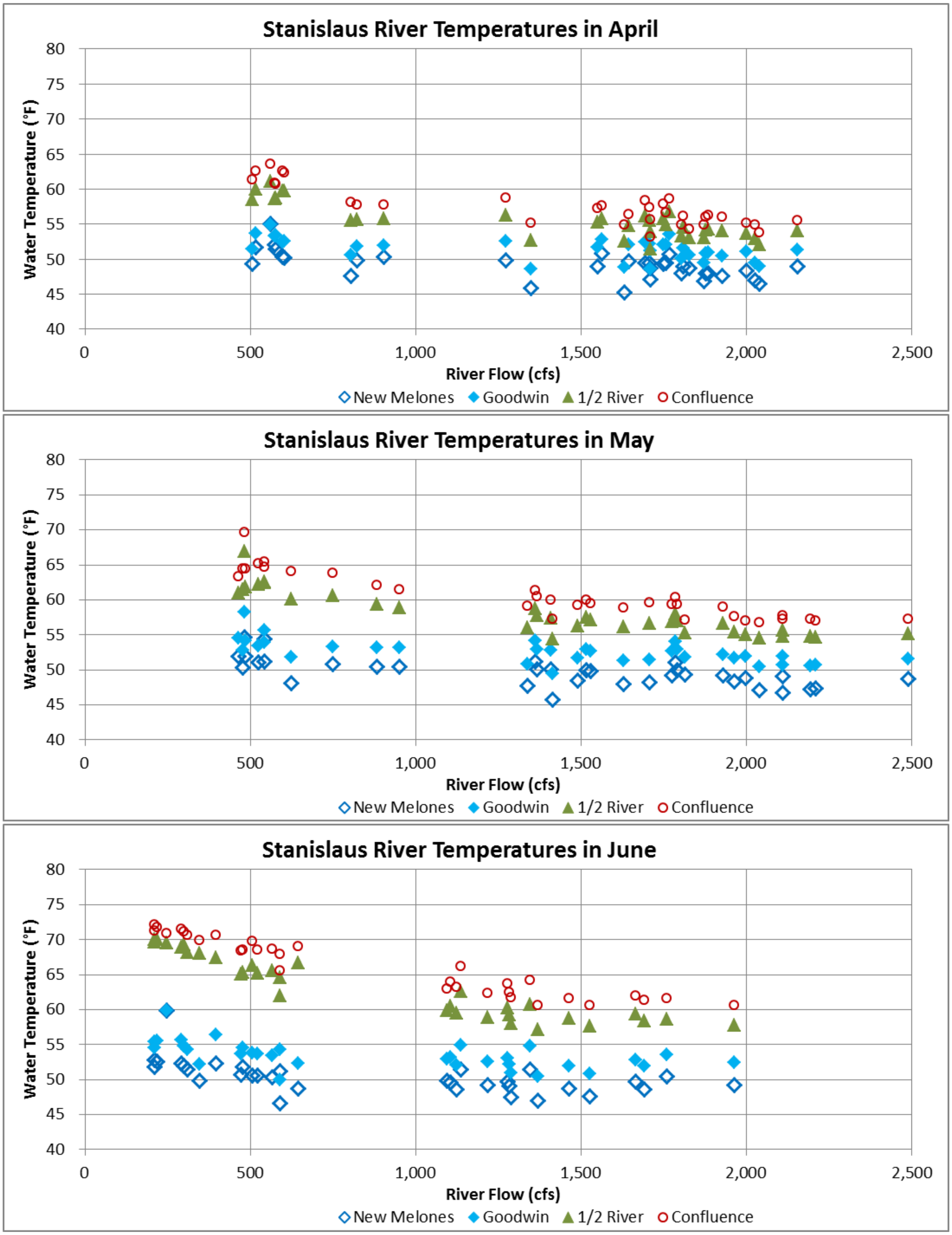
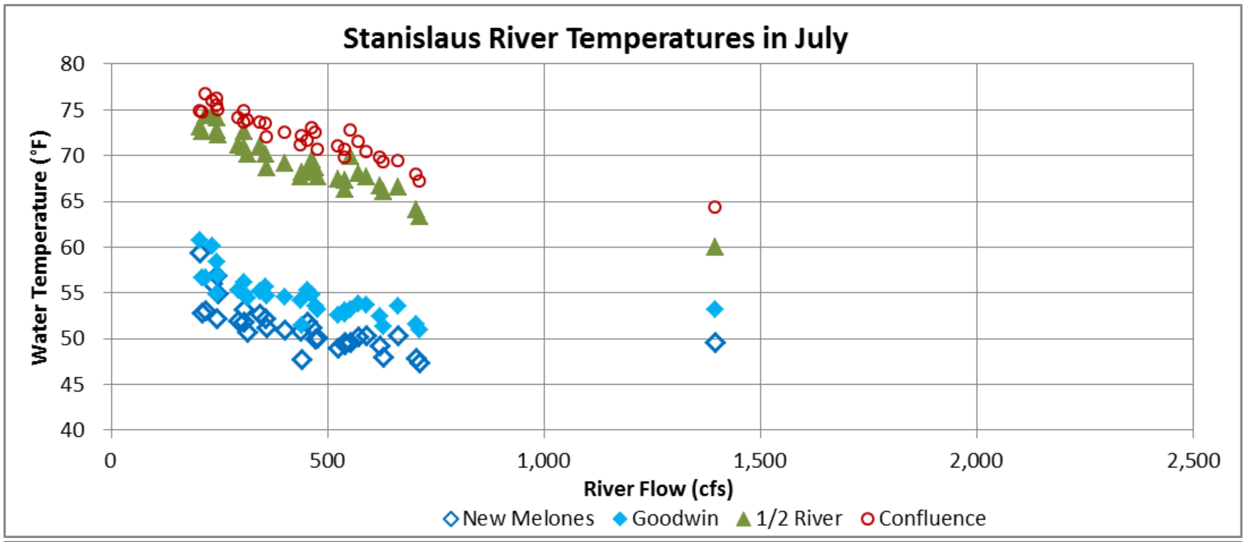
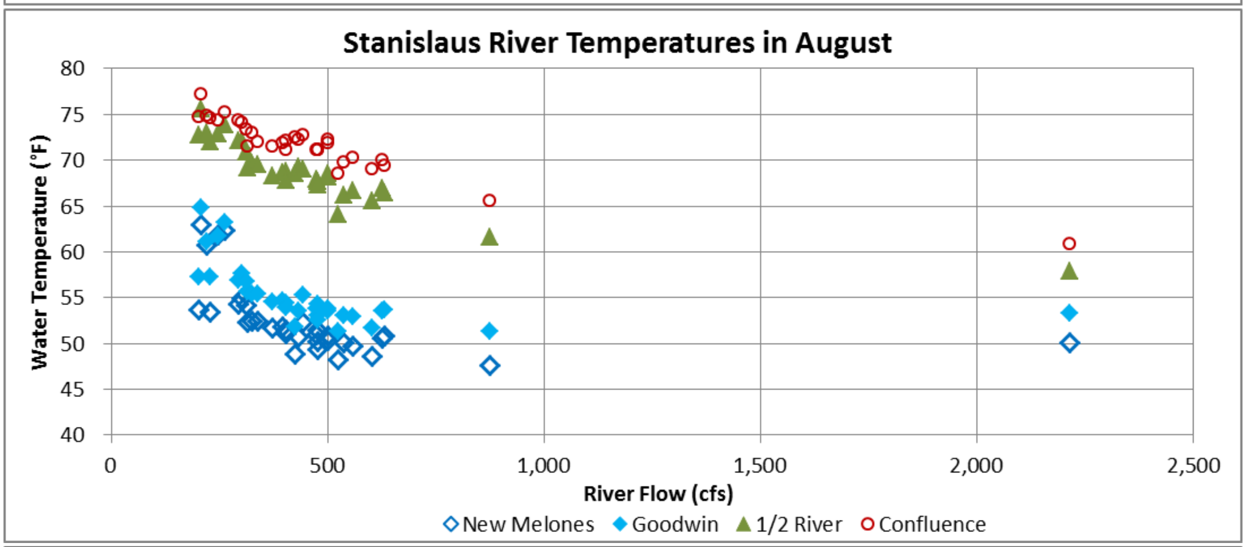


Figure F.1.6-5c. Effects of Stanislaus River Flow on Stanislaus River Water Temperatures April–June for Baseline Conditions 1970–2003





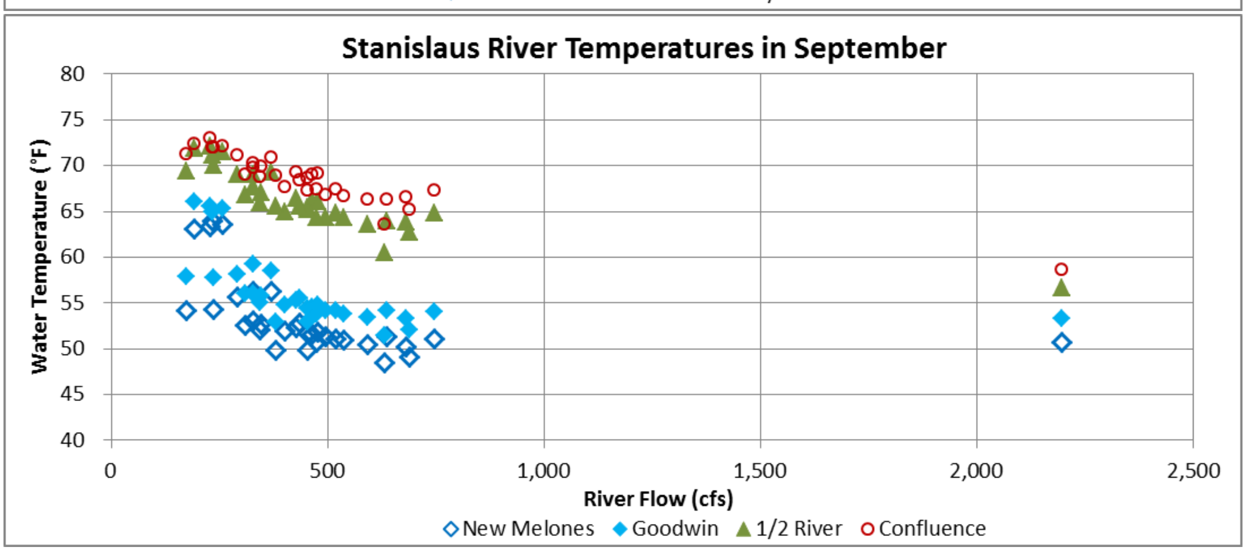


Figure F.1.6-5d. Effects of Stanislaus River Flow on Stanislaus River Water Temperatures July–September for Baseline Conditions 1970–2003

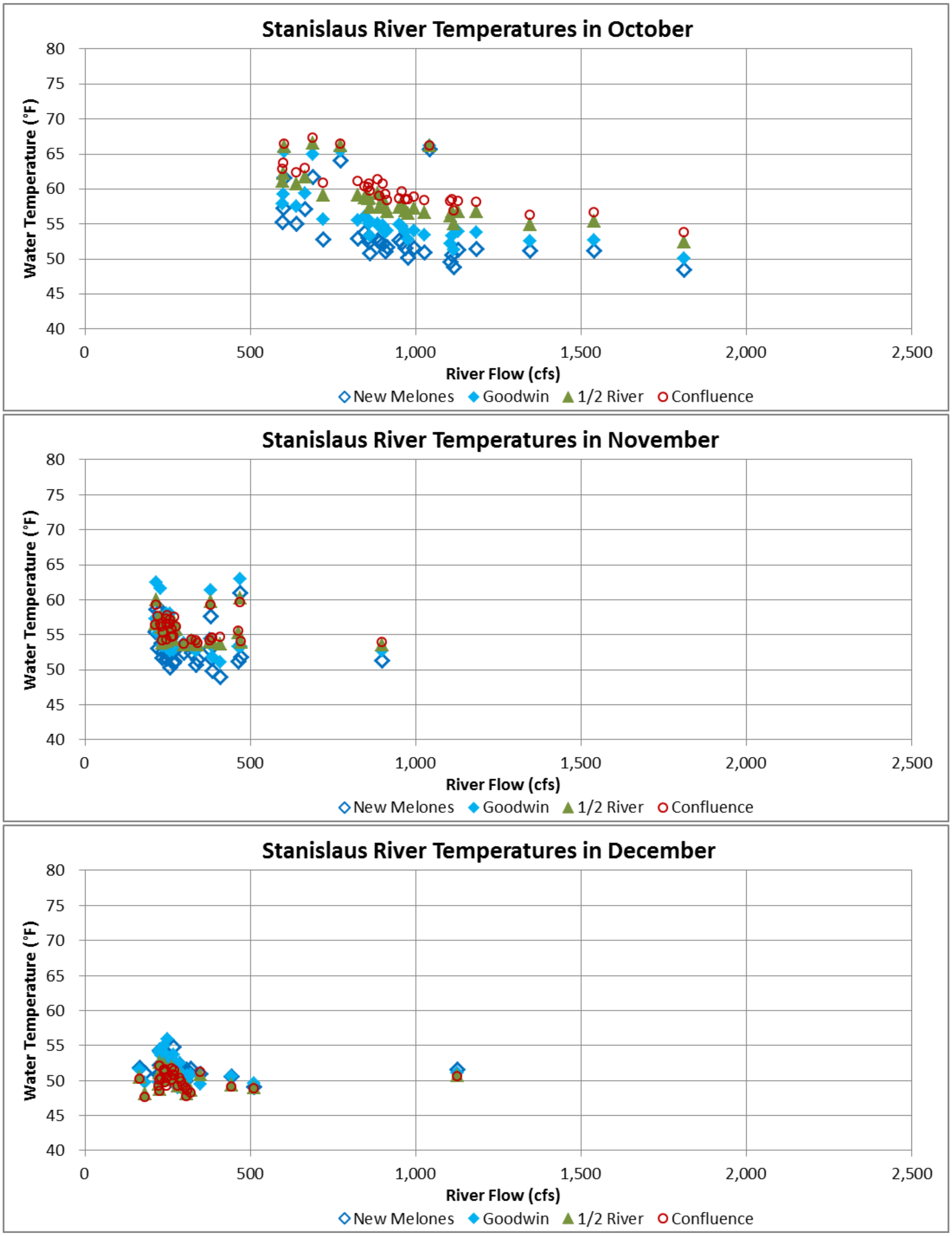


Figure F.1.6-5e. Effects of Stanislaus River Flow on Stanislaus River Water Temperatures October–December for Baseline Conditions 1970–2003

Tuolumne River Temperatures

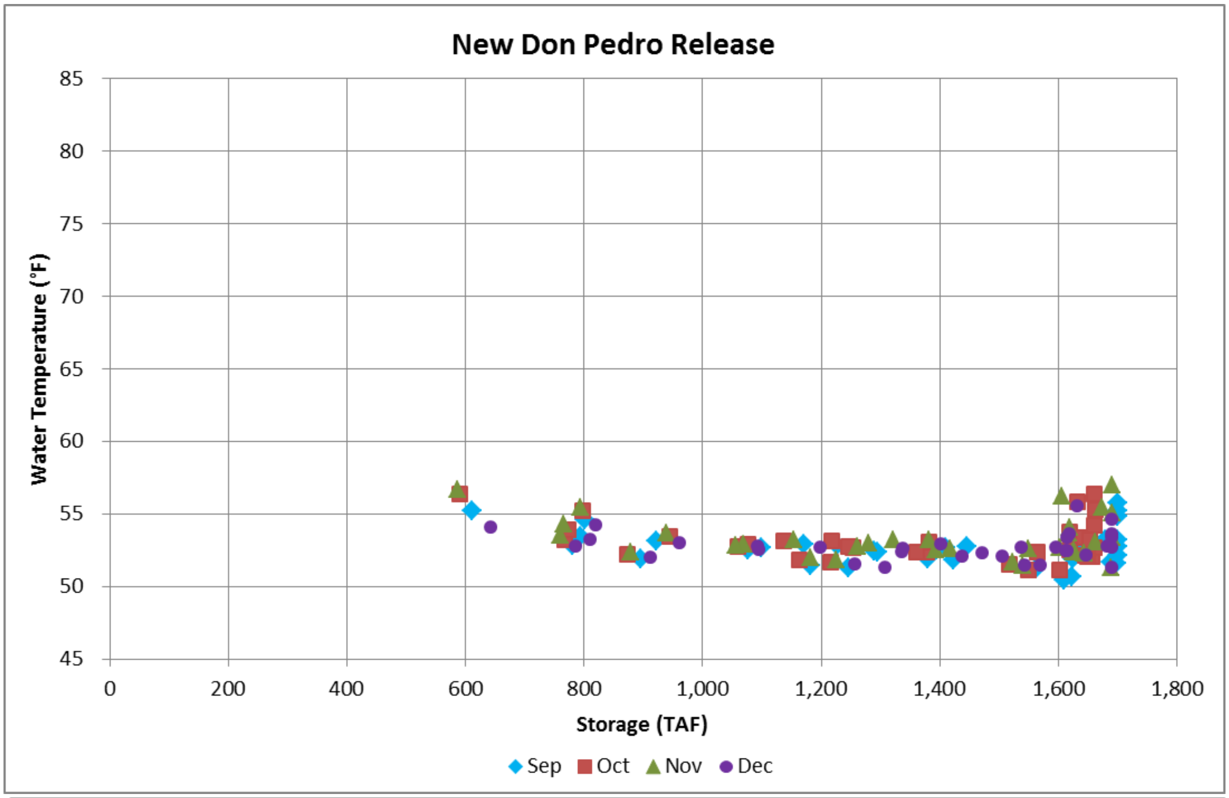
Figure F.1.6-6a shows the simulated monthly average Tuolumne River temperatures below New Don Pedro Dam and below La Grange Dam in September–December for 1970–2003. The September–December temperatures at New Don Pedro Dam were about 50°F–55°F in all months, except for a few instances when storage was less than 600 TAF or greater than 1,600 TAF. The September and October temperatures at La Grange Dam were only slightly warmer because La Grange Dam is just 2.5 miles below New Don Pedro Dam, and there isn't enough time for water released from New Don Pedro to warm significantly. Based on these results, the New Don Pedro carryover storage target of at least 800 TAF would likely provide La Grange Dam release temperatures of less than 56°F in September and October of most years.

Figure F.1.6-6b shows the simulated monthly average Tuolumne River temperatures below New Don Pedro Reservoir, below La Grange Dam, at RM 28.1 (about half way between the confluence and La Grange Dam), and at the confluence in January–March for 1970–2003 as a function of the river flow (at the confluence). During January, monthly average temperatures at all locations were between 45°F and 55°F. Sometimes there was a small amount of cooling between La Grange and the confluence because equilibrium water temperatures were less than the New Don Pedro release temperatures. During February, temperatures were slightly warmer at the confluence where temperatures ranged from about 52°F–58°F. Unlike in January, there was a small amount of warming between La Grange and the confluence (up to about 5°F at flows less than about 750 cfs). In addition, there were many instances when the temperatures at RM 28.1 were similar to the temperatures at the confluence, indicating that equilibrium temperatures had already been reached by RM 28.1. During March, there was significant longitudinal warming; at flows less than 500 cfs, temperatures increased from about 50°F at La Grange to between 60°F–65°F at the confluence.

Figure F.1.6-6c shows the simulated monthly average Tuolumne River temperatures below New Don Pedro, below La Grange, at RM 28.1, and at the confluence in April–June for 1970–2003 as a function of the river flow (at the confluence). La Grange temperatures for all three months were about 50°F, regardless of the river flow, and the downstream temperatures were controlled by the meteorology and the flow. In April, if flow was greater than 1,000 cfs, the temperature at RM 28.1 was generally slightly less than 55°F, and the temperature at the confluence was about 60°F. As flow decreased from 1,000 cfs to 400 cfs, the temperature at both locations increased by 5°F–10°F. For May conditions were similar to those in April, but temperatures were slightly warmer at downstream locations. If flow was greater than 1,000 cfs, the temperature at RM 28.1 was generally slightly more than 55°F, and the temperature at the confluence was about 60°F–65°F. As flow decreased from 1,000 cfs to 400 cfs, the temperature at both locations increased by 5°F–10°F. During June, confluence flows usually remained at or below 500 cfs, apart from a few high-flow years. When flow was less than 400 cfs, the temperature at RM 28.1 was about 75°F, and the temperature at the confluence was only slightly higher, indicating that river temperature had already reached the equilibrium temperature by RM 28.1.

Figure F.1.6-6d shows the simulated monthly average Tuolumne River temperatures below New Don Pedro, below La Grange, at RM 28.1, and at the confluence in July–September for 1970–2003 as a function of river flow (at the confluence). For all three months, La Grange temperatures were between 50°F–55°F, regardless of the river flow, and the downstream temperatures were controlled by the meteorology and the flow. During both July and August, confluence flows usually remained at or below 700 cfs, apart from a few high-flow years. In both months, for flows between 700 and 400 cfs, temperatures at RM 28.1 were consistently around 69°F, while temperatures at the confluence were between 75°F–80°F. Below 400 cfs, temperatures at RM 28.1 ranged from 75°F–80°F, while temperatures at the confluence remained around 80°F. September also shows similar longitudinal warming patterns compared to July; however, temperatures at the downstream locations are about 5°F cooler than in July and August. For all three months, at flows below 400 cfs, river temperatures have almost achieved equilibrium at RM 28.1, and there is little warming from there to the confluence.

Figure F.1.6-6e shows the simulated monthly average Tuolumne River temperatures below New Don Pedro, below La Grange, at RM 28.1, and at the confluence in October–December for 1970–2003 as a function of the river flow (at the confluence). During all three of these months, temperatures at La Grange remained at approximately 50°F–55°F. In October, longitudinal (downstream) warming was still present but was much less than in September (approximately a 15°F increase between La Grange and the confluence at flows less than 400 cfs). At flows greater than 400 cfs, temperatures at RM 28.1 were consistently slightly less than 60°F, while temperatures at the confluence were slightly less than 65°F. At flows less than 400 cfs, temperatures at RM 28.1 ranged from 60°F–65°F, while temperatures at the confluence were between 65°F–70°F. In November, there was very little downstream warming and temperatures at all locations ranged between 50°F–60°F. In December, temperatures everywhere were almost always below 55°F, while temperatures at the confluence were often cooler than temperatures at La Grange. These temperature results illustrate the combination of factors controlling Tuolumne River temperatures. The New Don Pedro and La Grange temperatures were very uniform, between 50°F and 55°F, because the New Don Pedro storage generally did not drop below 600 TAF. The meteorological warming of downstream river temperatures was substantial from March–October, with a maximum warming of about 30°F between La Grange and the confluence in July at flows less than 400 cfs. However, higher river flows reduce the maximum warming. The temperature effect of flows of 250–1,500 cfs is important because this is the typical range for the LSJR alternatives being evaluated. An increase of 250 cfs or more in March–June would have a substantial effect on reducing the downstream water temperatures at RM 28.1 and the confluence.



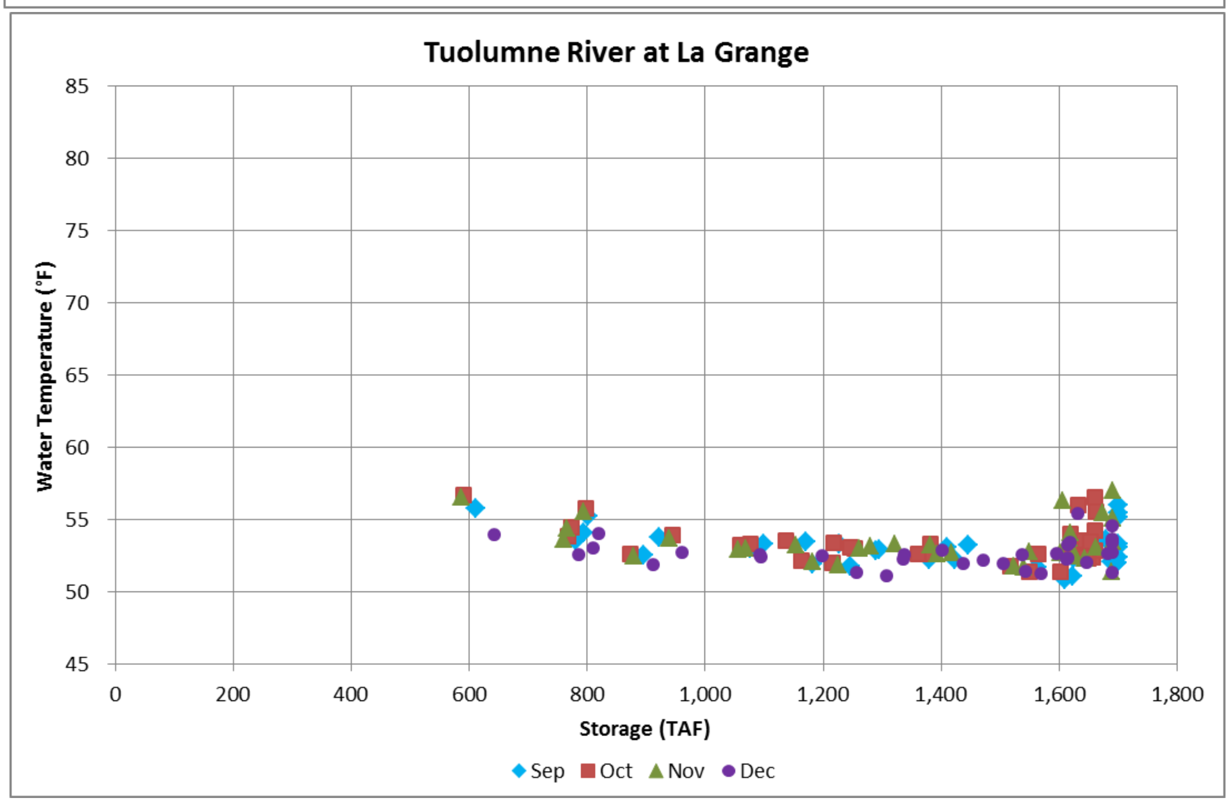


Figure F.1.6-6a. Effects of New Don Pedro Storage on New Don Pedro and La Grange Simulated Water Temperatures September–December for Baseline Conditions 1970–2003

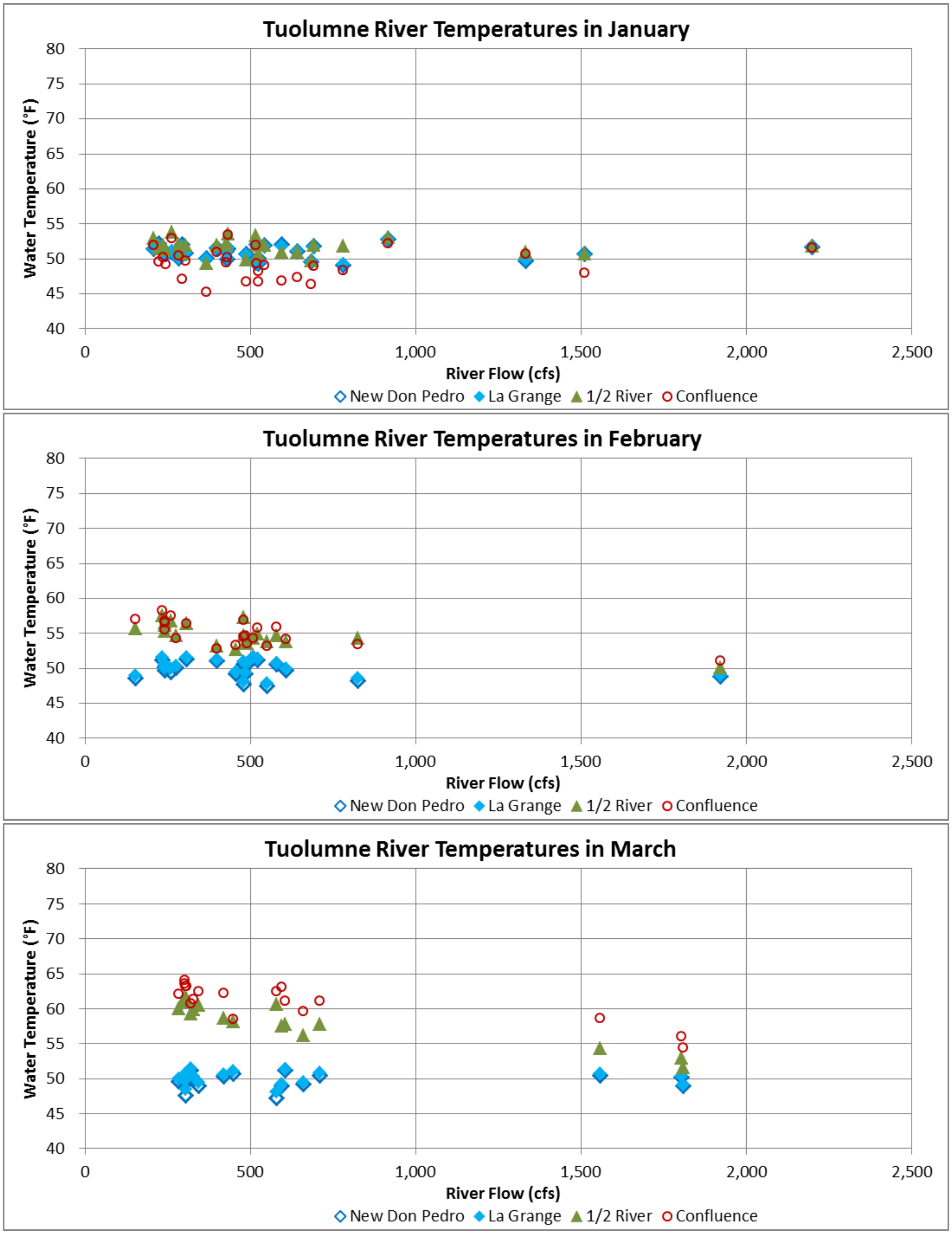


Figure F.1.6-6b. Effects of Tuolumne River Flow on Tuolumne River Water Temperatures January–March for Baseline Conditions 1970–2003

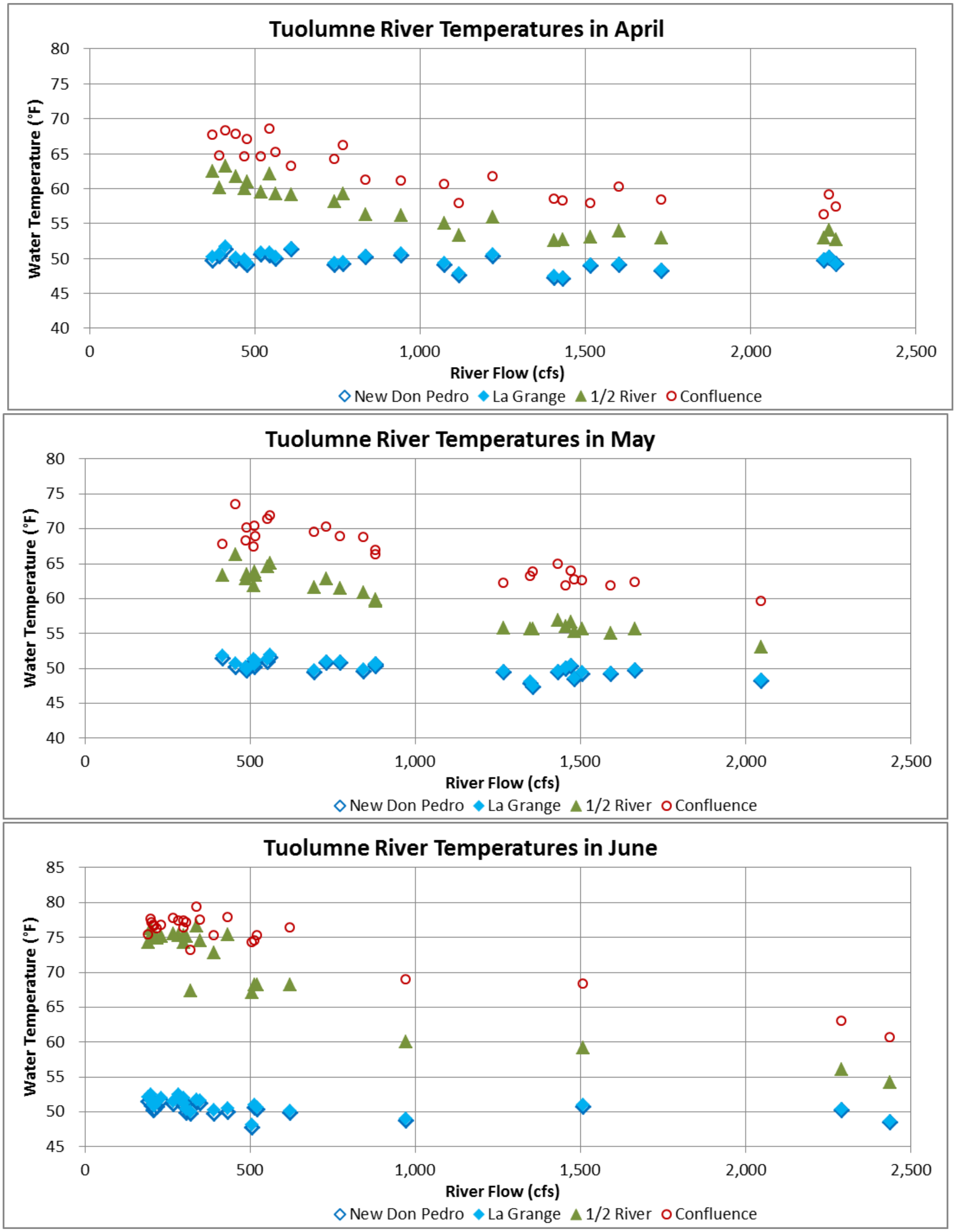


Figure F.1.6-6c. Effects of Tuolumne River Flow on Tuolumne River Water Temperatures April–June for Baseline Conditions 1970–2003

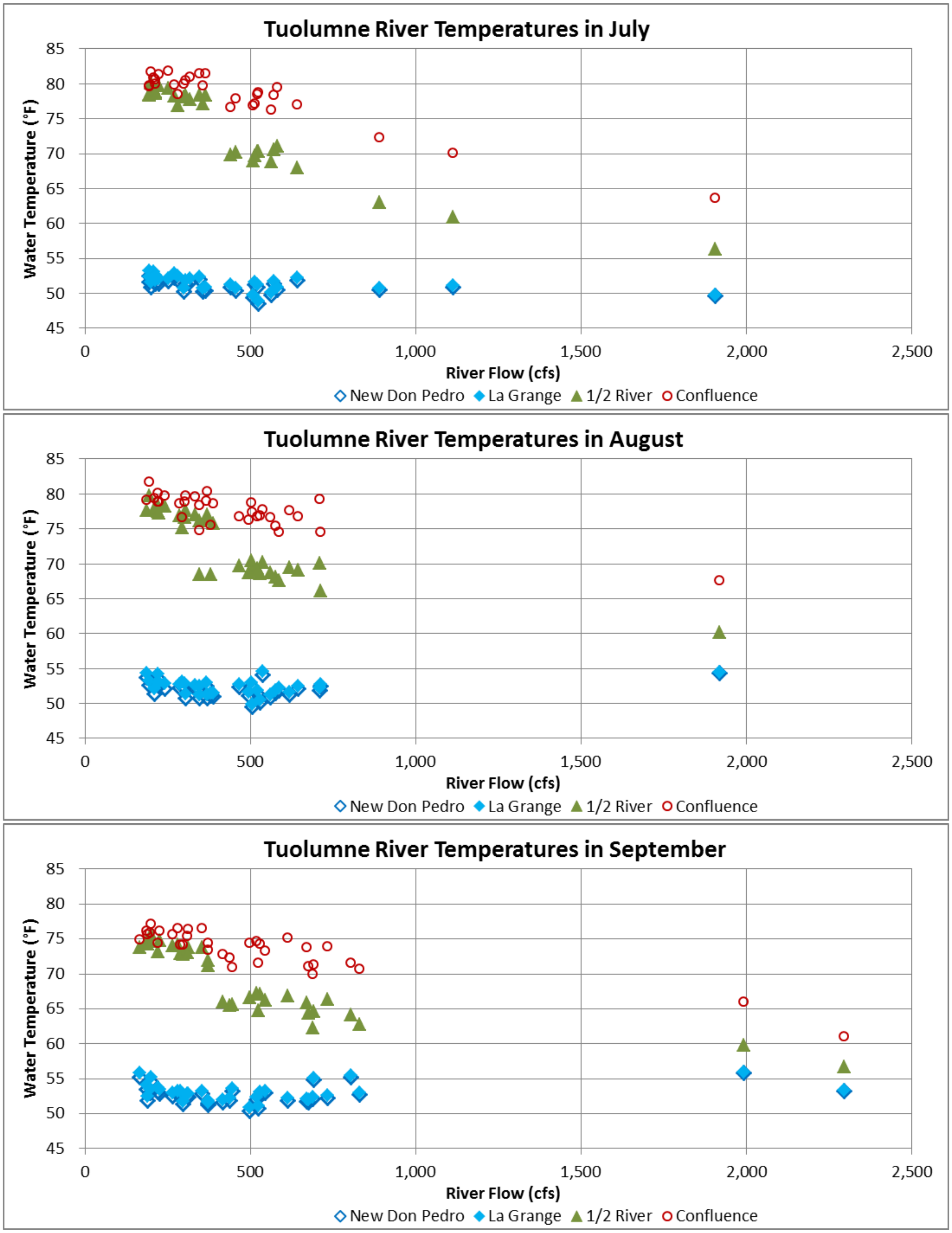


Figure F.1.6-6d. Effects of Tuolumne River Flow on Tuolumne River Water Temperatures July–September for Baseline Conditions 1970–2003

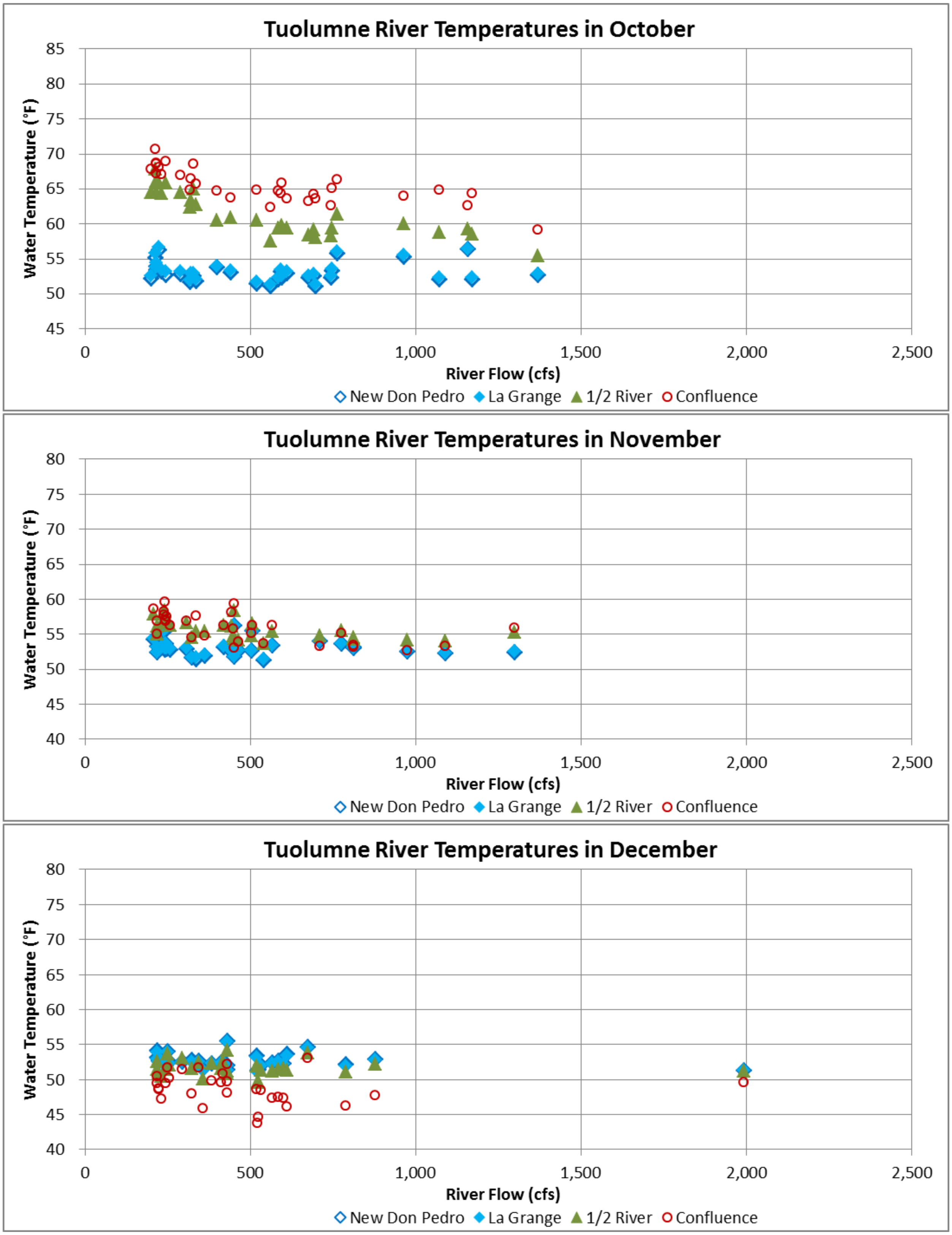


Figure F.1.6-6e. Effects of Tuolumne River Flow on Tuolumne River Water Temperatures October–December for Baseline Conditions 1970–2003

Merced River Temperatures

Figure F.1.6-7a shows the simulated monthly average Merced River temperatures at Lake McClure and below Crocker-Huffman Dam in September–December for 1970–2003. In general, there appears to be more warming along the Merced River between the Lake McClure release and the Crocker-Huffman release than along the Tuolumne River between New Don Pedro and La Grange. This is because there are a total of four dams on the Merced River. In addition to New Exchequer Dam, there is Lake McSwain, which has a small hydropower unit. The lake is about 6.5 miles long and about 80 feet deep. Merced Falls Dam is the diversion dam for the Northside Canal and is 1 mile long and about 40 feet deep. Finally, the Crocker-Huffman Dam is the diversion dam for the Merced Irrigation District Main Canal and is 3 miles long and 20 feet deep.

The September and October temperatures at Lake McClure ranged from about 50°F–70°F as Lake McClure storage was reduced from 700 to 100 TAF. In general, release temperatures from Lake McClure did not rise above 60°F until storage was below 200 TAF. The September and October temperatures at Crocker-Huffman Dam were generally a bit warmer than the temperatures at Lake McClure but usually within 5°F. In general, release temperatures from Crocker-Huffman did not rise above 60°F until Lake McClure storage was below 300 TAF. The November temperatures at Lake McClure and at Crocker-Huffman were less than 60°F when Lake McClure storage was greater than about 200 TAF. The December temperatures at both locations were approximately 50°F–55°F, regardless of storage, because the reservoir was fully mixed, and the release temperatures were controlled by the meteorology and not the reservoir storage. Based on these results, the Lake McClure carryover storage target of at least 300 TAF would likely provide a Crocker-Huffman Dam release temperature of approximately 60°F or less in September and October. Temperatures at Crocker-Huffman Dam are important for the Merced River Hatchery, which is located nearby.

Figure F.1.6-7b shows the simulated monthly average Merced River temperatures below Lake McClure, below Crocker-Huffman, at RM 27.1 (approximately half way between Crocker-Huffman and the confluence), and at the confluence in January–March for 1970–2003 as a function of the river flow (at the confluence). During January, almost all monthly average temperatures were between 45°F and 55°F and there was little change in temperature between Crocker-Huffman and the confluence. During February, average monthly temperatures were still usually between 45 and 60°F, but there was a small amount of warming between Crocker-Huffman and the confluence (allowing some temperatures to exceed 55°F at flows less than 500 cfs). During March, there was significant longitudinal warming. At flows less than 500 cfs, monthly average temperatures increased from about 48°F at McClure to about 52°F at Crocker-Huffman. As water moved downstream, it continued to warm. By the time it reached RM 27.1, the average temperature was about 57°F–58°F. However, there was only slight warming between RM 27.1 and the confluence, indicating that at flows less than 500 cfs, March equilibrium temperatures were already reached near RM 27.1.

Figure F.1.6-7c shows the simulated monthly average Merced River temperatures below Lake McClure, below Crocker-Huffman, at RM 27.1 (approximately half way between Crocker-Huffman and the confluence) and at the confluence in April–June for 1970–2003 as a function of the river flow (at the confluence). For all three months, the downstream temperatures were controlled by the meteorology and the flow. During April, Lake McClure temperatures were usually between 45°F and 55°F, while temperatures at Crocker Huffman were a bit higher, particularly at flows less than 400 cfs. At RM 27.1, the temperature was usually between 55°F and 60°F when flow was greater than 400 cfs but increased to about 65°F at lower flows. May showed similar trends compared to April, but temperatures were about 5°F warmer at all locations. During June, confluence flows usually remained at or below 300 cfs, apart from a few high-flow years. When the flow was less than 300 cfs, Lake McClure was generally between 50°F and 55°F, Crocker-Huffman was between 55°F and 60°F, and RM 27.1 was about 75°F. For all three months, confluence temperatures were only slightly higher than temperatures at RM 27.1, indicating that river temperature had already reached equilibrium temperature by RM 27.1.

Figure F.1.6-7d shows the simulated monthly average Merced River temperatures below Lake McClure, below Crocker-Huffman, at RM 27.1, and at the confluence in July–September for 1970–2003 as a function of the river flow (at the confluence). The summer flows on the Merced River were usually very low (less than 300 cfs), and simulated temperatures at RM 27.1 and the confluence were high (70°F–80°F) in July, August, and September. Crocker Huffman and Lake McClure temperatures were also higher than in previous months, particularly at low flows. For flows less than 250 cfs and Lake McClure storage less than 200 TAF, September Crocker-Huffman temperatures got as high as 65°F–70°F. Regardless of the simulated Crocker-Huffman temperature, confluence temperatures were about 70°F–75°F. In all three months, confluence temperatures were occasionally less than temperatures at RM 27.1, suggesting that shading at the confluence was greater (i.e., slightly lower equilibrium temperature) than at RM 27.1. At flows higher than 300 cfs, the warming downstream was much less in all three months—about 10°F–12°F higher at RM 27.1 compared to Lake McClure and a few additional degrees higher at the confluence.

Figure F.1.6-7e shows the simulated monthly average Merced River temperatures below Lake McClure, below Crocker-Huffman, at RM 27.1, and at the confluence in October–December for 1970–2003 as a function of the river flow (at the confluence). For all three months, temperatures at Lake McClure and Crocker-Huffman were typically between 50°F and 60°F. However, during October and November, when Lake McClure storage was low, temperatures at the two reservoirs were sometimes greater than 60°F. In October, longitudinal (downstream) warming was still present but less than in September. Downstream temperatures were mostly between 60°F and 65°F at flows greater than 400 cfs and between 65°F and 70°F at flows less than 400 cfs. In November, there was usually no downstream warming, and downstream temperatures were in the same range as those at the Crocker-Huffman. In December, temperatures at RM 27.1 and the confluence were often slightly cooler than temperatures at Lake McClure and Crocker-Huffman.

These temperature results illustrate the combination of factors controlling Merced River temperatures. The Lake McClure and Crocker-Huffman temperatures were strongly affected by low storage in August–November. The meteorological warming of locations downstream of Lake McClure was substantial in March–October, with maximum temperatures of 75°F–80°F in July and August at RM 27.1 and the confluence. However, higher river flows reduce the maximum downstream warming. For example, reducing the river flow from 1,000 to 500 cfs in May will allow the confluence temperatures to increase by about 5°F. Reducing the flow from 500 to 250 cfs will allow the confluence temperatures to increase another 5°F. The temperature effect of flows between 250 and 1,500 cfs is important because this is the typical range for the LSJR alternatives being evaluated. An increase of 250 cfs or more in April–June could have a substantial effect on reducing the downstream water temperatures at Snelling and the mouth of the Merced River.

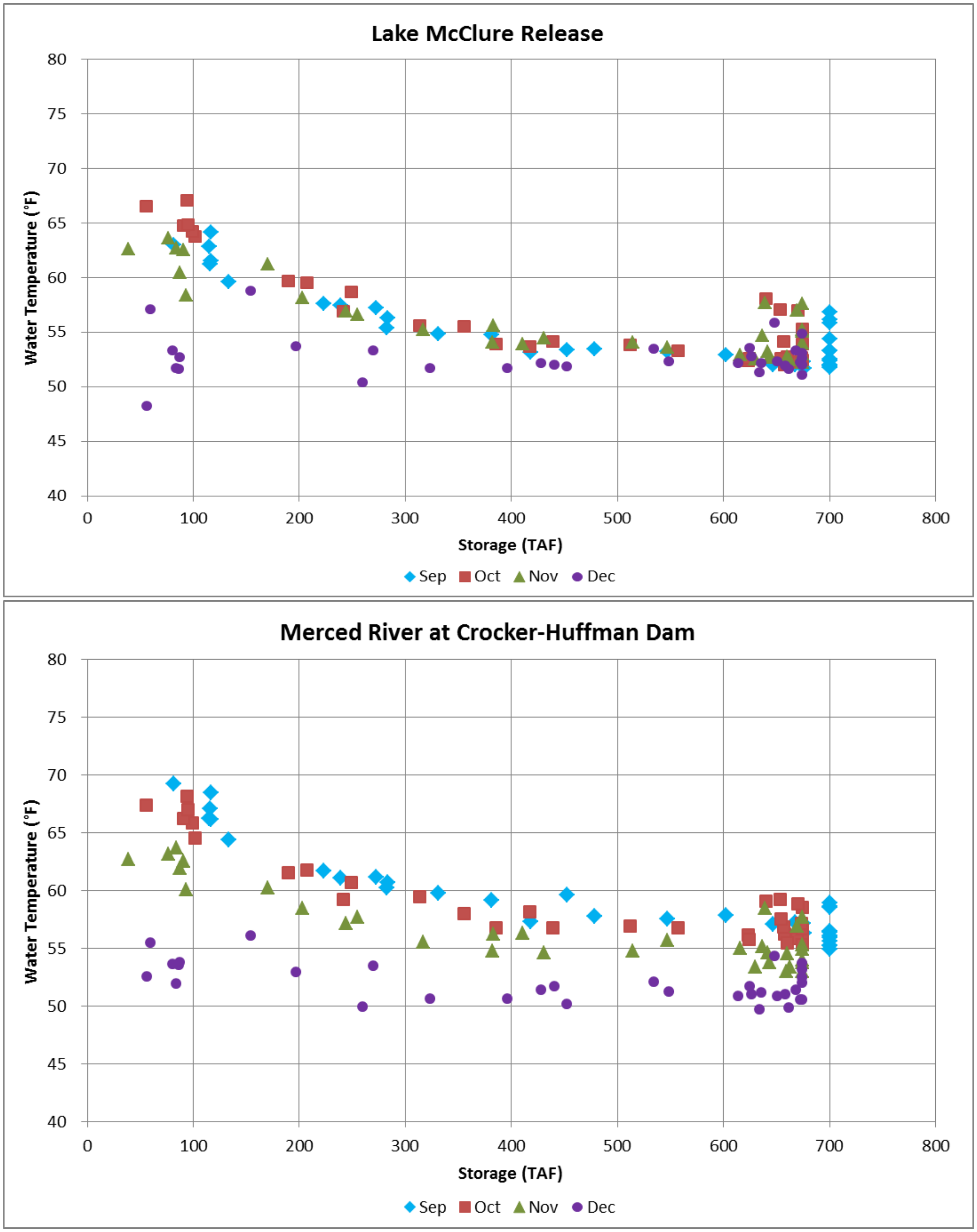


Figure F.1.6-7a. Effects of Lake McClure Storage on Lake McClure and Crocker-Huffman Release Temperatures September–December for Baseline Conditions 1970–2003

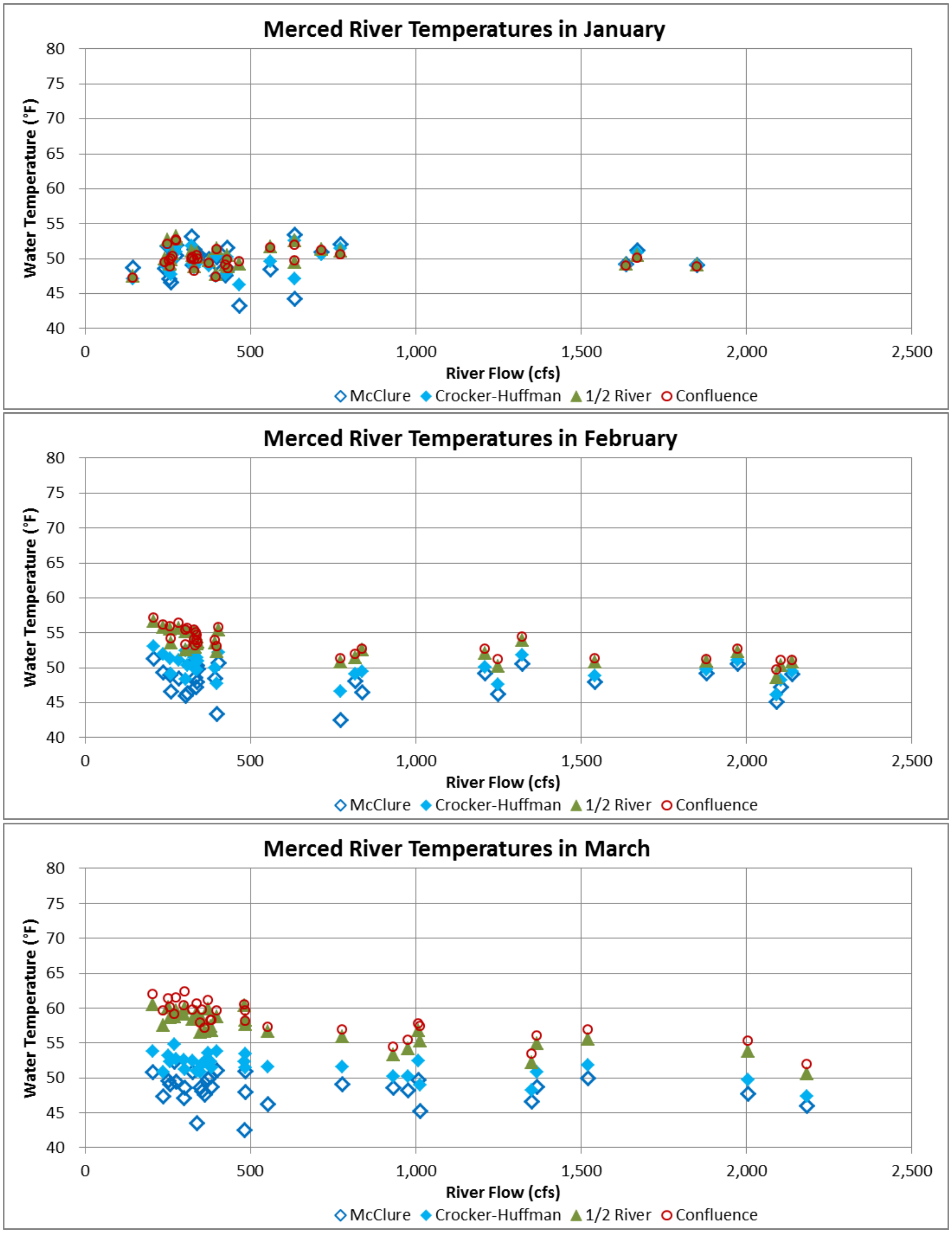


Figure F.1.6-7b. Effects of Merced River Flow on Merced River Water Temperatures in January–March for Baseline Conditions 1970–2003

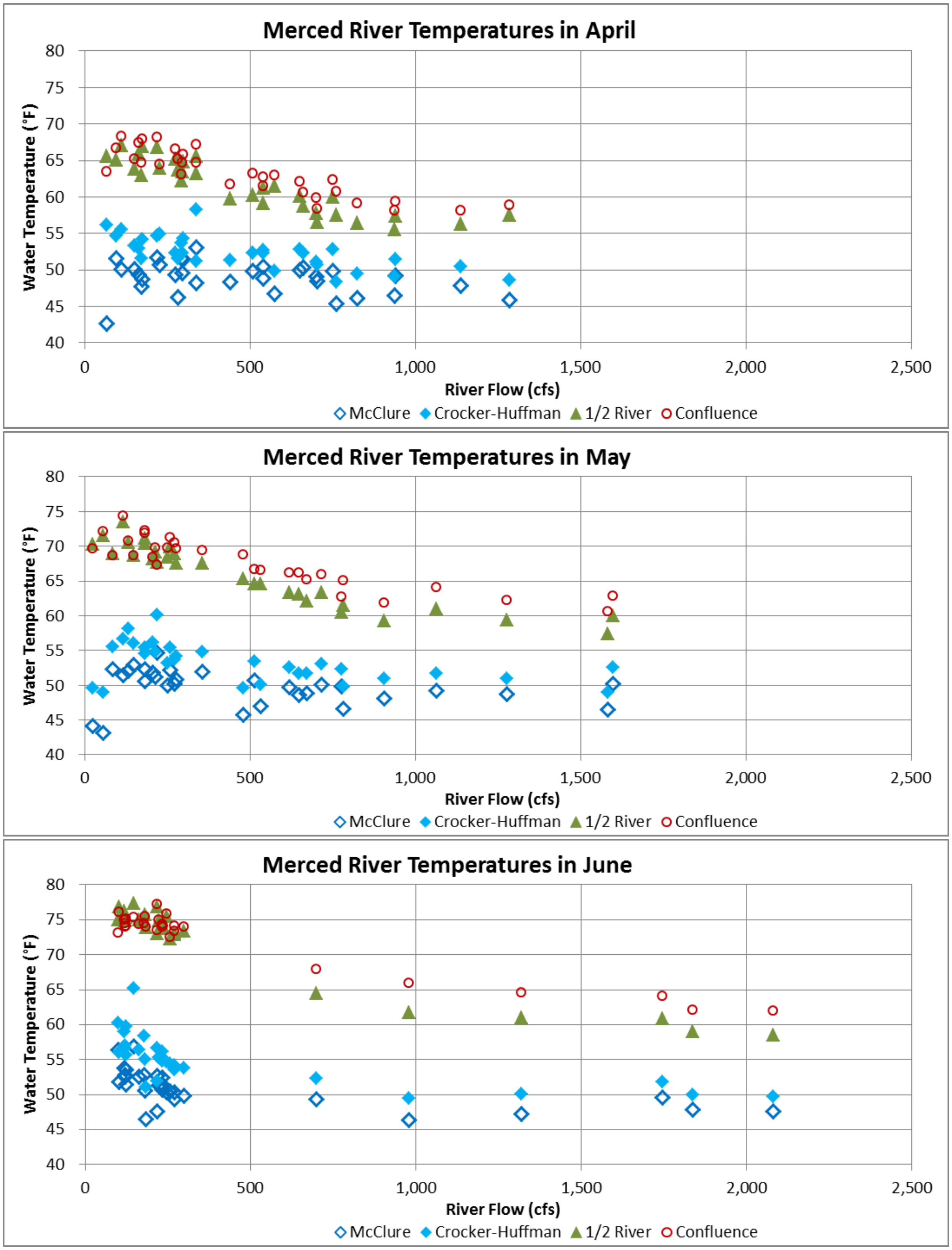


Figure F.1.6-7c. Effects of Merced River Flow on Merced River Water Temperatures in April–June for Baseline Conditions 1970–2003

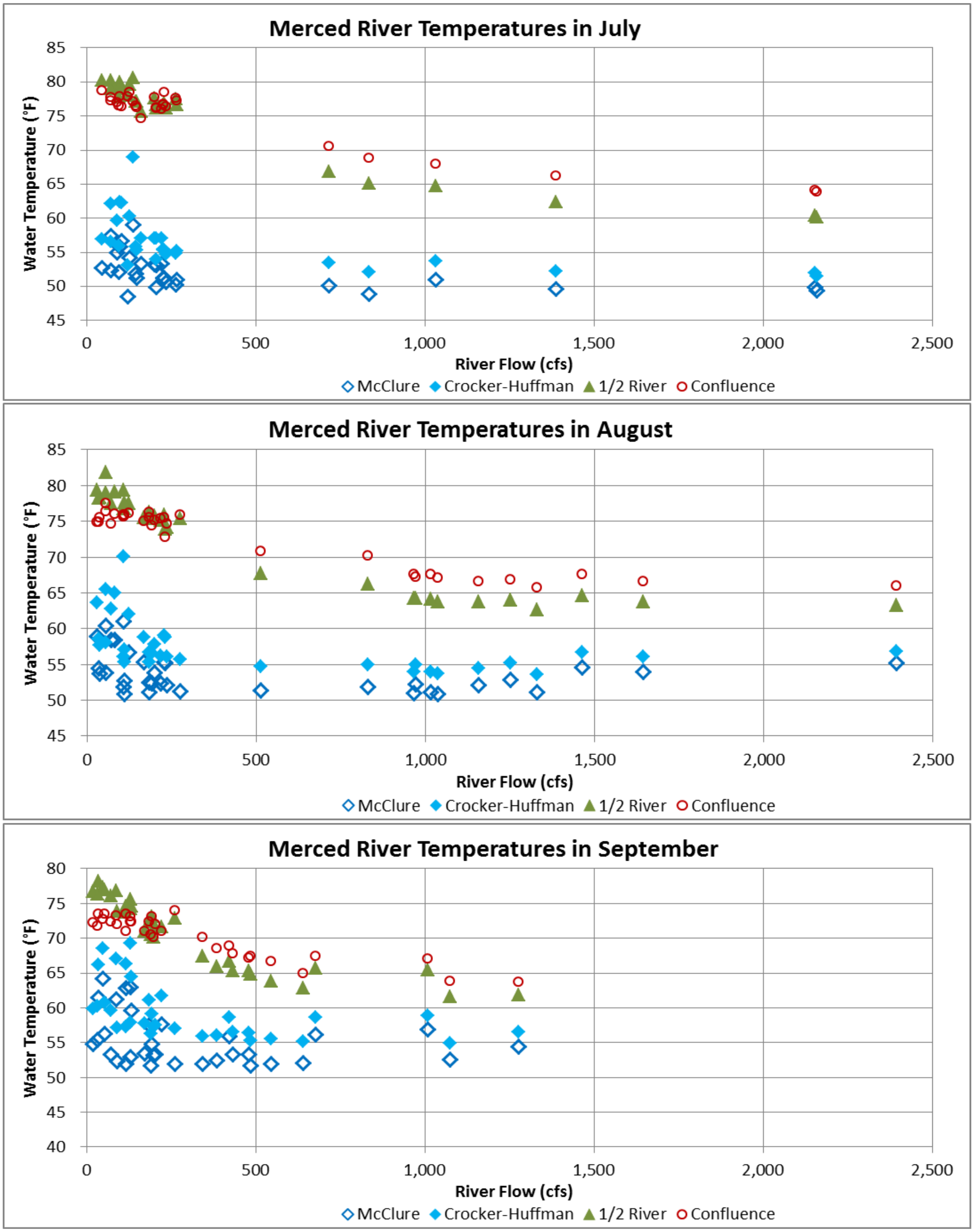


Figure F.1.6-7d. Effects of Merced River Flow on Merced River Water Temperatures July–September for Baseline Conditions 1970–2003

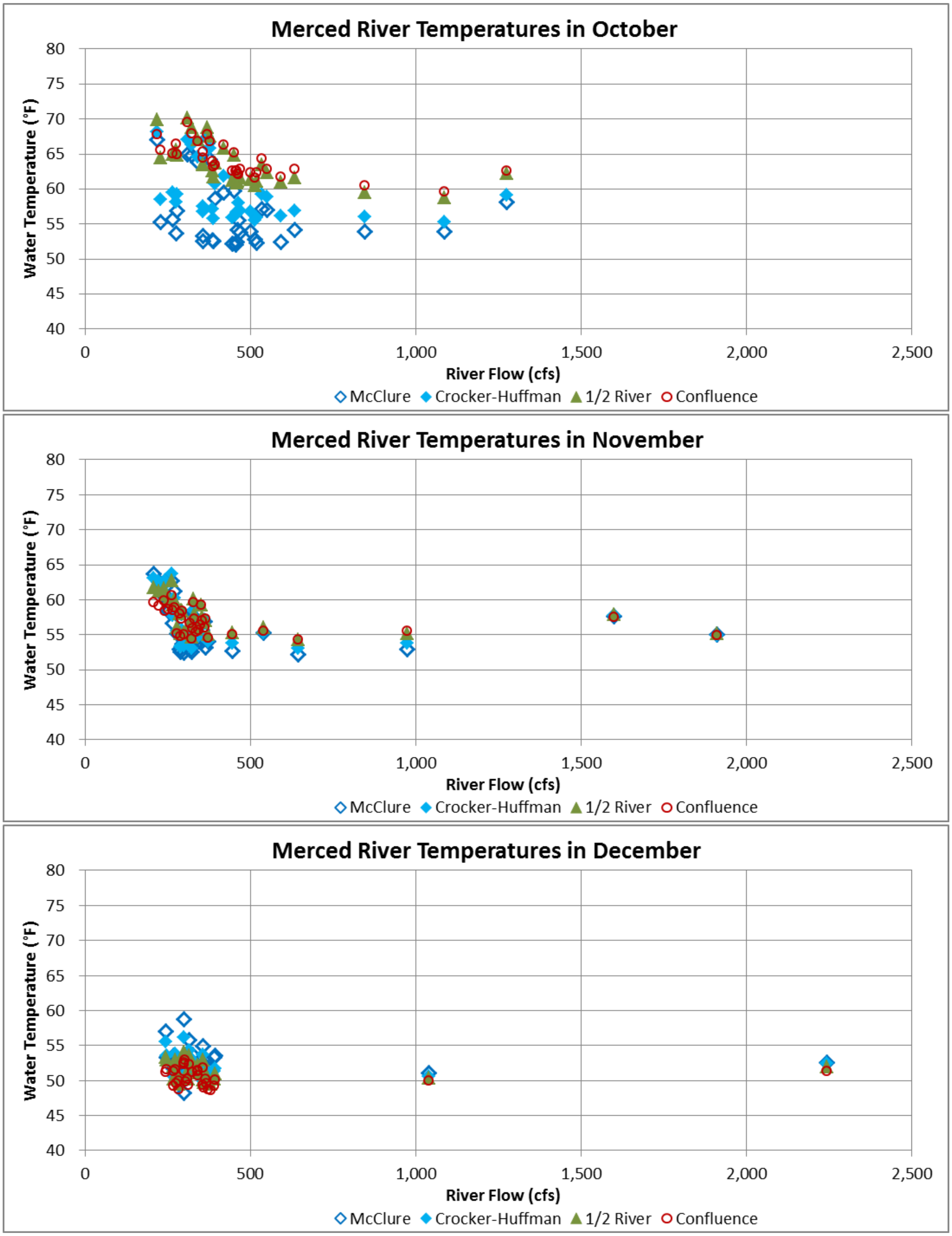


Figure F.1.6-7e. Effects of Merced River Flow on Merced River Water Temperatures October–December for Baseline Conditions 1970–2003

LSJR Alternatives Temperature Results

This discussion focuses on the temperature results for February–June, the period when the LSJR alternatives would most likely affect water temperature. In addition, this discussion focuses on a single location for each tributary, at RM 27.1 on the Merced River, at RM 28.1 on the Tuolumne River, and at RM 28.2 on the Stanislaus River. These are roughly the halfway points between the river confluences with the SJR and the upstream regulating reservoirs. These points were selected because they are good locations for capturing the general effect of flow on water temperature. In Chapter 7, *Aquatic Biological Resources*, and Chapter 19, *Analyses of Benefits to Native Fish Populations from Increased Flow Between February 1 and June 30*, water temperature results are evaluated by focusing on the time of year, river locations, and temperature criteria that are specific to individual Chinook salmon and steelhead life stages in the plan area. The calculated changes under 20, 40, and 60 percent minimum unimpaired flow (LSJR Alternatives 2, 3, and 4) are presented and discussed below. Results for the 30 percent and 50 percent unimpaired flow simulation would be intermediate between the 20 percent and 40 percent and 40 percent and 60 percent unimpaired flow simulations respectively and are shown in summary tables below.

Stanislaus River Temperatures

Figures F.1.6-8a and F.1.6-8b show the monthly average temperatures in the Stanislaus River at RM 28.2 simulated with the temperature model for baseline conditions and the LSJR alternatives plotted as a function of the monthly river flow at Ripon for February–June. For February, the temperatures were generally 47°F–55°F. The warmest temperatures corresponded to flows of less than 500 cfs. Although the LSJR alternatives generally increased flows relative to baseline in February, these flow changes generally had very little effect on RM 28.2 temperatures (generally less than 1°F change in cumulative distribution values). Because there is little meteorological warming in February, river flow increases would not substantially reduce water temperatures. In March, simulated temperatures in the Stanislaus River at RM 28.2 were 50°F–55°F when river flow was 500 cfs or more and generally increased to 54°F–60°F when river flows were less than 500 cfs. Because the March flows under LSJR Alternative 3 and 4 were generally higher than baseline flows, water temperatures tended to be lower. However, there were no substantial effects on water temperatures because meteorological warming at RM 28.2 was limited in March and water temperatures generally remained cool. The warmest temperatures were simulated for low flows of less than 500 cfs, but these temperatures were less than 60°F.

In April, the range of simulated temperatures at RM 28.2 was 50°F–62°F, with the warmer temperatures of 55°F–62°F generally simulated for the lower flows (less than 1,000 cfs). Because the April flows were always about 500 cfs or greater, no temperatures greater than 62°F were simulated. In May, the range of simulated temperatures at RM 28.2 was 53°F–66°F, which is 3°F–4°F warmer than in April. The warmer temperatures of 60°F–66°F in May were generally simulated for the lower flows (less than 1,000 cfs). Because the May flows were always about 500 cfs or greater, no temperatures of greater than 66°F were simulated in May at RM 28.2. In June, the flows were lower (lowest of about 250 cfs), and the temperatures were sometimes considerably warmer than in April and May, ranging from 55°F–70°F. The warmer temperatures of 65°F–70°F were generally simulated for the lower flows (less than 500 cfs).

The Stanislaus River warming curves (flow versus temperature) at RM 28.2 in April, May, and June indicate the general relationship between river flow and water temperatures in the upstream portion of the Stanislaus River. These figures suggest that temperature is more responsive to changes in flow when flow is less than 1,000 cfs and during warmer conditions (i.e., June).

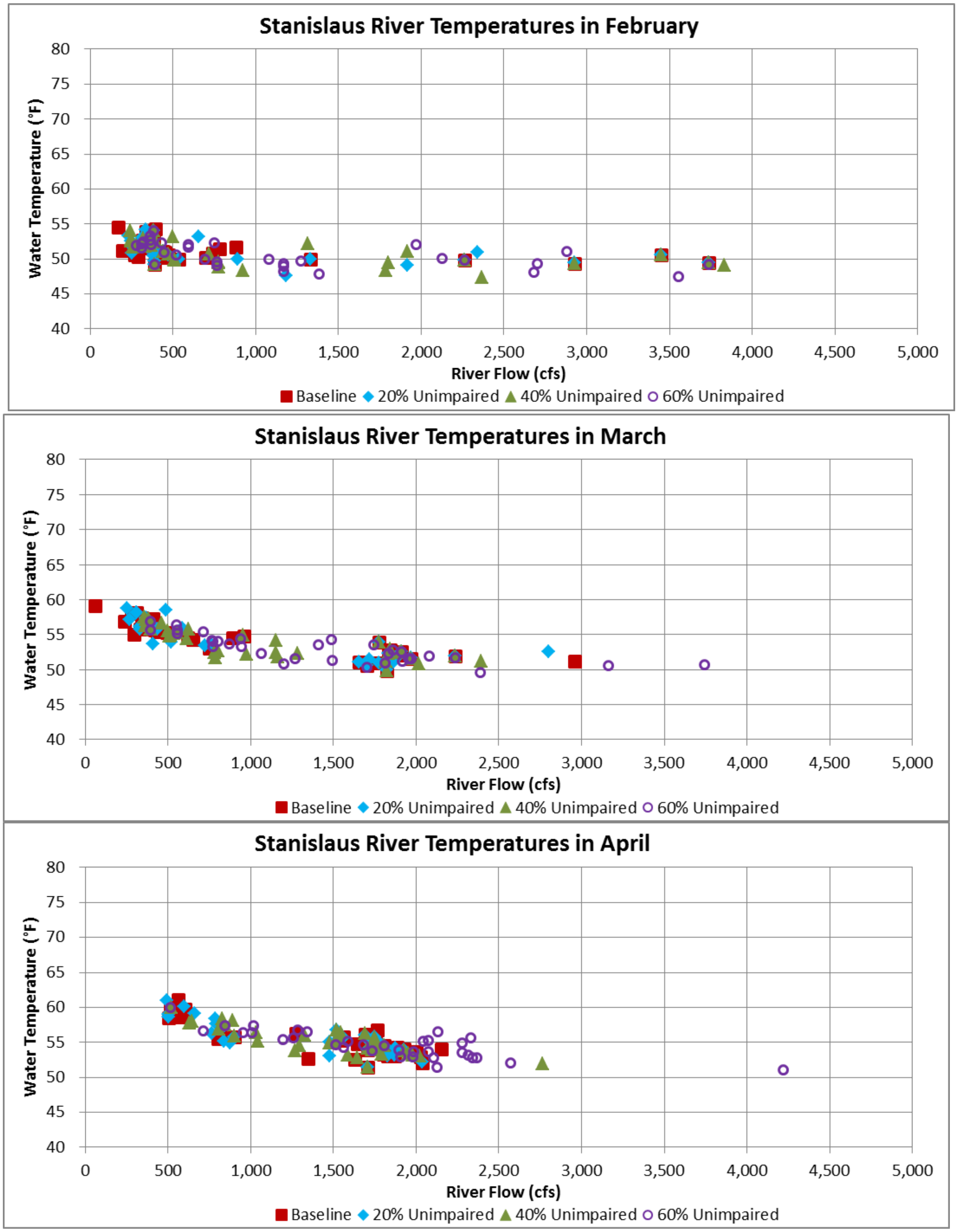


Figure F.1.6-8a. Effects of Stanislaus River Flows on Temperatures at RM 28.2 February–April for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

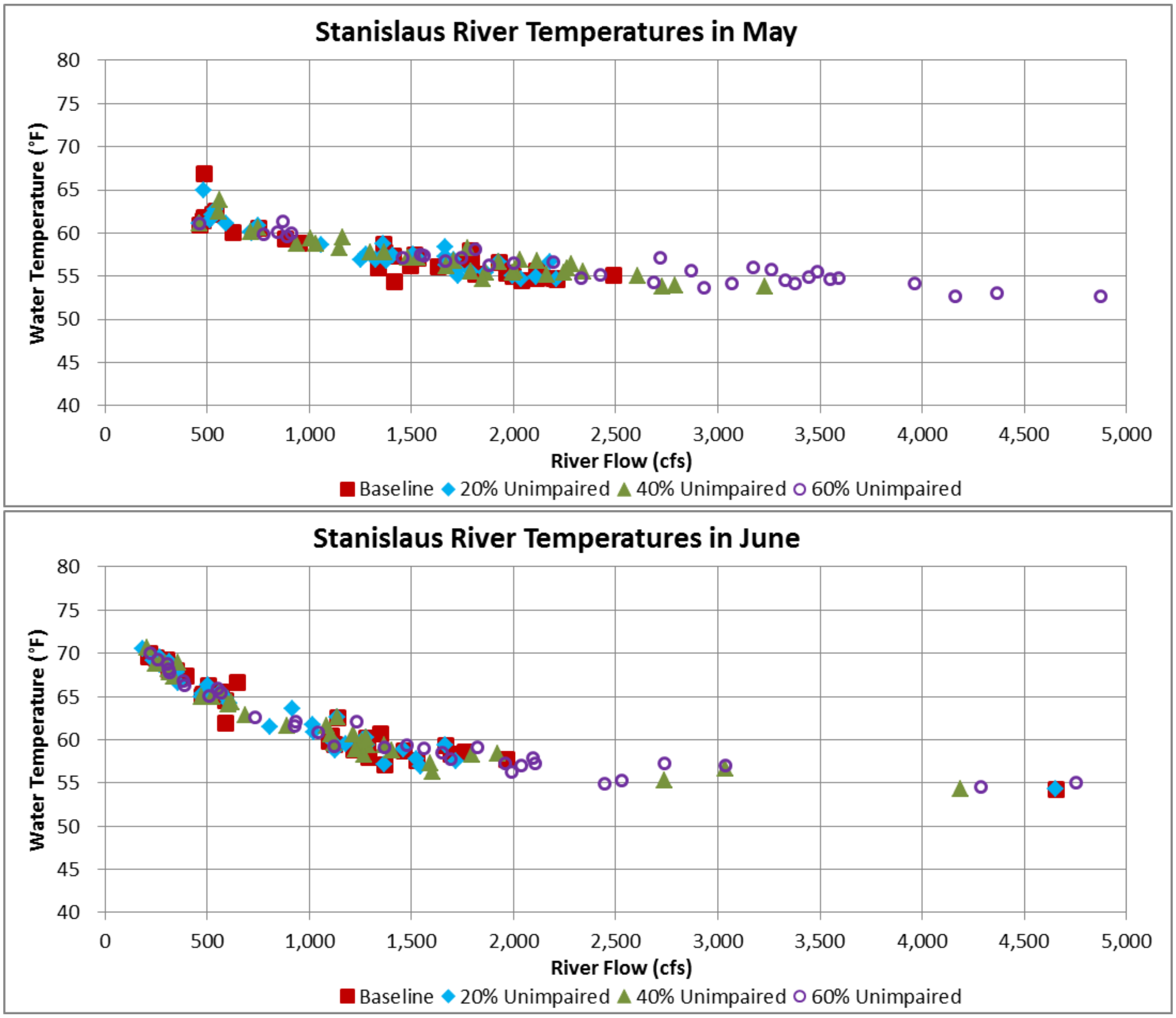


Figure F.1.6-8b. Effects of Stanislaus River Flows on Temperatures at Riverbank in May and June for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

Tables F.1.6-2a and F.1.6-2b give the monthly cumulative distributions of average simulated water temperatures in the Stanislaus River at RM 28.2 for 1970–2003 under baseline conditions and the change in the distribution under the LSJR alternatives. Baseline average water temperatures at RM 28.2 indicate the average seasonal warming January–July is about 20°F. The monthly increase in the average temperatures February–May was about 2°F–3°F per month, and the monthly increase May–July was about 5°F–6°F per month.

Changes in temperature associated with the LSJR alternatives were dependent on the combination of change in flow and amount of meteorological warming (i.e., difference between reservoir release temperatures and equilibrium temperatures). Overall average temperature decreased by more than 1°F under the 60 percent and 50 percent unimpaired flow objectives for the months of March, May, and June.

Figures F.1.6-9, F.1.6-10, F.1.6-11, and F.1.6-12 show Stanislaus River temperature model results under baseline conditions and under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow objectives Feb–June) for the water years 1985–1989, 1990–1994, 1995–1999, and 2000–2003, respectively. Each figure is composed of three separate charts to compare how reservoir storage and river flow can affect temperatures at different points along the river. Chart A shows reservoir storage at New Melones, Chart B shows the instream flows at Ripon, and Chart C gives the daily 7DADM temperature at New Melones release, Goodwin release, and 1/4 River location.

Figures F.1.6-13a and F.1.6-13b show temperature model 7DADM results at Orange Blossom Bridge (OBB) compared to monthly U.S. Environmental Protection Agency (USEPA) temperature criteria for optimal development of different fish lifestages (as described in Chapter 19) under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow Feb–June) and baseline conditions for water years 1985–1989 and water years 1990–1994, respectively. These show temperature effects of reservoir levels within the major drought sequence 1989–1993.

Figures F.1.6-14, F.1.6-15, F.1.6-16, F.1.6-17, F.1.6-18, and F.1.6-19 show longitudinal monthly average 7DADM temperature results for each month of the water year 1988 under baseline conditions and the LSJR alternatives. Water year 1988 is shown because it represents a year when New Melones Reservoir storage levels were around 1 million acre feet (about half storage) under the model scenarios. Figures F.1.6-20, F.1.6-21, F.1.6-22, F.1.6-23, F.1.6-24, and F.1.6-25 show longitudinal monthly average 7DADM temperature results for each month of the water year 1990 under baseline conditions and the LSJR alternatives. Water year 1990 is shown because it represents a year in the middle of the 1989–1992 drought sequence when reservoir storage would have been low.

Table F.1.6-2a. Monthly Distribution of Stanislaus River Water Temperatures at RM 28.2 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Stanislaus River Temperatures at RM 28.2 for Baseline Conditions												
Minimum	52.4	50.0	48.0	46.2	48.4	49.2	51.4	54.4	54.3	54.8	56.6	54.5
10%	55.6	53.6	48.6	47.2	49.5	51.0	52.7	54.7	57.8	64.7	64.5	61.1
20%	56.7	53.8	49.0	48.1	50.1	51.7	53.2	55.2	58.7	66.6	66.6	63.9
30%	56.8	54.0	49.4	48.4	50.5	52.5	54.0	56.0	59.3	67.6	67.6	64.3
40%	57.3	54.2	50.1	48.9	50.9	54.0	54.3	56.7	60.3	68.1	67.9	65.0
50%	57.4	55.0	50.5	49.3	51.2	54.7	55.1	57.1	62.3	68.7	68.5	65.6
60%	58.6	55.8	50.7	49.6	51.7	55.4	55.6	57.7	65.2	69.8	68.9	66.2
70%	59.1	56.4	51.0	49.8	51.9	55.8	55.9	58.9	66.3	70.8	69.6	67.1
80%	60.9	57.1	51.4	50.3	52.6	57.0	57.4	60.8	68.1	72.4	72.1	69.2
90%	65.3	57.5	51.7	50.9	53.8	57.3	59.4	62.1	69.4	73.0	72.8	70.8
Maximum	66.6	60.2	52.6	52.4	54.5	59.1	61.1	66.9	70.0	74.5	75.6	72.2
Average	58.8	55.4	50.2	49.2	51.3	54.3	55.4	57.9	63.0	68.7	68.3	65.6
Change in Stanislaus River Temperatures at RM 28.2 for 20% Unimpaired Flow Relative to Baseline												
Minimum	0.2	0.2	0.0	0.0	-0.8	0.0	0.0	0.3	0.0	0.0	0.0	-0.3
10%	0.0	0.0	0.0	0.1	-0.2	0.0	0.4	0.3	-0.2	1.4	1.1	1.1
20%	-0.1	-0.1	0.0	0.0	-0.3	-0.4	0.5	0.4	0.5	0.1	-0.2	-0.2
30%	-0.1	0.0	-0.1	0.0	-0.6	-0.5	0.0	0.6	0.3	-0.6	-0.4	-0.2
40%	-0.2	0.0	-0.3	0.2	-0.3	-1.2	0.6	0.2	0.7	-0.1	-0.4	-0.1
50%	-0.1	-0.5	-0.3	0.0	-0.3	-0.9	0.0	0.1	0.8	-0.1	-0.5	-0.1
60%	-0.1	-0.4	-0.3	0.0	0.1	0.4	0.0	-0.2	-0.3	-0.4	0.0	-0.1
70%	-0.2	-0.7	-0.3	0.0	0.4	0.2	0.2	-0.3	-0.7	-0.6	-0.1	-0.1
80%	-1.6	-0.7	-0.2	-0.2	0.2	0.1	0.1	-0.4	-0.2	-0.8	-1.2	-0.6
90%	-4.5	-0.6	-0.3	-0.2	-0.6	0.6	-0.6	-0.8	-0.5	-0.3	-0.7	-1.4
Maximum	-4.5	-2.6	-0.3	0.0	-0.3	-0.4	-0.1	-1.9	0.5	-0.7	-1.6	-1.7
Average	-0.9	-0.5	-0.2	0.0	-0.2	-0.2	0.1	0.0	0.0	-0.2	-0.4	-0.4
Change in Stanislaus River Temperatures at RM 28.2 for 40% Unimpaired Flow Relative to Baseline												
Minimum	1.6	0.3	0.0	0.0	-1.0	0.0	0.0	-0.7	0.1	0.4	0.0	1.3
10%	-0.2	0.0	0.1	0.0	-1.0	0.1	0.3	0.0	-1.0	-1.9	1.2	-0.4
20%	-0.8	0.1	0.0	0.0	-0.8	0.0	0.2	0.1	-0.3	-3.0	-0.3	-2.6
30%	-0.6	0.1	0.0	0.2	-1.1	-0.3	-0.1	-0.4	0.0	-2.9	-0.5	-2.2
40%	-0.7	0.0	-0.3	0.1	-1.0	-1.6	0.2	-0.5	-0.5	-1.2	-0.3	-1.0
50%	-0.1	-0.1	-0.3	0.0	-0.6	-1.9	-0.1	-0.3	-1.1	-0.5	-0.6	-0.7
60%	-0.6	-0.3	-0.2	-0.1	0.0	-1.0	0.0	-0.5	-2.4	-0.6	0.1	-0.1
70%	-0.4	-0.7	-0.2	0.0	0.1	-0.9	0.4	-0.7	-1.4	0.0	0.0	0.6
80%	-1.9	-0.8	-0.3	-0.2	0.0	-1.3	-0.6	-1.8	-0.5	-1.1	-1.3	-0.8
90%	-5.4	-0.6	-0.2	-0.2	-0.9	-0.8	-1.4	-1.6	-0.7	-0.4	-0.6	-1.3
Maximum	-5.0	-2.8	-0.4	0.0	-0.5	-1.6	-1.1	-3.0	0.7	-1.0	-1.6	-1.6
Average	-1.3	-0.4	-0.1	0.0	-0.5	-0.8	-0.2	-0.7	-0.9	-1.1	-0.1	-0.8
Change in Stanislaus River Temperatures at RM 28.2 for 60% Unimpaired Flow Relative to Baseline												
Minimum	2.3	2.1	-0.2	0.0	-0.9	0.0	-0.3	-1.7	-1.0	3.2	2.8	1.6
10%	0.0	0.1	0.2	-0.2	-1.2	-0.4	0.1	-1.0	-2.6	-2.3	0.5	-0.1

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
20%	-0.1	0.4	0.2	-0.2	-1.0	-0.6	-0.2	-1.0	-1.7	-3.3	0.1	-2.1
30%	0.0	0.3	0.2	0.1	-1.2	-0.9	-0.4	-1.2	-2.0	-2.9	-0.1	-1.5
40%	-0.2	0.4	-0.2	0.4	-1.2	-2.0	-0.4	-1.4	-1.7	-1.1	0.0	-0.5
50%	0.2	-0.1	-0.3	0.1	-1.2	-2.0	-0.4	-1.2	-3.0	-0.1	-0.1	0.0
60%	-0.5	-0.2	-0.1	0.0	-0.6	-1.9	-0.5	-1.1	-3.8	0.2	0.9	1.1
70%	-0.3	-0.6	-0.2	0.0	0.1	-1.8	-0.2	-1.8	-3.5	-0.1	0.8	0.8
80%	-1.6	-0.9	-0.1	-0.1	-0.4	-2.7	-1.0	-3.1	-2.1	-0.8	-1.0	-0.5
90%	-5.4	-0.4	-0.1	-0.2	-1.4	-1.8	-2.7	-2.2	-1.4	-0.3	-0.5	-1.3
Maximum	-4.7	-2.5	-0.4	0.1	-0.5	-2.2	-1.2	-5.5	0.0	-1.2	-1.4	-1.5
Average	-0.9	-0.2	-0.1	0.0	-0.9	-1.5	-0.7	-1.7	-2.2	-1.0	0.3	-0.3

Table F.1.6-2b. Monthly Change in Distribution of Stanislaus River Water Temperatures at RM 28.2 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average Stanislaus River Temperatures at RM 28.2												
Baseline Average												
	58.8	55.4	50.2	49.2	51.3	54.3	55.4	57.9	63.0	68.7	68.3	65.6
Change in Average Stanislaus River Temperatures at RM 28.2 relative to Baseline												
20% Unimpaired Flow Minus Baseline												
	-0.9	-0.5	-0.2	0.0	-0.2	-0.2	0.1	0.0	0.0	-0.2	-0.4	-0.4
30% Unimpaired Flow Minus Baseline												
	-0.7	-0.4	-0.1	0.0	-0.4	-0.6	-0.1	-0.4	-0.4	-0.5	-0.1	-0.2
40% Unimpaired Flow Minus Baseline												
	-1.3	-0.4	-0.1	0.0	-0.5	-0.8	-0.2	-0.7	-0.9	-1.1	-0.1	-0.8
50% Unimpaired Flow Minus Baseline												
	-1.1	-0.3	-0.1	0.0	-0.7	-1.1	-0.5	-1.2	-1.6	-1.1	0.1	-0.6
60% Unimpaired Flow Minus Baseline												
	-0.9	-0.2	-0.1	0.0	-0.9	-1.5	-0.7	-1.7	-2.2	-1.0	0.3	-0.3

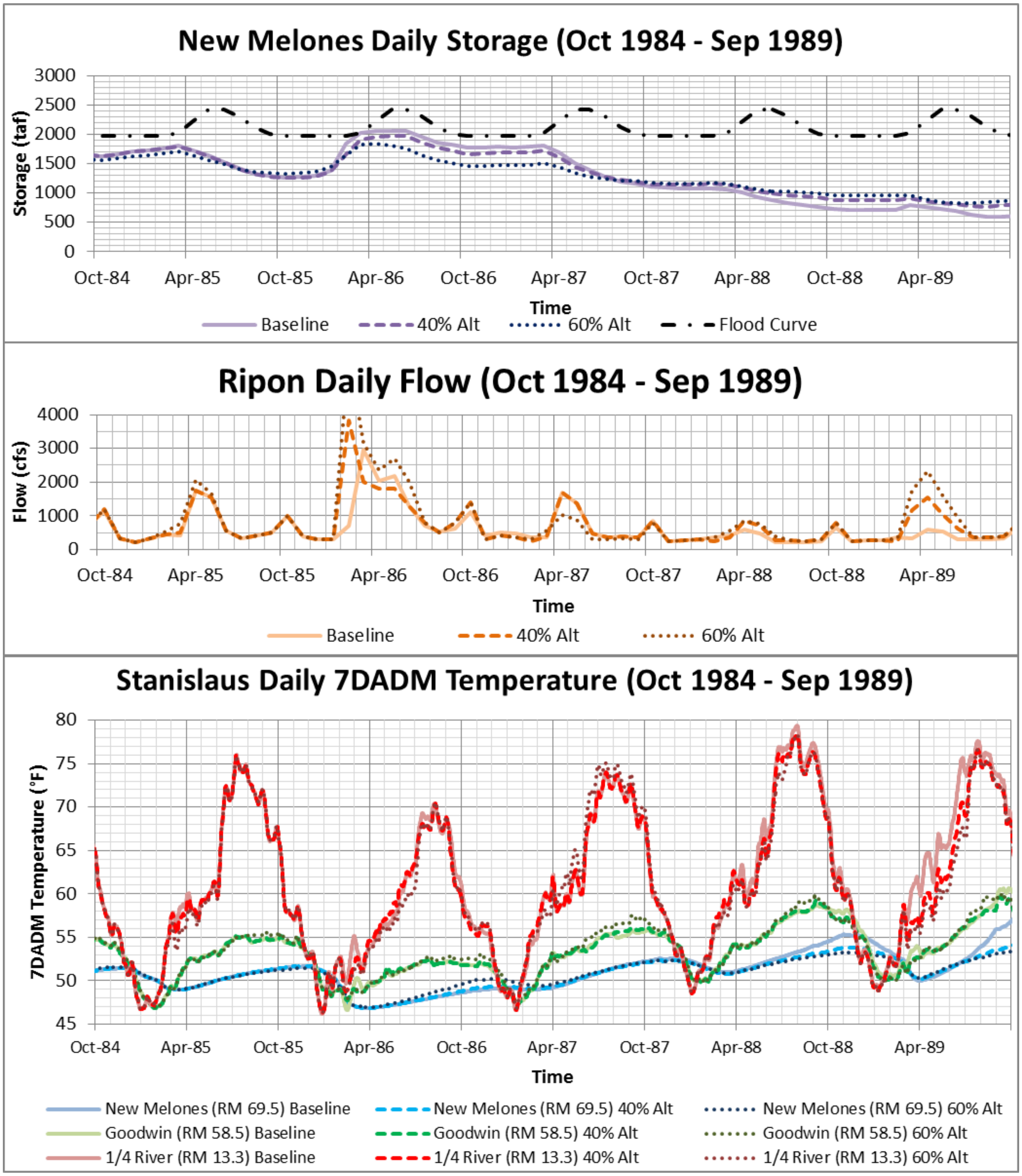


Figure F.1.6-9. Stanislaus River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline for Water Years 1985–1989, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Melones Release, Goodwin Release, and 1/4 River Locations

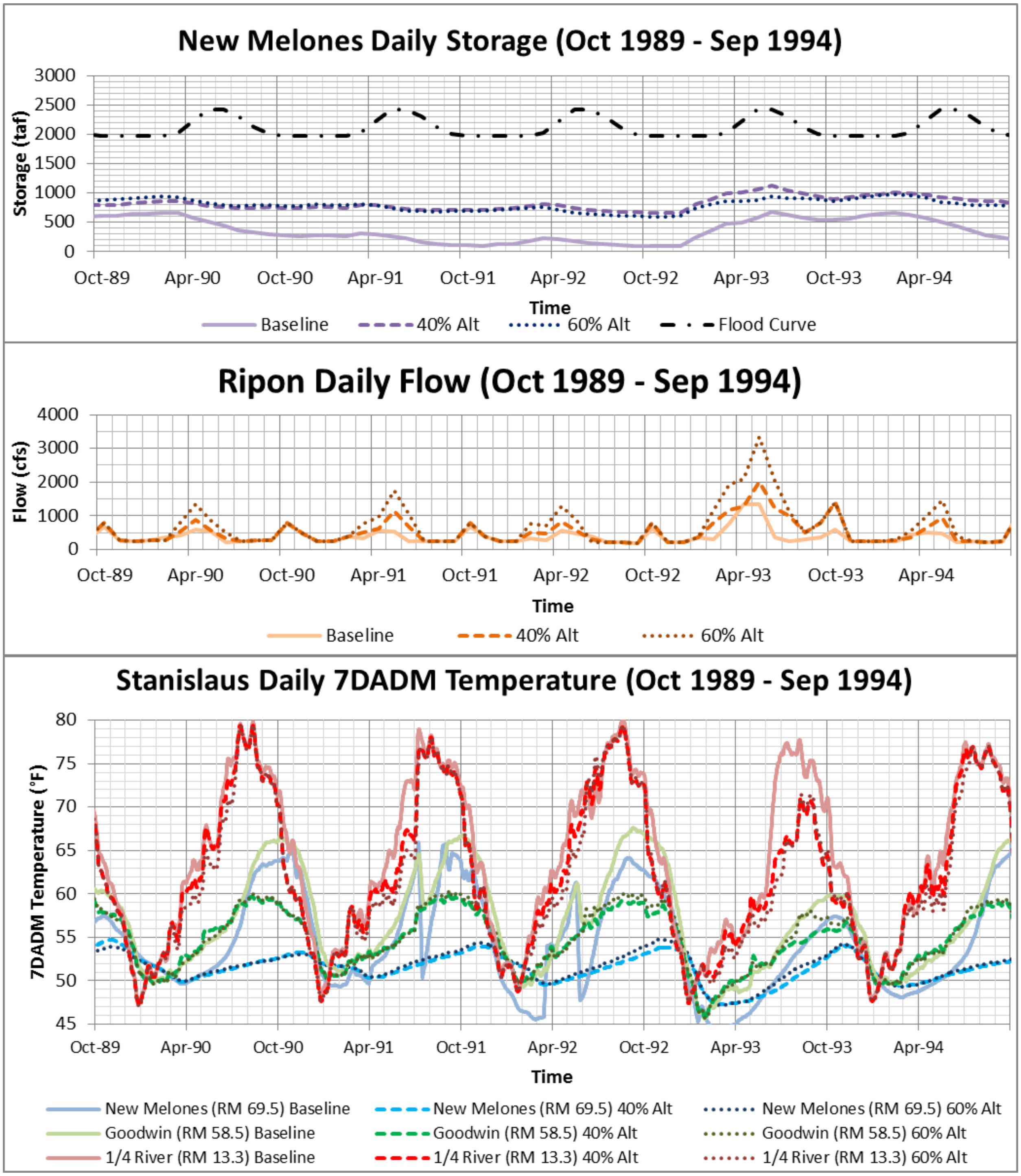


Figure F.1.6-10. Stanislaus River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline for Water Years 1990–1994, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Melones Release, Goodwin Release, and 1/4 River Locations

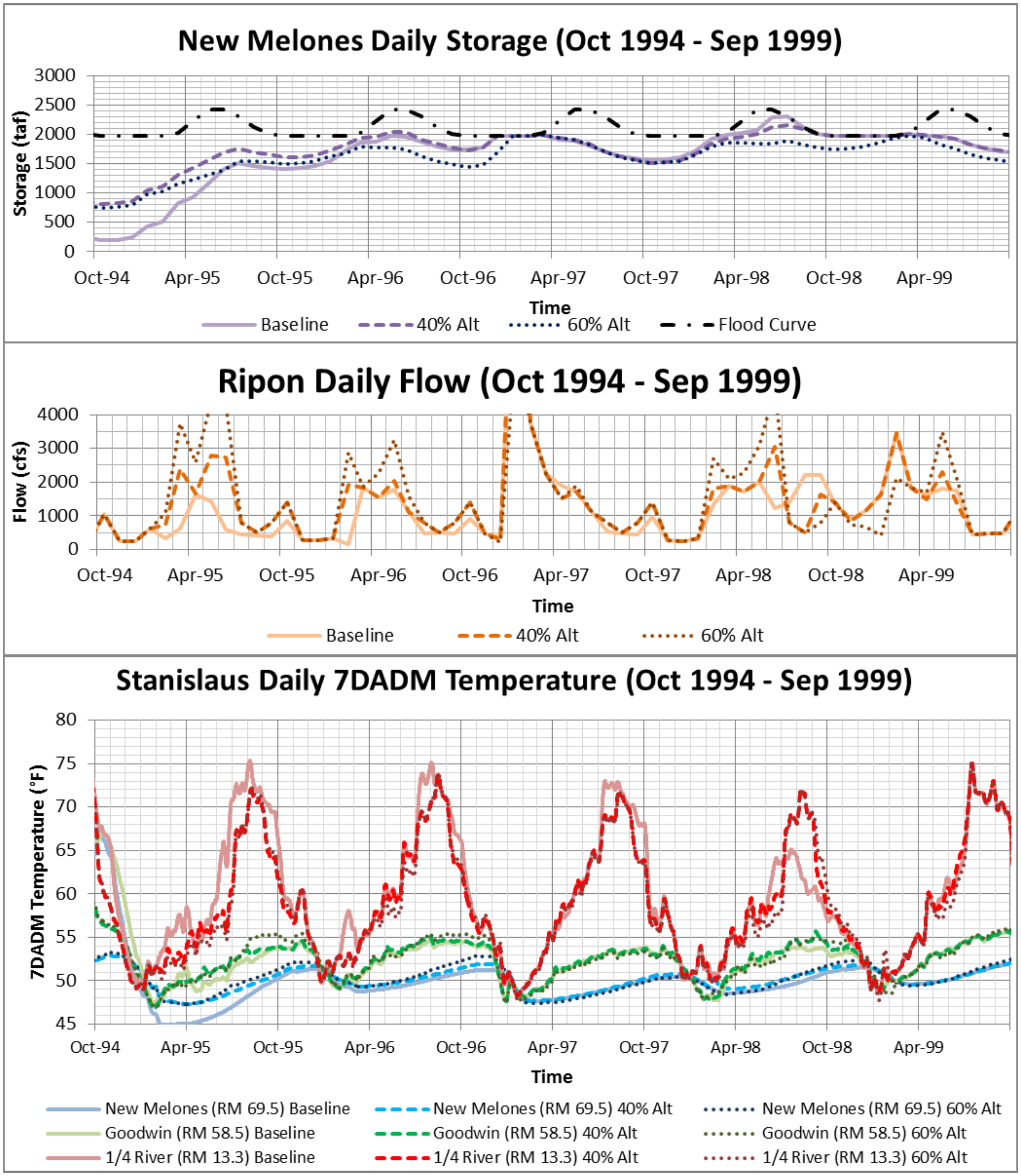


Figure F.1.6-11. Stanislaus River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline for Water Years 1995–1999, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Melones Release, Goodwin Release, and 1/4 River Locations

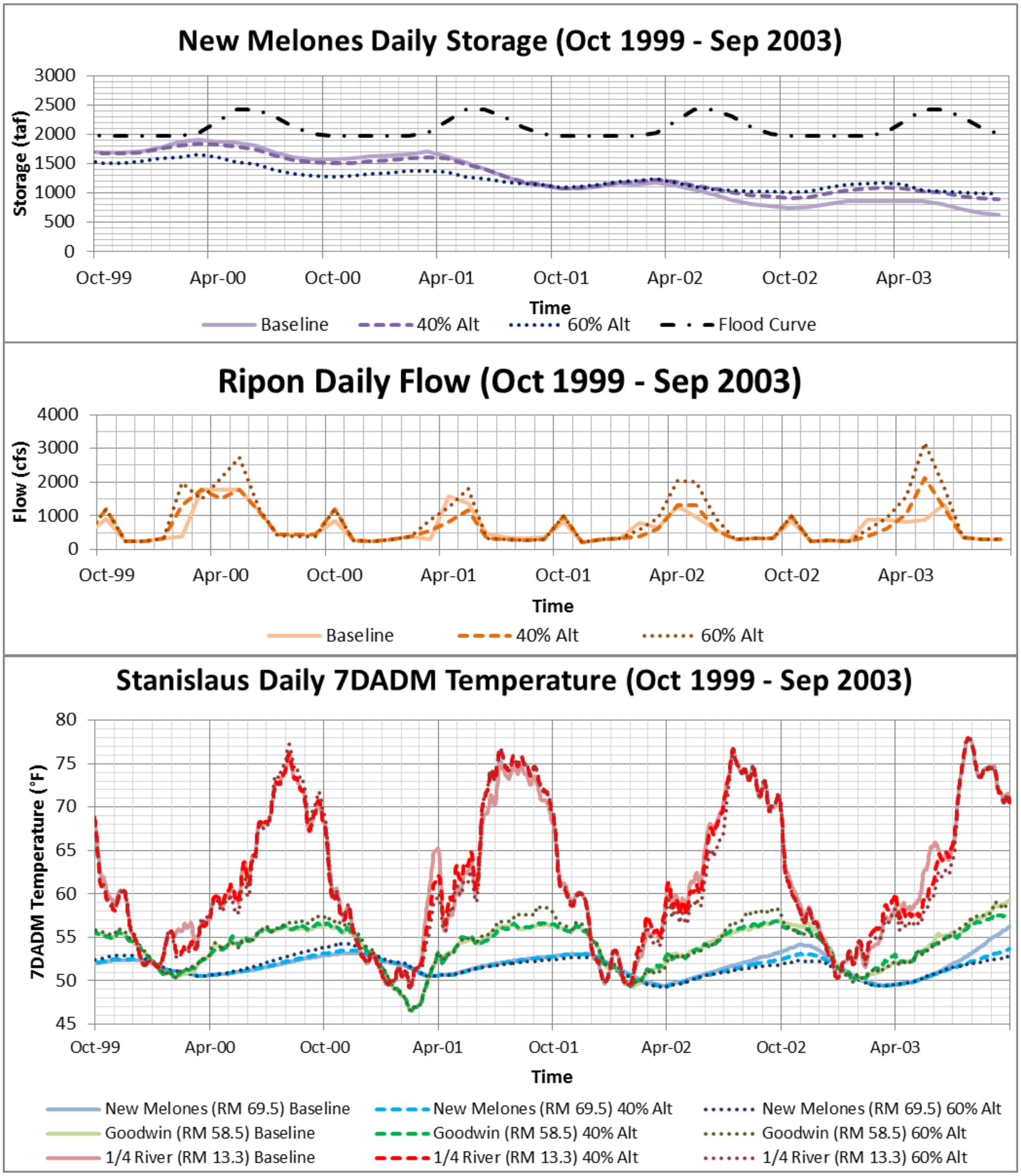
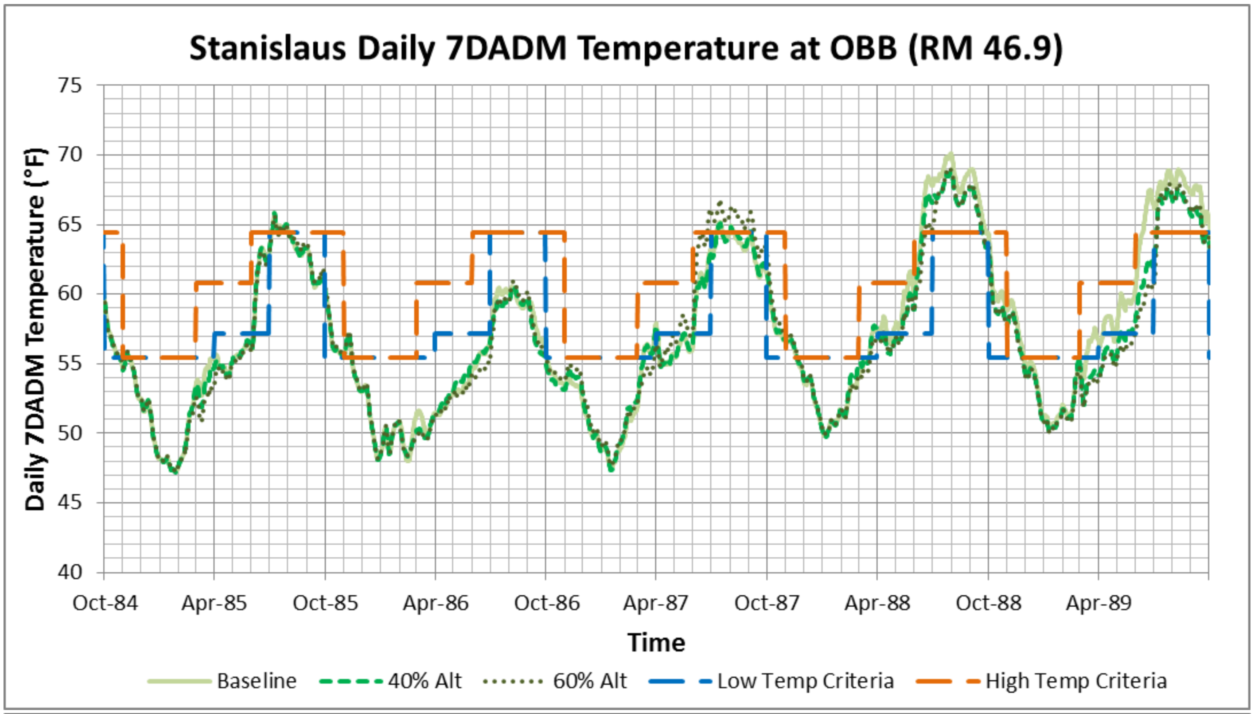


Figure F.1.6-12. Stanislaus River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline for Water Years 2000–2003, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Melones Release, Goodwin Release, and 1/4 River Locations



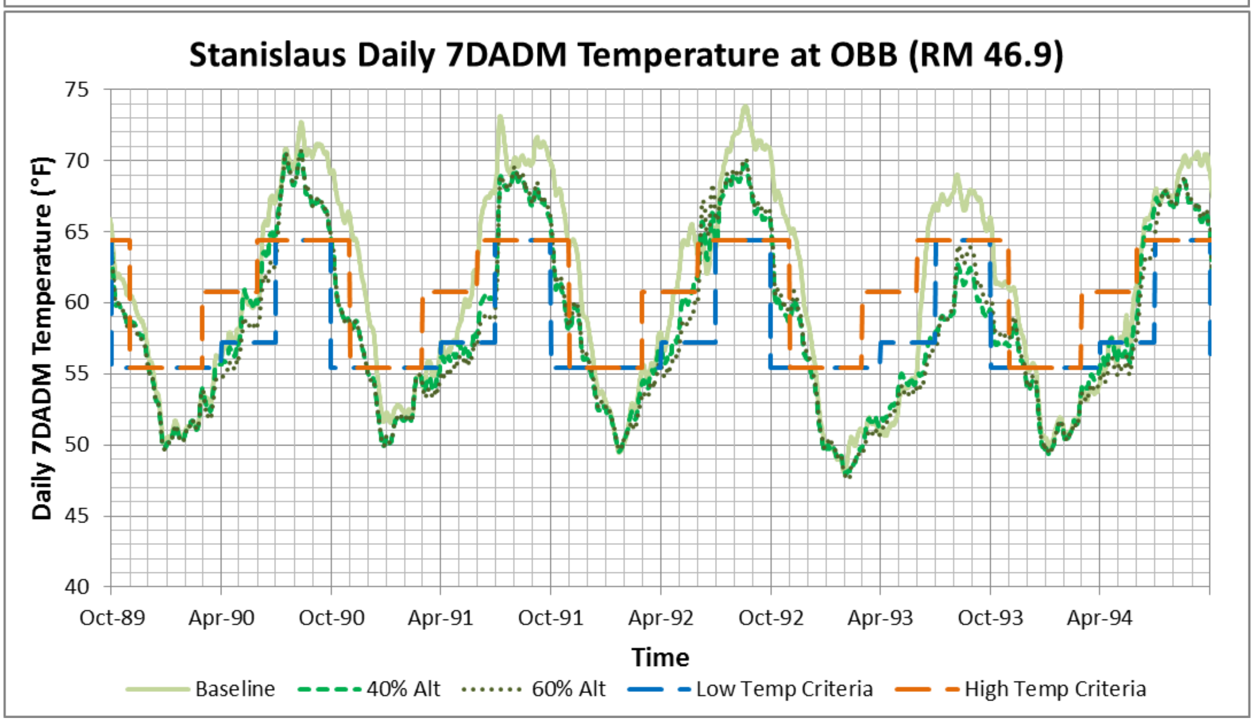
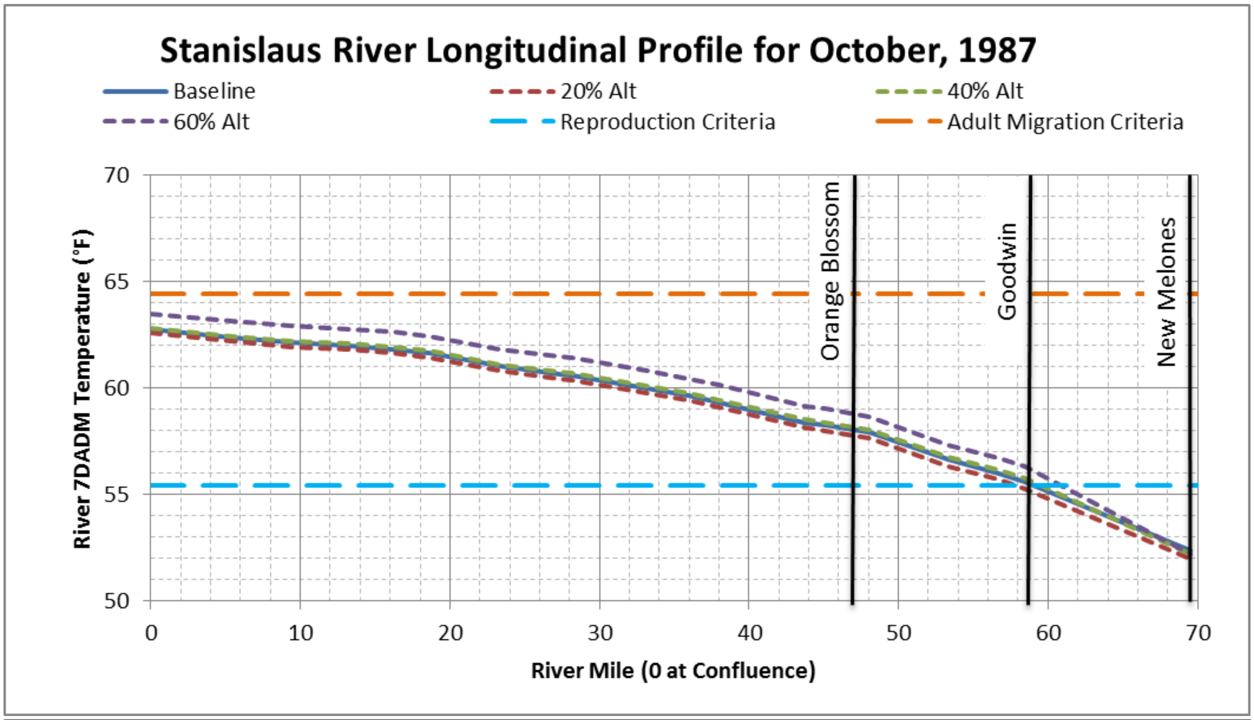


Figure F.1.6-13. Temperature Model 7DADM Results at OBB in the Stanislaus River Compared to Monthly USEPA Temperature Criteria for Optimal Development of Different Fish Lifestages under LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) for (a) Water Years 1985–1989 and (b) Water Years 1990–1994



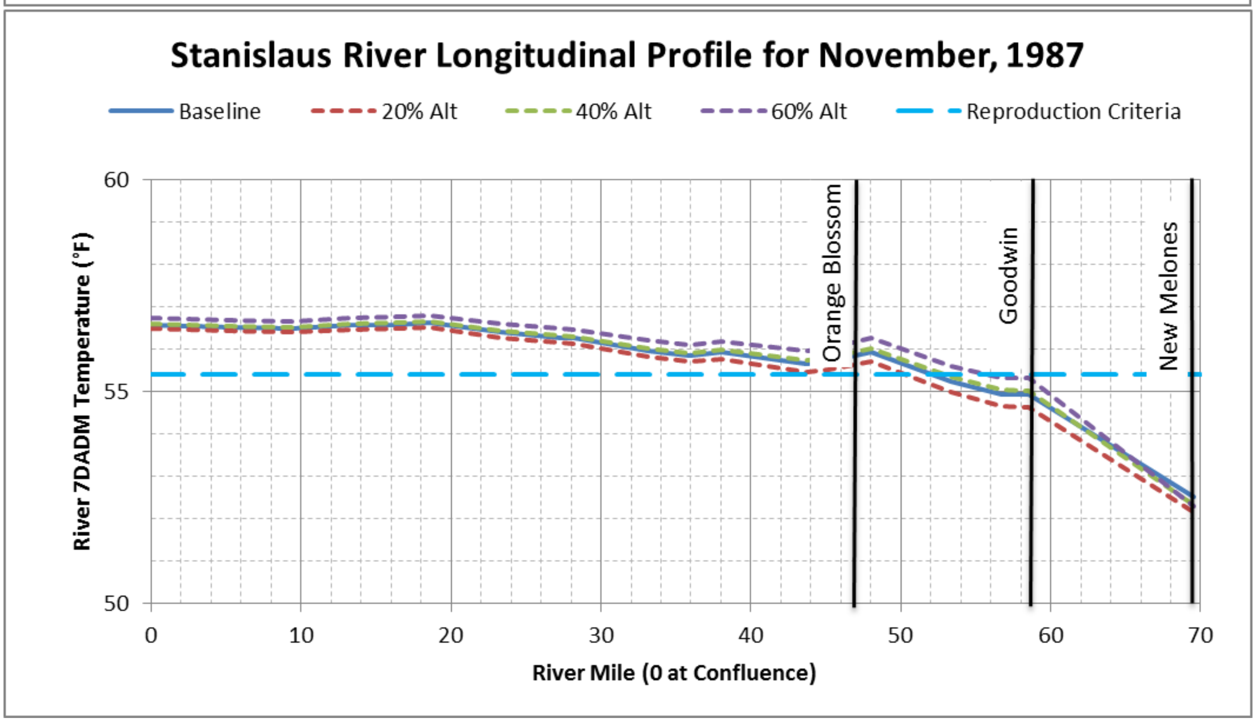


Figure F.1.6-14. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) October 1987 and (b) November 1987

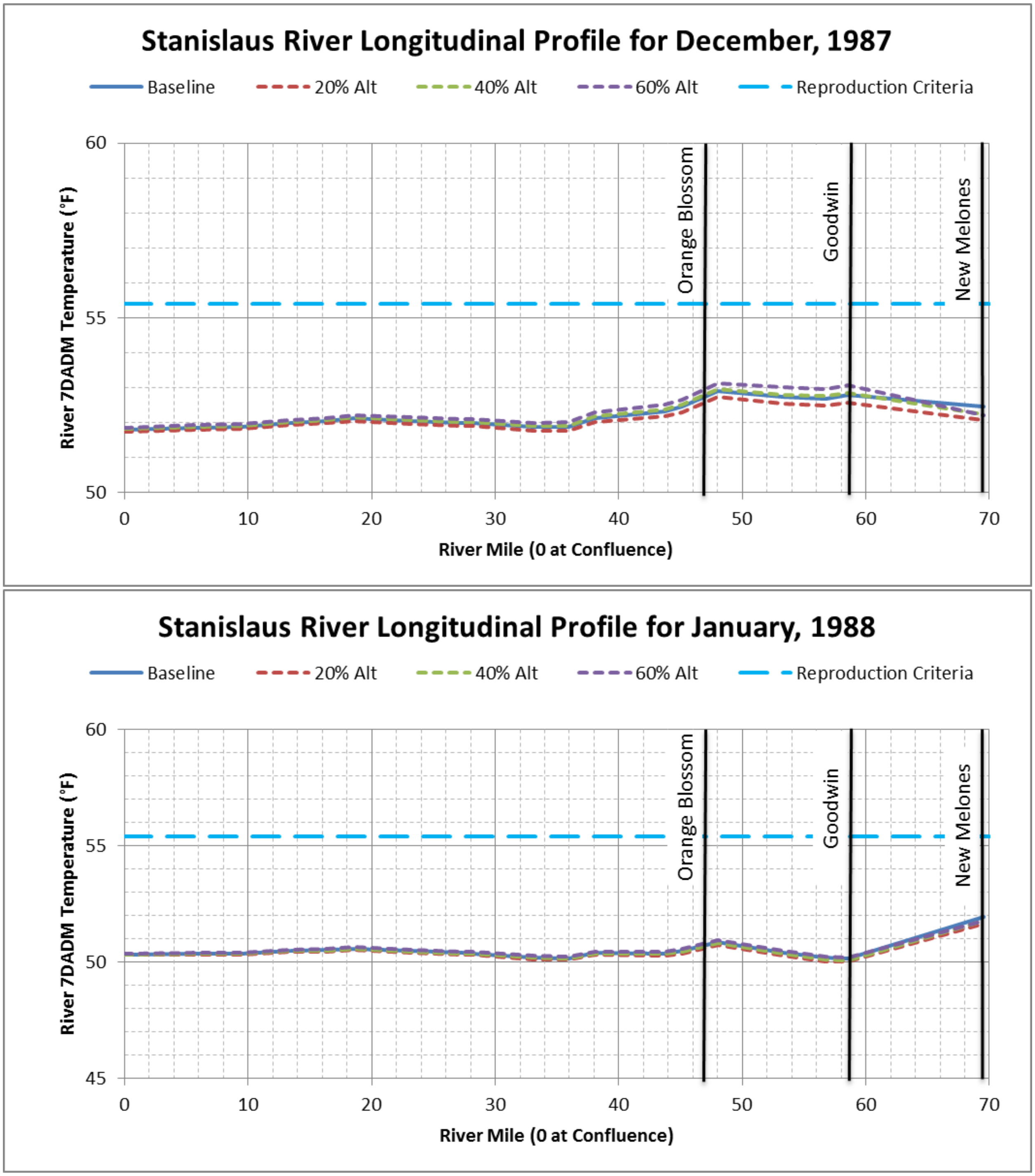
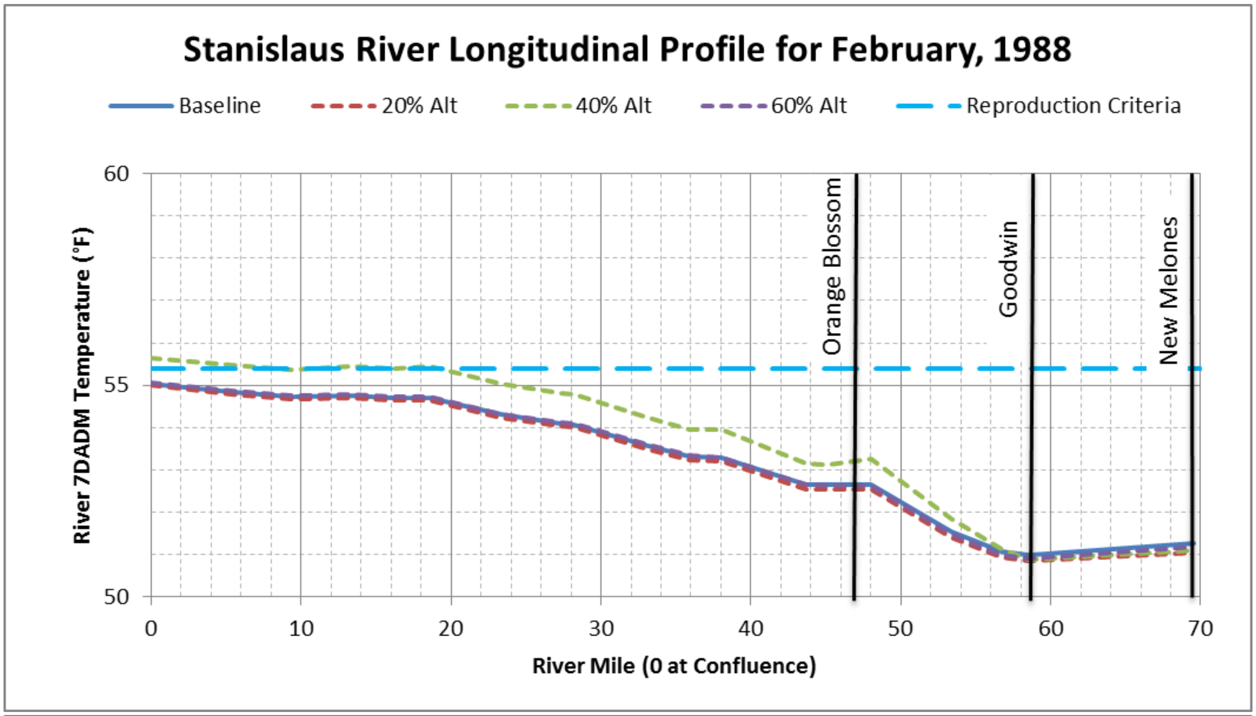


Figure F.1.6-15. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) December 1987 and (b) January 1988



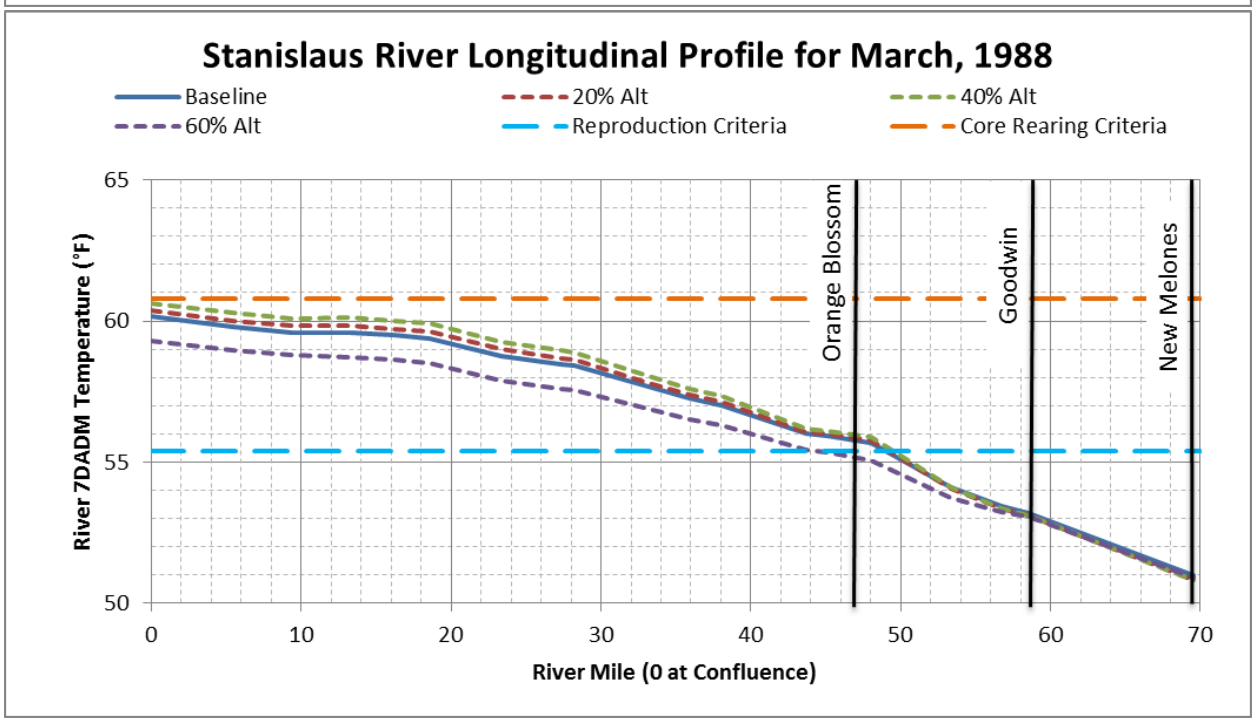
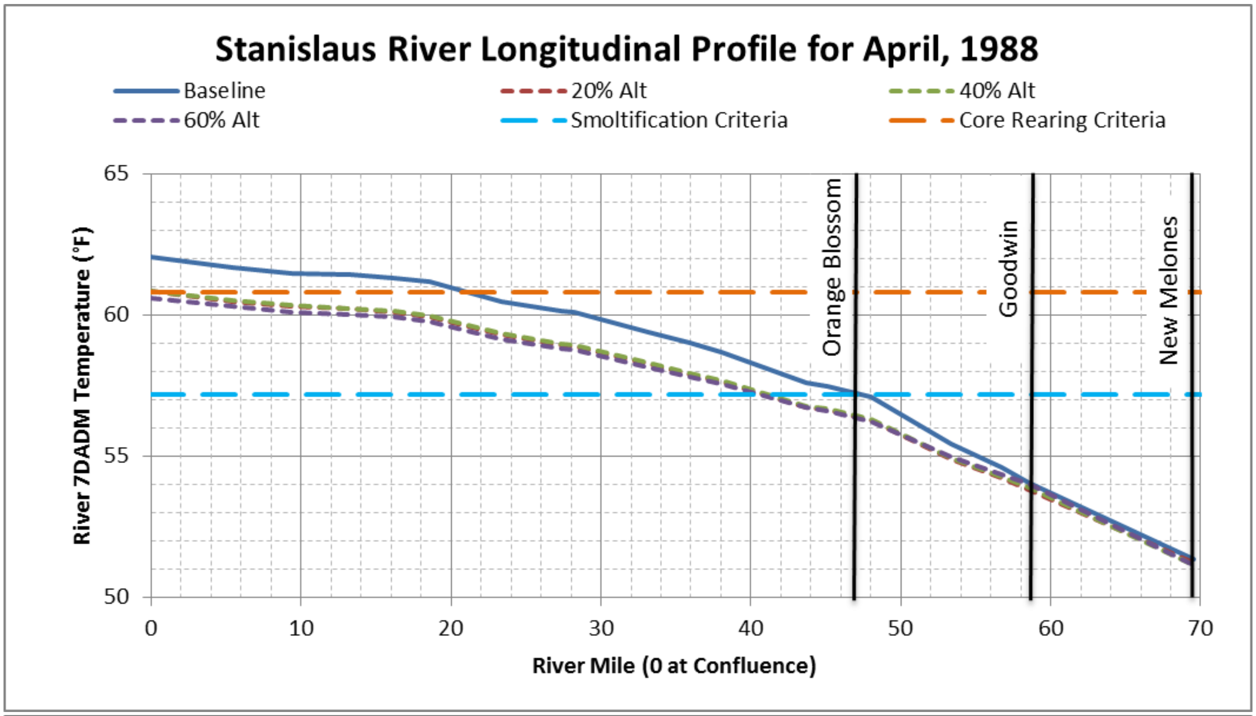


Figure F.1.6-16. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) February 1988 and (b) March 1988



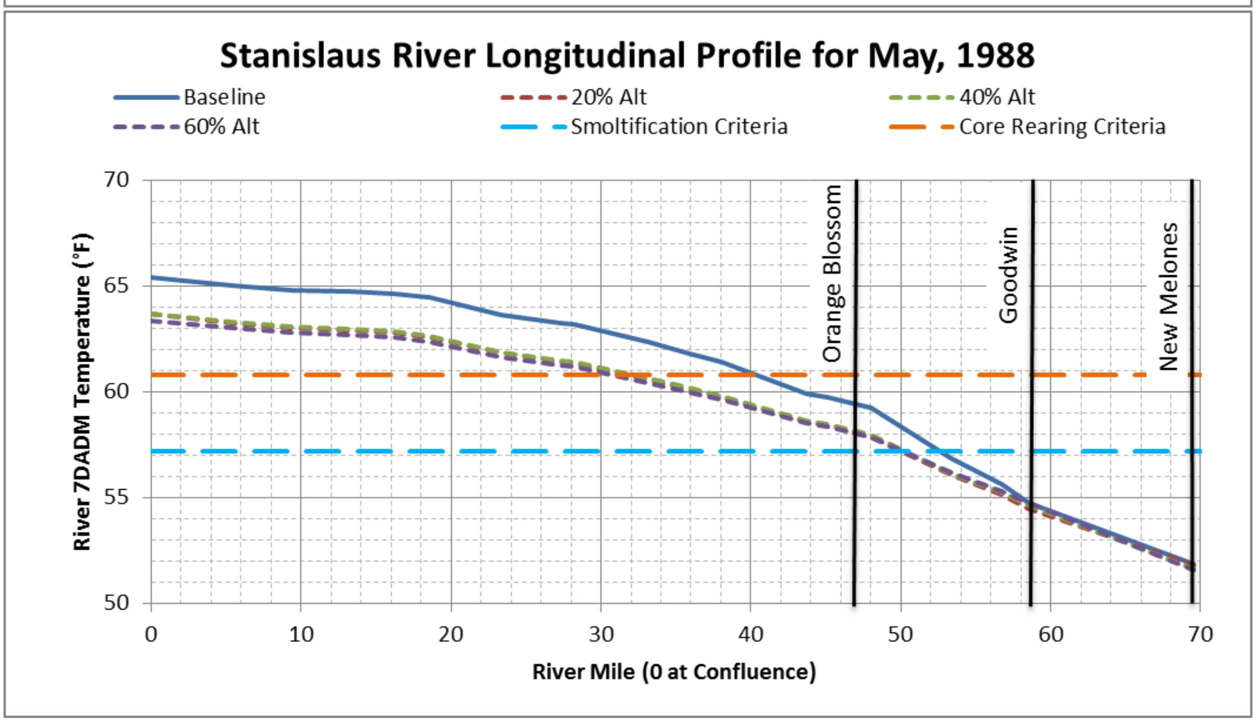
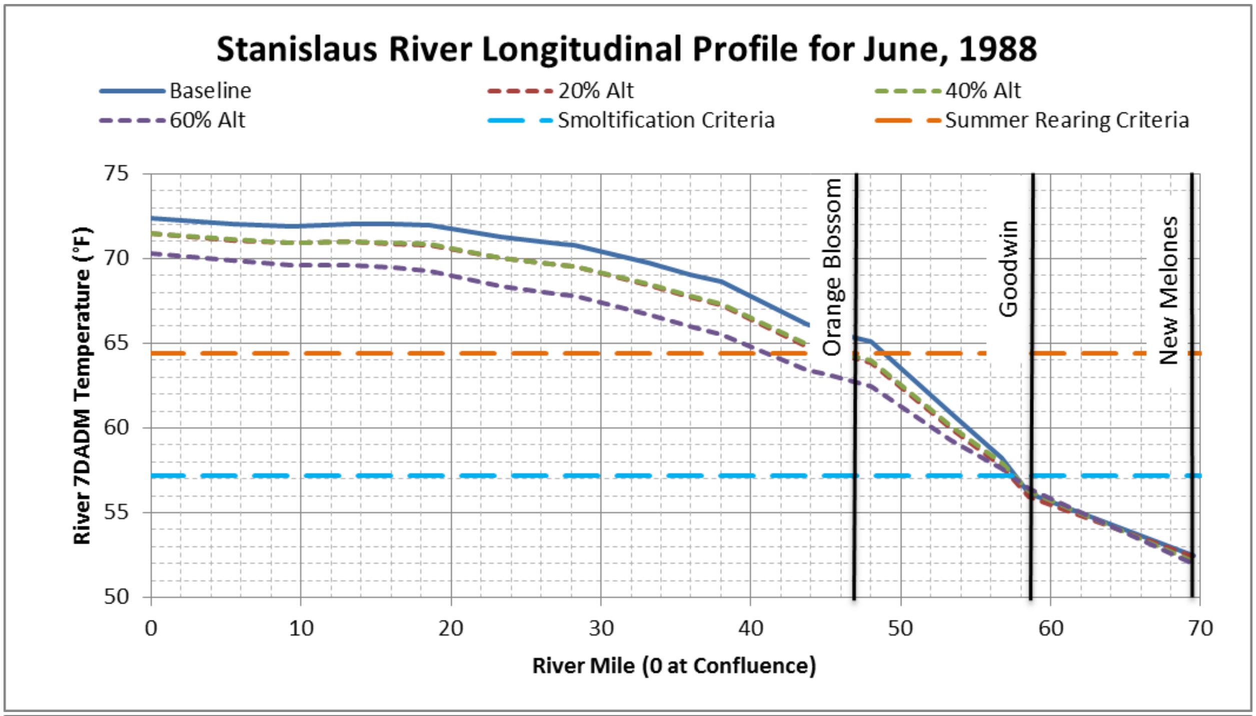


Figure F.1.6-17. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) April 1988 and (b) May 1988



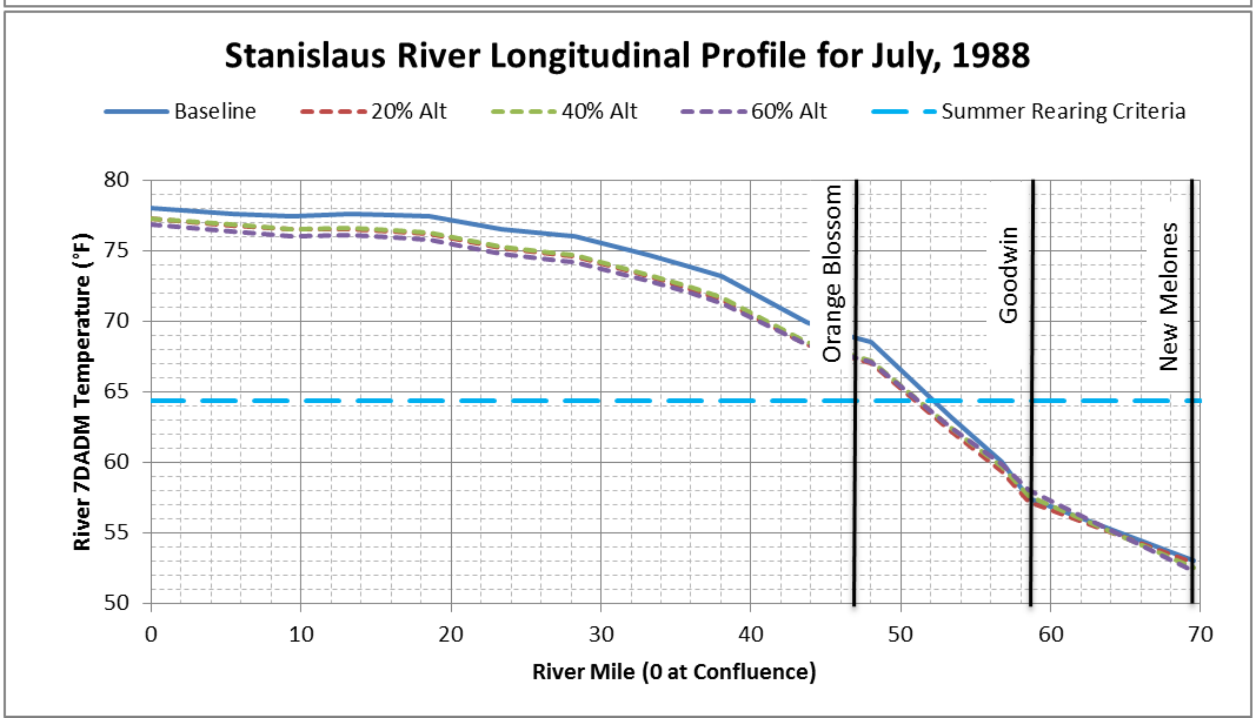


Figure F.1.6-18. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) June 1988 and (b) July 1988

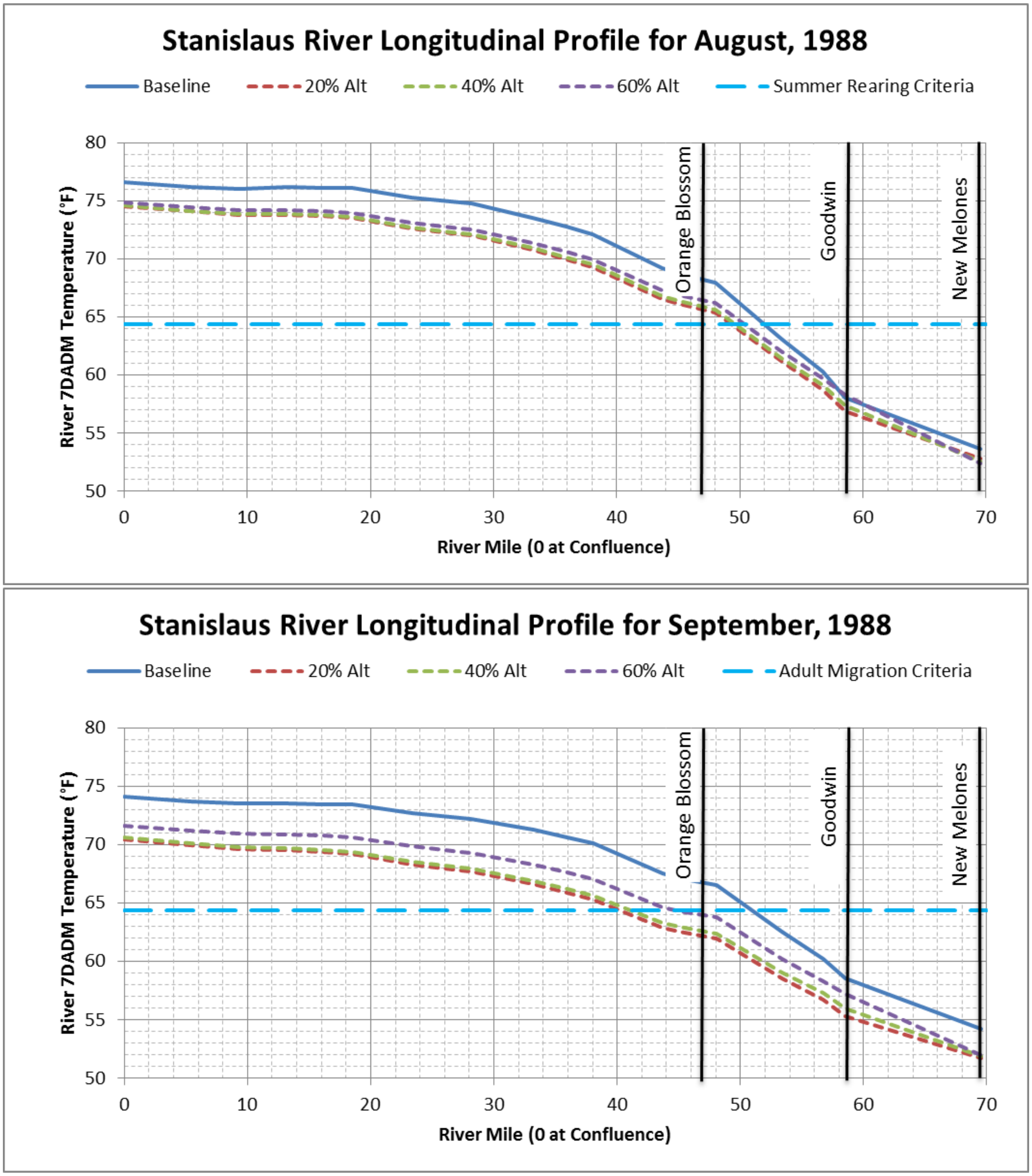


Figure F.1.6-19. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) August 1988 and (b) September 1988

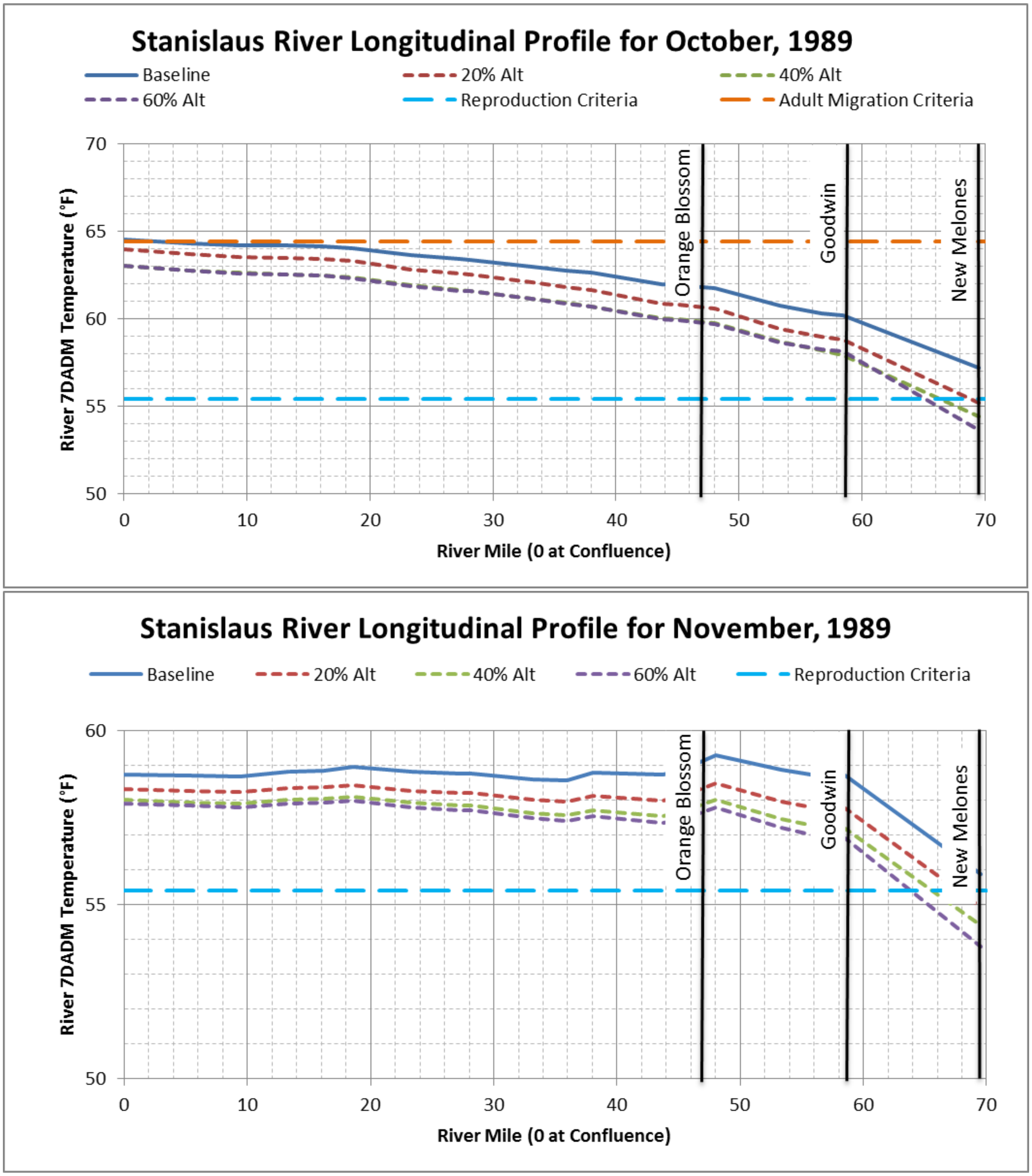
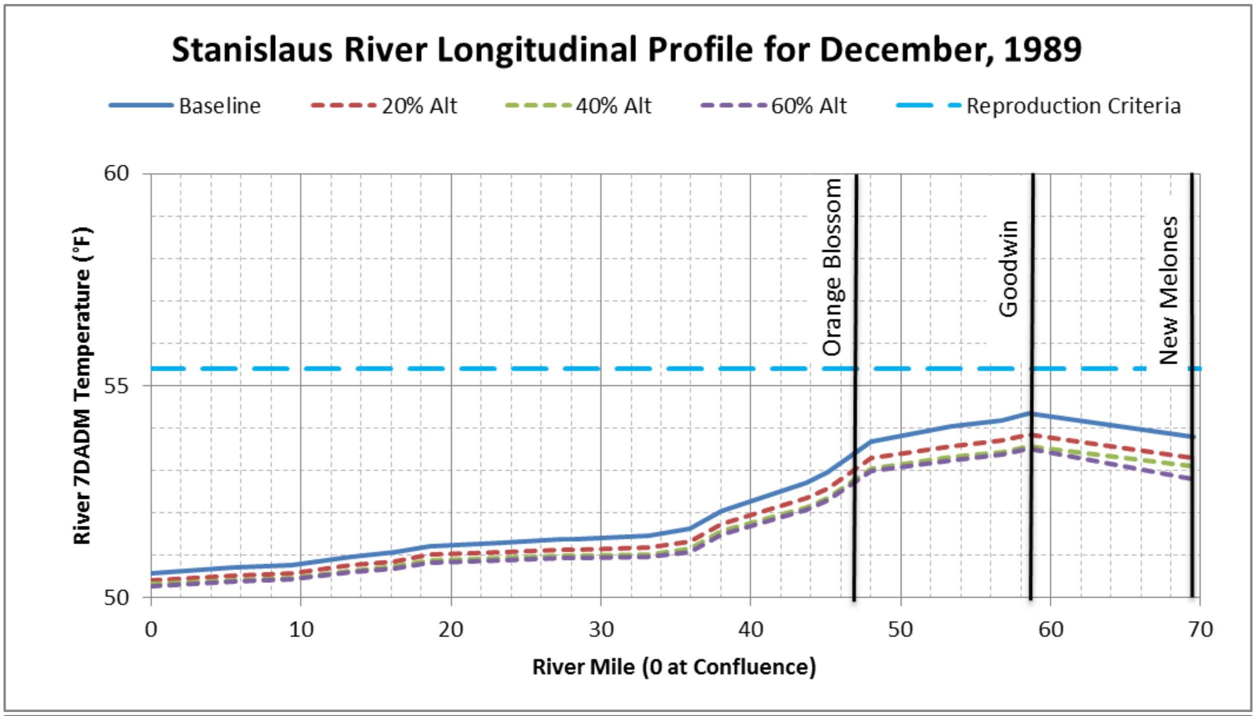


Figure F.1.6-20. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) October 1989 and (b) November 1989



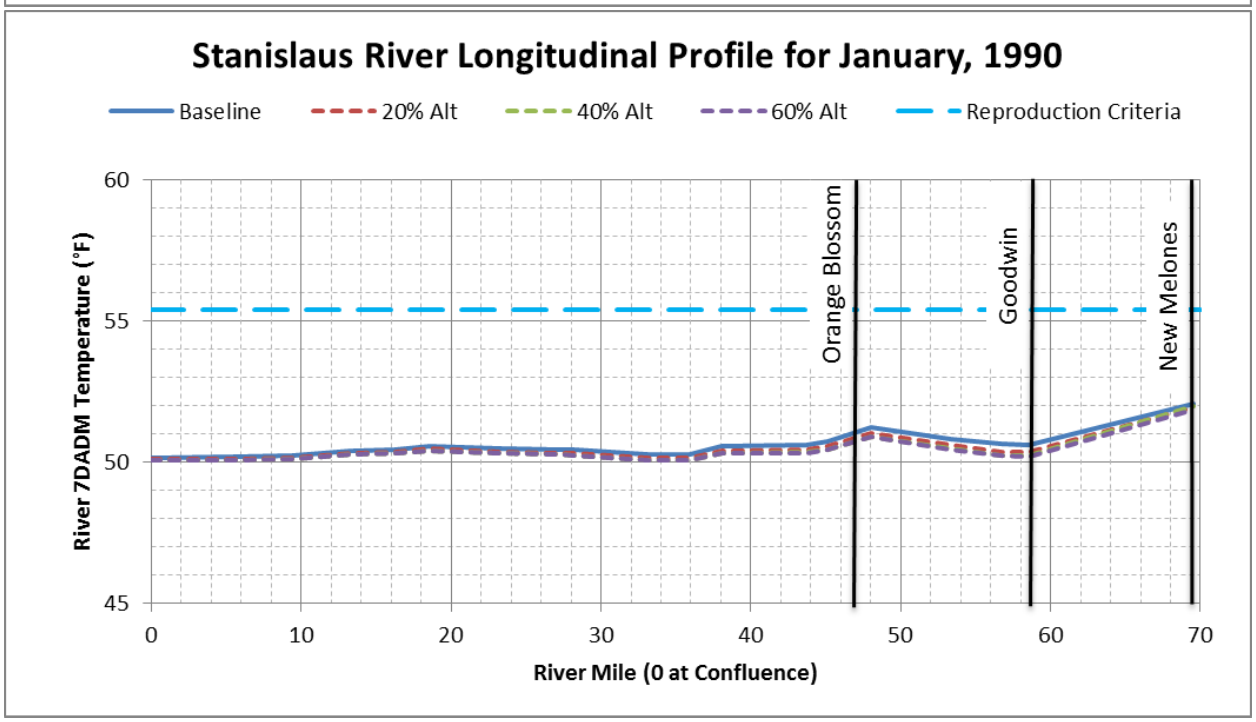
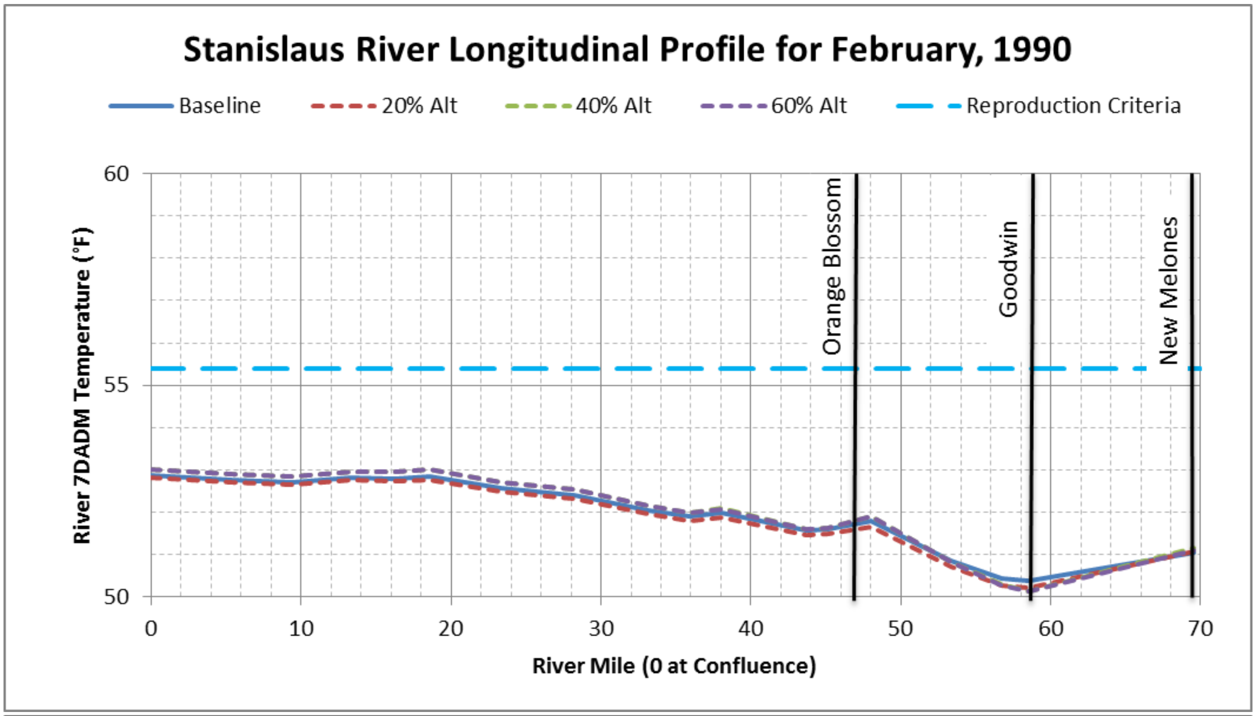


Figure F.1.6-21. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) December 1989 and (b) January 1990



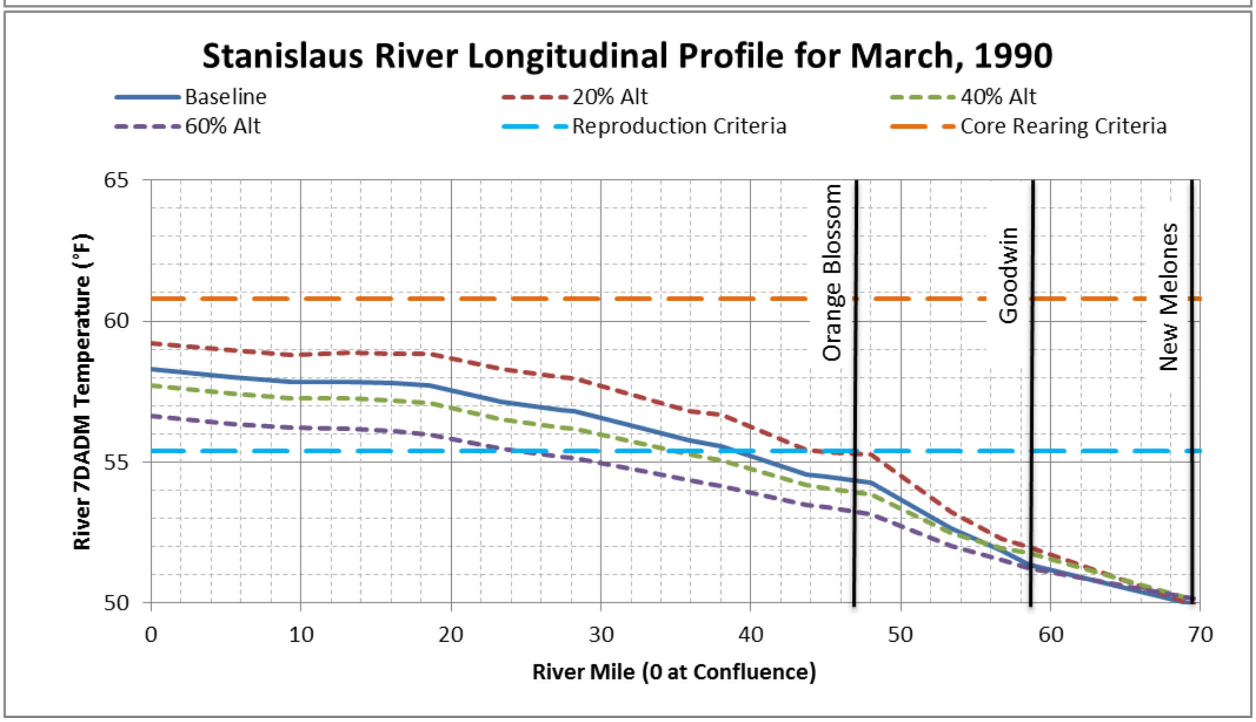
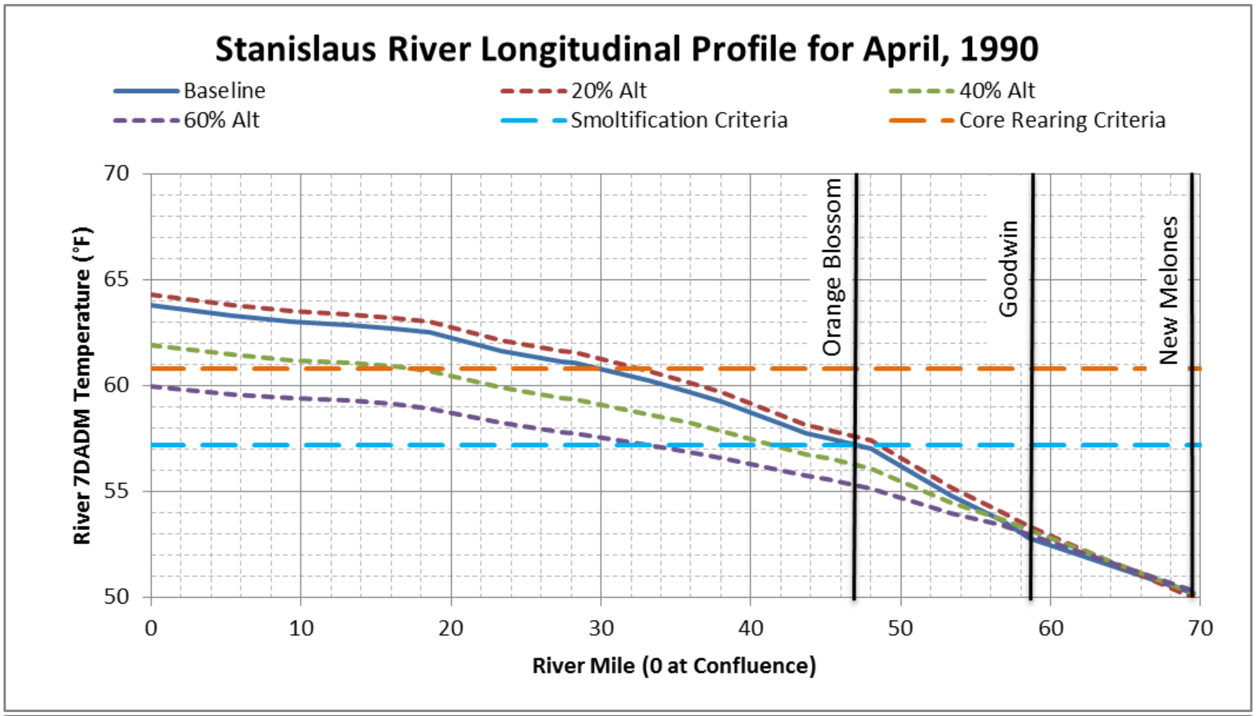


Figure F.1.6-22. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) February 1990 and (b) March 1990



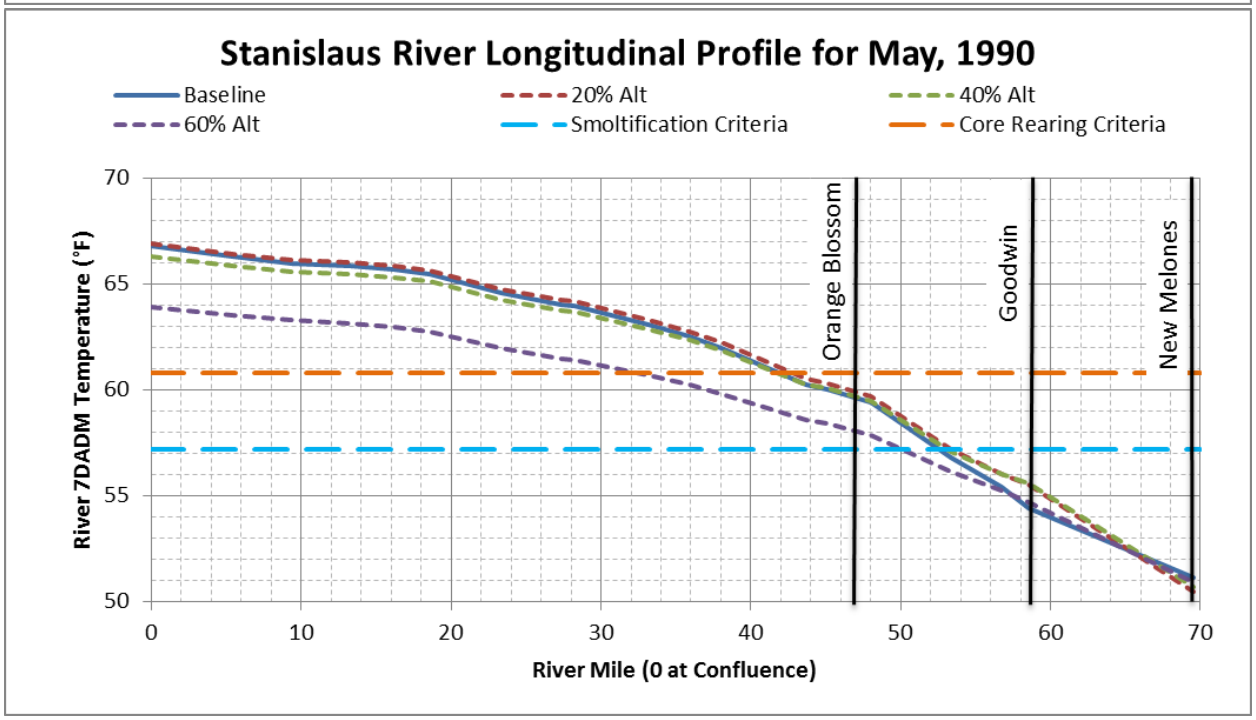
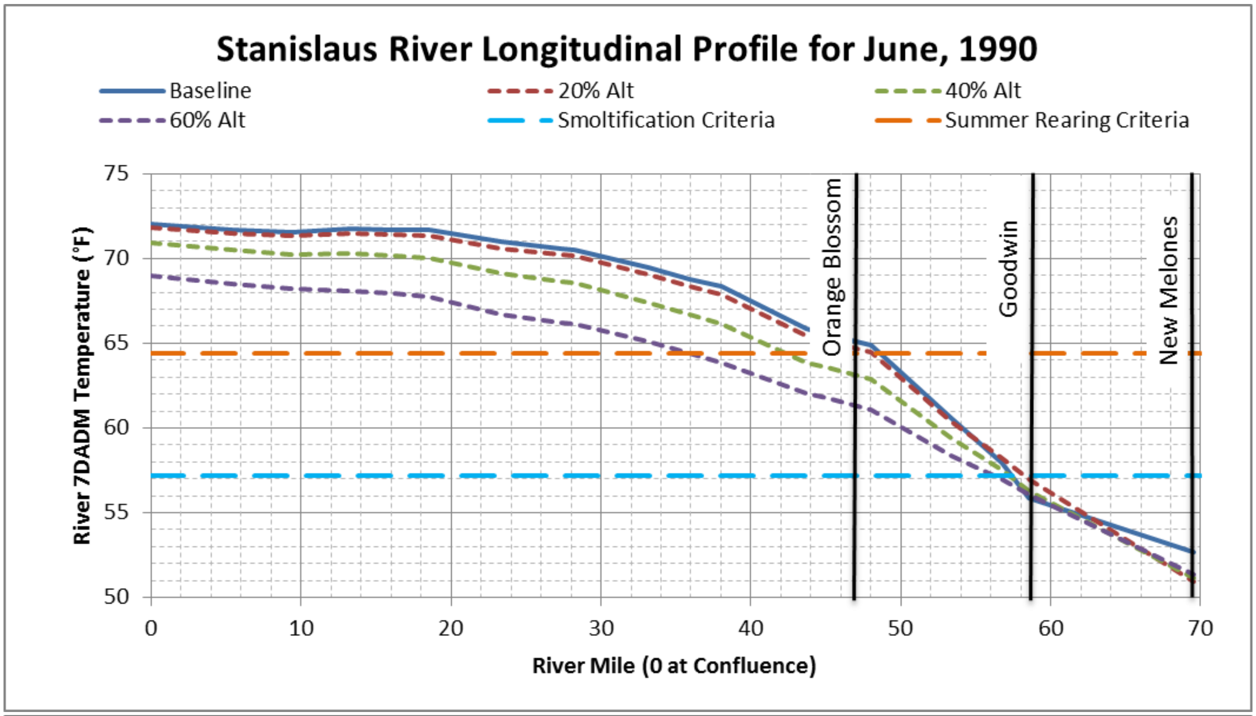


Figure F.1.6-23. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) April 1990 and (b) May 1990



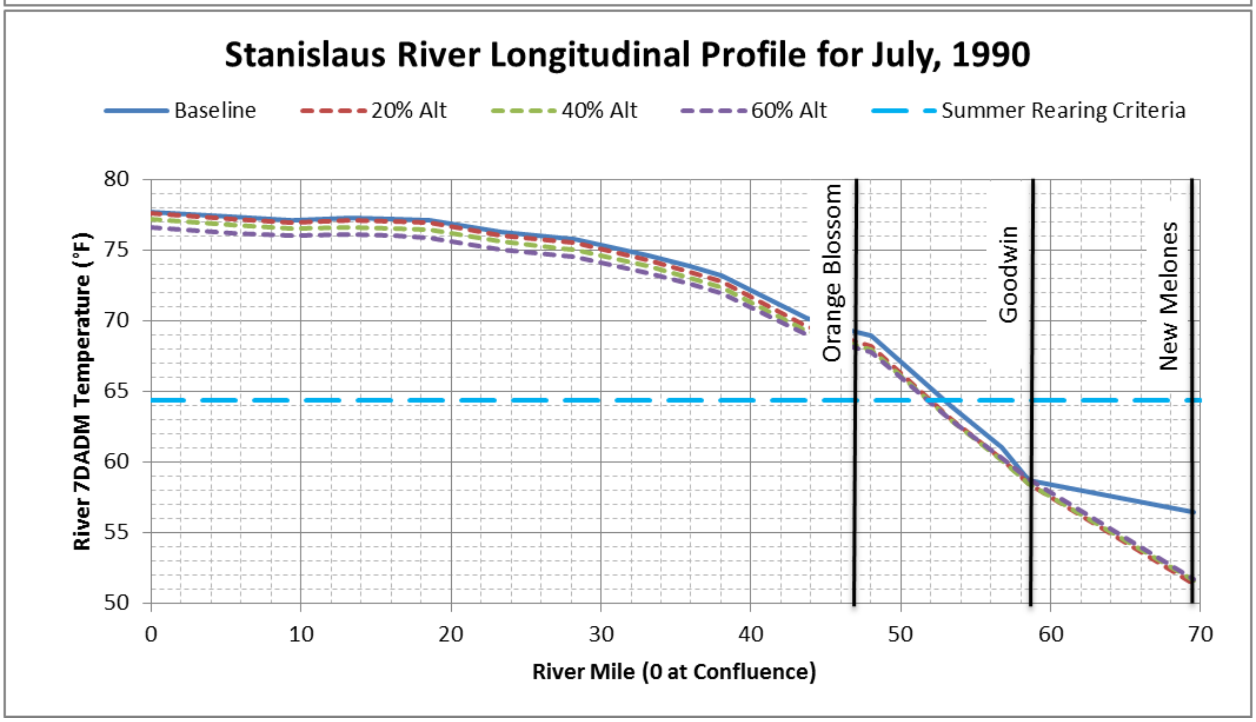
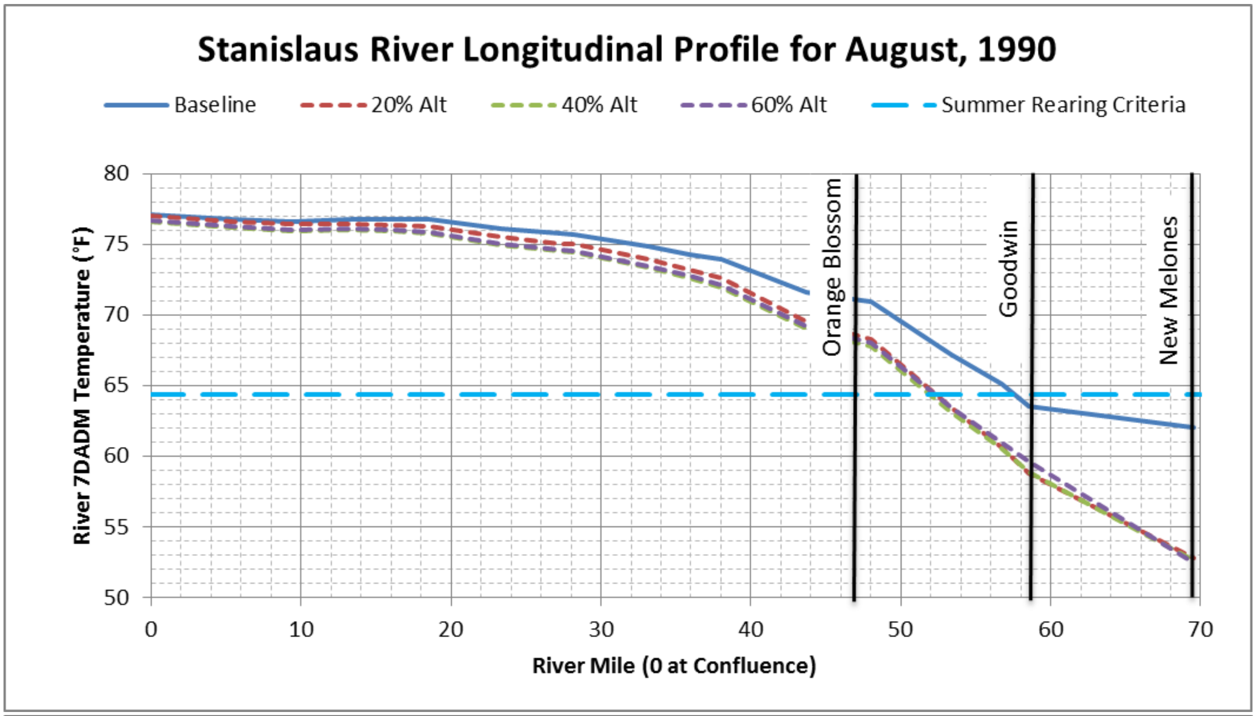


Figure F.1.6-24. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) June 1990 and (b) July 1990



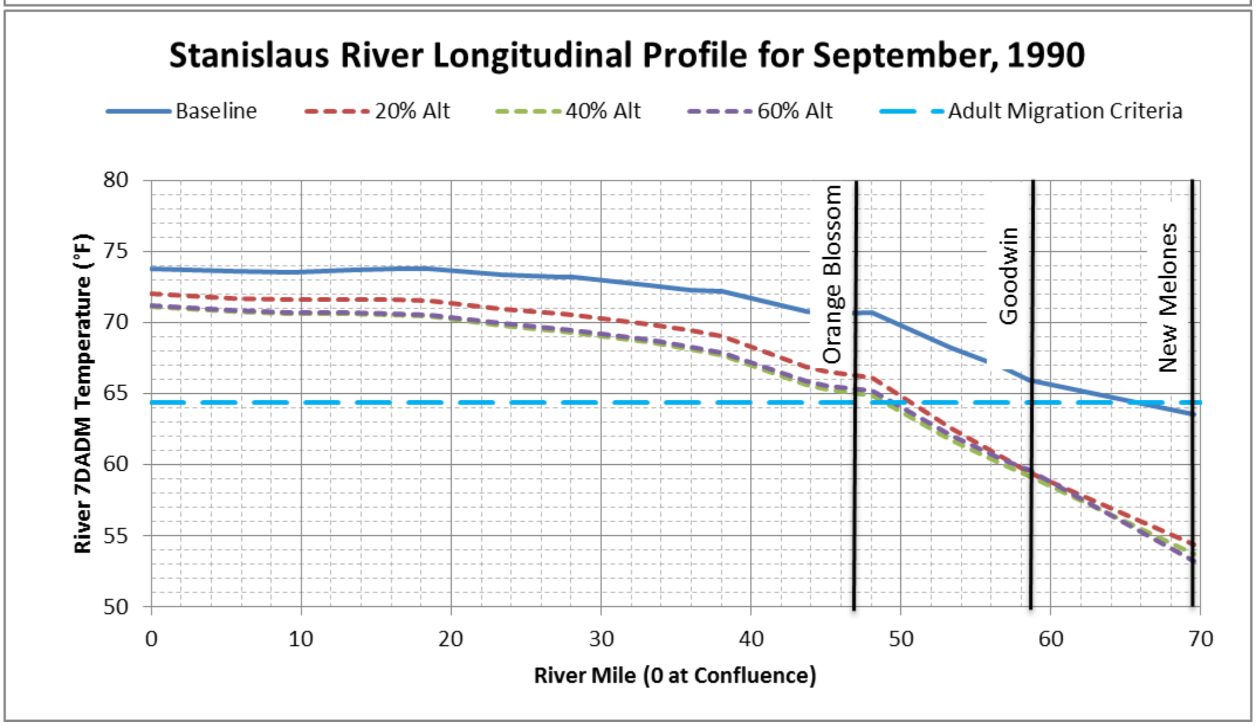


Figure F.1.6-25. Longitudinal Monthly Average 7DADM Temperature Results within the Stanislaus River for (a) August 1990 and (b) September 1990 Error! Bookmark not defined.

Tuolumne River Temperatures

Figures F.1.6-26a and F.1.6-26b show the monthly average temperatures in the Tuolumne River at RM 28.1 simulated with the SJR water temperature model for baseline conditions and the LSJR alternatives plotted as a function of the monthly river flow at Merced for February–June. For February, the temperatures were generally 48°F–57°F. The warmest temperatures corresponded to flows of less than 1,000 cfs. Although the LSJR alternatives generally increased flows relative to baseline in February, particularly under conditions of low baseline flow, these flow changes had only a small effect on RM 28.1 temperatures (decreases in temperature were generally less than 2°F). Because there is little meteorological warming in February, river flow increases would not substantially reduce water temperatures.

In March, simulated temperatures in the Tuolumne River at RM 28.1 were 49°F–52°F when river flow was 2,000 cfs or more and generally increased to 50°F–62°F when river flows were less than 2,000 cfs. Because the LSJR alternatives tended to increase the low- to mid-range flows relative to baseline (i.e., they increased all but the highest baseline flows), LSJR alternative water temperatures tended to be lower than baseline. However, there were no large effects on water temperatures because meteorological warming at RM 28.1 was limited in March and water temperatures generally remained cool. The warmest temperatures were simulated for low flows less than 500 cfs, but these temperatures remained less than 62°F.

In April, the range of simulated temperatures at RM 28.1 was 50°F to 64°F, with warmer temperatures 55°F–64°F generally simulated for the lower flows (less than 1,000 cfs). Because the April flows were always greater than 250 cfs, no temperatures of greater than 63°F were simulated. Here, the shift toward higher flows in the LSJR alternative was distinct; where flow under baseline conditions approached 400 cfs, flows under LSJR Alternatives 2, 3, and 4 didn't usually fall below about 600 cfs, 1000 cfs, and 1500 cfs, respectively. With the higher flows, the temperature at RM 27.1 was shifted down in each of the alternatives, with temperatures under LSJR Alternative 4 rarely going above 55°F. In May, the range of simulated temperatures at RM 28.1 was 51°F–66°F, about 1°F–3°F warmer than in April. The warmer temperatures of 58°F–66°F were generally simulated for the lower flows (less than 1,000 cfs). Because the May flows were always greater than 400 cfs, only a few temperatures of greater than 65°F were simulated in May at RM 28.1. Much like April, there were similar shifts toward higher flow and lower temperatures in each of the alternatives. In June, some flows were lower (lowest of about 250 cfs) and the temperatures were considerably warmer than in April and May, ranging from 53°F–77°F. The warmer temperatures of 60°F–77°F were generally simulated for the lower flows (less than 1,000 cfs).

The Tuolumne River warming curves (flow versus temperature) at RM 28.1 in April, May, and June indicate the general relationship between river flow and water temperatures in the upstream portion of the Tuolumne River. These figures suggest that temperature is most responsive to changes in flow when flow is less than 1,000 cfs and during warmer conditions (i.e., June).

Tables F.1.6-3a and F.1.6-3b give the monthly cumulative distributions of average simulated water temperatures in the Tuolumne River at RM 28.1 for 1970–2003 under baseline conditions and the change in the distribution under the LSJR alternatives. Baseline average water temperatures at RM 28.1 indicate the average seasonal warming January–July is about 19°F. This average seasonal warming is similar to the Stanislaus River average warming. The monthly increase in the average temperatures February–May was about 2°F per month, the monthly increase May–June was about 8°F, and the increase June–July was about 4°F.

Changes in temperature associated with the LSJR alternatives were dependent on the combination of change in flow and amount of meteorological warming (i.e., difference between reservoir release temperatures and equilibrium temperatures). The months of March–June showed significant drops in average monthly temperature under all the LSJR alternatives, with higher temperature reductions under higher unimpaired flow objectives. June had the highest temperature reductions, with average monthly temperatures falling 4.8°F under a 20 percent unimpaired flow objective and 9.1°F under a 60 percent unimpaired flow objective.

Figures F.1.6-27, F.1.6-28, F.1.6-29, and F.1.6-30 show Tuolumne River temperature model results under baseline conditions and under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow objectives Feb–June) for the water years 1985–1989, 1990–1994, 1995–1999, and 2000–2003, respectively. Each figure is composed of three separate charts to compare how reservoir storage and river flow can affect temperatures at different points along the river. Chart A shows reservoir storage at New Don Pedro, Chart B shows the instream flows at Modesto, and Chart C gives the daily 7DADM temperature at New Don Pedro release, La Grange release, and the 1/4 River location.

Figures F.1.6-31a and F.1.6-31b show temperature model 7DADM results at 3/4 River (Tuolumne RM 38.3) compared to monthly USEPA temperature criteria for optimal development of different fish lifestages (as described in Chapter 19) under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow Feb–June) and baseline conditions for water years 1985–1989 and water years 1990–1994, respectively. These show temperature effects of reservoir levels within the major drought sequence 1989–1993.

Figures F.1.6-32, F.1.6-33, F.1.6-34, F.1.6-35, F.1.6-36, and F.1.6-37 show longitudinal monthly average 7DADM temperature results in the Tuolumne River for each month of the water year 1988 under baseline conditions and the LSJR alternatives. Water year 1988 is shown because it represents a year when New Don Pedro Reservoir storage levels were around 1 million acre feet (about half storage) under the model scenarios. Figures F.1.6-38, F.1.6-39, F.1.6-40, F.1.6-41, F.1.6-42, and F.1.6-43 show longitudinal monthly average 7DADM temperature results for each month of the water year 1990 under baseline conditions and the LSJR alternatives. Water year 1990 is shown because it represents a year in the middle of the 1989–1992 drought sequence; however, New Don Pedro Reservoir levels do not show as much of a drawdown compared to the other major reservoirs in the drought period.

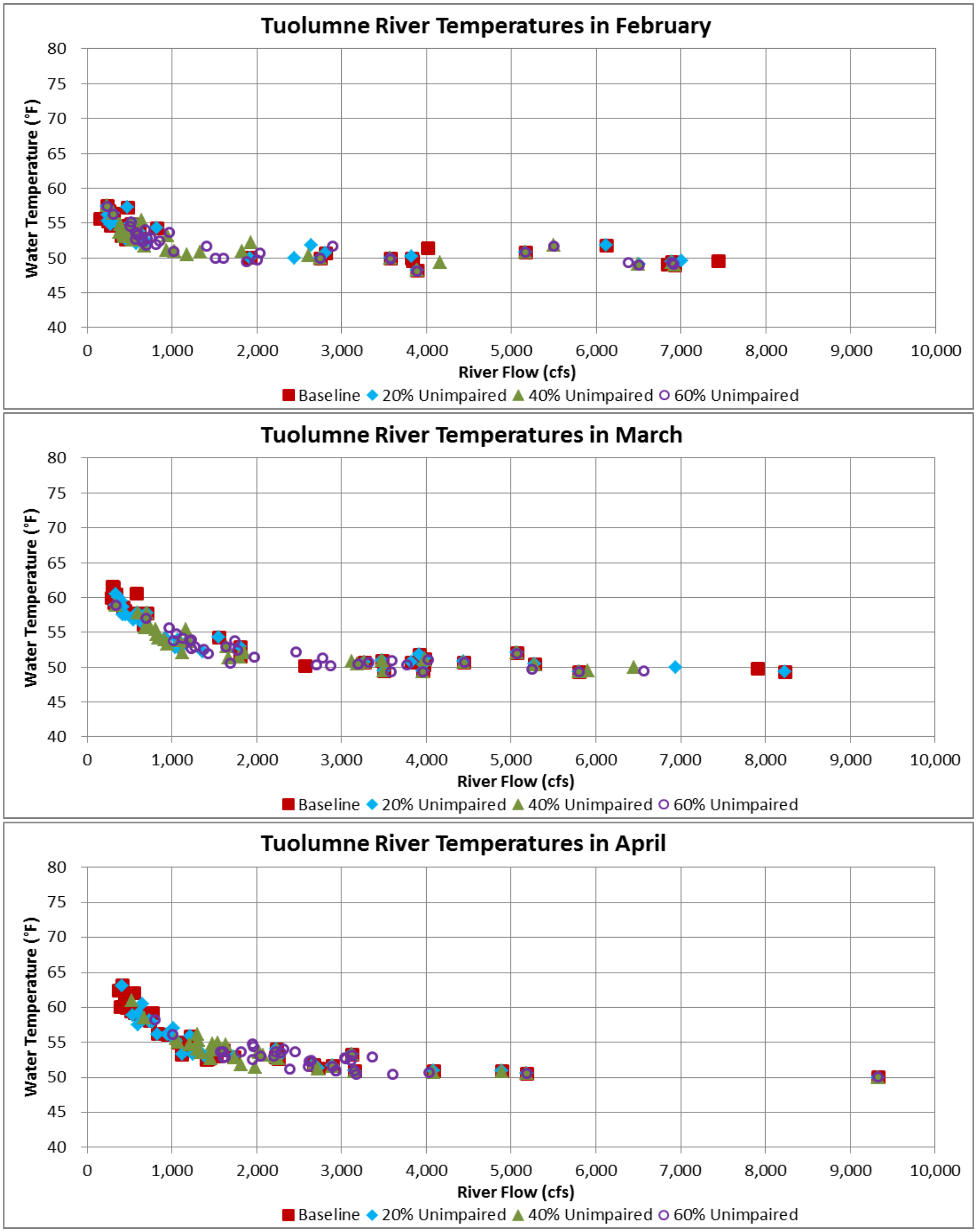
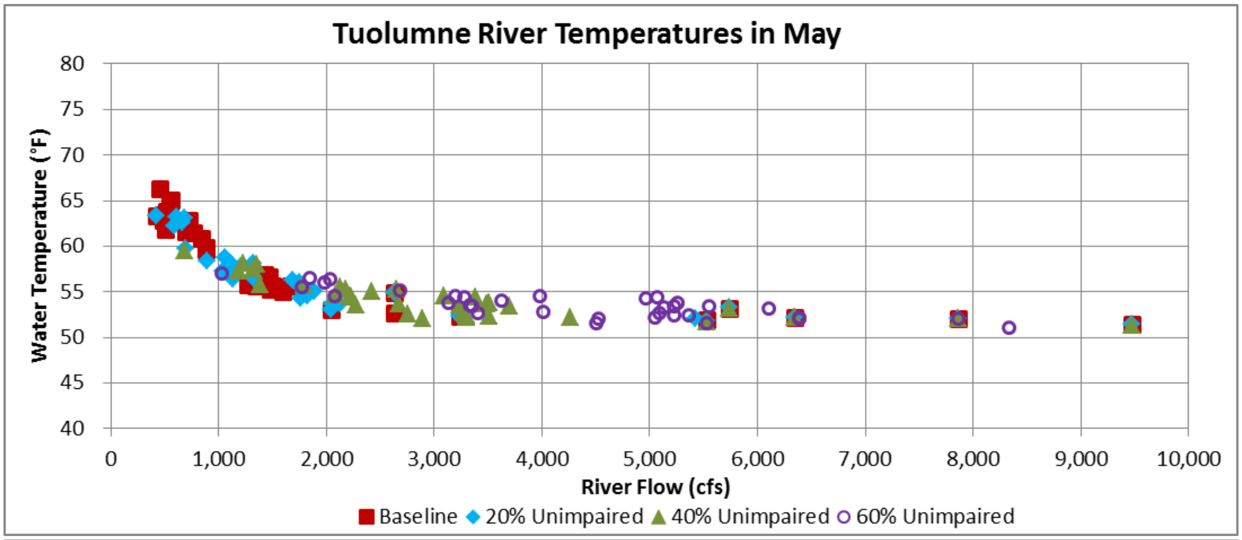


Figure F.1.6-26a. Effects of Tuolumne River Flows on Temperatures at RM 28.1 in February–April for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003



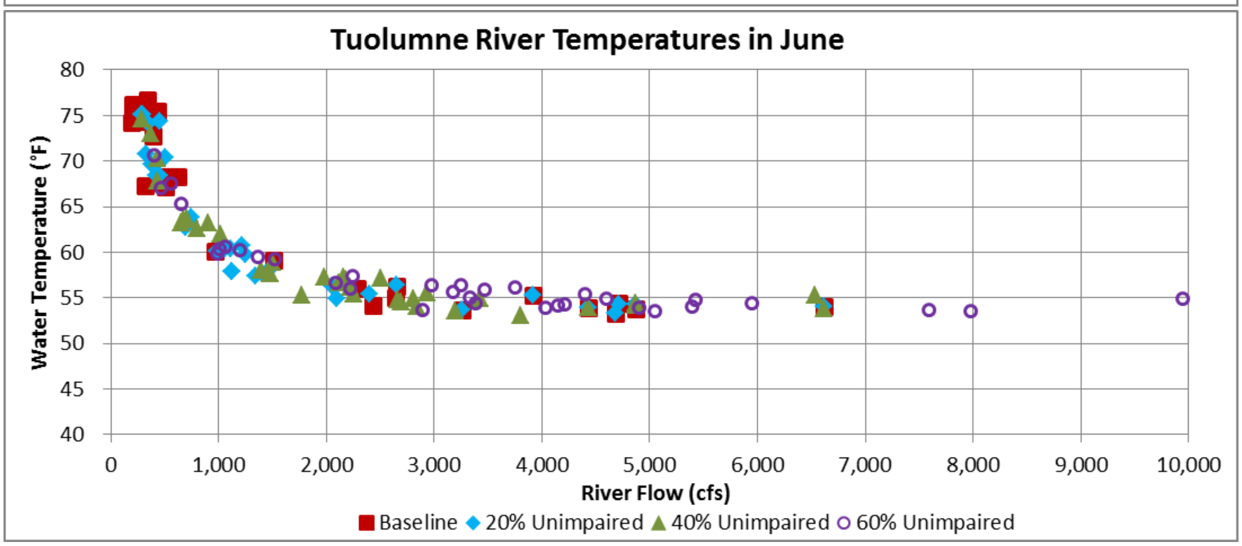


Figure F.1.6-26b. Effects of Tuolumne River Flows on Temperatures at RM 28.1 in May and June for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

Table F.1.6-3a. Monthly Distribution of Tuolumne River Water Temperatures at RM 28.1 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Tuolumne River Temperatures at RM 28.1 for Baseline Conditions												
Minimum	55.4	53.6	49.5	49.3	48.2	49.3	50.0	51.4	53.3	55.5	59.0	56.7
10%	58.1	54.2	50.5	49.7	49.4	49.6	51.0	52.2	54.0	56.5	67.7	63.2
20%	58.6	54.6	50.9	50.0	49.9	50.3	51.8	53.2	54.7	62.2	68.5	64.7
30%	59.4	54.8	51.2	50.6	50.7	50.7	52.7	55.2	56.3	68.9	69.1	65.8
40%	59.5	55.2	51.4	50.9	52.0	51.2	53.1	55.6	67.2	70.2	69.5	66.4
50%	60.5	55.4	51.5	51.4	53.6	52.5	54.0	56.3	68.2	70.8	70.3	67.2
60%	61.6	56.2	51.9	51.9	54.2	57.3	56.1	59.8	74.3	77.7	76.1	72.6
70%	63.8	56.6	52.4	51.9	54.7	58.2	59.2	61.6	75.1	78.3	76.9	73.2
80%	64.5	57.1	52.6	52.0	55.4	59.9	59.7	63.0	75.2	78.4	77.4	73.9
90%	65.8	57.8	53.4	53.0	56.5	60.9	61.5	63.8	75.5	79.2	77.8	74.5
Maximum	67.8	58.4	54.1	53.7	57.5	61.6	63.2	66.3	76.7	80.2	79.7	75.7
Average	61.3	55.8	51.8	51.3	52.9	54.6	55.6	58.0	66.5	71.0	72.2	68.9
Change in Tuolumne River Temperatures at RM 28.1 for 20% Unimpaired Flow Relative to Baseline												
Minimum	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
10%	0.2	0.1	0.0	0.0	0.0	0.0	0.0	-0.1	0.1	0.1	0.0	0.0
20%	0.0	0.1	0.0	0.0	0.0	0.1	0.0	0.1	0.4	0.0	0.0	0.0
30%	0.0	0.1	0.0	0.0	0.0	0.1	0.1	-1.0	0.0	-0.1	0.0	0.0
40%	0.0	0.0	0.0	0.0	-0.1	0.6	0.2	-0.6	-9.3	-0.5	0.1	0.0
50%	0.1	0.1	0.0	0.2	-0.6	0.2	0.0	-0.2	-8.3	-0.5	0.0	0.1
60%	0.0	0.0	0.0	0.0	-0.5	-3.2	-0.3	-2.8	-13.6	-0.8	0.0	0.0
70%	0.1	-0.1	0.0	0.0	0.0	-1.4	-2.9	-3.9	-10.8	-0.7	0.0	0.0
80%	0.0	-0.3	0.1	0.0	-0.3	-2.2	-1.8	-4.5	-5.8	-0.6	0.0	0.0
90%	-0.3	-0.2	-0.2	0.0	-0.1	-2.1	-2.8	-1.3	-2.4	-1.1	0.0	0.0
Maximum	-0.1	0.0	0.0	0.0	-0.1	-1.1	0.0	-3.0	-1.6	-0.6	0.0	0.0
Average	0.0	0.0	0.0	0.0	-0.1	-0.8	-0.7	-1.6	-4.8	-0.5	0.0	0.0
Change in Tuolumne River Temperatures at RM 28.1 for 40% Unimpaired Flow Relative to Baseline												
Minimum	0.2	0.7	0.1	0.0	0.0	0.0	0.0	-0.1	-0.3	0.0	0.0	0.0
10%	-0.9	0.3	-0.1	0.2	-0.1	0.0	-0.1	-0.1	0.0	0.5	-1.7	-3.3
20%	-0.5	0.2	0.3	0.2	0.3	0.1	-0.3	-0.9	-0.3	-2.5	-1.6	-4.3
30%	-0.4	0.2	0.1	-0.1	0.1	0.1	-0.1	-2.5	-1.4	-8.4	-1.4	-4.1
40%	-0.2	-0.2	0.1	0.1	-0.8	0.1	-0.1	-2.1	-11.8	-0.8	-0.3	-0.4
50%	-0.4	0.0	0.4	0.2	-1.2	-0.5	-0.4	-2.6	-11.4	-0.7	-0.3	0.3
60%	-0.2	-0.1	0.3	0.0	-1.1	-3.7	-2.2	-5.4	-17.0	-1.4	0.1	0.0
70%	0.2	-0.2	0.0	0.1	-1.0	-4.1	-4.7	-6.5	-15.9	-1.4	0.0	0.0
80%	0.0	-0.1	0.2	0.2	-1.4	-4.5	-4.8	-7.5	-12.1	-1.1	0.0	0.0
90%	-0.2	-0.4	-0.1	0.1	-1.6	-4.9	-6.1	-6.4	-8.9	-1.5	0.0	0.0
Maximum	-0.1	0.0	0.2	0.2	0.0	-2.7	-2.2	-6.9	-2.1	-1.3	0.0	0.0
Average	-0.2	0.0	0.1	0.1	-0.6	-1.8	-2.0	-3.8	-7.7	-1.7	-0.5	-1.2

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Change in Tuolumne River Temperatures at RM 28.1 for 60% Unimpaired Flow Relative to Baseline												
Minimum	0.2	0.7	-0.1	-0.1	-0.1	0.0	0.0	-0.3	0.2	1.4	1.1	0.0
10%	-0.3	0.6	-0.3	0.0	-0.1	0.0	-0.4	-0.2	-0.3	3.8	-1.5	-2.6
20%	0.0	0.4	0.1	0.2	-0.2	0.0	-0.8	-1.0	-0.6	-1.2	-1.2	-3.7
30%	-0.3	0.4	0.2	0.0	-0.7	-0.1	-1.2	-2.6	-1.9	-7.1	-0.8	-4.1
40%	0.2	0.0	0.2	0.2	-1.2	-0.3	-0.6	-2.5	-12.2	-0.7	-0.3	-0.3
50%	-0.5	0.4	0.4	0.2	-1.9	-0.9	-1.2	-2.9	-12.5	-0.7	-0.1	0.5
60%	-0.3	-0.1	0.4	0.0	-2.0	-5.0	-3.1	-6.0	-18.0	-1.8	0.0	0.0
70%	0.1	-0.3	0.3	0.1	-2.0	-5.3	-5.7	-7.3	-17.6	-1.7	0.0	0.0
80%	0.1	-0.2	0.5	0.2	-2.0	-6.1	-6.0	-8.5	-15.2	-1.4	0.0	0.0
90%	-0.2	-0.5	0.0	0.2	-2.1	-6.3	-7.2	-7.9	-11.6	-1.7	0.0	0.0
Maximum	-0.1	0.0	0.1	0.3	0.0	-2.8	-4.9	-9.3	-6.1	-1.6	0.0	0.0
Average	0.0	0.1	0.2	0.2	-1.2	-2.5	-2.9	-4.4	-9.1	-1.3	-0.3	-1.0

Table F.1.6-3b.Monthly Distribution of Tuolumne River Water Temperatures at RM 28.1 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average Tuolumne River Temperatures at RM 28.1												
Baseline Average	61.3	55.8	51.8	51.3	52.9	54.6	55.6	58.0	66.5	71.0	72.2	68.9
Change in Average Tuolumne River Temperatures at RM 28.1 Relative to Baseline												
20% Unimpaired Flow Minus Baseline	0.0	0.0	0.0	0.0	-0.1	-0.8	-0.7	-1.6	-4.8	-0.5	0.0	0.0
30% Unimpaired Flow Minus Baseline	0.2	0.1	0.0	0.1	-0.5	-1.3	-1.4	-3.1	-6.6	0.2	0.1	0.2
40% Unimpaired Flow Minus Baseline	-0.2	0.0	0.1	0.1	-0.6	-1.8	-2.0	-3.8	-7.7	-1.7	-0.5	-1.2
50% Unimpaired Flow Minus Baseline	-0.1	0.1	0.2	0.2	-0.9	-2.2	-2.5	-4.3	-8.6	-1.6	-0.4	-1.1
60% Unimpaired Flow Minus Baseline	0.0	0.1	0.2	0.2	-1.2	-2.5	-2.9	-4.4	-9.1	-1.3	-0.3	-1.0

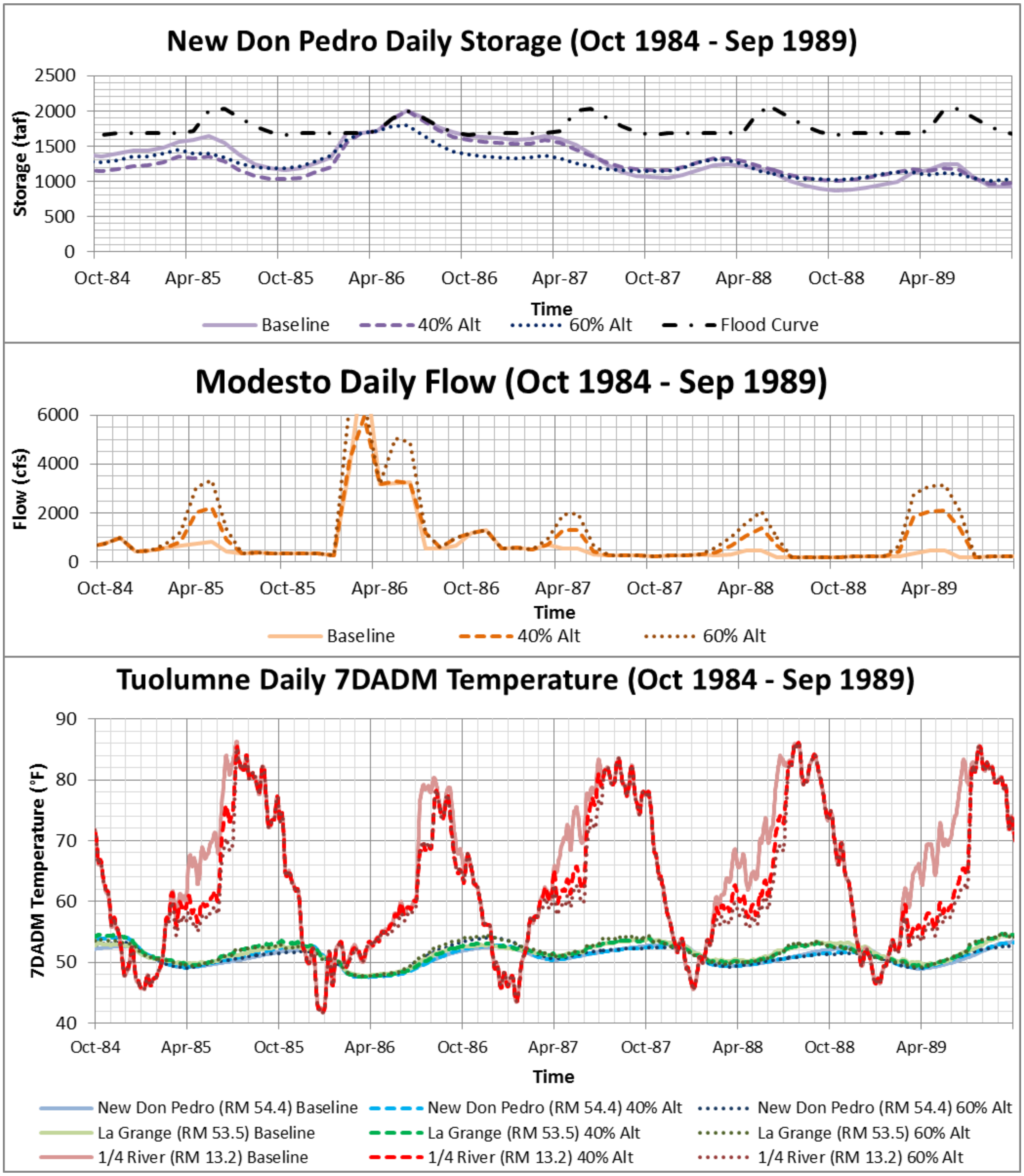


Figure F.1.6-27. Tuolumne River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1985–1989, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Don Pedro Release, La Grange Release, and 1/4 River Locations

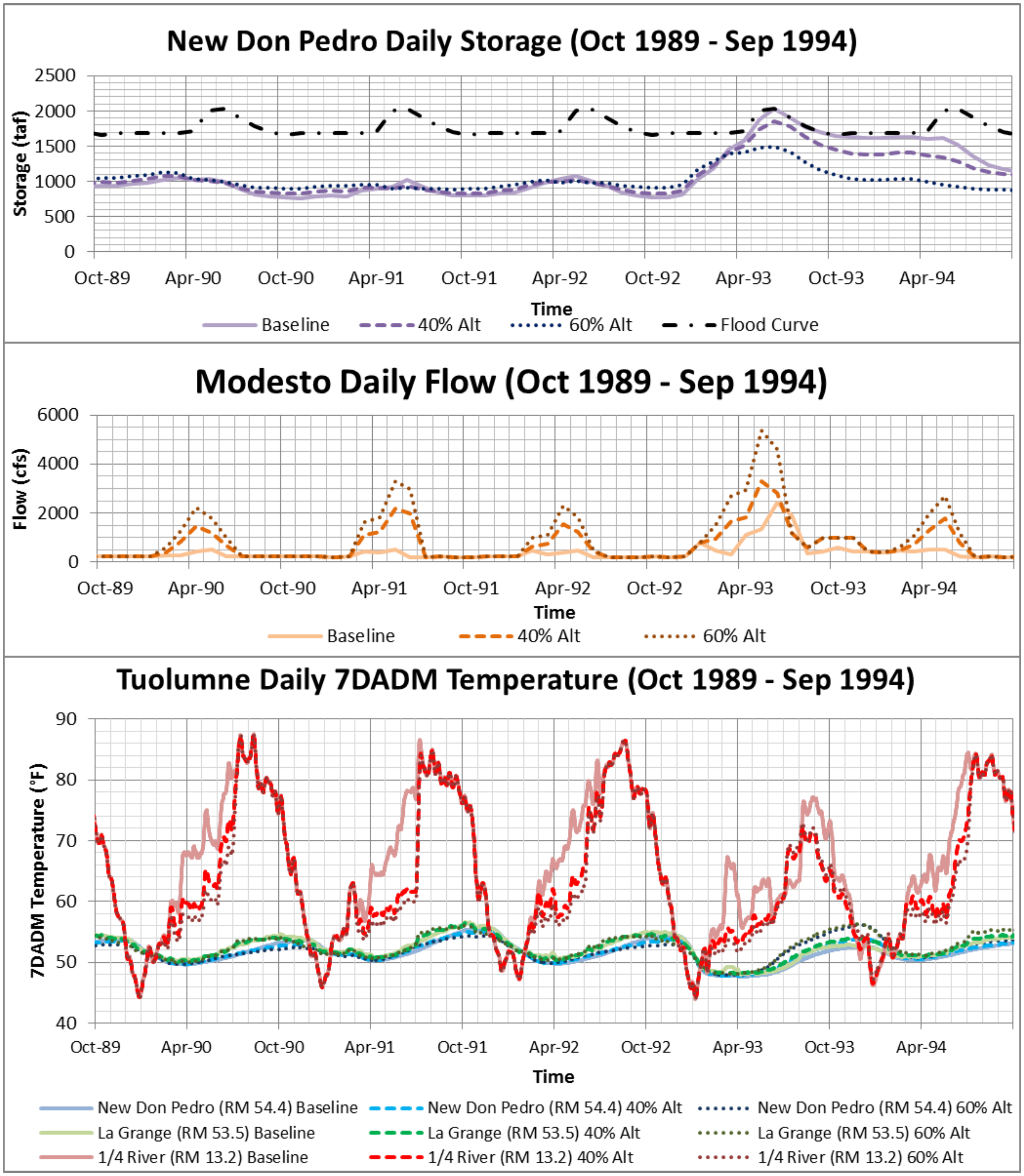


Figure F.1.6-28. Tuolumne River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1990–1994, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Don Pedro Release, La Grange Release, and 1/4 River Locations

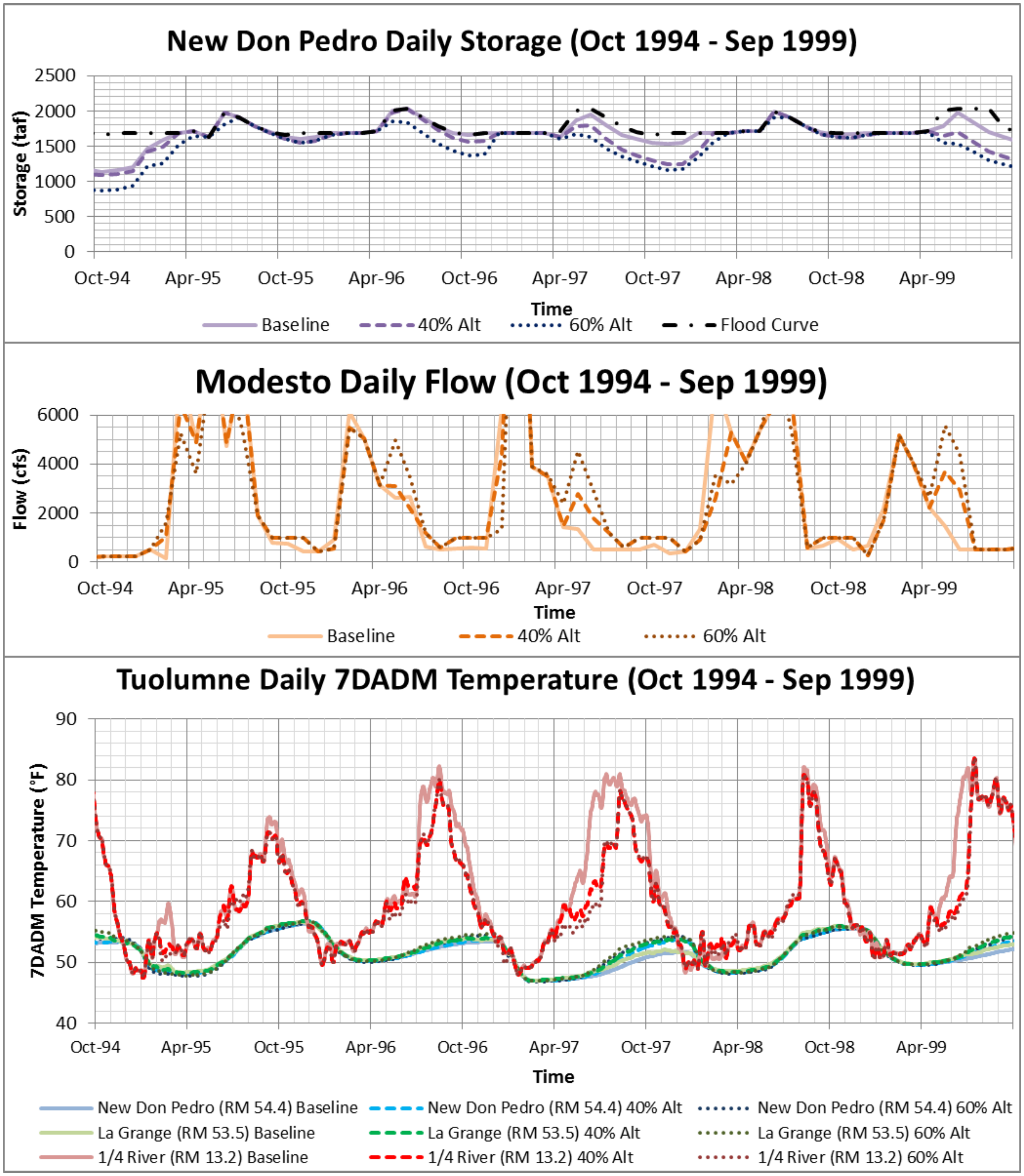


Figure F.1.6-29. Tuolumne River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1995–1999, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Don Pedro Release, La Grange Release, and 1/4 River Locations

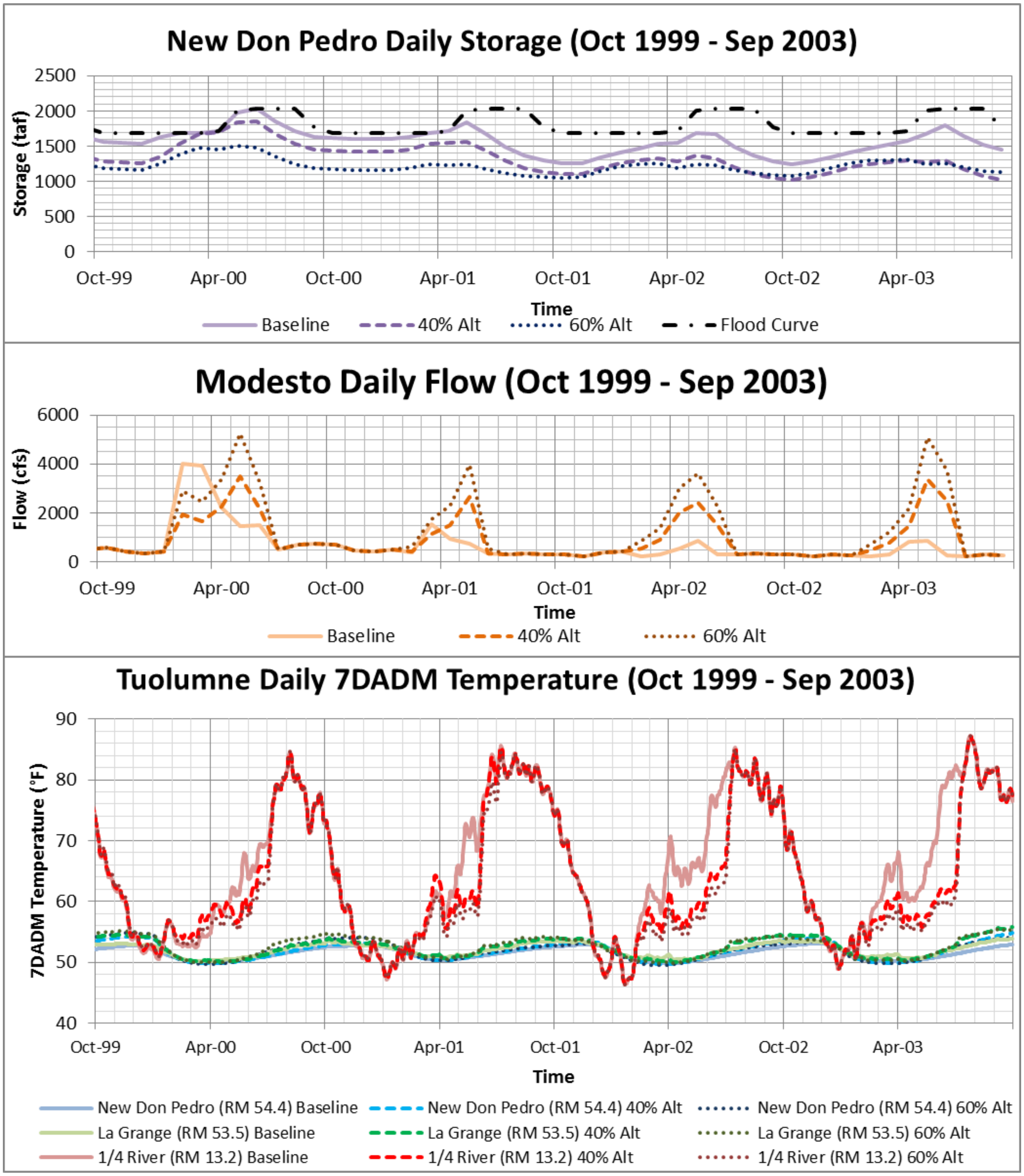


Figure F.1.6-30. Tuolumne River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 2000–2003, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at New Don Pedro Release, La Grange Release, and 1/4 River Locations

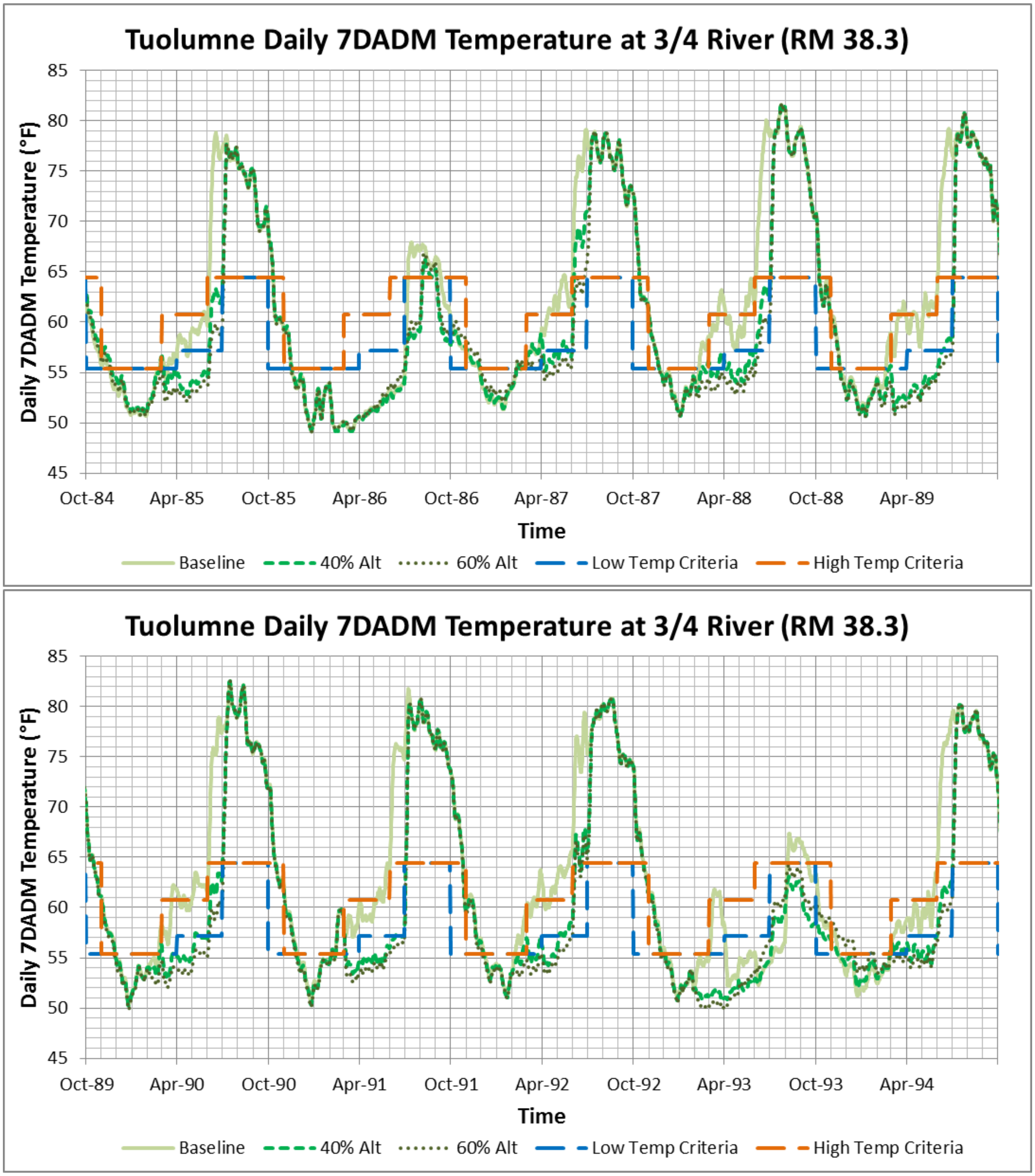


Figure F.1.6-31. Temperature Model 7DADM Results at Tuolumne RM 38.3 Compared to Monthly USEPA Temperature Criteria for Optimal Development of Different Fish Lifestages under Baseline and LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) for (a) Water Years 1985–1989 and (b) Water Years 1990–1994

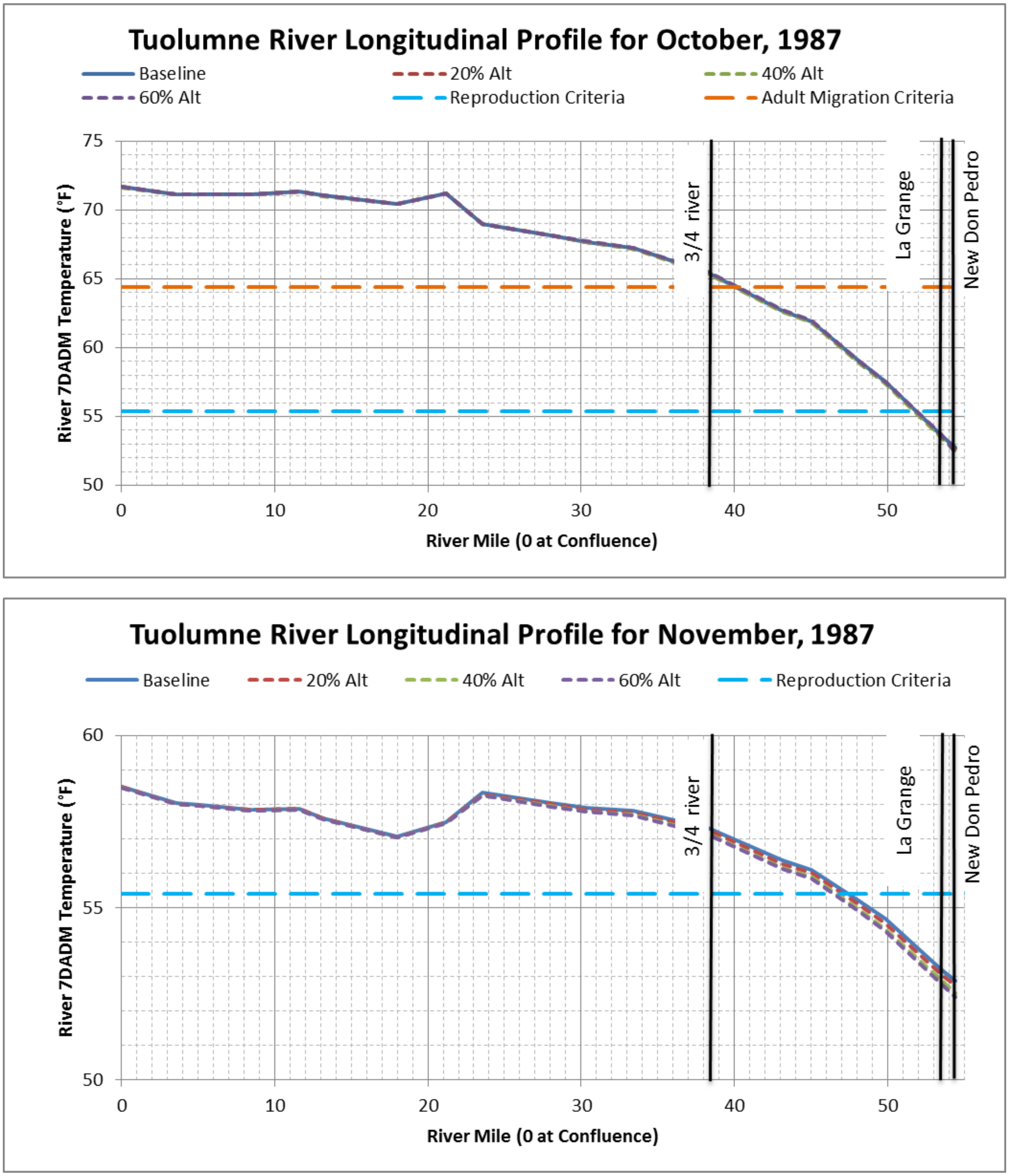


Figure F.1.6-32. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) October 1987 and (b) November 1987

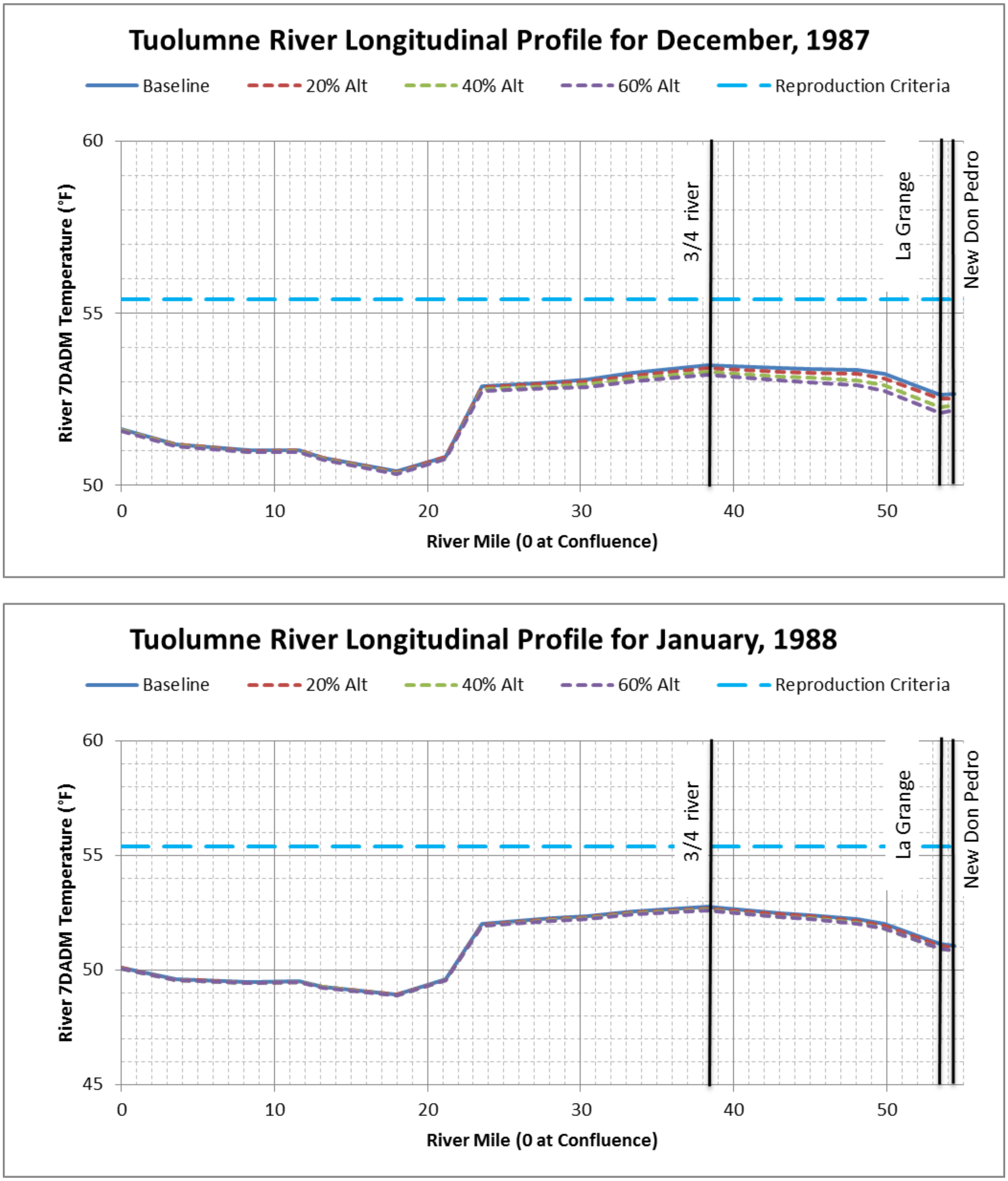
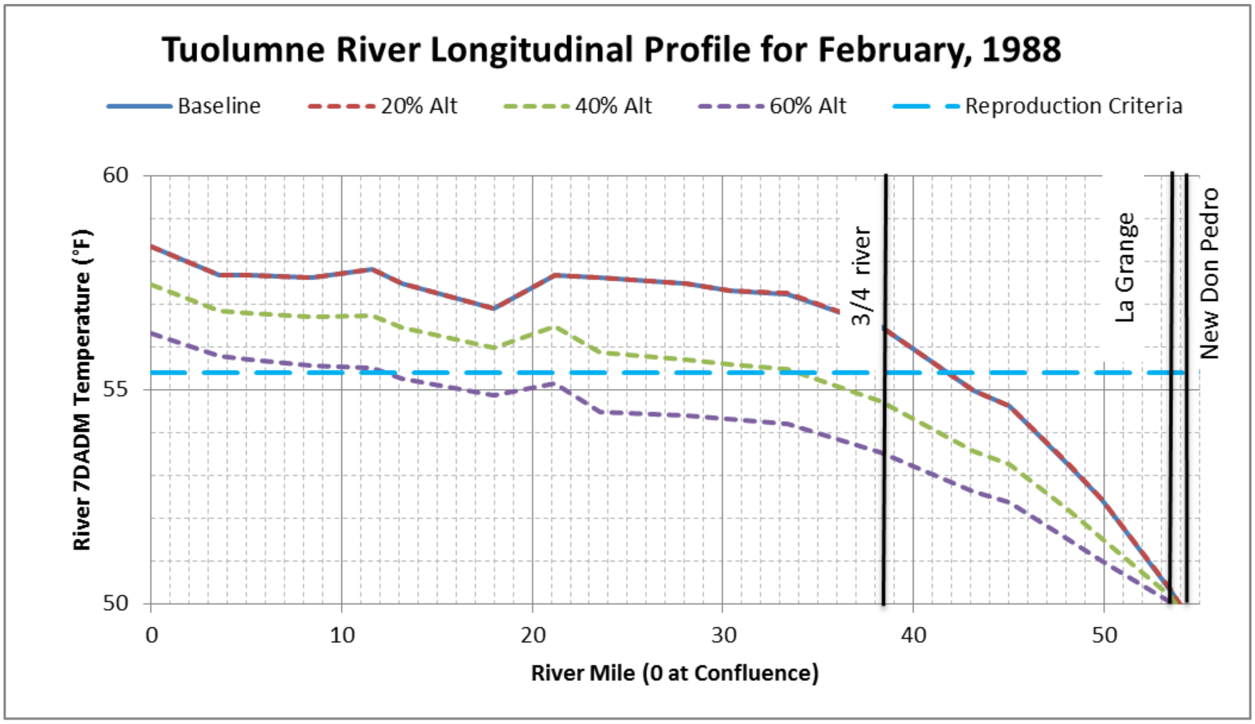


Figure F.1.6-33. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) December 1987 and (b) January 1988



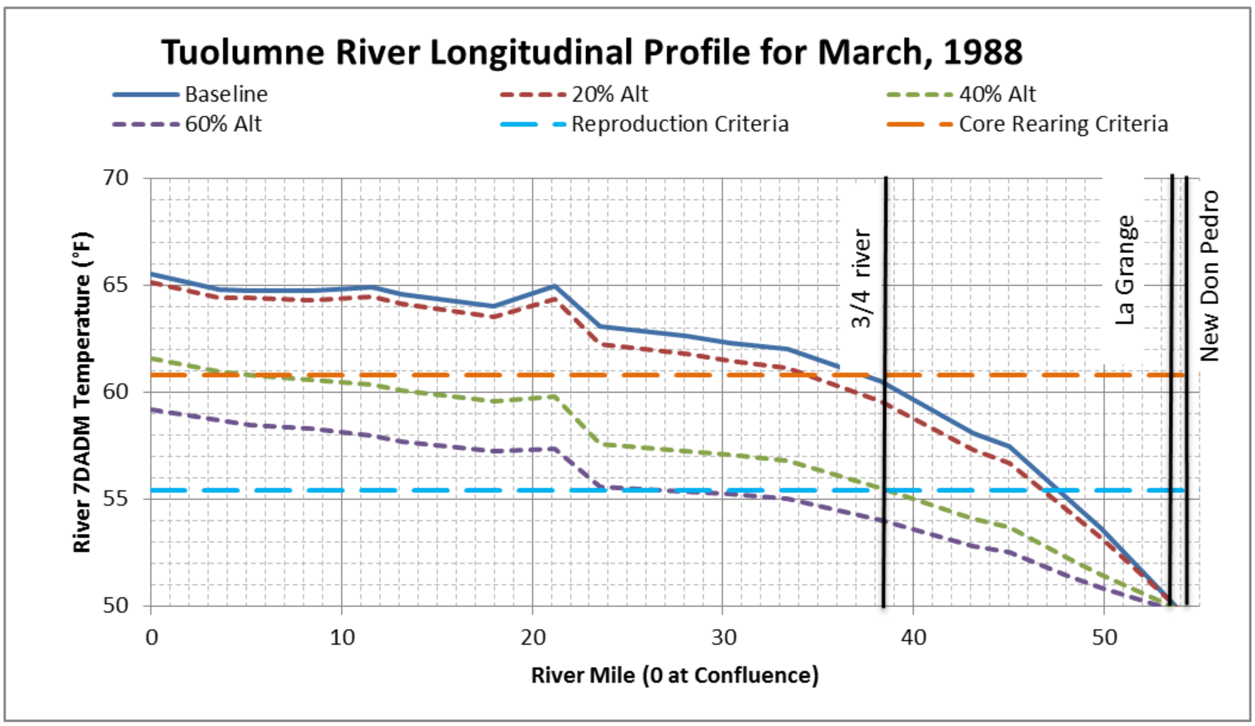
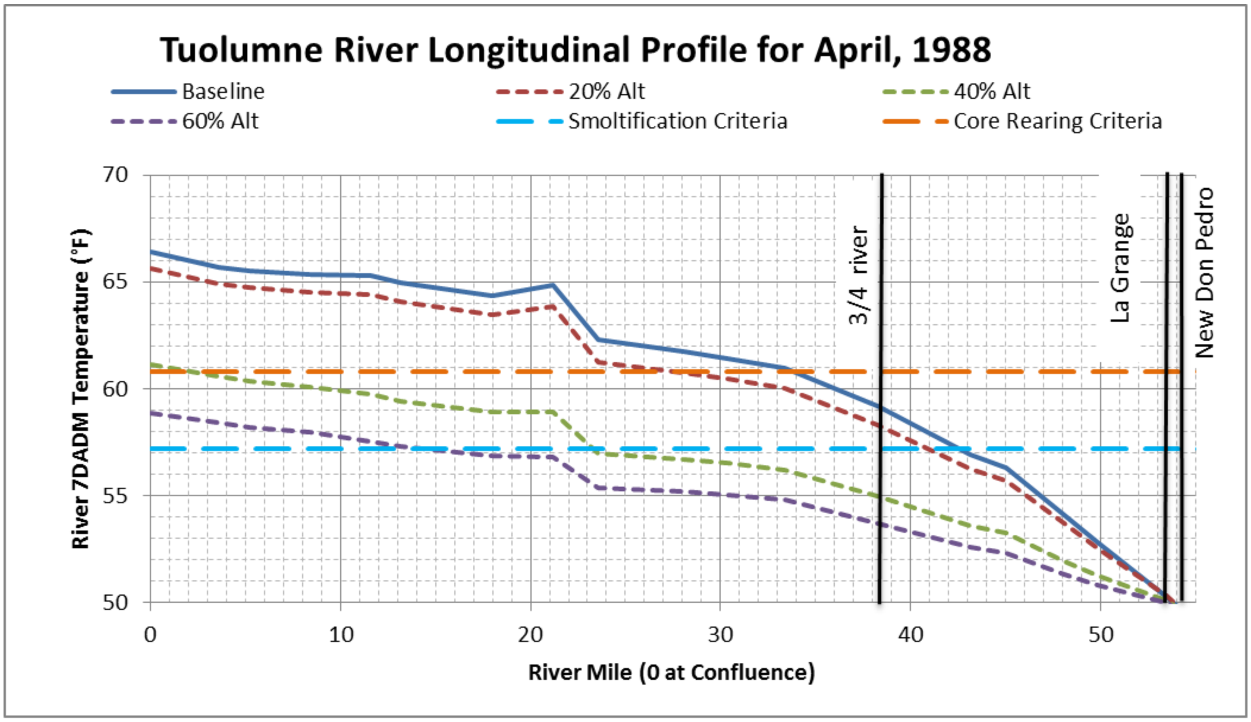


Figure F.1.6-34. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) February 1988 and (b) March 1988



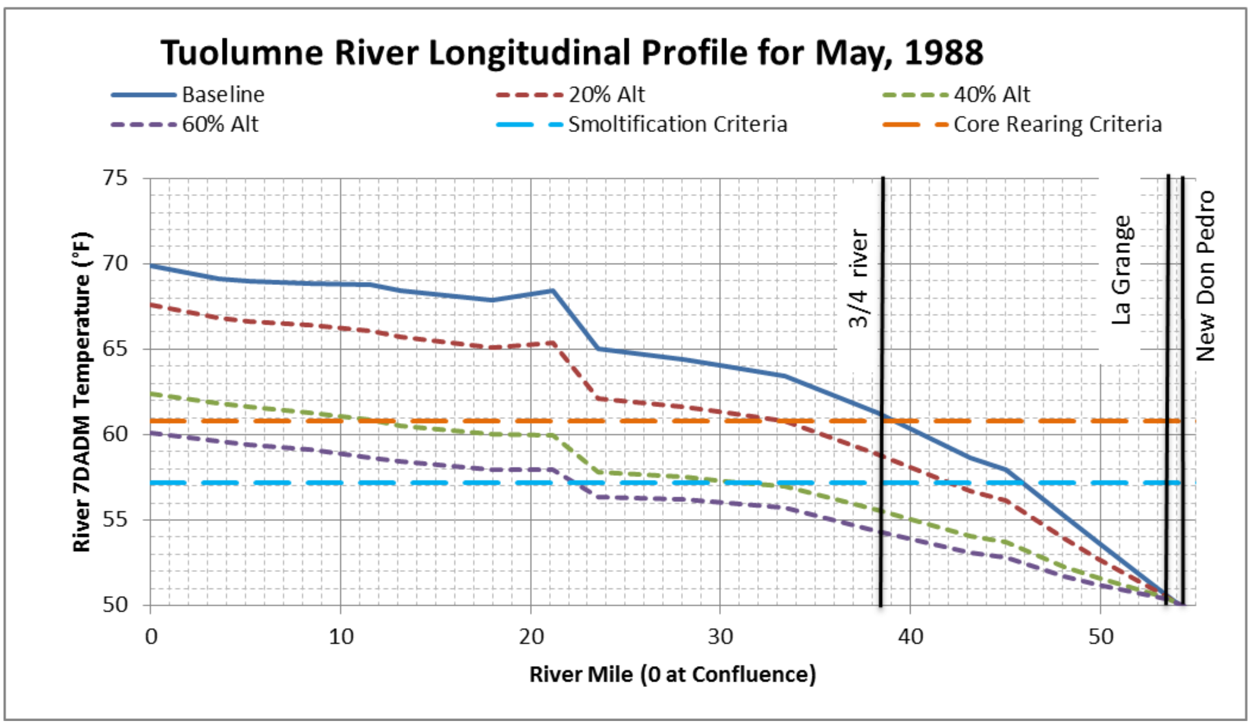
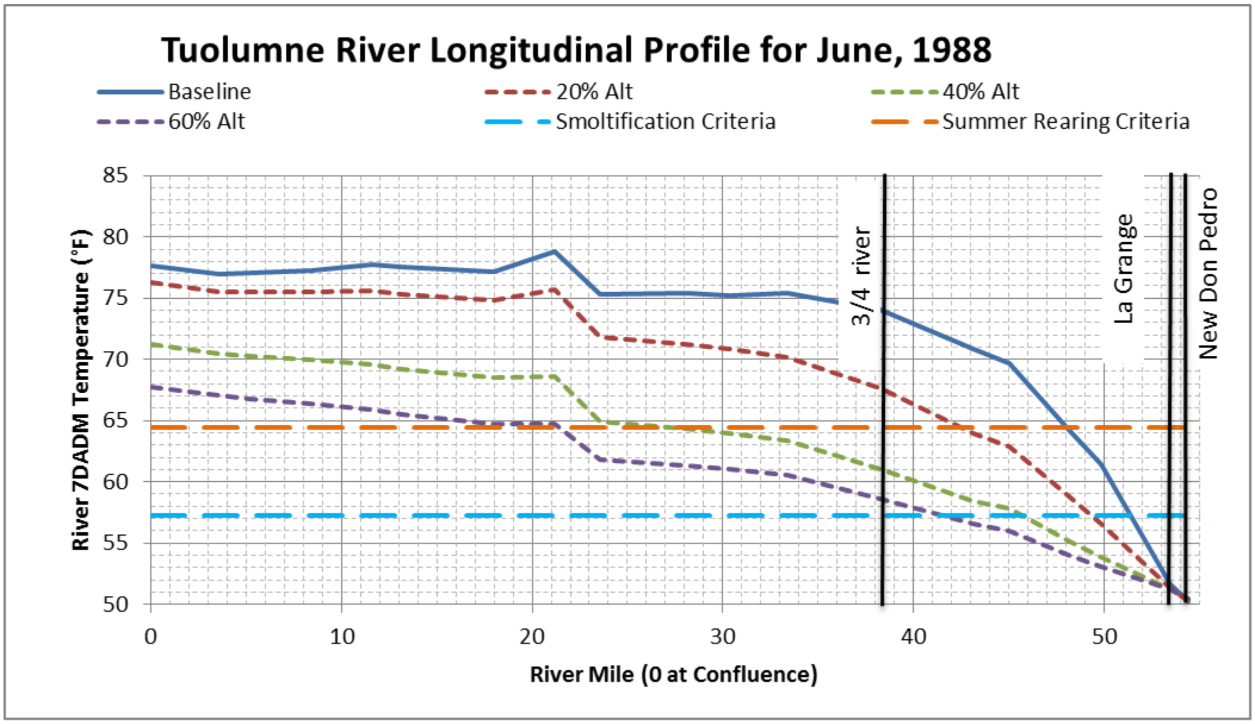


Figure F.1.6-35. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) April 1988 and (b) May 1988



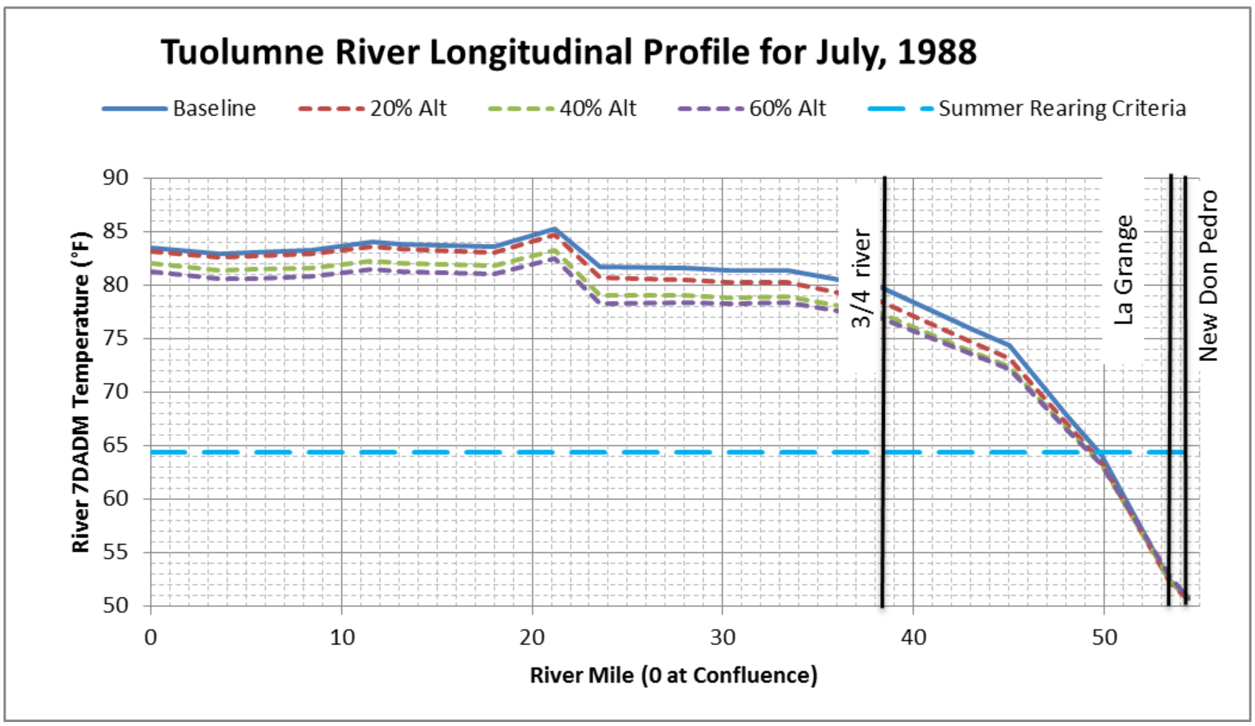
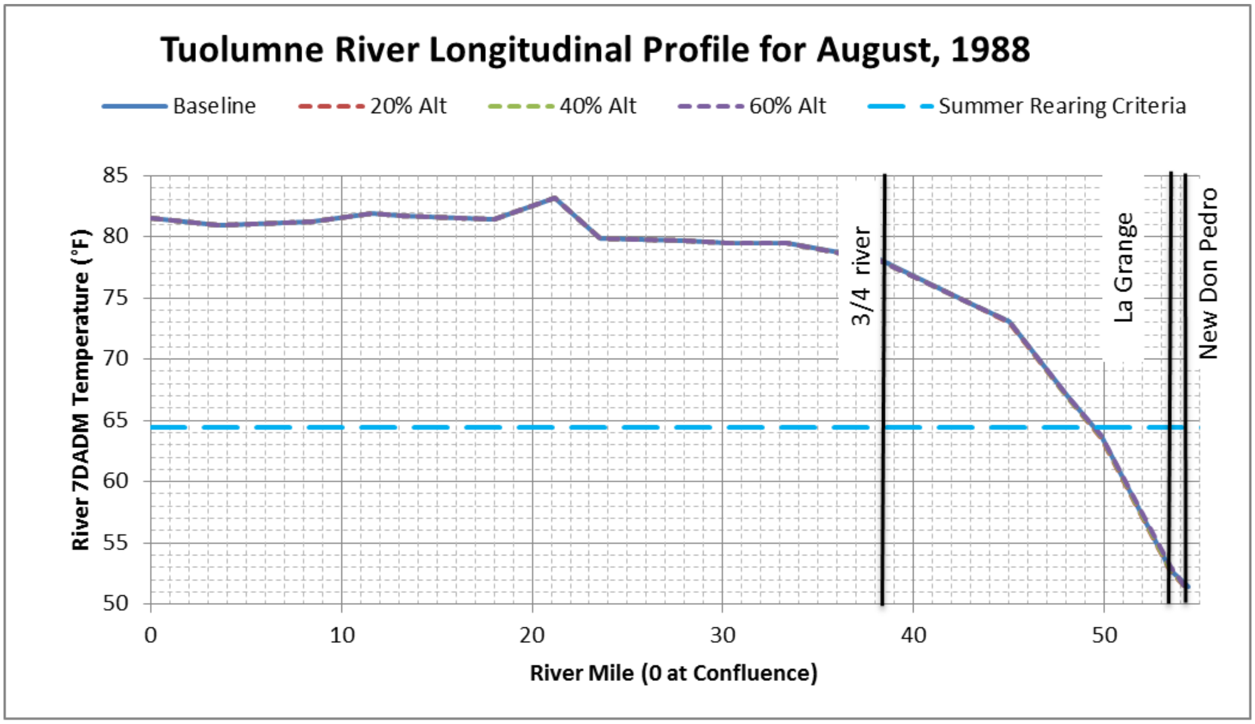


Figure F.1.6-36. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) June 1988 and (b) July 1988



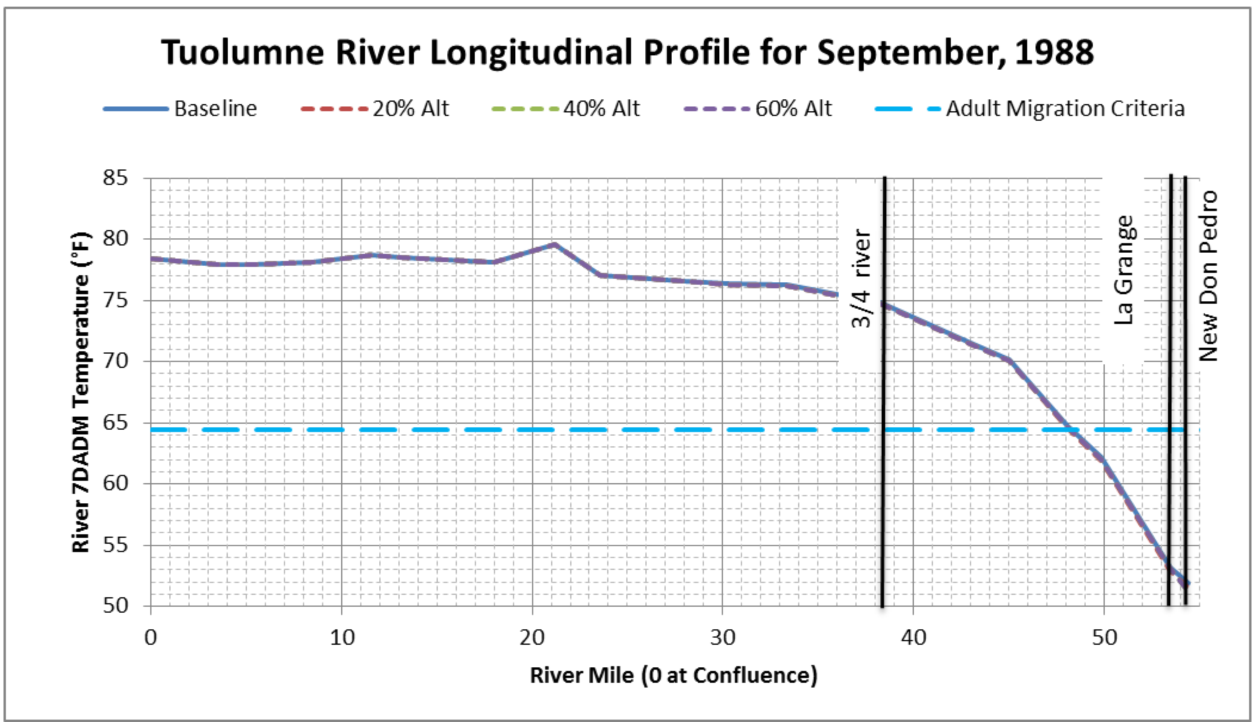
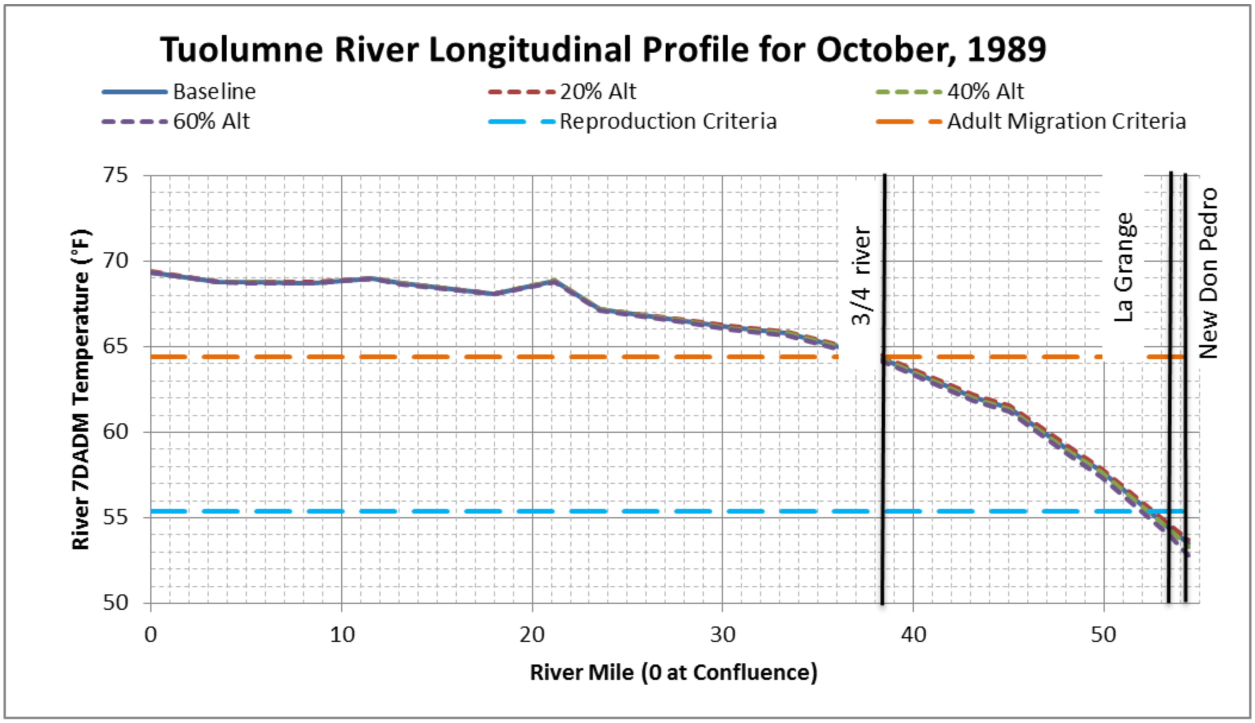


Figure F.1.6-37. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) August 1988 and (b) September 1988



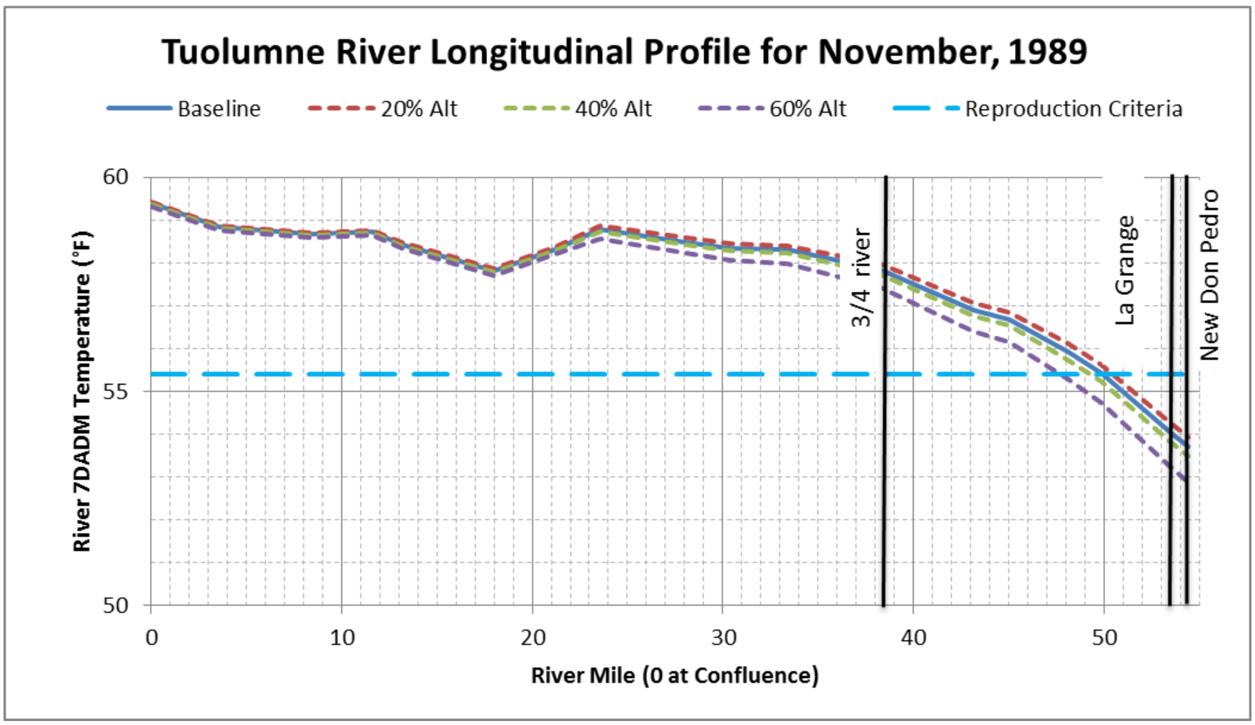
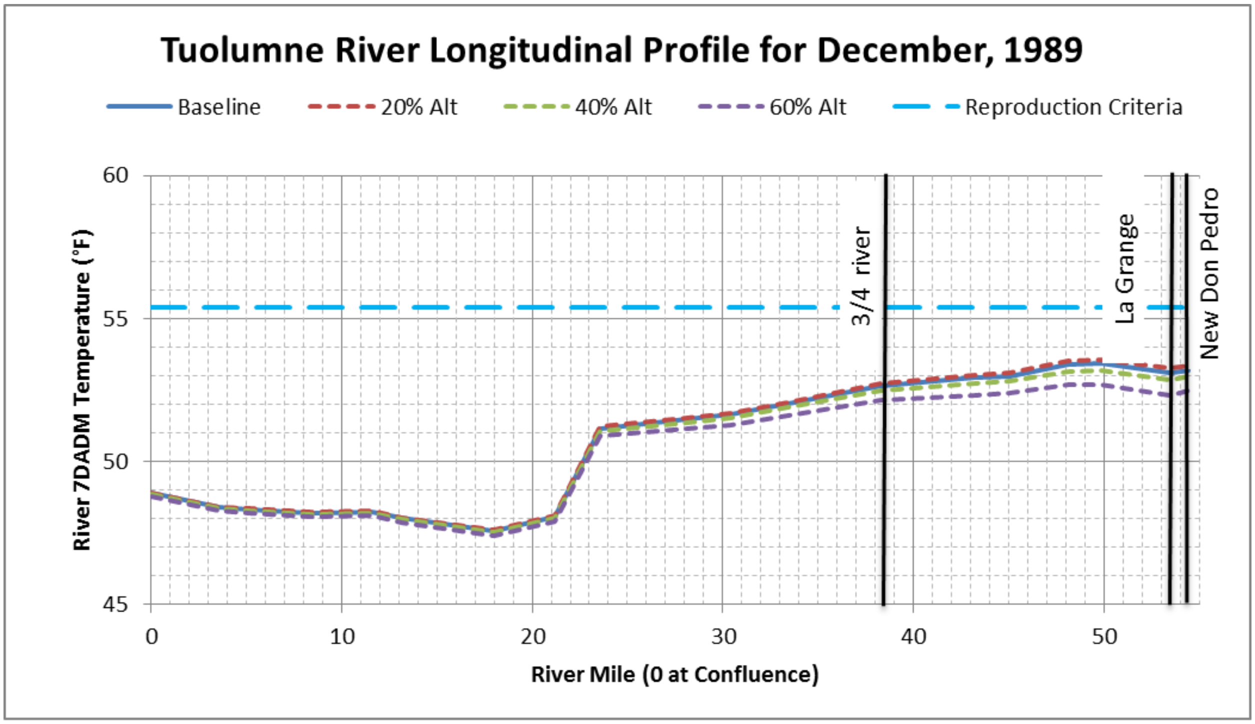


Figure F.1.6-38. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) October 1989 and (b) November 1989



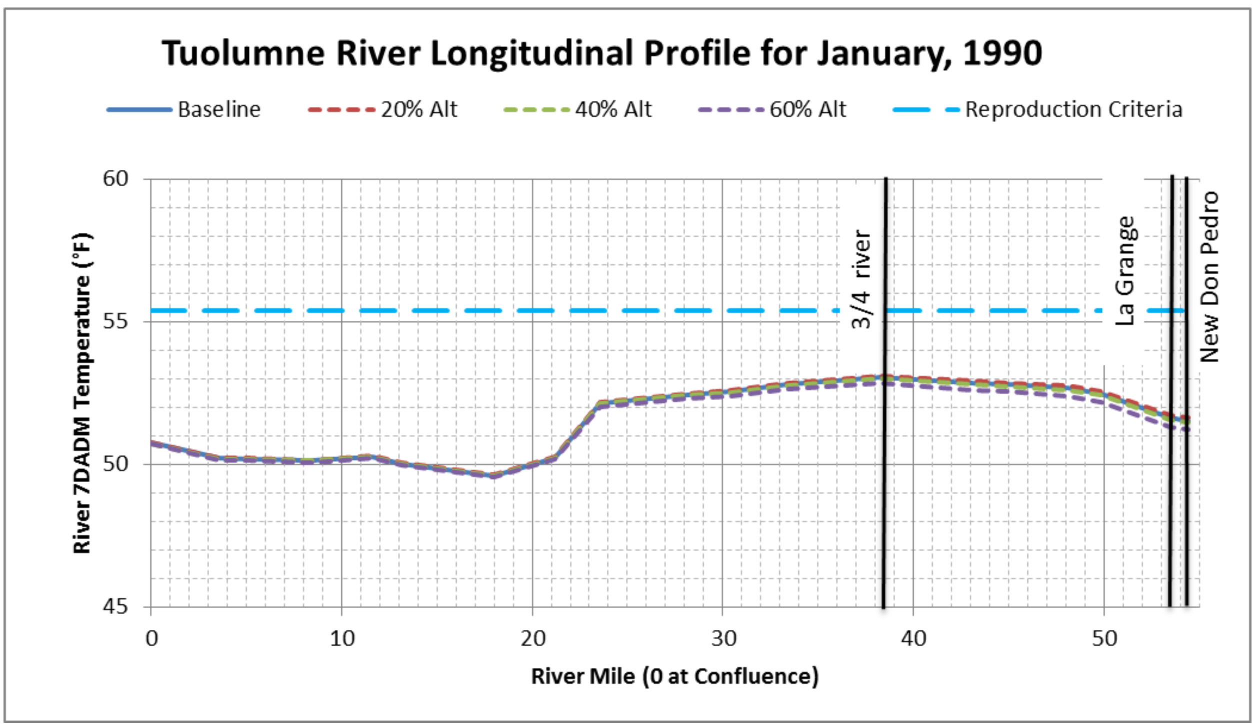
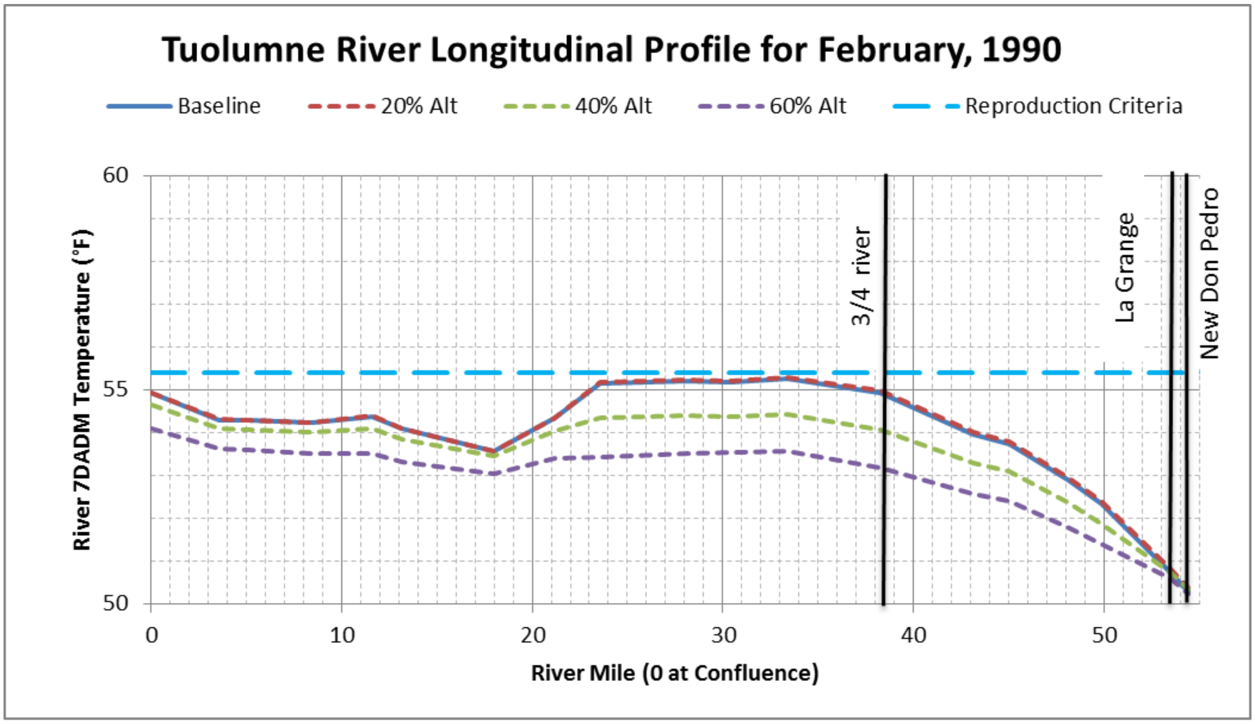


Figure F.1.6-39. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) December 1989 and (b) January 1990



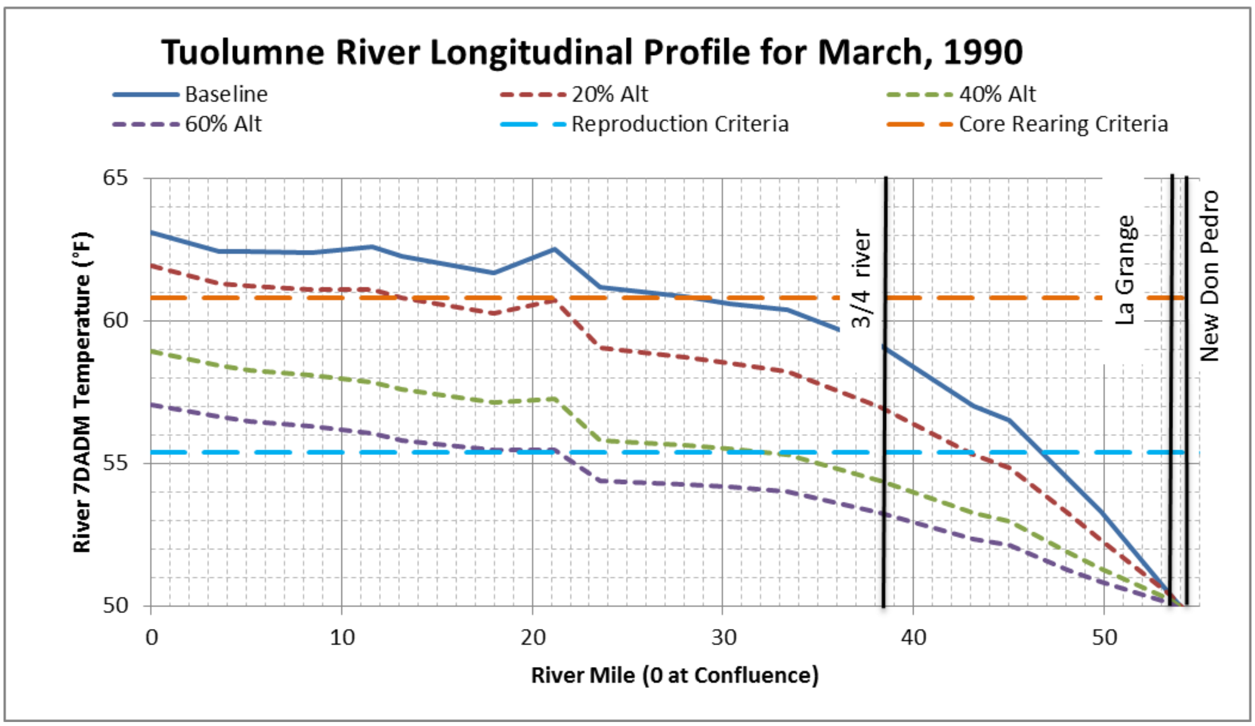
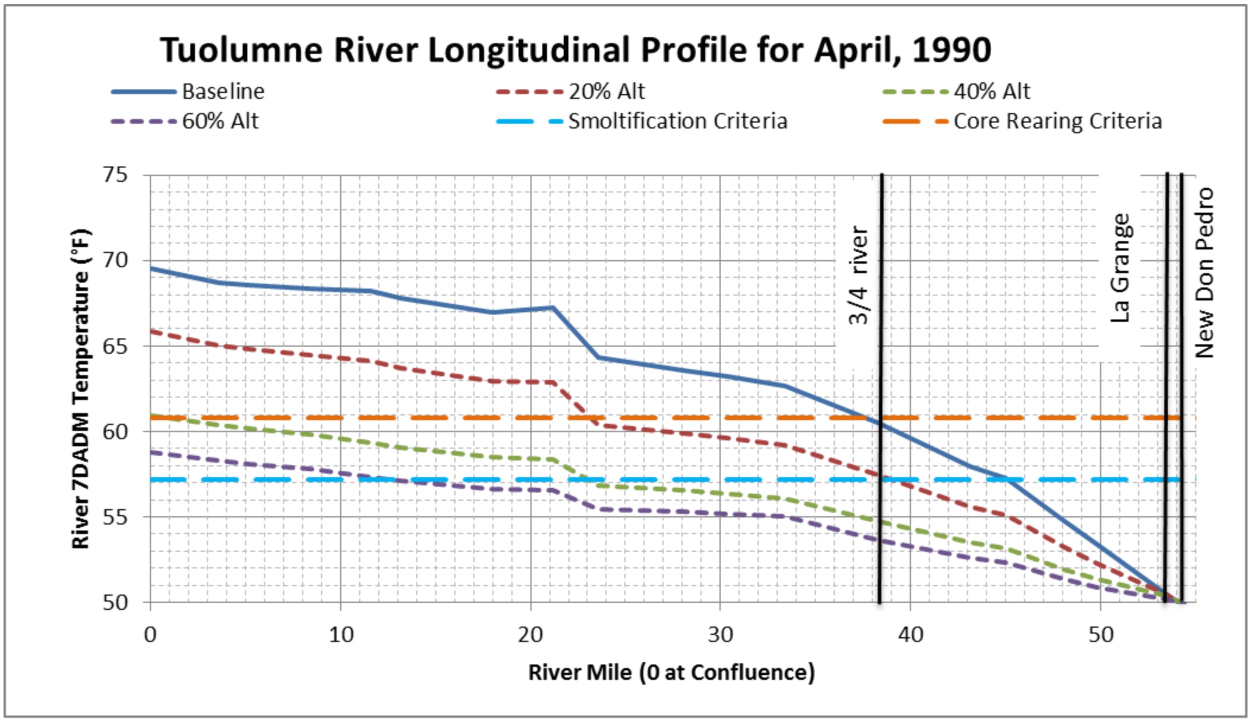


Figure F.1.6-40. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) February 1990 and (b) March 1990



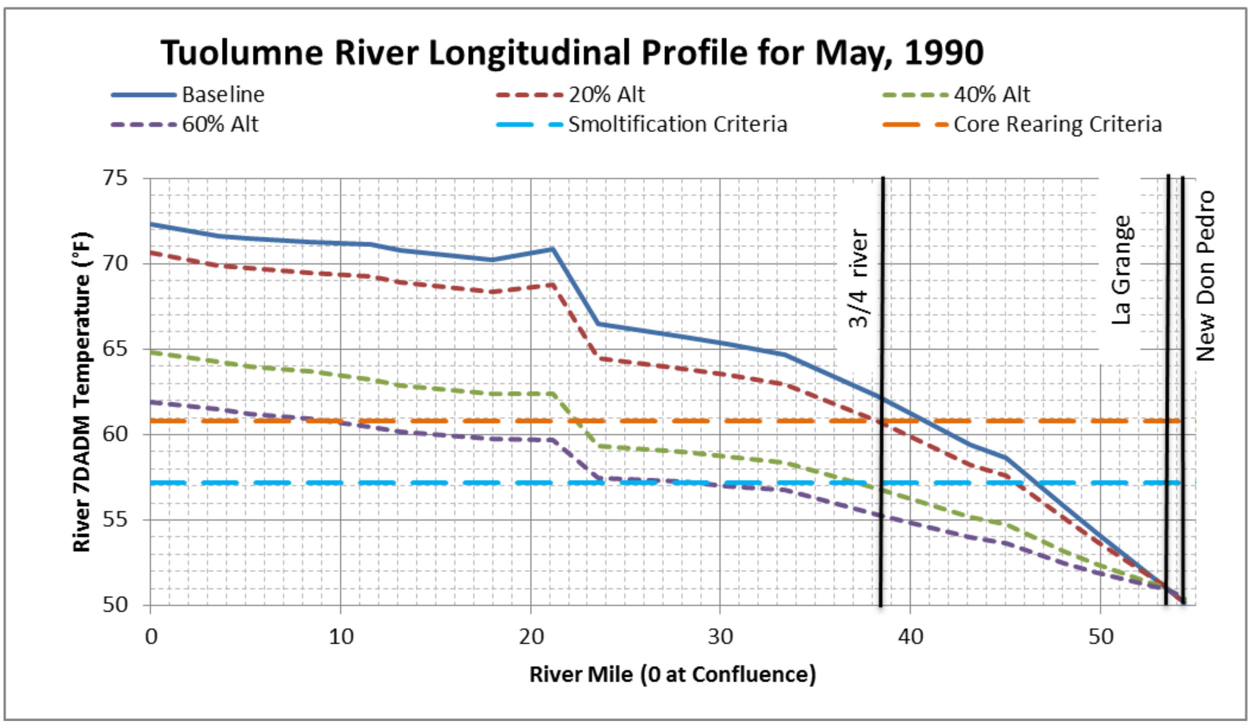


Figure F.1.6-41. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) April 1990 and (b) May 1990

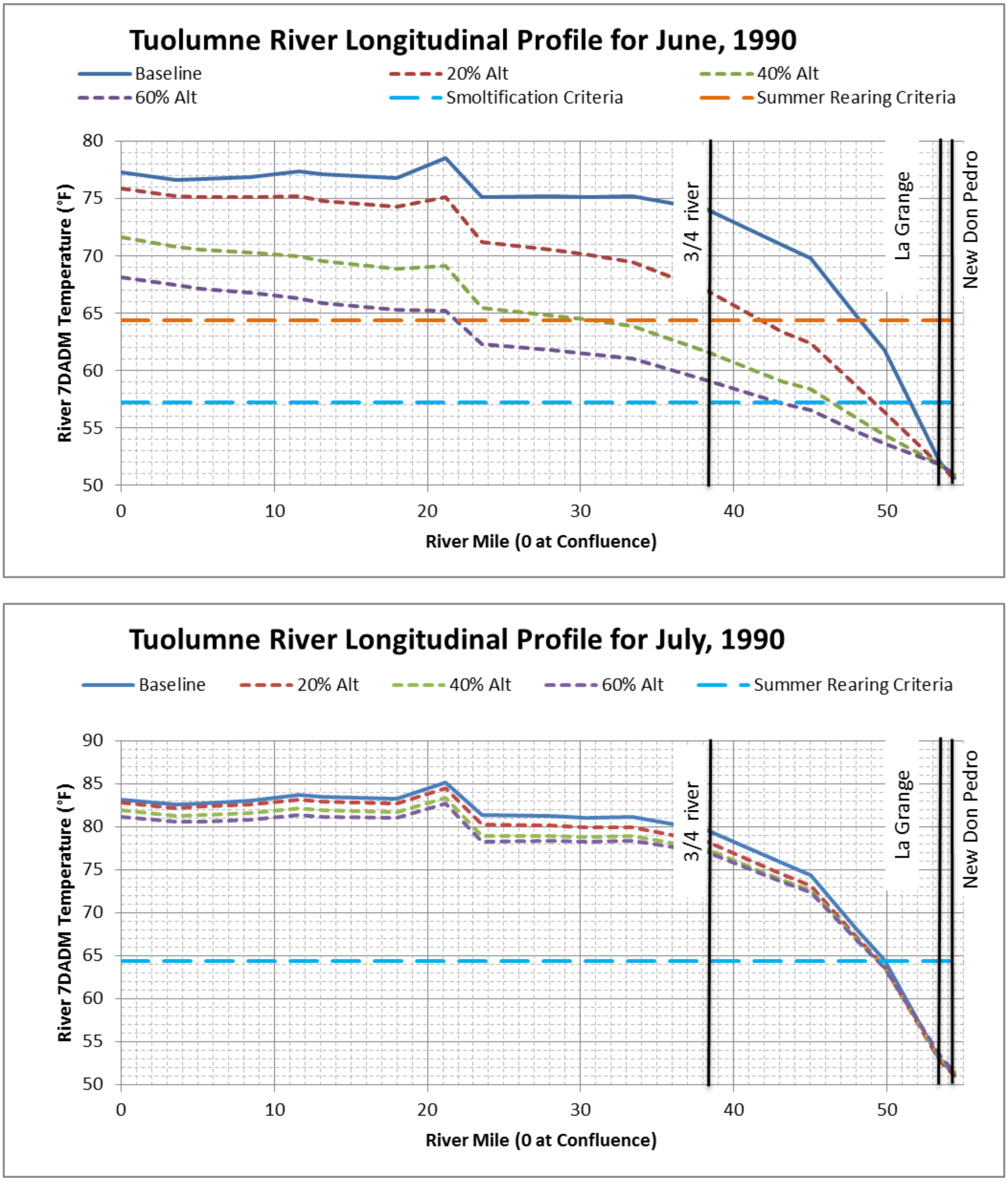
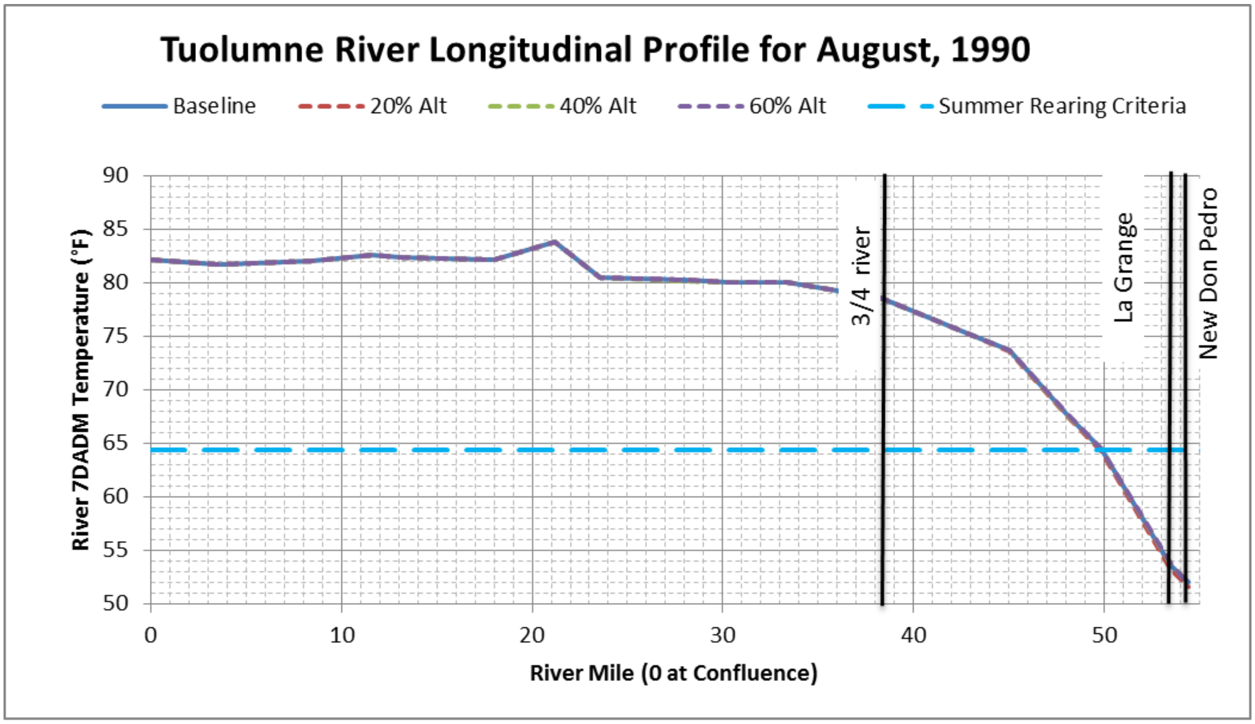


Figure F.1.6-42. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) June 1990 and (b) July 1990



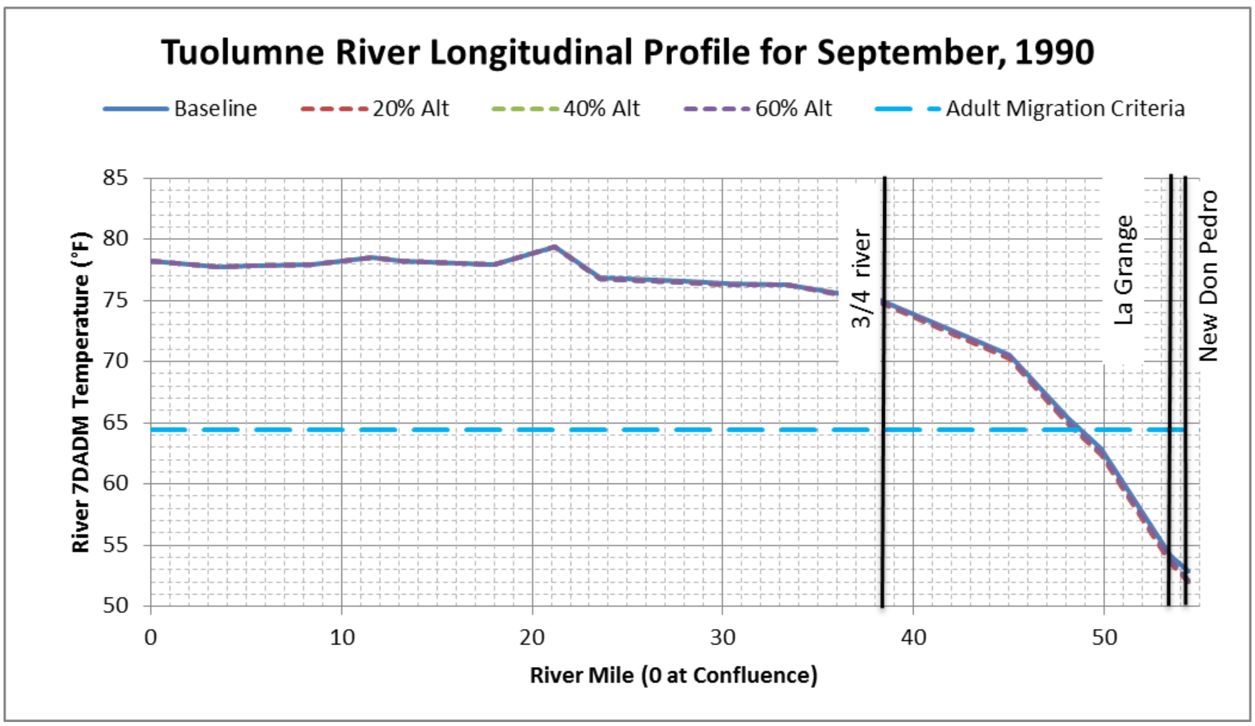


Figure F.1.6-43. Longitudinal Monthly Average 7DADM Temperature Results within the Tuolumne River for (a) August 1990 and (b) September 1990

Merced River Temperatures

Figures F.1.6-44a and F.1.6-44b show the monthly average temperatures in the Merced River at RM 27.1 simulated for baseline conditions and the LSJR alternatives, plotted as a function of the monthly river flow at Merced for February–June. For February, the temperatures were generally 49°F–56°F. The warmest temperatures corresponded to flows of about 250 cfs. Because there is little meteorological warming in February, river flow increases would not substantially reduce water temperatures.

In March, simulated temperatures in the Merced River at RM 27.1 were 50°F–55°F when river flows were 1,000 cfs or more and generally increased to 56°F–61°F when river flows were greater than 1,000 cfs. Because the LSJR alternatives tended to increase the low- to mid-range flows relative to baseline (i.e., they increased all but the highest baseline flows), LSJR alternative water temperatures tended to be lower than baseline. However, there were no large effects on water temperatures because meteorological warming at RM 27.1 was limited in March and water temperatures generally remained cool. The warmest temperatures were simulated for low flows of about 250 cfs, but these temperatures remained less than 61°F.

In April, the range of simulated temperatures at RM 27.1 was 50°F–67°F, with warmer temperatures of 60°F–67°F simulated for the lower flows (less than 500 cfs). Here, the shift toward higher flows in the LSJR alternative was distinct; where flow under baseline conditions approached 0, flows under LSJR Alternatives 2, 3, and 4 usually didn't fall below about 300 cfs, 500 cfs, and 800 cfs, respectively. With the higher flows, the temperature at RM 27.1 was shifted down in each of the alternatives, with temperatures under LSJR Alternative 4 rarely going above 60°F. In May, the range of simulated temperatures at RM 27.1 was 53°F–74°F, about 3°F–7°F warmer than in April. The warmer temperatures of 65°F–74°F were generally simulated for the lower flows (less than 500 cfs). Much like April, there were similar shifts toward higher flow and lower temperatures under each of the alternatives. In June, temperatures were considerably warmer than in April and May, ranging from 55°F–78°F. The warmer temperatures of 66°F–78°F were generally simulated for the lower flows (less than 500 cfs).

The Merced River warming curves (flow versus temperature) at RM 27.1 in April, May, and June indicate the general relationship between river flow and water temperatures in the upstream portion of the Merced River. These figures suggest that temperature is most responsive to changes in flow when flow is less than 1,000 cfs and during warmer conditions (i.e., June).Tables F.1.6-4a and F.1.6-4b give the monthly cumulative distributions of average simulated water temperatures in the Merced River at RM 27.1 for 1970–2003 under baseline conditions and the change in the distribution under the LSJR alternatives. Baseline average water temperatures at RM 27.1 indicate the average seasonal warming January–July is about 23°F. This seasonal warming is similar to the warming on the Stanislaus River at RM 28.2 and on the Tuolumne River at RM 28.1. The monthly increase in the average temperatures February–July was about 2°F–5°F per month.

Changes in temperature associated with the LSJR alternatives were dependent on the combination of change in flow and amount of meteorological warming (i.e., difference between reservoir release temperatures and equilibrium temperatures). The months of April–June showed significant drops in average monthly temperature under all the LSJR alternatives, with higher temperature reductions under higher unimpaired flow objectives. May had the highest temperature reductions, with average monthly temperatures falling 3.0°F under a 20 percent unimpaired flow objective and 6.6°F under a 60 percent unimpaired flow objective.

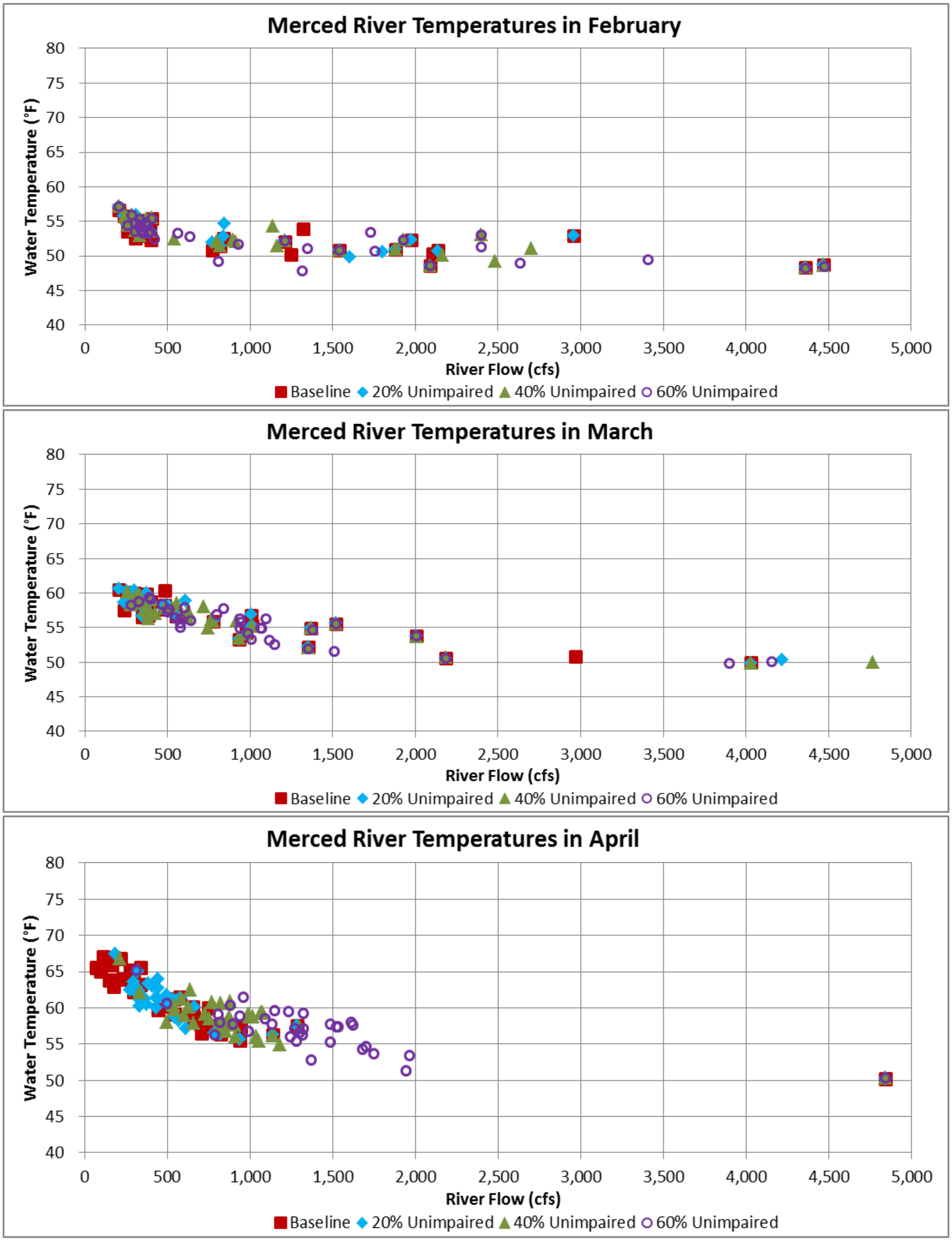


Figure F.1.6-44a. Effects of Merced River Flows on Temperatures at RM 27.1 in February–April for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

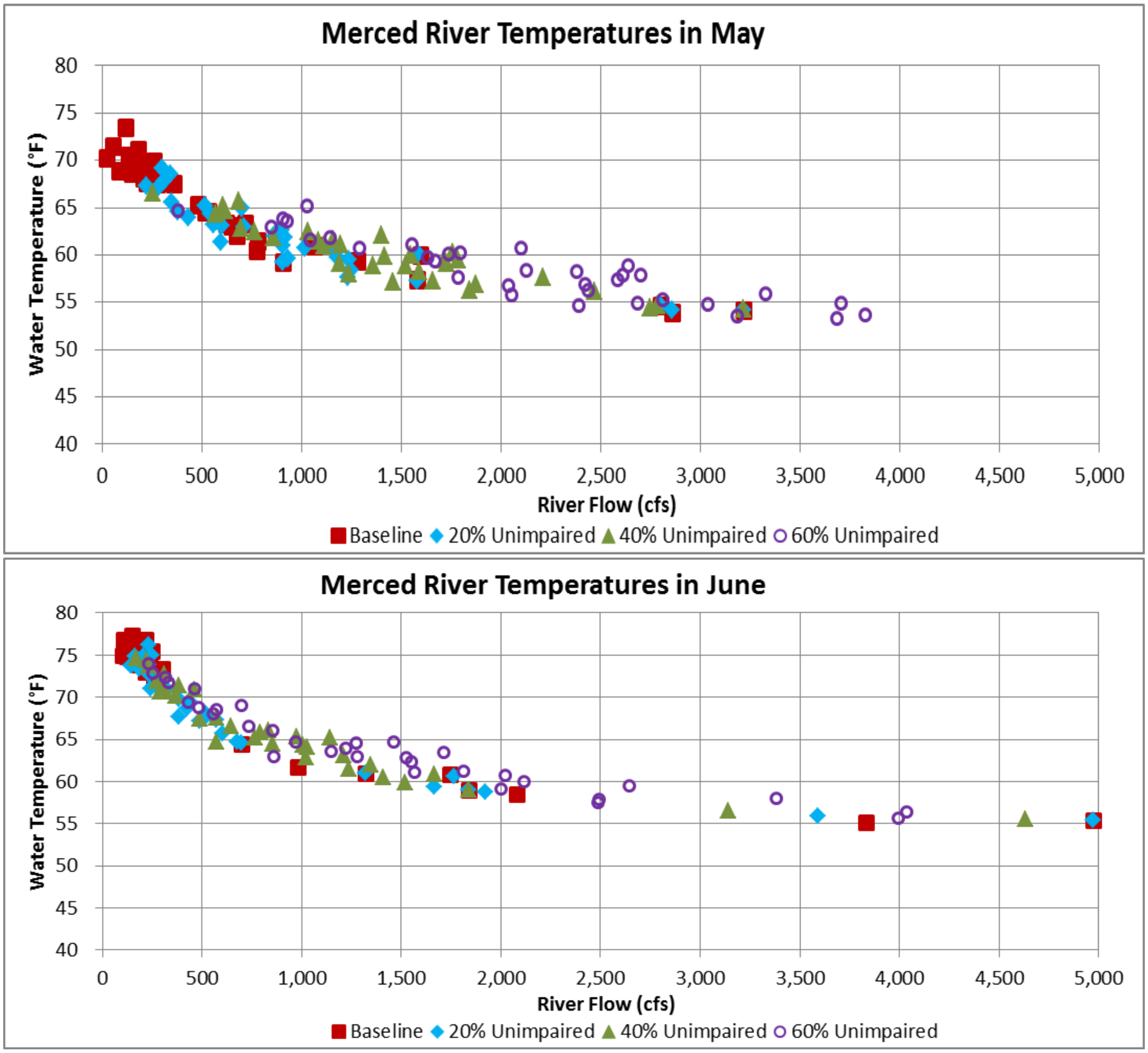


Figure F.1.6-44b. Effects of Merced River Flows on Temperatures at RM 27.1 in May and June for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4) 1970–2003

Table F.1.6-4a. Monthly Distribution of Merced River Water Temperatures at RM 27.1 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Merced River Temperatures at RM 27.1 for Baseline Conditions												
Minimum	58.7	54.2	49.5	47.5	48.3	48.7	50.2	53.9	54.1	58.2	62.7	61.6
10%	60.9	55.1	49.7	48.6	50.2	51.2	56.4	57.9	56.4	60.3	63.8	64.1
20%	61.2	55.2	50.2	49.1	50.8	54.0	57.5	60.3	60.9	63.8	64.2	65.4
30%	61.6	56.0	50.6	49.2	51.3	55.6	59.1	62.0	71.5	74.8	66.1	66.6
40%	61.7	56.6	51.0	49.8	52.4	56.6	60.1	63.6	73.2	76.3	74.3	70.6
50%	62.6	57.1	51.2	50.0	52.9	57.1	61.9	66.4	73.9	76.7	75.4	72.1
60%	63.6	57.9	52.0	50.5	53.6	58.1	63.2	68.0	74.6	77.1	75.9	73.6
70%	64.8	58.8	52.5	50.9	54.1	58.6	63.8	68.9	75.0	77.7	76.9	74.2
80%	65.7	60.0	52.9	51.2	55.1	59.3	65.1	70.1	75.4	79.1	77.9	75.8
90%	68.6	61.1	53.4	52.3	55.5	59.9	65.8	70.9	76.1	80.1	79.0	76.8
Maximum	70.2	62.7	54.0	53.2	56.7	60.4	67.1	73.5	77.4	80.7	81.8	78.2
Average	63.6	57.7	51.6	50.2	52.8	56.5	61.3	65.1	69.9	73.1	72.5	70.9
Change in Merced River Temperatures at RM 27.1 for 20% Unimpaired Flow Relative to Baseline												
Minimum	0.0	-0.4	-0.3	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
10%	-0.4	0.0	0.0	0.0	-0.3	-0.2	-0.1	-0.5	0.4	0.0	0.0	0.1
20%	-0.1	0.1	0.0	0.0	0.0	0.0	0.4	-0.9	-0.8	0.1	0.1	0.0
30%	-0.1	-0.2	-0.1	0.5	0.6	0.0	1.0	-1.9	-6.8	-0.4	1.3	0.0
40%	0.1	-0.4	0.0	0.3	0.4	0.2	0.4	-2.5	-5.8	-0.5	0.1	-0.2
50%	0.0	-0.1	0.0	0.3	0.5	0.4	-0.7	-4.2	-6.0	-0.4	0.0	-0.3
60%	-0.1	-0.6	-0.6	0.0	0.1	0.1	-1.9	-5.0	-4.8	-0.1	-0.1	-0.5
70%	-1.2	-0.9	-0.6	-0.1	0.4	0.0	-1.4	-4.9	-3.7	0.0	0.0	-0.2
80%	-1.3	-1.7	-0.8	0.1	-0.1	-0.3	-2.4	-5.0	-1.6	-0.4	0.0	-0.6
90%	-2.9	-1.9	-0.4	0.0	0.2	0.2	-2.3	-3.7	-1.4	-0.8	-0.4	-0.2
Maximum	-2.7	-2.5	-0.5	0.1	0.5	0.1	0.4	-4.4	-1.2	-0.1	-0.3	-0.2
Average	-0.8	-0.7	-0.3	0.1	0.2	0.1	-0.8	-3.0	-2.8	-0.3	0.1	-0.2
Change in Merced River Temperatures at RM 27.1 for 40% Unimpaired Flow Relative to Baseline												
Minimum	0.0	-0.1	-0.4	0.0	0.0	0.0	0.2	0.4	0.0	0.0	0.0	0.0
10%	-1.1	0.1	0.1	0.0	-0.7	-0.1	-0.5	-1.8	0.9	0.1	0.1	-0.1
20%	-0.3	0.4	0.1	0.0	0.2	-0.1	-0.5	-3.1	-0.2	2.7	0.4	-0.1
30%	-0.1	-0.1	-0.1	0.3	0.6	-0.4	-1.4	-3.8	-8.8	-4.8	2.8	-0.9
40%	-0.1	-0.6	0.0	0.3	-0.1	-0.6	-2.1	-4.5	-8.9	-1.7	-0.3	-0.1
50%	-0.6	-0.4	0.0	0.2	0.1	-0.5	-3.1	-6.8	-8.7	-1.0	-0.3	-0.7
60%	-0.9	-0.9	-0.5	0.0	0.1	-0.8	-4.1	-7.2	-8.6	-0.5	-0.2	-1.3
70%	-1.0	-1.4	-0.6	-0.1	0.1	-0.9	-4.4	-7.2	-7.2	-0.4	-0.3	-0.9
80%	-1.5	-1.8	-0.6	0.0	-0.2	-1.0	-4.7	-7.6	-4.6	-0.6	0.2	-0.7
90%	-2.7	-1.9	-0.5	0.0	-0.1	-0.9	-4.7	-6.4	-3.6	-1.0	-0.3	-0.1
Maximum	-2.5	-3.1	-0.3	0.2	0.5	-0.4	-0.2	-7.0	-2.8	-0.6	-0.2	0.0
Average	-1.0	-0.8	-0.3	0.1	0.0	-0.5	-2.7	-5.1	-4.7	-0.5	0.1	-0.4

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Change in Merced River Temperatures at RM 27.1 for 60% Unimpaired Flow Relative to Baseline												
Minimum	-0.1	0.8	-0.5	0.0	-0.5	0.0	0.1	-0.6	0.9	0.1	0.3	0.0
10%	-0.5	0.4	0.0	-0.1	-1.5	-0.3	-3.0	-3.3	1.2	5.5	1.4	0.3
20%	-0.3	0.5	0.2	0.1	-0.6	-1.1	-2.5	-5.1	-1.6	4.1	3.1	-0.4
30%	-0.1	-0.3	0.2	0.1	-0.1	-1.5	-2.8	-5.7	-10.4	-6.1	1.4	-1.0
40%	0.0	-0.3	0.2	0.1	0.0	-1.7	-3.2	-6.1	-10.4	-1.6	0.0	0.1
50%	-0.5	-0.5	0.2	0.1	0.2	-1.5	-4.5	-8.4	-10.3	-1.1	-0.1	-0.4
60%	-0.8	-0.8	-0.2	-0.2	-0.1	-1.9	-5.5	-8.8	-9.9	-0.5	0.2	-0.7
70%	-0.9	-1.1	-0.3	-0.2	-0.4	-2.2	-5.8	-8.6	-8.2	-0.2	-0.2	-0.5
80%	-1.1	-1.5	-0.3	0.0	-0.7	-1.6	-5.9	-8.8	-6.5	-0.4	0.5	0.0
90%	-1.5	-1.3	-0.4	0.0	-0.4	-1.5	-5.7	-7.5	-4.6	-0.8	0.0	0.1
Maximum	0.0	0.0	-0.3	0.0	0.5	-1.1	-1.8	-8.3	-3.4	-0.7	0.4	0.1
Average	-0.5	-0.5	-0.1	0.0	-0.3	-1.4	-4.2	-6.6	-5.9	0.1	0.6	-0.1

Table F.1.6-4b. Monthly Distribution of Merced River Water Temperatures at RM 27.1 1970–2003 for Baseline Conditions and 20%, 40%, 60% Unimpaired Flow (LSJR Alternatives 2–4)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average Merced River Temperatures at RM 27.1												
Baseline Average	63.6	57.7	51.6	50.2	52.8	56.5	61.3	65.1	69.9	73.1	72.5	70.9
Change in Average Merced River Temperatures at RM 27.1 Relative to Baseline												
20% Unimpaired Flow Minus Baseline	-0.8	-0.7	-0.3	0.1	0.2	0.1	-0.8	-3.0	-2.8	-0.3	0.1	-0.2
30% Unimpaired Flow Minus Baseline	-0.7	-0.7	-0.3	0.1	0.1	-0.2	-2.1	-4.4	-3.9	0.2	0.7	0.1
40% Unimpaired Flow Minus Baseline	-1.0	-0.8	-0.3	0.1	0.0	-0.5	-2.7	-5.1	-4.7	-0.5	0.1	-0.4
50% Unimpaired Flow Minus Baseline	-0.9	-0.7	-0.2	0.1	-0.1	-0.9	-3.5	-5.9	-5.4	-0.3	0.4	-0.3
60% Unimpaired Flow Minus Baseline	-0.5	-0.5	-0.1	0.0	-0.3	-1.4	-4.2	-6.6	-5.9	0.1	0.6	-0.1

Figures F.1.6-45, F.1.6-46, F.1.6-47, and F.1.6-48 show Merced River temperature model results under baseline conditions and under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow objectives Feb–June) for the water years 1985–1989, 1990–1994, 1995–1999, and 2000–2003, respectively. Each figure is composed of three separate charts to compare how reservoir storage and river flow can affect temperatures at different points along the river. Chart A shows reservoir storage at Lake McClure, Chart B shows the instream flows at Stevinson, and Chart C gives the daily 7DADM temperature at New Exchequer Dam release, Crocker-Huffman Dam release, and 1/4 River location.

Figures F.1.6-49a and F.1.6-49b show temperature model 7DADM results at 3/4 River (Merced RM 37.8) compared to monthly USEPA temperature criteria for optimal development of different fish lifestages (as described in Chapter 19) under LSJR Alternatives 2 and 3 (40 and 60 percent of unimpaired flow Feb–June) and baseline conditions for water years 1985–1989 and water years 1990–1994, respectively. These show temperature effects of reservoir levels within the major drought sequence 1989–1992.

Figures F.1.6-50, F.1.6-51, F.1.6-52, F.1.6-53, F.1.6-54, and F.1.6-55 show longitudinal monthly average 7DADM temperature results in the Merced River for each month of the water year 1988 under baseline conditions and the LSJR alternatives. Water year 1988 is shown because it represents a year when storage levels in New Exchequer Reservoir were around 400 thousand acre feet (medium storage level) under the model scenarios. Figures F.1.6-56, F.1.6-57, F.1.6-58, F.1.6-59, F.1.6-60, and F.1.6-61 show longitudinal monthly average 7DADM temperature results for each month of the water year 1990 under baseline conditions and the LSJR alternatives. Water year 1990 is shown because it represents a year in the middle of the 1989–1992 drought sequence when Lake McClure storage levels were generally low.

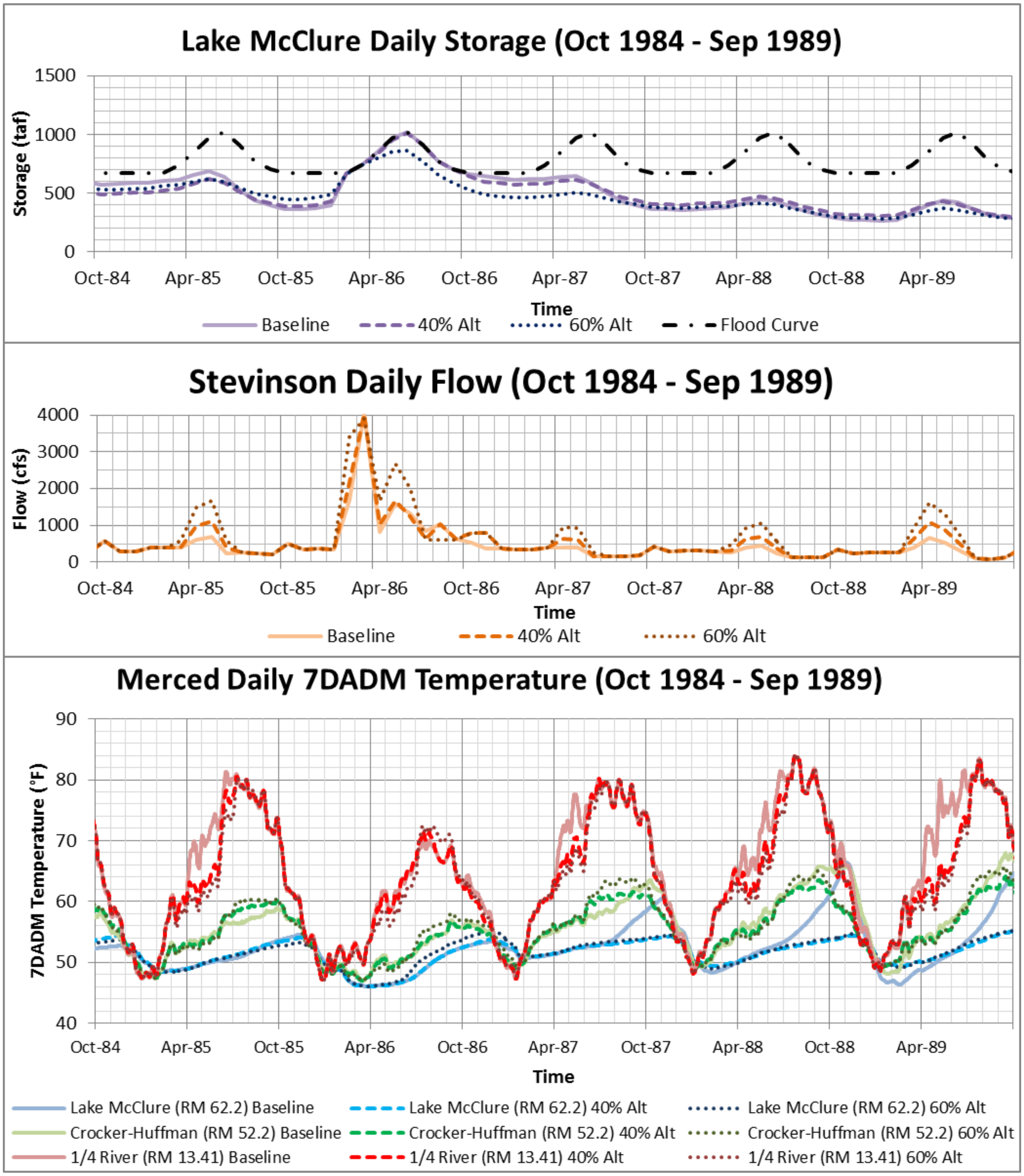


Figure F.1.6-45. Merced River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1985–1989, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at Lake McClure Release, Crocker-Huffman Dam Release, and 1/4 River Locations

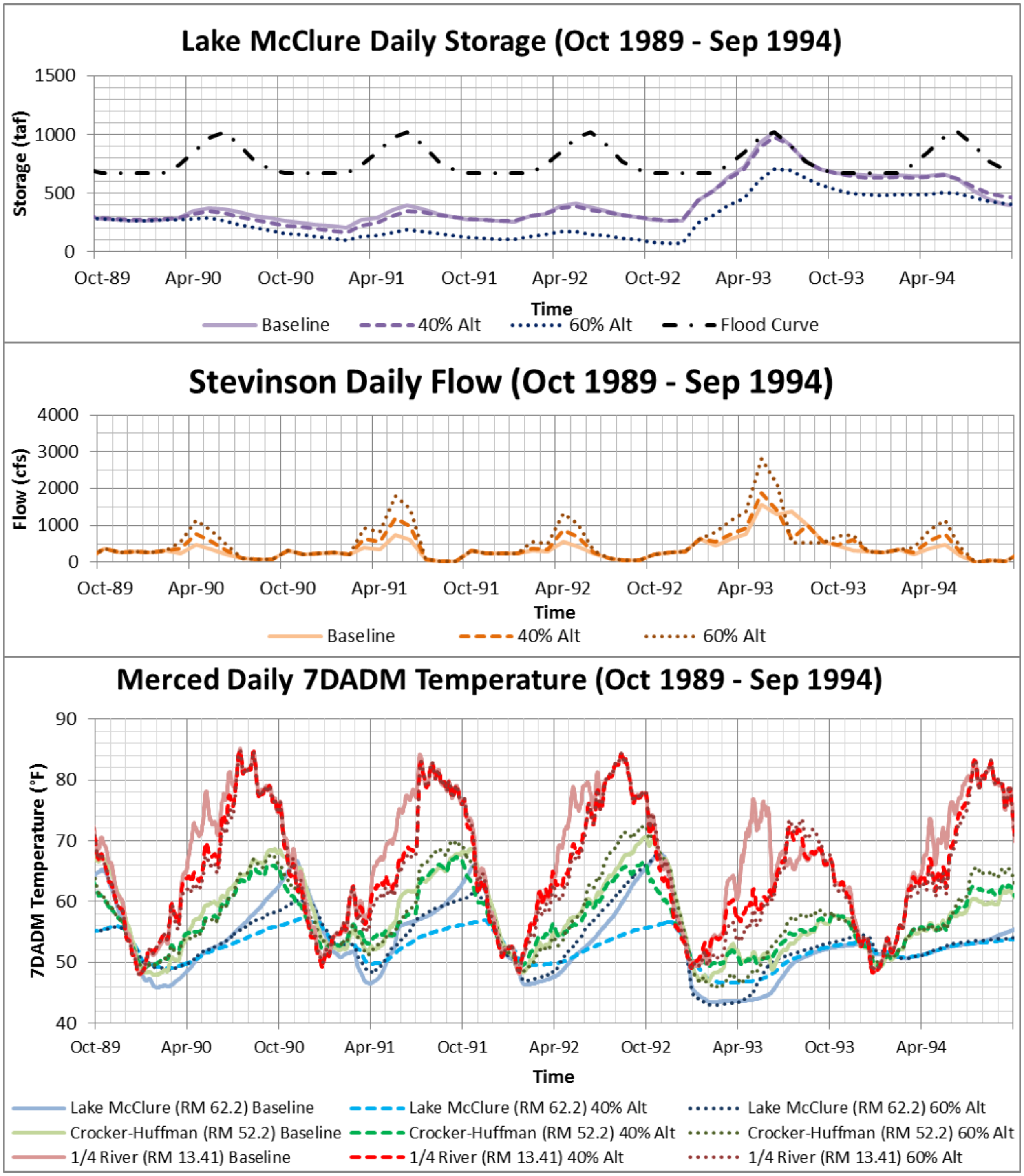


Figure F.1.6-46. Merced River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1990–1994, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at Lake McClure Release, Crocker-Huffman Dam Release, and 1/4 River Locations

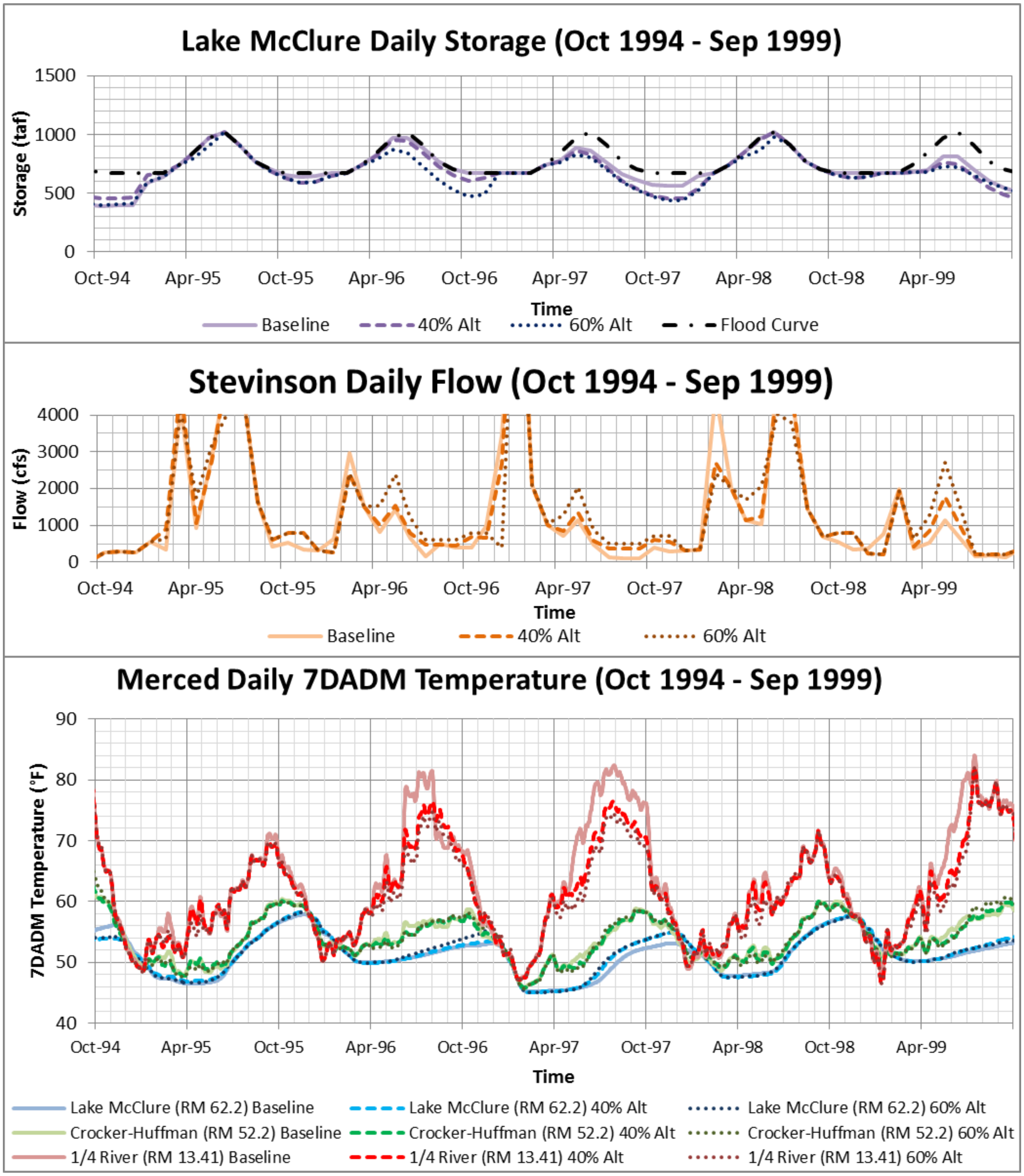


Figure F.1.6-47. Merced River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 1995–1999, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at Lake McClure Release, Crocker-Huffman Dam Release, and 1/4 River Locations

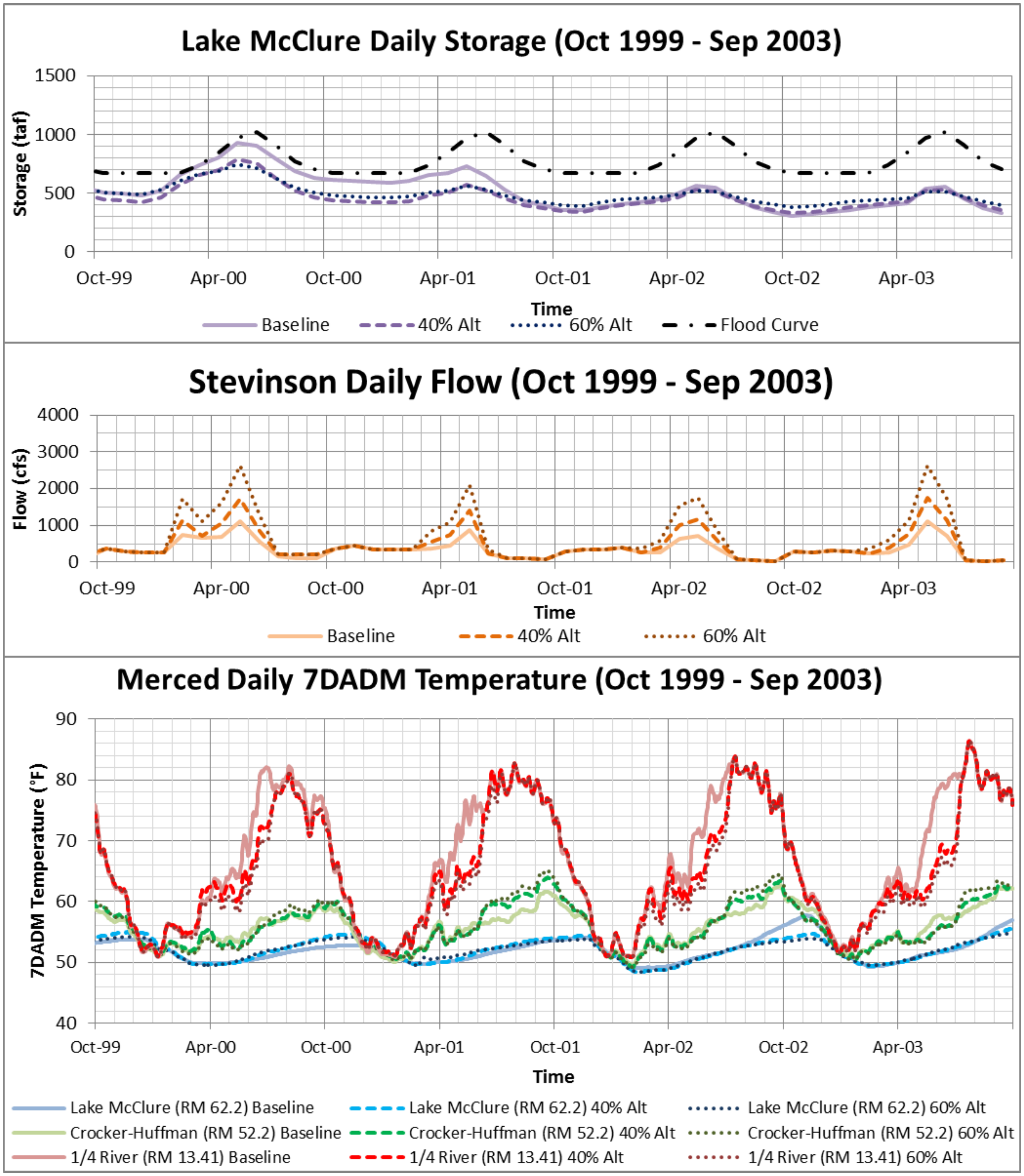
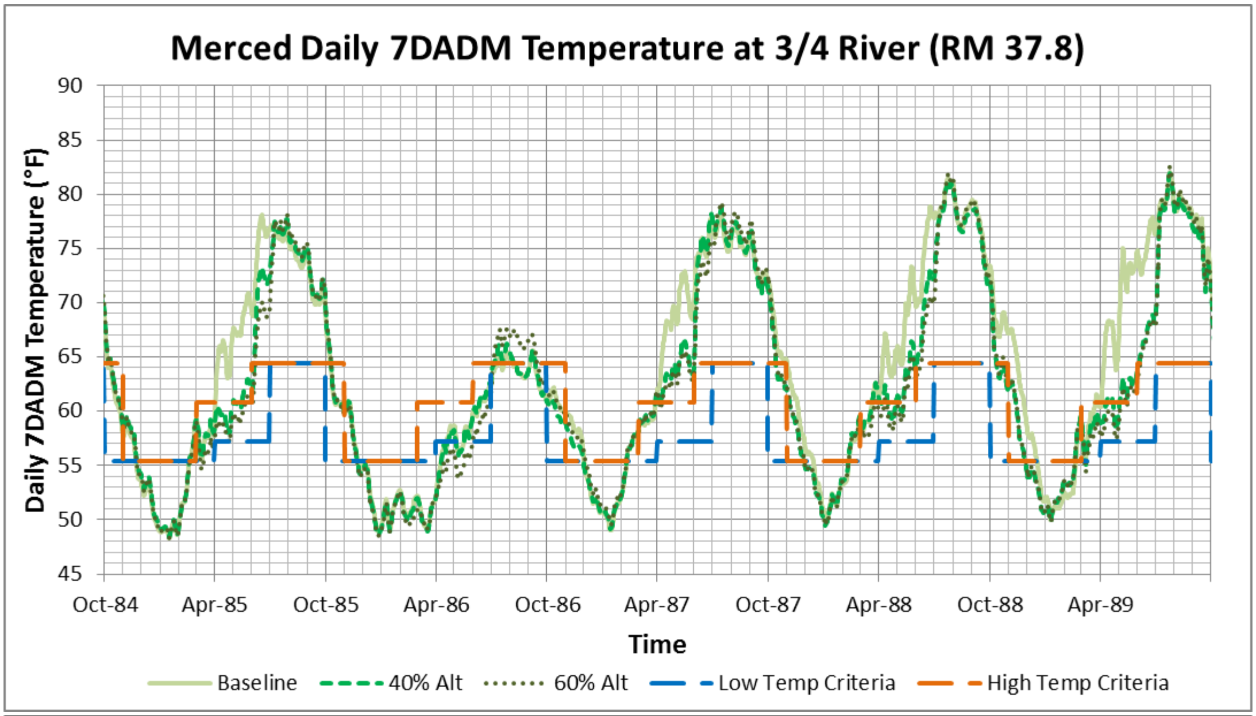


Figure F.1.6-48. Merced River Temperature Model Results for LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) and Baseline Scenarios for the Water Years 2000–2003, Showing (a) Reservoir Storage, (b) Instream Flows, and (c) Daily 7DADM Temperature at Lake McClure Release, Crocker-Huffman Dam Release, and 1/4 River Locations



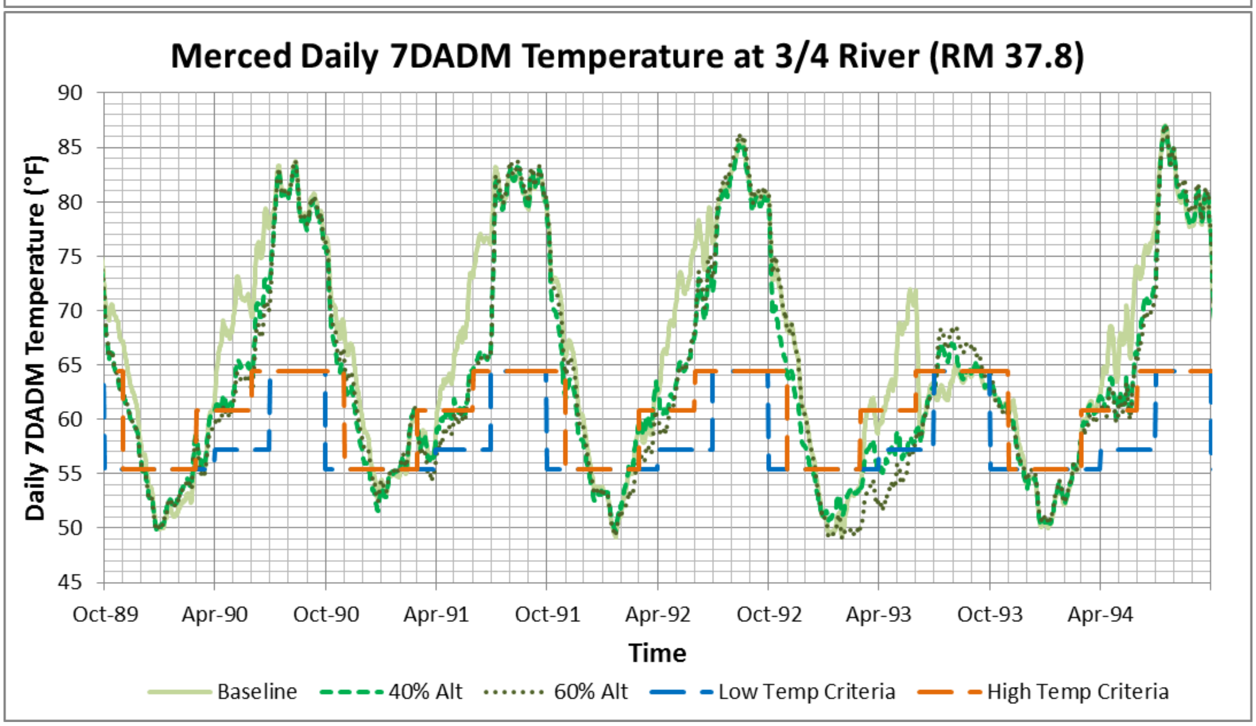
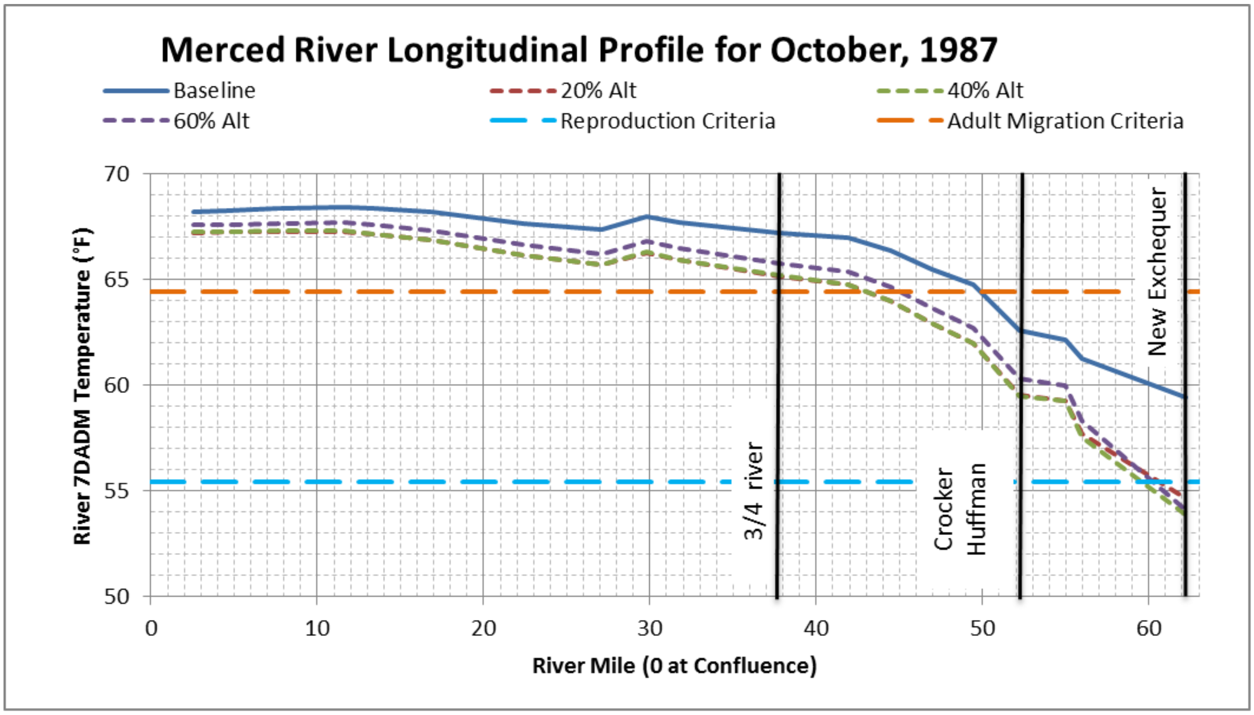


Figure F.1.6-49. Temperature Model 7DADM Results at Merced RM 37.8 Compared to Monthly USEPA Temperature Criteria for Optimal Development of Different Fish Lifestages under Baseline and LSJR Alternatives 2 and 3 (40% and 60% of Unimpaired Flow Feb–June) for (a) Water Years 1985–1989 and (b) Water Years 1990–1994



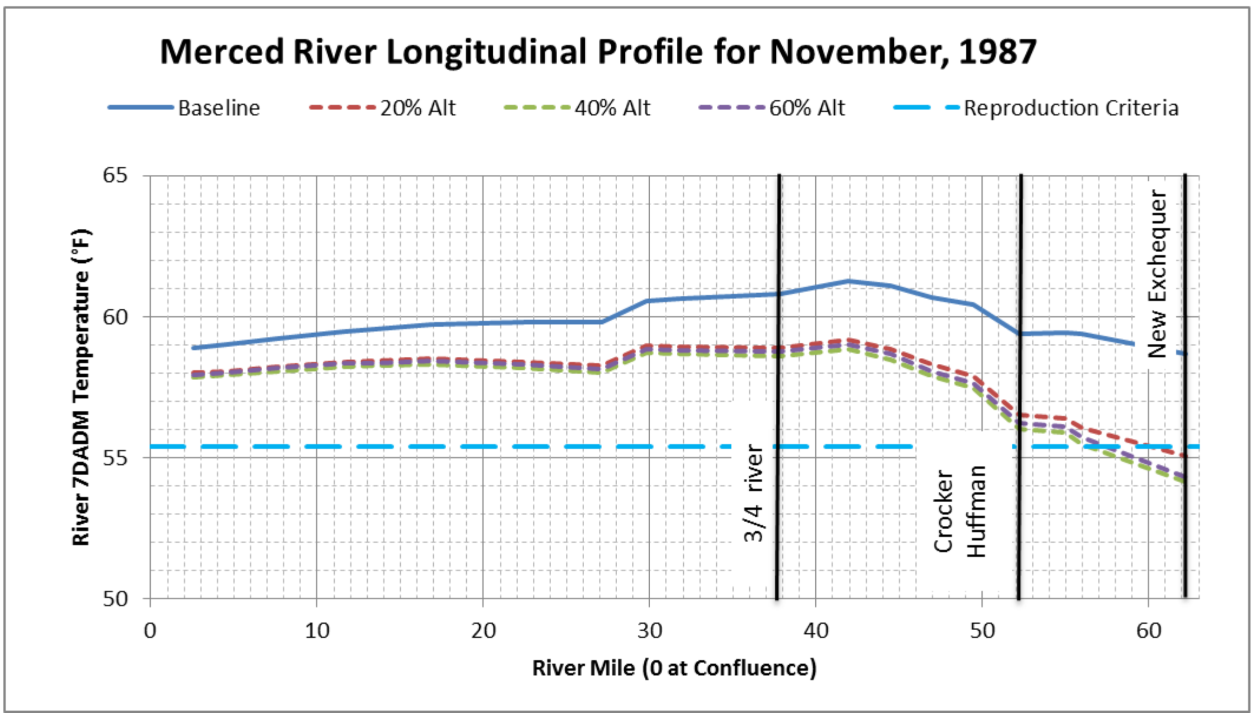
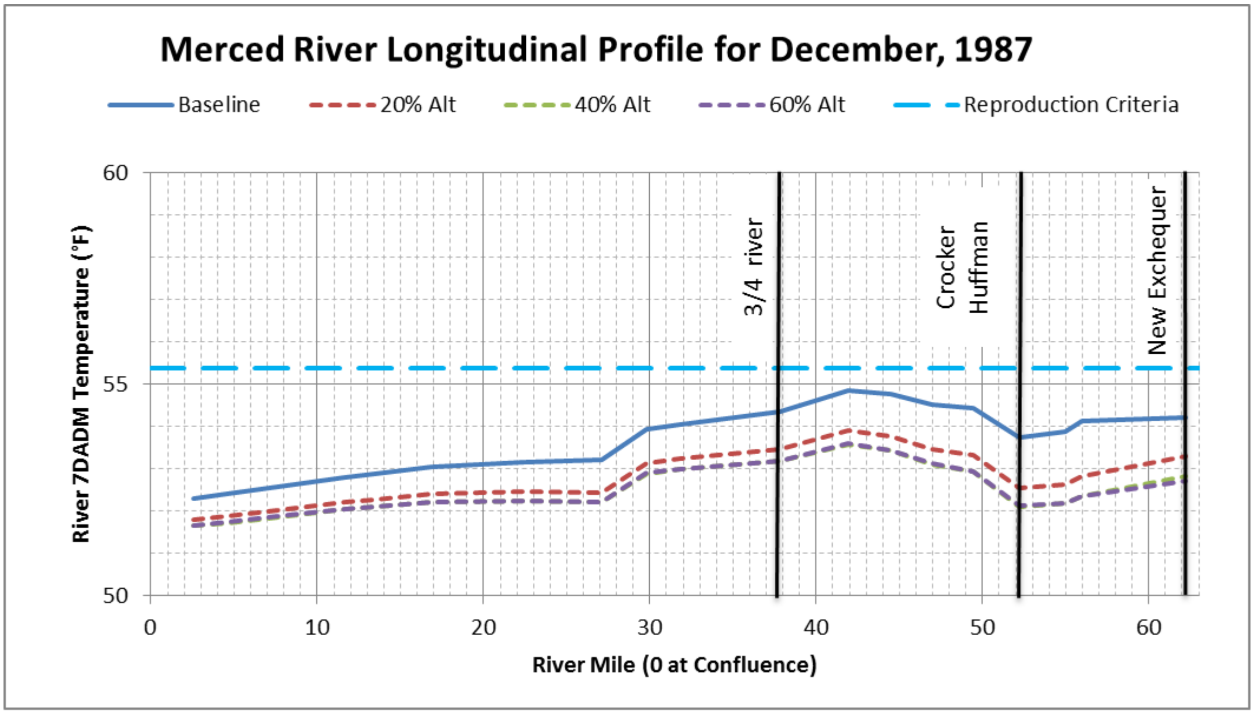


Figure F.1.6-50. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) October 1987 and (b) November 1987



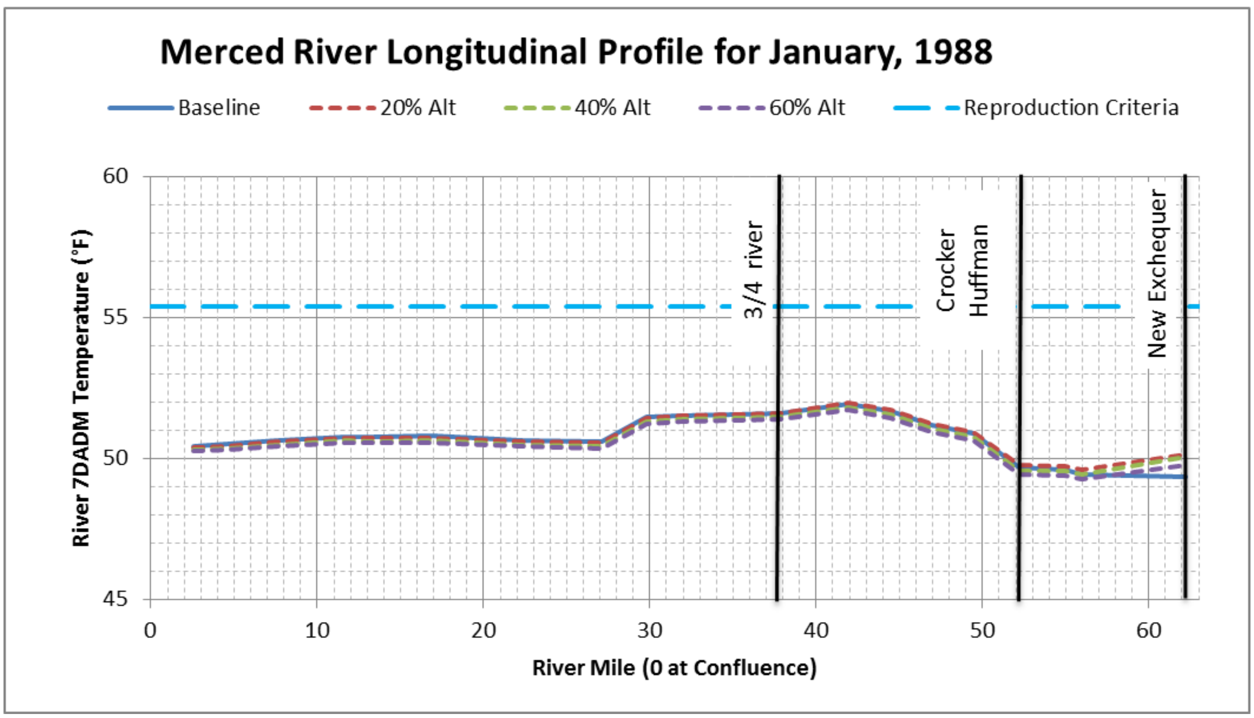
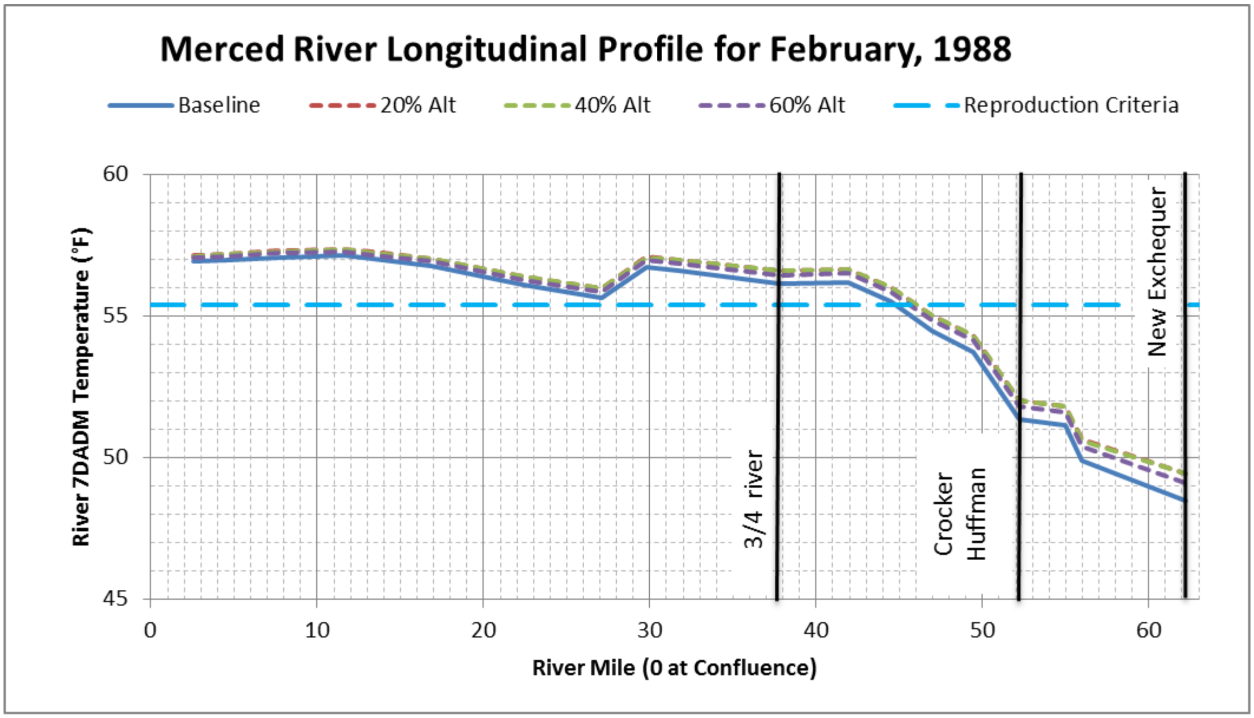


Figure F.1.6-51. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) December 1987 and (b) January 1988



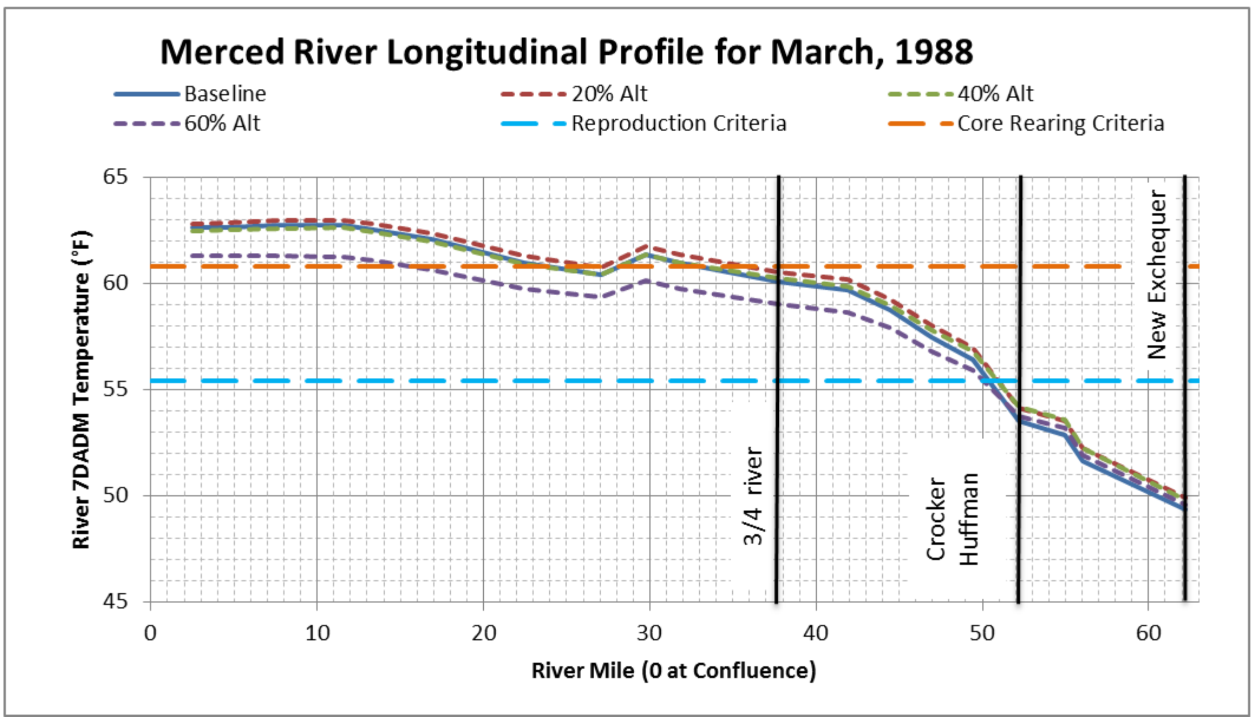
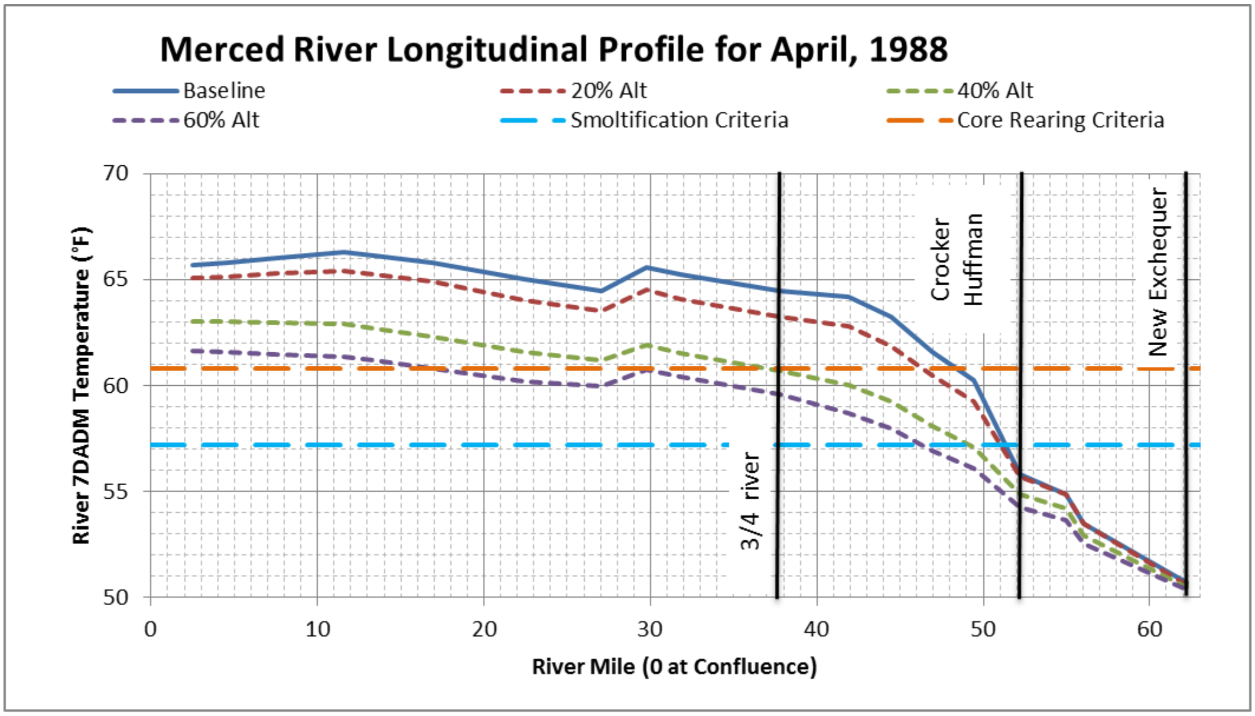


Figure F.1.6-52. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) February 1988 and (b) March 1988



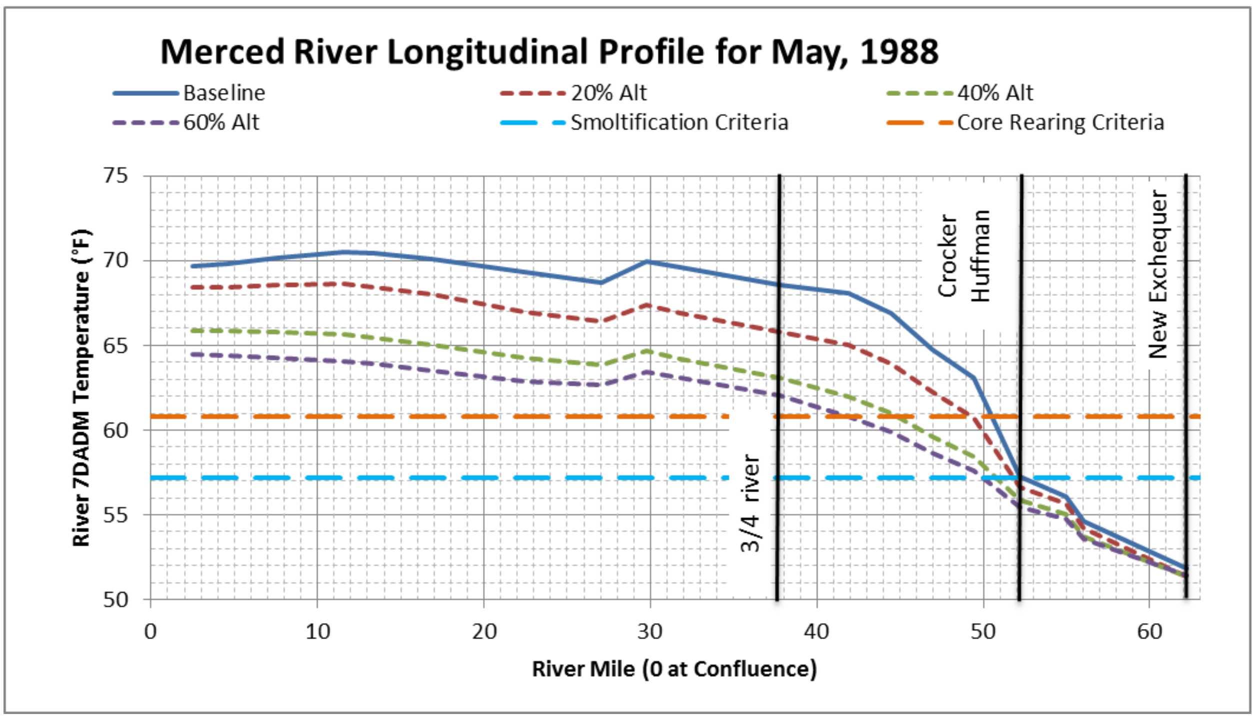


Figure F.1.6-53. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) April 1988 and (b) May 1988

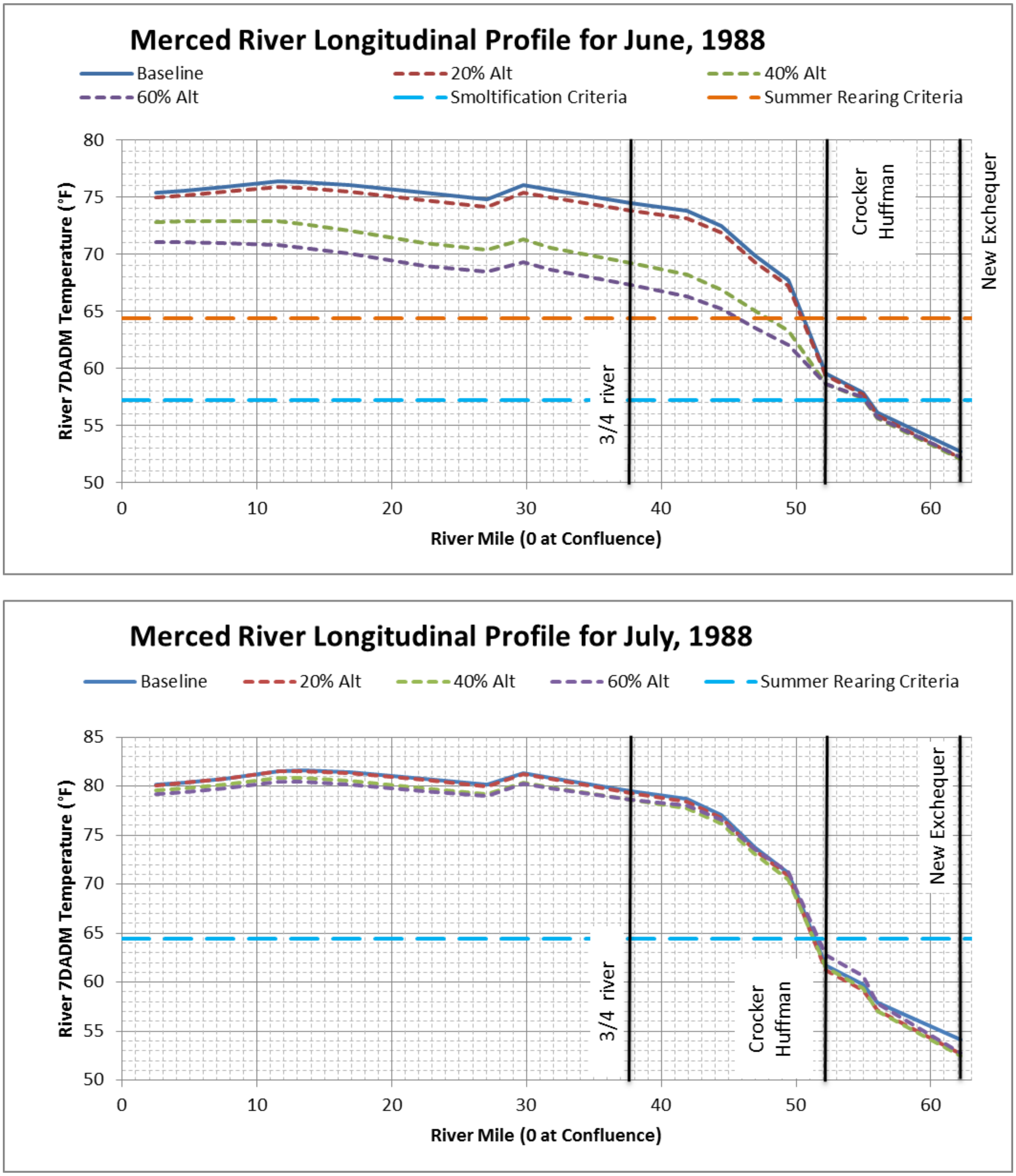
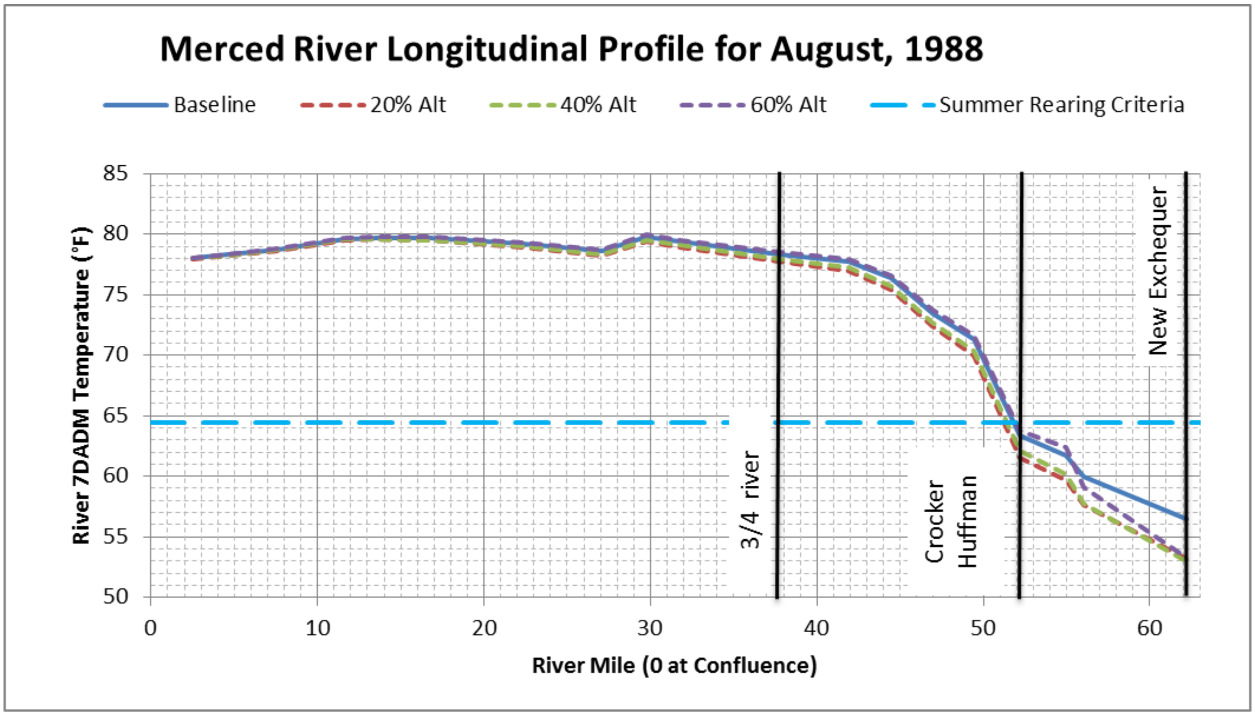


Figure F.1.6-54. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) June 1988 and (b) July 1988



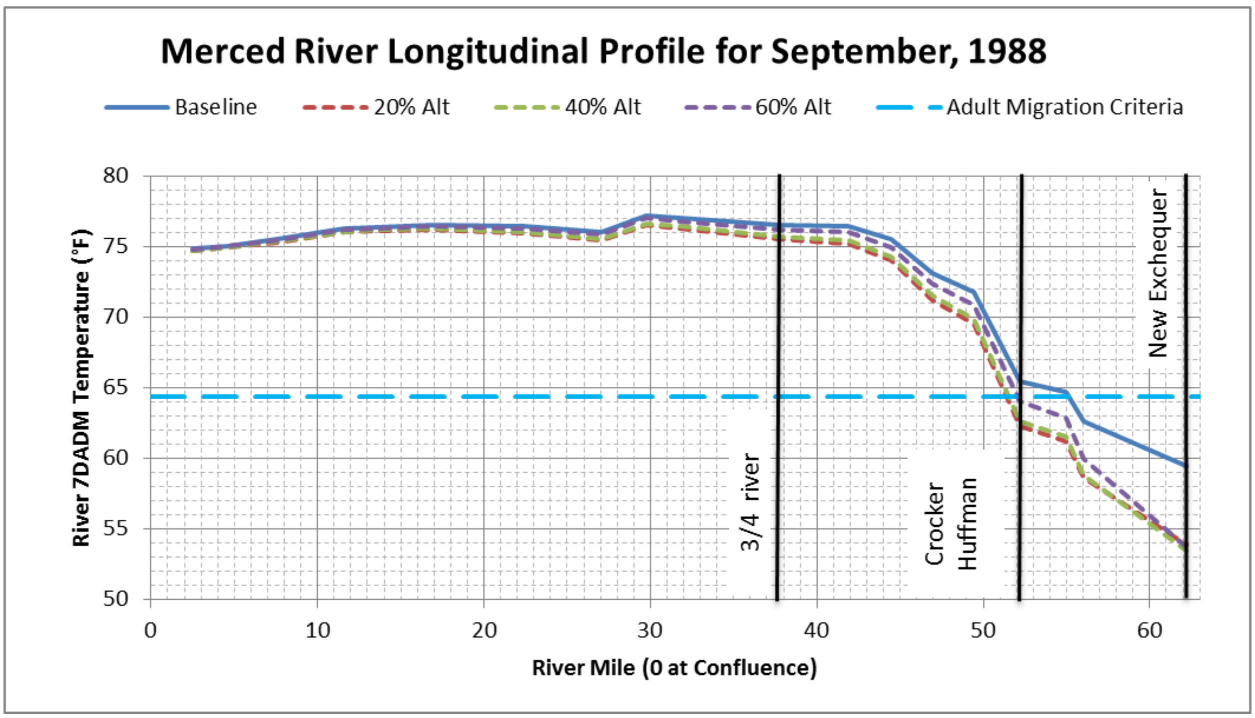
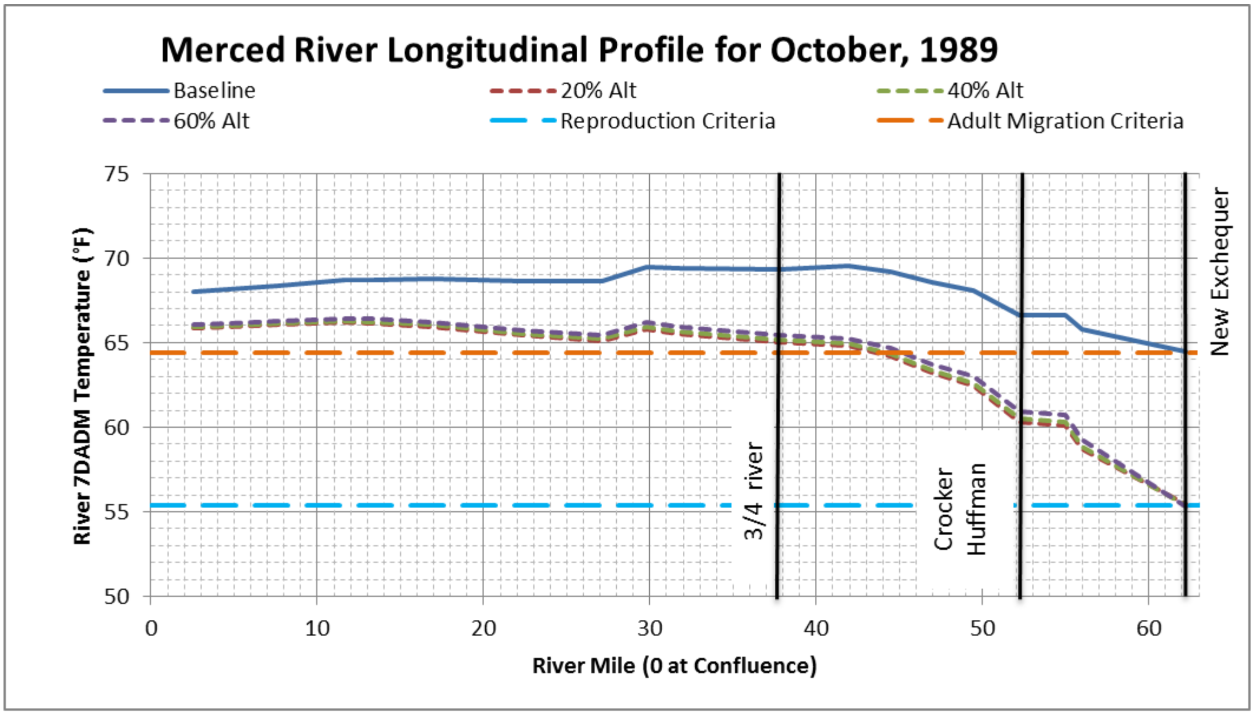


Figure F.1.6-55. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) August 1988 and (b) September 1988



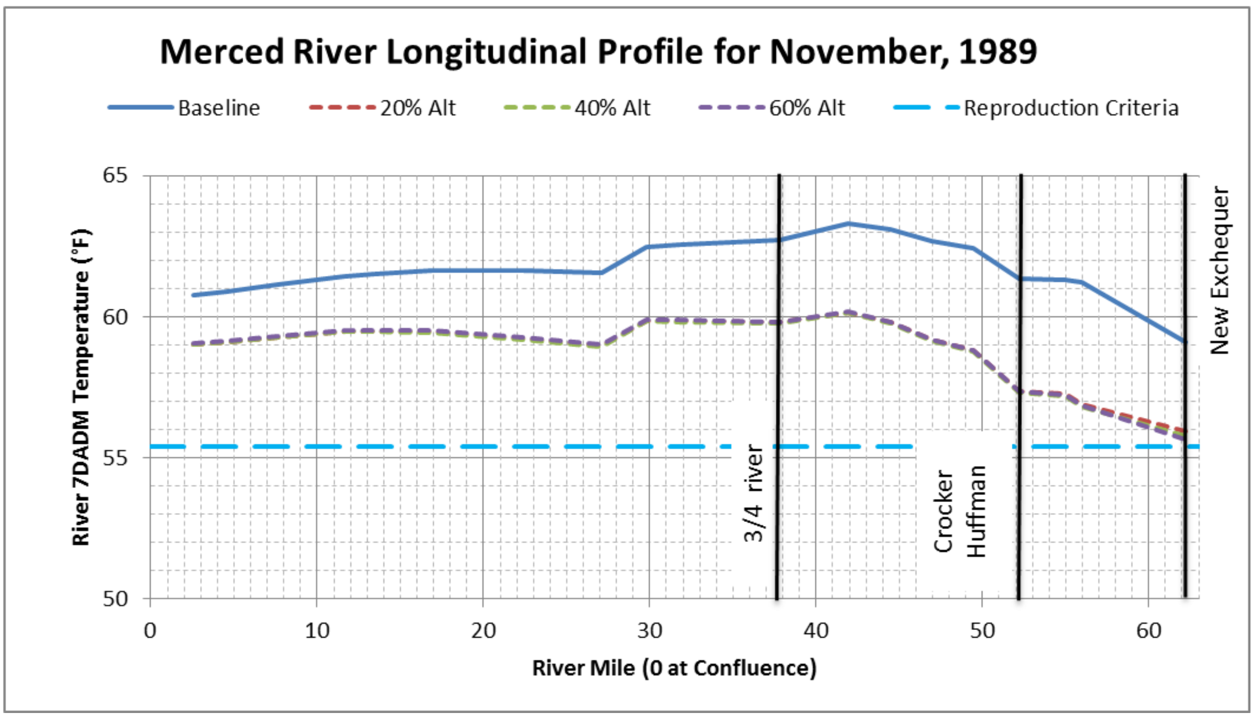
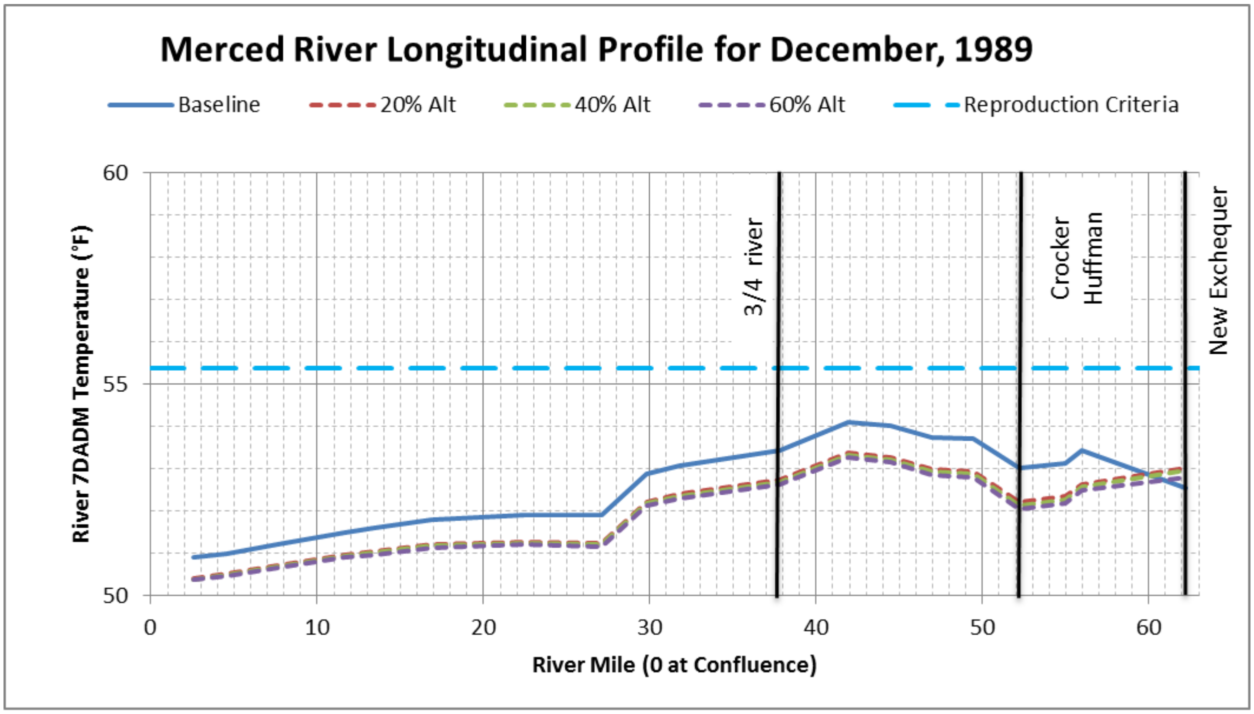


Figure F.1.6-56. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) October 1989 and (b) November 1989



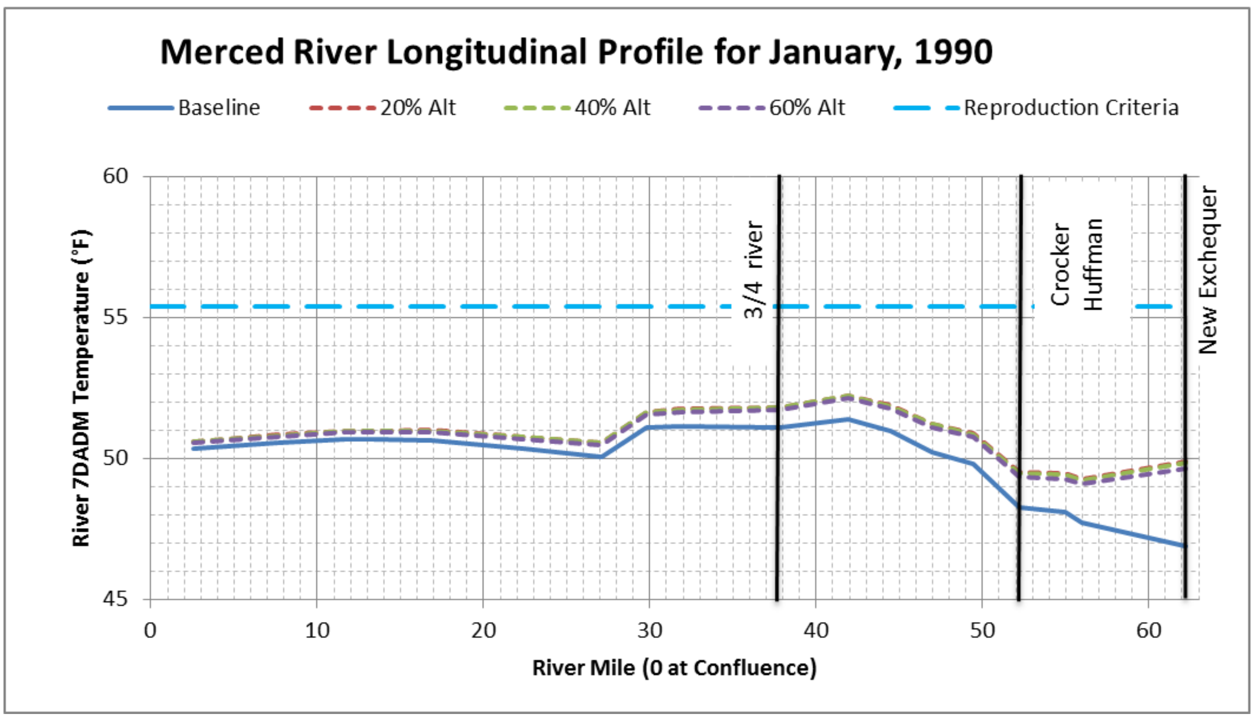


Figure F.1.6-57. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) December 1989 and (b) January 1990

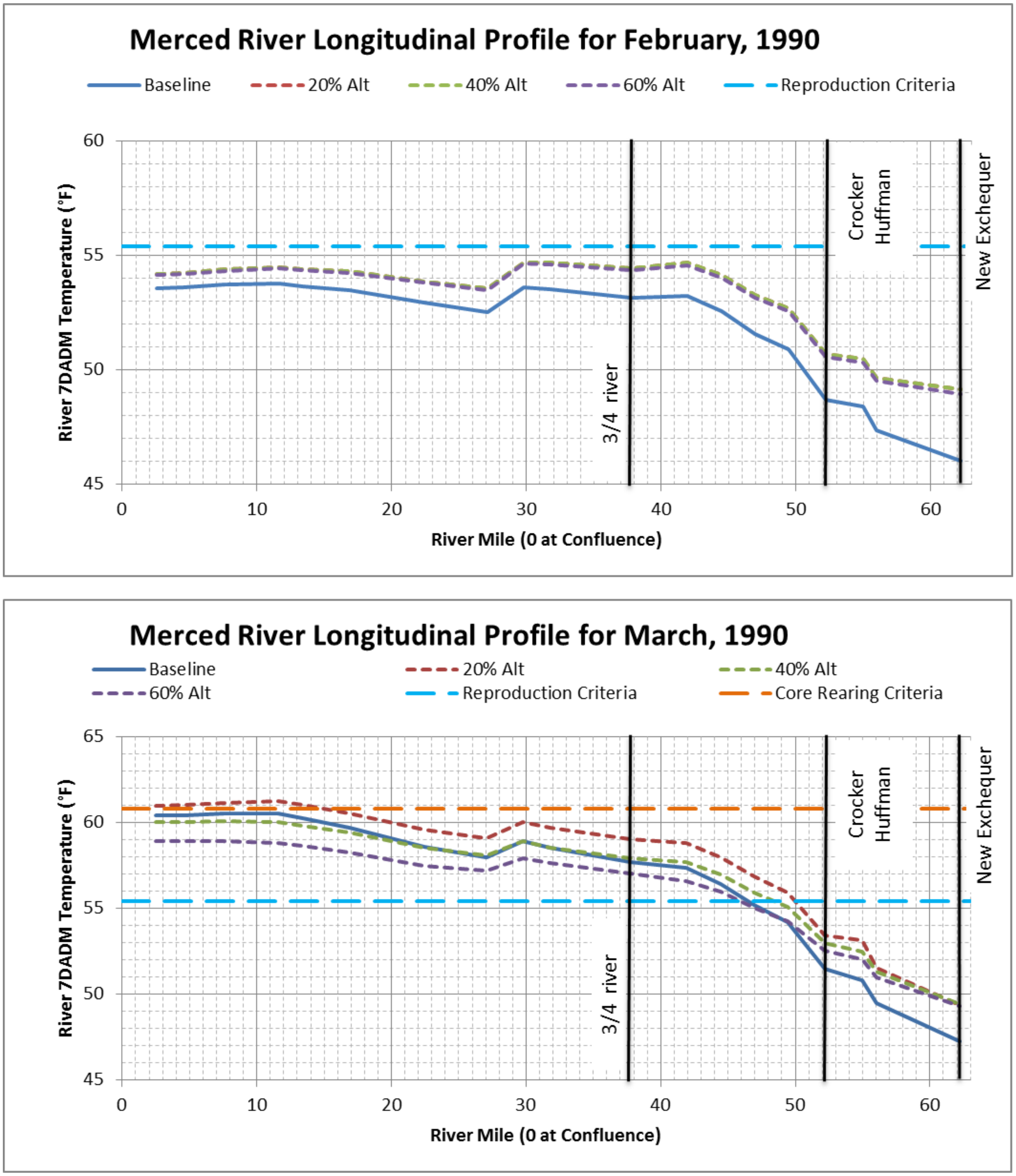
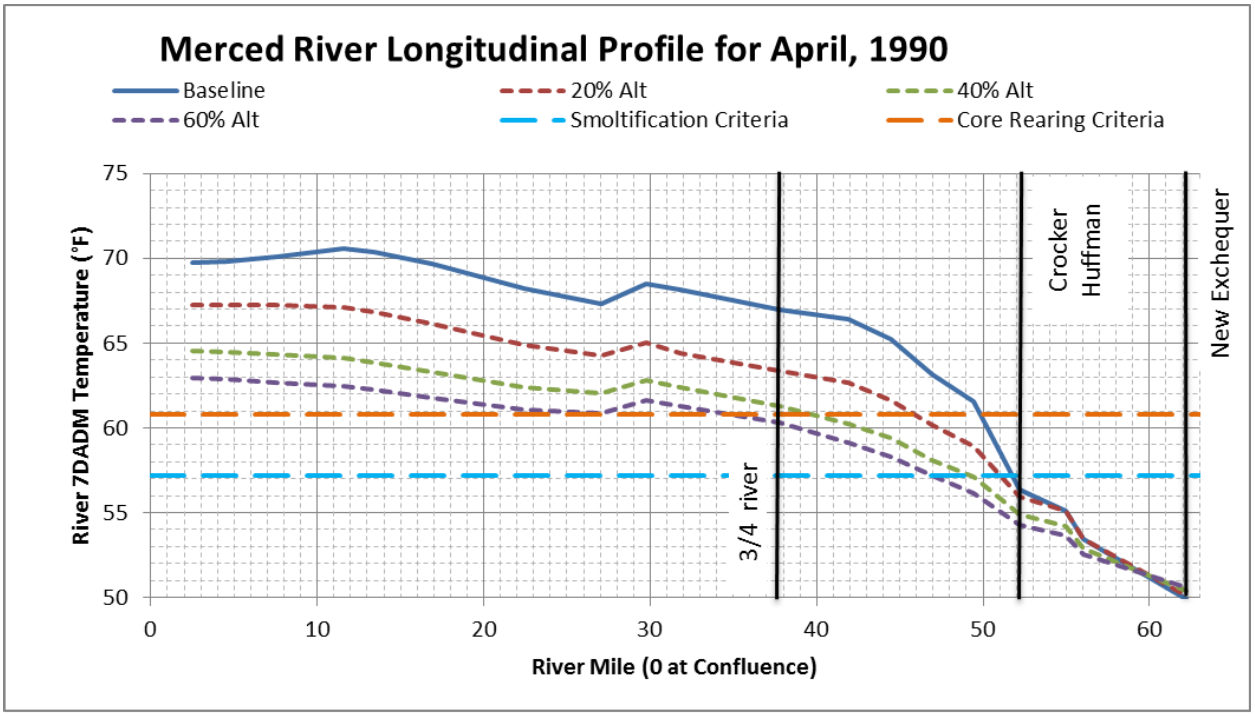


Figure F.1.6-58. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) February 1990 and (b) March 1990



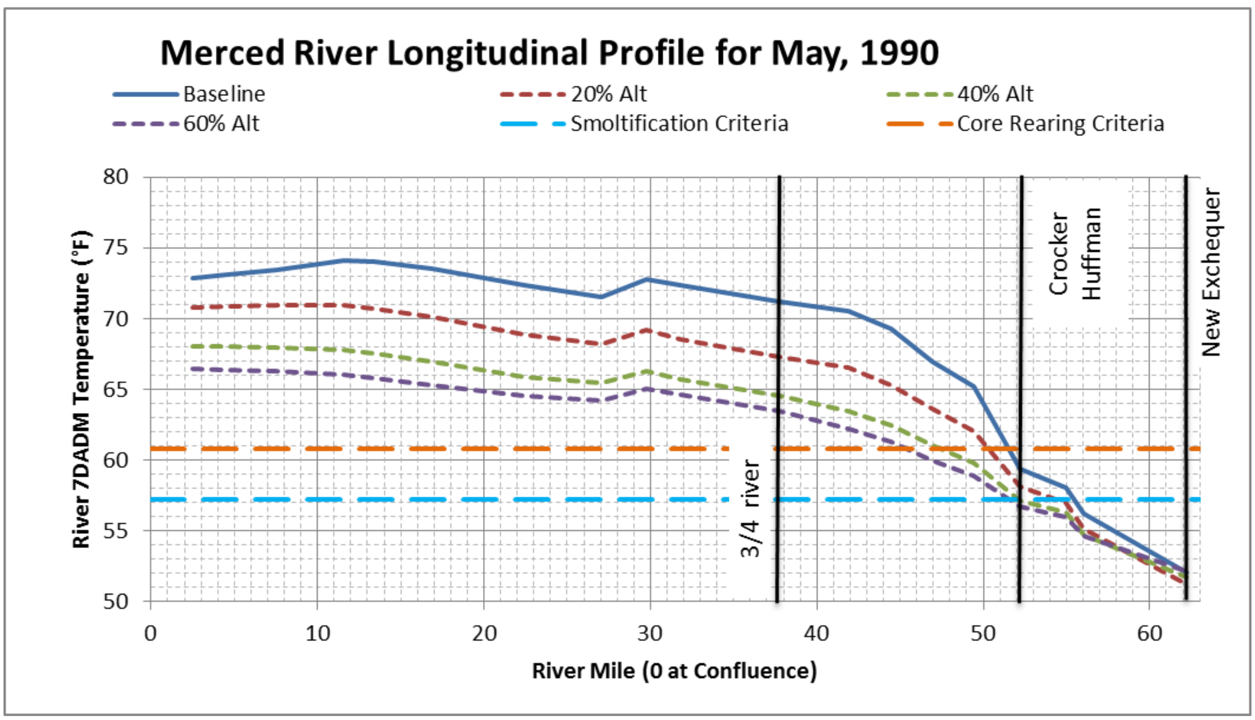
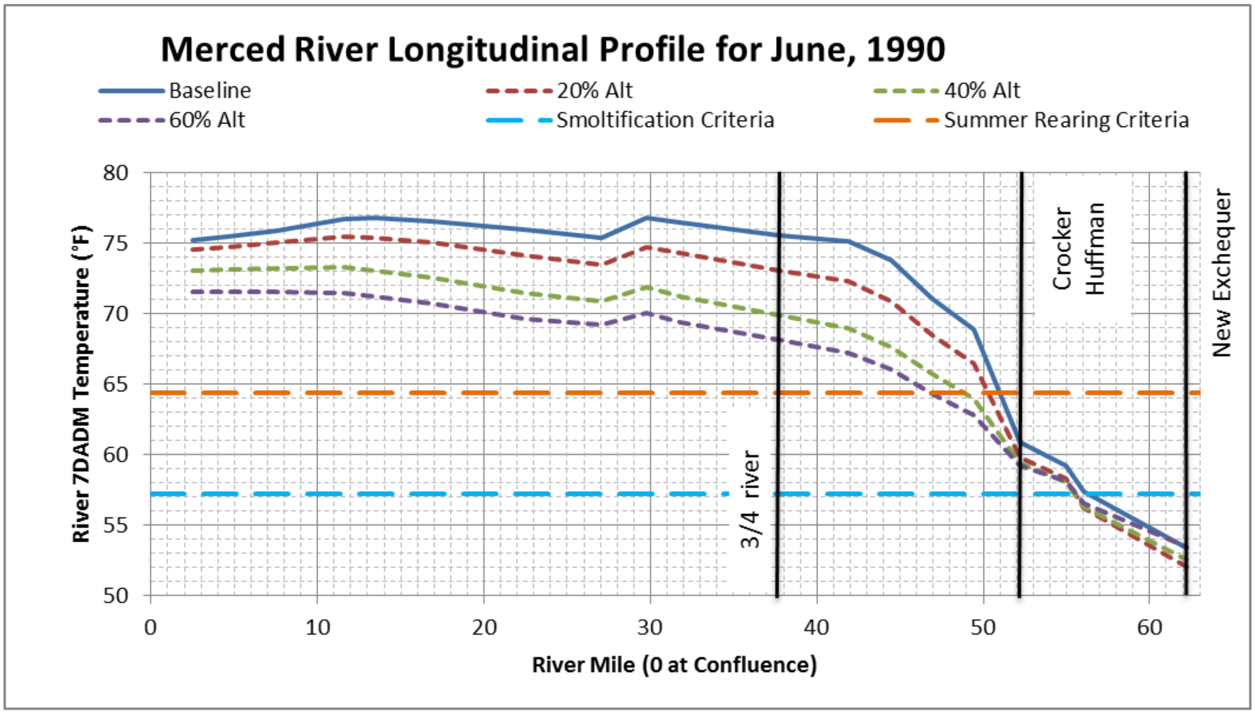


Figure F.1.6-59. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) April 1990 and (b) May 1990



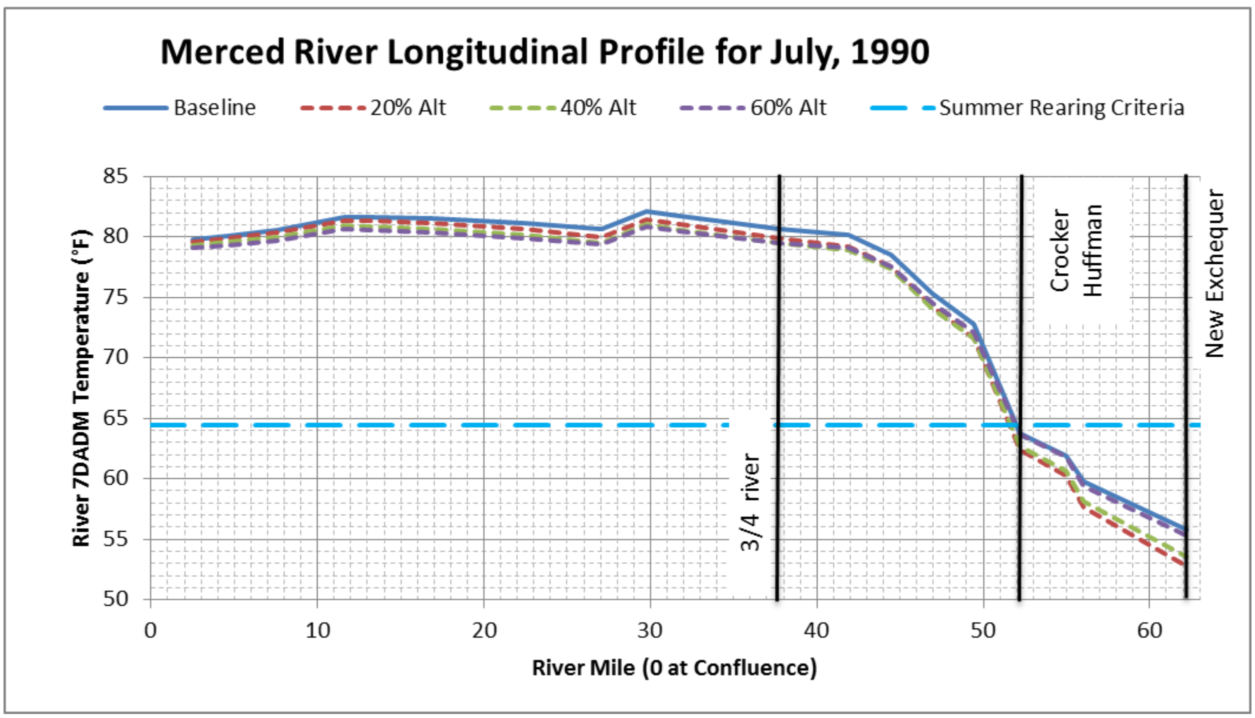
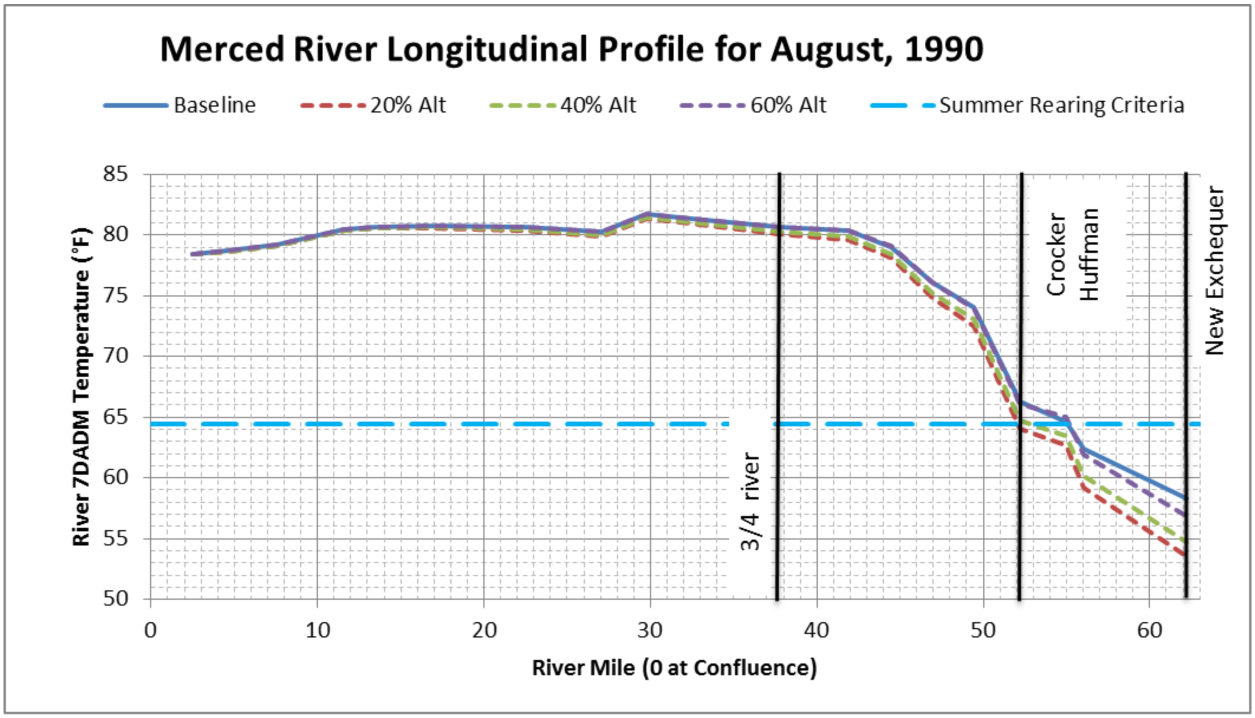


Figure F.1.6-60. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) June 1990 and (b) July 1990



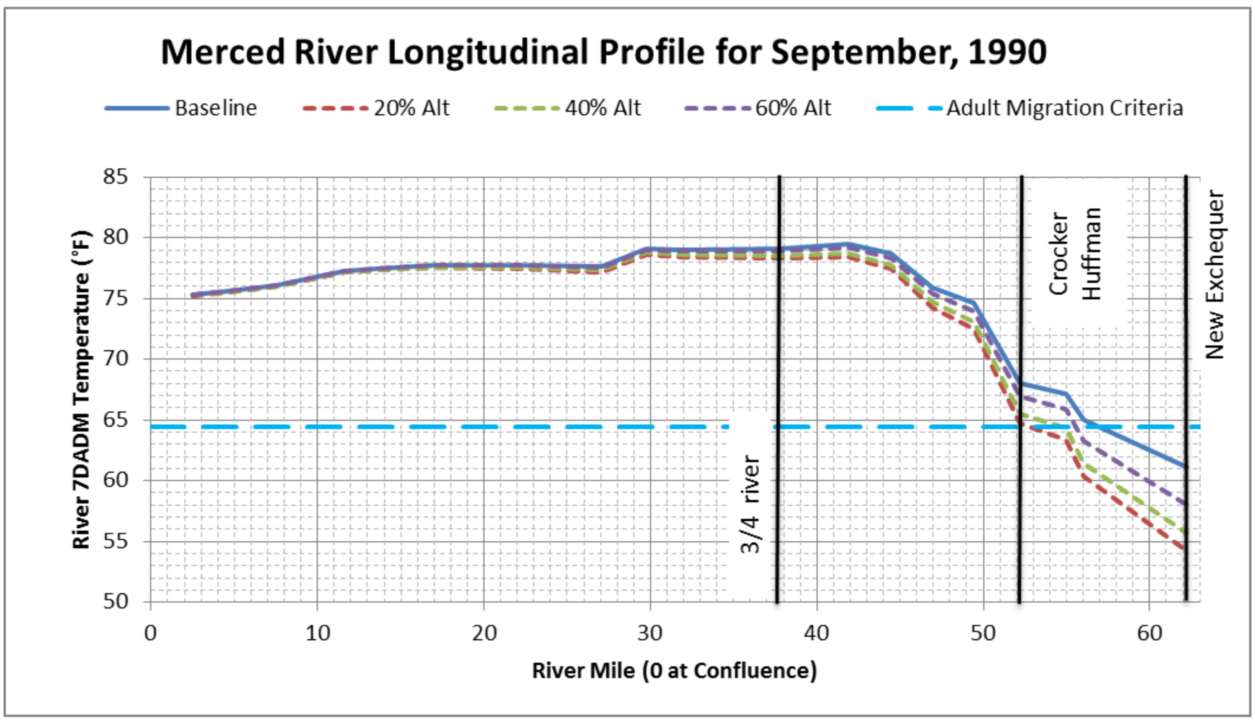


Figure F.1.6-61. Longitudinal Monthly Average 7DADM Temperature Results within the Merced River for (a) August 1990 and (b) September 1990

F.1.7 Potential Changes in Delta Exports and Outflow

Changes in SJR flow at Vernalis for LSJR Alternatives 2, 3, and 4 have been accurately estimated using the WSE model. The effects of these changes in SJR flow at Vernalis on southern Delta salinity have also been evaluated, based on approximate relationships between Vernalis flow and the salinity increases observed at the southern Delta salinity compliance stations. The changes in SJR flow at Vernalis also change flow in the Delta channels, and may change southern Delta exports and Delta outflow.

Changes in exports would affect water supply (beneficial uses) in the CVP and SWP service area south of the Delta; the salinity gradient (i.e., X2) in the western estuary (i.e., Suisun Bay and western Delta); and, could influence aquatic resources associated with salinity (i.e., low-salinity zone habitat distribution). The analysis below provides an accurate accounting of the two most likely changes in the Delta (exports and Delta outflow) that would result from changes in the LSJR flow at Vernalis. Changes in southern Delta exports associated with the LSJR alternatives are generally small. The combination of the modeled SJR flow changes and the likely export changes determine the likely changes in Delta outflow. Further evaluation of these Delta outflow and export changes will be included in the State Water Board's ongoing review of the 2006 Bay-Delta WQCP in Phases II, III and IV.

F.1.7.1 Current Operational Summary

The existing CVP and SWP Delta pumping operations are determined by several rules and objectives that guide the daily Delta operations. Many of these rules are included in D-1641 (which implemented the 1995 Bay-Delta WQCP objectives). Several additional rules have been added by the 2008 FWS BO (USFWS 2008) and the 2009 NMFS BO for the CVP and SWP Operations Criteria and Plan (OCAP) (NMFS 2009). The existing CVP and SWP Delta pumping operations are summarized in this section so that the possible changes in the southern Delta pumping can be identified for the LSJR alternatives.

Delta operations under D-1641 can be simplified into two sets of rules: 1) rules controlling the maximum allowable exports and 2) rules controlling the minimum required Delta outflow. Several objectives control the allowable exports and several objectives control the minimum Delta outflow. Both the 2008 FWS BO and the 2009 NMFS BO added pumping restrictions to limit reverse (negative) Old and Middle River (OMR) flows. There are two RPAs from the NMFS BO that apply to the SJR inflow and are associated with southern Delta pumping. The applicable Delta operational rules control the existing southern Delta pumping.

The CVP permitted pumping capacity is 4,600 cfs, which requires use of the new DMC Intertie facility in the winter months. The SWP pumping capacity is constrained by the CCF diversion limits (Rivers and Harbors Section 10) of 6,680 cfs, with additional diversions of 1/3 of the SJR flow at Vernalis (with a maximum monthly pumping of 8,500 cfs assumed in CALSIM) between December 15 and March 15. SWP pumping at the physical capacity of 10,300 cfs is not currently permitted. The export/inflow ratio limits the CVP and SWP combined pumping to 65 percent of the Delta inflow July–January, and to 35 percent of the Delta inflow February–June. The 35 percent ratio in February is increased to 45 percent if the January runoff is low. An additional pumping limit imposed by the 2009 NMFS BO was an export limit that applies in April and May (a similar export restriction during VAMP applied for 31 days). This ratio effectively limits the combined export to 1,500 cfs for SJR inflows of less than 6,000 cfs. The exports are limited to 25 percent of the SJR inflow if the inflow is greater than 6,000 cfs.

The FWS and NMFS BOs also introduced new limits on the reverse (negative) OMR flow in December–June of many years (adaptively managed based on temperature, turbidity, and fish monitoring). Because the southern Delta exports often come primarily from OMR channels north of the export facilities, the minimum OMR restrictions limit exports. For example, an OMR limit of -2,000 cfs restricts exports to about 2,000 cfs plus the head of Old River flow diverted from the SJR near Mossdale. About 50 percent of the SJR flow is diverted into Old River unless there is a physical barrier installed. The OMR limits vary each year with fish and turbidity conditions; however, CALSIM modeling has assumed a monthly OMR limit that varies generally with the water year type.

Another possible constraint on Delta exports is related to the seasonal (monthly) water supply deliveries that are assumed for south of Delta CVP and SWP contractors. The San Luis Reservoir provides about 2,000 TAF of seasonal storage for meeting the peak summer water demands. The San Luis Reservoir storage space allows relatively high exports to continue through the fall and winter period. Without the San Luis Reservoir, exports would be reduced in the fall and winter to match the monthly water demands. Once San Luis Reservoir is filled, pumping is generally reduced to the monthly water demand, with some additional SWP exports for Article 21 deliveries to contractors with local storage capacity (e.g., surface reservoirs or groundwater storage).

The minimum required Delta outflow also may limit the allowable exports. Minimum monthly outflows are specified in D-1641 for each month, which often depend on the water year type (i.e., runoff conditions). For example, a minimum monthly outflow of 3,000 cfs is specified in September of all years. A minimum monthly outflow of 8,000 cfs is specified in July of wet and above normal water year types (about half of the years).

Delta outflow is also controlled by the maximum salinity objectives specified in D-1641 for each month or period. For example, EC objectives are specified at Emmaton and Jersey Point to protect agricultural diversions, and salinity (chloride) objectives are specified at the Contra Costa Water District Rock Slough intake to protect drinking water supplies. Because Delta outflow is the major factor determining salinity within the Delta channels, these salinity objectives are satisfied by increasing Delta outflow (normally by reducing exports).

The D-1641 February–June X2 objectives are another example of salinity requirements, which are satisfied by adjusting Delta outflow. The maximum location of the 2 parts per thousand (ppt) salinity (i.e., upstream edge of estuarine salinity gradient) is specified (kilometers [km] upstream of the Golden Gate), based on the month and the unimpaired runoff in the previous month. This was formulated as an adaptive objective; the required monthly outflow increased with higher runoff conditions. D-1641 provides equivalent Delta outflows for the X2 objectives; X2 at Collinsville (81 km) can be satisfied with an outflow of 7,100 cfs and X2 at Chipps Island (75 km) can be satisfied with an outflow of 11,400 cfs. The 2008 FWS BO included an additional outflow requirement for September and October of wet and above normal water year types (about half the years). The "Fall X2" rule requires X2 to be downstream of Collinsville (7,100 cfs outflow) in above normal years and downstream of Chipps Island (11,400 cfs outflow) in wet years.

F.1.7.2 Methods to Estimate Changes in Delta Exports and Outflow

The CALSIM model does not currently include the option of using a specified fraction of the unimpaired flow as the required reservoir release flows, and cannot change Tuolumne or Merced diversions based on higher target release flows. Therefore, an approximate method for estimating the potential change in southern Delta pumping was used with the WSE model results. Changes in SJR flow at Vernalis would either change exports or change outflow. Because the WSE model does not include the Delta, there are no model results to help determine which factors would limit Delta exports. As a result, the potential change in export pumping was estimated by selecting the most likely limiting factor each month. Table F.1.7-1 summarizes the Delta regulations affecting exports and shows which regulations were used to assess whether changes in flow at Vernalis affected Delta exports or outflow. Following the table is a narrative summary of the export controls organized by month. These export controls were used to evaluate potential LSJR alternative changes.

Summary of Controls and Potential LSJR Alternative Changes

April and May. The most restrictive export regulations occur during April and May. The NMFS BO RPA 4.2.1 limits the exports to 1,500 cfs unless the SJR inflow is greater than 6,000 cfs in April and May. The maximum exports are limited to 25 percent of the SJR inflow at higher flows. It is therefore unlikely that the LSJR alternatives would result in increased exports during April or May. But if the Vernalis flow was greater than 6,000 cfs and the LSJR alternatives increased the flow to 7,000 cfs, for example, the pumping would increase by 250 cfs. Reductions in the SJR inflow would result in reduced pumping only if the pumping was greater than 1,500 cfs,

January, February, March, June, and December. In January, February, March, June, and December, the OMR regulations will likely limit exports. When OMR regulations are in effect, no extra water can be drawn from the north for exports. However, extra flow at Vernalis can be exported if it reaches the pumps by passing through the head of Old River. Because approximately 50 percent of the flow at Vernalis enters the Head of Old River, the pumping change would be 50 percent of the SJR flow increment.

July–November. From July–November, the most likely limit would be the E/I ratio of 65 percent. When a 65 percent E/I ratio is limiting, the pumping change would be 65 percent of the SJR flow increment.

In some instances, these assumptions about the export-limiting regulations would be incorrect. For example, if exports are at the minimum of 1,500 cfs, a reduction in flow at Vernalis would not cause a reduction in exports; if exports are at the maximum permitted export pumping of 11,280 cfs (11,780 cfs in July–September) then an increase in flow at Vernalis would not cause an increase in exports. Similarly, reductions in the SJR flow at Vernalis would cause a reduction in exports of the same amount if the baseline Delta outflow was equal to the minimum required Delta outflow. However, there were seldom decreases in Vernalis flow under the LSJR alternatives.

Changes in SJR flow at Vernalis would also cause changes in Delta outflow. Because the LSJR alternatives could reduce the SJR flow at Vernalis in some months and increase the SJR flow at Vernalis flow in other months, the possibility of increased and decreased Delta outflow must be considered. The most likely effect on a decrease in the SJR flow at Vernalis would be that Delta outflow would be reduced, but the reduction in outflow would be less than the reduction in SJR flow because there would be less exports (as calculated above). The change in outflow each month would be the change at Vernalis minus the change in exports.

Table F.1.7-1. Regulations that May Affect Export of Water Entering the Delta

Restriction: Regulation	January	February	March	April	May	June	July	August	September	October	November	December
Export Minimum (cfs): D-1641	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Export Maximum (cfs): D-1641	13,100[e]	13,100[e]	13,100/ 11,280[e]	11,280	11,280	11,280	11,780[f]	11,780[f]	11,780[f]	11,280	11,280	11,280/ 13,100[e]
Export Maximum (cfs): 2009 NMFS BO[a]				1,500	1,500							
E/I Ratio: D-1641	0.65	0.35	0.35[g]	0.35	0.35	0.35	0.65	0.65	0.65	0.65	0.65	0.65
HOR barrier in place: 2009 NMFS BO				X	X							
OMR Restrictions (cfs): 2008 FWS BO and 2009 NMFS BO[b]	0 to -5,000	0 to -5,000	0 to -5,000	0 to -5,000	0 to -5,000	0 to -5,000						0 to -5,000
Minimum Delta Outflow (cfs): D-1641	4,500[h]						4,000 to 8,000[i]	3,000 to 4,000[i]	3,000i	3,000 to 4,000[i]	3,500 to 4,500[i]	3,500 to 4,500[i]

Restriction: Regulation	January	February	March	April	May	June	July	August	September	October	November	December
Outflow for X2 Objectives (cfs): D-1641 and 2008 FWS BO		7,100-11,400[j]	7,100-11,400[j]	7,100-11,400[j]	7,100-11,400[j]	7,100-11,400[j]			7,100-11,400[k]	7,100-11,400[k]		
Western Delta Conductivity Standards for Agriculture (µS/cm): D-1641[c]				450 to 2,780	450 to 2,780	450 to 2,780	450 to 2,780	450 to 2,780				
Contra Costa Water District Drinking-Water Chloride Standards (mg/l): D-1641[d]	150 to 250	150 to 250	150 to 250	150 to 250	150 to 250	150 to 250	150 to 250	150 to 250	150 to 250	150 to 250	150 to 250	150 to 250

Footnotes:

HOR = Head of Old River

Shading indicates the regulations used for the export/outflow impact assessment.

Other factors that may control exports include:

- Delta water quality standards at other locations, although these other locations are less likely to affect exports than locations listed above.
- Capacity in San Luis Reservoir or with the water contractors (surface reservoirs or groundwater storage).

a. If SJR inflow (Vernalis) is > 6,000 cfs, exports can be increased to equal 0.25 * Vernalis.

b. Adaptively managed based on temperature, turbidity, and fish monitoring. SJR flows that pass through the Head of Old River can be diverted without affecting Old and Middle River flows. These flows are approximately equal to 0.5 * Vernalis when the Head of River barrier is not in place.

c. Value depends on location (Emmaton, Jersey Point, or San Andreas), water year type, and date. No objective after August 15. (Terminus also has similar standards, but these are unlikely to affect Delta exports). Salinity in the western Delta is largely controlled by Delta outflow, with higher Delta

Restriction: Regulation	January	February	March	April	May	June	July	August	September	October	November	December

outflow causing a reduction in seawater intrusion. Particular EC objectives can be met by maintaining sufficient Delta outflow. For example, 450 µS/cm and 2,780 µS/cm at Emmaton can be met by maintaining Delta outflow at approximately 7,500 cfs and 3,500 cfs, respectively.

d. Chlorides should stay below 150 mg/l for about half the year and below 250 mg/l at all times. Contra Costa Water District takes water from multiple locations within the Delta. Its intake at Rock Slough is the site most likely to exceed the chloride objective. Chlorides near Rock Slough can be maintained below the 150 mg/l and 250 mg/l objectives by limiting salinity intrusion from the ocean by maintaining Delta outflow above approximately 4,500 cfs and 3,500 cfs, respectively, although local agricultural drainage could cause the objectives to be exceeded regardless of Delta outflow.

e. From December 15–March 15, one-third of the SJR flow at Vernalis can be added to the SWP export limit of 6,680 cfs to bring SWP exports up to 8,500 cfs (upper limit assumed by CALSIM).

f. Extra 500 cfs allowed by USACE.

g. Increased to 0.45 if January runoff is low.

h. Increased to 6,000 cfs if December 8 river index > 800 TAF.

i. Depends on year type.

j. D-1641 criteria: Outflow needed to keep X2 at Collinsville or Chipps Island. Number of days at Chipps Island depends on previous month's river index. Outflow could be less than 7,100 cfs under drought conditions. Several other caveats exist.

k. 2008 FWS BO: 7,100 cfs (Collinsville) in above normal years and 11,400 cfs (Chipps Island) in wet years.

The most likely effect of an increase in the SJR flow at Vernalis would be that any water not exported would increase Delta outflow. It is possible that an increase in Delta outflow might allow upstream reservoir releases into the Sacramento River system to be reduced, with increased storage that could later be released for increased exports. However, a reduction in upstream reservoir releases (increase in storage) would generally not be possible if the Delta outflow was already greater than the required Delta outflow. In most spring months (February–June), the reservoir releases are controlled by maximum flood control storage or by minimum downstream flow requirements. Because the E/I ratio is only 35 percent in these months, exports can only be increased by 35 percent of the increased reservoir releases; releases of stored water for exports are unlikely in these months. With the additional FWS and NMFS restrictions on reverse OMR flow in these months, reservoir releases are almost always reduced to the minimum possible for flood control and downstream minimum requirements.

The likely changes in the baseline Delta outflow were calculated for each month for LSJR Alternatives 2, 3, and 4 to provide an initial estimate of the magnitude and frequency of the likely changes in Delta outflow. The increase in SJR flow (minus the estimated increase in exports) was assumed to be the increase in Delta outflow. These increases in Delta outflow are expected to be beneficial for estuarine habitat and fish survival.

This analysis provides a best estimate of how much of a change in flow at Vernalis would go to exports and how much would go to Delta outflow. An analysis of extremes could assume that all of the change in flow would go towards a change in Delta exports or that all of the change in flow would go towards a change in Delta outflow. The values presented here are between these two extremes. However, even if the extremes were used, the maximum potential changes in Delta exports or Delta outflow associated with the LSJR alternatives would be relatively small because of the relatively small contribution of the SJR to flow in the Delta. During water years 1995–2013, the average annual SJR flow of 3,360 TAF represented only about 14 percent of the combined average annual exports (5,185 TAF) and average annual Delta outflow (19,034 TAF) (data from DWR's DAYFLOW dataset).

F.1.7.3 Changes in Delta Exports and Outflow

Summary

The analysis of the change in exports and change in Delta outflow does not include an estimate of total Delta outflow or exports. As a result, the changes cannot be evaluated as a change in the distribution of outflow and exports. Some of the large changes are unlikely to be a concern because they would not affect the typical distribution of outflow and exports that would be expected. The primary result of interest from the Delta export and outflow analysis is the overall average change estimated for each month.

The annual and February–June cumulative distributions of SJR flow at Vernalis, change in SJR flow at Vernalis, change in southern Delta exports, and change in Delta outflow are summarized in Tables F.1.7-2a, F.1.7-2b, and F.1.7-2c. The monthly cumulative distributions of the likely changes in exports and outflow for the LSJR alternatives (20, 40, and 60 percent unimpaired flow) are described in more detail in tables below. Results for the 30 percent and 50 percent unimpaired flow are not described in detail, and only presented in the summary tables, because their results are, as expected, intermediate between the other percent unimpaired flows.

Table F.1.7-2a. Summary of Estimated Changes in SJR Flow at Vernalis (TAF)

Cumulative Distributions of Baseline and Changes in SJR Flow (TAF)			Percent of Unimpaired Flow									
	Baseline		20%		30%		40%		50%		60%	
	Annual SJR Flow (TAF)	Feb–June SJR Flow (TAF)	Annual SJR Flow Change	Feb–June SJR Flow Change	Annual SJR Flow Change	Feb–June SJR Flow Change	Annual SJR Flow Change	Feb–June SJR Flow Change	Annual SJR Flow Change	Feb–June SJR Flow Change	Annual SJR Flow Change	Feb–June SJR Flow Change
Minimum	875	364	40	17	49	25	81	53	124	96	168	140
10%	1,077	444	59	69	224	154	388	272	529	361	582	496
20%	1,386	604	65	64	214	244	387	374	546	506	745	674
30%	1,585	785	9	50	183	177	338	263	516	453	678	635
40%	1,778	935	47	-5	165	159	320	372	573	571	822	786
50%	2,041	1,103	61	118	234	357	463	633	777	845	1,112	1,016
60%	2,690	1,509	50	-22	132	162	232	417	535	654	901	1,017
70%	3,266	1,904	3	46	-35	193	146	310	447	526	733	823
80%	4,197	2,508	310	64	337	127	327	114	389	374	655	722
90%	5,542	3,554	-37	14	-84	75	-50	164	272	471	770	871
Maximum	15,907	9,415	0	0	0	72	-67	191	-167	410	-355	697
Average	2,965	1,742	59	56	149	174	294	288	469	485	693	728
	Percentage Change		2.0%	3.2%	5.0%	10.0%	9.9%	16.5%	15.8%	27.8%	23.4%	41.8%

Table F.1.7-2b. Summary of Estimated Changes in Delta Exports (TAF)

Cumulative Distributions of Changes in Delta Exports (TAF)	Percent of Unimpaired Flow									
	20%		30%		40%		50%		60%	
	Annual Exports Change	Feb–June Exports Change	Annual Exports Change	Feb–June Exports Change	Annual Exports Change	Feb–June Exports Change	Annual Exports Change	Feb–June Exports Change	Annual Exports Change	Feb–June Exports Change
Minimum	-74	-61	-132	-65	-190	-140	-263	-186	-376	-36
10%	-24	-10	-64	-7	-46	-36	-29	1	-4	45
20%	-16	-5	-15	6	3	0	28	28	58	87
30%	-1	0	1	13	29	14	62	57	100	117
40%	2	3	9	21	44	38	89	95	160	161
50%	9	8	18	30	69	58	122	119	187	196
60%	17	13	28	40	88	77	149	143	217	217
70%	32	24	52	55	125	99	174	168	268	265
80%	52	34	83	77	148	129	234	209	336	302
90%	77	60	127	118	216	202	316	307	450	439
Maximum	158	134	204	204	329	301	453	430	592	579
Average	18	16	27	41	76	67	124	128	194	211

Table F.1.7-2c. Summary of Estimated Changes in Delta Outflow (TAF)

Cumulative Distributions of Changes in Delta Outflow (TAF)	Percent of Unimpaired Flow									
	20%		30%		40%		50%		60%	
	Annual Exports Change	Feb–June Exports Change	Annual Exports Change	Feb–June Exports Change	Annual Exports Change	Feb–June Exports Change	Annual Exports Change	Feb–June Exports Change	Annual Exports Change	Feb–June Exports Change
Minimum	-88	-89	-88	-72	-168	-130	-189	-135	-31	64
10%	-23	-22	-9	17	-15	44	43	125	183	272
20%	-10	-4	19	45	88	81	166	189	293	338
30%	3	4	53	72	137	131	230	245	371	388
40%	14	14	78	81	166	153	282	271	432	444
50%	34	34	112	132	204	199	348	329	480	478
60%	48	50	150	151	246	234	375	377	521	503
70%	64	62	167	167	279	280	418	419	582	573
80%	89	81	207	203	372	371	537	535	698	698
90%	115	108	275	275	472	462	672	664	876	869
Maximum	300	300	437	450	590	577	836	823	1,071	1,058
Average	41	40	123	133	218	220	345	357	499	518

20 Percent Unimpaired Flow (LSJR Alternative 2)

Table F.1.7-3a shows the monthly cumulative distributions of the changes in the monthly Vernalis flows that were calculated with the WSE model of 1922–2003 (82 years) for LSJR Alternative 2. In some months, Vernalis flow increased significantly (the largest increase was 4,620 cfs in May 1978), while in other months, the flow decreased by a large amount (the largest decrease was 1,645 cfs in July 1941). The monthly flow reductions occurred most frequently in February–May, most likely due to reduced flood control releases. On average, all months, except March, July, and December, showed increased monthly flow. Annually, total flow at Vernalis increased more frequently than it decreased, with more than 70 percent of years registering an overall increase in flow. The average annual change in the SJR flow at Vernalis was an increase of 59 TAF/y, and the average change over February–June was an increase of 56 TAF/y.

Table F.1.7-3b shows the monthly cumulative distributions of the changes in monthly Delta exports, based on the monthly change in Vernalis flow under LSJR Alternative 2 and the regulations determined to control monthly exports (the shaded boxes in Table F.1.7-1). In some months, the Delta exports were estimated to increase significantly (the largest increase was 1,207 cfs in June 1932), while in other months, the exports decreased by a large amount (the largest decrease was 1,063 cfs in July 1941). The distribution of monthly export changes does not indicate whether the changes occurred in years with low baseline exports (larger effects) or in years with higher baseline exports (smaller effects). The overall changes in the monthly distributions of exports would generally be much smaller than the distribution of individual monthly export changes. Many of the large monthly export reductions would be compensated by increased exports in other months. On average, all months, except March, July, and December, showed increased exports. Annually, total Delta exports increased more frequently than they decreased, with more than 60 percent of years registering an overall increase. The average annual change in Delta exports was an increase of 18 TAF/y, and the average change over February–June was an increase of 16 TAF/y. This is relatively small compared to average historical exports of 5,185 TAF/y.

Table F.1.7-3c shows the monthly cumulative distributions of the changes in monthly Delta outflow, based on the changes in SJR flow at Vernalis and the estimated changes in Delta exports under LSJR Alternative 2. In some months, Delta outflow was estimated to increase significantly (the largest increase was 3,465 cfs in May 1978), while in other months, outflow decreased by a large amount (the largest decrease was 1,149 cfs in April 1953). Many of the large monthly reductions in outflow would be compensated by increased outflow in other months. On average, all months, except March, April, July, and December, showed increased monthly outflow. Annually, total Delta outflow increased more frequently than it decreased, with more than 70 percent of years registering an overall increase. The average annual change in Delta outflow was an increase of 41 TAF/y, and the average change over February–June was an increase of 40 TAF/y. This is relatively small compared to the average historical Delta outflow of about 19,000 TAF/y.

The results from this analysis indicate that about 31 percent of the average annual increase in the SJR flow at Vernalis would go toward an increase in exports, and 69 percent would go toward Delta outflow for LSJR Alternative 2.

Table F.1.7-3a. Cumulative Distributions of Monthly Changes in Vernalis Flow under LSJR Alternative 2

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Minimum	-45	-100	-1,101	-808	-1,587	-1,364	-1,149	-896	-850	-1,635	-409	-499	-162
10%	0	0	0	-114	-469	-476	-479	-250	-79	0	0	0	-39
20%	0	0	0	0	-123	-190	-284	-23	0	0	0	0	-23
30%	0	0	0	0	0	0	-136	144	48	0	0	0	0
40%	0	0	0	0	0	0	0	304	163	0	0	0	32
50%	0	0	0	0	0	0	0	402	267	0	0	0	52
60%	0	0	0	0	0	0	99	517	485	0	0	0	70
70%	0	0	0	0	0	0	188	680	594	0	0	0	82
80%	0	0	0	0	109	20	250	879	930	0	0	40	110
90%	51	0	0	6	550	273	420	1,121	1,281	50	50	50	181
Maximum	139	518	1,622	1,103	2,174	1,376	1,121	4,620	2,414	535	1,081	1,125	434
Average	10	11	-19	2	28	-15	8	468	431	-24	32	43	59

Table F.1.7-3b. Cumulative Distributions of the Estimated Monthly Changes in Delta Exports under LSJR Alternative 2

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual
Minimum	-29	-65	-550	-404	-794	-682	-94	-101	-425	-1,063	-266	-324	-74
10%	0	0	0	-57	-235	-238	0	0	-40	0	0	0	-24
20%	0	0	0	0	-61	-95	0	0	0	0	0	0	-16
30%	0	0	0	0	0	0	0	0	24	0	0	0	-1
40%	0	0	0	0	0	0	0	0	81	0	0	0	2
50%	0	0	0	0	0	0	0	0	134	0	0	0	9
60%	0	0	0	0	0	0	0	0	242	0	0	0	17
70%	0	0	0	0	0	0	0	0	297	0	0	0	32
80%	0	0	0	0	55	10	0	25	465	0	0	26	52
90%	33	0	0	3	275	136	57	96	641	33	33	33	77
Maximum	90	337	811	552	1,087	688	270	1,155	1,207	348	702	732	158
Average	6	7	-10	1	14	-8	12	35	216	-16	21	28	18

Table F.1.7-3c. Cumulative Distributions of the Estimated Monthly Changes in Delta Outflow under LSJR Alternative 2

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Minimum	-16	-35	-550	-404	-794	-682	-1,149	-896	-425	-572	-143	-175	-88
10%	0	0	0	-57	-235	-238	-479	-250	-40	0	0	0	-23
20%	0	0	0	0	-61	-95	-279	-23	0	0	0	0	-10
30%	0	0	0	0	0	0	-109	144	24	0	0	0	3
40%	0	0	0	0	0	0	0	238	81	0	0	0	14
50%	0	0	0	0	0	0	0	373	134	0	0	0	34
60%	0	0	0	0	0	0	89	517	242	0	0	0	48
70%	0	0	0	0	0	0	172	668	297	0	0	0	64
80%	0	0	0	0	55	10	246	870	465	0	0	14	89
90%	18	0	0	3	275	136	411	1,076	641	18	18	18	115
Maximum	49	181	811	552	1,087	688	1,121	3,465	1,207	187	378	394	300
Average	3	4	-10	1	14	-8	-4	433	216	-8	11	15	41

40 Percent Unimpaired Flow (LSJR Alternative 3)

Table F.1.7-4a shows the monthly cumulative distributions of the changes in the monthly Vernalis flows that were calculated with the WSE model of 1922–2003 (82 years) for LSJR Alternative 3. In some months, Vernalis flow increased significantly (the largest increase was 5,820 cfs in June 1932), while in other months, the flow decreased by a large amount (the largest decrease was 6,801cfs in February 1998). The monthly flow reductions occurred most frequently in December–March, most likely due to reduced flood control releases. On average, April–June and September–November showed monthly increases in Vernalis flow, while all other months had decreases. The September–November increases most likely occurred as a result of adaptive implementation flow shifting. Annually, total flow at Vernalis increased more frequently than it decreased, with more than 80 percent of years registering an overall increase in flow. The average annual change in the SJR flow at Vernalis was an increase of 294 TAF/y, and the average change over February–June was an increase of 288 TAF/y.

Table F.1.7-4b shows the monthly cumulative distributions of the changes in monthly Delta exports, based on the monthly change in Vernalis flow under LSJR Alternative 3 and the regulations determined to control monthly exports (the shaded boxes in Table F.1.7-1). In some months, the Delta exports were estimated to increase significantly (the largest increase was 2,910 cfs in June 1932), while in other months, the exports decreased by a large amount (the largest decrease was 3,401 cfs in February 1998). The distribution of monthly export changes does not indicate whether the changes occurred in years with low baseline exports (larger effects) or in years with higher baseline exports (smaller effects). The overall changes in the monthly distributions of exports would generally be much smaller than the distribution of individual monthly export changes. Many of the large monthly exports reductions would be compensated by increased exports in other months. On average, April–June and September–November showed monthly increases in Delta exports, while all other months had decreases. Annually, total Delta exports increased more frequently than they decreased, with more than 80 percent of years registering an overall increase. The average annual change in Delta exports was an increase of 76 TAF/y, and the average change over February–June was an increase of 67 TAF/y. This is relatively small compared to average historical exports of 5,185 TAF/y.

Table F.1.7-4c shows the monthly cumulative distributions of the changes in monthly Delta outflow, based on the changes in SJR flow at Vernalis and the estimated changes in Delta exports under LSJR Alternative 3. In some months, Delta outflow was estimated to increase significantly (the largest increase was 4,775 cfs in May 2003), while in other months, outflow decreased by a large amount (the largest decrease was 3,401 cfs in February 1998). Many of the large monthly reductions in outflow would be compensated by increases in outflow in other months. On average, April–June and September–November showed monthly increases in Delta outflow, while all other months had decreases. Annually, total Delta outflow increased more frequently than it decreased, with more than 80 percent of years registering an overall increase. The average annual change in Delta outflow was an increase of 218 TAF/y, and the average February–June change was an increase of 220 TAF/y. This is relatively small compared to the average historical Delta outflow of about 19,000 TAF/y. The results from this analysis indicate that about 26 percent of the average annual increase in the SJR flow at Vernalis would go toward an increase in exports, and 74 percent would go toward Delta outflow for LSJR Alternative 3.

Table F.1.7-4a. Cumulative Distributions of Monthly Changes in Vernalis Flow under LSJR Alternative 3

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Minimum	-410	-717	-3,095	-3,216	-6,801	-3,657	-1,354	-358	-2,272	-3,084	-1,651	-2,106	-358
10%	7	0	-620	-1,311	-1,479	-1,270	-216	731	96	-254	-190	-50	-66
20%	32	0	0	-234	-445	-635	28	1,210	418	-50	-35	0	77
30%	97	0	0	-6	-65	-55	210	1,516	615	0	0	0	183
40%	157	0	0	0	0	0	447	1,820	960	0	0	0	224
50%	199	0	0	0	0	0	611	2,216	1,399	0	0	0	281
60%	232	0	0	0	47	127	790	2,622	1,803	0	0	34	334
70%	337	0	0	0	245	300	1,104	3,038	2,131	0	0	98	415
80%	566	612	0	0	669	510	1,669	3,692	2,775	50	50	481	515
90%	974	834	0	6	1,572	934	2,135	4,269	3,674	212	98	816	680
Maximum	1,651	1,021	1,368	2,861	3,521	2,881	4,333	5,447	5,820	1,211	461	1,108	915
Average	327	176	-191	-294	-16	-44	810	2,400	1,602	-29	-31	154	294

Table F.1.7-4b. Cumulative Distributions of the Estimated Monthly Changes in Delta Exports under LSJR Alternative 3

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Minimum	-267	-466	-1,548	-1,608	-3,401	-1,828	-339	-66	-1,136	-2,005	-1,073	-1,369	-190
10%	4	0	-310	-656	-739	-635	0	0	48	-165	-124	-33	-46
20%	21	0	0	-117	-223	-318	0	0	209	-33	-23	0	3
30%	63	0	0	-3	-32	-27	0	0	308	0	0	0	29
40%	102	0	0	0	0	0	0	24	480	0	0	0	44
50%	129	0	0	0	0	0	0	178	700	0	0	0	69
60%	151	0	0	0	23	63	0	362	902	0	0	22	88
70%	219	0	0	0	123	150	30	442	1,066	0	0	64	125
80%	368	398	0	0	335	255	91	586	1,388	33	33	313	148
90%	633	542	0	3	786	467	180	835	1,837	138	64	531	216
Maximum	1,073	663	684	1,430	1,761	1,440	926	1,192	2,910	787	299	720	329
Average	212	114	-96	-147	-8	-22	50	299	801	-19	-20	100	76

Table F.1.7-4c. Cumulative Distributions of the Estimated Monthly Changes in Delta Outflow under LSJR Alternative 3

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Minimum	-144	-251	-1,548	-1,608	-3,401	-1,828	-1,016	-358	-1,136	-1,079	-578	-737	-168
10%	2	0	-310	-656	-739	-635	-216	648	48	-89	-67	-18	-15
20%	11	0	0	-117	-223	-318	25	1,105	209	-18	-12	0	88
30%	34	0	0	-3	-32	-27	175	1,337	308	0	0	0	137
40%	55	0	0	0	0	0	395	1,631	480	0	0	0	166
50%	70	0	0	0	0	0	548	2,036	700	0	0	0	204
60%	81	0	0	0	23	63	731	2,329	902	0	0	12	246
70%	118	0	0	0	123	150	1,104	2,781	1,066	0	0	34	279
80%	198	214	0	0	335	255	1,585	3,229	1,388	18	18	169	372
90%	341	292	0	3	786	467	2,016	3,661	1,837	74	34	286	472
Maximum	578	357	684	1,430	1,761	1,440	3,454	4,775	2,910	424	161	388	590
Average	114	62	-96	-147	-8	-22	761	2,102	801	-10	-11	54	218

60 Percent Unimpaired Flow (LSJR Alternative 4)

Table F.1.7-5a shows the monthly cumulative distributions of the changes in the monthly Vernalis flows, which were calculated with the WSE model of 1922–2003 (82 years) for LSJR Alternative 4. In some months, Vernalis flow increased significantly (the largest increase was 10,173 cfs in May 1973), while in other months, the flow decreased by a large amount (the largest decrease was 9,276 cfs in July 1983). The monthly flow reductions occurred most frequently in January, July, and August, most likely due to reduced flood control releases. On average, February–June and September–November showed monthly increases in Vernalis flow, while all other months had decreases. The September–November increases most likely occurred as a result of adaptive implementation flow shifting. Annually, total flow at Vernalis increased more frequently than it decreased, with more than 90 percent of years registering an overall increase in flow. The average annual change in the SJR flow at Vernalis was an increase of 693 TAF/y, and the average change over February–June was an increase of 728 TAF/y.

Table F.1.7-5b shows the monthly cumulative distributions of the changes in monthly Delta exports, based on the monthly change in Vernalis flow under LSJR Alternative 4 and the regulations determined to control monthly exports (the shaded boxes in Table F.1.7-1). In some months, the Delta exports were estimated to increase significantly (the largest increase was 4,730 cfs in June 1932), while in other months, the exports decreased by a large amount (the largest decrease was 6,029 cfs in July 1983). The distribution of monthly export changes does not indicate whether the changes occurred in years with low baseline exports (larger effects) or in years with higher baseline exports (smaller effects). The overall changes in the monthly distributions of exports would generally be much smaller than the distribution of individual monthly export changes. Many of the large monthly exports reductions would be compensated by increased exports in other months. On average, February–June and September–November showed monthly increases in Delta exports, while all other months had decreases. Annually, total Delta exports increased more frequently than they decreased, with more than 80 percent of years registering an overall increase. The average annual change in Delta exports was an increase of 194 TAF/y, and the average change over February–June was an increase of 211 TAF/y. This is relatively small compared to average historical exports of 5,185 TAF/y.

Table F.1.7-5c shows the monthly cumulative distributions of the changes in monthly Delta outflow, based on the changes in SJR flow at Vernalis and the estimated changes in Delta exports under LSJR Alternative 4. In some months, Delta outflow was estimated to increase significantly (the largest increase was 7,990 cfs in May 1973), while in other months, outflow decreased by a large amount (the largest decrease was 4,075 cfs in December 1996). Many of the large monthly reductions in outflow would be compensated by increases in outflow in other months. On average, February–June and September–November showed monthly increases in Delta outflow, while all other months had decreases. Annually, total Delta outflow increased more frequently than it decreased, with more than 90 percent of years registering an overall increase. The average annual change in Delta outflow was an increase of 499 TAF/y, and the average change over February–June was an increase of 518 TAF/y. This is relatively small compared to the average historical Delta outflow of about 19,000 TAF/y. The results from this analysis indicate that about 28 percent of the average annual increase in the SJR flow at Vernalis would go toward an increase in exports, and 72 percent would go toward Delta outflow for LSJR Alternative 4.

Table F.1.7-5a. Cumulative Distributions of Monthly Changes in Vernalis Flow under LSJR Alternative 4

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Minimum	-410	-2,198	-8,150	-6,963	-5,242	-2,476	-1,655	778	70	-9,276	-1,978	-2,106	-355
10%	1	0	-1,049	-2,316	-1,459	-1,567	487	2,281	941	-2,097	-402	-50	173
20%	34	0	-20	-744	-461	-208	1,032	2,843	1,463	-457	-126	-50	310
30%	97	0	0	-6	0	0	1,166	3,861	2,213	-50	-50	0	495
40%	157	0	0	-6	10	201	1,524	4,534	2,860	-50	-27	0	585
50%	199	0	0	0	276	454	1,979	4,986	3,217	0	0	0	674
60%	232	0	0	0	599	896	2,168	5,672	3,884	0	0	34	754
70%	337	0	0	0	1,018	1,187	2,657	6,309	4,788	0	0	67	880
80%	630	665	0	0	2,031	1,656	3,535	7,328	5,459	39	9	473	937
90%	1,036	842	0	6	2,850	2,115	4,462	8,209	6,446	96	72	802	1,322
Maximum	1,687	1,083	3,335	5,609	8,897	5,222	7,879	10,173	9,460	1,340	511	1,239	1,663
Average	340	171	-269	-434	638	586	2,178	5,149	3,531	-421	-98	141	693

Table F.1.7-5b. Cumulative Distributions of the Estimated Monthly Changes in Delta Exports under LSJR Alternative 4

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Minimum	-267	-1,428	-4,075	-3,482	-2,621	-1,238	-414	0	35	-6,029	-1,285	-1,369	-376
10%	0	0	-524	-1,158	-730	-783	0	0	470	-1,363	-261	-33	-4
20%	22	0	-10	-372	-231	-104	0	73	732	-297	-82	-33	58
30%	63	0	0	-3	0	0	0	356	1,107	-33	-33	0	100
40%	102	0	0	-3	5	101	24	594	1,430	-33	-17	0	160
50%	129	0	0	0	138	227	193	861	1,608	0	0	0	187
60%	151	0	0	0	300	448	271	1,153	1,942	0	0	22	217
70%	219	0	0	0	509	594	311	1,412	2,394	0	0	44	268
80%	409	432	0	0	1,016	828	406	1,471	2,730	25	6	307	336
90%	674	547	0	3	1,425	1,058	663	1,795	3,223	62	47	521	450
Maximum	1,097	704	1,668	2,804	4,448	2,611	1,812	2,468	4,730	871	332	805	592
Average	221	111	-135	-217	319	293	252	889	1,766	-274	-63	92	194

Table F.1.7-5c. Cumulative Distributions of the Estimated Monthly Changes in Delta Outflow under LSJR Alternative 4

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
Minimum	-144	-769	-4,075	-3,482	-2,621	-1,238	-1,241	778	35	-3,247	-692	-737	-31
10%	0	0	-524	-1,158	-730	-783	419	2,024	470	-734	-141	-18	183
20%	12	0	-10	-372	-231	-104	800	2,686	732	-160	-44	-18	293
30%	34	0	0	-3	0	0	962	3,412	1,107	-18	-18	0	371
40%	55	0	0	-3	5	101	1,287	3,821	1,430	-18	-9	0	432
50%	70	0	0	0	138	227	1,668	4,243	1,608	0	0	0	480
60%	81	0	0	0	300	448	2,006	4,764	1,942	0	0	12	521
70%	118	0	0	0	509	594	2,519	5,164	2,394	0	0	23	582
80%	220	233	0	0	1,016	828	3,492	5,750	2,730	14	3	165	698
90%	363	295	0	3	1,425	1,058	3,902	6,368	3,223	34	25	281	876
Maximum	591	379	1,668	2,804	4,448	2,611	6,066	7,990	4,730	469	179	434	1,071
Average	119	60	-135	-217	319	293	1,926	4,260	1,766	-147	-34	49	499

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Appendix F.1
Attachment 1

This attachment to Appendix F.1, *Hydrologic and Water Quality Modeling*, contains resulting flow and reservoir storage for the CALSIM II baseline and WSE model results of the three LSJR alternatives. The baseline is presented first followed by each of the alternatives and the preferred alternative. Tables 16 through 21 contain the baseline results, Tables 22 through 27 contain LSJR Alternative 2 (20% unimpaired flow),[1] Tables 28 through 33 contain LSJR Alternative 3 (40% unimpaired flow), and Tables 34 through 39 contain LSJR Alternative 4 (60% unimpaired flow). Flow results are presented for each tributary (Stanislaus, Tuolumne, and Merced Rivers) and the SJR at Vernalis. Storage results are presented for the three major reservoirs: New Melones, New Don Pedro, and New Exchequer (Lake McClure).

[1] Any reference in this appendix to 20% unimpaired, 40% unimpaired, and 60% unimpaired is the same as LSJR Alternative 2, LSJR Alternative 3, and LSJR Alternative 4, respectively. Any reference to 1.0 EC objective and 1.4 EC objective is the same as SDWQ Alternative 2 and SDWQ Alternative 3, respectively.

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TABLES

Table 1. Summary Table of Stanislaus River at 20 Percent Unimpaired Flow

	Year					District Diversions		Required Releases from Diversion Dam									
	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1389	993	49	0	1041	507	155	38	161	190	0	19	0	0	0	0	409
1923	1109	1292	56	0	1006	512	155	35	109	203	0	19	0	0	0	0	366
1924	385	1340	48	0	854	489	77	18	34	191	0	22	0	0	0	18	284
1925	1092	823	47	0	804	461	59	31	143	115	0	17	0	0	0	0	307
1926	619	1064	47	0	858	553	50	18	79	142	0	21	0	0	0	0	261
1927	1256	778	47	0	949	521	134	36	154	112	0	20	0	0	0	0	322
1928	952	1038	50	0	942	529	155	28	100	129	0	21	0	0	0	0	277
1929	506	998	41	0	706	455	31	13	66	121	0	21	0	0	0	1	222
1930	671	756	38	0	674	449	0	27	96	88	0	21	0	0	0	0	232
1931	438	715	36	0	487	225	0	61	48	102	0	19	0	0	0	26	256
1932	1160	630	41	0	879	512	47	33	193	94	0	20	0	0	0	0	340
1933	586	870	39	0	697	448	12	19	86	110	0	21	0	0	0	0	236
1934	498	720	39	0	475	231	0	58	57	100	0	18	0	0	0	14	249
1935	1082	704	43	0	778	460	47	45	136	95	0	18	0	0	0	0	295
1936	1291	965	53	0	969	491	136	58	122	194	0	18	0	0	0	0	392
1937	1080	1234	55	0	997	504	155	43	99	213	0	19	0	0	0	0	374
1938	2032	1263	66	47	1182	498	155	74	175	329	0	19	0	0	0	0	644
1939	562	2000	63	5	1090	536	155	12	68	299	0	20	0	0	0	0	404
1940	1327	1404	61	0	1163	522	155	45	153	305	0	19	0	0	0	0	522
1941	1290	1507	62	0	1115	493	155	42	43	398	0	18	0	0	0	0	502
1942	1450	1620	65	0	1098	477	155	39	149	296	0	17	0	0	0	0	501
1943	1538	1908	68	325	1186	503	155	61	164	334	0	19	0	0	0	0	904
1944	649	1866	60	0	1092	547	155	21	53	305	0	21	0	0	0	0	399
1945	1228	1363	59	0	1017	500	155	42	122	197	0	19	0	0	0	6	386
1946	1175	1516	60	0	1148	510	155	31	113	337	0	19	0	0	0	0	501
1947	632	1482	53	0	1040	613	155	15	68	165	0	23	0	0	0	3	274
1948	853	1022	44	0	862	495	78	29	120	130	0	19	0	0	0	1	299
1949	732	968	43	0	894	575	59	21	91	137	0	22	0	0	0	0	270
1950	1027	763	42	0	877	547	59	38	116	115	0	21	0	0	0	0	290
1951	1654	871	60	0	960	518	136	63	62	215	0	19	0	0	0	0	360
1952	1844	1504	67	90	1191	504	155	68	234	274	0	19	0	0	0	0	684
1953	965	2000	64	72	1227	548	155	24	78	412	0	21	0	0	0	0	607

	Year					District Diversions		Required Releases from Diversion Dam									
	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	882	1602	59	0	1104	577	155	37	122	200	0	22	0	0	0	0	381
1955	656	1322	49	0	942	521	155	26	79	155	0	19	0	0	0	0	279
1956	1825	986	59	0	1138	524	155	63	131	299	0	20	0	0	0	0	513
1957	878	1614	58	0	1074	552	155	18	98	237	0	21	0	0	0	0	374
1958	1599	1360	63	0	1046	441	155	71	154	273	0	17	0	0	0	0	515
1959	624	1850	62	0	1071	551	155	18	33	297	0	21	0	0	0	0	370
1960	574	1341	51	0	928	584	78	14	64	165	0	24	0	0	0	0	267
1961	446	936	40	0	603	360	12	9	40	141	0	22	0	0	8	7	227
1962	863	739	40	0	837	531	47	28	112	113	0	21	0	0	0	0	274
1963	1227	725	44	0	918	493	136	32	128	136	0	18	0	0	0	0	315
1964	632	990	42	0	813	530	31	17	51	167	0	23	0	0	0	0	257
1965	1666	767	53	0	981	510	124	61	130	185	0	19	0	0	0	0	395
1966	733	1399	55	0	971	558	155	20	58	165	0	21	0	0	0	0	264
1967	1831	1105	58	0	1099	492	155	64	202	227	0	18	0	0	0	0	511
1968	670	1779	61	0	1065	545	155	17	49	283	0	21	0	0	0	0	370
1969	2118	1323	69	156	1216	510	155	98	195	310	0	18	0	0	0	0	777
1970	1321	2000	66	432	1195	543	155	46	62	405	0	21	0	0	0	0	966
1971	1064	1628	60	0	1176	538	155	31	76	376	0	20	0	0	0	0	504
1972	764	1456	53	0	1125	600	155	20	71	262	0	23	0	0	0	0	376
1973	1237	1042	54	0	1001	508	155	51	104	202	0	20	0	0	0	4	381
1974	1500	1224	61	0	1094	479	155	46	114	321	0	18	0	0	0	0	499
1975	1210	1569	61	0	1143	507	155	33	105	349	0	19	0	0	0	0	506
1976	467	1574	54	0	941	512	155	10	19	217	0	23	0	0	0	0	269
1977	271	1046	42	0	526	250	31	9	12	169	0	21	4	0	0	24	239
1978	1311	750	48	0	890	447	124	50	207	87	0	17	0	0	0	0	362
1979	1139	1123	54	0	1047	535	155	47	138	184	0	19	0	0	0	0	388
1980	1721	1161	62	0	1131	502	155	48	84	362	0	19	0	0	0	0	513
1981	633	1688	60	0	1070	551	155	18	47	284	0	21	0	0	0	0	370
1982	2229	1192	69	204	1147	447	155	90	225	299	0	17	0	0	0	0	834
1983	2900	2000	72	1688	1141	436	155	120	267	265	0	16	0	0	0	0	2356
1984	1621	2000	68	693	1209	560	155	59	64	390	0	21	0	0	0	0	1227
1985	744	1651	61	0	1044	529	155	21	46	282	0	20	0	0	0	0	369
1986	1869	1289	65	23	1185	495	155	67	228	279	0	19	0	0	0	0	615
1987	497	1885	61	0	1066	539	155	13	28	308	0	22	0	0	0	0	371

	Year					District Diversions		Required Releases from Diversion Dam										
	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	389	1255	44	0	808	456	62	12	46	187	0	21	0	0	0	19	286
1989	648	792	36	0	701	440	8	12	110	103	0	21	0	0	0	6	252
1990	491	703	37	0	440	222	0	12	48	128	0	22	2	0	0	4	216
1991	502	717	36	0	502	279	0	15	63	119	0	21	0	0	0	7	225
1992	459	682	38	0	420	216	0	33	42	113	0	19	8	0	0	0	216
1993	1275	682	46	0	919	472	124	62	210	65	0	19	0	0	0	0	355
1994	501	992	42	0	689	421	31	19	65	115	0	19	0	0	0	18	235
1995	2160	762	57	0	1065	460	124	71	263	171	0	18	0	0	28	0	550
1996	1512	1799	72	131	1256	510	155	40	191	375	0	19	0	0	0	0	755
1997	1902	1852	70	864	1210	563	155	72	77	381	0	22	0	0	0	0	1416
1998	1876	1611	70	258	1159	454	155	79	215	317	0	16	0	0	0	0	885
1999	1326	2000	68	282	1201	526	155	39	157	335	0	20	0	0	0	0	834
2000	1062	1774	67	0	1122	477	155	40	128	336	0	17	0	0	0	0	521
2001	588	1647	60	0	989	493	155	40	64	248	0	19	0	0	0	0	372
2002	710	1187	51	0	903	558	78	16	115	118	0	21	0	0	0	1	272
2003	896	943	47	0	900	536	59	22	145	113	0	20	0	0	9	6	315
Avg:	1087	1262	54	64	969	489	115	38	110	220	0	20	0	0	1	2	455

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 2. Summary Table of Stanislaus River at 30 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1389	993	47	0	1146	507	155	38	286	170	0	19	0	0	0	0	514
1923	1109	1188	53	0	1035	512	155	35	195	147	0	19	0	0	0	0	395
1924	385	1210	46	0	702	383	31	18	55	172	0	22	0	0	0	16	284
1925	1092	847	46	0	958	457	124	31	250	102	0	17	0	0	0	0	399
1926	619	936	44	0	737	440	31	18	134	98	0	21	0	0	0	0	272
1927	1256	774	46	0	1028	514	124	36	268	94	0	20	0	0	0	0	418
1928	952	957	48	0	923	529	78	28	182	104	0	21	0	0	0	0	335
1929	506	938	40	0	630	369	12	13	112	104	0	21	0	0	0	1	251
1930	671	774	38	0	674	390	0	27	160	83	0	21	0	0	0	0	291
1931	438	732	37	0	497	221	0	61	74	98	0	19	0	0	0	17	270
1932	1160	637	39	0	988	512	47	33	306	89	0	20	0	0	0	0	448
1933	586	770	37	0	611	320	12	19	140	99	0	21	0	0	0	0	279
1934	498	708	38	0	478	220	0	58	91	94	0	18	0	0	0	0	263
1935	1082	690	42	0	867	460	47	45	242	79	0	18	0	0	0	0	385
1936	1291	863	49	0	1022	491	136	58	239	131	0	18	0	0	0	0	445
1937	1080	1083	51	0	1001	504	155	43	194	115	0	19	0	0	0	6	378
1938	2032	1111	62	0	1192	498	155	74	339	175	0	19	0	0	0	0	608
1939	562	1889	61	0	1068	536	155	12	111	233	0	20	0	0	0	0	376
1940	1327	1322	60	0	1126	522	155	45	272	149	0	19	0	0	0	0	485
1941	1290	1464	61	0	1122	493	155	42	152	296	0	18	0	0	0	0	509
1942	1450	1571	63	0	1123	477	155	39	256	215	0	17	0	0	0	0	526
1943	1538	1835	68	243	1205	503	155	61	284	224	0	19	0	0	0	9	841
1944	649	1857	60	0	1092	547	155	21	101	257	0	21	0	0	0	0	399
1945	1228	1354	58	0	1065	500	155	42	227	140	0	19	0	0	0	6	435
1946	1175	1459	61	0	1028	510	155	31	193	138	0	19	0	0	0	0	380
1947	632	1546	53	0	1147	613	155	15	118	226	0	23	0	0	0	0	381
1948	853	977	42	0	938	495	78	29	192	134	0	19	0	0	0	1	375
1949	732	851	41	0	793	481	12	21	151	115	0	22	0	0	0	0	309
1950	1027	749	41	0	935	538	47	38	212	98	0	21	0	0	0	0	368
1951	1654	800	58	0	973	518	136	63	128	162	0	19	0	0	0	0	372
1952	1844	1423	65	0	1259	504	155	68	388	188	0	19	0	0	0	0	662
1953	965	1943	64	16	1227	548	155	24	148	341	0	21	0	0	0	0	550

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	882	1602	58	0	1123	577	155	37	202	139	0	22	0	0	0	0	400
1955	656	1303	49	0	903	521	78	26	136	136	0	19	0	0	0	0	317
1956	1825	1007	59	0	1133	524	136	63	237	207	0	20	0	0	0	0	527
1957	878	1639	59	0	1104	552	155	18	176	189	0	21	0	0	0	0	405
1958	1599	1354	62	0	1121	441	155	71	291	211	0	17	0	0	0	0	590
1959	624	1770	61	0	1071	551	155	18	79	251	0	21	0	0	0	0	370
1960	574	1263	49	0	922	584	61	14	117	123	0	24	0	0	0	0	278
1961	446	866	39	0	532	285	7	9	73	114	0	22	0	0	8	7	234
1962	863	742	39	0	831	496	0	28	202	101	0	21	0	0	0	0	351
1963	1227	734	44	0	986	491	124	32	236	111	0	18	0	0	0	0	397
1964	632	931	41	0	736	438	31	17	97	137	0	23	0	0	0	0	273
1965	1666	785	53	0	1022	506	124	61	229	131	0	19	0	0	0	0	440
1966	733	1376	55	0	982	558	155	20	108	126	0	21	0	0	0	1	275
1967	1831	1073	56	0	1199	492	155	64	346	183	0	18	0	0	0	0	610
1968	670	1649	58	0	1077	545	155	17	105	239	0	21	0	0	0	0	382
1969	2118	1184	65	0	1287	510	155	98	340	236	0	18	0	0	0	0	692
1970	1321	1950	66	382	1195	543	155	46	128	339	0	21	0	0	0	0	916
1971	1064	1628	60	0	1176	538	155	31	156	296	0	20	0	0	0	0	504
1972	764	1456	53	0	1140	600	155	20	132	216	0	23	0	0	0	0	391
1973	1237	1027	52	0	1063	508	155	51	205	163	0	20	0	0	0	4	442
1974	1500	1149	59	0	1122	479	155	46	221	220	0	18	0	0	0	23	527
1975	1210	1468	59	0	1198	507	155	33	209	270	0	19	0	0	0	30	561
1976	467	1421	51	0	863	512	78	10	39	197	0	23	0	0	0	0	269
1977	271	974	40	0	487	234	12	9	24	157	0	21	1	0	0	24	235
1978	1311	718	45	0	1018	446	124	50	336	87	0	17	0	0	0	0	490
1979	1139	966	50	0	1064	535	155	47	238	101	0	19	0	0	0	0	405
1980	1721	991	58	0	1149	502	155	48	203	261	0	19	0	0	0	0	531
1981	633	1506	57	0	969	551	155	18	98	132	0	21	0	0	0	0	269
1982	2229	1114	67	93	1183	447	155	90	396	163	0	17	0	0	0	0	758
1983	2900	2000	72	1583	1246	436	155	120	468	169	0	16	0	0	0	0	2356
1984	1621	2000	68	687	1215	560	155	59	148	312	0	21	0	0	0	0	1227
1985	744	1651	61	0	1044	529	155	21	94	234	0	20	0	0	0	0	369
1986	1869	1289	65	0	1252	495	155	67	393	180	0	19	0	0	0	0	659
1987	497	1841	60	0	1066	539	155	13	57	279	0	22	0	0	0	0	371

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	389	1212	44	0	731	417	31	12	76	163	0	21	0	0	0	6	278
1989	648	827	36	0	717	402	0	12	180	100	0	21	0	0	0	1	314
1990	491	721	38	0	451	220	0	12	86	106	0	22	0	0	0	3	230
1991	502	724	36	0	506	250	0	15	110	105	0	21	0	0	0	7	258
1992	459	685	38	0	438	214	0	33	80	96	0	19	7	0	0	0	236
1993	1275	668	43	0	1131	472	124	62	334	65	0	19	0	0	0	88	568
1994	501	769	38	0	514	233	31	19	105	100	0	19	0	0	0	5	247
1995	2160	719	55	0	1167	447	124	71	436	111	0	18	0	0	28	0	664
1996	1512	1657	71	0	1212	510	155	40	321	200	0	19	0	0	0	0	579
1997	1902	1886	70	914	1194	563	155	72	129	313	0	22	0	0	0	0	1450
1998	1876	1611	70	206	1211	454	155	79	349	235	0	16	0	0	0	0	885
1999	1326	2000	68	263	1233	526	155	39	265	259	0	20	0	0	0	0	846
2000	1062	1762	66	0	1141	477	155	40	227	256	0	17	0	0	0	0	540
2001	588	1617	59	0	998	493	155	40	109	213	0	19	0	0	0	0	381
2002	710	1148	49	0	959	558	73	16	184	112	0	21	0	0	0	0	333
2003	896	850	44	0	919	536	18	22	226	97	0	20	0	0	9	0	375
Avg:	1087	1214	53	53	983	475	109	38	194	168	0	20	0	0	1	3	478

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 3. Summary Table of Stanislaus River at 40 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1389	993	46	0	1239	507	155	38	385	164	0	19	0	0	0	0	606
1923	1109	1097	49	0	1119	512	155	35	299	126	0	19	0	0	0	0	480
1924	385	1038	43	0	538	252	31	18	81	115	0	22	0	0	0	14	251
1925	1092	842	44	0	1046	451	124	31	347	98	0	17	0	0	0	0	493
1926	619	844	42	0	651	305	31	18	186	95	0	21	0	0	0	0	320
1927	1256	771	46	0	940	358	87	36	373	94	0	20	0	0	0	0	522
1928	952	1041	48	0	1031	522	102	28	276	102	0	21	0	0	0	0	427
1929	506	913	40	0	578	261	20	13	167	97	0	21	0	0	0	0	298
1930	671	802	39	0	662	314	0	27	224	83	0	21	0	0	0	0	354
1931	438	773	38	0	511	217	0	61	101	94	0	19	0	0	0	14	289
1932	1160	662	40	0	888	363	4	33	399	89	0	20	0	0	0	0	541
1933	586	894	40	0	658	319	1	19	204	94	0	21	0	0	0	0	338
1934	498	782	40	0	523	221	0	58	139	90	0	18	0	0	0	0	306
1935	1082	717	42	0	819	326	47	45	327	79	0	18	0	0	0	0	470
1936	1291	939	50	0	1117	483	136	58	364	107	0	18	0	0	0	0	547
1937	1080	1063	49	0	1073	504	155	43	274	114	0	19	0	0	0	0	450
1938	2032	1021	58	0	1348	498	155	74	524	147	0	19	0	0	0	0	764
1939	562	1647	56	0	982	536	44	12	170	199	0	20	0	0	0	0	401
1940	1327	1171	55	0	1186	522	128	45	382	126	0	19	0	0	0	0	572
1941	1290	1257	57	0	1091	493	155	42	252	165	0	18	0	0	0	0	478
1942	1450	1399	58	0	1214	476	155	38	373	188	0	17	0	0	0	0	617
1943	1538	1577	66	0	1227	503	155	61	404	136	0	19	0	0	0	0	620
1944	649	1821	59	0	1111	547	155	21	173	204	0	21	0	0	0	0	418
1945	1228	1301	56	0	1138	500	155	42	321	121	0	19	0	0	0	5	508
1946	1175	1335	56	0	1141	510	155	31	273	116	0	19	0	0	0	54	494
1947	632	1312	50	0	881	526	31	15	171	118	0	23	0	0	0	0	327
1948	853	1014	43	0	961	491	43	29	268	122	0	19	0	0	0	0	438
1949	732	862	41	0	772	400	10	21	215	114	0	22	0	0	0	0	371
1950	1027	781	42	0	838	381	13	38	306	98	0	21	0	0	0	0	463
1951	1654	928	61	0	993	512	128	63	195	129	0	19	0	0	0	0	407
1952	1844	1528	65	0	1405	504	155	68	546	176	0	19	0	0	0	0	808
1953	965	1902	63	0	1263	548	155	24	239	286	0	21	0	0	0	0	570

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	882	1542	56	0	1181	577	155	37	277	122	0	22	0	0	0	0	458
1955	656	1187	46	0	842	473	31	26	185	121	0	19	0	0	0	0	351
1956	1825	955	58	0	1199	521	124	63	335	190	0	20	0	0	0	0	608
1957	878	1524	54	0	1191	552	155	18	279	173	0	21	0	0	0	0	491
1958	1599	1156	56	0	1214	441	155	71	419	176	0	17	0	0	0	0	683
1959	624	1485	55	0	948	551	103	18	135	124	0	21	0	0	0	0	298
1960	574	1106	47	0	730	389	18	14	182	104	0	24	0	0	0	0	324
1961	446	904	41	0	510	256	0	9	104	107	0	22	0	0	5	3	249
1962	863	799	40	0	843	421	0	28	288	101	0	21	0	0	0	0	437
1963	1227	778	45	0	894	349	87	32	333	101	0	18	0	0	0	0	484
1964	632	1067	45	0	746	415	21	17	152	124	0	23	0	0	0	0	316
1965	1666	907	55	0	1093	506	124	61	319	113	0	19	0	0	0	0	512
1966	733	1425	54	0	1028	558	122	20	168	122	0	21	0	0	0	24	355
1967	1831	1075	55	0	1304	492	147	64	491	151	0	18	0	0	0	0	723
1968	670	1548	55	0	1025	545	72	17	171	204	0	21	0	0	0	0	413
1969	2118	1137	63	0	1385	510	135	98	492	202	0	18	0	0	0	0	810
1970	1321	1807	65	228	1207	543	155	46	210	269	0	21	0	0	0	0	774
1971	1064	1628	59	0	1207	538	155	31	247	237	0	20	0	0	0	0	535
1972	764	1425	53	0	1041	600	39	20	188	177	0	23	0	0	0	0	409
1973	1237	1095	53	0	1110	508	126	51	303	140	0	20	0	0	0	4	518
1974	1500	1169	59	0	1150	478	155	45	326	133	0	18	0	0	0	33	555
1975	1210	1460	59	0	1189	506	155	31	306	196	0	19	0	0	0	0	553
1976	467	1422	52	0	779	445	31	10	88	178	0	23	0	0	0	0	298
1977	271	1059	43	0	467	229	0	9	29	156	0	21	1	0	0	16	231
1978	1311	820	46	0	1147	446	124	50	454	98	0	17	0	0	0	0	620
1979	1139	938	47	0	1151	536	137	47	337	107	0	19	0	0	0	0	510
1980	1721	879	55	0	1152	502	150	48	325	147	0	19	0	0	0	0	538
1981	633	1393	54	0	912	551	60	18	157	111	0	21	0	0	0	0	307
1982	2229	1061	65	0	1293	447	132	90	556	137	0	17	0	0	0	0	799
1983	2900	1932	71	1313	1448	436	155	120	690	149	0	16	0	0	0	0	2288
1984	1621	2000	68	677	1224	560	155	59	227	243	0	21	0	0	0	0	1227
1985	744	1651	61	0	1054	529	155	21	153	185	0	20	0	0	0	0	379
1986	1869	1279	63	0	1367	495	155	67	538	149	0	19	0	0	0	0	774
1987	497	1718	58	0	960	537	31	13	109	248	0	22	0	0	0	0	392

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	389	1197	45	0	619	337	0	12	100	145	0	21	0	0	0	0	278
1989	648	922	38	0	747	354	0	12	252	106	0	21	0	0	0	0	391
1990	491	785	39	0	480	217	0	12	127	101	0	22	0	0	0	0	262
1991	502	757	36	0	505	209	0	15	151	104	0	21	0	0	0	7	298
1992	459	717	38	0	465	210	0	33	115	94	0	19	5	0	0	0	266
1993	1275	673	45	0	954	335	71	62	424	65	0	19	0	0	0	11	581
1994	501	950	42	0	557	222	17	19	177	97	0	19	0	0	0	3	315
1995	2160	852	57	0	1303	447	124	71	591	106	0	18	0	0	15	0	800
1996	1512	1652	70	0	1323	510	155	40	452	180	0	19	0	0	0	0	690
1997	1902	1772	69	769	1263	563	155	72	204	307	0	22	0	0	0	0	1375
1998	1876	1572	68	50	1330	454	155	79	512	191	0	16	0	0	0	0	848
1999	1326	2000	68	222	1320	526	155	39	375	236	0	20	0	0	0	0	893
2000	1062	1716	64	0	1185	477	155	40	324	203	0	17	0	0	0	0	583
2001	588	1529	57	0	914	493	120	40	157	116	0	19	0	0	0	0	332
2002	710	1145	49	0	862	452	22	16	252	103	0	21	0	0	0	0	392
2003	896	944	46	0	910	454	0	22	326	97	0	20	0	0	0	0	466
Avg:	1087	1190	52	40	996	446	91	38	281	142	0	20	0	0	0	2	524

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 4. Summary Table of Stanislaus River at 50 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1389	993	44	0	1347	507	155	38	511	147	0	19	0	0	0	0	714
1923	1109	990	46	0	1126	512	117	35	376	94	0	19	0	0	0	0	524
1924	385	927	40	0	514	223	21	18	110	104	0	22	0	0	0	11	266
1925	1092	758	43	0	796	220	0	31	453	98	0	17	0	0	0	0	600
1926	619	1011	46	0	693	311	0	18	244	104	0	21	0	0	0	0	387
1927	1256	891	45	0	1203	506	88	36	484	98	0	20	0	0	0	0	637
1928	952	898	44	0	952	441	21	28	358	102	0	21	0	0	0	0	509
1929	506	853	38	0	537	197	0	13	213	95	0	21	0	0	0	0	342
1930	671	783	38	0	645	233	0	27	288	83	0	21	0	0	0	0	418
1931	438	771	38	0	491	183	0	61	128	89	0	19	0	0	0	4	302
1932	1160	681	41	0	847	213	0	33	513	89	0	20	0	0	0	0	655
1933	586	953	41	0	666	263	0	19	261	102	0	21	0	0	0	0	403
1934	498	831	41	0	525	189	0	58	172	92	0	18	0	0	0	0	340
1935	1082	763	43	0	811	235	25	45	433	79	0	18	0	0	0	0	576
1936	1291	991	49	0	1223	478	131	58	482	107	0	18	0	0	0	0	665
1937	1080	1010	47	0	1154	504	139	43	374	111	0	19	0	0	0	0	547
1938	2032	890	53	0	1488	498	151	74	692	123	0	19	0	0	0	0	907
1939	562	1381	51	0	816	433	31	12	204	116	0	20	0	0	0	0	352
1940	1327	1076	51	0	1278	513	124	45	510	104	0	19	0	0	0	0	678
1941	1290	1073	51	0	1185	493	155	42	364	147	0	18	0	0	0	0	572
1942	1450	1127	52	0	1274	476	155	38	485	106	0	17	0	0	0	31	678
1943	1538	1251	58	0	1325	503	155	61	524	113	0	19	0	0	0	0	718
1944	649	1407	51	0	931	510	31	21	220	138	0	21	0	0	0	0	399
1945	1228	1075	49	0	1208	498	124	42	435	109	0	19	0	0	0	5	609
1946	1175	1046	48	0	1197	510	131	31	358	111	0	19	0	0	0	54	573
1947	632	977	43	0	697	303	25	15	223	111	0	23	0	0	0	0	372
1948	853	869	39	0	874	374	0	29	344	117	0	19	0	0	0	0	510
1949	732	808	39	0	729	302	0	21	279	114	0	22	0	0	0	0	436
1950	1027	772	42	0	773	233	0	38	402	98	0	21	0	0	0	0	558
1951	1654	984	60	0	1106	507	124	63	270	175	0	19	0	0	0	0	529
1952	1844	1471	62	0	1545	504	155	68	698	163	0	19	0	0	0	0	948
1953	965	1708	59	0	1211	548	155	24	312	161	0	21	0	0	0	0	518

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	882	1403	52	0	1143	577	38	37	358	121	0	22	0	0	0	0	537
1955	656	1090	45	0	759	374	2	26	242	109	0	19	0	0	0	0	395
1956	1825	942	56	0	1302	513	124	63	446	157	0	20	0	0	0	32	718
1957	878	1409	52	0	1148	552	47	18	357	159	0	21	0	0	0	0	556
1958	1599	1088	54	0	1302	441	128	71	565	145	0	17	0	0	0	0	798
1959	624	1331	52	0	842	480	31	18	183	114	0	21	0	0	0	0	336
1960	574	1061	46	0	679	301	0	14	237	104	0	24	0	0	0	0	379
1961	446	910	41	0	498	216	0	9	139	102	0	22	0	0	5	0	277
1962	863	817	40	0	847	335	0	28	378	101	0	21	0	0	0	0	527
1963	1227	793	45	0	877	252	60	32	440	101	0	18	0	0	0	0	591
1964	632	1098	46	0	732	377	15	17	201	106	0	23	0	0	0	0	346
1965	1666	952	56	0	1165	504	124	61	418	88	0	19	0	0	0	0	585
1966	733	1397	54	0	978	551	31	20	222	115	0	21	0	0	0	24	402
1967	1831	1099	55	0	1388	491	124	64	635	113	0	18	0	0	0	0	830
1968	670	1488	55	0	960	545	50	17	219	113	0	21	0	0	0	0	370
1969	2118	1143	62	0	1525	510	129	98	662	178	0	18	0	0	0	0	956
1970	1321	1674	64	84	1247	543	155	46	291	227	0	21	0	0	0	0	670
1971	1064	1600	59	0	1182	538	155	31	327	133	0	20	0	0	0	0	511
1972	764	1422	53	0	1000	522	31	20	251	160	0	23	0	0	0	0	454
1973	1237	1133	53	0	1188	505	124	51	408	119	0	20	0	0	0	4	602
1974	1500	1129	56	0	1255	478	155	45	435	108	0	18	0	0	0	54	660
1975	1210	1318	54	0	1284	506	155	31	413	184	0	19	0	0	0	0	647
1976	467	1190	47	0	639	304	31	10	111	155	0	23	0	0	0	0	300
1977	271	971	41	0	430	189	0	9	42	146	0	21	1	0	0	15	234
1978	1311	771	45	0	969	228	56	50	574	87	0	17	0	0	0	0	729
1979	1139	1068	50	0	1177	516	53	47	455	119	0	19	0	0	0	0	640
1980	1721	980	56	0	1236	502	134	48	435	135	0	19	0	0	0	3	639
1981	633	1408	55	0	884	503	31	18	207	109	0	21	0	0	0	0	356
1982	2229	1104	64	0	1439	445	124	90	726	121	0	17	0	0	0	0	954
1983	2900	1830	70	1029	1631	436	155	120	891	131	0	16	0	0	0	0	2187
1984	1621	2000	68	668	1263	560	155	59	311	197	0	21	0	0	0	0	1256
1985	744	1623	60	0	1041	529	134	21	209	137	0	20	0	0	0	0	387
1986	1869	1265	61	0	1504	495	150	67	704	127	0	19	0	0	0	0	916
1987	497	1569	56	0	844	518	31	13	135	125	0	22	0	0	0	0	295

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	389	1166	45	0	582	291	0	12	135	118	0	21	0	0	0	0	286
1989	648	929	38	0	739	278	0	12	322	104	0	21	0	0	0	0	460
1990	491	799	39	0	483	185	0	12	165	98	0	22	0	0	0	0	297
1991	502	768	36	0	522	179	0	15	198	104	0	21	0	0	0	7	345
1992	459	712	38	0	470	180	0	33	155	92	0	19	2	0	0	0	302
1993	1275	663	44	0	905	221	0	62	548	65	0	19	0	0	0	24	717
1994	501	990	43	0	557	203	0	19	217	94	0	19	0	0	0	3	352
1995	2160	890	55	0	1476	446	124	71	765	106	0	18	0	0	15	0	974
1996	1512	1519	65	0	1416	510	155	40	582	143	0	19	0	0	0	0	784
1997	1902	1550	68	542	1270	563	155	72	273	245	0	22	0	0	0	0	1154
1998	1876	1572	67	0	1447	454	155	79	670	151	0	16	0	0	0	0	916
1999	1326	1934	67	136	1398	526	155	39	483	206	0	20	0	0	0	0	885
2000	1062	1658	63	0	1196	477	155	40	421	117	0	17	0	0	0	0	595
2001	588	1461	56	0	839	465	31	40	204	112	0	19	0	0	0	0	375
2002	710	1154	50	0	831	375	0	16	321	103	0	21	0	0	0	0	461
2003	896	983	47	0	908	372	0	22	407	97	0	20	0	0	0	0	547
Avg:	1087	1132	50	30	1007	408	72	38	368	122	0	20	0	0	0	3	582

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 5. Summary Table of Stanislaus River at 60 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1389	993	43	0	1387	507	87	38	636	130	0	19	0	0	0	0	823
1923	1109	951	45	0	1065	469	14	35	462	94	0	19	0	0	0	0	610
1924	385	950	41	0	507	219	0	18	131	103	0	22	0	0	0	9	284
1925	1092	787	41	0	1012	329	0	31	560	98	0	17	0	0	0	0	706
1926	619	826	41	0	625	201	0	18	296	95	0	21	0	0	0	0	430
1927	1256	779	44	0	934	211	0	36	601	94	0	20	0	0	0	0	750
1928	952	1057	48	0	961	389	0	28	440	102	0	21	0	0	0	0	591
1929	506	1000	42	0	580	194	0	13	259	94	0	21	0	0	0	0	387
1930	671	884	40	0	671	184	0	27	354	92	0	21	0	0	0	0	493
1931	438	844	40	0	509	180	0	61	153	89	0	19	0	0	0	2	324
1932	1160	733	41	0	912	164	0	33	627	89	0	20	0	0	0	0	769
1933	586	941	41	0	637	181	0	19	315	100	0	21	0	0	0	0	455
1934	498	849	41	0	554	182	0	58	207	92	0	18	0	0	0	0	376
1935	1082	752	41	0	859	201	0	45	539	79	0	18	0	0	0	0	682
1936	1291	934	47	0	1219	476	11	58	599	107	0	18	0	0	0	0	782
1937	1080	959	45	0	1091	477	3	43	475	111	0	19	0	0	0	0	647
1938	2032	903	52	0	1620	496	124	74	859	116	0	19	0	0	0	0	1068
1939	562	1263	49	0	708	284	31	12	247	114	0	20	0	0	0	0	393
1940	1327	1068	50	0	1305	499	46	45	629	104	0	19	0	0	0	0	797
1941	1290	1040	49	0	1261	493	136	42	476	128	0	18	0	0	0	2	667
1942	1450	1020	47	0	1388	476	155	38	599	106	0	17	0	0	0	31	791
1943	1538	1035	51	0	1434	500	155	58	646	104	0	19	0	0	0	0	827
1944	649	1089	44	0	752	287	31	21	278	125	0	21	0	0	0	0	443
1945	1228	942	46	0	1159	483	0	42	531	100	0	19	0	0	0	8	699
1946	1175	965	46	0	1101	481	0	31	442	91	0	19	0	0	0	54	637
1947	632	992	44	0	658	236	0	15	284	102	0	23	0	0	0	0	424
1948	853	923	41	0	872	298	0	29	422	114	0	19	0	0	0	0	583
1949	732	863	41	0	731	239	0	21	344	114	0	22	0	0	0	0	500
1950	1027	824	41	0	986	350	0	38	497	98	0	21	0	0	0	0	654
1951	1654	824	57	0	1085	512	124	63	343	77	0	19	0	0	0	0	502
1952	1844	1337	57	0	1657	504	155	68	851	120	0	19	0	0	0	1	1059
1953	965	1467	54	0	1138	548	49	24	390	116	0	21	0	0	0	0	550

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	882	1240	49	0	1002	406	5	37	430	111	0	22	0	0	0	0	600
1955	656	1071	45	0	701	268	0	26	308	94	0	19	0	0	0	0	445
1956	1825	981	56	0	1402	507	124	63	557	137	0	20	0	0	0	49	825
1957	878	1349	51	0	1061	417	31	18	436	146	0	21	0	0	0	0	621
1958	1599	1115	53	0	1423	433	124	71	712	128	0	17	0	0	0	3	931
1959	624	1238	50	0	750	339	31	18	232	114	0	21	0	0	0	0	385
1960	574	1062	46	0	629	196	0	14	292	104	0	24	0	0	0	0	434
1961	446	961	42	0	495	180	0	9	175	100	0	22	0	0	5	0	310
1962	863	870	41	0	853	251	0	28	468	101	0	21	0	0	0	0	617
1963	1227	839	43	0	1168	472	24	32	548	101	0	18	0	0	0	0	699
1964	632	855	40	0	604	224	6	17	247	93	0	23	0	0	0	0	380
1965	1666	843	52	0	1257	497	124	61	520	84	0	19	0	0	0	0	684
1966	733	1201	50	0	836	361	31	20	277	108	0	21	0	0	0	24	451
1967	1831	1048	52	0	1507	476	124	64	779	104	0	18	0	0	0	0	964
1968	670	1321	51	0	827	376	31	17	275	113	0	21	0	0	0	0	426
1969	2118	1112	59	0	1658	502	124	98	823	163	0	18	0	0	0	0	1102
1970	1321	1513	62	0	1301	543	155	46	372	201	0	21	0	0	0	0	640
1971	1064	1471	56	0	1197	538	106	31	407	115	0	20	0	0	0	0	573
1972	764	1283	51	0	868	400	19	20	306	107	0	23	0	0	0	0	455
1973	1237	1128	53	0	1177	499	27	51	521	99	0	20	0	0	0	4	694
1974	1500	1136	55	0	1337	478	131	45	544	105	0	18	0	0	0	54	766
1975	1210	1244	51	0	1310	506	86	31	520	172	0	19	0	0	0	0	742
1976	467	1092	46	0	545	240	14	10	134	120	0	23	0	0	0	0	286
1977	271	968	41	0	428	184	0	9	59	132	0	21	1	0	0	16	237
1978	1311	770	44	0	1028	214	0	50	703	87	0	17	0	0	0	0	857
1979	1139	1009	49	0	1104	425	0	47	546	98	0	19	0	0	0	0	710
1980	1721	996	55	0	1414	498	124	48	563	135	0	19	0	0	0	66	831
1981	633	1248	51	0	758	326	31	18	257	111	0	21	0	0	0	0	407
1982	2229	1073	61	0	1602	438	124	90	897	121	0	17	0	0	0	0	1125
1983	2900	1639	69	639	1831	436	155	120	1091	131	0	16	0	0	0	0	1998
1984	1621	2000	68	658	1314	560	155	59	394	165	0	21	0	0	0	0	1297
1985	744	1582	60	0	927	478	31	21	265	122	0	20	0	0	0	0	427
1986	1869	1338	60	0	1641	493	124	67	869	127	0	19	0	0	0	0	1082
1987	497	1505	55	0	739	390	31	13	166	117	0	22	0	0	0	0	318

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	389	1208	46	0	551	243	0	12	165	105	0	21	0	0	0	0	303
1989	648	1000	40	0	745	214	0	12	392	104	0	21	0	0	0	0	530
1990	491	863	40	0	514	180	0	12	203	96	0	22	0	0	0	0	333
1991	502	800	36	0	569	179	0	15	245	104	0	21	0	0	0	7	392
1992	459	697	36	0	506	180	0	33	195	91	0	19	0	0	0	0	338
1993	1275	613	41	0	950	148	0	62	672	65	0	19	0	0	0	18	836
1994	501	897	40	0	573	179	0	19	256	94	0	19	0	0	0	3	391
1995	2160	785	52	0	1369	228	62	71	938	106	0	18	0	0	15	0	1147
1996	1512	1524	65	0	1486	486	140	40	712	123	0	19	0	0	0	0	893
1997	1902	1485	68	469	1289	563	155	72	347	191	0	22	0	0	0	0	1100
1998	1876	1562	65	0	1593	454	155	79	828	139	0	16	0	0	0	0	1061
1999	1326	1780	65	0	1489	526	155	39	591	189	0	20	0	0	0	0	839
2000	1062	1552	59	0	1258	477	117	40	520	117	0	17	0	0	0	0	694
2001	588	1297	53	0	694	286	21	40	250	109	0	19	0	0	0	0	418
2002	710	1139	50	0	768	244	0	16	389	103	0	21	0	0	0	0	529
2003	896	1031	48	0	882	264	0	22	488	97	0	20	0	0	0	0	628
Avg:	1087	1087	49	22	1016	362	49	38	456	112	0	20	0	0	0	4	652

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 6. Summary Table of Tuolumne River at 20 Percent Unimpaired Flow

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	2207	1370	66	516	1310	857	0	0	283	163	0	7	0	0	0	0	969
1923	1532	1685	64	370	1219	867	0	0	158	188	0	7	0	0	0	0	723
1924	351	1562	57	0	789	616	0	0	32	132	0	9	0	0	0	0	173
1925	1567	1067	64	16	1042	778	0	0	209	49	0	7	0	0	0	0	280
1926	862	1511	69	32	1121	938	0	0	100	74	0	8	0	0	0	0	214
1927	1745	1152	66	0	1208	888	0	0	213	99	0	7	0	0	0	0	320
1928	1296	1624	68	273	1193	927	0	0	149	109	0	8	0	0	0	0	539
1929	674	1385	52	0	996	811	0	0	95	82	0	8	0	0	0	0	185
1930	861	1011	44	0	920	745	0	0	114	53	0	8	0	0	0	0	175
1931	355	909	45	0	499	387	0	0	35	69	0	8	0	0	0	0	112
1932	1795	721	58	0	1217	867	0	0	226	116	0	8	0	0	0	0	350
1933	828	1241	49	0	1073	815	0	0	107	142	0	8	0	0	0	0	258
1934	618	947	51	0	629	508	0	0	42	71	0	8	0	0	0	0	121
1935	1721	885	64	0	1104	781	0	0	232	85	0	6	0	0	0	0	324
1936	1887	1437	71	437	1226	835	0	0	250	135	0	7	0	0	0	0	828
1937	1730	1590	69	480	1255	853	0	0	242	154	0	7	0	0	0	0	882
1938	3149	1516	68	1530	1368	856	0	0	375	131	0	6	0	0	0	0	2042
1939	755	1700	60	130	1141	936	0	0	69	128	0	8	0	0	0	0	335
1940	1949	1124	66	319	1253	882	0	0	226	138	0	7	0	0	0	0	690
1941	2259	1436	66	668	1293	831	0	0	306	149	0	7	0	0	0	0	1130
1942	2141	1668	63	919	1149	804	0	0	160	180	0	6	0	0	0	0	1265
1943	2137	1678	66	859	1212	872	0	0	193	139	0	7	0	0	0	0	1199
1944	1023	1678	60	80	1194	926	0	0	96	165	0	8	0	0	0	0	348
1945	1801	1366	64	350	1197	856	0	0	220	115	0	7	0	0	0	0	692
1946	1630	1555	62	584	1201	888	0	0	134	172	0	7	0	0	0	0	898
1947	839	1338	55	0	1083	870	0	0	79	125	0	9	0	0	0	0	212
1948	1102	1039	47	0	1084	855	0	0	140	82	0	7	0	0	0	0	229
1949	980	1010	50	0	1070	847	0	0	136	79	0	8	0	0	0	0	223
1950	1246	871	51	0	1156	912	0	0	169	67	0	8	0	0	0	0	243
1951	2190	911	59	682	1178	883	0	12	153	123	0	7	0	0	0	0	977
1952	2727	1181	66	843	1299	834	0	0	332	127	0	6	0	0	0	0	1308
1953	1302	1700	63	149	1236	952	0	0	136	140	0	8	0	0	0	0	433

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	1166	1555	65	66	1194	971	0	0	155	60	0	8	0	0	0	0	289
1955	837	1396	54	0	1113	905	0	0	104	96	0	8	0	0	0	0	208
1956	2877	1066	67	954	1231	894	0	0	221	108	0	7	0	0	0	0	1291
1957	1161	1693	64	74	1260	971	0	0	149	133	0	8	0	0	0	0	363
1958	2369	1455	69	898	1158	758	0	0	253	141	0	6	0	0	0	0	1298
1959	820	1700	65	146	1142	941	0	0	60	132	0	8	0	0	0	0	347
1960	785	1167	56	0	915	749	0	0	106	51	0	9	0	0	0	0	166
1961	444	981	46	0	517	386	0	0	60	62	0	8	0	0	0	0	130
1962	1460	863	53	0	1128	875	0	0	187	58	0	8	0	0	0	0	253
1963	1781	1142	63	0	1248	848	0	0	266	127	0	7	0	0	0	0	400
1964	883	1613	59	15	1237	991	0	0	101	137	0	8	0	0	0	0	262
1965	2442	1184	64	727	1234	876	0	2	244	106	0	7	0	0	0	0	1085
1966	1091	1602	65	233	1206	961	0	0	125	112	0	8	0	0	0	0	478
1967	2810	1190	67	924	1309	813	0	0	377	113	0	6	0	0	0	0	1420
1968	792	1700	61	86	1187	976	0	0	79	123	0	8	0	0	0	0	297
1969	3571	1158	70	1426	1533	864	0	68	512	82	0	7	0	0	0	0	2094
1970	1736	1700	64	701	1276	907	0	0	188	173	0	8	0	0	0	0	1069
1971	1424	1395	63	46	1198	908	0	0	151	131	0	8	0	0	0	0	336
1972	946	1512	61	0	1242	1041	0	0	121	71	0	9	0	0	0	0	201
1973	1754	1154	70	51	1226	878	0	0	218	123	0	7	0	0	0	0	399
1974	2011	1562	74	600	1211	820	0	0	209	175	0	7	0	0	0	0	991
1975	1795	1688	70	414	1298	875	0	0	224	193	0	7	0	0	0	0	838
1976	431	1700	59	41	891	710	0	0	29	143	0	9	0	0	0	0	221
1977	223	1141	45	0	507	387	0	0	28	75	0	9	7	0	0	0	120
1978	2470	812	67	370	1164	750	0	0	315	94	0	6	0	0	0	0	785
1979	1702	1680	70	648	1286	901	0	0	183	195	0	7	0	0	0	0	1033
1980	2748	1377	69	1064	1292	860	0	0	274	151	0	7	0	0	0	0	1496
1981	832	1700	69	90	1174	948	0	0	91	128	0	8	0	0	0	0	316
1982	3505	1199	69	1689	1247	776	0	0	374	91	0	6	0	0	0	0	2160
1983	4438	1700	62	3091	1284	755	0	0	372	151	0	6	0	0	0	0	3620
1984	2275	1700	72	1228	1343	949	0	8	198	179	0	8	0	0	0	0	1621
1985	976	1333	64	0	1140	913	0	0	95	125	0	8	0	0	0	0	227
1986	2698	1105	65	717	1325	850	0	0	376	93	0	7	0	0	0	0	1192
1987	422	1696	61	0	942	756	0	0	51	126	0	8	0	0	0	0	186

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	532	1116	47	0	618	481	0	0	81	48	0	8	0	0	0	0	137
1989	1050	983	43	0	1078	834	0	0	190	46	0	8	0	0	0	0	243
1990	583	912	47	0	566	415	0	0	92	49	0	8	3	0	0	0	152
1991	837	882	42	0	838	626	0	0	152	53	0	8	0	0	0	0	212
1992	704	838	51	0	629	468	0	0	85	55	0	7	13	0	0	0	161
1993	2235	862	71	108	1220	803	0	0	330	81	0	7	0	0	0	0	525
1994	599	1698	58	0	1105	879	0	0	110	109	0	8	0	0	0	0	227
1995	3576	1133	66	1649	1294	780	0	0	421	87	0	6	0	0	0	0	2163
1996	2117	1700	69	796	1263	850	0	0	262	144	0	7	0	0	0	0	1208
1997	2944	1689	66	1654	1355	973	0	0	225	149	0	8	0	0	0	0	2036
1998	3050	1558	67	1563	1277	761	0	0	353	158	0	6	0	0	0	0	2080
1999	1890	1700	66	628	1349	914	0	1	268	159	0	8	0	0	0	0	1064
2000	1702	1546	68	345	1202	804	0	0	250	141	0	7	0	0	0	0	743
2001	837	1633	62	64	1086	849	0	0	116	114	0	7	0	0	0	0	301
2002	1135	1259	57	0	1164	935	0	0	171	50	0	8	0	0	0	0	229
2003	1296	1172	57	0	1192	916	0	0	211	57	0	8	0	0	0	0	276
Avg:	1586	1344	61	394	1132	824	0	1	186	114	0	7	0	0	0	0	703

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 7. Summary Table of Tuolumne River at 30 Percent Unimpaired Flow

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	2207	1370	65	335	1492	857	0	0	493	134	0	7	0	0	0	0	970
1923	1532	1685	63	370	1303	867	0	0	285	145	0	7	0	0	0	0	807
1924	351	1480	55	0	710	507	0	0	67	126	0	9	0	0	0	0	203
1925	1567	1066	61	0	1201	774	0	0	372	49	0	7	0	0	0	0	427
1926	862	1370	65	0	1100	835	0	0	198	59	0	8	0	0	0	0	265
1927	1745	1068	60	0	1349	880	0	0	380	82	0	7	0	0	0	0	469
1928	1296	1404	66	0	1314	927	0	0	276	103	0	8	0	0	0	0	387
1929	674	1320	50	0	934	681	0	0	180	65	0	8	0	0	0	0	253
1930	861	1010	43	0	900	629	0	0	212	50	0	8	0	0	0	0	270
1931	355	929	45	0	525	380	0	0	73	65	0	8	0	0	0	0	146
1932	1795	714	55	0	1364	867	0	0	397	92	0	8	0	0	0	0	497
1933	828	1090	45	0	971	643	0	0	198	122	0	8	0	0	0	0	328
1934	618	902	50	0	587	414	0	0	109	55	0	8	0	0	0	0	172
1935	1721	883	60	0	1270	776	0	0	407	81	0	6	0	0	0	0	494
1936	1887	1274	69	189	1403	835	0	0	436	125	0	7	0	0	0	0	756
1937	1730	1501	67	341	1407	853	0	0	423	125	0	7	0	0	0	0	896
1938	3149	1415	68	1175	1622	856	0	0	635	125	0	6	0	0	0	0	1941
1939	755	1700	60	126	1144	889	0	0	135	112	0	8	0	0	0	0	380
1940	1949	1126	64	265	1400	878	0	0	410	106	0	7	0	0	0	0	788
1941	2259	1346	64	527	1464	831	0	0	502	125	0	7	0	0	0	0	1160
1942	2141	1550	63	684	1267	804	0	0	320	136	0	6	0	0	0	0	1148
1943	2137	1678	65	748	1374	872	0	0	370	125	0	7	0	0	0	0	1250
1944	1023	1627	58	30	1267	926	0	0	190	143	0	8	0	0	0	0	370
1945	1801	1295	62	228	1340	856	0	0	387	91	0	7	0	0	0	0	712
1946	1630	1465	61	463	1296	888	0	0	262	138	0	7	0	0	0	0	871
1947	839	1275	54	0	1018	746	0	0	165	98	0	9	0	0	0	0	271
1948	1102	1042	45	0	1161	837	0	0	254	63	0	7	0	0	0	0	324
1949	980	938	47	0	1021	698	0	0	237	77	0	8	0	0	0	0	323
1950	1246	850	49	0	1151	779	0	0	306	59	0	8	0	0	0	0	373
1951	2190	896	58	648	1260	876	0	12	272	93	0	7	0	0	0	0	1032
1952	2727	1119	65	560	1521	834	0	0	556	125	0	6	0	0	0	0	1247
1953	1302	1700	61	146	1317	952	0	0	247	109	0	8	0	0	0	0	511

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	1166	1478	62	0	1322	971	0	0	285	59	0	8	0	0	0	0	351
1955	837	1260	51	0	1008	734	0	0	196	70	0	8	0	0	0	0	274
1956	2877	1039	66	793	1364	878	0	0	397	82	0	7	0	0	0	0	1280
1957	1161	1693	63	56	1357	971	0	0	272	105	0	8	0	0	0	0	442
1958	2369	1378	69	653	1326	758	0	0	472	91	0	6	0	0	0	0	1221
1959	820	1700	63	146	1193	938	0	0	139	108	0	8	0	0	0	0	401
1960	785	1117	54	0	866	609	0	0	203	46	0	9	0	0	0	0	258
1961	444	981	45	0	557	376	0	0	121	52	0	8	0	0	0	0	181
1962	1460	823	49	0	1275	875	0	0	344	49	0	8	0	0	0	0	400
1963	1781	959	55	0	1390	848	0	0	433	102	0	7	0	0	0	0	542
1964	883	1296	52	0	1061	752	0	0	185	115	0	8	0	0	0	0	308
1965	2442	1066	62	584	1351	863	0	2	397	82	0	7	0	0	0	0	1072
1966	1091	1511	64	132	1261	931	0	0	221	101	0	8	0	0	0	0	462
1967	2810	1146	67	694	1496	810	0	0	588	91	0	6	0	0	0	0	1379
1968	792	1700	61	74	1222	949	0	0	167	98	0	8	0	0	0	0	348
1969	3571	1135	70	1133	1803	862	0	68	783	82	0	7	0	0	0	0	2074
1970	1736	1700	63	669	1383	907	0	0	311	157	0	8	0	0	0	0	1144
1971	1424	1322	61	0	1284	908	0	0	271	97	0	8	0	0	0	0	376
1972	946	1401	58	0	1159	876	0	0	219	54	0	9	0	0	0	0	282
1973	1754	1130	68	12	1347	868	0	0	384	87	0	7	0	0	0	0	490
1974	2011	1458	73	399	1333	820	0	0	367	140	0	7	0	0	0	0	912
1975	1795	1663	68	320	1438	875	0	0	389	168	0	7	0	0	0	0	883
1976	431	1632	58	0	833	631	0	0	63	130	0	9	0	0	0	0	202
1977	223	1172	46	0	511	381	0	0	57	63	0	9	1	0	0	0	130
1978	2470	837	67	194	1366	750	0	0	529	81	0	6	0	0	0	0	811
1979	1702	1680	69	586	1381	901	0	0	319	152	0	7	0	0	0	0	1065
1980	2748	1346	69	863	1462	860	0	0	471	125	0	7	0	0	0	0	1465
1981	832	1700	68	66	1246	948	0	0	177	114	0	8	0	0	0	0	364
1982	3505	1152	69	1377	1512	776	0	0	639	91	0	6	0	0	0	0	2112
1983	4438	1700	62	2828	1548	755	0	0	663	125	0	6	0	0	0	0	3621
1984	2275	1700	70	1193	1465	949	0	8	340	159	0	8	0	0	0	0	1708
1985	976	1248	61	0	1113	808	0	0	189	109	0	8	0	0	0	0	305
1986	2698	1051	65	433	1555	843	0	0	623	82	0	7	0	0	0	0	1145
1987	422	1696	61	0	902	675	0	0	100	119	0	8	0	0	0	0	227

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	532	1156	48	0	615	418	0	0	145	44	0	8	0	0	0	0	197
1989	1050	1025	44	0	1086	726	0	0	308	44	0	8	0	0	0	0	360
1990	583	945	47	0	596	383	0	0	161	44	0	8	0	0	0	0	213
1991	837	885	41	0	835	525	0	0	250	53	0	8	0	0	0	0	310
1992	704	846	50	0	623	409	0	0	152	44	0	7	11	0	0	0	215
1993	2235	877	69	0	1413	799	0	0	527	81	0	7	0	0	0	0	614
1994	599	1630	57	0	1026	734	0	0	185	100	0	8	0	0	0	0	292
1995	3576	1146	66	1416	1540	770	0	0	681	82	0	6	0	0	0	0	2185
1996	2117	1700	69	622	1436	850	0	0	454	125	0	7	0	0	0	0	1208
1997	2944	1689	64	1619	1487	973	0	0	380	125	0	8	0	0	0	0	2132
1998	3050	1463	67	1263	1484	761	0	0	592	125	0	6	0	0	0	0	1986
1999	1890	1700	64	595	1483	914	0	1	437	124	0	8	0	0	0	0	1164
2000	1702	1447	67	168	1358	804	0	0	423	125	0	7	0	0	0	0	723
2001	837	1557	60	0	1160	849	0	0	203	101	0	7	0	0	0	0	312
2002	1135	1174	53	0	1211	870	0	0	283	50	0	8	0	0	0	0	341
2003	1296	1044	51	0	1293	894	0	0	341	50	0	8	0	0	0	0	399
Avg:	1586	1296	60	314	1217	788	0	1	324	96	0	7	0	0	0	0	743

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 8. Summary Table of Tuolumne River at 40 Percent Unimpaired Flow

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	2207	1370	65	201	1651	857	0	0	662	125	0	7	0	0	0	0	995
1923	1532	1659	61	275	1458	867	0	0	456	128	0	7	0	0	0	0	866
1924	351	1397	53	0	639	401	0	0	102	126	0	9	0	0	0	0	237
1925	1567	1056	57	0	1360	769	0	0	535	49	0	7	0	0	0	0	591
1926	862	1206	60	0	992	627	0	0	299	59	0	8	0	0	0	0	365
1927	1745	1016	56	0	1498	863	0	0	546	82	0	7	0	0	0	0	636
1928	1296	1208	58	0	1376	868	0	0	405	95	0	8	0	0	0	0	508
1929	674	1069	44	0	783	445	0	0	265	65	0	8	0	0	0	0	338
1930	861	916	41	0	829	461	0	0	315	44	0	8	0	0	0	0	367
1931	355	908	43	0	551	369	0	0	117	57	0	8	0	0	0	0	182
1932	1795	669	54	0	1203	546	0	0	569	81	0	8	0	0	0	0	657
1933	828	1207	48	0	1002	589	0	0	291	114	0	8	0	0	0	0	413
1934	618	985	52	0	621	382	0	0	176	55	0	8	0	0	0	0	239
1935	1721	930	58	0	1443	774	0	0	582	81	0	6	0	0	0	0	669
1936	1887	1149	66	0	1589	835	0	0	622	125	0	7	0	0	0	0	753
1937	1730	1382	65	189	1550	853	0	0	565	125	0	7	0	0	0	0	886
1938	3149	1308	67	823	1884	856	0	0	897	125	0	6	0	0	0	0	1852
1939	755	1683	60	60	1136	775	0	0	249	104	0	8	0	0	0	0	421
1940	1949	1182	63	263	1551	868	0	0	593	82	0	7	0	0	0	0	946
1941	2259	1255	62	399	1615	831	0	0	653	125	0	7	0	0	0	0	1183
1942	2141	1438	62	417	1439	804	0	0	502	127	0	6	0	0	0	0	1053
1943	2137	1661	64	665	1544	872	0	0	540	125	0	7	0	0	0	0	1337
1944	1023	1525	54	0	1345	892	0	0	337	108	0	8	0	0	0	0	453
1945	1801	1148	60	8	1505	854	0	0	554	91	0	7	0	0	0	0	659
1946	1630	1375	59	346	1421	888	0	0	395	131	0	7	0	0	0	0	880
1947	839	1179	51	0	942	592	0	0	252	90	0	9	0	0	0	0	351
1948	1102	1024	44	0	1132	696	0	0	370	59	0	7	0	0	0	0	436
1949	980	949	47	0	1015	589	0	0	349	69	0	8	0	0	0	0	426
1950	1246	867	48	0	1151	642	0	0	442	59	0	8	0	0	0	0	509
1951	2190	913	58	632	1294	799	0	12	391	84	0	7	0	0	0	0	1127
1952	2727	1119	65	412	1690	829	0	0	730	125	0	6	0	0	0	0	1273
1953	1302	1679	60	72	1464	952	0	0	408	95	0	8	0	0	0	0	584

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	1166	1386	57	0	1388	907	0	0	414	59	0	8	0	0	0	0	481
1955	837	1107	47	0	904	547	0	0	291	59	0	8	0	0	0	0	358
1956	2877	993	65	683	1474	861	0	0	523	82	0	7	0	0	0	0	1296
1957	1161	1648	59	0	1517	971	0	0	445	93	0	8	0	0	0	0	546
1958	2369	1233	68	351	1502	758	0	0	648	91	0	6	0	0	0	0	1096
1959	820	1680	64	78	1193	827	0	0	265	93	0	8	0	0	0	0	445
1960	785	1164	55	0	870	515	0	0	301	46	0	9	0	0	0	0	355
1961	444	1024	45	0	606	370	0	0	183	45	0	8	0	0	0	0	236
1962	1460	817	49	0	1107	550	0	0	501	49	0	8	0	0	0	0	557
1963	1781	1121	57	0	1518	822	0	0	599	91	0	7	0	0	0	0	697
1964	883	1327	53	0	1047	666	0	0	269	102	0	8	0	0	0	0	380
1965	2442	1110	61	623	1441	858	0	2	491	82	0	7	0	0	0	0	1205
1966	1091	1427	64	0	1243	765	0	0	376	93	0	8	0	0	0	0	478
1967	2810	1212	67	633	1637	796	0	0	744	91	0	6	0	0	0	0	1474
1968	792	1686	61	0	1209	800	0	0	308	93	0	8	0	0	0	0	409
1969	3571	1208	70	990	2048	853	0	68	1038	82	0	7	0	0	0	0	2185
1970	1736	1670	61	589	1507	907	0	0	452	141	0	8	0	0	0	0	1189
1971	1424	1249	56	0	1400	908	0	0	392	93	0	8	0	0	0	0	492
1972	946	1216	54	0	1034	653	0	0	317	54	0	9	0	0	0	0	380
1973	1754	1075	63	0	1496	854	0	0	552	82	0	7	0	0	0	0	641
1974	2011	1270	72	188	1481	820	0	0	524	130	0	7	0	0	0	0	849
1975	1795	1541	67	188	1568	875	0	0	532	154	0	7	0	0	0	0	881
1976	431	1513	56	0	746	491	0	0	135	112	0	9	0	0	0	0	255
1977	223	1143	45	0	529	371	0	0	86	62	0	9	1	0	0	0	158
1978	2470	791	66	84	1519	742	0	0	690	81	0	6	0	0	0	0	861
1979	1702	1592	69	343	1568	901	0	0	526	133	0	7	0	0	0	0	1009
1980	2748	1315	68	675	1630	860	0	0	638	125	0	7	0	0	0	0	1445
1981	832	1689	68	22	1239	834	0	0	297	100	0	8	0	0	0	0	427
1982	3505	1192	69	1183	1745	769	0	0	879	91	0	6	0	0	0	0	2159
1983	4438	1700	61	2526	1851	755	0	0	965	125	0	6	0	0	0	0	3621
1984	2275	1700	68	1145	1599	949	0	8	494	139	0	8	0	0	0	0	1795
1985	976	1163	58	0	1043	650	0	0	286	99	0	8	0	0	0	0	393
1986	2698	1038	64	246	1792	832	0	0	871	82	0	7	0	0	0	0	1205
1987	422	1635	60	0	831	558	0	0	159	107	0	8	0	0	0	0	273

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	532	1166	47	0	627	367	0	0	208	44	0	8	0	0	0	0	260
1989	1050	1024	43	0	1071	592	0	0	426	44	0	8	0	0	0	0	479
1990	583	961	46	0	656	375	0	0	229	44	0	8	0	0	0	0	282
1991	837	842	39	0	808	400	0	0	348	53	0	8	0	0	0	0	408
1992	704	831	49	0	639	361	0	0	219	44	0	7	8	0	0	0	278
1993	2235	847	68	0	1491	739	0	0	665	81	0	7	0	0	0	0	753
1994	599	1523	53	0	963	543	0	0	318	94	0	8	0	0	0	0	420
1995	3576	1105	66	1188	1739	757	0	0	893	82	0	6	0	0	0	0	2170
1996	2117	1688	69	498	1616	850	0	0	635	125	0	7	0	0	0	0	1264
1997	2944	1622	64	1487	1644	973	0	0	538	125	0	8	0	0	0	0	2158
1998	3050	1372	67	927	1750	761	0	0	858	125	0	6	0	0	0	0	1916
1999	1890	1678	62	473	1684	914	0	1	637	124	0	8	0	0	0	0	1242
2000	1702	1349	64	0	1531	804	0	0	595	125	0	7	0	0	0	0	727
2001	837	1456	56	0	1104	708	0	0	296	93	0	7	0	0	0	0	396
2002	1135	1132	52	0	1162	709	0	0	394	50	0	8	0	0	0	0	453
2003	1296	1054	50	0	1273	744	0	0	471	50	0	8	0	0	0	0	529
Avg:	1586	1253	58	242	1289	725	0	1	465	91	0	7	0	0	0	0	807

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 9. Summary Table of Tuolumne River at 50 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	2207	1370	64	36	1861	857	0	0	872	125	0	7	0	0	0	0	1039
1923	1532	1616	60	189	1584	867	0	0	586	125	0	7	0	0	0	0	907
1924	351	1315	51	0	576	303	0	0	140	123	0	9	0	0	0	0	272
1925	1567	1039	54	0	1479	725	0	0	698	49	0	7	0	0	0	0	754
1926	862	1072	55	0	914	448	0	0	399	59	0	8	0	0	0	0	466
1927	1745	966	51	0	1632	830	0	0	713	82	0	7	0	0	0	0	802
1928	1296	1028	53	0	1272	637	0	0	534	93	0	8	0	0	0	0	635
1929	674	999	42	0	730	307	0	0	353	62	0	8	0	0	0	0	423
1930	861	901	40	0	809	339	0	0	417	44	0	8	0	0	0	0	470
1931	355	914	45	0	454	228	0	0	169	49	0	8	0	0	0	0	226
1932	1795	770	56	0	1152	324	0	0	740	81	0	8	0	0	0	0	828
1933	828	1357	52	0	1039	537	0	0	384	109	0	8	0	0	0	0	502
1934	618	1094	54	0	660	354	0	0	243	55	0	8	0	0	0	0	306
1935	1721	997	57	0	1561	717	0	0	757	81	0	6	0	0	0	0	844
1936	1887	1100	60	0	1771	831	0	0	808	125	0	7	0	0	0	0	940
1937	1730	1156	59	0	1731	853	0	0	747	125	0	7	0	0	0	0	878
1938	3149	1096	66	352	2145	856	0	0	1158	125	0	6	0	0	0	0	1641
1939	755	1683	60	49	1091	659	0	0	327	98	0	8	0	0	0	0	481
1940	1949	1237	61	236	1724	858	0	0	777	82	0	7	0	0	0	0	1103
1941	2259	1165	60	233	1811	831	0	0	849	125	0	7	0	0	0	0	1213
1942	2141	1321	61	161	1607	804	0	0	672	125	0	6	0	0	0	0	964
1943	2137	1633	62	545	1721	872	0	0	717	125	0	7	0	0	0	0	1394
1944	1023	1441	52	0	1273	722	0	0	447	96	0	8	0	0	0	0	551
1945	1801	1138	57	0	1662	843	0	0	721	91	0	7	0	0	0	0	818
1946	1630	1220	57	177	1456	796	0	0	528	125	0	7	0	0	0	0	837
1947	839	1159	50	0	911	475	0	0	339	88	0	9	0	0	0	0	436
1948	1102	1037	44	0	1120	567	0	0	487	59	0	7	0	0	0	0	552
1949	980	975	47	0	1014	477	0	0	463	66	0	8	0	0	0	0	538
1950	1246	894	48	0	1154	508	0	0	579	59	0	8	0	0	0	0	646
1951	2190	938	58	633	1257	642	0	12	510	84	0	7	0	0	0	0	1247
1952	2727	1180	65	261	1903	818	0	0	953	125	0	6	0	0	0	0	1345
1953	1302	1679	58	57	1573	952	0	0	520	93	0	8	0	0	0	0	678

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	1166	1293	54	0	1322	711	0	0	544	59	0	8	0	0	0	0	611
1955	837	1084	47	0	869	417	0	0	386	59	0	8	0	0	0	0	452
1956	2877	1005	63	644	1639	850	0	0	699	82	0	7	0	0	0	0	1433
1957	1161	1536	56	0	1469	799	0	0	569	93	0	8	0	0	0	0	670
1958	2369	1172	67	82	1712	748	0	0	868	91	0	6	0	0	0	0	1046
1959	820	1680	64	60	1155	706	0	0	348	93	0	8	0	0	0	0	509
1960	785	1220	56	0	872	420	0	0	398	46	0	9	0	0	0	0	452
1961	444	1077	48	0	529	231	0	0	245	44	0	8	0	0	0	0	298
1962	1460	945	48	0	1386	672	0	0	658	49	0	8	0	0	0	0	714
1963	1781	970	49	0	1696	832	0	0	766	91	0	7	0	0	0	0	863
1964	883	1008	45	0	872	415	0	0	354	95	0	8	0	0	0	0	457
1965	2442	973	59	438	1581	845	0	2	644	82	0	7	0	0	0	0	1174
1966	1091	1336	61	0	1164	591	0	0	473	93	0	8	0	0	0	0	573
1967	2810	1202	67	427	1833	782	0	0	954	91	0	6	0	0	0	0	1479
1968	792	1686	61	0	1176	679	0	0	396	93	0	8	0	0	0	0	497
1969	3571	1242	70	761	2311	845	0	68	1309	82	0	7	0	0	0	0	2227
1970	1736	1670	60	557	1602	894	0	0	575	125	0	8	0	0	0	0	1264
1971	1424	1188	54	0	1416	804	0	0	512	93	0	8	0	0	0	0	612
1972	946	1142	52	0	972	494	0	0	415	54	0	9	0	0	0	0	478
1973	1754	1064	60	0	1594	785	0	0	719	82	0	7	0	0	0	0	808
1974	2011	1164	69	33	1630	817	0	0	682	125	0	7	0	0	0	0	846
1975	1795	1442	64	56	1719	875	0	0	704	134	0	7	0	0	0	0	901
1976	431	1397	53	0	659	370	0	0	180	100	0	9	0	0	0	0	289
1977	223	1116	46	0	416	228	0	0	116	61	0	9	1	0	0	0	187
1978	2470	877	65	0	1719	728	0	0	904	81	0	6	0	0	0	0	991
1979	1702	1562	68	193	1718	901	0	0	685	125	0	7	0	0	0	0	1010
1980	2748	1284	68	449	1826	860	0	0	835	125	0	7	0	0	0	0	1415
1981	832	1689	68	12	1198	708	0	0	388	94	0	8	0	0	0	0	502
1982	3505	1244	69	977	2003	762	0	0	1144	91	0	6	0	0	0	0	2218
1983	4438	1700	61	2236	2141	755	0	0	1256	125	0	6	0	0	0	0	3622
1984	2275	1700	68	1112	1619	841	0	8	636	125	0	8	0	0	0	0	1890
1985	976	1177	58	0	1023	539	0	0	384	93	0	8	0	0	0	0	484
1986	2698	1072	63	144	2032	825	0	0	1118	82	0	7	0	0	0	0	1351
1987	422	1532	57	0	748	423	0	0	218	99	0	8	0	0	0	0	325

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	532	1149	47	0	558	235	0	0	271	44	0	8	0	0	0	0	323
1989	1050	1077	43	0	1076	479	0	0	545	44	0	8	0	0	0	0	597
1990	583	1008	48	0	572	222	0	0	298	44	0	8	0	0	0	0	350
1991	837	970	42	0	857	351	0	0	446	53	0	8	0	0	0	0	506
1992	704	908	51	0	639	297	0	0	287	44	0	7	4	0	0	0	342
1993	2235	922	65	0	1741	791	0	0	862	81	0	7	0	0	0	0	950
1994	599	1352	49	0	856	366	0	0	393	89	0	8	0	0	0	0	490
1995	3576	1045	65	882	1986	745	0	0	1152	82	0	6	0	0	0	0	2122
1996	2117	1688	67	400	1809	850	0	0	827	125	0	7	0	0	0	0	1359
1997	2944	1529	61	1354	1800	973	0	0	693	125	0	8	0	0	0	0	2180
1998	3050	1258	67	575	1989	761	0	0	1098	125	0	6	0	0	0	0	1804
1999	1890	1678	61	404	1853	914	0	1	806	124	0	8	0	0	0	0	1343
2000	1702	1250	58	0	1703	804	0	0	768	125	0	7	0	0	0	0	899
2001	837	1191	49	0	956	467	0	0	389	93	0	7	0	0	0	0	489
2002	1135	1023	49	0	1080	516	0	0	506	50	0	8	0	0	0	0	564
2003	1296	1029	49	0	1235	576	0	0	601	50	0	8	0	0	0	0	659
Avg:	1586	1220	57	180	1353	650	0	1	605	89	0	7	0	0	0	0	882

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 10. Summary Table of Tuolumne River at 60 Percent Unimpaired Flow

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	2207	1370	60	0	2071	857	0	0	1082	125	0	7	0	0	0	0	1214
1923	1532	1445	59	0	1588	741	0	0	715	125	0	7	0	0	0	0	847
1924	351	1331	51	0	587	280	0	0	183	115	0	9	0	0	0	0	307
1925	1567	1043	53	0	1446	529	0	0	862	49	0	7	0	0	0	0	917
1926	862	1111	56	0	892	326	0	0	500	59	0	8	0	0	0	0	566
1927	1745	1025	52	0	1622	653	0	0	879	82	0	7	0	0	0	0	969
1928	1296	1097	54	0	1261	498	0	0	663	93	0	8	0	0	0	0	764
1929	674	1078	44	0	749	241	0	0	442	58	0	8	0	0	0	0	508
1930	861	960	41	0	810	238	0	0	520	44	0	8	0	0	0	0	572
1931	355	970	46	0	496	221	0	0	221	46	0	8	0	0	0	0	275
1932	1795	783	54	0	1225	225	0	0	911	81	0	8	0	0	0	0	1000
1933	828	1300	51	0	958	363	0	0	478	108	0	8	0	0	0	0	595
1934	618	1119	55	0	628	255	0	0	310	55	0	8	0	0	0	0	373
1935	1721	1054	57	0	1530	510	0	0	932	81	0	6	0	0	0	0	1020
1936	1887	1187	61	0	1799	673	0	0	994	125	0	7	0	0	0	0	1126
1937	1730	1215	59	0	1726	666	0	0	928	125	0	7	0	0	0	0	1060
1938	3149	1159	64	264	2389	840	0	0	1418	125	0	6	0	0	0	0	1813
1939	755	1592	60	0	971	466	0	0	404	93	0	8	0	0	0	0	505
1940	1949	1316	61	247	1788	737	0	0	961	82	0	7	0	0	0	0	1297
1941	2259	1170	58	171	1997	821	0	0	1044	125	0	7	0	0	0	0	1347
1942	2141	1203	59	0	1776	804	0	0	842	125	0	6	0	0	0	0	973
1943	2137	1509	61	329	1898	872	0	0	894	125	0	7	0	0	0	0	1355
1944	1023	1358	50	0	1187	529	0	0	558	93	0	8	0	0	0	0	658
1945	1801	1143	56	0	1674	688	0	0	888	91	0	7	0	0	0	0	986
1946	1630	1215	58	161	1366	573	0	0	661	125	0	7	0	0	0	0	953
1947	839	1260	53	0	896	374	0	0	426	88	0	9	0	0	0	0	523
1948	1102	1149	46	0	1124	455	0	0	603	58	0	7	0	0	0	0	669
1949	980	1080	50	0	1028	379	0	0	579	62	0	8	0	0	0	0	649
1950	1246	983	50	0	1163	380	0	0	716	59	0	8	0	0	0	0	783
1951	2190	1016	59	690	1175	441	0	12	630	84	0	7	0	0	0	0	1424
1952	2727	1283	63	225	2113	804	0	0	1177	125	0	6	0	0	0	0	1533
1953	1302	1608	57	0	1507	775	0	0	631	93	0	8	0	0	0	0	732

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	1166	1346	55	0	1287	546	0	0	674	59	0	8	0	0	0	0	741
1955	837	1171	49	0	859	312	0	0	481	59	0	8	0	0	0	0	547
1956	2877	1100	61	695	1806	842	0	0	875	82	0	7	0	0	0	0	1660
1957	1161	1414	53	0	1368	575	0	0	693	93	0	8	0	0	0	0	793
1958	2369	1155	64	0	1918	734	0	0	1088	91	0	6	0	0	0	0	1184
1959	820	1541	63	0	1027	494	0	0	431	93	0	8	0	0	0	0	532
1960	785	1272	58	0	832	283	0	0	495	46	0	9	0	0	0	0	549
1961	444	1167	49	0	582	222	0	0	308	44	0	8	0	0	0	0	360
1962	1460	979	48	0	1381	510	0	0	815	49	0	8	0	0	0	0	871
1963	1781	1010	48	0	1720	690	0	0	932	91	0	7	0	0	0	0	1030
1964	883	1023	46	0	844	305	0	0	438	93	0	8	0	0	0	0	539
1965	2442	1017	58	426	1729	840	0	2	798	82	0	7	0	0	0	0	1315
1966	1091	1245	58	0	1065	395	0	0	569	93	0	8	0	0	0	0	669
1967	2810	1213	66	246	2027	765	0	0	1164	91	0	6	0	0	0	0	1507
1968	792	1686	61	0	1104	520	0	0	483	93	0	8	0	0	0	0	584
1969	3571	1313	69	572	2573	835	0	68	1581	82	0	7	0	0	0	0	2310
1970	1736	1670	61	527	1526	695	0	0	698	125	0	8	0	0	0	0	1358
1971	1424	1292	56	0	1388	656	0	0	632	93	0	8	0	0	0	0	732
1972	946	1272	55	0	968	392	0	0	513	54	0	9	0	0	0	0	576
1973	1754	1195	63	0	1584	608	0	0	886	82	0	7	0	0	0	0	976
1974	2011	1302	68	123	1778	807	0	0	839	125	0	7	0	0	0	0	1094
1975	1795	1344	60	0	1864	855	0	0	876	125	0	7	0	0	0	0	1008
1976	431	1216	48	0	598	268	0	0	226	95	0	9	0	0	0	0	330
1977	223	1001	41	0	437	221	0	0	149	57	0	9	1	0	0	0	216
1978	2470	745	60	0	1583	377	0	0	1119	81	0	6	0	0	0	0	1206
1979	1702	1571	67	153	1802	825	0	0	844	125	0	7	0	0	0	0	1129
1980	2748	1251	66	275	2020	857	0	0	1031	125	0	7	0	0	0	0	1438
1981	832	1637	67	0	1101	520	0	0	479	93	0	8	0	0	0	0	580
1982	3505	1302	69	782	2256	750	0	0	1409	91	0	6	0	0	0	0	2288
1983	4438	1700	60	1946	2432	755	0	0	1546	125	0	6	0	0	0	0	3623
1984	2275	1700	68	1082	1545	625	0	8	778	125	0	8	0	0	0	0	2001
1985	976	1280	61	0	1007	426	0	0	481	93	0	8	0	0	0	0	581
1986	2698	1189	61	124	2272	818	0	0	1366	82	0	7	0	0	0	0	1579
1987	422	1429	55	0	649	267	0	0	278	95	0	8	0	0	0	0	381

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	532	1148	46	0	602	216	0	0	334	44	0	8	0	0	0	0	386
1989	1050	1032	42	0	1026	310	0	0	663	44	0	8	0	0	0	0	715
1990	583	1015	47	0	643	224	0	0	366	44	0	8	0	0	0	0	419
1991	837	908	40	0	816	212	0	0	544	52	0	8	0	0	0	0	604
1992	704	889	50	0	623	217	0	0	354	44	0	7	0	0	0	0	406
1993	2235	921	60	0	1933	786	0	0	1059	81	0	7	0	0	0	0	1147
1994	599	1163	42	0	844	280	0	0	468	88	0	8	0	0	0	0	564
1995	3576	876	64	482	2218	718	0	0	1412	82	0	6	0	0	0	0	1982
1996	2117	1688	66	304	2001	850	0	0	1020	125	0	7	0	0	0	0	1456
1997	2944	1434	60	1224	1811	829	0	0	849	125	0	8	0	0	0	0	2206
1998	3050	1282	66	371	2217	749	0	0	1337	125	0	6	0	0	0	0	1839
1999	1890	1678	60	363	1903	795	0	1	975	124	0	8	0	0	0	0	1471
2000	1702	1241	56	0	1698	626	0	0	940	125	0	7	0	0	0	0	1072
2001	837	1190	49	0	915	333	0	0	482	93	0	7	0	0	0	0	582
2002	1135	1063	50	0	1052	376	0	0	618	50	0	8	0	0	0	0	676
2003	1296	1096	51	0	1214	425	0	0	731	50	0	8	0	0	0	0	789
Avg:	1586	1226	56	144	1389	546	0	1	746	88	0	7	0	0	0	0	987

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 11. Summary Table of Merced River at 20 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1421	508	26	205	998	452	0	116	189	83	94	17	0	0	0	0	610
1923	947	700	25	115	809	483	0	6	87	74	94	39	0	0	0	0	321
1924	258	698	20	0	538	280	0	17	32	84	94	29	0	0	0	0	162
1925	916	398	22	0	785	473	0	1	64	84	94	43	0	0	0	0	193
1926	615	506	21	0	743	433	0	8	92	67	94	36	0	0	0	0	203
1927	994	358	16	0	889	493	0	11	163	59	94	42	0	0	0	0	275
1928	790	447	18	0	831	518	0	1	84	74	94	42	0	0	0	0	201
1929	521	389	13	0	588	292	0	7	63	81	94	44	0	0	0	0	194
1930	518	310	11	0	519	216	0	15	76	72	94	37	0	0	0	0	200
1931	270	298	14	0	328	84	0	6	35	81	94	27	0	0	0	0	150
1932	1123	226	20	0	877	489	0	13	141	74	94	37	0	0	0	0	265
1933	525	452	16	0	636	333	0	5	73	82	94	38	0	0	0	0	199
1934	365	324	17	0	368	127	0	7	33	75	94	29	0	0	0	0	145
1935	1182	304	25	0	820	417	0	6	158	82	94	32	0	0	0	0	278
1936	1170	642	29	203	879	467	0	11	173	63	94	38	0	0	0	0	489
1937	1234	700	28	334	871	461	0	31	158	62	94	30	0	0	0	0	614
1938	2094	700	27	1113	954	451	0	9	228	65	94	39	0	0	0	0	1453
1939	498	700	22	18	747	455	0	2	37	86	94	46	0	0	0	0	189
1940	1113	411	27	0	805	472	0	18	125	59	94	42	0	0	0	0	244
1941	1481	692	27	640	806	432	0	4	143	75	94	39	0	0	0	0	901
1942	1308	700	25	413	869	457	0	3	141	86	94	47	0	0	0	0	690
1943	1309	700	26	408	876	507	0	22	94	72	94	49	0	0	0	0	643
1944	706	700	22	0	821	502	0	12	71	76	94	46	0	0	0	0	205
1945	1121	563	26	98	860	483	0	3	133	62	94	48	0	0	0	0	344
1946	967	700	24	160	869	521	0	5	88	86	94	45	0	0	0	0	384
1947	591	613	22	0	771	461	0	1	57	82	94	45	0	0	0	0	186
1948	711	410	15	0	789	443	0	5	99	87	94	47	0	0	0	0	238
1949	666	318	16	0	666	335	0	2	83	81	94	47	0	0	0	0	213
1950	747	302	17	0	728	383	0	15	89	82	94	41	0	0	0	0	226
1951	1248	304	23	241	757	482	0	50	60	70	94	44	0	0	0	0	466
1952	1584	532	26	576	813	444	0	14	132	72	94	42	0	0	0	0	835
1953	648	700	21	48	820	523	0	7	56	80	94	46	0	0	0	0	237

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	688	459	19	0	788	478	0	1	74	74	94	47	0	0	0	0	196
1955	554	340	14	0	579	274	0	0	58	88	94	46	0	0	0	0	192
1956	1696	302	26	474	798	453	0	47	125	60	94	43	0	0	0	0	749
1957	674	700	22	0	860	531	0	4	63	86	94	49	0	0	0	0	202
1958	1434	492	27	437	762	406	0	3	83	87	94	34	0	0	0	0	644
1959	480	700	23	3	743	456	0	0	35	83	94	48	0	0	0	0	168
1960	507	411	18	0	580	287	0	0	47	85	94	46	0	0	0	0	178
1961	333	319	14	0	348	87	0	0	28	88	94	41	0	0	0	0	157
1962	953	290	20	0	807	473	0	3	79	79	94	42	0	0	0	0	202
1963	1009	417	22	0	819	480	0	0	98	75	94	49	0	0	0	0	222
1964	468	584	19	0	650	368	0	0	37	88	94	47	0	0	0	0	172
1965	1314	384	25	88	885	469	0	15	75	73	94	45	0	0	0	0	296
1966	648	700	24	98	801	528	0	23	45	66	94	47	0	0	0	0	279
1967	1700	426	27	544	856	428	0	13	191	65	94	42	0	0	0	0	855
1968	429	700	22	18	679	429	0	18	19	69	94	49	0	0	0	0	174
1969	2197	410	28	894	985	433	0	31	254	66	94	35	0	0	0	0	1280
1970	887	700	24	261	734	491	0	36	54	44	94	44	0	0	0	0	438
1971	734	568	22	0	770	492	0	10	55	76	94	49	0	0	0	0	189
1972	576	511	19	0	701	445	0	28	42	59	94	45	0	0	0	0	173
1973	1143	367	27	7	776	463	0	25	107	63	94	42	0	0	0	0	244
1974	1180	700	30	344	806	476	0	25	119	49	94	44	0	0	0	0	581
1975	1133	700	27	279	826	480	0	30	136	55	94	45	0	0	0	0	545
1976	300	700	21	25	550	300	0	10	7	84	94	48	0	0	0	0	174
1977	142	405	12	0	341	87	0	1	2	95	94	47	4	0	0	0	149
1978	1759	194	28	417	808	384	0	39	208	71	94	26	0	0	0	0	760
1979	1085	700	29	225	830	473	0	20	91	56	94	37	0	0	0	0	429
1980	1653	700	27	703	923	489	0	0	108	71	94	49	0	0	0	0	930
1981	502	700	24	0	779	479	0	0	33	88	94	48	0	0	0	0	169
1982	2006	400	27	730	949	426	0	1	190	67	94	41	0	0	0	0	1029
1983	2871	700	27	1527	1317	420	0	0	114	92	94	37	0	0	0	0	1770
1984	1208	700	29	343	915	515	0	0	62	83	94	49	0	0	0	0	537
1985	574	621	24	0	771	481	0	3	43	84	94	47	0	0	0	0	177
1986	1580	400	26	403	850	442	0	21	207	62	94	42	0	0	0	0	735
1987	322	700	21	0	607	346	0	1	23	89	94	48	0	0	0	0	160

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	392	393	15	0	454	191	0	0	32	80	94	45	0	0	0	0	158
1989	536	316	14	0	543	247	0	14	75	67	94	39	0	0	0	0	194
1990	383	296	15	0	366	83	0	2	49	75	94	42	1	0	0	0	170
1991	531	298	14	0	519	231	0	8	75	72	94	38	0	0	0	0	193
1992	444	296	17	0	428	158	0	9	49	71	94	34	7	0	0	0	170
1993	1452	295	28	239	780	381	0	55	198	54	94	15	0	0	0	0	561
1994	347	700	20	28	594	359	0	41	47	57	94	29	0	0	0	0	202
1995	2173	405	29	916	933	425	0	11	258	58	94	35	0	0	0	0	1278
1996	1178	700	33	296	850	459	0	8	146	62	94	41	0	0	0	0	552
1997	1754	700	31	947	835	511	0	47	88	47	94	44	0	0	0	0	1173
1998	1836	641	29	936	813	414	0	9	147	63	94	39	0	0	0	0	1194
1999	880	700	26	128	851	526	0	6	97	67	94	48	0	0	0	0	347
2000	941	575	28	38	790	468	0	17	104	69	94	43	0	0	0	0	271
2001	508	660	23	0	745	469	0	8	60	75	94	37	0	0	0	0	179
2002	621	400	20	0	659	369	0	2	83	72	94	36	0	0	0	0	192
2003	770	342	20	0	766	450	0	2	110	70	94	38	0	0	0	0	220
Avg:	965	514	22	194	751	407	0	13	95	73	94	41	0	0	0	0	417

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 12. Summary Table of Merced River at 30 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1421	508	26	108	1095	452	0	116	310	59	94	17	0	0	0	0	610
1923	947	700	24	115	869	483	0	6	158	63	94	39	0	0	0	0	380
1924	258	639	20	0	468	194	0	17	50	84	94	29	0	0	0	0	179
1925	916	409	21	0	842	471	0	1	139	68	94	43	0	0	0	0	252
1926	615	462	20	0	697	340	0	8	148	58	94	36	0	0	0	0	250
1927	994	360	15	0	978	489	0	11	256	59	94	42	0	0	0	0	368
1928	790	362	15	0	791	421	0	1	142	73	94	42	0	0	0	0	258
1929	521	346	12	0	552	219	0	7	105	76	94	44	0	0	0	0	231
1930	518	304	10	0	513	172	0	15	121	66	94	37	0	0	0	0	239
1931	270	299	13	0	345	82	0	6	56	80	94	27	0	0	0	0	168
1932	1123	210	19	0	952	489	0	13	230	59	94	37	0	0	0	0	340
1933	525	363	14	0	572	229	0	5	117	78	94	38	0	0	0	0	239
1934	365	301	16	0	351	91	0	7	59	68	94	29	0	0	0	0	163
1935	1182	300	23	0	904	416	0	6	257	68	94	32	0	0	0	0	364
1936	1170	554	28	43	978	467	0	11	277	59	94	38	0	0	0	0	427
1937	1234	675	28	202	979	461	0	31	269	59	94	30	0	0	0	0	590
1938	2094	700	27	949	1118	451	0	9	395	61	94	39	0	0	0	0	1453
1939	498	700	22	18	710	389	0	2	71	80	94	46	0	0	0	0	217
1940	1113	448	26	0	893	469	0	18	216	59	94	42	0	0	0	0	335
1941	1481	641	27	491	905	432	0	4	258	59	94	39	0	0	0	0	850
1942	1308	700	25	333	950	457	0	3	237	70	94	47	0	0	0	0	690
1943	1309	700	25	334	960	507	0	22	190	59	94	49	0	0	0	0	653
1944	706	691	21	0	870	502	0	12	126	69	94	46	0	0	0	0	253
1945	1121	506	25	0	951	483	0	3	225	62	94	48	0	0	0	0	338
1946	967	650	23	111	926	521	0	5	153	78	94	45	0	0	0	0	392
1947	591	557	21	0	701	358	0	1	99	73	94	45	0	0	0	0	218
1948	711	426	15	0	791	389	0	5	158	83	94	47	0	0	0	0	294
1949	666	331	16	0	678	298	0	2	140	74	94	47	0	0	0	0	263
1950	747	302	17	0	726	328	0	15	153	71	94	41	0	0	0	0	279
1951	1248	307	22	245	796	480	0	50	112	59	94	44	0	0	0	0	511
1952	1584	491	26	427	922	444	0	14	249	63	94	42	0	0	0	0	795
1953	648	700	20	48	829	492	0	7	98	78	94	46	0	0	0	0	277

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	688	450	19	0	769	403	0	1	135	69	94	47	0	0	0	0	253
1955	554	350	14	0	583	239	0	0	100	85	94	46	0	0	0	0	231
1956	1696	308	26	405	872	451	0	47	207	53	94	43	0	0	0	0	756
1957	674	700	22	0	902	527	0	4	119	76	94	49	0	0	0	0	248
1958	1434	450	27	318	839	406	0	3	177	71	94	34	0	0	0	0	603
1959	480	700	23	3	706	390	0	0	74	72	94	48	0	0	0	0	196
1960	507	448	19	0	594	267	0	0	93	73	94	46	0	0	0	0	211
1961	333	342	15	0	369	86	0	0	52	86	94	41	0	0	0	0	179
1962	953	291	18	0	880	473	0	3	156	75	94	42	0	0	0	0	276
1963	1009	346	19	0	897	480	0	0	178	73	94	49	0	0	0	0	300
1964	468	438	16	0	534	222	0	0	67	88	94	47	0	0	0	0	202
1965	1314	357	24	0	949	467	0	15	148	67	94	45	0	0	0	0	275
1966	648	697	24	95	777	470	0	23	86	59	94	47	0	0	0	0	310
1967	1700	450	27	453	970	425	0	13	313	60	94	42	0	0	0	0	881
1968	429	700	22	18	641	369	0	18	53	58	94	49	0	0	0	0	197
1969	2197	448	28	794	1123	431	0	31	393	66	94	35	0	0	0	0	1318
1970	887	700	24	254	782	491	0	36	114	31	94	44	0	0	0	0	479
1971	734	527	20	0	816	492	0	10	111	66	94	49	0	0	0	0	235
1972	576	425	18	0	628	334	0	28	84	55	94	45	0	0	0	0	212
1973	1143	356	25	0	845	460	0	25	189	53	94	42	0	0	0	0	309
1974	1180	629	29	191	889	476	0	25	203	47	94	44	0	0	0	0	510
1975	1133	700	27	182	924	480	0	30	234	55	94	45	0	0	0	0	545
1976	300	700	21	25	514	254	0	10	22	79	94	48	0	0	0	0	183
1977	142	440	13	0	340	85	0	1	12	90	94	47	1	0	0	0	151
1978	1759	229	28	330	930	384	0	39	341	60	94	26	0	0	0	0	795
1979	1085	700	28	194	903	473	0	20	178	42	94	37	0	0	0	0	471
1980	1653	659	27	555	1030	489	0	0	224	62	94	49	0	0	0	0	889
1981	502	700	24	0	745	410	0	0	68	88	94	48	0	0	0	0	204
1982	2006	433	28	621	1091	425	0	1	340	61	94	41	0	0	0	0	1064
1983	2871	700	27	1423	1420	420	0	0	218	92	94	37	0	0	0	0	1770
1984	1208	700	28	343	966	515	0	0	131	66	94	49	0	0	0	0	588
1985	574	571	23	0	708	384	0	3	84	76	94	47	0	0	0	0	212
1986	1580	414	26	282	985	438	0	21	346	62	94	42	0	0	0	0	752
1987	322	700	22	0	575	295	0	1	42	89	94	48	0	0	0	0	179

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	392	425	15	0	466	177	0	0	65	73	94	45	0	0	0	0	184
1989	536	336	13	0	563	223	0	14	123	62	94	39	0	0	0	0	238
1990	383	296	14	0	391	82	0	2	80	71	94	42	0	0	0	0	196
1991	531	273	13	0	494	159	0	8	126	69	94	38	0	0	0	0	241
1992	444	297	17	0	428	132	0	9	86	59	94	34	6	0	0	0	195
1993	1452	296	28	134	887	380	0	55	309	51	94	15	0	0	0	0	564
1994	347	700	21	28	558	299	0	41	77	52	94	29	0	0	0	0	227
1995	2173	440	29	808	1076	423	0	11	408	54	94	35	0	0	0	0	1315
1996	1178	700	32	197	949	459	0	8	248	58	94	41	0	0	0	0	553
1997	1754	700	30	941	897	511	0	47	154	43	94	44	0	0	0	0	1229
1998	1836	586	28	754	940	414	0	9	282	55	94	39	0	0	0	0	1139
1999	880	700	25	117	918	526	0	6	171	61	94	48	0	0	0	0	403
2000	941	520	26	0	864	468	0	17	185	62	94	43	0	0	0	0	307
2001	508	570	22	0	658	347	0	8	104	66	94	37	0	0	0	0	215
2002	621	399	20	0	644	310	0	2	134	64	94	36	0	0	0	0	236
2003	770	356	20	0	766	392	0	2	175	63	94	38	0	0	0	0	278
Avg:	965	500	22	157	788	380	0	13	166	66	94	41	0	0	0	0	444

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 13. Summary Table of Merced River at 40 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1421	508	26	42	1168	452	0	116	382	59	94	17	0	0	0	0	616
1923	947	694	23	59	986	483	0	6	278	60	94	39	0	0	0	0	441
1924	258	573	19	0	407	116	0	17	69	82	94	29	0	0	0	0	196
1925	916	405	20	0	910	469	0	1	216	61	94	43	0	0	0	0	322
1926	615	391	18	0	649	239	0	8	203	56	94	36	0	0	0	0	304
1927	994	339	13	0	1015	434	0	11	348	59	94	42	0	0	0	0	460
1928	790	305	13	0	752	324	0	1	205	68	94	42	0	0	0	0	316
1929	521	330	11	0	535	166	0	7	146	71	94	44	0	0	0	0	268
1930	518	304	9	0	513	128	0	15	168	63	94	37	0	0	0	0	283
1931	270	299	13	0	362	80	0	6	77	77	94	27	0	0	0	0	187
1932	1123	194	18	0	959	407	0	13	319	59	94	37	0	0	0	0	429
1933	525	340	14	0	549	166	0	5	162	73	94	38	0	0	0	0	279
1934	365	302	16	0	365	82	0	7	88	62	94	29	0	0	0	0	186
1935	1182	286	21	0	995	415	0	6	356	60	94	32	0	0	0	0	454
1936	1170	452	25	0	1082	467	0	11	380	59	94	38	0	0	0	0	488
1937	1234	516	27	23	1052	461	0	31	342	59	94	30	0	0	0	0	484
1938	2094	647	27	745	1274	451	0	9	552	61	94	39	0	0	0	0	1406
1939	498	694	22	0	704	305	0	2	157	73	94	46	0	0	0	0	277
1940	1113	467	25	0	981	466	0	18	307	59	94	42	0	0	0	0	426
1941	1481	573	27	359	978	432	0	4	331	59	94	39	0	0	0	0	792
1942	1308	690	25	227	1053	457	0	3	340	70	94	47	0	0	0	0	687
1943	1309	693	25	291	1060	507	0	22	290	59	94	49	0	0	0	0	711
1944	706	627	19	0	879	421	0	12	221	65	94	46	0	0	0	0	343
1945	1121	435	21	0	1041	481	0	3	317	62	94	48	0	0	0	0	430
1946	967	493	21	0	971	505	0	5	219	73	94	45	0	0	0	0	342
1947	591	468	19	0	625	245	0	1	142	66	94	45	0	0	0	0	255
1948	711	414	15	0	777	319	0	5	218	80	94	47	0	0	0	0	350
1949	666	334	16	0	682	245	0	2	197	73	94	47	0	0	0	0	320
1950	747	302	16	0	726	271	0	15	217	64	94	41	0	0	0	0	337
1951	1248	307	22	247	798	433	0	50	169	51	94	44	0	0	0	0	561
1952	1584	489	26	359	992	442	0	14	320	63	94	42	0	0	0	0	798
1953	648	696	21	0	837	413	0	7	189	74	94	46	0	0	0	0	316

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	688	486	19	0	773	350	0	1	197	64	94	47	0	0	0	0	309
1955	554	382	15	0	596	213	0	0	143	82	94	46	0	0	0	0	271
1956	1696	325	26	369	926	450	0	47	262	53	94	43	0	0	0	0	775
1957	674	700	21	0	884	424	0	4	214	67	94	49	0	0	0	0	334
1958	1434	469	27	267	909	404	0	3	249	71	94	34	0	0	0	0	624
1959	480	699	23	0	694	301	0	0	161	62	94	48	0	0	0	0	271
1960	507	462	19	0	587	225	0	0	138	64	94	46	0	0	0	0	247
1961	333	362	15	0	390	85	0	0	78	83	94	41	0	0	0	0	202
1962	953	291	17	0	899	415	0	3	233	75	94	42	0	0	0	0	352
1963	1009	328	17	0	965	470	0	0	263	67	94	49	0	0	0	0	378
1964	468	354	15	0	478	136	0	0	101	84	94	47	0	0	0	0	231
1965	1314	330	23	0	990	466	0	15	191	67	94	45	0	0	0	0	318
1966	648	630	24	0	772	386	0	23	171	54	94	47	0	0	0	0	295
1967	1700	483	27	415	1040	422	0	13	389	58	94	42	0	0	0	0	917
1968	429	700	22	0	636	290	0	18	136	49	94	49	0	0	0	0	252
1969	2197	471	28	731	1209	430	0	31	481	66	94	35	0	0	0	0	1343
1970	887	700	23	168	912	491	0	36	245	31	94	44	0	0	0	0	523
1971	734	485	19	0	776	404	0	10	167	59	94	49	0	0	0	0	284
1972	576	424	18	0	612	275	0	28	128	54	94	45	0	0	0	0	254
1973	1143	371	24	0	930	458	0	25	282	46	94	42	0	0	0	0	395
1974	1180	560	29	90	938	476	0	25	252	47	94	44	0	0	0	0	459
1975	1133	683	27	73	1020	480	0	30	330	55	94	45	0	0	0	0	532
1976	300	696	21	2	506	197	0	10	79	72	94	48	0	0	0	0	211
1977	142	467	14	0	346	83	0	1	24	86	94	47	1	0	0	0	159
1978	1759	249	28	269	1010	384	0	39	422	60	94	26	0	0	0	0	815
1979	1085	700	27	115	1046	473	0	20	321	42	94	37	0	0	0	0	535
1980	1653	596	27	420	1109	489	0	0	303	62	94	49	0	0	0	0	834
1981	502	693	24	0	727	320	0	0	145	83	94	48	0	0	0	0	276
1982	2006	445	28	492	1232	423	0	1	483	61	94	41	0	0	0	0	1078
1983	2871	700	27	1295	1549	420	0	0	375	64	94	37	0	0	0	0	1770
1984	1208	700	26	329	1040	515	0	0	209	62	94	49	0	0	0	0	648
1985	574	513	22	0	651	289	0	3	131	67	94	47	0	0	0	0	249
1986	1580	413	26	190	1077	435	0	21	440	62	94	42	0	0	0	0	755
1987	322	700	21	0	565	222	0	1	111	83	94	48	0	0	0	0	242

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	392	436	16	0	460	143	0	0	98	68	94	45	0	0	0	0	211
1989	536	352	13	0	574	188	0	14	171	60	94	39	0	0	0	0	284
1990	383	301	14	0	421	81	0	2	113	69	94	42	0	0	0	0	226
1991	531	250	13	0	471	85	0	8	177	68	94	38	0	0	0	0	292
1992	444	298	16	0	429	103	0	9	123	55	94	34	4	0	0	0	225
1993	1452	296	28	70	950	379	0	55	373	51	94	15	0	0	0	0	565
1994	347	700	21	0	560	227	0	41	155	48	94	29	0	0	0	0	273
1995	2173	467	29	742	1180	421	0	11	513	54	94	35	0	0	0	0	1354
1996	1178	689	32	126	1057	459	0	8	356	58	94	41	0	0	0	0	589
1997	1754	653	29	855	984	511	0	47	241	43	94	44	0	0	0	0	1230
1998	1836	539	28	585	1062	414	0	9	404	55	94	39	0	0	0	0	1092
1999	880	700	25	64	1002	496	0	6	289	57	94	48	0	0	0	0	464
2000	941	490	24	0	945	467	0	17	271	59	94	43	0	0	0	0	390
2001	508	461	19	0	579	227	0	8	149	62	94	37	0	0	0	0	255
2002	621	371	19	0	614	233	0	2	184	60	94	36	0	0	0	0	283
2003	770	359	19	0	756	321	0	2	240	60	94	38	0	0	0	0	340
Avg:	965	482	21	122	823	346	0	13	239	63	94	41	0	0	0	0	479

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 14. Summary Table of Merced River at 50 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1421	508	24	0	1276	452	0	116	492	58	94	17	0	0	0	0	683
1923	947	629	22	0	1056	472	0	6	361	58	94	39	0	0	0	0	464
1924	258	498	16	0	408	100	0	17	88	80	94	29	0	0	0	0	213
1925	916	331	18	0	875	357	0	1	293	61	94	43	0	0	0	0	399
1926	615	354	16	0	630	164	0	8	259	56	94	36	0	0	0	0	359
1927	994	323	14	0	840	166	0	11	441	59	94	42	0	0	0	0	553
1928	790	464	17	0	819	334	0	1	267	63	94	42	0	0	0	0	373
1929	521	418	13	0	591	182	0	7	189	68	94	44	0	0	0	0	307
1930	518	336	10	0	545	116	0	15	214	61	94	37	0	0	0	0	327
1931	270	299	13	0	380	80	0	6	99	74	94	27	0	0	0	0	206
1932	1123	176	18	0	799	159	0	13	408	59	94	37	0	0	0	0	518
1933	525	481	17	0	620	197	0	5	208	67	94	38	0	0	0	0	319
1934	365	369	17	0	391	83	0	7	117	57	94	29	0	0	0	0	211
1935	1182	326	22	0	886	209	0	6	455	58	94	32	0	0	0	0	552
1936	1170	600	25	46	1180	461	0	11	484	59	94	38	0	0	0	0	638
1937	1234	519	26	0	1153	461	0	31	443	59	94	30	0	0	0	0	562
1938	2094	573	27	493	1452	451	0	9	730	61	94	39	0	0	0	0	1332
1939	498	694	22	0	687	253	0	2	192	72	94	46	0	0	0	0	312
1940	1113	484	24	0	1070	464	0	18	398	59	94	42	0	0	0	0	517
1941	1481	502	27	176	1091	432	0	4	444	59	94	39	0	0	0	0	722
1942	1308	689	24	148	1136	457	0	3	433	60	94	47	0	0	0	0	691
1943	1309	689	24	260	1153	507	0	22	389	53	94	49	0	0	0	0	772
1944	706	562	18	0	841	320	0	12	289	60	94	46	0	0	0	0	406
1945	1121	409	20	0	1080	428	0	3	409	62	94	48	0	0	0	0	522
1946	967	429	20	0	925	394	0	5	284	73	94	45	0	0	0	0	407
1947	591	451	19	0	604	186	0	1	185	62	94	45	0	0	0	0	294
1948	711	419	15	0	774	261	0	5	277	77	94	47	0	0	0	0	406
1949	666	341	16	0	689	195	0	2	257	71	94	47	0	0	0	0	377
1950	747	303	16	0	728	211	0	15	281	61	94	41	0	0	0	0	398
1951	1248	306	22	244	781	363	0	50	225	47	94	44	0	0	0	0	611
1952	1584	507	26	269	1101	440	0	14	438	57	94	42	0	0	0	0	820
1953	648	696	21	0	818	355	0	7	234	68	94	46	0	0	0	0	356

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	688	505	19	0	774	292	0	1	258	62	94	47	0	0	0	0	368
1955	554	400	15	0	600	177	0	0	188	76	94	46	0	0	0	0	311
1956	1696	339	26	315	999	449	0	47	340	50	94	43	0	0	0	0	795
1957	674	695	21	0	870	348	0	4	281	63	94	49	0	0	0	0	396
1958	1434	478	27	166	1019	403	0	3	367	65	94	34	0	0	0	0	635
1959	480	699	23	0	681	249	0	0	200	62	94	48	0	0	0	0	309
1960	507	476	19	0	587	181	0	0	183	62	94	46	0	0	0	0	290
1961	333	376	15	0	410	83	0	0	104	79	94	41	0	0	0	0	224
1962	953	284	16	0	902	341	0	3	309	75	94	42	0	0	0	0	429
1963	1009	319	17	0	964	389	0	0	347	62	94	49	0	0	0	0	458
1964	468	347	15	0	471	100	0	0	135	79	94	47	0	0	0	0	261
1965	1314	330	24	0	933	344	0	15	259	62	94	45	0	0	0	0	382
1966	648	687	24	39	767	326	0	23	229	50	94	47	0	0	0	0	388
1967	1700	506	27	323	1156	419	0	13	511	54	94	42	0	0	0	0	943
1968	429	700	22	0	621	244	0	18	172	44	94	49	0	0	0	0	284
1969	2197	486	28	608	1347	428	0	31	619	66	94	35	0	0	0	0	1359
1970	887	700	23	157	901	419	0	36	306	31	94	44	0	0	0	0	573
1971	734	507	19	0	773	348	0	10	223	56	94	49	0	0	0	0	337
1972	576	449	18	0	615	236	0	28	174	51	94	45	0	0	0	0	297
1973	1143	392	23	0	1024	457	0	25	377	46	94	42	0	0	0	0	490
1974	1180	488	28	9	1012	476	0	25	329	44	94	44	0	0	0	0	452
1975	1133	620	25	0	1118	480	0	30	428	55	94	45	0	0	0	0	557
1976	300	609	19	0	456	123	0	10	107	67	94	48	0	0	0	0	232
1977	142	434	13	0	355	80	0	1	36	86	94	47	1	0	0	0	170
1978	1759	208	27	133	1107	348	0	39	554	60	94	26	0	0	0	0	812
1979	1085	700	26	88	1136	473	0	20	411	42	94	37	0	0	0	0	598
1980	1653	534	26	243	1225	489	0	0	419	62	94	49	0	0	0	0	772
1981	502	693	24	0	712	270	0	0	188	75	94	48	0	0	0	0	311
1982	2006	459	27	357	1381	422	0	1	633	61	94	41	0	0	0	0	1094
1983	2871	700	27	1113	1731	420	0	0	559	62	94	37	0	0	0	0	1771
1984	1208	700	26	321	1052	458	0	0	277	62	94	49	0	0	0	0	708
1985	574	509	22	0	638	233	0	3	178	64	94	47	0	0	0	0	293
1986	1580	424	25	106	1214	433	0	21	579	62	94	42	0	0	0	0	810
1987	322	659	20	0	532	168	0	1	138	77	94	48	0	0	0	0	264

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	392	428	15	0	450	103	0	0	130	66	94	45	0	0	0	0	242
1989	536	355	13	0	573	141	0	14	220	58	94	39	0	0	0	0	330
1990	383	304	13	0	450	80	0	2	145	66	94	42	0	0	0	0	257
1991	531	224	11	0	516	80	0	8	228	68	94	38	0	0	0	0	342
1992	444	228	14	0	439	77	0	9	161	55	94	34	2	0	0	0	260
1993	1452	220	26	0	964	294	0	55	472	51	94	15	0	0	0	0	593
1994	347	682	20	0	541	168	0	41	198	45	94	29	0	0	0	0	313
1995	2173	468	29	595	1328	419	0	11	663	54	94	35	0	0	0	0	1357
1996	1178	689	31	99	1149	459	0	8	449	58	94	41	0	0	0	0	655
1997	1754	588	28	771	1053	507	0	47	321	37	94	44	0	0	0	0	1219
1998	1836	490	28	393	1204	413	0	9	547	55	94	39	0	0	0	0	1043
1999	880	700	24	53	995	414	0	6	363	57	94	48	0	0	0	0	527
2000	941	509	24	0	968	403	0	17	357	59	94	43	0	0	0	0	476
2001	508	458	19	0	571	175	0	8	197	59	94	37	0	0	0	0	300
2002	621	377	19	0	611	180	0	2	235	60	94	36	0	0	0	0	333
2003	770	367	19	0	756	255	0	2	305	60	94	38	0	0	0	0	405
Avg:	965	478	21	92	854	305	0	13	313	61	94	41	0	0	0	0	520

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

Table 15. Summary Table of Merced River at 60 Percent Unimpaired Flow

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1922	1421	508	22	0	1396	452	0	116	612	58	94	17	0	0	0	0	803
1923	947	511	19	0	984	327	0	6	434	58	94	39	0	0	0	0	537
1924	258	455	15	0	418	93	0	17	108	77	94	29	0	0	0	0	230
1925	916	279	16	0	854	259	0	1	370	61	94	43	0	0	0	0	476
1926	615	325	15	0	617	96	0	8	315	56	94	36	0	0	0	0	415
1927	994	308	13	0	877	111	0	11	533	59	94	42	0	0	0	0	645
1928	790	412	15	0	781	236	0	1	329	61	94	42	0	0	0	0	433
1929	521	406	12	0	578	127	0	7	233	65	94	44	0	0	0	0	349
1930	518	337	9	0	555	81	0	15	261	58	94	37	0	0	0	0	371
1931	270	292	12	0	397	79	0	6	122	69	94	27	0	0	0	0	224
1932	1123	152	17	0	843	113	0	13	497	59	94	37	0	0	0	0	607
1933	525	416	15	0	583	116	0	5	253	66	94	38	0	0	0	0	363
1934	365	342	16	0	416	81	0	7	146	57	94	29	0	0	0	0	239
1935	1182	275	20	0	938	162	0	6	554	58	94	32	0	0	0	0	651
1936	1170	500	23	0	1148	325	0	11	587	59	94	38	0	0	0	0	695
1937	1234	499	25	0	1201	397	0	31	554	59	94	30	0	0	0	0	673
1938	2094	507	27	263	1617	448	0	9	898	61	94	39	0	0	0	0	1270
1939	498	694	22	0	653	184	0	2	230	70	94	46	0	0	0	0	347
1940	1113	518	24	0	1067	370	0	18	489	59	94	42	0	0	0	0	608
1941	1481	539	26	102	1202	428	0	4	559	59	94	39	0	0	0	0	763
1942	1308	689	23	119	1233	457	0	3	530	60	94	47	0	0	0	0	759
1943	1309	622	23	159	1253	507	0	22	488	53	94	49	0	0	0	0	771
1944	706	497	16	0	801	223	0	12	348	58	94	46	0	0	0	0	463
1945	1121	386	19	0	1060	315	0	3	502	62	94	48	0	0	0	0	615
1946	967	428	20	0	895	299	0	5	350	72	94	45	0	0	0	0	472
1947	591	479	20	0	593	132	0	1	228	61	94	45	0	0	0	0	335
1948	711	458	15	0	780	210	0	5	336	73	94	47	0	0	0	0	462
1949	666	374	16	0	707	155	0	2	316	69	94	47	0	0	0	0	434
1950	747	318	16	0	735	154	0	15	346	61	94	41	0	0	0	0	463
1951	1248	314	22	245	750	275	0	50	282	47	94	44	0	0	0	0	670
1952	1584	545	26	192	1216	437	0	14	556	57	94	42	0	0	0	0	860
1953	648	696	21	0	781	276	0	7	281	63	94	46	0	0	0	0	397

	Rim Reservoir					District Diversions		Required Releases from Diversion Dam									
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1954	688	542	20	0	770	226	0	1	320	62	94	47	0	0	0	0	430
1955	554	440	16	0	606	143	0	0	234	70	94	46	0	0	0	0	350
1956	1696	374	25	304	1082	447	0	47	427	47	94	43	0	0	0	0	869
1957	674	659	20	0	828	249	0	4	338	62	94	49	0	0	0	0	452
1958	1434	485	27	59	1134	401	0	3	487	61	94	34	0	0	0	0	644
1959	480	699	23	0	653	181	0	0	239	62	94	48	0	0	0	0	349
1960	507	504	20	0	584	133	0	0	228	62	94	46	0	0	0	0	336
1961	333	407	15	0	431	81	0	0	131	74	94	41	0	0	0	0	246
1962	953	294	16	0	912	275	0	3	387	74	94	42	0	0	0	0	506
1963	1009	319	16	0	966	307	0	0	431	62	94	49	0	0	0	0	542
1964	468	346	14	0	486	85	0	0	169	74	94	47	0	0	0	0	291
1965	1314	315	23	0	936	279	0	15	330	60	94	45	0	0	0	0	451
1966	648	668	24	12	738	242	0	23	286	47	94	47	0	0	0	0	416
1967	1700	543	26	242	1275	416	0	13	633	54	94	42	0	0	0	0	984
1968	429	700	22	0	590	177	0	18	208	44	94	49	0	0	0	0	320
1969	2197	517	28	502	1484	427	0	31	767	57	94	35	0	0	0	0	1392
1970	887	700	23	150	870	327	0	36	366	31	94	44	0	0	0	0	627
1971	734	544	20	0	760	279	0	10	279	56	94	49	0	0	0	0	392
1972	576	499	19	0	615	192	0	28	219	49	94	45	0	0	0	0	340
1973	1143	441	23	0	1077	415	0	25	473	46	94	42	0	0	0	0	586
1974	1180	484	26	0	1088	476	0	25	409	41	94	44	0	0	0	0	520
1975	1133	549	22	0	1199	458	0	30	531	55	94	45	0	0	0	0	661
1976	300	461	16	0	436	89	0	10	127	62	94	48	0	0	0	0	246
1977	142	310	8	0	365	78	0	1	48	85	94	47	1	0	0	0	182
1978	1759	80	22	0	1144	249	0	39	689	60	94	26	0	0	0	0	814
1979	1085	673	26	37	1150	400	0	20	499	42	94	37	0	0	0	0	635
1980	1653	544	25	201	1339	487	0	0	535	62	94	49	0	0	0	0	846
1981	502	632	22	0	662	184	0	0	231	68	94	48	0	0	0	0	347
1982	2006	450	27	200	1529	420	0	1	783	61	94	41	0	0	0	0	1087
1983	2871	700	26	929	1915	420	0	0	742	62	94	37	0	0	0	0	1771
1984	1208	700	26	312	1023	360	0	0	346	62	94	49	0	0	0	0	769
1985	574	547	22	0	627	179	0	3	225	61	94	47	0	0	0	0	336
1986	1580	471	24	90	1350	432	0	21	717	62	94	42	0	0	0	0	932
1987	322	587	19	0	487	101	0	1	164	72	94	48	0	0	0	0	285

Year	Rim Reservoir					District Diversions		Required Releases from Diversion Dam										
Year	Res. Inflow	End of Sept. Storage	Res. Evap.	Res. Spills	Total Reservoir Release	Irrigation District Diversion	CVP Contractor Diversion	Balancing Releases*	UF Instream Flow Req.	Baseline Instream Flow Req.	CAD Flow Req.	Minor Diversion	Vernalis Min Flow Req.	VAMP Pulse	D1641 Flow Req.	Vernalis EC Req.	Total Diversion Dam Flow
WY	WY Sum	EOS begin	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum	WY Sum
	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF	TAF
1988	392	402	14	0	455	77	0	0	163	63	94	45	0	0	0	0	272
1989	536	325	12	0	558	80	0	14	268	55	94	39	0	0	0	0	376
1990	383	291	12	0	479	78	0	2	178	64	94	42	0	0	0	0	287
1991	531	182	7	0	567	80	0	8	279	68	94	38	0	0	0	0	393
1992	444	139	8	0	474	77	0	9	198	55	94	34	0	0	0	0	296
1993	1452	102	22	0	959	190	0	55	571	51	94	15	0	0	0	0	692
1994	347	572	18	0	492	79	0	41	240	43	94	29	0	0	0	0	353
1995	2173	410	29	390	1475	417	0	11	813	54	94	35	0	0	0	0	1302
1996	1178	689	30	69	1242	454	0	8	546	58	94	41	0	0	0	0	722
1997	1754	527	28	692	1028	407	0	47	396	37	94	44	0	0	0	0	1216
1998	1836	532	28	298	1342	409	0	9	689	55	94	39	0	0	0	0	1091
1999	880	700	24	42	968	313	0	6	437	57	94	48	0	0	0	0	591
2000	941	546	24	0	961	311	0	17	443	59	94	43	0	0	0	0	562
2001	508	502	20	0	573	132	0	8	244	56	94	37	0	0	0	0	344
2002	621	418	20	0	616	133	0	2	286	60	94	36	0	0	0	0	384
2003	770	404	20	0	759	193	0	2	369	60	94	38	0	0	0	0	470
Avg:	965	463	20	68	878	256	0	13	387	59	94	41	0	0	0	0	570

* Balancing releases accounts for the monthly net between instream accretions and depletions from CALSIM, maintaining nonzero flows, and change in unmodeled regulating reservoir operations (i.e., Tulloch or Goodwin).

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Baseline

Table 16. Baseline End-of-Month Storage at New Melones on the Stanislaus River in TAF from 1922 through 2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	951	960	990	1,015	1,120	1,199	1,166	1,351	1,567	1,495	1,399	1,340
1923	AN	1,291	1,307	1,377	1,439	1,487	1,487	1,492	1,582	1,558	1,482	1,382	1,340
1924	C	1,294	1,287	1,301	1,315	1,319	1,272	1,182	1,072	989	913	844	822
1925	BN	794	803	822	835	971	1,053	1,092	1,232	1,254	1,182	1,085	1,039
1926	D	996	989	993	996	1,044	1,037	1,063	992	904	803	720	677
1927	AN	645	662	716	760	898	949	1,032	1,126	1,123	1,030	938	899
1928	BN	880	912	937	951	998	1,172	1,170	1,224	1,162	1,062	977	935
1929	C	900	909	921	930	946	942	910	863	821	740	673	639
1930	C	608	606	617	639	673	735	729	672	672	596	531	495
1931	C	470	488	498	509	517	503	433	346	295	241	190	169
1932	AN	134	145	200	232	342	343	329	487	609	577	519	483
1933	D	453	451	471	482	491	471	424	392	399	322	253	216
1934	C	191	198	218	240	274	312	273	217	188	158	130	119
1935	AN	112	114	116	142	102	111	257	444	491	433	369	334
1936	AN	316	328	345	419	596	679	772	925	939	866	788	752
1937	W	722	725	742	764	860	969	1,003	1,175	1,180	1,095	1,016	974
1938	W	942	952	1,041	1,120	1,300	1,445	1,585	1,852	2,055	2,005	1,915	1,870
1939	D	1,831	1,827	1,841	1,859	1,875	1,901	1,805	1,657	1,551	1,438	1,342	1,299
1940	AN	1,248	1,235	1,240	1,340	1,475	1,646	1,713	1,817	1,808	1,694	1,598	1,543
1941	W	1,496	1,495	1,533	1,586	1,672	1,704	1,726	1,856	1,891	1,815	1,718	1,658
1942	W	1,613	1,611	1,659	1,749	1,827	1,812	1,893	2,020	2,145	2,097	1,997	1,944
1943	W	1,899	1,925	1,958	1,970	1,970	2,030	2,137	2,147	2,131	2,034	1,932	1,866
1944	BN	1,812	1,804	1,806	1,806	1,816	1,850	1,748	1,647	1,599	1,490	1,388	1,328
1945	AN	1,296	1,330	1,355	1,391	1,521	1,608	1,574	1,650	1,719	1,637	1,539	1,491
1946	AN	1,461	1,489	1,576	1,639	1,695	1,670	1,689	1,760	1,702	1,591	1,494	1,444
1947	D	1,400	1,416	1,436	1,451	1,470	1,441	1,368	1,278	1,196	1,083	990	945
1948	BN	926	926	930	933	933	911	922	956	1,045	974	901	866
1949	BN	839	843	857	865	875	911	869	893	869	782	709	669

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	625	612	620	668	732	781	790	897	957	881	808	779
1951	AN	757	1,035	1,425	1,532	1,629	1,729	1,702	1,643	1,593	1,482	1,386	1,330
1952	W	1,288	1,303	1,357	1,491	1,584	1,626	1,688	1,956	2,120	2,089	1,993	1,931
1953	BN	1,864	1,868	1,888	1,941	1,970	1,918	1,854	1,752	1,786	1,714	1,620	1,563
1954	BN	1,513	1,516	1,529	1,545	1,548	1,606	1,574	1,614	1,545	1,431	1,333	1,277
1955	D	1,226	1,235	1,253	1,283	1,304	1,322	1,303	1,257	1,246	1,157	1,079	1,036
1956	W	1,000	1,013	1,261	1,519	1,641	1,644	1,660	1,794	1,879	1,811	1,714	1,671
1957	BN	1,618	1,620	1,635	1,653	1,693	1,745	1,626	1,602	1,629	1,521	1,431	1,372
1958	W	1,311	1,316	1,322	1,372	1,451	1,531	1,686	1,977	2,106	2,039	1,941	1,878
1959	D	1,822	1,826	1,839	1,865	1,920	1,948	1,827	1,657	1,559	1,451	1,357	1,341
1960	C	1,286	1,280	1,284	1,289	1,330	1,355	1,309	1,230	1,164	1,068	990	934
1961	C	860	878	896	901	909	913	876	817	748	676	615	583
1962	BN	547	556	567	575	657	699	708	698	750	695	627	584
1963	AN	560	571	595	649	761	759	788	959	992	930	856	824
1964	D	804	835	856	891	910	914	871	818	785	707	643	599
1965	W	578	603	834	1,039	1,146	1,213	1,270	1,335	1,339	1,282	1,210	1,163
1966	BN	1,109	1,143	1,177	1,214	1,248	1,283	1,239	1,225	1,143	1,048	971	917
1967	W	880	893	977	1,082	1,094	1,130	1,214	1,406	1,677	1,717	1,630	1,578
1968	D	1,524	1,535	1,550	1,572	1,634	1,685	1,587	1,489	1,399	1,286	1,190	1,126
1969	W	1,091	1,116	1,127	1,419	1,615	1,681	1,830	2,091	2,219	2,160	2,055	1,983
1970	AN	1,941	1,951	1,970	1,970	1,970	1,997	1,933	1,868	1,842	1,722	1,615	1,562
1971	BN	1,518	1,546	1,613	1,671	1,713	1,767	1,700	1,682	1,699	1,611	1,515	1,462
1972	D	1,410	1,425	1,473	1,510	1,526	1,518	1,396	1,361	1,276	1,161	1,062	1,015
1973	AN	980	989	1,020	1,131	1,271	1,390	1,361	1,450	1,411	1,293	1,192	1,144
1974	W	1,121	1,168	1,246	1,360	1,439	1,508	1,606	1,703	1,719	1,635	1,534	1,477
1975	W	1,443	1,454	1,479	1,506	1,573	1,616	1,592	1,578	1,690	1,605	1,519	1,461
1976	C	1,428	1,444	1,464	1,473	1,486	1,459	1,383	1,285	1,192	1,111	1,051	1,012
1977	C	977	981	982	974	958	918	849	789	743	672	611	587
1978	W	544	538	559	637	725	879	991	1,123	1,211	1,163	1,074	1,064

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	1,019	1,031	1,051	1,118	1,235	1,364	1,333	1,419	1,299	1,180	1,080	1,032
1980	W	1,004	1,021	1,036	1,341	1,592	1,617	1,659	1,696	1,750	1,721	1,624	1,571
1981	D	1,534	1,532	1,553	1,600	1,608	1,654	1,575	1,446	1,325	1,207	1,116	1,074
1982	W	1,043	1,102	1,234	1,435	1,737	1,901	2,151	2,250	2,298	2,235	2,130	2,000
1983	W	1,970	1,970	1,970	1,970	1,970	2,030	2,090	2,200	2,420	2,300	2,130	2,000
1984	AN	1,970	1,970	1,970	1,970	1,970	1,990	1,930	1,919	1,871	1,775	1,692	1,651
1985	D	1,626	1,665	1,705	1,721	1,759	1,799	1,732	1,633	1,530	1,418	1,329	1,289
1986	W	1,260	1,271	1,289	1,368	1,836	2,030	2,065	2,059	2,063	1,950	1,856	1,817
1987	C	1,778	1,779	1,790	1,781	1,782	1,812	1,685	1,507	1,383	1,279	1,200	1,160
1988	C	1,103	1,086	1,078	1,079	1,076	1,056	1,008	931	881	830	790	758
1989	C	718	709	708	707	709	788	765	723	694	632	587	598
1990	C	602	612	636	647	657	653	583	509	442	367	320	297
1991	C	271	265	283	279	267	313	289	265	226	167	124	116
1992	C	106	101	120	130	178	220	216	175	144	122	105	100
1993	W	97	99	101	249	352	480	491	576	671	631	576	549
1994	C	541	568	607	635	657	624	572	518	442	352	284	248
1995	W	191	201	236	421	514	823	929	1,159	1,409	1,510	1,454	1,433
1996	W	1,414	1,420	1,457	1,536	1,732	1,851	1,873	1,976	1,965	1,866	1,786	1,744
1997	W	1,733	1,771	1,970	1,970	1,970	1,992	1,914	1,892	1,815	1,709	1,620	1,589
1998	W	1,557	1,573	1,602	1,716	1,916	1,990	2,029	2,081	2,295	2,300	2,130	2,000
1999	AN	1,970	1,970	1,970	1,970	1,970	2,002	1,981	1,971	1,923	1,828	1,750	1,713
2000	AN	1,692	1,695	1,712	1,770	1,880	1,901	1,881	1,851	1,800	1,693	1,613	1,581
2001	D	1,575	1,589	1,622	1,635	1,663	1,701	1,629	1,519	1,405	1,284	1,181	1,122
2002	D	1,067	1,070	1,108	1,152	1,145	1,177	1,130	1,063	972	881	807	774
2003	BN	738	757	810	861	862	862	855	851	803	724	659	627

Table 17. Baseline Monthly Average Flow at Ripon on the Stanislaus River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [TAF]
1922	W	763	259	310	322	391	381	1,877	1,476	596	435	463	469	283
1923	AN	970	354	403	356	235	629	1,755	1,430	1,254	534	463	469	319
1924	C	1,084	318	262	273	238	375	755	713	306	374	402	408	144
1925	BN	823	348	304	304	283	269	1,110	793	433	385	413	419	173
1926	D	832	320	262	267	515	728	919	792	378	385	413	419	199
1927	AN	832	455	288	321	274	699	1,145	950	1,625	385	413	419	281
1928	BN	832	348	304	295	219	481	1,137	1,012	382	385	413	419	195
1929	C	828	302	280	295	225	254	565	482	320	324	352	358	110
1930	C	768	263	94	308	218	380	457	668	256	324	352	358	119
1931	C	768	248	94	275	284	410	566	418	273	324	352	358	117
1932	AN	771	248	383	330	220	951	983	691	467	335	363	369	200
1933	D	780	266	94	308	230	662	464	619	374	335	363	369	141
1934	C	777	263	311	316	220	294	409	281	320	324	352	358	91
1935	AN	771	302	288	348	1,398	1,070	866	884	1,398	512	363	369	332
1936	AN	780	260	225	338	728	337	1,224	910	1,625	484	413	419	288
1937	W	832	266	262	321	350	491	1,048	818	1,122	484	413	419	229
1938	W	832	309	336	321	594	1,945	1,724	1,926	1,524	662	513	519	464
1939	D	1,110	356	280	294	238	238	1,569	1,527	481	435	463	469	244
1940	AN	970	266	225	371	233	451	1,897	1,638	596	534	463	469	290
1941	W	1,003	384	368	447	425	1,950	1,775	2,425	1,703	705	527	503	500
1942	W	1,035	588	383	323	574	1,802	1,537	1,746	1,205	729	552	575	413
1943	W	1,084	383	268	2,395	2,371	3,456	1,590	2,172	1,498	688	651	663	661
1944	BN	1,130	481	494	543	576	468	2,031	1,748	692	515	485	474	331
1945	AN	981	378	385	390	401	357	1,571	1,645	767	591	525	504	285
1946	AN	990	329	187	545	487	1,662	1,575	1,792	1,272	518	539	530	409
1947	D	976	343	347	404	376	805	891	852	428	356	368	379	201
1948	BN	782	341	292	362	352	1,047	690	809	743	514	414	389	220

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [TAF]
1949	BN	799	337	325	324	389	323	839	796	536	386	384	365	172
1950	BN	781	320	330	345	320	594	753	993	821	399	380	386	209
1951	AN	766	403	519	580	657	412	2,000	2,603	656	435	424	395	380
1952	W	867	281	223	397	174	1,641	1,632	2,089	1,767	957	696	666	442
1953	BN	1,116	434	423	504	646	1,674	1,722	2,322	1,313	688	509	513	462
1954	BN	1,005	325	316	351	615	308	1,248	1,362	581	428	418	391	246
1955	D	904	269	302	481	265	365	918	588	382	322	331	342	151
1956	W	774	290	357	841	555	1,720	1,849	1,704	1,431	686	542	495	438
1957	BN	975	294	281	341	369	336	2,003	1,919	613	484	463	462	315
1958	W	975	353	336	327	453	1,635	2,023	1,578	1,492	751	644	667	432
1959	D	1,071	360	403	434	368	477	1,970	1,656	537	406	425	443	301
1960	C	931	337	316	343	386	371	913	780	342	330	336	326	168
1961	C	875	305	307	333	384	394	575	512	245	229	243	247	126
1962	BN	663	282	286	294	342	369	981	1,580	276	370	336	338	214
1963	AN	759	343	304	346	817	1,349	1,073	1,278	1,659	505	426	422	369
1964	D	836	348	286	354	401	371	647	645	434	297	304	318	150
1965	W	725	338	-	449	231	314	1,744	1,932	1,906	491	530	513	368
1966	BN	1,017	325	301	386	467	388	1,231	1,118	412	340	336	335	216
1967	W	760	282	271	276	1,465	1,622	1,526	1,494	1,412	1,021	640	703	448
1968	D	1,192	260	288	380	385	345	1,842	1,432	535	393	409	406	273
1969	W	958	319	339	506	871	2,074	2,088	1,609	1,604	872	717	700	495
1970	AN	1,211	446	755	4,928	2,925	1,971	2,001	2,489	1,282	541	538	592	632
1971	BN	1,028	269	280	336	439	495	2,155	1,814	1,094	591	500	520	360
1972	D	1,184	248	181	342	455	959	1,755	1,409	523	401	403	400	307
1973	AN	891	300	306	310	534	295	1,925	1,627	1,692	540	477	538	363
1974	W	970	235	223	269	473	1,656	1,803	1,964	1,462	622	558	683	443
1975	W	1,110	335	444	349	198	1,778	1,827	2,110	1,665	662	632	637	458
1976	C	914	471	297	368	377	370	903	750	310	293	315	310	163

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [TAF]
1977	C	720	275	263	286	364	421	516	464	291	211	229	174	123
1978	W	599	213	226	343	271	58	803	624	645	553	433	454	143
1979	AN	886	377	320	204	267	238	1,877	1,491	1,964	476	475	463	350
1980	W	960	322	165	198	742	1,705	1,871	2,040	1,526	629	604	690	475
1981	D	1,104	385	305	377	387	368	1,706	1,517	505	463	397	428	269
1982	W	951	263	291	455	290	1,824	2,039	2,109	1,368	713	874	2,993	461
1983	W	1,810	2,651	3,175	4,217	5,177	6,223	1,710	2,208	4,653	4,340	2,664	3,050	1,185
1984	AN	1,538	3,453	5,126	2,177	2,262	1,912	1,808	1,930	1,277	572	626	746	550
1985	D	1,129	340	225	335	441	416	1,750	1,530	566	315	405	495	282
1986	W	995	383	311	311	701	2,960	2,026	2,193	1,289	705	524	631	553
1987	C	1,114	410	511	483	368	370	1,694	1,366	472	360	374	344	256
1988	C	858	238	270	295	369	409	577	485	218	217	201	238	123
1989	C	640	248	267	274	349	340	603	523	300	308	302	327	126
1990	C	667	257	248	260	348	409	599	542	211	244	262	257	126
1991	C	773	469	249	242	383	334	573	543	247	235	247	229	124
1992	C	689	379	239	241	339	278	562	482	395	205	208	192	123
1993	W	604	216	225	354	308	753	1,349	1,338	347	245	293	369	247
1994	C	600	247	232	233	254	438	507	478	210	247	221	235	113
1995	W	1,043	228	242	609	319	618	1,631	1,415	590	440	426	381	275
1996	W	861	270	272	336	168	1,843	1,550	1,775	1,105	471	500	475	390
1997	W	909	464	348	10,555	3,736	2,234	1,884	1,708	1,123	524	478	454	629
1998	W	977	257	247	324	1,330	1,903	1,708	1,996	1,218	1,396	2,214	2,196	488
1999	AN	1,347	898	1,127	1,621	3,452	1,835	1,644	1,791	1,759	439	476	478	617
2000	AN	901	250	241	327	394	1,777	1,767	1,786	1,137	455	443	435	415
2001	D	856	264	243	308	392	311	1,562	1,363	478	357	326	348	246
2002	D	826	220	286	321	783	653	1,272	952	590	307	340	328	253
2003	BN	846	233	262	249	879	890	823	882	1,345	344	312	292	287

Table 18. Baseline End-of-Month Storage at New Don Pedro on the Tuolumne River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	1,313	1,294	1,323	1,355	1,551	1,690	1,713	1,969	2,030	1,910	1,767	1,685
1923	AN	1,637	1,640	1,690	1,690	1,690	1,690	1,713	1,812	1,887	1,802	1,662	1,606
1924	C	1,556	1,538	1,529	1,523	1,528	1,498	1,469	1,408	1,293	1,183	1,094	1,048
1925	BN	1,049	1,062	1,128	1,184	1,372	1,488	1,665	1,780	1,879	1,763	1,625	1,552
1926	D	1,508	1,496	1,502	1,509	1,592	1,680	1,713	1,708	1,569	1,383	1,240	1,162
1927	AN	1,117	1,154	1,200	1,249	1,436	1,561	1,683	1,804	2,023	1,910	1,766	1,688
1928	BN	1,659	1,688	1,690	1,690	1,690	1,690	1,713	1,879	1,811	1,628	1,488	1,409
1929	C	1,351	1,340	1,338	1,337	1,355	1,389	1,396	1,372	1,410	1,242	1,108	1,029
1930	C	989	970	1,010	1,042	1,092	1,156	1,151	1,146	1,203	1,064	957	900
1931	C	871	871	909	920	962	961	909	854	759	651	575	543
1932	AN	520	514	694	847	1,104	1,260	1,277	1,332	1,431	1,368	1,235	1,156
1933	D	1,093	1,066	1,069	1,067	1,101	1,126	1,132	1,148	1,191	1,067	959	900
1934	C	854	840	862	907	979	1,107	1,104	1,053	989	879	800	767
1935	AN	754	767	808	984	1,126	1,256	1,522	1,600	1,753	1,621	1,477	1,389
1936	AN	1,353	1,343	1,338	1,404	1,690	1,690	1,713	1,806	1,973	1,857	1,708	1,623
1937	W	1,575	1,553	1,552	1,558	1,690	1,690	1,713	1,803	1,972	1,820	1,675	1,589
1938	W	1,534	1,523	1,690	1,690	1,690	1,690	1,690	1,730	2,025	1,910	1,779	1,700
1939	D	1,660	1,657	1,673	1,688	1,690	1,690	1,698	1,659	1,501	1,315	1,177	1,133
1940	AN	1,111	1,103	1,171	1,337	1,619	1,690	1,713	1,804	1,922	1,737	1,590	1,500
1941	W	1,448	1,431	1,536	1,690	1,690	1,690	1,690	1,803	2,030	1,910	1,767	1,682
1942	W	1,632	1,622	1,690	1,690	1,690	1,690	1,713	1,765	2,027	1,910	1,767	1,678
1943	W	1,617	1,652	1,690	1,690	1,690	1,690	1,713	1,939	2,030	1,910	1,767	1,678
1944	BN	1,624	1,607	1,600	1,606	1,680	1,690	1,685	1,740	1,751	1,608	1,469	1,390
1945	AN	1,364	1,409	1,457	1,495	1,690	1,690	1,713	1,743	1,931	1,851	1,700	1,610
1946	AN	1,607	1,638	1,690	1,690	1,690	1,690	1,713	1,734	1,766	1,583	1,430	1,343
1947	D	1,297	1,312	1,346	1,371	1,412	1,417	1,372	1,457	1,365	1,203	1,077	1,011
1948	BN	1,010	1,009	1,048	1,068	1,067	1,139	1,224	1,304	1,391	1,251	1,111	1,036
1949	BN	1,000	986	985	985	1,006	1,183	1,220	1,279	1,250	1,076	942	870

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	819	808	810	851	1,023	1,178	1,259	1,266	1,321	1,155	1,017	955
1951	AN	947	1,359	1,690	1,690	1,690	1,690	1,713	1,641	1,624	1,443	1,296	1,205
1952	W	1,161	1,159	1,273	1,512	1,690	1,690	1,690	1,895	2,030	1,910	1,778	1,700
1953	BN	1,639	1,624	1,642	1,690	1,690	1,690	1,701	1,707	1,866	1,804	1,673	1,597
1954	BN	1,552	1,550	1,554	1,574	1,633	1,690	1,713	1,862	1,829	1,650	1,507	1,427
1955	D	1,374	1,371	1,390	1,435	1,495	1,587	1,625	1,642	1,554	1,374	1,229	1,157
1956	W	1,108	1,102	1,664	1,690	1,690	1,690	1,713	1,815	2,030	1,910	1,769	1,693
1957	BN	1,648	1,632	1,629	1,636	1,690	1,690	1,620	1,706	1,878	1,713	1,576	1,501
1958	W	1,480	1,470	1,488	1,523	1,679	1,690	1,690	1,910	2,030	1,910	1,775	1,700
1959	D	1,635	1,612	1,595	1,632	1,690	1,690	1,697	1,626	1,487	1,303	1,162	1,155
1960	C	1,101	1,089	1,117	1,129	1,255	1,305	1,353	1,363	1,255	1,110	1,004	954
1961	C	925	923	1,009	1,024	1,044	1,049	1,026	983	895	793	722	688
1962	BN	665	658	688	705	904	1,032	1,085	1,142	1,346	1,238	1,103	1,029
1963	AN	999	990	1,005	1,052	1,279	1,353	1,456	1,654	1,893	1,830	1,694	1,620
1964	D	1,593	1,639	1,655	1,686	1,690	1,678	1,658	1,661	1,613	1,439	1,306	1,234
1965	W	1,216	1,237	1,665	1,690	1,690	1,690	1,713	1,730	1,852	1,839	1,753	1,680
1966	BN	1,619	1,690	1,690	1,690	1,690	1,690	1,703	1,763	1,611	1,430	1,288	1,216
1967	W	1,167	1,197	1,352	1,463	1,570	1,690	1,690	1,880	2,030	1,910	1,790	1,700
1968	D	1,641	1,626	1,625	1,638	1,690	1,690	1,648	1,667	1,570	1,384	1,251	1,173
1969	W	1,142	1,169	1,259	1,690	1,690	1,690	1,690	1,930	2,030	1,910	1,779	1,700
1970	AN	1,660	1,663	1,690	1,690	1,690	1,690	1,664	1,725	1,783	1,636	1,502	1,423
1971	BN	1,377	1,417	1,505	1,584	1,662	1,690	1,696	1,748	1,883	1,766	1,633	1,562
1972	D	1,517	1,522	1,570	1,633	1,690	1,690	1,629	1,643	1,619	1,443	1,314	1,246
1973	AN	1,215	1,226	1,309	1,450	1,639	1,690	1,713	1,956	2,030	1,849	1,707	1,622
1974	W	1,602	1,688	1,690	1,690	1,690	1,690	1,713	1,945	2,030	1,910	1,769	1,688
1975	W	1,657	1,643	1,646	1,664	1,690	1,690	1,713	1,794	2,030	1,910	1,789	1,700
1976	C	1,660	1,663	1,682	1,670	1,668	1,605	1,556	1,457	1,333	1,202	1,128	1,098
1977	C	1,077	1,069	1,093	1,095	1,096	1,041	960	902	811	711	641	611
1978	W	591	586	644	803	983	1,230	1,414	1,580	1,761	1,829	1,696	1,680

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	1,618	1,619	1,619	1,690	1,690	1,690	1,690	1,717	1,798	1,629	1,487	1,409
1980	W	1,381	1,381	1,402	1,690	1,690	1,690	1,713	1,890	1,960	1,910	1,781	1,700
1981	D	1,641	1,618	1,615	1,635	1,668	1,690	1,713	1,692	1,602	1,422	1,296	1,227
1982	W	1,217	1,321	1,473	1,690	1,690	1,690	1,713	1,876	2,003	1,910	1,790	1,700
1983	W	1,660	1,690	1,690	1,690	1,690	1,295	1,264	1,271	1,851	1,910	1,790	1,700
1984	AN	1,660	1,690	1,690	1,690	1,690	1,690	1,635	1,690	1,757	1,611	1,466	1,380
1985	D	1,360	1,393	1,438	1,441	1,485	1,568	1,588	1,650	1,554	1,375	1,247	1,182
1986	W	1,163	1,182	1,257	1,334	1,690	1,690	1,713	1,888	2,001	1,906	1,765	1,696
1987	C	1,650	1,626	1,612	1,594	1,600	1,641	1,609	1,523	1,398	1,245	1,134	1,076
1988	C	1,059	1,055	1,095	1,162	1,228	1,240	1,218	1,170	1,114	1,008	933	896
1989	C	872	878	913	950	994	1,123	1,157	1,247	1,245	1,068	939	922
1990	C	944	938	962	977	1,020	1,045	1,026	1,039	999	894	816	781
1991	C	767	761	787	793	787	870	892	928	1,028	923	843	801
1992	C	798	794	821	839	913	983	1,031	1,081	1,007	932	846	794
1993	W	774	765	811	1,031	1,192	1,455	1,571	1,886	2,030	1,910	1,776	1,698
1994	C	1,644	1,625	1,616	1,618	1,637	1,637	1,609	1,610	1,513	1,349	1,231	1,170
1995	W	1,137	1,154	1,199	1,468	1,589	1,690	1,713	1,630	1,983	1,910	1,790	1,700
1996	W	1,632	1,606	1,633	1,690	1,690	1,690	1,713	2,002	2,030	1,910	1,767	1,689
1997	W	1,653	1,690	1,690	1,690	1,690	1,690	1,636	1,871	1,954	1,801	1,664	1,609
1998	W	1,549	1,541	1,543	1,690	1,690	1,690	1,713	1,714	1,988	1,910	1,788	1,700
1999	AN	1,662	1,673	1,690	1,690	1,690	1,690	1,718	1,785	1,980	1,838	1,701	1,625
2000	AN	1,563	1,549	1,538	1,627	1,690	1,690	1,718	1,983	2,030	1,850	1,710	1,633
2001	D	1,619	1,603	1,596	1,601	1,633	1,690	1,718	1,836	1,674	1,495	1,362	1,294
2002	D	1,253	1,262	1,336	1,404	1,465	1,531	1,549	1,680	1,674	1,497	1,364	1,289
2003	BN	1,247	1,280	1,338	1,415	1,469	1,522	1,573	1,672	1,803	1,638	1,515	1,446

Table 19. Baseline Monthly Average Flow at Modesto on the Tuolumne River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [TAF]
1922	W	724	599	597	603	683	1,112	3,584	1,593	8,159	1,760	586	592	903
1923	AN	722	595	1,129	2,169	2,125	1,459	3,252	1,396	631	600	586	597	525
1924	C	737	605	580	579	601	597	556	546	366	356	362	366	160
1925	BN	428	442	440	427	454	475	1,107	2,110	493	405	410	421	279
1926	D	552	500	476	464	484	489	2,493	825	414	404	410	418	281
1927	AN	484	449	452	456	519	517	1,473	1,421	720	839	588	595	278
1928	BN	733	615	1,155	858	1,680	4,097	1,617	1,138	427	403	408	423	540
1929	C	552	495	477	468	498	479	631	619	367	358	361	376	155
1930	C	439	466	438	436	473	456	738	723	396	369	371	381	166
1931	C	462	453	449	437	465	448	560	548	368	359	364	367	142
1932	AN	429	437	430	427	520	466	1,423	1,464	721	602	588	591	276
1933	D	741	630	591	582	612	604	818	802	449	409	413	427	196
1934	C	544	501	481	464	491	477	558	644	367	356	361	366	151
1935	AN	438	445	437	436	468	429	1,527	1,564	731	587	585	600	283
1936	AN	736	609	597	593	2,179	4,073	3,584	1,748	681	590	585	595	737
1937	W	735	621	600	590	3,469	4,678	3,656	1,518	664	580	586	599	831
1938	W	737	614	1,712	1,803	7,280	7,992	5,665	5,398	3,996	3,535	592	715	1,803
1939	D	998	650	602	593	1,292	1,864	798	786	417	409	417	420	307
1940	AN	487	470	440	434	514	4,806	4,070	1,183	767	650	534	541	686
1941	W	645	526	755	1,211	5,180	5,100	4,622	1,075	977	2,392	638	560	1,001
1942	W	691	574	921	3,469	3,602	2,886	4,310	4,330	2,194	3,139	755	717	1,031
1943	W	819	641	797	3,855	3,424	6,406	3,999	1,400	1,658	920	521	449	1,007
1944	BN	758	584	626	650	752	2,170	1,169	1,454	513	439	425	372	366
1945	AN	529	453	389	529	2,520	4,144	2,599	1,542	560	713	654	585	678
1946	AN	684	466	3,250	2,893	3,189	3,405	1,948	1,777	805	662	620	593	660
1947	D	663	576	675	615	609	638	780	732	355	322	347	333	186
1948	BN	480	454	398	393	412	433	976	1,234	686	514	427	357	225

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [TAF]
1949	BN	530	463	407	514	480	740	809	864	408	379	379	356	198
1950	BN	530	475	463	686	427	522	1,127	1,117	583	420	399	380	226
1951	AN	513	206	2,684	3,950	3,887	3,072	1,643	1,113	562	622	594	558	604
1952	W	645	525	600	971	1,027	3,998	4,806	5,055	3,986	3,580	637	642	1,139
1953	BN	685	479	517	1,371	1,443	1,443	1,242	1,095	355	544	453	413	331
1954	BN	465	400	391	397	385	1,870	1,769	1,099	462	398	399	382	337
1955	D	473	385	420	702	365	486	794	768	391	363	373	354	168
1956	W	400	372	441	7,146	4,335	3,560	2,423	1,490	3,077	2,780	701	585	887
1957	BN	702	478	491	518	797	1,546	1,252	1,242	416	424	428	418	315
1958	W	489	380	432	561	844	5,254	6,374	4,863	4,664	2,571	692	659	1,326
1959	D	758	519	581	624	1,954	1,998	805	1,083	386	374	353	372	369
1960	C	466	364	307	362	513	446	612	585	305	301	315	334	147
1961	C	315	330	282	337	346	392	488	457	270	261	276	248	116
1962	BN	303	314	323	314	941	510	1,292	1,108	394	383	416	421	252
1963	AN	466	273	315	425	493	248	1,446	1,493	508	552	520	525	251
1964	D	548	381	400	518	871	526	737	671	296	281	288	293	185
1965	W	343	266	234	5,394	3,711	3,400	3,514	1,356	384	568	583	490	731
1966	BN	590	511	2,112	1,295	2,210	1,579	887	841	274	271	262	255	341
1967	W	394	267	318	582	285	2,253	4,636	3,885	6,079	6,352	653	759	1,031
1968	D	650	449	485	515	879	1,717	825	797	371	375	358	342	276
1969	W	401	367	288	1,752	5,624	4,123	5,386	6,786	7,110	3,661	479	623	1,727
1970	AN	1,289	761	1,105	6,185	2,753	3,267	1,517	1,505	319	457	380	438	556
1971	BN	676	503	532	524	456	1,808	1,073	1,267	390	358	370	371	301
1972	D	520	322	524	367	485	596	742	693	307	301	306	297	170
1973	AN	317	451	522	524	826	2,567	1,731	1,483	971	509	529	525	456
1974	W	560	540	1,992	3,021	1,922	3,971	2,891	1,592	2,644	891	495	670	778
1975	W	1,070	1,088	789	642	2,807	3,824	2,672	1,664	2,290	1,112	576	688	789
1976	C	1,369	812	584	543	509	604	610	562	283	270	295	290	154

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [TAF]
1977	C	289	307	322	295	308	320	411	418	199	195	187	166	99
1978	W	222	243	251	432	550	578	1,405	2,630	4,876	440	466	447	601
1979	AN	398	710	611	1,511	3,824	4,445	2,260	5,734	513	573	645	529	1,003
1980	W	612	813	877	2,800	6,927	3,963	2,720	2,046	4,677	3,352	587	829	1,208
1981	D	748	775	519	692	579	1,803	1,220	772	339	346	368	354	283
1982	W	441	421	600	683	6,846	5,797	9,332	6,347	4,430	3,527	712	2,296	1,946
1983	W	3,090	3,106	5,342	5,471	6,892	16,297	5,182	7,861	3,919	6,121	2,996	1,991	2,410
1984	AN	1,157	5,440	7,479	4,359	3,576	3,478	1,602	1,432	621	583	617	612	640
1985	D	743	974	430	489	609	660	768	844	432	366	387	372	198
1986	W	337	363	356	284	3,834	8,232	3,157	3,233	3,262	563	561	675	1,300
1987	C	1,171	1,300	566	596	523	711	544	553	299	282	285	266	157
1988	C	244	259	254	305	260	303	470	488	207	200	210	190	104
1989	C	199	220	245	244	243	345	477	489	211	213	223	220	106
1990	C	215	245	232	236	275	283	444	513	219	225	241	225	104
1991	C	216	239	223	208	235	449	392	517	193	208	221	201	107
1992	C	212	239	217	224	479	307	373	457	202	194	195	188	109
1993	W	216	208	217	781	481	305	1,117	1,348	2,436	1,906	346	417	340
1994	C	586	448	413	399	490	420	520	511	230	213	221	199	129
1995	W	233	218	223	518	152	7,910	4,890	9,474	4,718	8,190	1,918	804	1,649
1996	W	763	451	430	918	6,116	5,065	3,122	2,636	2,648	641	503	546	1,169
1997	W	592	565	6,298	17,925	3,886	3,498	1,431	1,357	505	524	506	499	630
1998	W	698	337	431	1,333	7,440	5,276	4,091	5,533	6,614	6,585	537	691	1,715
1999	AN	965	506	673	2,199	5,167	3,981	2,223	1,456	521	523	521	519	785
2000	AN	596	442	344	433	4,016	3,917	2,238	1,472	1,508	513	711	734	785
2001	D	692	465	418	518	400	1,557	943	732	349	318	334	313	240
2002	D	327	243	383	427	242	328	564	881	300	304	346	309	139
2003	BN	320	247	294	264	241	302	836	879	267	253	303	282	152

Table 20. Baseline End-of-Month Storage at New Exchequer on the Merced River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	469	457	482	505	647	735	801	970	1,024	910	770	700
1923	AN	669	669	675	675	675	674	769	927	955	887	770	700
1924	C	670	662	653	648	641	593	567	553	457	351	265	219
1925	BN	191	196	202	207	293	321	422	578	599	516	426	377
1926	D	346	338	333	327	372	361	459	400	364	307	242	192
1927	AN	154	142	147	135	160	187	207	363	431	398	374	386
1928	BN	391	387	399	413	424	417	382	432	412	370	340	339
1929	C	311	298	284	273	273	262	248	234	215	196	186	151
1930	C	114	100	86	74	62	24	23	39	67	94	119	121
1931	C	92	84	73	68	73	73	120	182	172	150	133	117
1932	AN	94	83	145	178	320	359	382	543	663	594	498	444
1933	D	401	387	376	375	374	361	329	346	417	319	219	169
1934	C	133	119	120	136	167	198	227	232	220	178	146	126
1935	AN	101	106	113	178	215	275	523	707	835	746	645	588
1936	AN	555	547	539	562	675	735	845	970	1,009	910	770	700
1937	W	675	663	666	673	675	735	837	970	1,024	910	770	700
1938	W	657	647	675	675	675	735	845	970	1,024	910	770	700
1939	D	675	675	675	672	675	685	729	701	610	488	381	336
1940	AN	311	299	289	399	521	650	775	947	965	857	753	693
1941	W	653	640	675	675	675	735	845	970	1,024	910	770	700
1942	W	673	672	675	675	675	723	842	970	1,024	910	770	700
1943	W	658	675	675	675	675	735	845	970	1,001	910	770	700
1944	BN	658	646	637	641	671	714	690	798	812	724	622	567
1945	AN	527	545	560	569	675	735	792	946	1,023	910	770	700
1946	AN	675	675	675	675	675	708	754	908	900	803	703	649
1947	D	622	640	671	675	675	676	661	714	640	520	413	356
1948	BN	330	324	314	310	298	271	293	427	526	434	333	279

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1949	BN	242	227	219	213	217	248	279	403	395	289	191	140
1950	BN	97	86	75	96	142	154	227	337	359	267	175	126
1951	AN	98	338	607	675	675	723	746	803	790	689	586	528
1952	W	492	484	526	673	675	735	845	970	1,024	910	770	700
1953	BN	657	648	659	675	675	661	652	652	695	612	508	450
1954	BN	407	395	385	387	417	476	560	671	628	516	403	345
1955	D	300	286	286	299	305	283	270	373	401	304	207	156
1956	W	113	99	467	675	675	725	802	970	1,024	910	770	700
1957	BN	667	660	653	650	673	657	623	707	762	658	553	492
1958	W	466	458	463	480	551	689	845	970	1,024	910	770	700
1959	D	659	645	632	637	675	659	665	632	559	433	322	301
1960	C	262	246	231	223	262	273	330	383	355	267	187	145
1961	C	109	100	97	89	91	90	141	200	206	169	137	116
1962	BN	89	77	70	64	210	248	338	416	490	415	315	254
1963	AN	219	204	192	217	372	393	431	565	655	591	499	445
1964	D	421	441	444	449	445	411	394	429	413	321	233	184
1965	W	158	161	367	434	475	494	572	675	783	743	674	624
1966	BN	583	635	658	675	675	692	728	761	682	563	459	407
1967	W	366	363	458	502	538	668	845	970	1,024	910	770	700
1968	D	675	665	661	662	675	665	666	656	585	456	349	294
1969	W	263	270	291	624	675	735	845	970	1,024	910	770	700
1970	AN	675	675	675	675	675	735	711	795	801	701	601	547
1971	BN	512	515	549	582	604	605	588	649	710	626	531	478
1972	D	439	431	453	466	485	479	471	530	513	403	306	273
1973	AN	249	244	260	312	425	521	598	838	918	821	729	676
1974	W	657	675	675	675	675	735	819	970	1,024	910	770	700
1975	W	672	663	662	673	675	735	741	906	1,024	910	770	700
1976	C	675	675	673	662	662	613	581	560	464	345	257	223
1977	C	190	171	154	140	120	101	99	109	127	113	97	81

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1978	W	56	39	56	152	286	460	682	963	1,024	910	770	700
1979	AN	675	675	668	675	675	735	797	970	990	890	770	700
1980	W	669	659	658	675	675	735	812	968	1,024	910	770	700
1981	D	657	636	625	627	634	647	677	715	657	538	436	381
1982	W	355	383	429	543	675	735	845	970	1,024	910	770	700
1983	W	675	675	675	675	675	735	820	970	1,024	910	770	700
1984	AN	640	675	675	675	675	725	757	885	877	792	698	646
1985	D	623	630	634	637	654	664	711	762	695	575	470	418
1986	W	385	382	396	423	675	735	845	970	1,024	910	770	700
1987	C	660	642	627	616	620	618	622	607	515	392	291	239
1988	C	207	203	197	207	210	212	253	292	274	218	163	134
1989	C	102	90	87	81	88	146	229	289	267	196	137	115
1990	C	99	93	84	83	87	104	175	218	208	172	137	116
1991	C	90	76	60	46	31	97	117	206	260	204	147	117
1992	C	95	88	80	76	121	142	222	258	217	182	138	117
1993	W	94	84	87	257	343	476	611	909	1,024	910	770	700
1994	C	675	660	650	643	655	641	643	666	600	481	382	331
1995	W	314	317	324	509	564	735	845	970	1,024	910	770	700
1996	W	654	639	648	675	675	735	841	970	1,000	910	770	700
1997	W	673	675	675	675	675	735	777	920	915	816	720	667
1998	W	624	615	614	675	675	735	845	970	1,024	910	770	700
1999	AN	670	669	675	675	675	683	692	840	867	761	658	603
2000	AN	557	547	535	574	675	735	800	947	951	835	729	675
2001	D	654	643	636	632	645	694	729	821	724	600	492	453
2002	D	417	410	441	466	484	497	528	601	563	439	334	282
2003	BN	242	255	270	294	310	328	334	499	540	431	337	283

Table 21. Baseline Monthly Average Flow at Stevinson on the Merced River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	356	318	436	432	829	629	(0)	1,018	3,266	1,285	799	359	342
1923	AN	280	254	1,020	1,217	963	277	151	371	526	130	409	501	134
1924	C	385	335	332	346	352	304	112	(0)	(0)	11	19	82	46
1925	BN	351	369	375	378	639	433	467	475	158	87	60	53	129
1926	D	299	304	325	325	286	296	135	597	(0)	(0)	(0)	101	79
1927	AN	338	272	263	331	391	282	279	268	109	107	75	66	79
1928	BN	420	302	339	311	452	355	608	568	215	150	83	49	132
1929	C	364	347	337	358	385	342	295	203	71	2	31	89	77
1930	C	350	322	309	311	325	326	482	177	(0)	(0)	(0)	92	78
1931	C	345	335	322	332	358	318	76	70	55	25	1	119	52
1932	AN	350	313	425	419	650	386	519	(0)	38	80	19	84	94
1933	D	401	336	333	376	321	356	508	182	24	17	(0)	72	83
1934	C	386	333	355	416	419	337	443	212	86	53	(0)	48	89
1935	AN	358	339	359	530	378	487	184	438	174	153	97	125	99
1936	AN	450	360	335	378	2,603	538	714	935	74	326	735	339	287
1937	W	453	374	367	366	4,359	1,139	253	2,058	457	476	728	345	481
1938	W	442	351	1,893	1,288	4,875	4,657	1,416	3,169	4,447	2,143	1,096	502	1,101
1939	D	566	405	358	393	566	474	324	471	114	80	88	122	116
1940	AN	426	374	368	523	449	204	381	512	181	116	101	142	103
1941	W	430	377	1,064	1,287	3,065	1,751	749	2,955	2,272	1,662	1,012	420	639
1942	W	483	397	1,308	1,474	1,666	520	293	964	2,882	1,547	952	414	373
1943	W	489	420	728	2,119	1,917	3,022	775	861	379	359	847	384	414
1944	BN	458	409	386	364	451	354	633	509	333	148	146	122	136
1945	AN	438	439	396	391	1,640	708	629	289	112	794	850	316	196
1946	AN	571	795	1,806	1,014	774	483	751	279	248	140	126	145	149
1947	D	473	384	403	512	811	344	585	96	126	77	101	150	114
1948	BN	398	347	348	338	337	335	596	203	141	153	97	101	96

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	430	354	336	352	371	373	523	194	207	92	118	135	99
1950	BN	414	344	344	378	353	399	612	301	273	133	127	169	115
1951	AN	402	352	33	580	1,590	459	848	328	252	157	113	139	202
1952	W	428	367	410	619	1,243	1,811	1,164	3,524	2,992	1,841	1,164	526	647
1953	BN	451	378	284	938	675	377	977	389	130	111	123	143	150
1954	BN	445	355	353	356	392	287	320	211	218	138	128	174	84
1955	D	402	342	359	487	392	359	215	207	100	101	120	158	75
1956	W	410	336	83	931	1,931	485	606	896	2,288	1,851	1,084	518	368
1957	BN	434	372	359	361	384	397	758	506	276	166	151	174	138
1958	W	462	331	355	431	671	721	2,104	3,409	2,665	1,649	1,080	591	575
1959	D	466	345	332	345	424	363	661	672	151	137	148	158	136
1960	C	400	324	333	347	411	364	286	345	143	132	159	130	93
1961	C	367	315	337	322	348	339	158	165	122	94	56	99	67
1962	BN	344	291	309	310	631	925	1,038	485	390	224	179	177	207
1963	AN	429	312	326	326	360	476	827	710	398	248	191	205	166
1964	D	438	347	348	354	334	348	430	386	146	144	120	164	99
1965	W	389	306	478	1,730	447	362	490	769	388	228	220	193	147
1966	BN	453	152	380	732	671	358	669	777	236	237	197	173	161
1967	W	392	316	350	358	374	407	536	2,525	4,079	3,989	1,448	715	476
1968	D	470	361	280	332	645	379	305	559	228	227	209	230	127
1969	W	378	381	384	853	3,232	1,416	2,010	5,379	4,045	2,323	1,159	613	958
1970	AN	565	328	531	2,886	1,211	779	941	619	271	227	219	203	225
1971	BN	468	325	309	375	334	350	700	776	258	227	186	171	145
1972	D	461	336	373	144	338	303	295	271	235	221	229	(0)	86
1973	AN	394	362	382	424	839	552	282	781	219	204	184	190	158
1974	W	457	644	1,039	1,637	817	978	441	1,277	700	715	966	483	252
1975	W	446	300	359	257	2,139	933	704	672	1,746	1,032	972	430	363
1976	C	847	373	312	342	337	326	293	258	234	205	232	221	87

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	450	271	300	323	304	272	337	219	149	137	109	128	76
1978	W	370	243	300	466	774	482	66	55	3,832	2,543	1,252	1,275	308
1979	AN	229	541	391	1,670	1,879	1,366	540	1,063	299	233	515	342	304
1980	W	519	324	342	4,027	4,472	1,352	574	531	2,081	2,153	1,157	478	531
1981	D	635	348	394	429	405	486	296	356	219	199	200	193	105
1982	W	465	355	364	434	1,250	2,184	4,845	3,215	1,838	2,158	1,331	1,073	799
1983	W	1,088	1,910	2,243	3,604	4,363	5,959	1,284	2,798	7,273	5,863	2,392	1,008	1,290
1984	AN	1,276	1,599	3,495	1,850	1,543	484	336	647	271	262	275	260	194
1985	D	591	288	284	396	393	382	275	251	248	267	237	198	92
1986	W	500	345	358	330	2,104	4,031	824	1,581	1,320	835	1,038	639	589
1987	C	514	366	368	331	330	399	218	181	163	161	167	185	77
1988	C	420	290	325	327	283	275	227	204	179	128	124	133	70
1989	C	342	224	272	254	260	353	162	(0)	121	90	71	117	53
1990	C	378	253	277	260	305	236	110	131	125	98	83	86	54
1991	C	323	208	245	249	207	361	172	147	100	72	29	35	59
1992	C	310	239	247	241	311	300	173	115	118	102	57	47	61
1993	W	219	263	300	634	399	338	(0)	22	979	1,388	1,016	546	103
1994	C	459	319	284	265	331	205	96	84	121	(0)	56	17	49
1995	W	264	277	267	561	336	2,971	936	2,861	5,050	4,805	1,644	421	733
1996	W	534	329	315	636	2,956	1,520	650	1,597	233	230	830	384	414
1997	W	387	974	3,439	9,859	2,091	1,013	761	479	184	120	111	115	264
1998	W	389	286	306	716	5,151	2,005	1,138	904	4,972	4,554	1,464	677	829
1999	AN	549	332	356	772	1,973	381	660	514	236	145	193	130	218
2000	AN	358	295	268	275	1,322	1,009	749	716	181	146	109	90	237
2001	D	356	446	342	339	341	372	150	181	223	94	110	72	75
2002	D	277	353	340	399	257	259	508	276	125	71	38	31	85
2003	BN	278	266	303	277	237	252	540	212	105	46	35	53	80

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LSJR Alternative 2 (20% Unimpaired Flow)

Table 22. LSJR Alternative 2 End-of-Month Storage at New Melones on the Stanislaus River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	951	960	990	1,015	1,120	1,199	1,166	1,342	1,519	1,447	1,351	1,292
1923	AN	1,243	1,260	1,329	1,391	1,440	1,462	1,467	1,557	1,558	1,482	1,382	1,340
1924	C	1,294	1,287	1,301	1,315	1,319	1,272	1,182	1,073	989	913	845	823
1925	BN	795	804	822	836	957	1,035	1,077	1,206	1,236	1,184	1,102	1,064
1926	D	1,025	1,023	1,031	1,036	1,101	1,124	1,150	1,085	1,001	902	820	778
1927	AN	747	764	818	862	983	1,051	1,134	1,220	1,264	1,170	1,077	1,038
1928	BN	1,019	1,051	1,075	1,090	1,136	1,286	1,290	1,347	1,268	1,148	1,047	998
1929	C	957	962	970	975	989	988	966	925	897	834	781	756
1930	C	730	731	743	765	800	865	864	833	842	788	740	715
1931	C	696	714	726	737	746	742	717	671	659	647	630	630
1932	AN	606	618	674	708	804	838	833	950	1,030	984	914	870
1933	D	834	830	847	856	864	874	846	835	847	794	745	720
1934	C	700	710	731	754	789	827	798	753	738	723	708	704
1935	AN	701	702	704	730	756	807	931	1,089	1,159	1,086	1,009	965
1936	AN	940	949	964	1,036	1,211	1,279	1,331	1,442	1,479	1,381	1,283	1,234
1937	W	1,190	1,188	1,201	1,219	1,310	1,415	1,397	1,520	1,524	1,415	1,317	1,263
1938	W	1,216	1,222	1,307	1,382	1,558	1,694	1,820	2,061	2,254	2,196	2,099	2,000
1939	D	1,958	1,949	1,956	1,966	1,970	1,996	1,900	1,763	1,657	1,544	1,447	1,404
1940	AN	1,352	1,339	1,344	1,444	1,558	1,648	1,724	1,824	1,780	1,664	1,564	1,507
1941	W	1,458	1,457	1,496	1,548	1,634	1,666	1,687	1,817	1,853	1,777	1,680	1,620
1942	W	1,575	1,573	1,621	1,711	1,789	1,774	1,856	1,982	2,108	2,060	1,960	1,908
1943	W	1,862	1,888	1,922	1,970	1,970	2,030	2,137	2,147	2,131	2,034	1,932	1,866
1944	BN	1,812	1,804	1,806	1,806	1,816	1,850	1,758	1,683	1,634	1,526	1,424	1,363
1945	AN	1,331	1,365	1,391	1,427	1,542	1,629	1,605	1,681	1,750	1,662	1,564	1,516
1946	AN	1,485	1,514	1,600	1,664	1,719	1,694	1,728	1,798	1,741	1,629	1,532	1,482
1947	D	1,439	1,454	1,474	1,489	1,508	1,507	1,435	1,356	1,274	1,161	1,067	1,022
1948	BN	1,003	1,003	1,006	1,009	1,010	1,030	1,046	1,066	1,149	1,077	1,004	968
1949	BN	942	946	959	968	977	1,013	972	989	964	877	804	763

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	719	706	714	762	827	888	890	990	1,050	974	900	871
1951	AN	849	1,126	1,516	1,624	1,720	1,820	1,813	1,819	1,769	1,658	1,561	1,504
1952	W	1,462	1,477	1,531	1,664	1,747	1,789	1,849	2,117	2,281	2,249	2,130	2,000
1953	BN	1,934	1,937	1,957	1,970	1,970	1,918	1,876	1,791	1,825	1,753	1,659	1,602
1954	BN	1,551	1,555	1,568	1,583	1,604	1,652	1,619	1,660	1,590	1,476	1,378	1,322
1955	D	1,271	1,280	1,298	1,328	1,349	1,363	1,340	1,274	1,239	1,131	1,038	986
1956	W	946	954	1,199	1,454	1,573	1,576	1,602	1,736	1,821	1,754	1,657	1,614
1957	BN	1,561	1,563	1,578	1,596	1,636	1,686	1,582	1,592	1,617	1,510	1,419	1,360
1958	W	1,299	1,304	1,311	1,361	1,439	1,520	1,675	1,949	2,078	2,011	1,913	1,850
1959	D	1,795	1,798	1,812	1,838	1,892	1,921	1,812	1,657	1,559	1,451	1,357	1,341
1960	C	1,286	1,280	1,283	1,289	1,330	1,357	1,312	1,232	1,166	1,070	992	936
1961	C	863	881	899	904	911	922	906	872	833	791	755	739
1962	BN	711	722	735	743	825	866	877	903	921	854	776	725
1963	AN	696	704	727	779	891	948	980	1,135	1,203	1,121	1,030	990
1964	D	964	991	1,008	1,040	1,056	1,063	1,009	956	937	867	808	767
1965	W	744	769	1,001	1,206	1,306	1,373	1,430	1,509	1,577	1,519	1,446	1,399
1966	BN	1,344	1,377	1,411	1,449	1,482	1,514	1,480	1,473	1,375	1,260	1,167	1,105
1967	W	1,062	1,071	1,151	1,253	1,319	1,356	1,439	1,624	1,880	1,919	1,832	1,779
1968	D	1,724	1,735	1,750	1,772	1,834	1,885	1,786	1,688	1,598	1,483	1,387	1,323
1969	W	1,287	1,312	1,322	1,614	1,810	1,876	2,025	2,265	2,393	2,300	2,130	2,000
1970	AN	1,958	1,967	1,970	1,970	1,970	1,997	1,949	1,934	1,908	1,788	1,681	1,628
1971	BN	1,583	1,611	1,678	1,736	1,781	1,754	1,711	1,690	1,702	1,611	1,511	1,456
1972	D	1,403	1,418	1,466	1,502	1,525	1,545	1,424	1,389	1,304	1,189	1,089	1,042
1973	AN	1,007	1,017	1,047	1,158	1,298	1,410	1,381	1,485	1,492	1,374	1,272	1,224
1974	W	1,201	1,248	1,326	1,439	1,518	1,588	1,685	1,797	1,812	1,729	1,626	1,569
1975	W	1,535	1,547	1,571	1,598	1,662	1,705	1,681	1,693	1,805	1,719	1,633	1,574
1976	C	1,542	1,557	1,577	1,586	1,599	1,569	1,489	1,379	1,269	1,168	1,094	1,046
1977	C	1,006	1,006	1,003	992	974	947	893	855	838	797	760	750
1978	W	715	710	732	812	894	1,007	1,114	1,205	1,271	1,223	1,133	1,123

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	1,078	1,090	1,110	1,177	1,287	1,399	1,368	1,469	1,430	1,310	1,209	1,161
1980	W	1,132	1,149	1,165	1,470	1,712	1,737	1,778	1,815	1,869	1,839	1,741	1,688
1981	D	1,651	1,649	1,670	1,717	1,728	1,774	1,695	1,566	1,445	1,326	1,235	1,192
1982	W	1,161	1,219	1,352	1,553	1,804	1,969	2,219	2,317	2,365	2,300	2,130	2,000
1983	W	1,970	1,970	1,970	1,970	1,970	2,030	2,090	2,200	2,420	2,300	2,130	2,000
1984	AN	1,970	1,970	1,970	1,970	1,970	1,990	1,930	1,919	1,871	1,776	1,692	1,651
1985	D	1,626	1,665	1,706	1,721	1,759	1,800	1,732	1,633	1,530	1,418	1,329	1,289
1986	W	1,260	1,272	1,290	1,368	1,769	2,030	2,079	2,098	2,111	2,006	1,917	1,885
1987	C	1,849	1,855	1,872	1,871	1,879	1,908	1,781	1,603	1,479	1,375	1,295	1,255
1988	C	1,197	1,181	1,172	1,174	1,170	1,152	1,087	993	935	876	829	792
1989	C	748	737	736	733	735	802	784	761	752	712	684	703
1990	C	710	723	748	759	770	795	774	737	725	708	711	717
1991	C	700	700	720	718	710	757	755	753	731	699	676	682
1992	C	676	673	693	703	751	793	794	754	727	705	688	682
1993	W	678	680	682	829	928	1,048	1,084	1,152	1,192	1,119	1,036	992
1994	C	973	994	1,027	1,050	1,068	1,041	1,002	959	906	838	787	762
1995	W	710	721	756	941	1,032	1,273	1,387	1,597	1,789	1,885	1,824	1,799
1996	W	1,779	1,784	1,821	1,899	1,970	2,030	2,039	2,116	2,095	1,988	1,901	1,852
1997	W	1,839	1,870	1,970	1,970	1,970	1,992	1,936	1,915	1,837	1,731	1,642	1,611
1998	W	1,579	1,595	1,624	1,738	1,937	2,011	2,050	2,103	2,287	2,300	2,130	2,000
1999	AN	1,970	1,970	1,970	1,970	1,970	2,002	1,991	1,988	1,985	1,889	1,811	1,774
2000	AN	1,753	1,755	1,772	1,831	1,925	1,947	1,941	1,918	1,866	1,759	1,679	1,647
2001	D	1,641	1,654	1,688	1,700	1,729	1,767	1,695	1,584	1,470	1,349	1,246	1,187
2002	D	1,131	1,134	1,172	1,216	1,240	1,291	1,272	1,219	1,144	1,052	977	943
2003	BN	907	926	979	1,030	1,061	1,097	1,093	1,078	1,072	992	926	893

Table 23. LSJR Alternative 2 Monthly Average Flow at Ripon on the Stanislaus River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	763	259	310	322	391	381	1,877	1,610	1,270	435	463	469	331
1923	AN	970	354	403	356	235	264	1,755	1,429	836	534	463	469	271
1924	C	1,084	318	262	273	238	375	755	713	306	374	402	408	144
1925	BN	823	348	304	304	551	390	1,110	1,158	578	385	413	419	226
1926	D	832	320	262	267	266	257	919	715	318	385	413	419	148
1927	AN	832	455	288	321	583	436	1,139	1,080	823	385	413	419	242
1928	BN	832	348	304	295	219	823	969	781	382	385	413	419	192
1929	C	828	302	280	295	225	254	560	638	329	324	352	358	120
1930	C	768	263	94	308	218	380	618	550	447	324	352	358	133
1931	C	768	248	94	275	284	410	393	299	261	324	352	358	98
1932	AN	771	248	383	330	459	381	775	1,252	1,005	385	413	419	233
1933	D	832	266	94	315	230	238	459	579	692	335	363	369	132
1934	C	777	263	311	316	220	329	475	321	320	324	352	358	100
1935	AN	771	302	288	348	216	339	1,172	1,233	837	562	413	419	228
1936	AN	832	260	225	344	728	501	1,842	1,392	915	534	463	469	322
1937	W	970	266	262	327	396	491	1,835	1,429	836	534	463	469	299
1938	W	970	309	336	327	634	2,072	1,957	2,329	1,684	791	613	1,412	522
1939	D	1,155	456	380	420	461	241	1,562	1,337	481	435	463	469	244
1940	AN	970	266	225	371	602	1,772	1,744	1,704	1,173	584	513	519	422
1941	W	1,026	384	368	454	432	1,950	1,775	2,425	1,703	705	527	503	500
1942	W	1,035	588	383	323	574	1,802	1,537	1,746	1,205	729	552	575	413
1943	W	1,084	383	268	1,796	2,371	3,456	1,590	2,172	1,498	688	651	663	661
1944	BN	1,130	481	494	543	576	468	1,860	1,327	692	515	485	474	295
1945	AN	981	378	385	390	659	357	1,403	1,645	773	687	525	504	289
1946	AN	990	329	187	545	487	1,662	1,329	1,792	1,272	518	539	530	394
1947	D	976	343	347	404	376	347	885	658	428	356	368	379	161
1948	BN	782	341	292	362	352	353	610	1,028	830	514	414	389	191

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	799	337	325	324	389	323	830	901	536	386	384	365	178
1950	BN	781	320	330	345	283	407	857	1,103	821	399	380	386	208
1951	AN	766	403	519	580	657	413	1,662	1,539	651	435	424	395	294
1952	W	867	281	223	397	369	1,641	1,632	2,089	1,767	957	1,071	1,791	453
1953	BN	1,116	434	423	1,158	1,168	1,674	1,342	2,054	1,313	688	509	513	452
1954	BN	1,005	325	316	351	306	472	1,248	1,362	581	428	418	391	239
1955	D	904	269	302	481	265	365	918	745	497	322	331	342	167
1956	W	774	290	357	841	555	1,720	1,681	1,704	1,431	686	542	495	428
1957	BN	975	294	281	341	369	377	1,745	1,379	635	484	463	462	270
1958	W	975	353	336	327	453	1,635	2,023	1,848	1,492	751	644	667	448
1959	D	1,071	360	403	434	368	477	1,751	1,426	537	406	425	443	274
1960	C	931	337	316	343	386	332	905	780	342	330	336	326	165
1961	C	875	305	307	333	384	394	575	512	245	229	243	247	126
1962	BN	663	282	286	294	342	369	914	905	692	420	386	388	193
1963	AN	811	343	304	353	778	337	952	1,356	784	505	426	422	251
1964	D	836	348	286	354	401	371	953	801	361	347	354	368	173
1965	W	777	338		449	371	325	1,744	1,683	823	491	530	513	297
1966	BN	1,017	325	301	386	467	388	978	826	372	340	336	335	181
1967	W	760	282	271	276	425	1,622	1,526	1,604	1,650	1,021	640	703	411
1968	D	1,192	260	288	380	385	345	1,842	1,429	535	393	409	406	273
1969	W	958	319	339	506	871	2,074	2,088	1,935	1,604	1,408	1,770	1,674	515
1970	AN	1,211	446	1,030	4,928	2,925	1,971	1,736	1,670	1,282	541	538	592	566
1971	BN	1,028	269	280	336	383	1,816	1,744	1,867	1,178	641	550	570	422
1972	D	1,206	248	181	349	333	491	1,755	1,409	523	401	403	400	272
1973	AN	891	300	306	310	534	410	1,925	1,381	920	540	477	538	309
1974	W	970	235	223	269	473	1,656	1,803	1,726	1,462	622	558	683	429
1975	W	1,110	335	444	349	256	1,778	1,827	1,675	1,665	662	632	637	434
1976	C	914	471	297	368	377	370	903	750	310	293	315	310	163

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	720	275	263	286	364	395	661	464	267	211	229	174	128
1978	W	599	213	226	343	389	725	877	1,278	1,015	553	433	454	257
1979	AN	886	377	320	204	389	520	1,877	1,252	596	476	475	463	278
1980	W	960	322	165	198	894	1,705	1,871	2,040	1,526	629	604	690	484
1981	D	1,104	385	305	377	329	368	1,706	1,511	505	463	397	428	265
1982	W	951	263	291	455	1,185	1,824	2,039	2,109	1,368	751	1,923	2,993	510
1983	W	1,810	2,651	3,175	4,217	5,177	6,223	1,710	2,208	4,653	4,340	2,664	3,050	1,185
1984	AN	1,538	3,453	5,126	2,177	2,262	1,912	1,808	1,926	1,277	572	626	746	550
1985	D	1,129	340	225	335	441	416	1,750	1,530	566	315	405	495	282
1986	W	995	383	311	311	1,916	1,867	1,793	1,789	1,129	576	424	531	505
1987	C	1,069	310	411	357	248	370	1,694	1,366	472	360	374	344	249
1988	C	858	238	270	295	369	370	847	715	268	267	251	288	154
1989	C	692	248	267	281	349	589	786	527	316	308	302	327	154
1990	C	667	257	248	260	348	270	599	542	238	244	262	257	119
1991	C	773	469	249	242	383	334	505	595	356	235	247	229	130
1992	C	689	379	239	241	339	254	495	482	353	205	208	192	115
1993	W	604	216	225	354	389	761	837	1,324	810	295	343	419	248
1994	C	651	247	232	239	261	438	504	517	188	247	221	235	114
1995	W	1,043	228	242	609	360	1,716	1,478	1,728	1,546	490	476	431	412
1996	W	884	270	272	343	2,341	2,801	1,775	2,179	1,265	600	600	575	622
1997	W	954	564	1,970	10,555	3,736	2,234	1,511	1,707	1,123	524	478	454	607
1998	W	977	257	247	324	1,330	1,903	1,708	1,996	1,718	1,264	2,214	2,196	517
1999	AN	1,347	898	1,127	1,621	3,452	1,835	1,476	1,668	1,021	439	476	478	556
2000	AN	901	250	241	327	657	1,777	1,522	1,668	1,137	455	443	435	408
2001	D	856	264	243	308	389	312	1,562	1,363	478	357	326	348	246
2002	D	826	220	286	321	234	332	790	721	326	307	340	328	144
2003	BN	846	233	262	249	316	312	764	1,057	608	344	312	292	183

Table 24. LSJR Alternative 2 End-of-Month Storage at New Don Pedro on the Tuolumne River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	1,313	1,294	1,323	1,355	1,551	1,690	1,713	1,923	2,030	1,910	1,767	1,685
1923	AN	1,637	1,640	1,690	1,690	1,690	1,690	1,713	1,793	1,842	1,758	1,618	1,562
1924	C	1,512	1,494	1,485	1,479	1,484	1,461	1,442	1,385	1,283	1,186	1,107	1,067
1925	BN	1,069	1,083	1,149	1,206	1,374	1,486	1,659	1,780	1,838	1,722	1,584	1,511
1926	D	1,467	1,456	1,462	1,468	1,552	1,639	1,713	1,698	1,559	1,373	1,230	1,152
1927	AN	1,107	1,144	1,191	1,239	1,410	1,535	1,657	1,774	1,942	1,845	1,702	1,624
1928	BN	1,595	1,624	1,659	1,675	1,690	1,690	1,713	1,860	1,786	1,604	1,464	1,385
1929	C	1,326	1,316	1,314	1,313	1,331	1,367	1,381	1,333	1,359	1,205	1,083	1,011
1930	C	973	956	996	1,028	1,080	1,146	1,145	1,142	1,180	1,056	960	909
1931	C	883	884	923	935	977	985	961	924	861	787	738	721
1932	AN	705	700	881	1,036	1,276	1,427	1,443	1,483	1,517	1,454	1,320	1,241
1933	D	1,178	1,151	1,154	1,152	1,185	1,211	1,221	1,239	1,228	1,109	1,004	947
1934	C	902	888	910	955	1,028	1,158	1,162	1,129	1,076	980	912	885
1935	AN	874	887	929	1,105	1,248	1,377	1,641	1,709	1,801	1,669	1,526	1,437
1936	AN	1,401	1,391	1,386	1,452	1,690	1,690	1,713	1,810	1,939	1,823	1,675	1,590
1937	W	1,542	1,520	1,518	1,525	1,690	1,690	1,713	1,770	1,898	1,746	1,602	1,516
1938	W	1,462	1,450	1,685	1,690	1,690	1,690	1,690	1,730	2,025	1,910	1,779	1,700
1939	D	1,660	1,657	1,673	1,688	1,690	1,690	1,689	1,650	1,493	1,307	1,168	1,124
1940	AN	1,103	1,094	1,162	1,328	1,590	1,690	1,713	1,763	1,857	1,672	1,525	1,436
1941	W	1,384	1,367	1,472	1,658	1,690	1,690	1,690	1,737	1,915	1,896	1,753	1,668
1942	W	1,619	1,608	1,690	1,690	1,690	1,690	1,713	1,765	2,027	1,910	1,767	1,678
1943	W	1,617	1,652	1,690	1,690	1,690	1,690	1,713	1,927	2,030	1,910	1,767	1,678
1944	BN	1,624	1,607	1,600	1,606	1,680	1,690	1,685	1,738	1,726	1,584	1,445	1,366
1945	AN	1,340	1,385	1,432	1,471	1,690	1,690	1,713	1,746	1,876	1,796	1,645	1,555
1946	AN	1,553	1,584	1,690	1,690	1,690	1,690	1,713	1,734	1,761	1,578	1,425	1,338
1947	D	1,292	1,307	1,341	1,366	1,407	1,417	1,381	1,451	1,368	1,217	1,100	1,039
1948	BN	1,039	1,039	1,079	1,098	1,099	1,170	1,255	1,324	1,366	1,225	1,085	1,010
1949	BN	975	961	959	959	981	1,160	1,197	1,239	1,205	1,052	933	871

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	826	816	818	860	1,031	1,187	1,267	1,250	1,276	1,110	972	911
1951	AN	903	1,315	1,690	1,690	1,690	1,690	1,713	1,635	1,600	1,420	1,272	1,181
1952	W	1,137	1,135	1,249	1,488	1,690	1,690	1,690	1,895	2,030	1,910	1,778	1,700
1953	BN	1,639	1,624	1,642	1,690	1,690	1,690	1,713	1,726	1,823	1,761	1,631	1,555
1954	BN	1,510	1,508	1,512	1,532	1,591	1,690	1,713	1,840	1,798	1,618	1,476	1,396
1955	D	1,343	1,340	1,359	1,404	1,464	1,556	1,594	1,585	1,462	1,283	1,139	1,066
1956	W	1,018	1,012	1,574	1,690	1,690	1,690	1,713	1,794	2,030	1,910	1,769	1,693
1957	BN	1,648	1,632	1,629	1,636	1,690	1,690	1,630	1,716	1,832	1,668	1,531	1,455
1958	W	1,435	1,425	1,442	1,478	1,634	1,690	1,690	1,910	2,030	1,910	1,775	1,700
1959	D	1,635	1,612	1,595	1,632	1,690	1,690	1,697	1,644	1,500	1,316	1,175	1,167
1960	C	1,114	1,102	1,130	1,142	1,268	1,320	1,365	1,363	1,253	1,121	1,026	981
1961	C	956	953	1,040	1,055	1,077	1,089	1,085	1,055	993	926	881	863
1962	BN	846	842	872	892	1,091	1,219	1,271	1,323	1,460	1,352	1,217	1,142
1963	AN	1,111	1,102	1,117	1,165	1,357	1,424	1,527	1,710	1,886	1,823	1,686	1,613
1964	D	1,586	1,632	1,648	1,679	1,690	1,678	1,658	1,638	1,563	1,389	1,256	1,184
1965	W	1,166	1,187	1,615	1,690	1,690	1,690	1,713	1,724	1,773	1,760	1,675	1,602
1966	BN	1,541	1,617	1,690	1,690	1,690	1,690	1,696	1,737	1,584	1,403	1,261	1,190
1967	W	1,140	1,171	1,325	1,437	1,537	1,690	1,690	1,880	2,030	1,910	1,790	1,700
1968	D	1,641	1,626	1,625	1,638	1,690	1,690	1,648	1,658	1,555	1,369	1,237	1,158
1969	W	1,127	1,154	1,244	1,690	1,690	1,690	1,690	1,930	2,030	1,910	1,779	1,700
1970	AN	1,660	1,663	1,690	1,690	1,690	1,690	1,674	1,745	1,755	1,608	1,474	1,395
1971	BN	1,350	1,390	1,478	1,556	1,634	1,690	1,698	1,758	1,832	1,715	1,583	1,512
1972	D	1,467	1,472	1,520	1,583	1,648	1,649	1,588	1,575	1,526	1,351	1,222	1,154
1973	AN	1,125	1,135	1,218	1,359	1,548	1,690	1,713	1,916	1,968	1,787	1,646	1,562
1974	W	1,541	1,628	1,690	1,690	1,690	1,690	1,713	1,931	2,030	1,910	1,769	1,688
1975	W	1,657	1,643	1,646	1,664	1,690	1,690	1,713	1,779	2,030	1,910	1,789	1,700
1976	C	1,660	1,663	1,682	1,670	1,668	1,612	1,569	1,472	1,356	1,234	1,167	1,141
1977	C	1,121	1,114	1,138	1,141	1,142	1,104	1,051	1,015	941	873	829	812
1978	W	797	794	853	1,014	1,187	1,403	1,587	1,580	1,761	1,829	1,696	1,680

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	1,618	1,619	1,619	1,690	1,690	1,690	1,690	1,717	1,765	1,597	1,455	1,377
1980	W	1,349	1,349	1,370	1,690	1,690	1,690	1,713	1,890	1,960	1,910	1,781	1,700
1981	D	1,641	1,618	1,615	1,635	1,668	1,690	1,713	1,674	1,574	1,394	1,269	1,199
1982	W	1,190	1,294	1,445	1,671	1,690	1,690	1,713	1,876	2,003	1,910	1,790	1,700
1983	W	1,660	1,690	1,690	1,690	1,690	1,295	1,264	1,271	1,851	1,910	1,790	1,700
1984	AN	1,660	1,690	1,690	1,690	1,690	1,690	1,635	1,671	1,708	1,563	1,418	1,333
1985	D	1,313	1,345	1,391	1,394	1,438	1,521	1,527	1,573	1,475	1,297	1,169	1,105
1986	W	1,086	1,105	1,180	1,257	1,690	1,690	1,713	1,888	2,001	1,906	1,765	1,696
1987	C	1,650	1,626	1,612	1,594	1,600	1,642	1,611	1,527	1,414	1,272	1,169	1,116
1988	C	1,100	1,096	1,137	1,205	1,271	1,285	1,267	1,218	1,168	1,078	1,013	983
1989	C	962	969	1,004	1,042	1,087	1,181	1,186	1,248	1,223	1,052	929	912
1990	C	936	930	954	969	1,013	1,041	1,028	1,054	1,033	958	903	882
1991	C	871	866	894	902	897	975	988	994	1,051	953	878	838
1992	C	836	832	860	877	952	1,019	1,050	1,106	1,035	979	906	862
1993	W	845	837	884	1,104	1,261	1,479	1,594	1,865	2,030	1,910	1,776	1,698
1994	C	1,644	1,625	1,616	1,618	1,637	1,637	1,602	1,580	1,474	1,310	1,194	1,133
1995	W	1,101	1,118	1,163	1,432	1,529	1,690	1,713	1,630	1,983	1,910	1,790	1,700
1996	W	1,632	1,606	1,633	1,690	1,690	1,690	1,713	2,002	2,030	1,910	1,767	1,689
1997	W	1,653	1,690	1,690	1,690	1,690	1,690	1,647	1,856	1,903	1,750	1,613	1,558
1998	W	1,499	1,490	1,492	1,666	1,690	1,690	1,713	1,714	1,988	1,910	1,788	1,700
1999	AN	1,662	1,673	1,690	1,690	1,690	1,690	1,718	1,761	1,899	1,758	1,622	1,546
2000	AN	1,484	1,470	1,459	1,548	1,690	1,690	1,718	1,966	2,030	1,850	1,710	1,633
2001	D	1,619	1,603	1,596	1,601	1,633	1,690	1,718	1,799	1,637	1,459	1,326	1,259
2002	D	1,217	1,226	1,300	1,368	1,427	1,484	1,476	1,588	1,555	1,379	1,246	1,172
2003	BN	1,130	1,164	1,221	1,298	1,352	1,399	1,450	1,500	1,573	1,409	1,288	1,220

Table 25. LSJR Alternative 2 Monthly Average Flow at Modesto on the Tuolumne River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	724	599	597	603	683	1,112	3,584	2,335	7,396	1,760	586	592	903
1923	AN	722	595	1,129	2,169	2,125	1,459	3,252	1,695	1,072	600	586	597	569
1924	C	737	605	580	579	601	597	556	680	366	356	362	366	168
1925	BN	428	442	440	427	817	540	1,176	2,012	1,183	405	410	421	343
1926	D	552	500	476	464	484	489	1,817	989	414	404	410	418	251
1927	AN	484	449	452	456	803	520	1,473	1,477	1,600	581	588	595	350
1928	BN	733	615	613	601	1,417	4,097	1,617	1,457	514	403	408	423	550
1929	C	552	495	477	468	498	479	631	1,229	756	358	361	376	215
1930	C	439	466	438	436	473	478	827	894	961	369	371	381	217
1931	C	462	453	449	437	465	448	560	680	368	359	364	367	150
1932	AN	429	437	430	427	834	559	1,423	1,704	1,791	602	588	591	378
1933	D	741	630	591	582	612	604	818	816	1,432	409	413	427	255
1934	C	544	501	481	464	491	488	625	546	367	356	361	366	150
1935	AN	438	445	437	436	468	446	1,563	1,727	1,718	587	585	600	355
1936	AN	736	609	597	593	3,015	4,073	3,584	1,691	1,311	590	585	595	819
1937	W	735	621	600	590	2,868	4,678	3,656	2,062	1,341	580	586	599	871
1938	W	737	614	611	1,728	7,280	7,992	5,665	5,398	3,996	3,535	592	715	1,803
1939	D	998	650	602	593	1,292	1,864	948	786	417	409	417	420	316
1940	AN	487	470	440	434	869	4,334	4,070	1,857	1,170	650	534	541	742
1941	W	645	526	755	683	4,611	5,100	4,622	2,157	1,798	757	638	560	1,084
1942	W	691	574	698	3,469	3,602	2,886	4,310	4,330	2,194	3,139	755	717	1,031
1943	W	819	641	797	3,855	3,424	6,406	3,999	1,610	1,443	920	521	449	1,007
1944	BN	758	584	626	650	752	2,170	1,169	1,483	897	439	425	372	391
1945	AN	529	453	389	529	2,084	4,144	2,599	1,480	1,553	713	654	585	709
1946	AN	684	466	2,366	2,893	3,189	3,405	1,948	1,777	891	662	620	593	665
1947	D	663	576	675	615	609	638	780	1,145	373	322	347	333	212
1948	BN	480	454	398	393	412	433	976	1,418	1,459	514	427	357	282

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	530	463	407	514	480	740	1,069	1,421	807	379	379	356	271
1950	BN	530	475	463	686	447	522	1,127	1,522	1,072	420	399	380	281
1951	AN	513	206	1,962	3,950	3,887	3,072	1,643	1,213	864	622	594	558	629
1952	W	645	525	600	971	615	3,998	4,806	5,055	3,986	3,580	637	642	1,115
1953	BN	685	479	517	1,371	1,443	1,443	1,047	974	1,391	544	453	413	374
1954	BN	465	400	391	397	385	1,186	1,769	1,457	622	398	399	382	326
1955	D	473	385	420	702	365	486	794	1,194	981	363	373	354	229
1956	W	400	372	441	5,679	4,335	3,560	2,423	1,821	2,736	2,780	701	585	887
1957	BN	702	478	491	518	797	1,546	1,084	1,236	1,361	424	428	418	361
1958	W	489	380	432	561	844	4,519	6,374	4,863	4,664	2,571	692	659	1,281
1959	D	758	519	581	624	1,954	1,998	805	791	467	374	353	372	356
1960	C	466	364	307	362	513	485	800	989	548	301	315	334	200
1961	C	315	330	282	337	346	392	555	716	410	261	276	248	145
1962	BN	303	314	323	314	941	510	1,307	1,177	1,499	383	416	421	323
1963	AN	466	273	315	425	1,113	364	1,446	1,737	1,556	552	520	525	370
1964	D	548	381	400	518	747	526	737	1,051	756	281	288	293	229
1965	W	343	266	234	4,586	3,711	3,400	3,514	1,460	1,600	568	583	490	809
1966	BN	590	429	932	1,295	2,210	1,579	1,005	1,155	289	271	262	255	368
1967	W	394	267	318	582	414	1,706	4,636	3,885	6,079	6,352	653	759	1,004
1968	D	650	449	485	515	879	1,717	825	937	474	375	358	342	291
1969	W	401	367	288	1,517	5,624	4,123	5,386	6,786	7,110	3,661	479	623	1,727
1970	AN	1,289	761	1,105	6,185	2,753	3,267	1,349	1,337	1,129	457	380	438	583
1971	BN	676	503	532	524	456	1,361	1,047	1,135	1,405	358	370	371	325
1972	D	520	322	524	367	341	592	742	1,119	739	301	306	297	213
1973	AN	317	451	522	524	826	1,088	1,731	2,130	1,344	509	529	525	427
1974	W	560	540	1,003	3,021	1,922	3,971	2,891	1,825	2,405	891	495	670	778
1975	W	1,070	1,088	789	642	2,807	3,824	2,672	1,893	2,055	1,112	576	688	789
1976	C	1,369	812	584	543	509	604	610	680	283	270	295	290	161

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	289	307	322	295	308	338	411	418	455	195	187	166	115
1978	W	222	243	251	432	706	1,077	1,405	5,421	4,876	440	466	447	812
1979	AN	398	710	611	1,511	3,824	4,445	2,260	5,734	1,059	573	645	529	1,036
1980	W	612	813	877	2,281	6,927	3,963	2,720	2,046	4,677	3,352	587	829	1,208
1981	D	748	775	519	692	579	1,803	1,220	1,067	508	346	368	354	311
1982	W	441	421	600	541	6,507	5,797	9,332	6,347	4,430	3,527	712	2,296	1,927
1983	W	3,090	3,106	5,342	5,471	6,892	16,297	5,182	7,861	3,919	6,121	2,996	1,991	2,410
1984	AN	1,157	5,440	7,479	4,359	3,576	3,478	1,602	1,743	1,109	583	617	612	688
1985	D	743	974	430	489	609	660	1,015	1,109	454	366	387	372	230
1986	W	337	363	356	284	2,445	8,232	3,157	3,233	3,262	563	561	675	1,223
1987	C	1,171	1,300	566	596	523	711	652	660	299	282	285	266	170
1988	C	244	259	254	305	260	342	534	693	329	200	210	190	130
1989	C	199	220	245	244	243	927	1,039	1,044	696	213	223	220	238
1990	C	215	245	232	236	275	423	739	592	379	225	241	225	144
1991	C	216	239	223	208	235	546	605	1,093	992	208	221	201	209
1992	C	212	239	217	224	479	374	773	615	422	194	195	188	159
1993	W	216	208	217	781	580	1,038	1,126	2,052	2,095	1,906	346	417	414
1994	C	586	448	413	399	490	420	655	894	400	213	221	199	171
1995	W	233	218	223	518	576	6,940	4,890	9,474	4,718	8,190	1,918	804	1,613
1996	W	763	451	430	918	6,116	5,065	3,122	2,636	2,648	641	503	546	1,169
1997	W	592	565	6,298	17,925	3,886	3,498	1,253	1,763	1,129	524	506	499	681
1998	W	698	337	431	899	7,010	5,276	4,091	5,533	6,614	6,585	537	691	1,691
1999	AN	965	506	673	2,199	5,167	3,981	2,223	1,851	1,465	523	521	519	865
2000	AN	596	442	344	433	2,643	3,917	2,238	1,753	1,219	513	711	734	706
2001	D	692	465	418	518	400	1,557	943	1,327	349	318	334	313	276
2002	D	327	243	383	427	284	459	1,012	1,210	750	304	346	309	223
2003	BN	320	247	294	264	241	403	836	1,691	1,250	253	303	282	266

Table 26. LSJR Alternative 2 End-of-Month Storage at New Exchequer on the Merced River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	469	457	482	505	647	735	776	924	1,024	910	770	700
1923	AN	669	669	675	675	675	674	746	870	898	830	738	698
1924	C	669	660	652	647	639	610	608	610	549	484	429	398
1925	BN	373	379	385	391	477	506	598	730	730	646	556	506
1926	D	475	467	462	456	501	497	566	524	494	454	403	358
1927	AN	323	311	316	305	323	350	351	464	493	459	435	447
1928	BN	452	447	460	473	485	468	440	484	462	420	390	389
1929	C	361	348	334	323	323	319	325	312	303	317	332	310
1930	C	277	263	250	239	228	193	204	211	225	260	293	298
1931	C	270	262	252	247	252	249	279	319	301	270	246	226
1932	AN	201	190	252	285	427	466	494	598	670	601	506	452
1933	D	408	394	383	382	381	380	388	420	490	431	361	324
1934	C	292	279	281	298	329	361	399	408	396	356	325	304
1935	AN	279	284	292	356	393	454	657	804	890	800	699	642
1936	AN	608	601	592	615	675	735	844	966	977	894	770	700
1937	W	675	663	666	673	675	735	819	970	1,013	910	770	700
1938	W	657	647	675	675	675	735	845	970	1,024	910	770	700
1939	D	675	675	675	672	675	689	734	728	652	546	451	411
1940	AN	388	376	366	477	598	709	820	962	964	856	751	692
1941	W	651	638	675	675	675	735	845	970	1,024	910	770	700
1942	W	673	672	675	675	675	723	822	953	1,024	910	770	700
1943	W	658	675	675	675	675	735	845	965	987	907	770	700
1944	BN	658	646	637	641	671	714	712	801	808	720	618	563
1945	AN	523	541	556	565	675	735	798	917	960	885	770	700
1946	AN	675	675	675	675	675	708	760	878	862	766	666	613
1947	D	585	604	634	645	669	675	685	722	660	556	461	410
1948	BN	385	379	369	366	354	331	370	474	546	463	369	318
1949	BN	282	268	259	253	257	296	355	470	484	411	341	302

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	265	254	243	265	312	324	405	495	518	435	350	304
1951	AN	276	517	675	675	675	723	770	813	794	693	590	532
1952	W	495	487	530	675	675	735	845	970	1,024	910	770	700
1953	BN	657	648	659	675	675	661	686	686	705	622	517	459
1954	BN	416	404	394	396	426	484	558	644	606	502	395	340
1955	D	296	283	283	296	302	294	306	413	457	401	338	302
1956	W	266	252	621	675	675	725	807	967	1,024	910	770	700
1957	BN	667	660	653	650	673	657	651	725	761	657	553	492
1958	W	466	458	463	479	550	689	845	970	1,024	910	770	700
1959	D	659	645	632	637	675	666	698	697	637	527	429	411
1960	C	374	358	344	336	375	391	450	510	493	421	355	319
1961	C	285	276	274	266	268	268	314	367	374	340	310	290
1962	BN	263	250	244	238	385	422	534	599	655	579	478	417
1963	AN	381	366	354	379	520	540	601	725	796	732	638	584
1964	D	560	580	583	588	584	556	558	599	586	507	428	384
1965	W	358	361	568	635	675	693	767	865	947	906	770	700
1966	BN	659	675	675	675	675	692	736	780	701	582	478	426
1967	W	385	381	477	521	557	679	845	970	1,024	910	770	700
1968	D	675	665	661	662	675	671	687	705	654	547	458	410
1969	W	381	388	409	675	675	735	845	970	1,024	910	770	700
1970	AN	675	675	675	675	675	735	747	826	822	723	623	568
1971	BN	533	536	570	603	625	626	632	703	743	659	564	511
1972	D	472	463	486	499	518	522	525	581	574	480	396	367
1973	AN	345	340	356	409	522	617	685	896	949	852	760	700
1974	W	675	675	675	675	675	735	813	970	1,024	910	770	700
1975	W	672	663	662	673	675	735	763	908	1,024	910	770	700
1976	C	675	675	673	662	662	634	625	634	571	490	430	405
1977	C	375	357	341	328	309	281	276	275	275	245	216	194
1978	W	165	148	165	262	395	561	740	948	1,024	910	770	700

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	675	675	668	675	675	735	802	970	977	877	770	700
1980	W	669	659	658	675	675	735	812	944	1,024	910	770	700
1981	D	657	636	625	627	634	648	676	711	659	548	452	400
1982	W	375	402	448	562	675	735	845	970	1,024	910	770	700
1983	W	675	675	675	675	675	735	820	970	1,024	910	770	700
1984	AN	640	675	675	675	675	725	751	866	851	766	673	621
1985	D	598	604	609	612	629	640	680	719	660	548	449	400
1986	W	368	366	380	406	675	735	845	970	1,024	910	770	700
1987	C	660	642	627	616	620	622	644	652	593	506	433	393
1988	C	364	361	355	365	369	375	415	452	441	392	344	316
1989	C	286	274	271	265	273	333	402	445	426	366	316	296
1990	C	280	274	265	264	269	289	348	385	377	347	317	298
1991	C	273	259	243	229	214	281	302	373	415	371	323	296
1992	C	274	267	260	257	302	323	391	421	381	353	315	295
1993	W	273	263	266	437	522	644	743	965	1,024	910	770	700
1994	C	675	660	650	643	655	647	650	670	624	527	447	405
1995	W	389	393	400	585	641	735	845	970	1,024	910	770	700
1996	W	654	639	648	675	675	735	840	970	982	897	770	700
1997	W	673	675	675	675	675	735	789	905	888	790	694	641
1998	W	598	589	588	671	675	735	845	970	1,024	910	770	700
1999	AN	670	669	675	675	675	683	706	829	839	733	630	575
2000	AN	530	520	507	546	675	735	812	947	936	820	714	660
2001	D	639	629	621	617	630	680	702	764	669	545	439	400
2002	D	365	358	389	414	432	450	502	577	557	463	382	342
2003	BN	306	320	335	359	376	395	416	545	566	465	378	327

Table 27. LSJR Alternative 2 Monthly Average Flow at Stevinson on the Merced River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	356	318	436	432	829	629	417	1,356	2,504	1,285	799	359	342
1923	AN	280	254	1,020	1,217	963	277	531	937	526	130	(0)	2	191
1924	C	385	335	332	346	352	304	225	296	44	11	19	82	73
1925	BN	351	369	375	378	639	433	605	849	494	87	60	53	180
1926	D	299	304	325	325	286	296	729	563	161	(0)	(0)	101	122
1927	AN	338	272	263	331	493	283	602	963	760	107	75	66	185
1928	BN	420	302	339	311	452	517	477	670	229	150	83	49	141
1929	C	364	347	337	358	385	342	262	628	326	2	31	89	116
1930	C	350	322	309	311	325	326	397	446	376	(0)	(0)	92	112
1931	C	345	335	322	332	358	318	249	299	67	25	1	119	77
1932	AN	350	313	425	419	650	386	440	904	844	80	19	84	193
1933	D	401	336	333	376	321	356	296	433	602	17	(0)	72	120
1934	C	386	333	355	416	419	337	309	182	111	53	(0)	48	80
1935	AN	358	339	359	530	378	487	924	1,047	867	153	97	125	222
1936	AN	450	360	335	378	3,535	538	736	973	548	79	469	339	373
1937	W	453	374	367	366	4,359	1,139	548	1,774	645	295	728	345	492
1938	W	442	351	1,893	1,288	4,875	4,657	1,416	3,169	4,447	2,143	1,096	502	1,101
1939	D	566	405	358	393	566	474	508	329	114	80	88	122	118
1940	AN	426	374	368	523	469	481	612	992	471	116	101	142	182
1941	W	430	377	1,041	1,287	3,065	1,751	749	2,955	2,272	1,662	1,012	420	639
1942	W	483	397	1,308	1,474	1,666	520	622	920	2,599	1,547	952	414	373
1943	W	489	420	728	2,119	1,917	3,022	775	950	511	189	802	384	427
1944	BN	458	409	386	364	451	354	269	813	447	148	146	122	140
1945	AN	438	439	396	391	1,570	708	524	859	692	179	444	316	256
1946	AN	571	795	1,806	1,014	774	483	649	852	383	140	126	145	186
1947	D	473	384	403	392	385	344	350	559	171	77	101	150	108
1948	BN	398	347	348	338	337	335	360	768	729	153	97	101	152

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	430	354	336	352	371	373	477	771	376	92	118	135	142
1950	BN	414	344	344	378	353	399	578	758	420	133	127	169	150
1951	AN	402	352	1,835	1,683	1,591	459	437	572	350	157	113	139	199
1952	W	428	367	410	657	1,263	1,811	1,164	3,524	2,992	1,841	1,164	526	648
1953	BN	451	378	284	938	675	377	403	397	531	111	123	143	141
1954	BN	445	355	353	356	392	322	571	725	249	138	128	174	135
1955	D	402	342	359	487	392	359	218	631	460	101	120	158	123
1956	W	410	336	83	3,440	1,936	485	518	1,038	2,230	1,851	1,084	518	369
1957	BN	434	372	359	361	384	397	296	651	592	166	151	174	139
1958	W	462	331	355	431	671	721	2,098	3,409	2,665	1,649	1,080	591	575
1959	D	466	345	332	345	424	363	397	364	171	137	148	158	102
1960	C	400	324	333	347	411	364	420	478	215	132	159	130	113
1961	C	367	315	337	322	348	339	282	309	148	94	56	99	85
1962	BN	344	291	309	310	631	925	665	670	689	224	179	177	214
1963	AN	429	312	326	326	623	476	440	872	706	248	191	205	186
1964	D	438	347	348	354	334	348	255	455	272	144	120	164	100
1965	W	389	306	478	1,730	471	362	555	842	813	228	1,301	533	182
1966	BN	453	752	757	1,002	671	358	534	592	236	237	197	173	141
1967	W	392	316	350	358	374	546	716	2,520	4,079	3,989	1,448	715	495
1968	D	470	361	280	332	645	379	316	394	228	227	209	230	117
1969	W	378	381	384	1,956	4,145	1,416	2,010	5,379	4,045	2,323	1,159	613	1,008
1970	AN	565	328	531	2,886	1,211	779	327	709	427	227	219	203	204
1971	BN	468	325	309	375	334	350	329	595	605	227	186	171	132
1972	D	461	336	373	144	338	303	295	543	323	221	229	(0)	108
1973	AN	394	362	382	424	839	552	440	1,239	676	204	184	304	223
1974	W	565	932	1,039	1,637	817	978	541	1,180	700	715	966	483	252
1975	W	446	300	359	257	2,139	933	329	1,015	1,764	1,032	972	430	363
1976	C	847	373	312	342	337	326	293	302	234	205	232	221	89

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	450	271	300	323	304	281	186	219	207	137	109	128	71
1978	W	370	243	300	466	774	611	786	1,229	3,589	2,543	1,252	1,275	417
1979	AN	229	541	391	1,670	1,879	1,366	444	1,156	521	233	302	342	317
1980	W	519	324	342	4,027	4,472	1,352	578	930	1,666	2,153	1,157	478	531
1981	D	635	348	394	429	405	486	410	517	232	199	200	193	122
1982	W	465	355	364	434	1,601	2,184	4,845	3,215	1,838	2,158	1,331	1,073	819
1983	W	1,088	1,910	2,243	3,604	4,363	5,959	1,284	2,798	7,273	5,863	2,392	1,008	1,290
1984	AN	1,276	1,599	3,495	1,850	1,543	484	434	862	383	262	275	260	220
1985	D	591	288	284	396	393	382	494	556	248	267	237	198	124
1986	W	500	345	358	330	1,804	4,031	824	1,581	1,320	835	1,038	639	573
1987	C	514	366	368	331	330	399	319	309	163	161	167	185	91
1988	C	420	290	325	327	283	275	313	348	185	128	124	133	84
1989	C	342	224	272	254	260	353	538	429	245	90	71	117	109
1990	C	378	253	277	260	305	236	383	283	183	98	83	86	83
1991	C	323	208	245	249	207	361	272	598	487	72	29	35	116
1992	C	310	239	247	241	311	300	440	342	230	102	57	47	97
1993	W	219	263	300	634	399	511	608	1,249	1,923	1,388	1,016	546	281
1994	C	459	319	284	265	331	205	292	381	145	(0)	56	17	80
1995	W	264	277	267	561	336	4,219	936	2,861	5,050	4,805	1,644	421	810
1996	W	534	329	315	636	2,956	1,520	662	1,586	528	160	617	384	432
1997	W	387	974	3,439	9,859	2,091	1,013	568	904	383	120	111	115	291
1998	W	389	286	306	344	5,092	2,005	1,138	904	4,972	4,554	1,464	677	825
1999	AN	549	332	356	772	1,973	381	430	917	518	145	193	130	246
2000	AN	358	295	268	275	844	1,009	558	898	437	146	109	90	225
2001	D	356	446	342	339	341	372	363	699	223	94	110	72	120
2002	D	277	353	340	399	257	259	508	579	286	71	38	31	113
2003	BN	278	266	303	277	237	252	376	878	571	46	35	53	139

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LSJR Alternative 3 (40% Unimpaired Flow)

Table 28. LSJR Alternative 3 End-of-Month Storage at New Melones on the Stanislaus River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	951	960	990	1,015	1,098	1,167	1,134	1,242	1,366	1,273	1,175	1,097
1923	AN	1,022	1,039	1,108	1,170	1,210	1,219	1,224	1,264	1,252	1,178	1,079	1,038
1924	C	985	978	993	1,006	1,011	984	951	899	870	852	833	842
1925	BN	825	838	859	876	969	1,020	1,024	1,075	1,056	985	889	844
1926	D	790	784	788	791	838	862	889	867	843	807	779	771
1927	AN	745	765	823	870	960	1,010	1,076	1,135	1,173	1,119	1,060	1,041
1928	BN	1,005	1,040	1,067	1,084	1,126	1,230	1,212	1,230	1,158	1,050	958	913
1929	C	866	873	883	890	905	910	906	864	848	825	806	802
1930	C	785	790	804	827	856	906	885	841	846	815	786	773
1931	C	757	776	788	800	809	805	767	704	691	679	662	662
1932	AN	636	648	704	738	808	827	812	891	957	953	917	894
1933	D	847	848	869	881	891	904	882	858	856	825	795	782
1934	C	754	766	788	812	841	860	819	767	752	737	722	717
1935	AN	712	714	716	742	760	808	888	1,004	1,059	1,017	966	939
1936	AN	895	906	922	995	1,129	1,169	1,220	1,288	1,306	1,209	1,112	1,063
1937	W	1,005	1,003	1,017	1,035	1,104	1,201	1,231	1,315	1,318	1,194	1,095	1,021
1938	W	949	955	1,040	1,115	1,256	1,401	1,531	1,709	1,855	1,797	1,708	1,647
1939	D	1,590	1,587	1,600	1,619	1,635	1,652	1,562	1,442	1,361	1,276	1,202	1,171
1940	AN	1,125	1,118	1,129	1,233	1,317	1,413	1,481	1,552	1,519	1,406	1,311	1,257
1941	W	1,199	1,198	1,236	1,289	1,356	1,453	1,465	1,595	1,652	1,571	1,477	1,399
1942	W	1,332	1,331	1,379	1,470	1,538	1,524	1,605	1,711	1,792	1,740	1,642	1,577
1943	W	1,512	1,539	1,572	1,723	1,808	1,973	2,066	2,101	2,095	1,991	1,895	1,821
1944	BN	1,751	1,749	1,757	1,764	1,782	1,816	1,724	1,627	1,571	1,463	1,361	1,301
1945	AN	1,268	1,302	1,327	1,363	1,441	1,514	1,489	1,539	1,566	1,480	1,382	1,335
1946	AN	1,292	1,320	1,352	1,416	1,472	1,506	1,528	1,593	1,560	1,452	1,359	1,312
1947	D	1,255	1,271	1,291	1,306	1,326	1,325	1,273	1,198	1,159	1,093	1,037	1,014
1948	BN	992	999	1,009	1,017	1,023	1,045	1,037	1,000	1,039	969	898	862
1949	BN	824	828	842	851	860	902	867	869	876	834	798	781

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	737	730	741	792	847	902	877	946	1,017	981	940	928
1951	AN	898	1,177	1,569	1,679	1,769	1,847	1,840	1,846	1,793	1,681	1,584	1,528
1952	W	1,464	1,479	1,533	1,667	1,728	1,770	1,800	1,972	2,100	2,068	1,973	1,902
1953	BN	1,818	1,822	1,842	1,895	1,927	1,875	1,830	1,745	1,764	1,693	1,599	1,542
1954	BN	1,491	1,495	1,508	1,523	1,543	1,564	1,502	1,524	1,454	1,341	1,243	1,187
1955	D	1,131	1,140	1,158	1,188	1,209	1,231	1,218	1,138	1,114	1,048	988	955
1956	W	912	928	1,178	1,438	1,553	1,556	1,582	1,683	1,755	1,681	1,584	1,524
1957	BN	1,444	1,446	1,461	1,480	1,516	1,543	1,439	1,422	1,411	1,304	1,215	1,156
1958	W	1,094	1,099	1,106	1,156	1,213	1,294	1,449	1,624	1,719	1,651	1,555	1,485
1959	D	1,410	1,413	1,427	1,453	1,502	1,531	1,472	1,362	1,284	1,192	1,113	1,106
1960	C	1,051	1,047	1,054	1,062	1,103	1,125	1,100	1,047	1,019	972	935	904
1961	C	843	865	886	894	904	923	913	881	851	827	806	799
1962	BN	767	779	792	801	864	903	877	888	899	864	812	778
1963	AN	744	757	783	837	909	964	1,004	1,117	1,187	1,144	1,087	1,067
1964	D	1,025	1,054	1,073	1,108	1,128	1,141	1,104	1,050	1,031	980	938	907
1965	W	873	899	1,131	1,336	1,416	1,469	1,526	1,605	1,640	1,563	1,489	1,425
1966	BN	1,346	1,380	1,390	1,427	1,461	1,481	1,431	1,417	1,327	1,220	1,134	1,075
1967	W	1,020	1,031	1,112	1,215	1,274	1,311	1,394	1,487	1,652	1,693	1,606	1,548
1968	D	1,481	1,492	1,507	1,529	1,575	1,616	1,522	1,435	1,364	1,271	1,192	1,137
1969	W	1,105	1,134	1,148	1,444	1,619	1,685	1,824	1,953	2,047	1,988	1,884	1,807
1970	AN	1,753	1,763	1,812	1,970	1,970	1,997	1,949	1,934	1,908	1,788	1,681	1,628
1971	BN	1,572	1,601	1,668	1,725	1,763	1,736	1,694	1,672	1,671	1,580	1,481	1,425
1972	D	1,372	1,387	1,435	1,471	1,495	1,492	1,376	1,352	1,293	1,207	1,130	1,095
1973	AN	1,061	1,077	1,113	1,229	1,351	1,440	1,410	1,439	1,436	1,318	1,217	1,169
1974	W	1,132	1,179	1,223	1,337	1,416	1,516	1,604	1,689	1,717	1,623	1,524	1,460
1975	W	1,409	1,420	1,444	1,472	1,521	1,625	1,592	1,569	1,666	1,573	1,490	1,422
1976	C	1,360	1,376	1,396	1,405	1,418	1,401	1,336	1,256	1,185	1,128	1,087	1,059
1977	C	1,024	1,031	1,035	1,029	1,017	992	948	912	902	863	829	820
1978	W	773	768	791	870	931	1,009	1,074	1,105	1,124	1,061	969	938

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	862	875	894	961	1,050	1,134	1,140	1,177	1,125	1,014	922	879
1980	W	838	856	873	1,179	1,370	1,452	1,485	1,535	1,585	1,546	1,452	1,393
1981	D	1,338	1,337	1,358	1,405	1,417	1,460	1,426	1,342	1,251	1,160	1,090	1,061
1982	W	1,034	1,097	1,234	1,439	1,629	1,794	2,000	2,061	2,096	2,029	1,936	1,932
1983	W	1,927	1,970	1,970	1,970	1,970	2,030	2,090	2,137	2,385	2,300	2,130	2,000
1984	AN	1,970	1,970	1,970	1,970	1,970	1,990	1,930	1,919	1,871	1,776	1,692	1,651
1985	D	1,622	1,661	1,701	1,717	1,755	1,789	1,722	1,623	1,520	1,408	1,319	1,279
1986	W	1,250	1,261	1,279	1,358	1,652	1,904	1,953	1,972	1,978	1,860	1,767	1,718
1987	C	1,662	1,669	1,686	1,685	1,693	1,727	1,607	1,447	1,351	1,279	1,223	1,197
1988	C	1,148	1,138	1,136	1,142	1,151	1,141	1,091	1,021	993	964	944	922
1989	C	880	871	872	871	881	915	864	824	811	783	764	785
1990	C	786	800	825	836	852	861	822	784	765	748	751	757
1991	C	738	738	758	756	748	784	785	762	733	715	704	717
1992	C	707	705	726	737	776	805	786	741	717	696	679	673
1993	W	657	659	661	808	885	985	1,011	1,066	1,122	1,050	994	950
1994	C	895	920	957	983	1,003	994	969	925	904	875	857	852
1995	W	809	821	858	1,043	1,115	1,314	1,418	1,563	1,683	1,761	1,699	1,652
1996	W	1,600	1,605	1,643	1,721	1,816	1,935	1,958	2,045	2,033	1,914	1,833	1,772
1997	W	1,731	1,768	1,970	1,970	1,970	1,992	1,936	1,915	1,837	1,714	1,623	1,572
1998	W	1,515	1,530	1,559	1,674	1,847	1,921	1,960	2,012	2,119	2,161	2,097	2,000
1999	AN	1,967	1,970	1,970	1,970	1,970	2,002	1,991	1,950	1,926	1,831	1,753	1,716
2000	AN	1,676	1,679	1,696	1,755	1,811	1,833	1,827	1,798	1,747	1,640	1,560	1,529
2001	D	1,502	1,516	1,549	1,562	1,590	1,615	1,590	1,496	1,400	1,290	1,198	1,145
2002	D	1,082	1,086	1,126	1,172	1,188	1,228	1,193	1,130	1,069	1,010	962	944
2003	BN	908	929	985	1,039	1,068	1,089	1,078	1,018	1,002	948	904	885

Table 29. LSJR Alternative 3 Monthly Average Flow at Ripon on the Stanislaus River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	763	259	310	322	771	567	1,877	2,723	2,149	800	500	800	485
1923	AN	1,400	354	403	356	396	490	1,755	2,264	1,058	534	463	469	359
1924	C	1,200	318	262	273	238	375	460	540	256	324	352	358	113
1925	BN	800	348	304	297	1,102	758	1,705	2,250	1,123	385	413	419	414
1926	D	1,000	320	262	267	533	477	1,349	840	268	335	363	369	207
1927	AN	1,000	455	288	314	1,167	821	1,691	2,035	1,552	385	413	419	433
1928	BN	1,200	348	304	295	334	1,590	1,390	1,508	435	385	413	419	318
1929	C	1,000	302	280	295	225	283	665	1,261	651	324	352	358	186
1930	C	800	263	94	308	346	671	1,227	1,090	887	324	352	358	253
1931	C	800	248	94	275	284	410	614	588	256	324	352	358	129
1932	AN	800	248	383	330	918	718	1,294	2,363	1,897	385	413	419	432
1933	D	1,200	266	94	315	230	238	666	1,083	1,295	335	363	369	211
1934	C	1,000	263	311	316	324	648	663	443	320	324	352	358	144
1935	AN	800	302	288	348	339	430	1,999	2,328	1,580	562	413	419	401
1936	AN	1,200	260	225	344	1,433	965	1,865	2,081	1,250	534	463	469	455
1937	W	1,200	266	262	327	792	621	1,048	2,058	864	800	500	800	322
1938	W	1,400	309	336	321	1,268	1,945	1,897	3,357	2,496	800	513	800	658
1939	D	1,400	356	280	294	238	476	1,562	1,337	481	435	463	469	246
1940	AN	1,000	266	225	371	1,203	1,667	1,897	2,184	1,011	534	463	469	479
1941	W	1,200	384	368	447	778	905	1,928	2,435	1,354	800	500	800	444
1942	W	1,400	588	383	317	742	1,802	1,537	2,095	1,975	800	552	800	490
1943	W	1,400	383	268	129	850	1,750	1,826	1,768	1,338	800	551	800	452
1944	BN	1,400	381	394	418	452	468	1,860	1,676	822	515	485	474	317
1945	AN	1,000	378	385	390	1,318	608	1,403	2,086	1,489	665	525	504	411
1946	AN	1,200	329	1,071	545	487	712	1,523	1,895	864	468	489	480	329
1947	D	1,200	343	347	397	369	568	885	1,100	428	356	368	379	201
1948	BN	1,000	341	292	362	352	332	1,006	1,972	1,593	514	414	389	317

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	1,000	337	325	324	389	376	1,236	1,708	733	386	384	365	267
1950	BN	1,000	320	330	345	526	593	1,644	2,115	1,251	399	380	386	368
1951	AN	1,000	403	519	580	814	758	1,662	1,539	703	435	424	395	327
1952	W	1,200	281	223	397	737	1,641	2,146	3,668	2,377	957	696	800	638
1953	BN	1,400	434	423	504	593	1,674	1,405	2,054	1,553	688	509	513	438
1954	BN	1,005	325	316	351	317	925	1,740	1,665	593	428	418	391	316
1955	D	1,000	269	302	481	266	365	918	1,392	930	322	331	342	233
1956	W	1,000	290	357	841	709	1,720	1,681	2,247	1,659	800	542	800	484
1957	BN	1,400	294	281	341	439	751	1,745	1,818	1,264	484	463	462	361
1958	W	1,000	353	336	327	843	1,635	2,023	3,481	2,058	800	644	800	604
1959	D	1,400	360	403	434	475	523	964	815	422	356	375	393	191
1960	C	1,000	337	316	337	424	653	1,064	1,004	469	330	336	326	218
1961	C	875	305	307	333	384	324	680	731	359	229	243	247	148
1962	BN	800	282	286	294	684	476	1,756	1,574	1,335	420	386	388	348
1963	AN	1,000	343	304	353	1,556	407	980	2,536	1,376	505	426	422	408
1964	D	1,200	348	286	354	401	371	953	1,102	660	347	354	368	210
1965	W	1,000	338		449	742	541	1,744	1,683	1,371	800	530	800	363
1966	BN	1,400	325	696	386	467	610	1,279	1,008	372	340	336	335	224
1967	W	1,000	282	271	276	583	1,622	1,526	3,098	3,188	1,021	640	800	603
1968	D	1,400	260	288	380	661	577	1,842	1,429	535	393	409	406	303
1969	W	1,000	319	339	506	1,304	2,074	2,254	3,752	2,189	872	717	800	695
1970	AN	1,400	446	273	2,362	2,925	1,971	1,736	1,670	1,282	541	538	592	566
1971	BN	1,200	269	280	336	511	1,816	1,744	1,867	1,405	641	550	570	442
1972	D	1,206	248	181	349	333	954	1,755	1,485	523	401	403	400	305
1973	AN	1,000	300	306	310	922	788	1,925	2,609	1,086	540	477	538	439
1974	W	1,200	235	766	269	473	1,164	1,956	2,166	1,257	800	508	800	422
1975	W	1,400	335	444	343	511	801	1,980	2,246	1,921	800	582	800	448
1976	C	1,400	471	297	361	370	370	903	750	310	293	315	310	162

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	800	275	263	286	364	395	519	464	205	211	229	174	116
1978	W	800	213	226	343	778	1,285	1,590	2,265	1,798	800	500	800	463
1979	AN	1,400	377	320	210	778	973	1,294	2,341	892	426	425	413	377
1980	W	1,200	322	165	198	1,787	783	2,024	1,848	1,594	800	554	800	480
1981	D	1,400	385	305	371	321	501	1,034	1,007	360	413	347	378	194
1982	W	1,000	263	291	455	2,370	1,824	2,766	2,726	1,604	800	677	887	671
1983	W	1,400	1,934	3,175	4,217	5,177	6,223	1,710	3,233	4,189	3,770	2,664	3,050	1,220
1984	AN	1,538	3,453	5,126	2,177	2,262	1,912	1,808	1,926	1,277	572	626	746	550
1985	D	1,200	340	225	335	441	513	1,750	1,530	566	315	405	495	288
1986	W	1,000	383	311	311	3,832	2,016	1,793	1,789	1,269	800	500	800	629
1987	C	1,400	310	411	357	248	384	1,694	1,366	472	360	374	344	250
1988	C	858	238	270	295	243	360	847	715	268	267	251	288	146
1989	C	800	248	267	281	249	1,155	1,544	1,034	620	358	352	377	277
1990	C	800	257	248	267	282	534	890	559	339	244	262	257	156
1991	C	800	469	249	242	383	508	628	1,147	687	235	247	229	201
1992	C	800	379	239	241	501	461	830	561	296	205	208	192	159
1993	W	800	216	225	354	778	1,154	1,269	2,008	1,228	986	500	800	386
1994	C	1,400	247	232	239	261	361	648	941	251	247	221	235	148
1995	W	1,043	228	242	609	720	2,393	1,645	2,791	2,741	800	500	800	620
1996	W	1,400	270	272	343	1,919	1,843	1,542	2,034	1,105	800	500	800	506
1997	W	1,400	464	314	10,555	3,736	2,234	1,511	1,707	1,123	800	500	800	607
1998	W	1,400	257	247	324	1,801	1,903	1,708	1,996	3,035	800	500	1,636	622
1999	AN	1,400	842	1,127	1,621	3,452	1,835	1,476	2,282	1,370	439	476	478	614
2000	AN	1,200	250	241	327	1,314	1,777	1,522	1,774	1,137	455	443	435	452
2001	D	1,200	264	243	308	389	559	806	1,164	315	307	276	298	194
2002	D	1,000	220	286	314	396	614	1,324	1,300	603	307	340	328	254
2003	BN	1,000	233	262	249	396	625	1,042	2,114	1,217	344	312	292	325

Table 30. LSJR Alternative 3 End-of-Month Storage at New Don Pedro on the Tuolumne River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	1,313	1,294	1,323	1,355	1,523	1,666	1,713	1,815	2,030	1,910	1,766	1,659
1923	AN	1,594	1,573	1,655	1,690	1,690	1,690	1,713	1,689	1,675	1,591	1,452	1,397
1924	C	1,348	1,330	1,320	1,315	1,319	1,315	1,306	1,243	1,181	1,125	1,078	1,056
1925	BN	1,060	1,076	1,144	1,202	1,327	1,406	1,509	1,539	1,528	1,414	1,278	1,206
1926	D	1,163	1,151	1,157	1,163	1,233	1,316	1,373	1,354	1,270	1,152	1,062	1,016
1927	AN	987	1,026	1,076	1,127	1,256	1,349	1,418	1,446	1,519	1,425	1,284	1,208
1928	BN	1,180	1,209	1,244	1,260	1,321	1,438	1,459	1,528	1,437	1,269	1,141	1,069
1929	C	1,015	1,005	1,003	1,002	1,021	1,060	1,092	1,039	1,084	1,012	952	916
1930	C	895	883	927	962	1,016	1,065	1,049	1,033	1,064	993	936	908
1931	C	892	895	935	949	993	1,002	949	871	808	735	686	669
1932	AN	653	648	829	984	1,176	1,298	1,337	1,327	1,323	1,331	1,252	1,207
1933	D	1,162	1,140	1,145	1,146	1,183	1,215	1,235	1,234	1,175	1,097	1,023	985
1934	C	948	937	961	1,008	1,073	1,177	1,161	1,120	1,071	998	948	930
1935	AN	922	936	979	1,156	1,283	1,385	1,556	1,518	1,509	1,379	1,237	1,149
1936	AN	1,114	1,104	1,099	1,165	1,435	1,603	1,683	1,676	1,727	1,613	1,466	1,382
1937	W	1,334	1,312	1,311	1,317	1,547	1,690	1,713	1,679	1,750	1,561	1,417	1,308
1938	W	1,238	1,204	1,439	1,512	1,690	1,690	1,690	1,730	2,004	1,910	1,779	1,683
1939	D	1,642	1,619	1,635	1,649	1,689	1,690	1,657	1,607	1,478	1,327	1,214	1,182
1940	AN	1,168	1,162	1,231	1,398	1,611	1,690	1,713	1,649	1,673	1,490	1,344	1,255
1941	W	1,204	1,187	1,292	1,478	1,689	1,690	1,690	1,637	1,736	1,691	1,549	1,438
1942	W	1,370	1,335	1,420	1,581	1,690	1,690	1,713	1,765	1,939	1,910	1,767	1,661
1943	W	1,589	1,603	1,651	1,690	1,690	1,690	1,713	1,859	1,930	1,793	1,646	1,525
1944	BN	1,456	1,415	1,408	1,413	1,487	1,578	1,576	1,545	1,488	1,354	1,222	1,148
1945	AN	1,122	1,168	1,216	1,255	1,468	1,657	1,713	1,655	1,693	1,614	1,464	1,375
1946	AN	1,373	1,404	1,615	1,690	1,690	1,690	1,690	1,625	1,599	1,417	1,266	1,179
1947	D	1,133	1,149	1,182	1,207	1,248	1,267	1,243	1,288	1,233	1,136	1,060	1,024
1948	BN	1,030	1,031	1,073	1,095	1,099	1,175	1,243	1,243	1,229	1,122	1,009	949
1949	BN	919	907	907	909	932	1,115	1,127	1,121	1,088	986	906	867

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	834	828	832	876	1,025	1,166	1,210	1,146	1,160	1,049	954	913
1951	AN	911	1,325	1,690	1,690	1,690	1,690	1,713	1,573	1,502	1,337	1,202	1,119
1952	W	1,078	1,076	1,191	1,431	1,616	1,690	1,690	1,895	2,030	1,910	1,778	1,679
1953	BN	1,598	1,552	1,570	1,663	1,690	1,690	1,667	1,637	1,652	1,591	1,461	1,386
1954	BN	1,341	1,339	1,344	1,363	1,403	1,492	1,490	1,539	1,474	1,310	1,179	1,107
1955	D	1,058	1,056	1,075	1,120	1,176	1,277	1,335	1,315	1,211	1,111	1,029	993
1956	W	964	962	1,527	1,690	1,690	1,690	1,713	1,714	1,912	1,890	1,749	1,648
1957	BN	1,585	1,538	1,535	1,542	1,591	1,624	1,559	1,570	1,606	1,443	1,307	1,233
1958	W	1,212	1,202	1,220	1,255	1,394	1,636	1,690	1,910	2,030	1,910	1,775	1,680
1959	D	1,600	1,548	1,531	1,568	1,688	1,690	1,672	1,596	1,447	1,288	1,166	1,164
1960	C	1,117	1,107	1,136	1,149	1,258	1,296	1,322	1,297	1,198	1,110	1,049	1,024
1961	C	1,007	1,007	1,095	1,112	1,136	1,144	1,107	1,033	946	880	835	817
1962	BN	801	796	827	846	1,005	1,113	1,119	1,162	1,278	1,242	1,161	1,121
1963	AN	1,104	1,099	1,116	1,167	1,300	1,345	1,434	1,511	1,596	1,534	1,399	1,327
1964	D	1,300	1,347	1,363	1,393	1,420	1,429	1,433	1,404	1,343	1,234	1,151	1,110
1965	W	1,099	1,123	1,553	1,690	1,690	1,690	1,713	1,672	1,667	1,615	1,530	1,427
1966	BN	1,341	1,384	1,487	1,532	1,624	1,669	1,641	1,645	1,515	1,374	1,265	1,212
1967	W	1,173	1,205	1,361	1,474	1,559	1,690	1,690	1,880	2,030	1,910	1,790	1,686
1968	D	1,605	1,558	1,556	1,569	1,618	1,680	1,636	1,621	1,524	1,374	1,269	1,208
1969	W	1,183	1,211	1,302	1,690	1,690	1,690	1,690	1,930	2,030	1,910	1,772	1,670
1970	AN	1,648	1,637	1,690	1,690	1,690	1,690	1,674	1,663	1,606	1,460	1,327	1,249
1971	BN	1,203	1,244	1,331	1,410	1,476	1,557	1,550	1,540	1,532	1,417	1,286	1,216
1972	D	1,173	1,178	1,225	1,288	1,342	1,340	1,315	1,301	1,279	1,179	1,109	1,075
1973	AN	1,058	1,071	1,157	1,301	1,464	1,604	1,627	1,699	1,672	1,493	1,353	1,270
1974	W	1,250	1,337	1,419	1,565	1,642	1,690	1,713	1,842	1,926	1,788	1,641	1,541
1975	W	1,510	1,497	1,500	1,518	1,647	1,690	1,713	1,697	1,866	1,742	1,620	1,513
1976	C	1,496	1,488	1,507	1,495	1,493	1,465	1,447	1,345	1,271	1,192	1,153	1,143
1977	C	1,130	1,125	1,151	1,155	1,160	1,122	1,061	1,009	920	852	808	791
1978	W	777	774	832	993	1,140	1,314	1,469	1,580	1,761	1,782	1,641	1,592

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	1,494	1,477	1,477	1,579	1,690	1,690	1,690	1,717	1,702	1,534	1,393	1,315
1980	W	1,287	1,287	1,308	1,690	1,690	1,690	1,713	1,838	1,960	1,910	1,780	1,689
1981	D	1,614	1,578	1,575	1,595	1,629	1,690	1,701	1,618	1,511	1,356	1,249	1,192
1982	W	1,185	1,290	1,443	1,669	1,690	1,690	1,713	1,876	2,003	1,910	1,790	1,700
1983	W	1,660	1,690	1,690	1,690	1,690	1,295	1,264	1,271	1,696	1,910	1,790	1,700
1984	AN	1,660	1,690	1,690	1,690	1,690	1,690	1,635	1,563	1,536	1,392	1,248	1,163
1985	D	1,144	1,176	1,221	1,224	1,268	1,347	1,323	1,352	1,281	1,160	1,076	1,038
1986	W	1,029	1,050	1,127	1,207	1,547	1,690	1,713	1,884	2,001	1,867	1,723	1,635
1987	C	1,589	1,566	1,552	1,533	1,539	1,585	1,542	1,454	1,372	1,272	1,201	1,166
1988	C	1,156	1,155	1,198	1,267	1,327	1,326	1,286	1,212	1,162	1,093	1,045	1,024
1989	C	1,008	1,016	1,051	1,090	1,125	1,170	1,149	1,190	1,171	1,051	965	961
1990	C	988	985	1,012	1,029	1,070	1,074	1,020	1,013	981	911	860	842
1991	C	831	827	855	863	859	906	913	894	937	887	849	831
1992	C	834	833	863	882	949	994	987	1,024	972	937	881	847
1993	W	832	826	873	1,095	1,233	1,414	1,505	1,738	1,860	1,784	1,635	1,523
1994	C	1,444	1,392	1,383	1,385	1,404	1,408	1,374	1,341	1,282	1,193	1,133	1,105
1995	W	1,084	1,104	1,151	1,424	1,499	1,690	1,713	1,630	1,974	1,910	1,790	1,688
1996	W	1,606	1,547	1,574	1,654	1,690	1,690	1,713	1,974	2,030	1,876	1,727	1,622
1997	W	1,561	1,572	1,690	1,690	1,690	1,690	1,634	1,783	1,791	1,598	1,456	1,372
1998	W	1,295	1,246	1,248	1,422	1,690	1,690	1,713	1,714	1,988	1,910	1,784	1,678
1999	AN	1,638	1,619	1,660	1,690	1,690	1,690	1,718	1,647	1,699	1,558	1,423	1,349
2000	AN	1,287	1,273	1,262	1,351	1,534	1,674	1,701	1,842	1,850	1,671	1,532	1,456
2001	D	1,442	1,426	1,419	1,424	1,455	1,537	1,541	1,568	1,437	1,292	1,184	1,132
2002	D	1,098	1,108	1,184	1,253	1,297	1,330	1,288	1,363	1,331	1,202	1,106	1,054
2003	BN	1,023	1,059	1,118	1,197	1,240	1,266	1,295	1,268	1,301	1,172	1,077	1,026

Table 31. LSJR Alternative 3 Monthly Average Flow at Modesto on the Tuolumne River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	724	599	597	603	1,195	1,033	3,189	4,099	5,583	1,760	600	1,000	904
1923	AN	1,000	1,000	620	1,599	2,125	1,459	3,252	3,389	2,144	600	586	597	737
1924	C	737	605	580	579	601	597	934	1,360	366	356	362	366	232
1925	BN	428	442	440	427	1,635	1,080	2,353	3,500	2,366	405	410	421	653
1926	D	552	500	476	464	727	833	2,568	1,978	598	404	410	418	402
1927	AN	484	449	452	456	1,606	1,041	2,366	2,953	3,200	581	588	595	666
1928	BN	733	615	613	601	611	2,231	1,775	2,914	1,028	403	408	423	518
1929	C	552	495	477	468	498	644	995	2,459	1,512	358	361	376	368
1930	C	439	466	438	436	504	956	1,654	1,789	1,923	369	371	381	410
1931	C	462	453	449	437	465	448	1,035	1,360	368	359	364	367	221
1932	AN	429	437	430	427	1,669	1,119	1,647	3,409	3,583	602	588	591	686
1933	D	741	630	591	582	612	604	1,149	1,633	2,864	409	413	427	410
1934	C	544	501	481	464	648	976	1,250	969	639	356	361	366	268
1935	AN	438	445	437	436	771	891	3,126	3,454	3,435	587	585	600	700
1936	AN	736	609	597	593	2,448	1,347	2,642	3,383	2,622	590	585	595	745
1937	W	735	621	600	590	1,696	2,360	3,656	3,544	2,305	1,200	600	1,000	812
1938	W	1,000	1,000	611	603	4,080	7,992	5,665	5,398	4,346	3,198	600	1,000	1,646
1939	D	1,000	1,000	602	593	625	1,914	1,896	1,405	497	409	417	420	381
1940	AN	487	470	440	434	1,738	4,685	4,070	3,715	2,339	650	534	541	998
1941	W	645	526	755	683	1,380	5,090	4,622	3,774	3,147	1,200	638	1,000	1,084
1942	W	1,000	1,000	641	849	1,636	2,886	4,310	4,330	3,679	1,710	755	1,000	1,010
1943	W	1,000	1,000	626	3,223	3,424	6,406	3,999	2,708	1,995	1,200	600	1,000	1,107
1944	BN	1,000	1,000	626	650	752	878	1,169	2,966	1,795	439	425	372	456
1945	AN	529	453	389	529	2,197	1,073	2,039	2,960	3,106	713	654	585	676
1946	AN	684	466	656	1,679	3,189	3,405	2,339	3,175	1,781	662	620	593	827
1947	D	663	576	675	615	609	885	1,291	2,290	746	322	347	333	350
1948	BN	480	454	398	393	412	475	1,486	2,836	2,917	514	427	357	489

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	530	463	407	514	480	800	2,138	2,843	1,613	379	379	356	474
1950	BN	530	475	463	686	893	833	2,212	3,044	2,144	420	399	380	547
1951	AN	513	206	2,166	3,984	3,930	3,091	1,747	2,426	1,728	622	594	558	764
1952	W	645	525	600	971	911	2,796	4,806	5,055	3,986	3,580	637	1,000	1,058
1953	BN	1,000	1,000	517	639	963	1,443	1,815	1,685	2,783	544	453	413	519
1954	BN	465	400	391	397	735	1,386	2,346	2,914	1,244	398	399	382	519
1955	D	473	385	420	702	439	540	968	2,387	1,963	363	373	354	379
1956	W	400	372	441	4,963	4,392	3,560	2,423	3,136	3,367	1,200	701	1,000	1,009
1957	BN	1,000	1,000	491	518	893	1,002	1,163	2,472	2,722	424	428	418	494
1958	W	489	380	432	561	1,147	1,504	5,471	4,863	4,664	2,571	692	1,000	1,058
1959	D	1,000	1,000	581	624	835	2,050	1,506	1,509	934	374	353	372	410
1960	C	466	364	307	362	828	969	1,600	1,978	1,096	301	315	334	389
1961	C	315	330	282	337	346	462	1,109	1,431	820	261	276	248	250
1962	BN	303	314	323	314	1,678	904	2,615	2,355	2,998	383	416	421	628
1963	AN	466	273	315	425	2,226	729	1,667	3,474	3,112	552	520	525	666
1964	D	548	381	400	518	485	526	1,136	2,101	1,512	281	288	293	347
1965	W	343	266	234	3,616	3,761	3,400	3,514	2,304	2,524	1,200	600	1,000	919
1966	BN	1,000	1,000	435	555	549	950	2,010	2,309	578	271	262	255	385
1967	W	394	267	318	582	719	2,065	4,636	3,885	6,079	6,352	653	1,000	1,043
1968	D	1,000	1,000	485	515	932	800	1,257	1,874	948	375	358	342	349
1969	W	401	367	288	2,481	5,652	4,123	5,386	6,786	7,110	3,661	600	1,000	1,728
1970	AN	1,000	1,000	679	6,185	2,753	3,267	1,349	2,674	2,259	457	380	438	733
1971	BN	676	503	532	524	677	950	1,304	2,270	2,810	358	370	371	480
1972	D	520	322	524	367	542	1,184	1,049	2,238	1,479	301	306	297	392
1973	AN	317	451	522	524	1,340	1,125	1,741	4,261	2,689	509	529	525	669
1974	W	560	540	688	639	542	3,185	2,891	3,269	2,661	1,200	600	1,000	757
1975	W	1,070	1,088	789	642	944	3,125	2,672	3,238	3,426	1,200	600	1,000	807
1976	C	1,000	1,000	584	543	509	604	672	1,360	283	270	295	290	207

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	289	307	322	295	308	338	531	690	706	195	187	166	154
1978	W	222	243	251	432	1,178	1,797	1,985	3,514	4,876	1,200	600	1,000	800
1979	AN	1,000	1,000	611	1,015	1,823	4,445	2,260	5,734	2,117	573	645	529	988
1980	W	612	813	877	1,275	6,927	3,963	2,720	2,892	3,808	3,352	600	1,000	1,208
1981	D	1,000	1,000	519	692	579	1,185	1,633	2,134	1,015	346	368	354	394
1982	W	441	421	600	541	6,494	5,797	9,332	6,347	4,430	3,527	712	2,296	1,926
1983	W	3,090	3,106	5,342	5,471	6,892	16,297	5,182	7,861	6,531	3,607	2,996	1,991	2,565
1984	AN	1,157	5,440	7,479	4,359	3,576	3,478	1,602	3,487	2,218	583	617	612	861
1985	D	743	974	430	489	609	820	2,030	2,218	907	366	387	372	395
1986	W	337	363	356	284	4,164	5,902	3,157	3,297	3,199	1,200	600	1,000	1,175
1987	C	1,171	1,300	566	596	523	711	1,304	1,321	437	282	285	266	258
1988	C	244	259	254	305	396	683	1,069	1,386	659	200	210	190	253
1989	C	199	220	245	244	439	1,854	2,077	2,088	1,391	213	223	220	473
1990	C	215	245	232	236	382	846	1,479	1,184	672	225	241	225	274
1991	C	216	239	223	208	235	1,093	1,210	2,186	1,983	208	221	201	405
1992	C	212	239	217	224	647	748	1,546	1,229	436	194	195	188	277
1993	W	216	208	217	781	934	1,671	1,813	3,305	2,836	1,200	600	1,000	634
1994	C	1,000	1,000	413	399	490	703	1,311	1,789	800	213	221	199	306
1995	W	233	218	223	518	1,029	6,449	4,890	9,474	4,866	8,047	1,918	1,000	1,617
1996	W	1,000	1,000	430	538	5,498	5,065	3,122	3,090	2,181	1,200	600	1,000	1,133
1997	W	1,000	1,000	4,381	17,925	3,886	3,498	1,458	2,761	1,769	1,200	600	1,000	793
1998	W	1,000	1,000	431	899	2,617	5,276	4,091	5,533	6,614	6,585	600	1,000	1,447
1999	AN	1,000	1,000	289	1,709	5,167	3,981	2,223	3,702	2,931	523	521	519	1,066
2000	AN	596	442	344	433	1,926	1,646	2,245	3,506	2,165	513	711	734	690
2001	D	692	465	418	518	432	1,164	1,526	2,654	370	318	334	313	372
2002	D	327	243	383	427	569	917	2,023	2,420	1,499	304	346	309	446
2003	BN	320	247	294	264	468	807	1,465	3,383	2,501	253	303	282	520

Table 32. LSJR Alternative 3 End-of-Month Storage at New Exchequer on the Merced River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	469	457	482	505	644	735	763	870	999	910	770	694
1923	AN	638	613	652	675	675	671	718	795	799	728	624	573
1924	C	543	535	526	521	513	499	509	520	486	453	424	405
1925	BN	383	389	395	401	481	505	561	642	613	530	440	391
1926	D	360	351	347	340	376	383	427	385	384	386	368	339
1927	AN	310	298	304	293	288	301	275	345	345	318	296	305
1928	BN	311	306	318	332	344	304	274	311	314	313	315	330
1929	C	309	296	283	272	273	273	278	248	241	281	317	304
1930	C	276	263	250	238	228	189	188	182	189	242	288	299
1931	C	274	266	256	251	256	253	269	290	268	238	213	194
1932	AN	168	157	219	253	376	411	427	498	544	486	394	340
1933	D	300	286	276	275	274	282	299	330	395	369	326	302
1934	C	274	262	264	281	313	342	369	372	360	329	304	286
1935	AN	262	267	275	340	377	434	586	673	712	620	513	452
1936	AN	420	412	403	426	593	649	720	790	773	683	577	516
1937	W	493	482	485	492	667	735	803	943	967	851	726	647
1938	W	587	555	675	675	675	735	845	970	1,024	910	770	694
1939	D	654	631	632	630	637	661	699	697	644	569	498	467
1940	AN	448	437	427	538	635	719	796	883	859	746	636	573
1941	W	533	520	594	646	675	735	842	970	1,024	910	770	690
1942	W	645	621	675	675	675	723	804	906	1,024	910	770	693
1943	W	635	634	655	675	675	735	825	916	924	823	704	627
1944	BN	568	537	528	532	563	597	589	643	640	570	483	435
1945	AN	398	416	431	440	565	624	657	726	730	654	555	493
1946	AN	475	499	584	616	628	660	680	753	720	623	523	468
1947	D	441	459	490	501	525	542	560	600	568	508	448	414
1948	BN	392	387	378	374	364	350	377	451	503	447	375	334
1949	BN	302	288	280	274	279	313	357	438	445	391	335	302

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	268	257	247	269	311	327	387	450	469	410	345	307
1951	AN	281	522	675	675	675	720	749	767	739	646	546	489
1952	W	453	446	488	635	675	735	845	970	1,024	910	770	696
1953	BN	631	597	609	660	672	664	679	673	681	621	535	486
1954	BN	447	435	425	428	458	500	557	619	590	512	427	382
1955	D	342	329	330	342	349	345	351	427	454	411	357	325
1956	W	291	278	646	675	675	725	792	919	1,024	910	770	700
1957	BN	649	622	615	612	635	629	619	668	689	608	521	469
1958	W	444	436	441	458	529	662	845	970	1,024	910	770	699
1959	D	638	597	584	589	628	632	661	665	624	546	474	462
1960	C	431	416	402	395	434	451	492	531	512	452	395	362
1961	C	331	322	320	312	314	314	343	377	375	341	311	291
1962	BN	264	251	245	239	357	395	474	509	536	473	384	328
1963	AN	295	279	268	293	399	420	456	528	559	498	407	354
1964	D	330	350	354	358	355	346	366	417	429	397	356	330
1965	W	306	309	517	584	626	644	702	774	832	778	694	630
1966	BN	576	604	627	650	666	685	718	750	695	605	524	483
1967	W	447	444	540	583	620	720	845	970	1,024	910	770	700
1968	D	654	619	615	616	646	651	666	685	653	574	508	471
1969	W	443	450	472	675	675	735	845	970	1,024	910	770	700
1970	AN	660	632	653	675	675	735	731	767	737	638	539	485
1971	BN	449	452	486	519	541	546	545	592	613	549	470	424
1972	D	388	380	402	416	435	445	455	505	509	448	391	371
1973	AN	352	348	365	417	527	611	653	788	801	705	613	560
1974	W	541	587	635	675	675	735	797	929	964	863	753	683
1975	W	639	609	608	619	675	735	753	867	989	905	770	696
1976	C	675	655	653	642	642	625	627	635	592	532	487	467
1977	C	440	421	406	393	375	347	341	337	331	300	271	249
1978	W	220	203	220	316	448	596	751	921	1,024	910	770	700

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	642	627	621	675	675	735	777	880	857	758	657	596
1980	W	565	556	554	675	675	735	792	892	981	910	770	693
1981	D	639	592	580	582	590	608	631	663	629	552	484	445
1982	W	422	450	496	611	675	735	845	970	1,024	910	770	700
1983	W	675	675	675	675	675	735	819	970	1,024	910	770	700
1984	AN	640	675	675	675	675	716	716	779	741	657	564	513
1985	D	490	496	500	504	521	539	577	617	586	514	448	413
1986	W	387	384	399	426	675	735	832	953	1,012	910	770	700
1987	C	642	598	583	573	576	581	602	613	579	518	466	436
1988	C	408	405	400	410	415	423	449	471	457	417	377	352
1989	C	323	312	309	303	311	356	403	429	408	360	319	301
1990	C	286	281	272	271	276	288	325	344	328	299	269	250
1991	C	225	211	195	181	166	219	242	304	348	337	313	298
1992	C	277	271	264	261	302	322	371	390	358	342	313	296
1993	W	276	266	269	440	518	624	705	888	978	910	770	700
1994	C	674	643	633	626	637	633	636	651	622	555	498	467
1995	W	454	458	465	651	675	735	838	970	1,024	910	770	689
1996	W	627	584	593	643	675	735	820	953	949	845	727	653
1997	W	608	627	675	675	675	735	772	861	832	718	606	539
1998	W	482	457	455	539	675	735	845	950	1,024	910	770	700
1999	AN	654	626	638	672	675	682	684	760	747	644	546	490
2000	AN	445	436	423	462	574	652	699	784	750	632	521	461
2001	D	441	430	423	419	432	476	505	569	525	457	395	371
2002	D	343	337	368	394	411	427	467	526	514	448	389	359
2003	BN	328	342	358	382	399	413	425	520	533	460	394	353

Table 33. LSJR Alternative 3 Monthly Average Flow at Stevinson on the Merced River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	356	318	436	432	880	589	625	2,035	2,017	876	799	466	367
1923	AN	682	676	470	853	963	328	955	1,685	937	200	200	200	290
1924	C	385	335	332	346	352	304	450	592	87	11	19	82	107
1925	BN	351	369	375	378	763	501	1,210	1,698	988	87	60	53	308
1926	D	299	304	325	325	454	358	1,459	1,125	323	(0)	(0)	101	222
1927	AN	338	272	263	331	930	533	1,134	1,814	1,432	200	200	200	349
1928	BN	420	302	339	311	452	1,034	955	1,340	457	150	83	49	256
1929	C	364	347	337	358	385	342	524	1,256	652	2	31	89	190
1930	C	350	322	309	311	325	475	793	891	753	(0)	(0)	92	194
1931	C	345	335	322	332	358	318	497	598	134	25	1	119	114
1932	AN	350	313	425	419	982	477	818	1,680	1,567	200	200	200	331
1933	D	401	336	333	376	321	356	592	865	1,203	17	(0)	72	200
1934	C	386	333	355	416	419	423	618	364	222	53	(0)	48	122
1935	AN	358	339	359	530	378	540	1,785	2,022	1,674	200	200	200	384
1936	AN	450	360	335	378	1,660	611	1,384	1,828	1,030	200	200	200	389
1937	W	415	374	367	366	1,221	1,021	822	1,952	968	498	494	504	357
1938	W	727	709	398	1,288	4,875	4,657	1,416	3,169	4,447	2,143	1,096	600	1,101
1939	D	800	800	333	393	482	474	1,015	657	215	80	88	122	170
1940	AN	426	374	368	523	901	924	1,174	1,904	903	200	200	200	349
1941	W	430	377	435	424	2,559	1,751	797	2,909	2,272	1,662	1,012	580	611
1942	W	786	782	477	1,474	1,666	520	933	1,381	1,816	1,547	952	524	373
1943	W	748	732	378	1,801	1,917	3,022	1,104	1,425	766	520	510	515	491
1944	BN	733	724	386	364	451	527	538	1,626	894	148	146	122	244
1945	AN	438	439	396	391	1,302	722	1,030	1,688	1,361	200	200	200	363
1946	AN	458	400	420	491	551	511	1,243	1,633	734	200	200	200	280
1947	D	473	384	403	392	385	403	699	1,119	343	77	101	150	177
1948	BN	398	347	348	338	337	335	719	1,535	1,459	153	97	101	264

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	430	354	336	352	371	507	955	1,542	753	92	118	135	248
1950	BN	414	344	344	378	439	399	1,156	1,516	840	133	127	169	261
1951	AN	402	352	1,919	1,686	1,594	531	829	1,086	663	200	200	200	277
1952	W	428	367	410	619	584	1,811	1,164	3,524	2,992	1,841	1,164	600	609
1953	BN	800	800	284	353	452	377	807	794	1,062	111	123	143	208
1954	BN	445	355	353	356	392	644	1,143	1,451	497	138	128	174	248
1955	D	402	342	359	487	392	359	437	1,262	921	101	120	158	202
1956	W	410	336	83	3,859	1,938	485	776	1,556	1,447	1,844	1,084	518	369
1957	BN	724	711	359	361	384	410	592	1,301	1,183	166	151	174	232
1958	W	462	331	355	431	671	815	1,653	3,409	2,665	1,649	1,080	600	554
1959	D	800	800	332	345	403	363	793	729	343	137	148	158	157
1960	C	400	324	333	347	411	397	840	956	430	132	159	130	182
1961	C	367	315	337	322	348	339	565	618	296	94	56	99	129
1962	BN	344	291	309	310	1,145	925	1,331	1,340	1,378	224	179	177	364
1963	AN	429	312	326	326	1,244	476	879	1,740	1,409	248	200	205	342
1964	D	438	347	348	354	334	348	511	911	544	144	120	164	159
1965	W	389	306	478	1,730	447	362	832	1,264	1,220	455	452	442	247
1966	BN	665	548	380	623	391	423	1,069	1,184	316	237	197	173	203
1967	W	392	316	350	358	374	900	1,403	2,525	4,079	3,989	1,448	715	558
1968	D	800	800	280	332	340	379	632	787	336	227	209	230	149
1969	W	378	381	384	2,985	4,149	1,416	2,010	5,379	4,045	2,323	1,159	613	1,009
1970	AN	800	800	196	2,529	1,211	779	598	1,418	854	227	219	203	289
1971	BN	468	325	309	375	334	384	659	1,190	1,210	227	186	171	227
1972	D	461	336	373	144	338	533	538	1,086	645	221	229	(0)	189
1973	AN	394	362	382	424	897	745	877	2,468	1,346	204	200	200	380
1974	W	457	166	249	999	817	978	812	1,591	1,023	497	489	489	312
1975	W	698	656	359	257	1,165	933	494	1,522	1,664	546	895	498	344
1976	C	781	709	312	342	337	326	329	605	234	205	232	221	110

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	450	271	300	323	304	281	208	254	309	137	109	128	81
1978	W	370	243	300	466	799	917	1,180	1,844	3,140	2,543	1,252	1,275	471
1979	AN	763	786	391	897	1,879	1,366	876	2,209	1,029	233	200	200	438
1980	W	519	324	342	2,338	4,472	1,352	905	1,457	1,521	1,456	1,157	600	574
1981	D	800	800	394	429	405	486	820	1,034	464	199	200	193	192
1982	W	465	355	364	434	2,480	2,184	4,845	3,215	1,838	2,158	1,331	1,073	867
1983	W	1,088	1,910	2,243	3,604	4,363	5,959	1,300	2,783	7,273	5,863	2,392	1,008	1,290
1984	AN	1,276	1,599	3,495	1,850	1,543	631	867	1,724	766	262	275	260	331
1985	D	591	288	284	396	393	384	988	1,112	383	267	237	198	195
1986	W	500	345	358	330	2,165	4,031	1,035	1,658	1,236	636	1,038	639	605
1987	C	800	800	368	331	330	399	639	618	168	161	167	185	129
1988	C	420	290	325	327	283	312	625	696	370	128	124	133	137
1989	C	342	224	272	254	260	625	1,076	859	491	90	71	117	199
1990	C	378	253	277	260	305	364	766	566	323	98	83	86	139
1991	C	323	208	245	249	207	625	544	1,197	975	72	29	35	214
1992	C	310	239	247	241	376	332	881	683	273	102	57	47	153
1993	W	219	263	300	634	540	766	913	1,874	1,412	643	1,016	546	331
1994	C	471	602	284	265	331	260	585	761	289	(0)	56	17	133
1995	W	264	277	267	561	911	4,768	1,055	2,747	5,050	4,805	1,644	600	876
1996	W	800	800	315	261	2,398	1,520	993	1,547	792	479	465	459	433
1997	W	686	670	2,672	9,859	2,091	1,013	852	1,356	575	379	375	377	347
1998	W	611	564	306	344	2,703	2,005	1,138	1,236	4,631	4,554	1,464	677	693
1999	AN	800	800	246	217	1,929	424	837	1,785	1,007	200	200	200	353
2000	AN	358	295	268	275	1,136	721	1,066	1,715	835	200	200	200	328
2001	D	356	446	342	339	341	559	726	1,399	223	94	110	72	196
2002	D	277	353	340	399	257	384	1,015	1,158	571	71	38	31	203
2003	BN	278	266	303	277	245	403	753	1,756	1,143	46	35	53	259

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LSJR Alternative 4 (60% Unimpaired Flow)

Table 34. LSJR Alternative 4 End-of-Month Storage at New Melones on the Stanislaus River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	951	960	990	1,015	1,077	1,128	1,098	1,117	1,181	1,105	1,021	951
1923	AN	881	901	974	1,039	1,071	1,073	1,072	1,070	1,065	1,034	970	950
1924	C	908	909	930	949	957	932	889	826	802	790	775	787
1925	BN	770	784	805	823	885	920	888	901	902	891	843	826
1926	D	788	791	802	810	848	861	853	821	807	789	777	779
1927	AN	757	779	836	884	942	972	1,003	1,034	1,070	1,068	1,050	1,057
1928	BN	1,029	1,070	1,102	1,124	1,160	1,220	1,179	1,183	1,140	1,077	1,022	1,000
1929	C	964	976	991	1,002	1,019	1,017	1,000	930	903	891	882	884
1930	C	870	876	890	914	933	966	925	868	869	860	848	844
1931	C	833	853	866	878	889	888	836	758	750	743	730	733
1932	AN	709	721	777	810	854	857	824	859	905	942	941	941
1933	D	905	912	934	947	958	968	942	900	877	866	852	849
1934	C	826	841	863	887	908	907	851	790	774	764	753	752
1935	AN	748	750	752	778	787	823	848	918	960	959	941	934
1936	AN	897	913	931	1,007	1,102	1,117	1,115	1,134	1,138	1,070	995	959
1937	W	909	913	932	955	1,006	1,084	1,087	1,112	1,116	1,029	959	903
1938	W	840	853	945	1,025	1,135	1,263	1,332	1,400	1,467	1,411	1,323	1,263
1939	D	1,207	1,204	1,217	1,236	1,253	1,263	1,203	1,147	1,123	1,097	1,073	1,068
1940	AN	1,037	1,037	1,049	1,156	1,208	1,255	1,288	1,301	1,256	1,164	1,085	1,040
1941	W	987	990	1,033	1,089	1,137	1,202	1,215	1,259	1,271	1,189	1,096	1,020
1942	W	954	953	1,001	1,092	1,140	1,179	1,213	1,252	1,272	1,192	1,099	1,035
1943	W	972	998	1,032	1,184	1,246	1,353	1,388	1,380	1,351	1,250	1,161	1,089
1944	BN	1,019	1,018	1,026	1,035	1,053	1,091	1,080	1,003	1,003	984	956	942
1945	AN	924	967	1,000	1,043	1,090	1,150	1,097	1,102	1,114	1,062	994	965
1946	AN	931	966	1,005	1,074	1,133	1,151	1,139	1,168	1,144	1,078	1,018	992
1947	D	945	968	995	1,015	1,034	1,039	1,007	944	942	929	918	923
1948	BN	907	916	927	937	947	974	955	886	923	902	872	863
1949	BN	835	846	862	874	888	922	872	842	852	838	826	824

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	787	783	795	847	888	925	852	858	897	868	833	824
1951	AN	795	1,076	1,468	1,579	1,647	1,700	1,693	1,675	1,600	1,489	1,392	1,337
1952	W	1,274	1,289	1,343	1,477	1,517	1,567	1,532	1,590	1,647	1,624	1,536	1,467
1953	BN	1,384	1,394	1,420	1,481	1,520	1,533	1,452	1,394	1,392	1,351	1,282	1,240
1954	BN	1,197	1,207	1,225	1,245	1,261	1,267	1,186	1,207	1,178	1,133	1,092	1,071
1955	D	1,032	1,049	1,074	1,111	1,130	1,152	1,150	1,058	1,044	1,019	994	981
1956	W	950	967	1,217	1,477	1,573	1,576	1,590	1,612	1,627	1,505	1,408	1,349
1957	BN	1,270	1,272	1,287	1,305	1,329	1,345	1,268	1,232	1,236	1,188	1,146	1,115
1958	W	1,065	1,079	1,093	1,148	1,187	1,268	1,381	1,442	1,473	1,402	1,307	1,238
1959	D	1,163	1,167	1,181	1,207	1,243	1,266	1,218	1,143	1,108	1,078	1,050	1,062
1960	C	1,023	1,029	1,040	1,053	1,085	1,098	1,064	1,010	1,000	985	975	961
1961	C	909	932	954	963	977	991	969	923	894	881	870	870
1962	BN	842	853	866	876	920	948	887	879	880	879	855	839
1963	AN	812	828	854	910	939	982	987	999	1,011	955	884	855
1964	D	814	846	868	904	924	946	927	873	867	857	850	843
1965	W	814	841	1,074	1,279	1,339	1,373	1,406	1,427	1,413	1,337	1,264	1,201
1966	BN	1,122	1,156	1,166	1,204	1,237	1,249	1,188	1,190	1,155	1,111	1,075	1,048
1967	W	1,010	1,026	1,113	1,221	1,269	1,290	1,361	1,356	1,423	1,464	1,378	1,321
1968	D	1,254	1,266	1,280	1,303	1,330	1,358	1,317	1,263	1,226	1,181	1,141	1,112
1969	W	1,089	1,121	1,139	1,436	1,576	1,642	1,712	1,723	1,750	1,693	1,589	1,513
1970	AN	1,460	1,470	1,519	1,790	1,882	1,909	1,861	1,800	1,750	1,630	1,524	1,471
1971	BN	1,416	1,445	1,512	1,569	1,593	1,615	1,566	1,523	1,490	1,416	1,329	1,283
1972	D	1,234	1,252	1,303	1,341	1,360	1,345	1,293	1,261	1,225	1,181	1,140	1,128
1973	AN	1,101	1,118	1,156	1,273	1,370	1,437	1,404	1,363	1,348	1,255	1,173	1,136
1974	W	1,105	1,157	1,207	1,303	1,374	1,434	1,501	1,511	1,498	1,405	1,307	1,244
1975	W	1,193	1,204	1,229	1,256	1,292	1,370	1,340	1,248	1,295	1,220	1,151	1,092
1976	C	1,035	1,055	1,078	1,090	1,107	1,110	1,084	1,031	999	984	974	968
1977	C	943	951	956	952	943	921	882	850	839	806	776	770
1978	W	725	720	743	822	862	906	940	960	1,003	1,026	1,003	1,009

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	956	978	1,005	1,079	1,151	1,210	1,190	1,181	1,141	1,075	1,018	996
1980	W	965	989	1,011	1,321	1,465	1,490	1,530	1,513	1,507	1,403	1,307	1,248
1981	D	1,194	1,192	1,213	1,261	1,266	1,297	1,259	1,188	1,136	1,099	1,074	1,073
1982	W	1,054	1,121	1,260	1,467	1,591	1,722	1,841	1,815	1,800	1,734	1,643	1,639
1983	W	1,635	1,766	1,925	1,970	1,970	2,030	2,065	2,011	2,133	2,232	2,130	2,000
1984	AN	1,970	1,970	1,970	1,970	1,970	1,990	1,930	1,861	1,801	1,706	1,623	1,582
1985	D	1,553	1,592	1,632	1,648	1,682	1,707	1,634	1,553	1,487	1,416	1,359	1,338
1986	W	1,319	1,337	1,361	1,446	1,638	1,819	1,835	1,800	1,763	1,646	1,553	1,505
1987	C	1,450	1,457	1,474	1,473	1,477	1,502	1,443	1,340	1,282	1,243	1,215	1,208
1988	C	1,168	1,160	1,158	1,166	1,168	1,151	1,110	1,052	1,031	1,019	1,013	1,000
1989	C	962	954	955	955	962	964	887	839	832	831	835	863
1990	C	869	884	910	922	939	933	871	820	795	784	791	800
1991	C	781	782	802	801	793	813	798	743	699	686	681	697
1992	C	688	687	708	719	744	757	714	656	642	627	615	613
1993	W	599	601	603	750	806	864	861	876	936	917	911	897
1994	C	857	887	929	959	980	961	918	845	823	800	787	785
1995	W	743	756	793	978	1,030	1,151	1,218	1,308	1,396	1,541	1,536	1,524
1996	W	1,491	1,506	1,548	1,630	1,672	1,791	1,770	1,781	1,743	1,626	1,546	1,485
1997	W	1,445	1,483	1,690	1,970	1,970	1,992	1,936	1,904	1,827	1,703	1,613	1,562
1998	W	1,504	1,520	1,549	1,663	1,786	1,850	1,855	1,842	1,847	1,889	1,826	1,780
1999	AN	1,747	1,757	1,785	1,860	1,933	1,965	1,942	1,828	1,761	1,666	1,589	1,552
2000	AN	1,513	1,516	1,533	1,592	1,610	1,652	1,612	1,531	1,483	1,390	1,321	1,297
2001	D	1,273	1,289	1,325	1,339	1,369	1,381	1,352	1,271	1,237	1,195	1,158	1,139
2002	D	1,093	1,103	1,149	1,199	1,210	1,235	1,183	1,111	1,066	1,044	1,028	1,031
2003	BN	1,005	1,028	1,085	1,139	1,159	1,167	1,142	1,049	1,030	1,012	998	998

Table 35. LSJR Alternative 4 Monthly Average Flow at Ripon on the Stanislaus River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	763	259	310	322	1,156	902	1,877	4,333	3,419	800	500	800	701
1923	AN	1,400	354	403	356	594	727	2,019	3,361	1,571	484	413	419	498
1924	C	1,200	318	262	267	282	375	695	817	256	324	352	358	146
1925	BN	800	348	304	297	1,653	1,149	2,582	3,408	1,701	385	413	419	627
1926	D	1,000	320	262	267	799	734	2,075	1,292	394	335	363	369	316
1927	AN	1,000	455	288	314	1,750	1,257	2,588	3,115	2,375	385	413	419	661
1928	BN	1,200	348	304	295	501	2,413	2,109	2,289	660	385	413	419	483
1929	C	1,000	302	280	295	248	426	1,001	1,898	981	324	352	358	275
1930	C	800	263	94	308	519	1,015	1,855	1,649	1,341	374	402	408	383
1931	C	820	248	94	281	263	376	927	887	256	324	352	358	163
1932	AN	800	248	383	330	1,377	1,099	1,980	3,616	2,902	385	413	419	660
1933	D	1,200	266	94	315	230	358	1,033	1,679	2,008	385	413	419	319
1934	C	1,000	263	311	322	486	976	999	667	420	324	352	358	212
1935	AN	800	302	288	348	508	658	3,058	3,560	2,417	562	413	419	613
1936	AN	1,200	260	225	344	2,149	1,466	2,833	3,161	1,899	534	463	469	690
1937	W	1,200	266	262	327	1,188	1,024	1,639	3,395	1,425	800	500	800	520
1938	W	1,400	309	336	321	1,901	2,230	2,919	5,166	3,840	800	513	800	963
1939	D	1,400	356	280	294	238	691	1,728	1,028	425	385	413	419	247
1940	AN	1,000	266	225	364	1,805	2,525	2,540	3,310	1,532	534	463	469	705
1941	W	1,200	384	368	447	1,167	1,429	1,928	3,843	2,137	830	500	800	631
1942	W	1,400	588	383	317	1,113	951	2,330	3,205	3,022	1,298	502	800	636
1943	W	1,400	383	268	122	1,275	2,702	2,819	2,479	1,760	800	501	800	662
1944	BN	1,400	381	394	411	445	653	1,073	2,453	1,204	465	435	424	352
1945	AN	1,000	378	385	384	1,977	908	2,011	3,115	2,224	665	475	454	609
1946	AN	1,200	329	1,071	539	529	1,066	2,280	2,837	1,293	418	439	430	482
1947	D	1,200	343	347	391	486	874	1,307	1,692	596	356	368	379	298
1948	BN	1,000	341	292	362	352	361	1,530	3,000	2,423	514	414	389	462

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	1,000	337	325	324	389	575	1,888	2,609	1,119	386	384	365	396
1950	BN	1,000	320	330	345	789	902	2,501	3,218	1,903	399	380	386	559
1951	AN	1,000	403	519	580	1,221	1,171	1,668	1,928	1,087	435	424	395	422
1952	W	1,200	281	223	397	1,106	1,514	3,234	5,529	3,583	852	596	800	902
1953	BN	1,400	334	323	378	465	711	2,102	1,869	2,323	638	459	463	448
1954	BN	1,000	325	316	345	475	1,370	2,578	2,466	879	378	368	341	468
1955	D	1,000	269	302	475	400	504	984	2,137	1,427	322	331	342	328
1956	W	1,000	290	357	841	1,064	1,720	1,882	3,535	2,611	1,593	542	800	652
1957	BN	1,400	294	281	341	659	1,128	1,745	2,732	1,899	484	463	462	491
1958	W	1,000	353	336	327	1,264	1,635	2,734	5,329	3,151	855	644	800	849
1959	D	1,400	360	403	434	713	806	1,416	1,065	651	356	375	393	278
1960	C	1,000	337	316	337	636	984	1,605	1,515	708	330	336	326	328
1961	C	875	305	307	333	338	430	1,043	1,121	550	229	243	247	209
1962	BN	800	282	286	294	1,026	724	2,667	2,390	2,027	420	386	388	528
1963	AN	1,000	343	304	353	2,334	625	1,505	3,892	2,112	505	426	422	623
1964	D	1,200	348	286	354	401	458	1,155	1,677	1,004	297	304	318	283
1965	W	1,000	338		449	1,113	867	2,131	2,652	2,194	800	530	800	536
1966	BN	1,400	325	696	386	467	938	1,968	1,552	394	340	336	335	320
1967	W	1,000	282	271	276	875	1,869	1,734	4,701	4,838	1,021	640	800	844
1968	D	1,400	260	288	380	991	843	1,394	1,509	678	343	359	356	325
1969	W	1,000	319	339	506	1,955	2,074	3,417	5,687	3,319	872	717	800	987
1970	AN	1,400	446	273	528	1,275	1,971	1,736	2,425	1,690	541	538	592	545
1971	BN	1,200	269	280	336	767	1,064	1,897	2,332	2,107	591	500	520	490
1972	D	1,184	248	181	342	449	1,410	1,196	2,194	733	351	353	350	362
1973	AN	1,000	300	306	304	1,383	1,198	2,073	3,965	1,651	540	477	538	616
1974	W	1,200	235	766	610	691	1,815	2,316	3,376	1,960	800	508	800	612
1975	W	1,400	335	444	343	767	1,266	1,980	3,550	3,037	800	582	800	637
1976	C	1,400	471	297	361	370	395	713	910	260	243	265	260	159

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	800	275	263	280	364	395	516	464	304	211	229	174	122
1978	W	800	213	226	343	1,167	1,956	2,366	3,447	2,737	800	500	800	701
1979	AN	1,400	377	320	204	1,167	1,493	1,987	3,593	1,370	426	425	413	577
1980	W	1,200	322	165	198	2,681	1,705	1,908	2,934	2,531	1,867	604	800	704
1981	D	1,400	385	305	377	432	767	1,586	1,544	551	413	347	378	293
1982	W	1,000	263	291	455	3,554	2,387	4,222	4,161	2,447	800	677	887	997
1983	W	1,400	454	588	3,488	5,177	6,223	2,128	4,872	6,313	800	1,560	3,050	1,472
1984	AN	1,538	3,453	5,126	2,177	2,262	1,912	1,808	2,870	1,478	572	626	746	620
1985	D	1,200	340	225	335	519	770	2,075	1,667	566	315	405	495	336
1986	W	1,000	383	311	311	5,747	3,164	2,343	2,689	1,991	800	500	800	937
1987	C	1,400	310	411	357	313	559	1,018	891	309	310	324	294	186
1988	C	800	238	270	289	365	552	847	776	387	267	251	288	176
1989	C	800	248	267	281	324	1,744	2,330	1,561	936	358	352	377	416
1990	C	800	257	248	267	282	804	1,341	842	510	244	262	257	227
1991	C	800	469	249	242	383	771	954	1,742	1,043	235	247	229	295
1992	C	800	379	239	241	751	714	1,287	870	221	205	208	192	230
1993	W	800	216	225	354	1,167	1,915	2,106	3,331	2,038	1,100	500	800	634
1994	C	1,400	247	232	239	313	559	1,005	1,458	389	247	221	235	224
1995	W	1,043	228	242	609	1,080	3,743	2,572	4,365	4,287	800	500	800	967
1996	W	1,400	270	272	343	2,879	1,859	2,279	3,260	1,564	800	500	800	709
1997	W	1,400	464	215	6,009	3,736	2,234	1,513	1,879	1,123	800	500	800	617
1998	W	1,400	257	247	324	2,701	2,079	2,278	3,069	4,752	800	500	800	885
1999	AN	1,400	732	674	407	2,128	1,835	1,684	3,485	2,093	439	476	478	670
2000	AN	1,200	250	241	327	1,971	1,488	2,134	2,716	1,230	405	393	385	572
2001	D	1,200	264	243	302	389	871	1,257	1,815	315	307	276	298	280
2002	D	1,000	220	286	314	594	946	2,040	2,002	929	307	340	328	391
2003	BN	1,000	233	262	249	594	937	1,563	3,171	1,825	344	312	292	487

Table 36. LSJR Alternative 4 End-of-Month Storage at New Don Pedro on the Tuolumne River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	1,313	1,294	1,323	1,355	1,485	1,592	1,686	1,644	1,778	1,694	1,551	1,445
1923	AN	1,381	1,360	1,441	1,536	1,607	1,634	1,699	1,594	1,544	1,490	1,374	1,331
1924	C	1,288	1,272	1,264	1,259	1,266	1,271	1,251	1,164	1,121	1,086	1,055	1,043
1925	BN	1,048	1,064	1,133	1,192	1,272	1,323	1,374	1,327	1,301	1,246	1,155	1,111
1926	D	1,081	1,073	1,080	1,089	1,141	1,213	1,217	1,188	1,144	1,087	1,043	1,025
1927	AN	1,010	1,051	1,102	1,156	1,243	1,307	1,320	1,292	1,311	1,261	1,153	1,097
1928	BN	1,074	1,104	1,141	1,158	1,208	1,263	1,276	1,322	1,274	1,183	1,113	1,078
1929	C	1,042	1,035	1,036	1,038	1,060	1,085	1,106	1,012	1,042	1,009	978	960
1930	C	946	937	982	1,019	1,061	1,090	1,053	1,017	1,032	1,003	979	970
1931	C	961	966	1,008	1,024	1,069	1,073	1,009	910	864	817	789	783
1932	AN	772	768	951	1,107	1,252	1,345	1,369	1,307	1,262	1,338	1,312	1,300
1933	D	1,271	1,254	1,261	1,265	1,304	1,331	1,348	1,326	1,220	1,181	1,139	1,119
1934	C	1,091	1,083	1,108	1,156	1,206	1,283	1,247	1,195	1,146	1,096	1,062	1,054
1935	AN	1,050	1,064	1,108	1,286	1,393	1,470	1,554	1,455	1,405	1,338	1,245	1,187
1936	AN	1,160	1,153	1,150	1,218	1,421	1,550	1,561	1,476	1,481	1,402	1,282	1,215
1937	W	1,173	1,153	1,153	1,160	1,337	1,513	1,602	1,474	1,506	1,360	1,248	1,159
1938	W	1,099	1,067	1,303	1,378	1,602	1,690	1,690	1,656	1,789	1,818	1,688	1,592
1939	D	1,552	1,528	1,544	1,559	1,597	1,638	1,596	1,556	1,475	1,389	1,327	1,316
1940	AN	1,316	1,314	1,386	1,556	1,690	1,690	1,713	1,554	1,532	1,374	1,247	1,170
1941	W	1,123	1,108	1,214	1,401	1,570	1,690	1,690	1,505	1,497	1,453	1,312	1,203
1942	W	1,136	1,100	1,185	1,346	1,466	1,559	1,648	1,699	1,753	1,757	1,615	1,509
1943	W	1,438	1,452	1,500	1,690	1,690	1,690	1,713	1,760	1,761	1,625	1,479	1,358
1944	BN	1,289	1,249	1,241	1,247	1,316	1,389	1,396	1,341	1,305	1,251	1,181	1,143
1945	AN	1,128	1,177	1,227	1,269	1,424	1,582	1,601	1,479	1,455	1,411	1,288	1,215
1946	AN	1,217	1,249	1,461	1,594	1,690	1,690	1,656	1,544	1,530	1,415	1,316	1,260
1947	D	1,227	1,246	1,282	1,309	1,341	1,349	1,315	1,321	1,277	1,216	1,168	1,149
1948	BN	1,159	1,162	1,205	1,228	1,235	1,307	1,352	1,294	1,243	1,189	1,115	1,080
1949	BN	1,059	1,050	1,052	1,056	1,083	1,246	1,224	1,162	1,117	1,054	1,003	983

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	959	955	961	1,006	1,132	1,252	1,259	1,145	1,147	1,090	1,037	1,016
1951	AN	1,019	1,435	1,690	1,690	1,690	1,690	1,695	1,545	1,495	1,407	1,330	1,283
1952	W	1,254	1,255	1,373	1,615	1,690	1,690	1,690	1,768	1,811	1,839	1,707	1,608
1953	BN	1,528	1,482	1,500	1,593	1,635	1,669	1,612	1,561	1,528	1,505	1,404	1,346
1954	BN	1,310	1,310	1,316	1,336	1,359	1,418	1,392	1,412	1,377	1,284	1,209	1,171
1955	D	1,139	1,140	1,162	1,210	1,257	1,347	1,393	1,336	1,217	1,164	1,117	1,100
1956	W	1,083	1,083	1,650	1,690	1,690	1,690	1,704	1,592	1,675	1,654	1,515	1,414
1957	BN	1,352	1,305	1,302	1,309	1,333	1,363	1,319	1,309	1,343	1,264	1,192	1,155
1958	W	1,143	1,139	1,159	1,198	1,305	1,495	1,637	1,730	1,805	1,770	1,636	1,541
1959	D	1,462	1,410	1,393	1,430	1,527	1,597	1,581	1,521	1,413	1,326	1,259	1,272
1960	C	1,243	1,237	1,269	1,285	1,375	1,398	1,400	1,349	1,254	1,206	1,174	1,167
1961	C	1,157	1,158	1,247	1,266	1,284	1,283	1,231	1,134	1,049	1,010	985	979
1962	BN	968	964	996	1,016	1,130	1,211	1,141	1,117	1,150	1,122	1,047	1,010
1963	AN	994	990	1,007	1,058	1,130	1,154	1,202	1,195	1,218	1,190	1,081	1,023
1964	D	1,001	1,049	1,066	1,097	1,122	1,142	1,165	1,133	1,090	1,052	1,024	1,017
1965	W	1,014	1,040	1,473	1,690	1,690	1,690	1,713	1,582	1,482	1,432	1,347	1,245
1966	BN	1,160	1,203	1,305	1,351	1,428	1,454	1,415	1,416	1,342	1,279	1,229	1,213
1967	W	1,193	1,228	1,387	1,503	1,568	1,659	1,690	1,764	1,869	1,910	1,790	1,686
1968	D	1,605	1,558	1,556	1,569	1,591	1,637	1,593	1,571	1,501	1,409	1,348	1,313
1969	W	1,297	1,327	1,421	1,690	1,690	1,690	1,690	1,805	1,925	1,910	1,772	1,670
1970	AN	1,648	1,637	1,690	1,690	1,690	1,690	1,679	1,626	1,546	1,447	1,349	1,292
1971	BN	1,256	1,298	1,387	1,468	1,517	1,574	1,553	1,514	1,472	1,409	1,318	1,272
1972	D	1,239	1,247	1,296	1,361	1,403	1,386	1,363	1,321	1,298	1,244	1,208	1,195
1973	AN	1,185	1,200	1,287	1,433	1,561	1,669	1,656	1,643	1,586	1,460	1,360	1,302
1974	W	1,286	1,375	1,459	1,607	1,678	1,690	1,713	1,730	1,726	1,589	1,443	1,344
1975	W	1,314	1,301	1,304	1,321	1,425	1,539	1,628	1,499	1,554	1,436	1,319	1,216
1976	C	1,200	1,192	1,212	1,199	1,197	1,193	1,183	1,078	1,038	1,003	994	1,001
1977	C	996	993	1,020	1,026	1,034	1,011	955	901	815	774	750	745
1978	W	735	733	793	955	1,064	1,173	1,261	1,334	1,540	1,655	1,587	1,571

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	1,496	1,483	1,486	1,591	1,690	1,690	1,672	1,684	1,615	1,457	1,324	1,251
1980	W	1,224	1,225	1,246	1,666	1,690	1,690	1,700	1,726	1,775	1,858	1,728	1,637
1981	D	1,563	1,526	1,523	1,543	1,571	1,635	1,634	1,543	1,471	1,384	1,328	1,302
1982	W	1,303	1,411	1,566	1,690	1,690	1,690	1,713	1,874	1,943	1,910	1,790	1,700
1983	W	1,660	1,690	1,690	1,690	1,690	1,295	1,264	1,271	1,493	1,856	1,790	1,700
1984	AN	1,660	1,690	1,690	1,690	1,690	1,690	1,650	1,531	1,501	1,425	1,333	1,280
1985	D	1,267	1,302	1,350	1,356	1,395	1,452	1,392	1,391	1,333	1,257	1,206	1,189
1986	W	1,187	1,209	1,288	1,369	1,588	1,690	1,713	1,776	1,792	1,659	1,516	1,429
1987	C	1,384	1,360	1,346	1,328	1,334	1,368	1,326	1,253	1,217	1,179	1,155	1,148
1988	C	1,146	1,149	1,194	1,265	1,317	1,303	1,244	1,150	1,107	1,066	1,040	1,032
1989	C	1,021	1,030	1,067	1,107	1,132	1,129	1,087	1,115	1,110	1,048	1,006	1,015
1990	C	1,046	1,048	1,076	1,095	1,130	1,119	1,041	1,014	987	945	915	908
1991	C	901	899	927	937	935	951	945	893	911	900	889	889
1992	C	895	897	928	949	999	1,023	981	1,005	980	975	942	921
1993	W	910	906	954	1,177	1,284	1,399	1,406	1,475	1,493	1,420	1,273	1,163
1994	C	1,085	1,033	1,023	1,026	1,040	1,040	998	946	920	891	877	876
1995	W	863	885	935	1,210	1,255	1,525	1,643	1,630	1,812	1,910	1,790	1,688
1996	W	1,606	1,547	1,574	1,654	1,690	1,690	1,713	1,859	1,839	1,686	1,538	1,434
1997	W	1,374	1,385	1,690	1,690	1,690	1,690	1,600	1,666	1,635	1,471	1,352	1,282
1998	W	1,212	1,165	1,168	1,343	1,558	1,686	1,713	1,714	1,906	1,910	1,784	1,678
1999	AN	1,638	1,619	1,660	1,690	1,690	1,690	1,706	1,543	1,532	1,418	1,304	1,241
2000	AN	1,187	1,174	1,164	1,254	1,383	1,475	1,447	1,503	1,483	1,349	1,244	1,190
2001	D	1,178	1,165	1,160	1,166	1,186	1,237	1,224	1,239	1,178	1,118	1,076	1,063
2002	D	1,048	1,061	1,140	1,212	1,244	1,255	1,190	1,243	1,228	1,164	1,117	1,096
2003	BN	1,082	1,120	1,181	1,262	1,295	1,304	1,318	1,239	1,259	1,195	1,149	1,128

Table 37. LSJR Alternative 4 Monthly Average Flow at Modesto on the Tuolumne River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	724	599	597	603	1,875	1,622	2,408	6,434	6,964	1,200	600	1,000	1,157
1923	AN	1,000	1,000	620	619	853	1,103	2,682	5,084	3,217	600	586	597	779
1924	C	737	605	580	579	601	597	1,402	2,039	366	356	362	366	302
1925	BN	428	442	440	427	2,452	1,620	3,529	5,250	3,549	405	410	421	980
1926	D	552	500	476	464	1,091	1,249	3,852	2,966	897	404	410	418	602
1927	AN	484	449	452	456	2,409	1,561	3,549	4,430	4,800	581	588	595	999
1928	BN	733	615	613	601	855	3,347	2,662	4,372	1,543	403	408	423	774
1929	C	552	495	477	468	498	966	1,492	3,688	2,269	358	361	376	538
1930	C	439	466	438	436	756	1,434	2,480	2,683	2,884	369	371	381	614
1931	C	462	453	449	437	486	644	1,553	2,039	494	359	364	367	314
1932	AN	429	437	430	427	2,503	1,678	2,470	5,113	5,374	602	588	591	1,028
1933	D	741	630	591	582	612	800	1,724	2,449	4,295	409	413	427	592
1934	C	544	501	481	464	972	1,464	1,875	1,454	958	356	361	366	402
1935	AN	438	445	437	436	1,156	1,337	4,689	5,181	5,153	587	585	600	1,051
1936	AN	736	609	597	593	3,672	2,020	3,963	5,074	3,932	590	585	595	1,117
1937	W	735	621	600	590	2,683	1,857	2,705	5,607	3,646	1,200	600	1,000	986
1938	W	1,000	1,000	611	603	3,276	6,567	5,665	6,595	6,739	1,200	600	1,000	1,729
1939	D	1,000	1,000	602	593	648	1,405	2,843	2,108	746	409	417	420	466
1940	AN	487	470	440	434	3,154	5,983	4,184	5,572	3,509	650	534	541	1,350
1941	W	645	526	755	683	2,169	3,145	4,622	5,931	4,945	1,200	638	1,000	1,248
1942	W	1,000	1,000	641	849	1,447	1,372	3,206	4,346	5,689	1,200	755	1,000	961
1943	W	1,000	1,000	626	761	3,424	6,406	3,999	4,318	3,182	1,200	600	1,000	1,277
1944	BN	1,000	1,000	626	650	834	1,317	1,654	4,450	2,692	439	425	372	661
1945	AN	529	453	389	529	3,295	1,610	2,864	4,440	4,658	713	654	585	1,003
1946	AN	684	466	656	759	1,478	3,483	3,509	4,762	2,672	662	620	593	957
1947	D	663	576	675	615	864	1,327	1,936	3,435	1,119	322	347	333	523
1948	BN	480	454	398	393	412	712	2,228	4,254	4,376	514	427	357	722

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	530	463	407	514	480	1,200	3,206	4,264	2,420	379	379	356	697
1950	BN	530	475	463	686	1,340	1,249	3,317	4,567	3,217	420	399	380	821
1951	AN	513	206	3,985	4,018	3,972	3,184	2,561	3,640	2,591	622	594	558	947
1952	W	645	525	600	971	2,889	3,998	4,806	7,127	5,530	1,200	637	1,000	1,465
1953	BN	1,000	1,000	517	639	681	1,044	2,722	2,527	4,174	544	453	413	668
1954	BN	465	400	391	397	1,102	2,078	3,519	4,372	1,865	398	399	382	778
1955	D	473	385	420	702	659	810	1,452	3,581	2,944	363	373	354	568
1956	W	400	372	441	6,985	4,426	3,560	2,579	4,957	5,323	1,200	701	1,000	1,249
1957	BN	1,000	1,000	491	518	1,340	1,503	1,744	3,708	4,084	424	428	418	742
1958	W	489	380	432	561	1,784	2,340	3,998	6,928	5,447	1,200	692	1,000	1,231
1959	D	1,000	1,000	581	624	1,253	1,161	2,259	2,264	1,402	374	353	372	498
1960	C	466	364	307	362	1,241	1,454	2,400	2,966	1,644	301	315	334	584
1961	C	315	330	282	337	497	693	1,664	2,147	1,230	261	276	248	374
1962	BN	303	314	323	314	2,517	1,356	3,922	3,532	4,497	383	416	421	941
1963	AN	466	273	315	425	3,338	1,093	2,501	5,211	4,669	552	520	525	1,000
1964	D	548	381	400	518	542	732	1,704	3,152	2,269	281	288	293	506
1965	W	343	266	234	2,348	3,816	3,400	3,514	3,765	4,124	1,200	600	1,000	1,107
1966	BN	1,000	1,000	435	555	810	1,425	3,015	3,464	867	271	262	255	577
1967	W	394	267	318	582	1,133	2,724	4,114	5,776	6,843	3,745	653	1,000	1,238
1968	D	1,000	1,000	485	515	1,398	1,200	1,886	2,810	1,422	375	358	342	524
1969	W	401	367	288	4,445	5,697	4,123	5,386	8,816	6,794	1,956	600	1,000	1,837
1970	AN	1,000	1,000	679	6,185	2,753	3,317	1,623	4,011	3,388	457	380	438	902
1971	BN	676	503	532	524	1,016	1,425	1,956	3,406	4,215	358	370	371	721
1972	D	520	322	524	367	814	1,776	1,573	3,357	2,218	301	306	297	588
1973	AN	317	451	522	524	2,009	1,688	2,612	6,391	4,033	509	529	525	1,004
1974	W	560	540	688	639	694	3,771	2,891	5,093	4,147	1,200	600	1,000	1,002
1975	W	1,070	1,088	789	642	1,406	1,975	1,603	5,131	5,430	1,200	600	1,000	933
1976	C	1,000	1,000	584	543	509	693	1,008	2,039	403	270	295	290	281

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	289	307	322	295	308	338	797	1,034	1,059	195	187	166	212
1978	W	222	243	251	432	1,884	2,873	3,175	5,226	5,947	1,200	600	1,000	1,145
1979	AN	1,000	1,000	611	1,015	2,039	4,455	2,622	6,108	3,176	573	645	529	1,108
1980	W	612	813	877	667	6,510	3,963	2,934	4,508	5,052	1,200	600	1,000	1,371
1981	D	1,000	1,000	519	692	681	1,229	2,450	3,201	1,523	346	368	354	547
1982	W	441	421	600	2,255	6,917	5,797	9,332	6,383	5,396	2,562	712	2,296	2,010
1983	W	3,090	3,106	5,342	5,471	6,892	16,297	5,182	7,861	9,946	1,200	2,123	1,991	2,768
1984	AN	1,157	5,440	7,479	4,359	3,576	3,593	2,047	5,230	3,327	583	617	612	1,068
1985	D	743	974	430	489	745	1,229	3,045	3,327	1,361	366	387	372	584
1986	W	337	363	356	284	6,382	6,567	3,157	5,053	4,903	1,200	600	1,000	1,549
1987	C	1,171	1,300	566	596	523	966	1,956	1,981	655	282	285	266	366
1988	C	244	259	254	305	595	1,025	1,603	2,078	988	200	210	190	379
1989	C	199	220	245	244	659	2,781	3,116	3,132	2,087	213	223	220	710
1990	C	215	245	232	236	573	1,269	2,218	1,776	1,008	225	241	225	411
1991	C	216	239	223	208	235	1,639	1,815	3,279	2,975	208	221	201	600
1992	C	212	239	217	224	970	1,122	2,319	1,844	469	194	195	188	404
1993	W	216	208	217	781	1,513	2,708	2,939	5,357	4,597	1,200	600	1,000	1,028
1994	C	1,000	1,000	413	399	573	1,054	1,966	2,683	1,200	213	221	199	450
1995	W	233	218	223	518	1,605	5,245	3,604	8,333	7,592	5,424	1,918	1,000	1,590
1996	W	1,000	1,000	430	538	5,498	5,065	3,122	4,963	3,464	1,200	600	1,000	1,325
1997	W	1,000	1,000	1,329	17,925	3,886	3,588	2,389	4,524	2,898	1,200	600	1,000	1,029
1998	W	1,000	1,000	431	899	3,578	3,196	4,029	5,533	7,976	5,274	600	1,000	1,450
1999	AN	1,000	1,000	289	1,709	5,167	4,019	2,642	5,552	4,396	523	521	519	1,294
2000	AN	596	442	344	433	2,889	2,469	3,368	5,260	3,247	513	711	734	1,035
2001	D	692	465	418	518	648	1,747	2,289	3,981	555	318	334	313	557
2002	D	327	243	383	427	853	1,376	3,035	3,630	2,249	304	346	309	670
2003	BN	320	247	294	264	702	1,210	2,198	5,074	3,751	253	303	282	779

Table 38. LSJR Alternative 4 End-of-Month Storage at New Exchequer on the Merced River in TAF from 1922–2003

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1922	W	469	457	482	505	616	688	695	731	792	722	595	511
1923	AN	449	416	455	503	528	523	550	598	604	569	495	455
1924	C	431	423	415	410	404	390	389	385	352	323	297	279
1925	BN	258	264	270	276	335	353	396	456	442	407	357	325
1926	D	301	293	289	283	307	314	326	273	289	321	327	308
1927	AN	283	272	278	268	235	238	209	279	298	343	378	412
1928	BN	420	416	430	444	454	386	339	348	353	370	386	406
1929	C	388	375	362	352	353	348	341	279	258	306	348	337
1930	C	310	297	285	273	263	213	194	167	161	224	277	292
1931	C	268	260	250	245	250	247	248	251	226	195	171	152
1932	AN	127	116	178	211	304	331	356	424	479	486	446	416
1933	D	387	374	364	365	364	371	375	384	420	401	364	342
1934	C	316	303	306	323	351	367	375	367	349	318	293	275
1935	AN	251	256	264	329	357	399	501	568	615	590	536	500
1936	AN	472	465	457	481	597	635	672	708	686	628	548	499
1937	W	477	466	469	477	613	682	726	808	812	706	586	507
1938	W	445	408	534	583	675	735	810	901	990	910	770	694
1939	D	654	631	632	630	637	656	681	679	642	592	542	518
1940	AN	501	491	482	593	663	718	767	809	777	686	593	539
1941	W	501	489	563	616	675	735	811	923	966	910	770	689
1942	W	643	618	675	675	675	712	759	811	876	821	703	622
1943	W	561	555	577	675	675	735	787	826	807	703	579	497
1944	BN	434	399	390	393	422	446	445	484	494	468	418	386
1945	AN	354	372	388	397	485	525	543	587	584	546	476	428
1946	AN	414	438	523	556	568	592	605	657	640	586	520	479
1947	D	457	476	507	518	540	552	565	587	565	527	484	458
1948	BN	437	432	424	421	411	404	419	461	491	459	406	374
1949	BN	345	331	324	318	323	345	374	421	422	386	343	318

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1950	BN	287	276	266	288	318	330	370	406	423	389	344	314
1951	AN	290	531	675	675	675	706	727	737	719	662	589	545
1952	W	514	506	549	675	675	735	811	930	1,009	910	770	696
1953	BN	631	597	609	660	672	671	679	672	673	643	580	542
1954	BN	507	495	486	489	513	539	577	615	593	541	476	440
1955	D	405	393	393	406	413	413	415	461	473	443	400	374
1956	W	342	328	675	675	675	713	753	825	880	844	734	659
1957	BN	604	571	564	561	581	580	576	608	626	581	524	485
1958	W	462	455	460	478	544	644	800	926	989	910	770	699
1959	D	638	597	584	589	616	621	641	644	616	563	510	504
1960	C	477	463	449	442	472	483	509	534	518	476	433	407
1961	C	378	369	368	360	362	362	374	389	378	344	314	294
1962	BN	267	254	248	242	329	369	422	441	457	427	363	319
1963	AN	290	275	264	290	362	380	404	450	473	448	386	346
1964	D	324	344	348	353	350	346	357	388	393	371	337	315
1965	W	291	294	502	569	608	624	681	760	833	826	739	668
1966	BN	608	625	648	671	675	686	709	729	691	631	575	543
1967	W	512	509	605	650	675	735	831	919	990	910	770	700
1968	D	654	619	615	616	636	643	656	669	648	592	545	517
1969	W	491	498	520	675	675	735	829	970	1,024	910	770	700
1970	AN	660	632	653	675	675	720	718	739	718	655	585	544
1971	BN	513	517	551	584	602	603	598	625	634	595	536	499
1972	D	467	459	482	495	514	517	521	550	549	503	457	441
1973	AN	424	420	437	489	575	635	654	721	703	618	533	484
1974	W	466	512	560	645	670	729	766	845	848	742	626	549
1975	W	500	461	460	470	540	596	599	662	731	650	538	461
1976	C	439	414	412	401	401	397	402	411	389	352	324	310
1977	C	286	268	253	240	223	195	183	172	158	128	101	80
1978	W	52	35	52	148	251	363	473	606	741	802	702	673

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1979	AN	612	597	590	668	675	735	756	803	766	684	598	544
1980	W	515	506	504	675	675	735	758	800	832	814	709	632
1981	D	579	531	520	522	529	549	565	590	570	523	479	450
1982	W	429	458	504	619	675	735	845	933	948	910	770	700
1983	W	675	675	675	675	675	735	779	875	974	910	770	700
1984	AN	640	675	675	675	675	703	699	736	706	653	587	547
1985	D	526	533	538	541	559	569	593	618	595	546	497	471
1986	W	447	444	459	486	666	735	794	851	865	766	654	587
1987	C	529	485	470	459	463	471	491	505	490	454	423	402
1988	C	377	374	369	380	385	389	402	414	401	375	345	325
1989	C	298	287	284	278	287	317	348	368	353	328	304	291
1990	C	277	272	264	263	268	269	283	285	260	231	201	182
1991	C	158	144	128	114	99	132	141	167	184	176	154	139
1992	C	119	113	106	102	133	143	170	174	147	138	115	102
1993	W	82	73	76	246	309	393	458	616	707	697	627	572
1994	C	532	493	484	477	489	485	489	501	493	460	429	410
1995	W	400	404	412	598	637	735	797	902	1,019	910	770	689
1996	W	627	584	593	643	675	735	789	871	843	733	609	527
1997	W	475	487	675	675	675	735	761	827	802	702	600	532
1998	W	473	439	438	522	675	735	812	866	976	910	770	700
1999	AN	654	626	638	672	675	679	677	728	720	655	588	546
2000	AN	508	499	487	527	604	661	687	743	714	631	549	502
2001	D	482	472	465	461	475	504	522	560	529	482	437	418
2002	D	392	387	418	444	455	462	486	525	514	469	426	404
2003	BN	376	390	407	431	441	447	452	512	516	470	425	395

Table 39. LSJR Alternative 4 Monthly Average Flow at Stevinson on the Merced River in cfs and February–June Flow Volume in TAF

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1922	W	356	318	436	432	1,381	896	981	3,192	3,164	600	600	600	575
1923	AN	800	800	470	444	504	510	1,486	2,622	1,458	200	200	200	396
1924	C	385	335	332	346	352	304	676	888	131	11	19	82	142
1925	BN	351	369	375	378	1,145	751	1,815	2,547	1,482	87	60	53	463
1926	D	299	304	325	325	681	537	2,188	1,688	484	(0)	(0)	101	334
1927	AN	338	272	263	331	1,423	816	1,735	2,777	2,191	200	200	200	534
1928	BN	420	302	339	311	501	1,552	1,432	2,010	686	150	83	49	374
1929	C	364	347	337	358	385	459	786	1,883	978	2	31	89	270
1930	C	350	322	309	311	325	712	1,190	1,337	1,129	(0)	(0)	92	282
1931	C	345	335	322	332	358	318	746	898	202	25	1	119	151
1932	AN	350	313	425	419	1,510	734	1,258	2,584	2,411	200	200	200	509
1933	D	401	336	333	376	321	420	887	1,298	1,805	17	(0)	72	284
1934	C	386	333	355	416	486	634	928	546	333	53	(0)	48	175
1935	AN	358	339	359	530	528	820	2,709	3,070	2,542	200	200	200	581
1936	AN	450	360	335	378	2,543	937	2,120	2,801	1,578	200	200	200	596
1937	W	415	374	367	366	1,931	1,011	1,300	3,087	1,531	600	600	600	528
1938	W	800	800	302	486	3,233	4,657	2,000	3,735	3,860	1,589	1,096	600	1,044
1939	D	800	800	333	393	482	693	1,523	986	323	80	88	122	240
1940	AN	426	374	368	523	1,370	1,405	1,786	2,896	1,374	200	200	200	531
1941	W	430	377	435	424	2,015	1,751	1,315	3,175	2,464	717	1,012	600	640
1942	W	800	800	427	1,474	1,666	702	1,492	2,209	2,710	600	600	600	522
1943	W	800	800	378	523	1,917	3,022	1,751	2,260	1,215	600	600	600	608
1944	BN	800	800	386	364	490	790	807	2,439	1,341	148	146	122	355
1945	AN	438	439	396	391	1,965	1,090	1,555	2,546	2,053	200	200	200	547
1946	AN	458	400	420	491	551	778	1,892	2,485	1,117	200	200	200	410
1947	D	473	384	403	392	432	605	1,049	1,678	514	77	101	150	257
1948	BN	398	347	348	338	337	335	1,079	2,303	2,188	153	97	101	376

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1949	BN	430	354	336	352	371	761	1,432	2,313	1,129	92	118	135	362
1950	BN	414	344	344	378	659	517	1,734	2,274	1,260	133	127	169	386
1951	AN	402	352	2,068	1,689	1,597	811	1,266	1,659	1,013	200	200	200	376
1952	W	428	367	410	979	1,269	1,811	1,735	3,626	2,568	1,603	1,164	600	663
1953	BN	800	800	284	353	452	400	1,210	1,190	1,593	111	123	143	290
1954	BN	445	355	353	356	519	966	1,714	2,176	746	138	128	174	368
1955	D	402	342	359	487	392	359	655	1,893	1,381	101	120	158	281
1956	W	410	336	449	4,319	1,940	678	1,227	2,459	2,286	600	600	600	513
1957	BN	800	800	359	361	443	615	887	1,952	1,775	166	151	174	341
1958	W	462	331	355	431	758	1,345	2,114	3,391	2,515	1,080	1,080	600	609
1959	D	800	800	332	345	605	537	1,190	1,093	514	137	148	158	235
1960	C	400	324	333	347	574	595	1,260	1,434	645	132	159	130	271
1961	C	367	315	337	322	348	339	847	927	444	94	56	99	174
1962	BN	344	291	309	310	1,718	925	1,996	2,010	2,067	224	179	177	518
1963	AN	429	312	326	326	1,867	595	1,319	2,612	2,115	248	200	205	505
1964	D	438	347	348	354	334	348	766	1,366	817	144	120	164	219
1965	W	389	306	478	1,730	494	505	1,248	1,895	1,830	569	568	566	358
1966	BN	771	746	380	623	610	634	1,603	1,776	474	237	197	173	306
1967	W	392	316	350	358	588	1,538	1,894	3,125	3,807	3,431	1,448	715	659
1968	D	800	800	280	332	501	468	948	1,181	504	227	209	230	217
1969	W	378	381	384	3,769	4,153	1,416	2,279	5,120	4,045	2,323	1,159	613	1,009
1970	AN	800	800	196	2,529	1,211	1,064	897	2,127	1,281	227	219	203	393
1971	BN	468	325	309	375	421	576	988	1,786	1,815	227	186	171	335
1972	D	461	336	373	144	355	800	807	1,630	968	221	229	(0)	275
1973	AN	394	362	382	424	1,347	1,119	1,317	3,708	2,021	204	200	200	570
1974	W	457	166	249	252	384	987	1,244	2,437	1,568	600	600	600	399
1975	W	800	800	359	257	928	1,009	786	2,422	2,647	600	600	600	467
1976	C	800	800	312	342	337	326	494	907	234	205	232	221	139

Year	WYT	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Feb-Jun [Taf]
1977	C	450	271	300	323	304	281	313	381	464	137	109	128	104
1978	W	370	243	300	466	1,317	1,511	1,944	3,039	3,381	600	600	600	670
1979	AN	800	800	391	515	1,753	1,378	1,320	3,328	1,550	233	200	200	557
1980	W	519	324	342	1,527	4,474	1,352	1,483	2,387	2,493	600	600	600	724
1981	D	800	800	394	429	405	507	1,230	1,552	696	199	200	193	264
1982	W	465	355	364	434	2,633	2,184	4,845	3,824	2,486	930	1,331	1,073	952
1983	W	1,088	1,910	2,243	3,604	4,363	5,959	1,963	3,683	6,535	5,048	2,392	1,008	1,341
1984	AN	1,276	1,599	3,495	1,850	1,543	947	1,301	2,586	1,149	262	275	260	452
1985	D	591	288	284	396	393	576	1,482	1,669	575	267	237	198	282
1986	W	500	345	358	330	3,406	3,899	1,677	2,686	2,002	600	600	600	813
1987	C	800	800	368	331	330	399	958	927	252	161	167	185	172
1988	C	420	290	325	327	283	468	938	1,044	555	128	124	133	198
1989	C	342	224	272	254	260	937	1,613	1,288	736	90	71	117	291
1990	C	378	253	277	260	305	546	1,149	849	484	98	83	86	200
1991	C	323	208	245	249	207	937	817	1,795	1,462	72	29	35	315
1992	C	310	239	247	241	563	498	1,321	1,025	315	102	57	47	223
1993	W	219	263	300	634	810	1,149	1,369	2,810	2,117	529	529	529	496
1994	C	706	743	284	265	331	390	877	1,142	434	(0)	56	17	191
1995	W	264	277	267	561	636	4,158	1,747	3,184	3,994	4,726	1,644	600	828
1996	W	800	800	315	261	2,398	1,521	1,529	2,382	1,219	600	600	600	541
1997	W	800	800	390	9,859	2,091	1,070	1,278	2,035	862	509	507	508	434
1998	W	722	703	306	344	2,400	2,005	1,698	2,052	4,038	3,779	1,464	677	724
1999	AN	800	800	246	217	1,929	642	1,268	2,702	1,525	200	200	200	479
2000	AN	358	295	268	275	1,730	1,098	1,624	2,612	1,271	200	200	200	500
2001	D	356	446	342	339	341	839	1,089	2,098	333	94	110	72	284
2002	D	277	353	340	399	378	576	1,523	1,737	857	71	38	31	305
2003	BN	278	266	303	277	367	605	1,129	2,635	1,714	46	35	53	389

Appendix F.2

Evaluation of Historical Flow and Salinity Measurements of the Lower San Joaquin River and Southern Delta

Section F.2
Evaluation of Historical Flow and Salinity Measurements of the Lower San Joaquin River and Southern Delta

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Tables

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F.2.1 Introduction

This appendix describes and evaluates the measured flow and salinity (electrical conductivity [EC]) patterns along the Lower San Joaquin River (LSJR) and in the southern Delta for 1984–2011. The data are summarized as monthly values, and a more detailed review of the daily flow and EC data from four relatively dry (i.e., low flow) years (2000–2003) is provided to better understand the relationships between flow and salinity in the LSJR. Daily flow and EC measurements provide the most accurate picture of the seasonal patterns of the various flows (e.g., tributaries and groundwater seepage) and the likely sources of relatively high salinity water that control the San Joaquin River SJR salinity at Vernalis and downstream in the southern Delta. The daily salt loads, which are proportional to the flow times the EC, are described for various locations along the SJR.

The evaluation of monthly data from 1984–2011 also allows the likely effects of changes in the existing conditions that might be expected with near-future changes in water management (e.g., Upper SJR Restoration Program) and salinity management (e.g., SJR Improvement Project implementation for the selenium Total Maximum Daily Load) within the SJR watershed to be generally considered (i.e., cumulative effects on future baseline conditions).

The standard measurement of salinity in rivers is EC. As salinity increases, the EC across a 1 centimeter (cm) electrode gap will increase. Devices have been developed that measure this electrical current for a constant voltage potential and adjust for the temperature of the water. EC measurements are generally adjusted to a temperature of 25°C. The calibration of field devices is achieved by comparing meter readings when the electrode is immersed in water standards prepared by dissolving a known quantity of salt in water.

The range of EC within the Delta is 100 µS/cm (freshwater) to more than 25,000 µS/cm (about 50 percent seawater).[1] Because each station is independently calibrated, EC station measurements on the same day (assumed to be measuring the same river water) may not be exactly the same. An EC variation of 25 µS/cm is often observed between adjacent stations. This can be used as an estimate of EC measurement accuracy.

Salinity is generally "conservative," meaning the mass of salts is neither increased nor reduced by chemical reactions (i.e., dissolving or precipitating) within the river. The river concentration of salt will be increased by the addition of salt (e.g., high salinity water) or by evaporation of some of the water. The river load of salt is the mass of salt in the river per time (e.g., day or month). The daily salt load can be calculated from daily flow and EC values as:

$$\textit{Salt load (tons/day)} = 5.4 \times \textit{flow (cfs)} \times \textit{EC}\ (\mu S/cm) / (1.54 \times 2{,}000) = 0.00175 \times \textit{flow} \times \textit{EC}$$

Where 1.54 is the assumed conversion between 1 milligram per liter (mg/L) of salt and 1 µS/cm of EC [0.65 mg/L = 1 µS/cm], and 5.4 is the conversion between 1 cubic foot per second (cfs) and 1 mg/L to 1 pound per day [1 cfs *x* mg/L = 5.4 lb/day].

[1] The analysis in Appendix F.1, *Hydrologic and Water Quality Modeling,* and Appendix F.2, *Evaluation of Historical Flow and Salinity Measurements of the Lower San Joaquin River and Southern Delta*, describes salinity (EC) in terms of microSiemens per cm (uS/cm). Chapter 5, *Surface Hydrology and Water Quality*, primarily describes salinity in terms of deciSiemens dS/m. The conversion is 1 dS/m = 1000 µS/cm.

The river salt load (mass/time) will increase substantially with the addition of relatively high salinity water from agricultural drainage or wastewater discharge, and will increase slightly with the addition of relatively low salinity water such as the eastside tributaries or with rainfall (rainfall EC is less than 25 µS/cm). The salt load of the river does not change with evaporation because the salt concentration will increase as the water evaporates. The salt load of irrigation water does not usually change with evaporation and crop transpiration; the salt concentration in the soil and in the drainage water increases as water evaporates.

The effects of increased SJR flow on EC can be generally described as a dilution response; higher flows (runoff or reservoir releases) will reduce the salinity of the river and add only slightly to the salt load. The monthly salt loads are not constant however, so predicting the monthly EC of the SJR above the Merced River or at Vernalis from the monthly flow alone will not be completely accurate. By understanding sources of salt within the SJR watershed (salt loads), the ability to determine expected salinity above the Merced River or at Vernalis will be improved. From this framework, likely effects of changes in the tributary flows with alternative flow objectives, and the likely effects of alternative salinity objectives at Vernalis, can be accurately evaluated.

An earlier model of the SJR flow and salinity was developed by Charlie Kratzer and Les Grober, while they worked for the State Water Board in 1987. The model was called the SJR Input-Output (SJRIO) model (Kratzer et al. 1987). The SJRIO modeling report remains the most comprehensive review of water budget and salinity budget information for the lower SJR. This model used one-mile segments to account for flow (inflows and diversions) and salinity along the 60 miles from the Lander Avenue Bridge (i.e., Highway 165, Stevinson gage) to the Airport Way Bridge (i.e., Vernalis gage). The SJRIO study period was 1977 through 1985, prior to any continuous EC measurements.

The SJR landscape can be summarized with the SJR miles for some major inflows and flow (or EC) measurement stations as the following.

- Stevinson gage (Lander Ave, Highway 165 bridge) at SJR mile 132.
- Salt Slough at SJR mile 129.
- Fremont Ford gage at SJR mile 125.
- Mud Slough at SJR mile 121.
- Newman Wasteway (from the Delta-Mendota Canal to the SJR) at SJR mile 119.
- Merced River at SJR mile 118.
- Newman gage (Hills Ferry Bridge) at SJR mile 117.
- Orestimba Creek at SJR mile 109.
- Crows Landing gage at SJR mile 108.
- Patterson gage at SJR mile 99.
- Patterson Irrigation District (ID) pumping-plant canal at SJR 98.
- Del Puerto Creek at SJR mile 93.
- West Stanislaus ID pumping-plant canal at SJR mile 85.
- Tuolumne River at SJR mile 84.

- Maze gage at SJR mile 77.
- Stanislaus River at SJR mile 75.
- Vernalis at SJR mile 72.
- Banta–Carbona pumping-plant canal (fish screen) at SJR mile 63.
- Mossdale gage at SJR mile 57.
- Head of Old River at SJR mile 53.

There are several inflows and several diversions along the river that influence the flows and EC along the SJR. The three tributary rivers provide a majority of the flows, but westside streams and agricultural drainage and groundwater seepage to the river provide the majority of the salinity (salt load). Two major inflows upstream of the Merced River are Salt Slough and Mud Slough, which drain agricultural lands (tile drainage) and wildlife refuge wetlands and duck clubs on the west side of the SJR (e.g., Grasslands Water District). The Merced River enters just upstream of the Newman gage and 10 miles upstream of the Crows Landing gage. Orestimba Creek enters from the coastal mountains at SJR mile 109, just upstream of the Crows Landing gage. The Patterson main canal and pumping plant is downstream of the Patterson gage at SJR mile 98. Del Puerto Creek enters from the west at SJR mile 93. The West Stanislaus Irrigation District main canal pumping plant is at SJR mile 85, just upstream of the Tuolumne River mouth at SJR mile 84. Hospital and Ingram Creeks join with their mouth at SJR mile 83. The Maze Road Bridge is upstream of the Stanislaus River mouth. The Vernalis gage is at SJR mile 72. The Banta–Carbona Irrigation District main canal and pumping plant is at SJR mile 63. Much of the Banta–Carbona Irrigation District lands have tile drainage systems; drainage water from the tile drainage systems enters the SJR just downstream of the diversion canal.

F.2.2 Monthly Flows EC and Salt Loads for the SJR

Daily data for these SJR and tributary streams were averaged as monthly values, to provide a summary of seasonal flow and salinity conditions in the SJR, from upstream of the Merced River to Vernalis. Although there are many flow and EC monitoring stations operated by the California Department of Water Resources (DWR) and United States Geological Survey (USGS) along the SJR and tributaries, there are incomplete records at many stations; some interpretation of available data is required to identify seasonal and flow-related patterns.

The historical monthly flow and EC data are summarized in tables for each station giving the cumulative distribution of monthly flow for the available data (1985–2011). The monthly data are summarized with the minimum value and in 10 percent cumulative distribution increments, (e.g., 10^{th} percentile, 20^{th} percentile, 30^{th} percentile, etc.) up to the maximum value, along with the average monthly value. These tables show the historical range and distribution of flow and EC values. The unimpaired flows (estimated flows without diversions or storage) for the entire period of record, 1922–2010, are given for each watershed. The comparison of unimpaired flows with recent historical flow data indicates the general degree of water resources development (storage and diversions) within each basin.

F.2.2.1 Comparison of Unimpaired and Historical SJR Flows

Table F.2-1a shows the monthly cumulative distribution of SJR unimpaired runoff (cfs) at Friant Dam for 1922–2003 (CALSIM 82-year analysis period). The range of monthly runoff is summarized with 10th percentile values from the minimum to the maximum. The median (50th percentile) monthly values provide a good summary of the seasonal pattern. The maximum runoff was in April, May, and June. The minimum runoff was in September, October, and November. The range of flows from year-to-year is large. The annual runoff ranged from less than 803 thousand acre-feet (TAF) (10th percentile) to about 3,044 TAF (90th percentile). The average annual runoff for the SJR at Friant Dam was 1,732 TAF, representing about 28 percent of the SJR unimpaired flow at Vernalis. The median runoff was 1,453 TAF.

Table F.2-1a. Monthly Cumulative Distribution of SJR Unimpaired Flow (cfs) at Friant Dam for WY 1922–2003

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	81	95	121	161	204	305	957	1,216	587	260	150	75	362
10%	115	171	237	296	541	1,079	2,134	3,400	2,029	667	233	127	803
20%	157	223	267	384	760	1,353	2,583	3,907	2,487	754	282	169	936
30%	171	257	345	535	956	1,545	2,889	5,063	3,552	920	363	194	1,128
40%	206	290	508	632	1,111	1,731	3,399	6,084	4,675	1,462	440	226	1,250
50%	266	354	584	768	1,340	1,925	3,966	6,916	5,430	1,868	556	259	1,453
60%	301	436	723	1,105	1,800	2,146	4,194	7,560	6,209	2,365	701	312	1,856
70%	338	546	894	1,332	2,050	2,614	4,693	8,283	8,052	2,968	840	382	2,048
80%	389	706	1,187	1,833	2,889	3,334	5,194	9,677	9,793	4,319	1,191	551	2,410
90%	544	1,101	1,892	2,743	3,741	3,773	5,879	11,456	10,789	5,982	2,056	699	3,044
maximum	2,048	4,151	7,489	11,953	8,506	7,895	10,300	17,826	19,597	12,225	4,558	2,853	4,642
average	315	563	969	1,351	1,837	2,342	3,978	7,043	6,275	2,736	850	404	1,732

Table F.2-1b shows the monthly cumulative distribution of historical (observed) flow below Friant Dam (cfs) for 1985–2009 (recent 25-year period). The median monthly flow values provide a good summary of the seasonal release pattern. The highest median flows of 200 cfs are in June, July, and August. The highest historical flows (90th percentile) were greater than 2,000 cfs in February–June, indicating that flood control releases were made in a few years in each of these months. The 90th percentile flows in April and May were greater than 4,500 cfs. The 80th percentile flows in March, April, and May were greater than 1,000 cfs. The monthly ranges of historical flows below Friant Dam were large only in months with flood control releases. The historical average annual flow volume released from Friant Dam was about 400 TAF. The median annual flow volume was about 130 TAF, indicating that the flood releases in a few years raised the average flow volume below Friant Dam to about 3 times the median flow.

Table F.2-1b. Monthly Cumulative Distribution of SJR Historical Flow (cfs) below Friant Dam for WY 1922–2009

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	61	56	36	32	39	36	97	121	136	150	124	114	64
10%	107	73	58	39	67	88	107	126	153	172	152	132	81
20%	124	96	78	58	78	92	119	144	182	198	191	157	103
30%	146	107	93	85	87	109	139	158	194	209	199	173	114
40%	155	118	97	94	95	119	144	165	244	219	208	183	121
50%	158	120	103	96	100	137	156	181	281	232	232	189	132
60%	160	125	104	100	110	174	192	218	301	260	245	219	161
70%	174	133	110	111	127	422	253	262	345	281	261	237	302
80%	190	147	117	118	457	1,004	1,258	1,016	637	573	278	251	766
90%	215	173	164	203	2,260	2,076	4,652	4,672	2,946	739	318	292	1,305
maximum	357	378	1,147	9,144	6,514	6,548	7,367	7,637	6,535	5,322	464	383	1,657
average	165	129	156	468	674	802	1,172	1,172	973	659	239	209	411

Table F.2-1c shows the monthly cumulative distribution of Merced River unimpaired runoff (cfs) at New Exchequer Dam for 1922–2003. The maximum runoff was in April, May, and June. The minimum runoff was in August, September, October, and November. The annual runoff ranged from less than 412 TAF (10th percentile) to about 1,718 TAF (90th percentile). The average annual runoff for the Merced River was 960 TAF, representing about 16 percent of the unimpaired SJR flow at Vernalis. The median runoff was 894 TAF.

Table F.2-1c. Monthly Cumulative Distributions of Merced River Unimpaired Flow (cfs) for 1922–2003

	Merced River Unimpaired Runoff (cfs) for Water Years 1922–2003												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	8	20	17	54	55	131	519	637	212	62	-	-	150
10%	23	59	89	162	337	601	1,352	1,650	741	129	27	-	412
20%	33	86	129	214	461	851	1,562	2,179	870	191	42	4	498
30%	46	102	167	326	579	970	1,927	2,832	1,400	292	63	22	566
40%	63	126	256	377	801	1,102	2,155	3,295	1,923	416	83	34	669
50%	81	152	354	571	969	1,303	2,391	3,955	2,451	529	121	58	894
60%	96	222	448	763	1,235	1,518	2,667	4,332	2,868	721	183	79	1,070
70%	116	302	560	1,069	1,821	1,875	2,880	4,730	3,462	842	221	102	1,158
80%	159	372	862	1,500	2,578	2,489	3,246	5,223	4,403	1,344	273	133	1,412
90%	255	699	1,647	2,579	3,514	2,718	3,643	6,400	5,633	1,991	514	203	1,718
maximum	835	4,346	6,058	10,306	6,295	6,013	7,206	9,194	11,025	5,719	1,578	798	2,787
average	115	335	703	1,073	1,496	1,643	2,473	3,932	2,875	909	208	93	960

Table F.2-1d shows the monthly cumulative distribution of historical (observed) Merced River flow (cfs) at Stevinson (downstream of Dry Creek) for 1985–2009 (recent 25-year period). The average unimpaired flow for this 25-year period was 937 TAF (98 percent of the 1922–2003 average). The highest median flows were in April and May, which are the months with highest unimpaired runoff.

The highest historical Merced River flows (90th percentile) were greater than 1,500 in February–June, indicating that flood control releases were made in a few years in each of these months. The 90th percentile flows in March, April, and May were greater than 2,500 cfs. The 80th percentile flows in March, April, and May were greater than 1,500 cfs. The monthly ranges of historical Merced River flows were large only in months with flood control releases. The median flows in the summer months of July–September were less than 150 cfs. The historical average annual flow volume for the Merced River at Stevinson was 438 TAF, about 47 percent of the average unimpaired flow for this period. The median annual flow volume was 267 TAF, indicating that flood releases in a few years raised the average flow volume in the Merced River to about 1.5 times the median flow.

Table F.2-1d. Monthly Cumulative Distribution of Historical Merced River Flow (cfs) at Stevinson for 1985–2009

	Historical Merced River Flow (cfs) at Stevinson for Water Years 1985–2009												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	32	131	171	129	69	166	136	91	25	6	18	25	73
10%	75	183	199	205	218	236	167	139	104	34	30	45	102
20%	159	231	218	226	243	250	183	191	126	59	65	78	140
30%	263	246	227	242	269	272	307	313	156	97	88	95	193
40%	298	248	236	259	312	285	357	647	180	125	100	114	220
50%	325	254	255	318	323	313	449	669	192	136	125	127	267
60%	374	271	293	421	351	363	622	734	257	178	145	186	324
70%	440	329	385	563	453	1,047	985	857	377	210	163	211	476
80%	526	423	473	697	933	2,360	1,425	1,409	609	321	313	371	703
90%	914	568	631	826	1,605	2,733	2,868	2,628	2,200	840	645	720	1,185
maximum	1,861	635	2,019	7,347	6,990	2,964	4,616	4,113	3,185	2,456	722	1,127	1,275
average	435	316	410	754	912	969	1,019	1,013	599	361	215	259	438

Table F.2-1e gives the monthly cumulative distribution of Tuolumne River unimpaired flows for 1922–2003. The peak runoff for the Tuolumne River is in May and June, and relatively high runoff (median monthly runoff greater than 2,000 cfs) is from February–June. The minimum flows are observed in August, September, and October. The annual unimpaired runoff ranged from 842 TAF (10th percentile) to 3,109 TAF (90th percentile), with a median runoff of 1,776 TAF. The average unimpaired flow was 1,853 TAF/year, slightly more than the median runoff. The average Tuolumne River runoff represents about 30 percent of unimpaired flow at Vernalis. Because about 290 TAF/year is diverted (to San Francisco) upstream of New Don Pedro Reservoir, the average inflow to New Don Pedro is about 1,563 TAF/year (85 percent of Tuolumne River unimpaired flow).

Table F.2-1e. Monthly Cumulative Distributions of Tuolumne River Unimpaired Flow (cfs) for 1922–2003

	Tuolumne River Unimpaired Runoff (cfs) for Water Years 1922–2003												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	-	21	55	81	142	379	1,326	1,724	283	166	-	-	383
10%	64	134	219	359	752	1,354	2,719	3,467	1,509	283	52	19	842
20%	87	150	332	529	1,046	1,881	3,136	4,730	2,280	364	104	42	1,055
30%	116	239	423	685	1,216	2,093	3,706	5,620	3,708	559	153	63	1,189
40%	149	284	550	887	1,514	2,358	4,144	6,162	4,850	919	212	85	1,414
50%	178	382	783	1,213	2,085	2,566	4,498	7,343	5,648	1,119	289	125	1,776
60%	193	564	920	1,715	2,496	2,870	4,927	8,071	6,722	1,781	359	165	2,024
70%	254	804	1,322	2,130	2,924	3,449	5,366	8,744	7,468	2,329	447	221	2,176
80%	329	1,153	1,774	2,818	4,034	4,163	5,809	9,355	8,923	3,114	563	294	2,516
90%	609	1,636	3,562	4,224	5,360	5,511	6,473	10,710	10,040	4,942	901	374	3,109
maximum	2,486	8,765	10,565	16,806	10,718	9,411	11,097	15,617	17,077	10,598	3,337	1,745	4,631
average	265	807	1,441	2,020	2,586	3,088	4,601	7,258	5,913	2,012	432	205	1,853

Table F.2-1f gives the monthly cumulative distribution (range) of historical flows in the Tuolumne River at Modesto for the recent period of 1984–2009. The average unimpaired flow for this 25-year period was 1,823 TAF (98 percent of the 1922–2003 average). The average monthly historical flows were about 500 cfs in summer and fall (July–December) and were 1,000 cfs to 2,000 cfs in winter and spring (January–June). The 10th percentile historical flows were greater than 200 cfs from November through May and were about 100 cfs in other months. The annual historical Tuolumne River flow volume ranged from 155 TAF (10th percentile) to 2,273 TAF (90th percentile). The median historical annual river flow was 361 TAF. The average annual historical flow was 811 TAF, more than 2.25 times the median, suggesting that the majority of historical flow was the result of flood control releases in wet years. The average historical flow was about 45 percent of the average unimpaired flow, but the majority of this historical flow was in wet years with flood control releases. New Don Pedro Reservoir allows considerable carryover storage from one year to the next. Although flood control releases are not necessary every year, it is difficult to anticipate when reservoir releases for flood control storage will be required. The LSJR alternatives will generally increase releases in February–June and thereby reduce flood control releases in wet years.

Table F.2-1f. Monthly Cumulative Distribution of Historical Tuolumne River Flow (cfs) at Modesto for 1985–2009

	Monthly Cumulative Distribution of Tuolumne River Flow (cfs) at Modesto for Water Years 1985–2009												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	135	162	176	154	166	239	271	144	104	97	97	111	134
10%	166	204	193	205	243	260	362	274	115	109	120	121	155
20%	233	227	237	287	266	288	389	412	143	134	142	167	202
30%	251	254	253	369	418	301	538	465	210	198	190	185	264
40%	337	294	314	462	458	353	683	604	248	241	241	222	303
50%	408	317	408	543	474	742	752	734	255	253	264	256	361
60%	579	445	429	643	1,373	1,113	1,006	871	386	330	357	422	550
70%	629	472	457	834	2,467	3,589	1,788	1,359	479	353	444	514	1,112
80%	728	494	745	1,396	3,163	4,746	3,402	2,943	981	503	556	689	1,440
90%	1,098	544	1,765	2,262	5,371	5,524	5,512	4,556	4,262	1,769	996	974	2,273
maximum	1,794	1,212	4,996	15,498	8,782	6,182	8,264	7,964	5,481	3,291	1,437	2,365	2,399
average	542	414	735	1,453	1,964	2,041	1,971	1,752	1,047	602	422	498	811

Table F.2-1g gives the monthly cumulative distribution of Stanislaus River unimpaired flows for 1922–2003. Each month has a range of runoff depending on rainfall and accumulated snowpack. The median (50^{th} percentile) monthly flows generally characterize the seasonal runoff pattern. The peak runoff for the Stanislaus River is in May and June, and relatively high runoff (median monthly runoff greater than 1,000 cfs) is from February–June. The lowest median flows of about 150 cfs are in August, September, and October. The annual unimpaired runoff ranged from 467 TAF (10^{th} percentile) to 1,921 TAF (90^{th} percentile), with a median runoff of 1,088 TAF. The average unimpaired flow was 1,120 TAF/year, only slightly more than the median runoff. The average Stanislaus River runoff represents about 18 percent of average unimpaired flow at Vernalis.

Table F.2-1g. Monthly Cumulative Distributions of Stanislaus River Unimpaired Flow (cfs) for 1922–2003

	Stanislaus River Unimpaired Runoff (cfs) for Water Years 1922–2003												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	-	35	56	47	25	218	586	723	190	-	-	-	155
10%	48	95	146	218	398	827	1,683	1,634	681	107	33	16	467
20%	70	125	189	301	576	1,142	2,108	2,637	978	213	60	37	593
30%	90	155	217	400	781	1,326	2,509	3,020	1,629	308	92	57	680
40%	107	170	310	512	954	1,569	2,900	3,807	2,105	426	111	68	892
50%	128	229	399	664	1,251	1,704	3,247	4,657	2,757	556	152	80	1,088
60%	155	288	515	923	1,759	2,023	3,485	5,236	3,215	814	180	89	1,250
70%	175	381	726	1,402	1,884	2,304	3,868	5,781	3,664	1,029	222	115	1,356
80%	195	520	951	1,895	2,339	2,622	4,274	6,361	4,184	1,368	302	162	1,570
90%	253	804	2,028	2,940	3,417	3,802	4,631	7,153	5,572	1,810	425	216	1,921
maximum	1,438	6,155	6,704	10,724	9,250	6,742	7,271	9,675	10,627	4,659	1,246	643	2,952
average	157	463	858	1,322	1,685	2,076	3,226	4,585	2,953	867	203	112	1,120

Table F.2-1h gives the monthly cumulative distribution (range) of historical flows in the Stanislaus River at Ripon for the recent period of 1984–2009. The average unimpaired flow for this 25-year period was 1,081 TAF (97 percent of the 1922–2003 average). The Stanislaus release flow requirements have generally increased during this period. The average monthly historical flows were about 500–600 cfs in summer and fall (July–December) and about 850–1,250 cfs from January–June. The 10th percentile historical flows were between 250 cfs and 500 cfs in all months. The annual historical Stanislaus River flow volume ranged from 309 TAF (10th percentile) to 1,172 TAF (90th percentile). The median historical annual river flow was 421 TAF. The average annual historical flow was 584 TAF, about 1.5 times the median flow, suggesting that a few years had substantial flood control releases. The average historical flow was about 52 percent of the average unimpaired flow, but the majority of this historical flow was in a few wet years with flood control releases. New Melones Reservoir allows considerable carryover storage from one year to the next. Although flood control releases are not necessary every year, it is difficult to anticipate when reservoir releases for flood control storage will be required. The LSJR alternatives will generally increase releases in February–June and thereby reduce flood control releases in wet years.

Table F.2-1h. Monthly Cumulative Distribution of Historical Stanislaus River Flow (cfs) at Ripon for 1985–2009

	Monthly Cumulative Distribution of Stanislaus River Flow (cfs) at Ripon for Water Years 1985–2009												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	251	218	179	168	183	260	251	349	218	262	215	207	191
10%	323	290	222	194	220	308	507	532	464	339	305	273	309
20%	339	312	262	240	297	381	595	742	578	408	327	304	330
30%	391	317	304	313	312	501	742	841	591	434	356	316	344
40%	434	322	316	378	349	643	813	877	609	480	368	325	384
50%	479	373	341	404	435	854	902	1,091	712	502	404	369	421
60%	505	392	402	458	623	1,013	976	1,302	848	560	417	416	480
70%	556	414	442	614	850	1,138	1,112	1,424	1,016	654	522	458	607
80%	613	428	817	1,064	1,510	2,250	1,299	1,506	1,176	743	657	490	798
90%	819	627	943	1,508	2,824	2,980	1,850	1,592	1,312	1,099	1,197	978	1,172
maximum	1,951	962	3,194	6,273	6,499	4,887	4,537	4,130	1,867	1,876	1,792	1,702	1,537
average	579	409	559	898	1,111	1,291	1,102	1,205	843	631	559	497	584

Table F.2-1i gives the monthly cumulative distribution of the SJR at Vernalis unimpaired flows for 1922–2003. Each month has a range of runoff depending on seasonal rainfall and accumulated snowpack. The median (50th percentile) monthly flows generally characterize the seasonal runoff pattern and are largely the sum of the unimpaired runoff from the four sub-basins draining the Sierra Nevada described above. The peak runoff for the SJR at Vernalis is in May, with relatively high median monthly runoff (> 15,000 cfs) in April, May, and June. The lowest median flows of about 500 cfs are in September and October. The annual unimpaired runoff ranged from 2,565 TAF (10th percentile) to 11,035 TAF (90th percentile), with a median runoff of 5,804 TAF. The average unimpaired flow was 6,176 TAF/year, only slightly more than the median runoff. The majority of the average SJR at Vernalis runoff originated above Friant Dam and the three tributary river dams. About 500 TAF (8 percent) of the Vernalis flow was from the westside creeks and the valley floor watersheds below the four major storage dams.

Table F.2-1i. Monthly Cumulative Distributions of SJR Unimpaired Flow (cfs) at Vernalis for 1922–2003

	SJR Unimpaired Runoff (cfs) at Vernalis for Water Years 1922–2003												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	135	226	270	370	469	1,065	3,421	4,332	1,271	596	179	119	1,060
10%	266	482	756	1,090	2,203	4,328	8,453	10,196	5,050	1,248	390	228	2,565
20%	402	679	961	1,631	3,242	5,925	9,345	13,532	6,683	1,558	556	298	3,294
30%	472	799	1,191	2,174	4,063	6,502	11,451	16,697	10,444	2,167	705	349	3,626
40%	573	875	1,687	2,771	4,846	7,239	13,180	19,843	13,957	3,397	821	449	4,372
50%	611	1,141	2,264	3,544	6,294	8,227	15,205	23,054	16,240	4,044	1,095	528	5,804
60%	771	1,607	3,037	5,522	8,656	9,940	16,063	26,775	19,258	5,671	1,475	631	6,471
70%	919	2,118	4,004	6,582	10,908	11,608	18,291	28,163	23,256	7,338	1,746	767	7,370
80%	1,093	3,163	5,635	10,125	15,598	15,808	19,438	31,439	27,828	10,359	2,165	1,102	8,745
90%	1,433	4,567	10,127	16,209	22,086	18,631	24,588	39,962	34,832	15,453	3,969	1,409	11,035
maximum	6,937	25,787	35,970	61,733	41,703	42,337	43,320	57,955	63,738	34,979	11,891	5,812	18,978
average	889	2,346	4,557	6,880	9,459	10,839	15,639	23,881	18,722	6,728	1,720	832	6,176

Table F.2-1j gives the monthly cumulative distribution (range) of the historical SJR flows observed at Vernalis for the recent period of 1984–2009. The average unimpaired flow for this 25-year period was 5,964 TAF (97 percent of the 1922–2003 average). The release flow requirements on the three tributary rivers have generally increased during this period. The average monthly historical flows were about 2,000–2,500 cfs in summer and fall (July–December) and were about 4,000–6,000 cfs from January–June. The 10th percentile historical flows were between 750 cfs and 1,500 cfs in all months. The annual historical SJR at Vernalis flow volume ranged from 886 TAF (10th percentile) to 6,644 TAF (90th percentile). The median historical annual SJR flow volume at Vernalis was 1,707 TAF. The average annual historical SJR at Vernalis flow volume was 2,777 TAF, about 1.5 times the median flow, suggesting that a few years had substantial flood control releases. The average historical SJR flow at Vernalis was about 46 percent of the average unimpaired flow for this 25-year period, but the majority of this historical flow was observed in a few wet years with flood control releases.

Table F.2-1j. Monthly Cumulative Distribution of Historical SJR Flow (cfs) at Vernalis for 1985–2009

	Monthly Cumulative Distribution of Historical SJR Flow (cfs) at Vernalis for Water Years 1985–2009												
	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	Annual (TAF)
minimum	788	956	895	816	758	1,422	1,168	892	481	447	483	574	656
10%	1,047	1,125	1,040	1,160	1,375	1,768	1,457	1,480	1,059	709	712	872	886
20%	1,343	1,285	1,292	1,437	1,789	2,097	1,905	1,968	1,115	1,110	980	939	1,144
30%	1,435	1,565	1,405	1,816	2,008	2,196	2,262	2,141	1,435	1,163	1,118	1,132	1,259
40%	1,734	1,685	1,548	2,106	2,175	2,429	2,545	2,638	1,660	1,306	1,236	1,335	1,385
50%	2,003	1,759	1,688	2,319	2,534	2,736	2,751	2,755	1,748	1,400	1,557	1,452	1,707
60%	2,567	2,004	2,085	2,500	3,152	3,421	3,173	3,560	2,157	1,682	1,913	1,970	1,928
70%	2,703	2,146	2,231	3,784	6,227	8,279	4,956	4,808	2,747	2,055	2,027	2,145	3,448
80%	3,181	2,528	2,587	4,625	7,796	12,285	8,012	8,490	4,238	2,624	2,604	2,484	4,206
90%	3,836	2,771	4,081	5,582	11,607	14,887	19,796	14,933	12,398	4,990	3,491	3,835	6,644
maximum	6,153	3,290	12,192	30,377	35,057	25,035	27,937	26,055	17,760	13,193	5,442	5,758	8,588
average	2,396	1,904	2,435	4,131	6,144	6,594	6,355	5,804	3,951	2,514	1,845	1,956	2,777

F.2.2.2 Historical Patterns of SJR Flow and Salinity

The salinity of runoff from Sierra Nevada watersheds is relatively low. Although rainfall has an EC of less than 25 μS/cm, water released from Millerton Lake (Friant Dam) and the major tributary reservoirs has a measured EC of about 25–75 μS/cm. The EC measurements below each major dam indicate that salinity of the runoff is constant and does not change substantially between dry years and wet years. The only daily EC data measured below the reservoirs is the station at Friant, with measurements beginning in 2004. Grab samples from below the tributary reservoirs generally indicate similar range of EC values. The EC generally increases downstream in the SJR and tributary rivers because of agricultural drainage and groundwater discharge to the river, with relatively high EC. The increase in EC is generally greater when river flow is low. Near the confluence with the SJR, the measured monthly EC in the Merced River (at Stevinson) ranged from about 50–400 μS/cm; the measured monthly EC in the Tuolumne River (at Modesto) ranged from about 50–300 μS/cm; the measured monthly EC in the Stanislaus River (at Ripon) ranged from about 75–150 μS/cm.

Figure F.2-1a shows the historical monthly flows at stations upstream of the Merced River. The SJR flows upstream of the Merced River can be estimated by subtracting the Merced River flow from the SJR at Newman flow (just downstream of the Merced River). The estimated SJR flow above the Merced River is dominated by flood-control releases from Friant Dam and local runoff in a few months during wet years.

In most years, the SJR flows at Stevinson are very low (25–50 cfs), with EC values of 1,000–2,000 μS/cm in the last 10 years; higher EC values were measured in the 1990–1992 drought period. These low SJR flows originate from Bear Creek and local agricultural drainage (irrigation return) flows during summer.

Downstream of Stevinson, the combined flows from Salt and Mud Sloughs contribute a relatively constant flow of about 250–500 cfs, with a Salt Slough EC of about 1,000–2,000 μS/cm since 1996 when the Grasslands Bypass project separated the high selenium drainage (with high EC) from Salt Slough. The Mud Slough EC, which now contains most of the high selenium and high EC drainage, has an EC of 1,000–4,000 μS/cm. The Fremont flow and EC (just upstream of Mud Slough) can be combined with the Mud Slough flow and EC to provide an estimate of the SJR flow and EC upstream of Merced River; these monthly estimates generally range from 1,500–2,500 μS/cm from 1986–1989 and 2002-2011, years when measurement data are available to make the estimates.

Figure F.2-1b shows the calculated monthly salt loads for the SJR upstream of the Merced River, estimated as the Fremont salt load plus the Mud Slough Salt load. Another estimate of the SJR upstream of the Merced River flow and salt loads was provided by subtracting the Merced River flow and EC from the SJR at Newman flow and EC (just downstream of the Merced River). These estimates did not always match. The Salt and Mud Slough combined salt loads are also shown on the graph because this was the majority of the flow and salt load during low flow conditions. These salt loads, shown with the SJR monthly flows, generally ranged from about 25,000 tons/month to 75,000 tons/month. The salt loads were sometimes greater than 100,000 tons/month in high flow months, but the EC in these months was relatively low (less than 1,000 μS/cm). There was considerable variation in the monthly flow and EC values and the corresponding salt loads upstream of the Merced River. This is a very important flow and salt measurement location, and every effort should be made to obtain consistent and accurate flow, EC, and salt load estimates for the SJR above the Merced River. The salinity along the SJR and at Vernalis will largely be controlled by the flow and salinity upstream of the Merced River. EC data at the SJR Fremont, Mud Slough, Merced at Stevinson, and SJR Newman stations would allow replicate estimates of the flow, EC, and salt load.

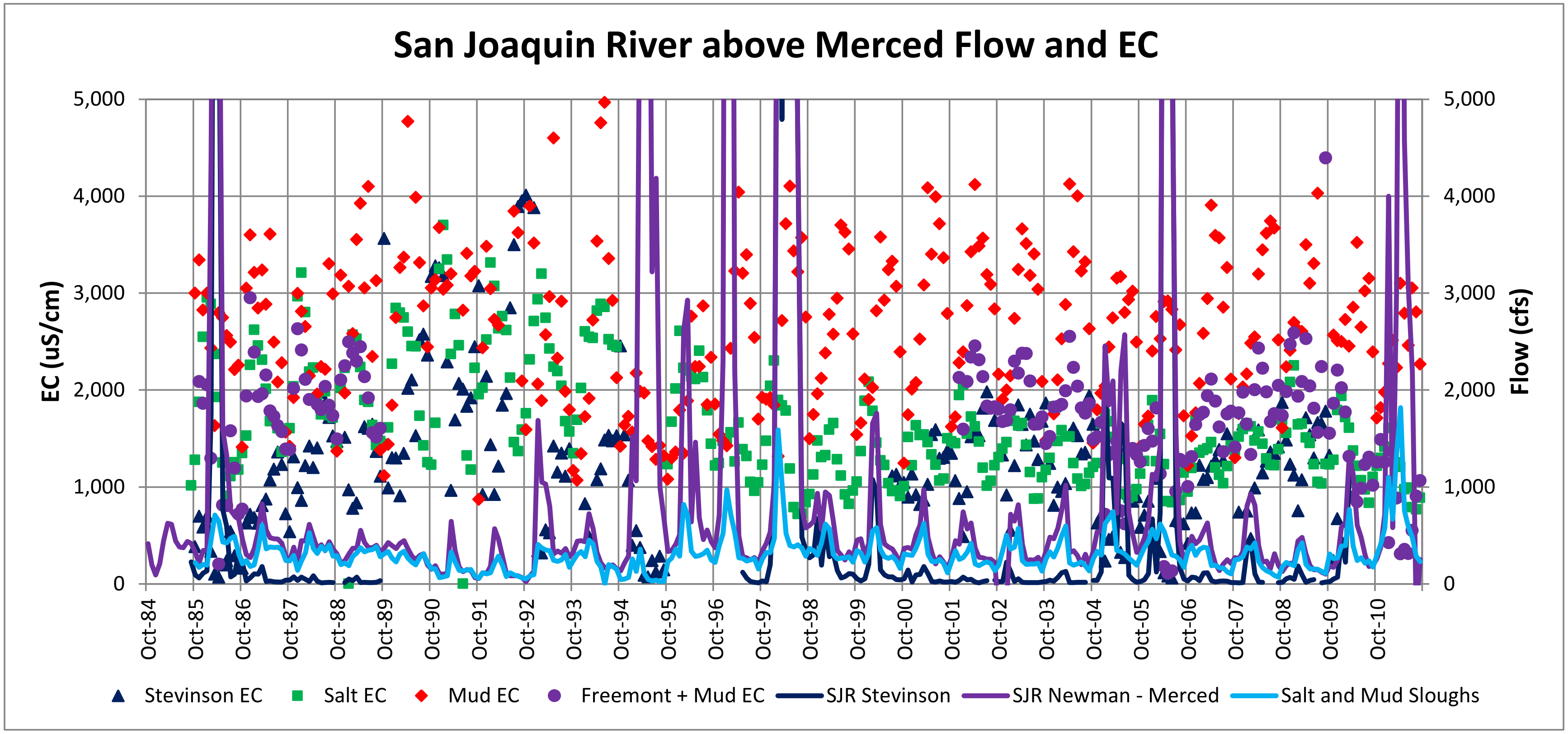


Figure F.2-1a. Historical Monthly Flow and EC in the San Joaquin River Upstream of the Merced River for WY 1985–2011

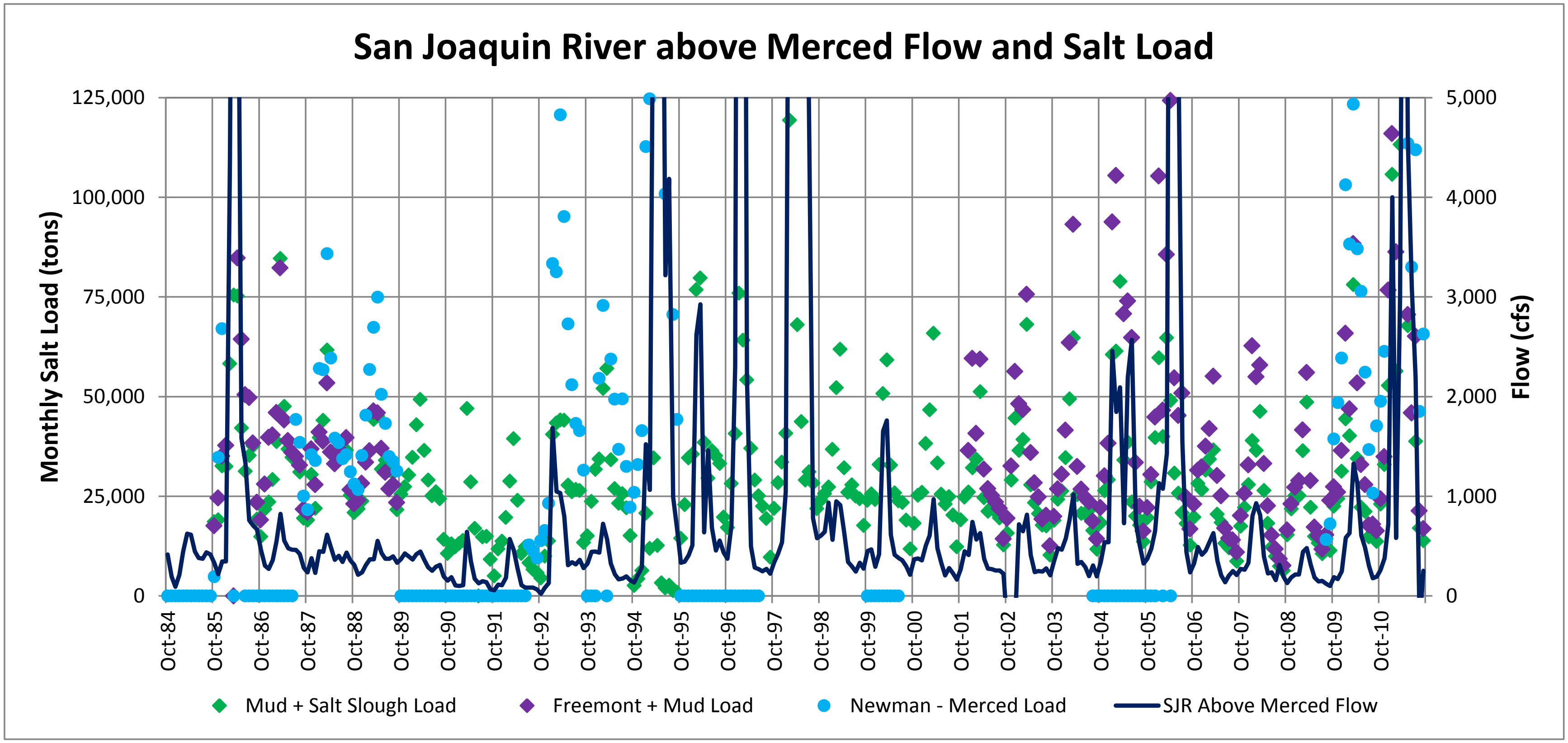


Figure F.2-1b. Historical Monthly Flow and Salt Load in the San Joaquin River Upstream of the Merced River for WY 1985–2011

Figure F.2-1c shows the Merced River flow and EC upstream at Cressy and downstream at Stevinson. The tributary river gains are an important part of the tributary water balance. The river flow generally increases between the upstream reservoir release and the mouth because of runoff (local streams), groundwater seepage, and irrigation return flow (some of which enters the rivers as shallow groundwater). There may be local riparian diversions that reduce the flow during the irrigation season. The volume and EC of these local inflows affect the EC in the river.

The Merced River EC upstream at Cressy was less than 100 μS/cm. EC increased along the length of the river, but was still relatively low at Stevinson (less than 400 μS/cm). For the Merced River, the data indicate that accretions between Cressy and Stevinson generally increased with higher flow (e.g., in association with local runoff). However, the EC at Stevinson tended to be higher at lower flows, when accretions were low or negative (Figure F.2-1d). This trend indicates that the increase in EC along the length of the Merced River is probably caused by a relatively small volume of salty inflow (e.g., agricultural drainage). Despite the longitudinal increase in EC along the length of the Merced River, EC at the downstream end of the Merced River at Stevinson (50-400 μS/cm) was still well below the EC in the SJR upstream of the Merced River (estimated as 1,500 to 2,500 μS/cm as described above), and, therefore, helped to reduce EC in the LSJR.

Figure F.2-1e shows the historical monthly flow and EC at stations downstream of the Merced River. The SJR flows at Newman generally ranged from 250 cfs–1,000 cfs, with lower flows in the dry years and flows of more than 5,000 cfs in wet years. The flows measured at Crows Landing and at Patterson were very similar to the Newman flows. The EC measurements at these three stations between the Merced and Tuolumne Rivers were generally similar, usually ranging from 1,000–1,500 μS/cm but with higher values of 1,500–2,000 μS/cm in the dry years of 1988–1994, and EC values of less than 500 μS/cm during high flows of more than 5,000 cfs.

Figure F.2-1f shows the historical monthly flows and salt loads downstream of the Merced River. The SJR salt loads at Newman, Crows Landing, and Patterson have been measured in different periods with limited overlap; the seasonal pattern is variable and the longitudinal pattern (increase or decrease) is difficult to discern from this graph. As indicated above, the SJR EC in this reach varies from 1,000–1,500 μS/cm in most months, so the monthly salt load generally follows the seasonal flows (i.e., highest in spring, lowest in summer). Because the monthly flows are 500–1,500 cfs in years without major storm flows, the monthly salt loads vary from about 25,000–75,000 tons. The majority of the salt load appears to originate from upstream of the Merced River, although the data suggest a moderate contribution between the Merced River and the Tuolumne River, perhaps from shallow groundwater and agricultural drainage.

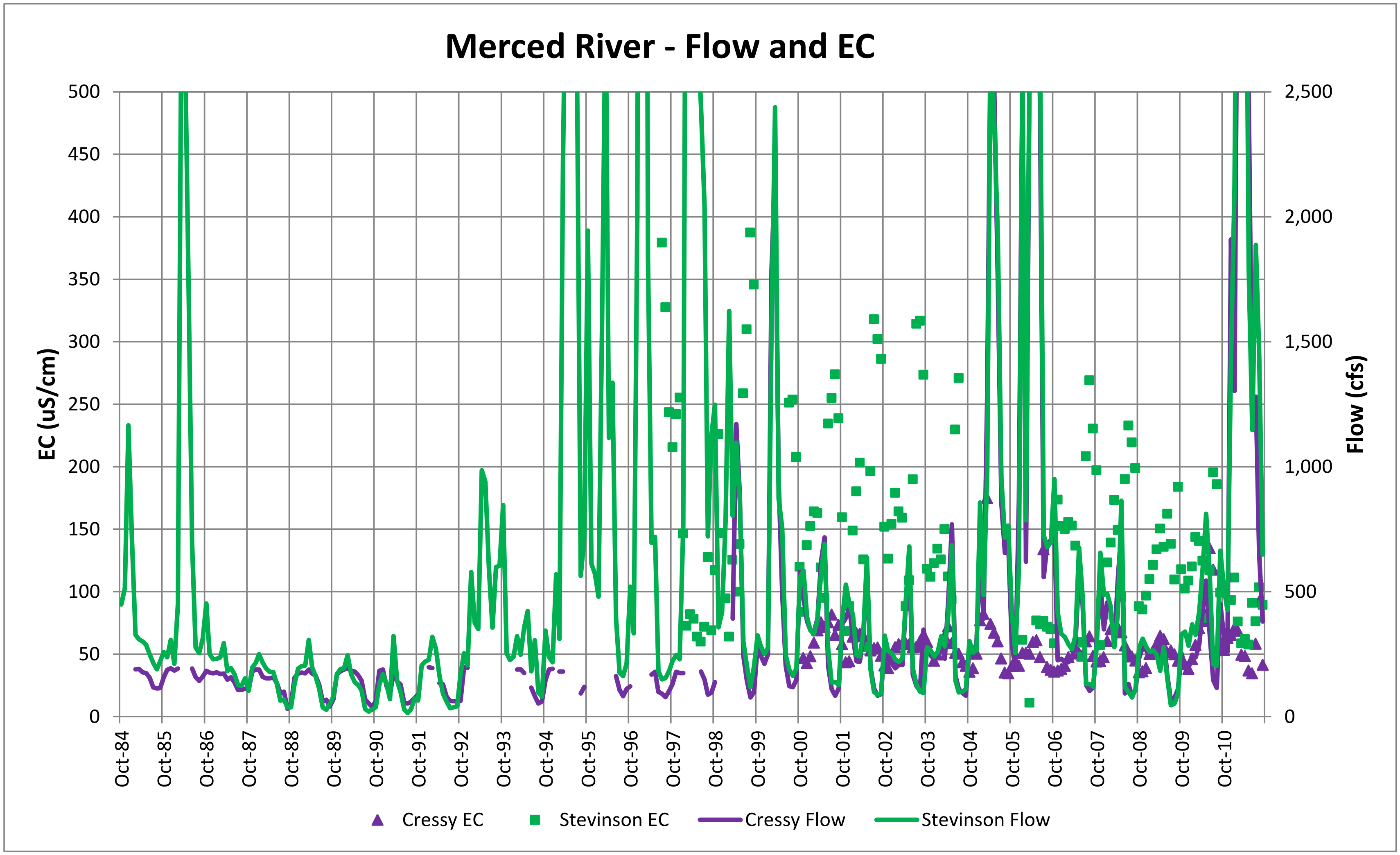


Figure F.2-1c. Time Series of Historical Monthly Flow and EC in the Merced River for WY 1985–2011

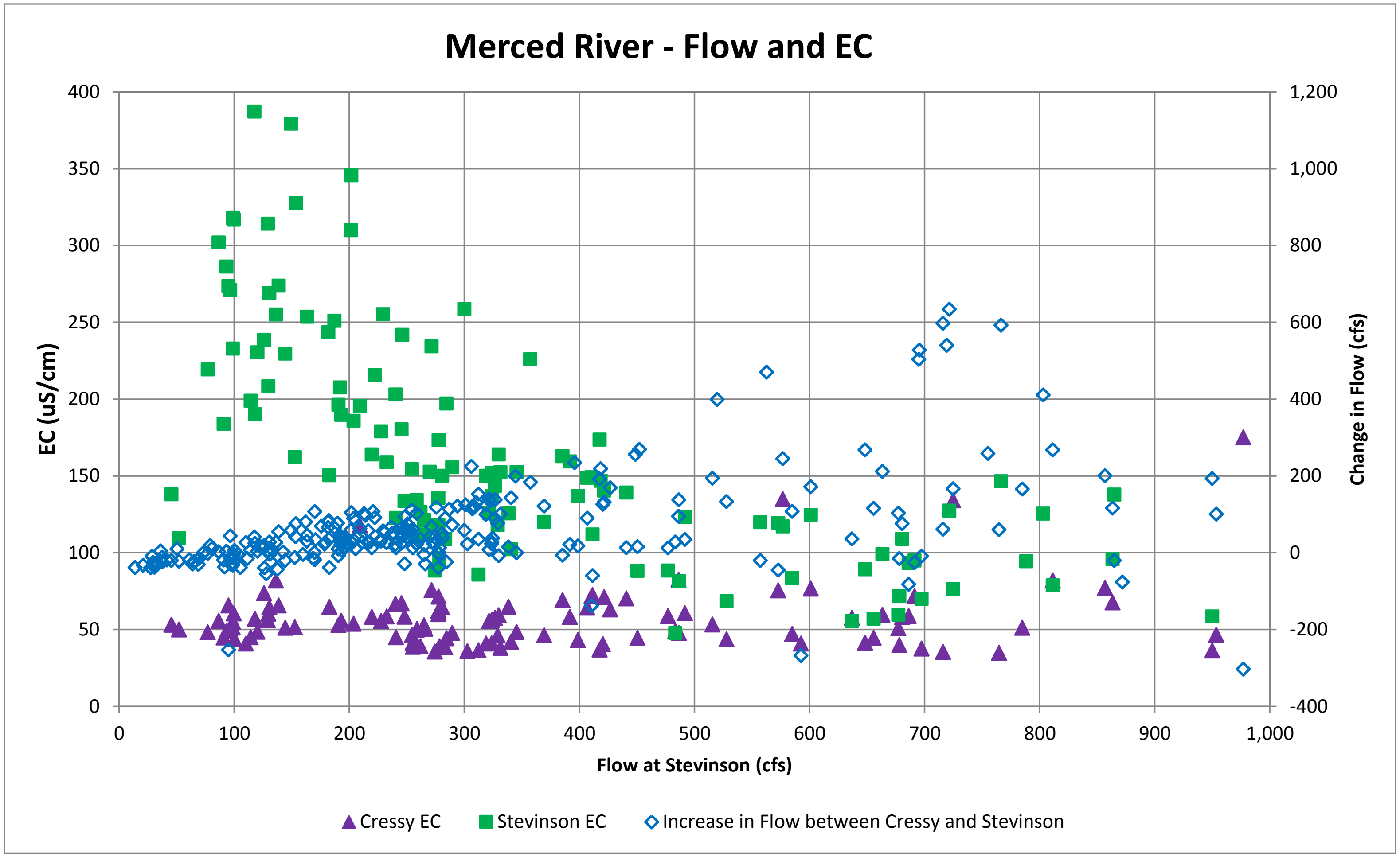


Figure F.2-1d. Relationship between Monthly Merced River Flow, Accretions, and EC for WY 1985–2011

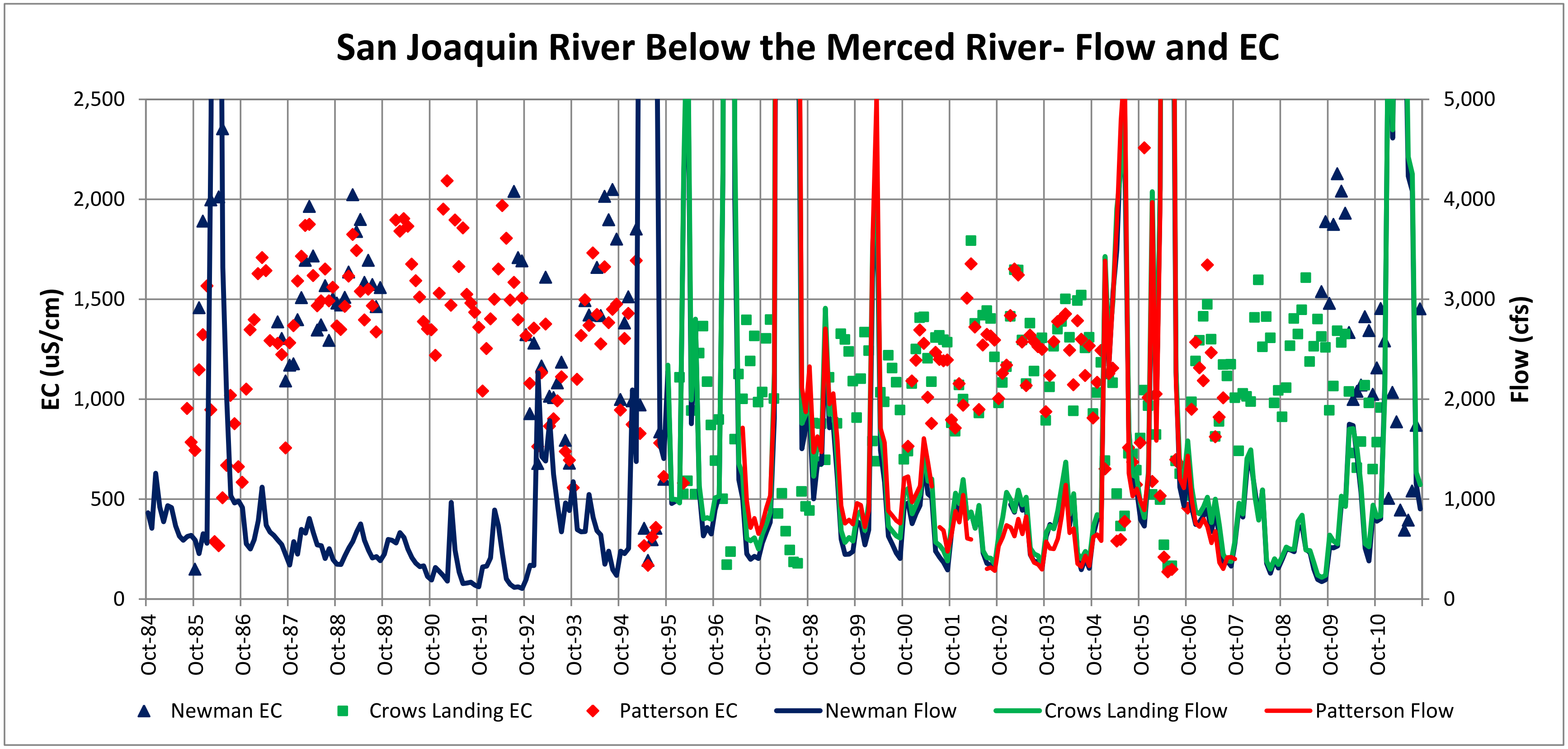


Figure F.2-1e. Historical Monthly Flow and EC in the San Joaquin River Downstream of the Merced River for WY 1985–2011

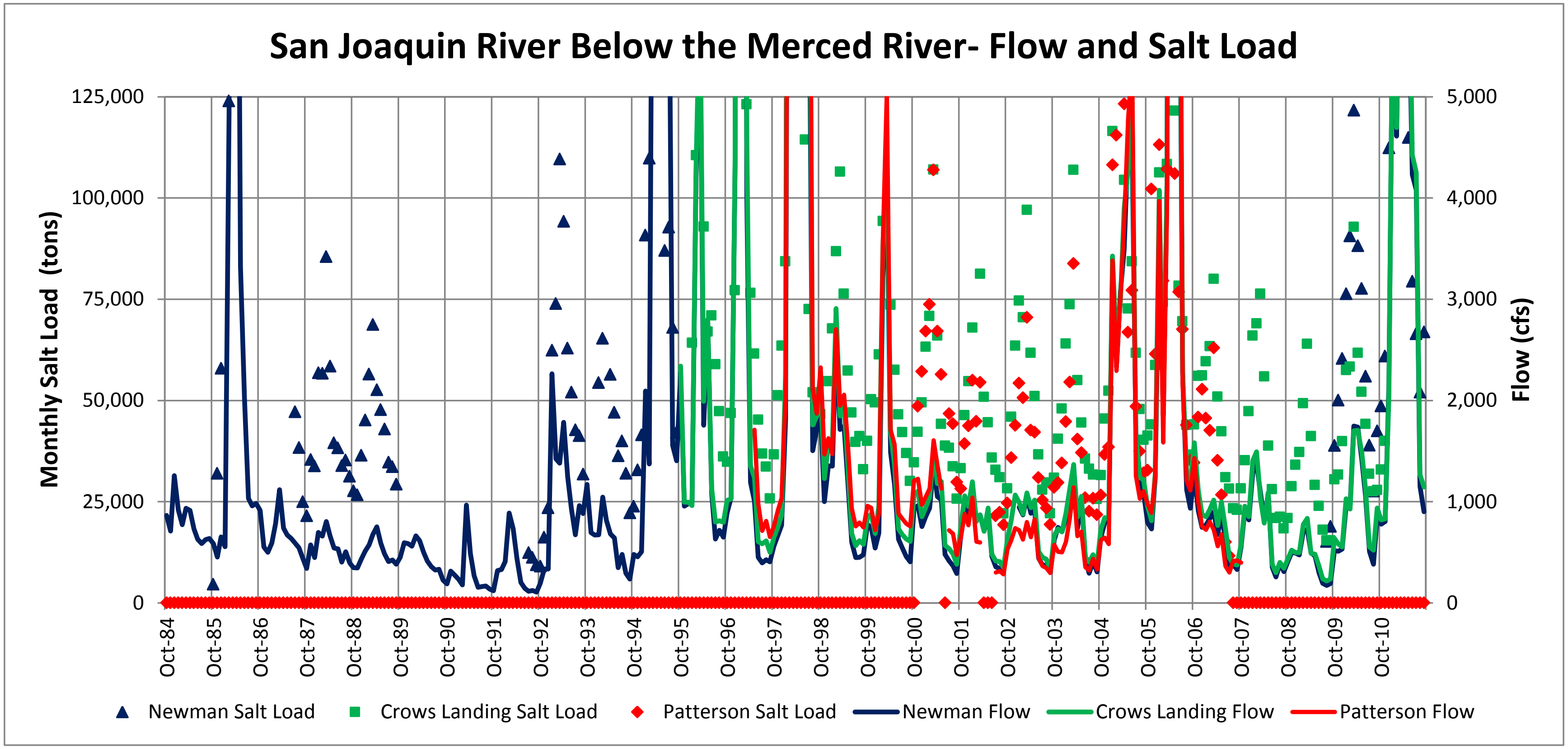


Figure F.2-1f. Historical Monthly Flow and Salt Load in the San Joaquin River Downstream of the Merced River for WY 1985–2011

Figure F.2-1g shows the Tuolumne River EC near the downstream end at Modesto as well as flow at Modesto and upstream at La Grange. Time series data for EC at La Grange is unavailable, but it is likely that EC along the Tuolumne River increases in a manner similar to the Merced River. The data indicate that accretions between La Grange and Modesto tend to increase with higher flow. However, the EC at Modesto tended to be higher at lower flows, when accretions were low (Figure F.2-1h). This trend indicates that Tuolumne River EC is probably affected by a relatively small volume of salty inflow (e.g., agricultural drainage). Despite the higher EC at lower flow, EC at the downstream end of the Tuolumne River at Modesto (50-300 μS/cm) was still well below the EC in the LSJR upstream of the Tuolumne River (usually 1,000 to 1,500 μS/cm as described above), and, therefore, helped to reduce EC in the LSJR.

Figure F.2-1i shows the historical monthly SJR flows and EC values at Maze, located downstream of the Tuolumne River and upstream of the Stanislaus River. The SJR flows at Maze generally ranged from 250–2,500 cfs, with lower flows in the dry years and flows of more than 5,000 cfs in wet years. The EC values at Maze were measured by DWR prior to 1992 and since 2007, but were estimated from the Vernalis flow and EC subtracting the Stanislaus flow and EC for the intermediate years. During wet years, the Maze EC ranged from less than 250 μS/cm to about 1,000 μS/cm. The Maze EC ranged from 1,000–2,000 μS/cm in the 1988–1994 dry period, but the EC has been less than 1,250 μS/cm since 2000. The Tuolumne River flows measured at Modesto are shown to indicate the dilution effect from the low EC water from the Tuolumne River. The Tuolumne River flow was generally 100–500 cfs, with flows of more than 1,000 cfs only in the wet years (flood control releases). This EC data suggests that the SJR at Maze has a moderate salinity with EC values generally less than 1,000 μS/cm, except when flow is less than 1,000 cfs.

Figure F.2-1j shows the Stanislaus River EC near the downstream end at Ripon as well as flow at Ripon and upstream at Goodwin. The data indicate that there is generally a 0 to 200 cfs increase in flow between Goodwin and Ripon, with only a slight trend for higher accretions at higher flows (Figure F.2-1k). EC at Ripon tends to be low (75-150 μS/cm), which indicates a relatively small increase in salt load along the length of the lower Stanislaus River. Even at the lowest flows (200-400 cfs at Ripon), EC generally remained below 150 μS/cm. EC at the downstream end of the Stanislaus River at Ripon was well below the EC in the LSJR upstream of the Stanislaus River (generally between 250 and 1,250 μS/cm since water year 1995 as described above for Maze), and, therefore, helped to reduce EC in the LSJR.

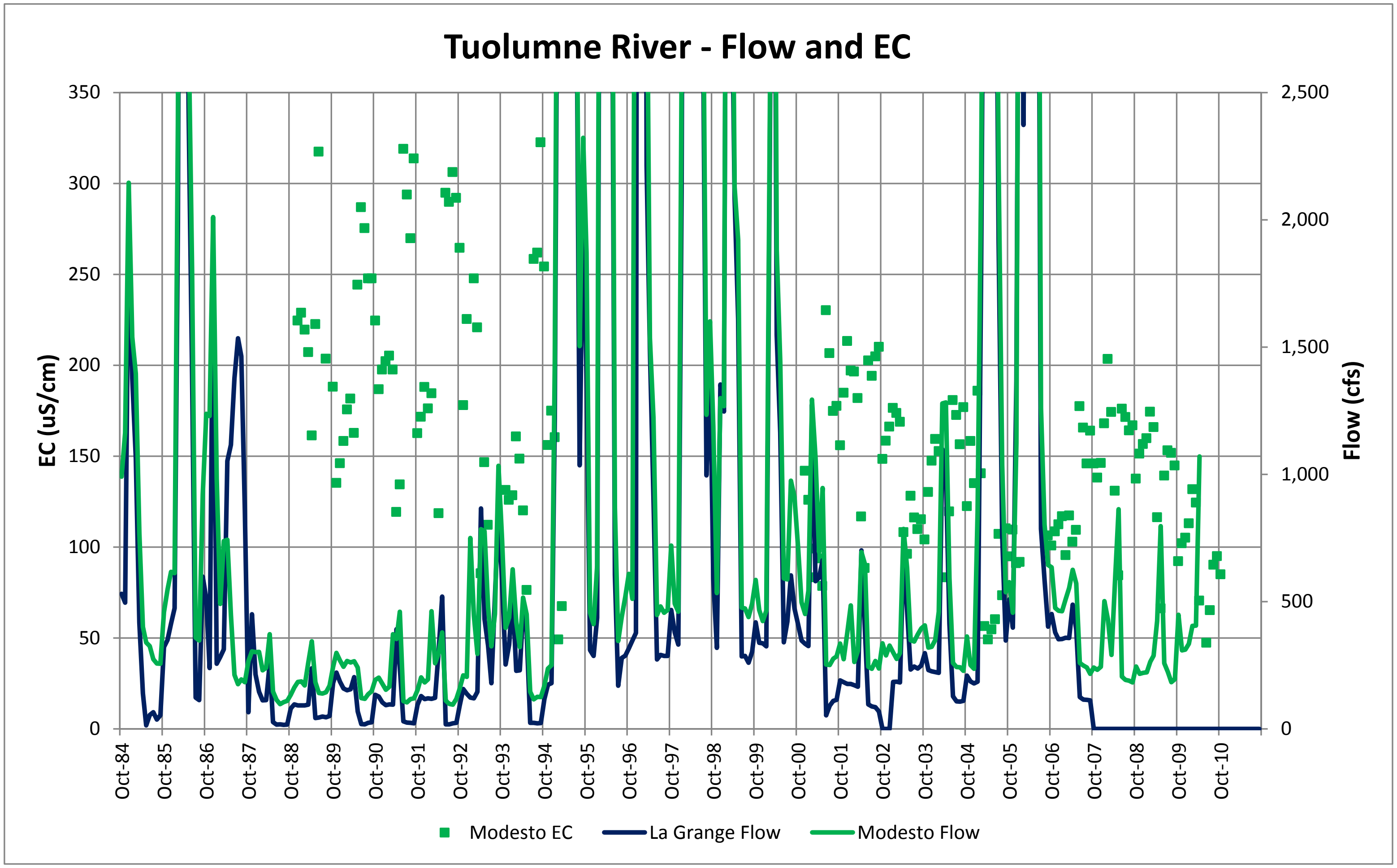


Figure F.2-1g. Time Series of Historical Monthly Flow and EC in the Tuolumne River for WY 1985–2011

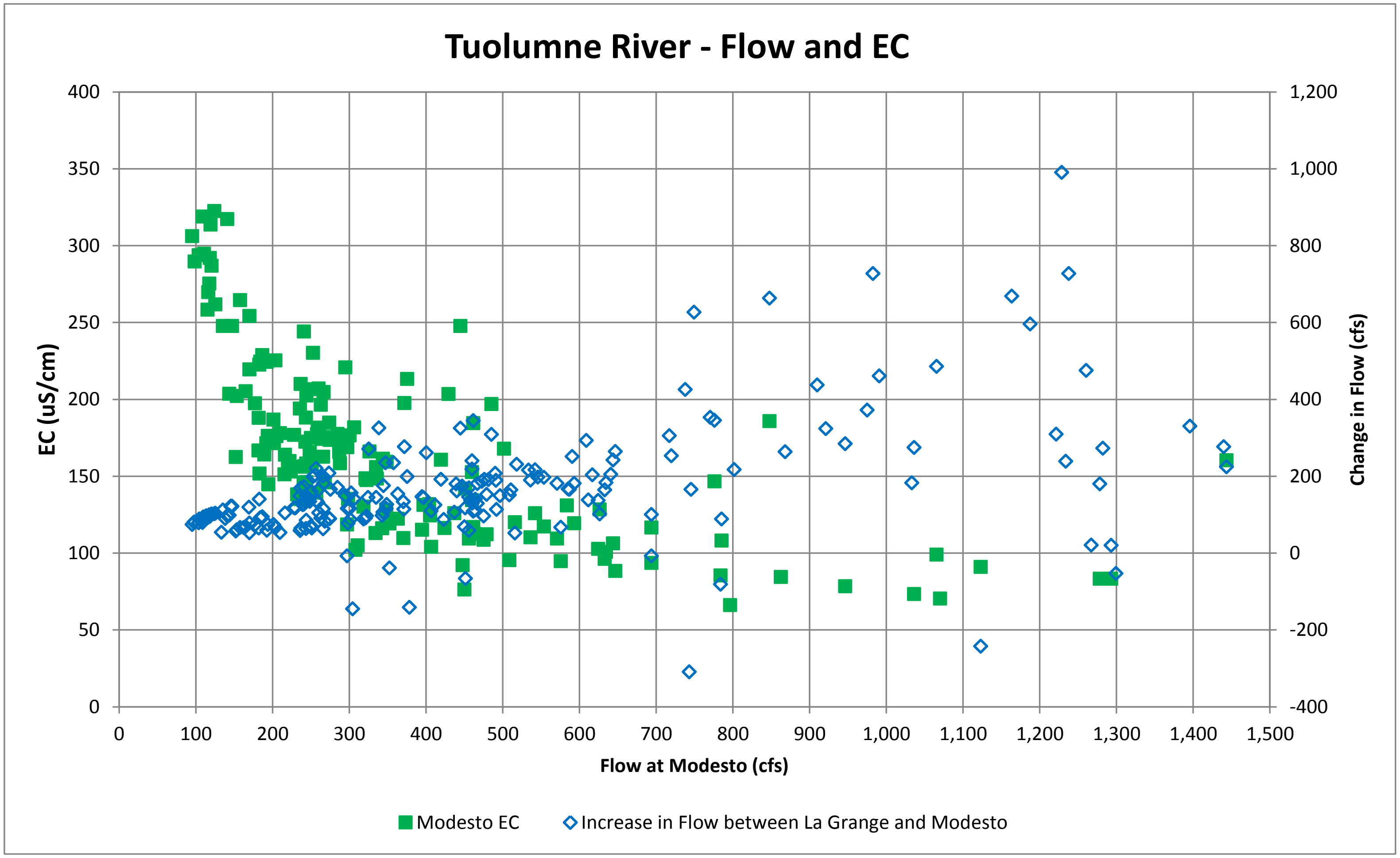


Figure F.2-1h. Relationship between Monthly Tuolumne River Flow, Accretions, and EC for WY 1985–2011

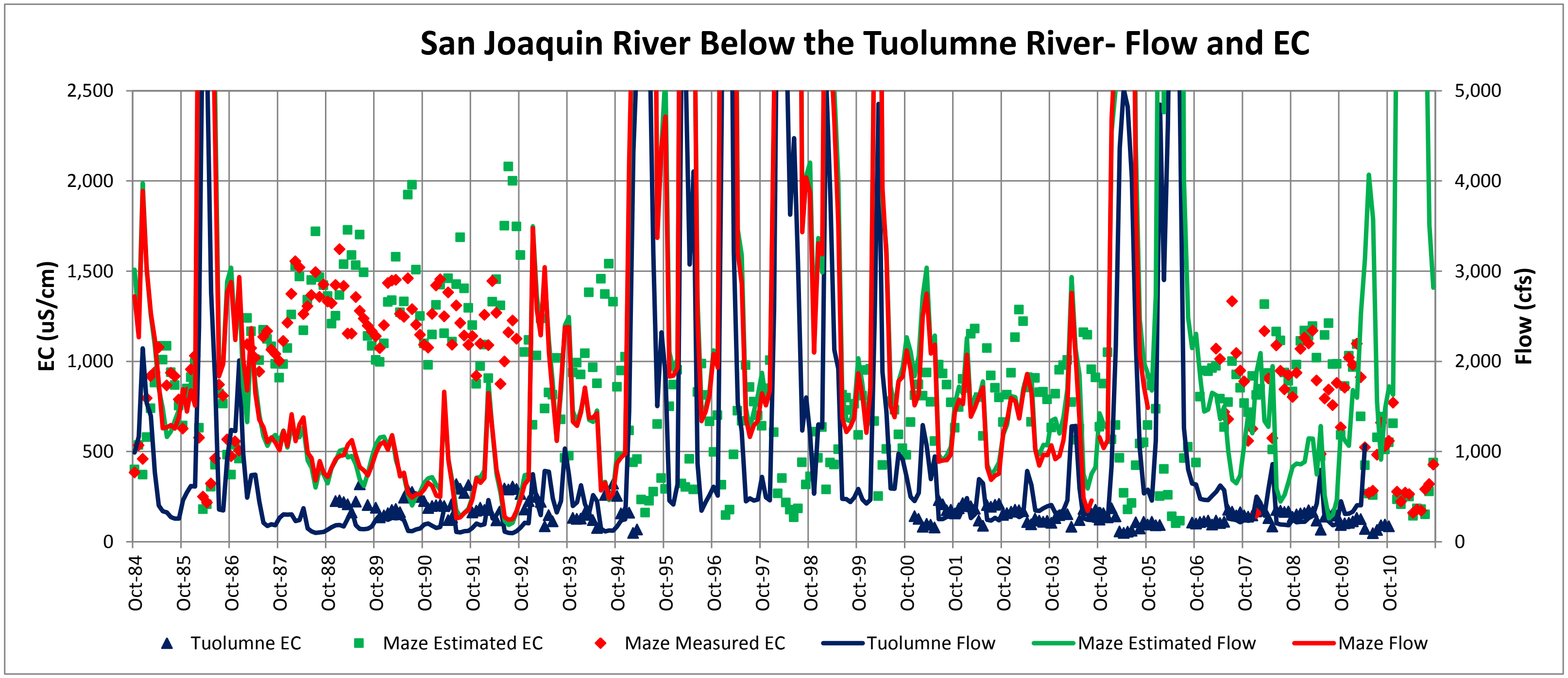


Figure F.2-1i. Historical Monthly Flow and EC in the San Joaquin River Downstream of the Tuolumne River for WY 1985–2011

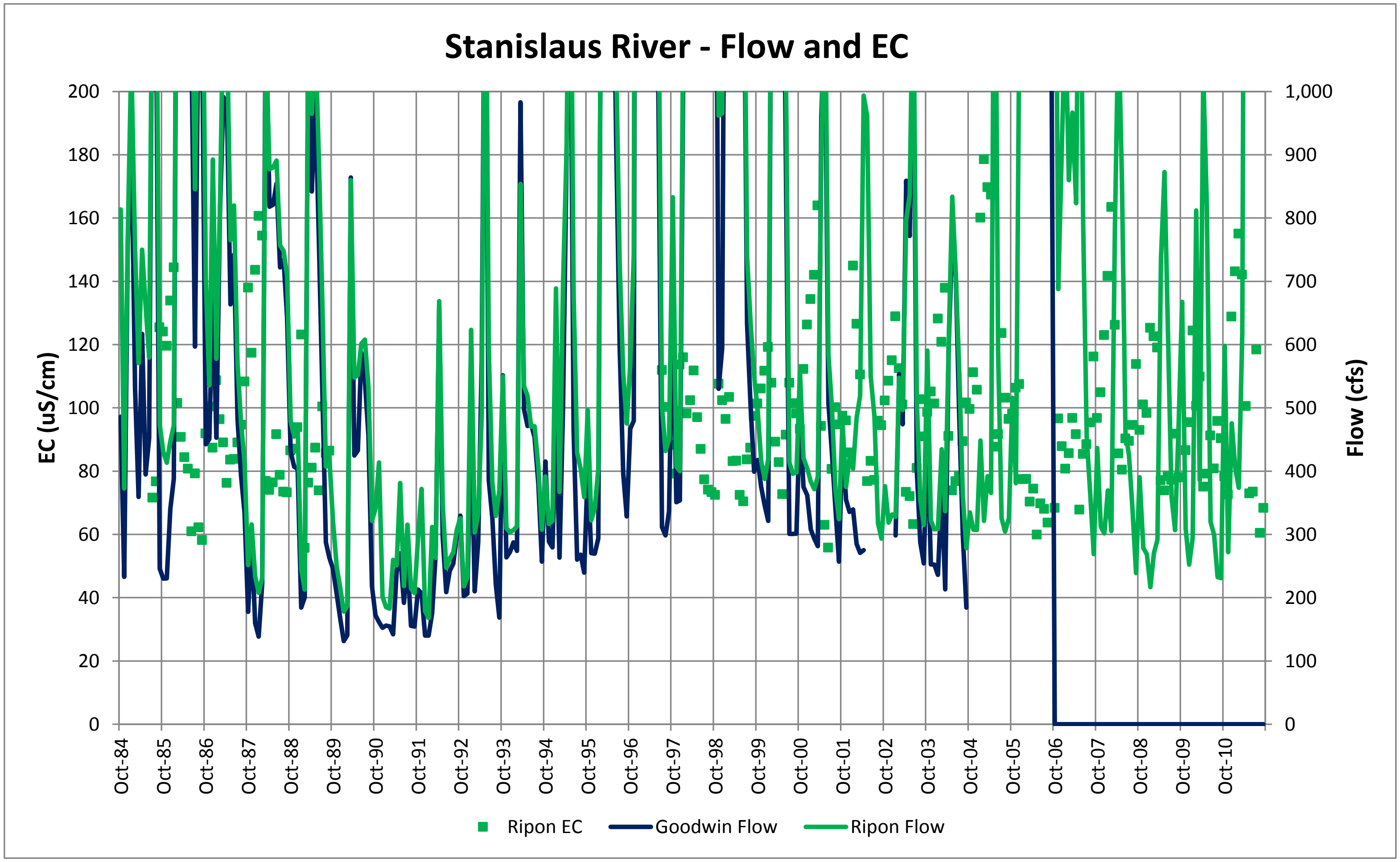


Figure F.2-1j. Time Series of Historical Monthly Flow and EC in the Stanislaus River for WY 1985–2011

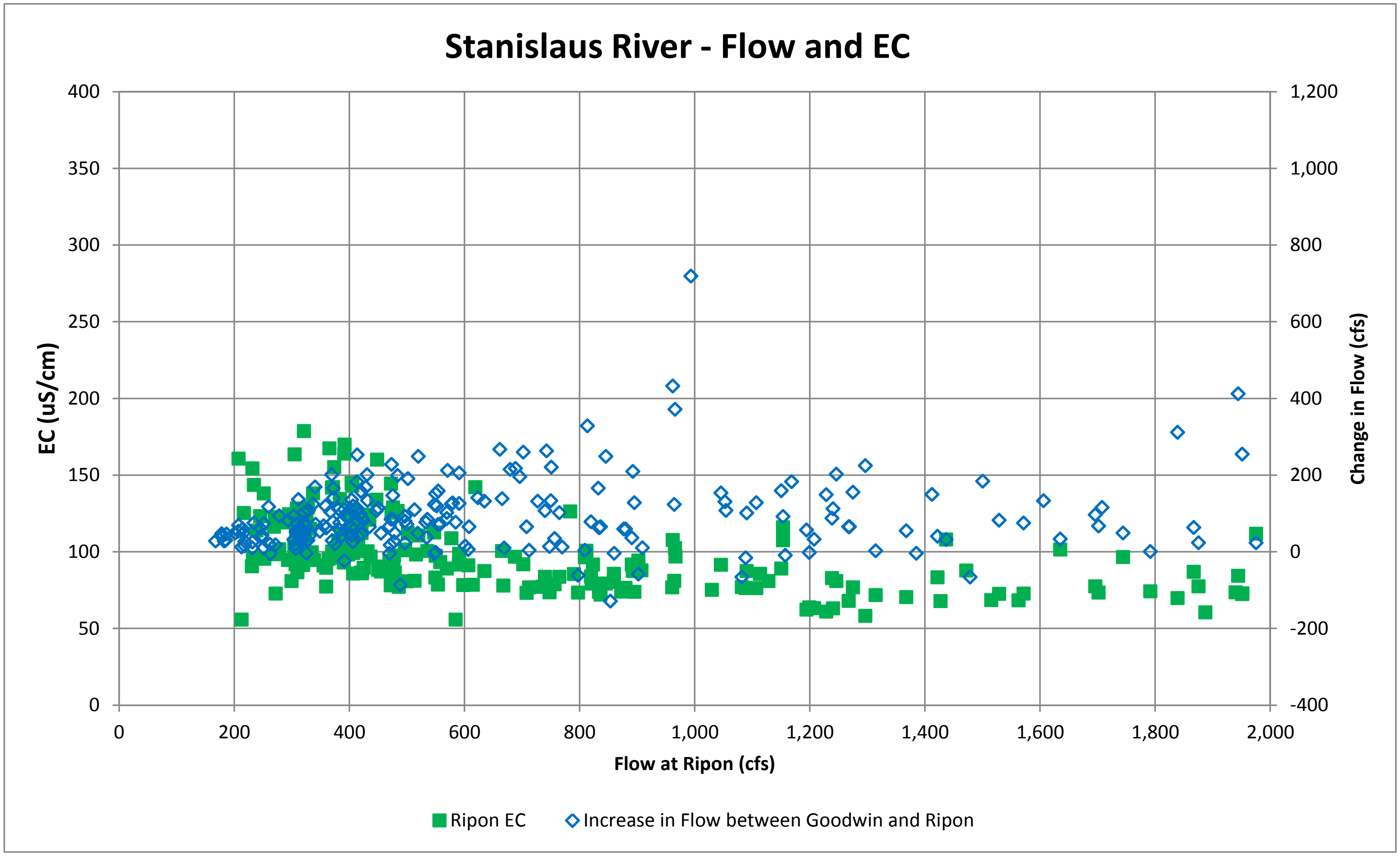


Figure F.2-1k. Relationship between Monthly Stanislaus River Flow, Accretions, and EC for WY 1985–2011

Figure F.2-1l shows the historical monthly flows and EC values at Vernalis, located just downstream of the Stanislaus River inflow. The SJR flows at Vernalis generally ranged from 1,000–5,000 cfs, with lower flows of 500 cfs in dry years and flows of more than 5,000 cfs in wet years. The EC values at Vernalis ranged from less than 250 µS/cm in high flow months to about 1,250 µS/cm. The Vernalis EC ranged from 750–1,250 µS/cm in the 1988–1994 dry period, but the EC has been less than 1,000 µS/cm since 2000. There are three separate EC measurements at Vernalis (DWR, United States Bureau of Reclamation [USBR], and USGS). There are often differences of 25 µS/cm between these monthly data. The existing Vernalis EC objectives of 700 µS/cm from April–August and 1,000 µS/cm from September–March have been applicable since 1996. The Stanislaus River flows measured at Ripon are shown to indicate dilution effects from the lower EC water. The Stanislaus River flows were generally 250 cfs–1,000 cfs, with flows of more than 1,000 cfs only in wet years (flood control releases). As described above, the Stanislaus River EC values were generally 75–150 µS/cm. This EC data suggests that the SJR at Vernalis has a moderate salinity with EC values generally between 250 µS/cm and 750 µS/cm, except when flow is less than 1,000 cfs.

Figure F.2-1m shows the historical monthly flows and calculated salt loads at Vernalis. The monthly salt load at Vernalis ranged from about 25,000 tons (when flow was about 1,000 cfs) to more than 150,000 tons (when flow was more than 5,000 cfs). Because the SJR at Vernalis EC was generally 250–750 µS/cm (average of 500 µS/cm) since 1996, the salt load was generally proportional to the flow. At low flows there can be a wide variation in the EC as the salt load in the SJR remains relatively constant from Salt and Mud Sloughs and from the groundwater inflow from agriculture along the SJR between the Merced River and the Stanislaus River. High releases from the Stanislaus River produce a strong dilution effect on salinity at Vernalis, while high runoff from watersheds downstream of the tributary reservoirs can add a larger salt load from surface soil leaching.

Figure F.2-1n provides a summary graph showing the general relationship between historical SJR at Vernalis flow and EC measurements from 1985–2011. For flows of less than 1,000 cfs, there have been a wide range of EC values, from 500–1,250 µS/cm. At a flow of 2,500 cfs, the range of EC values has also been large, from 400–800 µS/cm. At a flow of 5,000 cfs, the range of historical EC was 250–500 µS/cm. At a flow of 10,000 cfs, the SJR at Vernalis EC was generally about 250 µS/cm. This general dilution effect can be characterized as a partial flow dilution with an approximate relationship of:

$$\textit{Vernalis EC } (\mu S/cm) = 15{,}000 \times \textit{flow } (cfs)^{-0.4}$$

This general dilution pattern indicates the EC would be about 1,000 µS/cm at a flow of 1,000 cfs and would decrease to about 500 µS/cm at a flow of 5,000 cfs. The salt load always increases with flow, but at a slower rate as flow increases. The salt load would be about 50,000 tons/month at a flow of 1,000 cfs and would increase to 100,000 tons/month at a flow of 3,000 cfs. The salt load would be about 150,000 tons/month at a flow of 6,000 cfs and would be about 200,000 tons/month at a flow of 10,000 cfs. These approximate EC and salt load lines have been selected to provide a maximum likely EC and salt load at various river flows; most of the historical EC values have been less than the approximate line.

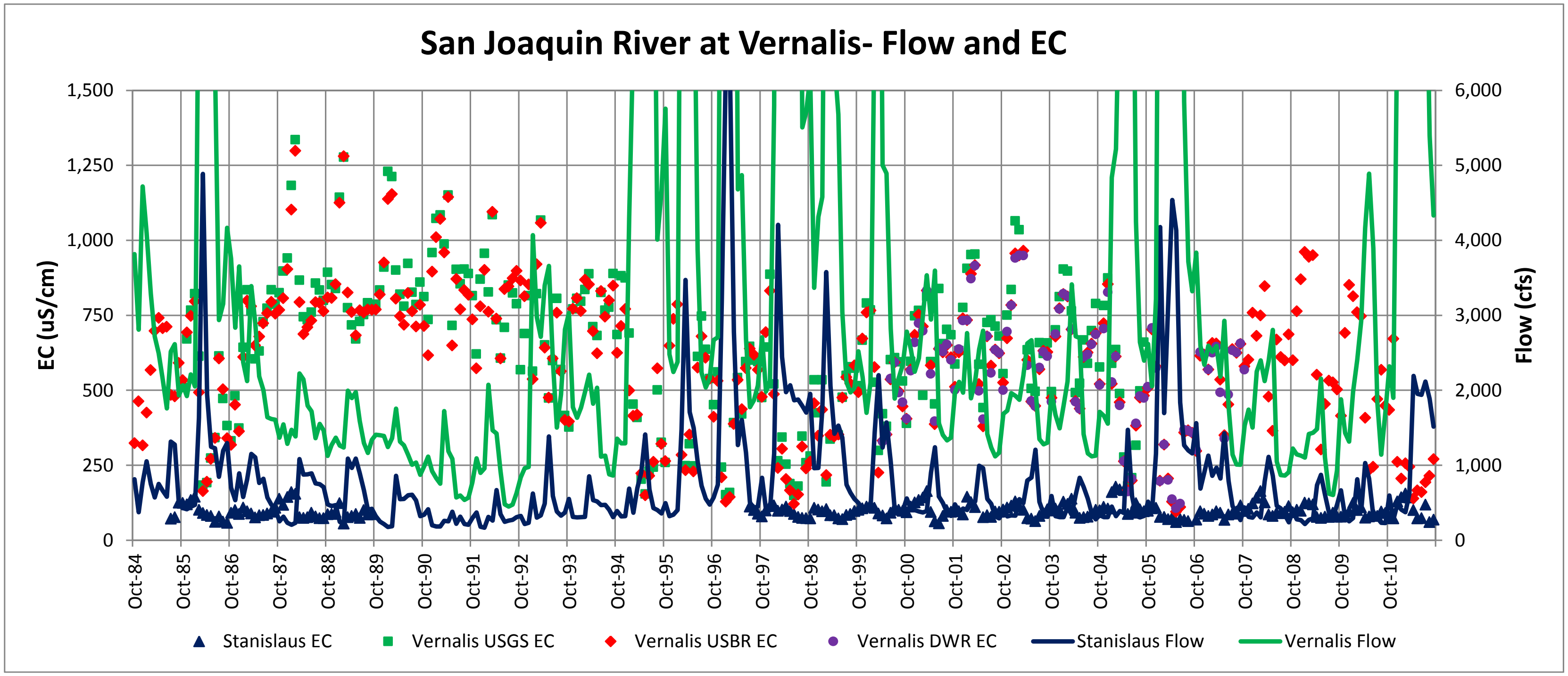


Figure F.2-1l. Historical Monthly Flow and EC in the San Joaquin River at Vernalis for WY 1985–2011

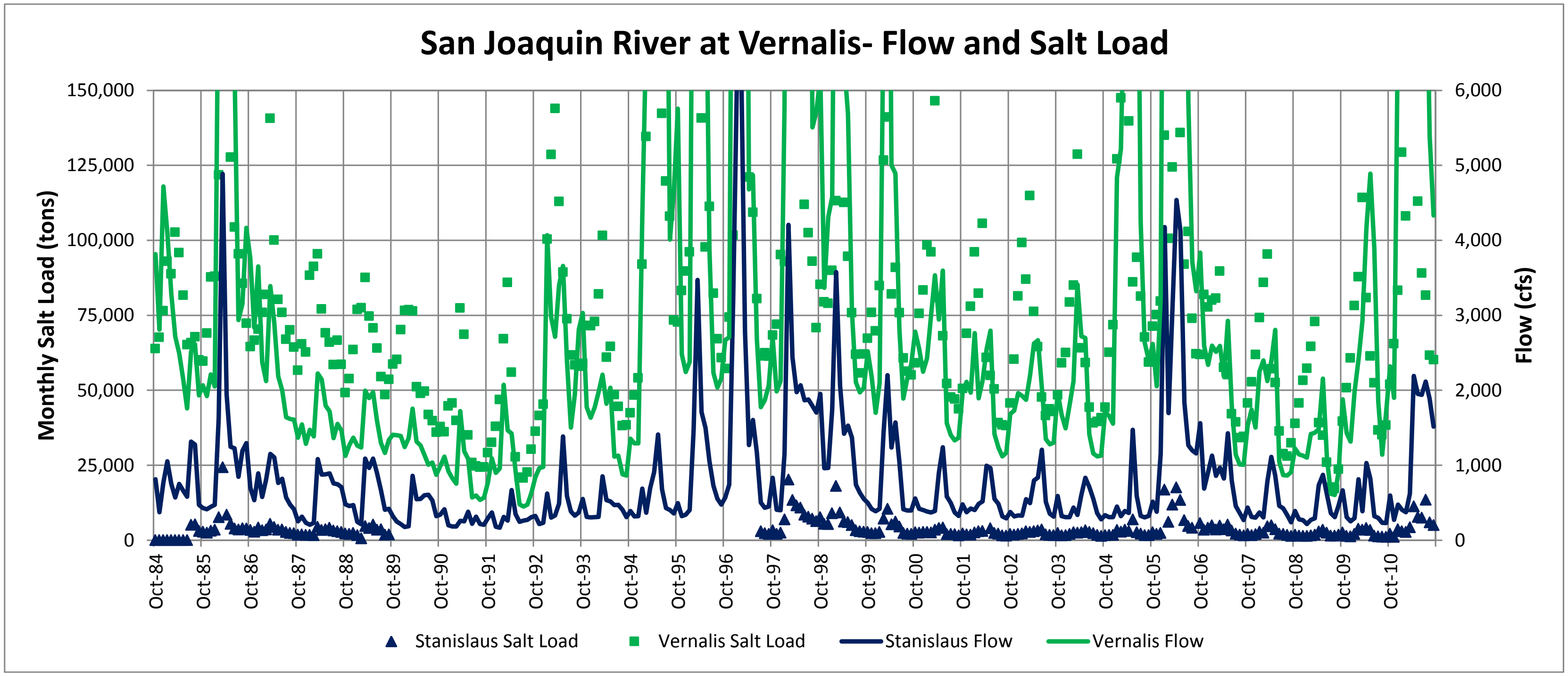


Figure F.2-1m. Historical Monthly Flow and Salt Load (tons) in the San Joaquin River at Vernalis for WY 1985–2011

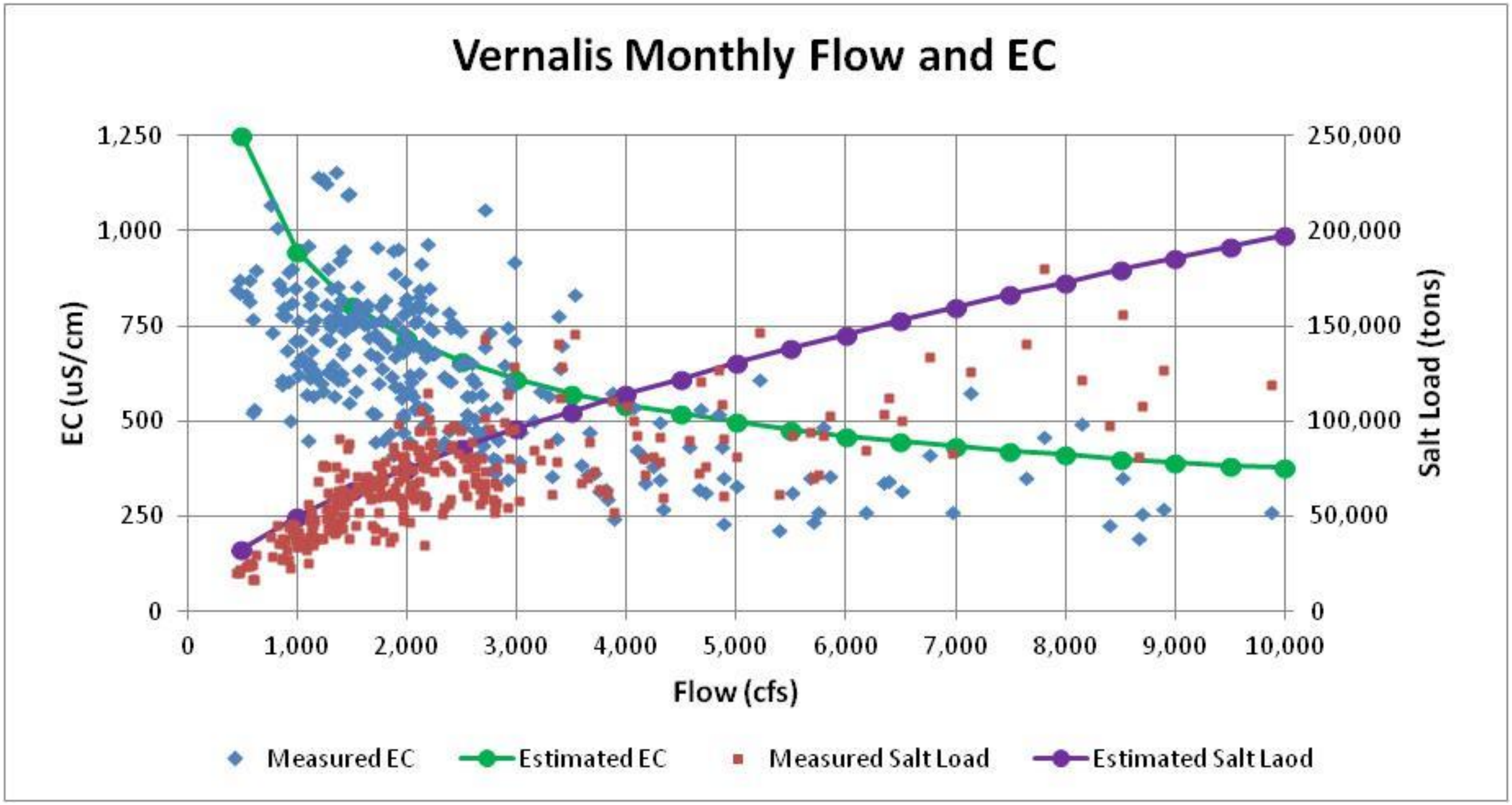


Figure F.2-1n. Relationship between SJR at Vernalis Monthly Measured Flow and EC and Calculated Salt Load for WY 1985–2011

F.2.3 Daily Flow and Salinity (EC) in the SJR for 2000–2003

The flow and salinity patterns along the SJR will be introduced and described by reviewing the measured flows and salinity from four recent years: 2000–2003. Daily flows and EC values at several gages along the SJR and for some tributary inflows will be shown to illustrate seasonal and storm event patterns of SJR flow and salinity.

F.2.3.1 Measured SJR Flow and Salinity in 2000

Figure F.2-2a shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR near Stevinson (upstream of Salt Slough) for 2000. The SJR at Stevinson flows are the combination of Bear River (watershed includes the City of Merced), irrigation return flows, and (in wet years) flood flow releases from Friant Dam. The highest flows are often observed in January–March. The flows in 2000 were increased by local storms in late January, February, March, and April; Friant Dam flood control releases were made in March. The spring flows in April–June were about 100 cfs, and the summer flows in July–September were about 50 cfs. The fall flows in October had two spikes (unknown source) and the flows in November and December were less than 25 cfs. The EC measurements in the SJR at Stevinson began in July 2000. The summer and fall EC was about 1,000–1,500 μS/cm when flow was 25–50 cfs and was reduced to less than 500 μS/cm when flows increased to 100 cfs or more. The salt load (tons/day) can be calculated for days with flow and EC measurements. The salt load was about 100 tons/day in August with a flow of 50 cfs and EC of about 1,000 μS/cm. The salt load was about 50 tons/day in the fall months with lower flows of about 25 cfs.

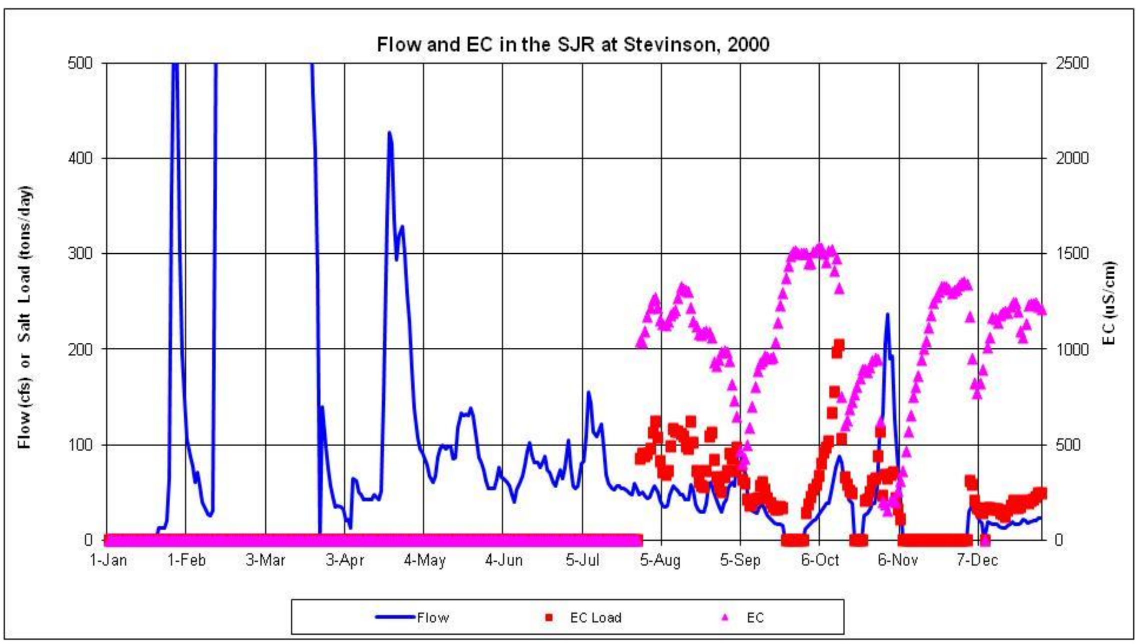


Figure F.2-2a. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in the SJR at Stevinson during 2000

Figure F.2-2b shows the daily flow and EC, with the calculated salt load (tons/day) for Salt Slough for 2000. The Salt Slough flows are the combination of irrigation return flows, discharges from the Grasslands wetlands, and local rainfall runoff. The tile drainage from the Grasslands Drainage Area (with high selenium) has been isolated from Salt Slough with the Grasslands Bypass Project since 1998, using the San Luis Drain, with discharges to Mud Slough. The highest flows are often observed January–April. The maximum flows were more than 500 cfs following local storms in late January, February, March, and April of 2000. The spring flows in April–June were about 200 cfs, and the summer flows in July–September decreased from about 200 cfs to about 150 cfs. The fall flows in October–December were about 150–200 cfs. The Salt Slough EC measurements in 2000 were about 2,000 μS/cm in January when flow was about 100 cfs, were gradually reduced to about 1,500 μS/cm by the end of March, were about 1,000 μS/cm during summer months, and were slightly increased to about 1,500 μS/cm in fall months. The salt load in Salt Slough in 2000 was 500–1,000 tons/day in winter months and was 250–500 tons/day in the spring, summer, and fall months. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough.

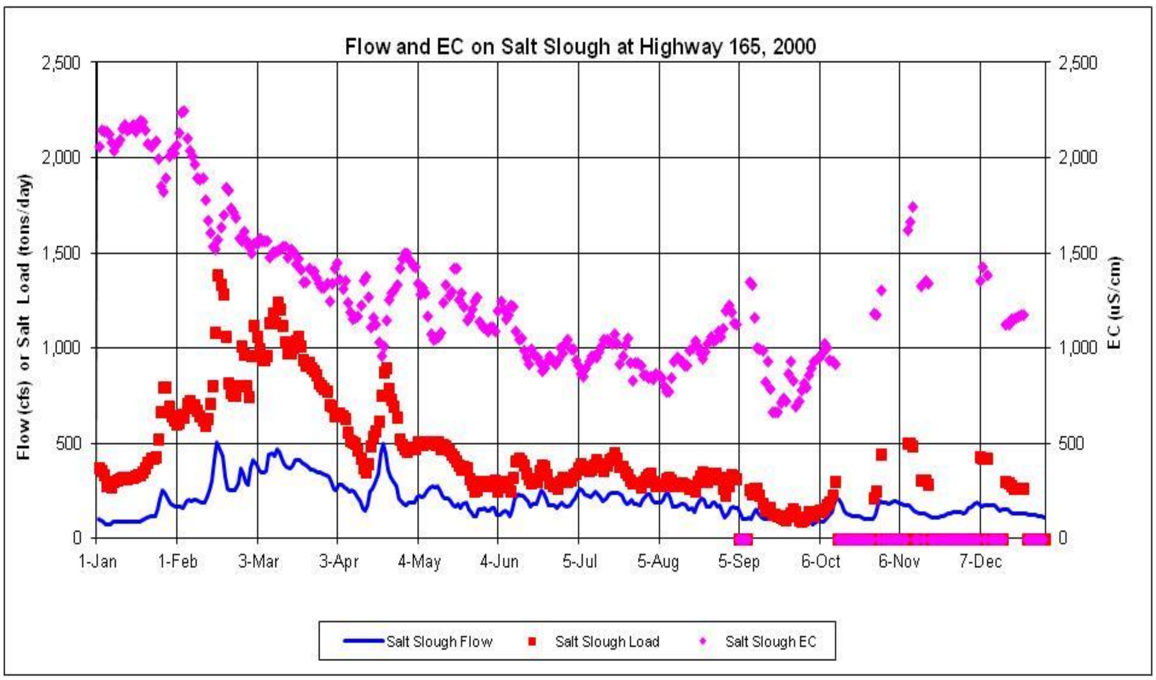


Figure F.2-2b. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in Salt Slough at Highway 165 during 2000

Figure F.2-2c shows the daily flow and EC, with the calculated salt load (tons/day) for Mud Slough for 2000. The Mud Slough flows are the combination of irrigation return flows, discharges from the San Luis Drain, discharges from Grasslands wetlands, and local runoff. The highest flows are often in January–April. The maximum flows in 2000 were about 300 cfs following local storms in late January and February; however, this is also when many wetlands are drained following duck season. The spring flows in April–June were about 50–100 cfs, the summer flows in July–September were about 50 cfs, and the fall flows in October–December were about 150–200 cfs. The San Luis Drain discharge flow is shown for comparison; the San Luis drain is the major source of flow in spring and summer months. Mud Slough EC measurements in 2000 were about 2,000–4,000 μS/cm in winter and fall when flows were about 100–250 cfs and were about 3,000 μS/cm in spring and summer months when the San Luis Drain contributed most of the 50 cfs flow. The EC in the San Luis Drain was generally 4,000–5000 μS/cm. The salt load in Mud Slough in 2000 was about 500 tons/day through most of 2000. The salt loads were about 1,000 tons/day in February and March (higher flows) and were about 250 tons/day in August and September. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough. Salt Slough and Mud Slough represent the major sources of salt load upstream of the Merced River; each contributes about 250–1,000 tons/day to the SJR.

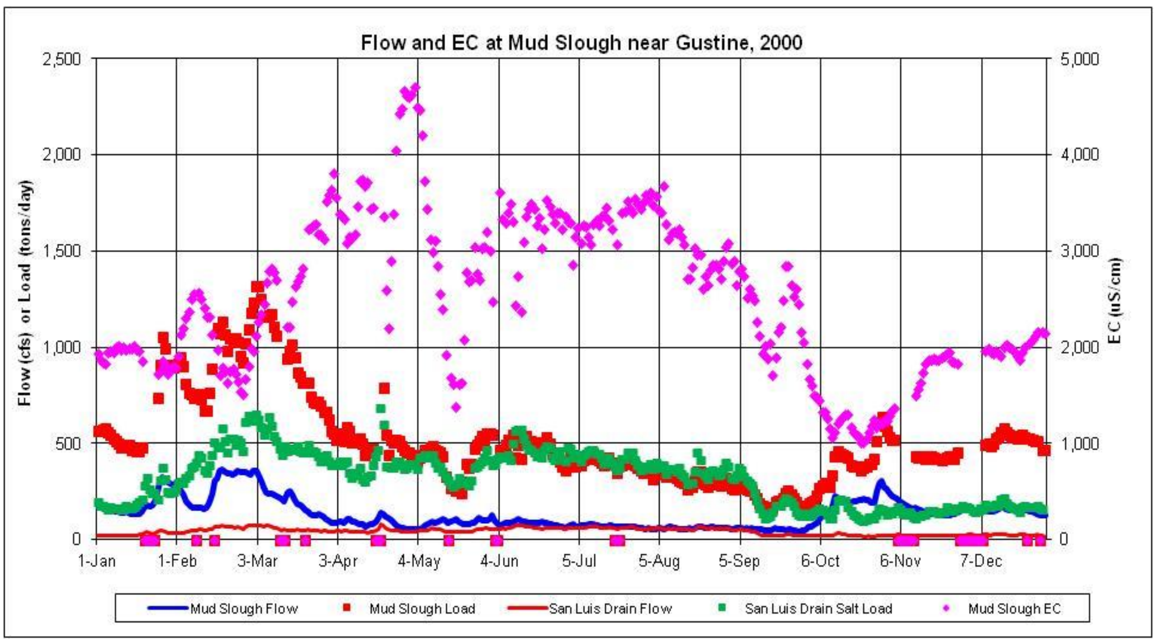


Figure F.2-2c. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in Mud Slough near Gustine and in the San Luis Drain Discharge to Mud Slough during 2000

Figure F.2-2d shows the daily flow and EC, with the calculated salt load (tons/day) for the Merced River for 2000. The Merced River flows are the combination of releases from Lake McClure, irrigation return flows, and local rainfall runoff. The highest flows are often observed in January–April. The maximum flows in 2000 were greater than 2,500 cfs in February and March. Merced River flows were about 250 in January and June, decreasing to about 150 cfs in the summer months of July–September, and increasing to 500–1,000 cfs in October–December for hydropower generation and flood control storage releases. The Merced River EC measurements began in August 2000 and were 200–300 μS/cm in August and September. The EC was reduced to 50–150 μS/cm by the higher flows of 500–1500 cfs in October–December. The Merced River salt load in 2000 was about 50–100 tons/day from August–December. Because the Merced River EC is low (50–300 μS/cm), the salt load is much less than the salt load from the SJR upstream of the Merced River.

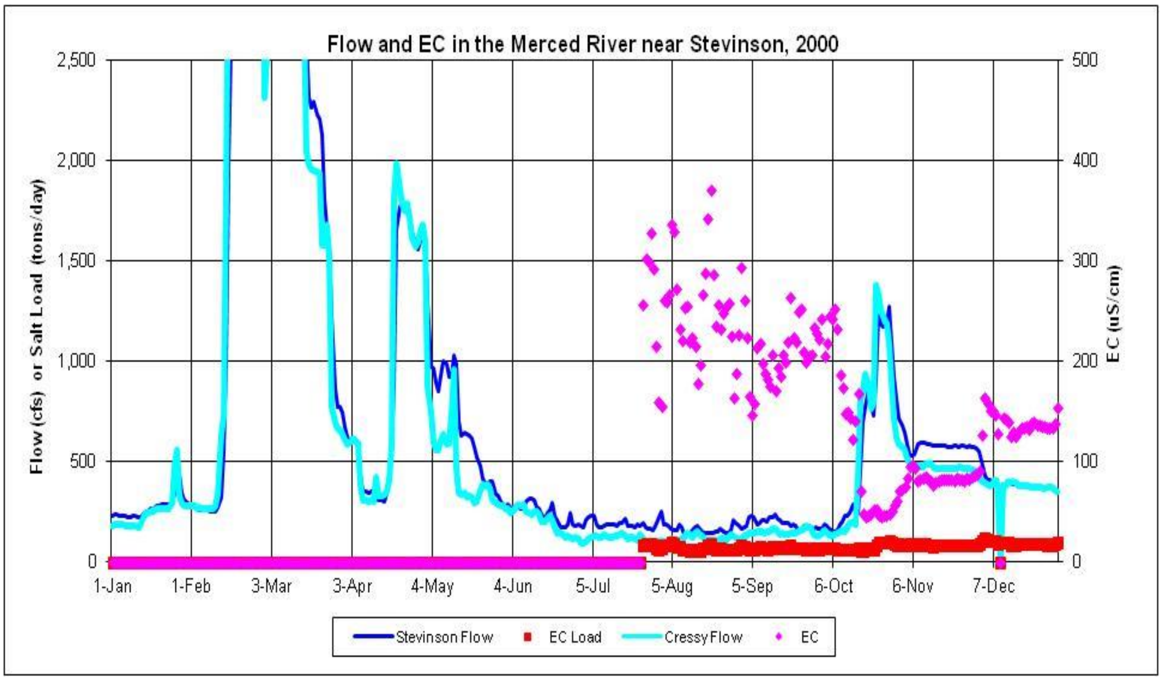


Figure F.2-2d. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in the Merced River near Stevinson during 2000

Figure F.2-2e shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Crows Landing (downstream of Merced River) for 2000. The Merced River flows are shown for comparison. The SJR flows at Crows Landing were greater than 5,000 cfs in February–March but were generally 750–1,000 cfs in most months without a flood event or reservoir release (October). Because the Merced River contributes about 25 to 50 percent of the SJR flow at Crows Landing, the maximum EC measurements of about 1,000–1,500 μS/cm were considerably less than the EC measured in the SJR at Stevinson or in Mud and Salt Sloughs (i.e., dilution). The Crows Landing EC measurements in 2000 were reduced to 500 μS/cm during higher flows in February–March and October. The SJR at Crows Landing salt loads in 2000 were about 1,000–2,000 tons/day in most months, with higher salt loads of 3,000–5,000 tons/day during high flows in February and March. Because the Merced River salt loads were generally 50–100 tons/day, the great majority of the salt load in the SJR at Crows Landing originated from upstream of the Merced River.

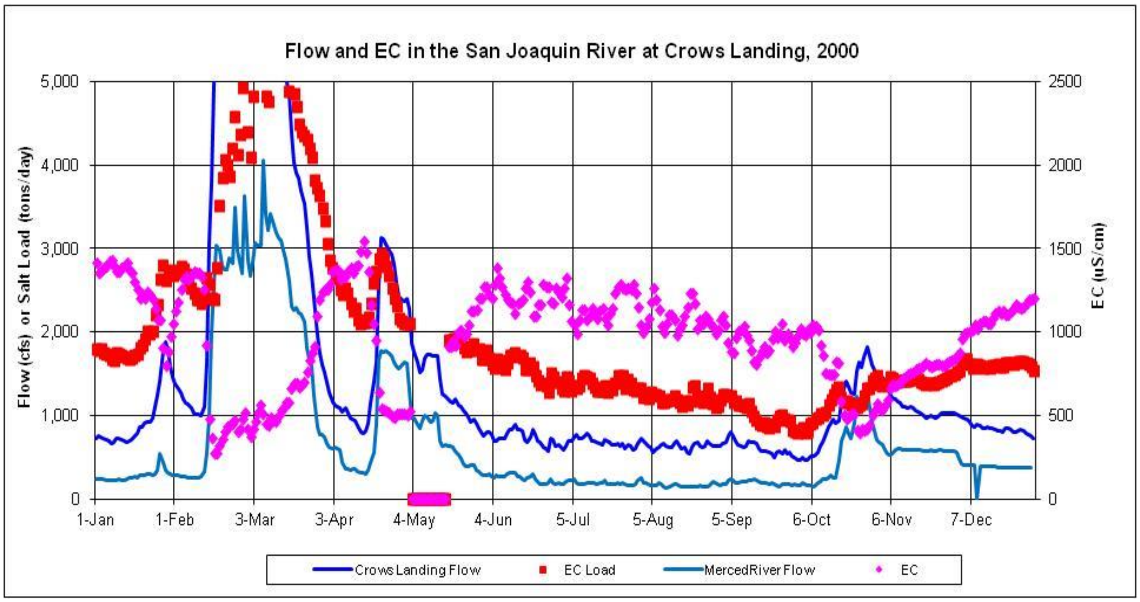


Figure F.2-2e. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in the SJR at Crows Landing (downstream of the Merced River) during 2000

Figure F.2-2f shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Maze (downstream of Tuolumne River, upstream of Stanislaus River) for 2000. The Tuolumne River flows are shown for comparison. The SJR flows at Maze were greater than 5,000 cfs for parts of February and March, and were greater than 2,500 cfs through May of 2000. Flows were 1,500–2,500 cfs for summer and fall. The Tuolumne River flow was about 500 cfs for most of the year, with major flood releases in winter and some additional releases in August. EC measurements at Maze were not made in 2000 but have been estimated by adjusting the SJR at Vernalis flow and EC with the Stanislaus at Ripon flow and EC. The Maze EC estimates in 2000 were about 1,000 μS/cm in January but were reduced to 250 μS/cm during higher flows in February–March. The estimated Maze EC values were 500–1,000 μS/cm for summer and fall. Because the Tuolumne River contributes about 25 to 50 percent of the SJR flow at Maze, the maximum EC measurements of about 1,000 μS/cm were somewhat less than the EC measured in the SJR at Crows Landing. There were some agricultural diversions between Crows Landing and Maze, and additional inflows to the SJR from agricultural drainage and shallow groundwater seepage to the river. The SJR at Maze salt loads in 2000 were about 2,000–3,000 tons/day in most months, with higher salt loads of 3,000–5,000 tons/day during high flows of February and March. Because the Tuolumne River salt loads were generally 100 tons/day, the great majority of the salt load in the SJR at Maze originated from upstream of the Merced River or from agricultural drainage and shallow groundwater seepage to the SJR.

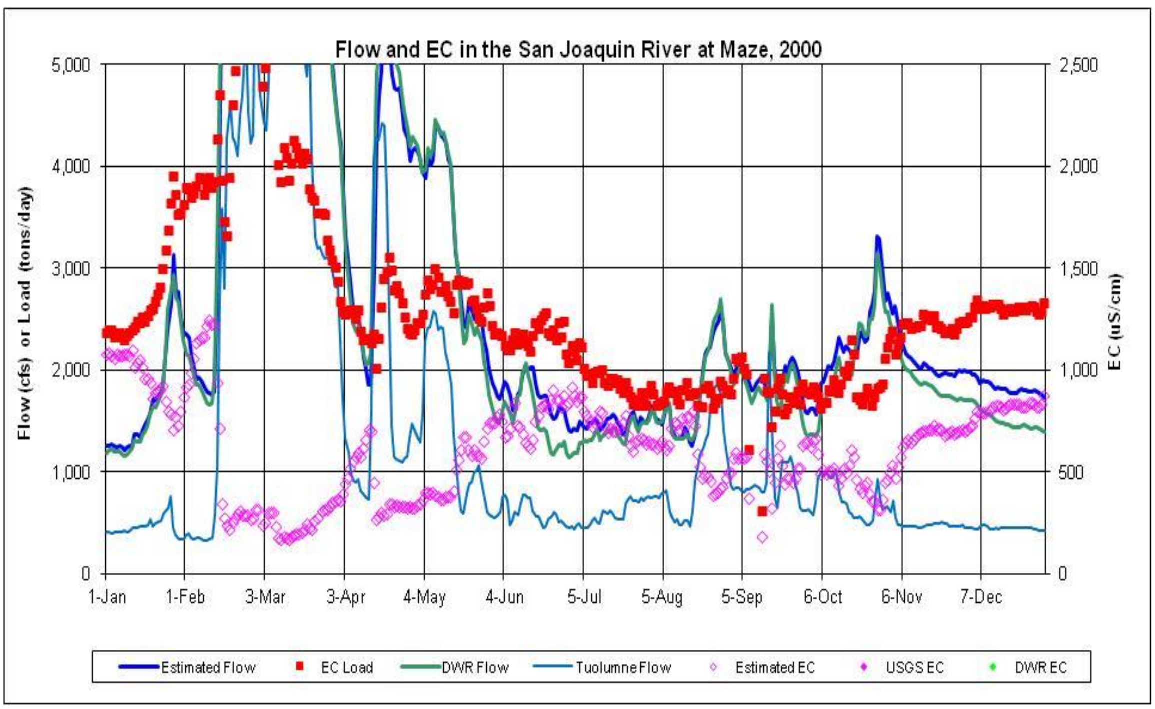


Figure F.2-2f. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in the SJR at Maze (downstream of the Tuolumne River) during 2000

Figure F.2-2g shows the daily flow and EC, with the calculated salt load (tons/day) for the Stanislaus River for 2000. The Stanislaus River flows are the combination of releases from New Melones Reservoir, irrigation return flows, and local rainfall runoff. The flows at Goodwin and Ripon are shown for comparison. The highest flows were more than 2,500 cfs in February–March (flood control release) and 1,500 cfs during the extended VAMP period from mid-April to mid-June. A mid-October pulse flow release of 1,000 cfs was made for adult fish attraction. The Stanislaus flows were about 400 cfs in other months of 2000. The Stanislaus River EC measurements at Ripon ranged from 75 µS/cm during high flow periods to about 150 µS/cm in January. The Ripon EC was about 100 µS/cm during summer. The Stanislaus River salt load in 2000 was a maximum of 500 tons/day during peak flows in February and March, about 200 tons/day in April–June (higher fish flows), and about 75–100 tons/day from July–December. The Stanislaus River flows are dominated by releases from Goodwin Dam to provide fish flows and flood control releases.

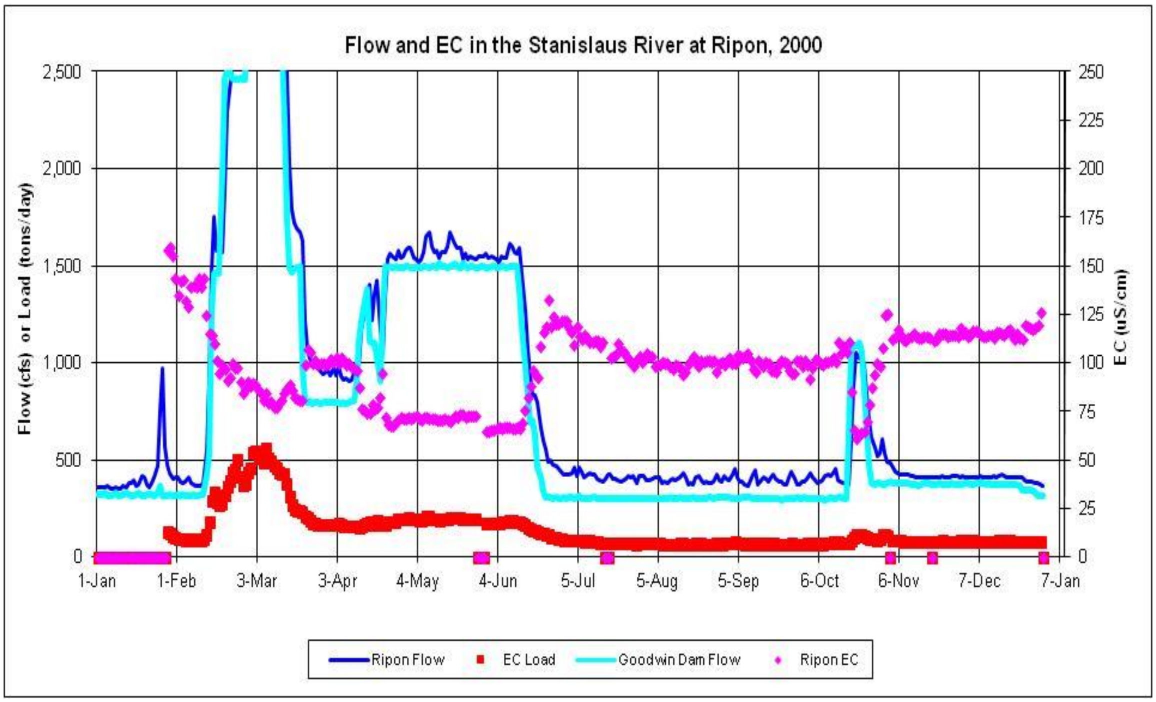


Figure F.2-2g. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Stanislaus River at Ripon during 2000

Figure F.2-2h shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Vernalis (downstream of Stanislaus River) for 2000. The Stanislaus River flows are shown for comparison. The SJR flows at Vernalis were greater than 5,000 cfs for parts of February –May and were greater than 2,000 cfs through the remainder of 2000. The minimum flows were observed in July and August, and flows of about 2,500 cfs were measured from mid-August through November. These Vernalis flows were much higher than the minimum 1,000 cfs measured in summer months of other years. The Vernalis EC measurements in 2000 were about 800 μS/cm in January but were reduced to 250 μS/cm during higher flows in February–March. The Vernalis EC values ranged from 250–750 μS/cm during the remainder of the year, generally following a flow-dilution relationship. For example, the Vernalis EC increased in November and December from about 500 μS/cm to 750 μS/cm as flows decreased from 2,500 cfs to 2,000 cfs. Some indication of the accuracy of the EC measurements is shown by the three separate Vernalis EC measurements; the USGS, USBR, and DWR each make independent measurements of the Vernalis EC. These independent EC measurements are generally within 25–50 μS/cm of each other (i.e., clock shop dilemma). The SJR at Vernalis salt loads in 2000 ranged from 2,000 tons/day from July–October to more than 5,000 tons/day during peak flow in February and March. Increased flows from rainfall runoff or reservoir releases will not increase the salt load by nearly as much as seasonal variations in tile drainage and shallow groundwater seepage flows. The monthly average Vernalis EC values were much less than EC objectives in 2000. Some daily EC values approached the objectives, but not the 30-day moving average (or monthly average) values. Because the Vernalis EC did not approach EC objectives in 2000, there were no additional New Melones releases for salinity control; all New Melones releases in 2000 were for fish flows or flood control.

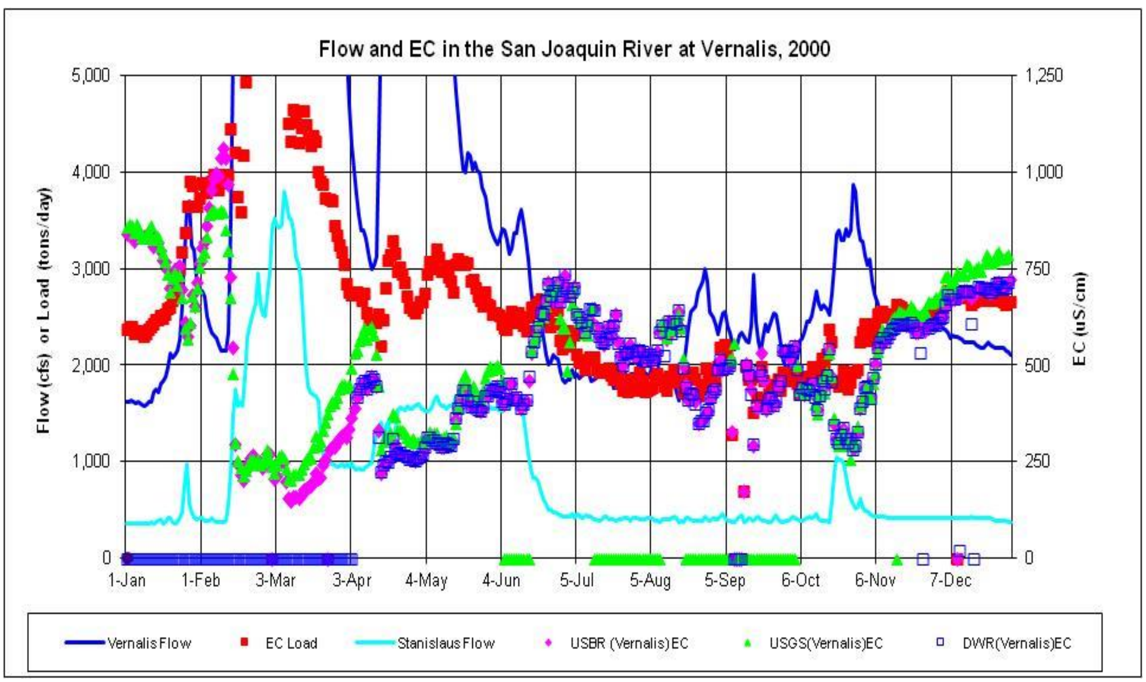


Figure F.2-2h. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in the San Joaquin River at Vernalis during 2000

F.2.3.2 Measured SJR Flow and Salinity in 2001

Figure F.2-3a shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR near Stevinson for 2001. The flows in 2001 were increased by a series of small storms; flows remained less than 500 cfs and were less than 25 cfs from May through November. The EC measurements in the SJR at Stevinson were about 1,000–1,500 µS/cm when the flow was 25–50 cfs and were reduced to less than 500 µS/cm when flows increased to 100 cfs or more. The salt load was 100–200 tons/day in winter with flows of 50–100 cfs and was less than 50 tons/day for most of the year with flows of about 25 cfs.

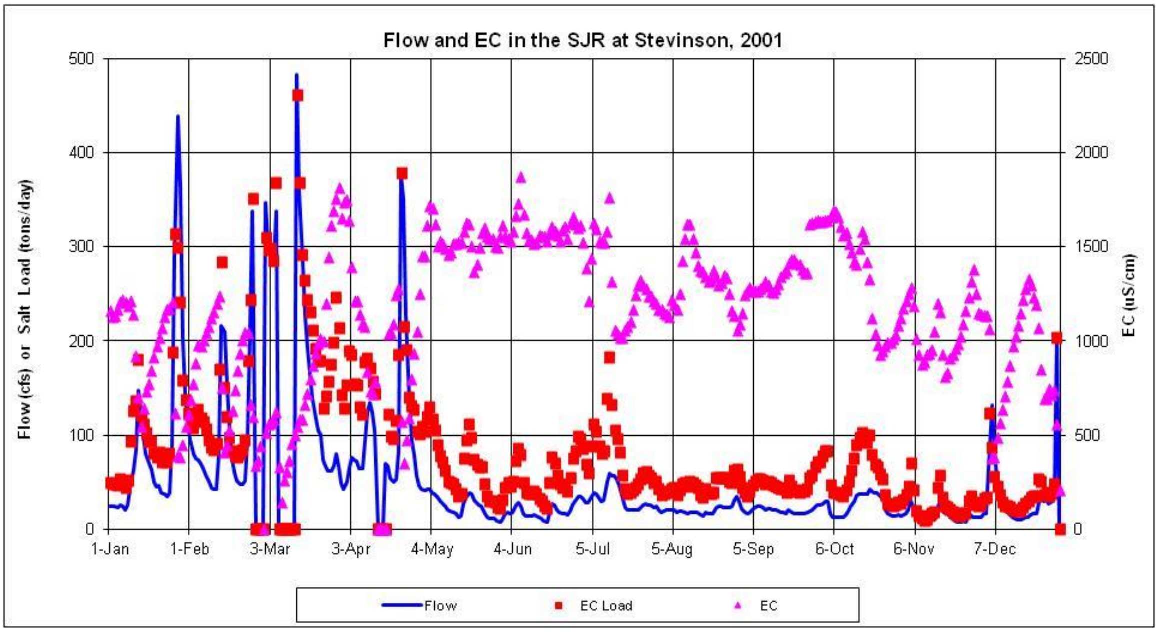


Figure F.2-3a. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Stevinson during 2001

Figure F.2-3b shows the daily flow and EC, with the calculated salt load (tons/day) for Salt Slough for 2001. The maximum flows were about 500 cfs in early March and were less than 250 cfs from April–December. The Salt Slough EC measurements in 2001 were about 1,500 µS/cm in January–April, gradually reduced to about 1,000 µS/cm in July and August, increased to 1,500 µS/cm when flows were reduced in September–November, and were about 2,500 µS/cm in December when flows were again reduced. The salt load in Salt Slough in 2001 was 500–1,000 tons/day in winter and was 250–500 tons/day in spring, summer, and fall. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough. Reduced flows appeared to be associated with increased EC values.

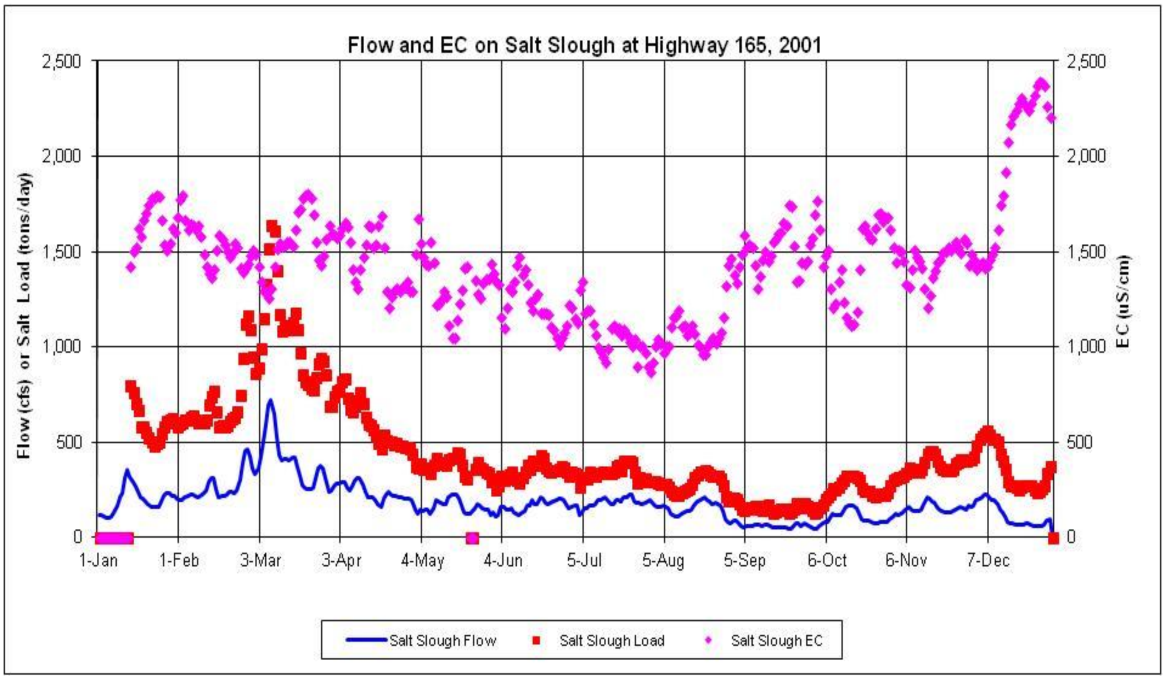


Figure F.2-3b. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Salt Slough at Highway 165 during 2001

Figure F.2-3c shows the daily flow and EC, with the calculated salt load (tons/day) for Mud Slough for 2001. The maximum flows in 2001 were about 400 cfs in early March when many wetlands are drained following duck season. The spring and summer flows were about 50cfs, and the fall flows were about 100 cfs. The San Luis Drain discharge flow is shown for comparison; the San Luis drain is the major source of flow in spring and summer. The Mud Slough EC measurements in 2001 were about 2,000–4,000 µS/cm throughout the year, with the lowest values when flows were about 100 cfs or more. The EC in the San Luis Drain was generally 4,000–5000 µS/cm. The salt load in Mud Slough in 2001 was about 500 tons/day through most of 2001. The salt loads were about 1,000 tons/day in January and February (higher flows) and were about 250 tons/day in September. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough. Salt and Mud Sloughs represent the major sources of salt load upstream of the Merced River; each contributes about 250–1,000 tons/day to the SJR.

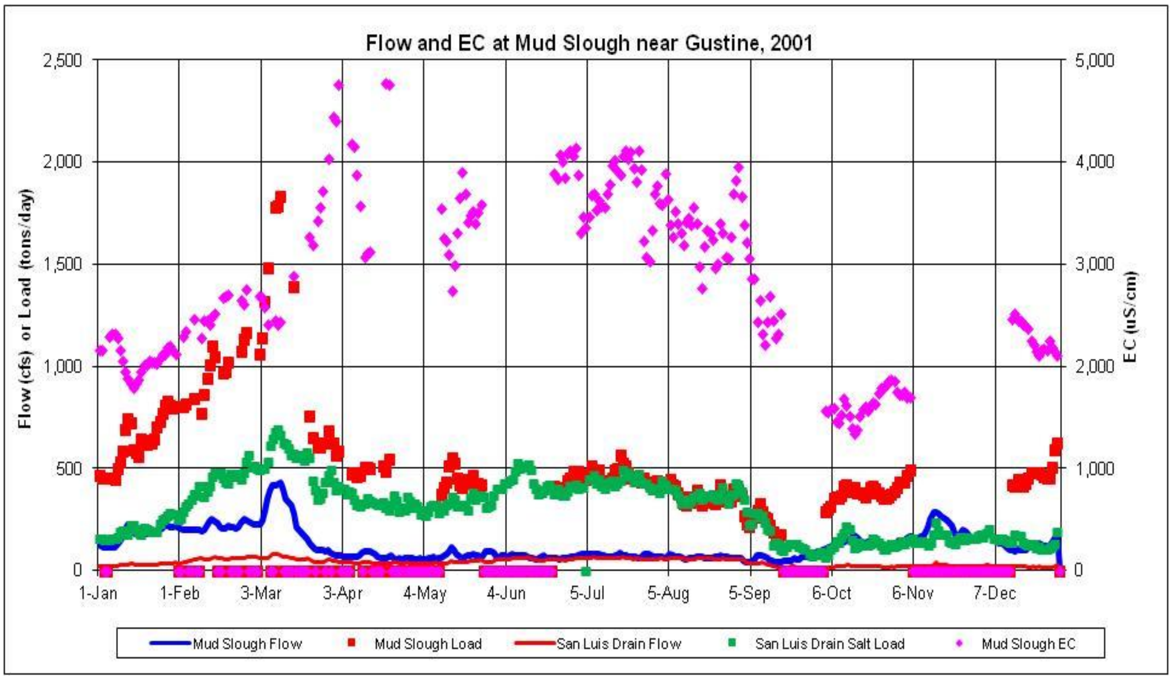


Figure F.2-3c. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Mud Slough near Gustine and in the San Luis Drain Discharge to Mud Slough during 2001

Figure F.2-3d shows the daily flow and EC, with the calculated salt load (tons/day) for the Merced River for 2001. The maximum flows in 2001 were about 1,250 cfs (VAMP flow releases) in April and May. Merced River flows were about 300 cfs in January–May, decreasing to about 100 cfs in July–September, and increased to 500 cfs in October–December for the fish pulse flow in late October and hydropower generation and flood control storage releases. The flows near Cressy (upstream) and at Stevinson (downstream) were very similar throughout the year. The Merced River EC measurements were 100–200 µS/cm in winter and reduced to 50 µS/cm during the VAMP pulse flows and the October pulse flow (for fish). The EC was about 200–300 µS/cm during summer low flows. The Merced River salt load in 2001 was about 50–100 tons/day throughout the year.

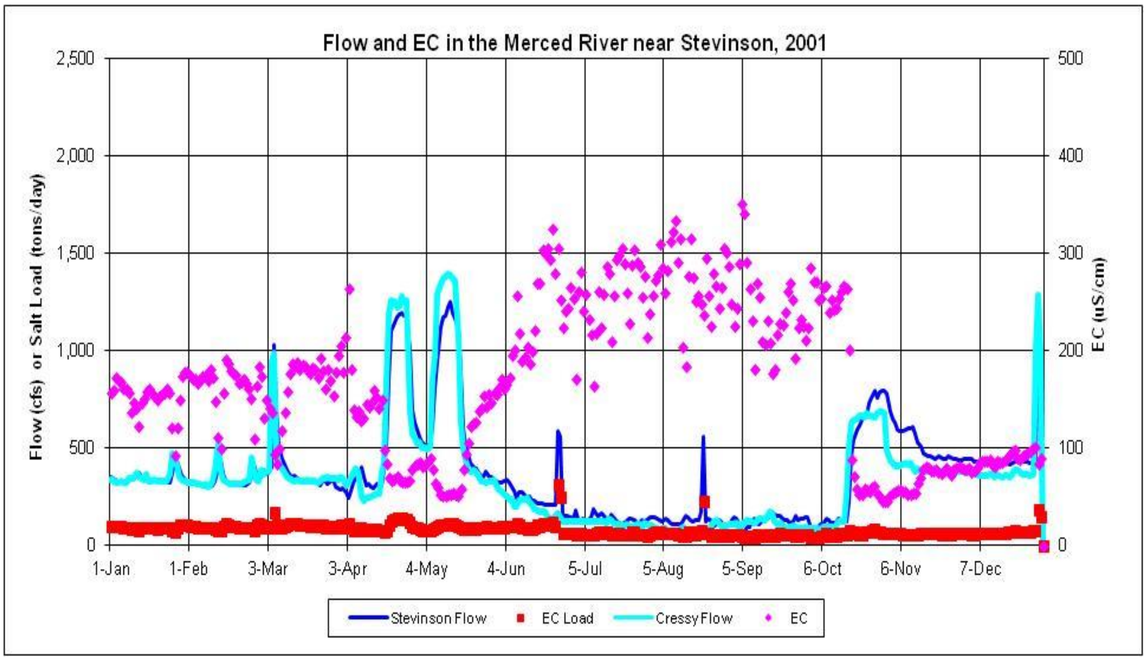


Figure F.2-3d. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Merced River near Stevinson during 2001

Figure F.2-3e shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Crows Landing (downstream of Merced River) for 2001. The Merced River flows are shown for comparison. The SJR flows at Crows Landing were generally 500–1,000 cfs in most months without a flood event (i.e., March). The Crows Landing EC was reduced to 500 µS/cm during higher flows (1,000 cfs) and were about 2,000–4,000 tons/day in winter and spring. The salt loads were 1,000 tons/day in summer and were about 2,000 tons/day at the end of 2001. Because the Merced River salt loads were generally 50–100 tons/day, the great majority of the salt load in the SJR at Crows Landing originated from upstream of the Merced River.

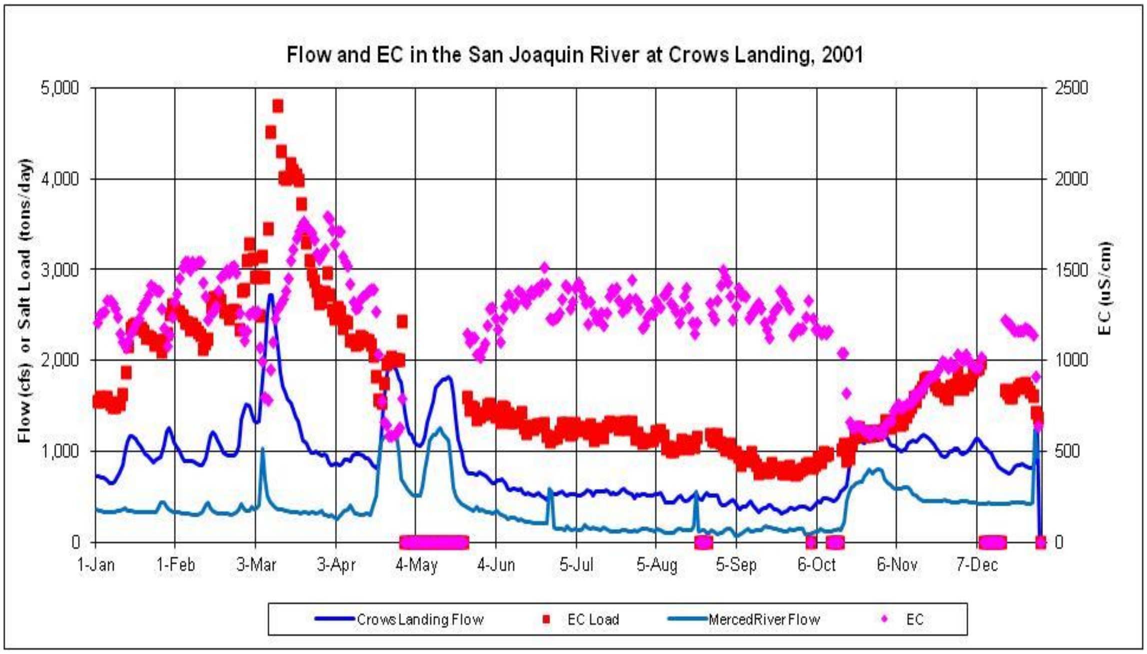


Figure F.2-3e. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Crows Landing (downstream of the Merced River) during 2001

Figure F.2-3f shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Maze (downstream of Tuolumne River) for 2001. The Tuolumne River flows are shown for comparison. The SJR flows at Maze were about 2,000 cfs in winter, increased to 5,000 cfs at the end of February, and were about 3,000 cfs during the VAMP period. Flows at Maze were 1,000 cfs from June–September, increased to 2,000 cfs during the late October peak, and were 1,500 cfs at the end of 2001. The Tuolumne River flow was about 500 cfs for winter, about 1,000 cfs during VAMP, and about 250 cfs from June through the end of 2001. The Maze EC estimates in 2001 were about 1,000 µS/cm in January, but were reduced to 500 µS/cm during higher flows in February–March and during VAMP. The estimated Maze EC values were 1,000 µS/cm for summer and fall and were 500 µS/cm during the October pulse flow. The Tuolumne River flow provided some dilution (10–25 percent of the SJR flow at Maze) of the EC measured at Crows Landing. There were some agricultural diversions between Crows Landing and Maze, and additional inflows to the SJR from agricultural drainage and shallow groundwater seepage to the river, so that salt loads at Maze were higher than at Crows Landing. The SJR at Maze salt loads in 2001 were about 3,000 tons/day in January and February, increased to 5,000 tons during March, were 2,000 tons/day in May, were about 1,500 tons/day during June–September, and were about 2,500 tons/day in November and December.

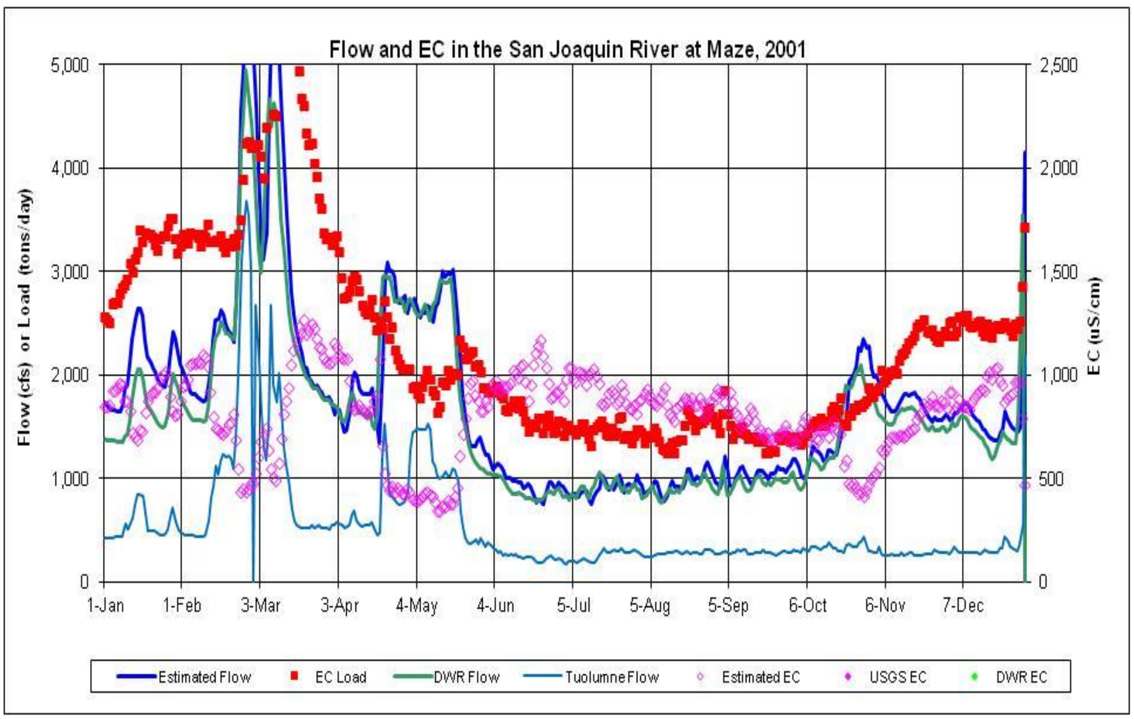


Figure F.2-3f. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Maze (downstream of the Tuolumne River) during 2001

Figure F.2-3g shows the daily flow and EC, with the calculated salt load (tons/day) for the Stanislaus River for 2001. The flows were about 400–500 cfs in winter, increased to 1,500 cfs during the VAMP period from mid-April to mid-May, were 500 cfs in June and July, and declined to about 300 cfs in October, prior to the pulse flow of 1,000 cfs for a week in mid-October. The flows at Goodwin (upstream) and at Ripon (downstream) were very similar in 2001. The Stanislaus River EC was about 150 µS/cm in winter, was reduced to 75 µS/cm during the VAMP period (1,500 cfs), and gradually increased to 125 µS/cm at the end of 2001. The Stanislaus River salt loads in 2001 were 50–100 tons/day.

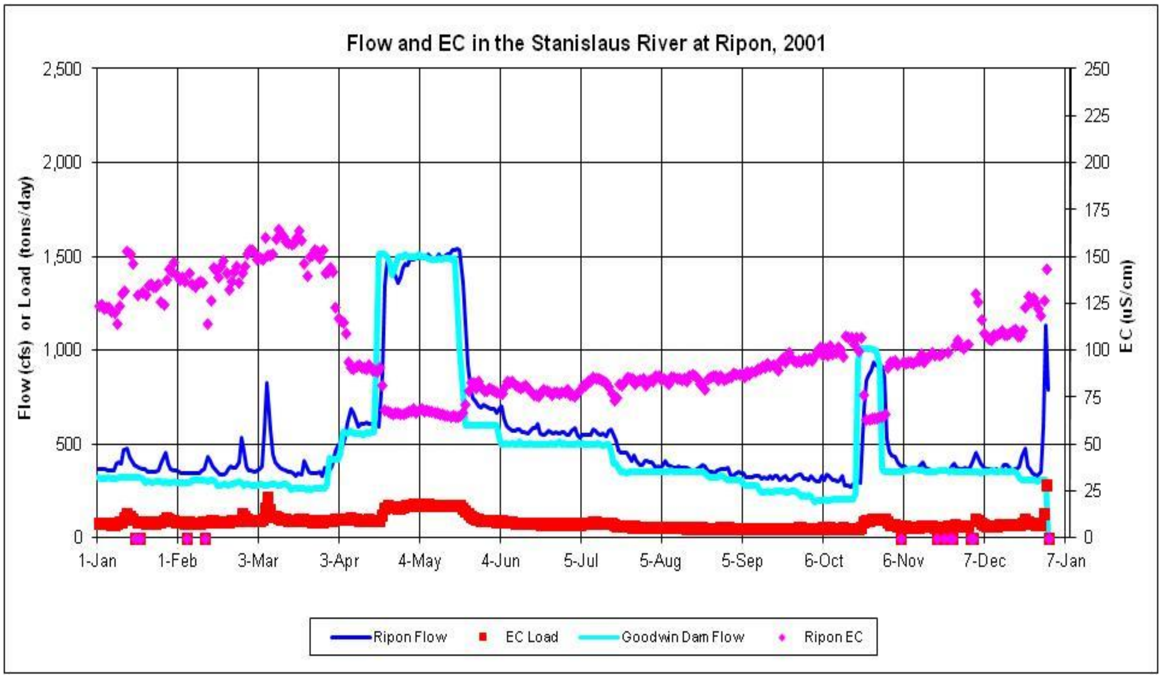


Figure F.2-3g. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Stanislaus River at Ripon during 2001

Figure F.2-3h shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Vernalis (downstream of Stanislaus River) for 2001. The Stanislaus River flows are shown for comparison. The SJR flows at Vernalis were 2,000–3,000 cfs in January–February and were about 5,000 cfs for a two-week period in late February and early March. The flow was 4,000 cfs during VAMP and decreased to about 1,500 cfs from June through mid-October. The October pulse flow was 3,000 cfs and was 2,000 cfs in November and December. The Vernalis EC measurements in 2001 were about 750 µS/cm in January and February, but were reduced to 500 µS/cm during higher flows in February–March, and were reduced to 250 µS/cm during VAMP and the October pulse. The Vernalis EC values ranged from 500–750 µS/cm during the remainder of summer and fall, generally following a flow-dilution relationship. The SJR at Vernalis salt loads in 2001 were 3,000 tons/day in January and February, increased to 4,000 tons/day in March (runoff), reduced to 2,000 tons/day during VAMP, ranged from 1,500 tons/day from June–October, and were 2,500 tons/day in November and December. The monthly average Vernalis EC values approached the EC objective (700 µS/cm) during June–August, and the Stanislaus flows in June–August may have been increased for salinity control.

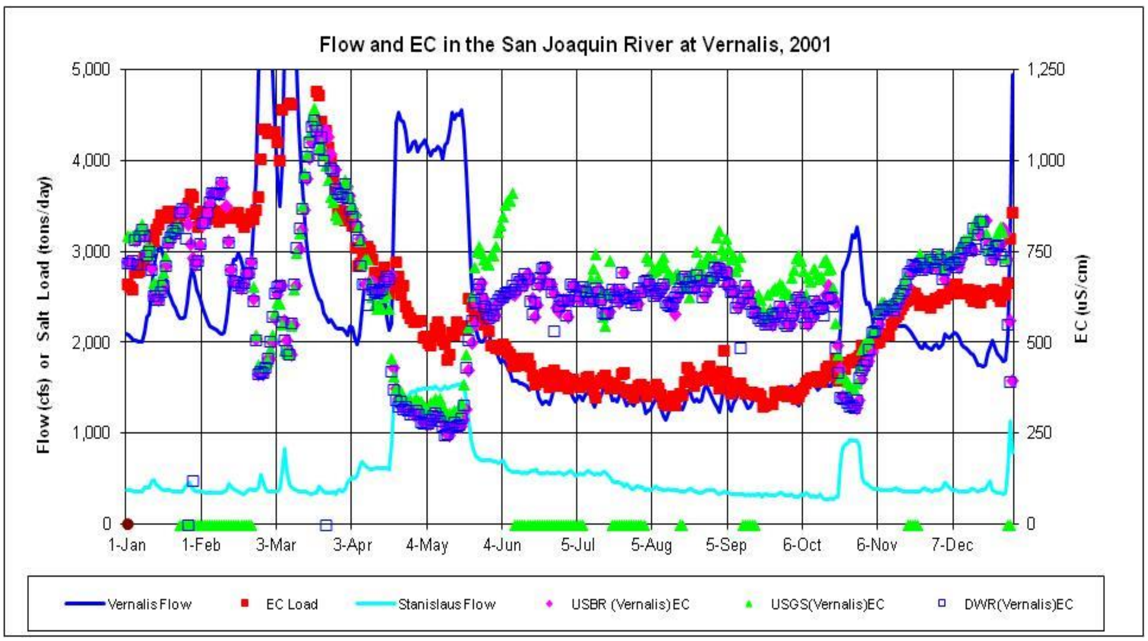


Figure F.2-3h. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the San Joaquin River at Vernalis during 2001

F.2.3.3 Measured SJR Flow and Salinity in 2002

Figure F.2-4a shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR near Stevinson for 2002. The flows in 2002 were extremely low; flows remained less than 50 cfs except for two short storms (January and December). Flows were less than 25 cfs from April through December. The EC measurements in the SJR at Stevinson were about 1,500–2,000 µS/cm most of the year (flows of about 25cfs) and were reduced to less than 500 µS/cm when flows increased to 100 cfs or more. The salt load was 50–200 tons/day in winter and was less than 25 tons/day for most of the year with flows of less than 25 cfs.

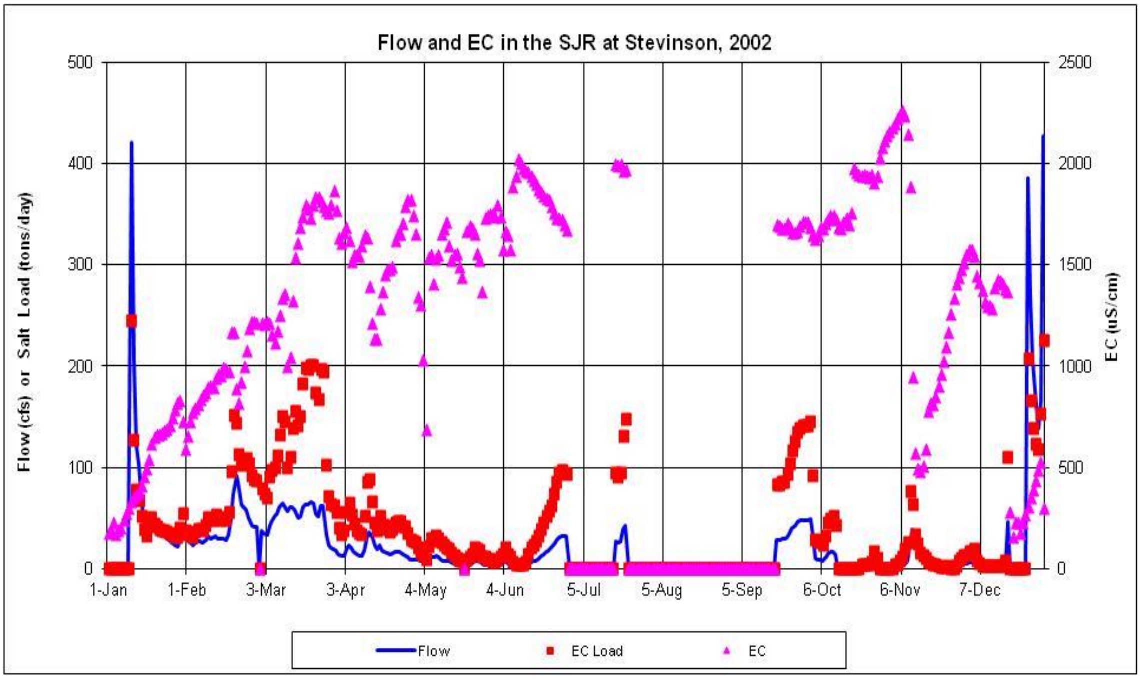


Figure F.2-4a. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Stevinson during 2002

Figure F.2-4b shows the daily flow and EC, with the calculated salt load (tons/day) for Salt Slough for 2002. The maximum flows were about 250 cfs in March and December and were 100–200 cfs from April–November. Salt Slough EC measurements in 2002 were about 2,000 μS/cm in January, 1,500 μS/cm in February–May, and 1,000–1,500 μS/cm for the remainder of the year. The salt load in Salt Slough was 500–1,000 tons/day in winter, was 250–500 tons/day in spring, summer, and fall, and increased to 1,000 tons/day at the end of December 2002. The monthly salt loads were lowest in summer.

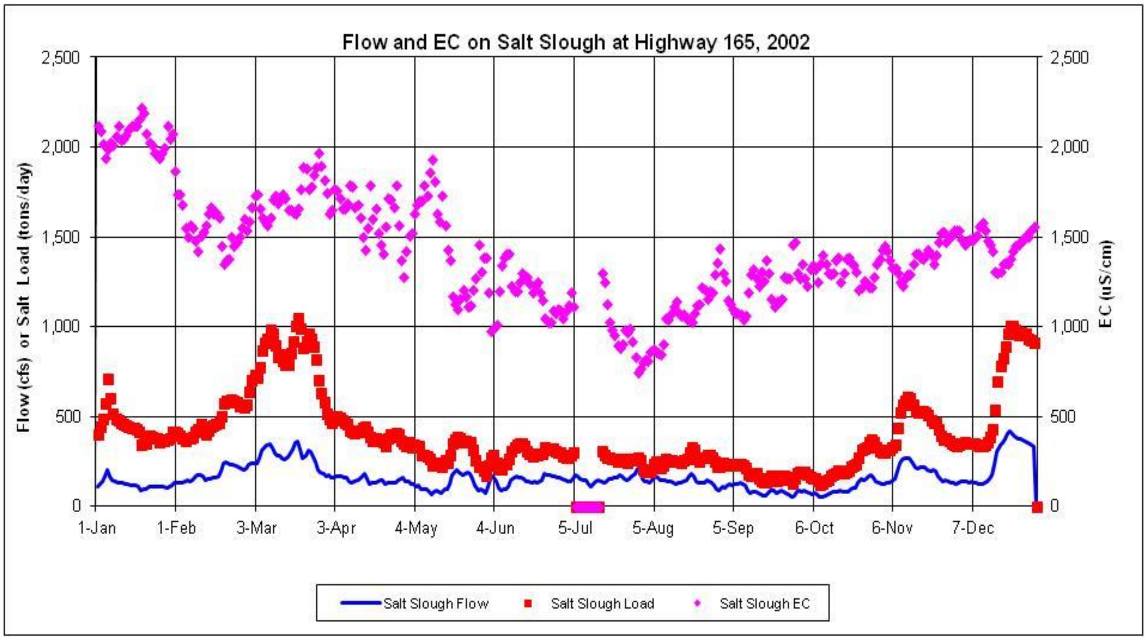


Figure F.2-4b. Daily Measured Flow (cfs) and EC (μS/cm) and Calculated Salt Load (tons/day) in Salt Slough at Highway 165 during 2002

Figure F.2-4c shows the daily flow and EC, with the calculated salt load (tons/day) for Mud Slough for 2002. The flows in 2002 were about 100cfs in winter, were 50 cfs in spring and summer, and increased to 100–500 cfs in fall (water deliveries to the wetlands). The San Luis Drain discharge flow is shown for comparison; the San Luis drain is the major source of flow in spring and summer. The Mud Slough EC was about 2,000–5,000 µS/cm throughout the year, with the lowest values when flows were about 100 cfs or more. The salt loads in Mud Slough in 2002 were about 250–500 tons/day through most of 2002. The salt loads were about 500–1,000 tons/day in winter and in November–December. The flow, EC measurements, and resulting salt load pattern were comparatively uniform through the year in Salt Slough. Salt and Mud Sloughs represent the major sources of salt load upstream of the Merced River; each contributes about 250–1,000 tons/day to the SJR.

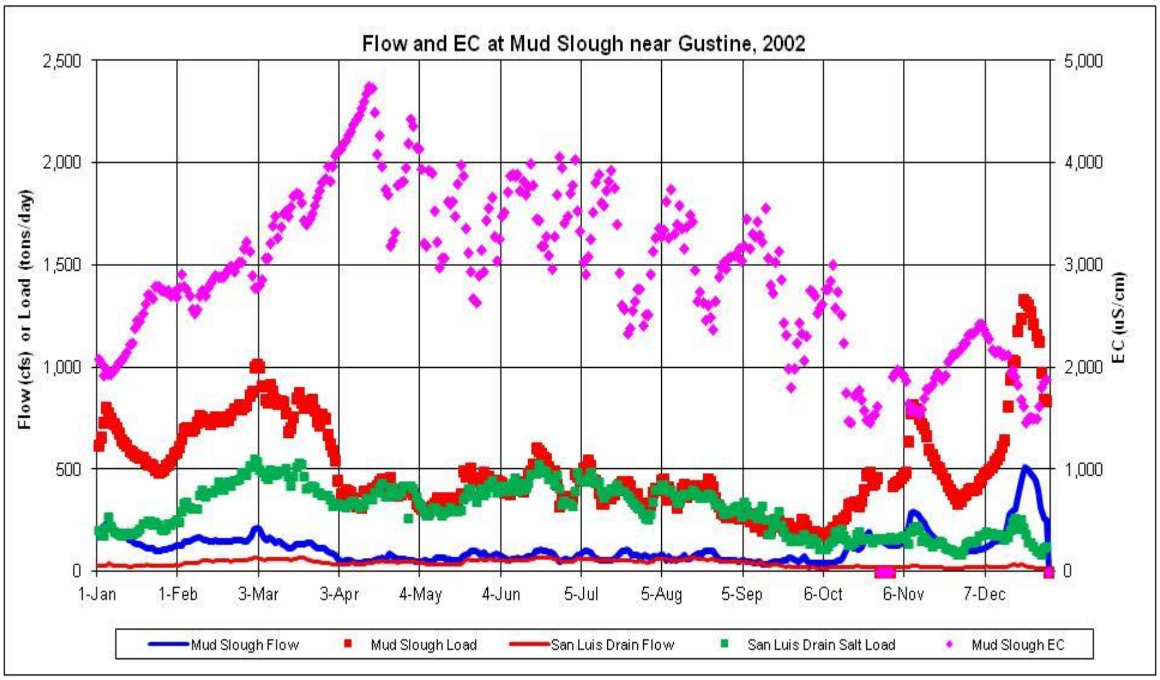


Figure F.2-4c. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Mud Slough near Gustine and in the San Luis Drain Discharge to Mud Slough during 2002

Figure F.2-4d shows the daily flow and EC, with the calculated salt load (tons/day) for the Merced River for 2002. The Merced River flows were about 250 cfs in winter and increased to about 1,250 cfs during VAMP. Summer flows were about 50 cfs, the October pulse flow was 750 cfs, and November–December flows were 250 cfs (fish flow requirement). The flows near Cressy (upstream) and at Stevinson (downstream) were very similar throughout 2002. The Merced River EC measurements were 100–200 µS/cm in winter and were reduced to 50 µS/cm during the VAMP pulse flows and the October pulse flow. The EC was about 200–400 µS/cm during summer low flows. The Merced River salt load in 2002 was about 25–50 tons/day throughout the year.

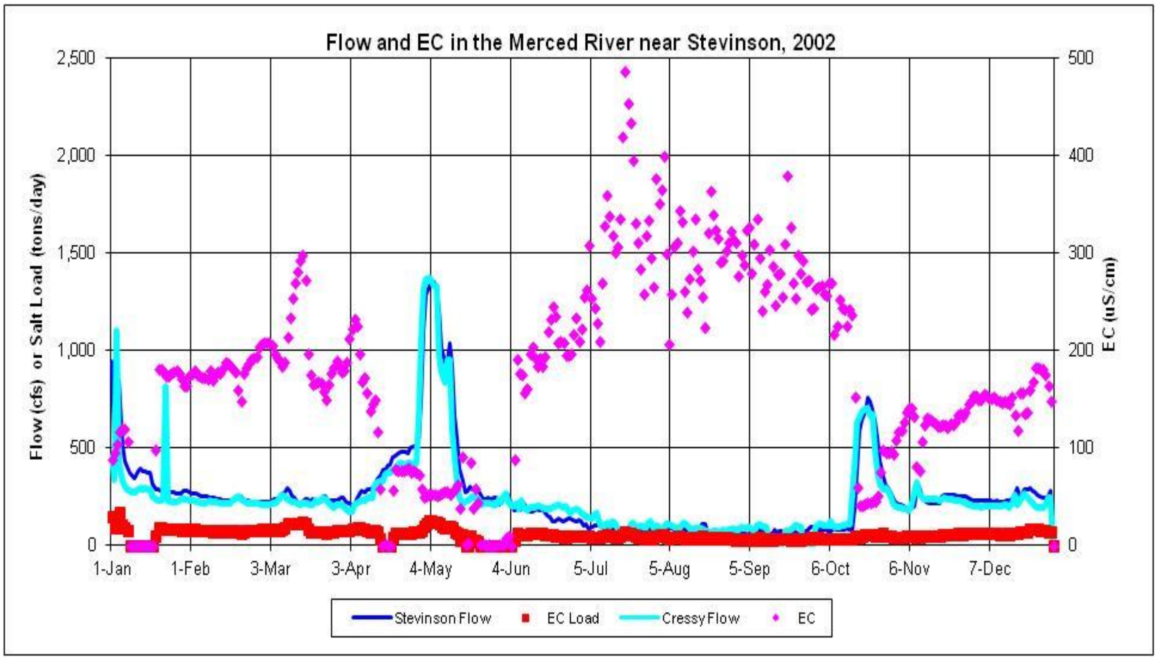


Figure F.2-4d. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Merced River near Stevinson during 2002

Figure F.2-4e shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Crows Landing for 2002. The Merced River flows are shown for comparison. The SJR flows at Crows Landing were generally 500–1,000 cfs in most months without a flood event (i.e., January and December). Because the Merced River contributes about 25 to 50 percent of the SJR flow at Crows Landing, the maximum EC measurements of 1,000–2,000 µS/cm were less than the EC measured in the SJR at Stevinson or in Mud and Salt Sloughs. The Crows Landing EC measurements were reduced to 500 µS/cm during the higher Merced River flows in April and October of 2002. The SJR at Crows Landing salt loads were about 2,000–3,000 tons/day in winter and spring, were 1,000 tons/day in summer, and were about 2,000 tons/day at the end of 2002. Because the Merced River salt loads were 25–50 tons/day, the great majority of the salt load in the SJR at Crows Landing originated from upstream of the Merced River.

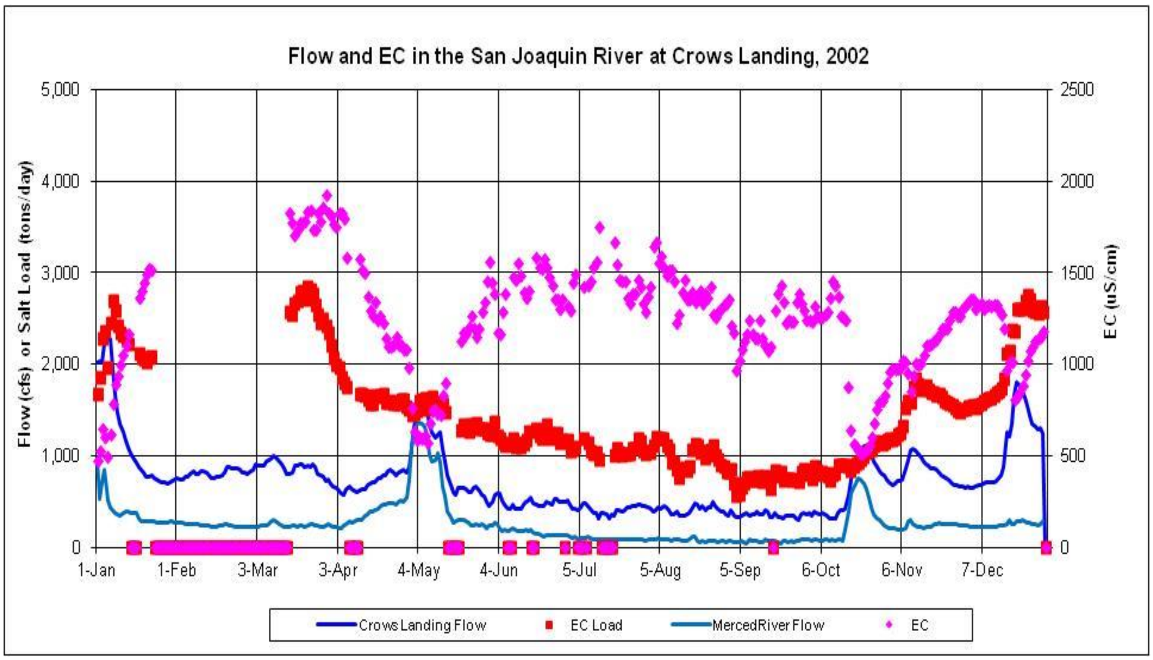


Figure F.2-4e. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Crows Landing (downstream of the Merced River) during 2002

Figure F.2-4f shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Maze for 2002. The Tuolumne River flows are shown for comparison. The SJR flows at Maze were about 5,000 cfs at the beginning of January, but were about 1,500 cfs in winter, and were about 2,500 cfs during VAMP. Flows at Maze were 750–1,000 cfs from June–September, increased to 1,500 cfs during the late October peak, and were 2,000 cfs at the end of December 2002. The Tuolumne River flow was about 250 cfs for winter, about 1,000 cfs during VAMP, and about 250 cfs from June through the end of 2002. The Maze EC estimates in 2002 were about 1,000–1,500 µS/cm in winter and 750–1,250 µS/cm during summer, but were reduced to 500 µS/cm during higher flows in early January, during VAMP, and during the October pulse flow. The SJR at Maze salt loads in 2002 were about 3,000 tons/day in winter, were about 1,500 tons/day in spring, were 1,000 tons/day in summer, and increased from 1,000 tons/day to 3,000 tons/day in fall. The salt loads at Maze were 250–500 tons/day higher than the salt load at Crows Landing, although the Maze EC was less than at Crows Landing EC.

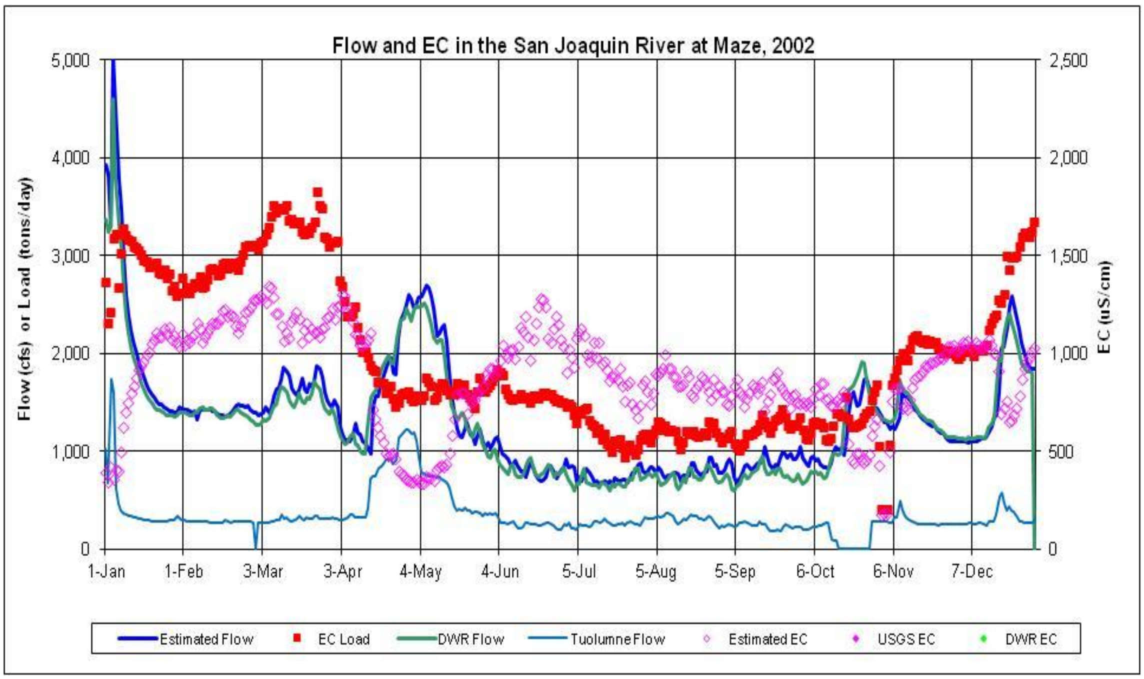


Figure F.2-4f. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Maze (downstream of the Tuolumne River) during 2002

Figure F.2-4g shows the daily flow and EC, with the calculated salt load (tons/day) for the Stanislaus River for 2002. The flows were about 250–500 cfs in winter, increased to 1,000–1,500 cfs during the VAMP period of April and May, were 500 cfs in June and July, and declined to about 300 cfs in October, prior to the pulse flow of 600 cfs for a week in late-October. The Stanislaus River EC was about 150 µS/cm in January, was 100 µS/cm in February and March, reduced to 75 µS/cm during VAMP, and gradually increased to 125 µS/cm at the end of 2002. The Stanislaus River salt loads in 2002 were 25–50 tons/day.

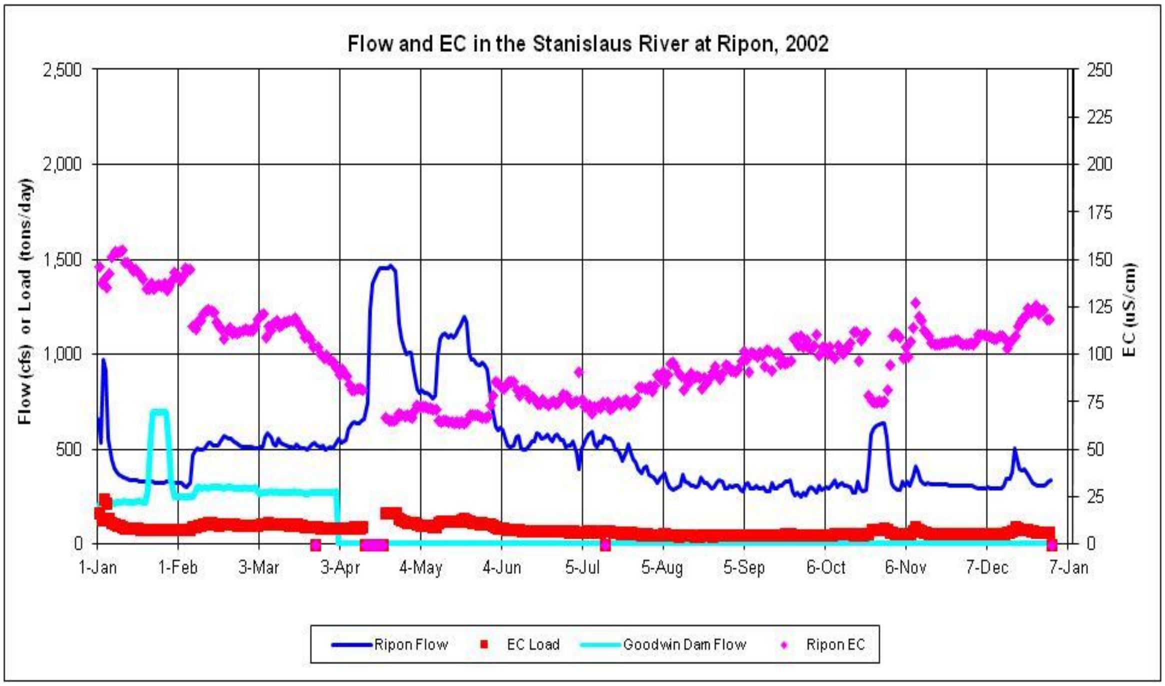


Figure F.2-4g. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Stanislaus River at Ripon during 2002

Figure F.2-4h shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Vernalis (downstream of Stanislaus River) for 2002. The Stanislaus River flows are shown for comparison. The SJR flows at Vernalis were 5,000 cfs at the beginning of January, about 2,000 cfs in February and March, about 3,000 cfs during VAMP, 1,000–1,500 cfs from June–October, 2,000 cfs in the October pulse, and about 2,500 cfs during the December storm. The Vernalis EC measurements in 2002 were about 900 µS/cm in January–March and reduced to 250 µS/cm during VAMP and the October pulse. The Vernalis EC values ranged from 500–750 µS/cm during the remainder of summer and fall. The SJR at Vernalis salt loads in 2002 were 3,000 tons/day in winter, were reduced to 2,000 tons/day during April and May, were 1,000–1,500 tons/day from June–October, were 2,000 tons/day in November, and increased to 3,000 tons/day at the end of 2002. The monthly average Vernalis EC values approached the EC objective of 1,000 µS/cm during winter (January–March) and approached the EC objective of 700 µS/cm during summer (June–August). Higher releases from New Melones (greater than the 250 cfs fish flow) for salinity control were apparently made in February–March and June–July 2002.

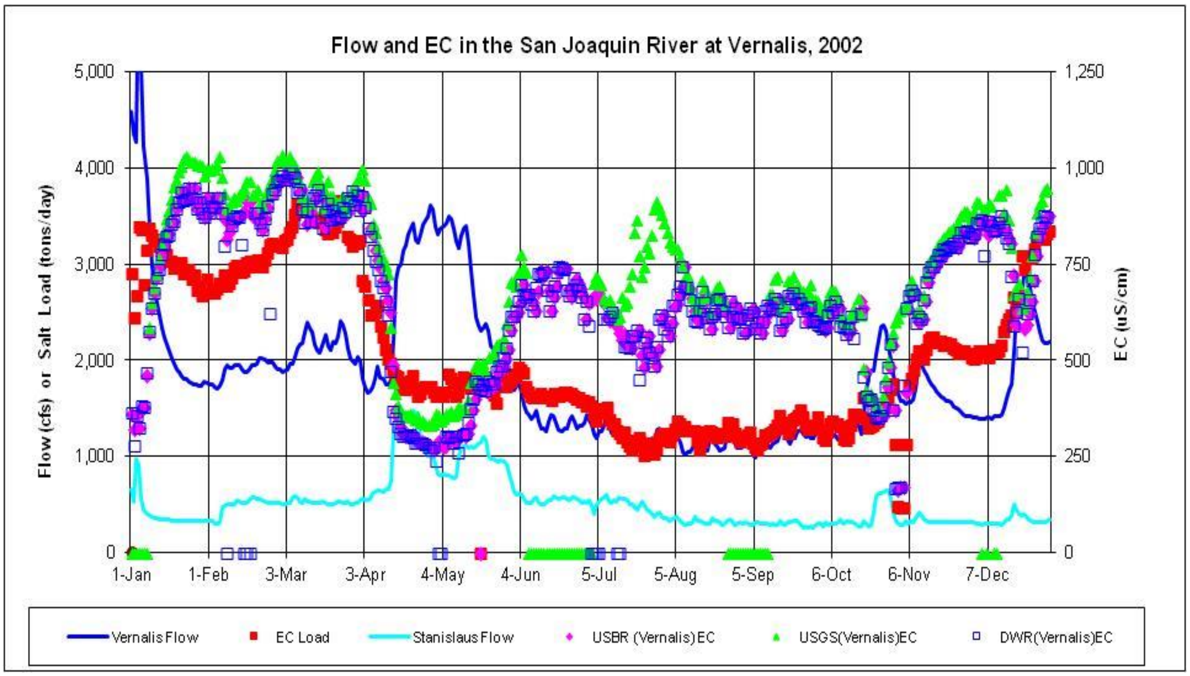


Figure F.2-4h. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the San Joaquin River at Vernalis during 2002

F.2.3.4 Measured SJR Flow and Salinity in 2003

Figure F.2-5a shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR near Stevinson for 2003. The flows in 2003 were again very low; flows remained less than 25 cfs except for two short storms (January and March). The SJR at Stevinson EC was about 1,500–2,000 µS/cm most of the year (flows of about 25cfs) but was reduced to less than 1,000 µS/cm when flows increased to 50 cfs or more. The salt loads were 100–200 tons/day in winter (with runoff) and were less than 25 tons/day for most of the year with flows of less than 25 cfs.

Figure F.2-5b shows the daily flow and EC, with the calculated salt load (tons/day) for Salt Slough for 2003. The maximum flows were about 500 cfs in March and 100–200 cfs from April–December.

The Salt Slough EC in 2003 was about 1,500–2,000 µS/cm in winter, 1,000–1,500 µS/cm in spring and summer, and 2,000 µS/cm in December. The salt loads in Salt Slough were 500–1,500 tons/day in winter and were 250–500 tons/day in spring, summer, and fall. The monthly salt loads in Salt Slough were lowest in summer.

Figure F.2-5c shows the daily flow and EC, with the calculated salt load (tons/day) for Mud Slough for 2003. The flows in 2003 were about 200 cfs in winter, were 50 cfs in spring and summer, and increased to 200 cfs in fall (water deliveries to the wetlands). The San Luis Drain discharge flow is the major source of flow in spring and summer. The Mud Slough EC was about 1,500–4,000 µS/cm throughout the year, with EC values of less than 2,000 µS/cm when flows were about 100 cfs or more. The salt loads in Mud Slough in 2003 were about 250–500 tons/day through most of 2003. The salt loads were about 1,000 tons/day in February–March. Salt and Mud Sloughs represent the major sources of salt load upstream of the Merced River; each contributes about 250–1,000 tons/day to the SJR.

Figure F.2-5d shows the daily flow and EC, with the calculated salt load (tons/day) for the Merced River for 2003. The Merced River flows were about 200 cfs in winter and increased to about 500–1,500 cfs during VAMP. Summer flows were about 50–100 cfs, the October pulse flow was 500 cfs, and the November–December flows were about 200 cfs (fish flow requirement). The flows near Cressy and at Stevinson were very similar throughout 2003. The Merced River EC measurements were 150–200 µS/cm in winter and reduced to 50 µS/cm during the VAMP pulse flows and the October pulse flow. The EC was about 200–400 µS/cm during summer low flows. The Merced River salt load in 2003 was about 25–50 tons/day throughout the year.

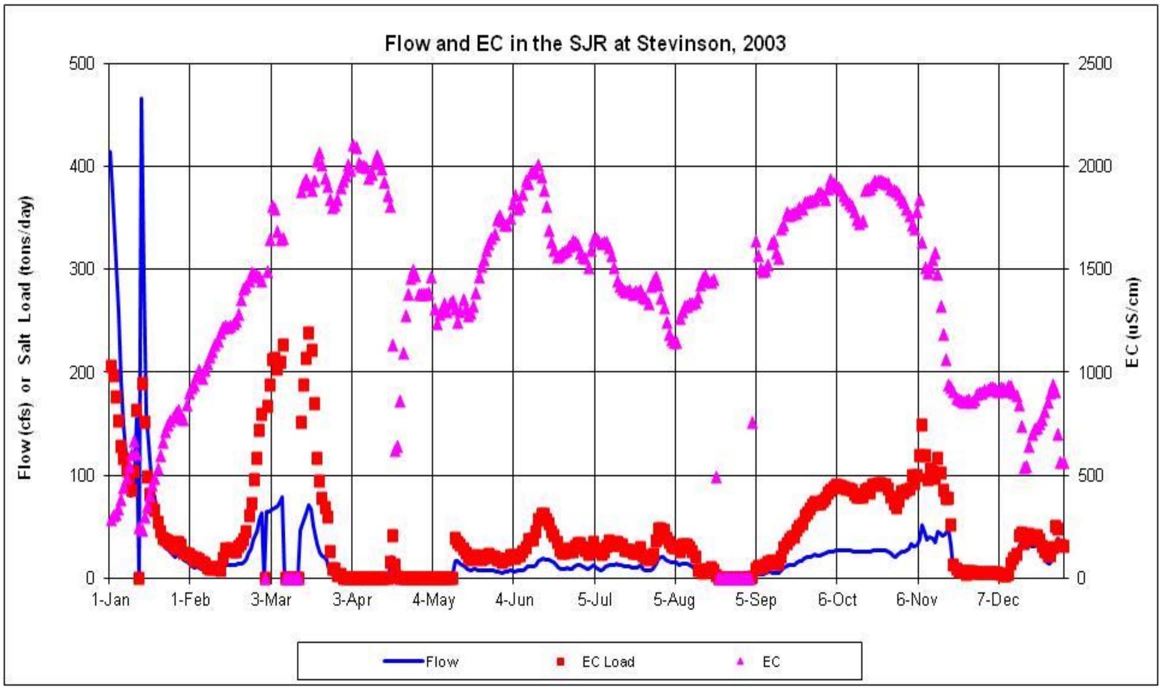


Figure F.2-5a. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Stevinson during 2003

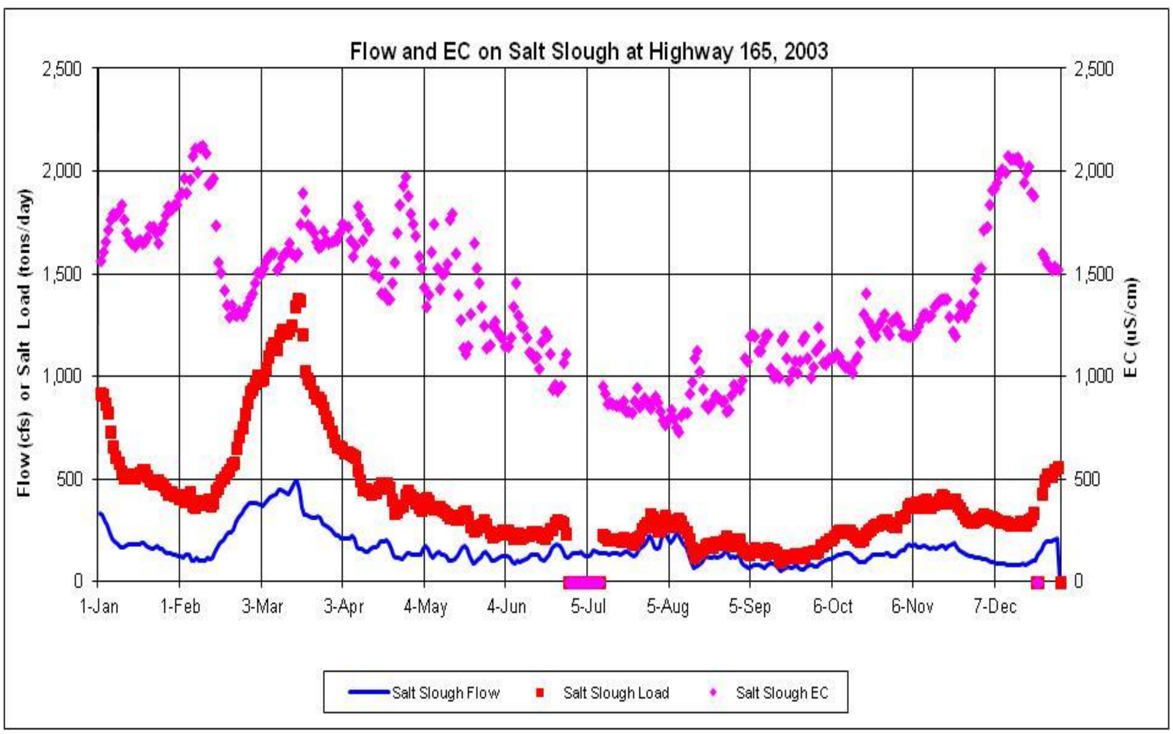


Figure F.2-5b. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Salt Slough at Highway 165 during 2003

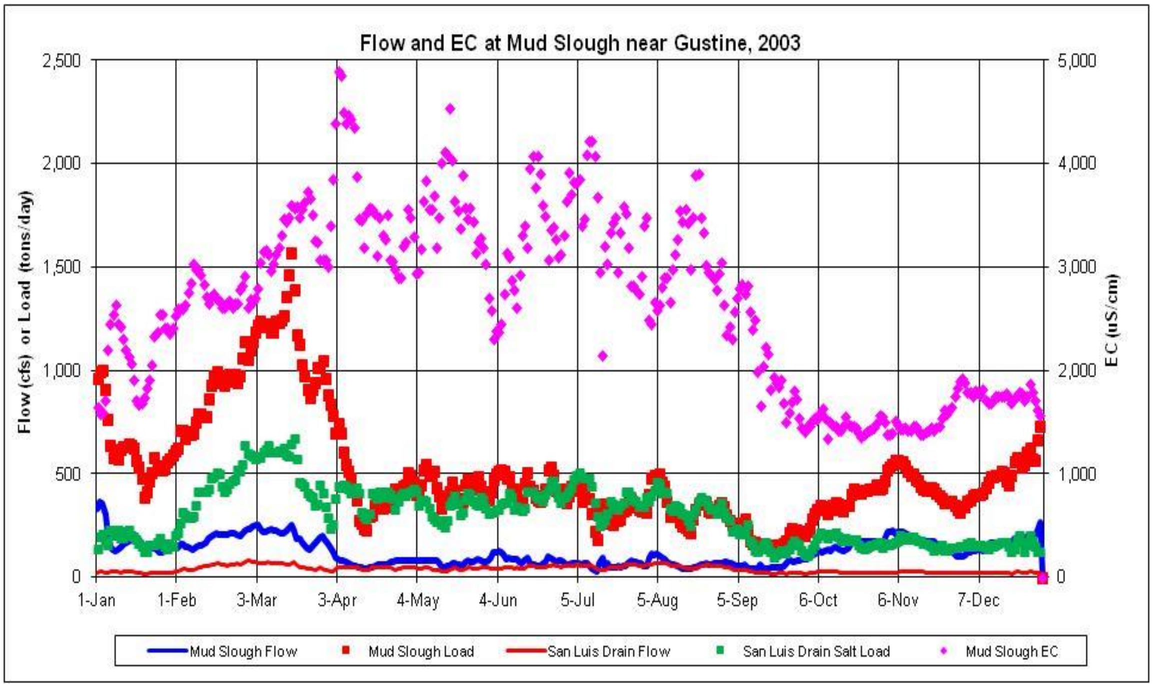


Figure F.2-5c. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in Mud Slough near Gustine and in the San Luis Drain Discharge to Mud Slough during 2003

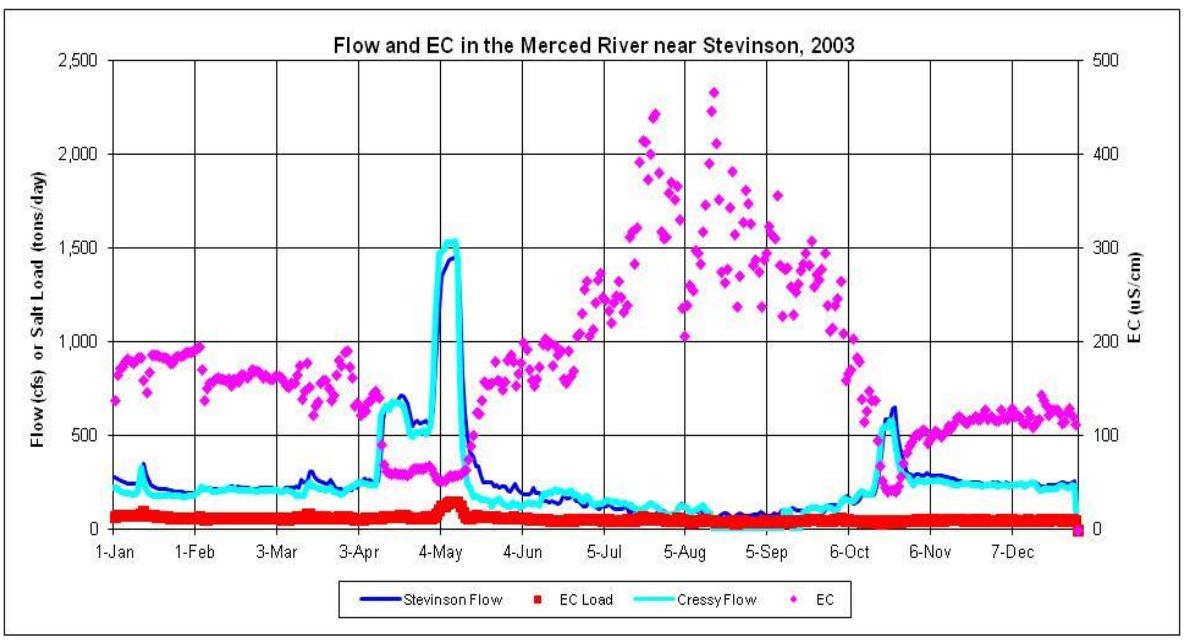


Figure F.2-5d. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Merced River near Stevinson during 2003

Figure F.2-5e shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Crows Landing for 2003. The Merced River flows are shown for comparison. The SJR flows at Crows Landing were generally 1,000 cfs in winter and spring, 1,750 cfs in early May, less than 500 cfs in summer, and 750 cfs in fall. The Crows Landing EC was about 1,500 µS/cm in winter, reduced to 1,000 µS/cm during VAMP, and was 1,000–1,500 µS/cm in summer and fall. The Crows Landing EC was reduced to 500 µS/cm during higher Merced River flows in May and October of 2003. The SJR at Crows Landing salt loads were about 2,000–3,000 tons/day in winter, 1,000–2,000 tons/day in spring, 1,000 tons/day in summer, and about 2,000 tons/day at the end of 2003. Because the Merced River salt loads were 25–50 tons/day, the great majority of the salt load in the SJR at Crows Landing originated from upstream of the Merced River.

Figure F.2-5f shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Maze for 2003. The Tuolumne River flows are shown for comparison. The SJR flows at Maze were about 1,500 cfs in winter, 2,000 cfs during VAMP, and 1,000 cfs in summer and fall, with an October pulse flow of 1,500 cfs. The Tuolumne River flow was about 250 cfs for winter, about 750–1,000 cfs during VAMP, and about 200–300 cfs from June through the end of 2003. The Maze EC estimates in 2003 were about 1,250 µS/cm in winter and 750–1,250 µS/cm during summer, but were reduced to 500 µS/cm during VAMP and the October pulse flow. The SJR at Maze salt loads in 2003 were about 3,000–4,000 tons/day in winter, about 2,000 tons/day in spring, 1,500 tons/day in summer, and 2,000 tons/day in fall. The salt loads at Maze were 250–500 tons/day higher than the salt load at Crows Landing, although the Maze EC was less than at Crows Landing EC.

Figure F.2-5g shows the daily flow and EC, with the calculated salt load (tons/day) for the Stanislaus River for 2003. The flows were about 250–500 cfs in winter, increased to 750–1,500 cfs during the extended VAMP period of April–June, were 400 cfs in July, and were about 300 cfs from August–December, with a pulse flow of 1,000 cfs in mid-October. The Stanislaus River EC was about 150 µS/cm in January, was 100 µS/cm in February and March, reduced to 75 µS/cm during VAMP, and gradually increased to 125 µS/cm at the end of 2003. The Stanislaus River salt loads in 2003 were 25–50 tons/day.

Figure F.2-5h shows the daily flow and EC, with the calculated salt load (tons/day) for the SJR at Vernalis for 2003. The Stanislaus River flows are shown for comparison. The SJR flows at Vernalis were 2,000 cfs in winter and spring, with a VAMP flow of 3,000 cfs. Flows were about 1,500 cfs in summer and fall with an October pulse flow of 2,500 cfs. The Vernalis EC measurements in 2003 were about 1,000 µS/cm in January–March and reduced to less than 500 µS/cm during VAMP and the October pulse. The Vernalis EC values ranged from 500–750 µS/cm during the remainder of summer and fall. The SJR at Vernalis salt loads in 2003 were 3,000–4,000 tons/day in winter, reduced to 2,000 tons/day during April and May, and were 1,500–2,000 tons/day from June–December. The monthly average Vernalis EC values approached the EC objective of 1,000 µS/cm during winter (January–March), and approached the EC objective of 700 µS/cm during summer (July–August). Higher releases from New Melones (greater than the 250 cfs fish flow) for salinity control were apparently made in February–March and July–August 2003.

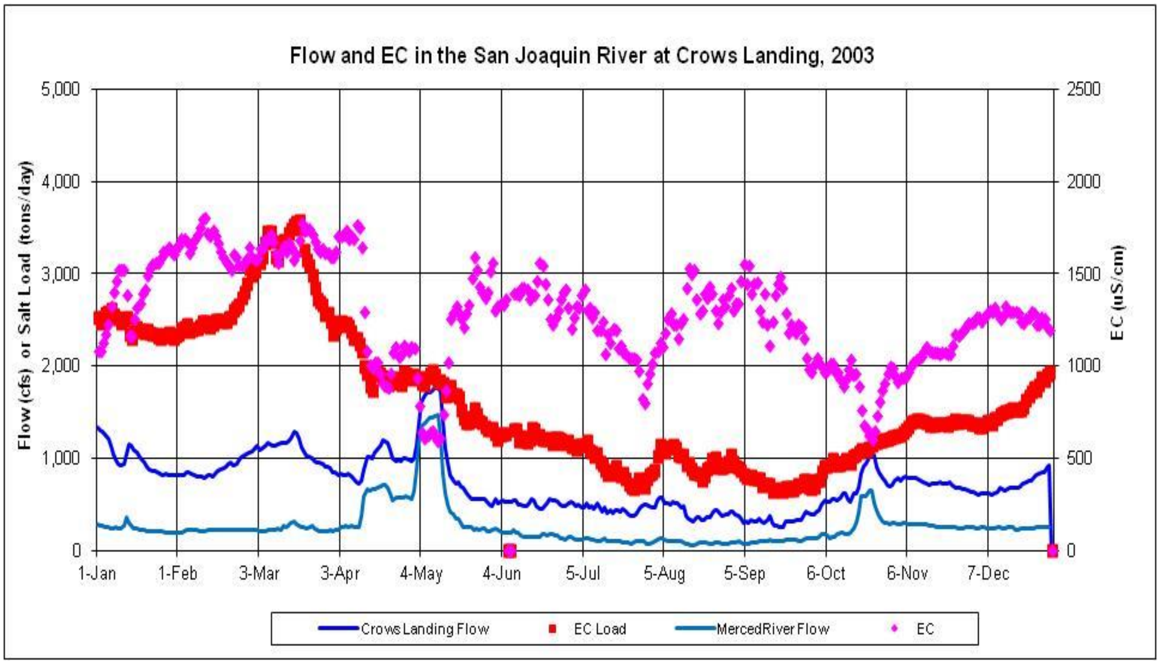


Figure F.2-5e. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Crows Landing (downstream of the Merced River) during 2003

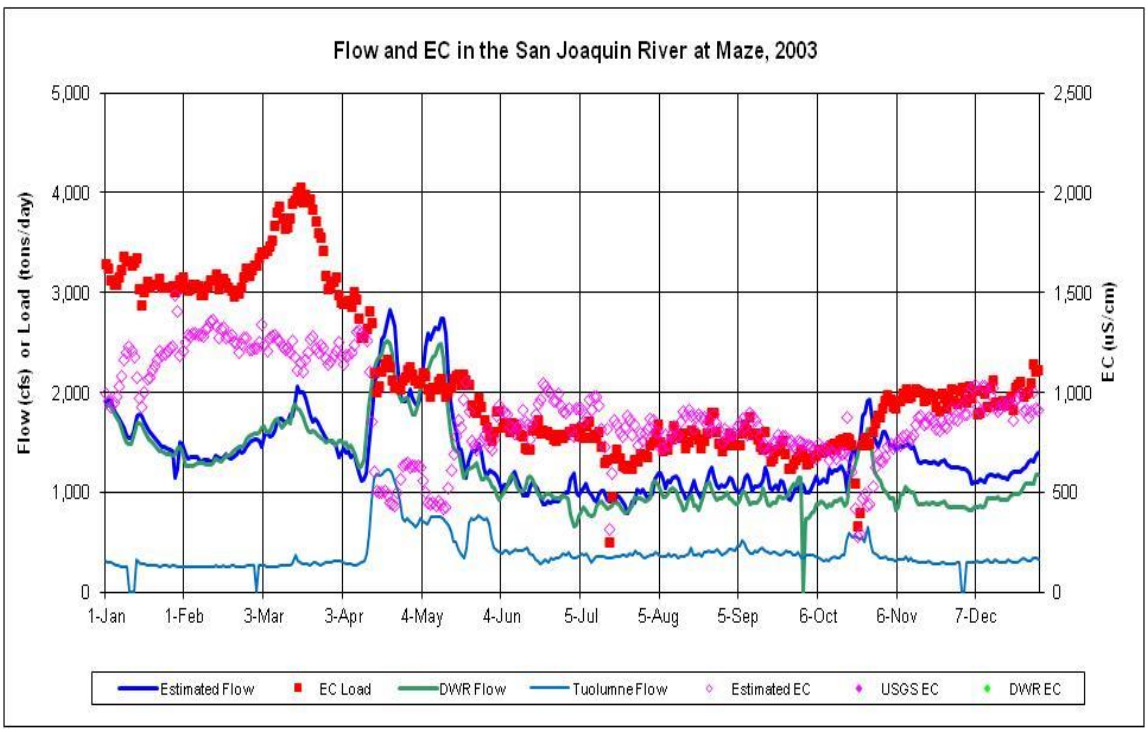


Figure F.2-5f. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the SJR at Maze (downstream of the Tuolumne River) during 2003

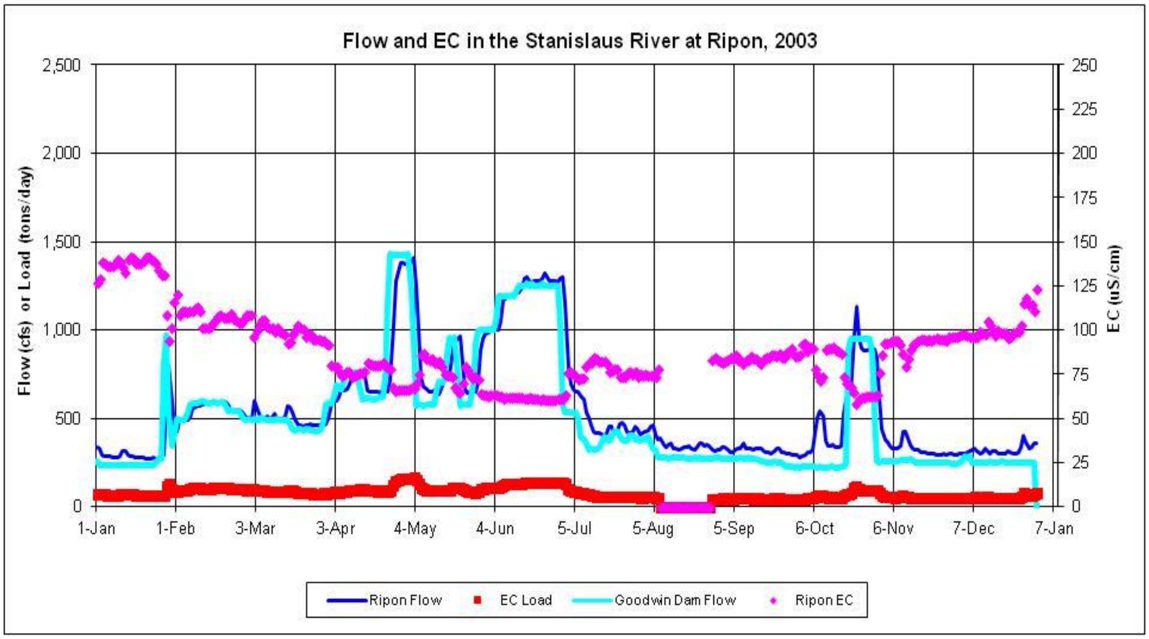


Figure F.2-5g. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the Stanislaus River at Ripon during 2003

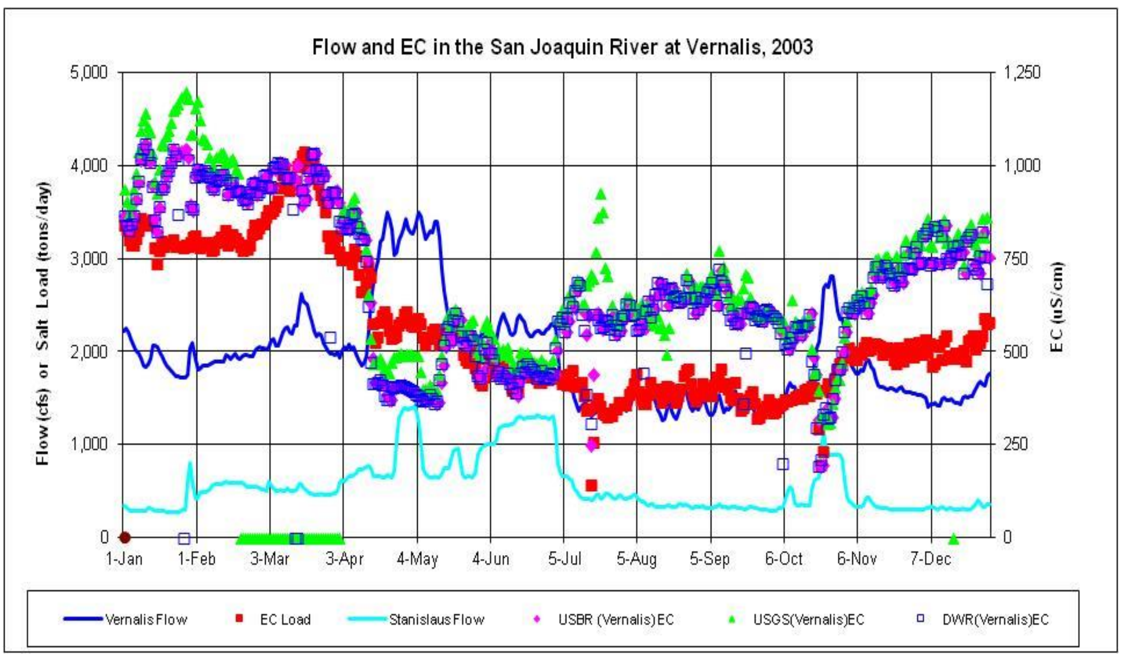


Figure F.2-5h. Daily Measured Flow (cfs) and EC (µS/cm) and Calculated Salt Load (tons/day) in the San Joaquin River at Vernalis during 2003

F.2.4 Southern Delta Salinity Patterns

The historical daily river flow and daily EC measurements at Vernalis, Mossdale, Brandt Bridge, Rough and Ready Island, Old River at Union Island, Old River at Tracy Boulevard Bridge, and at the DMC (Central Valley Project [CVP] Jones pumping plant) and the State Water Project (SWP) Banks pumping-plant can be compared to evaluate the sources of increased EC within these southern Delta channels. The distributions of EC values at these locations are shown in Tables F.2-2a through F.2-2h.

Table F.2-2a. Monthly Average Measured SJR at Vernalis EC (µS/cm) for WY 1985–2011 (27 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	262	452	210	128	144	163	128	95	110	152	214	239
10%	310	504	336	338	250	230	200	166	184	320	432	332
20%	398	579	587	490	338	314	276	230	264	473	498	410
30%	414	616	728	534	553	412	351	296	452	541	525	475
40%	476	657	752	639	630	672	470	352	500	586	570	550
50%	507	673	771	752	750	747	535	380	575	611	608	591
60%	524	692	782	778	784	800	570	438	627	633	629	626
70%	584	705	836	815	873	835	643	501	686	693	651	687
80%	696	755	853	945	940	904	695	644	731	758	758	762
90%	768	807	880	1,047	1,104	962	743	692	827	766	797	798
max	866	819	926	1,137	1,299	1,095	1,144	718	871	846	873	898
average	520	661	699	694	695	647	506	413	534	583	600	578

Table F.2-2b. Monthly Average Measured SJR at Mossdale EC (µS/cm) for WY 1985–2011 (27 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	252	396	235	133	146	195	123	96	103	181	237	278
10%	342	580	355	334	236	238	200	177	180	374	438	360
20%	427	600	596	526	332	318	316	249	313	519	512	454
30%	469	651	696	576	555	417	398	338	480	606	584	510
40%	480	674	782	749	594	720	483	359	548	665	602	586
50%	539	703	829	788	773	757	555	417	597	672	671	645
60%	592	727	862	834	876	798	611	481	674	703	705	711
70%	620	732	883	929	907	834	662	578	717	760	748	737
80%	720	775	912	1,001	984	906	733	642	750	801	831	799
90%	794	867	953	1,093	1,153	996	760	700	837	822	873	845
max	892	923	1,007	1,234	1,279	1,090	1,148	782	964	850	935	869
average	554	699	740	744	707	664	530	439	567	635	654	618

Table F.2-2c. Monthly Average Measured SJR at Brandt Bridge EC (µS/cm) for WY 1985–2009 (25 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	240	436	252	150	168	215	154	115	156	243	314	291
10%	337	560	392	424	299	253	228	199	228	356	488	399
20%	401	596	611	526	433	345	335	304	413	548	524	477
30%	467	621	742	574	617	428	397	333	508	609	580	528
40%	504	668	755	672	696	620	562	404	590	676	620	605
50%	530	699	777	772	778	719	636	427	613	695	653	652
60%	601	708	823	800	803	801	659	497	680	709	681	701
70%	659	747	837	863	875	868	686	517	773	739	694	751
80%	722	775	881	968	936	932	733	684	787	777	764	780
90%	808	845	929	1,011	1,047	969	787	734	823	851	801	833
max	941	961	955	1,063	1,213	1,108	827	840	961	888	872	959
average	560	694	734	719	715	662	548	459	593	648	639	631

Table F.2-2d. Monthly Average Measured SJR at Rough and Ready Island (RRI) EC (µS/cm) for WY 1985–2011 (27 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	246	513	301	165	177	175	156	109	126	191	310	289
10%	354	522	389	324	271	260	195	200	199	295	403	377
20%	451	536	633	461	357	348	309	229	313	462	465	444
30%	495	593	709	523	458	391	386	298	480	554	533	483
40%	525	650	743	605	587	497	509	381	524	591	549	554
50%	553	670	793	669	676	643	612	445	573	618	564	578
60%	616	714	818	756	723	739	643	475	629	656	602	614
70%	672	723	839	781	774	805	673	553	656	678	660	661
80%	754	796	867	813	870	861	744	638	707	696	692	751
90%	847	844	900	870	977	955	826	714	751	728	731	805
max	864	966	967	1,028	1,038	1,666	923	849	892	856	791	832
average	577	681	729	641	627	637	542	441	531	576	575	581

Table F.2-2e. Monthly Average Measured Old River at Middle River (Union Island) EC (µS/cm) for WY 1993–2009 (17 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	245	567	271	191	184	225	150	111	123	183	365	282
10%	300	588	536	391	280	278	257	179	195	360	457	396
20%	451	617	661	546	317	324	305	253	367	457	516	432
30%	472	653	759	591	439	402	354	338	514	617	566	503
40%	494	679	795	623	610	455	472	375	537	629	609	555
50%	510	711	818	761	695	682	543	402	565	634	630	588
60%	530	721	839	778	780	802	586	425	570	684	639	606
70%	541	731	864	808	918	873	616	439	639	713	704	650
80%	595	768	876	819	958	947	665	476	675	721	726	693
90%	616	787	890	948	971	1,016	711	517	750	779	732	722
max	660	853	907	1,008	979	1,043	855	649	899	853	918	913
average	491	696	754	679	651	639	501	376	530	610	619	574

Table F.2-2f. Monthly Average Measured Old River at Tracy Boulevard Bridge EC (µS/cm) for WY 1985–2009 (25 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	294	408	355	265	286	245	194	135	240	246	325	295
10%	437	630	646	399	407	339	282	266	245	461	534	512
20%	554	681	714	617	493	376	411	407	463	645	644	597
30%	667	716	756	727	677	467	482	433	569	703	694	626
40%	674	748	831	765	782	685	672	524	625	744	737	692
50%	730	801	870	872	877	906	721	591	697	815	776	761
60%	779	842	901	907	904	950	825	617	786	841	812	816
70%	828	858	928	1,016	1,044	968	858	709	839	904	872	871
80%	875	895	994	1,096	1,094	1,059	954	748	956	931	909	934
90%	1,048	978	1,054	1,167	1,174	1,114	976	778	1,034	985	980	945
max	1,094	1,136	1,246	1,233	1,326	1,174	1,206	1,008	1,210	1,186	1,194	1,541
average	726	798	848	834	827	757	684	562	692	769	771	770

Table F.2-2g. Monthly Average Measured DMC at Jones Pumping Plant EC (µS/cm) for WY 2000–2011 (12 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	290	264	353	258	317	243	186	133	156	206	230	263
10%	339	389	420	284	360	325	202	214	193	238	253	288
20%	359	420	508	484	489	366	339	250	220	241	269	340
30%	416	448	528	496	528	485	388	347	275	255	283	347
40%	436	491	573	520	538	519	398	412	314	281	297	367
50%	472	502	604	540	547	550	425	415	345	297	315	406
60%	489	514	620	548	555	583	454	422	362	304	376	441
70%	501	520	627	618	565	608	485	427	373	312	440	520
80%	506	524	632	647	570	619	507	439	421	318	446	542
90%	535	526	665	763	598	655	521	448	446	351	470	570
max	584	527	756	827	835	665	544	467	522	409	484	580
average	448	467	572	544	536	512	405	362	330	292	352	424

Table F.2-2h. Monthly Average Measured Banks Pumping Plant EC (µS/cm) for WY 1986–2011 (26 years)

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
min	202	214	269	225	236	258	187	132	143	170	189	212
10%	260	331	384	290	296	287	262	252	190	192	212	244
20%	340	420	477	345	335	318	296	295	215	203	239	292
30%	446	437	512	427	361	327	313	327	288	217	253	316
40%	476	485	549	463	410	391	325	367	324	260	276	365
50%	496	523	593	525	431	449	383	379	367	290	289	429
60%	542	553	602	544	457	473	416	398	389	310	385	490
70%	569	563	659	617	466	482	465	433	432	323	470	531
80%	611	627	713	672	512	514	501	451	442	458	480	602
90%	679	755	817	734	728	541	532	477	588	559	540	658
max	745	816	917	993	814	857	721	718	682	820	790	696
average	488	520	587	519	454	428	396	380	369	332	369	439

These historical flow and EC data provide a very accurate picture of salinity conditions in the southern Delta channels during relatively low flow conditions. Data from 2000–2003 will be evaluated here because these four years were relatively dry, with summer flows of less than 2,000 cfs at Vernalis. In addition, these years represent conditions after the establishment of the 1995 Bay-Delta Plan, which established the southern Delta EC objectives of 700 µS/cm during April–August and 1,000 µS/cm for the rest of the year. The measured EC values at Vernalis during the irrigation season of April–August were approaching the EC objective of 700 µS/cm for several months in each of these years.

The two major sources of water in the southern Delta channels are (1) diversions from the SJR at the head of Old River near Mossdale, and (2) Sacramento River water drawn across the central Delta by the CVP and SWP pumping-plants. The SJR at Vernalis is the primary flow and salinity measurement location for water entering the southern Delta. Although the SJR flow and EC at Vernalis vary daily, there is a general seasonal pattern, because flows are highest during winter and spring while the salt load contributed from groundwater discharge and agricultural drainage may be higher in summer.

Effects of Agricultural Diversion and Drainage

There are a number of agricultural diversions along the SJR downstream of Vernalis and in the southern Delta channels. Some of these are major irrigation district diversions, like the Banta–Carbona Irrigation District intake, with a maximum diversion flow of about 175 cfs. Others are small riparian diversion pumps for individual farmers with flows of 5 cfs or less. The diversion of water does not change the salinity of water remaining in the river. However, because downstream river flow is reduced, the effects of all downstream drainage flows or municipal discharges on salinity are greater because of the upstream diversion (i.e., lower flow).

The salt diverted in irrigation water must be returned to the river to maintain acceptable soil salinity, so the net effect of agricultural diversion on downstream river salinity can be estimated from the percentage of river flow diverted. Assuming the diversion is constant and the salt load diverted will be returned to the river, the average effect on downstream salinity can be estimated assuming the same salt load with a reduced downstream flow. However, the increased salinity will not usually be fully observed during the irrigation season, because much of the agricultural drainage of the applied salt will occur during the winter rainfall period, and some salt will enter the shallow groundwater beneath the fields and slowly migrate to the river during the fall, winter, and spring. Nevertheless, the average expected increase in the river EC is proportional to the fraction of water diverted.

Effects of Treated Wastewater Discharge

The effect of treated wastewater discharge on the river EC depends on the relative flows (i.e., dilution) and the difference between the effluent EC and the river EC (i.e., excess EC). The dilution of a river discharge is often expressed as the ratio of the river flow to the effluent flow. The fraction of effluent in downstream river water would be estimated as 1/ (dilution +1). For example, if river flow is 4 times the discharge, the dilution is 4 and downstream concentrations will be 1/5 of effluent concentrations (assuming the upstream river concentrations of the constituents are zero). The EC change downstream of the discharge can be calculated as:

(Eqn. F.2-1):

EC Change = (Discharge EC – River EC) x Discharge / (River flow + Discharge) = Excess EC / [Dilution + 1]

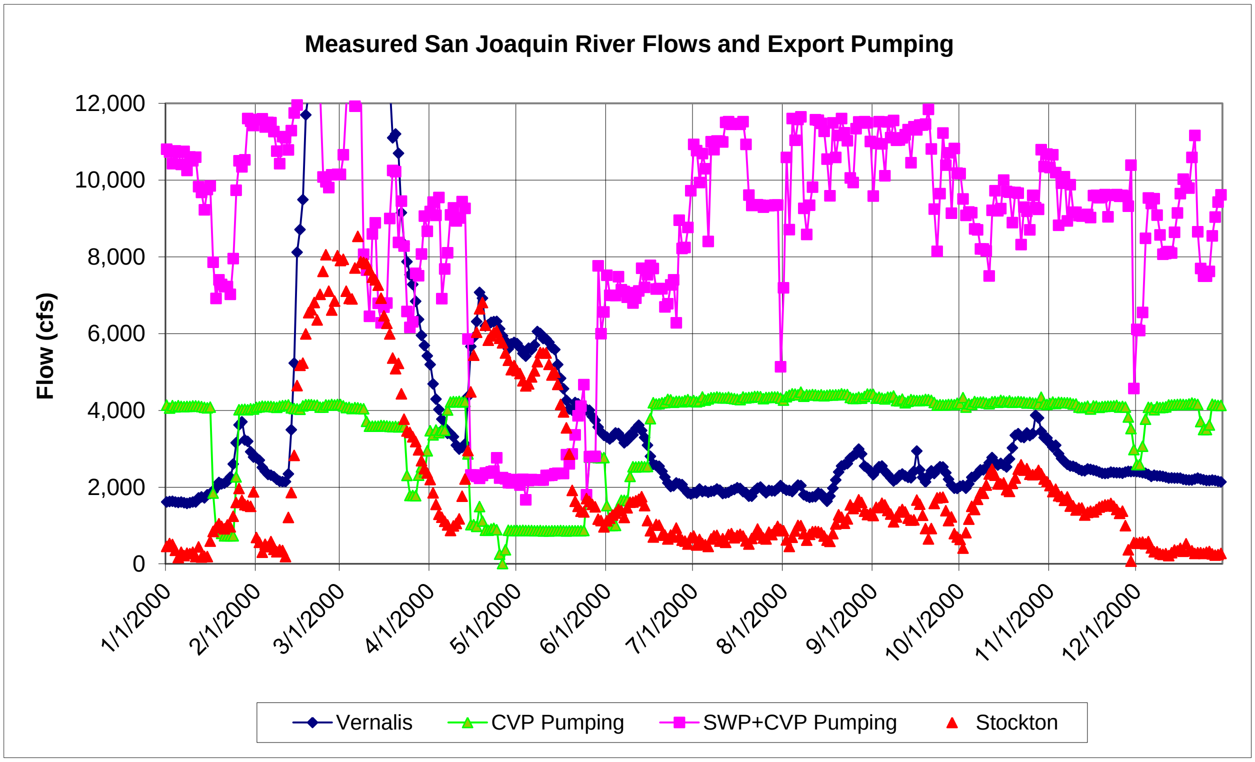
These equations can be used to determine how much discharge can be added to a river without causing a violation of EC standards. Low river flow with high EC provides little assimilative capacity for discharges. For example, if Vernalis EC in April is at 700 μS/cm, the San Joaquin River would have no assimilative capacity and the only way that a discharge could maintain river EC below the Bay-Delta Plan objective would be for the discharge to be at or below the 700 μS/cm objective. In contrast, if the SJR EC is at 600 μS/cm, there would be some assimilative capacity. For example, if river flow was 970 cfs and a discharge was 30 cfs with an EC of 1,500 μS/cm, the increase in river EC associated with the discharge would be 27 μS/cm and SJR EC would remain below the 700 μS/cm objective (i.e., [1500 μS/cm -600 μS/cm]/[970 cfs/30 cfs+1])

Daily Delta Flows and EC Data for 2000

Figure F.2-6a shows the measured flows and export pumping in calendar year 2000. The estimated flows at the head of Old River (diluting the City of Tracy discharge) and in Old River at the Tracy Boulevard Bridge (diluting the Mountain House discharge) are shown in the lower panel. The head of Old River flow can be calculated as the difference between the Vernalis flow and the measured Stockton flow (Garwood Bridge). The Old River flow at the Tracy Boulevard Bridge has been estimated as 10 percent of the head of Old River flow, based on DSM2 tidal hydraulic modeling results and recent tidal flow measurements. The majority of the flow moves down Grant Line Canal toward the CVP and SWP pumps.

Vernalis flow in 2000 was about 2,000 cfs in January and increased to about 15,000 cfs during the major storm runoff event in late February and March. The Vernalis flow had declined to about 3,000 cfs when the flow was raised during VAMP to about 6,000 cfs from April 15–May 15. Flows declined to about 4,000 cfs at the beginning of June and were 2,000 cfs from the end of June until the end of the year. A pulse flow release to attract adult Chinook salmon increased flows in the second half of October to about 3,000 cfs.

The bottom panel of Figure F.2-6a shows the flows measured at Stockton in 2000 were less than 50 percent of the Vernalis flow (i.e., the normal flow split) because high CVP and SWP export pumping (i.e., lower tidal elevations) shifted more SJR flow into Old River. The Stockton flows were about 500 cfs less than the Vernalis flows during VAMP when the head of Old River barrier was installed, and during October and November when the fall barrier was installed. The estimated flow at the Head of Old River can be compared to the calculated Vernalis flow minus Stockton flow. The estimated flow through the barrier culverts of about 500 cfs was generally confirmed by the calculated values. The estimated Old River flows in summer appear to be greater than the calculated (Vernalis minus Stockton) flows.



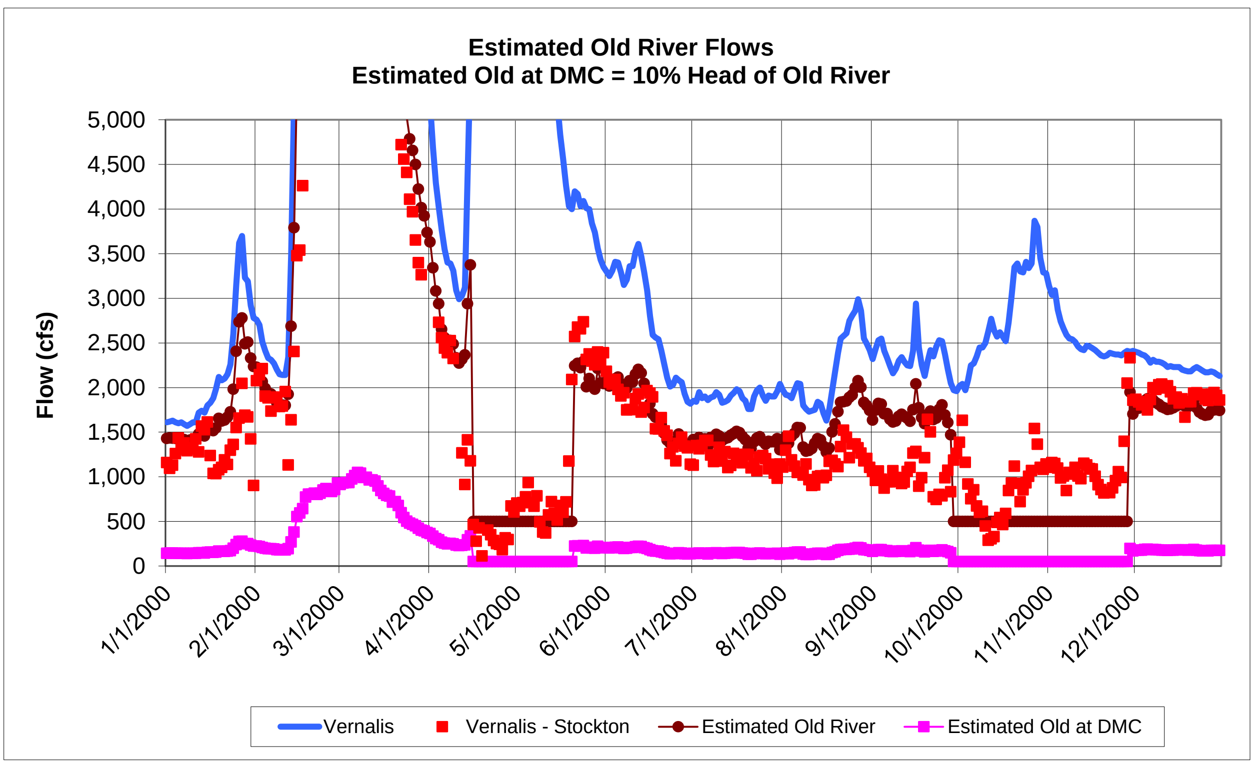
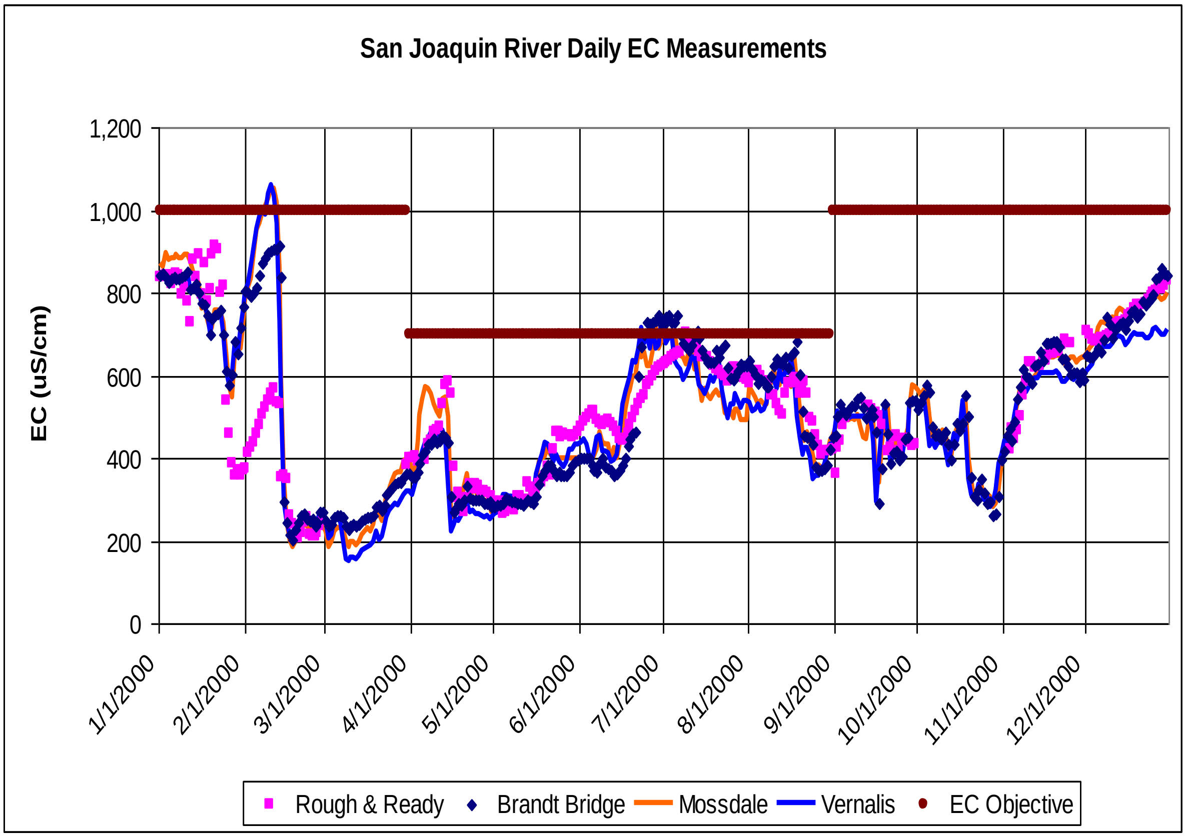


Figure F.2-6a. Historical Daily SJR Flows, CVP and SWP Export Pumping Flows, and Old River Flows for 2000

Figure F.2-6b shows the measured EC in the SJR and Old River during 2000. The four stations shown in the top panel are Vernalis, Mossdale, Brant Bridge, and Rough and Ready Island. The SJR EC was about 800 µS/cm in January and reduced to about 200 µS/cm during the large storm runoff period in February and March. The EC increased to 400 µS/cm in early April and reduced to 300 µS/cm during the VAMP flow of about 6,000 cfs. The EC reached 700 µS/cm at the end of June, then decreased slightly to 600 µS/cm in July and August, and was about 500 µS/cm in September and October. The Vernalis EC was about 600 µS/cm in November and approached 800 µS/cm at the end of December 2000. The EC values are expected to increase slightly at each downstream station from agricultural drainage and wastewater discharge at Lathrop and Stockton. However, EC values at each of four stations were very similar most of the time during 2000. Because the EC measurements are independently calibrated, some variation in measurements is expected. A measurement variation of about 25 µS/cm may be typical. Detecting difference of less than 25 µS/cm may not be reliable with these routine field measurements.

The bottom panel of Figure F.2-6b shows the EC along Old River. The Union Island station is just upstream of the Tracy discharge, and the EC values were similar to the Vernalis and Mossdale EC values. The Old River at Tracy Boulevard Bridge station EC values were similar to the Union EC values until August, but were higher than the Union EC values in September–December. The EC values at the DMC intake and at the SWP Banks pumping-plant were lower than the SJR EC values in January and throughout the summer months of June–September. The DMC and Banks EC values were similar to the SJR EC in October–December. The DMC and Banks EC values are influenced by Sacramento River EC (of about 200 µS/cm) and salinity intrusion from Suisun Bay in the fall when Delta outflow is generally reduced.



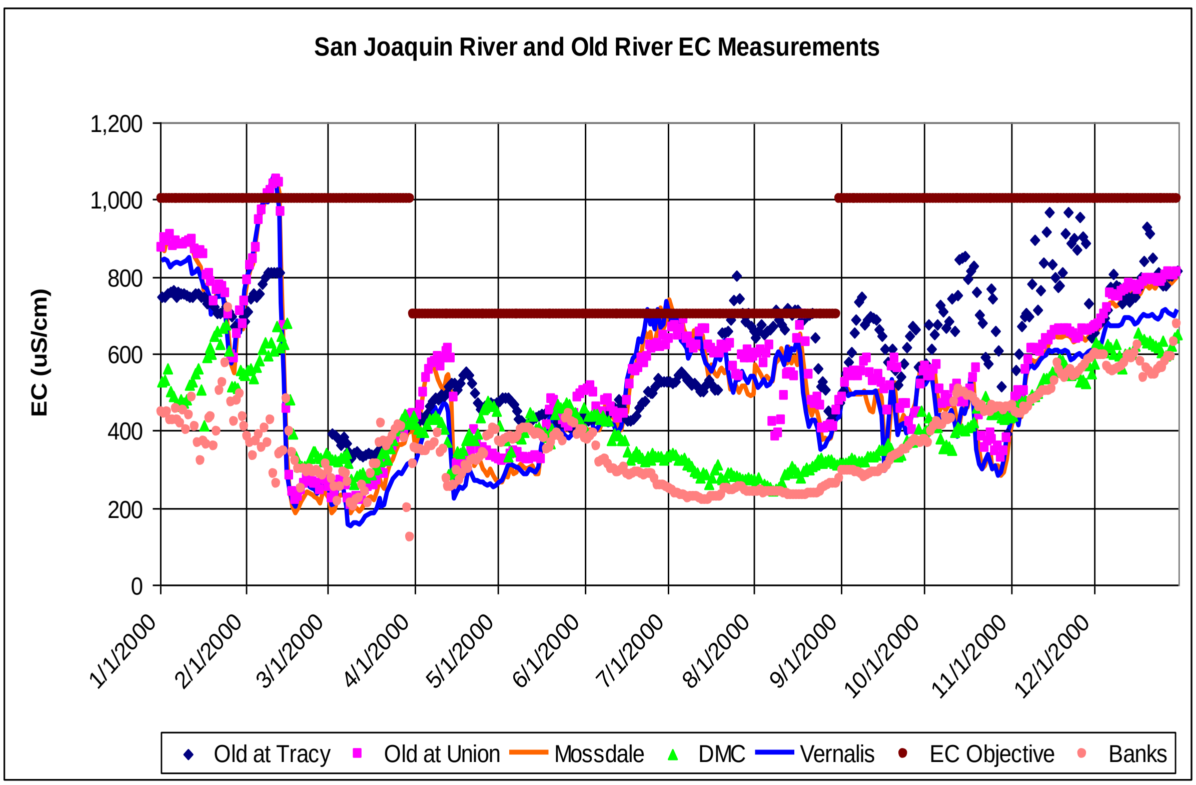
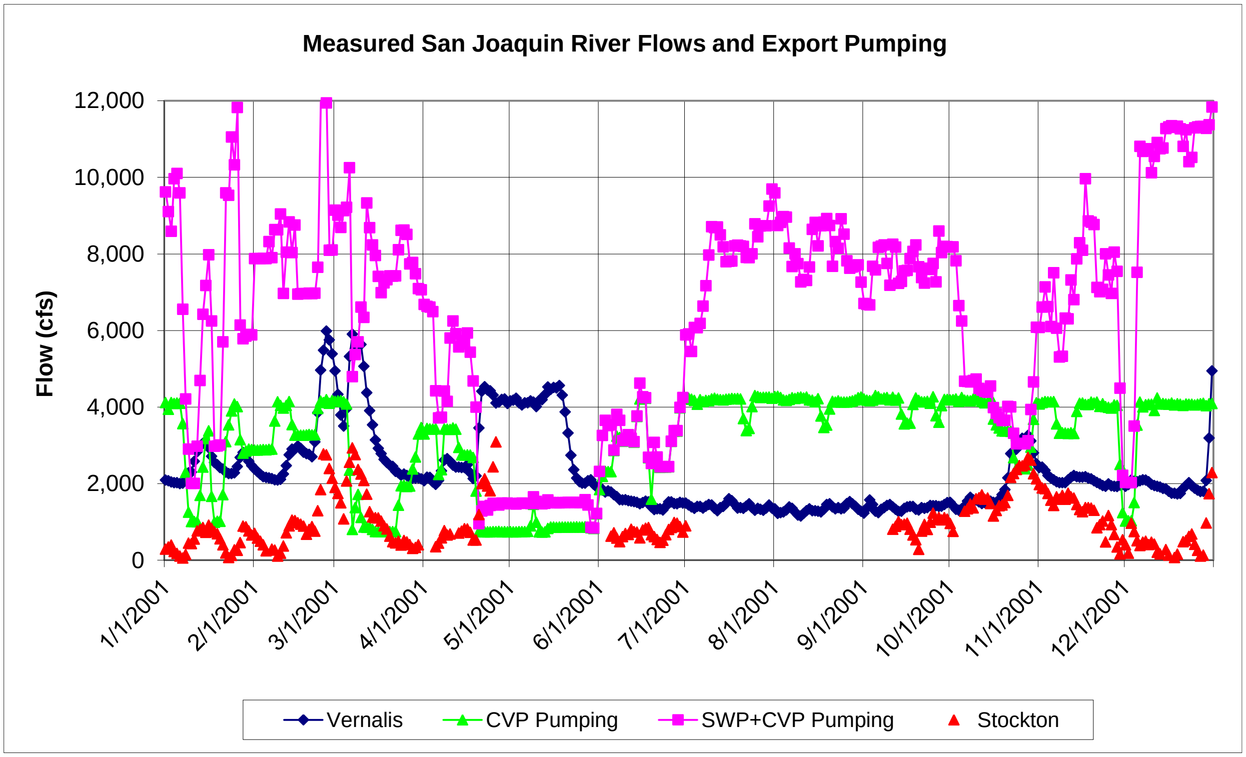


Figure F.2-6b. Historical Measured Daily EC in the SJR and Old River for 2000

Daily Delta Flows and EC Data for 2001

Figure F.2-7a shows the measured flows and export pumping in calendar year 2001. Vernalis flows in 2001 were about 2,000 cfs in January and February and increased to about 5,000 cfs during late February and early March. The Vernalis flow had declined to about 2,000 cfs at the beginning of VAMP, when the flows were raised to about 4,000 cfs from April 25 through May 25. Flows declined to about 2,000 cfs at the beginning of June and were 1,500 cfs from the end of June until mid-October. A pulse flow release to attract adult Chinook salmon increased flows in the second half of October to about 3,000 cfs. Flows were 2,000 cfs in November and December of 2001.

Flows measured at Stockton in 2001 indicate that less than 50 percent of the Vernalis flow reached Stockton during January–April, because the high CVP and SWP export pumping effects shifted more of the river flow into Old River. Stockton flows were higher during VAMP when the head of Old River barrier was installed, and during October and November when the fall barrier was installed. The USGS tidal flow meter at Stockton was out of service during the summer of 2001, but flows were assumed to be about 25 percent of Vernalis flows because Stockton flows are reduced by about 5 percent of the export pumping. Export pumping in 2001 was about 6,000–8,000 cfs in January–March, reduced in April–June (especially during VAMP), and was about 8,000 cfs in July–September. Pumping was greater than 10,000 cfs in December, and Stockton flows were reduced to less than 200 cfs.



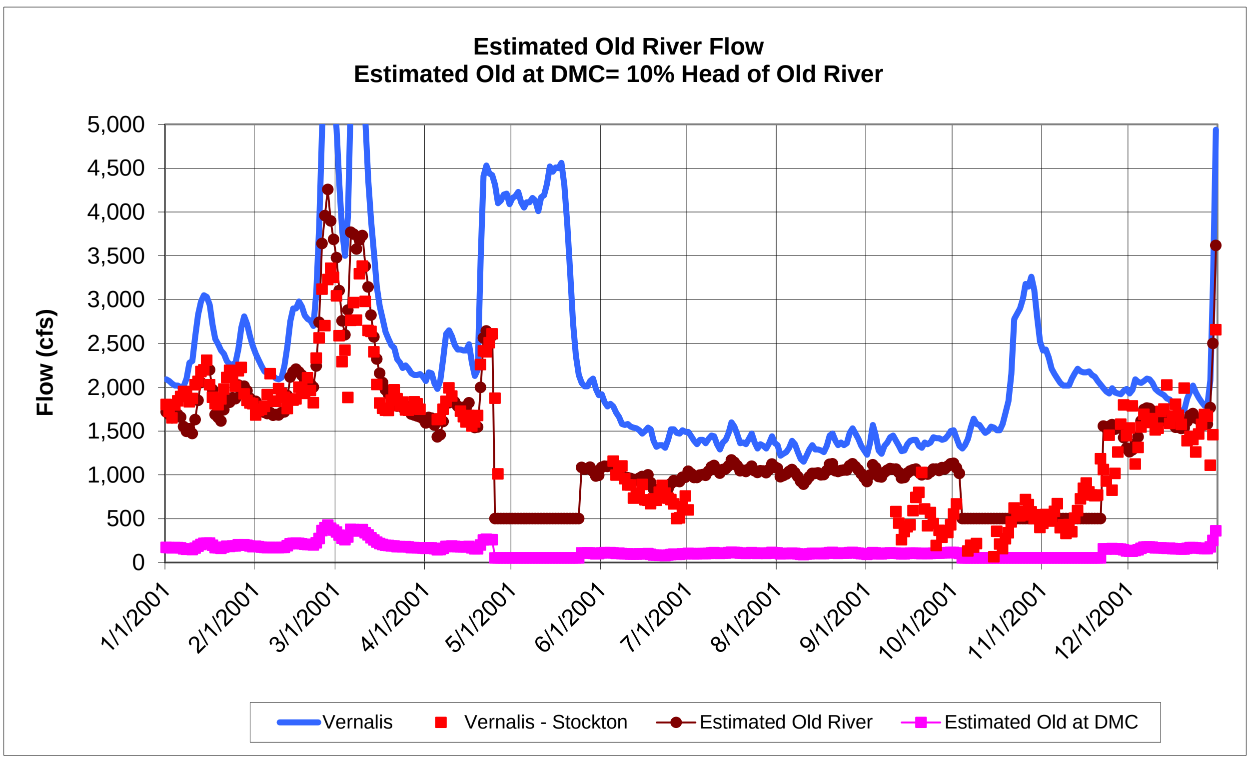
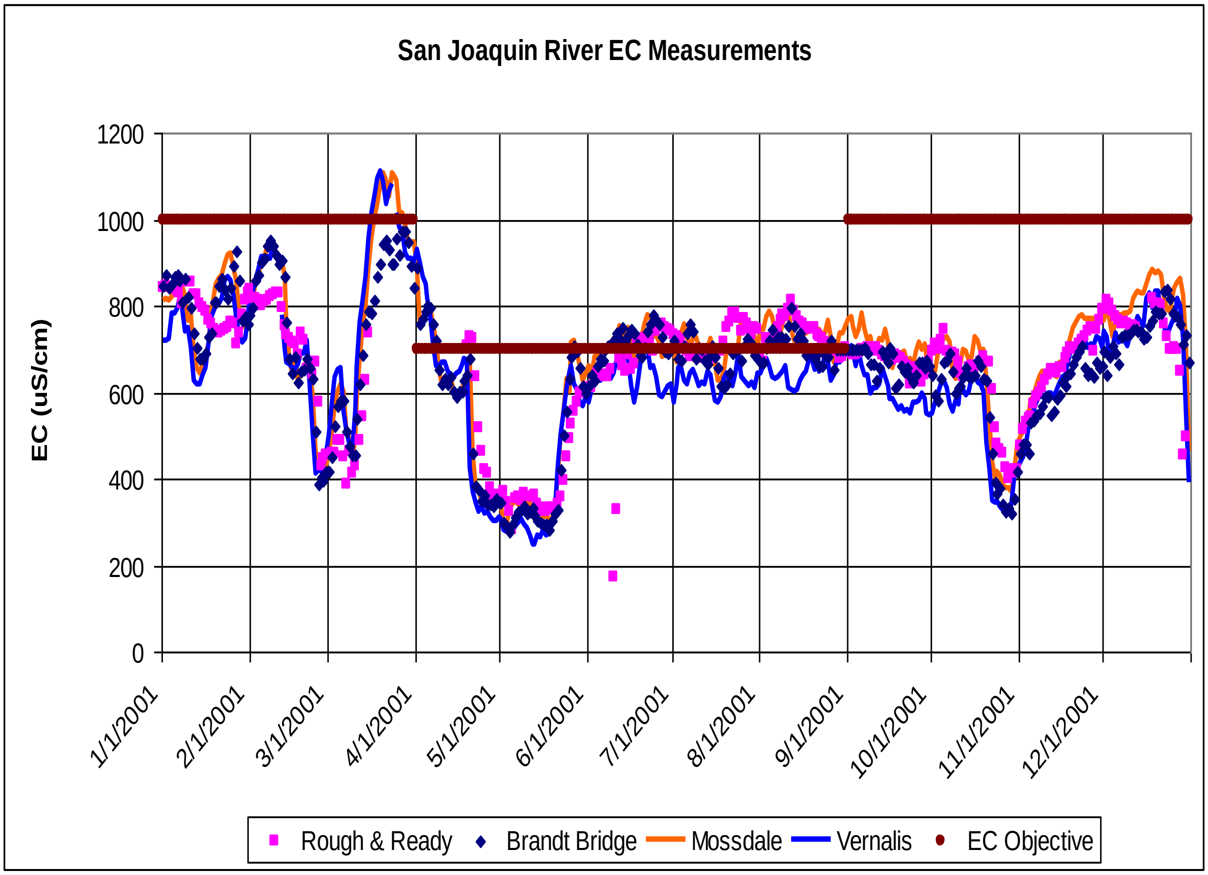


Figure F.2-7a. Historical Daily SJR Flows, CVP and SWP Export Pumping Flows, and Old River Flows for 2000

Figure F.2-7b shows the measured EC in the SJR during 2001. The measured SJR EC at all four stations was about 800 μS/cm in January and February and reduced to about 400 μS/cm during the runoff period in late February and early March. The EC increased to 1,000 μS/cm in late March but was reduced to about 350 μS/cm during the VAMP flow of about 4,000 cfs. The EC reached 700 μS/cm at the end of May and remained about 700 μS/cm through mid-October. The SJR EC was reduced to about 400 μS/cm during the late October pulse flow, but increased to 800 μS/cm by the end of November and December 2001. EC values at each of the four EC stations were very similar during most of 2001. The Vernalis EC was slightly lower than the other 3 stations during summer, suggesting the influence of downstream agriculture drainage and wastewater discharges.

The Old River at Union Island EC values were similar to the Vernalis EC and Mossdale EC values. The Old River at Tracy Boulevard EC was similar to the Union EC values until the VAMP period in May, when the EC at the Tracy Boulevard Bridge remained at 600 μS/cm, while the other EC values were reduced to 400 μS/cm. The Old River at Tracy Boulevard EC was 800–1,000 μS/cm from June–December, considerably higher than the SJR EC or Union EC. The EC values at the DMC intake and at the SWP Banks pumping-plant were lower than the SJR EC values in January–April and during June–August. The DMC and Banks EC values were lower than the SJR EC in November and December.



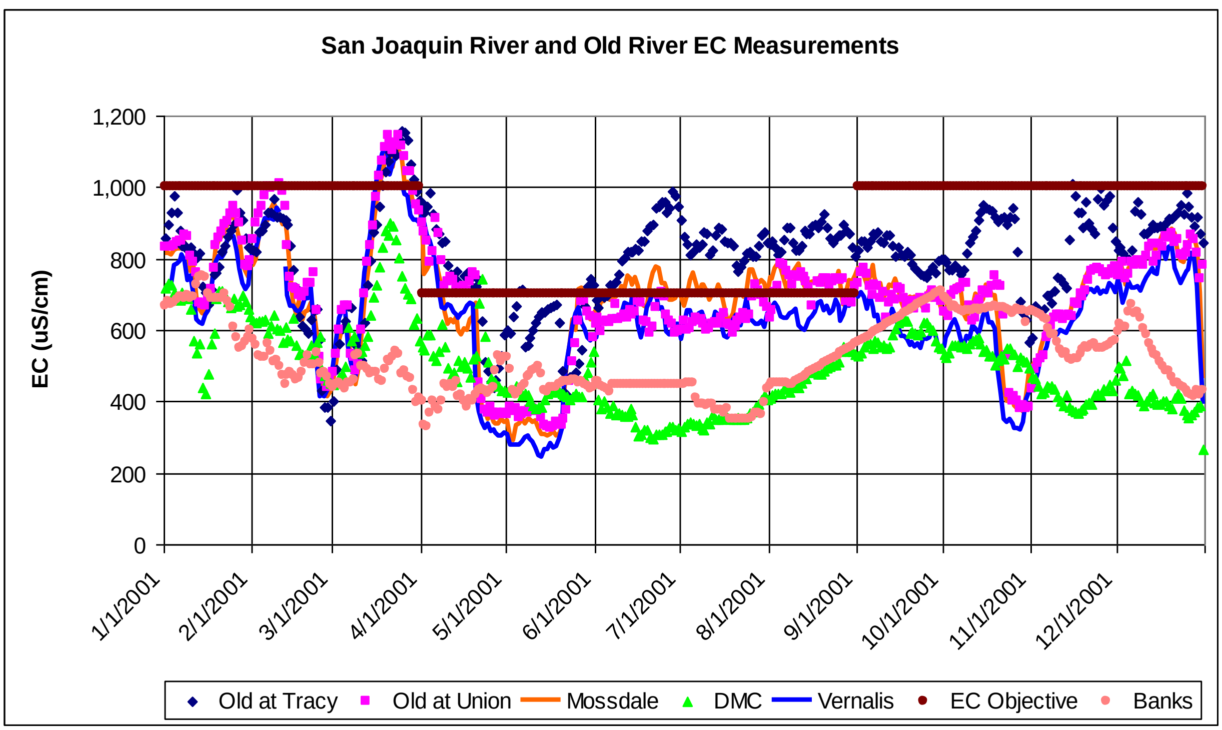


Figure F.2-7b. Historical Measured Daily EC in the SJR and Old River for 2001

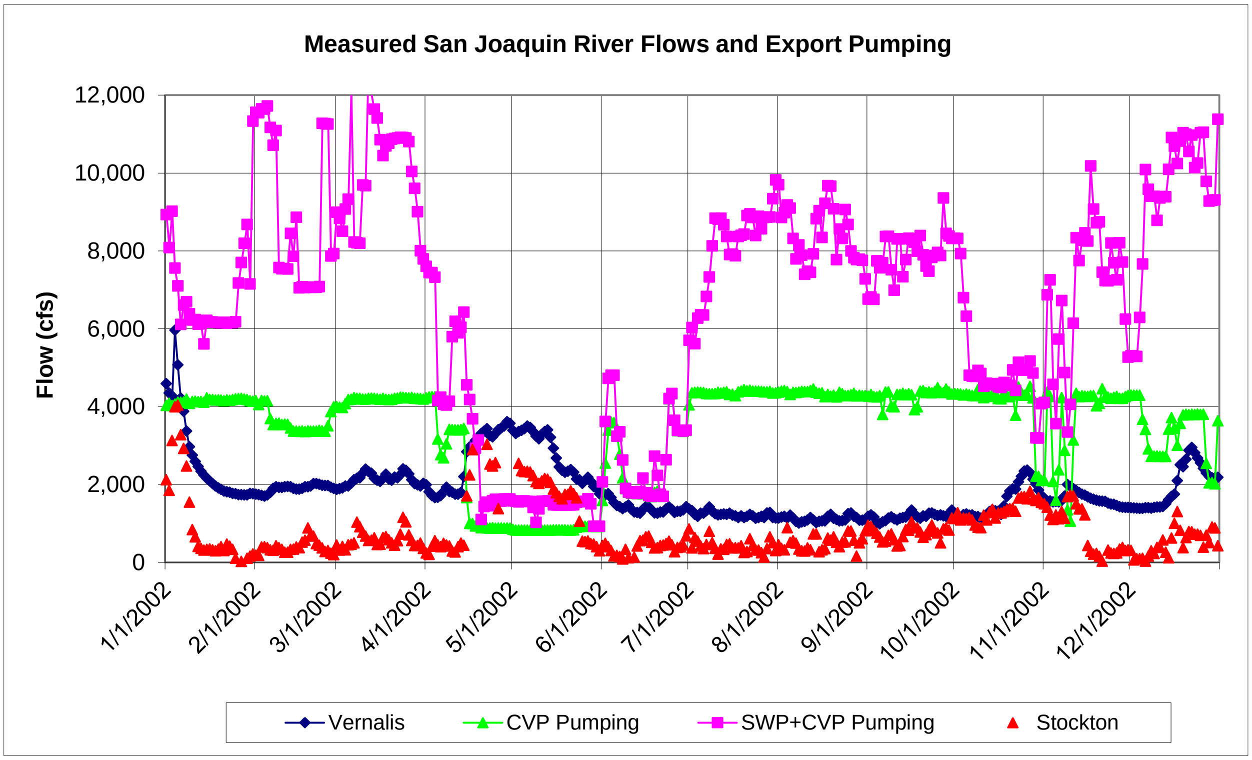
Daily Delta Flows and EC Data for 2002

Figure F.2-8a shows the measured flows and export pumping in calendar year 2002. The estimated flows at the head of Old River and in Old River at the Tracy Boulevard Bridge are shown in the lower panel. Vernalis flow in 2002 was about 4,000 cfs at the beginning of January but declined to 2,000 cfs at the end of January, and remained at 2,000 cfs until the VAMP period in mid-April. VAMP flow was about 3,500 cfs. Flows declined to about 2,000 cfs at the beginning of June and were less than 1,500 cfs from the end of June until the pulse at the end of October. Vernalis flows were a minimum of 1,000 cfs in August and September. Flows were about 1,500 cfs in November and increased to 2,000 cfs at the end of December 2002.

Export pumping in 2002 was about 6,000–12,000 cfs in January–March, reduced to less than 4,000 cfs in April–June (less than 2,000 cfs during VAMP), and was about 8,000 cfs in July–September. Pumping was just 4,000 cfs in October and then increased to about 8,000 cfs in November and 10,000 cfs in December.

Flows measured at Stockton in 2002 indicate much less than 50 percent of the Vernalis flow reached Stockton during much of the year, because of the high CVP and SWP export pumping. Stockton flows were higher during VAMP when the head of Old River barrier was installed and during October and early November when the fall barrier was installed.

The bottom panel of Figure F.2-8a shows the estimated Old River flows at the City of Tracy Discharge (similar to head of Old River flows) and at the DMC near the Mountain House discharge (Old River at DMC). The estimated head of Old River flows in August and September were greater than the Vernalis minus Stockton flows. As a result, the actual flows at the City of Tracy and Mountain House discharges were likely lower than the estimated flows during this period.



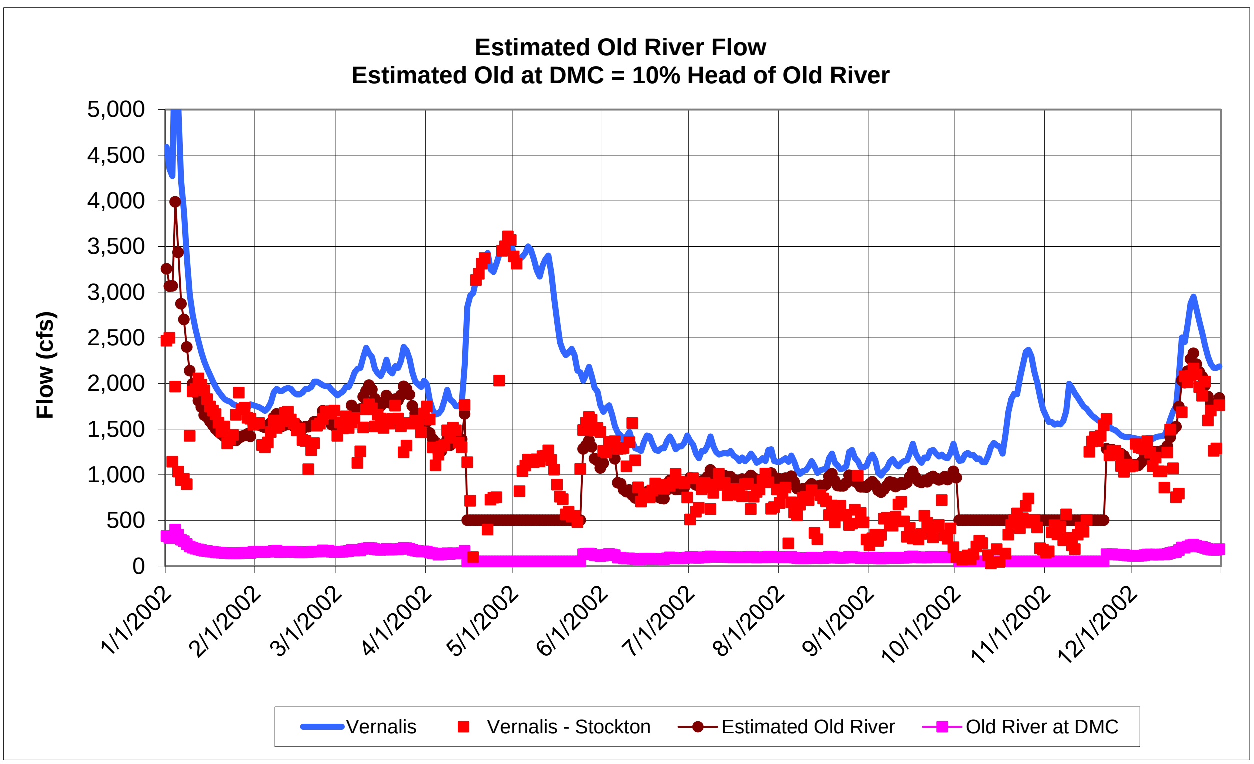
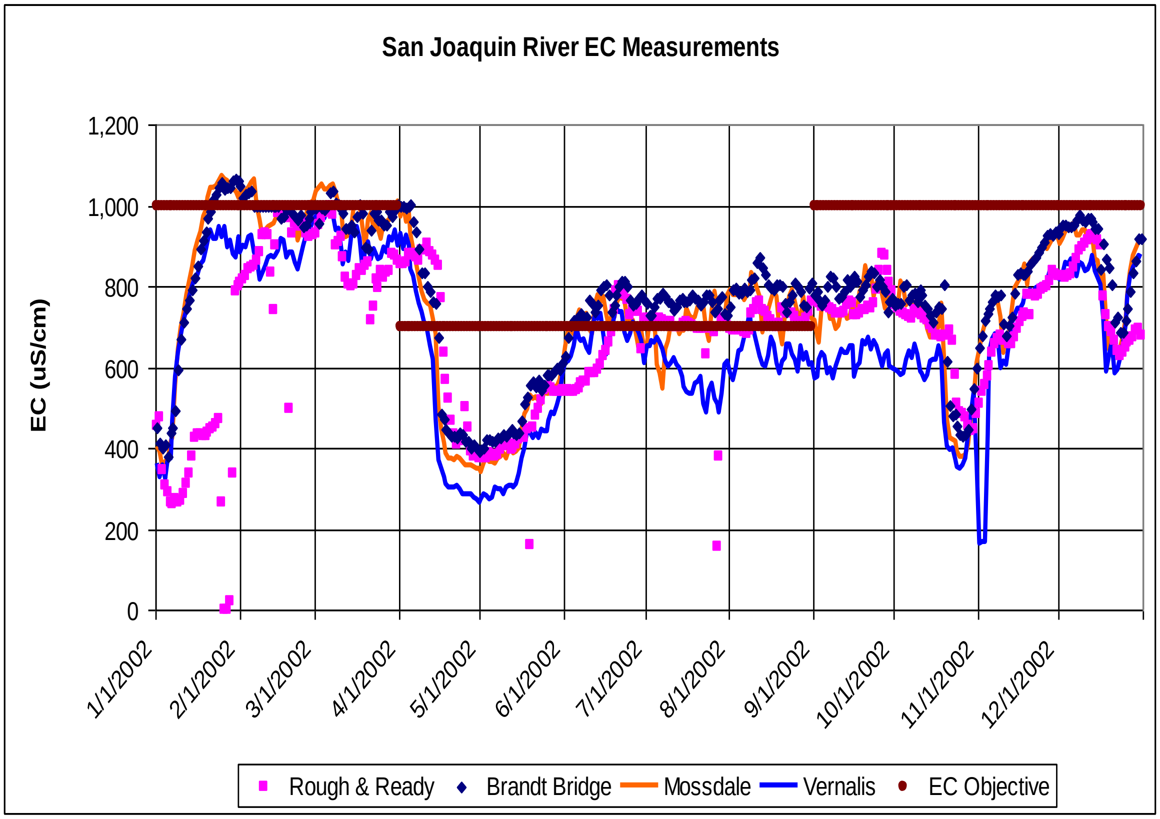


Figure F.2-8a. Historical Daily SJR Flows, CVP and SWP Export Pumping Flows, and Old River Flows for 2002

Figure F.2-8b shows the measured EC in the SJR during 2002. The Vernalis EC was about 100–200 μS/cm lower than the other three stations during most of the year. Because of these differences, it is difficult to determine the actual SJR EC values. The SJR EC was just 400 μS/cm during the early January storm but increased to 1,000 μS/cm in late January until VAMP. The EC was reduced to about 400 μS/cm during the VAMP flow of about 3,500 cfs. The EC reached 600 μS/cm at the end of May and was about 700 μS/cm from mid-June through mid-October. The Vernalis EC was reduced to about 400 μS/cm during the late October pulse flow, but increased to 800 μS/cm by the end of November, and was 1,000 μS/cm in December 2002. A small storm event diluted the EC to 600 μS/cm in mid-December 2002.

The bottom panel of Figure F.2-8b shows the EC along Old River in 2002. The Old River at Union EC values were similar to the Mossdale EC values. The Old River at Tracy Boulevard EC values were similar to the Union EC values until May, when the EC values at Tracy Boulevard increased to about 800 μS/cm. The EC at Tracy Boulevard was slightly higher than the EC at Mossdale or at Union. The EC values at the DMC intake and at the SWP Banks pumping plant were lower than the SJR EC values throughout most of 2002.



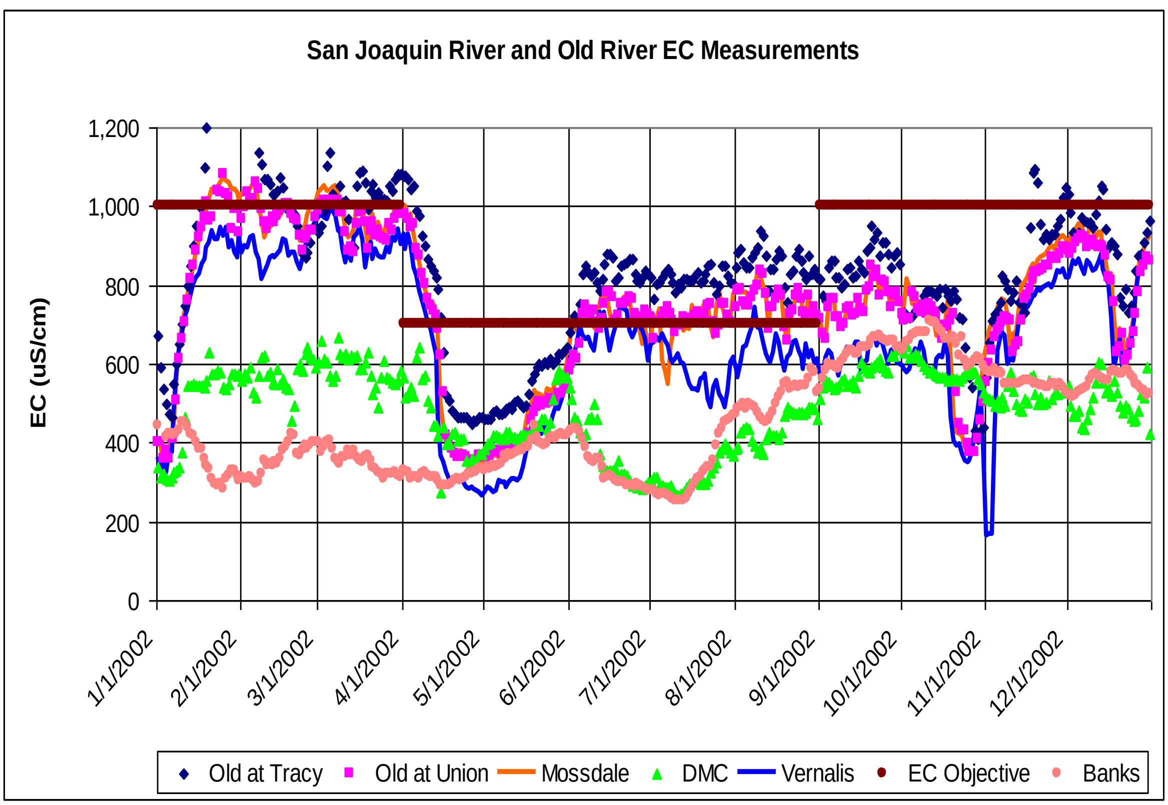


Figure F.2-8b. Historical Measured Daily EC in the SJR and Old River for 2002

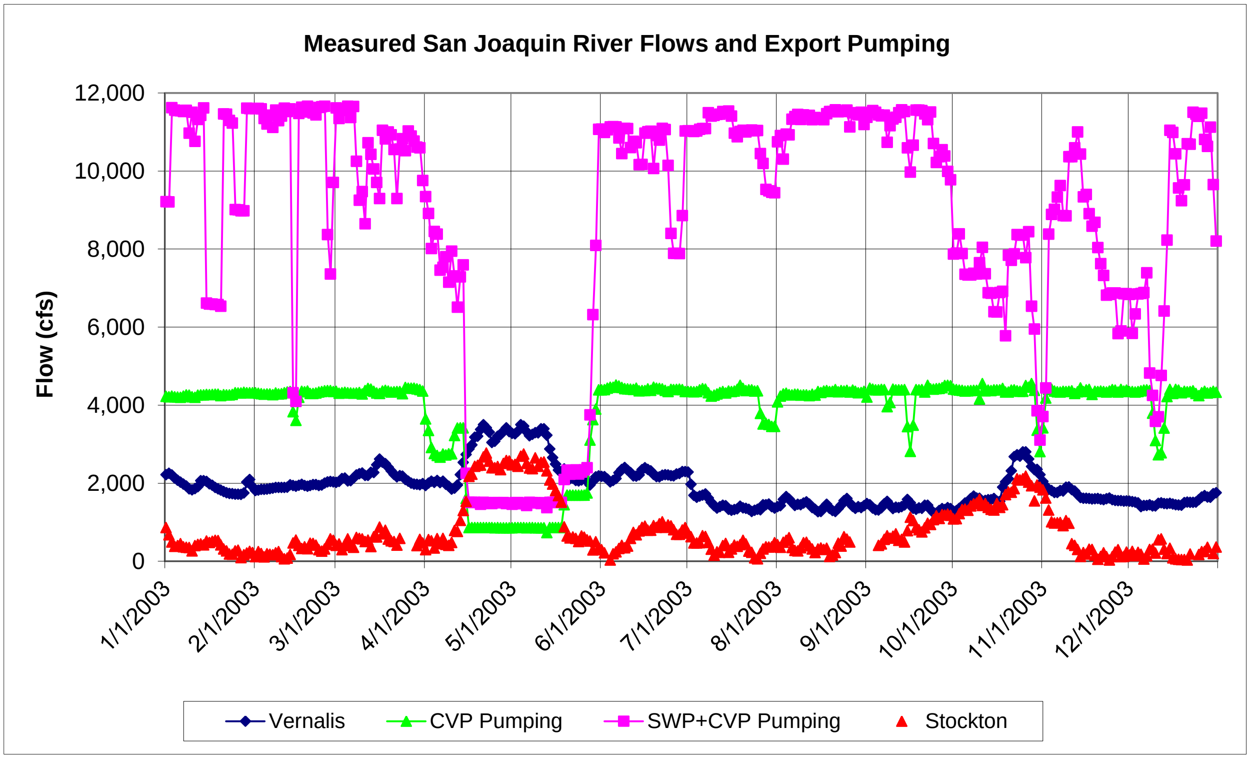
Daily Delta Flows and EC Data for 2003

Figure F.2-9a shows the measured flows and export pumping in calendar year 2003. The estimated flows at the head of Old River and in Old River at the Tracy Boulevard Bridge are shown in the lower panel. Vernalis flow in 2003 was extremely low with no major runoff events. Flow was 2,000 cfs from early January until the VAMP pulse in mid-April. The VAMP target was 3,500 cfs and the June flow was about 2,000 cfs. The summer flow was extremely low, with less than 1,500 cfs from July through mid-October when the fall pulse to attract chinook raised the flow to about 2,500 cfs in late October. Flows were just 2,000 cfs in November and December.

Export pumping in 2003 was generally high. CVP pumping was about 4,000 cfs all year except during April and May when reductions for fish protection were made. SWP pumping was near capacity of 6,680 cfs during most months, with reductions in April and May for VAMP and Environmental Water Account fish protections and in October–November. Total pumping was more than 10,000 cfs in January–March, June–September, and the end of December 2003.

Flows measured at Stockton in 2003 indicate less than 10 percent of the Vernalis flow reached Stockton during much of the year, because of the high CVP and SWP export pumping effects on the head of Old River diversions. The Stockton flows were higher during VAMP when the head of Old River barrier was installed, and during October and early November when the fall barrier was installed.

The bottom panel of Figure F.2-9a shows the estimated Old River flows at the City of Tracy discharge (similar to the head of Old River flows) and at the DMC near the Mountain House discharge. The estimated head of Old River flows matched the Vernalis minus Stockton flows. The Old River flows were greater than the assumed 500 cfs during the VAMP period and were less than the assumed 500 cfs when the fall barrier was installed.



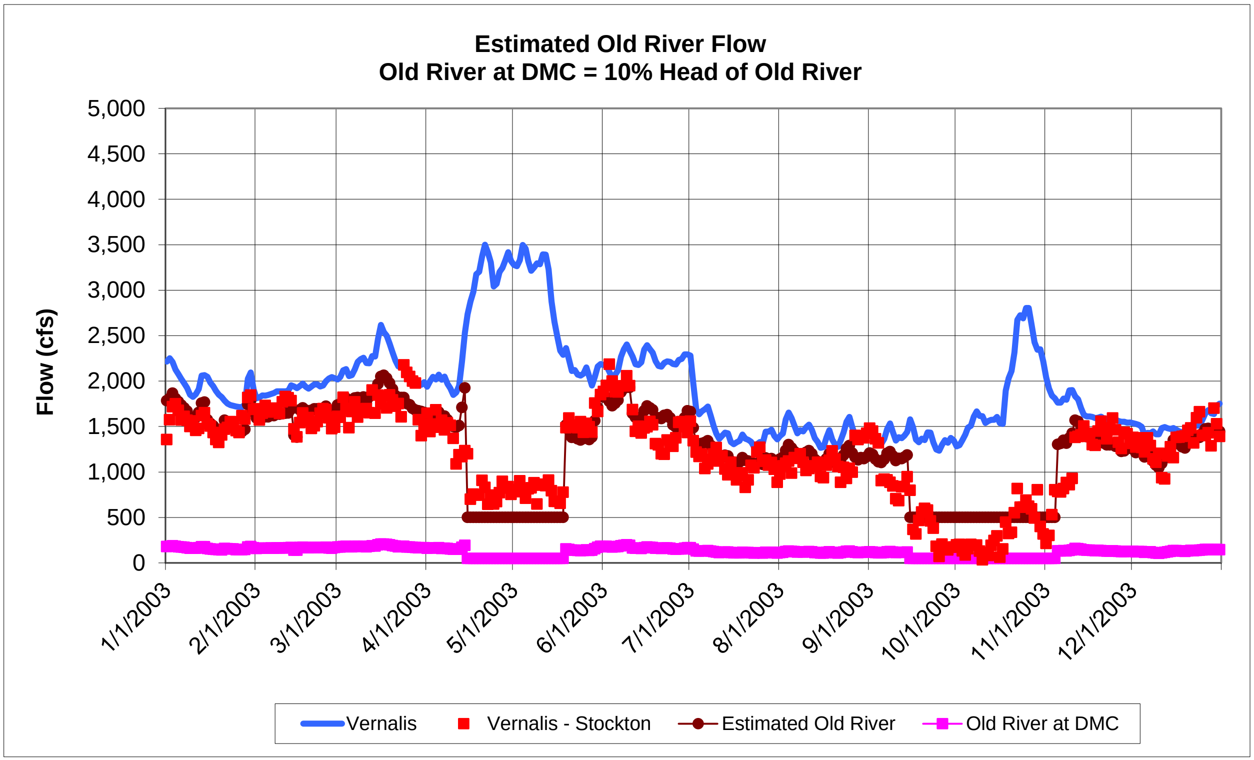
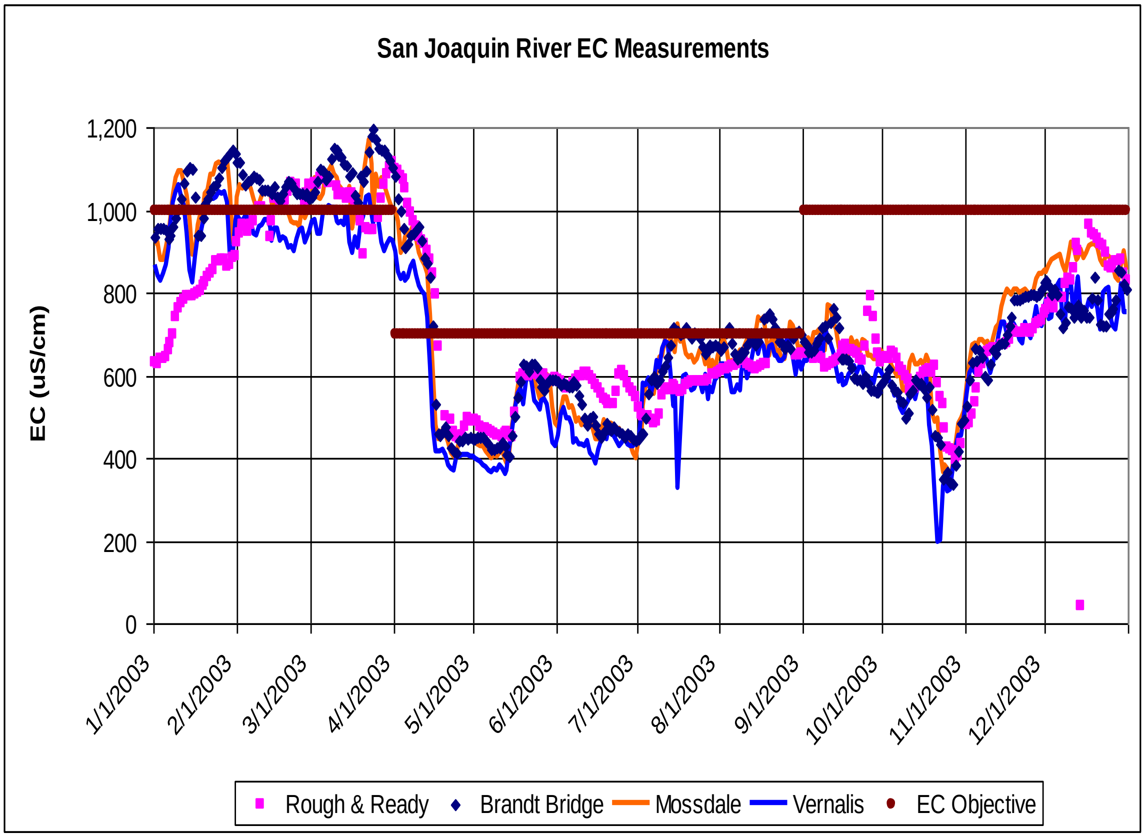


Figure F.2-9a. Historical Daily SJR Flows, CVP and SWP Export Pumping Flows, and Old River Flows for 2003

Figure F.2-9b shows the measured EC in the SJR during 2003. All four of the SJR EC stations recorded a similar pattern in 2003. The SJR EC was 900–1,100 µS/cm from January through March and reduced to about 400 µS/cm during the VAMP flow of about 3,500 cfs. The SJR EC reached 600 µS/cm at the end of May and remained at 600 µS/cm in June because the Vernalis flow was about 2,000 cfs through June. The EC increased to 700 µS/cm in July and August and decreased slightly to 600 µS/cm in September. The EC was reduced to about 400 µS/cm during the late October pulse flow but increased to 800 µS/cm by the end of November and in December 2003.

The bottom panel of Figure F.2-9b shows the EC along Old River in 2002. The Old River at Union EC values were similar to the Mossdale EC values. The Old River at Tracy Boulevard EC values were also similar to the Mossdale EC values throughout the year. This was in contrast to other years that indicated higher EC values at Tracy Boulevard. The EC values at the DMC intake and at the SWP Banks pumping-plant were much lower than the SJR EC values throughout all of 2003, except during the VAMP and late October pulse flows. The Banks EC values were lower than the DMC EC values in January–March but were nearly identical in May–December.



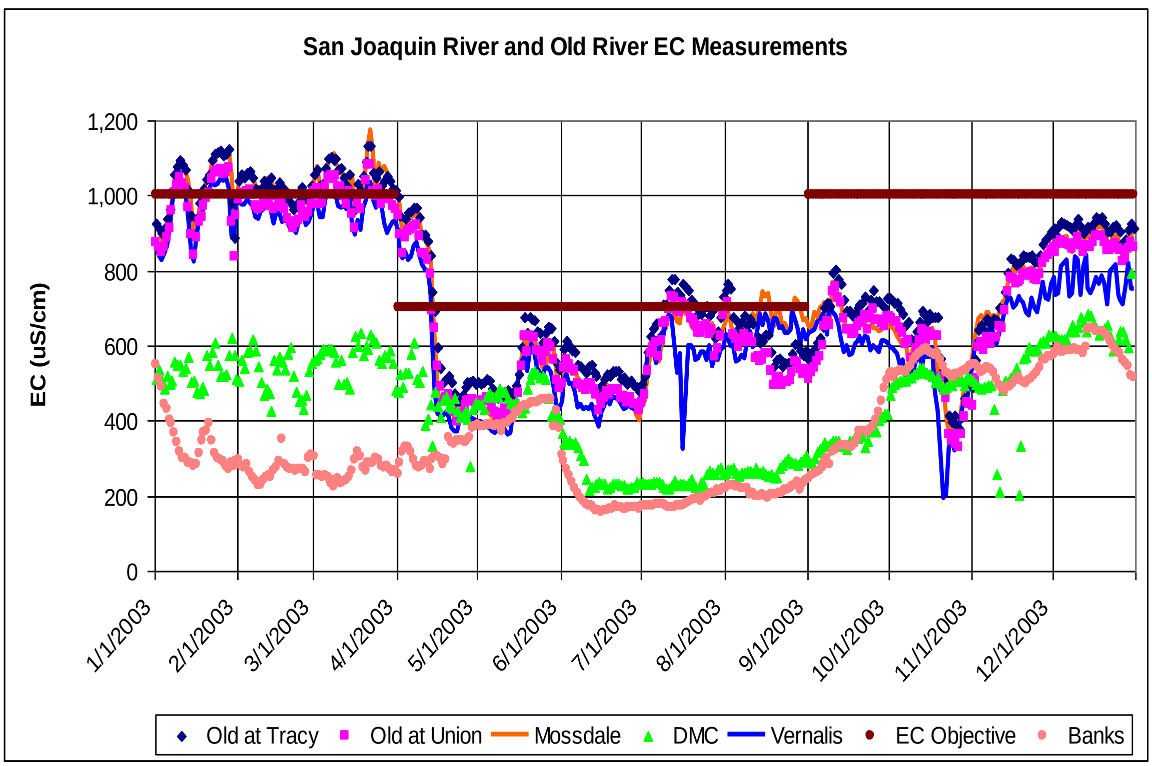


Figure F.2-9b. Historical Measured Daily EC in the SJR and Old River for 2003

Southern Delta Salinity (EC) Increments

Appendix C, *Technical Report On The Scientific Basis For Alternative San Joaquin River Flow And Southern Delta Salinity Objectives*, and the special study by DWR and USBR (USBR 2011) have suggested that the increased SJR EC downstream of Vernalis at Brandt Bridge, and in Old River at Union Island, as well as in Old River at Tracy Boulevard, can be generally estimated as a fraction of Vernalis plus a constant increase. Neither study was able to determine any other factor that could be shown to contribute to the patterns of measured EC increases between Vernalis and these downstream stations. However, an important possibility would be that the EC increases are caused by a somewhat constant monthly load of salt, so that the EC increases might be inversely related to the Vernalis flow. Evaluating the downstream EC as a function of the Vernalis EC and the Vernalis flow could provide a better tool for trying to attain EC compliance at the southern Delta stations (Brandt, Union, and Tracy). A graphical analysis of the monthly average EC data from 1985–2010 will introduce this approach.

Figures F.2-10a and F.2-10b show that the measured monthly Vernalis EC and the downstream southern Delta EC values (Brandt, Union, and Tracy) are generally reduced at higher flows. This effect of higher flow on reduced EC is apparent during both the agricultural irrigation season (April–August, EC objective of 700 µS/cm) and the non-irrigation season (September–March, EC objective of 1,000 µS/cm).

Figures F.2-11a and F.2-11b show the measured monthly EC increments from Vernalis to the downstream southern Delta stations. Although there is more scatter in these increments, and sometimes there are reduced EC values downstream, the EC increments are also generally reduced at higher flows. This effect of higher flow on reduced EC increments was observed during both the agricultural irrigation season and the non-irrigation season. Simple flow dilution relationships have been added to these data: the green line shows a flow dilution where the EC increment would be 100 µS/cm at a Vernalis flow of 1,000 cfs, the blue line shows a flow dilution with twice the EC increment (200 µS/cm at a flow of 1,000 cfs), and the red line shows a flow dilution with four times the EC increment (400 µS/cm at a flow of 1,000 cfs). All these increments are reduced to half at a flow of 2,000 cfs and are reduced to 20 percent at a flow of 5,000 cfs. More complicated estimates of the EC increments could be developed, but the Brandt Bridge and Union Island EC increments are well represented by the 100 µS/cm or the 200 µS/cm increment lines.

Because the Vernalis EC and the downstream EC increments are both reduced with higher Vernalis flow, control of the downstream EC will be possible with moderate increases in Vernalis flow in months when the Vernalis EC is approaching EC objectives and the downstream EC at Brandt or Union are above EC objectives. Attempting to reduce the EC increment at Tracy Boulevard Bridge with Vernalis flow will be more difficult; the EC at Tracy does not seem to be strongly related to the Vernalis EC or the Vernalis flow. If reduction of Tracy EC was attempted with Vernalis flow, much more Vernalis flow would be needed to reduce the Vernalis EC to Tracy EC increment.

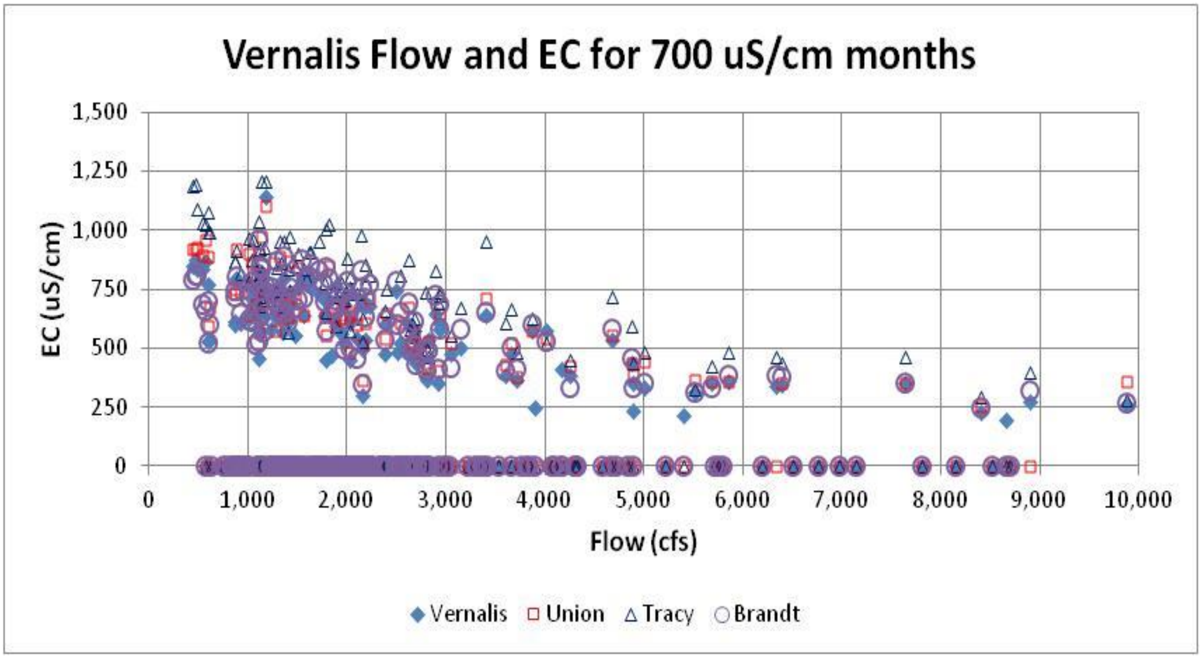


Figure F.2-10a. Monthly Average Vernalis Flow and Monthly Average Measured EC at Vernalis, Brandt Bridge, Union Island and Tracy Boulevard for April–August (700 µS/cm EC objective) of WY 1985–2010

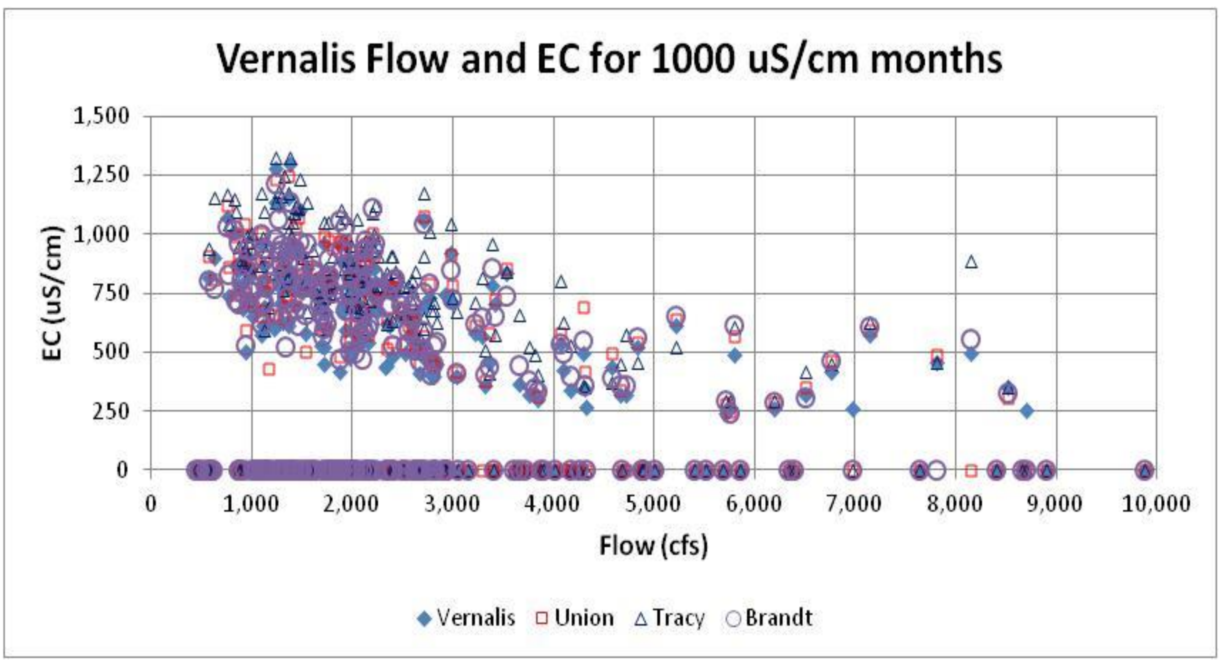


Figure F.2-10b. Monthly Average Vernalis Flow and Monthly Average Measured EC at Vernalis, Brandt Bridge, Union Island and Tracy Boulevard for September–March (1,000 µS/cm EC objective) of WY 1985–2010

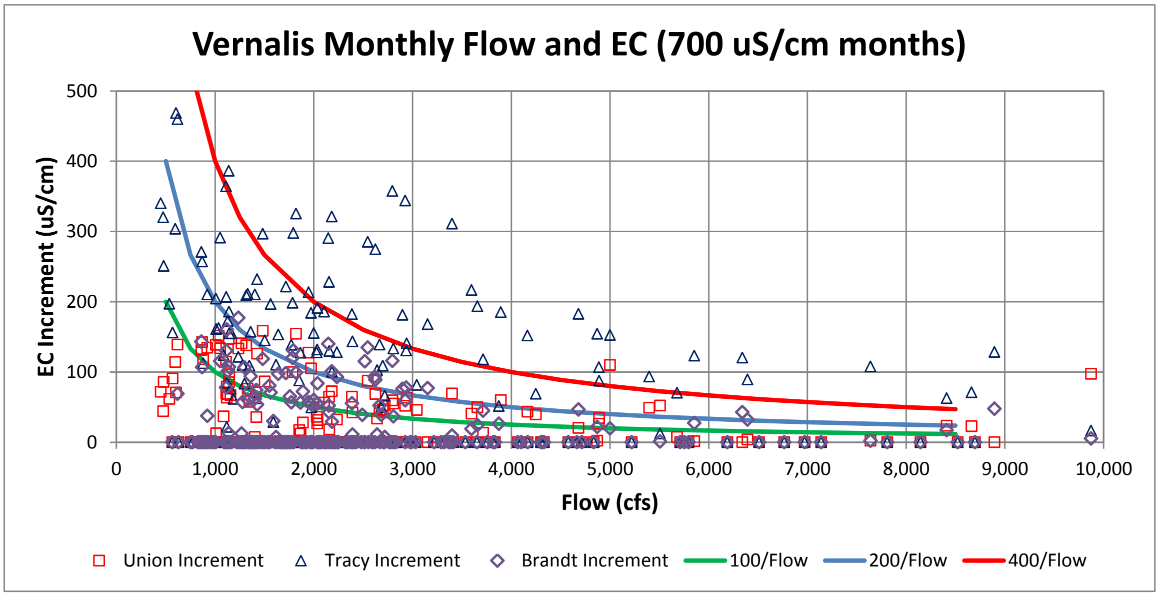


Figure F.2-11a. Monthly Average Vernalis Flow and Monthly Average EC Increments from Vernalis to Brandt Bridge, Union Island and Tracy Bridge for April–August (700 µS/cm EC objective) of WY 1985–2010

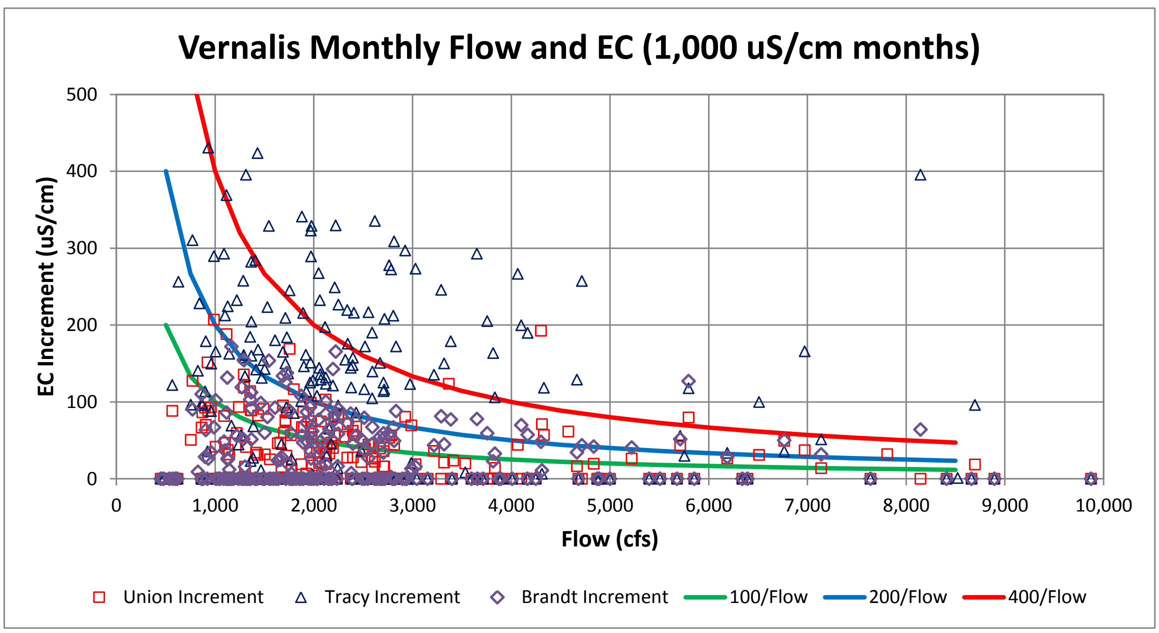


Figure F.2-11b. Monthly Average Vernalis Flow and Monthly Average EC Increments from Vernalis to Brandt Bridge, Union Island and Tracy Bridge for September–March (1,000 µS/cm EC objective) of WY 1985–2010

Figures F.2-12a and F.2-12b show the historical patterns of Vernalis flow and Vernalis EC as well as the southern Delta EC data for 1985–2010. The measured monthly EC at Vernalis has never exceeded EC objectives, and the southern Delta EC values have been higher than EC objectives in only a few months during the past 15 years (since 1995 when the Bay-Delta Plan specified the 700/1000 EC objective).

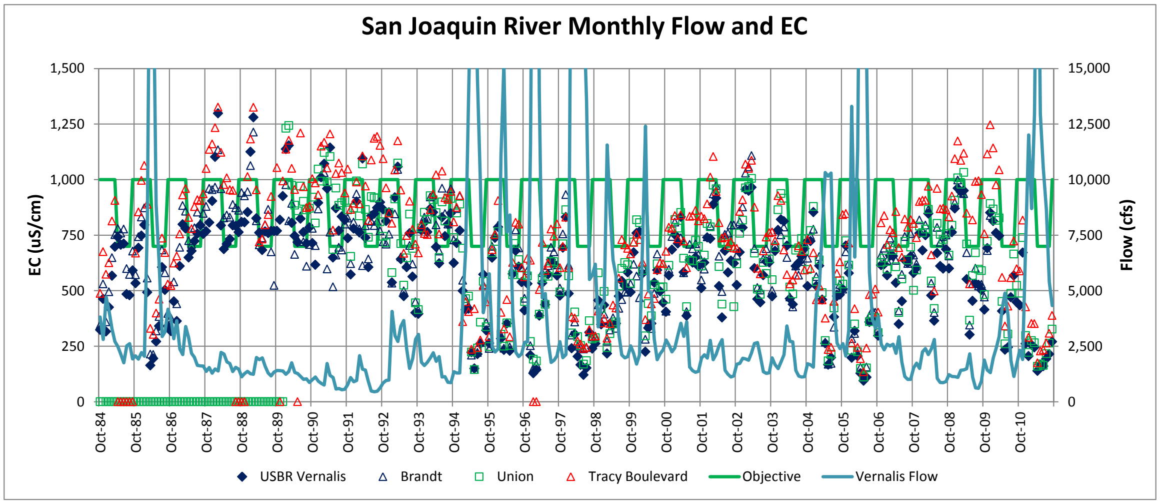


Figure F.2-12a. Monthly Average Vernalis Flow and Monthly Average Measured EC at Vernalis, Brandt Bridge, Union Island and Tracy Bridge for WY 1985–2010

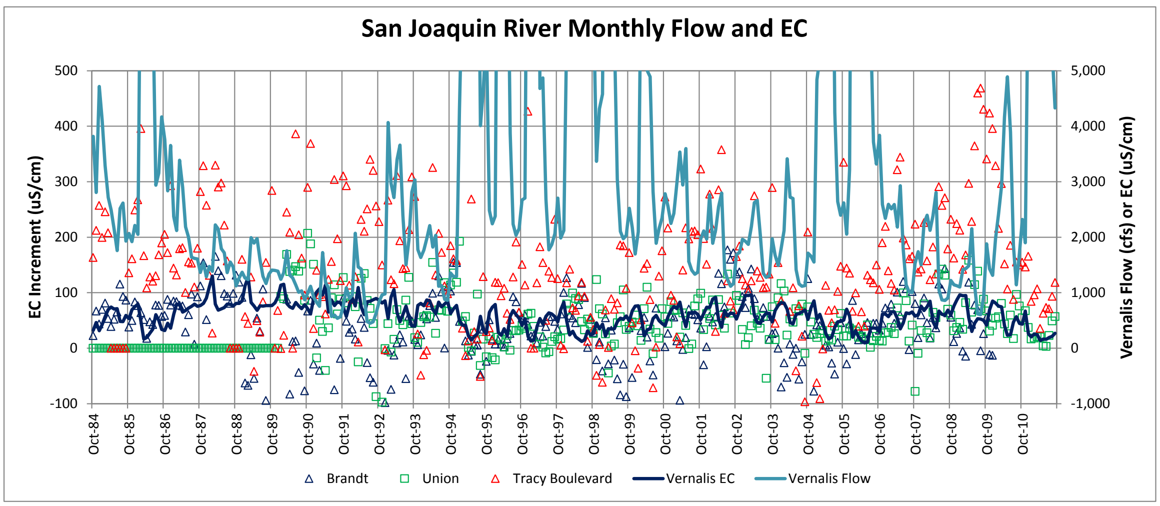


Figure F.2-12b. Monthly Average Vernalis Flow and Monthly EC Increments from Vernalis to Brandt Bridge, Union Island and Tracy Bridge for WY 1985–2010

Increased Stanislaus Flows for Southern Delta EC Compliance

An SJR at Vernalis EC buffer is needed to keep the SJR at Brandt Bridge EC or Old River at Tracy Boulevard EC less than the southern Delta EC objective. The EC buffer is equal to the calculated EC increment to Brandt Bridge or Tracy Boulevard. A review of historical EC data has suggested that the EC increment from Vernalis to Brandt Bridge or Tracy Boulevard can be estimated as:

Brandt EC Increment (µS/cm) = 100,000/Vernalis Flow (cfs)

Tracy Boulevard EC Increment (µS/cm) = 300,000/Vernalis flow (cfs)

The needed reduction in the Vernalis EC (if any) can then be calculated as:

Vernalis EC Reduction = Vernalis EC – EC objective + EC Increment (buffer)

The amount of Stanislaus water needed to reduce the Vernalis EC to provide the required buffer EC is:

*Stanislaus flow for EC buffer (cfs) = Vernalis flow x Vernalis EC reduction /
(Vernalis EC – Vernalis EC reduction – Stanislaus EC)*

These equations can be rearranged to calculate the additional Stanislaus flow needed to meet the EC objective at Brandt Bridge or at Tracy Boulevard. These equations were used to estimate the additional Stanislaus flows for the No Action Vernalis flows and Vernalis EC values. It should be noted that an increase in Vernalis flow would slightly reduce the Brandt or Tracy Boulevard EC increment, which would mean that the Vernalis EC buffer needed to meet the objectives at Brandt Bridge and Tracy Boulevard would be slightly smaller than initially estimated and the calculated increase in flow needed to attain the desired EC buffer at Vernalis would be conservative (i.e., would be slightly more than needed). Although the EC increment for Tracy Boulevard is 3 times the Brandt Bridge EC increment, there are many times when the Brandt EC meets the EC objective but the Tracy EC will be greater than the EC objective. Therefore, much more Stanislaus flow will be needed for meeting the Tracy Boulevard EC objective. The most added water would be needed in months when the Vernalis EC is at the EC objective.

F.2.5 References Cited

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Appendix G

Agricultural Economic Effects of Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results

Appendix G
Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results

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Tables

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Acronyms and Abbreviations

AW_{dem}	Demand for applied water
AWMP	Agricultural Water Management Plan
CAD	Cowell Agreement Diversion
CALAG	California Agriculture
CALVIN	California Value Integrated Network
C_{dem}	Demand for CUAW
CSJWCD	Central San Joaquin Water Conservation District
C_{SWdem}	Surface water demand for CUAW
CUAW	consumptive use of applied water
CVP	Central Valley Project
CVPM	Central Valley Production Model
DAUs	Detailed Analysis Units
DWR	California Department of Water Resources
ETAW	evapotranspiration of applied water
FERC	Federal Energy Regulatory Commission
F_{SWdem}	Demand for farm surface water
GIS	geographic information systems
GWMPs	groundwater management plans
IMPLAN	Impact Analysis for Planning
kWh	kilowatt hour
LSJR	Lower San Joaquin River
M&I	municipal and industrial
Merced ID	Merced Irrigation District
MID	Modesto Irrigation District
NCRMs	Net Crop Revenue Models
NWR	National Wildlife Refuge
OID	Oakdale Irrigation District
PF	percolation factors

PMP	Positive Mathematical Programming
ResLoss	reservoir losses
SED	substitute environmental document
SEWD	Stockton East Water District
SOI	sphere of influence
SSJID	South San Joaquin Irrigation District
State Water Board	State Water Resource Control Board
SWAP	Statewide Agricultural Production
SWRCB	State Water Resources Control Board
TAF/y	thousand acre-feet per year
TID	Turlock Irrigation District
USBR	U.S. Bureau of Reclamation
WEAP	Water Evaluation and Planning
WMP	Water Management Plan
WSE	Water Supply Effects
WTP	Water Treatment Plant

G.1 Introduction

Agricultural production in the Lower San Joaquin River (LSJR) Watershed is dependent on irrigation water supply from various sources, including surface water diversions, groundwater pumping, and deliveries from the federal Central Valley Project (CVP). Implementation of the LSJR alternatives would have the potential to affect the amount of allowable surface water diversions from within the LSJR Watershed and would also potentially affect groundwater levels. Thus, agricultural production would, in turn, depend upon the LSJR alternatives' effects on these irrigation water supplies.

This appendix describes the methods and modeling results that estimate the potential effects of the LSJR alternatives on groundwater and agricultural production, as well as the associated economic effects in the LSJR Watershed. Estimated changes in allowable surface water diversions and groundwater pumping that result from implementation of the LSJR alternatives were used to analyze effects on the economy. The study area evaluated in this appendix includes the irrigation districts that regularly receive surface water from the Stanislaus, Tuolumne, or Merced Rivers and the four primary groundwater subbasins under this area. They are collectively referred to as "irrigation districts" and include: South San Joaquin Irrigation District (SSJID), Oakdale Irrigation District (OID), Stockton East Water District (SEWD), Central San Joaquin Water Conservation District (CSJWCD),Turlock Irrigation District (TID), Modesto Irrigation District (MID), and Merced Irrigation District (Merced ID). District boundaries, counties in which they are located, and key municipalities in the region are identified in Figure G.1-1.

The agricultural economic analysis described in this appendix follows three major steps, described in Sections G.2, G.4, and G.5. First, total annual applied water for agriculture in each of the irrigation districts, along with annual agricultural groundwater use, is determined based on surface water diversions and agricultural demands calculated in the State Water Resource Control Board's (State Water Board) Water Supply Effects (WSE) model as described in Appendix F.1, *Hydrologic and Water Quality Modeling*. Second, the Statewide Agricultural Production (SWAP) model, a regional economic model for agricultural production, is used to estimate how changes in surface water diversions and groundwater pumping will affect agricultural production and related revenues in the irrigation districts. Third, multipliers derived from the Impact Analysis for Planning (IMPLAN) input-output model, a regional economic impact model widely used for assessing the economic impacts of changes in natural resources, are used to estimate the total (direct, indirect, and induced) economic impacts on employment and sector output resulting from predicted changes in agricultural production. The discussion describes the effects on all inter-connected sectors of the regional economy.

Section G.3, *Estimation of Groundwater Balance*, estimates the net change in the annual contribution from the irrigation districts to the groundwater subbasins that may result from the LSJR alternatives. The net change in the annual groundwater balance is derived from changes in surface water diversions and groundwater pumping described in Section G.2, *Total Applied Water for Agricultural Production*. This groundwater evaluation is used to determine the groundwater impacts described in Chapter 9, *Groundwater Resources*. This groundwater analysis is not part of the SWAP and IMPLAN analyses, but it uses the same assumptions regarding the fate of surface water diversions and groundwater pumping.

There are three LSJR alternatives, each consisting of a specified percentage of unimpaired flow[1] requirement for the Stanislaus, Tuolumne, and Merced Rivers (the three eastside tributaries of the LSJR). For a particular alternative, each of the three eastside tributaries of the LSJR must maintain or exceed the specified percentage of its own unimpaired flow at the LSJR confluence from February–June. The percentage unimpaired flow requirements are 20 percent, 40 percent, and 60 percent, respectively, for LSJR Alternative 2, LSJR Alternative 3, and LSJR Alternative 4.[2] Flows must not drop below the specified percent of unimpaired flow or below existing flow requirements, whichever is larger, on each of the three eastside tributaries. In addition, each of the alternatives includes adaptive implementation. Adaptive implementation consists of four methods that generally allow the percent of unimpaired flow to increase or decrease, depending on the alternative and certain criteria, or be shifted within February–June, or outside of that time period (i.e., to the fall). In addition, adaptive implementation allows for a minimum flow on the SJR at Vernalis. Specific details of the LSJR alternatives are presented in Chapter 3, *Alternatives Description*, of this recirculated substitute environmental document (SED), and are the basis for how the alternatives are modeled in this appendix. The results presented in this appendix are organized by 20 percent, 40 percent, and 60 percent of unimpaired flow.

The allowable surface water diversions and supplemental groundwater pumping for each of the LSJR alternatives are used to estimate groundwater impacts discussed in the following chapters: Chapter 9, *Groundwater Resources*; Chapter 11, *Agricultural Resources* (the agricultural production generated by SWAP and agricultural impacts); Chapter 20, *Economic Analyses* (economic value estimated by IMPLAN and economic effects); and Chapter 22, *Integrated Discussion of Potential Municipal and Domestic Water Supply Management Options*. This appendix, and the respective chapters that use information from this appendix, compare the results of the LSJR alternatives to baseline results. The difference between baseline and an alternative for groundwater, agricultural production, or crop revenue is the effect attributed to implementing that alternative. In general, the modeling results indicate that as flow requirements on each of the rivers increase, the surface water diversions decrease; in response, groundwater pumping increases, agricultural production may decrease, and the regional economy may be affected.

G.2 Total Applied Water for Agricultural Production

This section describes the methods for estimating changes in applied water associated with the LSJR alternatives and presents a summary of these changes. *Applied water* refers to water that is applied directly to a crop and can come from either groundwater pumping, surface water diversions, or both. Some of the applied water will be used consumptively by the crops (consumptive use of applied water [CUAW]) and the rest will seep into the soil and contribute to groundwater (deep

[1] *Unimpaired flow* represents the water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds.It differs from natural flow because unimpaired flow is the flow that occurs at a specific location under the current configuration of channels, levees, floodplain, wetlands, deforestation and urbanization.

[2] Any reference in this appendix to 20 percent Unimpaired, 40 percent Unimpaired, and 60 percent Unimpaired is the same as LSJR Alternative 2, LSJR Alternative 3, and LSJR Alternative 4, respectively. Any reference to 1.0 EC objective and 1.4 EC objective is the same as SDWQ Alternative 2 and SDWQ Alternative 3, respectively.

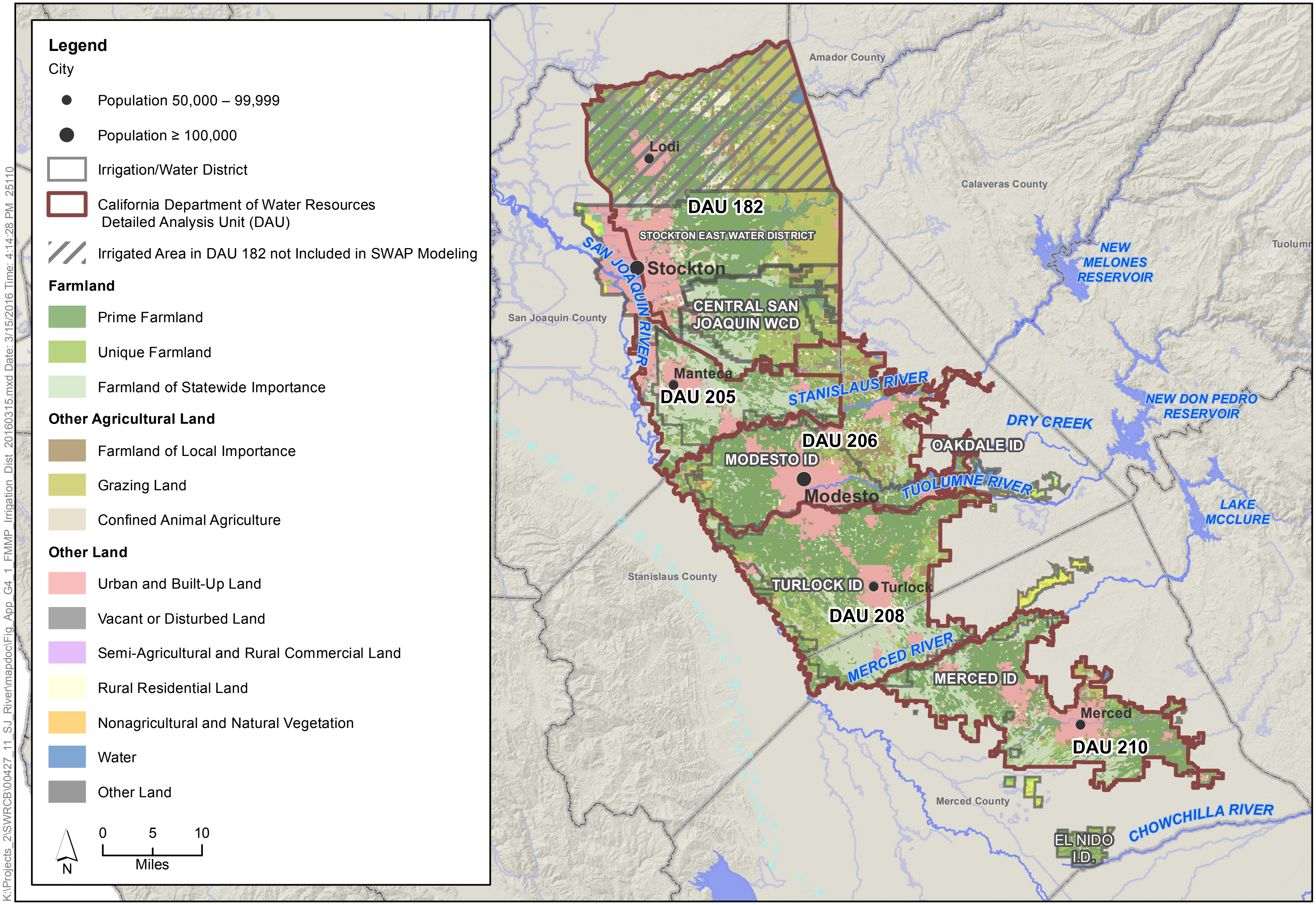

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Figure G.1-1
Vicinity Map

percolation[3]). The term CUAW is considered to be synonymous with evapotranspiration of applied water (ETAW).

The amount of applied water available will depend on whether there is sufficient water to meet demand. There are several levels of demand, starting with the most basic—demand for CUAW. The following terms are used in subsequent text regarding methodology for calculating applied water.

- Demand for CUAW ($\mathbf{C_{dem}}$), also referred to as crop demand, is the amount of water that crops would use consumptively, assuming there is no water shortage.
- Surface water demand for CUAW ($\mathbf{C_{SWdem}}$), also referred to as crop surface water demand, is the portion of $\mathbf{C_{dem}}$ that the crop growers intend to meet using surface water diversions after applying minimum groundwater pumping. (See below for further description of minimum groundwater pumping.)
- Demand for applied water ($\mathbf{AW_{dem}}$) is $\mathbf{C_{dem}}$ plus the amount of water that would be lost to deep percolation under conditions of full water supply.
- Surface water demand for applied water ($\mathbf{AW_{SWdem}}$) is the portion of $\mathbf{AW_{dem}}$ that is not met by minimum groundwater pumping.
- Demand for farm surface water ($\mathbf{F_{SWdem}}$) is the demand for applied surface water plus the amount of water that would be lost from the distribution system if the full applied water demand were to be satisfied.
- Full surface water demand, also referred to as demand for diversion, is the total amount of surface water that would need to be diverted from a river in order to meet all municipal surface water demands that have surface water rights and irrigate all crops that are typically grown when surface water rights can be fully diverted. It includes water that would be lost from the distribution system due to seepage and evaporation and assumes a typical minimum amount of groundwater pumping each year.

Applied surface water was estimated by partitioning diversions from each river between different types of uses and losses. Applied surface water is the amount of water diverted from the river that reaches a farm, after riparian water rights and municipal and industrial (M&I) needs are satisfied and all losses (including offstream reservoir seepage, distribution system losses, and spills) are subtracted. If groundwater pumping is not sufficient to make up any deficit in applied surface water, then agriculture would be affected.

As described in Appendix F.1, *Hydrologic and Water Quality Modeling*, the State Water Board's WSE model was used to estimate the various levels of demand and surface water diversions for each LSJR alternative. If crop needs are not fully satisfied by minimum groundwater pumping and surface water diversions, there may be additional groundwater pumping up to a maximum that is based on the capacity of the groundwater pumping and distribution infrastructure.

The WSE model results were post-processed in the GW and SW Use Analysis V16 spreadsheet to estimate additional groundwater pumping for surface water replacement and to calculate overall effects on groundwater subbasins. The results were further post-processed to estimate the percent

[3] Surface runoff from irrigated land, which is tracked separately as part of the spills and return for each district, may also contribute to deep percolation, but for the SED, this contribution is assumed to be small and was not modeled.

of applied water demand met from all sources, which was used as an input to the SWAP model. The methods and results for estimating groundwater pumping, the fate of water diverted from rivers, and the volume of applied surface water are described below. These estimates are then used as inputs to the groundwater analysis described in Section G.3, *Estimation of Groundwater Balance*, and as inputs to the SWAP model described in Section G.4, *Estimating Agricultural Production, Associated Revenue, and Groundwater Pumping Costs*. Ultimately, the results of this analysis are used to inform the environmental impact analysis in the following chapters: Chapter 9, *Groundwater Resources*; Chapter 11, *Agricultural Resources*, and Chapter 14, *Energy and Greenhouse Gases*. It is also used to inform the economic analyses in Chapter 20, *Economic Analyses*, and provide context for groundwater use in Chapter 22, *Integrated Discussion of Potential Municipal and Domestic Water Supply Management Options*.

G.2.1 Inputs from the WSE Model

The WSE model is a monthly water balance spreadsheet model that estimates allowable surface water diversions and reservoir operations needed to achieve the target flow requirements of the LSJR alternatives on the three eastside tributaries. A more detailed description of the model is presented in Appendix F.1, *Hydrology and Water Quality Modeling*. Within the constraints of reservoir storage rules, instream flow requirements, and diversion demands, the model uses a water balance to calculate the resulting river flows, allowable surface water diversions, and reservoir storage levels. Model calculations are performed on a monthly time step for each tributary using the 82 years of CALSIM II[4] hydrology (water years 1922–2003) as input to New Melones Reservoir, New Don Pedro Reservoir, and Lake McClure, respectively. The CALSIM II model run that was used as a source of information for the WSE model is the CALSIM II "Current Conditions" case used in the California Department of Water Resources (DWR) *2009 Delivery Reliability Report* (DWR 2010a). This version of CALSIM II closely represents the baseline conditions over 82 years of climate history.

For the calculation of applied water and groundwater recharge over each irrigation year, March–February, the necessary time series to extract from the WSE model includes the information listed below.

- Municipal and Industrial (M&I) surface water demands for the city of Modesto and Degroot Water Treatment Plant (WTP).
- Riparian demands for diversion from each river.
- Spills/return flows for each irrigation district.
- The Woodward, Turlock, and Modesto Reservoir seepages.
- Minimum groundwater pumping for each irrigation district.
- Constant deep percolation and distribution loss factors (for the groundwater assessment).
- Crop surface water demands (surface water demand for CUAW) for each irrigation district.

[4] CALSIM is a generalized water resources simulation model for evaluating operational alternatives of the SWP/CVP system. CALSIM II is the latest application of the generic CALSIM model to simulate SWP/CVP operations. CALSIM and CALSIM II are products of joint development between DWR and the U.S. Bureau of Reclamation. This SED uses the terms CALSIM and CALSIM II interchangeably.

- Merced ID sphere of influence (SOI) demands for Stevinson, Merced National Wildlife Refuge (NWR), and other areas.
- Merced ID SOI delivery for each alternative.
- SEWD municipal delivery for each alternative.
- The percent of crop surface water demands met for each alternative for each river.

All these parameters are summed annually over each irrigation year. Only the last three parameters vary between alternatives as discussed in the following sections.

G.2.1.1 Diversions

The calculation of applied water starts with the WSE model's estimated diversions for the Stanislaus, Tuolumne, and Merced Rivers. Some of the diversions go towards meeting riparian water rights, but the majority go to large irrigation districts. The analysis of water supply for the irrigation districts is separated as follows.

- Stanislaus River—SSJID
- Stanislaus River—North OID (north of the Stanislaus River)
- Stanislaus River—South OID (south of the Stanislaus River)
- Stanislaus River—SEWD and CSJWCD
- Tuolumne River—MID
- Tuolumne River—TID
- Merced River—Merced ID (Diversions for Merced ID include water that goes to irrigation districts that are within the Merced ID SOI, including Stevinson Water District, Le Grand-Athlone Water District, and Lone Tree Mutual Water Company.)

The WSE model calculates the amount of surface water diverted as the lesser between the amount of surface water available from the associated watershed, the maximum diversion allowed by water rights, or the amount needed to satisfy full surface water demand. On the Stanislaus River, if water is still available for diversion after the SSJID and OID diversions are determined, water is allocated to SEWD and CSJWCD. Deliveries to SEWD and CSJWCD are defined by their contract terms with the U.S. Bureau of Reclamation (USBR) and not by their demand; therefore, the maximum combined diversion for SEWD and CSJWCD is 155 thousand acre-feet per year (TAF/y) as specified in their contracts with USBR. The irrigation district diversions are calculated as a total for each tributary; irrigation district diversions from the Stanislaus River combine SSJID and OID, and diversions from the Tuolumne River combine MID and TID. The SEWD and CSJWCD diversions are calculated as a total.

G.2.1.2 Apportionment of Surface Water Diversions between Districts

Since the WSE model calculates irrigation district diversions as totals for each tributary, the surface water diversions need to be apportioned between the individual districts. On the Stanislaus River, diversions for SSJID and OID are apportioned by assuming that each district would receive the same percent of its crop surface water demand (i.e., CUAW minus minimum groundwater pumping that would not be lost to deep percolation). For the Tuolumne River, diversions for MID and TID are apportioned using the same method as for SSJID and OID. On the Merced River, Merced ID is the only irrigation district modeled; however, Merced ID passes some of its water to areas outside the district boundary to areas within its SOI. The SOI demands for the Merced National Wildlife Refuge and Stevinson are met before Merced ID's own demands, while the other SOI demands are met after the districts.

If water is available for SEWD and CSJWCD, but it totals less than their contract amount, the diversion is apportioned between these districts using the following steps, which are based on information in CALSIM II.

1. When the Total Contractor Diversion is between 155 and 98 TAF, CSJWCD receives (80/155)* Div and SEWD receives (75/155)* Div.
2. When the Total Contractor Diversion is between 98 and 59 TAF, CSJWCD receives 49 TAF and SEWD receives the remainder.
3. When the Total Contractor Diversion is between 59 and 10 TAF, SEWD receives 10 TAF (for municipal demands) and CSJWCD receives the remainder.
4. When the Total Contractor Diversion is below 10 TAF, SEWD receives it all.

G.2.1.3 Parameter Estimates

In order to estimate applied surface water and groundwater recharge, multiple parameters need to be extracted from the WSE model. A description of these parameters, as well as numeric values and data sources used to estimate these terms are described below.

Municipal and Industrial Surface Water Supply

Municipal and industrial water suppliers use a relatively small portion of the total surface water diversion from the Stanislaus and Tuolumne Rivers. On the Stanislaus River, water is delivered to the DeGroot WTP through SSJID. The water use of the plant is assumed to be 16 TAF/y, based on information in the SSJID Agricultural Water Management Plan (AWMP) (SSJID 2012). On the Tuolumne River, the City of Modesto has an agreement with MID to purchase surface water from the district. In the WSE model, the City of Modesto is assumed to divert 30 TAF/y (MID 2012). For a more conservative estimate of the groundwater and agricultural impacts, it is assumed that municipal deliveries would not be cut in times of surface water shortage. This is a simplifying assumption based on the program of implementation in Chapter 3, *Alternatives Description*, which describes actions to assure that implementation of the LSJR alternatives (i.e., percent of unimpaired flow requirement) does not impact supplies of water for minimum health and safety needs. Potential impacts on municipal and industrial water users are evaluated in Chapter 13, *Service Providers*.

There is one exception to the analytical assumption that all municipal demands for surface water would be met. In the WSE model, SEWD and CSJWCD diversions from the Stanislaus River are calculated separately from the SSJID and OID diversions because they only receive water after SSJID and OID water rights have been met. As a result, in some years SEWD is not able to meet its municipal demand for Stanislaus River water, which is assumed to be 10 TAF/y (SEWD 2014). These municipal needs, however, could be met by either Calaveras River water or groundwater.

Riparian Diversions

WSE model riparian diversions are the same as those used in the CALSIM model. Demands for riparian diversions are met before diversions are allocated to the irrigation districts. Cowell

Agreement Diversion (CAD) demands on the Merced River are treated as riparian demands in the WSE model. However, the CALSIM II time series of CAD diversions does not fully divert the Cowell Agreement Flow described in Appendix F.1, *Hydrologic and Water Quality Modeling*. Therefore, in the WSE model, the monthly CAD diversions are increased so that they equal the full Cowell Agreement Flows.

Spills/Returns

Estimates of spills/returns come from CALSIM II. Operational spills and returns represent water diverted by the districts that returns to the river, including surface runoff from irrigated land. In addition, irrigation districts often use excess flow to maintain constant pressure head in the distribution system and maintain delivery. This water is eventually spilled or released from the distribution system and returned to the river. These estimates vary monthly, but are assumed to be the same for all LSJR alternatives. However, spills, returns, and riparian demands may actually vary based on crop water use, but the variability is relatively small and it is difficult to model how these parameters may change in response to changes in water availability.

Offstream Reservoir Losses

A large amount of water seeps into the ground from Woodward Reservoir, Turlock Lake, and Modesto Reservoir. The estimated annual loss for these reservoirs is 30 TAF/y, 47 TAF/y, and 31 TAF/y, respectively. The estimates for Woodward and Modesto Reservoirs are based on information in the SSJID Agricultural Water Management Plan (AWMP) and MID AWMP, respectively. The value for Turlock Lake is from TID's response to an August 2015 information request (pers. comm. Hashimoto, P.E.). These offstream reservoirs lose a relatively small amount of water to evaporation, with evaporation being within the margin of error for the seepage estimate. The estimates for offstream reservoir losses also account for distribution system seepage upstream of the regulating reservoirs.

Merced ID SOI Demands and Deliveries

Merced ID SOI demands include the Stevinson Entitlement, required deliveries to Bear Creek in the Merced NWR as part of the Merced ID Federal Energy Regulatory Commission (FERC) license, deliveries to El Nido, and water sales by Merced ID to other nearby entities (Merced ID 2013). Merced ID SOI demands occur outside of the district but share the district's distribution system. El Nido was incorporated into the district in 2005 (Merced ID 2013); however, CALSIM II represents El Nido separately from the district, so the WSE model represents them separately. In the WSE model, Merced NWR has an annual demand of 15 TAF/y, which is the same as in CALSIM. The values for El Nido, Stevinson, and other SOI demands are 13 TAF/y, 24 TAF/y, and 16 TAF/y, respectively, and they were extracted from the Merced Operations Model released as part of Merced ID's FERC relicensing process (Merced ID 2015).

The Stevinson Entitlement is an adjudicated delivery from Merced ID and the delivery to Merced NWR is part of the districts FERC license, so it is assumed in the WSE model that in times of shortage both demands are satisfied before water is delivered to the district itself. Since El Nido was incorporated with Merced ID in 2005, they receive the same cut as the rest of the district in the WSE model if there is a shortage. Finally, other SOI demands are assumed to represent voluntary water sales by Merced ID, and these SOI water users will only receive delivery if the Merced ID demands are fully satisfied. For the groundwater analysis, it is assumed that any cuts to SOI demands besides

El Nido can be replaced with groundwater (groundwater pumping capabilities for El Nido are assumed to be included in the total district groundwater pumping estimate described in Section G.2.2, *Methodology for Calculating Applied Water*).

Minimum Groundwater Pumping

For the estimation of irrigation district demand for applied surface water, it is assumed that some of the total irrigation district demand for applied water would be met by minimum groundwater pumping. A minimum groundwater pumping amount was applied to account for irrigated areas that are not supplied by surface water. These minimum amounts are likely to occur each year regardless of water year type. However, in the WSE model there are a few months in certain years when the estimated applied water demand is less than the minimum groundwater pumping for that month, so the minimum groundwater pumping is reduced to prevent demands from being oversatisfied.

Minimum groundwater pumping estimates are based on evaluation of irrigation district pumping estimates in CALSIM, AWMPs, groundwater management plans (GWMPs), and information provided by the irrigation districts. The final values selected come primarily from the AWMPs and the irrigation districts (Table G.2-1).

Table G.2-1. Annual Minimum Groundwater Pumping Estimates for each Irrigation District

Irrigation District	Annual Minimum Groundwater Pumping (TAF/y)	Source
SSJID	25.6	SSJID Information Request (Rietkerk pers. comm.)
OID North[a]	7.9	OID Information Request (Knell pers. comm.)
OID South[a]	10.4	OID Information Request (Knell pers. comm.)
MID	12.0	MID Information Request (Salyer pers. comm.)
TID	80.6	TID AWMP (2012)
Merced ID	37.0	Merced ID AWMP (2013)

TAF/y = thousand acre-feet per year

[a] OID provided information that total minimum pumping for OID was 18.3 TAF/y. This value is divided between North and South OID based on the relative irrigated area of each.

To simplify calculating the water supply, agricultural, and groundwater impacts on SEWD and CSJWCD, it is assumed that they have no minimum groundwater pumping. This is justified because the LSJR alternatives will only affect the districts' access to surface water diversions from the Stanislaus River, which are contract amounts not based on either districts crop demand. However, to provide context for groundwater use in the Eastern San Joaquin Basin, it is necessary to characterize the total water use of these districts, which does include some level of minimum groundwater pumping.

From Table G.4-3 shown in Section G.4.2, *Crop Distribution and Applied Water Inputs for SWAP*, the applied water demand for SEWD and CSJWCD are 157 and 119 TAF/y, respectively. SEWD also supplies urban demands at about 50 TAF/y (SEWD 2014). Both districts can divert Stanislaus river water as described above (up to 75 TAF/y for SEWD and up to 80 TAF/y for CSJWCD), but SEWD also has an agreement to divert water from the Calaveras River up to 67 TAF/y (San Joaquin County Department of Public Works 2004). The total water demand for both districts is 326 TAF/y, and the maximum total surface water supply after accounting for distribution losses is 192 TAF/y (distribution loss factors are described below). The remaining demand is 133 TAF/y, which is the minimum groundwater pumping for SEWD and CSJWCD combined. In this case the minimum groundwater pumping refers to applied water demand of SEWD and CSJWCD that can't be met with surface water even if they receive their full surface water allotments from all sources.

Distribution Loss Factors

Distribution losses are primarily caused by seepage from canals and ditches, although a small amount of water is also lost to evaporation. Total distribution losses are estimated as a fraction of the applied surface water and spills based on information from the district AWMPs. These factors are referred to as demand side distribution loss factors, or **DF**, as they represent the losses as a percent of the demands. The calculation is performed in this manner as opposed to using a fraction of total diversions because there are some portions of the total diversion that are assumed not to contribute to distribution losses (e.g., offstream reservoir seepage and M&I water use). The values for the demand side distribution loss factors range between 5 and 32 percent (Table G.2-2). These factors can be adjusted to provide supply side distribution loss factors, which represent the distribution losses as a percent of diversions made to account for applied water, operational spills, and return flows. These fractions are equal to **DF**/(1+**DF**) and vary between 5 and 24 percent.

Calculations of **DF** for all districts, except SEWD and CSJWCD, are described in Appendix F.1, *Hydrologic and Water Quality Modeling*. For SEWD and CSJWCD, supply side distribution loss factors are first calculated and then converted to demand side factors. From the SEWD Water Management Plan (WMP), the 2010 surface water supply was 118,216 AF (SEWD 2014: Section 5, Table 6), conveyance seepage was 7,136 AF (only includes losses for Calaveras and New Melones diversion systems [SEWD 2014: Section 5, Table 4]), and conveyance evaporation was 2,068 AF (includes evaporation losses and precipitation gains for Calaveras and New Melones diversion systems [SEWD 2014: Section 5, Table 4]). The supply side distribution loss factor is calculated as (7136+2,068)/118,216 = 0.078 and it is converted to a demand side factor by dividing it by 1 minus itself, 0.078/(1- 0.078) = 0.084. From the CSJWCD WMP the 2009 surface water supply was 31,957 AF (page 4, CSJWCD 2013), and the conveyance seepage was 7,500 AF (page 18, CSJWCD 2013). There was no estimate of conveyance evaporation. The supply side distribution loss factor is calculated as 7,500/31,957 = 0.23 and the demand side factor is, 0.23/(1- 0.23) = 0.31.

Table G.2-2. Distribution Losses as a Percent of Demand and Diversion

District	Demand Side Distribution Loss Factors (%)	Supply Side Distribution Loss Factors (%)	Source or Notes
SSJID	17	15	SSJID AWMP 2012
North OID	17	15	Assumed to be the same as SSJID
South OID	29	22	OID AWMP 2012
SEWD	8	8	SEWD WMP 2014
CSJWCD	31	23	CSJWCD WMP 2013
MID	5	5	MID AWMP 2012
TID	8	7	TID AWMP 2012
Merced ID	32	24	Merced ID AWMP 2013

Deep Percolation Factors for Applied Water

Deep percolation represents the portion of applied water that is not consumptively used and instead seeps into groundwater. Much like the demand side distribution loss factors, deep percolation factors (**PF**) represent deep percolation of applied water as a percent of consumptive use. The factors vary by district between 10 and 46 percent (Table G.2-3). These factors can be adjusted to provide supply side deep percolation factors, which represent the deep percolation as a percent of total applied water. These fractions are equal to **PF**/(1+**PF**) and vary between 9 and 32 percent. The factors for all districts except SEWD and CSJWCD are estimated based on information in the AWMPs, as shown in Appendix F.1, *Hydrologic and Water Quality Modeling*.

From the SEWD WMP, the 2010 crop water need was estimated at 127,575 AF (SEWD 2014: Section 5, Table 6), and the deep percolation from agricultural land was estimated at 12,965 AF (SEWD 2014: Section 5, Table 6). The demand side deep percolation factor is calculated as 12,965/127,575 = 0.10. The deep percolation factor for CSJWCD was assumed to be the same as SEWD, as there was not enough information in the CSJWCD WMP to calculate a district specific factor.

Table G.2-3. Field Losses to Deep Percolation as a Percent of Consumptive Use and Applied Water

District	Deep Percolation as Percent of Consumptive Use	Deep Percolation as Percent of Total Applied Water	Source
SSJID	28	22	SSJID AWMP 2012
North OID	19	16	OID AWMP 2012
South OID	19	16	OID AWMP 2012
SEWD/CSJWCD[a]	10	9	SEWD WMP 2014
MID	38	28	MID AWMP 2012
TID	46	32	TID AWMP 2012
Merced ID	25	20	Merced ID AWMP 2013

[a] The deep percolation factor for CSJWCD is assumed to be the same as for SEWD because CSJWCD WMP 2013 did not present the necessary information to calculate the district's own factor.

G.2.1.4 Crop Surface Water Demand

One of the primary values used in the WSE model, the groundwater assessment, and the agricultural assessment is the total consumptive use demand for each irrigation district, $\mathbf{C_{dem}}$, which is based on CALSIM II data. The estimates for $\mathbf{C_{dem}}$ are first used in the WSE model as part of the calculations for determining the diversion demand. The portion of the CUAW demand that is to be met by surface water, $\mathbf{C_{SWdem}}$, is a key value transferred from the WSE model to the post-processing analysis files for groundwater and agriculture. $\mathbf{C_{SWdem}}$, also referred to as the *crop surface water demand*, is defined for each irrigation district as:

$$\overbrace{C_{SWdem} = C_{dem} - MinGW * \left(1 - \left(\frac{PF}{1+PF}\right)\right)}^{for\ each\ district\ except\ SEWD\ and\ CSJWCD}$$

Where,

PF is the deep percolation factor for the district.

MinGW is the annual minimum groundwater pumping for the irrigation district. Multiplying **MinGW** by 1-(**PF**/(1+**PF**)) gives the portion of the **MinGW** that is used consumptively by the crops and does not percolate to groundwater.

The CUAW demand of SEWD and CSJWCD is calculated based on the contract with USBR. In total, up to 80 TAF/y can be diverted by CSJWCD, and up to 75 TAF/y can be diverted by SEWD. All of the contract diversions are assumed to be used for applied water demands and distribution losses, except for the first 10 TAF/y diverted by SEWD, which goes to municipal demands. Using the deep percolation and distribution loss factors given above, the annual CUAW demand for SEWD and CSJWCD to be met with Stanislaus River water are estimated at 54 TAF/y and 56 TAF/y, respectively.

G.2.1.5 Percent of Crop Surface Water Demand Met

The final parameter needed from the WSE model for input to the groundwater and agricultural post-processing spreadsheets is the percent of crop surface water demand met for each district. This is determined by distributing the total tributary diversions described above to each of the individual irrigation district demands. For all districts except SEWD and CSJWCD, the first step is to subtract district demands assumed to not be cut in times of shortage from the total non-CVP and non-riparian river diversion, **Div$_T$**, where **T** is the tributary name. These *off-the-top demands* include the offstream reservoir losses (**ResLoss**), municipal and industrial demands (**M&I**), and return flows (**R**). In addition, on the Merced River, SOI deliveries met prior to the district demands (Merced NWR and Stevinson) must be subtracted as well. The equation is:

$$DivF_T = Div_T - \overbrace{\left(ResLoss + M\&I + R * (1 + DF)\right)}^{for\ each\ district\ on\ tributary\ T} - \overbrace{(SOI_{NWR} + SOI_{Stev}) * (1 + DF)}^{Merced\ River\ only}$$

Note that return flows and SOI demands have distribution losses associated with them. This equation gives the total surface water diversion on tributary **T** for farm diversions, **DivF$_{,T}$**. Farm diversions represent water diverted for applied water demand and associated distribution losses.

Farm diversions are then compared to the farm surface water demand for each irrigation district, **F$_{SWdem}$**. For each irrigation district except SEWD and CSJWCD, farm surface water demand is calculated as:

$$\overbrace{F_{SWdem} = (C_{dem} * (1 + PF) - MinGW) * (1 + DF)}^{for\ each\ district\ except\ SEWD\ and\ CSJWCD}$$

Note that there are no distribution losses associated with groundwater pumping. When the total applied water demand (**C$_{dem}$***(1+**PF**)) is reduced by the minimum groundwater pumping, this also reduces the distribution losses that would have occurred if the demand was met entirely with surface water.

Finally, the percent of farm surface water demand met for tributary **T**, or **F$_{\%SWmet,T}$**, is calculated as:

$$F_{\%\,SWmet\,,T} = \frac{DivF_T}{(Sum\ of\ all\ F_{SWdem}\ on\ tributary\ T)} * 100 = C_{\%\,SWmet\,,T}$$

Since farm diversion is just the CUAW multiplied by constant factors to account for deep percolation and distribution losses, the **F$_{\%\,SWmet,T}$** is equal to the percent of crop surface water demand met, **C$_{\%SWmet,T}$**. Though **C$_{\%SWmet,T}$** is calculated for the tributary as a whole, it is assumed that any districts that share tributary **T** (SSJID and OID on the Stanislaus and MID and TID on the Tuolumne) will both have the same $\mathbf{C_{\%SWmet,T}}$ in any given year.

For SEWD and CSJWCD, the percent of crop surface water demand met is calculated after apportioning the total CVP diversion between them, as described above. $\mathbf{Div_{SEWD}}$ and $\mathbf{Div_{CSJWCD}}$ represent the total diversion to each of the contractors. The volume of these diversions that goes to consumptive use, $\mathbf{C_{met}}$, is calculated as:

$$\overbrace{C_{met,Z} = \left((Div_Z - (M\&I_{SEWD}\ for\ SEWD\ only))/\left((1+PF_Z)*(1+DF_Z)\right)\right)}^{Z=SEWD\ or\ CSJWCD}$$

The percent crop surface water demand met for contractor **Z**, $\mathbf{C_{\%SWmet,Z}}$, is $\mathbf{C_{met,Z}}$ divided by contractor **Z**'s crop surface water demand, $\mathbf{C_{dem}}$. Note that because the minimum groundwater pumping for the contractors is zero in this analysis, the crop surface water demand, $\mathbf{C_{SWdem}}$, equals the total crop demand, $\mathbf{C_{dem}}$.

G.2.2 Methodology for Calculating Applied Water

Once the above parameters are extracted from the WSE model, a spreadsheet is used to calculate impacts on groundwater and surface water use in the study area. The following steps are used in the calculation of total applied water, which is the total amount of surface water and groundwater applied to the crops by each of the irrigation districts.

G.2.2.1 Applied Water Demand

Applied water demand, $\mathbf{AW_{dem}}$, is the amount of water needed at the farm gate to meet crop consumptive use demands and account for deep percolation. Here $\mathbf{AW_{dem}}$ is calculated for district **D** using the following equation:

$$AW_{dem,D} = C_{SWdem,D} * (1 + PF_D) + MinGW_D$$

Where,

$\mathbf{C_{SWdem,D}}$ is district **D**'s crop surface water demand from the WSE model.

$\mathbf{PF_D}$ is district **D**'s deep percolation factor.

$\mathbf{MinGW_D}$ is district **D**'s minimum groundwater pumping.

G.2.2.2 Applied Surface Water

Applied surface water, **ASW**, is the portion of surface water diversions used to satisfy the applied water demand. **ASW** is calculated for district **D** using the following equation:

$$ASW_D = C_{SWdem,D} * C_{\%SWmet,D} * (1 + PF_D)$$

Where,

$\mathbf{C_{\%SWmet,D}}$ is the percent of crop surface water demand met for district **D**.

G.2.2.3 Additional Groundwater Pumping

Additional groundwater pumping, or groundwater replacement pumping, refers to pumping performed, above the minimum required groundwater pumping, to replace surface water in times of shortage. If minimum groundwater pumping and applied surface water are sufficient to meet crop demand, then no additional groundwater pumping is needed, otherwise additional groundwater pumping is applied up to the maximum pumping amount, **MaxGW**. A high value for maximum groundwater pumping can reduce potential for agricultural impacts, but it increases the potential for groundwater impacts.

The demand for additional groundwater pumping was calculated for each irrigation district and each LSJR alternative. The additional groundwater pumping performed annually for district D, $\mathbf{AddGW_D}$, was calculated as either the remaining applied water demand after applying surface water and minimum groundwater pumping, or the difference between minimum and maximum groundwater pumping, whichever is smaller:

$$AddGW_D = MIN\left(\left(AW_{dem,D} - ASW_D - MinGW_D\right), \left(MaxGW_D - MinGW_D\right)\right)$$

Because baseline is representative of 2009 infrastructure, the primary groundwater analysis utilizes estimates of maximum groundwater pumping that were typical in 2009 (Table G.2-4). However, as a result of recent drought conditions, more wells have been drilled, and therefore an assessment using estimates of maximum groundwater pumping for 2014 is also discussed (Table G.2-4). Unless specified otherwise, results presented in this appendix were generated using the maximum groundwater pumping estimates for 2009 infrastructure.

Table G.2-4. Annual Maximum Groundwater Pumping Estimates for each Irrigation District

	Annual Maximum Groundwater Pumping (TAF/y)	
Irrigation District	2009 Estimate	2014 Estimate
SSJID	59	74
OID North[a]	17	28
OID South[a]	22	37
MID	28	139
TID	125	251
Merced ID	253	253
SEWD[b]	60	60
CSJWD[b]	61	61
In-District Total	626	903

TAF/y = thousand acre-feet per year

[a] Total OID maximum GW pumping estimates of 39.5 TAF/y for 2009 infrastructure and 64.3 TAF/y for 2014 infrastructure are divided between North and South OID based on the relative irrigated area of each.

[b] SEWD and CSJWD estimates are based on total replacement of CVP contract surface water supplies only (total 155 TAF), minus estimated conveyance losses (see text).

The 2009 values are the maximum annual district and private groundwater pumping estimates presented in each district's respective AWMP (SSJID 2012; OID 2012; MID 2012; TID 2012; Merced ID 2013), while the 2014 estimates primarily are sourced from the district's responses to the September information request letters (Rietkerk pers. comm.; Knell pers. comm.; Hashimoto pers. comm.; Salyer pers. comm.). All of the 2014 maximum groundwater pumping estimates are greater than the 2009 maximum groundwater estimates, except for Merced ID. The Merced ID information request response (Eltal pers. comm.) did not report an estimate of the district's groundwater pumping capacity; therefore, Merced ID is assumed to have the same GW pumping capacity in 2014 as in 2009. This is reasonable because Merced ID had well-developed groundwater pumping capabilities in 2009, and it is unlikely that they significantly increased their capacity within 5 years. The MID response letter reported district pumping capacity at 78 TAF/y but did not report an estimate of private pumping capacity within the district; therefore, the increase in private pumping capacity from 2009 to 2014 was estimated based on the private pumping increase in neighboring TID. As of 2014, TID had a private pumping capacity of 1.03 AF/acre (Hashimoto pers. comm.). Using the TID value of 1.03 AF/acre private capacity with the Modesto irrigated area of 58,611 acres (MID AWMP 2012) would be equivalent to 60.6 TAF/y of private pumping capacity for MID in 2014, resulting in a total maximum district plus private 2014 pumping capacity for MID of 138.6 TAF/y.

The SEWD and CSJWCD analysis focused only on the portion of the CVP contract delivery that could come from the Stanislaus River. The other water used by these districts would not be affected by the LSJR alternatives. If no Stanislaus River water is available to these districts, then it is assumed there would be enough groundwater pumping capacity to fully replace any lost surface water supply, which would be 60 and 61 TAF/y for SEWD and CSJWCD, respectively (full contract amount minus estimated distribution losses, and not including 10 TAF/y assumed to be minimum M&I delivery for SEWD, that would not be considered a part of crop demand).

G.2.2.4 Total Applied Water and Percent Crop Demand Satisfied

Applied water represents water applied to crops to satisfy CUAW demands and to account for deep percolation. Because groundwater pumping is generally applied directly to the crops, it is used entirely for applied water demands. The total applied water, $\mathbf{AW_{total}}$, is the sum of the minimum ground water pumping, applied surface water, and additional ground water pumping, as shown below:

$$AW_{total\,,D} = ASW_D + MinGW_D + AddGW_D$$

The total applied water is also compared to the total demand for applied water. The percent of applied water demand met annually, $\mathbf{AW_{\%met}}$, is calculated for each irrigation district and each alternative as:

$$AW_{\%met\,,D} = 100 * AW_{total\,,D} / AW_{dem\,,D}$$

These percentages are then passed to the SWAP model and used with the crop distribution information for the calibration year in SWAP (2010) to calculate how crop acreages would be affected in years with some level of scarcity. Crop distributions are discussed further in Section G.4.2, *Crop Distribution and Applied Water Inputs for SWAP*.

G.2.3 Estimates of Groundwater Use and Unmet Demand

The net impact of the LSJR alternatives in the form of reduced surface water availability to irrigation districts would be moderated by increased groundwater pumping. Knowledge of the current and future rates of groundwater pumping, therefore, are needed to determine the net water supply impact. In other words, groundwater pumping must be estimated to determine the overall unmet demand for agricultural water. Unmet demand is defined as a shortage of water supply to satisfy field crop applied water needs, after accounting for both surface water and groundwater supplies.

Table G.2-5 shows the likely increase in groundwater pumping within irrigation district boundaries, assuming 2009 annual groundwater pumping capacity estimates and no change in the assumed irrigation efficiencies of the irrigation districts. Based on this assumption, mean annual groundwater pumping is expected to increase by 21 TAF under LSJR Alternative 2, 105 TAF under LSJR Alternative 3, and 216 TAF under LSJR Alternative 4. Groundwater pumping increases are highest in below normal, dry and critically dry years, and lowest in wet and above normal years.

Table G.2-5. Annual Average In-District Groundwater Use Based on Estimated 2009 Groundwater Pumping Capacities

	Average Annual Groundwater Use					
	All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
Total GW pumping capacity (TAF/y)	626	626	626	626	626	626
Baseline GW use (TAF)	260	185	203	228	221	485
LSJR Alt 2 (20% UF) GW use (TAF)	281	178	193	242	284	554
Increase over Baseline (TAF)[a]	21	-8	-10	15	63	69
LSJR Alt 3 (40% UF) GW use (TAF)	364	192	235	376	524	614
Increase over Baseline (TAF)[a]	105	6	32	149	302	129
LSJR Alt 4 (60% UF) GW use (TAF)	476	260	457	578	616	624
Increase over Baseline (TAF)[a]	216	75	254	350	395	139

GW = groundwater

TAF/y = thousand acre-feet per year

UF = unimpaired flow

[a] LSJR Alt 2/3/4 minus baseline may be different from increase due to rounding.

Table G.2-6 shows the change in mean annual in-district unmet applied water demand after accounting for the surface water diversions and groundwater pumping based on estimated 2009 pumping capacities. The mean annual baseline unmet demand for all year types is 45 TAF/y. Most of the unmet demand occurs in critically dry years, with some also in dry years—the mean annual baseline unmet demand in critically dry years is 224 TAF/y. Under LSJR Alternatives 2, 3, and 4 the mean annual unmet demand for all year types increases by 29, 137, and 360 TAF/y, respectively, compared to baseline. For the LSJR alternatives, most of the unmet demand occurs in dry and critically dry years, but for LSJR Alternatives 3 and 4, all year types see greater unmet demand.

Table G.2-6. Annual Average In-District Applied Water Demand, Groundwater Pumping, and Unmet Demand Based on Estimated 2009 Groundwater Pumping Capacities

Plan Area			All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
Baseline and LSJR Alternatives		Total Applied Water Demand (TAF)	1,604	1,483	1,565	1,643	1,696	1,720
Baseline	Surface Water Supply	Baseline Applied Surface Water (TAF)	1,300	1,298	1,362	1,415	1,465	1,011
	Baseline GW pumping (2009 Max)	Baseline GW Pumping (TAF)	260	185	203	228	221	485
		Baseline Unmet Demand (TAF)	45	0	0	0	9	224
		Baseline Unmet Demand (%)	3%	0%	0%	0%	1%	13%
LSJR Alternative 2	Surface Water Supply	Alt. 2 Applied Surface Water (TAF)	1,249	1,305	1,372	1,396	1393	803
	With additional GW pumping (2009 Max)	Alt. 2 GW Pumping (TAF)	281	178	193	242	284	554
		Alt. 2 Unmet Demand (TAF)	75	0	0	5	19	363
		Alt. 2 Unmet Demand (%)	5%	0%	0%	0%	1%	21%
		Alt. 2 Increase in Unmet Demand from Baseline (TAF)	29	0	0	5	10	139
LSJR Alternative 3	Surface Water Supply	Alt. 3 Applied Surface Water (TAF)	1,058	1,287	1,293	1,163	943	489
	With additional GW pumping (2009 Max)	Alt. 3 GW Pumping (TAF)	364	192	235	376	524	614
		Alt. 3 Unmet Demand (TAF)	182	4	37	104	230	618
		Alt. 3 Unmet Demand (%)	11%	0%	2%	6%	14%	36%
		Alt. 3 Increase in Unmet Demand from Baseline (TAF)	137	4	37	104	221	394
LSJR Alternative 4	Surface Water Supply	Alt. 4 Applied Surface Water (TAF)	723	1,180	890	632	409	201
	With additional GW pumping (2009 Max)	Alt. 4 GW Pumping (TAF)	476	260	457	578	616	624
		Alt. 4 Unmet Demand (TAF)	405	43	218	433	671	896
		Alt. 4 Unmet Demand (%)	25%	3%	14%	26%	40%	52%
		Alt. 4 Increase in Unmet Demand from Baseline (TAF)	360	43	218	433	661	672

The recent drought has provided insight into how groundwater pumping may increase in response to surface water supply shortages. In the last few years, groundwater pumping capacity and utilization has increased to historically high levels. Table G.2-7 shows that groundwater pumping would be greater under baseline and the LSJR alternatives when applying the 2014 annual groundwater pumping capacity estimates instead of the 2009 estimates. Mean annual in-district groundwater pumping under baseline conditions for all year types is 30 TAF higher with the 2014 pumping capacity estimates compared to 2009 levels (290 TAF versus 260 TAF). Under LSJR Alternatives 2,3, and 4 the mean annual groundwater pumping in all year types increases by 32, 172, and 357 TAF/y, respectively, over baseline conditions. Most of the groundwater pumping occurs in below normal, dry, and critically dry years, but under LSJR Alternative 4, above normal years also have high groundwater use.

Table G.2-7. Annual Average In-District Groundwater Use Based on Estimated 2014 Groundwater Pumping Capacities

	Average Annual Groundwater Use					
	All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
Total GW pumping capacity (TAF/y)	903	903	903	903	903	903
Baseline GW use (TAF)	290	185	203	228	231	633
LSJR Alt 2 (20% UF) GW use (TAF)	322	178	193	247	302	742
Increase over Baseline (TAF)[a]	32	-8	-10	20	71	110
LSJR Alt 3 (40% UF) GW use (TAF)	462	194	259	460	690	883
Increase over Baseline (TAF)[a]	172	9	56	233	460	250
LSJR Alt 4 (60% UF) GW use (TAF)	647	283	600	826	890	901
Increase over Baseline (TAF)[a]	357	97	397	598	659	268

GW = groundwater

TAF/y = thousand acre-feet per year

UF = unimpaired flow

[a] LSJR Alt 2/3/4 minus baseline may be different from increase due to rounding.

Table G.2-8 shows the change in mean annual unmet in-district water demand after taking into account the substitution of reduced surface water with additional groundwater pumping based on estimated 2014 pumping capacities. The mean annual baseline unmet demand is 15 TAF, which is 30 TAF/y lower than mean annual baseline unmet demand using estimated 2009 pumping capacities. Under baseline conditions, demands can be fully satisfied in all year types except critically dry years, when unmet demand averages about 76 TAF/y. When compared to baseline, the mean annual unmet demand increases by 19 TAF/y in LSJR Alternative 2, by 69 TAF/y in LSJR Alternative 3, and by 219 TAF/y in LSJR Alternative 4. For the LSJR alternatives, most of the unmet demand occurs in dry and critically dry years, but for LSJR Alternatives 3 and 4, all year types see greater unmet demand.

Table G.2-8. Annual Average In-District Applied Water Demand, Groundwater Pumping, and Unmet Demand Based on Estimated 2014 Groundwater Pumping Capacities

Plan Area			All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
Baseline and LSJR Alternatives		Total Applied Water Demand (TAF)	1,604	1,483	1,565	1,643	1,696	1,720
Baseline	Surface Water Supply	Baseline Applied Surface Water (TAF)	1,300	1,298	1,362	1,415	1,465	1,011
Baseline	Baseline GW pumping (2009 Max)	Baseline GW Pumping (TAF)	290	185	203	228	231	633
Baseline	Baseline GW pumping (2009 Max)	Baseline Unmet Demand (TAF)	15	0	0	0	0	76
Baseline	Baseline GW pumping (2009 Max)	Baseline Unmet Demand (%)	1%	0%	0%	0%	0%	4%
LSJR Alternative 2	Surface Water Supply	Alt. 2 Applied Surface Water (TAF)	1,249	1,305	1,372	1,396	1393	803
LSJR Alternative 2	With additional GW	Alt. 2 GW Pumping (TAF)	322	178	193	247	302	742
LSJR Alternative 2	With additional GW	Alt. 2 Unmet Demand (TAF)	34	0	0	0	1	175

Plan Area			All Year types	Wet	Above Normal	Below Normal	Dry	Critically Dry
	pumping (2009 Max)	Alt. 2 Unmet Demand (%)	2%	0%	0%	0%	0%	10%
		Alt. 2 Increase in Unmet Demand from Baseline (TAF)	19	0	0	0	1	98
LSJR Alternative 3	Surface Water Supply	Alt. 3 Applied Surface Water (TAF)	1,058	1,287	1,293	1,163	943	489
	With additional GW pumping (2009 Max)	Alt. 3 GW Pumping (TAF)	462	194	259	460	690	883
		Alt. 3 Unmet Demand (TAF)	84	2	13	20	63	349
		Alt. 3 Unmet Demand (%)	5%	0%	1%	1%	4%	20%
		Alt. 3 Increase in Unmet Demand from Baseline (TAF)	69	2	13	20	63	273
LSJR Alternative 4	Surface Water Supply	Alt. 4 Applied Surface Water (TAF)	723	1,180	890	632	409	201
	With additional GW pumping (2009 Max)	Alt. 4 GW Pumping (TAF)	647	283	600	826	890	901
		Alt. 4 Unmet Demand (TAF)	234	21	75	185	397	619
		Alt. 4 Unmet Demand (%)	15%	1%	5%	11%	23%	36%
		Alt. 4 Increase in Unmet Demand from Baseline (TAF)	219	21	75	185	397	543

These results show the sensitivity of the calculation of unmet demand to assumed levels of groundwater pumping. With higher groundwater pumping, the severity of water shortages can be reduced, but this also puts greater strain on groundwater supplies. Whether such increased levels can be maintained over the long term has not been determined. The estimated 2009 pumping capacities, therefore, are used to determine the economic impacts of reduced overall water supply, with the understanding that higher pumping capacities may be possible for a limited time in some areas.

G.2.4 Estimates of Total Applied Water

Figures G.2-1A through G.2-1D show the annual allocation of surface water diversions to meet the various demands on each tributary for baseline and each LSJR alternative, with the combination of "CUAW-SW" and "Applied SW Percolation" representing applied surface water. Municipal supplies, riparian diversions, and regulating reservoir losses remain relatively unchanged from year to year and between alternatives. Applied surface water, applied surface water percolation, distribution system percolation, and distribution system evaporation vary as a function of annual surface water allocation. Operational spills and return flows are held fixed between alternatives, with some annual variation inherent in the CALSIM estimates also used in the WSE model.

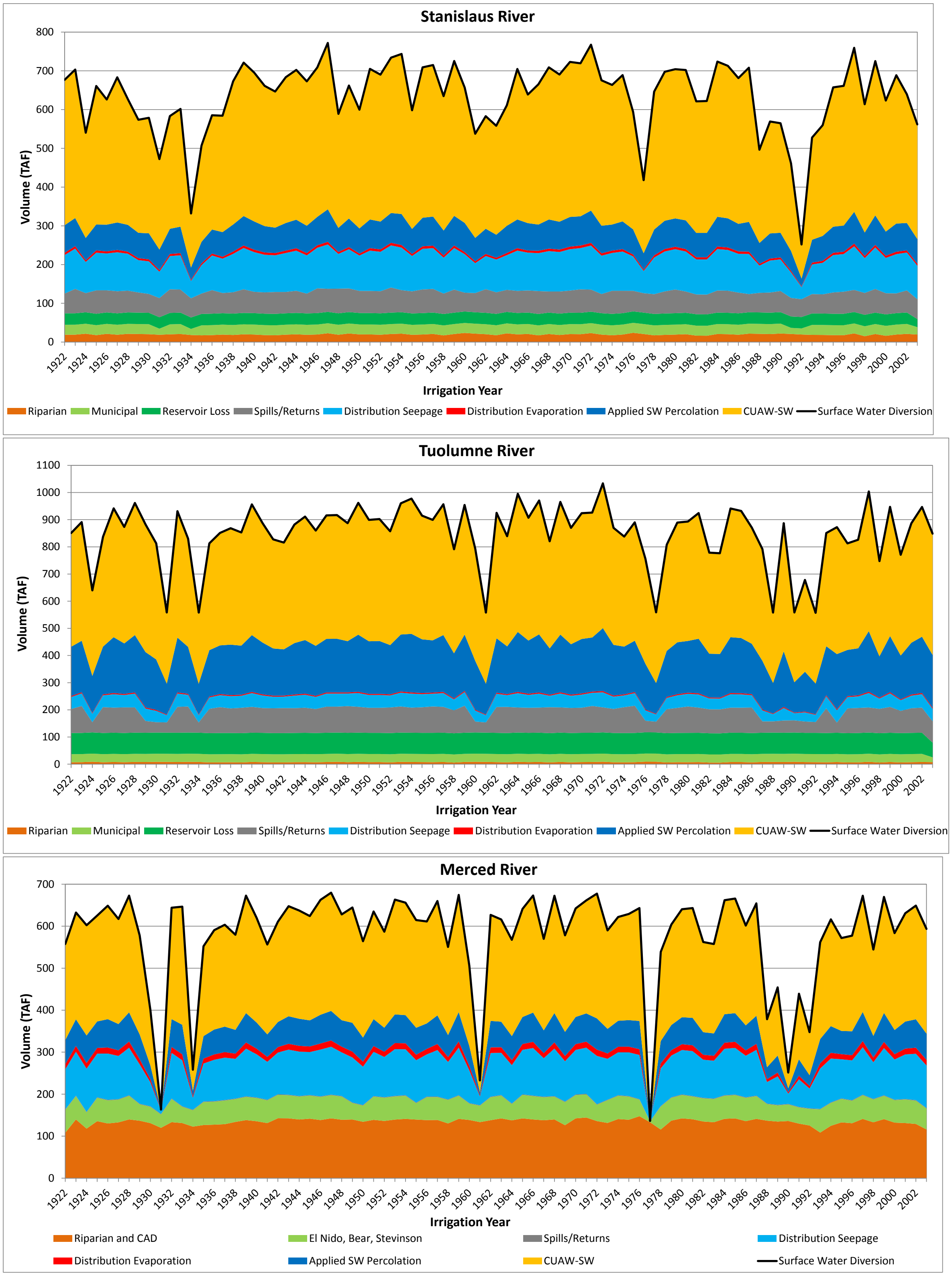


Figure G.2-1A. Partitioning of Baseline Diversions into End Uses

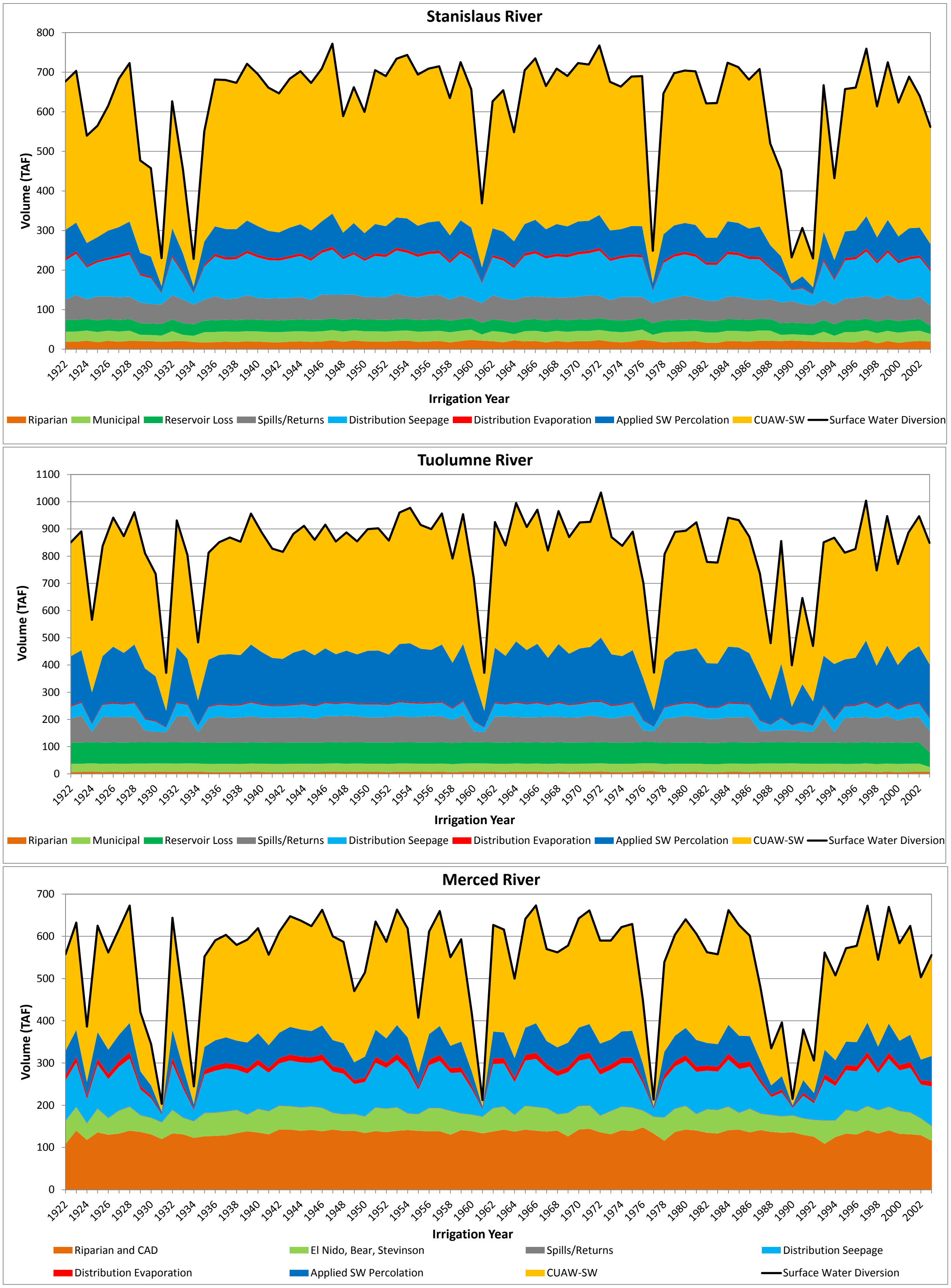


Figure G.2-1B. Partitioning of LSJR Alternative 2 Diversions into End Uses

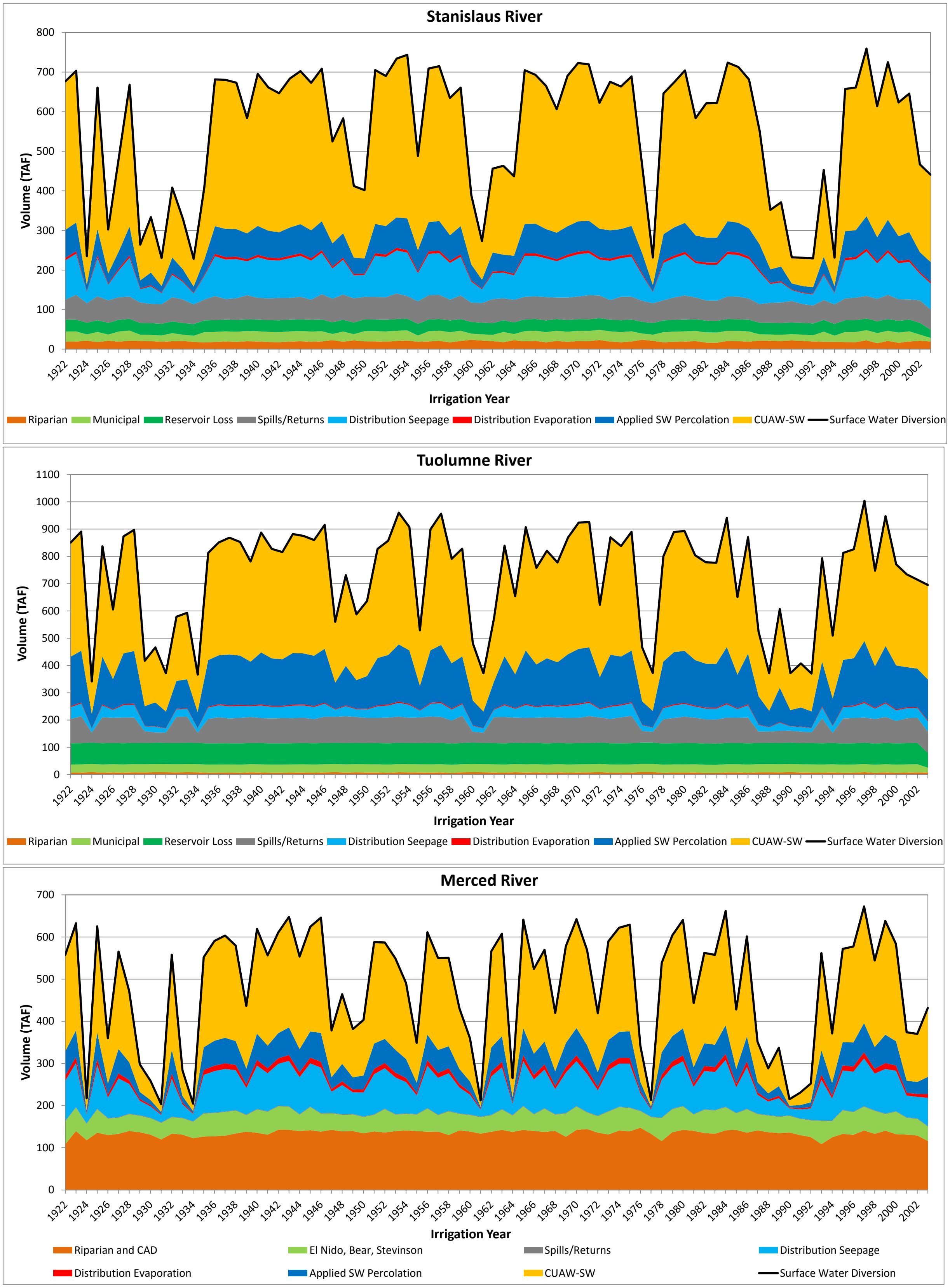


Figure G.2-1C. Partitioning of LSJR Alternative 3 Diversions into End Uses

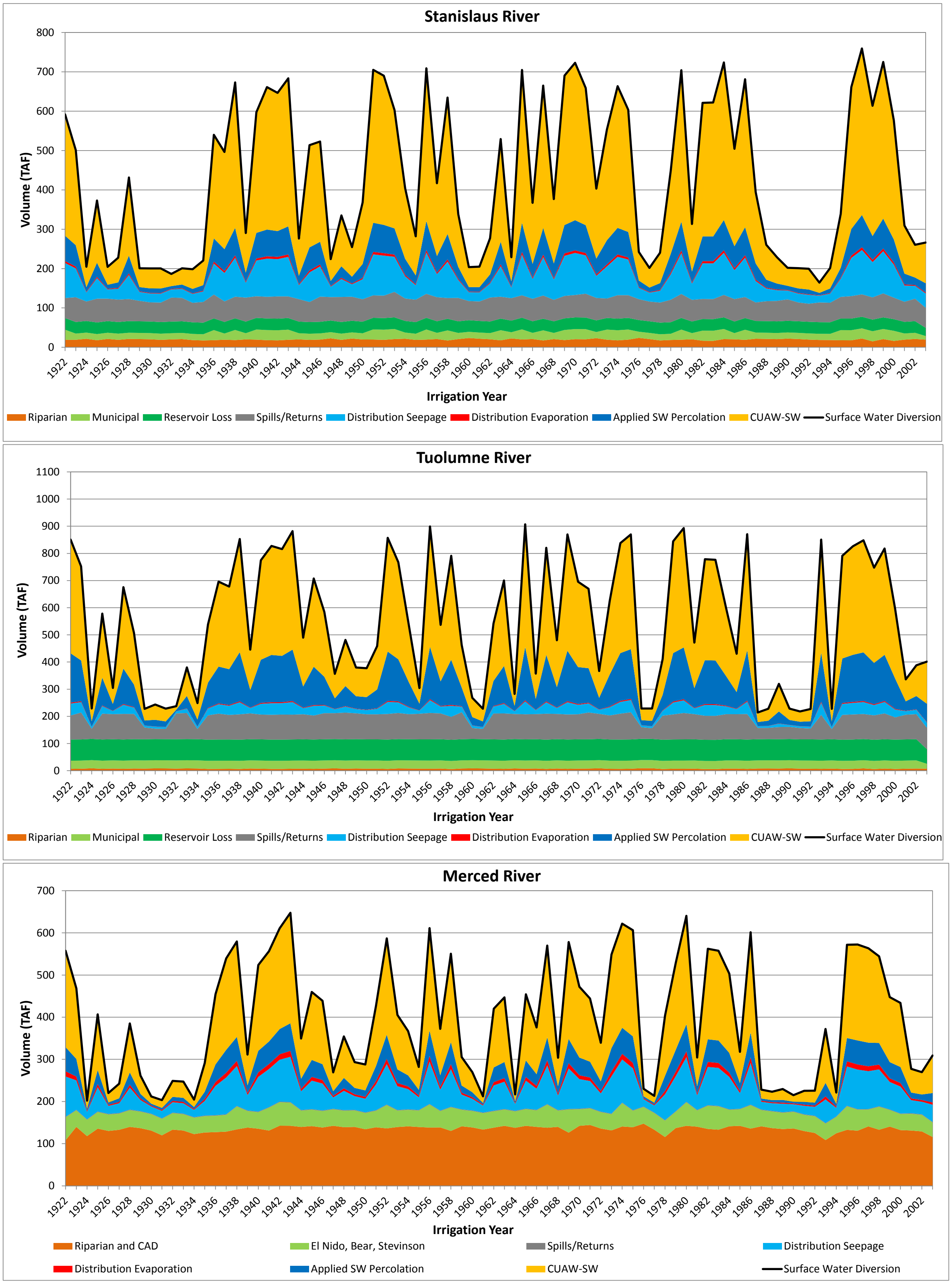


Figure G.2-1D. Partitioning of LSJR Alternative 4 Diversions into End Uses

On the Stanislaus and Tuolumne Rivers, average annual applied water deliveries to the districts account for over 50 percent of the average annual surface water diversions for each of the LSJR alternatives and baseline. On the Merced River, the average annual applied water deliveries to Merced ID account for between 40 and 50 percent of the average annual surface water diversions for each of the LSJR alternatives and baseline. However, this does not include the portion of riparian diversions used for applied water, which is especially significant on the Merced because more than 100 TAF/y goes to Cowell Agreement diversions and other riparian users. On the Stanislaus and Tuolumne Rivers, water use by holders of riparian water rights is relatively small.

As the percent of unimpaired flow used for instream flow requirements increases from LSJR Alternative 2 to LSJR Alternative 4, the amount of water available for diversions becomes progressively smaller, as does the distribution system seepage, CUAW supplied by surface water, and percolation from applied water. Furthermore, because some end uses do not vary between the alternatives (i.e., riparian diversions, municipal and industrial water use, spills, and offstream reservoir losses), the percent decrease in CUAW, and deep percolation is greater than the percent decrease in total diversions. However, even under LSJR Alternative 4, on average approximately 30–50 percent of diversions goes to CUAW (depending on the river). However, with this alternative, the year-to-year variations in applied water are very large, with some large shortages occurring in years that had almost full water supply under baseline conditions.

In years with low water supply, surface water diversions are not sufficient to meet full agricultural demand for applied surface water (i.e., total demand for CUAW and deep percolation that is not met by minimum groundwater pumping). As a result, groundwater pumping increases. However, even under baseline conditions, there are some years when increased groundwater pumping will not be enough to fully mitigate surface water shortages for the agricultural demands of the irrigation districts (Figure G.2-2A). The capacity of each irrigation district to pump groundwater varies and depends on existing infrastructure. Capacity for increased groundwater pumping (2009 values) by Merced ID is almost sufficient to meet full demand in drought years. There is moderate capacity to compensate for a reduction in surface water supply on the Stanislaus River, but this comes largely from SEWD and CSJWCD, which can fully compensate for a reduction in their Stanislaus River supply. In contrast, SSJID and OID have only a limited ability to increase groundwater pumping because their surface water supply has historically been reliable and they have not needed to increase their groundwater pumping capacity. The irrigation districts that get their water from the Tuolumne River, TID and MID, similarly have limited ability to increase groundwater pumping (Table G.2-4).

Most of the applied water for the irrigation districts comes from surface water. Under baseline conditions, almost all of the demand for applied water is met with surface water and minimum groundwater pumping, but there is a small to moderate amount of supplemental groundwater pumping during dry years (Figure G.2-2A). As the required percent of unimpaired flow increases for the LSJR alternatives, the amount of surface water available for crop application decreases, (Figures G.2-2B, G.2-2C, and G.2-2D). Much of the deficit in surface water diversions from the Stanislaus and Merced Rivers can be compensated by increased groundwater pumping by SEWD, CSJWCD, and Merced ID, but there is little compensation for deficits in surface water diversions from the Tuolumne River.

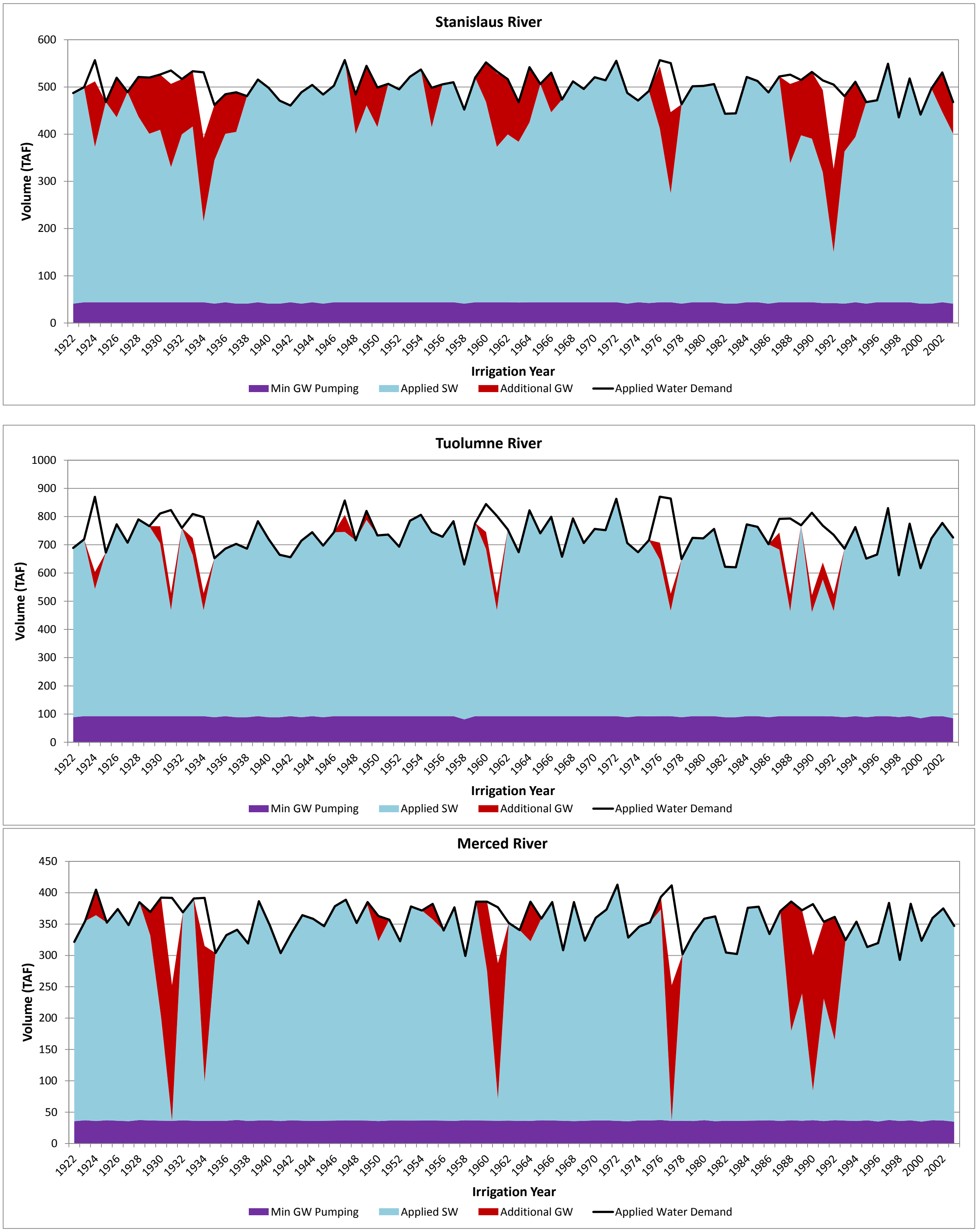
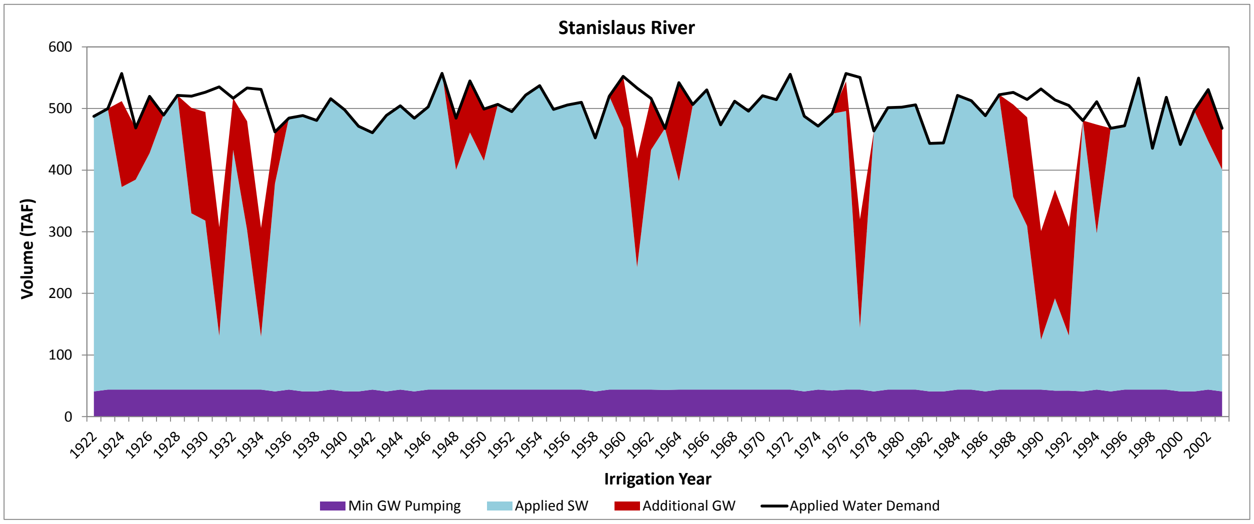
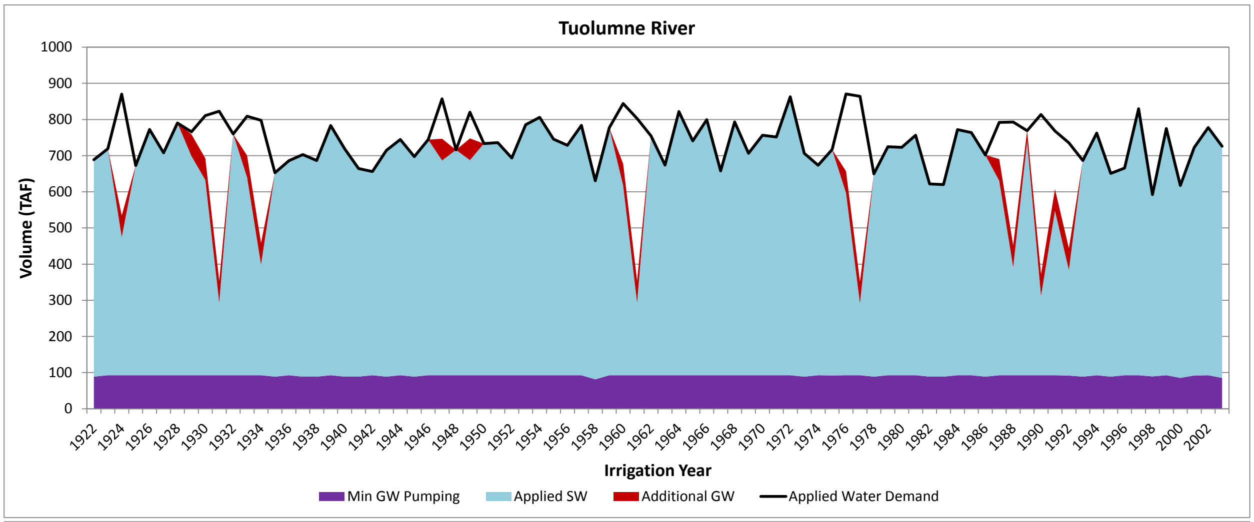


Figure G.2-2A. Baseline Groundwater and Surface Water Application to Meet Applied Water Demand for the Stanislaus, Tuolumne, and Merced Rivers





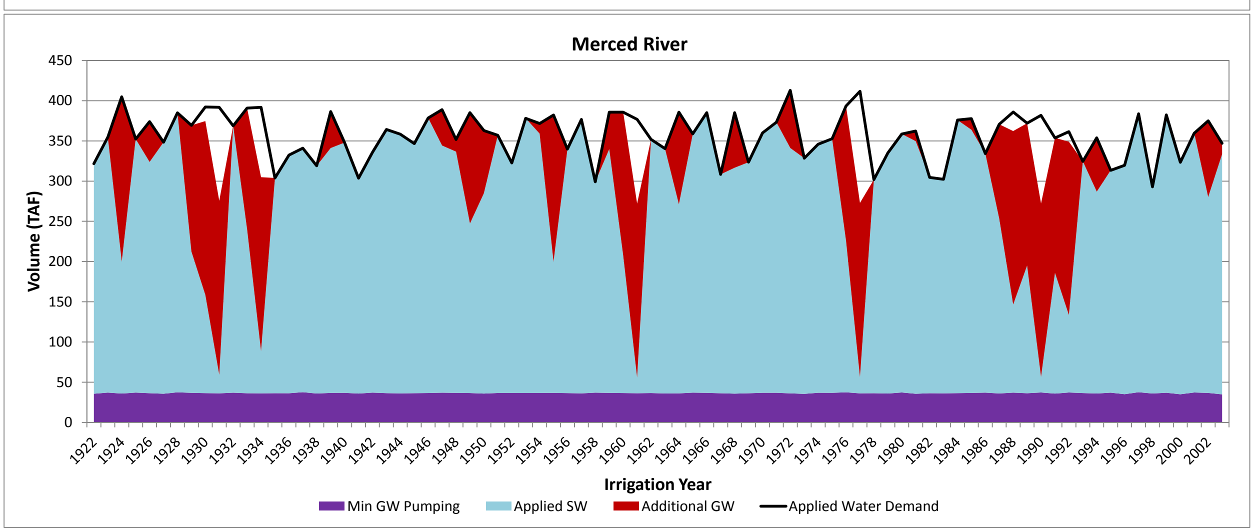


Figure G.2-2B. Groundwater and Surface Water Application to Meet Applied Water Demand for the Stanislaus, Tuolumne, and Merced Rivers for LSJR Alternative 2

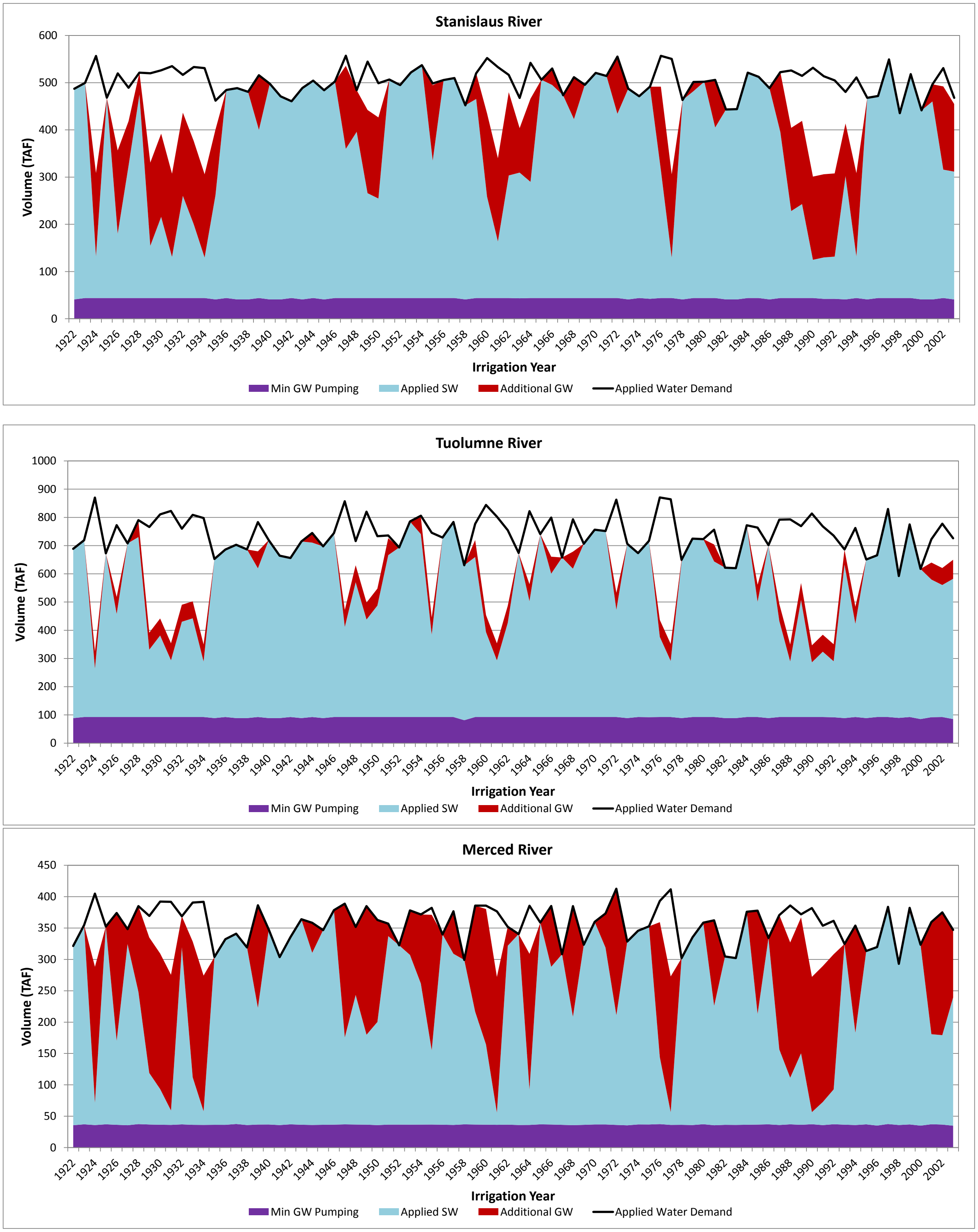


Figure G.2-2C. Groundwater and Surface Water Application to Meet Applied Water Demand for the Stanislaus, Tuolumne, and Merced Rivers for LSJR Alternative 3

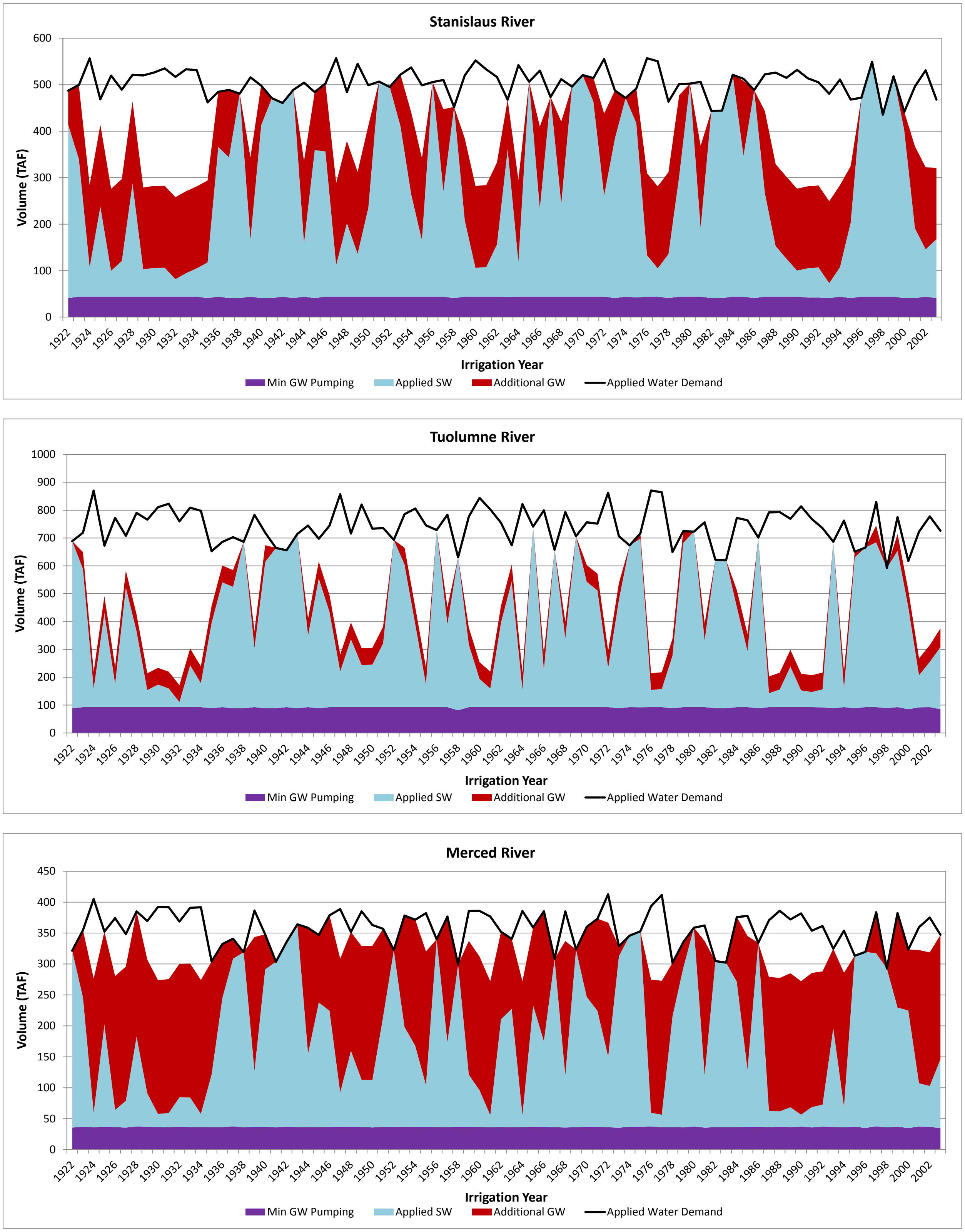


Figure G.2-2D. Groundwater and Surface Water Application to Meet Applied Water Demand for the Stanislaus, Tuolumne, and Merced Rivers for LSJR Alternative 4

The results for applied surface water deficit are separated by irrigation district in Table G.2-9, pre-groundwater replacement, and Table G.2-10, post-groundwater replacement (2009 maximum groundwater pumping). The deficit in applied surface water ranges from an average total for all irrigations districts of 134 TAF/y for baseline conditions to a total of 709 TAF/y under LSJR Alternative 4. This represents 9 percent and 50 percent of the total annual demand for applied surface water for baseline and LSJR Alternative 4, respectively. When additional groundwater pumping is considered, the deficit in average total applied water drops from 134 TAF/y to 48 TAF/y under baseline, and drops from 709 TAF/y to 413 TAF/y under LSJR Alternative 4, which reduces the total average percent deficit in surface water demand to 3 percent for baseline and 29 percent for LSJR Alternative 4.If the additional groundwater pumping is based on 2014 infrastructure capacity, the average annual percent deficit in applied surface water demand of all district decreases from 3 percent to 1 percent for baseline and from 29 percent to 17 percent for LSJR Alternative 4 (Table G.2-11).

Table G.2-9. Average Annual Applied Surface Water Deficit Pre-Groundwater Replacement

Irrigation District	Applied Surface Water Deficit				Change from Baseline		
	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Deficit in Average TAF/y							
SSJID	5	13	28	57	7	22	52
OID	7	17	37	78	10	30	70
SEWD	24	19	26	42	-5	2	18
CSJWCD	17	14	25	41	-3	8	24
MID	14	20	49	101	6	34	87
TID	32	45	108	224	13	76	192
Merced ID	34	58	102	167	23	67	132
All Districts	134	185	375	709	51	241	575
Deficit as Average Percent of Annual Demand for Applied Surface Water							
SSJID	4	9	20	40	5	16	36
OID	4	9	19	39	5	15	36
SEWD	40	32	44	71	-9	4	31
CSJWCD	28	22	40	68	-5	13	40
MID	7	10	24	50	3	17	43
TID	7	10	24	50	3	17	43
Merced ID	11	18	32	52	7	21	41
All Districts	9	13	26	50	4	17	40

Table G.2-10. Average Annual Applied Surface Water Deficit Post-Groundwater Replacement (2009 Maximum Groundwater Pumping)

Irrigation District	Applied Surface Water Deficit				Change from Baseline		
	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Deficit in Average TAF/y							
SSJID	2	7	16	37	5	14	36
OID	5	13	30	65	8	25	60
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	11	17	41	89	5	30	78
TID	23	35	86	190	12	63	167
Merced ID	7	7	15	31	1	8	25
All Districts	48	79	187	413	31	139	365
Deficit as Average Percent of Annual Demand for Applied Surface Water							
SSJID	1	5	11	26	3	10	25
OID	2	7	15	33	4	13	30
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	5	8	20	44	3	15	38
TID	5	8	19	43	3	14	37
Merced ID	2	2	5	10	0	2	8
All Districts	3	6	13	29	2	10	25

Table G.2-11. Average Annual Applied Surface Water Deficit Post-Groundwater Replacement (2014 Maximum Groundwater Pumping)

Irrigation District	Applied Surface Water Deficit				Change from Baseline		
	Baseline	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4	LSJR Alt 2	LSJR Alt 3	LSJR Alt 4
Deficit in Average TAF/y							
SSJID	1	5	11	29	4	10	28
OID	3	9	21	51	6	18	48
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	0	2	4	23	2	4	23
TID	6	14	38	108	8	32	102
Merced ID	7	7	15	31	1	8	25
All Districts	17	38	89	242	21	72	226
Deficit as Average Percent of Annual Demand for Applied Surface Water							
SSJID	1	4	8	21	3	7	20
OID	1	4	11	26	3	9	24
SEWD	0	0	0	0	0	0	0
CSJWCD	0	0	0	0	0	0	0
MID	0	1	2	11	1	2	11
TID	1	3	8	24	2	7	23
Merced ID	2	2	5	10	0	2	8
All Districts	1	3	6	17	1	5	16

G.3 Estimation of Groundwater Balance

G.3.1 Methodology for Estimating Change in Groundwater Recharge

The LSJR alternatives would likely cause changes in groundwater recharge and groundwater pumping in the four groundwater subbasins (the Eastern San Joaquin, Modesto, Turlock, and Merced) that underlie the surface water delivery areas from the three eastside tributaries (the Stanislaus, Tuolumne, and Merced Rivers) (Figure G.3-1). In addition, a portion of the Merced ID delivery area (El Nido) overlies the northern portion of the Chowchilla Subbasin. Consequently, the small part of the Chowchilla Subbasin that is north of the Chowchilla River has been combined with the Merced Subbasin to form an "Extended" Merced Subbasin to avoid diluting some Merced ID groundwater effects into the entirety of the Chowchilla Subbasin, which will be largely unaffected.

A groundwater subbasin can be used sustainably as a water source if the average annual water balance is not negative. The inflows to the basin (recharge) may be from adjacent subbasins; from overlying rivers and streams; or from infiltration from rainfall, irrigation canals, reservoirs, and water applied to crops (i.e., applied water). The outflows from the subbasin are predominantly pumping from wells by irrigation districts, municipalities, or individual users for irrigating crops or as potable water sources, but outflows can also include seepage to springs and rivers when the groundwater elevation is higher than the surface water. Figure G.3-2 depicts a conceptual water budget with various inflows and outflows.

In order to assess the effect of the LSJR alternatives on groundwater, groundwater in the four subbasins was considered to be four separate pools of water with no separation between shallow and deep aquifers. However, groundwater can move slowly between subbasins and there may be differences in effects between shallow (semi-confined) and deep (confined) sections of the aquifer. To the extent that water moves between subbasins, some of the groundwater impacts could have slight effects on adjoining subbasins, which would reduce the effects within the subbasins of concern. In some areas, deeper sections of the aquifer may be separated from shallower sections by substrate with low permeability. The evaluation of groundwater effects was not separated by depth because (1) there is some connectivity between the different depths, and (2) increased groundwater pumping would occur in both shallow and deep wells. Substrate with low permeability (e.g., the Corcoran Clay at the western side of the four subbasins) might slow the interaction between deeper confined and shallower unconfined sections of the aquifer, but water pumped from a deeper confined section of the aquifer would eventually be replaced by water from above or from the edges. Furthermore, within the four subbasins, the number of deep and shallow wells is too large to feasibly assign pumping increases to separate sections of the aquifer. The simplifying assumptions of separating the aquifers by subbasin and not depth are acceptable because the purpose of the analysis is to estimate the average effect of the LSJR alternatives on the subbasins as a whole, not effects at specific well locations.

To evaluate potential groundwater effects, all components of the groundwater balance that potentially could be altered by the LSJR alternatives were evaluated. All of these components are related to irrigation district operations. The annual net contribution of irrigation district water to the groundwater subbasins was calculated by summing the offstream reservoir seepage, conveyance losses, and deep percolation from irrigated lands and subtracting total groundwater pumping for each irrigation district overlying the subbasin. For shorthand, this groundwater balance is referred to as the *irrigation district groundwater balance*.

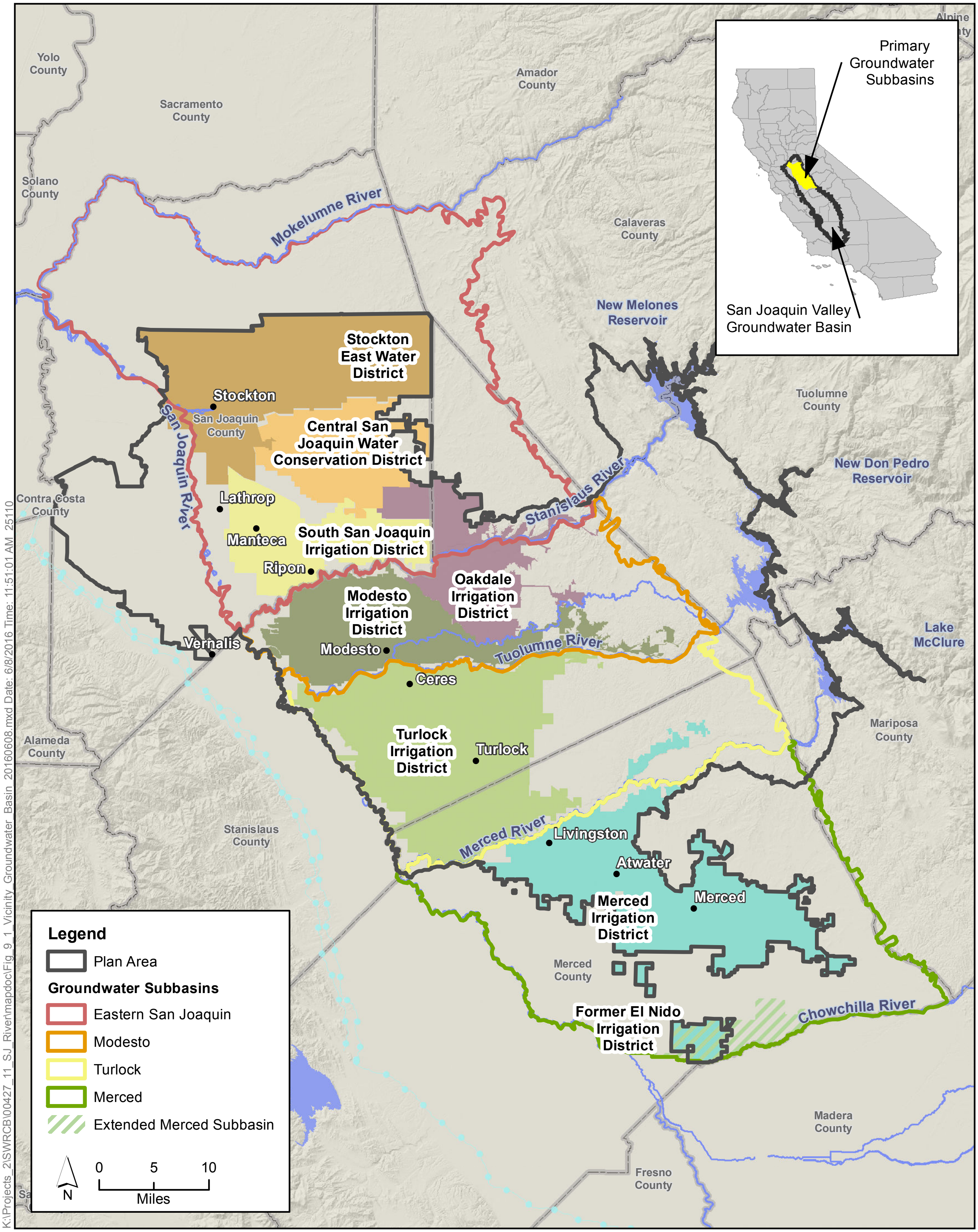


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Figure G.3-1
Vicinity Map of Groundwater Subbasins

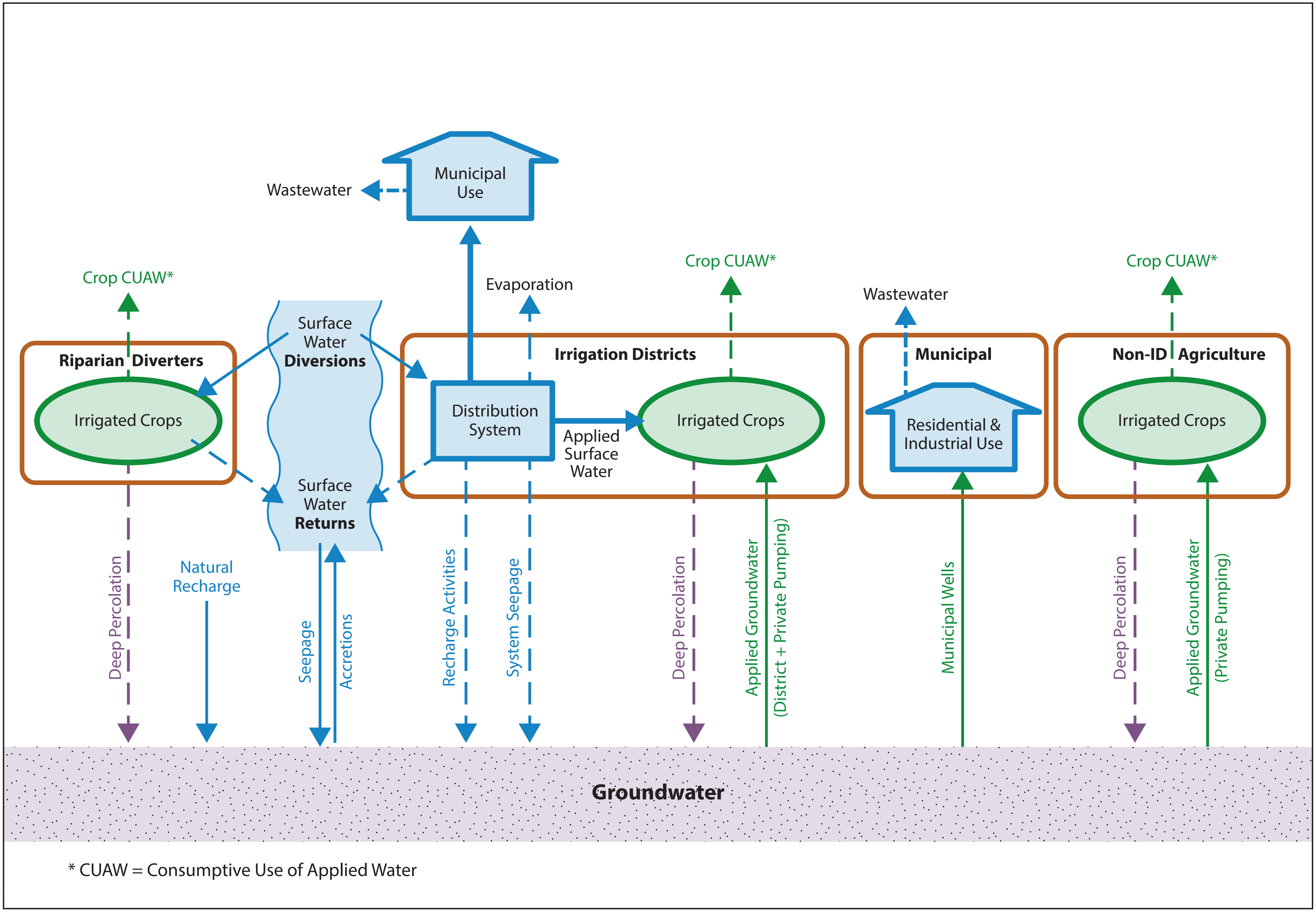

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Figure G.3-2
Conceptual Water Budget

For SEWD and CSJWCD, only the portion of their water use that could be affected by water supply from the Stanislaus River was included in the analysis. Two of the irrigation districts, OID and Merced ID, affect the results for two subbasins because their service area boundaries are not confined to a single subbasin; the OID service area is above Eastern San Joaquin and Modesto Subbasins, and the Merced ID service area is above the Turlock and Extended Merced Subbasins. Based on GIS mapping, the OID irrigated land was divided with 43 percent of the total assumed to be north of the Stanislaus River (in the Eastern San Joaquin Subbasin) and 57 percent of the total assumed to be south of the Stanislaus River (in the Modesto Subbasin)(OID 2012). Based on information in the Turlock GWMP (Turlock Groundwater Basin Association 2008) and the Merced AWMP (2013), Merced ID was divided with 5 percent of the irrigated acres assumed to be north of the Merced River (in the Turlock Subbasin) and 95 percent south of the Merced River (in the extended Merced Subbasin).

If the irrigation districts were able to use groundwater to fully replace any surface water shortage, then the effect of the LSJR alternatives on groundwater would approximately be equal to the decrease in river diversions (with a minor difference due to evaporation from the distribution system). If the irrigation districts had no ability to use groundwater to compensate for a reduction in surface water supply, then the effect of the LSJR alternatives on groundwater would be equal to the reduction in percolation from the distribution system plus the reduction in percolation from applied water. Because the irrigation districts have some ability to replace reductions in surface water supply with groundwater, the effect of the LSJR alternatives on groundwater is intermediate between the reduction in diversion and the reduction in percolation.

Net change in the groundwater balance associated with the different LSJR alternatives was calculated by comparing the irrigation district groundwater balance for the LSJR alternatives with the irrigation district groundwater balance for baseline conditions. The average annual LSJR alternative-related change in the groundwater balance was then compared to the total surface area of the groundwater subbasin. This metric was used in the impact analysis described in Chapter 9, *Groundwater Resources*.

G.3.2 Subbasin Groundwater Pumping and Recharge from Areas Outside of Irrigation Districts

Agricultural groundwater pumping outside of the irrigation districts, but within the subbasins, was estimated in order to provide perspective on the full groundwater effect of irrigation district pumping. Agricultural land outside of the irrigation districts is irrigated almost entirely with groundwater. Agricultural water demand for irrigated lands outside of the irrigation districts was estimated by multiplying estimates of applied water rates for different crop types by the number of acres of each crop type. The groundwater pumping in these areas remains relatively constant during droughts because crop demands are generally met with groundwater regardless of how much surface water is available (although crop demands may be somewhat greater during drought years, especially if spring conditions were dry).

Total irrigated acres outside of the irrigation districts was estimated by using geographic information systems (GIS) software to analyze DWR's agricultural land survey that is available as GIS coverages for each of DWR's Detailed Analysis Units (DAUs). DWR organizes its DAU data by county. DAU data from the following three counties were used: San Joaquin County (data were from 1996), Stanislaus County (data were from 2004), and Merced County (data were from 2002).

Irrigated acres within the irrigation districts were excluded. The irrigated acres for each subbasin were then subdivided into acres for each of the top 20 most common crops based on DWR data for the distribution of crops in DAU 182 (Eastern San Joaquin Subbasin), DAU 207 (Modesto Subbasin), DAU 209 (Turlock Subbasin), and DAUs 211 and 212 (Merced Subbasin) (Table G.3-1). The total irrigated acres outside of the irrigation districts is 204,634 acres in the Eastern San Joaquin Subbasin, 26,675 acres in the Modesto Subbasin, 117,759 acres in the Turlock Subbasin, and 182,363 acres in the Merced Subbasin. The acreage for each type of crop outside of the irrigation districts was then multiplied by the average estimate for applied water needed for that particular type of crop in terms of feet per irrigation season (i.e., AF/acre per irrigation season) (Table G.3-1).

Table G.3-1. Percent of Crop Acres Relative to Total Crop Area and Applied Water Rates for Areas Outside Irrigation Districts

Groundwater Subbasin	Eastern San Joaquin		Modesto		Turlock		Merced	
DAU	182		207		209		211 and 212	
	% of Irrigated Acres	Applied Water Rate	% of Irrigated Acres	Applied Water Rate	% of Irrigated Acres	Applied Water Rate	% of Irrigated Acres	Applied Water Rate
Crop Category:	%	AF/ac	%	AF/ac	%	AF/ac	%	AF/ac
Alfalfa	5	4.6	0	NA	2	4.3	20	4.3
Almond/Pist	1	3.4	58	3.3	64	3.2	17	3.2
Corn	11	2.5	2	2.5	8	2.4	21	2.6
Cotton	0	NA	0	NA	0	NA	5	3.2
Cucurbits	1	1.8	0	NA	0	NA	0	1.5
Dry Beans	2	2.3	0	NA	0	2.2	0	2.2
Grain	5	0.3	0	1.0	1	1.0	4	0.9
Onion And Garlic	0	1.5	0	NA	0	NA	0	NA
Other Deciduous	27	3.4	7	3.5	3	3.5	1	3.4
Other Field	1	3.2	11	2.4	5	2.3	7	2.5
Other Truck	1	3.0	4	1.0	5	1.1	6	1.1
Pasture	4	4.9	11	4.0	4	4.3	8	4.4
Potato	0	NA	0	NA	0	NA	0	NA
Rice	1	5.3	0	NA	0	NA	0	5.7
Safflower	0	1.1	0	NA	0	NA	0	NA
Subtropical	0	3.0	0	NA	0	NA	0	2.8
Sugar Beets	0	NA	0	NA	0	NA	0	NA
Tomato, Fresh	1	2.1	0	NA	0	NA	2	1.6
Tomato, Processing	6	2.8	0	NA	0	NA	6	2.5
Vine	35	0.9	7	2.3	7	2.3	2	2.4

Source: DWR 2010b.
NA = Not Applicable, which means that the crop is not grown in this particular DAU
AF/ac = Acre-foot per acre (for an irrigation season)

Total applied water demand for irrigated areas outside of the irrigation districts in the four groundwater basins is estimated to be 476 TAF/y in the Eastern San Joaquin Subbasin, 83 TAF/y in the Modesto Subbasin, 351 TAF/y in the Turlock Subbasin, and 556 TAF/y in the Merced Subbasin. It is assumed that most of the irrigated land outside of the irrigation districts is irrigated with pumped groundwater and all demands are met. However, these estimates of groundwater pumping outside of the irrigation districts may be slightly high because some surface water may be available to these areas (e.g., Mokelumne River water for North SJWCD, Merced ID deliveries to land outside the ID, and surface water diversions by riparian users along the three eastside tributaries). Within the Eastern San Joaquin Subbasin, 13,000 acres of Woodbridge ID[5] is supplied with surface water from the Mokelumne River (San Joaquin County Department of Public Works 2004). Using an average applied water rate of 476,000 AF/204,634 acres = 2.32 AF/acre for non-district areas in the Eastern San Joaquin Subbasin the applied water demand for Woodbridge is about 30 TAF/y. This demand is subtracted from the computation of groundwater pumping for areas outside of the irrigation districts.

In addition, some municipal groundwater demands based on DWR Bulletin 118 (DWR 2003a, 2003b, 2003c, 2003d, 2003e) are included for each of the subbasins. The municipal demands account for 47 TAF/y in the Eastern San Joaquin Subbasin, 81 TAF/y in the Modesto Subbasin, 65 TAF/y in the Turlock Subbasin, and 54 TAF/y in the Merced Subbasin.

Unfortunately, calculating groundwater recharge from agricultural land outside the irrigation districts is difficult, as water use data for these areas is limited. Therefore, to estimate percolation to groundwater, average supply side deep percolation factors are calculated for each subbasin based on the in-district areas of each subbasin. These factors represent deep percolation as a percent of applied water in each groundwater subbasin and they are estimated from data in the district AWMPs and WMPs. However, based on information in the AWMPs and WMPs it is easier to calculate the demand side deep percolation factor (deep percolation as a percent of CUAW) first and then convert it to a supply side factor. The demand side factor is equal to the total deep percolation over all irrigation districts in the subbasin divided by the sum of total CUAW demand for all irrigation districts in the subbasin. The subbasin deep percolation factors are summarized in Table G.3-2.

[5] In this document, the term *irrigation districts* is generally meant to refer only to those districts that have significant surface water supplies, even though there are some districts outside of the irrigation-district area.

Table G.3-2. Calculation of Average Deep Percolation Factors for each Groundwater Subbasin

Irrigation Districts in Subbasin[a]	Groundwater Subbasin						
	Eastern San Joaquin[b]			Modesto		Turlock[e]	Merced
	SSJID	North OID[c]	SEWD	South OID[c]	MID[d]	TID	Merced ID
Sources	Table 5-1, SSJID AWMP	Table 5-14, OID AWMP	Table 6 Section 5, SEWD WMP	Table 5-14, OID AWMP	Tables 44 and 47, MID AWMP	Table 4.9, TID AWMP	Table 5.20, Merced ID AWMP
Deep Percolation (AF)	42,321	10,571	12,965	13,925	58,132	159,111	60,116
Consumptive use of Applied Water (AF)	152,454	55,621	127,575	73,263	153,067	349,690	237,838
Demand Side Deep Percolation Factor	20%			32%		46%	25%
Supply Side Deep Percolation Factor	16%			24%		31%	20%

[a] Irrigation Districts refers to the districts described above in Section G.2.1, *Inputs to the SWAP Model.*

[b] The CSJWCD WMP did not present information on deep percolation or consumptive use so it was not included in these calculations even though it is part of the Eastern San Joaquin Subbasin.

[c] OID deep percolation and consumptive use of applied water was divided between North and South OID based on the relative irrigated area of each.

[d] Modesto ID consumptive use of applied water was determined using the Crop ET (173,179 AF, Table 44) and subtracting Annual Effective Precipitation (20,112 AF, Table 47).

[e] 5% of Merced ID is located in the Turlock Subbasin, but it was ignored for calculating the deep percolation factors.

Since the LSJR alternatives would only affect the availability of surface water in the LSJR Watershed, groundwater pumping and recharge for areas outside of the districts would not change in any of the LSJR alternatives. These values are primarily used for context and to characterize the magnitude of groundwater use in the LSJR Watershed. The estimates of irrigated acres and applied water associated with the irrigated acres outside of the irrigation districts are provided in Chapter 9, *Groundwater Resources* (Tables 9-5 and 9-6). The estimates of total groundwater pumping for each subbasin and estimates of net input to each subbasin including the areas outside of the irrigation district are presented in Chapter 22, *Integrated Discussion of Potential Municipal and Domestic Water Supply Management Options* (Tables 22-4 and 22-5).

G.3.3 Change in Net Subbasin Inputs

The annual net irrigation district groundwater balance (Section G.3.1, *Methodology for Estimating Change in Groundwater Recharge*) is the sum of the inputs discussed above and extractions from the groundwater basin that occur as a result of the operations of the irrigation districts that receive surface water supplies. If this balance is negative, it represents a situation in which more water is extracted than recharged. Although this may lead to subbasin overdraft, it is not the same as subbasin overdraft. There are more factors that influence whether subbasins are in overdraft that are not included here, such as stream-groundwater interaction, natural percolation from precipitation, groundwater effects from holders of riparian water rights, groundwater pumping for irrigated land outside of irrigation districts, municipal groundwater pumping, and lateral groundwater movement. These factors are not included in this discussion because they can be assumed to be constant for each LSJR alternative; for some terms, reliable information is limited.

G.3.2.1 Baseline

During most years, under baseline conditions irrigation districts contribute more surface water to groundwater stores than the districts remove by groundwater pumping (Figure G.3-3). However, during times of drought, seepage from the conveyance system and deep percolation from applied surface water is reduced at the same time groundwater pumping increases. This can cause the irrigation districts to temporarily become net users of groundwater. In general, however, the irrigation district contributions to groundwater help to offset the groundwater pumping for irrigated land outside of the irrigation districts, which is primarily irrigated with groundwater. For context, groundwater pumping for irrigation outside of the irrigation districts is estimated to be approximately 450 TAF/y for the Eastern San Joaquin Subbasin, 80 TAF/y for the Modesto Subbasin, 350 TAF/y for the Turlock Subbasin, and 560 TAF/y for the Merced Subbasin (Table 9-6).

The baseline contribution of the irrigation districts to the subbasins is typically 100 to 200 TAF/y if surface water supply meets the irrigation district needs (Figure G.3-3). However, during droughts, contributions to groundwater are reduced, and in some years, the irrigation districts above the Eastern San Joaquin and Extended Merced Subbasins become net users of groundwater under baseline conditions. Drought affects the net irrigation district contribution to groundwater more often in the Eastern San Joaquin Subbasin than it affects the other subbasins. However, during the worst droughts, drought affects the Extended Merced Subbasin more severely. The severity and frequency of water shortage and the ability of the irrigation districts to increase groundwater pumping directly affects the irrigation district contributions to the subbasins.

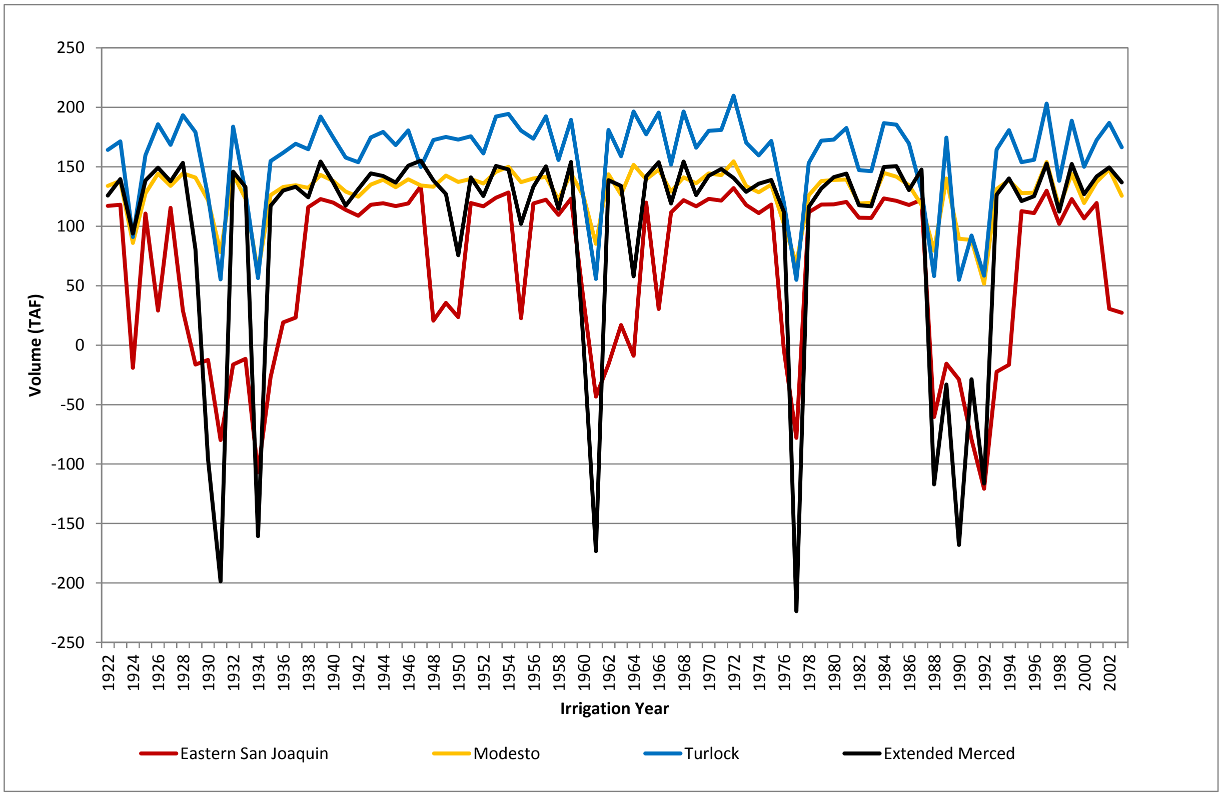

Figure G.3-3. Net Annual Contribution to Groundwater Subbasins by the Irrigation Districts under Baseline Conditions (Assuming 2009 Maximum Groundwater Pumping)

G.3.2.2 Change in Groundwater Balance Associated with the LSJR Alternatives

Under the LSJR alternatives, the contributions to groundwater from the irrigation districts are expected to diminish and be more frequently negative (net groundwater pumping) as the instream flow requirement increases. Figures G.3-4A through G.3-4D show the estimated net groundwater balance for each subbasin for all LSJR alternatives as time-series plots assuming 2009 maximum groundwater pumping rates for the 82 years simulated by the WSE model. In both the Eastern San Joaquin and Extended Merced Subbasins, the irrigation district groundwater balance shows negative net input to groundwater much more frequently in all alternatives, especially in LSJR Alternative 4. In the Turlock Subbasin, the district groundwater balance shows a negative contribution to groundwater only under LSJR Alternative 4, primarily in severe drought years. The district groundwater balance for the Modesto Subbasin always remains positive even under LSJR Alternative 4. However, even when the irrigation district groundwater balance remains positive, a reduction in net groundwater recharge from the districts would increase the impact of non-district groundwater pumping for drinking water and irrigation. The estimates of annual district groundwater contribution shown in these figure are used to produce the exceedance curves for the discussion of groundwater impacts in Chapter 9, *Groundwater Resources*. These annual estimates are also used to generate average annual results for the impact analysis in Chapter 9 and to create the summary of groundwater effects described in the following section.

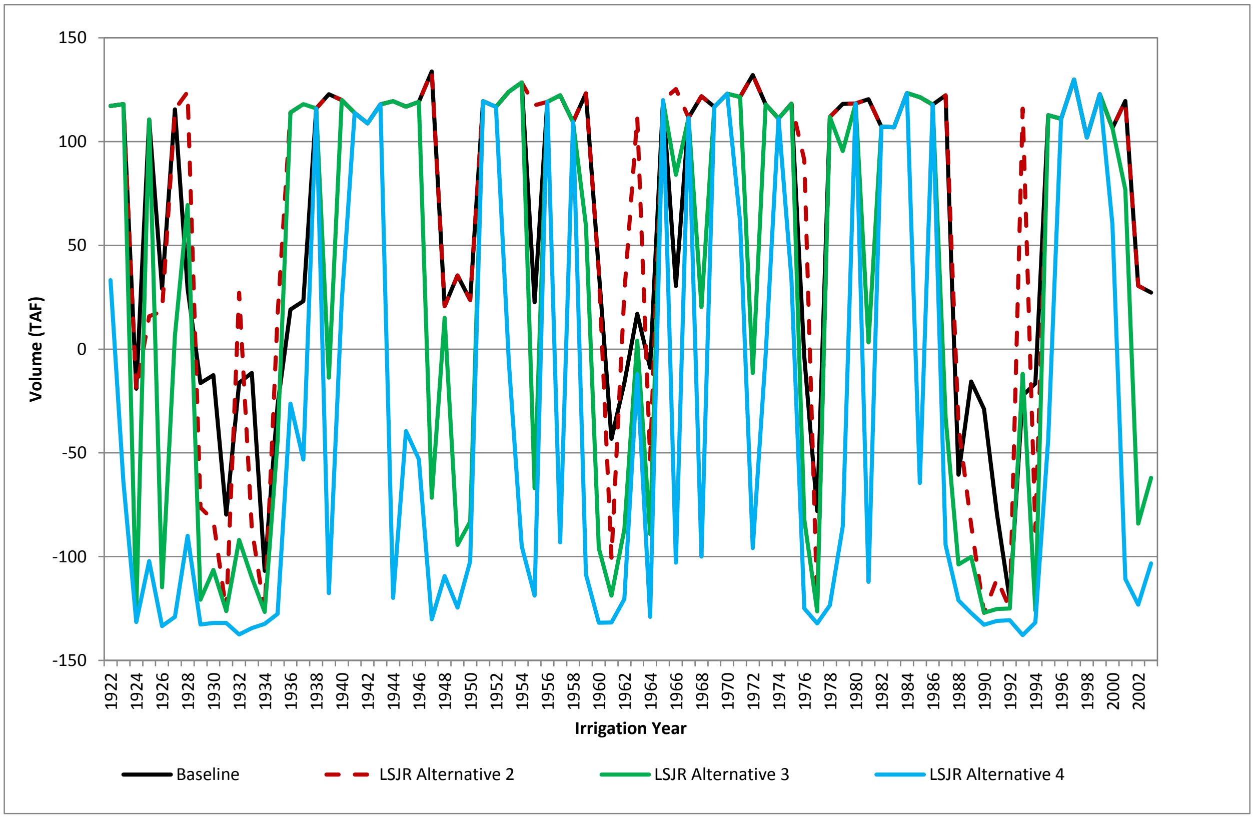

Figure G.3-4A. Annual Net Contribution to the Eastern San Joaquin Groundwater Subbasin by SSJID, OID, SEWD, and CSJWCD

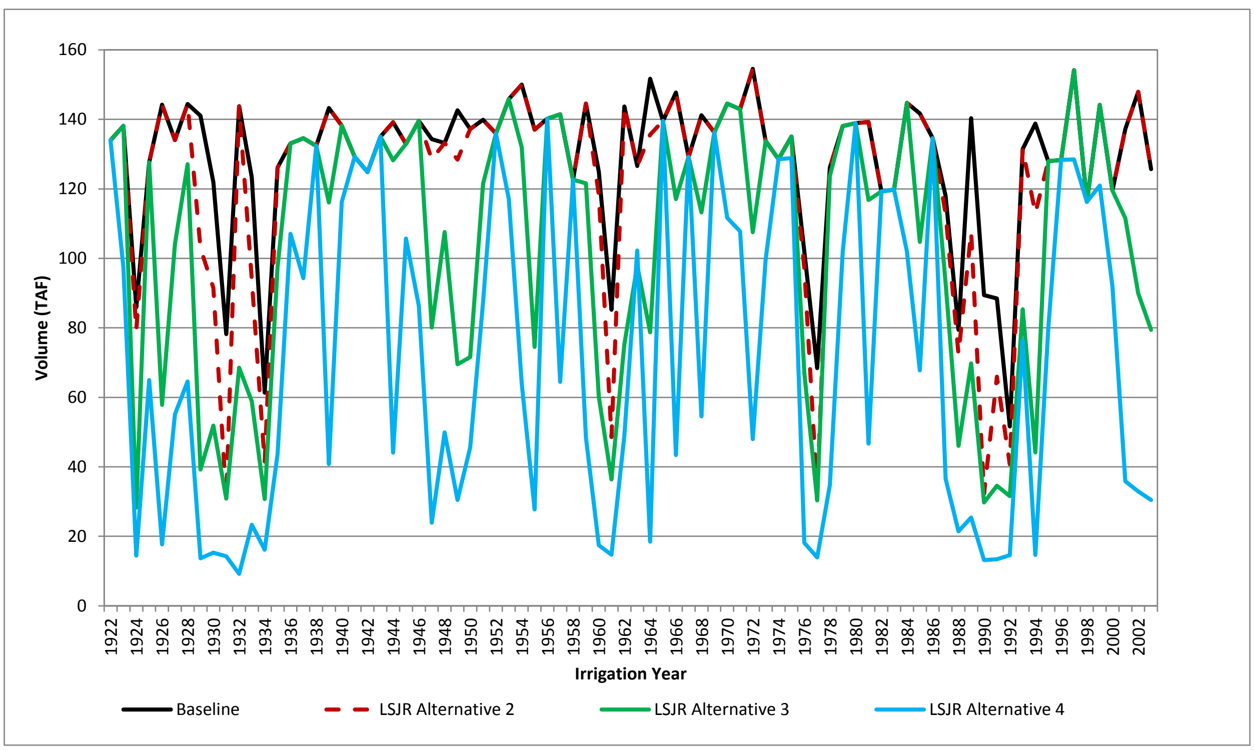

Figure G.3-4B. Annual Net Contribution to the Modesto Groundwater Subbasin by MID and OID

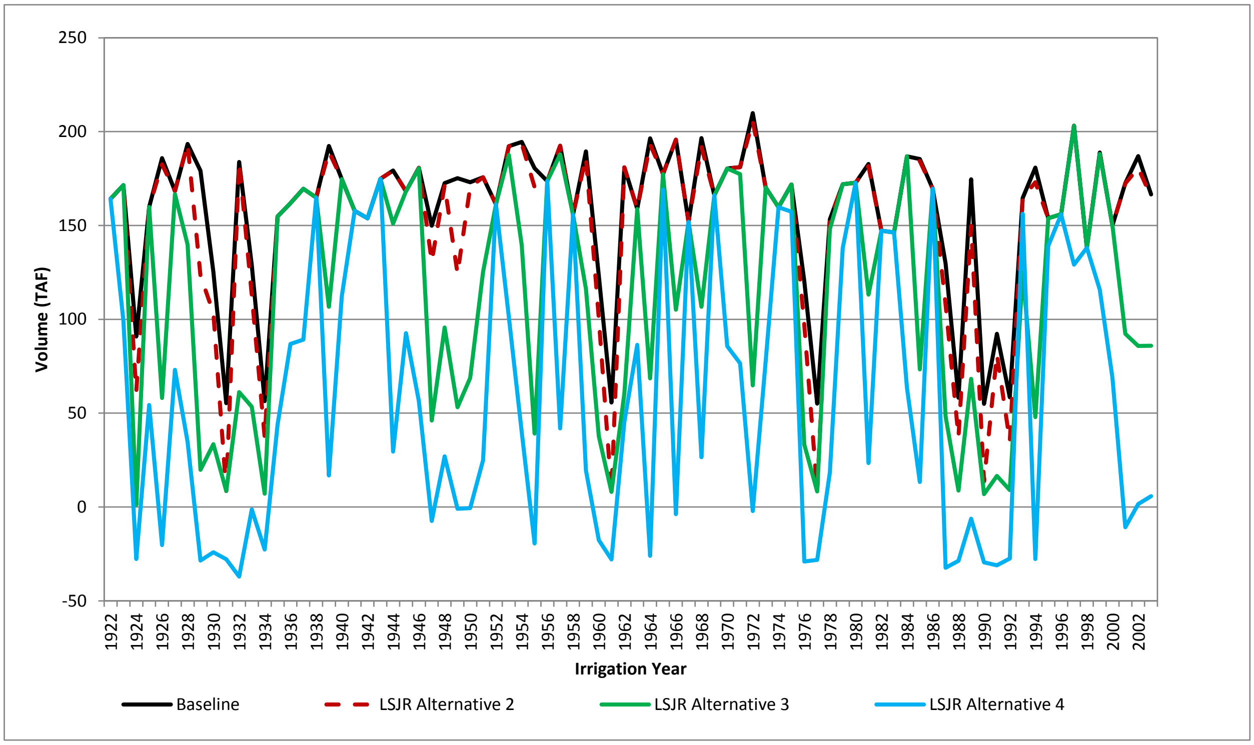

Figure G.3-4C. Annual Net Contribution to the Turlock Groundwater Subbasin by TID and Merced ID

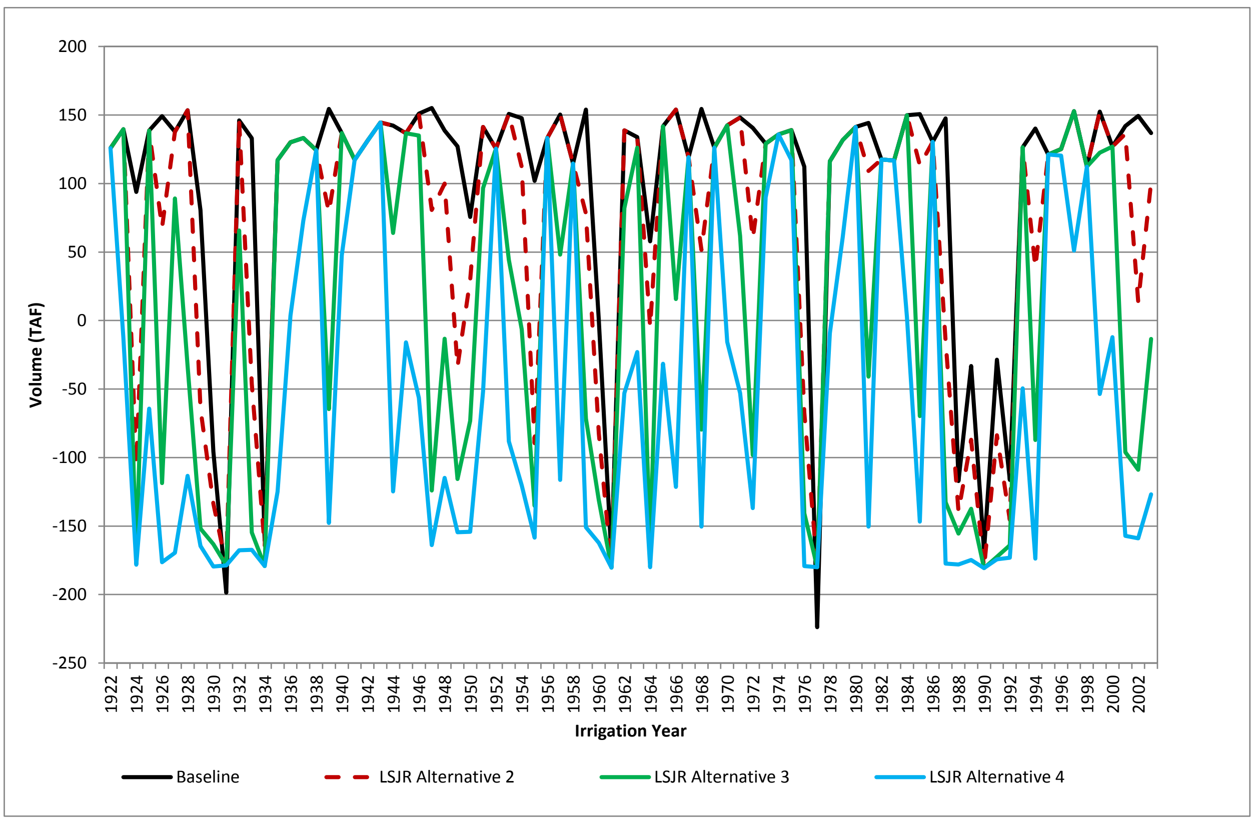

Figure G.3-4D. Annual Net Contribution to the Extended Merced Groundwater Subbasin by Merced ID

G.3.2.3 Summary of Groundwater Effects Associated with LSJR Alternatives

Under the LSJR Alternatives, groundwater pumping is expected to increase (Table G.3-3) at the same time groundwater recharge is expected to decrease (Table G.3-4), both as a result of decreased surface water supply for the irrigation districts. The average annual net effect of reduced surface water supplies on the irrigation district groundwater balance is shown in Table G.3-5. Assuming 2009 levels of maximum groundwater pumping, under LSJR Alternative 2, changes in the irrigation district groundwater balance would be relatively small compared to baseline values, with the average annual change varying from an increase of 2 TAF/y (increased net recharge) for the Eastern San Joaquin Subbasin to a decrease of 30 TAF/y (decreased net recharge) for the Extended Merced Subbasin,. Under LSJR Alternative 3, all subbasins have a negative change in the district groundwater balance, ranging from 25 TAF/y for the Modesto Subbasin to 82 TAF/y for the Extended Merced Subbasin. For LSJR Alternative 4, the average annual reduction in the district groundwater balance is even greater, ranging from 57 TAF/y for the Modesto Subbasin to 152 TAF/y for the Extended Merced Subbasin.

If the higher 2014 maximum pumping rates are used in the analysis, there would be correspondingly higher impact to groundwater in the Eastern San Joaquin, Modesto, and Turlock Subbasins. Using LSJR Alternative 4 as an example, the average annual district groundwater balance decreases by an additional 11 TAF/y, 46 TAF/y, and 44 TAF/y compared to the 2009 max groundwater pumping scenario in the Eastern San Joaquin, Modesto, and Turlock Subbasins, respectively. There is no change in the impact on the Extended Merced Subbasin (because for this subbasin, there was no difference between the 2009 and 2014 maximum groundwater pumping estimates as described in section G.2.2, *Methodology for Calculating Applied Water*). For the analysis of groundwater impacts in Chapter 9, *Groundwater Resources*, the average net change in groundwater balance for each subbasin is divided by the subbasin area to determine the decrease in net irrigation district contributions to groundwater relative to total subbasin area for each LSJR alternative.

Table G.3-3. Estimated Effect of LSJR Alternatives on Average Annual Groundwater Pumping by the Irrigation Districts

Groundwater Subbasin	Baseline Groundwater Pumping (TAF/y)	Increase in Groundwater Pumping Relative to Baseline (TAF/y)		
		LSJR Alternative 2[a]	LSJR Alternative 3	LSJR Alternative 4
Results assuming maximum groundwater pumping based on 2009 infrastructure				
Eastern San Joaquin	79	-4	23	69
Modesto	27	1	8	15
Turlock	91	2	16	30
Extended Merced	65	23	61	110
Results assuming maximum groundwater pumping based on 2014 infrastructure				
Eastern San Joaquin	80	-2	30	81
Modesto	39	6	37	76
Turlock	109	6	48	95
Extended Merced	65	23	61	110

TAF/y = thousand-acre feet per year
[a] Under LSJR Alternative 2, there is a slight decrease in groundwater pumping for the Eastern San Joaquin Subbasin because changes in the New Melones Index for the Alternative compared to Baseline lead to slightly higher annual diversions on average for SEWD and CSJWCD.

Table G.3-4. Estimated Effect of LSJR Alternatives on Average Annual Groundwater Recharge by the Irrigation Districts

Groundwater Subbasin	Baseline Groundwater Recharge (TAF/y)	Change in Recharge Relative to Baseline (TAF/y)		
		LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Results assuming maximum groundwater pumping based on 2009 infrastructure				
Eastern San Joaquin	144	-2	-12	-33
Modesto	155	-4	-17	-43
Turlock	250	-5	-27	-70
Extended Merced	164	-7	-21	-42
Results assuming maximum groundwater pumping based on 2014 infrastructure				
Eastern San Joaquin	144	-2	-11	-30
Modesto	159	-3	-10	-26
Turlock	255	-4	-17	-49
Extended Merced	164	-7	-21	-42

Table G.3-5. Estimated Effect of LSJR Alternatives on Average Annual Irrigation District Groundwater Balance

Groundwater Subbasin	Baseline Irrigation District Groundwater Balance (TAF/y) (positive indicates recharge)	Change in Groundwater Balance Relative to Baseline (TAF/y)		
		LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Results assuming maximum groundwater pumping based on 2009 infrastructure				
Eastern San Joaquin	65	2	-36	-101
Modesto	129	-6	-25	-57
Turlock	158	-7	-43	-100
Extended Merced	99	-30	-82	-152
Results assuming maximum groundwater pumping based on 2014 infrastructure				
Eastern San Joaquin	64	0	-41	-112
Modesto	120	-9	-46	-103
Turlock	146	-10	-65	-144
Extended Merced	99	-30	-82	-152

G.4 Estimating Agricultural Production, Associated Revenue, and Groundwater Pumping Costs

The SWAP model is used to estimate agricultural production and associated revenues under baseline conditions and for each of the LSJR alternatives. SWAP uses estimates of applied water identified in Section G.2.4, *Estimates of Total Applied Water*, along with crop distribution inputs for each district to estimate agricultural production and associated revenues under baseline conditions and for each of the LSJR alternatives. This section describes the SWAP model, including the reasons for using it in this analysis, and then describes the model inputs and presents modeling results.

G.4.1 Description of the Statewide Agricultural Production Model

The SWAP model employs Positive Mathematical Programming (PMP), which is a self-calibrating method for modeling agricultural production that ensures that crop production matches base dataset of inputs in a given year (Howitt 1995). PMP introduces a non-linear cost function derived from the first order conditions of a Leontief production constrained model. Additional details on the PMP methodology are presented in several reports and peer reviewed publications, including: Howitt et al. (2012), Medellín-Azuara et al. (2010), and Medellín-Azuara et al. (2012).

PMP has become a widely accepted method for analyzing water demand and undertaking policy analysis. PMP is considered a deductive method, which is superior to inductive (statistical) based methods for analyzing the effects of changes in the availability of water for agricultural production (Young 2005; Scheierling et al. 2006). This type of model works well with the multitude of resource, policy, and environmental constraints often observed in practice (Griffin 2006). Furthermore, PMP does not require large datasets, is directly based on profit-maximizing behavior of farmers, and is better suited to estimate policy response of farming activities than strictly statistical methods (Howitt et al. 2010). In contrast to statistical methods, SWAP more explicitly accounts for changes in water availability due to reduced diversions as part of the constraint set in the model. By comparing a base case with current diversions and a policy scenario with reduced diversions, the analyst is able to economically quantify changes in revenue, cropping patterns, and applied water per unit area by crop and region.

The SWAP model estimates the agricultural production (crop acreages) and revenues (total production value) associated with the different levels of surface water diversions predicted to be needed under baseline conditions and the LSJR alternatives. The SWAP model predicts the production decisions of farmers at a regional level based on principles of economic optimization. The model assumes that farmers maximize net returns to land and management subject to resource, technical, and market constraints. The model selects those crops, water supplies, and irrigation technology that maximize profit subject to these equations and constraints. The model accounts for land and water availability constraints given a set of factors for production and their cost, and calibrates to *observed* (baseline) yearly values of land, labor, water, and supplies used in each region.

The SWAP model also has some comparative advantages over other agricultural production models, including DWR's California Agriculture (CALAG) and DWR's Net Crop Revenue Models (NCRMs). The following is a brief description of those models and the comparative advantages of SWAP.

CALAG is an extended and improved version of Central Valley Production Model (CVPM). As is the case for SWAP, PMP is the numerical basis of CALAG (DWR 2008). CALAG, however, does not explicitly include the cost of production factors in its formulation and instead uses constant variable production costs by crop and region. The SWAP model, in contrast, can capture farmer adjustments in use of inputs, such as water per acre changes during drought conditions. Thus, CVPM and CALAG are well suited to represent water supply operations but are less useful for modeling detailed changes in production, such as water per unit area, labor per unit area, or supplies per unit area. SWAP estimates cropping patterns and input use for all policies evaluated, capturing adaptation of crop farming production to changing water availability conditions. When faced with increasing water scarcity, farmers have been shown to adjust in three ways: make changes in water per acre, make changes in crop mix, and make changes in the total number of irrigated acres. Although CVPM and CALAG are considered robust models in that they can account for two of these changes, SWAP can incorporate all three of these potential adjustments. The SWAP model incorporates sources of region-specific, water supply information consistent with both models and has additional modules to account for technological improvement, climate change, changes in crop prices, and changes in water quality.

The NCRMs are spreadsheet programs that estimate average net crop revenues for 26 crop groups in 27 California counties and regions. These models combine data on acres and average yields and prices from various county and state sources. The price-level feature of the NCRMs spreadsheets adjusts cost and gross revenue data to a common year, adjusts for changes in various types of costs, and then calculates weighted-average estimates of a typical grower's annual net crop revenue, whether profit or loss (DWR 2008). Because NCRMs use fixed budgets, they cannot model farmer reactions to changes in water availability based on profit-maximizing behavior, as can be done in SWAP. Instead, the NCRM spreadsheets provide a snapshot of agriculture production, but do not capture changes in cropping patterns or use of production inputs in response to changes in water availability.

The SWAP model has been used in a wide range of policy analysis projects. The first formal application of SWAP was to estimate the economic scarcity costs of water for agriculture in the statewide hydro-economic optimization model for water management in California, known as the California Value Integrated Network (CALVIN) model. The SWAP model provided the economic value of water shortages in agriculture, by month and region, for CALVIN. Then, CALVIN determines monthly water allocation in storage and deliveries for urban, agricultural, and environmental uses based on water availability, operating costs, economic costs of shortages, and minimum environmental flow constraints (Draper et al. 2003). DWR used SWAP to develop planning scenarios and analyses supporting preparation of the 2009 Water Plan Update (DWR 2009). In conjunction with USBR and the CH2M HILL consulting firm, SWAP was used by the Stockholm Environment Institute as a subsidiary model in the application of a Water Evaluation and Planning (WEAP) model in the California Central Valley. WEAP is a climate-driven, water resource model that systematically simulates natural water flows and management of infrastructure to balance supply and demand (Yates et al. 2005). SWAP takes advantage of the WEAP priority-based allocation and provides cropping patterns for a wide range of water availability conditions. In doing this, SWAP converts a water allocation simulation model into a hydro-economic model that allocates water based on the economic value of final uses.

Recently, SWAP applications have been expanded to include drought impact analysis (Howitt et al. 2015; Medellin-Azuara et al. 2015). In addition, SWAP has been used to evaluate salinity in soil and shallow groundwater for both the Sacramento–San Joaquin Delta of California (Lund et al. 2007) and areas south of the Delta (Howitt et al. 2009; Tanaka et al. 2008), and for studying the effects of climate change (Medellin-Azuara 2012).

G.4.2 Crop Distribution and Applied Water Inputs for SWAP

For this analysis, SWAP was initially configured to model agricultural production in the main agricultural areas of the LSJR Watershed and calibrated to land use and applied water data for 2010. SWAP outputs were generated for two groundwater pumping scenarios, one for 2009 level of groundwater pumping, which represents a typical year of pumping, and a second assuming estimates of 2014 groundwater pumping. Using the estimates of applied water described in Section G.3, *Estimation of Groundwater Balance*, SWAP estimates of agricultural production (crop acreages) and revenues (total production value) were generated for baseline and each of the LSJR alternatives. Annual results for each of the LSJR alternatives are then compared to results for baseline conditions to estimate the net effects of the alternatives.

Each of the seven irrigation districts have published AWMPs or WMPs that include information on the number of irrigated acres within their service areas. These numbers were similar to estimates of irrigated acres obtained from GIS clips from DWR DAU crop surveys. Attachment 1 to this appendix, *Comparison of AWMP and DAU Crop Distributions for Irrigation Districts*, provides additional information regarding the acreage numbers in the AWMPs and those provided by DWR, as well as irrigated acre totals used for each district. For the purposes of this analysis, the irrigated acreage estimates provided by the irrigation districts in the AWMPs are used. These values are summarized in Table G.4-1.

Table G.4-1. Irrigation District Irrigated Acres

Irrigation District	Irrigated Acres	Description	Source
SEWD	50,981	Value for 2010	Table 2, SEWD WMP 2014
CSJWCD	48,000	Value for 2009	Table 2, CSJWCD WMP 2013
SSJID	58,551	Average Value for 1994 to 2008	Table 5-3, SSJID AWMP 2012
OID	54,317	Average Value for 2005 to 2011	Table 5-3, OID AWMP 2012
MID	58,611	Value for 2009 minus 542 acres of open land	Table 21, MID AWMP 2012
TID	146,030	Average Assessed Acres for 2007 to 2011	Text page 13, TID AWMP 2012
Merced ID	100,237	Average Value for 2000 to 2008	Table 5.3, Merced ID AWMP 2013

Using the total irrigated acres described above, a crop distribution (relative percentages of each crop type) was then applied to distribute the acreages among different crop types. Two potential crop type distributions were obtained, one from DWR based on 2010 DAU data (refer to map in Figure G.1-1) and one from the district AWMPs. In addition, district applied water rates for each crop were also obtained from both sources (except for CSJWCD, which did not have applied water estimates in its WMP). These land use distributions and associated applied water rates are compared for each district in Attachment 1 of this appendix. For all irrigation districts except SEWD and CSJWCD, the crop distribution and applied water rates based on DWR DAU data were used. For SEWD and CSJWCD, the crop distribution was taken from their respective AWMPs, but the DWR DAU applied water rates were still used.

To develop crop distribution estimates for each DAU, DWR surveys land and water uses within each county periodically, depending on changes that have occurred within that county. Surveys began in 1947, with the first digitized survey completed in 1988, and are available from the DWR website. Table G.4-2 below lists the counties within the study area. DWR uses the Agriculture Commissioner annual reports to then update crop yields appropriate for subsequent water years until a new crop survey is done. Table G.4-2 also shows the years in which the last survey was performed in each county in the study area and indicates which data year was used. Even if later years were available, 2010 data was used because it is a good representation of baseline conditions. For CEQA purposes, the baseline is considered to be anytime between 2009 and 2011; 2010 is considered a good year for modeling purposes because it was a year when there was enough water available to generally meet the full crop demand.

Table G.4-2. Counties within Study Area and Date Last Surveyed by the California Department of Water Resources (DWR)

County	Year Last Land Surveyed	Date Last Estimated by DWR from Commissioner Reports
Calaveras	2000	2010
Madera	2001	2010
Mariposa	1998	2010
San Joaquin	1996	2010
Stanislaus	2004	2010
Tuolumne	1997	2010
Merced	2002	2010

Each DAU has a specific cropping pattern and crop applied water rates. The water demand for each DAU is calculated by distributing the AWMP irrigated acreage among the different crop categories based on the DAU cropping pattern and then multiplying the acreage of each crop by its applied water rate. Table G.4-3 shows the 2010 cropping pattern for each irrigation district, and Table G.4-4 shows the 2010 crop applied water demands for each irrigation district. At the top of the tables, the irrigation districts are matched to their corresponding DAU. Some irrigation districts (OID and TID) include parts of two counties and each DAU–County combination has a different cropping pattern. The relative area for these irrigation districts was measured using GIS, and then the total irrigated acres were distributed over each DAU in the same proportion. SEWD and CSJWCD share the same DAU and were combined into a single regional unit for the SWAP analysis.

The crop groups in SWAP follow the DWR classifications and include: Almonds and Pistachios, Alfalfa, Corn, Cotton, Cucurbits, Dry Beans, Fresh Tomato, Processing Tomato, Grains, Onion and Garlic, Pasture, Rice, Safflower, Subtropical (includes citrus), and Vineyards, as well as Other Orchards, Other Field Crops, and Other Truck Crops.

Table G.4-3. Estimated 2010 Crop Distribution for Each Irrigation District and DAU (acres)

Irrigation District:	SSJID	OID			SEWD	CSJWCD	SEWD + CSJWCD	MID	TID			Merced ID
DAU-County:	205-SJ	206-SJ	206-Stan	206-Total	182-SJ	182-SJ	182-SJ	206-Stan	208-Stan	208-Merc	208-Total	210-Merc
Crop Categories:	Crop Irrigated Area (acres)											
Alfalfa	3,175	0	2,131	2,131	823	6,070	6,893	2,674	11,993	2,378	14,371	5,810
Almond/Pist	27,032	28	10,486	10,513	17	0	17	13,157	25,185	8,591	33,776	30,615
Corn	8,332	1,370	8,389	9,758	925	15,174	16,098	10,525	31,308	12,042	43,350	19,088
Cotton	0	0	0	0	0	0	0	0	0	0	0	2,490
Cucurbits	490	0	101	101	819	0	819	127	316	153	469	646
Dry Beans	175	11	203	214	770	0	770	255	1,073	0	1,073	0
Grain	1,670	207	169	376	1,228	7,081	8,310	212	379	77	455	3,135
Onion And Garlic	602	0	0	0	179	0	179	0	0	0	0	0
Other Deciduous	6,854	10	6,494	6,504	37,092	6,070	43,161	8,149	6,628	1,611	8,238	4,887
Other Field	210	297	7,509	7,806	0	0	0	9,422	19,567	9,511	29,078	7,193
Other Truck	437	0	2,807	2,807	1,124	0	1,124	3,523	6,060	1,918	7,977	11,803
Pasture	1,664	1,871	6,968	8,839	1,528	2,529	4,057	8,743	3,787	997	4,784	5,994
Potato	0	0	0	0	0	0	0	0	0	0	0	0
Rice	84	3,709	541	4,250	0	0	0	679	0	0	0	1,199
Safflower	162	0	0	0	0	0	0	0	0	0	0	0
Subtropical	1,747	103	34	137	0	0	0	42	63	0	63	0
Sugar Beets	0	0	0	0	0	0	0	0	0	0	0	277
Tomato, Fresh	70	0	0	0	2,199	5,867	8,066	0	379	0	379	1,844
Tomato, Processing	454	0	0	0	0	0	0	0	0	0	0	1,383
Vine	5,393	0	879	879	4,276	5,210	9,485	1,103	1,326	690	2,016	3,873
Total Acres:	58,551	7,605	46,712	54,317	50,981	48,000	98,981	58,611	108,063	37,967	146,030	100,237

Sources: Merced ID 2013; MID 2012; OID 2012; TID 2012; SEWD 2014; SSJID 2012; DWR 2010b.

Table G.4-4. Estimated 2010 Applied Water Demand by Crop and Irrigation District (acre-feet)

Irrigation District:	SSJID	OID			SEWD	CSJWCD	SEWD + CSJWCD	MID	TID			Merced ID
DAU-County:	205-SJ	206-SJ	206-Stan	206-Total	182-SJ	182-SJ	182-SJ	206-Stan	208-Stan	208-Merc	208-Total	210-Merc
Crop Categories:	Crop Applied Water Demand (Acre-Feet)											
Alfalfa	15,745	0	9,751	9,751	3,816	28,132	31,948	12,235	54,530	10,647	65,177	26,010
Almond/Pist	93,721	88	38,586	38,673	58	0	58	48,415	78,929	26,922	105,851	100,953
Corn	24,271	3,916	20,968	24,885	2,337	38,350	40,687	26,310	79,088	29,986	109,074	48,220
Cotton	0	0	0	0	0	0	0	0	0	0	0	7,659
Cucurbits	988	0	159	159	1,446	0	1,446	200	505	238	743	951
Dry Beans	434	25	445	470	1,786	0	1,786	558	2,379	0	2,379	0
Grain	1,285	109	164	273	400	2,303	2,703	205	355	76	431	2,957
Onion And Garlic	1,123	0	0	0	265	0	265	0	0	0	0	0
Other Deciduous	26,494	38	22,787	22,825	127,239	20,821	148,059	28,591	23,080	5,761	28,841	16,583
Other Field	705	960	18,357	19,317	0	0	0	23,033	48,530	23,892	72,422	17,838
Other Truck	1,393	0	3,144	3,144	3,407	0	3,407	3,945	6,957	2,134	9,091	13,551
Pasture	8,917	9,630	32,215	41,845	7,551	12,496	20,048	40,421	17,508	4,474	21,982	26,896
Potato	0	0	0	0	0	0	0	0	0	0	0	0
Rice	454	19,459	3,079	22,537	0	0	0	3,863	0	0	0	6,532
Safflower	231	0	0	0	0	0	0	0	0	0	0	0
Subtropical	5,942	335	94	429	0	0	0	118	175	0	175	0
Sugar Beets	0	0	0	0	0	0	0	0	0	0	0	434
Tomato, Fresh	165	0	0	0	4,606	12,290	16,896	0	596	0	596	2,951
Tomato, Processing	1,355	0	0	0	0	0	0	0	0	0	0	3,280
Vine	6,471	0	2,063	2,063	3,719	4,531	8,250	2,588	2,946	1,515	4,461	9,187
Total Applied Water Demand:	189,695	34,560	151,810	186,370	156,628	118,924	275,552	190,480	315,578	105,645	421,223	284,003

Sources: Merced ID 2013; MID 2012; OID 2012; TID 2012; SEWD 2014; SSJID 2012; DWR 2010b.

The SWAP output for a particular LSJR alternative or for baseline conditions is a time-series of 82 annual estimates of the associated crop acreages, applied water, and revenue across the period of simulation. For the purpose of evaluating each LSJR alternative, this range of annual estimates is compared against those for baseline. The SWAP model output was aggregated into six regions, V01 through V06, which correspond to the irrigation districts, as described in Table G.4-5.

Table G.4-5. SWAP Analysis Regions

SWAP Analysis Region	Irrigation Districts
V01	SSJID
V02	OID
V03	SEWD/CSJWCD
V04	MID
V05	TID
V06	Merced ID

G.4.3 SWAP Modeling Results

This section presents SWAP model output characterizing the total agricultural production (crop acreages) and associated revenues (total production value) associated with baseline conditions and the three LSJR alternatives. Also presented are the changes in production and revenue values between the baseline and LSJR alternatives. As indicated in Section G.4.2, *Crop Distribution and Applied Water Inputs for SWAP*, SWAP results (crop acreage and associated revenues) are presented by irrigation district.

G.4.1.1 Effects on Crop Acreage

As described in Section G.4.1, *Description of the Statewide Agricultural Production Model*, the SWAP model optimizes available land and water such that net returns to farmers are maximized. As water becomes more scarce, the crops most affected, in general, are Pasture, Alfalfa, Rice, and Other Field Crops. These crops are affected more because they require relatively high water-use, as compared to annual crops and/or crops that generate lower net revenue per acre. The lower net-revenue crops cover large portions of the study area; consequently, these crop groups are substantially reduced for the LSJR alternatives with higher unimpaired flow requirements, particularly for LSJR Alternative 4. The SWAP model output (Tables G.4-6a–f) identifies crop acreage in each district in the study area under baseline conditions and LSJR Alternatives 2–4; predicted changes in crop acreage in each district also are shown for each LSJR alternative relative to baseline conditions.

Table G.4-6a. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for SSJID (V01)

	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
SSJID(V01)	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	3,080	5.3	-166	-5.4	-523	-17.0	-1,350	-43.8
Almonds and Pistachios	27,022	46.4	-59	-0.2	-162	-0.6	-505	-1.9
Corn	8,248	14.2	-376	-4.6	-788	-9.6	-2,318	-28.1
Cotton	0							
Cucurbits	486	0.8	-24	-4.9	-43	-8.8	-139	-28.6
Dry Bean	172	0.3	-9	-5.1	-23	-13.7	-65	-37.7
Grain	1,666	2.9	-15	-0.9	-38	-2.3	-242	-14.5
Onion and Garlic	602	1.0	-1	-0.1	-2	-0.3	-5	-0.9
Orchards	6,847	11.8	-21	-0.3	-55	-0.8	-150	-2.2
Other Field Crops	203	0.3	-11	-5.3	-35	-17.4	-90	-44.1
Other Truck Crops	431	0.7	-21	-4.9	-52	-12.1	-143	-33.2
Pasture	1,582	2.7	-107	-6.8	-419	-26.5	-802	-50.7
Rice	82	0.1	-4	-5.1	-13	-16.3	-35	-42.8
Safflower	158	0.3	-9	-5.5	-23	-14.8	-64	-40.5
Subtropical	1,743	3.0	-6	-0.3	-22	-1.3	-49	-2.8
Sugarbeet	0							
Tomato (Fresh)	70	0.1	-1	-0.8	-2	-2.2	-5	-7.7
Tomato (Processing)	446	0.8	-23	-5.1	-61	-13.6	-168	-37.8
Vine	5,391	9.3	-6	-0.1	-16	-0.3	-50	-0.9
TOTAL	58,229		-857	-1.5	-2,277	-3.9	-6,181	-10.6

Table G.4-6b. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for OID (V02)

	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
OID(V02)	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	2,098	3.9	-121	-5.8	-302	-14.4	-851	-40.5
Almonds and Pistachios	10,519	19.4	-19	-0.2	-52	-0.5	-158	-1.5
Corn	9,810	18.1	-79	-0.8	-204	-2.1	-1,291	-13.2
Cotton	0							
Cucurbits	103	0.2	-1	-0.8	-2	-2.0	-7	-7.0
Dry Bean	216	0.4	-3	-1.5	-8	-3.8	-52	-24.3
Grain	387	0.7	-2	-0.5	-5	-1.3	-16	-4.1
Onion and Garlic	0							
Orchards	6,508	12.0	-11	-0.2	-29	-0.5	-89	-1.4
Other Field Crops	7,865	14.5	-419	-5.3	-795	-10.1	-2,388	-30.4
Other Truck Crops	2,854	5.3	-14	-0.5	-37	-1.3	-129	-4.5
Pasture	8,597	15.9	-511	-5.9	-2,001	-23.3	-4,191	-48.8
Rice	4,188	7.7	-214	-5.1	-535	-12.8	-1,557	-37.2
Safflower	0							
Subtropical	137	0.3	-1	-0.4	-2	-1.4	-4	-2.9
Sugarbeet	0							
Tomato (Fresh)	0							
Tomato (Processing)	0							
Vine	881	1.6	-2	-0.2	-5	-0.5	-14	-1.6
TOTAL	54,162	100	-1,395	-66.5	-3,978	-7.3	-10,748	-19.8

Table G.4-6c. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for SEWD/CSJWCD (V03)

	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
SEWD/CSJWCD(V03)	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	6,870	6.9	0	0.0	0	0.0	0	0.0
Almonds and Pistachios	17	0.0	0	0.0	0	0.0	0	0.0
Corn	16,096	16.3	0	0.0	0	0.0	0	0.0
Cotton	0							
Cucurbits	818	0.8	0	0.0	0	0.0	0	0.0
Dry Bean	768	0.8	0	0.0	0	0.0	0	0.0
Grain	8,320	8.4	0	0.0	0	0.0	0	0.0
Onion and Garlic	179	0.2	0	0.0		0.0		0.0
Orchards	43,174	43.6	0	0.0	0	0.0	0	0.0
Other Field Crops	0							
Other Truck Crops	1,119	1.1	0	0.0	0	0.0	0	0.0
Pasture	4,019	4.1	0	0.0	0	0.0	0	0.0
Rice	0							
Safflower	0							
Subtropical	0							
Sugarbeet	0							
Tomato (Fresh)	8,064	8.2	0	0.0	0	0.0	0	0.0
Tomato (Processing)	0							
Vine	9,487	9.6	0	0.0	0	0.0	0	0.0
TOTAL	98,931	100	0	0.0	0	0.0	0	0.0

Table G.4-6d. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for MID (V04)

MID(V04)	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	2,513	4.4	-111	-4.4	-581	-23.1	-1,258	-50.0
Almonds and Pistachios	13,139	22.9	-27	-0.2	-105	-0.8	-329	-2.5
Corn	10,506	18.3	-266	-2.5	-725	-6.9	-3,537	-33.7
Cotton	0							
Cucurbits	128	0.2	-1	-1.1	-5	-3.7	-39	-30.5
Dry Bean	254	0.4	-12	-4.8	-30	-11.9	-101	-39.7
Grain	215	0.4	-3	-1.3	-13	-6.0	-71	-32.8
Onion and Garlic	0							
Orchards	8,138	14.2	-15	-0.2	-59	-0.7	-197	-2.4
Other Field Crops	9,376	16.3	-500	-5.3	-1,816	-19.4	-4,428	-47.2
Other Truck Crops	3,548	6.2	-24	-0.7	-86	-2.4	-1,028	-29.0
Pasture	7,754	13.5	-217	-2.8	-2,094	-27.0	-4,434	-57.2
Rice	639	1.1	-33	-5.1	-146	-22.9	-324	-50.8
Safflower	0							
Subtropical	42	0.1	0	-0.1	-1	-1.5	-1	-3.2
Sugarbeet	0							
Tomato (Fresh)	0							
Tomato (Processing)	0							
Vine	1,103	1.9	-2	-0.2	-9	-0.8	-28	-2.5
TOTAL	57,354	100	-1,211	-2.1	-5,670	-9.9	-15,774	-27.5

Table G.4-6e. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for TID (V05)

TID(V05)	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	13,115	9.1	-284	-2.2	-3,023	-23.1	-6,599	-50.3
Almonds and Pistachios	33,741	23.5	-43	-0.1	-183	-0.5	-509	-1.5
Corn	43,283	30.1	-470	-1.1	-1,554	-3.6	-11,442	-26.4
Cotton	0							
Cucurbits	469	0.3	-3	-0.7	-12	-2.6	-39	-8.4
Dry Bean	1,065	0.7	-31	-2.9	-87	-8.2	-392	-36.8
Grain	460	0.3	-4	-0.8	-14	-3.1	-50	-10.8
Onion and Garlic	0							
Orchards	8,221	5.7	-13	-0.2	-54	-0.7	-150	-1.8
Other Field Crops	28,848	20.1	-1,537	-5.3	-4,687	-16.2	-13,102	-45.4
Other Truck Crops	8,020	5.6	-41	-0.5	-156	-1.9	-505	-6.3
Pasture	4,106	2.9	-171	-4.2	-1,166	-28.4	-2,458	-59.9
Rice	0							
Safflower	0							
Subtropical	63	0.0	0	-0.2	-1	-1.5	-2	-3.2
Sugarbeet	0							
Tomato (Fresh)	379	0.3	-1	-0.2	-3	-0.9	-9	-2.4
Tomato (Processing)	0							
Vine	2,014	1.4	-3	-0.2	-13	-0.7	-37	-1.8
TOTAL	143,783	100	-2,600	-1.8	-10,954	-7.6	-35,294	-24.5

Table G.4-6f. Average Annual Acreage of Irrigated Crops for Baseline and Average Difference (in acres and percent) Between LSJR Alternatives and Baseline by Crop Group for Merced ID (V06)

Merced ID(V06)	Baseline		LSJR Alternative 2		LSJR Alternative 3		LSJR Alternative 4	
	Acres	% of Total	+/- Acres	% Change	+/- Acres	% Change	+/- Acres	% Change
Alfalfa	5,634	5.6	-35	-0.6	-154	-2.7	-470	-8.3
Almonds and Pistachios	30,616	30.7	-3	0.0	-27	-0.1	-87	-0.3
Corn	19,109	19.2	-3	0.0	-62	-0.3	-211	-1.1
Cotton	2,482	2.5	0	0.0	-11	-0.4	-38	-1.5
Cucurbits	649	0.7	0	0.0	-2	-0.3	-6	-0.9
Dry Bean	0							
Grain	3,177	3.2	-1	0.0	-9	-0.3	-30	-0.9
Onion and Garlic	0	0.0						
Orchards	4,884	4.9	-1	0.0	-5	-0.1	-16	-0.3
Other Field Crops	7,145	7.2	36	0.5	-10	-0.1	-129	-1.8
Other Truck Crops	11,912	11.9	-2	0.0	-27	-0.2	-91	-0.8
Pasture	5,622	5.6	-17	-0.3	-468	-8.3	-1,468	-26.1
Rice	1,158	1.2	4	0.4	-13	-1.1	-57	-4.9
Safflower	0							
Subtropical	0							
Sugarbeet	277	0.3	0	0.0	-1	-0.2	-2	-0.6
Tomato (Fresh)	1,847	1.9	0	0.0	-2	-0.1	-5	-0.3
Tomato (Processing)	1,383	1.4	0	0.0	-6	-0.5	-22	-1.6
Vine	3,874	3.9	0	0.0	-4	-0.1	-13	-0.3
TOTAL	99,769	100	-22	0.0	-800	-0.8	-2,644	-2.6

It should be noted that the SWAP results presented in Tables G.4-6a through G.4.6f assume a maximum groundwater pumping capacity similar to what was available in 2009. If groundwater pumping capacity for 2014 is used instead, the results show an overall decrease in the reduction (or fallowing) of average annual crop acreage within all irrigation districts, but particularly MID. For SSJID, OID, MID, and TID higher groundwater pumping capacities based on 2014 estimates allow them to pump more groundwater in times of need and prevent crops from being fallowed, as shown in Table G.4-7 for LSJR Alternatives 3 and 4. For example, the predicted reduction in crop acreage in OID under LSJR Alternative 3 (3,978 acres or 7.3 percent compared to 2009 levels, as shown in Table G.4-6b) would decrease to an estimated 2,491 acres (4.6 percent reduction compared to 2009 conditions) under the higher 2014 groundwater pumping scenario.

Table G.4-7. Percent Decrease in Average Annual Crop Area Associated with 2009 and 2014 Groundwater Pumping under LSJR Alternatives 2, 3, and 4, by Irrigation District

	Percent Reduction in Crop Area (% of district crop area)	
LSJR Alternative	Max Groundwater Pumping for 2009	Max Groundwater Pumping for 2014
LSJR Alternative 2		
SSJID	1.5	1.3
OID	2.6	1.7
MID	2.1	0.3
TID	1.8	0.8
LSJR Alternative 3		
SSJID	3.9	2.6
OID	7.3	4.6
MID	9.4	0.7
TID	7.6	2.5
LSJR Alternative 4		
SSJID	10.6	8.4
OID	19.8	13.8
MID	27.5	5.3
TID	24.5	11.3

Over the wide range of value-based farm sizes potentially affected in the study area, the predicted effects under the LSJR alternatives would not be expected to have a disproportionate effect based on farm size. Factors contributing to this conclusion include that an estimated 60 percent of farming operations in San Joaquin, Stanislaus, and Merced Counties report net revenue gains in 2012, with the remaining operations reporting net revenue losses (USDA 2012). An additional consideration is that the median annual value of agricultural sales within the three counties analyzed was at least $50,000 in 2012. Although the lack of readily available information linking farm size and access to water, either from diversions or groundwater, limits our ability to explore potential effects based on farm size, the combination of these factors contribute to reaching this conclusion.

Livestock (beef cattle) and dairies, the two main animal operations in California, require both irrigated and non-irrigated crops as production inputs. Evaluating the effects of the LSJR alternatives on these two sectors requires a forward-linkage assessment that typically is beyond the capabilities of traditional input-output analysis, including IMPLAN. Nevertheless, it is possible to draw some inferences using economic information about the affected dairy and livestock sectors and the built-in information about the relationships in IMPLAN for the study area.

Beef cattle require pasture (including non-irrigated winter pasture) and other fodder crops, whereas dairy cattle rely heavily on alfalfa, locally grown silage corn, and a concentrate that is usually imported from out of state. Implementation of some of the LSJR alternatives may limit the economic feasibility of growing feed crops near affected water districts. Thus, these districts would experience some cost increase for inputs during water-short years. Dry forms of feed crops, such as alfalfa hay, can be imported to replace the limited supply of locally grown feed crops when regional markets for these crops are operating. However, silage corn, which has higher water content, is more costly to transport and is often not sold in the market. Because of the higher transport cost, this product is more often produced by farm operators. The ability to substitute various crops in the milk cow and the beef cattle diet with imported feed crop or concentrate is considered the determining factor for potential economic impacts of the LSJR alternatives on livestock and dairy net returns. In addition, the ability to substitute corn for fodder crops is limited by dairy dietary restrictions.

G.4.1.2 Effects on Agricultural Revenue

Based on the redistribution of crop production during times of water scarcity, the SWAP model also (in addition to crop redistribution, described above) estimates the gross revenues generated by the redistribution of crop acreage.

For the agricultural revenue effects analysis, SWAP estimates total direct gross crop revenues generated in the seven irrigation districts identified in Table G.4-5, which were aggregated into six SWAP analysis regions (also shown in Table G.4-5.) These direct revenues generated by farming operations are measured in terms of gross total production value and do not include any of the associated indirect or induced effect on the regional economy; these effects are addressed in the following section, G.5 *Estimating Effects of Agricultural Production on the Regional Economy and Local Fiscal Conditions*. Although SWAP output is calibrated and reported in 2005 dollars, the output is subsequently adjusted with a deflation factor of 1.08 derived from U.S. Bureau of Economic Analysis (BEA) data (BEA 2016) to report results in 2008 dollars, consistent with the results of the regional economic analysis.

As described in Section G.2, *Total Applied Water for Agricultural Production*, water supply conditions in the LSJR Watershed are highly variable over time; consequently, associated data or modeling results are sometimes better characterized by exceedance plots than by simple average or median statistics. To characterize the magnitude and variability of revenues, Figure G.4-1 presents an exceedance plot of SWAP estimates of annual revenues for crop production across the total LSJR Watershed over the 82-year historical record under baseline conditions and for each of the LSJR alternatives. The difference in the cumulative distribution of annual revenue above or below baseline is calculated for each LSJR alternative and presented in Table G.4-8.

SWAP estimates of average annual agricultural revenues by district are presented in Table G.4-9. As shown, farm operators in the TID would account for $16 million (45percent) of the estimated $36 million reduction in average annual revenues under LSJR Alternative 3. Under LSJR Alternative 4, farm operators in the TID would account for $50 million (43 percent) and in the Modesto ID would account for $29 million (25 percent) of the estimated $117 million reduction in average annual revenues.

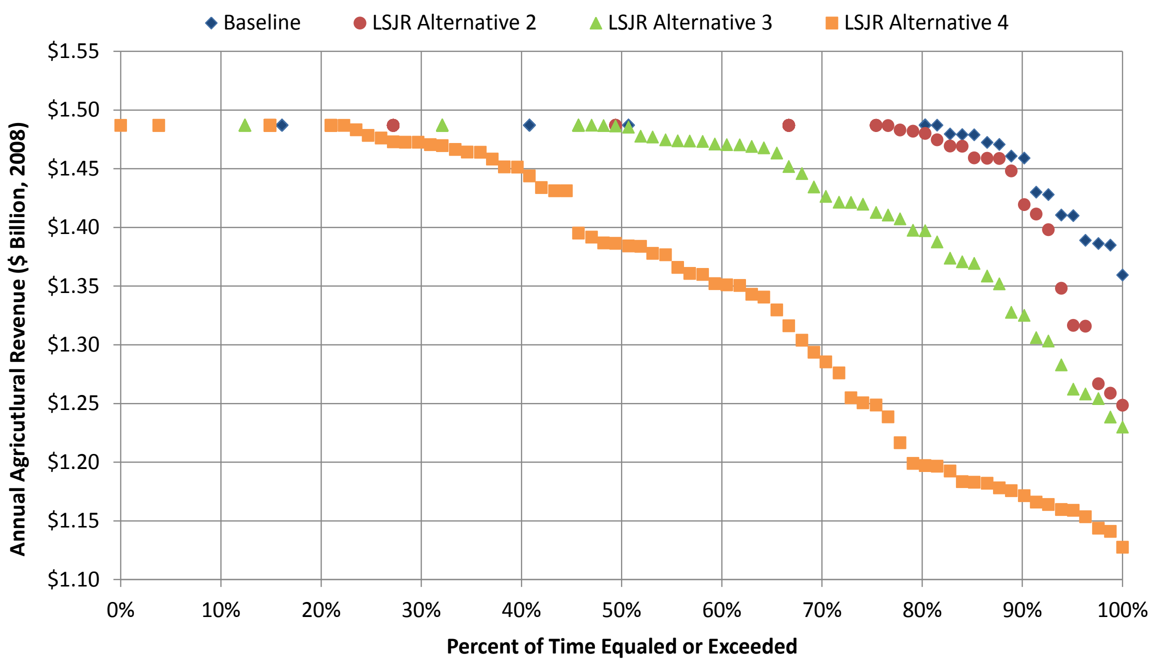

Figure G.4-1. Exceedance Plot of SWAP Estimates for Annual Agricultural Revenue in the Irrigation Districts for the LSJR Alternatives and Baseline Across the 82 Years of Simulation

Table G.4-8. Baseline Statistics for Annual Agricultural Revenue in the Irrigation Districts based on SWAP Results and the Change in those Statistics for each of the LSJR Alternatives

	Baseline	LSJR Alternative 2 (20% Unimpaired) Difference from Baseline		LSJR Alternative 3 (40% Unimpaired) Difference from Baseline		LSJR Alternative 4 (60% Unimpaired) Difference from Baseline	
Statistics	($Million, 2008/y)	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change
Avg	1,477	-9	-0.6	-36	-2.5	-117	-7.9
Min	1,359	-111	-8.1	-129	-9.5	-232	-17.1
90th Percentile	1,459	-37	-2.5	-134	-9.2	-287	-19.7
80th Percentile	1,487	-6	-0.4	-90	-6.0	-289	-19.5
70th Percentile	1,487	0	0.0	-58	-3.9	-199	-13.4
60th Percentile	1,487	0	0.0	-16	-1.1	-136	-9.1
50th Percentile	1,487	0	0.0	-1	-0.1	-102	-6.8
40th Percentile	1,487	0	0.0	0	0.0	-39	-2.6
30th Percentile	1,487	0	0.0	0	0.0	-15	-1.0
20th Percentile	1,487	0	0.0	0	0.0	0	0.0
10th Percentile	1,487	0	0.0	0	0.0	0	0.0
Max	1,487	0	0.0	0	0.0	0	0.0

Table G.4-9. SWAP Estimates of Annual Average Agricultural Revenues (and Changes in Revenues) from Baseline Conditions for the LSJR Alternatives, by Irrigation District

	Baseline	LSJR Alternative 2 (20% Unimpaired) Difference from Baseline		LSJR Alternative 3 (40% Unimpaired) Difference from Baseline		LSJR Alternative 4 (60% Unimpaired) Difference from Baseline	
Irrigation District	($Million, 2008/y)	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change
SSJID	229	-2	-1.0	-6	-2.6	-19	-8.1
OID	129	-2	-1.4	-5	-3.9	-14	-11.1
SEWD and CSJWCD	334	0	0.0	0	0.0	0	0.0
MID	148	-2	-1.2	-7	-5.0	-29	-19.5
TID	341	-3	-1.0	-16	-4.8	-50	-14.7
Merced ID	296	0	-0.1	-2	-0.5	-5	-1.7
Total	1,477	-9	-0.6	-36	-2.5	-117	-7.9

G.4.4 Groundwater Pumping Costs

In addition to the impacts on crop acreage and revenues described above, increased groundwater pumping under the LSJR alternatives would incur additional costs to farm operators. The levels of increased groundwater pumping are described in section G.2.1, *Inputs from the WSE Model*, and G.2.2, *Methodology for Calculating Applied Water*, and are summarized in Table G.4-11 below.

The additional costs for groundwater pumping are estimated assuming average groundwater levels, energy costs, and pump efficiency for the irrigation districts. An average energy price of $0.189/kilowatt hour (kWh), as used in the SWAP model (DWR 2012), was applied for the entire irrigation season. Many irrigation districts have hydropower projects and receive discounted power that would be less expensive than the average price assumed; thus, this represents a conservative assumption. Note that kilowatt is a metric unit, so the calculations below relied on several conversion factors.

To calculate pumping energy the following equation was used:

$$Pumping\ Energy = \frac{Volume\ Pumped * Depth\ to\ GW * Water\ Density * Acc.Due\ to\ Gravity}{Pump\ Efficiency}$$

Acceleration due to gravity is a constant of 9.81 m/s^2 and the density of water was considered to be constant at 1000 kg/m^3. The pumping energy efficiency was assumed to be 0.7.

The average groundwater depth across each irrigation district was extracted from the latest version of the SWAP model as described in Medellin-Azuara et al. (2015). Table G.4-10 summarizes the assumed average groundwater depths for each irrigation district.

Table G.4-10. Average Groundwater Depth by Irrigation District

Groundwater Subbasin	Average Depth (feet)
SSJID	128
OID	88
SEWD/CSJWCD	83.3
MID	90.7
TID	90.7
Merced ID	90.7

In addition to the energy cost, SWAP also represents a fixed cost of $27 for every AF of groundwater pumped to the surface, based on well design in the Northern San Joaquin Valley, and an operation and maintenance cost for the equipment of $0.025 for every AF of groundwater pumped up 1 foot (DWR 2012).

Pumping costs are part of the farm crop production budget. In some cases, farms rely entirely on groundwater for irrigation. In other cases, groundwater supplements or augments surface water sources, especially during droughts or water cutbacks. This supplementation with groundwater pumping has an effect on farm profits. Potential effects on farm profits were modeled assuming that the increase in pumping costs represents a reduction in sole proprietor income (profits). This follows the approach in Medellin-Azuara et al. (2015). This loss in profits is associated with the remaining cultivated area and is in addition to the gross revenue losses associated with water curtailments-related fallowing. The reduction in farm profit also has an induced effect on both employment and economic activity in the local area. These effects are estimated using multipliers derived from the IMPLAN model (described in the next section) that relate farm profit loss to sector output of the local economy in dollars and employment in the local economy. For every million dollars of farm profit that is lost, an additional $774,000 is lost in the local economy, and 5.8 jobs are eliminated. The regional effects are usually smaller than the proprietor income losses because a proportion of the induced expenses is leaked from the area of study.

As shown in Table G.4-11, with greater groundwater pumping in each of the alternatives there is an increased cost, which cuts into farm profits. Under baseline conditions average groundwater pumping costs are about $15.3 million per year, and this cost increases by $1.3 million, $6.2 million, and $12.7 million per year in LSJR Alternatives 2, 3, and 4, respectively. The IMPLAN-based results indicate that there is an additional induced cost to the local economy ranging from $1 million per year in LSJR Alternative 2 to $9.8 million per year in LSJR Alternative 4. The total estimated impact on economic output from increased groundwater pumping and the associated cost would range from $2.3 million per year under the LSJR Alternative 2 to $22.6 million per year under LSJR Alternative 4. Loss in proprietor income may also have some impact on employment in the area of study. The induced employment impact ranges from about 7 jobs per year in LSJR Alternative 2 to about 74 jobs per year in LSJR Alternative 4. However, there would likely be more jobs lost in the agricultural industry itself as a direct effect (e.g., with less profit, farmers cannot hire as many workers) and as indirect effects (e.g., jobs would be lost in industries that support agriculture, such as fertilizer companies).

One of the effects of increased pumping costs would be to transfer income from farming to mostly power utilities. Most of the benefits in employment and economic output from this transfer would be expected to occur outside the area of the LSJR Watershed.

Table G.4-11. The Average Annual Cost of Groundwater Pumping in the Irrigation Districts, and its Associated Induced Effects on Total Economic Output and Employment under Baseline Conditions and for the LSJR Alternatives

			Change from Baseline		
		Baseline[a]	LSJR Alternative 2 (20% Unimpaired)	LSJR Alternative 3 (40% Unimpaired)	LSJR Alternative 4 (60% Unimpaired)
Avg. Annual GW Pumping	TAF/y	258	21	104	216
Avg. Annual Cost of GW Pumping	$Millions, 2008/y	15.3	1.3	6.2	12.7
Induced Economic Effect	$Millions, 2008/y	11.9	1.0	4.8	9.8
Induced Employment Effect	Jobs/y	89	7	36	74

GW = groundwater
TAF/y = thousand acre-feet per year
$Millions, 2008/y = millions of $ per year (in 2008 $)
[a] The baseline induced effects are approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

G.5 Estimating Effects of Agricultural Production on the Regional Economy and Fiscal Conditions

This section describes the methods used to estimate how changes in agricultural production will impact the regional economy in the LSJR alternatives. Baseline conditions are first characterized, followed by an assessment of each of the LSJR alternatives. This analysis uses marginal multipliers from the Impact Analysis for Planning (IMPLAN) economic input-output model to estimate regional economic impacts associated with the direct agricultural-related production and revenue effects from the SWAP analysis (refer to Section G.4.3, *SWAP Modeling Results*).

G.5.1 Description of the IMPLAN Input-Output Model

To estimate the regional economic effects of agricultural production under baseline conditions and for the LSJR alternatives, the 2010 IMPLAN model was used (IMPLAN Group LLC 2015). IMPLAN is an input-output multiplier model that provides a snapshot of the interrelationships among sectors and institutions in a regional economy. Production in the various economic sectors of the economy is simulated in IMPLAN by using fixed factors, which account for dynamics such as production per unit of input, value added, and employment. It then applies these factors in a social accounting matrix, which accounts for changes in transactions between producers, and intermediate and final consumers in other sectors of the economy. In addition, IMPLAN uses region/sector-specific multipliers to estimate the indirect and induced economic effects (positive or negative) of changes in one sector on all other connected sectors in the regional economy. The IMPLAN model and data also can be used to develop order-of magnitude estimates of tax revenue effects on the local, state and the federal government.

The IMPLAN model has been used for many years by state, federal, and municipal entities to calculate economic effects of public policies and programs. These entities include the DWR, the State Water Resources Control Board (SWRCB), the U.S. Army Corps of Engineers, USBR, the Bureau of Economic Analysis, and the Bureau of Land Management. The IMPLAN model was used previously by the State Water Board to estimate the potential regional effects of reduced farm production in the San Joaquin Valley in the *Environmental Impact Report for the Implementation of the 1995 Bay/Delta Water Quality Control Plan* (State Water Board 1999), and in the Economic Analysis for the *Environmental Impact Report on the Irrigated Lands Regulatory Program* (State Water Board 2011). These previous uses were similar to the current use of IMPLAN to estimate the regional economic effects of the LSJR alternatives. The multipliers employed in this analysis, however, generally follow a finer resolution because they are crop-group specific, and have been developed based on IMPLAN results from county-level models. For the IMPLAN analysis Eastern San Joaquin, Stanislaus, and Merced Counties are treated as an aggregate three-county area.

The input-output analysis approach employed by IMPLAN typically results in overestimates of the indirect effects on jobs and personal income. One of the fundamental assumptions in input-output analysis is that trading patterns between industries are fixed. This assumption implies that suppliers always cut production and lay off workers in proportion to the amount of product supplied (to farms or other industries reducing production). In reality, businesses are always adapting to changing conditions. For example, when a farm cuts production, some suppliers would be able to replace part of their sales losses by finding new markets in other areas. Growth in other parts of a local economy can be expected to provide opportunities for firms. For these and other reasons, effects on job and income estimated using input-output analysis should generally be considered as upper limits on the actual effects experienced (State Water Board 1999).

In general, changes in agricultural production also would affect businesses serving farming operations and farm workers. Job and output multipliers derived from IMPLAN can be used to estimate the effects to other connected sectors of a regional economy. For this application, direct agricultural-related revenues generated by the SWAP model, and indirect and induced economic effects estimated using the IMPLAN multipliers together provide an estimate of the total economic effects on economic output and jobs within the study area.

Potential reductions in surface water deliveries to agricultural operators would be expected to affect several sectors of the economy, not just agriculture. When farm production falls as a result of reduced water availability, farmers would be expected to hire fewer seasonal workers and may lay off some year-round workers. Without jobs, household spending by these workers is likely to fall, affecting retailers and other businesses in the region. In addition, farmers would reduce purchases of equipment, materials, and services from local businesses, thereby reducing jobs and income of these suppliers. The total regional economic effect is the sum of the direct effects on agriculture and the indirect and induced effects associated with these direct effects on farmers.

G.5.2 Modeling Inputs for Regional Economic Impact Analysis

For this analysis, the 19 SWAP crop categories are aggregated into the eight default IMPLAN crop groups, as shown in Table G.5-1 below. The IMPLAN model contains two other default crop groups, “Greenhouse, Nursery, and Floriculture Production” and “Tobacco Farming”, but these groups are not used in this analysis.

For this analysis, direct agricultural revenue effects, which are outputs of the SWAP model and are summarized in section G.4.3, *SWAP Modeling Results*, are summed for the SWAP categories in each IMPLAN crop group. The total revenue associated with agricultural production, including the direct, indirect, and induced effects, is then calculated by multiplying the direct revenue for each IMPLAN crop group by the corresponding IMPLAN multiplier, shown in Table G.5-2. The total annual economic impact is then estimated as the change in total annual revenue (including direct, indirect, and induced effects) for each alternative relative to the total annual revenue under baseline conditions. The majority of the study area modeled in IMPLAN is contained within San Joaquin, Merced, and Stanislaus Counties, which are considered a good representation of the agricultural area in the LSJR Watershed.

Table G.5-1. Comparison of SWAP Crop Categories to IMPLAN Crop Groups

IMPLAN Crop Group	SWAP Crop Category
Code 1 - Oilseed	Safflower
Code 2 - Grain	Grain
	Corn
	Dry beans
	Rice
Code 3 - Vegetable and Melon	Cucurbits
	Tomatoes, Fresh
	Tomatoes, Processing
	Onion and Garlic
	Other Truck Crops
Code 4 - Fruit	Subtropical
	Vine
	Other Deciduous/Orchard Crops
Code 5 - Tree Nut	Almonds and Pistachios
Code 8 - Cotton	Cotton
Code 9 - Sugar Beets	Sugar Beets
Code 10 - All Other Crops	Alfalfa
	Pasture
	Other Field Crops

Changes in agricultural revenues from SWAP, with respect to baseline conditions, are considered a direct impact on the agricultural sector. The IMPLAN model incorporates ratios of jobs per unit of sector output that can be used to estimate changes in jobs associated with direct agricultural revenue losses. In other words, for a certain level of production, there will be a corresponding number of jobs supported. The total employment associated with a particular level of agricultural production can be estimated by multiplying agricultural revenues from SWAP by the employment-to-revenues ratio (or the total employment multiplier) for the agricultural sector. The total employment multipliers, which include direct, indirect, and induced effects on employment measure the number of jobs per million dollars of sector revenue in 2008 dollars. IMPLAN data used starts in 2010 dollars, but is converted to 2008 dollars with an deflation factor of 0.98 derived from BEA data (BEA 2016) before calculating the employment multipliers. The employment multipliers are shown in Table G.5-2 for each crop group. The total annual employment impact is then estimated as the change in total annual employment for each alternative relative to total annual employment under baseline conditions. The IMPLAN-derived total economic output and total employment multipliers for the three-county region are presented in Tables G.5-2 and G.5-3.

Table G.5-2. IMPLAN Total Economic Output Multipliers, by Crop Group

	Three-County Region IMPLAN Economic Multipliers			
IMPLAN Industry Code	Direct	Indirect	Induced	Total
Code 1 - Oilseed	1.00	0.39	0.18	1.57
Code 2 - Grain	1.00	0.59	0.20	1.79
Code 3 - Vegetable and Melon	1.00	0.36	0.40	1.76
Code 4 - Fruit	1.00	0.34	0.44	1.78
Code 5 - Tree Nut	1.00	0.32	0.38	1.70
Code 8 - Cotton	1.00	0.60	0.27	1.88
Code 9 - Sugar Beets	1.00	0.44	0.23	1.68
Code 10 - All Other Crops	1.00	0.47	0.29	1.76
Code 11 - Livestock	1.00	0.88	0.16	2.03
Code 12 - Dairy	1.00	0.57	0.12	1.69

Table G.5-3. IMPLAN Total Employment Multipliers, by Crop Group (jobs/$ Million of revenue, 2008)

	Three-County Region IMPLAN Employment Multipliers			
IMPLAN Industry Code	Direct	Indirect	Induced	Total
Code 1 - Oilseed	7.49	3.07	1.51	12.08
Code 2 - Grain	11.83	4.47	1.68	17.97
Code 3 - Vegetable and Melon	2.15	3.60	3.34	9.09
Code 4 - Fruit	3.11	4.06	3.69	10.86
Code 5 - Tree Nut	7.44	3.91	3.16	14.51
Code 8 - Cotton	2.81	4.77	2.27	9.85
Code 9 - Sugar Beets	21.07	4.08	1.95	27.09
Code 10 - All Other Crops	2.84	4.15	2.39	9.38
Code 11 - Livestock	4.73	4.71	1.30	10.74
Code 12 - Dairy	4.39	2.63	0.99	8.01

Note: The data in IMPLAN represents the employment in some crop categories higher than what would be expected in reality. In particular, the employment multipliers for Grain and Sugar Beets are expected to be lower than shown here.

G.5.3 Results of Regional Impact Analysis

This section presents estimates of the total economic output and total employment within the three-county region using the IMPLAN-based multipliers shown in Tables G.5-2 and G.5-3 applied to estimated changes in crop production revenues associated with the LSJR alternatives. Total effects include both the direct effects based on agricultural-related revenues (as estimated by the SWAP model), and the associated indirect and induced effects on the regional economy. This section also provides estimates of the total effects on both economic output and employment.

G.5.3.1 Effects on Total Economic Output

As an overview, Table G.5-4, presents effects on average annual total economic output (including direct, indirect, and induced Effects) related to agricultural production in the irrigation districts under baseline conditions. The table also presents differences from baseline conditions, both in dollars and as a percent, for each LSJR alternative. Information in the table includes average direct effects and average induced and indirect effects. In general, as the flow requirements in the alternatives get larger, the negative effect on total economic output increases.

Table G.5-4. Average Annual Total Economic Output Related to Agricultural Production in the Irrigation Districts under Baseline Conditions and the Change for Each of the LSJR Alternatives

Economic Effects	Baseline Total Economic Output ($ Millions, 2008)[a]	Change from Baseline ($ Millions, 2008) LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Direct Economic Output	1,477	-9	-36	-117
Indirect and Induced Economic Output	1,109	-7	-27	-89
Total Economic Output	2,586	-17	-64	-206
% of Baseline Total Economic Output	100	-0.6	-2.5	-8.0

[a] The baseline economic output is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

To characterize the magnitude and variability of the results, Figure G.5-1 presents an exceedance plot of total economic output related to agricultural production in the irrigation districts across the 82 years of simulation under baseline conditions and for each of the LSJR alternatives.

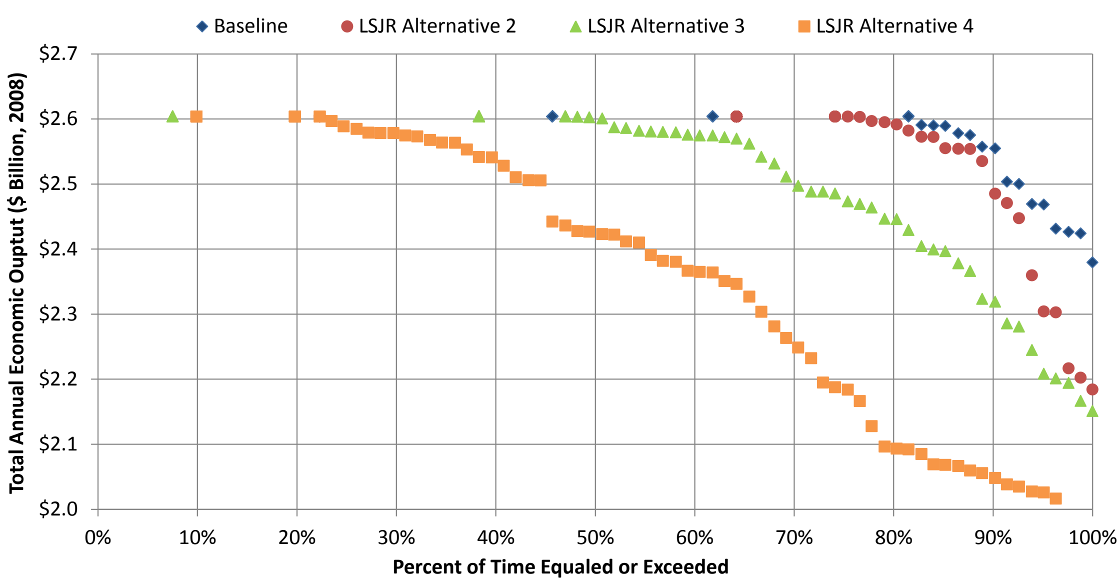

Figure G.5-1. Exceedance Plot of Total Economic Output Related to Agricultural Production in the Irrigation Districts for the LSJR Alternatives and Baseline across 82 Years of Simulation

Table G.5-5 presents several summary statistics for the exceedance timeseries above, including the cumulative distribution of the total economic output. These statistics are shown for baseline conditions while the change in each statistic relative to the baseline value is shown for each LSJR alternative.

It should be noted that the results of the IMPLAN modeling are not disaggregated by tributary watershed. As explained in Section G.3, *Estimation of Groundwater Balance*, the LSJR alternatives would be expected to reduce overall surface water diversions on the Tuolumne and Merced Rivers more than those on the Stanislaus River. Similarly, corresponding effects on economic activity would not be expected to be distributed equally across the three eastside tributary watersheds. Effects on total economic output would be concentrated in the larger urban areas (Stockton, Modesto, and Merced) where most of the trade takes place.

G.5.3.2 Effects on Total Employment

In addition to estimating total economic output, the IMPLAN model is used to estimate how changes in agricultural production in the irrigation districts might affect employment in the agricultural and other sectors. Any change in employment would not be isolated in the irrigation districts, but would likely occur over a wider area around the affected districts, particularly in larger urban areas where most of the trade takes place. The percent change in the total employment is similar to the percent change in total economic output for each LSJR alternative. Table G.5-6 presents a summary of the total number of jobs associated with crop production and related economic activity under baseline conditions, as well as the change, both in total jobs and as a percent, for each LSJR alternatives. Information in the table includes average direct effects and average induced and indirect effects. In general, as the flow requirements in the alternatives get larger, the negative effect on total employment increases.

Table G.5-5. Baseline Statistics for Total Economic Output Related to Agricultural Production in the Irrigation Districts and the Change in those Statistics for each of the LSJR Alternatives

	Baseline Total Economic Output[a]	LSJR Alternative 2 Difference from Baseline		LSJR Alternative 3 Difference from Baseline		LSJR Alternative 4 Difference from Baseline	
Statistics	($ Million, 2008/y)	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change	($Million, 2008/y)	% Change
Avg	2,586	-17	-0.6	-64	-2.5	-206	-8.0
Min	2,379	-195	-8.2	-228	-9.6	-408	-17.1
90th Percentile	2,555	-64	-2.5	-235	-9.2	-506	-19.8
80th Percentile	2,604	-11	-0.4	-158	-6.1	-510	-19.6
70th Percentile	2,604	0	0.0	-103	-3.9	-351	-13.5
60th Percentile	2,604	0	0.0	-29	-1.1	-238	-9.1
50th Percentile	2,604	0	0.0	-2	-0.1	-179	-6.9
40th Percentile	2,604	0	0.0	0	0.0	-68	-2.6
30th Percentile	2,604	0	0.0	0	0.0	-26	-1.0
20th Percentile	2,604	0	0.0	0	0.0	0	0.0
10th Percentile	2,604	0	0.0	0	0.0	0	0.0
Max	2,604	0	0.0	0	0.0	0	0.0

[a] The baseline economic output is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

Table G.5-6. Average Annual Total Employment Related to Agricultural Production in the Irrigation Districts under Baseline Conditions and the Change for Each of the LSJR Alternatives

Employment Effects	Baseline Total Employment (# of Jobs)[a]	Change from Baseline (# of Jobs)		
		LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Direct Employment	8,087	-53	-190	-692
Indirect and Induced Employment	10,514	-64	-242	-782
Total Employment	18,601	-117	-433	-1474
% of Baseline Total Employment	100	-0.6	-2.3	-7.9

[a] The baseline employment is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

To characterize the magnitude and variability of the employment results over time, Figure G.5-2 presents an exceedance plot of total employment from crop production and related economic activity in the irrigation districts across the 82 years of simulation under baseline conditions and for each of the LSJR alternatives.

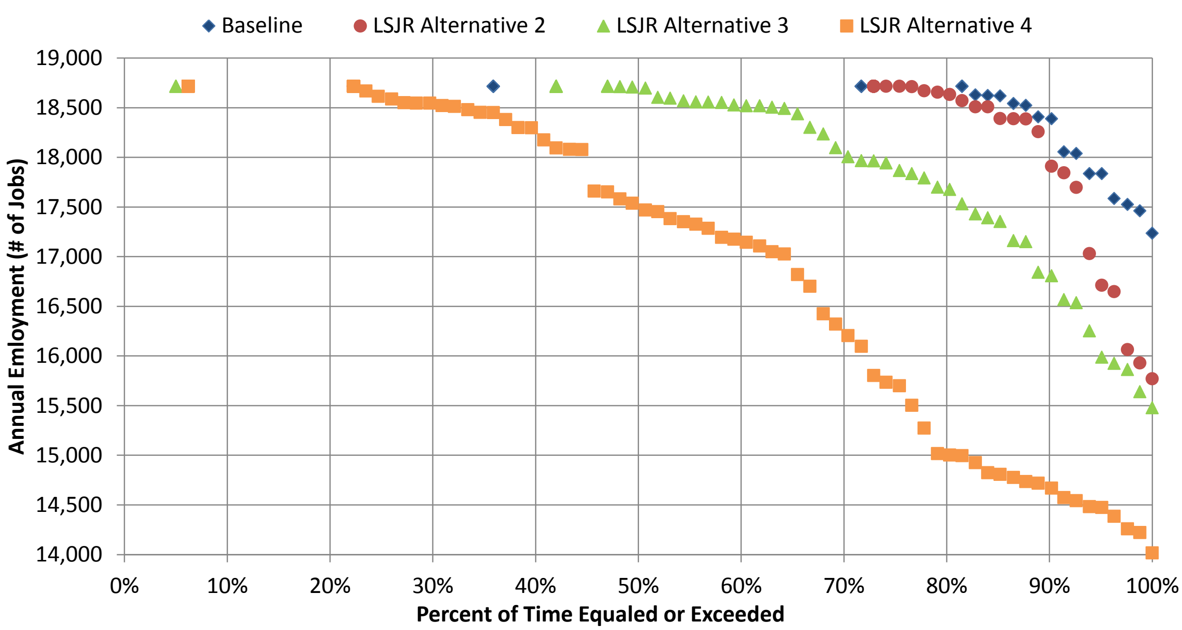

Figure G.5-2. Exceedance Plot of Total Employment Related to Agricultural Production in the Irrigation Districts for the LSJR Alternatives and Baseline across 82 Years of Simulation

Table G.5-7 presents several summary statistics for the exceedance timeseries above, including the cumulative distribution of the total employment. These statistics are shown for baseline conditions while the change in each statistic relative to the baseline value is shown for each LSJR alternative.

Table G.5-7. Baseline Statistics for Total Employment Related to Agricultural Production in the Irrigation Districts and the Change in those Statistics for Each of the LSJR Alternatives

	Baseline Total Employment[a]	LSJR Alternative 2 Difference from Baseline		LSJR Alternative 3 Difference from Baseline		LSJR Alternative 4 Difference from Baseline	
Statistics	(Jobs/y)	(Jobs/y)	% Change	(Jobs/y)	% Change	(Jobs/y)	% Change
Avg	18,601	-117	-0.6	-433	-2.3	-1,474	-7.9
Min	17,236	-1,467	-8.5	-1,758	-10.2	-3,219	-18.7
90th Percentile	18,391	-445	-2.4	-1,580	-8.6	-3,717	-20.2
80th Percentile	18,716	-78	-0.4	-1,034	-5.5	-3,711	-19.8
70th Percentile	18,716	0	0.0	-683	-3.6	-2,477	-13.2
60th Percentile	18,716	0	0.0	-193	-1.0	-1,558	-8.3
50th Percentile	18,716	0	0.0	-14	-0.1	-1,211	-6.5
40th Percentile	18,716	0	0.0	0	0.0	-467	-2.5
30th Percentile	18,716	0	0.0	0	0.0	-177	-0.9
20th Percentile	18,716	0	0.0	0	0.0	0	0.0
10th Percentile	18,716	0	0.0	0	0.0	0	0.0
Max	18,716	0	0.0	0	0.0	0	0.0

[a] The baseline employment is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

G.5.4 Fiscal Effects

G.5.4.1 Overview

Agricultural production encourages economic activity throughout local economies, generating millions of dollars in revenue for farmers and related industries. Federal, state, and local governments also collect a portion of this income by imposing various taxes. Tax revenue is used to support government operation and maintain necessary programs, such as health and safety, public protection, and transportation systems. In the agricultural sector, taxes are usually levied on farmer income, the sale of farm products and farming related goods, and the assessed value of agricultural property itself. Furthermore, farm production has a ripple effect creating economic activity in other sectors that in turn generates more tax revenue.

Each level of government uses a general fund in which most of the annual tax revenue is deposited. From the general fund, the county allocates money to all of its activities and services that are not paid for through a special fund. The San Joaquin, Stanislaus, and Merced County general funds receive 32 percent, 45 percent, and 20 percent of their revenue from taxes, respectively. Overall, about 85 percent to 90 percent of the tax revenue for each county goes to the general fund. Most of the remaining tax revenue is assigned to special revenue funds such as library funds, road funds, or fire prevention funds if given voter approval. In San Joaquin and Stanislaus Counties, a small amount of tax revenue goes to governmental business type activities.

Reductions in agricultural production may have fiscal impacts on tax revenue for cities, counties, the state, and the federal government. First, there is a direct impact on sales tax revenue associated with the reduction in agricultural production because there is less crop product to sell. Property taxes may also take a small hit as property values fall from fallowing of farmland and reduced economic activity in the area. Second, indirect impacts will result in industries that provide inputs to the agricultural industry. With fewer crops to grow, farmers will not buy as much fertilizer, pesticides, or farm equipment. Lastly, induced impacts result because of the changes in spending throughout the economy as labor income has changed. Farmers won’t need as much help during the growing and harvesting seasons, which may force some people to relocate and limit spendable income for others.

Were there to be a significant drop in tax revenue from reduced agricultural production, it could result in impacts on public services. Although vital services, such as health and safety, would likely maintain funding by tapping into other available sources of revenue, less critical services, such as public transportation and road systems, could be forced to operate with smaller budgets. Furthermore, when crop production falls, so does the number of farm-related jobs, and with more people unemployed, there could be a greater need for social welfare services. Some workers may leave the area to find work elsewhere, thereby reducing the local tax base, while those who can’t leave the area due to lack of funds would most likely be unable to contribute much to the government in the form of taxes.

Any impacts from the LSJR alternatives on fiscal revenue that could result from decreases in agricultural production are expected to be limited. Tax revenue directly or indirectly related to agricultural production comprises a small fraction of the total tax revenue for the federal and state governments. The total tax revenue collected by the federal and state governments are both several magnitudes larger than the tax revenue collected in any one county, so these entities are insulated from regional impacts. A summary of 2010 total tax revenue for San Joaquin, Stanislaus, and Merced Counties, the state of California, and the federal government is shown in Table G.5-8.

Table G.5-8. 2010 Total Revenue and Total Tax Revenue for Different Levels of Government

Level of Government	Name	Total Revenue ($ Millions, 2010)[a,b]	Total Tax Revenue ($ Millions, 2010)[a,b]	Major Sources of Tax Revenue (% of total tax revenue)	
Federal	United States	2,162,724	2,162,724	Individual Income Tax (42)	Payroll Taxes (40)
State	California	192,857	94,520	Individual Income Tax (46)	Sales Taxes (36)
County	San Joaquin	911	234	Property Taxes (83)	Sales Taxes (9)
	Stanislaus	678	106	Property Taxes (76)	Sales Taxes (22)
	Merced	435	70	Property Taxes (93)	Sales Taxes (6)

Sources: State of California 2010; County of San Joaquin 2010; County of Stanislaus 2010; County of Merced 2010.

[a] Total for 2010 fiscal year. California state and county fiscal year is from July 1 2009 to June 30 2010, while the federal government fiscal year is from September 1 2009 to October 30 2010.

[b] Includes revenue to all funds besides business type activity funds.

Although reductions in federal and state tax revenue would be larger under the LSJR alternatives than at the local level in absolute terms, county and municipal governments could likely experience a greater impact as their tax revenue reductions would represent a larger portion of their total funds. In addition, there are numerous city governments within each of the affected counties of the three-county study area that also depend on tax dollars related to agriculture, as farm products are often distributed and sold within the cities. Potential effects on local governments, however, may not be severe. One recent report found that lost agricultural production during California's drought between 2012 and 2014 did not substantially impact the finances of most local governments (MIS 2014).

Table G.5-9 presents total tax revenue received by local governments for each county within the three-county study area, and the contribution of crop farming related production and import tax revenues to each county's total. Taxes on production and imports represent sales tax, property tax, and other miscellaneous taxes (severance, motor vehicle license); it does not include income or corporate taxes, but these taxes primarily go to the state and federal governments. Of the three counties, the agricultural sector makes the greatest percent contribution in Merced County, where it generates about 4.5 percent of the tax revenue. The San Joaquin and Stanislaus Counties receive greater total tax revenue than Merced, but a smaller percent contribution from agriculture because they have significantly larger urban populations.

Table G.5-9. Estimates of Local Government Tax Revenue and Crop Farming Contribution from IMPLAN

County	Total Annual Tax Revenue to Local Governments[a] ($ Millions, 2010)	Total Annual Tax Revenue from Crop Farming to Local Governments[b] ($ Millions, 2010)	Crop Farming Contribution as % of Total Tax Revenue (%)
San Joaquin	983	18	1.9
Stanislaus	736	11	1.4
Merced	283	13	4.5

Source: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.

$ Million, 2010 = millions of 2010 dollars.

[a] Local government includes the governments of both the county and cities within the county.

[b] Includes only Taxes on Production and Imports, not Personal Taxes.

G.5.4.2 Fiscal Analysis Methods

This section presents the methods used to assess the potential effects on federal, state, and local tax revenues that could result from implementing the LSJR alternatives. To estimate the effect of agricultural revenue losses on tax revenue, information from the IMPLAN input-output model was employed to estimate fiscal economic multipliers. These multipliers were developed from IMPLAN tax revenue results based on consideration of an agricultural revenue loss of 1 million dollars in crop farming (represented in IMPLAN as an aggregate economic sector, North American Industry Classification System, or NAICS, 111) within the three-county region of San Joaquin, Stanislaus, and Merced Counties, and for each of the three counties individually. At the federal level, total (direct, indirect, and induced) tax revenue losses were estimated from the IMPLAN results template. State and local taxes, however, are lumped in the default IMPLAN report templates so state and county financial reports and other tax information were used to develop a breakdown between state and local tax revenues; this breakdown is shown in table G.5-10.

Table G.5-10. IMPLAN Tax Revenue Breakdown between State and Local Governments

Description of IMPLAN Tax Source	State Portion (%)	Local Portion (%)
Dividends	100	
Social Ins Tax- Employee Contribution	100	
Social Ins Tax- Employer Contribution	100	
Tax on Production and Imports: Property Tax		100
Tax on Production and Imports: Sales Tax[a]	Depends on County	
- San Joaquin County	82.5	17.5
- Stanislaus County	86.6	13.4
- Merced County	87.9	12.1
Tax on Production and Imports: Motor Vehicle Lic		100
Tax on Production and Imports: Severance Tax	100	
Tax on Production and Imports: Other Taxes[b]	50	50
Tax on Production and Imports: S/L NonTaxes[b]	50	50
Corporate Profits Tax	100	
Personal Tax: Income Tax	100	
Personal Tax: NonTaxes (Fines- Fees)[b]	50	50
Personal Tax: Motor Vehicle License		100
Personal Tax: Property Taxes		100
Personal Tax: Other Tax (Fish/Hunt)	100	

Sources: ILG 2013; BOE 2009; BOE 2015.

[a] Sales tax rates can differ from city to city in a county, but a single average county tax rate is assumed for this assessment. The proportions are based on county tax rates for 2010 (8.25% in Merced, 8.375% in Stanislaus, and 8.5% in San Joaquin). The 2010 base sales tax rate was 8.25%, with 7.25% of the tax revenues going to the state and 1.00% going to local governments. Values for 2010 are used because IMPLAN data for 2010 was used in the regional economy assessment described above.

[b] For a few categories, the proportion of revenues shared between state and local governments is not available, so it was assumed to be shared equally.

Table G.5-11 presents estimates of the fiscal impact on the entire three-county region associated with a reduction of 1 million dollars in agricultural revenue; the fiscal impact multipliers derived from these estimates also are presented in Table G.5-11. The results show that a 1 million dollar reduction in agricultural revenue over this region would have a direct impact of $119,245 in tax revenue over all levels of government. Accounting for the indirect and induced effects of the 1 million dollar reduction would increase the tax revenue losses to $257,932. To develop fiscal impact multipliers for the different levels of government, the total loss at each level was divided by 1 million dollars. In other words, the total federal tax impact is 15.2 percent ($152,471/$1,000,000) of the agricultural revenue loss, the total state tax impact is 6.1 percent ($60.848/$1,000,000) of the loss, and the total local tax impact is 4.5 percent ($44,613/$1,000,000) of the loss.

Table G.5-11. Resulting Fiscal Impact in Response to a $1 Million Loss in Agricultural Revenue for the Three-County Region

Level of Government	Tax Revenue Impact ($, 2010)		Fiscal Impact Multipliers	
	Direct	Total[a]	Direct	Total
Federal	-76,222	-152,471	0.076	0.152
State	-27,094	-60,848	0.027	0.061
Local	-15,928	-44,613	0.016	0.045

Sources: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.
[a] Includes direct, Indirect, and induced effects of a $1 million (in 2010 dollars) loss in agricultural revenue.

Fiscal impacts for individual counties also were analyzed using the same approach described above, applying a 1 million dollar revenue loss to all crop agriculture in each county by itself. Subsequently, Table G.5-12 presents the tax impacts on the individual county analysis and the fiscal impact multipliers used to calculate these impacts. Depending on the county, the total federal tax impact would be between 10.9 percent and 15.4 percent of the agricultural revenue loss, the total state tax impact would be between 4.7 percent and 6.1 percent of the loss, and the total local tax impact would be between 3.3 percent and 4.5 percent of the revenue loss.

Table G.5-12. Fiscal Impacts by County of a Hypothetical $1 Million Crop Revenue Loss

Level of Government	Tax Revenue Impact ($ Million, 2010)		Fiscal Impact Multipliers	
	Direct	Total[a]	Direct	Total
San Joaquin				
Federal	-75,482	-154,003	0.075	0.154
State	-27,156	-61,415	0.027	0.061
Local	-15,691	-44,731	0.016	0.045
Stanislaus				
Federal	-83,268	-153,658	0.083	0.154
State	-28,707	-60,647	0.029	0.061
Local	-15,998	-40,519	0.016	0.041
Merced				
Federal	-70,966	-108,684	0.071	0.109
State	-26,757	-47,082	0.027	0.047
Local	-15,404	-32,610	0.015	0.033

Sources: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.
$ Million, 2010 = millions of 2010 dollars.
[a] Includes direct, indirect, and induced effects of a $1 million (in 2010 dollars) loss in agricultural revenue.

These county fiscal impact multipliers were then used with the SWAP results for crop revenue as described in Section G.4.3, *SWAP Modeling Results*, to estimate the tax revenue losses. Though the tax revenue impacts reported in both Table G.5-11 and G.5-12 are in 2010 dollars the fiscal multipliers are unitless and can be applied directly to the SWAP results. Since the SWAP results were calculated by irrigation district and not county, the crop revenue for districts that shared a county were added together. For OID and TID, which fall across two counties, the revenue was divided between the counties based on the relative area of the irrigation districts in each county. According to the OID AWMP (2012), 20 percent of OID falls in San Joaquin County and 80 percent falls in Stanislaus County. TID was estimated to have 74 percent of its area in Stanislaus County and 26 percent of its area in Merced County, based on GIS analysis.

G.5.4.3 Results

This section presents potential effects on federal, state and local tax revenues that could result from implementing the LSJR alternatives. Table G.5-13 shows the annual average tax revenue for each level of government related to agricultural production in the three counties individually and over the three-county region as a whole. Under baseline, the federal government receives about $210 million and the state receives about $85 million from agricultural production over all three counties, which is only 0.01 percent and 0.09 percent of their total tax revenue for 2010 (after accounting for inflation), respectively. Both federal and state tax revenue from agricultural production over the three counties decrease by about 0.7 percent in LSJR Alternative 2 up to about 8.1 percent in LSJR Alternative 4, relative to Baseline; however, these changes are relatively small compared to the total revenue for 2010 (after accounting for inflation).

Table G.5-13. Estimated Change in Tax Revenue Associated with Predicted Changes in Annual Agricultural Production for LSJR Alternatives 2, 3, and 4 Relative to Baseline Conditions

		Tax Revenue Effects of Agricultural Production			
		Baseline	Change Relative to Baseline ($ Millions, 2008)		
County	Level of Government	($ Millions, 2008)[a]	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
San Joaquin	Federal	91	-0.41	-1.08	-3.29
	State	36	-0.16	-0.43	-1.31
	Local	26	-0.12	-0.31	-0.96
Stanislaus	Federal	77	-0.89	-3.60	-11.88
	State	31	-0.35	-1.42	-4.69
	Local	20	-0.23	-0.95	-3.13
Merced	Federal	42	-0.12	-0.63	-1.98
	State	18	-0.05	-0.27	-0.86
	Local	13	-0.03	-0.19	-0.59
All Counties	Federal	210	-1.41	-5.31	-17.15
	State	85	-0.56	-2.12	-6.86
	Local	59	-0.39	-1.45	-4.68

Sources: 2010 IMPLAN county data files, and IMPLAN model runs for LSJR alternatives.

$ Millions, 2008 = millions of 2008 dollars.

[a] The baseline tax revenue is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

Table G.5-14 focuses effects of the LSJR alternatives on local governments and how these effects compare to the total annual tax revenue from Table G.5-8. Under baseline, local governments in San Joaquin, Stanislaus, and Merced Counties receive $26, $20, and $13 million in tax revenue annually from agricultural production, respectively. These revenues represent about 2.7 percent to 4.5 percent of the total annual tax revenue for local governments in each of the three counties. For the LSJR alternatives, the impact of changes in agricultural production and revenues on tax revenue is relatively small compared to the total annual tax revenue. Stanislaus County has the largest reduction in tax revenue of the three counties, but its losses do not exceed 0.4 percent of the total annual tax revenue under any alternative.

Table G.5-14. Estimates of Local Tax Revenue Associated with Predicted Changes in Annual Agricultural Production, as a Percent of Total Tax Revenue

County	Estimates of Total Annual Tax Revenue to Local Governments[a,b] ($ Millions, 2008)	Tax Revenue Related to Predicted Annual Agricultural Production, by County			
		Baseline Value as % of Estimated Total Annual Tax Revenue[c]	Change Relative to Baseline as % of Estimated Total Annual Tax Revenue		
			LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
San Joaquin	963	2.7	0.0	0.0	-0.1
Stanislaus	722	2.8	0.0	-0.1	-0.4
Merced	278	4.5	0.0	-0.1	-0.2

Sources: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.

$ Million, 2008 = millions of 2008 dollars.

[a] Local government includes the governments of both the county and cities within the county.

[b] Dollar values from IMPLAN are in $2010 and had to be converted to $2008 with a conversion factor of 0.980 derived from BEA data (BEA 2016).

[c] The baseline tax revenue is approximated using the marginal impact multipliers, but these values likely differ to some extent from the actual values.

Based on these results, only relatively minor impacts would be expected on tax revenues at all levels of government as a result of implementing the LSJR alternatives. Tax revenue from agricultural production is a larger percentage of income for local governments than for the federal or state government, but the impact would still be small compared to tax revenue from other sources. Although the three counties are some of the largest agricultural producers in the state, most local governments do not heavily depend on tax revenue from agriculture. Some localized impacts on small towns that rely on agriculture could result, but overall cities within these counties would not be expected to experience major budgetary changes that could impact the delivery of public services.

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Attachment 1

Comparison of AWMP and DAU Crop Distributions for Irrigation Districts

Appendix G
Attachment 1

For the analysis of agricultural impacts that could result from the LSJR alternatives, it was necessary to estimate the crop mixture produced in the various irrigation districts that rely on surface water from the Stanislaus, Tuolumne, and Merced Rivers. Information on the crop mixtures was acquired from two sources: irrigation district Agricultural Water Management Plans (AWMPs) (or Water Management Plans [WMPs] for the CVP contractors) and DWR crop survey data for each Detailed Analysis Unit (DAU). These distributions are compared below for each irrigation district. The distributions are compared using the same estimate of total irrigated acres for each district, which are from the AWMPs as described in Table G.4-1 of Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results*.

Stockton East Water District (SEWD)

Most of SEWD's irrigated acres fall within DAU 182, with a small portion located in DAU 185; since the irrigated acres in DAU 185 is small the crop distribution for DAU 182 was applied over the whole district. The SEWD WMP suggests that the district devotes more acreage to other deciduous crops (non-almond or pistachio tree crops such as orchards), cucurbits, and other truck crops and less acreage to alfalfa, almonds, corn, grain and vineyards when compared with the crop distribution for DAU 182. In the WMP the acreage for other deciduous crops is about 73 percent of the total acreage compared to 27 percent in the DAU crop distribution. In the DAU distribution vine crops represent 35 percent of the crop acreage compared to only 8 percent in the WMP distribution. The WMP also groups several smaller crops into a single "other" category, which is less than 1 percent of the crop mix.

In the WMP, all crops, except grain and vine crops, have lower applied water rates than for the DAU distribution. The vine crops need 3 times more water per acre and grain crops need 5.5 times more water per acre in the WMP. On the other hand, onions and other truck crops need 2 times more water per acre and bean crops need 3.5 times more water per acre when using the DAU distribution. The total applied water demand resulting from the DAU distribution is about 22,000 acre-feet (AF) lower than the AWMP distribution estimate. Other deciduous crops account for about 80 percent of the applied water demand in the AWMP distribution, but only account for 40 percent of the applied water demand in the DAU distribution.

Table 1. Comparison of SEWD WMP and DAU 182 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	WMP	DAU	WMP	DAU	WMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	821	2,376	3.5	4.6	2,858	11,012
Almond/Pistachio	17	727	2.4	3.4	40	2,475
Corn	922	5,487	1.8	2.5	1,676	13,868
Cotton						
Cucurbits	817	298	1.2	1.8	984	525
Dry Beans	768	886	0.7	2.3	508	2,055
Grain	1,225	2,401	1.8	0.3	2,227	781
Onion and Garlic	179	140	0.7	1.5	118	206
Other Deciduous	36,990	13,643	3.0	3.4	110,270	46,800
Other Field		444		3.2		1,414
Other Truck	1,121	449	1.5	3.0	1,661	1,361
Pasture	1,524	1,843	3.4	4.9	5,247	9,106
Potato						
Rice		645		5.3		3,408
Safflower		28		1.1		31
Subtropical		187		3.0		559
Sugar Beets						
Tomato, Fresh	2,193	530	1.3	2.1	2,754	1,110
Tomato, Processing		2,999		2.8		8,252
Vine	4,264	17,899	2.8	0.9	11,743	15,567
Other	140		2.8		386	
Total	50,981	50,981	2.8	2.3	140,472	118,530

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre

Central San Joaquin Water Conservation District (CSJWCD)

All of CSJWCD's irrigated acres fall within DAU 182. The CSJWCD WMP suggests that the district devotes more acreage alfalfa, corn, grain, and tomatoes and less acreage to other deciduous crops and vineyards when compared with the crop distribution for DAU 182. In the WMP the acreage for corn is about 31 percent of the total acreage compared to 11 percent in the DAU crop distribution. In the DAU distribution other deciduous crops and vine crops represent 62 percent of the crop acreage compared to only 24 percent in the WMP distribution. The WMP also groups several smaller crops into a single "other" category, which is only 1percent of the crop mix. The CSJWCD WMP gave no estimates for crop water use.

Table 2. Comparison of CSJWCD WMP and DAU 182 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	WMP	DAU	WMP	DAU	WMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	6,000	2,237		4.6		10,368
Almond/Pistachio		684		3.4		2,330
Corn	15,000	5,166		2.5		13,057
Cotton						
Cucurbits		280		1.8		494
Dry Beans		834		2.3		1,935
Grain	7,000	2,260		0.3		735
Onion and Garlic		132		1.5		194
Other Deciduous	6,000	12,845		3.4		44,063
Other Field		418		3.2		1,331
Other Truck		423		3.0		1,281
Pasture	2,500	1,735		4.9		8,574
Potato						
Rice		607		5.3		3,209
Safflower		27		1.1		29
Subtropical		177		3.0		527
Sugar Beets						
Tomato, Fresh	5,800	499		2.1		1,045
Tomato, Processing		2,824		2.8		7,769
Vine	5,150	16,852		0.9		14,657
Other	550					
Total	48,000	48,000		2.3		111,599

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre

Southern San Joaquin Irrigation District (SSJID)

All of SSJID's irrigated acres fall within DAU 205. The SSJID AWMP suggests that the district grows more acreage for pasture and almonds and less acreage for other deciduous crops compared to the DAU distribution. In both distributions, almonds account for a large percent of the irrigated acres, about 58 percent in the AWMP distribution and 46 percent in the DAU distribution. Using the DAU distribution, about 14,500 acres or 25 percent of the total irrigated acres is assigned to other crop types not used in the AWMP distribution, primarily corn, grain, and subtropical crops. However, the AWMP groups several smaller crops into a single "other" category and includes about 5,000 acres of double cropped grain and corn.

In the AWMP all crops, except vine crops, have lower applied water rates than in the DAU distribution. Vine crops need 2 times more water per acre in the AWMP, while pasture receives about 1.5 times more water in the DAU distribution. The total applied water demand resulting from the DAU distribution is similar to the AWMP distribution estimate.

Table 3. Comparison of SSJID AWMP and DAU 205 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	2,516	3,175	3.8	5.0	9,618	15,745
Almond/Pistachio	34,170	27,032	3.3	3.5	113,868	93,721
Corn		8,332		2.9		24,271
Cotton						
Cucurbits		490		2.0		988
Dry Beans		175		2.5		434
Grain		1,670		0.8		1,285
Onion and Garlic		602		1.9		1,123
Other Deciduous	3,793	6,854	3.4	3.9	12,973	26,494
Other Field		210		3.4		705
Other Truck		437		3.2		1,393
Pasture	4,327	1,664	3.5	5.4	15,157	8,917
Potato						
Rice		84		5.4		454
Safflower		162		1.4		231
Subtropical		1,747		3.4		5,942
Sugar Beets						
Tomato, Fresh		70		2.3		165
Tomato, Processing		454		3.0		1,355
Vine	4,594	5,393	2.4	1.2	10,809	6,471
Double Cropping Grain/Corn	5,515		2.7		15,109	
Other	3,635		3.2		11,562	
Total	58,551	58,551	3.2	3.2	189,096	189,695

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre

Oakdale Irrigation District (OID)

All of OID's irrigated acres fall within DAU 206; however, DAU 206 falls in both the San Joaquin and Stanislaus Counties and both portions have different crop distributions. The total irrigated acres for the district was divided between the two counties based on a GIS determination of the relative acres of DAU 206 that fall within both counties and the corresponding DAU crop distributions were applied to both areas. The OID AWMP suggests that the district grows more acreage for pasture and less acreage for almonds, truck crops, and other deciduous crops compared to the DAU distribution. In the AWMP distribution pasture accounts for 60 percent of the total acreage, compared to only 16 percent in the DAU crop distribution. Using the DAU distribution about 20,500 acres or 38 percent of the total irrigated acres is assigned to other crop types not used in the AWMP distribution, primarily single crop corn, alfalfa, and other field crops. However, the AWMP also includes about 8,500 acres of double cropped grain and corn.

In the AWMP all crops, except other truck and other deciduous crops, have lower applied water rates than in the DAU distribution. Truck crops need 2 times more water per acre in the AWMP. The total applied water demand resulting from the DAU distribution is about 18,000 AF higher than the AWMP distribution estimate. Pasture accounts for about 64 percent of the applied water demand in the AWMP distribution, but only accounts for 22 percent of the applied water demand in the DAU distribution.

Table 4. Comparison of OID AWMP and DAU 206 Crop Distributions

	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
Crop Type	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa		2,131		4.6		9,751
Almond/Pistachio	5,607	10,513	2.8	3.7	15,794	38,673
Corn		9,758		2.6		24,885
Cotton						
Cucurbits		101		1.6		159
Dry Beans		214		2.2		470
Grain		376		0.7		273
Onion and Garlic						
Other Deciduous	2,582	6,504	3.9	3.5	10,182	22,825
Other Field		7,806		2.5		19,317
Other Truck	134	2,807	2.5	1.1	335	3,144
Pasture	32,596	8,839	3.3	4.7	107,605	41,845
Potato						
Rice	3,626	4,250	3.8	5.3	13,762	22,537
Safflower						
Subtropical		137		3.1		429
Sugar Beets						
Tomato, Fresh						
Tomato, Processing						
Vine	1,093	879	1.7	2.3	1,891	2,063
Double Cropping Grain/Corn	8,500		2.2		18,735	
Other	179					
Total	54,317	54,317	3.1	3.4	168,303	186,370

WMP = water management plan DAU = Detailed Analysis Unit AF/acre = acre-feet per acre

Modesto Irrigation District (MID)

All of MID's irrigated acres fall within the Stanislaus County portion of DAU 206. The MID AWMP suggests that the district grows more acreage for almonds, grain, and other deciduous crops and less acreage for corn, field crops, and truck crops compared to the DAU distribution. In the AWMP distribution almonds and pistachios account for 34 percent of the total acreage, compared to only 22 percent in the DAU crop distribution. In the DAU distribution field and truck crops account for another 22 percent of the total irrigated acres, but total less than 1 percent of the area in the AWMP distribution. In addition, the DAU distribution accounts for a small amount of acreage for beans and subtropical crops that are not accounted for in the AWMP distribution. However, the AWMP also groups several smaller crops into a single "other" category and includes about 431 acres of double cropped grain and corn.

In the AWMP all crops, except rice crops, have higher applied water rates than in the DAU distribution. Grain crops need 2 times more water per acre and truck crops need 3.5 times more water per acre in the AWMP. The total applied water demand resulting from the DAU distribution is about 50,000 AF lower than the AWMP distribution estimate.

Table 5. Comparison of MID AWMP and DAU 206 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	3,417	2,674	5.1	4.6	17,303	12,235
Almond/Pistachio	20,006	13,157	4.0	3.7	80,327	48,415
Corn	4,622	10,525	2.8	2.5	13,010	26,310
Cotton						
Cucurbits	3	127	2.3	1.6	7	200
Dry Beans		255		2.2		558
Grain	5,730	212	2.0	1.0	11,668	205
Onion and Garlic						
Other Deciduous	11,624	8,149	4.5	3.5	51,827	28,591
Other Field	293	9,422	2.6	2.4	752	23,033
Other Truck	200	3,523	3.8	1.1	765	3,945
Pasture	9,377	8,743	5.6	4.6	52,234	40,421
Potato						
Rice	366	679	4.6	5.7	1,666	3,863
Safflower						
Subtropical		42		2.8		118
Sugar Beets						
Tomato, Fresh						
Tomato, Processing						
Vine	1,340	1,103	3.4	2.3	4,622	2,588
Double Cropping Grain/Corn	431		3.0		1,308	
Other	1202		2.9		3,460	
Total	58,611	58,611	4.1	3.2	238,951	190,480

WMP = water management plan DAU = Detailed Analysis Unit AF/acre = acre-feet per acre

Turlock Irrigation District (TID)

All of TID's irrigated acres fall within DAU 208; however, DAU 208 falls in both the Stanislaus and Merced Counties and both portions have different crop distributions. The total irrigated acres for the district was divided between the two counties based on a GIS determination of the relative acres of DAU 208 that fall within both counties and the corresponding DAU crop distributions were applied to both areas. The TID AWMP suggests that the district grows more acreage for almonds, grain, pasture, vine, and other deciduous crops and less acreage for corn, field crops, and truck crops compared to the DAU distribution. In the DAU distribution Single cropped corn and other field crops represent 50 percent of the crop acreage compared to only 8 percent in the AWMP distribution. However, in the AWMP 27 percent of the total acreage or 39,000 acres is used for double cropping, mostly for grain and corn or unirrigated forage and corn. In addition, the AWMP accounts for 2,000 acres of potatoes not in the DAU distribution and groups several smaller crops into a single "other" category.

In the AWMP all crops, except for pasture and alfalfa, have higher applied water rates than in the DAU distributions. Truck crops, tomatoes, and grain crops need about 2.5 times more water per acre and cucurbits need 2 times more water per acre in the AWMP. The total applied water demand resulting from the DAU distribution is about 110,000 AF lower than the AWMP distribution estimate.

Table 6. Comparison of TID AWMP and DAU 208 Crop Distributions

	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
Crop Type	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	15,162	14,371	4.1	4.5	62,189	65,177
Almond/Pistachio	45,685	33,776	3.7	3.1	169,587	105,851
Corn	9,650	43,350	3.0	2.5	29,352	109,074
Cotton						
Cucurbits	379	469	2.8	1.6	1,045	743
Dry Beans	680	1,073	2.5	2.2	1,696	2,379
Grain	3,113	455	2.5	0.9	7,782	431
Onion and Garlic	17		3.9		66	
Other Deciduous	12,153	8,238	3.9	3.5	47,768	28,841
Other Field	868	29,078	2.5	2.5	2,153	72,422
Other Truck	37	7,977	2.6	1.1	95	9,091
Pasture	11,684	4,784	3.9	4.6	45,357	21,982
Potato	1,974		2.7		5,366	
Rice						
Safflower						
Subtropical	64	63	3.0	2.8	195	175
Sugar Beets	0		3.6		0	
Tomato, Fresh	4	379	3.6	1.6	15	596
Tomato, Processing						
Vine	3,197	2,016	2.7	2.2	8,653	4,461

	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
Crop Type	Acres	Acres	AF/acre	AF/acre	AF	AF
Double Cropping Grain/Corn	18,949		4.2		79,271	
Double Cropping Unirrigated Forage/Corn	9,944		3.5		34,693	
Double Cropping Other	10,368		3.4		35,609	
Other	2,104		3.7		7,753	
Total	146,030	146,030	3.7	2.9	538,645	421,223

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre

Merced Irrigation District (Merced ID)

Most of Merced ID's irrigated acres fall within DAU 210 with a few small areas falling in other DAUs. Since the other areas were small the crop distribution for DAU 210 was applied for the entire district. The Merced ID AWMP suggests that the district grows more acreage for alfalfa, cotton, pasture, and tomatoes and less acreage for corn compared to the DAU distribution. Using the DAU distribution about 33,000 acres or 33 percent of the total irrigated acres is assigned to other crop types not used in the AWMP distribution, primarily other truck, other field, and other deciduous crops. However, the Merced ID AWMP only presents a distribution of the district's major crops and leaves out many of the smaller ones. Overall, the total crop area from the AWMP distribution falls about 29,000 acres short of the total irrigated acres for the district, 100,237 acres, specified in Table G.4-1 of Appendix G.

Both distributions have similar applied water rates, except for fresh tomatoes which require 50 percent more water per acre in the AWMP. The total applied water demand resulting from the DAU distribution is about 37,000 AF higher than the AWMP distribution estimate. This difference should be significantly smaller because the AWMP does not have an estimate of the applied water rate or demand for the 29,000 acres of "other" crops.

Table 7. Comparison of Merced ID AWMP and DAU 210 Crop Distributions

Crop Type	Total Irrigated Acres		Applied Water Rate		Applied Water Demand	
	AWMP	DAU	AWMP	DAU	AWMP	DAU
	Acres	Acres	AF/acre	AF/acre	AF	AF
Alfalfa	8,615	5,810	4.3	4.5	37,324	26,010
Almond/Pistachio	29,771	30,615	3.7	3.3	109,712	100,953
Corn	12,543	19,088	2.5	2.5	31,820	48,220
Cotton	4,819	2,490	2.8	3.1	13,382	7,659
Cucurbits		646		1.5		951
Dry Beans						
Grain		3,135		0.9		2,957
Onion and Garlic						
Other Deciduous		4,887		3.4		16,583
Other Field		7,193		2.5		17,838
Other Truck		11,803		1.1		13,551
Pasture	10,055	5,994	4.1	4.5	41,568	26,896
Potato						
Rice		1,199		5.4		6,532
Safflower						
Subtropical						
Sugar Beets		277		1.6		434
Tomato, Fresh	5,745	1,844	2.4	1.6	13,914	2,951
Tomato, Processing		1,383		2.4		3,280
Vine		3,873		2.4		9,187
Other	28,689					
Total	100,237	100,237	2.5	2.8	247,721	284,003

WMP = water management plan
DAU = Detailed Analysis Unit
AF/acre = acre-feet per acre

Appendix H

Supporting Materials for Chapter 16

Attachment 1

Water Transfers—Applicable Mitigation Measures

Appendix H
Attachment 1

H.1 Introduction

The mitigation measures described below in Section H.2 are taken from Chapter 6, Section 6.1 Mitigation Measures to Minimize Water Supply and System Operations Impacts of the San Francisco Public Utilities Commission's (SFPUC's) Water System Improvement Program (WSIP) Final Program Environmental Impact Report (PEIR) (SFPUC 2008). These mitigation measures are meant to reduce biological resource impacts to less than significant from a water transfer with MID/TID as described in Chapter 16, *Evaluation of Indirect Actions and Other Actions* and Appendix L, *City and County of San Francisco Analyses*. The mitigation measures described below in Section H.3 are taken from Chapter 6, Section 6.5 4, Measures that Affect Other Water Sources. These are measures that could be applied to other areas to reduce impacts associated primarily with construction or operation of new facilities or other actions as a result of Measure 5.3.6-4a Avoidance of Flow Changes by Reducing Demand for Don Pedro Water. These measures are similar to mitigation summarized in Table 16-38 for impacts discussed in Section 16.2.2, *Substitution of Surface Water with Groundwater*, Section 16.2.4, *Recycled Water Sources for Water Supply* or Section 16.4.1, *New Source Water Supplies*.

H.2 Potential Mitigation Measures for Upper Tuolumne River Watershed

H.2.1 Fisheries

Overview of Measures 5.3.6-4a, 5.3.6-4b, and 5.3.7-6

The SFPUC will attempt to implement Measure 5.3.6-4a as described below, which could mitigate both Impacts 5.3.6-4 and 5.3.7-6 to a less than significant level. Measure 5.3.6-4a involves some uncertainty because its implementation depends on the SFPUC negotiating and reaching agreement with MID/TID and possibly other water agencies. If Measure 5.3.6-4a proves to be infeasible, the SFPUC will implement Measure 5.3.6-4b to lessen fisheries impacts and Measure 5.3.7-6 to lessen impacts on riparian vegetation.

Avoidance of Flow Changes by Reducing Demand for Don Pedro Reservoir Water

Measure 5.3.6-4a: The SFPUC will pursue a water transfer arrangement with MID/TID and/or other water agencies such that the water acquired is developed through actions that result in reduction of demand on Don Pedro Reservoir as a result of conservation, improved delivery efficiency, inter-agency transfer of conserved water, or use of an alternative supply such as groundwater. The TID and MID would deliver less water from Don Pedro Reservoir. The consequent increase in water storage in Don Pedro Reservoir would offset the reduction in inflow to Don Pedro Reservoir attributable to the WSIP. The release pattern from La Grange Dam would be the same or similar to the existing condition thus lessening or eliminating Impacts 5.3.6-4 and 5.3.7-6. The actions necessary to reduce demand for Don Pedro Reservoir water may themselves have environmental effects. See Section 6.5 for a review of potential environmental effects associated with the expected actions of this mitigation measure. Further environmental review would be undertaken prior to approving a specific water transfer agreement.

Fishery Habitat Enhancement

Measure 5.3.6-4b: If Measure 5.3.6-4a is not implemented, then the SFPUC will mitigate potential fishery effects on the lower Tuolumne River by implementing (or funding) one of

the following two habitat enhancement actions that are designed to sustain fishery resources under the river's flow regime, which are consistent with the Habitat Restoration Plan for the Lower Tuolumne River Corridor: gravel augmentation/habitat enhancement to provide salmonid spawning and rearing habitat, or isolating or filling a captured former gravel quarry pit along the river that provides habitat for salmonid predators.

The gravel augmentation/habitat enhancement project will be implemented to increase salmonid spawning success and to improve the survival of rearing salmonids in the reach of the river downstream of La Grange Dam. Spawning success will be improved by the addition of suitable gravel to the stream channel. Other habitat features will be created to provide cover for juvenile salmonids and to increase the availability of substrate for macroinvertebrates that would be used as food by rearing juvenile salmon and steelhead. The gravel augmentation/habitat enhancement project will involve the planning, design, permitting, purchase, placement, and monitoring of suitable gravel and associated habitat enhancements at three riffle locations within the spawning reach between Basso Bridge and La Grange Dam. The three locations will meet the criteria for suitable habitat as described

in the Habitat Restoration Plan for the Lower Tuolumne River Corridor. The gravel will preferentially be rounded river rock of native origin that would be sized and pre-washed before placement into the river. The gravel augmentation/habitat enhancement project will also involve the addition of large woody debris and boulders to create increased habitat complexity and diversity at each of the three enhancement sites. After construction of the gravel augmentation/habitat enhancement project, it will be surveyed to establish its baseline condition. A survey of the three sites will be made at a minimum of five-year intervals by a qualified fisheries biologist. The fisheries biologist will determine whether the three sites continue to meet established criteria for salmonid spawning and rearing habitat. If the sites do not meet the criteria, as part of its long-term operations, the SFPUC will make the improvements necessary to return it to the baseline conditions.

As an alternative to the gravel augmentation project, the SFPUC will remove from the lower river channel one of the former gravel quarry pits that has been "captured" by the river and acts as predator zones for fish such as largemouth and striped bass to prey on rearing and emigrating juvenile salmonids. Removal could be accomplished by filling the pit or installing a levee berm around the pit to isolate it permanently from the river channel. The SFPUC could implement this action directly or fund implementation by another entity involved in river restoration.

The performance standard for gravel pit removal would be an established permanent reduction in area of salmonid predator habitat. The SFPUC will monitor the pit removal project at five-year intervals. If floods have eroded the fil1 or damaged the levees in a manner that restores salmonid predator habitat, the SFPUC will make the necessary repairs. The SFPUC will continue periodic monitoring and repair as part of long-term system operations.

H.2.2 Terrestrial Biological Resources

Controlled Releases to Recharge Groundwater in Streamside Meadows and Other Alluvial Deposits

Measure 5.3.7-2: To mitigate for potential WSIP effects on meadow resources along the Tuolumne River below Hetch Hetchy Reservoir, the SFPUC will manage releases from Hetch Hetchy Reservoir during the spring to recharge groundwater in the riverside meadows in the Poopenaut Valley and streamside alluvial deposits. The goal of the release pattern will be to approximate conditions characteristic of most Sierra meadows, which are mainly wetlands or semi-wetlands supporting a cover of both emergent wetlands plants and upland vegetation (Ratliff, 1982), and which depend on precipitation and upslope flows to recharge the upper soil layers with water (Ratliff, 1985). The performance standard to be achieved by this measure is no net loss of the extent, diversity, and condition of the existing meadow and wetland vegetation types in the Poopenaut Valley.

The SFPUC will manage reservoir releases for this purpose by releasing the expected available volume of water in the reservoir in a pattern that provides flows of a magnitude that inundate the meadows and streamside alluvial deposits for as long as possible. For example, rather than making releases at a constant rate each day (e.g., releasing 1,000 cfs for seven days), the SFPUC could release the same volume of water but with varying cfs rates, creating flow pulses to meet the objective.

As part of this measure the SFPUC will gather baseline data regarding the extent, species composition and condition of the existing meadow vegetation within the Poopenaut Valley. Some of these environmental baseline data may be available as a result of current study efforts in the Poopenaut Valley[51]. As needed, the SFPUC will augment this information by carrying out vegetation composition surveys in the meadow before implementing the WSIP and at 5 year intervals after WSIP implementation to assess the efficacy of mitigation releases in maintaining or improving the percentage cover of meadow species as described by Ratliff (1985). The basic methodology for baseline vegetation survey and subsequent mitigation monitoring will be generally accepted quantitative vegetation sampling methods to permit statistical comparison of vegetation composition over time, as well as mapping the meadow vegetation in the Poopenaut Valley. The SFPUC will retain the services of a qualified biologist to assist in shaping the releases from Hetch Hetchy Reservoir in consideration of baseline and future meadow vegetation data. If a significant decline in the extent or diversity of native meadow vegetation occurs, releases will be modified as needed to achieve the mitigating effect of sustaining the existing meadow communities.

[1] In 2006 the SFPUC, National Park Service (and USFWS) began a collaborative study effort in the Poopenaut Valley. The effort has led to geomorphology test releases in May 2006, fieldwork in the channel in 2006 and 2007 to examine sediment transport and deposition relationships with flow. Two transects with ten recording piezometers have been installed across the meadow to measure groundwater recharge and drainage patterns. Supplementary stream staff gages have been installed to allow manual readings during high flows. Surveys have been done of the meadow to define the topography and the location and elevation of the piezometers. Infiltration of water from the stream to the meadow soils will be monitored during high flows to develop a better understanding of groundwater dynamics in the meadow so that reservoir operations, flow pulses, and minimum streamflow releases can be managed to improve meadow conditions within the constraints of water supply and facility limitations.

Avoidance of Flow Changes by Reducing Demand for Don Pedro Reservoir Water

See **Measure 5.3.6-4a** in the Fisheries section, above. This measure also addresses impact 5.3.7-6 Impacts on biological resources along the Tuolumne River below La Grange. The SFPUC will attempt to implement Measure 5.3.6-4a as described above, which could mitigate both Impacts 5.3.6-4 and 5.3.7-6 to a less than significant level. Measure 5.3.6-4a involves some uncertainty because its implementation depends on the SFPUC negotiating and reaching agreement with MID/TID and possibly other water agencies. If Measure 5.3.6-4a proves to be infeasible, the SFPUC will implement Measure 5.3.6-4b to lessen fisheries impacts and Measure 5.3.7-6 to lessen impacts on riparian vegetation.

Lower Tuolumne River Riparian Habitat Enhancement

Measure 5.3.7-6: To mitigate the WSIP effects on riparian vegetation, the SFPUC will both protect and enhance one mile of riparian vegetation along the contemporary floodplain of the lower Tuolumne River. This will include funding the acquisition of fee title to or a conservation easement over riparian land totaling one mile (consisting of one or multiple sites) in order to permanently protect that land, and also funding riparian enhancement and on-going vegetation management to maintain the enhanced riparian values in perpetuity along one mile of river. The enhancement and management may be carried out along one river mile either on the land acquired by the SFPUC as described above or on land already under the permanent management of a public agency or conservation organization.

The SFPUC will implement this measure consistent with the Habitat Restoration Plan for the Lower Tuolumne River Corridor (McBain and Trush, 2000) and in coordination with the Tuolumne River Technical Advisory Committee. The SFPUC will also strive to implement these projects in partnership with those groups currently working to restore riparian floodplains on the lower Tuolumne River.

The SFPUC may implement riparian enhancement in accordance with site locations and plans already developed as part of the Habitat Restoration Plan for the Lower Tuolumne River Corridor or on other appropriate sites along the river. For sites that haven't already had plans developed, a riparian enhancement plan will be prepared for each. The plan shall include, but not be limited to, the following:

- Clearly stated objectives and goals consistent with the Habitat Restoration Plan for the Lower Tuolumne River Corridor (McBain and Trush, 2000).
- Location, size, and type of mitigation actions proposed.
- Documentation of performance and monitoring standards.
- Performance and monitoring standards shall indicate success criteria to be met within
- 5 years for vegetation, removal of exotic species, etc. Adaptive management
- standards shall include contingency measures that shall outline clear steps to be taken if and when it is determined, through monitoring or other means, that the enhancement or restoration techniques are not meeting success criteria.
- Documentation of the necessary long-term management and maintenance requirements, and provisions for sufficient funding.

H.3 Potential Mitigation Measures for Potential Selling Party

The following PEIR mitigation measure would be in this category: Measure 5.3.6-4a (Avoidance of Flow Changes by Reducing Demand for Don Pedro Reservoir Water). At this time, it is unknown what sources of water or water users could be affected by a water transfer arrangement with TID, MID, or other agency or agencies that involves use only of conserved water. Supplemental water could be made available as a result of:

- Water use efficiency and conservation for agricultural, residential and commercial users
- Land use changes, either agricultural to urban, or more water intensive (e.g., pasture) to less intensive (e.g., orchard)
- Conjunctive use of groundwater
- Recycled water
- Tiered water pricing
- Land fallowing of agricultural lands.

In general, the types of potential environmental impacts associated with water transfers from these types of sources include:

- *Land use*: reduced agricultural activity (which could be mitigated through siting measures similar to Measure 4.3-2)
- *Biological resources*: indirect effects on aquatic and/or terrestrial biological resources due to possible reductions in irrigation/drainage system return flows, reductions in discharges of treated wastewater, changes in land use from more water intensive uses to less water intensive uses, or lowered groundwater tables (which could be mitigated through habitat protection/restoration measures similar to Measures 4.6-1a, 4.6-1b, 4.6-2, 4.6-3a, 4.6-3b, and 4.6-4)
- *Water quality and hydrology*: reduced groundwater recharge due to agricultural water conservation practices such as lining irrigation canals or conversion to drip irrigation, or land use changes (which could be mitigated through groundwater protection measures similar to Measure 4.5-2)
- *Agricultural resources*: reduced agricultural activity due to farming; potential conversion of idle agricultural land to other uses (which could be mitigated through measures similar to Measure 4.13-2, avoidance of Prime Farmland)
- *Noise*: increased noise from use of pumps for conjunctive-use groundwater program (which could be mitigated through standard construction measures for noise controls)
- *Energy*: increased use of energy for conjunctive-use groundwater or recycled water programs (similar to Impact 4.15-2 for the Groundwater Projects, SF-2) and Recycled Water Projects, SF-3, which could be mitigated through energy efficiency measures similar to Measure 4.15-2)
- *Air Quality*: increased particulate emissions from on-farm efficiency measures like land leveling (which could be mitigated through standard dust control measures similar to those listed in Measure 4.9-1a)

As indicated above, standard mitigation approaches are available, and implementation of those measures as well as any applicable water quality or biological resource permit conditions could reduce these impacts to less than significant.

Facility Siting Studies

Measure 4.3-2: It is the policy of the SFPUC to construct and operate its facilities on SFPUC-owned lands to the extent feasible. When use of SFPUC-owned land is not feasible, and where additional permanent easement or land acquisition is required, the SFPUC will conduct project-specific facility siting studies and implement these studies' recommendations to avoid or minimize impacts on existing land uses to the maximum extent feasible. Siting studies will identify and evaluate alternative site locations, access roads, building configurations and facility operations to minimize or avoid land use impacts. The studies will also consider existing and planned land uses on and adjacent to proposed facility sites and rights-of-way on non-SFPUC-owned land. To the extent feasible, the SFPUC will implement the recommendations in the siting studies

Site-Specific Groundwater Analysis and Identified Measures

Measure 4.5-2: As part of the project-specific CEQA review for the New Irvington Tunnel project (SV-4), the SFPUC will inventory springs and wells in the area of the planned tunnel and conduct a project-specific analysis of the potential for tunnel dewatering to stop or decrease spring flow, lower groundwater levels in nearby wells, or to otherwise cause adverse effects on groundwater resources and beneficial uses of the groundwater. If a significant impact is identified, then measures such as altering groundwater withdrawal rates and/or providing an alternate water supply for affected users will be implemented to ensure that groundwater resources or beneficial uses are not adversely affected

Wetlands Assessment

Measure 4.6-1a: As part of project-specific CEQA review, a qualified wetland scientist will review project plans, air photos, and topographic maps and conduct a site visit to determine whether wetlands are present and could be affected by the project. If the review shows that wetlands could be affected, the wetland scientist will perform a formal wetland delineation and develop mitigation as per Measure 4.6-1b, below.

Compensation for Wetlands and Other Biological Resources

Measure 4.6-1b: If the wetland delineation indicates that the WSIP project will affect jurisdictional wetlands or aquatic resources, then, in accordance with state and federal permit requirements, the SFPUC will avoid and minimize direct and indirect impacts such as erosion and sedimentation, alteration of hydrology, and degradation of water quality. As a first priority, the SFPUC will implement (1) avoidance measures. For unavoidable impacts, the SFPUC will implement (2) minimization of unavoidable impacts, (3) restoration procedures, and (4) compensatory creation or enhancement to ensure no net loss of wetland extent or function.

In addition to wetlands, the SFPUC will compensate for sensitive riparian and upland habitats and habitats which support key special-status species or other species of concern lost as a result of WSIP project construction and operation. Similar habitat will be identified, protected, restored, enhanced, created and managed off-site[2] to ensure no net loss of habitat extent or function. For each WSIP project, a qualified biologist will quantify the magnitude and extent of

[2] Off-site means the compensatory action is located other than within the project construction footprint, but could be on lands already under SFPUC ownership. Measure 4.6-2 addresses compensatory actions to be taken within the construction footprint.

impacts to wetlands, sensitive habitats, and key special-status species and other species of concern, and the SFPUC will develop and implement restoration and/or compensation plans that meet the appropriate regulatory requirements and permit conditions with respect to restoration and/or compensation ratios. Compensation ratios typically range from a minimum of 1:1 for common habitats to 2:1 or higher for rare and sensitive habitats. If individual project requirements of the RWQCB, CDFG, or USFWS differ somewhat from these ratios, they are still intended to achieve the same purpose of full restoration and/or compensation, to mitigate project impacts to less-than- significant levels, and to ensure no net reduction in the populations of any species listed as threatened or endangered by the state or federal resource agencies.

The SFPUC will obtain required permits for each project and comply with applicable environmental regulations addressing sensitive habitats and species. Compensatory lands, including those restored or enhanced as well as those acquired or designated as protected as part of program or project mitigation, will be established in perpetuity with a commitment that such lands will not be used for any purpose that conflicts with the primary purpose of maintaining intact wildlife and plant habitat.

One alternative for implementing off-site habitat compensation is the Habitat Reserve Program (HRP) currently being developed by the SFPUC. The purpose of the HRP is to provide a comprehensive, coordinated approach to mitigation and related regulatory compliance for WSIP projects. This related SFPUC project is described further in Chapter 3.0, Section 3.11. Under the proposed HRP, the SFPUC would proceed as soon as possible with securing (through designation, management agreement, conservation easement, or acquisition of fee title) and improving lands to be used for habitat compensation so that mitigation is underway before or concurrent with habitat loss related to WSIP project activities, further ensuring no net loss of resources. CEQA environmental review for the proposed HRP will commence in 2007 and is targeted for implementation as soon as possible thereafter. Once the HRP is approved and implemented, the SFPUC will use this as one vehicle or method for implementing the mitigation requirements for individual WSIP projects. Otherwise, where appropriate and necessary, the SFPUC will develop and implement appropriate habitat compensation mitigation for individual WSIP projects.

Habitat Restoration/Tree Replacement

Measure 4.6-2: If the biological screening survey identifies sensitive habitats or heritage trees, the following measures, as modified and applied to WSIP projects, will be implemented:

- Temporarily-impacted sensitive habitats (natural communities identified as sensitive by CDFG, and USFWS-designated critical habitat) would be restored to their pre- project condition.
- If specific trees to be removed are designated as heritage trees (or similar local designation), then SFPUC will replace the trees, consistent with requirements in local ordinances. If such heritage trees occur near extensive areas of sensitive habitats, locally collected, native species will be used as replacement trees where possible.
- Where possible, the loss of sensitive habitats will be minimized by coordinating WSIP projects to make repeated use of staging/construction areas and access roads. For example, tunnel spoils could be considered for borrow material for other projects.

Protection Measures during Construction for Key Special-Status Species and Other Species of Concern

Measure 4.6-3a: The following general practice measures, as modified and applied to the WSIP projects, will be implemented if the initial biological screening survey (SFPUC Construction Measure #8) indicates the potential for the presence of key special-status species and other species of concern:

- Preconstruction surveys for key special-status species and other species of concern will be conducted by a qualified biologist to verify their presence or absence. Surveys will occur during the portion of the species' life cycle when the species is most likely to be identified within the appropriate habitat. Key special-status species and other species of concern will be avoided during construction when possible.
- A worker awareness program (environmental education) will be developed and implemented to inform project workers of their responsibilities in regards to sensitive biological resources.
- An environmental inspector will be appointed to serve as a contact for issues that may arise concerning implementation of mitigation measures, and to document and report on adherence to these measures during construction.
- Loss of habitat will be minimized through the following measures: (1) the number and size of access routes and staging areas and the total area of the project activity will be limited to the minimum necessary to achieve the project goal; (2) the introduction or spread of invasive non-native plant species and plant pathogens will be avoided or minimized by developing and implementing a weed control plan; and (3) all areas temporarily disturbed by construction will be revegetated to pre-project or native conditions, as specified in project-specific revegetation plans.

Standard Mitigation Measures for Specific Plants and Animals

Measure 4.6-3b: Table H-1 identifies the key special-status species mitigation measures that the program analysis indicates would apply to each WSIP project. Measures listed in Table H-1 (listed by species) are generic measures and will be modified to fit site-specific conditions and applied to each WSIP project wherever special-status species could be affected by the projects. Surveys required under Measure 4.6-3a will refine the list of species that could be affected by a project. Table H-1 is intended as the minimum necessary actions. In addition to adopting the generic measures, as more site-specific information is available, project-specific CEQA analysis may identify additional measures for key special-status species and additional measures for other species.

Measure 4.6-4 Pipeline and Water Treatment Plant Treated Water Discharge Restrictions

Measure 4.6-4: Planned discharges of regional system water from the WSIP pipelines and water treatment plants (such as crossover facilities) to creeks, rivers or other natural water bodies will be designed to minimize impacts to riparian and aquatic resources to the extent feasible. This will include dechlorination and/or pH adjustment facilities and energy dissipation structures that avoid or reduce bank erosion. In addition, the facilities should include design features to avoid or minimize temperature effects on aquatic resources; or alternatively, whenever possible, planned discharges should be scheduled to occur in the winter, when stream flows are high and temperatures low in the receiving waters to avoid or minimize temperature effects.

Measure 4.9-1a SJVAPCD Dust Control Measures

Measure 4.9-1a: In the San Joaquin Region, the SJVAPCD has determined that compliance with the following Regulation VIII (Fugitive PM10 Prohibitions) and Regulation IX (Mobile and Indirect Sources, Rule 9510, where applicable) control measures would mitigate PM10 impacts to a less-than-significant level. The SFPUC will include these measures, where applicable, in contract specifications:

- SJVAPCD Basic Control Measures (applies to all construction sites)
  - All disturbed areas, including storage piles that are not being actively utilized for construction purposes, shall be effectively stabilized of dust emissions using water, chemical stabilizer/suppressant, covered with a tarp or other suitable cover, or vegetative ground cover.
  - All onsite unpaved roads and offsite unpaved access roads shall be effectively stabilized of dust emissions using water or chemical stabilizer/suppressant.
  - All land clearing, grubbing, scraping, excavation, land leveling, grading, cut and fill, and demolition activities shall be effectively controlled of fugitive dust emissions utilizing application of water or by presoaking.
  - When materials are transported offsite, all material shall be covered, or effectively wetted to limit visible dust emissions, and at least 6 inches of freeboard space from the top of the container shall be maintained.
  - All operations shall limit or expeditiously remove the accumulation of mud or dirt from adjacent public streets at the end of each workday. The use of dry rotary brushes is expressly prohibited except where preceded or accompanied by sufficient wetting to limit the visible dust emissions. Use of blower devices is expressly forbidden.
  - Following the addition of materials to, or the removal of materials from, the surface of outdoor storage piles, said piles shall be effectively stabilized of fugitive dust emissions utilizing sufficient water or chemical stabilizer/suppressant.
  - Within urban areas, trackout shall be immediately removed when it extends 50 or more feet from the site and at the end of each workday.
  - Any site with 150 or more vehicle trips per day shall prevent carryout and trackout.
- *SJVAPCD Enhanced Control Measures* (also applies when required to mitigate significant PM10 impacts)
  - Traffic speeds on unpaved roads shall be limited to 15 mph.
  - Sandbags or other erosion control measures shall be installed to prevent silt runoff to public roadways from sites with a slope greater than 1 percent.
- *SJVAPCD Additional Control Measures* (also applies to construction sites that are large in area, located near sensitive receptors, or which for any other reason warrant additional emissions reductions)

  - Wheel washers shall be installed for all exiting trucks, or all trucks and equipment leaving the site shall be washed off.
  - Wind breaks shall be installed at windward side(s) of construction areas.
  - Excavation and grading activity shall be suspended when winds exceed 20 mph and, regardless of windspeed, an owner/operator must comply with Regulation VIII's 20 percent opacity limitation.
  - The area subject to excavation, grading, and other construction activity at any one time shall be limited.
- SJVAPCD Rule 9510, Indirect Source Review, Section 6.1, Construction Equipment Emissions (applies to any project subject to discretionary approval by a public agency that ultimately results in the construction of a new building, facility, or structure or reconstruction of a building, facility, or structure for the purpose of increasing capacity or activity and also involving 9,000 square feet of space).
- 6.1.1: The exhaust emissions for construction equipment greater than fifty (50) horsepower used or associated with the development project shall be reduced by the following amounts from the statewide average as estimated by the ARB:
  - 6.1.1.1: 20% of the total NO_X emissions, and
  - 6.1.1.2: 45% of the total PM10 exhaust emissions.
- 6.1.2: An applicant may reduce construction emissions on-site by using less- polluting construction equipment, which can be achieved by utilizing add-on controls cleaner fuels, or newer lower emitting equipment.
- 6.3: The requirements listed in Section 6.1 above can be met through any combination of on-site emission reduction measures or off-site fees.

Siting Facilities to Avoid Prime Farmland

Measure 4.13-2: The SFPUC will avoid areas identified as Prime Farmland, Unique Farmland, or Farmland of Statewide Importance in the siting of facilities for the 40-mgd

Treated Water project (SV-3), Treated Water Reservoirs project (SV-5), and ancillary power supply facilities for the SJPL System project (SJ-3). If avoidance is not feasible, the SFPUC will adopt a permanent set-aside for an equivalent acreage of similarly-valued farmland in the area

Measure 4.15-2: Incorporation of Energy Efficiency Measures

Measure 4.15-2: Consistent with the Energy Action Plan II priorities for reducing energy usage, the SFPUC will ensure that energy efficient equipment is used in all WSIP projects. A repair and maintenance plan will also be prepared for each facility to minimize power use. The potential for use of renewable energy resources (such as solar power) at facility sites will be evaluated during project-specific design.

Standard Construction Measures for Noise Controls

Noise: The contractor will comply with local noise ordinances regulating construction noise to the extent feasible, and will undertake efforts to minimize any noise disruption to nearby neighbors and sensitive receptors during construction.

H.4 References Cited

San Francisco Public Utilities Commission (SFPUC). 2008. *Water System Improvement Program Final Program EIR*. Chapter 6, Mitigation Measures. Available: http://www.sf-planning.org/index.aspx?page=1829. Accessed: May 9, 2016.

Attachment 2

Annual Delta Diversion—Environmental Issues

1.0 WS3-1 ANNUAL DELTA DIVERSION – ENVIRONMENTAL ISSUES

Environmental issues associated with construction of the Delta Diversion are discussed below. This analysis assumes that water is taken from the State Water Project, although issues associated with taking water from the Central Valley Project at the Delta-Mendota Canal would be similar. The list of environmental issues was based on the standard CEQA checklist used for Initial Studies, and each issue is discussed, along with mitigation opportunities.

Delta Diversion			
Topic	**Potential Effects**	**Mitigation Opportunities**	**Comments / References**
Aesthetics	**Intake** The intake and pumping plant would be located where the San Joaquin Pipeline crosses the California Aqueduct. The site would be visible from Blewett Road, which is not designated as a scenic route. The pumping plant would be located in a vacant field west of the aqueduct. Neither facility is expected to degrade the visual character of the area. **Pipeline** Once construction is completed the buried pipeline would have no visual effects. **Treatment Plant** The treatment plant would be visually compatible with existing facilities at the Tesla Portal and would not alter the aesthetics of the site.	Design facility to blend with surrounding land uses. Use appropriate architectural treatment and landscaping.	Because the SJPL crosses over the aqueduct, views at the site are already dominated by water supply facilities, and addition of additional structures would not result in a substantial change of the character of the site. www.dot.ca.gov/hq/LandArch/scenic_highways/index.htm
Agriculture	**Intake** The pumping plant would be constructed on vacant agricultural land adjacent to the aqueduct. This would likely require acquisition of land outside the existing easement, but this land is not currently cultivated. **Pipeline** The pipeline would be located in the existing Hetch-Hetchy right-of-way, which crosses agricultural lands, but construction would take place in existing easements. **Treatment Plant** It should be possible to construct the treatment facility entirely within the lands owned by the City at the Tesla Portal.	Construct facilities in such a manner as to minimize any minor disruption to existing agricultural operations.	

Delta Diversion			
Topic	**Potential Effects**	**Mitigation Opportunities**	**Comments / References**
Air Quality	Construction of all facilities would result in short-term generation of dust (PM_{10}). **Intake and Treatment Plant** Operation would result in indirect impacts associated with generating energy for the pumping plant and treatment facility **Pipeline** No operational impacts expected.	Comply with air district regulations. Control dust from construction. Minimize energy consumption.	The San Joaquin Valley Air Basin is currently not in compliance with all federal and state air quality standards, and is designated "serious non-attainment" for PM_{10} (Hsiao et al. 2004).
Biological Resources (Aquatic)	**Intake** Because water would be taken from the aqueduct, fisheries impacts would be avoided. **Pipeline** The pipeline would not require any river crossings. **Treatment Plant** No construction or operational impacts expected.	Mitigation for fisheries impacts would not be necessary for this alternative.	

Delta Diversion			
Topic	**Potential Effects**	**Mitigation Opportunities**	**Comments / References**
Biological Resources (Terrestrial)	Project facilities are located in agricultural lands and ruderal/grassland habitat, which provide habitat for the following species: • Swainson's hawk • California tiger salamander • Burrowing owl • San Joaquin kit fox • California red-legged frog	Conduct preconstruction surveys to verify presence or absence of species. Avoid impacts to special status species to the extent feasible. Specific measures include: • Implement mitigation in accordance with the Programmatic Biological Opinion for construction impacts to the California red-legged frog, which would also afford protection for western pond turtle. • Protect California tiger salamander by avoiding aestivation sites or moving aestivation burrows that cannot be avoided; use drift fences and pitfall traps to keep salamanders out of construction areas. • Avoid construction within ¼ mile of Swainson's hawk nests during nesting season (Mar 1 – Sept 15) • Avoid construction within 300 feet of other raptor nests during breeding season (Mar 1 – Jul 30) • Avoid occupied burrowing owl burrows or relocate the owls before the nesting season (relocation can take place from Aug. to Feb.) • Avoid construction disturbance to active kit fox dens, and employ measures to avoid accidental entrapment of kit fox or other animals during construction.	Mapping of habitats by Hsiao et al. (2004), which also has additional information about species of concern. Additional details regarding standard mitigation can be found in Hsiao et al. (2004)
Biological Resources (Wetlands)	All facilities have the potential to affect wetlands and waters of the U.S. The acreage affected would determine whether the project is eligible for a Nationwide permit or whether an individual permit would be required.	Wetlands must be avoided to the extent feasible. Where wetlands cannot be avoided minimize impacts and provide compensation for any unavoidable impacts. Mitigation ratios would be determined by the Army Corps of Engineers with consultation with USFWS.	

Delta Diversion			
Topic	**Potential Effects**	**Mitigation Opportunities**	**Comments / References**
Cultural Resources	Because most of the facilities would be constructed in existing easements or at existing disturbed sites, the potential to disturb cultural resources is limited. However there is the possibility of encountering previously undiscovered resources during construction.	Complete cultural resource surveys before construction, and avoid any identified resources to the extent feasible. If previously undiscovered resources are encountered during construction stop work and have a qualified archaeologist evaluate the resources and conduct data recovery, as necessary.	
Geology and Soils	Section 5.1.4 discusses geologic and geotechnical issues associated with siting of the project facilities. The potential impacts are summarized here. None of the project facilities would be subject to surface fault rupture hazards, but facilities would be subject to groundshaking. Because there are no river crossings, liquefaction potential would be reduced, but would still need to be evaluated. The project area is generally level and not subject to landslide hazards.	Conduct geotechnical studies (as described in Section 5.1.4) to characterize potential geologic and seismic hazards and to develop appropriate design measures. Design to meet standards in the Uniform Building Code.	
Hazards and Hazardous Materials	**Intake** No hazardous materials sites are believed to be present at the intake. **Pipeline** The pipeline alignment crosses one historic leaking underground storage tank sites. **Treatment Plant** Delivery, storage and use of chemicals at the treatment plant could increase the risk of accidents.	If any contaminated soils or water are encountered during construction, use proper excavation and disposal methods per local, county and state regulations. Prepare an HMMP per county and state requirements, comply with regulations concerning the use, storage and handling of hazardous materials.	Hsiao et al. (2004) contains a map of identified sites.
Hydrology and Water Quality	Operation of the project would not be expected to have adverse effects on water quality. Construction of all elements of the project would have the potential to have adverse short-term effects on quality of storm water runoff. Impacts on hydrology of the Delta and rivers feeding the Delta are unknown and would depending on the location of the seller and conditions of the sale. A detailed evaluation of hydrologic effects would be needed.	Do construction in accordance with a Storm Water Pollution Prevention Plan, which minimizes impacts to storm water runoff.	

Delta Diversion			
Topic	**Potential Effects**	**Mitigation Opportunities**	**Comments / References**
Land Use and Planning	**Intake** The intake and pumping station are in an agricultural area. **Pipeline** The pipeline crosses large areas of agricultural land but would be located primarily within the existing easement for the SJPL. **Treatment Plant** Addition of new facilities within the Tesla Portal site would be consistent with existing uses.	Comply with adopted plans, policies and regulations. Locate facilities consistent with land use and zoning designations.	
Mineral Resources	None of the facilities would be expected to interfere with extraction of mineral resources. Facilities would be located within existing easements or public facilities sites.	No mitigation is expected to be required.	
Noise	**Intake** The intake and pumping station do not appear to have nearby sensitive receptors. **Pipeline** Sensitive receptors include nine residences east of Tesla Portal subject that would be to peak construction noise levels above 69 dBA with controls. **Treatment Plant** There appear to be no receptors close enough to be affected by construction or operational noise.	Construction noise impacts are minimized by the short-term duration of exposure (less than two weeks at any given receptor along the pipeline). Limit construction to daytime hours, and implement noise controls. To mitigate for operational noise use mufflers on equipment and install noise attenuation where applicable. Design facilities to meet applicable noise standards of affected jurisdictions.	Hsiao et al. (2004) identify receptors along the SJPL. Detailed noise control measures are presented there.
Population and Housing	The facilities are an element of the Water Supply Improvement Program, one of whose purposes is to meet "customer purchase requests through the years 2030, which increase by 35 mgd to 300 mgd over the current mgd, requiring an increase in average annual water delivery of 25 mgd from the regional water system. " There is no proposal to expand the service area of the SFPUC, but the increase in water supply would meet the needs of planned growth within the current service area. The effects of this alternative would be the same as other alternatives.	Planned growth in the service area would be subject to growth management provisions of applicable general plans.	City of San Francisco 2005 (Notice of Preparation for Water Supply Improvement Program).

Delta Diversion			
Topic	**Potential Effects**	**Mitigation Opportunities**	**Comments / References**
Public Services	None of the facilities would be expected to require new or altered police, fire, schools or road maintenance services.	Coordinate construction with police and fire departments to ensure that emergency access is available at all times.	
Recreation	**Intake** Intake construction would take place at an existing public facilities site, and is thus not expected to interfere with recreation. **Pipeline** Construction would take place in public right-of-ways and easements and is thus generally not expected to interfere with recreation. However, jacking pits for the I-580 crossing would need to be located on a private golf course. **Treatment Plant** Construction would take place at an existing public facilities site, and is thus not expected to interfere with recreation.	Pipeline construction would take place within an existing easement at the golf course. Coordinate construction with the golf course operators.	
Transportation /Traffic	**Pipeline** Pipeline construction would take place in the existing SJPL easement, requiring crossing of Interstate 580. **Intake and Treatment Plant** Traffic disruption during construction would be limited to construction trucks on local roads, and would be minimal.	Prepare traffic plans for all construction within roadways. Minimize disruption at I-580 crossing by using bore-and-jack or other tunneling techniques.	
Utilities and Service Systems	**Intake** The pumping plant would require electrical service, but no other utility requirements are expected. **Pipeline** No utility requirements are expected. **Treatment Plant** The treatment plant and pump station at the Tesla Portal would require additional electrical service at that site. No other new utilities are expected to be required at the site.	Coordinate electrical needs with service providers.	

REFERENCES

Caltrans, 2005 Scenic Highways website, Accessed November 4, 2005. www.dot.ca.gov/hq/LandArch/scenic_highways/index.htm

City of San Francisco. 2005. Notice of Preparation for Water Supply Improvement Program, September 6, 2005.

Hsiao, Joyce, Barbara Leitner, Valerie Geier and Mary McDonald. 2004. Technical Memorandum – San Joaquin Pipeline No. 4-Environmental Considerations, April 9, 2004

National Oceanic and Atmospheric Administration Fisheries Service (National Marine Fisheries Service). 2005a. Endangered and Threatened Species: Designation of Critical Habitat for Seven Evolutionarily Significant Units of Pacific Salmon and Steelhead in California; Final Rule (50 CFR Part 226), September 5, 2005

National Oceanic and Atmospheric Administration Fisheries Service (NOAA Fisheries). 2005b. Central Valley Chinook Salmon Current Stream Habitat Distribution Table. National Oceanic and Atmospheric Administration Fisheries Service, Southwest Regional Office, Long Beach, CA. http://swr.ucsd.edu/hcd/dist2.htm

Attachment 3

Water Supply Desalination—Applicable Mitigation and Construction Measures

Appendix H
Attachment 3

H.1 Introduction

Table H-1 below was modified from Table 6.3, Impact and Mitigation Summary for Facility Construction and Operation of San Joaquin Region Projects, in Section 6.6, Summary Tables of All Impacts and Mitigation Measures of the San Francisco Public Utilities Commission's (SFPUC's) Water System Improvement Program (WSIP) Final Program Environmental Impact Report (PEIR) (SFPUC 2008). In Table H-1, mitigation measures are identified for those impacts that were determined to be potentially significant or significant as a result of constructing and operating an advanced disinfection facility as part of the WSIP. In addition, applicable SFPUC Construction Measures are also identified. Where no mitigation or construction measures are noted, impacts were determined to be less than significant, and therefore would not require mitigation.

The WSIP advanced disinfection project would provide for the planning, design, and construction of a new advanced disinfection facility for the Hetch Hetchy water supply to comply with the new federal drinking water regulatory requirements contained in the Long Term 2 Enhanced Surface Water Treatment Rule. The types of impacts, mitigation measures and standard construction measures for minimizing impacts identified in Table H-1 are relevant or applicable to the construction of a desalination plant on Mallard Slough (discussed in Chapter 16, *Evaluation of Other Indirect and Additional Actions,* of this recirculated SED), as part of the Bay Area Regional Desalination Plant (BARDP). The conceptual analysis of the BARDP in the WSIP PEIR indicates that the programmatic impact analysis for the WSIP program includes impact analysis and mitigation measures for the construction and operation of generic facility types, including pipelines, pump stations, and treatment facilities and that much of this information is applicable to the regional desalination plant and associated facilities. As such, impacts that are likely not to occur and mitigation measures that would not be needed during construction and operation of the desalination plant at Mallard Slough and associated facilities were not included in Table H-1.

The desalination plant and associated facilities could require mitigation measures not identified in the table below which would be determined during project-level environmental review when more detailed siting, design, construction and operation information is available. For example, potentially significant impacts on water quality and aquatic resources could occur due to disposal of brine concentrate, a waste product from the desalination process. However, the WSIP PEIR did not identify potential mitigation for this type of possible water quality impact because the BARDP was in the conceptual planning phase.

Narrative descriptions of the SFPUC Construction Measures and mitigation measures that could be applied to reduce construction- and operation-related impacts are provided in Sections H.2 and H.3, respectively.

Table H-1. Mitigation Measures and San Francisco Public Utility Commission's Construction Measures for the Water System Improvement Program's Advanced Disinfection Project

PEIR Mitigation Measures	SFPUC Construction Measures
4.3 Land Use and Visual Quality	
Impact 4.3-1: Temporary disruption or displacement of existing land uses during construction	
None required	No. 1: Neighborhood Notice No. 3: On-Site Air and Water Quality Measures during Construction No. 5: Traffic No. 6: Noise No. 10: Project Site
Impact 4.3-2: Permanent displacement or long-term disruption of existing land uses	
None required	
Impact 4.3-3: Temporary construction impacts on scenic vistas or visual character	
No. 10: Project Site	
Impact 4.3-4: Permanent adverse impacts on scenic vistas or visual character	
4.3-4a: Architectural Design 4.3-4b: Landscaping Plans 4.3-4c: Landscape Screens 4.3-4d: Minimize Tree Removal	None applicable
Impact 4.3-5: New permanent sources of light glare	
4.3-5: Reduce Lighting Effects	None applicable
4.4 Geology, Soils, and Seismicity	
Impact 4.4-1: Slope instability during construction	
None required	No. 2: Seismic and Geotechnical Studies

PEIR Mitigation Measures	SFPUC Construction Measures
Impact 4.4-2: Erosion during construction	
None required	No. 3: On-Site Air and Water Quality Measures during Construction
Impact 4.4-3: Substantial alteration of topography	
None required	No. 10: Project Site
Impact 4.4-4: Squeezing ground and subsidence during tunneling	
N/A	None applicable
Impact 4.4-5: Surface fault rupture	
None required	No. 2: Seismic and Geotechnical Studies
Impact 4.4-6: Seismically induced groundshaking	
None required	No. 2: Seismic and Geotechnical Studies
Impact 4.4-7: Seismically induced ground failure, including liquefaction and settlement	
None required	No. 2: Seismic and Geotechnical Studies
Impact 4.4-8: Seismically induced landslides or other slope failures	
None required	No. 2: Seismic and Geotechnical Studies
Impact 4.4-9: Expansive or corrosive soils	
4.4-9: Characterize Extent of Expansive and Corrosive Soil	No. 2: Seismic and Geotechnical Studies

PEIR Mitigation Measures	SFPUC Construction Measures
4.5 Surface Water Hydrology and Water Quality	
Impact 4.5-1: Degradation of water bodies as a result of erosion and sedimentation or a hazardous materials release during construction	
None required	No. 3: On-Site Air and Water Quality Measures During Construction
Impact 4.5-2: Depletion of groundwater resources	
None required	None applicable
Impact 4.5-3a: Degradation of water quality due to construction dewatering discharges	
None required	No. 4: Groundwater
Impact 4.5-3b: Degradation of water quality due to construction-related discharges of treated water	
None required	None applicable
Impact 4.5-4: Flooding and water quality impacts associated with impeding or redirecting flood flows	
N/A	None applicable
Impact 4.5-5: Degradation of water quality and increased flows due to discharges to surface water during operation	
N/A	None applicable
Impact 4.5-6: Degradation of water quality as a result of alteration of drainage patterns or an increase in impervious surfaces	
None required	No. 10: Project Site
4.6 Biological Resources	
Impact 4.6-1: Impacts on wetlands and aquatic resources	
4.6-1a: Wetlands Assessment 4.6-1b: Compensation for Wetlands and Other Biological Resources	No. 8: Biological Resources
Impact 4.6-2: Impact to sensitive habitats, common habitats, and heritage trees	
4.6-2: Habitat Restoration/Tree Replacement Biological Resources Measure 4.6-1b	No. 8: Biological Resources

PEIR Mitigation Measures	SFPUC Construction Measures
Impact 4.6-3: Impact on key special-status species – direct mortality and/or habitat effects	
4.6-3a: Protection Measures During Construction for Key Special-Status Species and Other Species of Concern 4.6-3b: Standard Mitigation Measures for Key Special-Status Plants and Animals Biological Resources Measure 4.6-1b	No. 8: Biological Resources
Impact 4.6-4: Water discharge effects on riparian and/or aquatic resources	
None required	None applicable
Impact 4.6-5: Conflict with adopted conservation plans or other approved biological resources plans	
N/A	None applicable
4.7 Cultural Resources	
Impact 4.7-1: Impacts on paleontological resources	
4.7-1: Suspend Construction Work if Paleontological Resource is Identified	No. 9: Cultural Resources
Impact 4.7-2: Impacts on archaeological resources	
4.7-2a: Archaeological Testing, Monitoring, and Treatment of Human Remains 4.7-2b: Accidental Discovery Measures	No. 9: Cultural Resources
Impact 4.7-3: Impacts on historical significance of a historic district or a contributor to a historic district	
4.7-3: Protection of Historic Districts Cultural Resources Measures 4.7-4a thru 4.7-4f	None applicable

PEIR Mitigation Measures	SFPUC Construction Measures
Impact 4.7-4: Impacts on the historical significance of individual facilities resulting from demolition or alteration	
4.7-4a: Alternatives Identification and Resource Relocation 4.7-4b: Historical Resources Documentation 4.7-4c: Secretary of the Interior's Standards for Treatment of Historic Properties 4.7-4d: Historic Resources Survey and Redesign 4.7-4e: Historic Resources Protection Plan 4.7-4f: Pre-construction Surveys and Vibration Monitoring	No. 9: Cultural Resources
Impact 4.7-5: Impacts on adjacent historic architectural resources	
None required	No. 9: Cultural Resources
4.8 Traffic, Transportation, and Circulation	
Impact 4.8-1: Temporary reduction in roadway capacity and increased traffic delays	
None required	No. 5: Traffic
Impact 4.8-2: Short-term traffic increases on roadways	
Traffic, Transportation, and Circulation Measure 4.8-1a Traffic, Transportation, and Circulation Measure 4.8-1b	No. 5: Traffic
Impact 4.8-3: Impaired access to adjacent roadways and land uses	
None required	No. 5: Traffic
Impact 4.8-4: Temporary displacement of on-street parking	
None required	No. 5: Traffic
Impact 4.8-5: Increased traffic safety hazards during construction	
Traffic, Transportation, and Circulation Measure 4.8-1a	No. 5: Traffic
Impact 4.8-6: Long-term traffic increases during facility operation	
None applicable. None required	None applicable

PEIR Mitigation Measures	SFPUC Construction Measures
4.9 Air Quality	
Impact 4.9-1: Construction emissions of criteria pollutants	
4.9-1a: SJVAPCD Dust Control Measures 4.9-1b: SJVAPCD Exhaust Control Measures	No. 3: On-Site Air and Water Quality Measures during Construction
Impact 4.9-2: Exposure to diesel particulate matter during construction	
None required	None applicable
Impact 4.9-3: Exposure to emissions (possibly including asbestos) from tunneling	
N/A	None applicable
Impact 4.9-4: Air pollutant emissions during project operation	
None required	None applicable
Impact 4.9-5: Odors generated during project operation	
None required	None applicable
Impact 4.9-6: Secondary emissions at power plants	
None required	None applicable
Impact 4.9-7: Conflict with implementation of applicable regional air quality plans addressing criteria air pollutants and state goals for reducing GHG emissions	
N/A	None applicable
4.10 Noise and Vibration	
Impact 4.10-1: Disturbance from temporary construction-related noise increases (PSU)	
4.10-1a: Noise Controls 4.10-1b: Vacate SFPUC Caretaker's Residence at Tesla Portal	No. 6: Noise

PEIR Mitigation Measures	SFPUC Construction Measures
Impact 4.10-2: Temporary noise disturbance along construction haul routes	
4.10-2a: Limit Hourly Truck Volumes 4.10-2b: Restrict Truck Operations	None applicable
Impact 4.10-3: Disturbance due to construction-related vibration (PSU)	
None required	None applicable
Impact 4.10-4: Disturbance due to long-term noise increases	
None required	No. 6: Noise
4.11 Public Services and Utilities	
Impact 4.11-1: Potential temporary damage to or disruption of existing regional or local public utilities	
None required	No. 1: Neighborhood Notice
Impact 4.11-2: Temporary adverse effects on solid waste landfill capacity	
4.11-2: Waste Reduction Measures	None applicable
Impact 4.11-3: Impacts related to compliance with statutes and regulations related to solid waste	
Public Services and Utilities Measure 4.11-2	None applicable
Impact 4.11-4: Impacts related to the relocation of utilities	
Public Services and Utilities Measures 4.11-1a thru 4.11-1h	No. 1: Neighborhood Notice
4.12 Recreational Resources	
Impact 4.12-1: Temporary conflicts with established recreational uses during construction	
N/A	N/A
Impact 4.12-2: Conflicts with established recreational uses due to facility siting and project operation	
N/A	None applicable

PEIR Mitigation Measures	SFPUC Construction Measures
4.13 Agricultural Resources	
Impact 4.13-1: Temporary conflicts with established agricultural resources	
N/A	N/A
Impact 4.13-2: Conversion of farmlands to non-agricultural uses	
N/A	None applicable
4.14 Hazards	
Impact 4.14-1: Potential to encounter hazardous materials in soil and groundwater	
None required	No. 4: Groundwater No. 7: Hazardous Materials
Impact 4.14-2: Exposure to naturally occurring asbestos	
N/A	None applicable
Impact 4.14-3: Risk of fires during construction	
None required	None applicable
Impact 4.14-4: Gassy conditions in tunnels	
N/A	None applicable
Impact 4.14-5: Exposure to hazardous building materials	
N/A	None applicable
Impact 4.14-6: Accidental hazardous materials release from construction equipment	
None required	No. 3: On-site Air and Water Quality Measures During Construction
Impact 4.14-7: Increased use of hazardous materials during operation	
None required	None applicable

PEIR Mitigation Measures	SFPUC Construction Measures
Impact 4.14-8: Emission or use of hazardous materials within ¼ mile of a school	
N/A	None applicable
4.15 Energy	
Impact 4.15-1: Construction-related energy use	
Air Quality Measures 4.9-1b and 4.9-1d	None applicable
Impact 4.15-2: Long-term energy use during operation	
4.15-2: Incorporation of Energy Efficiency Measures	None applicable
N/A = Not applicable because the impact does not apply to the advanced disinfection project PSU = potentially significant and unavoidable impact	

H.2 SFPUC Construction Measures

The SFPUC standard construction measures are aimed at minimizing disruptions to surrounding neighborhoods, resources, and land uses during any SFPUC construction, maintenance, or repair activity or project that requires CEQA review. As required by the SFPUC, each project must include the SFPUC standard construction measures in the construction contract or project implementation procedures, as appropriate. Some of the SFPUC standard construction measures may not be appropriate for certain kinds of projects, but each of the measures must be addressed, either by explaining why the measure is not applicable to the particular site, undertaking the activities listed, or undertaking further investigation and developing a more detailed work plan to address the issue (SFPUC 2008).

1. *Neighborhood Notice:* The SFPUC will provide reasonable advance notification to the businesses, owners and residents of adjacent areas potentially affected by the Water System Improvement Program (WSIP) projects about the nature, extent and duration of construction activities. Interim updates should be provided to such neighbors to inform them of the status of the construction.

   Where schools would be affected, the SFPUC will coordinate with school facility managers to schedule construction for time periods with the least impact on school activities and facilities to ensure student safety and to minimize disruption to educational and recreational uses of the school property.

2. *Seismic and Geotechnical Studies:* Projects will incorporate review of existing information and, if necessary, new engineering investigations to provide relevant geotechnical information about the particular site and project, including a characterization of the soils at the site, and the potential for subsidence and other ground failure. Construction will address any recommendations by such geotechnical reports to ensure seismic stability and reliability of the proposed project. All SFPUC projects must be designed for seismic reliability and minimum potential water loss and property damage. All components of the water system improvement program must be designed to continue water service during a major earthquake.

3. *On-Site Air and Water Quality Measures during Construction:* All construction contractors must take measures to minimize fugitive dust and dirt emissions resulting from the construction, and implement measures to minimize any construction effects on local air and water quality, including a local storm drain system or watercourse. These measures could include preparation of a Stormwater Pollution Prevention Plan (SWPPP), if required by the California Regional Water Quality Control Board. At a minimum, construction contractors should undertake the following measures, as applicable, to minimize any adverse effects:

   - Erosion and sedimentation controls tailored to the site and project
   - Dust control plan
   - Placement of straw rolls around each of the nearby stormwater inlets;
   - Preservation of existing vegetation;
   - Installation of silt fences;
   - Use of wind erosion control (e.g., – geotextile or plastic covers on stockpiled soil);

- Sweeping of nearby streets at least once a day; and/or;
- Stabilization of site ingress/egress locations to minimize erosion.
- Spraying the disturbed areas of the site, or any stockpiled soil, with water to minimize fugitive dust emissions.

4. *Groundwater:* If groundwater is encountered during any excavation activities, the construction contractor shall prepare a dewatering plan so that water is discharged to the stormwater system in compliance with the local standards and discharge permit requirements.
5. *Traffic:* Each contractor shall prepare a traffic control plan which will minimize the impacts on traffic and on-street parking on any streets affected by construction of the proposed project. As appropriate, SFPUC or the contractor will consult with local traffic and transit agencies.
6. *Noise:* The contractor will comply with local noise ordinances regulating construction noise to the extent feasible, and will undertake efforts to minimize any noise disruption to nearby neighbors and sensitive receptors during construction.
7. *Hazardous Materials:* Appropriate measures will be implemented to characterize and dispose of hazardous materials should they be encountered during excavation and construction. Contract specifications will mandate full compliance will all applicable local, state and federal regulations related to the identification, transportation and disposal of hazardous materials/soils. As necessary, a spill prevention and countermeasure plan will be prepared.

   A qualified environmental professional will conduct any necessary site assessment. The site assessment would include a regulatory database review to identify permitted hazardous materials and environmental cases in the vicinity of each project no more than three months before construction, and a review of appropriate standard information sources to determine the potential for soil or groundwater contamination to occur. Follow-up sampling would be conducted as necessary to characterize soil and groundwater quality prior to construction and, if needed, site investigations or remedial activities would be performed in accordance with applicable laws. The environmental professional would prepare a report documenting the activities performed, summarize the results and make recommendations for appropriate handling of any contaminated materials during construction. A contingency plan would also be prepared identifying measures to be taken should unanticipated contamination be identified during construction. Construction contractors will conduct asbestos and lead abatement in accordance with established regulations.
8. *Biological Resources:* As an initial matter, SFPUC project managers will screen the project site and area to determine whether biological resources may be affected by construction activities. In the event further investigation is necessary, the SFPUC will comply with all requirements for investigation, analysis and protection of biological resources. A qualified biologist must conduct any required biological screening survey. The biologist will review standard information sources to determine special status species with the potential to occur on the project site. The biologist would carry out a site survey by walking or driving over the project site, as appropriate, to note the general resources and whether any habitat for special-status species is present. The biologist would then document the survey with a brief letter report or memo, setting forth the date of the visit, whether habitat for special-status species is present, providing a map or description showing where sensitive areas exist within the site, and identifying any appropriate avoidance measures.

9. *Cultural Resources:* As an initial matter, SFPUC project managers will screen the project site and area to determine whether cultural resources, including archaeological and other historical resources, may be affected by construction activities. In the event further investigation is necessary, the SFPUC will comply with all requirements for investigation, analysis and protection of cultural resources.

   CEQA considers paleontological resources to be "cultural resources." Any screening for cultural resources would include screening for archaeological, paleontological and historic resources. For projects requiring excavation, deep grading, well drilling or tunneling into geologic material at sites identified as having high potential for encountering paleontological resources, a state-registered professional geologist or qualified professional paleontologist will conduct a site-specific evaluation of the paleontological sensitivity. The assessment will include a report of findings for the SFPUC.

   A qualified archaeologist, historian or paleontologist will conduct all cultural resources survey and screening work. Screening surveys for cultural resources would include a cultural resources records search to be conducted at the appropriate office member of the California Historical Resources Information System. A field survey will be conducted if determined necessary after the cultural resources records search. Any impacts on identified cultural resources will be avoided to the extent feasible.

   Any initial historic resource screening will identify historic resources on the project site as well as adjacent to the project site.

   It is possible that project work may affect accidentally discovered buried or submerged cultural resources. Any contractor must distribute the Planning Department archaeological resource "ALERT" sheet to any person involved in soil-disturbing activities. If there is any indication of an archaeological or a paleontological resource during the soils disturbing activity of the project, the contractor shall immediately suspend any soils disturbing activities in the area and notify the SFPUC of such discovery. The SFPUC will then work with the Planning Department's Environmental Review Officer to determine what additional measures should be implemented, based on reports from a qualified archaeological or paleontological consultant.

10. *Project Site:* The SFPUC will conduct construction activities on SFPUC-owned lands to the extent feasible and minimize the need for use of non-SFPUC-owned land during construction. In cases where construction easement or staging areas are needed on non- SFPUC land, the SFPUC will restore these areas to their prior condition so that the owner may return them to their prior use, unless otherwise arranged with the property owner. The site will be maintained to be clean and orderly. Construction staging areas will be sited away from public view where possible. Nighttime lighting will be directed away from residential areas.

    Upon project completion, the construction contractor will return the SFPUC project site to its general condition before construction, including re-grading of the site and re-vegetation of disturbed areas.

H.3 Description of Mitigation Measures

This section provides a description of all mitigation measures identified in Table H-1 for potentially significant and mitigable impacts, by resource, as presented in Chapter 6, Section 6.3 of the WSIP PEIR.

H.3.1 Land Use and Visual Resources

Architectural Design

Measure 4.3-4a: The design of permanent new, above-ground facilities will consider the existing visual character of the site and surrounding area, including the visibility of facilities and related structures from scenic highways and scenic roads. Structures will be designed to incorporate building features and design elements that are compatible with the surroundings.

Landscaping Plans

Measure 4.3-4b: The SFPUC will prepare and implement landscaping plans to restore project sites to their pre-construction condition such that short-term construction disturbance does not result in long-term visual impacts. To retain the existing visual character of the site and surrounding area, disturbed areas will be recontoured and revegetated and recontoured to pre-construction condition. Landscape vegetation will include noninvasive, and where possible, native grasses, shrubs, and trees similar to existing landscaping. The SFPUC will monitor landscape plantings annually for five years after project completion to ensure that sufficient ground coverage has developed and will implement additional measures, such as replanting or modifying irrigation systems, as determined necessary.

Landscape Screens

Measure 4.3-4c: In addition to revegetation of disturbed areas, the landscaping plans will include new plantings and landscape berms to screen views of new structures and equipment from scenic roads to the extent possible, provided that such landscaping does not affect security of SFPUC facilities.

Minimize Tree Removal

Measure 4.3-4d: The SFPUC will minimize or avoid the removal of existing trees that currently screen existing and proposed sites of WSIP facilities by modifying the proposed alignments of new temporary and permanent roads to the extent feasible. The SFPUC will consult with a qualified arborist regarding the minimum buffer zones required to prevent root damage to remaining trees and to provide the SFPUC with any necessary maintenance requirements for remaining trees. Also, the arborist will develop and assist the SFPUC in implementing an appropriate landscaping plan (see Measure 4.3-4b, above), including tree replacement, that is compatible with project operation and maintenance.

Reduce Lighting Effects

Measure 4.3-5: To the extent possible, all permanent exterior lighting will incorporate cutoff shields and non-glare fixture design. All permanent exterior lighting will be directed onsite and downward. In addition, new lighting will be oriented to ensure that no light source is directly visible from neighboring residential areas and will be installed with motion-sensor activation. In addition, highly reflective building materials and/or finishes will not be used in the designs for proposed structures, including fencing and light poles. Vegetation selected for landscaping will be selected, placed and maintained to minimize offsite light and glare in surrounding areas as part of the landscaping plans described in Measure 4.3-4b.

H.3.2 Geology, Soils and Seismicity

Characterize Extent of Expansive and Corrosive Soil

Measure 4.4-9: If the screening analysis conducted in accordance with SFPUC Construction Measure #2 identifies a potential for expansive or corrosive soils, the site- specific geotechnical investigation will include a characterization of the presence and extent of expansive and corrosive soil at the project facility site. The results and recommendations of the investigation will be incorporated into the final project design.

H.3.3 Biological Resources

Wetlands Assessment

Measure 4.6-1a: As part of project-specific CEQA review, a qualified wetland scientist will review project plans, air photos, and topographic maps and conduct a site visit to determine whether wetlands are present and could be affected by the project. If the review shows that wetlands could be affected, the wetland scientist will perform a formal wetland delineation and develop mitigation as per Measure 4.6-1b, below.

Compensation for Wetlands and Other Biological Resources

Measure 4.6-1b: If the wetland delineation indicates that the WSIP project will affect jurisdictional wetlands or aquatic resources, then, in accordance with state and federal permit requirements, the SFPUC will avoid and minimize direct and indirect impacts such as erosion and sedimentation, alteration of hydrology, and degradation of water quality. As a first priority, the SFPUC will implement (1) avoidance measures. For unavoidable impacts, the SFPUC will implement (2) minimization of unavoidable impacts, (3) restoration procedures, and (4) compensatory creation or enhancement to ensure no net loss of wetland extent or function.

In addition to wetlands, the SFPUC will compensate for sensitive riparian and upland habitats and habitats which support key special-status species or other species of concern lost as a result of WSIP project construction and operation. Similar habitat will be identified, protected, restored, enhanced, created and managed off-site[1] to ensure no net loss of habitat extent or function. For each WSIP project, a qualified biologist will quantify the magnitude and extent of impacts to wetlands, sensitive habitats, and key special-status species and other species of concern, and the SFPUC will develop and implement restoration and/or compensation plans that meet the appropriate regulatory requirements and permit conditions with respect to restoration and/or compensation ratios. Compensation ratios typically range from a minimum of 1:1 for common habitats to 2:1 or higher for rare and sensitive habitats. If individual project requirements of the RWQCB, CDFG, or USFWS differ somewhat from these ratios, they are still intended to achieve the same purpose of full restoration and/or compensation, to mitigate project impacts to less-than- significant levels, and to ensure no net reduction in the populations of any species listed as threatened or endangered by the state or federal resource agencies.

[1] Off-site means the compensatory action is located other than within the project construction footprint, but could be on lands already under SFPUC ownership. Measure 4.6-2 addresses compensatory actions to be taken within the construction footprint.

The SFPUC will obtain required permits for each project and comply with applicable environmental regulations addressing sensitive habitats and species. Compensatory lands, including those restored or enhanced as well as those acquired or designated as protected as part of program or project mitigation, will be established in perpetuity with a commitment that such lands will not be used for any purpose that conflicts with the primary purpose of maintaining intact wildlife and plant habitat.

One alternative for implementing off-site habitat compensation is the Habitat Reserve Program (HRP) currently being developed by the SFPUC. The purpose of the HRP is to provide a comprehensive, coordinated approach to mitigation and related regulatory compliance for WSIP projects. This related SFPUC project is described further in Chapter 3.0, Section 3.11. Under the proposed HRP, the SFPUC would proceed as soon as possible with securing (through designation, management agreement, conservation easement, or acquisition of fee title) and improving lands to be used for habitat compensation so that mitigation is underway before or concurrent with habitat loss related to WSIP project activities, further ensuring no net loss of resources. CEQA environmental review for the proposed HRP will commence in 2007 and is targeted for implementation as soon as possible thereafter. Once the HRP is approved and implemented, the SFPUC will use this as one vehicle or method for implementing the mitigation requirements for individual WSIP projects. Otherwise, where appropriate and necessary, the SFPUC will develop and implement appropriate habitat compensation mitigation for individual WSIP projects.

Habitat Restoration/Tree Replacement

Measure 4.6-2: If the biological screening survey identifies sensitive habitats or heritage trees, the following measures, as modified and applied to WSIP projects, will be implemented:

- Temporarily-impacted sensitive habitats (natural communities identified as sensitive by CDFG, and USFWS-designated critical habitat) would be restored to their pre- project condition.
- If specific trees to be removed are designated as heritage trees (or similar local designation), then SFPUC will replace the trees, consistent with requirements in local ordinances. If such heritage trees occur near extensive areas of sensitive habitats, locally collected, native species will be used as replacement trees where possible.
- Where possible, the loss of sensitive habitats will be minimized by coordinating WSIP projects to make repeated use of staging/construction areas and access roads. For example, tunnel spoils could be considered for borrow material for other projects.

Protection Measures during Construction for Key Special-Status Species and Other Species of Concern

Measure 4.6-3a: The following general practice measures, as modified and applied to the WSIP projects, will be implemented if the initial biological screening survey (SFPUC Construction Measure #8) indicates the potential for the presence of key special-status species and other species of concern:

- Preconstruction surveys for key special-status species and other species of concern will be conducted by a qualified biologist to verify their presence or absence. Surveys will occur during the portion of the species' life cycle when the species is most likely to be identified within the appropriate habitat. Key special-status species and other species of concern will be avoided during construction when possible.

- A worker awareness program (environmental education) will be developed and implemented to inform project workers of their responsibilities in regards to sensitive biological resources.
- An environmental inspector will be appointed to serve as a contact for issues that may arise concerning implementation of mitigation measures, and to document and report on adherence to these measures during construction.
- Loss of habitat will be minimized through the following measures: (1) the number and size of access routes and staging areas and the total area of the project activity will be limited to the minimum necessary to achieve the project goal; (2) the introduction or spread of invasive non-native plant species and plant pathogens will be avoided or minimized by developing and implementing a weed control plan; and (3) all areas temporarily disturbed by construction will be revegetated to pre-project or native conditions, as specified in project-specific revegetation plans.

Standard Mitigation Measures for Specific Plants and Animals

Measure 4.6-3b: Table H-1 identifies the key special-status species mitigation measures that the program analysis indicates would apply to each WSIP project. Measures listed in Table H-1 (listed by species) are generic measures and will be modified to fit site-specific conditions and applied to each WSIP project wherever special-status species could be affected by the projects. Surveys required under Measure 4.6-3a will refine the list of species that could be affected by a project. Table H-1 is intended as the minimum necessary actions. In addition to adopting the generic measures, as more site-specific information is available, project-specific CEQA analysis may identify additional measures for key special-status species and additional measures for other species.

H.3.4 Cultural Resources

Suspend Construction Work if Paleontological Resource is Identified

Measure 4.7-1: This mitigation measure builds on SFPUC Construction Measure # 9 for cultural resources, which requires that construction work will be suspended immediately if there is any indication of a paleontological resource. When a paleontological resource (fossilized invertebrate, vertebrate, plant or micro-fossil) is discovered at any of the project sites, an appointed representative of the SFPUC will notify a qualified paleontologist, who will document the discovery as needed, evaluate the potential resource, and assess the significance of the find under the criteria set forth in Section 15064.5 of the CEQA Guidelines. When a fossil is found during construction, excavations within 50 feet of the find will be temporarily halted or diverted until the discovery is examined by a qualified paleontologist, in accordance with Society of Vertebrate Paleontology standards (SVP 1995, 1996, as cited in SFPUC 2008). The paleontologist will notify the SFPUC to determine procedures to be followed before construction is allowed to resume at the location of the find. If the SFPUC determines that avoidance is not feasible, the paleontologist will prepare an excavation plan for mitigating the effects of the project.

Archaeological Testing, Monitoring, and Treatment of Human Remains

Measure 4.7-2a: SPFUC Construction Measure #9 for cultural resources requires that a pre-construction screening be conducted by a qualified archaeologist. Based on the results of this screening, the Environmental Review Officer (ERO) shall determine if implementation of an archaeological testing or archaeological monitoring program or both is the appropriate strategy for avoidance of potential adverse effects to significant archaeological resource. For those projects that require a federal permit and compliance with the NHPA, Section 106, the ERO will review the SHPO-approved requirements in the permit conditions and consider protective approaches that limit undue duplication of efforts.

Archaeological Testing Program. The archaeological consultant shall prepare and submit to the ERO for review and approval an archaeological testing plan (ATP). The archaeological testing program shall be conducted in accordance with the approved ATP. The ATP shall identify the property types of the expected archaeological resource(s) that potentially could be adversely affected by the proposed project, the testing method to be used, and the locations recommended for testing. The purpose of the archaeological testing program will be to determine to the extent possible the presence or absence of any expected archaeological resources and to identify and to preliminarily evaluate the integrity and significance of the resource.

At the completion of the archaeological testing program, the archaeological consultant shall submit a written report of the findings to the ERO. If based on the archaeological testing program the archaeological consultant finds that significant archaeological resources may be present, the ERO in consultation with the archaeological consultant shall determine if additional measures are warranted. Additional measures that may be undertaken include additional archaeological testing, archaeological monitoring, preparation of an archaeological research design and treatment plan, or an archaeological data recovery program.

Archaeological Monitoring Program. The archaeological consultant shall prepare and submit to the ERO for review and approval an archaeological monitoring plan (AMP). The archaeological monitoring program shall be conducted in accordance with the approved AMP. The AMP shall specify what project activities in areas sensitive for buried resources shall be archaeologically monitored. Project activities that may require monitoring may include the installation of pipelines and crossover facilities and certain soils-altering activities such as grading and access road construction associated with construction or improvement of water storage facilities. The archaeological monitoring program shall include the following:

- All project contractors shall be advised to be on the alert for evidence of the presence of the expected resource(s), of how to identify the evidence of the expected resource(s), and of the appropriate protocol in the event of apparent discovery of an archaeological resource;
- The archaeological monitor(s) shall be present on the project site according to a schedule agreed upon by the archaeological consultant and the ERO until the ERO has, in consultation with project archaeological consultant, determined that project construction activities are unlikely to have effects on significant archaeological deposits;
- The archaeological monitor shall record and be authorized to collect soil samples and artifactual/ecofactual material as warranted for analysis;
- If an intact archaeological deposit is encountered, all soils-disturbing activities within the area specified in the AMP of the deposit shall cease. The archaeological monitor shall be empowered to temporarily redirect demolition/excavation/pile driving/construction activities and equipment until the deposit is evaluated. The archaeological consultant shall immediately notify the ERO of the encountered archaeological deposit. The archaeological consultant shall make a reasonable effort to assess the identity, integrity, and significance of the encountered archaeological deposit, and present the findings of this assessment to the ERO.

Whether or not significant archaeological resources are encountered, the archaeological consultant shall submit a written report of the findings of the monitoring program to the ERO.

Additional Requirements: the following requirements, as applicable, are requisite in implementation of either an archaeological testing or monitoring program.

Archaeological Data Recovery Program. The archaeological data recovery program shall be conducted in accord with an archaeological data recovery plan (ADRP). The archaeological consultant, project sponsor, and ERO shall meet and consult on the scope of the ADRP prior to preparation of a draft ADRP. The archaeological consultant shall submit a draft ADRP to the ERO. The ADRP shall identify how the proposed data recovery program will preserve the significant information the archaeological resource is expected to contain. That is, the ADRP will identify what scientific/historical research questions are applicable to the expected resource, what data classes the resource is expected to possess, and how the expected data classes would address the applicable research questions. Data recovery, in general, should be limited to the portions of the historical property that could be adversely affected by the proposed project. Destructive data recovery methods shall not be applied to portions of the archaeological resources if nondestructive methods are practical.

The scope of the ADRP shall include the following elements:

- Field Methods and Procedures. Descriptions of proposed field strategies, procedures, and operations.
- Cataloguing and Laboratory Analysis. Description of selected cataloguing system and artifact analysis procedures.
- Discard and Deaccession Policy. Description of and rationale for field and post-field discard and deaccession policies.
- Interpretive Program. Consideration of an on-site/off-site public interpretive program during the course of the archaeological data recovery program.
- Security Measures. Recommended security measures to protect the archaeological resource from vandalism, looting, and non-intentionally damaging activities.
- Final Report. Description of proposed report format and distribution of results.
- Curation. Description of the procedures and recommendations for the curation of any recovered data having potential research value, identification of appropriate curation facilities, and a summary of the accession policies of the curation facilities.

Human Remains and Associated or Unassociated Funerary Objects. The treatment of human remains and of associated or unassociated funerary objects discovered during any soils disturbing activity shall comply with applicable State laws. This shall include immediate notification of the coroner of the county within which the project is located and in the event of the coroner's determination that the human remains are Native American remains, notification of the California State Native American Heritage Commission (NAHC) who shall appoint a Most Likely Descendant (MLD) (Pub. Res. Code Sec. 5097.98). The archaeological consultant, project sponsor, and MLD shall make all reasonable efforts to develop an agreement for the treatment of, with appropriate dignity, human remains and associated or unassociated funerary objects (CEQA Guidelines. Sec. 15064.5(d).) The agreement should take into consideration the appropriate excavation, removal, recordation, analysis, custodianship, curation, and final disposition of the human remains and associated or unassociated funerary objects. State law allows 24 hours to reach agreement on these matters. If the MLDs do not agree on the reburial method, the Project will follow Section 5097.98(b) of the California Public resources code which states, "the landowner or his or her authorized representative shall reinter the human remains and items associated with Native American burials with appropriate dignity on the property in a location not subject to further subsurface disturbance."

Final Archaeological Resources Report. The archaeological consultant shall submit a Draft Final Archaeological Resources Report (FARR) to the ERO that evaluates the historical significance of any discovered archaeological resource and describes the archaeological and historical research methods employed in the archaeological testing/monitoring/data recovery program(s) undertaken. Information that may put at risk any archaeological resource shall be provided in a separate removable insert within the final report. Once approved by the ERO, copies of the FARR shall be distributed as follows: the relevant California Historical Resources Information System Information Center shall receive one (1) copy and the ERO shall receive a copy of the transmittal of the FARR to the Information Center. The Major Environmental Analysis division of the Planning Department (MEA) shall receive three copies of the FARR along with copies of any formal site recordation forms (CA DPR 523 series) and/or documentation for evaluation under National Register of Historic Places/California Register of Historical Resources criteria. The SFPUC shall receive copies of the FARR as requested in number. In instances of high public interest in or the high interpretive value of the resource, the ERO may require a different final report content, format, and distribution than that presented above.

Accidental Discovery Measures

Measure 4.7-2b: SFPUC Construction Measure # 9 for cultural resources requires that construction activities be suspended immediately if there is any indication of an archaeological resource.

To avoid any potential adverse effect from the proposed project on accidentally discovered buried or submerged historical resources as defined in CEQA Guidelines Section 15064.5(a)(c), the project sponsor shall distribute the Planning Department archaeological resource "ALERT" sheet to the project prime contractor; to any project subcontractor (including demolition, excavation, grading, foundation, pile driving, etc. firms); or utilities firm involved in soil disturbing activities within the project site. Prior to any soil disturbing activities being undertaken, each contractor is responsible for ensuring that the "ALERT" sheet is circulated to all field personnel including, machine operators, field crew, pile drivers, supervisory personnel, etc. The project sponsor shall provide the Environmental Review Officer (ERO) with a signed affidavit from the responsible parties (prime contractor, subcontractor(s), and utilities firm) to the ERO confirming that all field personnel have received copies of the "ALERT" sheet.

If the ERO determines that an archaeological resource may be present within the project site, the project sponsor shall retain the services of a qualified archaeological consultant. The archaeological consultant shall advise the ERO as to whether the discovery is an archaeological resource, retains sufficient integrity, and is of potential scientific/historical/cultural significance. If an archaeological resource is present, the archaeological consultant shall identify and evaluate the archaeological resource. The archaeological consultant shall make a recommendation as to what action, if any, is warranted. Based on this information, the ERO may require, if warranted, specific additional measures to be implemented by the project sponsor.

Measures might include: preservation in situ of the archaeological resource; an archaeological monitoring program; or an archaeological testing program. If an archaeological monitoring program or archaeological testing program is required, it shall be consistent with the MEA guidelines for such programs. The ERO may also require that the project sponsor immediately implement a site security program if the archaeological resource is at risk from vandalism, looting, or other damaging actions.

The project archaeological consultant shall submit a Final Archaeological Resources Report (FARR) to the ERO that evaluates the historical significance of any discovered archaeological resource and describing the archaeological and historical research methods employed in the archaeological monitoring/data recovery program(s) undertaken. Information that may put at risk any archaeological resource shall be provided in a separate removable insert within the final report. Once approved by the ERO, copies of the FARR shall be distributed as follows: the relevant California Historical Resources Information System Information Center shall receive one (1) copy and the ERO shall receive a copy of the transmittal of the FARR to the Information Center. The MEA shall receive three copies of the FARR along with copies of any formal site recordation forms (CA DPR 523 series) and/or documentation for nomination to the National Register of Historic Places/California Register of Historical Resources. The SFPUC shall receive copies of the FARR as requested in number. In instances of high public interest in or the high interpretive value of the resource, the ERO may require a different final report content, format, and distribution than that presented above.

Protection of Historic Districts

Measure 4.7-3: The city's water system facilities affected by WSIP facility projects will be assessed by a qualified historian for their potential contribution to an historic district, following the guidelines identified under Impact 4.7-3. To qualify as an historic district, each resource within that potential district would need to be reliant upon the other resources within the district to be historically significant. Impacts on one resource within the potential district may or may not affect the others, and this conclusion would determine the ultimate significance of the impact.

If an historic district would be affected by one or more proposed WSIP facility projects, the SFPUC, in consultation with the ERO, will develop mitigation measures for effects with attention to the potential district as a whole, with utmost effort made to maintain the district's function, appearance, cohesive site organization, and ability to convey historic significance. Appropriate measures may also include but not be limited to: refinement of facility sites to minimize effects on district appearance and site organization as well as visual screening efforts to reduce the impact of adding new facilities or otherwise modifying the landscape.

Should an historic district be identified at the project level, it should be recorded as such, using the four National/California Register criteria of significance to explain its historical importance as a cohesive group of resources. The district should be documented by completing the State of California Department of Parks and Recreation 523 forms, using a 523D (District) form as an umbrella record to unify the 523A (Primary Record) and 523B (Building, Structure, Object) forms completed for each individual resource within the potential district, and submitting them to SHPO.

Alternatives Identification and Resource Relocation

Measure 4.7-4a: If a project proposes to demolish or remove a historical resource, including individual historic resources and/or historic districts, the SFPUC will attempt to identify feasible project alternatives that eliminate or reduce the need for demolition or removal to the greatest extent possible. The SFPUC will pursue and implement these project alternatives to the extent feasible, consistent with the goals and objectives of the WSIP.

Relocation of a resource will always be preferable to demolition, although relocation might not mitigate impacts to a less-than-significant level. If preservation of the affected historical resource at the current site is determined to be infeasible, the structure shall, if feasible, be stabilized and relocated to other nearby sites appropriate to their historic setting and general environment. This may not be possible in some cases, like in the replacement of Calaveras Dam (if it were identified as a historical resource for the purposes of CEQA). After relocation, the resource shall be treated according to preservation, rehabilitation, or restoration standards, as appropriate, that follow the Secretary of the Interior's Standards. This will ensure that the building, structure, object, site, or district retains historic integrity and its historic significance (Measure 4.7-4c). If the affected historical resource can neither be preserved at its current site nor moved to an alternative site and is to be demolished, the SFPUC shall consult with local historical societies and governmental agencies regarding salvage of materials from the affected historical resource for public information or reuse in other locations. Demolition may proceed only after any significant historic features or materials have been identified, preserved (as feasible), and their removal completed.

Representative features such as aqueduct/pipe sections, valves subject to replacement, decorative elements, or plaques/inscriptions from buildings or other portions of structures demolished as a part of the WSIP projects could be preserved and displayed. Most of these types of structures are of sufficient size that they would form "monumental" commemorative structures. For example, an original pipeline valve replaced by modern equipment might be mounted and displayed on publicly accessible SFPUC property with informative placards. Such displays, if located in other jurisdictions, might be subject to those jurisdiction's requirements related to public art, safety, and liability considerations.

Historical Resources Documentation

Measure 4.7-4b: Documentation of a historical resource, including resources identified as contributors to a historic district or as individually significant, prior to demolition or removal is a standard mitigation measure. Such documentation is often tied to meeting the documentation standards of the Historic American Buildings Survey/Historic American Engineering Record (HABS/HAER). The publication Recording Historic Structures: Historic American Buildings Survey/Historic American Engineering Record (Burns 1989, as cited in SFPUC 2008, page 6-27) provides four levels of documentation corresponding to the level of importance of the historic resource to be documented. For the purpose of this PEIR, the standards for photography in Documentation Levels III and IV have been modified to allow for the use of digital photographs instead of large-format negatives.

Documentation Level I:

1. Drawings: a full set of measured drawings depicting existing or historic conditions.
2. Photographs: photographs with large-format negatives of exterior and interior views; photocopies with large-format negatives of select existing drawings or historic views where available. Photographs would follow the HABS/HAER Photographic Specifications.
3. Written data: history and description.

Documentation Level II:

1. Drawings: select existing drawings, where available, should be photographed with large-format negatives or photographically reproduced on Mylar.
2. Photographs: photographs with large-format negatives of exterior and interior views, or historic views, where available. Photographs would follow the HABS/HAER Photographic Specifications.
3. Written data: history and description.

Documentation Level III:

1. Drawings: sketch plan.
2. Photographs: digital photographs of exterior and interior views.
3. Written data: architectural data form.

Documentation Level IV:

1. Drawings: sketch plan.
2. Photographs: digital photographs of exterior and interior views.
3. HABS/HAER inventory cards.

Digital photography will follow the standards in the National Register of Historic Places and National Historic Landmarks Survey, Photo Policy Expansion, March 2005 (Table VV). Digital image files would be burned to archival-quality disks, such as the eFilm Archival Gold CD-R or DVD-R; or MAM-A Mitsui Gold Archive CD-R or DVD-R.

The SFPUC will prepare, or retain a consultant to prepare, documentation of historical resources prior to any construction work associated with demolition or removal. The appropriate level of documentation will be selected by a qualified professional who meets the standards for history, architectural history, and/or architecture (as appropriate) set forth by the Secretary of the Interior (Secretary of the Interior's Professional Qualification Standards, 36 CFR 61) in consultation with a preservation specialist assigned by the San Francisco Planning Department and the local jurisdiction if deemed appropriate by the Planning Department. In addition to the four levels of documentation listed above, salvage and/or interpretive display may also be required if determined appropriate. The professional in history, architectural history and/or architecture (as appropriate) will prepare the documentation and submit it for review and approval by the Planning Department's preservation specialist. One set of the documentation will be archived at each of the following repositories: San Francisco Planning Department, SFPUC, the History Room of the San Francisco Public Library and the Water Resources Center Archive at the University of California Berkeley. Additional dissemination of documentation to local historical societies or historic preservation organizations may be appropriate. The San Francisco Planning Department will identify additional appropriate recipients of historical documentation during the project-level analysis.

Secretary of the Interior's Standards for Treatment of Historic Properties

Measure 4.7-4c: Compliance with the Secretary of the Interior's Standards for the Treatment of Historic Properties would reduce potential impacts associated with the alteration or modification of a historical resource (including historic districts and individually eligible resources) to a less-than-significant level. (In accordance with CEQA Section 15064.5(b)(3), a project that follows the

Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for Preserving, Rehabilitating, Restoring, and Reconstructing Historic Buildings or the Secretary of the Interior's Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings is generally considered to have impacts of a less-than-significant level.)

The SFPUC will prepare materials describing and depicting the proposed project, including but not limited to plans, drawings, and photographs of existing conditions (digital, following the standards in Measure 4.7-4a as well as proposed project plans, drawings, specifications, and description). Prepared materials will be submitted to the San Francisco Planning Department. The Planning Department will review the proposed project, for compliance with the Secretary of the Interior's Standards for the Treatment of Historic Properties.

If a project is determined to be inconsistent with the Secretary of the Interior's Standards for the Treatment of Historic Properties, the SFPUC will pursue and implement redesign of the project to the extent feasible, consistent with the goals and objectives of the WSIP, such that consistency with the standards is achieved.

Historic Resources Survey and Redesign

Measure 4.7-4d: The SFPUC will undertake a historic resources survey within a designated area of potential effect that encompasses the proposed project to identify and evaluate potential historical resources, including districts, which may exist within or partially within the project's study area or area of potential effect. The survey will be conducted by a qualified professional who meets the Secretary of the Interior's Professional Qualification Standards for architectural history, history, or architecture (36 CFR 61).

If a survey identifies one or more historical resources in the projects' study area, or area of potential effect (i.e., historically significant resources), the qualified professional will then assess the impact the project may have on those historical resources. If the project will cause a substantial adverse change to a historical resource, the SFPUC will prepare materials describing and depicting the proposed project, including but not limited to plans, drawings, and photographs of existing conditions (digital, following the standards in Measure 4.7-1a) as well proposed project plans, drawings, specifications, and description. Prepared materials will be submitted to the San Francisco Planning Department. The San Francisco Planning Department will assign a preservation specialist to review the proposed project, for compliance with the Secretary of the Interior's Standards for the Treatment of Historic Properties.

If a project is determined to be inconsistent with the Secretary of the Interior's Standards for the Treatment of Historic Properties, the SFPUC will pursue and implement redesign of the project to the extent feasible, consistent with the goals and objectives of the WSIP, such that consistency with the standards is achieved.

Historic Resources Protection Plan

Measure 4.7-4e: A qualified historian will prepare a plan that specifies procedures for protecting historical resources and a monitoring method to be employed by the contractor while working near these resources. At a minimum, the plan will address the operation of construction equipment near adjacent historical resources, storage of construction materials away from adjacent resources, and education/training of construction workers about the significance of the historical resources.

Preconstruction Surveys and Vibration Monitoring

Measure 4.7-4f: If vibration-related impacts could impact historical resources, one or more geotechnical investigations by a California-licensed geotechnical engineer will be included as part of the proposed project. The SFPUC and its contractors will follow the recommendations of the final geotechnical reports regarding any excavation and construction for the project. The SFPUC will ensure that the construction contractor conducts a preconstruction survey of existing conditions and monitors the adjacent buildings for damage during construction, if recommended by the geotechnical engineer. Any preconstruction surveys and construction monitoring would include the services of a professional meeting the Secretary of the Interior's Professional Qualification Standards for architecture.

H.3.5 Traffic, Transportation, and Circulation

Traffic Control Plan Measures

Measure 4.8-1a: SFPUC Construction Measure #5 for traffic requires each contractor to prepare a traffic control plan to minimize traffic and on-street parking impacts on any streets affected by construction of the proposed program. SFPUC and construction contractor(s) will prepare and implement a traffic control plan, and coordinate with Caltrans and local jurisdictions, as appropriate, for affected roadways and intersections. Each project may require the implementation of different measures, depending on the project's site- specific construction details, the characteristics of the transportation network, and daily and peak hour vehicle, pedestrian and bicycle volumes. As applicable, elements of the traffic control plan could include, but are not necessarily limited to, the following:

- Circulation and detour plans will be developed to minimize impacts on local street circulation. Flaggers and/or signage will be used to guide vehicles through and/or around the construction zone.
- Truck routes designated by cities and counties will be identified in the traffic control plan. Haul routes that minimize truck traffic on local roadways and residential streets will be utilized to the extent possible.
- Sufficient staging areas will be provided for trucks accessing construction zones to minimize disruption of access to adjacent land uses, particularly at entries to onsite pipeline construction within residential neighborhoods.
- Access to driveways and private roads will be maintained by using steel trench plates. If access must be restricted for brief periods, property owners will be notified in advance.
- Construction vehicle movement will be controlled and monitored through the enforcement of standard construction specifications by onsite inspectors.
- Along major arterials, truck trips will be scheduled outside of the peak morning and evening commute hours to the extent possible.
- Lane closures will be limited during peak hours to the extent possible. Outside of allowed working hours or when work is not in progress, roads will be restored to normal operations, with all trenches covered with steel plates.

- Where possible, pipeline construction work in roadways will be limited to a width that, at a minimum, maintains alternate one-way traffic flow past the construction zone. Parking may be prohibited if necessary to facilitate construction activities or traffic movement. If the work zone width will not allow a 10-foot-wide paved travel lane, then the road will be closed to through-traffic (except emergency vehicles), and detour signing on alternative access roads will be used.
- Pedestrian and bicycle access and circulation will be maintained during project construction where safe to do so. If construction activities encroach on a bicycle lane, warning signs will be posted that indicate bicycles and vehicles are sharing the lane.
- Detours will be included for bicycles and pedestrians in all areas potentially affected by project construction.
- All equipment and materials will be stored in designated contractor staging areas on or adjacent to the worksite, in such a manner to minimize obstruction of traffic.
- Locations will be identified for parking by construction workers, either within the construction zone or, if necessary, at a nearby location with transport provided between the parking location and the worksite.
- Roadside safety protocols will be implemented. Advance "Road Work Ahead" warning signs and speed control (including signs informing drivers of state-legislated double fines for speed infractions in a construction zone) will be provided to achieve required speed reductions for safe traffic flow through the work zone.
- Construction will be coordinated with facility owners or administrators of sensitive land uses such as police and fire stations (including all fire protection agencies), transit stations, hospitals, and schools. Facility owners or operators will be notified in advance of the timing, location, and duration of construction activities and the locations of detours and lane closures.
- Construction will be coordinated with local transit service providers, including temporary relocation of bus routes or bus stops in work zones as necessary.
- Roadway right-of-ways will be repaired or restored to their original conditions or better upon completion of construction.
- To the extent applicable, the traffic control plan will conform to the California Manual on Uniform Traffic Control Devices for Streets and Highways: Part 6 Temporary Traffic Control and Caltrans' 2006 Standard Plans.

Coordination of Individual Traffic Control Plans

Measure 4.8-1b: To the extent that the adopted SFPUC Construction Measure #5 does not contain such provisions already, or the provisions are not required for a project as a result of local encroachment or right-of-way permit conditions, the contract specifications for individual contracts within a single WSIP project will include the following:

- In the event that more than one construction contract is issued for work along existing or new pipelines, and where construction could occur within and/or across multiple streets in the same vicinity, the SFPUC and construction contractor(s) will coordinate the traffic control plans in order to mitigate the impact of traffic disruption. The coordinated plan will include measures that address overlapping construction schedules and activities, truck arrivals and departures, lane closures and detours, and the adequacy of on-street staging requirements.

H.3.6 Air Quality

SJVAPCD Dust Control Measures

Measure 4.9-1a: In the San Joaquin Region, the SJVAPCD has determined that compliance with the following Regulation VIII (Fugitive PM10 Prohibitions) and Regulation IX (Mobile and Indirect Sources, Rule 9510, where applicable) control measures would mitigate PM10 impacts to a less-than-significant level. The SFPUC will include these measures, where applicable, in contract specifications:

SJVAPCD Basic Control Measures (applies to all construction sites)

- All disturbed areas, including storage piles that are not being actively utilized for construction purposes, shall be effectively stabilized of dust emissions using water, chemical stabilizer/suppressant, covered with a tarp or other suitable cover, or vegetative ground cover.
- All onsite unpaved roads and offsite unpaved access roads shall be effectively stabilized of dust emissions using water or chemical stabilizer/suppressant.
- All land clearing, grubbing, scraping, excavation, land leveling, grading, cut and fill, and demolition activities shall be effectively controlled of fugitive dust emissions utilizing application of water or by presoaking.
- When materials are transported offsite, all material shall be covered, or effectively wetted to limit visible dust emissions, and at least 6 inches of freeboard space from the top of the container shall be maintained.
- All operations shall limit or expeditiously remove the accumulation of mud or dirt from adjacent public streets at the end of each workday. The use of dry rotary brushes is expressly prohibited except where preceded or accompanied by sufficient wetting to limit the visible dust emissions. Use of blower devices is expressly forbidden.
- Following the addition of materials to, or the removal of materials from, the surface of outdoor storage piles, said piles shall be effectively stabilized of fugitive dust emissions utilizing sufficient water or chemical stabilizer/suppressant.
- Within urban areas, trackout shall be immediately removed when it extends 50 or more feet from the site and at the end of each workday.
- Any site with 150 or more vehicle trips per day shall prevent carryout and trackout.

SJVAPCD Enhanced Control Measures (also applies when required to mitigate significant PM10 impacts)

- Traffic speeds on unpaved roads shall be limited to 15 mph.
- Sandbags or other erosion control measures shall be installed to prevent silt runoff to public roadways from sites with a slope greater than 1 percent.

SJVAPCD Additional Control Measures (also applies to construction sites that are large in area, located near sensitive receptors, or which for any other reason warrant additional emissions reductions)

- Wheel washers shall be installed for all exiting trucks, or all trucks and equipment leaving the site shall be washed off.

- Wind breaks shall be installed at windward side(s) of construction areas.
- Excavation and grading activity shall be suspended when winds exceed 20 mph and, regardless of windspeed, an owner/operator must comply with Regulation VIII's 20 percent opacity limitation.
- The area subject to excavation, grading, and other construction activity at any one time shall be limited.

SJVAPCD Rule 9510, Indirect Source Review, Section 6.1, Construction Equipment Emissions (applies to any project subject to discretionary approval by a public agency that ultimately results in the construction of a new building, facility, or structure or reconstruction of a building, facility, or structure for the purpose of increasing capacity or activity and also involving 9,000 square feet of space).

- 6.1.1: The exhaust emissions for construction equipment greater than fifty (50) horsepower used or associated with the development project shall be reduced by the following amounts from the statewide average as estimated by the ARB:
  - 6.1.1.1: 20% of the total NO_X emissions, and
  - 6.1.1.2: 45% of the total PM10 exhaust emissions.
- 6.1.2: An applicant may reduce construction emissions on-site by using less- polluting construction equipment, which can be achieved by utilizing add-on controls cleaner fuels, or newer lower emitting equipment.
- 6.3: The requirements listed in Section 6.1 above can be met through any combination of on-site emission reduction measures or off-site fees.

SJVAPCD Exhaust Control Measures

Measure 4.9-1b: To limit exhaust emissions within the San Joaquin Region, the SJVAPCD specifies the following exhaust controls for heavy-duty equipment (scrapers, graders, trenchers, earthmovers, etc.). The SFPUC will include these measures, where applicable, in contract specifications:

- Alternative-fueled or catalyst-equipped diesel construction equipment shall be used.
- Idling time (e.g., 10-minute maximum) shall be minimized.
- The hours of operation of heavy-duty equipment and/or the amount of equipment in use shall be limited.
- Fossil-fueled equipment shall be replaced with electrically driven equivalents (provided they are not run via a portable generator set).
- Construction shall be curtailed during periods of high ambient pollutant concentrations; this may include ceasing construction activity during the peak hour of vehicular traffic on adjacent roadways.
- Activity management (e.g., rescheduling activities to reduce short-term impacts) shall be implemented.

H.3.7 Noise and Vibration

Noise Controls

Measure 4.10-1a: SFPUC Construction Measure #6 for noise requires compliance with local noise ordinances to the extent feasible. Many of these ordinances restrict hours when construction can occur, but do not specify noise limits for construction noise. For most projects, the SFPUC will conduct construction activities during the daytime hours to the extent feasible. However, if nighttime construction cannot be avoided, noise generated by these activities will be required to comply with applicable noise ordinance nighttime limits or not exceed 50-dBA sleep interference criterion (with windows open at night) to the extent feasible.

To ensure that construction noise impacts are mitigated to a less-than-significant level, all WSIP projects located within 500 feet of any noise-sensitive receptors (e.g., residences, schools, childcare centers, churches, hospitals, and nursing homes) will be required to implement appropriate noise controls to reduce daytime construction noise levels to meet the 70-dBA daytime speech interference criterion to the extent feasible. For nighttime construction, all WSIP projects located within 3,000 feet of any noise-sensitive receptors will be required to implement appropriate noise controls to maintain noise levels at or below any applicable ordinance nighttime noise limits or the 50-dBA nighttime sleep interference criterion to the extent feasible. Such controls could include any of the following, as appropriate:

- Best available noise control techniques (including mufflers, intake silencers, ducts, engine enclosures, and acoustically attenuating shields or shrouds) will be used for all equipment and trucks in order to minimize construction noise impacts. If feasible, construction equipment noise will not exceed the mitigated noise levels listed in Table 4.10-4 (see measure below for limits on impact equipment).
- If impact equipment (e.g., jack hammers, pavement breakers, and rock drills) is used during project construction, hydraulically or electric-powered equipment will be used wherever feasible to avoid the noise associated with compressed-air exhaust from pneumatically powered tools. However, where use of pneumatically powered tools is unavoidable, an exhaust muffler on the compressed-air exhaust will be used (a muffler can lower noise levels from the exhaust by up to about 10 dBA). External jackets on the tools themselves will be used, where feasible, which could achieve a reduction of 5 dBA. Quieter procedures, such as drilling rather than impact equipment, will be used whenever feasible.
- Pile holes will be pre-drilled wherever feasible to reduce potential noise and vibration impacts. Where feasible, sonic or vibratory pile drivers will be used instead of impact pile drivers (sonic pile drivers are only effective in some soils).
- Pile driving activities shall be prohibited during the evening and nighttime hours (7 p.m. to 7 a.m.).
- Operation of equipment requiring use of back-up beepers will be avoided near sensitive receptors to the extent feasible during nighttime hours (10 p.m. to 7 a.m.).
- Stationary noise sources will be located as far from sensitive receptors as feasible. If they must be located near receptors, adequate muffling (with enclosures where feasible and appropriate) will be used to ensure local noise ordinance limits are met to the extent feasible. Enclosure opening or venting will face away from sensitive receptors. If any stationary equipment (e.g.,

ventilation fans, generators, dewatering pumps) is operated beyond the time limits specified by the pertinent noise ordinance, this equipment will conform to the affected jurisdiction's pertinent day and night noise limits to the extent feasible.

- Material stockpiles as well as maintenance/equipment staging and parking areas will be located as far as feasible from residential and school receptors.
- Wherever feasible, pipeline alignments will be located at least 100 feet away from sensitive receptors.
- Where pipeline construction zones are within 100 feet of school classrooms or childcare facilities, pipeline construction activities (or at least the noisier phases of construction) will be scheduled on weekend or school vacation days to the extent feasible, avoiding weekday hours when schools are in session. If construction must occur when school is in session, interior noise levels in classrooms will not exceed 60 dBA if possible to avoid speech interference problems, which would allow for a maximum exterior noise level of 70 to 80 dBA, depending on whether windows are open or closed.
- Given the long duration of construction activities at tunnel shafts/portals and proposed nighttime activities, tunnel-related construction activities will be designed to comply with nighttime noise limits specified in local noise ordinances. Measures that could be implemented to comply with these limits include: using quiet ventilation fans (pure tone components of fan noise will be considered), using line power instead of generators, erection of temporary sound barriers, restricting heavy equipment operation during the nighttime hours, using nonmetallic containers in the muck removal system to prevent clanging/banging noises, limiting controlled detonations in the tunnel shaft/portal vicinities to the daytime hours, retrofitting windows/doors of affected homes, and/or prohibiting use of backup alarms on equipment during the nighttime hours.
- Where controlled detonation activities will occur, surrounding cities and residents should be notified of the blasting schedule, indicating the time range when blasting could occur (hours and duration).
- Proposed jack-and-bore pits will be located as far from sensitive receptors as technically feasible. If ventilation fans, dewatering pumps, or generators are required as part of this type of pipeline crossing, such equipment will comply with daytime and nighttime noise limits specified in pertinent noise ordinances to the extent feasible (also see Measure 4.9-1d in Section 4.9, Air Quality, for additional restrictions on generator operation).
- Wherever necessary, temporary or permanent noise barriers will be erected to maintain construction noise levels at or below the 70-dBA daytime speech interference criterion and the 50-dBA nighttime sleep interference criterion.
- A designated project liaison will be responsible for responding to noise complaints during the construction phases. The name and phone number of the liaison will be conspicuously posted at construction areas and on all advanced notifications. This person will take steps to resolve complaints, including periodic noise monitoring, if necessary. Results of noise monitoring will be presented at regular project meetings with the project contractor, and the liaison will coordinate with the contractor to modify any construction activities that generated excessive noise levels to the extent feasible.

- A reporting program will be required for each project that documents complaints received, actions taken to resolve problems, and effectiveness of these actions.

Vacate SFPUC Caretaker's Residence at Tesla Portal

Measure 4.10-1b: The SFPUC caretaker's residence at Tesla Portal will be vacated during construction of the Advanced Disinfection (SJ-1) and Tesla Portal Disinfection (SJ-5) projects as well as those portions of the SJPL System (SJ-3) and SJPL Rehabilitation (SJ-4) projects located at Tesla Portal.

Limit Hourly Truck Volumes

Measure 4.10-2a: In addition to SFPUC Construction Measure #6 for noise, which requires compliance with local noise ordinances to the extent feasible, haul and delivery truck routes for all WSIP projects will avoid local residential streets and will follow local designated truck routes to the extent feasible. Total project-related haul and delivery truck volumes on any particular haul truck route will be limited to 80 trucks per hour.

Restrict Truck Operations

Measure 4.10-2b: Haul and delivery trucks will be prohibited from operating within 200 feet of any residential uses during the nighttime hours (10 p.m. to 7 a.m.). If there are receptors, but they are beyond 200 feet from the haul route, limited truck operations will be allowed during the more sensitive nighttime hours, but noise generated by these operations cannot exceed the 50-dBA sleep interference criterion at the closest receptors. If trucks must operate during these hours and residential uses are located within 200 feet of the haul route, deliveries will be made to staging areas outside residential areas, then transferred to the construction site during daytime hours (7 a.m. to 7 p.m.).

Vacate SFPUC Land Manager's Residence

Measure 4.10-2c: To minimize nighttime noise impacts, the SFPUC Land Manager's residence adjacent to Alameda East Portal will be vacated during off-site truck operations associated with the New Irvington Tunnel project (SV-4), if truck operations occur during the nighttime hours (10 p.m. to 7 a.m.) and are estimated to exceed the 50-dBA sleep interference criterion at this residence.

H.3.8 Public Services and Utilities

Notify Neighbors of Potential Utility Service Disruption

Mitigation 4.11-1a: As part of the neighborhood notice, the SFPUC will notify residents and businesses in project area of potential utility service disruption two to four days in advance of construction.

Locate Utility Lines Prior to Excavation

Measure 4.11-1b: Prior to excavation, the SFPUC or its contractors will locate overhead and underground utility lines, such as natural gas, electricity, sewer, telephone, fuel, and water lines, that may be encountered during excavation work prior to opening an excavation.

Confirmation of Utility Line Information

Measure 4.11-1c: The SFPUC or its contractors will find the exact location of underground utilities by safe and acceptable means. Information regarding the size, color, and location of existing utilities must be confirmed before construction activities commence.

Safeguard Employees from Potential Accidents Related to Underground Utilities

Measure 4.11-1d: While any excavation is open, the SFPUC or its contractors will protect, support, or remove underground utilities as necessary to safeguard employees.

Notify Local Fire Departments

Measure 4.11-1e: The SFPUC or its contractors will notify local fire departments any time damage to a gas utility results in a leak or suspected leak, or whenever damage to any utility results in a threat to public safety.

Emergency Response Plan

Mitigation 4.11-f: The SFPUC will develop an emergency response plan in the event of a leak or explosion prior to commencing construction activities.

Prompt Reconnection of Utilities

Measure 4.11-2g: The SFPUC or its contractors will promptly reconnect any disconnected utility lines.

Coordinate Final Construction Plans with Affected Utilities

Measure 4.11-1h: The SFPUC or its contractors will coordinate final construction plans and specifications with affected utilities.

Waste Reduction Measures

Measure 4.11-2: The following requirements will be incorporated into contract specifications for each WSIP project:

The contractor(s) will obtain any necessary waste management permits prior to construction and will comply with conditions of approval attached to project implementation. As part of the waste management permit process, the contractor(s) will submit a solid waste recycling plan to the affected agencies. Elements of the plan will likely include, but are not necessarily limited to, the following:

- Identification of the types of debris that will be generated by the project and identify how all waste streams will be handled.
- Actions to reuse or recycle construction debris and clean excavated soil to the extent possible.
- Actions to divert at least 50% of inert solids (asphalt, brick, concrete, dirt, fines, rock, sand, soil, and stone) from disposal in a landfill.

H.3.9 Energy Resources

Incorporation of Energy Efficiency Measures

Measure 4.15-2: Consistent with the Energy Action Plan II priorities for reducing energy usage, the SFPUC will ensure that energy efficient equipment is used in all WSIP projects. A repair and maintenance plan will also be prepared for each facility to minimize power use. The potential for use of renewable energy resources (such as solar power) at facility sites will be evaluated during project-specific design.

H.4 References Cited

Burns, J. 1989. Recording Historic Structures: Historic American Buildings Survey/Historic American Engineering Record, Washington, D.C.: The American Institute of Architects Press. As cited in San Francisco Public Utilities Commission (SFPUC). 2008. *Water System Improvement Program Final Program EIR*. Chapter 6, Mitigation Measures, 6–27 pp.

San Francisco Public Utilities Commission (SFPUC). 2008. *Water System Improvement Program Final Program EIR*. Chapter 6, Mitigation Measures. Available: http://www.sf-planning.org/index.aspx?page=1829. Accessed: May 9, 2016.

Attachment 4

Environmental Considerations for South Delta Low Head Pump System

ICF INTERNATIONAL

Memorandum

Date:	April 7, 2011
To:	Robert Pedlar California Department of Water Resources, Bay-Delta Office 1416 Ninth Street Sacramento, CA 95814
From:	Gregg Roy, Jennifer Pierre, and Lesa Erecius
Subject:	**Environmental Considerations for South Delta Low Head Pump System**

The following information was compiled to address your request for information about the potential environmental requirements associated with the placement of temporary or permanent pump systems at select sites in the south Delta to encourage flow to improve water quality. The information is presented separately for the permanent and temporary pump systems and is further divided into an overall discussion of the potential impacts and mitigation, and a specific discussion about permitting approach.

Summary

The analysis of environmental considerations has been based on current requirements of the Title 14. Chapter 3, of the California Code of Regulations and Division 13, of the California Public Resource Code (CEQA Guidelines), our extensive experience working in the south Delta for the temporary barriers project (TBP) and the South Delta Improvements Project, various site visits over the years, and review of conceptual drawings and modeling outputs provided by DWR. Both permanent and temporary pumping systems are considered to be a modification of the currently implemented TBP and environmental considerations of this modification would require minor modifications to existing permits and mitigation obligations.

Overall, the permanent systems would require that DWR provide mitigation for the footprint of the new pumping systems in addition to the mitigation already in place for the TBP. This could be accomplished at a bank, such as was done at Kimball Island for the TBP. The temporary pumping systems would not require additional mitigation for species, but the installation and removal of these systems each year could result in air quality effects that could require mitigation above and beyond what is currently require for the TBP. However, some components of the temporary facilities would be left in place year-round on the crown of the levee to ease installation in subsequent years and minimize construction-related effects.

Project Description and Purpose

The Low Head Pump Salinity Control Study would consist of installing temporary pump systems, or permanent pumping systems near the Middle River (MR), Grant Line Canal (GLC) and/or Old River at Tracy (ORT) temporary barriers.

The purpose of the project is to improve water circulation and quality in the interior southern Delta for the purpose of improving flows and controlling salinity to comply with the State Water Resources Control Board's agricultural salinity standards for the South Delta.

Project Alternatives

As part of the Low Head Pump Salinity Control Study, four alternative locations, for either permanent or temporary pump system placement in July through October, are being considered: MR; GLC, ORT, or MR and ORT. Additionally, under each of these alternatives, different pumping rates are being considered: 250, 500, or 1000 cubic feet per second [cfs]).

Middle River Pumping

Under this alternative, pump systems would be installed, either permanently or temporarily, with intake downstream and discharge upstream of the MR barrier (MRB) and run 24 hours per day at 250, 500, or 1000 cfs while the temporary barriers are in place.

Grant Line Canal Pumping

Under this alternative, pump systems would be installed, either permanently or temporarily, with intake downstream and discharge upstream of the GLC barrier and run 24 hours per day at 250, 500, or 1000 cfs while the temporary barriers are in place.

Old River at Tracy Pumping

Under this alternative, pump systems would be installed, either permanently or temporarily, with intake downstream and discharge upstream of the ORT barrier and run 24 hours per day at 250, 500, or 1000 cfs while the temporary barriers are in place.

Middle River and Old River Pumping

Under this alternative, pump systems would be installed, either permanently or temporarily, with intake downstream and discharge upstream of the MRB and with intake downstream and discharge upstream of the ORT barrier. All pumps would run simultaneously 24 hours per day at 125, 250, or 500 cfs while the temporary barriers are in place.

Environmental Considerations

Permanent Pump Systems

This section provides a summary assessment of the environmental impacts and permitting requirements for the low-head permanent pump system.

Impacts and Potential Mitigation Obligations

This section provides a summary of the potential environmental impacts (physical and biological) that may occur if the permanent low-head pump system is constructed and operated. The results of this assessment are shown in Table 1.

Also shown for comparison in Table 1 are potential impacts and mitigation commitments for a temporary pump system. Environmental considerations for a temporary pump system are presented on Page 13. These impacts could change as more detailed information regarding construction and operation of the pump system is developed. The impacts included in Table 1 assume the following regarding construction and operation of the permanent pump system:

- Project construction would require up to a year;
- Project construction would require the temporary installation of a cofferdam and dewatering within the cofferdam;
- Pump system would be operated 24 hours per day from July 1 to October 31;
- Pump system operation would require a high voltage power source. This power would need to be brought in from the nearest Western Area Power Administration (WAPA) service lines, which could be several miles or more from the MR, ORT and GLC barrier sites. As such, it would be necessary to install multiple power poles and tie in to existing WAPA lines;
- To the extent possible, staging areas used for construction of the MR, ORT, and/or GLC barriers would also be used for the installation of the permanent pump system at these locations. However, it may be necessary to establish new or additional staging areas, as would be the case for pump system installation at GLC under the 1000 cfs pumping scenario, for example, and this has been taken into account in assessing impacts;
- With the exception of water conveyance pipelines, most of the pump systems would be confined to the crown and landside of the levee; and
- All of the MR permanent pump systems would require channel dredging for the intakes to meet flow requirements.

Table 1. Potential Impacts—Low Head Pump Salinity Control Study (Permanent vs. Temporary Pump Systems)

Permanent Pump System	Temporary Pump System	Mitigation/Environmental Commitment
AESTHETICS		
Temporary Changes in Views during Project Construction	Temporary Changes in Views during Project Construction/Removal	*This potential impact would be less than significant and therefore would not require mitigation.*
Create a New Source of Light or Glare	Create a New Source of Light or Glare	• Construct structures with low-sheen and non-reflective surface materials (PP[1]) Apply minimum lighting standards (PP,TP[2])
Temporary Changes in Nighttime Lighting in the Proposed Project Area during Project Operation	Temporary Changes in Nighttime Lighting in the Proposed Project Area during Project Operation	• Apply minimum lighting standards (PP, TP)
Permanent Changes in Views	Permanent Changes in Views	• Reduce visibility of new structures (PP, TP) • Construct structures with low-sheen and non-reflective surface materials (PP, TP)
AGRICULTURAL RESOURCES		
Temporary Conversion of Prime Farmland during Construction/Installation	Temporary Conversion of Prime Farmland during Construction/Installation	• Return disturbed areas to pre-project conditions (PP, TP)
Permanent Conversion of Prime Farmland		*Project is not expected to result in substantial conversion of prime farmland*
AIR QUALITY		
Conflict with Applicable Air Quality Plan or Regulation	Conflict with Applicable Air Quality Plan or Regulation	*Project would not result in population and/or employment growth, and therefore it is not inconsistent with applicable air quality plans. This potential impact would be less than significant and therefore would not require mitigation.*
Generation of Criteria Pollutants during Project Construction	Generation of Criteria Pollutants during Project Installation/Removal	*This potential impact would likely be less than significant and therefore would not require mitigation.*

Permanent Pump System	Temporary Pump System	Mitigation/Environmental Commitment
Generation of Criteria Pollutants during Project Operation	Generation of Criteria Pollutants during Project Operation	• Utilize aqueous diesel fuel (PP, TP) • Install a Diesel Particulate Filter (PP, TP) • Utilize a diesel oxidation catalyst (PP, TP) • Install other after-treatment products (PP, TP) • Require the pump system be electric or alternatively fueled (PP, TP)
Generation of Criteria Pollutants during Project Construction or Operation, Resulting in a Cumulative Air Quality Impact	Generation of Criteria Pollutants during Project Construction or Operation, Resulting in a Cumulative Air Quality Impact	• Utilize aqueous diesel fuel (PP, TP) • Install a Diesel Particulate Filter (PP, TP) • Utilize a diesel oxidation catalyst (PP, TP) • Install other after-treatment products (PP, TP) • Require the pump system be electric or alternatively fueled (PP, TP)
Generation of Diesel Particulate Matter Emissions during Project Construction or Operation, Resulting in an Increased Health Risk	Generation of Diesel Particulate Matter Emissions during Project Construction/Removal or Operation, Resulting in an Increased Health Risk	• Utilize aqueous diesel fuel (PP, TP) • Install a Diesel Particulate Filter (PP, TP) • Utilize a diesel oxidation catalyst (PP, TP) • Install other after-treatment products (PP, TP) • Require the pump system be electric or alternatively fueled (PP, TP) • Locate pump system as far from sensitive receptors as possible (PP, TP)
Generation of Odors during Project Construction and Operations	Generation of Odors during Project Installation/Removal and Operations	• Locate the pump systems as far from sensitive receptors as possible (PP, TP) • Encase the pump system (may be specified for noise) (PP, TP) • Require the pump system be electric or alternatively fueled (PP, TP)

Permanent Pump System	Temporary Pump System	Mitigation/Environmental Commitment
BIOLOGICAL RESOURCES		
Disturbance of Active Swainson's Hawk Nests	Disturbance of Active Swainson's Hawk Nests	• Conduct surveys to locate Swainson's hawk nest sites (PP, TP) • Minimize Project-Related Disturbances within ¼ Mile of Active Swainson's Hawk Nest Sites (PP, TP)
Loss or Disturbance of Raptor Nests	Loss or Disturbance of Raptor Nests	• Conduct Surveys to Locate Raptor Nest Sites (PP, TP) • Minimize Project-Related Disturbances within ¼ Mile of Active Nest Sites (PP, TP)
Loss or Disturbance of Migratory Bird Nests	Loss or Disturbance of Migratory Bird Nests	• Avoid and Minimize Effects on Nesting Birds (PP, TP)
Potential Injury or Mortality of Western Pond Turtle	Potential Injury or Mortality of Western Pond Turtle	• Conduct preconstruction surveys (PP, TP) • Install Exclusion Fencing for Western Pond Turtle (PP, TP)
Loss or Disturbance of Western Pond Turtle Habitat *(degree of impact would increase w/increasing flow regime [pumping capacity] because footprint would increase)*	Loss or Disturbance of Western Pond Turtle Habitat *(degree of impact would increase w/increasing flow regime [pumping capacity] because footprint would increase)*	• Install Exclusion Fencing for Western Pond Turtle (PP, TP)

Permanent Pump System	Temporary Pump System	Mitigation/Environmental Commitment
Loss or Disturbance of Special-Status Plants		• Conduct preconstruction surveys • Locations of special-status plants in proposed construction areas will be recorded using a global positioning system unit and flagged • Establish an adequate buffer area to exclude activities that would directly remove or alter the habitat of an identified special-status plant population or result in indirect adverse effects on the species • Install a temporary, plastic mesh–type construction fence (Tensor Polygrid or equivalent) at least 1.2 meters (4 feet) tall around any established buffer areas to prevent encroachment by construction vehicles and personnel. A qualified biologist will determine the exact location of the fencing
Pile-driving Effects on Fish		• Conduct pile driving with a vibratory driver (PP)
Decreased Water Quality and Increased Aquatic Habitat Disturbance During Project Construction *(degree of impact would increase w/increasing flow regime [pumping capacity] because footprint would increase)*	Decreased Water Quality and Increased Aquatic Habitat Disturbance During Project Construction/Removal	• Implement Turbidity Monitoring During Construction (PP) • Implement Turbidity Monitoring During Construction/Removal (TP)
Fish Harassment and Displacement During Project Construction	Fish Harassment and Displacement During Project Construction/Removal	• Environmental Awareness Program for Construction Personnel (PP,TP)
Fish Harassment and Displacement During Project Operation	Fish Harassment and Displacement During Project Operation	*This potential impact would likely be less than significant and therefore would not require mitigation.*

Permanent Pump System	Temporary Pump System	Mitigation/Environmental Commitment
CULTURAL RESOURCES		
Damage to or Destruction of As-Yet-Unidentified Cultural Resources, Including Human Remains		• Stop Work and Evaluate the Significance of Inadvertent Discoveries; Devise Treatment Measures as Needed (PP)
GEOLOGY AND SOILS		
Accelerated Erosion during Project Construction	Accelerated Erosion during Project Construction and Removal	• Prepare and implement a SWPPP (PP, TP)
Potential Structural Damage from Development on Materials Subject to Liquefaction		*This potential impact would be less than significant and therefore would not require mitigation.*
Potential Structural Damage from Development on Expansive Soils		*This potential impact would be less than significant and therefore would not require mitigation.*
GREENHOUSE GAS EMISSIONS		
Generation of GHG Emissions from Project Construction	Generation of GHG Emissions from Project Construction/Removal	*This potential impact would likely be less than significant and therefore would not require mitigation.*
Generation of GHG Emissions from Project Operation	Generation of GHG Emissions from Project Operation	• Require the pump system be electric or alternatively fueled (PP, TP)
Conflict with Applicable GHG Reduction Plan or Regulation	Conflict with Applicable GHG Reduction Plan or Regulation	• Require the pump system be electric or alternatively fueled (PP, TP)
HAZARDS AND HAZARDOUS MATERIALS		
Inadvertent Release of Hazardous Materials during Project Construction and Operation	Release of Hazardous Materials during Project Construction, Operation and Removal	• Prepare and implement a Hazardous Materials Management Program (PP, TP)
HYDROLOGY AND WATER QUALITY		
Accelerated Erosion During Project Construction	Accelerated Erosion during Project Construction and Removal	• Prepare and implement SWPPP (PP, TP) • Implement Turbidity Monitoring During Construction (PP) • Implement Turbidity Monitoring During Construction and Removal (TP)

Permanent Pump System	Temporary Pump System	Mitigation/Environmental Commitment
Inadvertent Release of Hazardous Materials to Adjacent Water Body during Construction	Inadvertent Release of Hazardous Materials to Adjacent Water Body during Construction/Removal	• Prepare and implement a Hazardous Materials Management Program (PP, TP)
LAND USE AND PLANNING		
Conflict with Existing Zoning for Agricultural Use *(degree of impact would increase w/increasing flow regime [pumping capacity] because footprint would increase)*	Conflict with Existing Zoning for Agricultural Use *(degree of impact would increase w/increasing flow regime [pumping capacity] because footprint of delivery pipeline would increase)*	• Avoid agricultural lands to the greatest extent possible (PP, TP)
Incompatible with Existing Adjacent Land Uses *(degree of impact would increase w/increasing flow regime [pumping capacity] because footprint would increase)*	Incompatible with Existing Adjacent Land Uses *(degree of impact would increase w/increasing flow regime [pumping capacity] because footprint of pipeline would increase*	• Avoid agricultural lands to the greatest extent possible (PP, TP)
MINERAL RESOURCES		
None		
NOISE		
Exposure of Noise-Sensitive Land Uses to Project Construction Noise	Exposure of Noise-Sensitive Land Uses to Project Construction/Removal Noise	• Employ noise-reducing construction measures (PP, TP)
Exposure of Noise-Sensitive Land Uses to Project Operation Noise	Exposure of Noise-Sensitive Land Uses to Project Operation Noise	• Employ noise-reducing operational measures (PP, TP)
POPULATION AND HOUSING		
None		
PUBLIC SERVICES		
None		
RECREATION		
None		

Permanent Pump System	Temporary Pump System	Mitigation/Environmental Commitment
TRANSPORTATION/TRAFFIC		
Temporary Increase in Traffic during Construction	Temporary Increase in Traffic during Construction/Removal	*This potential impact would be less than significant and therefore would not require mitigation.*
UTILITIES AND SERVICE SYSTEMS		
Generation of Solid Waste during Project Construction		*This potential impact would be less than significant and therefore would not require mitigation.*
Increase in Power Consumption during Project Operation	Increase in Power Consumption during Project Operation	*This potential impact would be less than significant and therefore would not require mitigation.*
Temporary Disruption of Electricity Service		• Coordinate power outages and notify potentially affected utility users of the temporary loss of electricity.
Disruption to Underground Utility Lines during Excavation Activities		• Existing underground utility lines at excavation sites will be identified prior to construction and underground utility lines will be avoided or relocated in coordination with the utility company or service provider.

[1]PP: permanent pump system
[2]TP: temporary pump system

Permitting Process

Assuming the impacts described above, Table 2 provides an overview of the environmental permits that may be required for the construction and operation of the permanent pump system. The actual permits that would be required and the time to acquire them would depend on the actual estimated effects of the final proposal and coordination with resource and regulatory agencies. This also assumes that there would be no need to re-consult on the CVP/SWP Long Term Operations BOs (OCAP) primarily because there are no expected increased effects on federally-listed species resulting from the proposed annual July through October system operation. However, the NMFS and FWS may require that re-consultation is necessary to address the minor changes in the project description of the BOs that would occur as a result of modifying the TBP. As described above, the estimates included in Table 2 assume that the pump system would be included as an amended project description for the temporary barriers, similar to previous modifications (i.e., MRB raise). As such, permit documents would be abbreviated and would indicate that implementation of the pump system would be a modified component of the overall TBP. Should this be unacceptable to the regulatory agencies, timeline to obtain these permits would likely increase.

Table 2. Regulatory Compliance Permits and Approvals for Permanent Pump System

Authority/Agency	Permit/Approval	Timeline	Trigger
U.S. Army Corps of Engineers	Clean Water Act Section; 404/ Rivers and Harbors Act, Section 10	NWP: up to 3 months IP: up to 8 months[1]	Work within waters of the United States; Construction of any structure in or over any navigable water of the United States, or any other work affecting the course, location, condition, or physical capacity of these waters.
California Department of Water Resources	CEQA	Addendum: 1 month Supplemental IS/MND: 4 months	Potential impacts to the physical environment
U.S. Fish and Wildlife Service	ESA Take Permit (Section 7 consultation)	9 months[2]	Potential effects on delta smelt or its designated critical habitat
National Marine Fisheries Service	ESA Take Permit (Section 7 consultation) Magnusson-Stevens Act, EFH Consultation	12 months[2]	Potential take of steelhead, winter-run and spring-run Chinook salmon, green sturgeon or effects to designated critical habitat
California Department of Fish and Game	Incidental Take Permit	9 months[2]	Potential take of delta smelt, longfin smelt, spring-run Chinook salmon, or Swainson's hawk
California Department of Fish and Game	Streambed Alteration Agreement	6 months	Construction activity within waterside hinges of the levee
Central Valley Regional Water Quality Control Board	Section 401 Certification or Waiver	Up to 12 months[3]	Work within waters of the United States
San Joaquin Valley Air Pollution Control District	Emission Reduction Credit Lease	Up to 5 months	Particulate and exhaust emission impacts beyond established thresholds

ESA = federal Endangered Species Act.
CESA = California Endangered Species Act.
EFH = Essential Fish Habitat.
[1] If an individual permit is required, NEPA documentation may also be required.
[2] This timeline assumes that no re-consultation on OCAP is necessary.
[3] This timeline assumes the RWQCB does not issue a permit until NMFS and FWS issue BOs

Temporary Pump System

This section provides a summary of the environmental impacts and permitting requirements for the low-head temporary pump system. The description of environmental considerations for the temporary pump system assumes these pumps would be placed on the levee adjacent to the barrier(s) during the irrigation season while the agricultural barriers are in place. There would be no permanent fill associated with the pump system and any in-water structures would be removed upon removal of the barriers. Some components of the pump facilities may be left in place on the crown of the levee to facilitate ease of installation in subsequent years.

Summary of Impacts and Potential Mitigation Obligations

Table 1 provides a summary of the potential environmental impacts that may occur if the temporary low-head pump system is constructed and operated; potential mitigation obligations are also included. These impacts could change as more detailed information regarding construction and operation of the pump system is developed. The impacts included in Table 1 assume the following regarding construction and operation of the temporary pump system:

- Installation of the pump system would occur in the spring and would require up to 90 days the first year. After the first installation, subsequent annual installation would likely require less time because some infrastructure may remain in place after the pump system is removed;;
- Pump system would be operated 24 hours per day from July 1 to October 31;
- To the extent possible, staging areas used for construction of the MR, ORT, and/or GLC barriers would also be used for installation of the temporary pumps at these locations; and
- Skid-mounted pumps would be located along the levee crown and hooked up, via temporary water conveyance pipes. Water conveyance pipes would be located on the waterside of the levee and would be designed to avoid entrainment of fish that could be present between July and October.
- All in-water features would be removed and re-installed each year.

Permitting Process

Based on preliminary discussions with the U.S. Army Corps of Engineers and California Department of Fish and Game, it is assumed that the placement and operation of temporary pump systems would not require permits for federal Clean Water Act, California Fish and Game Code Section 1602, or other in-water effects regulated by these agencies. Based on this input and assuming that there would be no need to re-consult on OCAP, it is assumed that consultation under the federal Endangered Species Act (ESA) would also not be required primarily because there are no expected increased effects on federally-listed species during the proposed annual July through October operation period. As such, the only potential effects are related primarily to noise and pollutant emissions that would occur when the pump systems are placed and operated (Table 3). However, the NMFS and FWS may require that re-consultation is necessary to address the minor changes in the project description of the BOs that would occur as a result of modifying the TBP. If this were to occur, the permitting requirements for the temporary pump system would likely be the same as those described above for the permanent pump system.

Table 3. Regulatory Compliance Permits and Approvals for Temporary Pump System

Authority/Agency	Permit/Approval	Trigger
California Department of Fish and Game	Incidental Take Permit	Potential effects on Swainson's hawk
San Joaquin Valley Air Pollution Control District	Emission Reduction Credit Lease	Particulate and exhaust emission impacts beyond established thresholds

ESA = federal Endangered Species Act.
CESA = California Endangered Species Act.

Appendix I

Cultural Resources Overview

Appendix I

Cultural Resources Overview

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I.1 Introduction

The plan area for the Lower San Joaquin River (LSJR) alternatives, as described in Chapter 1, *Introduction*, includes the northern San Joaquin Valley and the adjacent Sierra Nevada foothills. This appendix provides an overview of the prehistoric and historic cultural setting, as well as the paleontological setting, for this region for reference.

I.2 Prehistoric and Historic Cultural Setting

I.2.1 Prehistoric Overview

The San Joaquin Valley and western Sierra Nevada foothills were occupied by different prehistoric cultures dating to as early as 12,000 years ago. Evidence for the presence of humans prior to about 8,000 years ago is relatively sparse and scattered throughout the state. In the alternatives region, fluted Clovis-like projectile points associated with the Paleo-Indian Period some 12,000 years ago have been found in the foothills near Copperopolis and in the San Joaquin Valley at Tracy Lake and near the confluence of the Merced River and the San Joaquin River (SJR) (Rondeau et al. 2007:65; Rosenthal et al. 2007:151). Few archaeological sites that predate 6,000 years ago have been discovered in the region. In the Central Valley, Paleo-Indian and subsequent Lower Archaic Period sites were buried by periodic episodes of landscape evolution and deposition (Rosenthal et al. 2007:151). Above the valley floor, the Skyrocket site excavated in the foothills of Calaveras County is one of the few Lower Archaic archaeological sites recorded in the region (Rosenthal et al. 2007:152).

Between 8,000 and 3,000 years ago during the Middle Archaic Period, regional subsistence strategies shifted to an increased emphasis on plant resources as a result of climatic changes and the drying of pluvial lakes (Rosenthal et al. 2007:152-155). The abundance of milling implements in archaeological sites dating to this period attests to the addition of hard seeds, acorns, and pine nuts to a wide range of natural resources (game animals, wild plants, waterfowl, and fish) procured as part of a seasonal foraging pattern. Although sites dating to the Middle Archaic are scarce on the valley floor and more common in the foothills, the archaeological assemblages indicate that as groups became better adapted to their regional or local environments, the subsistence and settlement patterns varied somewhat among the foothills and valley floor.

After approximately 3,000 years ago during the Upper Archaic and Late Prehistoric periods, the complexity of the prehistoric archaeological record within the valley and foothills reflects increases in specialized adaptations to locally available resources such as acorns and salmon, in permanently occupied settlements, and in the expansion of regional populations and trade networks (Rosenthal et al. 2007:155-159). Large shell midden/mounds at coastal and inland sites in the Sacramento Valley and northern San Joaquin Valley attest to the regular reuse of these locales over hundreds of years or more from the Upper Archaic into the Late Prehistoric period. During the Upper Archaic, marine shell beads and obsidian continue to be the hallmark of long-distance trade and exchange networks developed during the preceding period (Hughes and Milliken 2007:259-270).

Changes in the technology used to pursue and process resources are some of the hallmarks of the Late Prehistoric period. These include an increase in the prevalence of mortars and pestles, a diversification in types of watercraft and fishhooks, and the use of the bow and arrow (Jones and Klar 2007:305-307). The period also witnessed the beginning of ceramic manufacture in parts of the Central Valley, as well as in California's southeast desert region and southwest basin ranges.

The increase in sedentism and exchange networks during the Late Prehistoric period was accompanied by the development of social stratification and craft specialization, as indicated by the variety of artifacts, including bone tools, basketry, marine shell beads, obsidian tools, and brownware ceramics, the use of clamshell disk beads as a form of currency, architectural features such as house floors and rock-lined ovens in large mounded villages, and variation in burial types and associated grave goods (Rosenthal et al. 2007:157-159). Many of the numerous large and small villages arrayed along the major rivers and tributaries in the valley and foothills have been attributed to known ethnographic settlements.

I.2.2 Ethnographic Overview

At the time of European contact, the Northern Valley Yokuts occupied the northern San Joaquin Valley while the Central and Southern Sierra Miwok (also Me-wuk or Miwuk) inhabited the Sierra Nevada foothills in the vicinity of today's three large reservoirs on the Stanislaus, Tuolumne, and Merced Rivers (Kroeber 1925:474-491; Levy 1978:398-413; Wallace 1978:462-470).

The Northern Valley Yokuts generally established villages on low, natural rises along major watercourses. The eastern side of the SJR, with its permanent waterways flowing from the Sierra Nevada, was more heavily populated than the land to the west of the river, where semi-permanent watercourses predominate. In the foothills, the semi-permanent settlements or winter villages of the seasonally mobile Sierra Miwok were clustered along the river drainages: Central Sierra Miwok along the Stanislaus and Tuolumne drainages, and Southern Sierra Miwok along the Merced and Fresno drainages. Archaeological sites and prehistoric burials have been identified along the various river banks, many at the locations of ethnographic Miwok or Yokuts villages.

The abundant natural resources hunted, gathered, and fished by the Yokuts and Sierra Miwok varied seasonally (Levy 1978:402-406; Wallace 1978:464-465). As resources became available, the Sierra Miwok groups dispersed to higher or lower elevations. Acorns from valley, foothills, and mountain oaks were of particular importance to the diet of the three groups. A variety of tools, implements, and enclosures, including tule canoes, were employed by each group to gather plant foods, fish, hunt land mammals, and capture waterfowl and other birds. The Yokuts and Sierra Miwok also participated in an extensive east-west trade network connected by trails between the coast and the Great Basin with salt and obsidian moving westward, marine shell and steatite moving eastward, and basketry traded in both directions (Levy 1978:411–412; Wallace 1978:465).

The influence of the northern California coastal missions established by the Spanish and the Franciscan Order between 1770 and 1797 soon reached into the interior San Joaquin Valley. By 1805, Northern Valley Yokuts were being transported to the San José, Santa Clara, Soledad, San Juan Bautista, and San Antonio missions (Wallace 1978:468-469). During the following period of Mexican colonization on large land grants in the interior, disease and military raids claimed many lives in the valley and foothills. The discovery in 1848 of gold in the Sierra foothills and the ensuing Gold Rush resulted in drastic changes in population, resource access, and native lifeways for the Yokuts and Miwok as thousands of prospectors traveled through the northern San Joaquin Valley and into the foothills, and hundreds more settled in the valley and began farming (Levy 1978:401; Wallace 1978:469).

Today, there are three federally recognized Miwok tribes who live on reservation lands in Calaveras and Tuolumne Counties. The Tuolumne Rancheria in Central Sierra Miwok territory in Tuolumne County was established in 1910. Near New Melones Lake in Tuolumne County, the Chicken Ranch Rancheria of Me-wuk Indians are also descendants of Central Sierra Miwok. Members of the California Valley Miwok Tribe reside on a rancheria in Calaveras County. The Southern Sierra Miwuk Nation has petitioned for federal recognition status, but no reservations have been established in Southern Sierra Miwok territory. Additionally, there are no Miwok or Yokuts reservations in Merced, Mariposa, San Joaquin, or Stanislaus Counties.

I.2.3 Historic Overview

The earliest significant European exploration and settlement of California began during the Spanish period with the establishment in 1769 of the first of a series of 21 missions on the coast between San Diego and Sonoma. Under Spanish law, large tracts of land, including cattle ranches and farms, fell under the jurisdiction of the missions. Native Americans were removed from their traditional lands, converted to Christianity, concentrated at the missions, and used as labor on the mission farms and ranches (Castillo 1978:100-102). Since the mission friars had civil as well as religious authority over their converts, they held title to lands in trust for indigenous groups. The lands were to be repatriated once the native peoples learned Spanish laws and culture.

Following independence from Spain in 1822, Mexico opened California to exploration by American fur trappers and mountain men. In 1826, Jedediah Smith was the first American trapper to enter California; his party explored along the Sierra Nevada and entered the Sacramento Valley (Gunsky 1989:9-11). The following year he journeyed eastward across the Sierra, possibly along the Stanislaus River. The Mexican economy depended on an extensive rancho system, which was carved from the former Franciscan missions and hundreds of land grants awarded in the state's interior to Mexican citizens (Beck and Haase 1974:24; Castillo 1978:104-105; Staniford 1975:98-100). Although secularization schemes had called for redistribution of lands to Native American neophytes who enabled construction of the mission empire, the distribution was a practical failure. Most Native American converts returned to traditional lands that had not yet been colonized or found work with the large cattle ranchos being generated from the mission lands.

The rancho landowners mainly focused on the cattle industry and devoted large tracts to grazing and dry farming of wheat (Staniford 1975:100-101, 103). Rancheria del Río Estanislao included 48,887 acres in Stanislaus and Calaveras Counties near New Melones Lake (Beck and Haase 1974:28, 32). On its western boundary, 35,533-acre Thompson's Ranch extended into eastern San Joaquin County. Three large grants were awarded along the SJR in southern San Joaquin County, through Stanislaus County, and into northern Merced County (El Pescador 34,446 acres; Rancho del Puerto 13,340 acres; Rancho de Orestimba 26,666 acres). To the east in Mariposa County, the 44,387 acres comprising the Las Mariposas grant extended west along the Merced River to Lake McClure.

In 1848, shortly after California became a territory of the United States with the signing of the Treaty of Guadalupe Hidalgo ending Mexican rule, gold was discovered on the American River at Sutter's Mill in Coloma. The resulting Gold Rush era influenced the history of the state and the nation. Thousands of people flocked to the gold fields in the Mother Lode region that stretches along the western Sierra foothills and includes the drainages around New Don Pedro Lake, Lake McClure, and New Melones Lake. The continual discoveries of placer gold deposits in the first few years of the Gold Rush led to the establishment of hundreds of foothills mining camps and towns. The locations of several mining communities are now covered by the reservoir waters, including Jacksonville beneath Don Pedro Lake, Robinson's Ferry (later renamed Melones) beneath New Melones Lake, and Benton Mills (later renamed Bagby), Camp Horseshoe Bend, and Exchequer Camp beneath Lake McClure (Hoover et al. 2002:45; Merced Irrigation District [Merced ID] 2008:7.12/12; Turlock Irrigation District [TID] and Modesto Irrigation District [MID] 2011a:5.252).

California became the 31st state in 1850, largely as a result of the Gold Rush. Outside the city ports of Sacramento, Stockton, and San Francisco, the increasing demand of miners for commodities and foodstuffs was met by enterprising individuals and businesses (Staniford 1975:176-177). The demand boosted the expansion and success of the agriculture industry, as well as an increase in ranching and raising beef and dairy cattle, pigs, sheep, turkeys, and chickens to feed the thousands of miners. The manufacture of all types of goods and clothing, the ore processing industry, lumber production, and the beginning of a fishing industry were also prompted during this period in California's history.

The availability of a reliable supply of water was a critical component of successful farm and ranch homesteading and the related growth of riverside towns (California Department of Transportation [Caltrans] 2006:16-17, 34-35; Caltrans 2007:31-35; Hoover et al. 2002:212-213, 378, 517-521). Farms and ranches in the San Joaquin Valley were thus initially established along the rivers and large perennial streams as a source of water for stock or crop irrigation and for transport to consumer markets. Overflow lands in the valley, such as historically found along the LSJR and the Stanislaus, Tuolumne, and Merced Rivers, were particularly suitable for cultivating feed or row crops, and also used for grazing livestock. Settlements and towns that served the needs of the farming and ranching homesteads were typically established at river crossing points by trails or roadways, and many became important commercial centers for trade and transport. Examples of riverside towns established in this region during the Gold Rush era include Knight's Ferry and Murphy's Ferry (now Ripon) on the Stanislaus River; French Bar (later La Grange and now listed on the National Register of Historic Places) and Tuolumne City on the Tuolumne River; Merced Falls, Hopeton, and Snelling on the Merced River; and Grayson and San Joaquin City on the LSJR. With the construction of the railroads through the valley in the early 1870s and the availability of rail transport for agricultural products, some of the farming communities, such as Hill's Ferry on the SJR and Burneyville on the Stanislaus River, were displaced by railside towns (replaced by Newman and Oakdale, respectively).

By 1853, the population of the state exceeded 300,000 and in 1854, Sacramento became the state capital. With the completion of the transcontinental railroad in 1869, settlers and immigrants continued to arrive. Thousands of miles of railway lines were constructed throughout the state in the 1870s—along the coast, southern California, and the Central Valley (Beck and Haase 1974:68; Caltrans 2007:98). Southward expansion of the Central Pacific Railroad on the east side of the San Joaquin Valley reached Merced County in 1871. A year later the Southern Pacific Railroad completed its line through the west side of the valley. Settlement of the American West was also encouraged by the passage of the Swampland Acts of the mid-1800s to early 1900s and the Homestead Act of 1862.

Mining shifted toward more industrialized methods of extraction as the placer gold disappeared along the rivers and channels (Caltrans 2008:50-59). Developed in the mid-1850s and outlawed in 1884, hydraulic mining used water directed from low pressure nozzles or high pressure "monitors" that destroyed the contours of the land. The development of dredge mining in 1898 renewed gold mining as a major industry in the state. Dredgers were massive machines capable of processing tons of riverbed gravels that left behind tailing piles still visible today along many of the rivers in the

Central Valley, including segments of the Tuolumne and Merced Rivers between the Don Pedro and Exchequer Dams, respectively, and the LSJR (Merced ID 2010:2.5-2.6; TID and MID 2011:5.8).

The growth and variety of techniques employed for gold mining was accompanied by the development of water conveyance systems (JRP and Caltrans 2000:33-39). In the early 1850s, ditches were dug to get water to the "dry diggings" and companies were soon organized and building ditches, canals, and flumes to supply water to miners using sluices to extract gold from the river gravels. With the advent of hydraulic mining, the demand for water increased and its supply by ditch companies became even more lucrative. Soon, ditch and canal networks radiated across the Mother Lode. Major companies also dug tunnels and dammed streams or lakes to create storage reservoirs. By 1865, over 5,300 miles of mining ditches and canals had been officially recorded in the Mother Lode region. Of these, many are still used for agricultural irrigation, municipal water services, and hydroelectric power systems, and remain an important feature of the state's cultural landscape (JRP and Caltrans 2000:53).

In 1878, the Miller and Lux Company, a cattle company with vast land holdings in the West, including 1 million acres in California, mostly in Merced and Madera Counties, completed the first extensive agricultural irrigation canal in the state, the 67-mile San Joaquin and Kings River Canal in the San Joaquin Valley (Beck and Haase 1974:69; Clough and Secrest 1984:187). The company was a pioneer of larger-scale irrigation projects, and also organized mutual canal companies to control water in drier regions. This prompted the formation of irrigation districts and the passage of the Wright Act in 1887. Established in June 1887, TID was the first such district formed under the Wright Act; MID was established shortly thereafter in July 1887 (TID and MID 2011:3.14).

To provide year-round crop irrigation needed by the local farmers along the Tuolumne River, TID and MID constructed LaGrange Dam in 1893, followed by MID's Modesto Reservoir on the Tuolumne River in 1911 and TID's Davis Reservoir in 1914 (TID and MID 2011:3.15). In 1917, Davis Reservoir was renamed Owen Reservoir and then renamed Turlock Lake when it was leased by TID to the state in 1950 (Paterson 2004:202, 333). The two districts constructed the original Don Pedro Dam in 1923, and completed construction of the New Don Pedro Dam and Powerhouse in 1971 (TID and MID 2011a:3.3).

The Oakdale Irrigation District (OID) was established in 1909, and joined with the South San Joaquin Irrigation District (SSJID) to complete the Goodwin Dam in 1912. In 1921, the SSJID, which was also established in 1909 (SSJID 2012), agreed with OID to build the original Melones dam and powerplant. The project was completed in December 1926 (OID 2002). The two districts also constructed Tulloch Dam and enlarged Goodwin Dam on the Lower Stanislaus River in the 1950s.

Established in 1919, the Merced ID selected the Exchequer Mining Company on the Merced River as the ideal location to construct the district's first dam (Merced ID 2008:7.12/10-11). Planning for the dam began in 1921 and it was operational 5 years later. With an ever increasing demand for water, Merced ID was granted a license from the Federal Power Commission in 1964 to expand the facilities. By 1967, the district had completed construction of the New Exchequer Dam, as well as a second dam 6 miles downstream. The downstream McSwain Dam serves as a regulating reservoir.

The formation of irrigation districts and related canal development, coupled with the extensive levee systems constructed after passage of the Swampland Act of 1850 to prevent flooding of prime agricultural lands and settlements in the greater Sacramento–San Joaquin Delta region, foreshadowed the extensive, twentieth century federally funded water projects, like the Central Valley Project (CVP) that delivers Sacramento River water to the arid San Joaquin Valley (JRP and

Caltrans 2000:73-74). Irrigation and related flood control management had become an integral component of the history of the productive agricultural and livestock economy of the state.

The Flood Control Act of 1944 authorized improvement of the lower reaches of the SJR and its tributaries. The LSJR and Tributaries Project, completed in 1972, provided for improvement of the existing channel and levee system on the LSJR from the Delta upstream to the mouth of the Merced River and on the lower reaches of the Stanislaus and Tuolumne Rivers. Improvements included raising and strengthening existing levees, constructing new levees, constructing revetments on riverbanks where required, and removing accumulated snags in the main river channel (Central Valley Flood Management Planning Program 2010:2.52-2.53).

The Flood Control Act of 1944 also authorized construction of the New Melones Dam to replace the original Melones Dam. The project was reauthorized by the Flood Control Act of 1962, begun by the United States Army Corps of Engineers in 1966, and completed in 1979. Management of the project was transferred to the U.S. Bureau of Reclamation (USBR) in 1979, and the reservoir is now part of the CVP (USBR 2010:1.3, 1.12, 1.14).

I.3 Paleontological Resources Setting

The San Joaquin Valley and the Sacramento Valley form the Central Valley (or the Great Valley), an elongated depression that lies between the Coast Ranges and the Sierra Nevada. Geologically, the Central Valley is a large sediment-filled basin, where interbedded mud, silt, sand, and gravel thousands of feet deep overlie Sierran basement rocks that extend downward at an angle from the western slope of the Sierra Nevada. Most of the surface of the Central Valley is covered with alluvial deposits dating to less than 11,700 years ago during the Holocene and between 2.6 million and 11,700 years ago during the Pleistocene (Table I-1). The alluvium deposited on the valley floor is composed of sediments transported by water from the Coast Ranges to the west and the Sierra Nevada to the east. Generally, the maximum thickness of Holocene sediments in the Central Valley is estimated at 150 feet toward its center and in the Bay/Delta regions, pinching out to near zero along the valley margins (Page 1986:19). The thickness of Holocene sediments is important because in almost all areas of the Central Valley, such sediments are underlain by Pleistocene or older sedimentary rocks with a high paleontological potential.

Table I-1. Divisions of Geologic Time

Era	Period	Time in Millions of Years Ago	Epoch
Cenozoic	Quaternary	<0.01	Holocene
		2.60	Pleistocene
	Tertiary	5.30	Pliocene
		23.00	Miocene
		33.90	Oligocene
		55.80	Eocene
		65.50	Paleocene
Mesozoic	Cretaceous	145.50	
	Jurassic	199.60	
	Triassic	251.00	
Paleozoic	Permian	299.00	
	Carboniferous	359.20	
	Devonian	416.00	
	Silurian	443.70	
	Ordovician	488.30	
	Cambrian	542.00	
Precambrian		2500.00	

Source: U.S. Geological Survey Geologic Names Committee 2010.

Note: Approved change from 1.6 to 2.6 million years ago for the base of the Pleistocene boundary at the start of the Quaternary, and age of the Pleistocene/Holocene boundary at 11,700 years ago.

Paleontological potential refers to the likelihood that a rock unit will yield a unique or significant paleontological resource. All sedimentary rocks, some volcanic rocks, and some low-grade metamorphic rocks have potential to yield significant paleontological resources. Depending on location, the paleontological potential of subsurface materials generally increases with depth beneath the surface, as well as with proximity to known fossiliferous deposits.

Criteria for screening the paleontological potential of rock units has been established and recently updated by the Society of Vertebrate Paleontology (SVP 2010). Table I-2 lists the criteria for high-potential, undetermined, low-potential, and no-potential rock units.

Table I-2. Paleontological Potential Criteria

Paleontological Potential	Description
High	Geologic units from which vertebrate or significant invertebrate, plant, or trace fossils have been recovered. Also rock units that contain potentially datable organic remains older than late Holocene, including deposits associated with animal nests or middens, and rock units that may contain new vertebrate deposits, traces, or trackways.
Undetermined	Geologic units for which little to no information are available.
Low	Geologic units that are not known to have produced a substantial body of significant paleontological material.
None	Geologic units with no potential for containing significant paleontological resources.
Source: SVP 2010.	

Pleistocene or older (older than 11,000 years) continental sedimentary deposits are considered as having a high paleontological potential because they have a history of yielding numerous vertebrate fossils of extinct mammals or other fauna. Pleistocene or older sedimentary rock units mapped at the surface along the edges of the northern San Joaquin Valley and in many foothill areas, as well as underneath Holocene-age deposits closer to the valley's center, include the Laguna, Mehrten, Modesto, Moreno, Riverbank, and Turlock Lake Formations (Page 1986: Plate 2). These formations have all yielded numerous vertebrate fossils (University of California Museum of Paleontology [UCMP] 2012).

Holocene-age deposits (less than 10,000 years old) are considered to have a low paleontological potential because they are geologically immature and are unlikely to have fossilized the remains of organisms (fossilization processes take place over millions of years). The thickness of Holocene sediments is important because in almost all areas of the Central Valley such sediments are underlain by Pleistocene or older sedimentary rocks with a high paleontological potential. Holocene-age deposits blanket the majority of the Central Valley floor and primarily consist of the following (Page 1986:18-19, 22).

- Flood-basin deposits of mud, muck, loam, and sand, which occur during the flood-stages of major streams. These deposits are found along the LSJR and are extensive along the long-axis of the Central Valley.
- River deposits of gravel, sand, and silt along channels, floodplains, and natural levees of major streams. Typically, the widths of river floodplains are proportional to the size of their contributing watershed. Thus, these deposits range in width from about 1 mile in the foothills to several miles along the LSJR.
- Younger (Holocene-age) alluvial fan deposits of gravel, sand, and silt, typically located along the edges of the Central Valley, where streams exit the Sierra Nevada or Coast Range mountains. Alluvial fans form large lobes centered on a stream's outlet from the mountain, and develop due to the rapid deposition of their sediment load (triggered by the distinct break in stream gradient), and due to the lateral migration of steam channels over the land surface.

Metamorphic and igneous rock units have a low paleontological potential, either because they formed beneath the surface of the earth (such as granite), or because they have been altered under high heat and pressures, chaotically mixed or severely fractured. Generally, the processes that form igneous and metamorphic rocks are too destructive to preserve identifiable fossil remains. The bulk of the Sierra Nevada range is formed by granitic intrusions and metamorphic rock complexes.

Areas of the region with disturbed soils, reworked sediment, or artificial fills from agricultural, mining, settlement, or other development, are considered to have a low paleontological potential. In agricultural areas, native soils have been greatly reworked due to historic plowing and crop-ripping, as well as irrigation practices. Native soils in mining areas have been extensively reworked by a variety of mineral extraction or processing techniques, including dredging, use of hydraulics, tunneling, and construction of ditches, canals, and earthen dams, to name a few. Such disturbed or destroyed soils do not represent in-situ geologic deposits and it is highly unlikely that paleontological resources would be present near the surface.

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Appendix J

Hydropower and Electric Grid Analysis of Lower San Joaquin River Flow Alternatives

Appendix J
Hydropower and Electric Grid Analysis of Lower San Joaquin River Flow Alternatives

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Acronyms and Abbreviations

AGC	Automatic Generation Control
BA	Balancing Authority
BANC	Balancing Authority of Northern California
CAISO	California Independent System Operator
Commission	California Energy Commission
CPUC	California Public Utilities Commission
CVP	Central Valley Project
ft	feet
kV	kilovolt
LCR	local capacity requirement
LCT Study	Local Capacity Technical Study
LSE	load serving entity
LTE	Long-Term Emergency
Merced ID	Merced Irrigation District
MID	Modesto Irrigation District
MSS	metered subsystem
MW	megawatts
NERC	North American Electric Reliability Corporation
PSLF	Positive Sequence Load Flow
RA	Resource Adequacy
RPS	Renewable Portfolio Standard
SCs	Scheduling coordinators
SMUD	Sacramento Municipal Utility District
SNR	Sierra Nevada Region
TID	Turlock Irrigation District
WECC	Western Electricity Coordinating Council

J.1 Introduction

This appendix provides estimates of the potential effects on hydropower generation and electric grid reliability in the Lower San Joaquin River (LSJR) Watershed caused by implementation of the LSJR alternatives. The LSJR alternatives propose a specified percent of unimpaired flows[1] (i.e., 20, 40, or 60 percent) from February–June on the Stanislaus, Tuolumne, and Merced Rivers (three eastside tributaries). The proposed LSJR alternatives could affect reservoir operations and surface water diversions and the associated timing and amount of hydropower generation from the LSJR Watershed, which includes the plan area[2] as described in Chapter 1, *Introduction*.

This analysis relies on the State Water Resources Control Board's (State Water Board's) water supply effects (WSE) model to estimate the effects of the LSJR alternatives on reservoir releases and storage (elevation head), and allowable diversions to off-stream generation facilities, and then calculates the associated change in monthly and annual energy production This output then provides input to electric grid reliability modeling, which evaluates the potential impacts of these changes on the electric grid reliability under peak load and outage contingency scenarios.

There are three different LSJR alternatives, each consisting of a specified percentage of unimpaired flow requirement for the Stanislaus, Tuolumne, and Merced Rivers. For a particular alternative, each tributary must meet the specified percentage of its own unimpaired flow at its mouth with the LSJR during the months of February–June.[3] Details of the LSJR alternatives are presented in Chapter 3, *Alternatives Description*, Section 3.3, *Lower San Joaquin River (LSJR) Alternatives,* of this recirculated substitute environmental document (SED).

Numerous hydropower generation facilities on the three eastside tributaries are evaluated in this analysis. The major facilities potentially affected, however, are those associated with the New Melones Reservoir (New Melones Dam) on the Stanislaus River, New Don Pedro Reservoir (New Don Pedro Dam) on the Tuolumne River, and Lake McClure (New Exchequer Dam) on the Merced River.[4] Figure J-1 shows the location of these and other hydropower facilities in and around the LSJR Watershed.

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[1]*Unimpaired flow* represents the water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. It differs from natural flow because unimpaired flow is the flow that occurs at a specific location under the current configuration of channels, levees, floodplain, wetlands, deforestation and urbanization.

[2] In this appendix plan area and project area are used interchangeably and refer to the area described in Chapter 1, *Introduction*.

[3] Any reference in this appendix to 20 percent unimpaired, 40 percent unimpaired, and 60 percent unimpaired is the same as LSJR Alternative 2, LSJR Alternative 3, and LSJR Alternative 4, respectively. The specific minimum unimpaired flow requirement on a tributary for a particular alternative would not apply once flows in the river or downstream are at a level of concern for flooding or public safety. As described in the program of implementation for the flow objectives, such levels will be coordinated by the State Water Board with the appropriate federal, state, and local agencies.

[4] In this document, the term *rim dams* is used when referencing the three major dams and reservoirs on each of the eastside tributaries: New Melones Dam and Reservoir on the Stanislaus River; New Don Pedro Dam and Reservoir on the Tuolumne River; and New Exchequer Dam and Lake McClure on the Merced River.

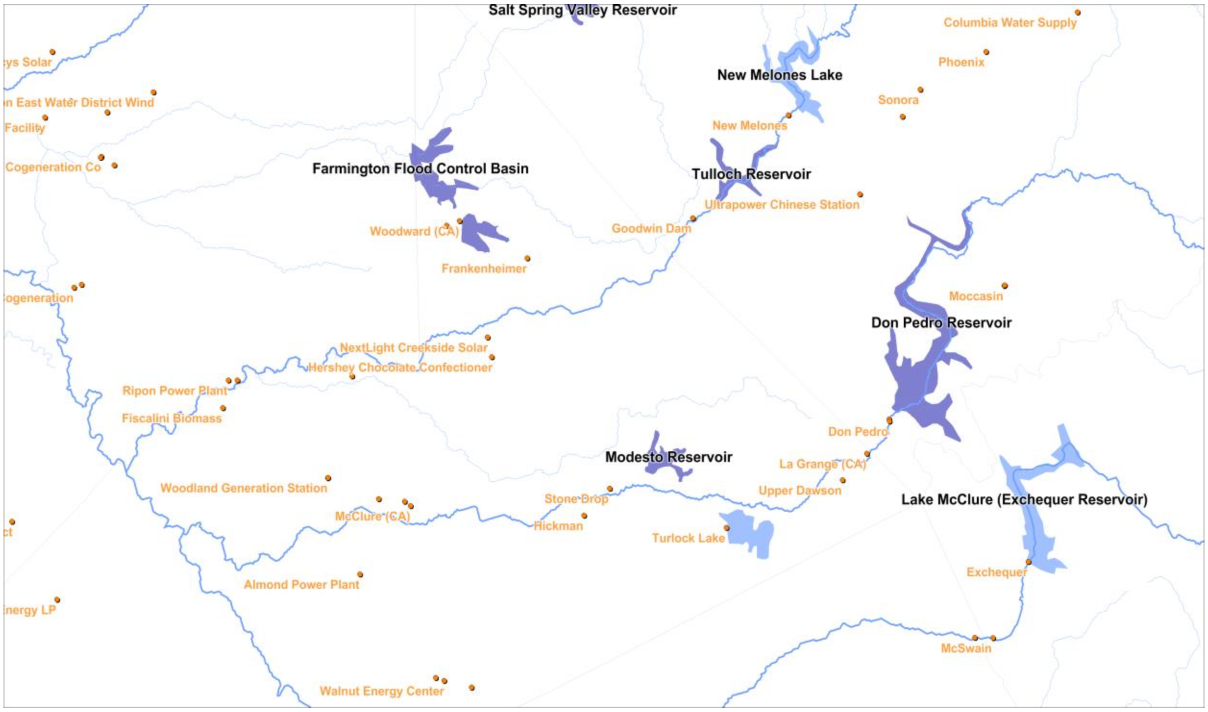


Figure J-1. Location of Hydropower Facilities in the LSJR Watershed (Source: Ventyx n.d.)

J.2 Energy Generation Effects

The analysis in this section estimates the timing and amount of energy in gigawatt hours (GWh) generated by hydropower facilities on the eastside tributaries for the different LSJR alternatives and compares them against baseline. The timing and amounts of energy generated are calculated from the timing, rates of release, and elevation head of reservoirs at in-stream hydropower facilities and allowable diversions to off-stream facilities, estimated across 82 years (between water years 1922 and 2003) by the WSE model for the LSJR alternatives and baseline. The average annual energy generation and the distribution of average monthly energy generation across these 82 years for each LSJR alternative are then compared to those for baseline.

J.2.1 Methodology

For each of the LSJR alternatives, this analysis estimates the amount of energy (GWh) that would be generated on a monthly and annual basis from the various facilities on the eastside tributaries for comparison against the amount generated under baseline conditions. Unless otherwise specified, the quantitative results presented in the figures, tables, and text of this appendix present WSE modeling of the specified unimpaired flow requirement of each LSJR alternative (i.e., 20, 40, or 60 percent). The specified unimpaired flow requirements include the potential range of effects at other percentages of unimpaired flow (i.e., 30 percent and 50 percent) that could occur under adaptive management. Hydropower facilities on the eastside tributaries were grouped into four categories for this analysis based on where they are located relative to the three rim dams, and whether they are in-stream facilities or off-stream. Table J-1 contains a list of the hydropower facilities on the LSJR grouped into these categories, along with some basic facility information.

Table J-1. List of Hydropower Facilities in the LSJR Watershed (CEC 2012)

River Basin	Hydro-electric Power Plant Name	Nameplate Capacity (MW)	% of Power Capacity in Basin	Location Relative to Rim Dams
Stanislaus	Woodward	2.85	0.4	Off-stream
	Frankenheimer	5.04	0.6	Off-stream
	Tulloch	17.10	2.2	Inline
	Angels	1.40	0.2	Upstream
	Phoenix	1.60	0.2	Upstream
	Murphys	4.50	0.6	Upstream
	New Spicer	6.00	0.8	Upstream
	Spring Gap	6.00	0.8	Upstream
	Beardsley	9.99	1.3	Upstream
	Sand Bar	16.20	2.1	Upstream
	Donnells-Curtis	72.00	9.2	Upstream
	Stanislaus	91.00	11.6	Upstream
	Collierville Ph	249.10	31.8	Upstream
	New Melones	300.00	38.3	Rim Dam
	Upstream Capacity	457.79	58.5	NA
	Affected Capacity	324.99	41.5	NA
Tuolumne	Stone Drop	0.20	0.0	Off-stream
	Hickman	1.08	0.2	Off-stream
	Turlock Lake	3.30	0.5	Off-stream
	La Grange	4.20	0.7	Inline
	Upper Dawson	4.40	0.7	Upstream
	Moccasin Lowhead	2.90	0.5	Upstream
	Moccasin	100.00	16.6	Upstream
	R C Kirkwood	118.22	19.6	Upstream
	Dion R. Holm	165.00	27.4	Upstream
	Don Pedro	203.00	33.7	Rim Dam
	Upstream Capacity	390.52	64.8	NA
	Affected Capacity	211.78	35.2	NA
Merced	Fairfield	0.90	0.8	Off-stream
	Reta - Canal Creek	0.90	0.8	Off-stream
	Merced ID – Parker	3.75	3.2	Off-stream
	Mcswain	9.00	7.6	Inline
	Merced Falls	9.99	8.4	Inline
	New Exchequer	94.50	79.4	Rim Dam
	Upstream Capacity	0.00	0.0	NA
	Affected Capacity	119.04	100%	NA

NA = not applicable

Energy generated from in-stream facilities, and at the rim dams, is estimated by the power equation presented below (*Eqn. J-1*) using reservoir head and release rates obtained from the WSE model. As described in Appendix C, *Technical Report On The Scientific Basis For Alternative San Joaquin River Flow And Southern Delta Salinity Objectives,* the WSE model provides estimates of reservoir operations and allowable surface water diversions associated with the different LSJR alternatives. As operations change for each LSJR alternative, reservoir release rates and storage levels also change, thus affecting the power generated.

The monthly energy generated from facilities at the rim dams, or facilities in-stream and downstream of the rim dams, was calculated using the following power equation on a monthly time step:

$$HP = \left(e_p \gamma Q h_g\right) \div 550 \qquad \textit{(Eqn. J-1)}$$

where HP is the total horsepower generated by the facility, e_p is the power plant efficiency, (assumed to be 80 percent for all facilities), γ is weight of 1 cubic foot of water (62.4 pounds), Q is the flow released from the reservoir and through the turbines (in cubic feet per second), and h_g is the elevation head (in feet) behind the dam (The Engineering Toolbox 2016). The reservoir release rates (Q) and reservoir elevations (h_g) are obtained from the WSE model output. All hydropower facilities were assumed to operate within the constraints of the facility; spills causing flows greater than capacity do not produce energy above the maximum capacity. In-stream facilities located downstream of the rim dams were assumed to have constant h_g equal to the maximum head of the reservoir as these facilities are generally run-of-the-river. Horsepower obtained from the above equation is then converted to megawatts and multiplied by the number of hours in the month to provide the total energy generated in GWh for that month. Annual energy estimates are the sum of the associated monthly estimates.

An off-stream facility is one supplied by diversions of surface water from the associated river. Energy generated from off-stream facilities for each LSJR alternative was estimated by multiplying the monthly percent of surface water demand met (100 percent means surface water demand is fully met) on the associated river by the facility's nameplate capacity. Additional information related to calculation methods and terminology related to surface water demands is found in Appendix F.1, *Hydrologic and Water Quality Modeling.* The calculation of hydropower generation is completed using the following equation to determine the off-stream generation of each alternative and baseline on a monthly basis:

Power = (% of Surface Water Demand Met) x (Off-stream Nameplate Capacity) *(Eqn. J-2)*

where the *Power* is calculated in megawatts (MW), *% of Surface Water Demand Met* is taken from the WSE model and only includes demands by irrigation districts that are routed through the off-stream reservoirs, for theassociated tributary (for the respective alternative and baseline), and the *Off-Stream Nameplate Capacity* is the maximum generating capacity of the off-stream power generation facility. This methodology assumes that facilities have been designed and are operated at the nameplate capacity when surface water demands are met in full, but would not be able to operate at nameplate capacity if those demands are not met in full. This methodologyis a simplifying and conservative assumption for facilities that represent a relatively small portion of the overall generating capacity in their respective watersheds (1.0 percent on the Stanislaus, 0.7 percent on the Tuolumne, and 4.8 percent on the Merced as shown in Table J-1). The power calculated by Eqn.*J-2* is then multiplied by the number of hours in the month to provide the total amount of energy in GWh generated for that month. Annual energy estimates are the sum of the associated monthly estimates.

Hydropower generated from facilities upstream of the rim dams on the Stanislaus and Tuolumne Rivers is not included in the WSE model because the largest hydrologic effects in terms of volume of water will be at and downstream of the rim dams. The Merced River has no major hydropower reservoirs upstream of Lake McClure (New Exchequer Dam). This appendix focuses on the modeling of hydropower at and downstream of the rim dams. Upstream hydropower effects are qualitatively discussed in Chapter 14, *Energy and Greenhouse Gases*, in Section 14.4.4, *Impacts and Mitigation Measures: Extended Plan Area*.

J.2.2 Results

The LSJR alternatives slightly reduce the annual energy generation and change the monthly generation pattern. Table J-2 contains a summary of the average annual change in total energy generation (GWh) on each of the tributaries due to the LSJR alternatives. Generally, as the percent of unimpaired flow increases from 20 percent to 60 percent, the amount of energy generated annually is slightly reduced. Relative to baseline, hydropower generation is expected to increase with LSJR Alternative 2, remain about the same with LSJR Alternative 3, and decrease with LSJR Alternative 4. These changes are also represented as a percent of baseline energy generation in Table J-3. Although annual generation is only slightly affected, the effect on the monthly pattern is slightly more pronounced.

Table J-2. Average Annual Baseline Energy Generation and Difference from Baseline by Tributary (GWh) (Note: 20% unimpaired flow, 40% unimpaired flow, and 60% unimpaired flow represent LSJR Alternative 2, 3, and 4, respectively)

Alternative	Stanislaus	Tuolumne	Merced	Plan Area
Baseline	586	656	408	1,650
20% UF	18	2	8	29
40% UF	4	-6	-3	-4
60% UF	-23	-41	-23	-87

GWh = gigawatt hours
UF = unimpaired flow

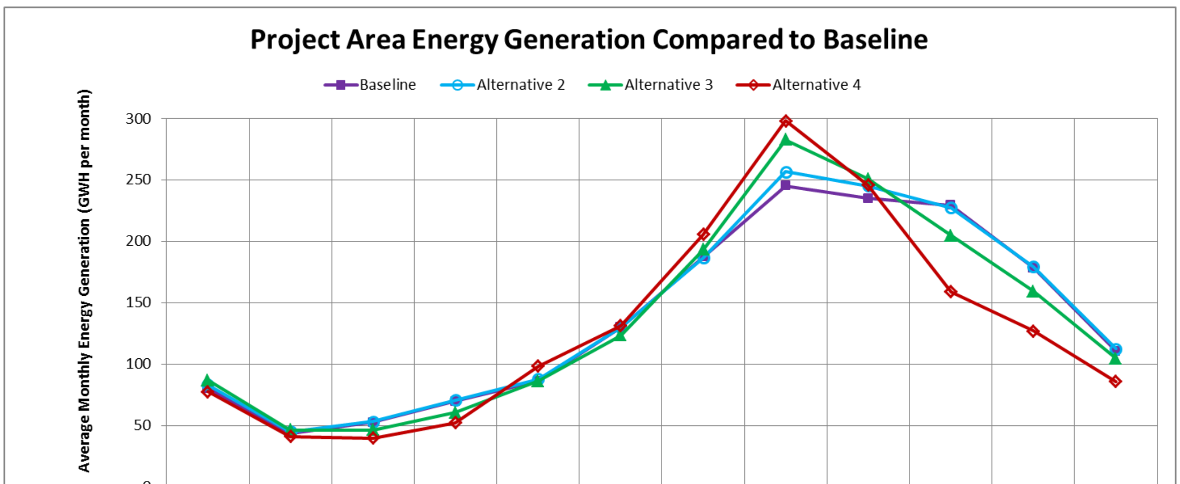
Table J-3. Average Annual Energy Generation Difference as Percent Change from Baseline by Tributary (Note: 20% unimpaired flow, 40% unimpaired flow, and 60% unimpaired flow represent LSJR Alternative 2, 3, and 4, respectively)

Alternative	Stanislaus (% difference from Baseline)	Tuolumne (% difference from Baseline)	Merced (% difference from Baseline)	Plan Area (% difference from Baseline)
Baseline	0%	0%	0%	0%
20% UF	3%	0%	2%	2%
40% UF	1%	-1%	-1%	0%
60% UF	-4%	-6%	-6%	-5%

UF = unimpaired flow

The pattern of total monthly energy generation (over 82 years of simulation) for the LSJR alternatives and baseline are presented in Figure J-2a and the associated average changes in monthly energy generation are presented in Figure J-2b. These figures show an increase in energy produced in February–June, greatest in May, due to increases in flow relative to baseline (i.e., reservoir releases) in those months under each LSJR alternative. This is followed by reductions in July–September for LSJR Alternatives 3 and 4, primarily due to less water being released from the major reservoirs as a result of reduced diversions downstream, reduced flood control releases, and, to a lesser extent, reduced reservoir elevations relative to baseline. From December–January, a decrease in hydropower generation associated with LSJR Alternatives 3 and 4 is primarily related to reduced flood control releases and, to a lesser extent, lower reservoir elevations. These effects are more pronounced as the percentage of unimpaired flow requirement of the LSJR alternatives increases.

Changes in summer hydropower generation will have a slightly greater effect on revenues because the price of energy is generally greater in summer than during the cooler months. An evaluation of the corresponding revenue loss and associated economic effects is evaluated Chapter 20, *Economic Analyses*.



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Baseline	80	44	53	70	86	130	187	245	235	230	179	111
Alternative 2	83	45	53	71	88	130	187	257	245	227	179	112
Alternative 3	87	46	46	60	86	123	193	283	251	205	159	105
Alternative 4	78	41	40	52	98	131	206	298	246	159	127	86

Figure J-2a. Average (across 82 Years of Simulation) of Total Monthly Energy Generation from Hydropower Facilities in the Stanislaus, Tuolumne, and Merced River Watersheds (GWh = gigawatt hours)

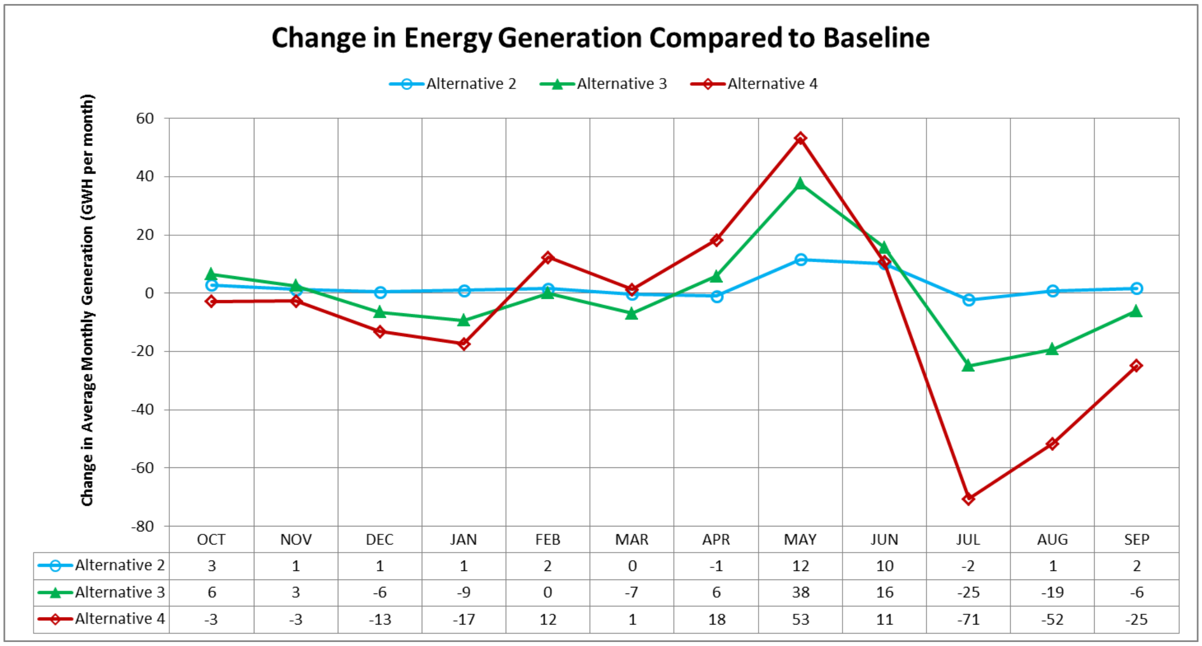


Figure J-2b. Change in Average (across 82 Years of Simulation) of Total Monthly Energy Generation Compared to Baseline (GWh = gigawatt hours)

J.3 Overview of the Transmission System in Central California

The following is a brief overview of the transmission systems and the balancing authorities in which the three hydropower plants, New Melones, New Don Pedro, and New Exchequer are located.[5] The balancing authorities are listed in Table J-4 and discussed in the sections below. This information is provided to give context for the capacity reduction calculation and power flow analysis discussed in Section J.4, *Effects on Generating Capacity and Electric Grid*.

Table J-4. Balancing Authority of Power Plants Under Study

Power Plant	Balancing Authority
New Exchequer	California Independent System Operator (CAISO)
New Melones	Balancing Authority of Northern California (BANC)
New Don Pedro	Turlock Irrigation District (TID—68%) and Sacramento Municipal Utility District (SMUD)—32%

Source: SNL Financial LC n.d. (Distributed under license from SNL.)
Note: Don Pedro Hydro Power Plant is jointly owned by TID and Modesto Irrigation District (MID). BANC performs the balancing authority function for MID's portion of the plant while TID is the balancing authority for its portion. SMUD is a member of BANC.

[5] Balancing authorities are entities responsible for maintaining load-generation balance in their area and supporting the frequency of the interconnected system.

J.3.1 California Independent System Operator

The California Public Utilities Commission (CPUC) adopted the Resource Adequacy (RA) program in 2004 with the twin objectives of providing sufficient resources to the California Independent System Operators (CAISO) to ensure the safe and reliable operation of the grid in real time; and providing appropriate incentives for the siting and construction of new resources needed for reliability in the future (CPUC 2011). As part of the RA program, each load serving entity (LSE) is required to procure enough resources to meet 100 percent of its total forecast load plus a 15 percent reserve. In addition, each LSE is required to file with CPUC demonstrating procurement of sufficient local RA resources to meet its RA obligations in transmission-constrained local areas. Each year CAISO performs the Local Capacity Technical Study (LCT Study) to identify local capacity requirements within its territory. The results of this study are provided to CPUC for consideration in its RA program. These results are also be used by CAISO for identifying the minimum quantity of local capacity necessary to meet the North American Electric Reliability Corporation (NERC) reliability criteria used in the LCT Study (California Independent System Operator 2010).

The LCT Study identifies the local capacity requirement (LCR) under normal and contingency system conditions. The three system conditions under which LCR is evaluated are given below.

- Category A: No Contingencies
- Category B: Loss of a single element (N-1)
- Category C: Category B contingency followed by another Category B contingency but with time between the two to allow operating personnel to make any reasonable and feasible adjustments to the system to prepare for the second Category B contingency.

For any given area or sub-area, the requirement for Category A, B, and C are compared and the most stringent one will dictate that area's LCR requirement. Figure J-3 shows the 10 LCR areas in CAISO for study year 2012. The New Exchequer hydropower plant lies in the Greater Fresno LCR area. The Greater Fresno LCR area is therefore discussed briefly below.

Locational Capacity Requirement in Greater Fresno Area

Table J-5 shows the historical LCR, peak load, and total dependable local area generation for the Greater Fresno area from 2006 to 2015. The exhibit also shows the LCR as a percentage of the total dependable local generation. For example, in 2011, the LCR in Greater Fresno was 2,448 MW while the peak load stood at 3,306 MW; the LCR was 74 percent of the peak load. At the same time, the total dependable generation stood at 2,919 MW, which meant that the LCR was 84 percent of the total dependable generation. In other words, the Greater Fresno has had sufficient local resources available to meet its LCR requirements.

CAISO also identifies sub-areas within the larger LCR area. It is possible that the sub-areas are resource deficient even though the larger area may have sufficient resources to meet its LCR requirement. For 2015, the Greater Fresno LCR area is divided into four sub-areas: Wilson, Herndon, Handford and Reedley. While Wilson, Herndon, and Hanford have sufficient resources to meet their current LCR requirement, Reedley shows a deficiency of 46 MW under Category C contingency conditions. A summary of each sub-area critical contingencies and LCRs is presented below.

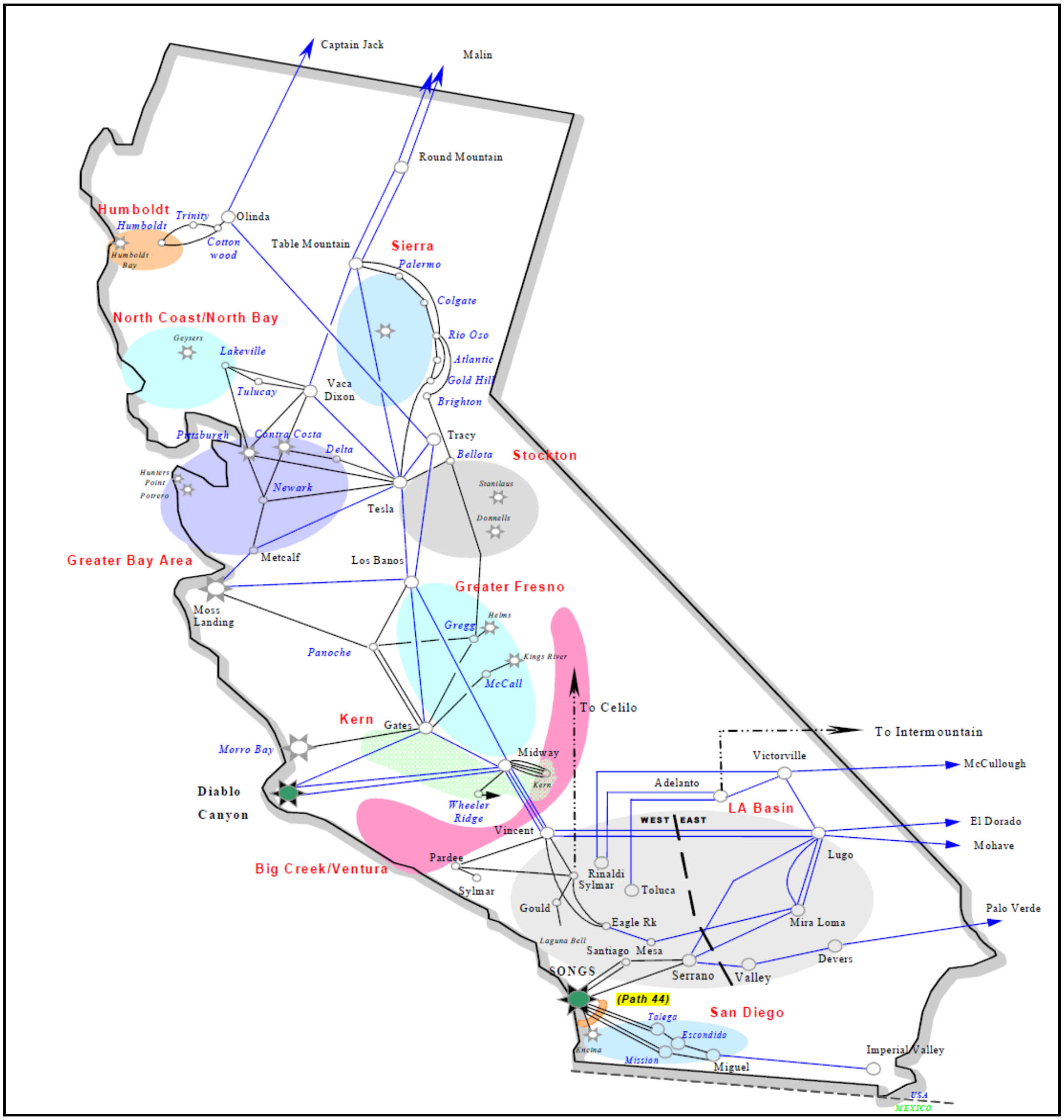


Figure J-3. Local Capacity Area Map of CAISO (Source: CAISO 2010b)

Table J-5. Local Capacity Needs vs. Peak Load and Local Area Generation for Greater Fresno Area

Year	LCR (MW)	Peak Load (MW)	LCR as % of Peak Load	Dependable Local Area Generation (MW)	LCR as % of Total Area Generation
2006	2,837	3,117	91	2,651	107
2007	2,219	3,154	70	2,912	76
2008	2,382	3,260	73	2,991	80
2009	2,680	3,381	79	2,829	95
2010	2,640	3,377	78	2,941	90
2011	2,448	3,306	74	2,919	84
2012	1,907	3,120	61	2,770	69
2013	1,786	3,032	59	2,817	63
2014	1,857	3,246	57	2,828	66
2015	2,439	3,217	76	2,848	86

Source: CAISO 2005.
MW = megawatts

The Wilson sub-area largely defines constraints on importing power into Fresno. The most critical contingency in the Wilson sub-area is the loss of the Melones-Wilson 230 kilovolt (kV) line concurrent with one of the Helms units out of service. The worst overload under this contingency would occur on the Warnerville-Wilson 230 kV line and establishes an LCR of 2,393 MW in 2015. A number of generation units in the Wilson sub-area are found to be capable of reducing the overload with varying degree of effectiveness. New Exchequer is one of these units.

The most critical contingency for the Herndon sub-area is the loss of the Herndon-Barton 230 kV line concurrent with Kerckhoff II generator out of service, which would overload the Herndon-Manchester 115 kV line and establishes an LCR of 439 MW in 2015 as the minimum generation capacity necessary for reliable load serving capability within this sub-area. A number of generation units in the Herndon sub-area are found to be capable of reducing the overload with varying degrees of effectiveness.

In the Hanford sub-area, the most critical contingency is the loss of both 115 kV circuits between McCall and Kingsburg Circuit 1, which would overload Henrietta-GWF 115 kV line. This limiting contingency establishes an LCR of 128 MW in 2015.

The Reedley sub-area is a new sub-area identified by CAISO in 2015 Local Capacity Technical Analysis, and loss of McCall-Reedley 115 kV line followed by Sangar-Reedley 115 kV line establishes an LCR of 56 MW in 2015. In the study, CAISO has identified deficiency of 46 MW in the Reedley sub-area.

Transmission Expansion Plans and New Generator Additions

In the board-approved 2010/2011 transmission plan, CAISO identified a number of transmission upgrades that are needed in the Greater Fresno area to maintain system reliability between 2011 and 2020. PG&E proposed a number of projects to mitigate these reliability violations during the 2010 request window (CAISO 2011). Table J-6 lists the major PG&E projects that were found to be needed by CAISO to maintain system reliability in the Greater Fresno Area.

Table J-6. Reliability Based Transmission Projects in Greater Fresno

Transmission Project Name	Purpose	In-Service Date
Kerckhoff PH #2–Oakhurst 115 kV Line Project	Relieve expected overload on the Corsgold to Oakhurst 115 kV line under 2016–2020 system conditions	2015
Wilson 115 kV Area Reinforcement Project	Relieve a number of reliability violations expected under 2015–2020 system conditions	2015
Oro Loma 70 kV Area Reinforcement Project	Relieve overloads on lines and transformers in the Oro Loma Area under 2015–2020 system conditions	2015
Gates-Gregg 230 kV Transmission Line	Improve transmission reliability in the Greater Fresno area. Assist in the integration of renewable energy, helping to meet California's Renewable Portfolio Standard (RPS). Alleviate constraints at the Helms pumped storage plant.	2022

Source: CAISO 2015a.
kV = kilovolt

A number of generators are also seeking interconnection in the Greater Fresno Area through 2018. Table J-7 provides a list of selected projects that are at an advanced stage of the interconnection process.

Table J-7. Expected New Generator Additions in Greater Fresno

Fuel Type	Interconnecting Sub-Station	Capacity (MW)	Expected In-Service Date	County
Natural Gas	Gates Substation 230kV bus	600	6/1/2017	Kings
Solar	Schindler-Coalinga #2 70kV line	20	12/31/2015	Fresno
Solar	Corcoran- Kingsburg #1 115kV line	20	6/1/2015	Kings
Solar	Schindler-Huron-Gates 70kV line	20	12/1/2016	Fresno
Solar	Panoche-Oro Loma 115kV Line	20	3/31/2016	Fresno
Solar	Merced #1 70 kV	20	5/31/2018	Merced
Solar	Los Banos-Westley 230kV	110	1/26/2016	Merced
Solar	Henrietta-GWF 115 kV Line	100	1/10/2016	Kings
Solar	Mendota Substation 115 kV bus	60	1/12/2016	Fresno
Solar	Henrietta-Tulare Lake 70kV	20	12/30/2015	Kings
Solar	Gates-Gregg 230 kV and Gates-McCall 230 kV	100	9/30/2016	Kings
Solar	Helm-Panoche 230 kV and Panoche-Kearney 230kV	200	9/30/2016	Fresno
Solar	Dairyland - Legrand 115 kV	20	12/1/2015	Madera
Solar	Henrietta-Tulare Lake 70kV	20	12/31/2015	Kings
Solar	Panoche-Schindler #1 & #2 115kV	60	10/1/2016	Fresno
Solar	Giffen substation 70 KV	20	12/20/2016	Fresno
Solar	Borden Sub 230 KV Bus	50	4/10/2016	Madera
Solar	Los Banos-Panoche #1 230kV	200	10/1/2016	Merced
Solar	Mustang Switchyard 230kV	150	30/9/2016	Kings

Source: CAISO 2015b.
Note: All above listed generators have signed interconnection agreements.
kV = kilovolt

J.3.2 Ancillary Service Market

CAISO procures various ancillary services in the market. In the day-ahead and real-time markets, CAISO procures regulation reserve, spinning reserve, and non-spinning reserve. In the hour-ahead market, it procures only operating reserves, which comprise spinning and non-spinning reserves. The ancillary services procured in the market are defined below.

- Regulation Reserves: The generating resources that are running and synchronized with the grid, which can provide reserve capacity so that the operating levels can be increased or decreased within 10 minutes through Automatic Generation Control (AGC) signal based on the regulating ramp rate of the resource. CAISO operates two distinct capacity markets for this service, upward and downward regulation reserve.
- Spinning Reserves: Reserved capacity provided by generating resources that are running with additional capacity that is capable of ramping over a specified range within 10 minutes and able to run for at least 2 hours. CAISO needs this reserve to maintain system frequency stability during emergency operating conditions.
- Non-Spinning Reserves: Reserved capacity provided by the generating resources that are available but not running. These generating resources must be capable of being synchronized to the grid and ramping to a specified level within 10 minutes, and then able to run for at least 2 hours. The CAISO needs non-spinning reserve to maintain system frequency stability during emergency conditions.

The market participants (i.e., electricity providers) can self-provide any or all of these ancillary service products, bid them into the CAISO markets, or purchase them from CAISO. The same resource capacity may be offered for more than one ancillary service into the same CAISO market at the same time. In addition, resources that have registered with a metered subsystem (MSS) that has elected the load following option may submit self-provision bids for load following up and load following down. Scheduling coordinators (SCs) simultaneously submit bids to supply the ancillary service products to CAISO in conjunction with their preferred day-ahead and hour-ahead schedules.

J.3.3 Balancing Authority of Northern California and Sacramento Municipal Utility District

The Balancing Authority of Northern California (BANC) is a joint powers authority comprised of the Sacramento Municipal Utility District (SMUD), MID, Roseville Electric, Redding Electric Utility and Trinity Public Utility District. The third largest balancing authority in California, BANC assumed balancing authorities from SMUD in 2011.

The SMUD, established in 1946, is the nation's sixth largest community-owned electric utility in terms of customers served (approximately 590,000) and covers a 900 square-mile area that includes Sacramento County and a small portion of Placer County. The service territory of SMUD is shown in Figure J-4.

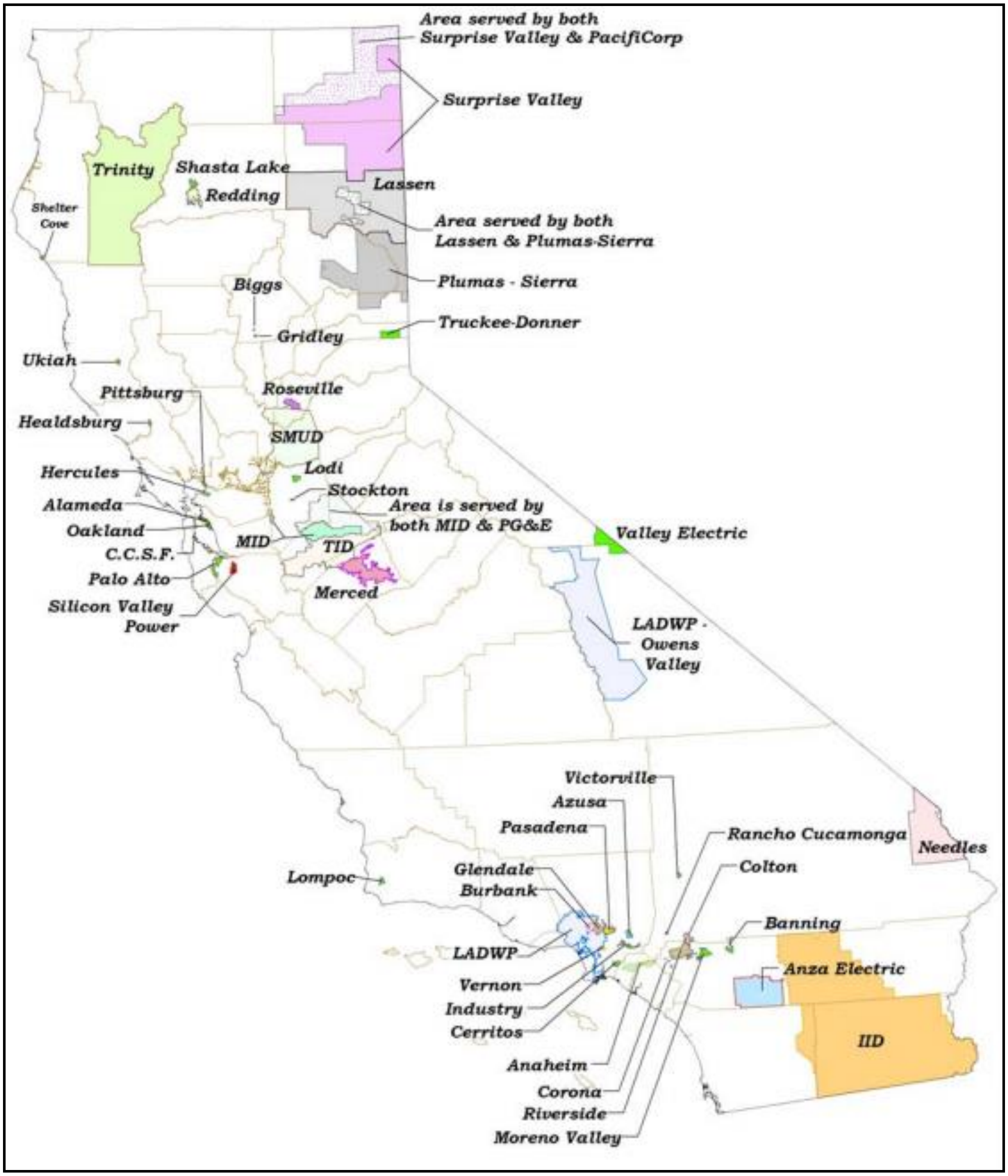


Figure J-4. SMUD Service Territory and Other Territories in California (Source: CEC 2012)

As part of the biennial resource adequacy and resource plan assessments for publically owned utilities, California Energy Commission (Commission) published its biennial report in November 2009 detailing the need and availability of generation resources to meet the future load and planning reserve margin requirements within the territory of publically owned utilities (California Energy Commission 2009). The report indicates that SMUD will be able to meet its resource adequacy requirements in the near term; however, in 2018 SMUD's generation resources may not be sufficient to meet its load and planning reserve margin obligations. The deficiency expected in 2018 is estimated at 347 MW, but the Commission does not expect this to be an issue due to the lead time available to resolve the expected deficiency.

Transmission Expansion Plans and New Generator Additions

SMUD also carries out an annual 10-year transmission planning process to ensure that NERC and Western Electricity Coordinating Council (WECC) Reliability Standards are met each year of the 10-year planning horizon. Major projects that have been proposed in the 2010 transmission plan for the 2016 to 2020 time period are listed in Table J-8 (Sacramento Municipal Utility District 2010). These projects are expected to improve the reliability of SMUD's electric system as well as increase its load serving capability.

Table J-8. Proposed Transmission Upgrades in SMUD 2016–2020

Project Name	Project Description	Expected In-Service Date
Franklin 230/69 kV Substation	New Distribution Substation	May 31, 2016
O'Banion-Sutter 230 kV Double Circuit Transmission Line Conversion	Add circuit breakers to convert O'Banion-Sutter line to double circuit tower line	May 31, 2016
Installation of 200 MVAr transmission capacitors	Install transmission capacitors	May 31, 2019
400 MW Iowa Hill Pump Storage Facility	New Hydropower Plant in the Upper American River Project	May 31, 2020
Lake-Folsom 230 kV and Folsom - Orangevale 230 kV Reconductoring	Reconductor the Lake-Folsom –Orangevale 230 kV Lines	May 31, 2020

kV = kilovolt
MW = megawatts

The New Melones Power Plant physically resides in the CAISO Balancing Authority (BA) Area. However, Sierra Nevada Region (SNR)[6], SMUD, and the CAISO operate New Melones as a pseudo-tie generation export from CAISO into the SMUD BA Area (Western 2010). This arrangement implies that New Melones is electronically and operationally included as part of the SMUD BA Area. For purposes of qualifying capacity, SNR has designated the New Melones Power Plant as part of the Central Valley Project (CVP) resource in the SMUD BA Area. The location of New Melones is shown in Figure J-1.

[6] Sierra Nevada Region (SNR), is a certified scheduling coordinator and an LSE for certain loads and resources within the CAISO Balancing Authority Area.

J.3.4 Turlock Irrigation District

The Turlock Irrigation District (TID) operates as a BA located between Sacramento and Fresno in California's Central Valley (California Transmission Planning Group 2011). Westley 230 kV and Oakdale 115 kV lines provide import access for TID. The TID BA incorporates all 662 square miles of TID's electric service territory (Figure J-5) as well as a 115 kV loop with three 115 kV substations owned by the Merced Irrigation District (Merced ID). The Merced ID facilities are interconnected to TID's August and Tuolumne 115 kV substations and are located just south of TID's service territory and north of the city of Merced. TID is the majority owner and operating partner of the Don Pedro Hydroelectric Project, with 68.46 percent ownership; MID has a 31.54 percent ownership.

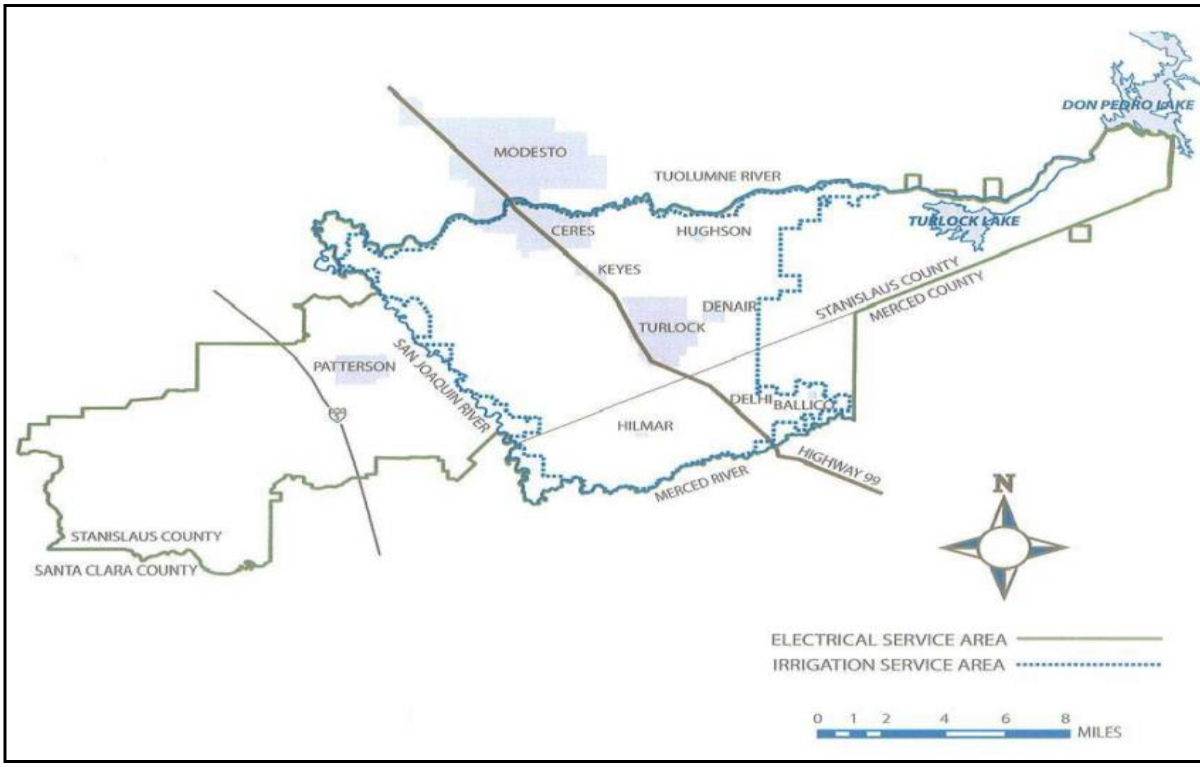


Figure J-5. Turlock Irrigation District Service Area (Source: California Transmission Planning Group 2011)

J.4 Effects on Generating Capacity and Electric Grid

In Section J.2, *Energy Generation Effects*, the total annual or monthly amounts of energy generated (in GWh) by each LSJR alternative and the baseline were estimated and compared. This section considers the effect of the LSJR alternatives on the amount of available power generating capacity during the peak energy-use months of July and August (peak generating capacity) from the major hydropower facilities in the LSJR Watershed (New Melones, New Don Pedro, and New Exchequer) and the corresponding potential to affect the functioning of the electric grid (power flow assessment) during the peak energy-use months of July and August.

J.4.1 Peak Generating Capacity

Peak generating capacity, expressed as MW, refers to the available generating capacity during the peak energy-use months of July and August. This is the power that can be generated with full design flow through the turbines at a given set of reservoir storages during July and August. As the storage elevation in the reservoir is increased, the generating capacity through the turbines is increased. The WSE model was used to estimate the end-of-month reservoir storage elevations for each LSJR alternative and baseline across the 82 years of simulation.

Generating capacity during July and August is calculated based on estimates of the available head (i.e. the difference between end-of-month reservoir storage elevation and tail-water elevation) for generating electric power. The maximum potential capacity is assumed to occur at maximum head (i.e., difference between the maximum elevation and tail-water elevation). Table J-9 shows the maximum head and the corresponding maximum potential capacity for the New Melones, Don Pedro, and New Exchequer hydropower facilities. Since the power generation capacity in MW is directly proportional to the available head, the available capacity of affected hydropower plants in any month under each LSJR alternative is estimated by prorating the maximum plant capacity by the available head estimated from the WSE model. For example, if for any month, the model estimated available head for New Melones is 500 feet (ft); using the maximum head and maximum capacity values from Table J-9, its available capacity for that month is estimated at 256 MWor (300 MW x [500 ft/585 ft]).

Available capacity = maximum potential capacity X (available head/maximum potential head)

Figures J-6 and J-7 present the total available generating capacity (MW) from New Melones, New Don Pedro, and New Exchequer using this approach for peak demand months July and August respectively across the 82 years of WSE model simulated hydrology for the LSJR alternatives and baseline.At times when reservoir levels and hydropower capacity has been low under baseline, reservoir levels and hydropower capacity under all three LSJR alternatives are higher. This is primarily due to the increased storage in the driest years. These figures also show a decrease in the available generation capacity for LSJR Alternatives 3 and 4 relative to baseline during at times when reservoir levels and generating capacities were relatively high under baseline. LSJR Alternative 2 is either similar to or higher than baseline at all capacity levels.

Table J-9. Existing Maximum Potential Power Generation Capacity

Power Plants	Maximum Potential Elevation (Feet)	Tail-water Elevation (Feet)	Maximum Potential Head (Feet)	Maximum Potential Capacity (MW)
New Melones	1,088	503	585	300
Don Pedro	830	310	520	203
New Exchequer	867	400	467	95
MW = megawatt				

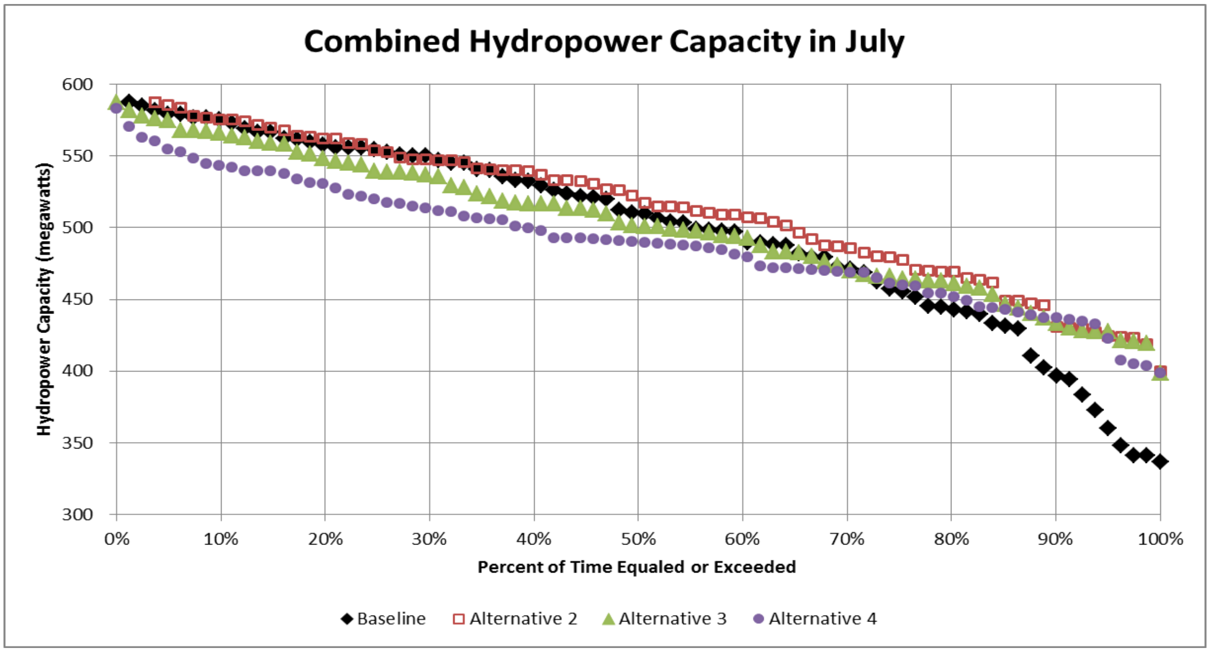


Figure J-6. Exceedance Plot of Total Generating Capacity (megawatts) in July, Across 82 Years of Simulation, from the Three Major Tributary Hydropower Facilities, Comparing LSJR Alternatives 2–4 and Baseline.

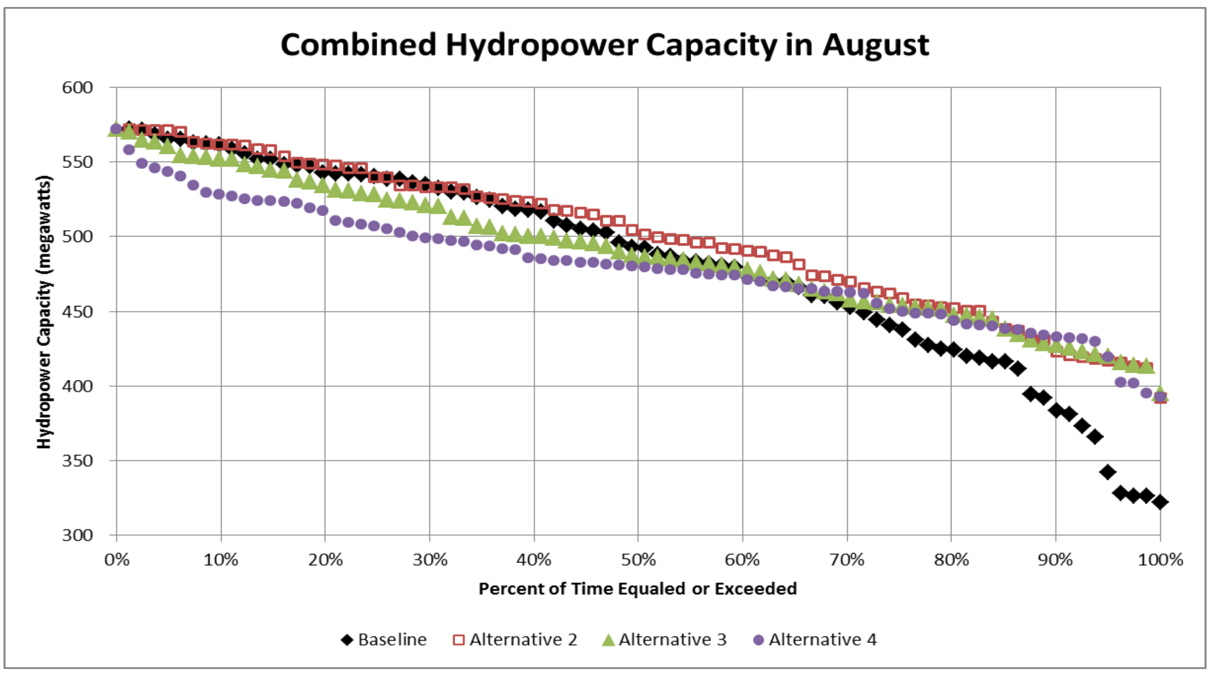


Figure J-7. Exceedance Plot of Total Generating Capacity (megawatts) in August, Across 82 Years of Simulation, from the Three Major Tributary Hydropower Facilities, Comparing LSJR Alternatives 2–4 and Baseline.

J.4.2 Power Flow Assessment Methodology

As shown in the previous section, the LSJR alternatives have the potential to reduce hydropower generation in the summer months because less water would be stored during those months as a result of it being released earlier in the year, thereby reducing the amount of water available for hydropower generation. Because California's electric grid is most stressed during the summer months of June–August, with peak demand typically occurring in the month of July, a reduction in hydropower capacity during this time has the potential to further stress the grid.

LSJR Alternative 2 would not cause a reduction in power capacity from the baseline condition. LSJR Alternatives 3 and 4 resulted in reductions of 2 percent and 4 percent, respectively, to median July hydropower capacity of the three main facilities. The largest reductions in the distributions of the July-August hydropower capacities occurred at the 60th to 70th percentiles (i.e., 40th to 30th percent exceedance levels) and were 3 percent and 7 percent under LSJR Alternatives 3 and 4, respectively. Percent reductions during August were similar to July.

In the WSE modeling, the reduced capacity available from hydropower facilities is not materially different from the previous WSE model results provided in the Public 2012 SED used for the power flow analysis. The previous power flow analysis conducted for LSJR Alternatives 3 and 4 assumed a reduction in July capacity of 5 percent and 8 percent, respectively (slightly greater than the currently modeled largest reductions of 3 percent and 7 percent). The results of 5 percent and 8 percent can inform potential impacts on California's electric grid.

According to NERC, reliability of an electric system comprises two interrelated elements—adequacy and security. Adequacy refers to the amount of capacity resources required to meet peak demand and security refers to the ability of the system to withstand contingencies or other system disturbances, such as the loss of a generating unit or transmission line. Both of these reliability aspects can be gauged from sub-station voltages and transmission line loadings. A steady state power flow assessment of the California grid was performed to check if reduction in hydropower capacities of the three rim dams would adversely impact the grid reliability as defined by NERC.[7]

The power flow assessment was a multi-step process. These steps and assumptions are listed below.

- Prepare a Base Case (California electric grid model under normal and contingency conditions, assuming the facility is in normal operation).[8]
- Prepare two separate Change Cases (California electric grid model under normal and contingency conditions assuming reduced output of the facilities) assuming a 5 percent and 8 percent reduction in available hydropower generating capacity from the New Melones, New Don Pedro, and New Exchequer hydropower facilities.
- Develop criteria for selection of generator and transmission contingencies.
- Develop criteria for voltage and thermal limits.
- Select the areas where transmission line/transformer loadings and sub-station voltages would be monitored.

[7] Power flow software models simulate the operation of the grid and calculate substation voltages and power flowing on transmission lines/transformers. These calculated values can then be compared with standard voltage limits and line/transformer thermal ratings to identify violations.

[8] Under normal conditions, all generation and transmission facilities are assumed to be in service. Contingency conditions refer to the unplanned outage of power system equipment.

Base and Change Case Development

The base case was the latest 2011 heavy summer (high summer power demand) electric grid model of the entire Western Interconnection developed by WECC. This case had a detailed representation of the California electric grid. A summary of load, generation, area interchange, and area losses in the base case is shown in Table J-10.

Table J-10. Representation of the California Electric Grid (Base Case)

Power Flow Area #	Power Flow Area Name	Area Generation (MW)	Area Load (MW)	Area Interchange (MW)	Area Loss (MW)
10	NEW MEXICO	2,955	2,690	105	159
11	EL PASO	978	1,644	-730	64
14	ARIZONA	26,323	19,753	6,284	286
18	NEVADA	5,721	6,338	-708	91
20	MEXICO-CFE	2,108	2,304	-230	34
21	IMPERIALCA	1,100	978	90	31
22	SANDIEGO	3,666	4,930	-1,371	107
24	SOCALIF	17,929	25,278	-7,842	492
26	LADWP	4,554	6,537	-2,410	427
30	PG AND E	27,231	27,050	-784	966
40	NORTHWEST	30,956	25,165	4,507	1,285
50	B.C.HYDRO	11,137	7,900	2,572	665
52	FORTISBC	879	733	127	20
54	ALBERTA	9,971	10,022	-400	349
60	IDAHO	4,058	3,703	139	216
62	MONTANA	3,192	1,837	1,252	102
63	WAPA U.M.	56	-44	92	7
64	SIERRA	1,889	2,037	-208	60
65	PACE	7,914	8,528	-918	304
70	PSCOLORADO	7,531	7,840	-510	200
73	WAPA R.M.	5,998	4,870	941	188

MW = megawatt

Two change cases were developed for the hydropower generation facilities. One change case was prepared with the peak generating capacity of each hydropower facility (New Melones, New Don Pedro, and New Exchequer) reduced by 5 percent of its value in the base case (5 percent less available peak generating capacity than in the base case). The second change case was prepared assuming 8 percent of its value in the base case. Table J-11 summarizes the modeled cases. The total peak generating capacity for these three hydropower facilities assumed in the WECC base case simulation is approximately 400 MW and represents a level that is exceeded about 90 percent of years in both July and August as shown in Figures J-6 and J-7, respectively.

Table J-11. Description of Test Cases Modeled

Case Description	Peak Generating Capacity	Normal Conditions	Contingency Conditions
Base Case	Normal[(a)]	√	√
Change Case #1	Reduced by 5%	√	√
Change Case #2	Reduced by 8%	√	√

a. WECC base case peak generating capacities for New Melones, New Don Pedro, and New Exchequer facilities.

Contingency Selection Criteria

Base and change cases were analyzed for single contingency outage of all the transmission facilities rated 115 kV and above within the BA of the generating facilities, and 230 kV and above in the neighboring BAs or regions.[9] Single contingency outage of all generators rated 100 MW or above, both within the BA of the facilities and in the neighboring BAs, were also used to analyze the performance of electric grid under base and change cases. In the power flow, all the facilities are shown to be a part of PG&E area with Southern California Edison, Northwest, and Sierra as neighboring regions.

Voltage and Transmission Line Limits

The transmission line limits used in the study were the normal and Long-Term Emergency (LTE) ratings. Under normal and contingency conditions, transmission line flows are expected to remain within the normal and long-term emergency ratings, respectively. Similarly, voltage limits were established relative to the nominal voltages. Under normal conditions, system operators regulate nodal voltages within ±5 percent of their nominal values. Under contingency conditions, this limit is relaxed to ±10 percent of the nominal value.

Criteria for Monitoring Transmission Elements

Within the BA of the facilities, the following criteria for monitoring transmission line/transformer loadings and sub-station voltages were used:[10]

- All transmission lines with nominal voltage greater than 115 kV.
- All transformers with both nominal primary and secondary voltage greater than 115 kV.

In the neighboring Balancing Authorities, the following criteria for monitoring transmission/transformer loadings and sub-station voltages were used:

- All transmission lines with nominal voltage greater than 230 kV.
- All transformers with both primary and secondary voltage greater than 230 kV.

[9] In the context of this analysis, neighboring region or neighboring BA is defined as a region which has a direct transmission link with the region in which the facility is located.

[10] The loading of a transmission line or transformer is measured as a ratio of the actual flow across the facility in amperes or mega-volt amperes to the rated value of current. In this analysis, only those lines/transformers whose loading exceeds 90% of the applicable rating are recorded.

The WECC paths in California (referred to as "interfaces" hereafter) were also monitored. These are listed in Table J-12.[11]

Table J-12. WECC Paths Monitored

WECC Path Number	WECC Path Name
15	Midway-Los Banos
24	PG&E-Sierra
25	PacifiCorp/PG&E 115 kV Interconnection
26	Northern-Southern California
52	Silver Peak-Control 55 kV
60	Inyo-Control 115 kV Tie
66	COI
76	Alturas Project

Source: Western Congestion Analysis Task Force 2006.
kV = kilovolt

J.4.3 Power Flow Simulation Tools

The *GE® Positive Sequence Load Flow* (PSLF) model was used for this analysis. PSLF is ideal for simulating the transfer of large blocks of power across a transmission grid or for importing or exporting power to neighboring systems. The model can be used to perform comprehensive and accurate load flow, dynamic simulation, short circuit and contingency analysis, and system fault studies. Using this tool, engineers can also analyze transfer limits while performing economic dispatch. PSLF can simulate large-scale power systems of up to 80,000 buses.[12]

J.4.4 Assumptions for Facilities

The assumptions for the generation facility characteristics and interconnection substations are shown in Table J-13. Other assumptions, including transmission facility normal and long-term emergency ratings, transmission line impedances, and substation nominal voltages were defined in the WECC power flow cases used for the assessment.

Table J-13. Unit Assumptions for the Engineering Assessment

Unit Name	Unit Bus Number in WECC Power Flow Case	Interconnection Voltage (kV)
New Melones	37561, 37562	230
Don Pedro	38550, 38552, 38554	69
New Exchequer	34306	115

kV = kilovolt

[11] WECC Paths refer to either an individual transmission line or a combination of parallel transmission lines on which the total power flow should not exceed a certain value to maintain system reliability.

[12] In Power Flow modeling a "bus" represents all the sub-station equipment that is at the same voltage level and is connected together.

J.4.5 Results and Conclusions

Thousands of transmission lines, nodal voltages, and interfaces under normal system conditions and contingency outages of hundreds of transmission lines and generators were monitored under the base and change cases. The base case sub-station voltages and line/transformer loadings were then compared with those of the change cases. If the comparison showed that sub-station voltages or transmission line/transformer loadings are within limits in the base case, but outside the limits in the change cases (i.e., the 5 percent and 8 percent identified in Section J.4.2, *Power Flow Assessment Methodology*), the unimpaired flow alternatives could be considered to have an adverse impact on the reliability of California's electric grid. Results of the power flow assessment are discussed below.

Comparison between Base and Change Case Line/Transformer Loadings under Normal Conditions

Under normal operating conditions, no transmission line or transformer was found that violated the ratings exclusively in the change cases.

Comparison between Base and Change Case Line/Transformer Loadings under Line/Transformer Contingencies

When base and change cases were studied under transmission line and transformer contingencies, no line/transformer limit violation was found for the base case and change case #1. However, for change case #2, the 230 kV line between Borden and Gregg substations showed a minor violation (100.04 percent of its LTE rating) under the outage of the 230 kV line between Gregg and Storey substations. This minor overload was mitigated through a 5 MW reduction in the total power dispatch (1,148 MW in the base case) of the three Helms units. The new loading of the monitored element after this re-dispatch was 99.81 percent.

Comparison between Base and Change Case Line/Transformer Loadings under Generator Contingencies

Under generator contingencies, no line/transformer limit violations were found that could be exclusively attributed to either change case.

Comparison between Base and Change Case Substation Voltages under Normal and Line/Transformer/Generator Contingencies

No voltage violations were found that could be exclusively attributed to the reduced hydropower capacity in the change cases.

Comparison between Base and Change Case Interface Loadings under Normal and Line/Transformer/Generator Contingencies

No interface limit violations were found that could be exclusively attributed to the reduced hydropower capacity in the change cases.

In conclusion, an engineering assessment was performed to determine if implementation of the unimpaired flow alternatives on the tributaries, and the resulting change in hydropower generation at the hydropower plants, would adversely impact the reliability of California's electric grid.

As described in Section J.4.1, *Peak Generating Capacity*, there is a less-than-significant reduction in available hydropower generating capacity associated with the LSJR alternatives in the peak summer load months of July and August. Additional evaluation determined the electric grid could adapt to 5 percent and 8 percent reductions in available generating capacity from the New Melones, New Don Pedro, and New Exchequer hydropower facilities with less-than-significant impact on its reliability. Based on the results of this study, the San Joaquin River Flow Objectives project would not adversely impact the reliability of California's electric grid.

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Appendix K

Revised Water Quality Control Plan

Appendix K
Revised Water Quality Control Plan

This appendix shows the State Water Resources Control Board's (State Water Board's) proposed changes to the December 13, 2006 *Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary* (2006 Bay-Delta Plan). Proposed changes to the plan are shown in underline and ~~strikeout~~. Some headings from the original 2006 Bay-Delta Plan were originally styled using underlining, and such headings remain underlined in this version.

The 2006 Bay-Delta Plan designates beneficial uses of water within 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.

The plan amendments would establish the following updates to the 2006 Bay-Delta Plan.

- New flow objectives on the Lower San Joaquin River (LSJR) and its three eastside tributaries for the protection of fish and wildlife beneficial uses.
- Revised water quality objectives for the protection of agricultural beneficial uses in the southern Delta.
- A program of implementation to achieve these objectives.
- Monitoring and special studies necessary to fill information needs and determine the effectiveness of, and compliance with, the new objectives.

The new LSJR flow objectives and revised southern Delta water quality (SDWQ) objective and associated program of implementation would replace the existing San Joaquin River (SJR) flow and southern Delta salinity objectives and associated program of implementation in the 2006 Bay-Delta Plan. These objectives are analyzed in the recirculated substitute environmental document (SED) as the LSJR and SDWQ alternatives.

The 2006 Bay-Delta Plan is available at:
http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/2006wqcp/docs/2006_plan_final.pdf.

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ACRONYMS AND ABBREVIATIONS

AFRP	Anadromous Fish Restoration Program
Board	State Water Resources Control Board
BOD	Biochemical Oxygen Demand
BPA	Basin Plan Amendment
CALFED	aka California Bay Delta Authority
CALFED OPS	CALFED Water Operations Management Team
CBDA	California Bay Delta Authority
CEQA	California Environmental Quality Act
cfs	cubic feet per second
COP	Comprehensive Operations Plan
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DBP	Disinfection by-product
DCC	Delta Cross Channel
DFG or DFW	California Department of Fish &and Wildlife (formerly California Department of Fish and Game)
DO	Dissolved Oxygen
DWR	California Department of Water Resources
DWSC	Deep Water Ship Channel
EC	electrical conductivity
EMP	Environmental Monitoring Program
FERC	Federal Energy Regulatory Commission
IEP	Interagency Ecological Program
LSJR	Lower San Joaquin River
MAF	million acre-feet
mg/L	milligram(s) per liter
mmhos/cm	millimhos per centimeter
NDOI	Net Delta Outflow Index
NOAA Fisheries or NMFS	National Marine Fisheries Service
NPDES Permit	National Pollutant Discharge Elimination System Permit
OAL	California Office of Administrative Law
POD	Pelagic Organism Decline
ppt	parts per thousand
Regional Water Board	Regional Water Quality Control Board
ROD	Record of Decision
SDIP	South Delta Improvements Program
SDWA	South Delta Water Agency
SFSU	San Francisco State University
SJRA	San Joaquin River Agreement
SJRGA	San Joaquin River Group Authority
SJRMEP	San Joaquin River Monitoring and Evaluation Program
SLDMWA	San Luis Delta-Mendota Water Authority

SMCG	Suisun Marsh Charter Group
SMPA	Suisun Marsh Preservation Agreement
SMSCP	Suisun Marsh Salinity Control Project
SRCD	Suisun Resource Conservation District
STM Working Group	Stanislaus, Tuolumne and Merced Working Group
SWC	State Water Contractors
SWP	State Water Project
State Water Board	State Water Resources Control Board
TAF	thousand acre-feet
TMDL	Total Maximum Daily Load
UC DAVIS	University of California Davis
UDWA	Urban Drinking Water Agency
USBR	United States Bureau of Reclamation
USCOE	United States Army Corps of Engineers
USDOI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VAMP	Vernalis Adaptive Management Plan
WDR	Waste Discharge Requirements
WQCP	Water Quality Control Plan

References within the text use the above acronyms and abbreviations.

BAY-DELTA PLAN

Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary

Chapter I. Introduction

A. Background

The San Francisco Bay/Sacramento-San Joaquin River Delta Estuary (Bay-Delta Estuary or Estuary) (Figure 1) is important to the natural environment and economy of California. The watershed of the Bay-Delta Estuary provides drinking water to two-thirds of the State's population and water for a multitude of other urban uses, and it supplies some of the State's most productive agricultural areas, both inside and outside of the Estuary. The Bay-Delta Estuary itself is one of the largest ecosystems for fish and wildlife habitat and production in the United States. Historical and current human activities (e.g., water development, land use, wastewater discharges, introduced species, and harvesting), exacerbated by variations in natural conditions, have degraded the beneficial uses of the Bay-Delta Estuary, as evidenced by the declines in populations of many biological resources of the Estuary. Most recently, populations of Delta smelt and other pelagic organisms have exhibited significant declines, leading to investigations as to the possible causes of the degradation of the health of the Delta.

The State Water Resources Control Board (State Water Board) has previously adopted water quality control plans and policies to protect the water quality and to control the water resources that affect the beneficial uses of the Bay-Delta Estuary. These plans and policies were adopted consistent with section 13000 et seq. of the California Water Code and pursuant to the authority contained in section 13170. This Water Quality Control Plan covers the Bay-Delta Estuary and tributary watersheds (Bay-Delta Plan or Plan). ~~This plan supersedes the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary adopted in May 1995 (1995 Bay-Delta Plan or 1995 Plan) as well as the preceding plans that the 1995 Plan superseded.~~ The State Water Board periodically will review this Plan pursuant to Water Code section 13240 to ensure that it provides reasonable protection for the designated beneficial uses.[1] The State Water Board's measures to implement this Plan will consist of the regulation of existing water rights, regulatory measures to protect water quality, and recommendations to other entities. Current and previous versions of the Bay-Delta Plan[2] and supporting documents are available at:

[1] The federal Clean Water Act, at section 303 (c), also requires a review of federal "standards," as defined in the Act, contained in state water quality control plans. (33 U.S.C. § 1313 (c).) The review under section 13240 ordinarily is combined with a review of any federal standards in a state water quality control plan.
[2] References herein to the 1995 Plan refer to the 1995 Bay-Delta Plan. References to the 2006 update refer to the update of the 2006 Bay-Delta Plan.

http://www.waterboards.ca.gov/waterrights/water_issues/programs/bay_delta/wq_control_plans/index.shtml
A summary description of the most recent updates to the Plan and issues of concern are provided in Section D: Key Issues and Plan Updates.

~~Appendix 1 of this plan, titled "Plan Amendment Report," explains the State Water Board's considerations in developing this Water Quality Control Plan. Appendix 1 provides the reasoning for any changes to the 1995 Plan, as well the environmental~~

FIGURE 1
BAY-DELTA ESTUARY

~~analysis for those changes. Documents used to develop this amendment of the 1995 Plan are listed in Appendix 2, titled "Referenced Documents". Appendix 3,~~

~~titled "Responses to Comments," contains the State Water Board's responses to comments received in conjunction with the public hearing held to solicit feedback on this plan.~~

B. Purpose and Applicability

This plan establishes water quality objectives for which implementation can be fully accomplished only if the State Water Board assigns some measure of responsibility to water right holders and water users to mitigate for the effects on the designated beneficial uses of their diversions and use of water. Like all water quality control plans, this plan consists of: (1) beneficial uses to be protected; (2) water quality objectives for the reasonable protection of beneficial uses; and (3) a program of implementation for achieving the water quality objectives. Together, the beneficial uses and the water quality objectives established to reasonably protect the beneficial uses are called water quality standards under the terminology of the federal Clean Water Act.

For the geographic area of the Bay-Delta Estuary, this plan is complementary to the other water quality control plans adopted by the State and Regional Water Quality Control Boards (Regional Water Boards) and State policies for water quality control adopted by the State Water Board. This plan provides reasonable protection for the Estuary's beneficial uses that require control of salinity (caused by saltwater intrusion, municipal discharges, and agricultural drainage) and water project operations (flows and diversions). This plan supersedes the regional water quality control plans to the extent of any conflict between this plan and the regional water quality control plans. The other plans and policies establish water quality objectives and requirements for parameters such as toxic chemicals, bacterial contamination, and other parameters which have the potential to impair beneficial uses or cause nuisance.

Most of the objectives in this plan are being implemented by assigning responsibilities to water right holders because the parameters to be controlled are primarily impacted by flows and diversions. This plan, however, is not to be construed as establishing the responsibilities of water right holders. Nor is this plan to be construed as establishing the quantities of water that any particular water right holder or group of water right holders may be required to release or forego to meet the objectives in this plan. The State Water Board will consider, in a future water rights proceeding or proceedings, the nature and extent of water right holders' responsibilities to meet these objectives. If necessary after a water rights proceeding, this plan will be amended to reflect any changes that may be needed to ensure consistency between the plan and the water right decision.

C. Legal Authority

The State Water Board has prepared this Water Quality Control Plan under the Porter-Cologne Water Quality Control Act. The Regional Water Boards have primary responsibility for formulating and adopting water quality control plans for their respective regions (Wat. Code § 13240), but the State Water Board also is authorized, under Water Code section 13170, to adopt water quality control plans in accordance with the provisions of section 13240 *et seq*[3]. When the State Water Board adopts a water quality control plan, it supersedes regional water quality control plans for the same waters to the extent of any conflict. (Wat. Code § 13170.)

This plan ~~includes an~~ was informed by an environmental report prepared in compliance with Public Resources Code section 21080.5. The Secretary for Resources has certified the State Water Board's basin planning program as meeting the requirements of Public Resources Code section 21080.5. (Cal. Code Regs. tit. 14, § 15251(g).) Section 21080.5 authorizes state agencies acting under a certified program to assess the environmental effects of their actions within the decision-making document instead of in a separate environmental impact report or negative declaration.

a. Program of Implementation. A program of implementation for achieving water quality objectives shall include, but not be limited to: (1) a description of the nature of actions which are necessary to achieve the objectives, including recommendations for appropriate action by any entity, public or private; (2) a time schedule for the actions to be taken; and (3) a description of surveillance to be undertaken to determine compliance with the objectives. (Wat. Code, § 13242.)

b. U.S. Environmental Protection Agency Approval of This Plan. After adopting this Water Quality Control Plan, the State Water Board will submit this plan to the U.S. Environmental Protection Agency (USEPA) for approval under the federal Clean Water Act. (33 U.S.C. section 1251 et seq.) To the extent that this plan addresses matters outside the scope of the Clean Water Act, this plan will be provided to the USEPA for its consideration as a matter of State/federal comity. The State Water Board does not concede that it is required under the Clean Water Act to submit all parts of this plan to the USEPA. Assuming the USEPA has authority under the Clean Water Act to approve the objectives for flow and operations, the State Water Board believes that the USEPA could not adopt standards for these parameters under the Clean Water Act.[4] If the USEPA attempted to adopt such standards, it could fundamentally interfere with the State's water allocation authority under section 101(g) of the Clean Water Act.[5]

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[3] The State Water Board also has authority to adopt State policy for water quality control under Water Code section 13140.

[4] The State Water Board reserves its arguments regarding the USEPA's authority to adopt standards for flow and operations, including standards for salinity intrusion. The State Water Board's legal comments regarding the USEPA's authority are set forth in the State Water Board's comments on the USEPA's January 6, 1994 draft standards, which were provided to the USEPA on March 11, 1994.

[5] The Supreme Court, in *PUD No. 1 of Jefferson County v. Washington Dep't of Ecology* (1994) 114 S.Ct. 1900, upheld a state's ability to impose an instream flow requirement under Clean Water Act section 401 to protect fish habitat which had been designated as a beneficial use in a water quality standard under Clean Water Act section 303. In reaching this result, the Supreme Court rejected arguments based on Clean Water Act section 101(g) that water quantities could not be regulated under the Clean Water Act. The Supreme Court pointed out that insufficient flows can cause water quality violations, and that reduced habitat caused by low flows may constitute pollution. The Court's narrow interpretation of section 101(g) allows regulation of water users by a state to prevent their having an adverse effect on water quality, but does not go so far as to allow a fundamental interference by the USEPA with a state's water allocation authority.

D. ~~Emerging~~ Key Issues and Plan Updates

This ~~Water Quality Control~~ Plan is periodically updated. The most recent update of the Plan was completed in 2016, at which time the following elements were updated:

- San Joaquin River flow objectives to protect fish and wildlife beneficial uses and southern Delta salinity objective to protect agricultural beneficial uses;
- Programs of implementation to achieve and determine compliance with the above objectives; and
- Monitoring and special studies to fill information needs and inform future updates to the objectives.

This 2016 update of the San Joaquin River flow objectives implements the Delta Stewardship Council's Delta Plan recommendation for the State Water Board to adopt, and as soon as reasonably possible, implement flow objectives for high-priority tributaries in the Delta watershed that are necessary to achieve the coequal goals.[6]

The 2016 amendments to this Plan primarily address portions of the Plan concerning the San Joaquin River flow objectives and southern Delta salinity objectives. In addition, updates without regulatory effect were made to descriptions of non-State Water Board programs related to salinity, key Bay-Delta issues and the State Water Board's planning efforts. Not all elements of the Bay-Delta Plan were updated in 2016. Some of the information in the Plan may therefore be out of date. This information will be updated as part of the State Water Board's process of reviewing and updating other elements of the Plan, including water quality objectives and programs of implementation for:

- Delta outflows
- Sacramento and other tributary inflows other than San Joaquin River
- Interior Delta flows
- Suisun Marsh and Suisun Bay salinity

This subsequent review will also address two key issues identified in the 2006 update of the Plan:

~~primarily a planning document that serves to identify the water quality objectives and the beneficial uses to be protected. At the time of this 2006 update to the Plan there are a number of emerging issues that this Plan either does not currently regulate or may not fully regulate because circumstances and scientific knowledge are changing. Those emerging issues are identified here. In addition to the activities described in the *Program of Implementation Chapter*, the State Water Board will~~

[6] The 2009 Delta Reform Act declared that State policy for the Delta must serve two "coequal goals": providing a more reliable water supply for California, and protecting, restoring, and enhancing the Delta ecosystem; and to do so in a manner that protects and enhances the unique cultural, recreational, natural resource, and agricultural values of the Delta as an evolving place.

~~immediately begin a process to evaluate and prioritize water quality control planning activities to address the following emerging issues:~~

1. Ecosystem Regime Shift~~Pelagic Organism Decline (POD)~~
2. Climate Change
3. ~~Delta and Central Valley Salinity~~
4. ~~San Joaquin River Flows~~

~~The State Water Board will conduct these planning activities in conjunction with the Delta Vision Process to develop a sustainable use and protection plan for the Delta, Suisun Bay, and Suisun Marsh. The Delta Vision Process, an interagency effort and outgrowth of the Little Hoover Commission's review of CALFED, was just commencing at the time of this Bay-Delta Plan update. Consistent with this process,~~ The State Water Board will conduct these planning activities with the support of the Delta Stewardship Council's Delta Science Program and the Independent Science Board to assure that Plan updates are based on the best available science. ~~t~~The State Water Board recognizes that planning for and management of the Delta's multiple uses, resources, and ecosystem should occur in cooperation with elected officials, government agencies, stakeholders, academia, and affected Delta and California communities.

1. Ecosystem Regime Shift ~~Pelagic Organism Decline~~

There was a rapid decline in the populations of numerous pelagic fishes in the Sacramento-San Joaquin Delta Estuary and Suisun Bay starting in 2002. This decline became known as the Pelagic Organism Decline (POD), and was studied intensely by the Interagency Ecological Program (IEP) POD work team and numerous other researchers. The POD studies largely concluded that the decline resulted from multiple adverse conditions, with no single explanatory factor. Ongoing research is largely focused on the working hypothesis that the Bay-Delta has undergone an ecosystem regime shift from highly variable environmental conditions that favored native and other estuarine-dependent species to less variable conditions that favor invasive species. Work to better understand the influence that these and other factors have in relation to POD is ongoing. ~~There is a marked decline in numerous pelagic fishes in the Sacramento-San Joaquin Delta Estuary and Suisun Bay. Currently, the Interagency Ecological Program (IEP), through its POD work team, is conducting studies to evaluate the potential causes of these declines. Some of the possible causes that are being considered include invasive species, water project operations, and toxins. The results of the POD studies will be available in 2007. At that time, the State Water Board will review the study results and may amend portions of this Plan to improve habitat conditions in the Estuary.~~

2. Climate Change

A growing body of information suggests that climate change could result in: (1) sea level rise that would adversely impact levees, water quality, and conveyance of water supplies through the Delta; (2) decreased snowmelt in the Sierra Nevada that would reduce effectiveness of existing water storage facilities; (3) increased rainfall that could exacerbate flooding; and (4) adverse biological effects from changes in flow and water quality. Water quality control planning must begin to address these possible effects. Future State Water Board activities therefore should be responsive to the impacts of climate change and provide timely response and guidance to water resources agencies, consistent with the Water Quality Control Plan, as they submit plans and requests to process applications for water conveyance facilities and flow control structures. ~~such as the current South Delta Improvements Project or potential future conveyance structures such as a Delta peripheral canal.~~

3. Delta and Central Valley Salinity

~~A joint State and Regional Board Workshop on Central Valley salinity issues held in January 2006 resulted in broad stakeholder support for development of a Salinity Management Plan for the Central Valley and Delta (Salinity Management Plan) to protect beneficial uses of both surface waters and ground waters. Development and full implementation of the Salinity Management Plan is expected to take 40 to 50 years and to reduce economic hardship related to managing salinity. The State Water Board will develop regulations and provide regulatory encouragement to ensure that infrastructure is developed that improves and maintains Central Valley and Delta salinity while providing certainty to local and regional planners, municipalities, agriculture, water suppliers, food processors, and others.~~

~~The State Water Board will continue to coordinate updates of the Bay-Delta Plan with on-going development of this comprehensive Salinity Management Plan. As part of this larger planning effort, the State Water Board has issued a public notice of a workshop to be held in January 2007 to review: (1) the salinity requirements of the beneficial uses of water in the southern Delta; (2) the causes of salt loading in the southern Delta; (3) practices that could reduce salt loading from Delta sources; (4) flow and salt load reduction measures to implement the salinity objectives; and (5) the timeline for implementation of these measures. The State Water Board intends to develop and manage a study of salinity in the southern Delta as part of this effort. This process could result in amendments to the Bay-Delta Plan, further changes in water rights, or changes in both the Bay-Delta Plan and water rights.~~

4. San Joaquin River Flows

~~Data submitted by fisheries agencies suggest that various fish species within the Delta and San Joaquin River basin have not shown significant signs of recovery since adoption of the San Joaquin River Spring Flow and Pulse Flow objectives in the 1995 Plan and the implementation of the Spring Flow objectives in D-1641. Some species have shown significant declines. The San Joaquin River flow objectives are not changed in the 2006 Plan due to a lack of scientific information on which to base any changes.[7] While the Department of Fish and Game (DFG)~~

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[6] ~~The Program of Implementation for the Pulse Flow Objectives is amended in the 2006 Plan to allow for staged implementation of the objectives by conducting the Vernalis Adaptive Management Plan (VAMP) until 2011. These changes are consistent with the current implementation of the objectives since 2000 pursuant to D-1641.~~

recommended changes to the objectives, those recommendations were based on modeling that had not yet been completed. In addition, other parties also recommended changes to the objectives that were not substantiated by sufficient scientific information. In recognition of the species recovery concerns within the San Joaquin River basin and the Delta, the State Water Board will schedule a workshop after revisions are completed to DFG's San Joaquin River salmon escapement model in response to peer review (anticipated for summer of 2007) to receive additional information concerning the model and its findings and other scientific information concerning the San Joaquin River flow objectives. The State Water Board may receive additional information concerning implementation of the objectives in response to concerns raised by the Department of Interior (DOI) and others. Based on information received during the workshop, the State Water Board may amend the Bay-Delta Plan objectives, the Program of Implementation for those objectives, and/or make changes in water rights. If adequate information is not available to support changes to the objectives, the State Water Board may direct the completion of additional studies and analyses.

In response to concerns raised by DFG and others concerning the interim San Joaquin River Pulse Flow objectives being implemented as part of the Vernalis Adaptive Management Plan (VAMP) experiments, prior to the workshop, the State Water Board recommends that parties to the San Joaquin River Agreement (SJRA) conduct a peer review of the VAMP study design. The State Water Board requests that the peer review analyze whether the experimental flows are providing adequate protection for San Joaquin River and Delta species and whether changes should be made to the experimental design to ensure that adequate information is obtained from the experiment on which to base long term objectives. The State Water Board requests that the parties to the SJRA present the findings of the peer review to the State Water Board during its workshop.

Chapter II. Beneficial Uses

A water quality control plan must establish beneficial uses. (Wat. Code § 13050(j).) Beneficial uses serve as a basis for establishing water quality objectives. The beneficial uses to be protected were established in the 1978 Delta Plan and the 1991 Bay-Delta Plan. Since all of the beneficial uses exist and there were no requests for changes in the beneficial uses, these uses are carried over in this plan from earlier plans, including the 1995 Plan. The beneficial uses protected by this plan are presented below.

Municipal and Domestic Supply (MUN) – Uses of water for community, military, or individual water supply systems including, but not limited to, drinking water supply.

Industrial Service Supply (IND) – Uses of water for industrial activities that do not depend primarily on water quality including, but not limited to, mining cooling water supply, hydraulic conveyance, gravel washing, fire protection, and oil well repressurization.

Industrial Process Supply (PRO) – Uses of water for industrial activities that depend primarily on water quality.

Agricultural Supply (AGR) – Uses of water for farming, horticulture, or ranching including, but not limited to, irrigation, stock watering, or support of vegetation for range grazing.

Ground Water Recharge (GWR) – Uses of water for natural or artificial recharge of ground water for purposes of future extraction, maintenance of water quality, or halting of saltwater intrusion into freshwater aquifers.

Navigation (NAV) – Uses of water for shipping, travel, or other transportation by private, military, or commercial vessels.

Water Contact Recreation (REC-1) – Uses of water for recreational activities involving body contact with water, where ingestion of water is reasonably possible. These include, but are not limited to, swimming, wading, water-skiing, skin and scuba diving, surfing, white water activities, fishing, or use of natural hot springs.

Non-Contact Water Recreation (REC-2) – Uses of water for recreational activities involving proximity to water, but not normally involving body contact with water, where ingestion is reasonably possible. These include, but are not limited to, picnicking, sunbathing, hiking, beachcombing, camping, boating, tide pool and marine life study, hunting, sightseeing, or aesthetic enjoyment in conjunction with the above activities.

Shellfish Harvesting (SHELL) – Uses of water that support habitats suitable for the collection of filter-feeding shellfish (e.g., clams, oysters, and mussels) for human consumption, commercial or sports purposes.

Commercial and Sport Fishing (COMM) – Uses of water for commercial or recreational collection of fish, shellfish, or other organisms including, but not limited to, uses involving organisms intended for human consumption or bait purposes.

Warm Freshwater Habitat (WARM) – Uses of water that support warm water ecosystems including, but not limited to, preservation of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Cold Freshwater Habitat (COLD) – Uses of water that support cold water ecosystems including, but not limited to, preservation or enhancements of aquatic habitats, vegetation, fish, or wildlife, including invertebrates.

Migration of Aquatic Organisms (MIGR) – Uses of water that support habitats necessary for migration or other temporary activities by aquatic organisms, such as anadromous fish.

Spawning, Reproduction, and/or Early Development (SPWN) – Uses of water that support high quality aquatic habitats suitable for reproduction and early development of fish.

Estuarine Habitat (EST) – Uses of water that support estuarine ecosystems including, but not limited to, preservation or enhancement of estuarine habitats, vegetation, fish, shellfish, or wildlife (e.g., estuarine mammals, waterfowl, shorebirds).

Wildlife Habitat (WILD) – Uses of water that support estuarine ecosystems including, but not limited to, preservation and enhancement of terrestrial habitats, vegetation, wildlife (e.g., mammals, birds, reptiles, amphibians, invertebrates), or wildlife water and food sources.

Rare, Threatened, or Endangered Species (RARE) – Uses of water that support habitats necessary, at least in part, for the survival and successful maintenance of plant or animal species established under State or federal law as being rare, threatened, or endangered.

Chapter III. Water Quality Objectives

A water quality control plan must contain such water quality objectives as are needed to ensure the reasonable protection of beneficial uses and the prevention of nuisance. (Wat. Code, § 13241.) The State Water Board must consider, in establishing water quality objectives:

- The past, present, and probable future beneficial uses of water;
- The environmental characteristics of the hydrographic unit under consideration, including the quality of water available thereto;
- The water quality conditions that could reasonably be achieved through the coordinated control of all factors that affect water quality in the area;
- Economic considerations;
- The need for developing housing within the region;
- The need to develop and use recycled water. (Wat. Code, § 13241.)

Flow and water project operations are within the scope of objectives that can be adopted in a water quality control plan under the Porter-Cologne Water Quality Control Act.

This chapter establishes water quality objectives which, in conjunction with the water quality objectives for the Bay-Delta Estuary that are included in other State Water Board adopted water quality control plans and in water quality control plans for the Central Valley and San Francisco Bay Basins, when implemented, will: (1) provide for reasonable protection of municipal, industrial, and agricultural beneficial uses; (2) provide reasonable protection of fish and wildlife beneficial uses at a level which stabilizes or enhances the conditions of aquatic resources; and (3) prevent nuisance. These water quality objectives are established to attain the highest quality of water that is reasonable, considering all the demands being made on waters in the Estuary.

The water quality objectives in this plan apply to waters of the San Francisco Bay system and the legal Sacramento-San Joaquin Delta, as specified in the objectives. Unless otherwise indicated, water quality objectives cited for a general area, such as for the southern Delta, are applicable for all locations in that general area and compliance locations will be used to determine compliance with the cited objectives. Tables 1, 2, and 3 contain the water quality objectives for the protection of municipal and industrial, agricultural, and fish and wildlife beneficial uses, respectively.

A. Water Quality Objectives for Municipal and Industrial Beneficial Uses

The water quality objectives in Table 1 provide reasonable protection of the beneficial uses MUN, IND, and PRO, from the effects of salinity intrusion. These municipal and industrial objectives also provide protection for the beneficial uses of REC-1, REC-2, and GWR. ~~These objectives are unchanged from the 1995 Bay-Delta Plan.~~

B. Water Quality Objectives for Agricultural Beneficial Uses

The water quality objectives in Table 2 provide reasonable protection of the beneficial use AGR, from the effects of salinity intrusion and agricultural drainage in the western, interior, and southern Delta. ~~These objectives are unchanged from the 1991 Bay-Delta Plan~~.

C. Water Quality Objectives for Fish and Wildlife Beneficial Uses

The water quality objectives in Table 3 provide reasonable protection of fish and wildlife beneficial uses in the Bay-Delta Estuary including EST, COLD, WARM, MIGR, SPWN, WILD, and RARE. Protection of these fish and wildlife beneficial uses also provides protection for the beneficial uses of SHELL, COMM, and NAV. The parameters to be regulated under Table 3 are dissolved oxygen, salinity (expressed as electrical conductivity), Delta outflow, river flows, export limits, and Delta Cross Channel gate operation. Information available in 1995 indicated that, unlike water quality objectives for parameters such as dissolved oxygen, temperature, and toxic chemicals, which have threshold levels beyond which adverse impacts to the beneficial uses occur, there were no defined threshold conditions that could be used to set objectives for flows and project operations. Instead, available information indicated that a continuum of protection exists. Based on that information, higher flows and lower exports provided greater protection for the bulk of estuarine resources up to the limit of unimpaired conditions. Therefore, these objectives were set based on a subjective determination of the reasonable needs of all the consumptive and nonconsumptive demands on the waters of the Estuary. After completion of the POD studies, the State Board will review the study results and may consider amending this Plan to improve water quality protections for fish and wildlife in the Estuary.

Table 1
Water Quality Objectives For Municipal and Industrial Beneficial Uses

COMPLIANCE LOCATIONS	INTERAGENCY STATION NUMBER (RKI [1])	PARAMETER	DESCRIPTION (UNIT)	WATER YEAR TYPE [2]	TIME PERIOD	VALUE
Contra Costa Canal at Pumping Plant #1 ***-or-*** *San Joaquin River at Antioch Water Works Intake*	*C-5 (CHCCC06)* *D12 (near) (RSAN007)*	*Chloride (Cl^-)*	*Maximum mean daily 150 mg/L Cl^- for at least the number of days shown during the calendar year. Must be provided in intervals of not less than two weeks duration. (Percentage of calendar year shown in parenthesis)*			*No. of days each calendar year ≤150 mg/L Cl^-*
				W		*240 (66%)*
				AN		*190 (52%)*
				BN		*175 (48%)*
				D		*165 (45%)*
				C		*155 (42%)*
Contra Costa Canal at Pumping Plant #1 ***-and-*** *West Canal at mouth of Clifton Court Forebay* ***-and-*** *Delta-Mendota Canal at Tracy Pumping Plant* ***-and-*** *Barker Slough at North Bay Aqueduct Intake* ***-and-*** *Cache Slough at City of Vallejo Intake [3]*	*C-5 (CHCCC06)* *C-9 (CHWST0)* *DMC-1 CHDMC004* *--- (SLSAR3)* *C-19 (SLCCH16)*	*Chloride (Cl^-)*	*Maximum mean daily (mg/L)*	*All*	*Oct-Sep*	*250*

Table 1 Footnotes:

[1] *River Kilometer Index station number.*
[2] *The Sacramento Valley 40-30-30 water year hydrologic classification index (see Figure 2) applies for determinations of water year type.*
[3] *Cache Slough objective to be effective only when water is being diverted from this location.*

Table 2
Water Quality Objectives For Agricultural Beneficial Uses

COMPLIANCE LOCATIONS	INTERAGENCY STATION NUMBER (RKI [1])	PARAMETER	DESCRIPTION (UNIT) [2]	WATER YEAR TYPE [3]	TIME PERIOD	VALUE
WESTERN DELTA						
Sacramento River at Emmaton	*D-22 (RSAC092)*	*Electrical Con-ductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Jul 1*	*0.63*
				BN	*Jun 20*	*1.14*
				D	*Jun 15*	*1.67*
				C	*----*	*2.78*
San Joaquin River at Jersey Point	*D-15 (RSAN018)*	*Electrical Con-ductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Aug 15*	*----*
				BN	*Jun 20*	*0.74*
				D	*Jun 15*	*1.35*
				C	*----*	*2.20*
INTERIOR DELTA						
South Fork Mokelumne River at Terminous	*C-13 (RSMKL08)*	*Electrical Con-ductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Aug 15*	*----*
				BN	*Aug 15*	*----*
				D	*Aug 15*	*----*
				C	*----*	*0.54*
San Joaquin River at San Andreas Landing	*C-4 (RSAN032)*	*Electrical Con-ductivity (EC)*	*Maximum 14-day running average of mean daily EC (mmhos/cm)*		*0.45 EC April 1 to date shown*	*EC from date shown to Aug 15 [4]*
				W	*Aug 15*	*----*
				AN	*Aug 15*	*----*
				BN	*Aug 15*	*----*
				D	*Jun 25*	*0.58*
				C	*----*	*0.87*
SOUTHERN DELTA						
San Joaquin River at Airport Way Bridge, Vernalis	*C-10 [5] (RSAN112)*	*Electrical Con-ductivity (EC)*	*Maximum 30-day running average of mean daily EC (~~mmhos~~dS/m/~~cm~~ [6])*	*All*	*Year-round~~Apr-Aug~~* *~~Sep-Mar~~*	*~~0.7~~1.0* *~~1.0~~*
-and-						
San Joaquin River from Vernalis to~~at~~ Brandt Bridge ~~site~~	*C-6 [5] (RSAN073)*					
-and-						
Old River ~~near~~from Middle River to Victoria Canal	*C-8 [5] (ROLD69)*					
-and-						
Old River/Grant Line Canal from Head of Old River to ~~at Tracy Road Bridge~~West Canal	*P-12 [5] (ROLD59)*					
EXPORT AREA						
West Canal at mouth of Clifton Court Forebay	*C-9 (CHWST0)*	*Electrical Con-ductivity (EC)*	*Maximum monthly average of mean daily EC (mmhos/cm)*	*All*	*Oct-Sep*	*1.0*
-and-						
Delta-Mendota Canal at Tracy Pumping Plant	*DMC-1 (CHDMC004)*					

Table 2 Footnotes:

[1] River Kilometer Index station number.

[2] Determination of compliance with an objective expressed as a running average begins on the last day of the averaging period. The averaging period commences with the first day of the time period for the applicable objective. If the objective is not met on the last day of the averaging period, all days in the averaging period are considered out of compliance.

[3] The Sacramento Valley 40-30-30 water year hydrologic classification index (see Figure 2) applies for determinations of water year type.

[4] When no date is shown, EC limit continues from April 1.

[5] Salinity objectives are subject to the Variance Policy, Salinity Variance Program and Salinity Exception Program adopted in Central Valley Regional Water Board Resolution No. R5-2014-0074.

[6] 1 mmhos/cm = 1 dS/m. The International System of Units for EC is dS/m. As other portions of Table 2 are updated in future amendments to the Bay-Delta Plan, the units of measurement for EC will be updated to the international system.

Table 3
WATER QUALITY OBJECTIVES FOR FISH AND WILDLIFE BENEFICIAL USES

COMPLIANCE LOCATIONS	INTERAGENCY STATION NUMBER (RKI [1])	PARAMETER	DESCRIPTION (UNIT) [2]	WATER YEAR TYPE [3]	TIME PERIOD	VALUE
DISSOLVED OXYGEN						
San Joaquin River between Turner Cut & Stockton	*(RSAN050-RSAN061)*	*Dissolved Oxygen (DO)*	*Minimum DO (mg/L)*	*All*	*Sep-Nov*	*6.0*
SALMON PROTECTION			*narrative*	*Water quality conditions shall be maintained, together with other measures in the watershed, sufficient to achieve a doubling of natural production of chinook salmon from the average production of 1967-1991, consistent with the provisions of State and federal law.*		
SAN JOAQUIN RIVER SALINITY						
San Joaquin River at and between Jersey Point and Prisoners Point [4]	*D-15 (RSAN018)* ***-and-*** *D-29 (RSAN038)*	*Electrical Conductivity (EC)*	*Maximum 14-day running average of mean daily EC(mmhos/cm)*	*W,AN,BN, D*	*Apr-May*	*0.44 [5]*
EASTERN SUISUN MARSH SALINITY[6]						
Sacramento River at Collinsville ***-and-*** *Montezuma Slough at National Steel* ***-and-*** *Montezuma Slough near Beldon Landing*	*C-2 (RSAC081)* *S-64 (SLMZU25)* *S-49 (SLMZU11)*	*Electrical Conductivity (EC)*	*Maximum monthly average of both daily high tide EC values (mmhos/cm), or demonstrate that equivalent or better protection will be provided at the location*	*All*	*Oct* *Nov-Dec* *Jan* *Feb-Mar* *Apr-May*	*19.0* *15.5* *12.5* *8.0* *11.0*
WESTERN SUISUN MARSH SALINITY[6]						
Chadbourne Slough at Sunrise Duck Club ***-and-*** *Suisun Slough, 300 feet south of Volanti Slough* ***-and-*** *Cordelia Slough at Ibis Club* ***-and-*** *Goodyear Slough at Morrow Island Clubhouse* ***-and-*** *Water supply intakes for waterfowl management areas on Van Sickle and Chipps islands*	*S-21 (SLCBN1)* *S-42 (SLSUS12)* *S-97 (SLCRD06)* *S-35 (SLGYR03)* *No locations Specified*	*Electrical Conductivity (EC)*	*Maximum monthly average of both daily high tide EC values (mmhos/cm), or demonstrate that equivalent or better protection will be provided at the location*	*All but deficiency period*	*Oct* *Nov* *Dec* *Jan* *Feb-Mar* *Apr-May*	*19.0* *16.5* *15.5* *12.5* *8.0* *11.0*
				Deficiency period [7]	*Oct* *Nov* *Dec-Mar* *Apr* *May*	*19.0* *16.5* *15.6* *14.0* *12.5*
BRACKISH TIDAL MARSHES OF SUISUN BAY			*narrative*	*Water quality conditions sufficient to support a natural gradient in species composition and wildlife habitat characteristic of a brackish marsh throughout all elevations of the tidal marshes bordering Suisun Bay shall be maintained. Water quality conditions shall be maintained so that none of the following occurs: (a) loss of diversity; (b) conversion of brackish marsh to salt marsh; (c) for animals, decreased population abundance of those species vulnerable to increased mortality and loss of habitat from increased water salinity; or (d) for plants, significant reduction in stature or percent cover from increased water or soil salinity or other water quality parameters.*		

Table 3 (continued)
WATER QUALITY OBJECTIVES FOR FISH AND WILDLIFE BENEFICIAL USES

COMPLIANCE LOCATIONS	INTERAGENCY STATION NUMBER (RKI [1])	PARAMETER	DESCRIPTION (UNIT) [2]	WATER YEAR TYPE [3]	TIME PERIOD	VALUE
DELTA OUTFLOW						
		Net Delta Outflow Index (NDOI) [8]	*Minimum monthly average [9] NDOI(cfs)*	*All*	*Jan*	*4,500 [10]*
				All	*Feb-Jun*	*[11]*
				W,AN	*Jul*	*8,000*
				BN		*6,500*
				D		*5,000*
				C		*4,000*
				W,AN,BN	*Aug*	*4,000*
				D		*3,500*
				C		*3,000*
				All	*Sep*	*3,000*
				W,AN,BN,D	*Oct*	*4,000*
				C		*3,000*
				W,AN,BN,D	*Nov-Dec*	*4,500*
				C		*3,500*
RIVER FLOWS						
Sacramento River at Rio Vista	*D-24 (RSAC101)*	*Flow rate*	*Minimum monthly average [12] flow rate (cfs)*	*All*	*Sep*	*3,000*
				W,AN,BN,D	*Oct*	*4,000*
				C		*3,000*
				W,AN,BN,D	*Nov-Dec*	*4,500*
				C		*3,500*
LOWER SAN JOAQUIN RIVER FLOWS						
San Joaquin River at Airport Way Bridge, Vernalis	*C-10 (RSAN112)*	*Flow rate*	*Minimum monthly average ~~[13]~~ flow rate (cfs) ~~[14]~~*	~~*W,AN*~~	~~*Feb-Apr 14 and May 16-Jun*~~	~~*2,130 or 3,420*~~
				~~*BN,D*~~		~~*1,420 or 2,280*~~
				~~*C*~~		~~*710 or 1,140*~~
				~~*W*~~	~~*Apr 15-May 15 [15]*~~	~~*7,330 or 8,620*~~
				~~*AN*~~		~~*5,730 or 7,020*~~
				~~*BN*~~		~~*4,620 or 5,480*~~
				~~*D*~~		~~*4,020 or 4,880*~~
				~~*C*~~		~~*3,110 or 3,540*~~
				All	*Oct*	*1,000 [13]~~[16]~~*
San Joaquin River at Airport Way Bridge, Vernalis	*C-10*	*Flow Rate*	*Narrative & Minimum 7-day running average flow rate (cfs) for February through June*	*Maintain inflow conditions from the San Joaquin River watershed to the Delta at Vernalis sufficient to support and maintain the natural production of viable native San Joaquin River watershed fish populations migrating through the Delta. Inflow conditions that reasonably contribute toward maintaining viable native migratory San Joaquin River fish populations include, but may not be limited to, flows that more closely mimic the natural hydrographic conditions to which native fish species are adapted, including the relative magnitude, duration, timing, and spatial extent of flows as they would naturally occur. Indicators of viability include population abundance, spatial extent, distribution, structure, genetic and life history diversity, and productivity.* *A percent of unimpaired flow between 30% - 50%, inclusive, from each of the Stanislaus, Tuolumne, and Merced Rivers shall be maintained from February through June. [14]* *Notwithstanding the above unimpaired flow requirement, a minimum base flow value between 800 – 1,200 cfs, inclusive, at Vernalis shall be maintained at all times during February through June.*		
Stanislaus River at Koetitz	*DWR Gage KOT*					
Tuolumne River at Modesto	*USGS Gage 1129000*					
Merced River near Stevenson	*DWR Gage MST*					

EXPORT LIMITS						
		Combined export rate [~~17~~15]	*Maximum 3-day running average (cfs)*	*All*	*Apr 15-May 15 [~~18~~16]*	*[~~19~~17]*
			Maximum percent of Delta inflow diverted [~~20~~18] [~~21~~19]	*All*	*Feb-Jun*	*35% Delta inflow [~~22~~20]*
				All	*Jul-Jan*	*65% Delta inflow*
DELTA CROSS CHANNEL GATES CLOSURE						
Delta Cross Channel at Walnut Grove	—	*Closure of gates*	*Closed gates*	*All*	*Nov-Jan*	*[~~23~~21]*
					Feb-May 20	*----*
					May 21-Jun 15	*[~~24~~22]*

Table 3 Footnotes:

[1] River Kilometer Index station number.

[2] Determination of compliance with an objective expressed as a running average begins on the last day of the averaging period. The averaging period commences with the first day of the time period of the applicable objective. If the objective is not met on the last day of the averaging period, all days in the averaging period are considered out of compliance.

[3] The Sacramento Valley 40-30-30 Water Year Hydrologic Classification Index (see Figure 2) applies unless otherwise specified.

[4] Compliance will be determined at Jersey Point (station D15) and Prisoners Point (station D29).

[5] This standard does not apply in May when the best available May estimate of the Sacramento River Index for the water year is less than 8.1 MAF at the 90% exceedance level. [Note: The Sacramento River Index refers to the sum of the unimpaired runoff in the water year as published in the California Department of Water Resources' (DWR) Bulletin 120 for the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total unimpaired inflow to Oroville Reservoir; Yuba River at Smartville; and American River, total unimpaired inflow to Folsom Reservoir.]

[6] An exceedance of any of these objectives at a time when it is established through certification by the entity operating the Suisun Marsh Salinity Control Gates that the Gates are being operated to the maximum extent shall not be considered a violation of the objective.

[7] A deficiency period is: (1) the second consecutive dry water year following a critical year; (2) a dry water year following a year in which the Sacramento River Index (described in footnote 5) was less than 11.35; or (3) a critical water year following a dry or critical water year. The determination of a deficiency period is made using the prior year's final Water Year Type determination and a forecast of the current year's Water Year Type; and remains in effect until a subsequent water year is other than a Dry or Critical water year as announced on May 31 by DWR and U.S. Bureau of Reclamation (USBR) as the final water year determination.

[8] Net Delta Outflow Index (NDOI) is defined in Figure 4.

[9] For the May-January objectives, if the value is less than or equal to 5,000 cfs, the 7-day running average shall not be less than 1,000 cfs below the value; if the value is greater than 5,000 cfs, the 7-day running average shall not be less than 80% of the value.

[10] The objective is increased to 6,000 cfs if the best available estimate of the Eight River Index for December is greater than 800 TAF. [Note: The Eight River Index refers to the sum of the unimpaired runoff as published in the DWR Bulletin 120 for the following locations: Sacramento River flow at Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River flow at Smartville; American River, total inflow to Folsom Reservoir; Stanislaus River, total inflow to New Melones Reservoir; Tuolumne River, total inflow to Don Pedro Reservoir; Merced River, total inflow to Exchequer Reservoir; and San Joaquin River, total inflow to Millerton Lake.]

[11] The minimum daily Delta outflow shall be 7,100 cfs for this period, calculated as a 3-day running average. This requirement is also met if either the daily average or 14-day running average EC at the confluence of the Sacramento and the San Joaquin rivers is less than or equal to 2.64 mmhos/cm (Collinsville station C2). If the best available estimate of the Eight River Index (described in footnote 10) for January is more than 900 TAF, the daily average or 14-day running average EC at station C2 shall be less than or equal to 2.64 mmhos/cm for at least one day between February 1 and February 14; however, if the best available estimate of the Eight River Index for January is between 650 TAF and 900 TAF, the Executive Director of the State Water Board shall decide whether this requirement applies. If the best available estimate of the Eight River Index for February is less than 500 TAF, the standard may be further relaxed in March upon the request of the DWR and the USBR, subject to the approval of the Executive Director of the State Water Board. The standard does not apply in May and June if the best available May estimate of the Sacramento River Index (described in footnote 5) for the water year is less than 8.1 MAF at the 90% exceedance level. Under this circumstance, a minimum

14-day running average flow of 4,000 cfs is required in May and June. Additional Delta outflow objectives are contained in Table 4.

[12] The 7-day running average shall not be less than 1,000 cfs below the monthly objective.
~~[13] Partial months are averaged for that period. For example, the flow rate for April 1-14 would be averaged over 14 days. The 7-day running average shall not be less than 20% below the flow rate objective, with the exception of the April 15-May 15 pulse flow period when this restriction does not apply.~~

~~[14] The water year classification will be established using the best available estimate of the 60-20-20 San Joaquin Valley Water Year Hydrologic Classification (see Figure 3) at the 75% exceedance level. The higher flow objective applies when the 2-ppt isohaline (measured as 2.64 mmhos/cm surface salinity) is required to be at or west of Chipps Island.~~

~~[15] This time period may be varied based on real-time monitoring. One pulse, or two separate pulses of combined duration equal to the single pulse, should be scheduled to coincide with fish migration in San Joaquin River tributaries and the Delta. The USBR will schedule the time period of the pulse or pulses in consultation with the USFWS, the NOAA Fisheries, and the DFG. Consultation with the CALFED Operations Group established under the Framework Agreement will satisfy the consultation requirement. The schedule is subject to the approval of the Executive Director of the State Water Board.~~

[1~~6~~3]Plus up to an additional 28 TAF pulse/attraction flow during all water year types. The amount of additional water will be limited to that amount necessary to ~~provide~~ achieve a monthly average flow of 2,000 cfs. The additional 28 TAF pulse flow is not required in a critical year following a critical year. The pulse flow will be scheduled ~~by the DWR and the USBR~~ in consultation with the USFWS, the NOAA Fisheries and the DF~~G~~W. ~~Consultation with the CALFED Operations Group established under the Framework Agreement will satisfy the consultation requirement.~~

[14] Unimpaired flow represents the natural water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds.

[1~~7~~5]Combined export rate for this objective is defined as the Clifton Court Forebay inflow rate (minus actual Byron-Bethany Irrigation District diversions from Clifton Court Forebay) and the export rate of the Tracy pumping plant.

[1~~8~~6]This time period may be varied based on real-time monitoring. ~~and will coincide with the San Joaquin River pulse flow described in footnote 15.~~ The DWR and the USBR, in consultation with the USFWS, the NOAA Fisheries and the DF~~G~~W, will determine the time period for this 31-day export limit. Consultation with the CALFED Operations Group established under the Framework Agreement will satisfy the consultation requirement.

[1~~9~~7]Maximum export rate is 1,500 cfs or 100% of the 3-day running average of San Joaquin River flow at Vernalis, whichever is greater. Variations to this maximum export rate may be authorized if agreed to by the USFWS, the NOAA Fisheries and the DF~~G~~W. This flexibility is intended to result in no net water supply cost annually within the limits of the water quality and operational requirements of this plan. Variations may result from recommendations of agencies for protection of fish resources, including actions taken pursuant to the State and federal Endangered Species Act. Any variations will be effective immediately upon notice to the Executive Director of the State Water Board. If the Executive Director does not object to the variations within 10 days, the variations will remain in effect. The Executive Director of the State Water Board is also authorized to grant short-term exemptions to export limits for the purpose of facilitating a study of the feasibility of recirculating export water into the San Joaquin River to meet flow objectives.

[~~20~~18]Percent of Delta inflow diverted is defined in Figure 4. For the calculation of maximum percent Delta inflow diverted, the export rate is a 3-day running average and the Delta inflow is a 14-day running average, except when the Central Valley Project or the State Water Project (SWP) is making storage withdrawals for export, in which case both the export rate and the Delta inflow are 3-day running averages.

[~~21~~19]The percent Delta inflow diverted values can be varied either up or down. Variations are authorized subject to the process described in footnote 1~~9~~7.

[2~~2~~0]If the best available estimate of the Eight River Index (described in footnote 10) for January is less than or equal to 1.0 MAF, the export limit for February is 45% of Delta inflow. If the best available estimate of the Eight River Index for January is greater than 1.5 MAF, the February export limit is 35% of Delta inflow. If the best available estimate of the Eight River Index for January is between 1.0 MAF and 1.5 MAF, the DWR and the USBR will set the export limit for February within the range of 35% to 45%, after consultation with the USFWS, the NOAA Fisheries and the DF~~G~~W. Consultation with the CALFED Operations Group established under the Framework Agreement will satisfy the consultation requirement.

[2~~3~~1]For the November-January period, close Delta Cross Channel gates for a total of up to 45 days. The USBR will determine the timing and duration of the gate closure after consultation with the USFWS, the NOAA Fisheries and the DF~~G~~W. Consultation with the CALFED Operations Group established under the Framework Agreement will satisfy the consultation requirement.

[2~~4~~2]For the May 21-June 15 period, close the Delta Cross Channel gates for a total of 14 days. The USBR will determine the timing and duration of the gate closure after consultation with the USFWS, the NOAA Fisheries and the DF~~G~~W.

Consultation with the CALFED Operations Group established under the Framework Agreement will satisfy the consultation requirement. Gate closures shall be based on the need for the protection of fish. The process for approval of variations shall be similar to that described in footnote 197.

FIGURE 2

Sacramento Valley Water Year Hydrologic Classification

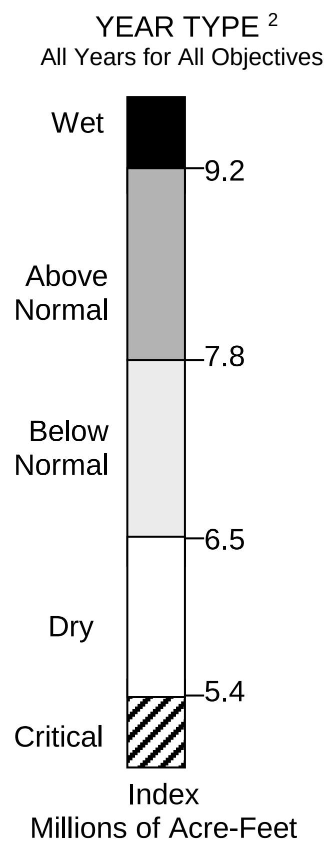
Year classification shall be determined by computation of the following equation:

INDEX = 0.4 * X + 0.3 * Y + 0.3 * Z

Where: X = Current year's April – July Sacramento Valley unimpaired runoff

Y = Current October – March Sacramento Valley unimpaired runoff

Z = Previous year's index[1]



The Sacramento Valley unimpaired runoff for the current water year (October 1 of the preceding calendar year through September 30 of the current calendar year), as published in California Department of Water Resources Bulletin 120, is a forecast of the sum of the following locations: Sacramento River above Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River at Smartville; American River, total inflow to Folsom Reservoir. Preliminary determinations of year classification shall be made in February, March, and April with final determination in May. These preliminary determinations shall be based on hydrologic conditions to date plus forecasts of future runoff assuming normal precipitation for the remainder of the water year.

Classification	Index Millions of Acre-Feet (MAF)
Wet………………	Equal to or greater than 9.2
Above Normal…..	Greater than 7.8 and less than 9.2
Below Normal…..	Equal to or less than 7.8 and greater than 6.5
Dry……………...	Equal to or less than 6.5 and greater than 5.4
Critical………..…	Equal to or less than 5.4

1 A cap of 10.0 MAF is put on the previous year's index (Z) to account for required flood control reservoir releases during wet years.

2 The year type for the preceding water year will remain in effect until the initial forecast of unimpaired runoff for the current water year is available. The San Joaquin Valley Water Year Hydrologic Classification may be used to inform adaptive implementation of the LSJR flow objectives.

FIGURE 3

San Joaquin Valley Water Year Hydrologic Classification

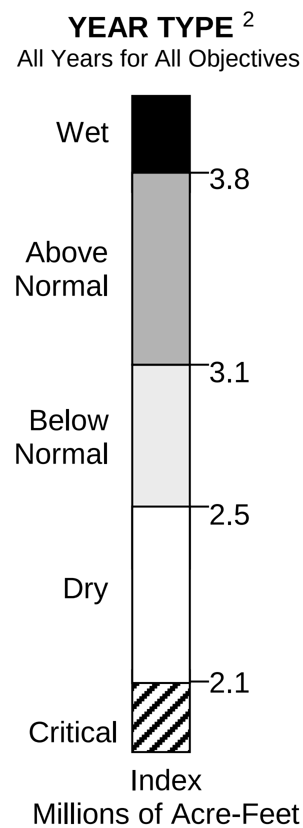
Year classification shall be determined by computation of the following equation:

INDEX = 0.6 * X + 0.2 * Y + 0.2 * Z

Where: X = Current year's April – July San Joaquin Valley unimpaired runoff

Y = Current October – March San Joaquin Valley unimpaired runoff

Z = Previous year's index[1]



The San Joaquin Valley unimpaired runoff for the current water year (October 1 of the preceding calendar year through September 30 of the current calendar year), as published in California Department of Water Resources Bulletin 120, is a forecast of the sum of the following locations: Stanislaus River, total flow to New Melones Reservoir; Tuolumne River, total inflow to Don Pedro Reservoir; Merced River, total flow to Exchequer Reservoir; San Joaquin River, total inflow to Millerton Lake. Preliminary determinations of year classification shall be made in February, March, and April with final determination in May. These preliminary determinations shall be based on hydrologic conditions to date plus forecasts of future runoff assuming normal precipitation for the remainder of the water year.

Classification	Index Millions of Acre-Feet (MAF)
Wet………………	Equal to or greater than 3.8
Above Normal…..	Greater than 3.1 and less than 3.8
Below Normal…..	Equal to or less than 3.1 and greater than 2.5
Dry………………	Equal to or less than 2.5 and greater than 2.1
Critical…………..	Equal to or less than 2.1

1 A cap of 4.5 MAF is put on the previous year's index (Z) to account for required flood control reservoir releases during wet years.

2 The year type for the preceding water year will remain in effect until the initial forecast of unimpaired runoff for the current water year is available. The San Joaquin Valley Water Year Hydrologic Classification may be used to inform adaptive implementation of the LSJR flow objectives.

FIGURE 4

NDOI and PERCENT INFLOW DIVERTED [1]

The NDOI and the percent inflow diverted, as described in this figure, shall be computed daily by the DWR and the USBR using the following formulas (all flows are in cfs):

NDOI = DELTA INFLOW - NET DELTA CONSUMPTIVE USE - DELTA EXPORTS

PERCENT INFLOW DIVERTED = (CCF + TPP) ÷ DELTA INFLOW

where *DELTA INFLOW = SAC + SRTP + YOLO + EAST + MISC + SJR*

SAC	=	Sacramento River at Freeport mean daily flow for the previous day; the 25-hour tidal cycle measurements from 12:00 midnight to 1:00 a.m. may be used instead.
SRTP	=	Sacramento Regional Treatment Plant average daily discharge for the previous week.
YOLO	=	Yolo Bypass mean daily flow for the previous day, which is equal to the flows from the Sacramento Weir, Fremont Weir, Cache Creek at Rumsey, and the South Fork of Putah Creek.
EAST	=	Eastside Streams mean daily flow for the previous day from the Mokelumne River at Woodbridge, Cosumnes River at Michigan Bar, and Calaveras River at Bellota.
MISC	=	Combined mean daily flow for the previous day of Bear Creek, Dry Creek, Stockton Diverting Canal, French Camp Slough, Marsh Creek, and Morrison Creek.
SJR	=	San Joaquin River flow at Vernalis, mean daily flow for the previous day.

where *NET DELTA CONSUMPTIVE USE = GDEPL - PREC*

GDEPL	=	Delta gross channel depletion for the previous day based on water year type using the DWR's latest Delta land use study.[2]
PREC	=	Real-time Delta precipitation runoff for the previous day estimated from stations within the Delta.

and where *DELTA EXPORTS* [3] *= CCF + TPP + CCC + NBA*

CCF	=	Clifton Court Forebay inflow for the current day.[4]
TPP	=	Tracy Pumping Plant pumping for the current day.
CCC	=	Contra Costa Canal pumping for the current day.
NBA	=	North Bay Aqueduct pumping for the current day.

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1 Not all of the Delta tributary streams are gaged and telemetered. When appropriate, other methods of estimating stream flows, such as correlations with precipitation or runoff from nearby streams, may be used instead.

2 If up to date channel depletion estimates are available they shall be used. If these estimates are not available, DAYFLOW channel depletion estimates shall be used.

3 The term "Delta Exports" is used only to calculate the NDOI. It is not intended to distinguish among the listed diversions with respect to eligibility for protection under the area of origin provisions of the California Water Code.

4 Actual Byron-Bethany Irrigation District withdrawals from Clifton Court Forebay shall be subtracted from Clifton Court Forebay inflow. (Byron-Bethany Irrigation District water use is incorporated into the GDEPL term.)

Table 4. Number of Days When Maximum Daily Average Electrical Conductivity of 2.64 mmhos/cm Must Be Maintained at Specified Location

Number of Days When Maximum Daily Average Electrical Conductivity of 2.64 mmhos/cm Must Be Maintained at Specified Location [a]																	
PMI[b] (TAF)	Chipps Island (Chipps Island Station D10)					PMI[b] (TAF)	Port Chicago (Port Chicago Station C14) [d]					PMI[b] (TAF)	Port Chicago (Port Chicago Station C14)[d]				
	FEB	MAR	APR	MAY	JUN		FEB	MAR	APR	MAY	JUN		FEB	MAR	APR	MAY	JUN
≤ 500	0	0	0	0	0	**0**	0	0	0	0	0	**5250**	27	29	25	26	6
750	0	0	0	0	0	**250**	1	0	0	0	0	**5500**	27	29	26	28	9
1000	28[c]	12	2	0	0	**500**	4	1	0	0	0	**5750**	27	29	27	28	13
1250	28	31	6	0	0	**750**	8	2	0	0	0	**6000**	27	29	27	29	16
1500	28	31	13	0	0	**1000**	12	4	0	0	0	**6250**	27	30	27	29	19
1750	28	31	20	0	0	**1250**	15	6	1	0	0	**6500**	27	30	28	30	22
2000	28	31	25	1	0	**1500**	18	9	1	0	0	**6750**	27	30	28	30	24
2250	28	31	27	3	0	**1750**	20	12	2	0	0	**7000**	27	30	28	30	26
2500	28	31	29	11	1	**2000**	21	15	4	0	0	**7250**	27	30	28	30	27
2750	28	31	29	20	2	**2250**	22	17	5	1	0	**7500**	27	30	29	30	28
3000	28	31	30	27	4	**2500**	23	19	8	1	0	**7750**	27	30	29	31	28
3250	28	31	30	29	8	**2750**	24	21	10	2	0	**8000**	27	30	29	31	29
3500	28	31	30	30	13	**3000**	25	23	12	4	0	**8250**	28	30	29	31	29
3750	28	31	30	31	18	**3250**	25	24	14	6	0	**8500**	28	30	29	31	29
4000	28	31	30	31	23	**3500**	25	25	16	9	0	**8750**	28	30	29	31	30
4250	28	31	30	31	25	**3750**	26	26	18	12	0	**9000**	28	30	29	31	30
4500	28	31	30	31	27	**4000**	26	27	20	15	0	**9250**	28	30	29	31	30
4750	28	31	30	31	28	**4250**	26	27	21	18	1	**9500**	28	31	29	31	30
5000	28	31	30	31	29	**4500**	26	28	23	21	2	**9750**	28	31	29	31	30
5250	28	31	30	31	29	**4750**	27	28	24	23	3	**10000**	28	31	30	31	30
≤ 5500	28	31	30	31	30	**5000**	27	28	25	25	4	**>10000**	28	31	30	31	30

[a] The requirement for number of days the maximum daily average EC (EC) of 2.64 mmhos per centimeter (mmhos/cm) must be maintained at Chipps Island and Port Chicago can also be met with maximum 14-day running average EC of 2.64 mmhos/cm, or 3-day running average NDOIs of 11,400 cfs and 29,200 cfs, respectively. If salinity/flow objectives are met for a greater number of days than the requirements for any month, the excess days shall be applied to meeting the requirements for the following month. The number of days for values of the PMI between those specified in this table shall be determined by linear interpolation.

[b] PMI is the best available estimate of the previous month's Eight River Index. (Refer to Footnote 10 for Table 3 for a description of the Eight River Index.)

[c] When the PMI is between 800 TAF and 1000 TAF, the number of days the maximum daily average EC of 2.64 mmhos/cm (or maximum 14-day running average EC of 2.64 mmhos/cm, or 3-day running average NDOI of 11,400 cfs) must be maintained at Chipps Island in February is determined by linear interpolation between 0 and 28 days.

[d] This standard applies only in months when the average EC at Port Chicago during the 14 days immediately prior to the first day of the month is less than or equal to 2.64 mmhos/cm.

Chapter IV. Program of Implementation

The Porter-Cologne Water Quality Control Act states that a water quality control plan consists of a designation or establishment of beneficial uses to be protected, water quality objectives, and program of implementation needed for achieving water quality objectives. (Wat. Code, § 13050(j).) The implementation program shall include, but not be limited to:

1. A description of the nature of actions which are necessary to achieve the objectives, including recommendations for appropriate action by any entity, public or private;
2. A time schedule for the actions to be taken; and
3. A description of surveillance to be undertaken to determine compliance with the objectives. (Wat. Code, § 13242.)

This program of implementation for the Water Quality Control Plan for the Bay Delta Estuary consists of five general components: (1) implementation measures within State Water Board authority; (2) measures requiring a combination of State Water Board authorities and actions by other agencies; (3) recommendations to other agencies; (4) a monitoring and special studies program; and (5) other studies that are being conducted by other entities but may provide information relevant to future proceedings. The specific actions identified within these components include time schedules for implementation, if appropriate. No time schedule is included for actions that have already been implemented.

The State Water Board will exercise its legislative or adjudicative powers involving water rights and water quality to require implementation of the water quality objectives. Water quality actions include water quality certifications, waste discharge requirements, and water quality permitting. ~~Currently, the water right permits of the DWR and USBR include terms and conditions that define their responsibilities to implement the municipal and industrial, agricultural, and fish and wildlife objectives.~~ In the future, the State Water Board may amend this program of implementation, take action in a water right proceeding or proceedings to change the water right responsibilities of ~~the DWR, the USBR, and other~~ water right holders to implement these objectives, or take other actions that implement the objectives.

A. Implementation Measures within State Water Board Authority

Under its water rights and water quality authority, the State Water Board will continue, as necessary and appropriate, to determine the contributions from water right permit and license holders needed to implement the objectives in this Plan. Water right responsibilities may be assigned by conducting a water right proceeding at which the Board will take into consideration the requirements of the Public Trust Doctrine and the California Constitution, article X, section 2. The State Water Board will also continue, as necessary and appropriate, to use its Clean Water Act section 401 water quality certification authority to implement objectives in this Plan, and may take other actions under its water quality authority to implement objectives in this Plan. The following water quality objectives are currently, or may in the future be, primarily implemented ~~in whole or in part~~ using water rights authority, but may also be implemented through water quality actions:

1. Delta Outflow
2. River Flows: Sacramento River at Rio Vista
3. River Flows: Lower San Joaquin River ~~at Airport Way Bridge, Vernalis~~
4. Export Limits
5. Delta Cross Channel Gates Operation
6. Salinity

~~The first five are flow-based objectives that rely upon water rights authorities to implement. Salinity, though a water quality objective, is still implemented, in part, through the State Water Board's water rights authority.~~

The State Water Board may require compliance with these objectives in stages or may shift responsibility for meeting an objective among water right holders and other entities based on evidence it receives in a water right proceeding or in a water quality proceeding.

1. Delta Outflow Objective

The Delta Outflow Objective is to be implemented through water right actions. It requires a minimum amount of outflow, measured in cubic feet per second (cfs) as defined in footnote 11 of Table 3. The permits and license of the DWR and the USBR are conditioned to establish responsibilities to ensure that the Delta Outflow Objective is met on an interim basis until the State Water Board adopts a water right decision or order that assigns permanent responsibility for meeting the Delta Outflow Objective. This water right decision or order would follow a water right proceeding after a request for such a proceeding by the DWR or USBR.

2. River Flows: Sacramento River at Rio Vista

This objective is to be implemented through water right actions. The permits and license of the DWR and the USBR are conditioned to establish responsibilities to ensure that the flow objectives at Rio Vista on the Sacramento River are met on an interim basis until the State Water Board adopts a decision that assigns permanent responsibility for meeting the Sacramento River at Rio Vista flow objectives. This water right decision would follow a water right proceeding after a request for such a proceeding by the DWR or USBR.

3. River Flows: Lower San Joaquin River at Airport Way Bridge, Vernalis

The Lower San Joaquin River (LSJR) water quality objectives for the reasonable protection of fish and wildlife beneficial uses, referred to as the LSJR flow objectives, include all of the LSJR flow objectives for February through June, the LSJR base flow objective for February through June at Vernalis, and the October pulse flow objective, as set forth in Table 3.

This program of implementation focuses on flow-related actions on the Stanislaus, Tuolumne, and Merced Rivers (collectively, "LSJR Tributaries") that are necessary to achieve the LSJR flow objectives. The State Water Board also recognizes that Recommended Actions, including non-flow measures, such as habitat restoration, must also be part of efforts to comprehensively address Delta aquatic ecosystem needs as a whole. The State Water Board encourages voluntary agreements that will assist in implementing the LSJR flow objectives, and will consider such agreements as part of its proceedings to implement this Plan, consistent with its obligations under applicable law.

Implementation of February through June LSJR Flow Objectives

By 2022, the State Water Board will fully implement the February through June LSJR flow objectives through water right actions or water quality actions, such as Federal Energy Regulatory Commission (FERC) hydropower licensing processes.[8]

The State Water Board will exercise its water right and water quality authority to help ensure that the flows required to meet the LSJR flow objectives are used for their intended purpose and are not diverted for other purposes. In order to help ensure that actions taken in response to implementation of the LSJR flow objectives do not result in unreasonable redirected impacts to groundwater resources, the State Water Board will take actions as necessary pursuant to its authorities, including its authorities to prevent the waste, unreasonable use, unreasonable method of use, and unreasonable method of diversion of water (Cal. Const., art. X, § 2; Wat. Code, §§ 100, 275) and to enforce the Sustainable Groundwater Management Act (SGMA) (Wat. Code, § 10720 et seq.).

When implementing the LSJR flow objectives, the State Water Board will include minimum reservoir carryover storage targets or other requirements to help ensure that providing flows to meet the flow objectives will not have adverse temperature or other impacts on fish and wildlife or, if feasible, on other beneficial uses. The State Water Board will also take actions as necessary to ensure that implementation of the flow objectives does not impact supplies of water for minimum health and safety needs, particularly during drought periods. Actions may include, but are not limited to, assistance with funding and development of water conservation efforts and regional water supply reliability projects and regulation of public drinking water systems and water rights.

Although the lowest downstream compliance location for the LSJR flow objectives is at Vernalis, the objectives are intended to protect migratory LSJR fish in a larger area, including within the Delta, where fish that migrate to or from the LSJR

[8] To refine the implementation actions and provide for coordination with ongoing FERC proceedings in the LSJR watershed, the February through June LSJR flow objective may be phased in over time, but must be fully implemented by 2022.

watershed depend on adequate flows from the LSJR and its salmon-bearing tributaries.

It is the State Water Board's intention that an entity's implementation of the LSJR flow objectives, including implementation through flow requirements imposed in a FERC process, will meet any responsibility to contribute to the LSJR inflow component of the Delta outflow objective in this Plan. The State Water Board, however, may further consider and reallocate responsibility for implementing the Delta outflow objective in any subsequent proceeding, including a water right proceeding.

Flow Requirements for February through June

The LSJR flow objectives for February through June shall be implemented by requiring 40 percent of unimpaired flow, based on a minimum 7-day running average, from each of the Stanislaus, Tuolumne, and Merced Rivers. This required percentage of unimpaired flow, however, may be adjusted within the range allowed by the LSJR flow objectives through adaptive methods detailed below. The required percentage of unimpaired flow is in addition to flows in the LSJR from sources other than the LSJR Tributaries. The required percentage of unimpaired flow does not apply to an individual tributary during periods when flows from that tributary could cause or contribute to flooding or other related public safety concerns, as determined by the State Water Board or Executive Director through consultation with federal, state, and local agencies and other persons or entities with expertise in flood management.

In addition, the LSJR base flow objective for February through June shall be implemented by requiring a minimum base flow of 1,000 cfs, based on a minimum 7-day running average, at Vernalis at all times. This minimum base flow, however, may be adjusted within the range allowed by the LSJR base flow objective through adaptive methods detailed below. When the percentage of unimpaired flow requirement is insufficient to meet the minimum base flow requirement, the Stanislaus River shall provide 29 percent, the Tuolumne River 47 percent and the Merced River 24 percent of the additional total outflow needed to achieve and maintain the required base flow at Vernalis.

The Executive Director may approve changes to the compliance locations and gage station numbers set forth in Table 3 if information shows that another location and gage station more accurately represent the flows of the LSJR tributary at its confluence with the LSJR.

Adaptive Methods for February through June Flows

Adjustments to the February through June unimpaired flow requirements allowed by the LSJR flow objectives should be implemented in a coordinated and adaptive manner, taking into account current information. Specifically, FERC licensing proceedings on the Merced and Tuolumne Rivers, other scientific review processes initiated to develop potential management strategies on a tributary basis, and the San Joaquin River Monitoring and Evaluation Program (SJRMEP) described below are expected to yield additional scientific information that will inform future management of flows for the protection of fish and wildlife beneficial uses.

Adaptive implementation could also optimize flows to achieve the objectives while allowing for consideration of other beneficial uses, provided that these other considerations do not reduce intended benefits to fish and wildlife.

Adaptive adjustments to the flow requirements as forth in (a) – (d) below may be approved by the State Water Board on an annual or long-term basis, or by the Executive Director as provided below, if information produced through the monitoring and review processes described in this program of implementation, or other best available scientific information, indicates that the change for the period at issue will satisfy the following criteria for adaptive adjustments: (1) it will be sufficient to support and maintain the natural production of viable native San Joaquin River watershed fish populations migrating through the Delta; and (2) it will meet any existing biological goals approved by the State Water Board.

a) The required percent of unimpaired flow may be adjusted to any value between 30 percent and 50 percent, inclusive. The Executive Director may approve changes within this range on an annual basis if all members of the Stanislaus, Tuolumne, and Merced Working Group (STM Working Group), described below, agree to the changes.

b) The required percent of unimpaired flow for February through June may be managed as a total volume of water and released on an adaptive schedule during that period where scientific information indicates a flow pattern different from that which would occur by tracking the unimpaired flow percentage would better protect fish and wildlife beneficial uses. The total volume of water must be at least equal to the volume of water that would be released by tracking the unimpaired flow percentage from February through June. The Executive Director may approve such changes on an annual basis if the change is recommended by one or more members of the STM Working Group.

c) The release of a portion of the February through June unimpaired flow may be delayed until after June to prevent adverse effects to fisheries, including temperature, that would otherwise result from implementation of the February through June flow requirements. The ability to delay release of flow until after June is only allowed when the unimpaired flow requirement is greater than 30 percent. If the requirement is greater than 30 percent but less than 40 percent under (a) above, the amount of flow that may be released after June is limited to the portion of the unimpaired flow requirement over 30 percent. (For example, if the flow requirement is 35 percent, 5 percent may be released after June.) If the requirement is 40 percent or greater under (a) above, then 25 percent of the total volume of the flow requirement may be released after June. (For example, if the requirement is 50 percent, at least 37.5 percent unimpaired flow must be released in February through June and up to 12.5 percent unimpaired flow may be released after June.) If after June the STM Working Group determines that conditions have changed such that water held for release after June should not be released by the fall of that year, the water may be held until the following year. The Executive Director may approve changes on an annual basis if the change is recommended by one or more members of the STM Working Group.

d) The required base flow for February through June may be adjusted to any value between 800 and 1,200 cfs, inclusive. The Executive Director may approve changes within this range on an annual basis if all members of the STM Working Group agree to the changes.

Any of the adjustments in (a)-(d) above may be made independently of each other or combined. The adjustments in (a), (b), and (c) may also be made independently on each of the Stanislaus, Tuolumne, and Merced Rivers, so long as the flows are coordinated to achieve beneficial results in the LSJR related to the protection of fish and wildlife beneficial uses. Experiments may also be conducted within the adaptive adjustments in (a)-(d), subject to the approvals provided therein, in order to improve scientific understanding of needed measures for the protection of fish and wildlife beneficial uses, such as the optimal timing of required flows. Any experiment shall be coordinated with the SJRMEP and identify the scientific uncertainties to be addressed and the actions that will be taken to reduce those uncertainties, including monitoring and evaluation.

Stanislaus, Tuolumne and Merced Working Group

The State Water Board will establish a STM Working Group to assist with the implementation, monitoring and effectiveness assessment of the February through June LSJR flow requirements. Specifically, the State Water Board will seek recommendations from the STM Working Group on biological goals; procedures for implementing the adaptive methods described above; annual adaptive operations plans; and the SJRMEP, including special studies and reporting requirements. Each of these activities is described in more detail below.

The State Water Board will seek participation in the STM Working Group by the following entities who have expertise in LSJR, Stanislaus, Tuolumne, and Merced Rivers fisheries management, hydrology, operations, and monitoring and assessment needs: the DFW; NMFS; USFWS; and water users on the Stanislaus, Tuolumne, and Merced Rivers. The STM Working Group will also include State Water Board staff and may include any other persons or entities the Executive Director determines to have appropriate expertise. Subgroups of the STM Working Group may be formed as appropriate and State Water Board staff may also initiate activities in coordination with members of the STM Working Group.

Biological Goals

Biological goals will be used to inform the adaptive methods, evaluate the effectiveness of this program of implementation, the SJRMEP, and future changes to the Bay-Delta Plan. The State Water Board will seek recommendations on the biological goals from the STM Working Group, State Water Board staff, and other interested persons. The State Water Board will consider approval of the biological goals within 180 days from the date of the Office of Administrative Law's (OAL) approval of this amendment to the Bay-Delta Plan and may modify them based on new information developed through the monitoring and evaluation activities described below or other pertinent sources of scientific information. Biological goals will specifically be developed for LSJR salmonids, as salmonids are among the fish species most sensitive to LSJR flow modifications. The State Water Board may seek recommendations on biological goals for other LSJR species as appropriate. Biological goals will specifically be developed for abundance; productivity as measured by population growth rate; genetic and life history diversity; and population spatial extent, distribution, and structure. Within a given tributary, reasonable contributions to productivity may include meeting measures of quality and quantity of spawning and rearing habitat, fry production, and juvenile outmigrant survival to the confluence of each tributary to the LSJR.

The salmonid biological goals for this program of implementation will be specific to the LSJR and its tributaries and will contribute to meeting the overall goals for each population, including the salmon doubling objective established in state and federal law. Biological goals for salmonid populations will be consistent with best available scientific information, including information regarding viable salmonid populations, recovery plans for listed salmonids, or other appropriate information.

Unimpaired Flow Compliance

Implementation of the unimpaired flow requirement for February through June will require the development of information and specific measures to achieve the flow objectives and to monitor and evaluate compliance. The STM Working Group, or State Water Board staff as necessary, will, in consultation with the Delta Science Program, develop and recommend such proposed measures. The State Water Board or Executive Director will consider approving the measures within 180 days from the date of OAL's approval of this amendment to the Bay-Delta Plan. The approved measures will inform State Water Board water right proceedings, FERC licensing proceedings, or other implementation actions to achieve the February through June flows.

Procedures for Implementation of Adaptive Methods

The STM Working Group, or State Water Board staff as necessary, will, in consultation with the Delta Science Program, develop proposed procedures for allowing the adaptive adjustments to the February through June flow requirements discussed above. The State Water Board or Executive Director will consider approving procedures for allowing those adaptive adjustments within one year following the date of OAL's approval of this amendment to the Bay-Delta Plan.

Annual Adaptive Operations Plan

The STM Working Group or members or subsets of the STM Working Group, as appropriate, will be required to submit proposed annual plans for adaptive implementation actions (annual operations plans) for the coming season by January 10 of each year for approval by the State Water Board or Executive Director. The State Water Board recognizes that an annual operations plan is based on a forecast from the best available information and may not accurately reflect actual conditions that occur during the February through June period. Accordingly, the State Water Board will consider this factor and whether the hydrologic condition could have been planned for in evaluating deviations from approved operations plans. An annual operations plan shall include actions and operations that consider and will work under a reasonable range of hydrological conditions. It shall also identify how unimpaired flows are calculated and adjustments to be made as updated information becomes available, such as DWR's Bulletin 120.[9] An annual operations plan shall be informed by the review activities described below and may be modified with the approval of the State Water Board or Executive Director.

Implementation of October Pulse Flow Objective

The October pulse flow objective is currently implemented through water right actions. The State Water Board will reevaluate the assignment of responsibility for meeting the October pulse flow objective during a water right proceeding, FERC licensing proceeding, or other proceeding.

Through water right, FERC licensing, or other processes, the State Water Board will require monitoring and special studies to determine what, if any, changes should be made to the October pulse flow objective and its implementation. The State Water Board may require such monitoring and special studies to be part of the SJRMEP. The State Water Board will evaluate the need to modify the October pulse flow objective in a future update of the Bay-Delta Plan based on information developed through these processes.

[9] Bulletin 120 is a publication issued four times a year, in the second week of February, March, April, and May by the California Department of Water Resources. It contains forecasts of the volume of seasonal runoff from the state's major watersheds, and summaries of precipitation, snowpack, reservoir storage, and runoff in various regions of the State.

State of Emergency

At its discretion, or at the request of any affected responsible agency or person, the State Water Board may authorize a temporary change in the implementation of the LSJR flow objectives in a water right proceeding if the State Water Board determines that either (i) there is an emergency as defined in the California Environmental Quality Act (Pub. Resources Code, § 21060.3) or (ii) the Governor of the State of California or a local governing body has declared a state or local emergency pursuant to the California Emergency Services Act (Gov. Code, § 8550 et seq.) and LSJR flow requirements affect or are affected by the conditions of such emergency. Before authorizing any temporary change, the State Water Board must find that measures will be taken to reasonably protect the fish and wildlife beneficial use in light of the circumstances of the emergency.

San Joaquin River Monitoring and Evaluation Program

In order to determine compliance with the LSJR flow objectives, inform adaptive implementation, investigate the technical factors involved in water quality control, and potential needed future changes to the LSJR flow objectives, including flows for other times of the year, a comprehensive monitoring, special studies, evaluation, and reporting program is necessary. The State Water Board will require in water right permits and water quality certifications, as appropriate, annual and comprehensive monitoring, evaluation, and reporting. Pursuant to its authorities, including Water Code section 13165, comprehensive monitoring will be required to address both the individual and cumulative impacts of diversions and discharges to fish and wildlife beneficial uses. The following requirements, at a minimum, shall be imposed:

1) Monitoring, special studies, and evaluations of the effects of flow and other factors on the viability of native LSJR watershed fish populations throughout the year, including assessment of abundance, spatial extent (or distribution), diversity (both genetic and life history), and productivity.
2) Consideration of recommendations from entities with relevant Central Valley monitoring plans to improve standardization of methods, including the quantification of bias and precision of population estimates.
3) Regular external scientific review of monitoring, evaluation, and reporting.

Monitoring should be integrated and coordinated with new and ongoing monitoring and special studies programs in the LSJR, including pursuant to federal biological opinion requirements, FERC licensing proceedings for the Tuolumne and Merced Rivers, Central Valley Regional Water Board requirements, and the Delta Science Program.

Annual reporting

To inform the next year's operations and other activities, the State Water Board will require preparation and submittal of an annual report to the State Water Board by December 31 of each year. The annual report shall describe implementation of flows, including any flow shifting done pursuant to the annual adaptive operations plan, monitoring and special studies activities, and implementation of other measures to protect fish and wildlife during the previous water year, including the actions by other entities identified in this program of implementation. The annual report shall also identify any deviations from the annual adaptive operations plan and describe future special studies. The State Water Board may hold public meetings to receive and discuss the annual report.

Comprehensive Reporting

Additionally, every three to five years following implementation of this update to the Bay-Delta Plan, the State Water Board will require preparation and submittal of a comprehensive report that, in addition to the requirements of annual reporting, reviews the progress toward meeting the biological goals and identifies any recommended changes to the implementation of the flow objectives. The comprehensive report and any recommendations shall be peer-reviewed by an appropriate independent science panel, which will make its own conclusions and recommendations. The State Water Board will hold public meetings to consider the comprehensive report, technical information, and conclusions or recommendations developed through the peer review process. This information will be used to inform potential adaptive changes to the implementation of the flow objectives and, as appropriate, future potential changes to the Bay-Delta Plan.

In order to leverage expertise and limited resources (financial and otherwise), parties are encouraged to work collaboratively in one or more groups and in consultation with the STM Working Group, USBR and DWR, in meeting the above monitoring and reporting requirements. The State Water Board may streamline monitoring and reporting obligations of parties working collaboratively with each other, the STM Working Group, USBR, DWR, the Delta Science Program or other appropriate parties.

Voluntary Agreements

The State Water Board recognizes that voluntary agreements can help inform and expedite implementation of the water quality objectives and can provide durable solutions in the Delta watershed.

Subject to acceptance by the State Water Board, a voluntary agreement may serve as an implementation mechanism for the LSJR flow objectives for the LSJR Tributaries as a whole, an individual tributary or some combination thereof. Voluntary agreements may include commitments to meet the flow requirements and to undertake non-flow actions. If the voluntary agreements include non-flow actions recommended in this Plan or by DFW, the non-flow measures may support a change in the required percent of unimpaired flow, within the range prescribed by the flow objectives, or other adaptive adjustments otherwise allowed in this program of implementation. Any such changes must be supported by DFW and satisfy the criteria for adaptive adjustments contained within this program of implementation. At a minimum, to be considered by the State Water Board, voluntary agreements must include provisions for transparency and accountability, monitoring and reporting, and for planning, adaptive adjustments, and periodic evaluation, that are comparable to similar elements contained in the program of implementation for the LSJR flow objectives.

The State Water Board encourages parties to present any executed voluntary agreement to the State Water Board for its review as soon as feasible to improve conditions in the watershed.
This objective is to be implemented through water right actions. This plan includes a time schedule for completing implementation. Flow objectives for the San Joaquin River at the Airport Way Bridge near Vernalis have been established for three time periods:

- Spring flow objectives, February through April 14 and May 16 through June;
- Spring pulse flow objectives, April 15 through May 15; and
- Fall pulse flow objectives in October

The USBR is assigned responsibility under its water right permits, on an interim basis until the Board assigns permanent responsibility, to ensure that all of these objectives are met. During the Spring pulse flow period in April and May while the SJRA[10] is in effect, however, the experimental target flows in the VAMP will be implemented in lieu of the Spring flow objectives for the April-May period. After the SJRA terminates or adequate information is otherwise received, the State Water Board may review or consider amending the objectives in a water quality proceeding or may immediately conduct a water right proceeding to decide how to assign responsibility for implementing these objectives.

Additional data and scientific analyses are needed to either support or modify the current spring flow objectives. These data and analyses are described in the 'Recommendations to Other Agencies' section of this chapter. In addition, as indicated in the Emerging Issues section of Chapter 1, the State Water Board will conduct a workshop after revisions are made in response to peer review of DFG's San Joaquin River salmon escapement model (anticipated for summer of 2007) to receive information and conduct detailed discussions regarding the various San Joaquin River flow objectives. Following the workshop, the State Water Board may make changes to the objectives, the program of implementation for the objectives, and/or water rights. The State Water Board may also direct additional studies to determine flow needs on the San Joaquin River.

[10] The SJRA is a settlement agreement among numerous parties to the water rights hearing resulting in D-1641 to meet the San Joaquin River portions of various flow-dependent water quality objectives in the 1995 Plan.

The staged implementation of the Spring pulse flow objectives, with the first stage consisting of variations on the objectives, allows additional scientific investigation into flow needs on the San Joaquin River during the pulse flow period. In the first stage of implementation, the USBR and other parties are conducting a 12-year study referred to as the Vernalis Adaptive Management Plan (VAMP). The VAMP is designed to protect juvenile chinook salmon migrating down the San Joaquin River and to evaluate the effects of varying the San Joaquin River flow and the State Water Project (SWP) and Central Valley Project (CVP) water exports at times when the head of Old River flow barrier[11] is restricting the flow of water into Old River, on the survival of marked juvenile chinook salmon migrating through the Sacramento-San Joaquin Delta.

The VAMP study has been ongoing for seven years, but the study has not yet yielded conclusive results regarding needed changes to the Spring pulse flow objectives. The completed study will provide critical data about flow needs on the San Joaquin River during the Spring pulse flow period.

Until no later than December 31, 2011, or until the SJRA is terminated or adequate information is otherwise received, if earlier, the following interim Spring pulse flows may be implemented on the San Joaquin River at Vernalis during the 31-day April and May[12] pulse period in order to obtain additional scientific information concerning flow needs on the San Joaquin River during the pulse flow period. The target flow should be based on the existing flow, as defined in table 5.

Table 5. Interim San Joaquin River Pulse Flows

Existing Flow[13](cfs)	Target Flow (cfs)
0-1999	2,000
2,000-3,199	3,200
3,200-4,449	4,450
4,450-5,699	5,700
5,700-6,999	7,000
7,000 or greater	Existing Flow

[11] The purpose of the head of Old River barrier is to reduce the downstream movement of juvenile San Joaquin River chinook salmon into the southern Delta via Old River where fish mortality increases due to predation and higher levels of exposure to export facilities and agricultural diversions.

[12] The timing of the 31-day pulse flow is to be determined by the San Joaquin River Technical Committee (SJRTC). The SJRTC is composed of technical experts appointed by the parties to the SJRA to implement the VAMP experiment and other technical activities that its members deem appropriate to meet the goals of the SJRA.

[13] "Existing flows" will be determined by the SJRTC. Existing flow is defined as the forecasted flows in the San Joaquin River at Vernalis during the pulse flow period that would exist absent the SJRA or water acquisitions, including but not limited to the following:

- Tributary minimum instream flows pursuant to Davis-Grunsky, Federal Energy Regulatory Commission, or other regulatory agency orders existing on the date of this agreement;
- Water quality or scheduled fishery releases from New Melones Reservoir;
- Flood control releases from any non-federal storage facility required to be made during the pulse flow period pursuant to its operating protocol with the U.S. Army Corps of Engineers in effect when the SJRA is executed;
- Uncontrolled spills not otherwise recaptured pursuant to water right accretions (less natural depletions) to the system; and/or
- Local runoff.

~~Table 6 contains the numeric indicators for the San Joaquin Valley 60-20-20 Water Year Hydrologic Classification.[14] During years when the sum of the current year's 60-20-20 numeric indicator and the previous year's 60-20-20 numeric indicator is seven (7) or greater, target flows should be one step higher than those required in table 5. The licensee is not required to meet the target flow during years when the sum of the numeric indicators for the current year and the previous two years is four (4) or less.~~

~~**Table 6. San Joaquin Valley 60-20-20 Water Year Hydrologic Classification Numeric Indicators**~~

~~SJR Basin 60-20-20 Classification~~	~~60-20-20 Indicator~~
~~Wet~~	~~5~~
~~Above Normal~~	~~4~~
~~Below Normal~~	~~3~~
~~Dry~~	~~2~~
~~Critical~~	~~1~~

~~Certain water right holders in the San Joaquin Basin are authorized under their water right licenses to provide the experimental flows specified in the SJRA until December 31, 2011, or until the SJRA is terminated, whichever occurs first. After the SJRA terminates or adequate information is otherwise received to support changes, the State Water Board will use the information gained from the VAMP study and other pertinent information to determine what, if any, changes are needed to the pulse flow objectives. The State Water Board will then make any appropriate changes to the Water Quality Control Plan and after a water right proceeding will assign, as appropriate, long-term responsibility for meeting the pulse flow objectives to water right holders whose water diversions impact the flow of water.~~

4. Export Limits

These objectives are to be implemented through water right actions. The water right permits and licenses of the DWR and the USBR are conditioned upon meeting the objectives for export pumping.

5. Delta Cross Channel Gates Operation

This objective is to be implemented through water right actions. The USBR, as the owner and operator of the Gates, is solely responsible under its water right permits and licenses for implementing the Delta Cross Channel Gates Closure objective~~s~~.

6. Salinity Control

Salinity objectives are implemented through a mix of water right actions (flow) and salinity control measures depending on the location and beneficial use affected. Salinity objectives and their implementation fall into the following broad categories:

~~[14] The classification method for the 60-20-20 San Joaquin Valley Water Year Classification Index is provided in Figure 3.~~

i. Municipal and Industrial Uses: These~~is~~ objectives are ~~is~~ to be implemented through a combination of water right actions and other actions, depending on the location at which the objective applies. The water right permits and licenses of the DWR and the USBR currently are conditioned upon implementation of chloride objectives to protect municipal and industrial uses. The salinity objectives at Contra Costa Water District's Pumping Plant No. 1 on Rock Slough, however, are being implemented in part through flows provided by the DWR and the USBR on Old River at the head of Rock Slough and in part through infrastructure improvements that reduce water quality degradation caused by localized drainage into Rock Slough.

ii. Fish and Wildlife in Suisun Marsh: These~~is~~ objectives are ~~is~~ to be implemented through water right actions because the salinity levels are determined by flows and control structure operations. The water right permits and licenses of the DWR and the USBR currently are conditioned upon implementation of the numeric salinity objectives for Suisun Marsh at stations S-21, and S-42 (Figure 5). Due to evidence showing a potential for the objectives at stations S-97 and S-35 to cause harm to the beneficial uses they are intended to protect, the State Water Board in Decision 1641 (D-1641) did not require that DWR and USBR attain the objectives at stations S-97 and S-35. Implementation of the salinity objectives at these two stations is discussed in section B.5.

iii. Fish and Wildlife in the San Joaquin River: These~~is~~ objectives are ~~is~~ to be implemented through water right actions. The water right permits and licenses of the DWR and the USBR currently are conditioned upon implementation of the San Joaquin River salinity objective to protect fish and wildlife uses.

iv. Agriculture in the Western Delta, Interior Delta, and Export Area: These objectives are to be implemented through water right actions. The water right permits and licenses of the DWR and the USBR currently are conditioned upon implementation of the Western Delta, Interior Delta, and Export Area salinity objectives to protect agricultural uses.

v. Agriculture in the Southern Delta: The water rights of the DWR and the USBR are conditioned upon implementation of the southern Delta salinity objective~~s~~ to protect agricultural beneficial uses. Implementation of salinity objective~~s~~ in the southern Delta requires a mix of salt load control and flow related measures. It is therefore discussed in section B of the Program of Implementation: 'Measures Requiring a Combination of State Water Board Authorities and Actions by Other Agencies.

B. Measures Requiring a Combination of State Water Board Authorities and Actions by Other Agencies

Implementation of the following water quality objectives will require water rights and water quality measures by the State Water Board, in concert with actions taken by other agencies:

Implementation of these objectives can be accomplished through a combination of the following: dilution flows, regulation of water diversions, pollutant discharge controls, best management practices to control the amount of waste produced, and improvements in water circulation. In addition to describing the actions taken, or to be taken, by the State Water Board, this section describes the actions taken, and that should be taken, by other agencies to implement these objectives. The State Water Board will use its authority, as needed and appropriate, under section 13165 of the California Water Code to require that studies are conducted.

1. Southern Delta Agricultural Salinity Objectives

The program of implementation for the southern Delta salinity objective describes the actions necessary to achieve the objective and the monitoring, special studies, and reporting requirements that the State Water Board will require to evaluate compliance with the objective and to obtain additional information to inform implementation of the objective and understanding of salinity conditions in the southern Delta. The southern Delta salinity objective will be achieved through water right and water quality control actions, including through the regulation of discharges by municipal and other dischargers.

~~Elevated salinity in the southern Delta is caused by various factors, including low flows; salts imported to the San Joaquin Basin in irrigation water; municipal discharges; subsurface accretions from groundwater; tidal actions; diversions of water by the SWP, CVP, and local water users; channel capacity; and discharges from land-derived salts, primarily from agricultural drainage. These salinity objectives currently are implemented through a mix of water right actions and salinity control. The water rights of the USBR are conditioned upon implementation of the salinity objectives on the San Joaquin River at Vernalis and the water rights of DWR and USBR are conditioned upon implementation of the salinity objectives at the other three southern Delta stations (San Joaquin River at Brandt Bridge, Old River at Middle River and Old River at Tracy Road Bridge (interior southern Delta stations)). Salinity objectives on the San Joaquin River at Vernalis are also being implemented through non-water right actions, including the San Joaquin River Salinity Control Program in the Central Valley Regional Water Quality Control Board's (Regional Water Board) Water Quality Control Plan for the Sacramento and San Joaquin River Basins. In October of 2005, the State Water Board approved an Amendment to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins. The amendment consists of a Control Program for Salt and Boron Discharges into the Lower San Joaquin River and other actions to implement salinity objectives in the SJR at Vernalis. The salt and boron basin plan amendment includes implementation measures and a timeline for implementation of salt load allocations.~~

The salinity objectives at Vernalis can be attained by releasing dilution water from New Melones and other sources, completing a drain to remove the salts generated by agricultural drainage and municipal discharges from the San Joaquin Valley, and conducting measures in the San Joaquin Valley such as the measures discussed below for controlling salinity in the interior southern Delta. The salinity objectives for the interior southern Delta can be implemented by measures that include state regulatory actions, state funding of projects and studies, regulation of water diversions, pollutant discharge controls, improvements in water circulation, and long-term implementation of best management practices to control saline discharges.

State Regulatory Actions

San Joaquin River at Airport Way Near Vernalis

i. For the San Joaquin River at Airport Way near Vernalis, Revised Water Right Decision 1641 imposes conditions on USBR's water rights requiring implementation of EC levels of 0.7 mmhos/cm from April through August and 1.0 mmhos/cm from September through March (units of mmhos/cm are equal to units of dS/m). As part of implementing the salinity water quality objective for the interior southern Delta, USBR shall be required to continue to comply with these salinity levels, as a condition of its water rights. Implementation of the southern Delta salinity objective at Vernalis may be modified by the State Water Board in a future Bay-Delta Plan update and a subsequent water right proceeding, if necessary, after adoption of a Total Maximum Daily Load (TMDL) or other salinity management plan by the State Water Board or Central Valley Regional Water Quality Control Board (Central Valley Regional Water Board) that identifies more appropriate salinity management measures.The State Water Board has conditioned the water rights of some water right holders on the presence of dilution flows. Currently, the water rights of USBR are conditioned upon implementation of the Vernalis objectives, and the water rights of USBR and DWR are conditioned upon implementation of the interior southern Delta objectives. The State Water Board could also require releases from other non-SWP/CVP reservoirs after notice and an opportunity for a hearing. In lieu of some water releases, water right holders such as USBR and DWR could use measures that affect circulation of water in the southern Delta (including permanent operational gates).

Interior Southern Delta Compliance Locations

ii. Revised Water Right Decision 1641 imposes conditions on DWR's and USBR's water rights requiring implementation of EC levels of 0.7 mmhos/cm from April through August and 1.0 mmhos/cm from September through March at the three compliance stations in the interior southern Delta (Interagency Stations No. C-6, C-8, and P-12).

As part of implementing the salinity water quality objective for the interior southern Delta, DWR and USBR shall be required to comply with the 1.0 dS/m water quality objective year-round as a condition of their water rights.

The interior southern Delta salinity compliance locations are comprised of three river segments rather than three specific point locations so that compliance with the southern Delta salinity objective can be better determined in a Delta environment subject to alternating tidal flows. DWR's and USBR's water rights shall be conditioned to require completion of the Comprehensive Operations Plan, Monitoring Special Study, Modeling, and Monitoring and Reporting Plan described below. Information from these activities will be used to determine the appropriate locations and methods to assess attainment of the salinity objective in the interior southern Delta. Prior to State Water Board approval of the Monitoring and Reporting Plan, attainment of the salinity objective for the interior southern Delta will be assessed at stations C-6, C-8, and P-12, which USBR and DWR shall be required to continue to operate as a condition of their water rights.

iii. Comprehensive Operations Plan: The State Water Board will continue to require DWR and USBR to address the impacts of their operations on interior southern Delta salinity levels. Specifically, the State Water Board will require the development and implementation of a Comprehensive Operations Plan (COP). The COP must:

- describe the actions that will fully address the impacts of SWP and CVP export operations on water levels and flow conditions that may affect salinity conditions in the southern Delta, including the availability of assimilative capacity for local sources of salinity;
- include detailed information regarding the configuration and operations of any facilities relied upon in the plan; and
- identify specific performance goals (i.e., water levels, flows, or other similar measures) for these facilities.

Monitoring requirements needed to measure compliance with the specific performance goals in the COP must be included in the Monitoring and Reporting Plan, discussed below. DWR and USBR shall be required to consult with the South Delta Water Agency (SDWA), State Water Board staff, other state and federal resource agencies, and local stakeholders to develop the COP, and will be required to hold periodic coordination meetings, no less than quarterly, throughout implementation of the plan.

DWR and USBR shall submit the COP to the Executive Director for approval within six months from the date of the OAL's approval of this amendment to the Bay-Delta Plan. Once approved, the COP shall be reviewed annually, and updated as needed, with a corresponding report submitted by October 31 each year to the Executive Director for approval. The State Water Board will require compliance with this measure pursuant to its Porter-Cologne Water Quality Control Act authority to require technical and monitoring requirements, or as a requirement of a water right order.

iv. Special Studies, Modeling and Monitoring and Reporting: To implement and determine compliance with the salinity objective in these river segments, and to inform the COP, the State Water Board will require DWR and USBR to complete the following activities. The State Water Board will require compliance with these activities pursuant to its Porter-Cologne Water Quality Control Act authority to require technical and monitoring requirements, or as a requirement of a water right order:

a. Monitoring Special Study: Prior to development of the long-term Monitoring and Reporting Plan, described below, DWR and USBR shall work with State Water Board staff and solicit stakeholder input to develop and implement a special study to characterize the spatial and temporal distribution and associated dynamics of water level, flow, and salinity conditions in the southern Delta waterways. The study shall identify the extent of low or null flow conditions and any associated concentration of local salt discharges. The State Water Board will request local agricultural water users and municipal dischargers to provide data regarding local diversions and return flows or discharges. DWR and USBR shall submit a plan for this special study to the Executive Director for approval within six months from the date of OAL's approval of this amendment to the Bay-Delta Plan. Once approved, the monitoring contained in this plan shall be conducted until superseded by the long-term Monitoring and Reporting, described below, is approved.

b. Modeling: DWR and USBR shall provide modeling and other technical assistance necessary to prepare and update the COP, and otherwise assist in implementing the southern Delta agricultural salinity objective. DWR and USBR will be required to continue to provide this assistance as required by State Water Board Order WR 2010-0002, which modifies paragraph A.3 of Order WR 2006-0006.

c. Monitoring and Reporting: DWR and USBR shall develop long-term monitoring protocols to measure compliance with the performance goals of the COP, and to assess attainment of the salinity objective in the interior southern Delta. These monitoring and reporting protocols shall be based on the information obtained in the Monitoring Special Study, and shall include specific alternative compliance locations in, or monitoring protocols for, the three river segments that comprise the interior southern delta salinity compliance locations. The Executive Director may approve changes to the gage stations at which compliance is determined, except monitoring station C-10, in Table 2, if information shows that other gage stations more accurately represent salinity conditions in the interior southern Delta.

The Monitoring and Reporting Plan will be required to be integrated and coordinated with existing monitoring and special studies programs in the Delta. DWR and USBR shall submit the Monitoring and Reporting Plan to the Executive Director for approval within 18 months from the date of OAL's approval of this amendment to the Bay-Delta Plan.

v. DWR's and USBR's water rights shall be conditioned to require continued operations of the agricultural barriers at Grant Line Canal, Middle River, and Old River at Tracy, or other reasonable measures, to address the impacts of SWP and CVP export operations on water levels and flow conditions that might affect southern Delta salinity conditions, including the assimilative capacity for local sources of salinity in the southern Delta. The water right conditions shall require any necessary modifications to the design and operations of the barriers or other measures as determined by the COP.

vi. In addition to the above requirements, the salinity water quality objective for the southern Delta will be implemented through the Lower San Joaquin River flow objectives, which will increase inflow of low salinity water into the southern Delta during February through June and thereafter under adaptive implementation to prevent adverse effects to fisheries. This will assist in achieving the southern Delta water quality objective.

~~ii.~~vii. The Central Valley Regional Water Board shall regulate ~~impose discharge controls on~~ in-Delta discharges of salts by agricultural, domestic, and municipal dischargers consistent with applicable state and federal law, including, but not limited to, establishing water-quality based effluent limitations and compliance, monitoring and reporting requirements as part of the reissuance of National Pollutant Discharge

Elimination System (NPDES) permits under the Clean Water Act and the regulations thereunder. Publicly-owned treatment works (POTWs) regulated by NPDES permits that discharge salinity constituents above water quality objectives for EC may qualify for a variance of up to ten years pursuant to the Central Valley Regional Water Board Resolution R5-2014-0074. Actions by POTWs to comply with water quality objectives for EC include, without limitation, source control, such as reducing salinity concentrations in source water supplies; pretreatment programs, such as reducing water softener use among water users; and desalination.

iii.viii. The Central Valley Regional Water Board shall implement the Total Maximum Daily Load (TMDL) for the San Joaquin River at Vernalis, develop and adopt a basin plan amendment and TMDL a salinity control program for areas upstream of Vernalis, and implement the TMDL and Water Quality Ccontrol Plan program to reduce salinity and other pollutants reaching the southern Delta.

iv. The State Water Board will conduct a workshop in January 2007 to commence proceedings to receive information and conduct detailed discussions regarding the southern Delta salinity objectives, the causes of salinity in the southern Delta, measures to implement salinity objectives for southern Delta agriculture, and other factors. The proceedings following the workshop may result in water right and/or water quality actions.

Central Valley Regional Water Board Actions

The Central Valley Regional Water Board is undertaking the following efforts, which will assist in implementing the southern Delta salinity objective:

i. Central Valley Salinity Alternatives for Long-Term Sustainability (CV-SALTS): CV-SALTS is a stakeholder-led effort initiated by the State Water Board and the Central Valley Regional Water Board in 2006 to develop comprehensive long-term measures to address salinity and nitrate problems in California's Central Valley, including formulation of a basin plan amendment and implementation actions. The State Water Board may consider modifications to the southern Delta salinity objective and program of implementation in a future Bay-Delta Plan update, as well as requirements imposed through water right actions, based on information and recommendations generated from the CV-SALTS initiative.

ii. San Joaquin River at Vernalis Salt and Boron TMDL: The Central Valley Regional Water Board is implementing the salinity and boron TMDL at Vernalis. Actions described in the program of implementation for the TMDL include execution of a Management Agency Agreement with USBR addressing salt imported into the San Joaquin River basin via the Delta-Mendota Canal, development of new numeric salinity objectives, and establishment of the Real Time Management Program for the control of salinity discharges to the San Joaquin River.

iii. Upstream of Vernalis San Joaquin River Salinity Objectives: CV-SALTS has established a subcommittee that has developed a proposal for a basin plan amendment to the Water Quality Control Plan for the Sacramento River Basin and San Joaquin River Basin to establish numerical salinity objectives and a program of implementation for the Lower San Joaquin River upstream of Vernalis.

iv. Irrigated Lands Regulatory Program: Under the Irrigated Lands Regulatory Program, the Central Valley Regional Water Board issues waste discharge requirements (WDRs) to coalition groups and individual dischargers requiring surface water quality monitoring and the preparation and implementation of management plans to address identified water quality problems, including those associated with salinity. The most recent WDRs require third parties to develop regional water quality management plans for areas where irrigated agriculture is contributing to water quality problems. It requires growers to implement practices consistent with those plans to address the identified problems.

v. Variances from Surface Water Quality Standards for Point Source Dischargers, Variance Program for Salinity, and Exception from Implementation of Water Quality Objectives for Salinity: The Central Valley Regional Water Board adopted Resolution R5-2014-0074 to amend water quality control plans for the Sacramento River and San Joaquin River basins and the Tulare Lake basin to add policies for *Variances from Surface Water Quality Standards for Point Source Dischargers (Variance Policy)*, a *Variance Program for Salinity (Salinity Variance Program)* and an *Exception from Implementation of Water Quality Objectives for Salinity (Salinity Exception Program)*. The amendments were approved by the State Water Board on March 17, 2015, (Resolution No. 2015-0010) and by OAL on June 19, 2015. USEPA approval of the amendments is anticipated in 2016.

- The *Variance Policy* will allow the Central Valley Regional Water Board the authority to grant short-term exceptions from meeting water quality based effluent limitations to dischargers subject to NPDES permits. The policy will only apply to non-priority pollutants, which include~~s~~ salinity.
- The *Salinity Variance Program* will allow the Central Valley Regional Water Board the authority to grant multiple discharger variances from

meeting water quality based effluent limitations for salinity constituents to publicly owned treatment works. A multiple discharger variance provides a streamlined approval procedure in which an individual discharger variance application, which is consistent with the multiple discharger variance, does not require separate review and approval from the USEPA once the multiple discharger variance is approved by USEPA.

- The *Salinity Exception Program* establishes procedures for dischargers that are subject to WDRs and conditional waivers to obtain a short-term exception from meeting effluent or groundwater limitations for salinity constituents.

The above programs will support the development and initial implementation of the comprehensive salt and nitrate management plans in the Central Valley by requiring dischargers to participate in the CV-SALTS effort.

State Funding of Programs

i. The State Water Board has various financial assistance programs under which it can contribute funding for programs that will help meet the salinity objectives or to improving understanding about salinity conditions in the southern Delta (primarily the San Joaquin River upstream of Vernalis). To date, it has funded tens of millions of dollars worth of projects and studies for such programs. The State Water Board provides funds through the State Revolving Fund Loan Program, the Agricultural Drainage Loan Program, the Agricultural Drainage Management Loan Program, Proposition 13, 40, and 50 grant funding through the Nonpoint Source Pollution Control Programs and Watershed Protection Programs.

Current Projects and Actions by Other Agencies

The following projects may assist in meeting the southern Delta salinity objectives by reducing high salinity drainage to the San Joaquin River; improving circulation in the southern Delta; and supplementing flows through recirculation. All or a portion of these projects are being funded through the above referenced programs. Each of these projects, described below, should be pursued by the identified agencies. If successful, these projects and the actions they contain could make additional regulatory measures by the State Water Board and the Central Valley Regional Water Board unnecessary.

i. Grasslands Bypass Project: The Grasslands Bypass Project manages discharges of agricultural drainage water from 97,000 acres in the Grasslands Watershed. The purpose of the project is to prevent discharges of water containing high levels of selenium to wildlife refuges and wetlands in the San Joaquin Valley. Recent monitoring data shows that from 1995-2015 the discharge of salts was reduced by 83% compared to~~, but it has reduced the load of salts by 39 percent (from 187,300 tons to 113,600 tons) from~~ pre-project conditions through various management measures including sump management, recycled tail and tile water programs, on-farm tile and tail water management, and various source control measures. The Grassland Areas farmers, USBR, the Central Valley Regional Water Board, and other agencies should continue to evaluate the various management measures in the Grasslands Bypass Project and should continue to implement those measures that are effective in reducing salinity and selenium discharges to the San Joaquin River to meet the goal of zero discharges to the San Joaquin River from the Grasslands area by 2019.

ii. West Side Regional Drainage Plan: The West Side Regional Drainage Plan evolved from the Grasslands Bypass Project as a long-term solution to eliminate discharges to the San Joaquin River of drainage water from irrigated agriculture containing high amounts of selenium, salt and other constituents. The plan uses the following practices:

a) Reduction of drainage volumes by using source control/efficient water management techniques such as replacing furrow irrigation with micro-irrigation technology and lining unlined delivery canals;
b) Recirculation of tailwater on primary irrigation lands;
c) Collection and reuse of tile drainage water on halophytic croplands to concentrate drainage;
d) Installation and pumping of groundwater wells in strategic locations to eliminate groundwater infiltration into tile drains; and
e) Treatment and disposal of remaining drainage water through reverse osmosis, evaporation and disposal or reuse of salts.

When fully implemented, the parties implementing the plan expect to assure achievement of the salinity objective~~s~~ at Vernalis and reduce the frequency of exceedances of the salinity objective~~s~~ at Brandt Bridge by 71 percent over a 73-year hydrology. ~~They expect to complete the plan by 2010.~~ Stakeholder parties to the Westside Regional Drainage Plan should continue work to implement the various practices discussed above to achieve the goal of zero discharges to the San Joaquin River from the Grasslands area by ~~2010~~2019.

iii. San Luis Unit Feature Reevaluation Project: USBR ~~currently is~~ evaluat~~ing~~ed seven alternatives as part of the San Luis Unit Feature Reevaluation Project to provide drainage service to the San Luis Unit of the CVP. This project would reduce discharges to the San Joaquin River and sustain long-term agricultural production on drainage-impacted lands. The alternatives ~~under~~ consider~~ation~~ed included: on-farm, in-district drainage reduction actions; federal facilities to collect and convey drain water to regional reuse facilities; and some level of land retirement. Additional options ~~under~~ consider~~ation~~ed included options for in-valley disposal of drain water, ocean disposal, and Delta disposal. USBR's preferred alternative is an in-valley/land retirement alternative~~, and would~~that involves treatment of drain water through reverse osmosis and selenium biotreatment before disposal in evaporation basins. USBR expects implementation to help reduce saline discharges to the lower

San Joaquin River. A desalination demonstration project is currently being implemented as part of this effort.

iv. Central Valley Project Improvement Act (CVPIA) Land Retirement Program: USBR and Westland's Water District are implementing land retirement projects under the CVPIA Land Retirement Program and under settlement agreements in drainage-impacted areas of the San Luis Unit of the Joaquin Valley. ~~The projects will reduce the volume of subsurface drain water discharged to the San Joaquin River.~~

v. San Joaquin River Real-time ~~Water Quality~~ Salinity Management Program: The San Joaquin River Real-time ~~Water Quality~~ Salinity Management Program is a ~~project by~~partnership effort between agricultural dischargers within the Lower San Joaquin River Basin, DWR, USBR, USFWS and United States Geological Survey (USGS) that uses telemetered stream stage and salinity data and computer models to simulate and forecast water quality conditions along the lower San Joaquin River. The main objective of the project is to control and time the releases of wetland and agricultural drainage to coincide with periods when dilution flow is sufficient to meet the Vernalis salinity objective~~s~~. The Central Valley Regional Water Board adopted a resolution in 2014 approving the proposed framework to establish the program (R5-2014-0151). The framework document describes completed pilot studies that establish the feasibility of the program and describes the steps to be taken to implement the program.

~~DWR, DFG, University of California Davis (UC Davis), and other parties are undertaking various projects to determine whether there are wetlands management practices that can improve water quality in the San Joaquin River and conditions for wildlife. Wetlands discharges may account for more than nine percent of the total salt load in the San Joaquin River at Vernalis. The research is focused on coordinating the release of high salinity wetlands discharges to the river at times when assimilative capacity is available. DFG, USFWS, and USBR in coordination with CALFED, DWR, UC Davis, and other appropriate parties should diligently pursue completion of research to determine opportunities for improving wetlands management for the benefit of wildlife and water quality. Any cost effective and reasonable opportunities to improve water quality through improved wetlands management without adversely impacting fish and wildlife should be implemented as soon as practicable.~~

vi. South Delta Improvements Program: DWR and USBR propose to construct permanent tidal gates in the southern Delta as part of the South Delta Improvements Program (SDIP) to replace the temporary barriers that are currently constructed on an annual basis. DWR and USBR expect that the gates project will assist in achieving the salinity objective~~s~~ at the two Old River compliance measurement locations by improving water circulation in the southern Delta. Due to concern regarding the impact the gates project may have on migratory fish, additional studies are being conducted prior to the re-initiation of consultation for Endangered Species Act permits required for this project. Consequently, implementation of this project has been postponed indefinitely.

~~Currently, DWR and USBR expect the project to be operational in the spring f 2009.~~

~~Delta-Mendota Canal Recirculation: Several agencies and water districts are considering releasing water from the Delta-Mendota Canal to the San Joaquin River to meet water quality objectives at Vernalis. Water Right D-1641 requires USBR to conduct such a study. However, other agencies including DWR have also been involved in assessing this alternative. USBR in coordination with other agencies should complete the recirculation analyses and assess the feasibility of using recirculation to meet southern Delta salinity objectives. If recirculation is cost effective and does not have significant unavoidable impacts to water quality, fish and wildlife, water supplies, and other beneficial uses of water, USBR and/or other agencies should implement a recirculation project to meet and/or supplement the southern Delta salinity objectives.~~

~~Recommended Projects, Studies, and Actions:~~

~~The following recommended projects, studies, and actions will provide information that can be used during subsequent updates of the Water Quality Control Plan and water rights proceedings to implement the Plan:~~

~~i. Central Valley Salinity Committee and Salinity Study Task Force: At a January of 2006 joint workshop, the State Water Board and Central Valley Regional Water Board established a Salinity Committee to address salinity issues in the Central Valley. The Committee will establish a Salinity Study Task Force to evaluate the impact of salinity on water resources and develop a viable salinity management plan; sponsor a follow-up joint State Water Board/Regional Water Board salinity workshop to receive comments on the salinity management plan; conduct meetings to gather additional public input; contract for preparation of an economic study of salinity impacts and the social and economic consequences of not implementing a viable salinity management program; and sponsor a conference that will highlight the major salinity-related issues and their statewide impacts.~~

~~ii. Southern Delta Salinity Objectives: There is a need for an updated independent scientific investigation of irrigation salinity needs in the southern Delta (similar to the investigation on which the current objectives are based). The scientific investigation should address whether the agricultural beneficial uses in the southern Delta would be reasonably protected at different salinity~~

~~levels, whether management practices are available that would allow for protection of the beneficial uses at a higher salinity level in the channels of the southern Delta, and whether such management practices are technically and financially feasible. The investigation could address the feasibility of providing an alternative method of delivering fresh water to agricultural water users in the southern Delta. The scientific investigation must be specific to the southern Delta. The State Water Board will conduct a workshop to discuss this subject in January 2007.~~

2. San Joaquin River Dissolved Oxygen Objective
D-1641 directs the Central Valley Regional Water Board to establish a TMDL to address the dissolved oxygen (DO) impairment in the San Joaquin River. In November of 2005, the State Water Board approved an Amendment to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins. The amendment, approved by the Office of Administrative Law in August 2006, consists of a Control Program for Factors Contributing to the DO impairment in the Stockton Deep Water Ship Channel (DWSC) and other actions to implement DO objectives in the DWSC portion of the San Joaquin River. The DO basin plan amendment includes implementation measures and a timeline for implementation for both the 1995 Plan DO objective and the DO objective in the Water Quality Control Plan for the Sacramento River Basin and the San Joaquin River Basin.

The Central Valley Regional Water Board should continue to implement the recently adopted DO TMDL. Further, the United States Army Corps of Engineers (USCOE) and other agencies and parties that contribute to the DO impairment should complete the measures recommended by the Central Valley Regional Water Board in the basin plan amendment. In addition, the responsible entities should complete their investigations into the feasibility of operating an aeration facility in the Stockton DWSC to assist in achieving the objectives. If the pilot project and other information demonstrates that permanent installation and operation of aeration devices is feasible and would not have immitigable adverse impacts on fish, wildlife, water quality and other resources, DWR, CALFED, and the other implementing agencies should pursue operation of such a facility with operating assistance from the State Water Contractors (SWC), the Port of Stockton, San Luis Delta-Mendota Water Authority (SLDMWA), the San Joaquin River Group Authority ~~(SJRGA)~~, and other appropriate agencies.

DWR and USBR should continue to expeditiously pursue installation of a permanent operable gate (barrier) at the head of Old River or equivalent measures to assist in achieving the DO objective.

3. Narrative Objective for Salmon Protection
D-1641 assigned responsibility to the USBR and DWR to comply with the river flow and operational objectives for fish and wildlife. These objectives help protect salmon migration through the Bay-Delta Estuary. D-1641 did not require separate actions to implement the narrative objective for salmon because the State Water

Board expects that implementation of the numeric flow-dependent objectives and other non-flow measures will implement this objective.

The narrative objective for salmon protection in the Delta is consistent with the anadromous fish doubling goals of the CVPIA. Under the Anadromous Fish Restoration Program (AFRP), State, federal and local entities are continuing to implement programs within and outside the Delta geared towards achieving the CVPIA anadromous fish doubling goals.

The State Water Board intends to invite DFG, NOAA Fisheries, and other agencies monitoring the progress of the salmon doubling effort to present to the Board the results from ongoing studies, fishery improvement programs, and any recommendations for a specific numeric objective at subsequent workshops every two years starting from the date of the adoption of this Plan. The State Water Board will consider monitoring results when determining whether numeric objectives either should replace or augment the narrative objective. The Board may use the information it receives to modify the objective in future proceedings.

Actions by parties other than the State Water Board are required to implement the narrative objective for salmon protection if implementation of the flow-dependent objectives does not achieve the objective. Other agencies are implementing the following actions. These actions not only benefit the salmonids while they are in the Estuary, but also help improve habitat for other species.

i. Through the CVPIA, Section 3406 (b) 21, Anadromous Fish Screen Program, the USBR, USFWS, and other participating agencies should continue to work towards the implementation of new screening facilities on diversions in the Bay-Delta Estuary to reduce losses of fish in all life stages to unscreened water diversions. In evaluating Delta diversions, these agencies should: (1) decide where screens are needed; (2) consider whether diversion points should be relocated or consolidated; and (3) provide their recommendations on changes in points of diversion to the State Water Board for consideration in a water rights proceeding.

ii. The DWR and the USBR, in consultation with the DFG, USFWS, and NOAA Fisheries, should continue to evaluate and implement all feasible measures and programs to reduce entrainment and mortality of fish salvaged at the Skinner Fish Protection Facility (Banks Pumping Plant) and the Tracy Fish Collection Facility (Tracy Pumping Plant). These measures should include: (1) monitoring entrainment on a real-time basis to identify periods of peak susceptibility of various species; (2) coordinating operations of the two diversions, including interchangeable pumping, to reduce combined losses; (3) increasing screening efficiency; (4) improving fish salvage and handling; and (5) controlling predators at the SWP and CVP intakes.

4. Narrative Objective for Brackish Tidal Marshes of Suisun Bay

In the 1995 Plan, the State Water Board recommended that DWR convene a Suisun Marsh Ecological Work group (SEW) consisting of representatives from various State, federal and private agencies and other interested parties. The SEW was assigned eight tasks, one of which was to determine a numeric objective to replace the narrative objective for tidal brackish marshes of Suisun Bay. However, the SEW was unable to determine a single numeric objective for the tidal marshes. In 2001 the Suisun Marsh Charter Group (SMCG[15]) was formed to develop a plan to balance the competing needs in Suisun Marsh. The SMCG is currently preparing a Programmatic Environmental Impact Statement/Environmental Impact Report (PEIS/EIR) for the Habitat Management, Preservation, and Restoration Plan for the Suisun Marsh (Suisun Marsh Plan). In the preparation of the Suisun Marsh Plan, the principal Suisun Marsh agencies are evaluating Plan alternatives with a tidal wetland habitat restoration component ranging from 3,000 to 36,000 acres.

State Water Board staff will use the results of the final PEIS/EIR and the resulting Suisun Marsh Plan during the next Water Quality Control Plan update to determine whether and how to convert the narrative objective to a numeric objective for the Brackish Tidal Marshes.

5. Numeric Objectives for Suisun Marsh

State Water Board staff will use the results of the final PEIS/EIR and the resulting Suisun Marsh Plan currently being prepared by the Suisun Marsh Charter Group (SMCG), to determine in a future plan amendment whether the objectives at stations S-97 and S-35 should be amended or deleted. The objectives at stations S-97 and S-35 may be amended and/or implemented in stages, as appropriate, and shall be implemented no later than either January 1, 2015, or an earlier date, if a further review of these objectives does not determine that they are not needed.

The objectives for water supply intakes for waterfowl management areas on Van Sickle and Chipps islands, which have no locations specified, may be amended and/or implemented in stages, and shall be implemented no later than January 1, 2015 if a further review of these objectives does not determine that they are not needed. Other measures to control Suisun Marsh soil and channel water salinities are discussed in section C9.

C. Recommendations to Other Agencies

Consistent with the Porter-Cologne Water Quality Control Act, this Water Quality Control Plan identifies control actions recommended for implementation by agencies other than the State Water Board. Actions are recommended both for the attainment of water quality objectives and to obtain additional information on the effects of flow and water quality on beneficial uses.

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[15] The SMCG Principle Agencies include Suisun Resource Conservation District, DFG, DWR, USBR, CBDA, NMFS and USFWS.

Numerous actions can be taken, in addition to establishing and implementing water quality objectives for the Bay-Delta Estuary, to improve fish and wildlife beneficial uses in the Estuary. These actions involve improvements to habitat conditions both inside and outside of the Estuary, many of which are under the authorities of other agencies, as well as studies needed to better understand the effects of flow and water quality on beneficial uses.

There is an ongoing effort by State agencies, the federal government, and agricultural, urban, and environmental interests to identify, fund, and implement, as warranted, measures to address the broader non-flow-related range of factors potentially affecting water quality and habitat in the Bay-Delta Estuary. Potential measures under consideration by these entities include those that would be implemented outside of the Estuary itself. These efforts, in connection with the other measures to implement the objectives in this plan, are among the ongoing programs to provide better protection for the beneficial uses that depend on the Bay-Delta Estuary.

The State Water Board will use its authority, as needed and appropriate, under section 13165 of the California Water Code to require that the following actions and studies be conducted.

1. Review and modify, if necessary, existing commercial and sport fishing regulations

Current levels of sport and commercial fishing may be contributing to reduced fish populations in the Bay-Delta Estuary. Since the implementation of the 1995 Plan, the Fish and Game Commission was granted authority over all state managed bottom trawl fisheries not managed under a federal fishery management plan or state fishery management plan. (Fish & Game Code, § 8841.) This authority ensures the sustainable management of resources, protects the health of ecosystems, and assists in the orderly transition to sustainable gear types when bottom trawling is incompatible with these goals.

The DFG, California Fish and Game Commission, Pacific Fisheries Management Council, and NOAA Fisheries should take the following actions within their respective authorities: (1) develop and implement a fisheries management program to provide short-term protection for aquatic species of concern through seasonal and area closures, gear restrictions to reduce capture and mortality of sub-legal fish, and other appropriate means; and (2) review immediately, and then at least every two years, and modify, if necessary, existing harvest regulations to ensure that they adequately protect aquatic species.

2. Reduce illegal harvesting

Illegal harvesting has a certain but un-quantified impact on fisheries of the Bay-Delta Estuary. The DWR and the DFG should expand the current illegal harvest enforcement program. Additionally, the DFG should continue to develop and implement educational programs to curb poaching of fishery resources.

3. Reduce the impacts of introduced species on native species in the Estuary
The intentional and accidental introduction of non-native species has caused major changes in the composition of aquatic resources in the Bay-Delta Estuary; however, the exact impacts of existing introduced species on native species in the Estuary are not clear. The impact of introduced species is being investigated as a potential cause of the POD. The results of the ongoing POD studies may provide insight into the reasons for the decline, and provide the scientific basis for actions that can be taken to reverse the trend.

Until the results from the POD studies are made available, other programs are being implemented by other agencies to lessen the propagation of invasive species. The National Invasive Species Act of 1996 established various programs intended to decrease the propagation of invasive species into waters of the U.S. and to prevent the spread of aquatic nuisance species. These programs include the Ballast Water Management Demonstration Program and the Aquatic Nuisance Species Program and allows for State Invasive Species Management Plans to be created independent of federal action. Under the National invasive Species Act of 1996, the DFG, USFWS, and NOAA Fisheries should continue to pursue programs to determine the impacts of introduced species, including striped bass, on the native aquatic resources of the Estuary, and the potential benefits of control measures. The DFG should also continue its efforts under the Fish and Game Code sections 6430-6439, enacted in 1992, concerning introduced species. Additionally, the California Fish and Game Commission should deny all requests for the introduction of new aquatic species into the watershed of the Bay-Delta Estuary unless it finds, based on strong, reliable evidence, that an introduction will not have deleterious effects on native species.

4. Improve hatchery programs for species of concern
Existing fish hatcheries are operated in order to provide mitigation for the loss of stream spawning and rearing habitat due to the construction of large dams. As noted by NOAA Fisheries in the Biological Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan (OCAP), the viability of natural fish populations has been compromised due to the operation of hatcheries, as the hatchery fish are not isolated from the natural systems. Hatchery fish, while increasing the abundance of fish numbers, often result in increased harvesting pressure on natural fish stocks. Additionally the hybridization between hatchery and natural fish stocks has caused deterioration of the natural population.

To assist in the management of natural fish stocks, Congress has mandated that all federal and federally funded salmon and steelhead hatcheries implement a marking program on the fish they release to visually distinguish between hatchery and natural stock. DFG, NOAA Fisheries, and USFWS should continue to: (1) carefully examine and periodically re-examine the role and contribution of existing hatchery production for various fish species (e.g., chinook salmon, steelhead trout), including a consideration of the need for genetic diversity and maintaining the integrity of different salmon runs and (2) evaluate strategies for improving the survival of hatchery fish, before and after release, including diet and pre-release conditioning, selection of the life stage and size of fish to be released, timing releases relative to the presence or absence of other species, and using multiple release locations.

5. Expand the gravel replacement and maintenance programs for salmonid spawning habitat

The presence of dams on the major tributaries of the Delta blocks the movement of gravel eroding from upstream areas and causes fine sediments to infiltrate the remaining gravels. Reduction in the riverbed gravels required for salmonid spawning limits the success of chinook salmon and steelhead trout reproduction in the watershed of the Bay-Delta Estuary.

Under the AFRP, and other gravel replacement and maintenance programs, the DWR, the USBR, and other agencies that currently conduct gravel replacement and spawning habitat improvement programs on the Sacramento and San Joaquin River systems should continue and, where possible, increase their efforts in the reaches where salmonids are likely to spawn.

6. Evaluate alternative water conveyance and storage facilities of the SWP and CVP in the Delta

The current water diversion facilities of the CVP and the SWP in the southern Delta adversely impact fish populations. These facilities or alternative facilities are needed to meet water supply demands in areas south and west of the Delta. Various alternatives have been identified to minimize impacts to fish while meeting water supply demands. The proposed alternatives include construction of a water diversion intake on the Sacramento River equipped with state-of-the-art fish screens, isolated and through-Delta water conveyance facilities, and new water storage facilities within and south of the Delta. The DWR and USBR should continue their efforts to develop alternative water conveyance and storage facilities in the Delta, and should evaluate these alternatives and their feasibility and take action as necessary to minimize impacts to fish.

7. Develop an experimental study program on the effects of pulse flows on fish eggs and larvae in the Delta

The magnitude of freshwater outflow passing through the Delta affects the geographic distribution of many planktonic fish eggs and larvae. The egg and larval stages of many fish species occur in the Delta during a relatively short period of time in the spring (April-June). When there is high freshwater outflow, the planktonic eggs and larvae are moved downstream into Suisun Bay where they are less susceptible to entrainment at the SWP and CVP diversions and at other diversion points within the Delta. Absent high freshwater flows, pulse flows can be used to move the eggs and larvae downstream into Suisun Bay. To improve the efficiency of water used for this purpose, it would be helpful to experimentally quantify the magnitude and duration of pulse flows needed to move a substantial proportion of fish eggs and larvae into Suisun Bay.

DWR and USBR should conduct experiments to investigate and evaluate the biological benefits of pulse flows to move planktonic fish eggs and larvae into Suisun Bay. These experiments, which should be conducted as soon as feasible, should: (1) include flows from both the Sacramento and San Joaquin Rivers; (2) include real-time biological monitoring to determine the most favorable times for the pulse flows and the effects of the pulse flows on the eggs and larvae; (3) determine whether short-term pulse flows have a lasting benefit or whether, when outflows are reduced after a pulse flow, the larval fish are drawn back into interior Delta areas; and (4) take into account base flows and availability of water supplies. The experiments should be designed so that they can be used to refine potential pulse flow requirements in the future.

8. Implement actions needed to restore and preserve marsh, riparian, and upland habitat in the Delta

Most of the historical fish and wildlife habitat in the Delta has been eliminated or disturbed. In the Delta, less than 100,000 acres of the total 738,000 acres remains as marsh, riparian, and upland habitat. The remainder of the area is highly altered due to conversion to agricultural land, industrial and urban development, and actions for flood control and navigation, such as dredging channels and riprapping banks. Furthermore, many of the alterations that have already occurred require extensive ongoing maintenance, which also disrupts fish and wildlife habitat. Restoration of fish and wildlife habitat in the Delta would benefit many species of the Bay-Delta Estuary.

State and federal agencies should require, to the extent of their authorities, habitat restoration in the Delta as a condition of approving projects. For example, the Delta Protection Commission, in all of its actions under the Delta Protection Act of 1992 (Pub. Resources Code § 29700 *et seq*.) that provide for the coordination of local land use decisions in the Delta, should continue to implement and support programs such as the Delta Mercury TMDL Collaborative (AB 2901), the Lower Bypass Collaborative/Management Plan and the Delta-wide Conservation Easement Concept. The DFG, when it considers approving stream alterations, and the DFG, USFWS, and NOAA Fisheries, when they consider projects that affect endangered species, should consider habitat requirements. The USCOE should consider habitat requirements in connection with applications for permits under Clean Water Act section 404. Within their authorities, these agencies should provide for: (1) levee setback requirements; (2) reductions in the depth of selected Delta channels, by using either dredge material from navigational channels or natural infill, to restore more productive shallows and shoals; (3) conversion of low-lying Delta islands to habitat areas; and (4) other habitat enhancement measures. The State Water Board will consider habitat requirements where needed to meet water quality standards under the Clean Water Act when approving section 401 certifications.

9. Suisun Marsh soil and channel water salinity objectives

In addition to the formation of the SEW discussed above, the 1995 Plan recommended three measures to be implemented to control Suisun Marsh soil and channel water salinities. The first measure, calling for continuation of the actions identified for implementation in the Suisun Marsh Preservation Agreement (SMPA), is included in the Revised Suisun Marsh Preservation Agreement executed on June 25, 2005. The Suisun Marsh Charter Group is evaluating two additional actions that may be added to the SMPA in a future amendment. The second measure, calling for a study to determine the relationship between channel water salinity and soil water salinity under alternative management practices, was completed in 2001 by DWR as part of the Comprehensive Review of Suisun Marsh Monitoring Data, 1985-1995. The third measure, requiring that DWR, USBR, DFG, and Suisun Resource Conservation District (SRCD), together with the property owners in Suisun Marsh, to employ a watermaster, has been accomplished through implementation of the Water Manager Program under the Revised SMPA.

In June of 2005, SRCD, DWR, USBR, and DFG signed the Revised SMPA. This agreement funded the Water Manager Program to help coordinate and improve water management practices on individual private managed wetlands throughout the Marsh. The duties of the Water Managers include:

- promote and encourage wetland management activities, including flooding, draining and circulation, so that they occur at the appropriate critical times of the year to produce desired wildlife habitats.
- provide technical support in the field to answer questions and educate landowners on beneficial management techniques.
- protect and enhance endangered species habitat, manage water application, and provide new scientific information pertaining to common management activities.
- supervise and coordinate the portable pump program to ensure proper maintenance and operation of the pumps.
- assist landowners in planning yearly maintenance and enhancement projects.
- additional activities may include assisting DFG on water management of State owned property, assisting in yearly salt marsh harvest mouse monitoring, California clapper rail surveys, and inspections of levees during storms to identify damages and assist in flood fight coordination.

10. San Joaquin River ~~Spring Flow Objectives~~ Non-Flow Actions

In addition to the recommendations in the preceding sections, the following recommendations apply specifically to the San Joaquin River. The recommendations are for non-flow actions that are complementary to the LSJR flow objectives for the protection of fish and wildlife. These recommended actions, together with the coordinated monitoring and adaptive implementation of the LSJR flow objectives, are expected to improve habitat conditions that benefit native fish and wildlife, or are expected to improve related science and management within the LSJR watershed.

Additionally, educational outreach programs should be developed and conducted with interested stakeholders or watershed groups to promote collaborative development, funding, and implementation of habitat enhancement and protection projects, and to promote resource stewardship among stakeholders. In many cases, the recommended actions will require authorizations by the appropriate agencies, which should consider this Plan when acting on them.

i. Restore, Enhance, and Protect Floodplain and Riparian Habitat: The USCOE, USBR, DFW, USFWS, FERC licensees, water districts, local landowners, and other appropriate entities should undertake, participate in, fund or authorize riparian and floodplain habitat corridor restoration, enhancement and protection actions along the LSJR and its tributaries, including but not limited to the following:

  a) Obtain easements or acquire land for riparian and floodplain habitat restoration.
  b) Reduce salmon stranding events in ponds, pits, and other unnatural features by physically modifying problem areas within river corridors.
  c) Facilitate the establishment and maintenance of self-sustaining native riparian and floodplain vegetation.
  d) Restore, enhance, and protect secondary/side-channel habitats to increase habitat diversity and function within the Stanislaus, Tuolumne, and Merced Rivers.
  e) Import silt or fine sediment onto floodplain restoration projects to improve soil moisture properties and encourage riparian vegetation success.
  f) Identify locations in the LSJR and its tributaries that are appropriate for levee modification (e.g. rip-rap removal and levee set back or removal) for the purpose of improving native fish and wildlife habitat.

ii. Reduce Vegetation Disturbing Activities in Floodplains and Floodways, Where Safe and Appropriate: The NMFS, DFW, USFWS, Central Valley Flood Protection Board, USACE, local landowners, county governments, local agricultural commissions and other land management agencies in the LSJR, Stanislaus, Tuolumne, and Merced River watersheds should reduce grazing, mowing, cutting, spraying, discing and other vegetation disturbing activities in floodplains and floodways, where safe and appropriate, to promote and restore these areas with riparian vegetation. Actions include but are not limited to the following:

a) Develop grazing strategies that protect and improve streamside vegetation, and that minimize bank disturbance.
b) Conduct outreach to inform landowners of state and federal laws and regulations that protect riparian, wetland, and Endangered Species Act (state and federal) protected vegetation.
c) Review and potentially modify existing floodplain, floodway, and riparian vegetation management plans, or develop new ones using the best available science, to balance the needs of the ecosystem and the needs of public safety and other considerations.
d) Compile data, conduct studies, and review literature to determine the influence that large trees and other vegetation types have on levee and floodway safety, and use this information to make science based management decisions.

iii. Provide and Maintain Coarse Sediment for Salmonid Spawning and Rearing: DWR, USBR, DFW, USFS, NMFS, FERC, FERC licensees and other entities performing or otherwise participating in habitat restoration, enhancement and protection projects should provide and maintain an adequate supply of coarse sediment for salmonid spawning and rearing habitat. In addition, entities that can control contributions of fine sediment in the Stanislaus, Tuolumne, and Merced River watersheds should reduce the input of fine sediment in spawning areas. These actions, include but are not limited to the following:

a) Develop and maintain coarse sediment management plans for the major LSJR tributaries that consist of two temporal stages: (1) short-term restoration and gravel augmentation to re-build spawning habitat and to restore functional processes important to native fish and wildlife; and (2) long-term course sediment augmentation program to maintain the functioning of the restored habitat and to compensate for the blockage, by dams, of the natural gravel supply.
b) Develop and implement erosion control measures including the construction of sediment retention basins within the Stanislaus, Tuolumne, and Merced River watersheds.
c) Identify and remediate unpaved roads or other disturbed areas that may be contributing to fine sediment input.

iv. Enhance In-Channel Complexity: The DFW, USFWS, NMFS, FERC, FERC licensees, conservation groups, water districts and other appropriate entities should enhance in-channel complexity within the LSJR tributaries by adding instream structures, including but not limited to the following:

a) Add boulders, large woody debris, or other structures where appropriate in river channels, taking human safety into consideration.
b) If large woody debris or coarse sediment is removed from upstream reservoirs, it should be transported downstream and placed into the Stanislaus, Tuolumne, and Merced Rivers due to that reservoir's contribution to deficits of large woody debris and coarse sediment

supply in these rivers.

v. Improve Reservoir Operations and/or Physical Structures to Maintain Adequate Water Temperature Conditions: The USBR, NMFS, USFWS, DFW, FERC, FERC licensees, dam owners or operators, and others, should evaluate and implement temperature control solutions, including but not limited to the following:

a) Cold water pool management.
b) Installation or modification of selective withdrawal structures (e.g. temperature control curtains or shutters).

vi. Expand Fish Screening: The DFW, NMFS, USFWS, water districts, local landowners, and others should evaluate unscreened diversions on the Stanislaus, Tuolumne, and Merced Rivers and the LSJR for their potential to cause mortality to migrating salmonids and implement fish screening solutions where appropriate and effective.

vii. Improve Fish Passage Above Dams: The USBR, NMFS, USFWS, DFW, FERC, FERC licensees, dam owners or operators, and others, should evaluate and implement fish passage solutions to all human-made barriers which block native fishes from accessing important habitats, including but not limited to the following:

a) Near-term actions assessing habitat suitability upstream of dams, investigating fish passage options and developing plans for long-term reintroductions of salmonids upstream of existing dams.
b) Provide fish passage at existing dams which block or impede native fish movements.

viii. Improve Fish and Water Barrier Programs: The USBR, DWR, DFW, USFWS, and NMFS should develop and implement improvements to fish and water barrier programs within the Delta, including but not limited to the following:

a) Research, monitor, and report the effects of physical and non-physical barriers within the delta on water quality and fish.
b) Develop and evaluate physical and non-physical barrier designs to maximize their effectiveness in reducing adverse impacts on native fish and wildlife and their habitat.

ix. Reduce Predation and Competition by Non-Native Fish: The DFW, NMFW, USFWS, FERC, FERC licensees, local water districts, conservation groups, landowners, water users and other appropriate entities should reduce impacts that non-native predators and competitors have on native fish and modify habitats which currently favor non-native fish over native fish in the LSJR and its tributaries to favor native fish. Actions include but are not limited to the following:

a) Study and report the effects that predators and non-native fish have on native fish.
b) Identify gravel pits, scour pools, ponds, weirs, diversion dams, and other structures or areas that harbor significant numbers of non-native fish and predatory fish that may currently reduce native fish survival.
c) Modify priority structures and areas to reduce predation and non-native fish effects and to improve native fish success.
d) Evaluate and implement changes to fishing regulations to reduce the impact that non-native competitor and predator fish have on native fish.

x. Reduce Invasive Species: The NMFS, DFW, USFWS, USBR, United States Department of Agriculture, California Department of Food and Agriculture, the State Lands Commission, the California Fish and Game Commission, the California State Parks Division of Boating and Waterways, local agencies in LSJR Tributaries' watersheds, and other appropriate entities should reduce the impacts aquatic invasive species (plants and animals) have on native fish and wildlife of the Bay-Delta watershed. Actions include but are not limited to the following:

a) Fund and launch prevention, early detection, and rapid response actions, including efforts to coordinate various aquatic invasive species monitoring programs and expand monitoring of freshwater systems.
b) Evaluate and implement appropriate actions to minimize the effects of aquatic invasive species on native fishes in the Bay-Delta watershed.
c) Monitor and regulate the importation of aquatic invasive species to minimize the effects of such species on native fishes in the Bay-Delta watershed.
d) Conduct a statewide assessment of the risk from various aquatic invasive species vectors.
e) Support public education preventing the introduction of aquatic invasive species, including promoting the use of native and noninvasive alternatives.

The DFG, USFWS, and NOAA Fisheries, in coordination with the IEP and other interested parties, should compile information and conduct specific studies to determine whether and what changes should be made to the Spring Flow Objectives to protect San Joaquin River chinook salmon and steelhead, pelagic organisms (see the POD section for additional information concerning these studies) and other applicable fish and wildlife species. These entities also should conduct analyses to determine whether it is appropriate to revise the methodology for determining when the higher spring flow objectives apply, to better reflect hydrological conditions within the San Joaquin River Basin. In addition, these entities should conduct modeling to determine the water costs of the various flow proposals and the sustainability of such proposals given current water storage capacities and consumptive use needs within the San Joaquin River Basin. These entities should present any available information from such studies during the State Water Board's workshop on the San Joaquin River flow issues.

11. San Joaquin River Pulse Flow Objectives Restoration Program

The historic operation of the Friant Dam resulted in significant portions of the main stem of the San Joaquin River between Friant Dam and the confluence of the Merced River being dry. In 2006, in response to litigation over those impacts, the Department of Interior, the Natural Resources Defense Council, and the Friant Division long-term contractors reached a settlement to restore and maintain fish in "good condition" from below Friant Dam to the confluence of the Merced River, including naturally-reproducing and self-sustaining populations of salmon and other fish. In addition, the parties to the settlement agreed to reduce or avoid adverse water supply impacts to the Friant Division long-term contractors that could result from the implementation of interim and restoration flows. The settlement also acknowledged the potential for significant public benefits beyond its restoration and management goals including water quality benefits downstream of the Merced River.

The DFW, USBR, NMFS, and USFWS in coordination with the IEP, STM Working Group, and other interested parties should evaluate San Joaquin River Restoration Program flow contributions to flow and water quality requirements at Vernalis. The State Water Board may consider water quality objectives for the stream system above the San Joaquin River's confluence with the Merced River in future updates to this Plan.

DWR, in cooperation with parties to the SJRA, should establish procedures to install the head of Old River barrier at flows in excess of 5,000 cfs during the pulse flow period to further increase the survival of out-migrating San Joaquin River chinook salmon smolts and to provide additional data for the VAMP experiment.

In addition, parties to the SJRA should conduct a peer review of the VAMP study design to determine whether changes may be needed to the study to obtain necessary data points and to ensure the protection of San Joaquin River and Delta species. This peer review should be conducted prior to the State Water Board's workshop on San Joaquin River flow issues, anticipated for summer of 2007. Conclusions from the peer review should be presented during the workshop. If the findings of the peer review indicate that changes may be needed to water rights implementing the VAMP study, parties to the SJRA may file a petition to change their water rights with the State Water Board.[16] Alternatively, the State Water Board could undertake its own proceeding to make changes to water rights, the objectives, and/or the program of implementation for the objectives.

D. Monitoring and Special Studies Program

[16] The State Water Board could then determine whether changes would also be needed to the Plan and undertake proceedings to make any necessary changes.

This Plan requires, and the permits and license of the DWR and the USBR include conditions for, a monitoring program to provide baseline information and determine compliance with water quality objectives. This Plan also requires, and the permits of DWR and USBR include conditions for, special studies that will (1) evaluate the response of the aquatic habitat and organisms to the objectives; and (2) increase understanding of the large-scale characteristics and functions of the Estuary ecosystem to better predict system-wide responses to management options.

The monitoring and special studies program, also known as the Environmental Monitoring Program (EMP) is predicated on the ongoing monitoring efforts of the IEP. IEP member agencies include the State Water Board, DFG, USGS, NOAA Fisheries, USCOE, USEPA, DWR, and the USBR. The program is coordinated with the CBDA and UC Davis to minimize duplication and facilitate the exchange of data.

Table 4 of the 1995 Plan (now Table 7), established a preliminary compliance and baseline monitoring program. Condition 11 (e) on page 149 of D-1641 required the DWR and the USBR to complete an assessment of the EMP every three years to evaluate whether the goals of the monitoring program were being attained. This review was completed in 2003 and based on the conclusions of the review, several changes to the EMP were proposed that were considered to be functionally equivalent to the existing program. IEP participants developed a more appropriate compliance and baseline monitoring program. The new program contains Geographic Information System (GIS) coordinates for each monitoring and baseline station. In addition the modifications will: 1) enhance continuous monitoring at key locations to better measure the temporal variability in the system; 2) enhance shallow water monitoring to better measure the spatial variability in the system; 3) reduce the tidal spring-neap bias that occurs in the current program; 4) improve the quality assurance and quality control of the program by providing continuous monitoring data that can be used as crosschecks against discrete or periodic sampling data; and 5) improve employee safety.

Prior to the release of the 1995 Plan, the IEP had been conducting a special studies program including the 20mm delta smelt survey and the juvenile salmon and delta fishes abundance and distribution sampling. These studies emphasize understanding the ecological responses of species of special concern to water project operations resulting from implementation of this Plan. Other ongoing studies, such as the Bay shrimp and crab abundance and distribution sampling, and the Bay salinity monitoring, enhance knowledge of how the Estuary responds to factors other than the operational impacts of water development facilities.

Since the release of the 1995 Plan, various State and federal agencies and interested parties developed a near-real-time monitoring program managed by the Water Operations Management Team (WOMT) to assist the CALFED Ops group acting pursuant to the Principles for Agreement. The State and federal agencies should continue to conduct a process like the CALFED Ops process to ensure that the SWP and CVP operations developed to comply with the Plan are as efficient as possible.

Table 7. Water Quality Compliance and Baseline Monitoring

Station Number[1]	Station Description[2]	Latitude[3]	Longitude[3]	Cont. Rec.[4]	Cont. Multi-para-meter[5]	Disc. Physical Chemical[6]	Disc. Phyto-plankton[7]	Discr. Zoo-plankton[8]	Discrete Benthos[9]
C2 ■	Sacramento River @ Collinsville	38.07395	-121.85010	*					
C3A ▲	Sacramento River @ Hood	38.36772	-121.52051		*	*	*	*	
C4 ■	San Joaquin River @ San Andreas Ldg.	38.10319	-121.59128	*					
C5 ■	Contra Costa Canal @ Pumping #1	37.99520	-121.70244	*					
C6 ■	San Joaquin River @ Brandt Bridge site	37.86454	-121.32270	*					
C7 ▲	San Joaquin River @ Mossdale Bridge	37.78604	-121.30666		*				
C8 ■	Old River near Middle River	37.82208	-121.37517	*					
C9 ●	West Canal at mouth of CCForebay Intake	37.8218	-121.55275						*
		37.83075	-121.55703		*	*	*	*	
C10 ●	San Joaquin River near Vernalis	37.67575	-121.26500						
		37.69734	-121.26472		*	*	*	*	
C13 ■	Mokelumne River @ Terminous	38.11691	-121.49888	*					
C14 ■	Sacramento River @ Port Chicago	38.05881	-122.02607	*					
C19 ■	Cache Slough @ City of Vallejo Intake	38.29687	-121.74784	*					
D4 ▲	Sacramento River above Point Sacramento	38.06214	-121.81792			*	*	*	*
D6 ▲	Suisun Bay @ Bulls Head Pt. near Martinez	38.04427	-122.11764			*	*	*	*
D6A ▲	Suisun Bay @ Martinez	38.02762	-122.14052		*				
D7 ▲	Grizzly Bay @ Dolphin near Suisun Slough	38.11708	-122.03972	*		*	*	*	*
D8 ▲	Suisun Bay off Middle Point near Nichols	38.05992	-121.98996			*	*	*	
D9 ▲	Honker Bay near Wheeler Point	38.07245	-121.93923	*		*	*		
D10 ●	Sacramento River @ Chipps Island	38.04288	-121.92011		*	*			
		38.04631	-121.91829					*	
D11 ▲	Sherman Island near Antioch	38.04228	-121.79951	*		*	*		
D12 ●	San Joaquin River @ Antioch Ship Canal	38.01770	-121.80273		*	*			
		38.02162	-121.80638					*	
D15 ■	San Joaquin River @ Jersey Point	38.05190	-121.68927	*					
D16 ▲	San Joaquin River @ Twitchell Island	38.09690	-121.66912					*	*
D19 ▲	Frank's Tract near Russo's Landing	38.04376	-121.61477	*		*	*	*	
D22 ●	Sacramento River @ Emmaton	38.08406	-121.73912	*					
		38.08453	-121.73914					*	
D24 ●	Sacramento River below Rio Vista Bridge	38.15891	-121.68721		*	*			
		38.15550	-121.68113						*
D26 ▲	San Joaquin River @ Potato Point	38.07667	-121.56696			*	*	*	
D28A ▲	Old River near Rancho Del Rio	37.97038	-121.57271			*	*	*	*
		37.96980	-121.57210	*					

D29 ■	San Joaquin River @ Prisoners Point	38.05793	-121.55736	*					
…….. ⮝		38.05793	-121.55736			*	*	*	
D41 ⮝	San Pablo Bay near Pinole Point	38.03016	122.37287			*	*	*	*
D41A ⮝	San Pablo Bay near mouth of Petaluma R.	38.08472	-122.39067			*	*	*	*
DMC1 ●	Delta-Mendota Canal at Tracy Pump. Plt.	37.78165	-121.59050		*				
P8 ⮝	San Joaquin River @ Buckley Cove	37.97815	-121.38242			*	*	*	*
P8A ⮝	San Joaquin River @ Rough and Ready Island	37.96277	-121.36587		*				
P12 ■	Old River @ Tracy Road Bridge	37.80493	-121.44929	*					
MD10 ⮝	Disappointment Slough near Bishop Cut	38.04229	-121.41935			*	*	*	
S21 ■	Chadbourne Slough @ Sunrise Duck Club	38.18476	-122.08315	*					
S35 ⮝	Goodyear Slough @Morrow Island Clubhouse	38.1181	-112.09580	*					
S42 ●	Suisun Slough 300' south of Volanti Slough	38.18053	-122.04696	*		*	*		
		38.18027	-122.04779					*	
S49 ■	Montezuma Slough near Beldon Landing	38.18686	-121.97080	*					
S64 ■	Montezuma Slough @ National Steel	38.12223	-121.88800	*					
S97 ⮝	Cordelia Slough @ Ibis Club	38.15703	-122.11378	*					
NZ032 ⮝	Montezuma Slough, 2nd bend from mouth	38.16990	-122.02112					*	
SLBAR3 ■	Barker Sl. at No. Bay Aqueduct (SLBAR3)	38.27474	-121.79499	*					
--- ■	Sacramento R. (I St. Bridge to Freeport) (RSAC155)	38.589 to 38.45585	-121.504 to -121.50302	*					
--- ⮝	San Joaquin R. (Turner Cut to Stockton) (RSAN050-RSAN061)	37.99746 to 37.95242	-121.44435 to -121.31750	*					
--- ⮝	Water supply intakes for waterfowl management areas on Van Sickle Island and Chipps Island			*					

■Compliance monitoring station ⮝Baseline monitoring station ●Compliance and baseline monitoring station

Footnotes for Table 7

1 All stations with compliance monitoring component are identified by historical "interagency" station numbers as given in State Water Board D-1641 (2000) and Water Right Decision 1485 (1978). Modified station ID numbers (e.g. C3A) identify baseline stations near historical stations.

2 All stations with a compliance monitoring component retain their historical "interagency" station descriptions as given in State Water Board D-1641 (2000) and D-1485 (1978). Baseline stations with modified station ID numbers (e.g. C3A) have modified station descriptions.

3 Coordinates are geographic North American Datum 1983 and have been verified to be accurate for 1:24,000 scale mapping.

4 Continuous recording (every 15 minutes) of water temperature, electrical conductivity (EC), and/or dissolved oxygen. For municipal and industrial intake chloride objectives, EC can be monitored and converted to chloride concentration.

5 Continuous, multi-parameter monitoring (recording every 1 to 15 minutes with telemetry capabilities) includes the following variables: water temperature, EC, pH, dissolved oxygen, turbidity, chlorophyll *a* fluorescence, tidal elevation, and meteorological data (air temperature, wind speed and direction, solar radiation).

6 Discrete physical/chemical monitoring is conducted on a year-round, near-monthly basis that alternates between spring and neap tides and includes the following variables: macronutrients (inorganic forms of nitrogen, phosphorus and silicon), total suspended solids, total dissolved solids, total particulate and dissolved organic nitrogen and carbon, chlorophyll *a*, pH, dissolved DO, EC (specific conductance), turbidity, secchi depth, and water temperature. In addition, on-board continuous recording is conducted intermittently for the following variables: water temperature, dissolved oxygen, electrical conductivity, turbidity, and chlorophyll *a* fluorescence.

7 Discrete sampling for phytoplankton enumeration or algal pigment analysis is conducted on a year-round, near-monthly basis that alternates between spring and neap tides.

8 Tow or pump sampling for zooplankton, mysids, and amphipods is conducted on a year-round, near-monthly basis that alternates between spring and neap tides.

9 In water years 2004 and 2005, replicated benthos and sediment grab samples are taken quarterly (every three months) and during special studies; more frequent monitoring sampling resumes in water year 2006.

E. Other Studies conducted by agencies that may provide information relevant to future proceedings

The following studies are currently in progress and are being completed by other agencies independent of State Water Board action. Upon completion, the State Water Board may use the information provided by these studies to amend portions of this Plan.

1. Delta Cross Channel Gate

In the fall of 2000, the CALFED Bay Delta Program and the IEP began investigating the costs and benefits associated with re-operating the Delta Cross Channel (DCC) gate to address water quality and fisheries concerns. These studies have been delayed due to lack of funding and staffing problems. When completed, the Board expects the CALFED Bay Delta Program multidisciplinary studies to address the multi-purpose aspects of DCC gate operation (balancing the beneficial uses of fisheries, water quality, water supply and flood control), and provide evidence for future amendments to the DCC objective.

2. Potential New Municipal and Industrial Objectives

Further understanding of the chemical reactions which form disinfection by-products (DBPs) is required before water quality objectives for bromides and organic carbon can be set. However, USEPA may require compliance with new federal drinking water standards as soon as 2012. The preferred methods for developing this information are collaborative processes such as the CALFED Drinking Water Quality Program (DWQP), which includes the Central Valley Drinking Water Policy. DWR, CALFED, and the Central Valley Regional Water Board are planning to complete development of the Central Valley Drinking Water Policy by 2009. This work may include development of bromide objectives and other constituents for the Central Valley Drinking Water Policy. After the Drinking Water Policy is completed, the State Water Board may convene a workshop to receive comments as to whether there is a need for objectives in the Bay-Delta Plan for bromides and organic carbon.

3. Pelagic Organism Decline

The IEP formed a POD work team to evaluate the potential causes of the marked declines in numerous pelagic fishes in the Sacramento-San Joaquin Delta Estuary and Suisun Bay. This multi-agency effort has produced a work plan that provides an overview of the problem, and a description of the studies used to examine some of the suspected causes of the decline.

In order to better understand the results of the POD studies, the IEP has created a conceptual model of the decline. The model is based on three general factors that may be acting individually or in concert to lower pelagic productivity. The three main suspected factors are: toxins, invasive species and water project operations. The POD studies were designed to provide insight into the reasons for the decline and to set the scientific basis for future work, with the eventual goal of narrowing down the causes of the decline and determining what actions can be taken to reverse the trend. The proposed studies represent an interdisciplinary, multi-agency effort including staff from DFG, DWR, USBR, USEPA, USGS, CBDA, San Francisco State University and UC Davis. The proposed work falls into three general types: (1) an expansion of existing monitoring (five expanded surveys); (2) ongoing studies (19 studies); and (3) new studies (15 studies).

The program will be run by the existing IEP Pelagic Organisms Decline Project Work Team to develop, direct, review and analyze the results of the effort. The program will yield a range of products and deliverables including management briefs, publications and reports, web-based monitoring data, and presentations at conferences, workshops and meetings.

In February 2006, the CBDA provided an independent review of the initial results of the 2005 IEP POD Workplan and the 2005 IEP POD Synthesis Report entitled *Review Panel Report: San Francisco Estuary Sacramento-San Joaquin Delta Interagency Ecological Program on Pelagic Organism Decline*. The report provides perspectives on data synthesis presented and makes recommendations for improvements in analyzing, interpreting and defining appropriate context for future IEP POD-oriented investigations.

The expected completion date for the POD studies is 2007. Once the study results have been compiled; the State Water Board will ask the IEP to make a presentation of findings to the State Water Board at a subsequent workshop. Study results will be considered in the ongoing Plan review, and may be used to determine whether changes should be made to existing Water Quality Objectives, i.e. adding flexibility to the Delta Outflow Objective or the Delta Export Limits Objective. After the initial presentation to the State Water Board, the IEP shall give the State Water Board updates of current studies and new findings at subsequent workshops on an annual basis. The IEP presentations to the State Water Board shall continue until the next review of this Plan. The information collected by the State Water Board may be used to modify the water quality objectives in this Plan in the future.

4. Suisun Marsh

In 2001, the SMCG was formed to resolve issues of amending the SMPA, obtain a Regional General Permit, implement the Suisun Marsh Levee Program, and recover endangered species. The broader purpose of the SMCG is to develop and agree on a long-term implementation plan. The SMCG principal agencies are USFWS, USBR, DFG, DWR, Suisun Resource Conservation District, and NOAA Fisheries. The proposed Suisun Marsh Plan would be consistent with the goals and objectives of the Resources Agency's Bay-Delta Program, and would balance them with the SMPA, federal and State Endangered Species Acts and other management and restoration programs within the Suisun Marsh in a manner responsive to the concerns of all stakeholders and based upon voluntary participation of private landowners. In March 2006, the Plan was undergoing California Environmental Quality Act (CEQA)/National Environmental Policy Act review. The final CEQA document will be released in December 2008. The State Water Board will use the final Suisun Marsh Plan and the analysis in the final CEQA document in its next periodic review to determine what amendments, if any, to make to Suisun Marsh soil and channel water salinity objectives, and the narrative objective for brackish tidal marshes of Suisun Bay.

Appendix L

City and County of San Francisco Analyses

Appendix L
City and County of San Francisco Analyses

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Acronyms and Abbreviations

AF	acre-feet
BARDP	Bay Area Regional Desalination Program
CCSF	City and County of San Francisco
CEQA	California Environmental Quality Act
DWR's	California Department of Water Resources'
FERC	Federal Energy Regulatory Commission
mgd	million gallons per day
MID	Modesto Irrigation District
OID	Oakdale Irrigation District
PEIR	Programmatic Environmental Impact Report
SED	substitute environmental document
SFPUC	San Francisco Public Utilities Commission
TID	Turlock Irrigation District
WSIP	Water System Improvement Program

L.1 Introduction

The San Francisco Public Utilities Commission (SFPUC) is a department of the City and County of San Francisco (CCSF) that provides retail drinking water and wastewater services to San Francisco, wholesale water to three Bay Area counties, and green hydroelectric and solar power to San Francisco's municipal departments. The Hetch Hetchy Watershed, in the Tuolumne River Watershed, provides approximately 85 percent of San Francisco's total water needs. The LSJR alternatives may affect the amount of surface water diversions to the SFPUC service area.

CCSF's water rights for the Hetch Hetchy water system on the Tuolumne River are junior to the most senior rights held by Turlock Irrigation District (TID) and Modesto Irrigation District (MID). Under the Raker Act, which authorized the construction of the Hetch Hetchy water system, CCSF must recognize the prior rights of TID and MID. Based on these prior rights and the Raker Act, CCSF cannot store water in Hetch Hetchy or directly divert water unless they first bypass minimum flows during spring and summer. Various agreements between CCSF and MID/TID, made in conjunction with the construction of New Don Pedro Reservoir, have reduced the effects of the storage and diversion constraints imposed on CCSF's reservoirs by the Raker Act by allowing CCSF to obtain storage credits in New Don Pedro Reservoir. These storage credits allow CCSF to store and directly divert water, within prescribed limits, when Raker Act constraints would not otherwise allow them to do so. There is some question, however, regarding how the latest of these agreements, (i.e., "Fourth Agreement"), could affect CCSF's water supply during periods of extended drought, especially when combined with the increased instream flow requirements under LSJR Alternatives 2, 3, and 4.

The purposes of this appendix are as follows.

1. To generally describe how CCSF's water supply could be affected by changed flow objectives.
2. To quantify the potential water supply effects on CCSF based on two different interpretations of how the Fourth Agreement could affect CCSF's responsibility to contribute to instream flows if new flow objectives are imposed as a condition of water quality certification associated with the Federal Energy Regulatory Commission (FERC) relicensing process for the New Don Pedro Project.
3. To describe the water transfer and other actions CCSF could take to meet water supply demand if water supplies are reduced.
4. To summarize the potential economic effects of water supply changes associated with a water transfer.

Although this appendix quantifies and describes how CCSF's water supply could be affected by changed flow objectives, the specific ultimate effect cannot be determined. The ultimate effect would likely be determined as it has in the past during times of water shortage--changes in overall water availability for the CCSF would most likely be resolved through agreements to purchase water. This appendix, therefore, includes analyses of the economic effects in the SFPUC service area that would result from the need for SFPUC to purchase water (i.e., water transfer) from willing sellers in the Central Valley. This appendix also summarizes information from other parts of this recirculated substitute environmental document (SED) that analyze actions CCSF may take to develop alternative water supplies: transfers, in-Delta diversions, and desalination. This appendix uses SFPUC and CCSF interchangeably as the public agency that provides potable water to the service area defined in Section L.3.1, *Service Area*.

L.2 General Background

Existing dams, water diversions, and downstream minimum flow agreements influence the hydrology of the Tuolumne River. New Don Pedro Dam, the major dam on the Tuolumne River, provides water to TID and MID. The Hetch Hetchy Dam and other dams constructed on tributaries in the Upper Tuolumne River Watershed provide hydropower and water supply for the CCSF).

CCSF operates several water supply and hydroelectric facilities in the upper reaches of the Tuolumne above New Don Pedro Dam. O'Shaughnessy Dam on the mainstem Tuolumne River impounds approximately 360 TAF to address CCSF's water needs and to provide instream flows in the Tuolumne River below O'Shaughnessy Dam. Two other storage facilities upstream of New Don Pedro Reservoir, Lake Eleanor and Cherry Lake, are also operated by CCSF for hydropower and water supply purposes. The combined capacity of these two reservoirs is about 300 TAF. Water from Lake Eleanor is diverted through the Lake Eleanor Diversion Tunnel and into Cherry Lake where it is released to supplement flows of the Upper Tuolumne River. The Hetch-Hetchy aqueduct conveys water from the Tuolumne River to the CCSF service area; the physical capacity of about 500 cubic feet per second (cfs) is limited by the Coastal Tunnel.

The current CCSF demand for water is about 290 TAF/y, or about 15 percent of the annual average unimpaired flow[1] of the Tuolumne River. The water rights and operating agreement for New Don Pedro Reservoir include seasonal storage in the CCSF upstream reservoirs and water banking (accounting) between TID, MID, and CCSF. CCSF has the right to store up to 740,000 AF/y in New Don Pedro Reservoir (CCSF, TID, and MID 1966)

Existing dams, water diversions, and downstream minimum flow agreements influence the hydrology of the Tuolumne River. Hetch Hetchy (360 TAF), Cherry Lake (270 TAF) and Lake Eleanor (27 TAF) in the Upper Tuolumne River Watershed provide hydropower and water supply for San Francisco and other Bay Area cities.

TID and MID have senior water rights on the Tuolumne River and control much of the river flow in most years. Under the Raker Act, which authorized the construction of the Hetch Hetchy system, the CCSF must recognize the prior rights of TID and MID to receive a certain amount of the daily natural flow of the Tuolumne River as measured at La Grange Dam when the water can be beneficially used by the districts. Under the Raker Act, CCSF must bypass 2,350 cfs, or the entire natural daily flow of the Tuolumne River whenever the flow is less than that amount. From April 15–June 13 (peak snowmelt) CCSF must bypass 4,066 cfs. (FERC 1996).

[1] *Unimpaired flow* represents the water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. It differs from natural flow because unimpaired flow is the flow that occurs at a specific location under the current configuration of channels, levees, floodplain, wetlands, deforestation and urbanization.

With the construction of New Don Pedro Reservoir, in which CCSF participated financially, TID, MID, and CCSF entered into a series of agreements establishing a water bank accounting system that provides CCSF with credit for water stored in the reservoir so that CCSF can store more water and make diversions when the water would otherwise be required to be delivered to MID and TID under the Raker Act. CCSF does not hold water rights to, or physically divert water from, New Don Pedro Reservoir.

The 1966 Fourth Agreement, between CCSF, TID, and MID, in part, sets forth the parties' responsibilities for water banking and operations involving New Don Pedro Reservoir, including sharing responsibility for additional instream flow requirements imposed as a result of FERC licensing. CCSF does not actually divert or store water in New Don Pedro Reservoir; instead it has a water bank account in the reservoir that provides flexibility in satisfying TID's and MID's Raker Act entitlements and its Fourth Agreement obligations. Under the Fourth Agreement, CCSF is allocated 570,000 AF of storage in Don Pedro Reservoir, with an additional 170,000 AF of storage when flood control is not required, to a maximum of 740,000 AF of storage space. Certain excess flows above the Raker Act requirements are credited to CCSF, which then "banks" the amount of water for later use. CCSF debits the water bank account when it diverts or stores water that would otherwise be within the districts' entitlements. A negative balance (CCSF bank depleted) would require prior agreement with the two irrigation districts. The Fourth Agreement also states that in the event any future changes to the New Don Pedro FERC water release conditions negatively impact the two irrigation districts, CCSF, MID, and TID would apportion the burden prorated at 51.7121 percent to CCSF and 48.2879 percent to MID and TID (CCSF, TID, and MID 1966).

Figure L.2-1 shows two examples of how water supplies are divided (on a daily basis) between TID and MID and CCSF under different hydrologic regimes. During a dry year in 1992, only 68 TAF (mostly in April) accrued for CCSF (68 TAF is equivalent to 1,143 cfs for 30 days). CCSF asked customers to conserve water and bought additional supplies from the California Department of Water Resources' (DWR's) emergency drought water bank due to the drought conditions that year. Rain and snow returned to the Sierra Nevada in 1993, allowing full water deliveries and replenishing surface storage in the Tuolumne River Watershed (including water banked by CCSF in New Don Pedro) and the Bay Area.

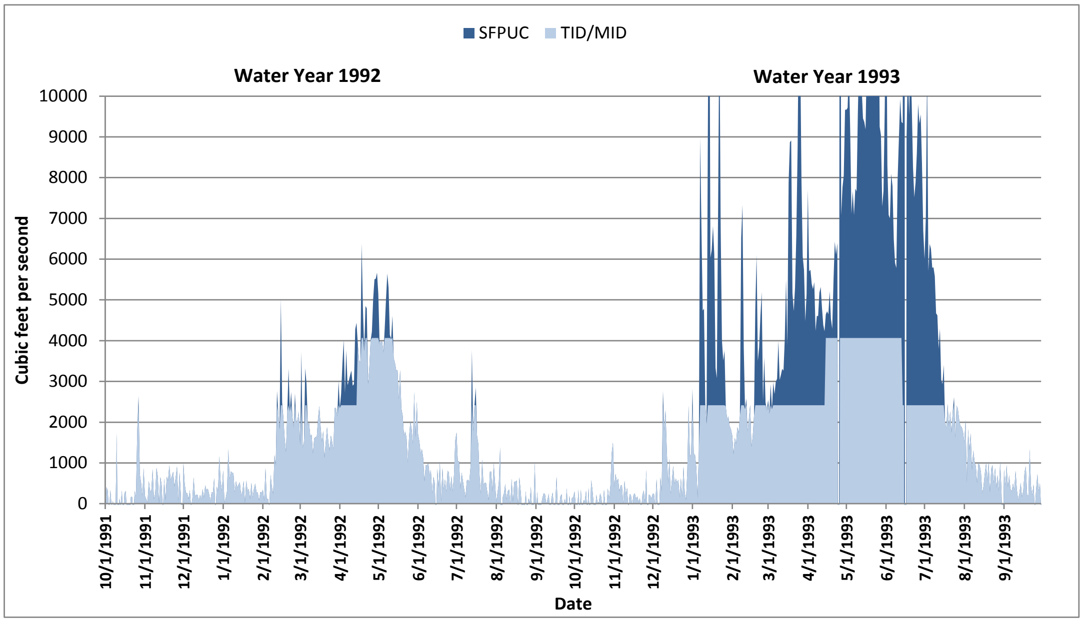

Figure L.2-1. Division of Water Supply between Turlock and Modesto Irrigation Districts (TID/MID) and the City and County of San Francisco (CCSF) for 1992 and 1993 (Source: California Department of Water Resources in Environmental Defense 2004)

The 1922-2003 average calculated volume of water potentially available to CCSF under the Raker Act was about 750 TAF/y, roughly the amount CCSF can bank in New Don Pedro Reservoir under the Fourth Agreement between CCSF and MID and TID, which represents about 40 percent of the Tuolumne River unimpaired flow at La Grange of 1,853 TAF/y for the 1922–2003 evaluation period. According to a SFPUC planning document, an average of 244 TAF/y is diverted from the Tuolumne River at Early Intake, located below Hetch Hetchy, Cherry, and Eleanor Reservoirs, based on data from 1989-2005, which represents 32.5 percent of the average annual unimpaired flow at that location (CCSF 2008). This CCSF diversion represents about 13 percent of the 1,853 TAF/y average annual unimpaired flow at La Grange.

L.2.1 CCSF Responsibility

CCSF may be one of the entities responsible for implementing an unimpaired flow requirement. The principal means by which CCSF would be responsible are as follows.

1. Responsibility is assigned specifically to CCSF in a proceeding amending the agency's water rights.
2. Responsibility is assigned to MID and TID in a proceeding amending the districts' water rights, and the SFPUC's water availability is determined by agreements with the irrigation districts.

The State Water Board may assign responsibility for meeting the flow objectives through a proceeding amending the agency's water rights to require compliance with the objectives. In a water right proceeding amending water users' rights, the State Water Board generally would assign responsibility for meeting the objectives in accordance with the rule of priority and other applicable law. At this time, it cannot be predicted how such responsibility would be allocated in a future proceeding among the water right holders on the Tuolumne River. Prior to assigning any responsibility, the State Water Board would comply with the California Environmental Quality Act (CEQA) on a project-level basis. Alternatively, or in addition, the CCSF may either continue any existing agreements, or enter into a new one, with the irrigation districts governing the responsibility for meeting instream flows required through the FERC relicensing process for New Don Pedro. The irrigation districts may be required to comply with the unimpaired flow requirements as a condition of the water quality certification under the FERC proceedings. Under an agreement such as the Fourth Agreement between CCSF and the irrigation districts, CCSF may contribute to minimum flow requirements imposed through the FERC process through an allocation of storage credits in New Don Pedro Reservoir or, under a different agreement with the irrigation districts, CCSF could pay the districts to release flows. The parties can negotiate amended or new agreements at any time, as they have done in the past (See the April 21, 1995 agreement between CCSF, TID, and MID [CCSF, TID, and MID 1995]).

L.3 Service Area and Ratepayer Background

L.3.1 Service Area

CCSF, through the SFPUC, owns and operates a regional water system that provides retail water directly to customers in San Francisco and wholesale water to 27 water agencies and water companies in three Bay Area counties, including those serving parts of Alameda, San Mateo, and Santa Clara Counties. The system also provides water to a small number of isolated retail and wholesale customers along the water system, including customers in Tuolumne County. In 2015, the SFPUC retail and wholesale service areas included service to about 2.6 million residents (SFPUC 2016).

The SFPUC water system has the capacity to deliver an annual average of about 265 million gallons per day (mgd) (296,800 acre-feet [AF]), of which about 85 percent is from the Tuolumne River Watershed through SFPUC's Hetch Hetchy Project, and about 15 percent is from the combined Alameda and Peninsula Watersheds (CCSF Planning Department 2008). During drought periods, the water provided by the Hetch Hetchy Project can amount to more than 93 percent of the total water delivered within SFPUC's retail and wholesale service areas (SFPUC 2011a).

In the 2010 baseline year established for this assessment, SFPUC water deliveries (excluding a small amount of groundwater deliveries) totaled about 226 mgd (253,100 AF), somewhat lower than average-year deliveries. The reduced demand in 2010 was due to several factors, including dry water conditions during the previous 2 years, resulting in SFPUC asking customers to reduce water consumption by 10 percent; a wet spring and cool summer during 2010, which slowed urban water demand throughout the state; and the effects of the economic recession (starting in 2008) that resulted in lower commercial and industrial water demands in subsequent years (SFPUC 2011a).

In 2010, SFPUC delivered about one-third of its regional water supply to its retail customers, primarily located in the city and county of San Francisco, with deliveries totaling about 76.5 mgd (85,690 AF) (Table L.3-1). About 55 percent of the demand for water in the retail service area was from residential customers, with commercial and industrial customers accounting for 32 percent of deliveries (Table L.3-2). Remaining demands (13 percent) were attributable to government and other water uses (e.g., system losses and meter under-registration losses).

Water deliveries in 2010 to SFPUC's wholesale customers in Alameda, San Mateo, and Santa Clara Counties totaled about 149.5 mgd (167,460 AF). These wholesale deliveries, which are annually made according to a contractual agreement, accounted for the remaining two-thirds of SFPUC's total water deliveries (Table L.3-1). In 2010, the wholesale customers, most of which are represented by the Bay Area Water Supply and Conservation Agency, consisted of 24 cities and water districts, plus Stanford University, one mutual water association, and one private utility. Within SFPUC's wholesale service area, about 50 percent of its total deliveries were made to customers in San Mateo County, 31 percent to customers in Santa Clara County, and 19 percent to customers in Alameda County (Table L.3-1).

The SFPUC regional water system met approximately 65 percent of the total demand for water of its wholesale customers in 2010 (Sunding 2014). As Table L.3-1 shows, individual water agencies rely on SFPUC supplies to varying extents. Based on fiscal year 2010–2011 water demands and deliveries, SFPUC provided at least 90 percent of the water used by 19 of the 27 wholesale agencies it served that year. An additional five agencies received at least half their water supply from SFPUC.

Water use by customer class also varies widely among the wholesale agencies, as shown in Table L.3-2. Across the entire wholesale service area, about 59 percent was delivered to residential customers, 21 percent to commercial and industrial customers, 11 percent to government and other users, and 9 percent to dedicated irrigation users.

Table L.3-1. SFPUC Water Deliveries to Retail and Wholesale Agencies and Reliance of Agencies on SFPUC Water, 2010

County/Agency	SFPUC Water Deliveries (mgd)	Percent of Total SFPUC Water Deliveries	Percent of Total Demand Met by SFPUC Regional Water System[a]
Retail Agency			
San Francisco City/County San Francisco Retail Area	76.50[b]	33.9	100.0
Wholesale Agencies			
Alameda County			
Alameda County Water District	10.81	4.8	18.3
City of Hayward	17.25	7.6	100.0
County subtotal	28.06	12.4	41.5
San Mateo County			
City of Brisbane/Guadalupe Valley Municipal Improvement District[c]	0.58	0.3	100.0
City of Burlingame	3.93	1.7	93.1
California Water Service Company[d]	32.57	14.4	95.1
Coastside County Water District	1.82	0.8	90.2
Cordilleras Mutual Water Association	0.01	0.0	100.0
City of Daly City	3.21	1.4	69.2
City of East Palo Alto	1.81	0.8	100.0
Estero Municipal Improvement District	4.90	2.2	100.0
Town of Hillsborough	2.97	1.3	100.0

County/Agency	SFPUC Water Deliveries (mgd)	Percent of Total SFPUC Water Deliveries	Percent of Total Demand Met by SFPUC Regional Water System[a]
City of Menlo Park	3.04	1.3	100.0
Mid-Peninsula Water District	2.87	1.3	100.0
City of Millbrae	2.24	1.0	99.1
North Coast County Water District	3.02	1.3	100.0
City of Redwood City	9.61	4.3	94.3
City of San Bruno	1.46	0.6	42.7
Westborough Water District	0.84	0.4	100.0
County subtotal	74.88	33.1	92.4
Santa Clara County			
City of Milpitas	6.28	2.8	61.0
City of Mountain View	8.95	4.0	82.8
City of Palo Alto	10.99	4.9	93.6
Purissima Hills Water District	1.75	0.8	100.0
City of San Jose (north)	4.13	1.8	90.8
City of Santa Clara	2.35	1.0	10.3
Stanford University	2.14	0.9	66.5
City of Sunnyvale	9.92	4.4	44.3
County subtotal	46.51	20.6	54.4
TOTAL RETAIL & WHOLESALE	225.95	100.0	73.6

Sources: SFPUC 2011a; Bay Area Water Supply and Conservation Agency 2012.

mgd = million gallons per day (1 mgd equals 1,120.147 AF of water).

[a] Based on water production and purchases during Fiscal Year 2010–2011.

[b] Includes water delivered to Lawrence Livermore Lab and the Groveland Community Services Districts. Excludes groundwater used for City of San Francisco irrigation uses and groundwater delivered to Castlewood and Sunol golf courses.

[c] The City of Brisbane and the Guadulupe Valley Municipal Improvement District represent two separate wholesale customers to SFPUC. However, their water demand data is reported together.

[d] CWS provides water to three separate service areas (Bear Gulch, Mid Peninsula, and South San Francisco).

Table L.3-2. Percentage Distribution of SFPUC Water Deliveries By Customer Class, 2010

County/Agency	Residential	Commercial & Industrial	Government & Other[a]	Dedicated Irrigation[b]
Retail Agency				
San Francisco City/County	55.2	32.1	12.7	NA
San Francisco Retail Area[c]				
Wholesale Agencies[d]				
Alameda County				
Alameda County Water District	61.0	14.9	14.5	9.6
City of Hayward	51.6	19.1	18.1	11.2
County subtotal	58.3	16.1	15.5	10.1
San Mateo County				
City of Brisbane/Guadalupe Valley Municipal Improvement District[c]	38.3	27.6	5.4	28.7
City of Burlingame	55.0	23.2	16.7	5.1
California Water Service Company[d]	67.5	22.2	10.3	0.0
Coastside County Water District	60.8	24.1	6.2	8.9
Cordilleras Mutual Water Association	100.0	0.0	0.0	0.0
City of Daly City	79.6	12.1	6.3	2.0
City of East Palo Alto	76.7	17.8	5.5	0.0
Estero Municipal Improvement District	61.4	11.0	4.1	23.5
Town of Hillsborough	94.7	0.2	3.7	1.4
City of Menlo Park	44.3	33.8	11.3	10.6
Mid-Peninsula Water District	60.7	14.8	24.5	0.0
City of Millbrae	66.4	16.1	10.1	7.4
North Coast County Water District	82.8	7.4	7.6	2.2
City of Redwood City	64.8	17.2	5.7	12.3
City of San Bruno	68.2	18.2	13.6	0.0
Westborough Water District	68.8	16.7	3.7	10.8
County subtotal	67.5	18.6	9.4	4.5
Santa Clara County				
City of Milpitas	43.0	24.5	13.6	18.9
City of Mountain View	53.2	18.8	4.2	23.8
City of Palo Alto	53.9	19.8	19.1	7.2
Purissima Hills Water District	93.6	0.0	5.8	0.6
City of San Jose (north)	22.9	43.2	4.5	29.4
City of Santa Clara	43.4	40.6	9.7	6.3
Stanford University	29.1	18.3	19.0	33.6
City of Sunnyvale	61.6	19.9	7.6	10.9

County/Agency	Residential	Commercial & Industrial	Government & Other[a]	Dedicated Irrigation[b]
County subtotal	49.6	26.5	10.4	13.5
TOTAL WHOLESALE	58.5	20.8	11.4	9.3

Sources: SFPUC 2011a; Bay Area Water Supply and Conservation Agency 2012.

NA = not available.

[a] Includes government uses, recycled water uses, unaccounted-for uses, meter under-registration loses, and other system losses.

[b] Includes dedicated irrigation uses for both private and government customers.

[c] Based on 2010 demands. Does not included city irrigation uses and golf course uses served by groundwater.

[d] Based on fiscal year 2010–2011 demands.

L.3.2 Ratepayers

SFPUC funds its water system through two separate budgets, its Hetch Hetchy Water and Power Budget and its Water Enterprise Budget. The Hetch Hetchy Water and Power Budget operates the collection and conveyance of approximately 85 percent of SFPUC's total water supply, employing a system of reservoirs, hydroelectric power plants, aqueducts, pipelines, and transmission lines that carry water and power to customers in San Francisco and to SFPUC's wholesale customers elsewhere in the Bay Area. The Water Enterprise is responsible for collecting, treating, and distributing SFPUC's water supply to its retail and wholesale customers, including operating and maintaining pipelines in San Francisco and the region, 27 pump stations, 28 dams and reservoirs, 9 water tanks, and 3 water treatment plants (SFPUC 2011b). An overview of recent budget expenditures under the Water Enterprise Budget and the water portion of the Hetch Hetchy Water and Power Budget are shown in Table L.3-3.

Table L.3-3. Overview of SFPUC Water Enterprise and Hetch Hetchy Water Budgets

Budget/Expenditure Category	Fiscal Year			
	2010–2011[a]	2011–2012[b]	2012–2013[c]	2013–2014[c]
Water Enterprise				
Operations and maintenance	149.1	178.5	173.4	176.8
Debt service	98.3	155.9	173.6	210.0
General reserve	16.5	1.3	2.4	5.4
Capital/revenue reserve	42.7	34.7	17.2	31.9
Programmatic projects	4.8	12.2	20.4	22.2
Water Enterprise subtotal	311.4	382.6	387.0	446.3
Hetch Hetchy Water				
Operations and maintenance	43.7	50.7	56.8	54.3
Reclassification of power only & joint operating costs[d]	(18.8)	(22.2)	(21.7)	(19.9)
Capital/revenue reserve	41.6	38.5	18.9	22.6
Programmatic project	0.0	0.2	3.6	2.5
Reclassification of power only & joint capital costs	(30.3)	(24.4)	(18.9)	(22.6)
Water Enterprise subtotal	36.2	42.8	38.7	36.9
TOTAL—BOTH BUDGETS	347.6	425.4	425.7	483.2

Source: SFPUC 2011b.

Note: Budget amounts shown in millions of dollars.

[a] Audited actual budget expenditures.

[b] Pre-audit actual budget expenditures.

[c] Adopted budget expenditures.

[d] Reflects expenditures reallocated to the Hetch Hetchy Power Budget for its share of costs shared with the Hetch Hetchy Water Budget.

SFPUC sets its retail water rates based on an independent rate study conducted at least once every 5 years. As shown by Table L.3-4, retail water rates consist of a monthly service charge based on meter size and a commodity charge based on usage volumes. Retail water rates through the 2013–2014 fiscal year were established by a 2009 rate study that examined the future revenue requirements and cost of service of the Water Enterprise. Annual rate increases are set to meet project costs and debt coverage requirements. Over the past 7 fiscal years, single-family retail water rates have increased from 6.5 percent to 15.0 percent per year (Table L.3-4). Annual non-residential rate increases have ranged from 6.0 percent to 15.8 percent.

SFPUC's water rates for its 27 wholesale customers are based on the Water Supply Agreement established in 2009. Wholesale customers pay a proportionate share of regional water system operating expenses, debt service on bonds sold to finance regional system improvements, and other regional system improvements funded from current revenues, along with the repayment of previously constructed capital assets that were not otherwise fully depreciated (SFPUC 2011b). In general, costs are apportioned to wholesale customers based on proportionate water use, and rates are reset annually to cover costs as mandated by the Water Supply Agreement.

Wholesale water rates over the past 7 fiscal years are shown in Table L.3-4. The wholesale rate structure consists of a monthly service charge based on meter size and type, and a uniform volume charge. Monthly service charges to wholesale customers vary depending upon meter size and type. For example, during fiscal year 2013–2014, the monthly charge for a 5/8-inch disc/compound meter was $11.00, while charges for a 6-inch meter ranged from $476 for a disc/compound meter to $1,256.00 for a turbine meter. The volume charge currently stands at $2.45 per hundred cubic feet of water use, with annual rate changes varying from a decrease of 16.4 percent in fiscal year 2013-14 to an increase of 38.4 percent in fiscal year 2011-12 (Table L.3-4). The relatively large wholesale rate increase in fiscal year 2011–2012 was primarily due to the need to generate revenues to compensate for wholesale revenue underpayments during the previous 3 years resulting from decreased water purchases, and to continue paying for seismic upgrades to the Hetch Hetchy water pipeline system (Bay Area Water Supply and Conservation Agency 2011). (Note that the 2013–2014 rate decrease was due to a 1-year adjustment in the rate calculation, as explained in the footnote to Table L.3-4.) Based on SFPUC wholesale water costs, costs for other water supplies (if applicable), and other budgetary conditions faced by the 27 agencies that purchase water from SFPUC, retail water rates are then set for end-use customers (e.g., residential, commercial, and industrial) in cities and districts served by the agencies.

Table L.3-4. SFPUC Retail and Wholesale Water Rates, FY 2007/08– FY 2013/14

Fiscal Year	Retail Water Rates									Wholesale Rates[c]	
		Single-Family			Multiple-Family			Non-Residential			
	Service Charge Rate[a] ($)	Volume Charge ($/ccf) (0-3 ccf)	Volume Charge ($/ccf) (over 3 ccf)	Percent Increase	Volume Charge ($/ccf) (0-3 ccf)	Volume Charge ($/ccf) (over 3 ccf)	Percent Increase	Volume Charge ($/ccf)	Percent Increase	Volume Charge ($/ccf)	Percent Increase/ (Decrease)
2007–2008	4.60	2.08	2.50	15.0	2.47	2.47	15.0	2.52	15.2	1.30	6.6
2008–2009	4.70	2.28	2.89	15.0	2.87	2.87	15.0	2.92	12.7	1.43	10.0
2009–2010	5.40	2.61	3.48	15.0	2.87	3.82	10.5	3.35	14.8	1.65	15.4
2010–2011	6.20	3.09	4.12	8.2	3.28	4.37	6.6	3.89	15.8	1.90	15.2
2011–2012	7.00	3.50	4.60	12.5	3.70	4.90	12.5	4.52	15.5	2.63	38.4
2012–2013	7.90	3.90	5.20	12.5	4.20	5.50	12.8	5.10	12.8	2.93	11.4
2013–2014	8.40	4.20	5.50	6.5	4.50	5.90	7.0	5.40	6.0	2.45[b]	(16.4)[b]

Source: SFPUC 2013.
ccf = hundred cubic feet of water.

[a] Monthly service charge for 5/8-inch meter.

[b] The early payment by the wholesale customers of their liability of the pre-2009 Water Supply Agreement assets, and their projected higher water consumption for Fiscal Year 2013–2014, translated into a reduction of the wholesale water rate for that year.

[c] Note that wholesale service rate charges are not shown because these rates vary across meter size and type.

L.4 Water Bank Account Modeling

As described above, the Fourth Agreement between CCSF, TID, and MID currently governs the New Don Pedro Reservoir water bank account. Under certain conditions, excess flows exceeding TID's and MID's entitlements can be credited to CCSF. CCSF may have a credit balance up to 570,000 AF with an additional 170,000 AF of credit storage during times when encroachment into flood control space is permitted. Absent the prior consent of TID and MID, CCSF can never have a debit balance in the water bank account.

In addition, the Fourth Agreement allocates responsibility to meet instream flow requirements below New Don Pedro Reservoir that are imposed on TID and MID as licensees under the FERC hydropower license for the New Don Pedro Project. The irrigation districts and CCSF agreed to allocate such responsibility in Article 8 as follows:

(b) That at any time Districts demonstrate that their water entitlements, as they are presently recognized by the parties, are being adversely affected by making water releases that are made to comply with Federal Power Commission license requirements, and that the Federal Power Commission has not relieved them of such burdens, City and Districts agree that there will be a re-allocation of storage credits so as to apportion such burdens on the following basis: 51.7121% to City and 48.2879% to Districts.

The parties can modify this responsibility through other agreements. For example, in 1995 CCSF and TID and MID entered into an agreement where CCSF agreed to pay the irrigation districts $3.5 million per year and the irrigation districts agreed to provide all of the water necessary to meet the FERC-license related minimum flow schedules set forth in a settlement agreement. (See the April 21, 1995 agreement between CCSF, TID, and MID [CCSF, TID, and MID 1995].) The agreement provided that once CCSF discontinued the payments, it would thereafter meet its obligations under Article 8 of the Fourth Agreement.

The LSJR flow objectives may be imposed on TID and MID as a condition of water quality certification associated with FERC relicensing for the New Don Pedro Project. It cannot be predicted whether and how CCSF and the irrigation districts would agree to apportion responsibility for meeting future flow requirements. In the past, the parties have agreed to either an allocation of storage credits or payments. This appendix, nonetheless, analyzes the potential water supply effects associated with the allocation of responsibility under paragraph (b) of Article 8 of the Fourth Agreement. Under Scenario 1, storage credits would be reallocated only if CCSF has a positive credit balance in the water bank account. Under Scenario 2, storage credits would be reallocated even if CCSF has a negative balance in the water bank account.

L.4.1 Bank Account Analysis Methods

A mass balance of the water bank in New Don Pedro Reservoir was performed to evaluate the effects of the LSJR alternatives. The daily bank account was computed using historical inputs for the baseline and adjusted releases for the LSJR alternatives. The time period modeled was from water year 1983–2002. The balance in the account, at time t, is defined as:

$$\mathbf{Vol_{CCSF,t} = Vol_{CCSF,t-1} + NDP\ Inflow_{t-1} - Raker\ Act_{t-1} - Evap_{t-1} - Flood_{t-1} - Increased\ FERC\ flows_{t-1}}$$

Where:

$\mathbf{Vol_{CCSF,t}}$ = Current balance of water in the CCSF's account ≤ 570 TAF plus ½ of permitted encroachment in the flood control space.

$\mathbf{Vol_{CCSF,t-1}}$ = Previous days balance in the CCSF's account.

NDP Inflow = Estimated inflow to New Don Pedro Reservoir, credits to the account (Column D) (Source: CCSF 2011a, 2011b).

Raker Act = Debits from the account, set forth in the Raker Act as:

4/15 - 6/14: 4066 cfs or natural flow at La Grange, whichever is less
6/15 – 4/14: 2416 cfs or natural flow at La Grange, whichever is less
(Source: CCSF 2011a, 2011b).

Evap = Evaporation and other losses are subtracted from the balance on a daily basis proportionate to the net credit balance in the water bank account (Source: CCSF 2011a, 2011b).

Flood = Flood releases are subtracted when required under the US Army Corps Flood Control requirements on the basis 50% Districts, 50% CCSF. Flood space was estimated using historic daily maximum storage (Source: CCSF 20011a, 2011b).

Increased FERC flows = Increased FERC releases are to be apportioned 51.71% to the City out of the City's credit. Under Scenario 1, 51.71% of the increased FERC flows are debited from the account only when the balance is positive. Under Scenario 2, 51.71% of the increased FERC releases are always subtracted from the account balance.

The daily bank account volume was calculated using historical data and compared with observed account balance provided by SFPUC. This account volume is considered the analysis baseline and represents historical conditions.

Baseline

The baseline credit balance was developed using historical inflows, Raker Act requirements, evaporation and flood control releases provided by SFPUC (Figure L.4-1) (CCSF 2011a, 2011b). During the drought of the late 1980s, the baseline is lower than historically reported because, during this time, the account dropped below zero and the City purchased water from the districts. The details of the purchase agreement between the City and the districts during this period are unknown, but the difference from baseline and the reported balance can be attributed to this purchase.

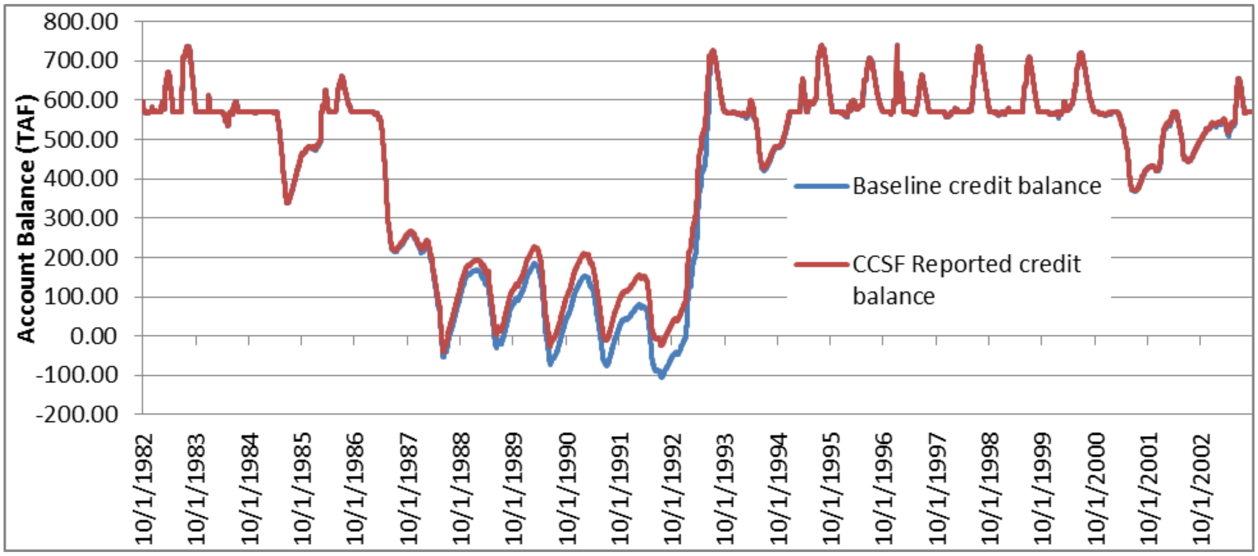

Figure L.4-1. Baseline Credit Balance and Historic Balance Showing Agreement

Under historic conditions the maximum amount of water needed to be purchased by the City to make it through the 6-year drought was about 105 TAF, or an average of 18 TAF per year for the 6-year period (1987–1992).

LSJR Alternatives

Three LSJR alternatives were analyzed—LSJR Alternative 2, 3, and 4 (20 percent, 40 percent, 60 percent unimpaired flow, respectively, between February and June).[2] The increased flow requirement for each alternative was estimated for each month by calculating the percentage of unimpaired flow. This method of determining the instream flow requirement at the compliance point near the confluence with the LSJR, which is different than the current FERC instream flow compliance location, which is at La Grange. To accurately compare the two instream flow requirements, the current FERC requirement(s) were adjusted by subtracting accretions and adding depletions for the reach between La Grange and the confluence. Each of the LSJR alternatives were analyzed under the two scenarios of the Fourth Agreement.

Assumptions

This analysis includes the following assumptions.

- Inflows to New Don Pedro Reservoir will remain as historical under each of the LSJR alternatives.
- Diversions through the Canyon Tunnel will remain as historical under each LSJR alternative.
- Accretions and depletions between La Grange and the confluence will remain constant from baseline for each LSJR alternative.

[2] A reference in this appendix to 20, 40, and 60 percent unimpaired flow is the same as LSJR Alternative 2, 3, and 4, respectively.

- Alternative flow requirements on the Lower Tuolumne do not affect evaporation rates in New Don Pedro Reservoir. In reality, evaporation is a function of surface area, which in turn is a function of storage. WSE model results do show changes in reservoir storage and, therefore, may change evaporation rates. This change in evaporation is assumed to be negligible. Flood control releases do not change from baseline for each LSJR alternative. Changes in reservoir storage may affect flood control storage volumes and releases. This may affect flood releases and, ultimately, bank account balances. This is assumed not to affect CCSF because water supply would be affected during times of drought and not during times of flood.

L.4.2 Water Bank Account Analysis Results

The LSJR alternatives were compared with baseline to determine how the changes in flow requirements would affect the water bank account balance in New Don Pedro Reservoir. The results showed that the only time the water bank account reached zero under all of the alternatives was during times of drought. The largest drought sequence in the study period was the 1987–1992 drought. This drought sequence is, therefore, the period compared to baseline in this section. Under the LSJR Alternative 4, the account reached zero in the early 2000s as well. In drought years, the account balance dropped below baseline, and during the 1980s drought, the credit balance was reduced below zero under all of the LSJR alternatives (Table L.4-1). Each LSJR alternative under each of the two scenarios created an annual average increase in shortage over the 6-year drought period from baseline (Table L.4-1 and Figures L.4-2 and L.4-3). The account reached zero more often under LSJR Alternative 4, such as in 1994 and 2001–2002, than it did under the other LSJR alternatives (Figure L.4-2).

Table L.4-1. Annual Supplement Needed to Maintain a Positive Balance in the New Don Pedro Reservoir CCSF Water Bank Account for Each Scenario (The drought 6-year average is for the years 1987–1992.)

		Scenario 1 Supplement Needed			Scenario 2 Supplement Needed		
Calendar Year	Baseline Supplement Needed (TAF)	LSJR Alt. 2 (20% UF) (TAF)	LSJR Alt. 3 (40% UF) (TAF)	LSJR Alt. 4 (60% UF) (TAF)	LSJR Alt. 2 (20% UF) (TAF)	LSJR Alt. 3 (40% UF) (TAF)	LSJR Alt. 4 (60% UF)(TAF)
1983	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0
1985	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0
1987	0	0	0	0	0	0	0
1988	54.6	70.5	147.5	209.3	73.6	185.1	311.8
1989	0.0	19.9	20.4	0.0	45.4	188.4	330.7
1990	20.2	58.6	68.0	46.5	73.7	142.2	213.9
1991	3.8	12.8	3.8	3.8	64.9	182.4	300.6
1992	29.6	29.6	29.6	29.6	58.5	125.5	198.2
1993	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	61.3
1995	0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0
2002	0	0	0	11.4	0	0	57.7
2003	0	0	0	0	0	0	119.4
Drought Total	108.2	191.3	269.3	300.5	316.2	823.6	1593.7
6-yr Average	18.0	31.9	44.9	48.2	52.7	137.3	225.9
21-yr Average	5.2	9.1	12.8	14.3	15.1	39.2	75.9

UF = unimpaired flow
TAF = thousand acre-feet

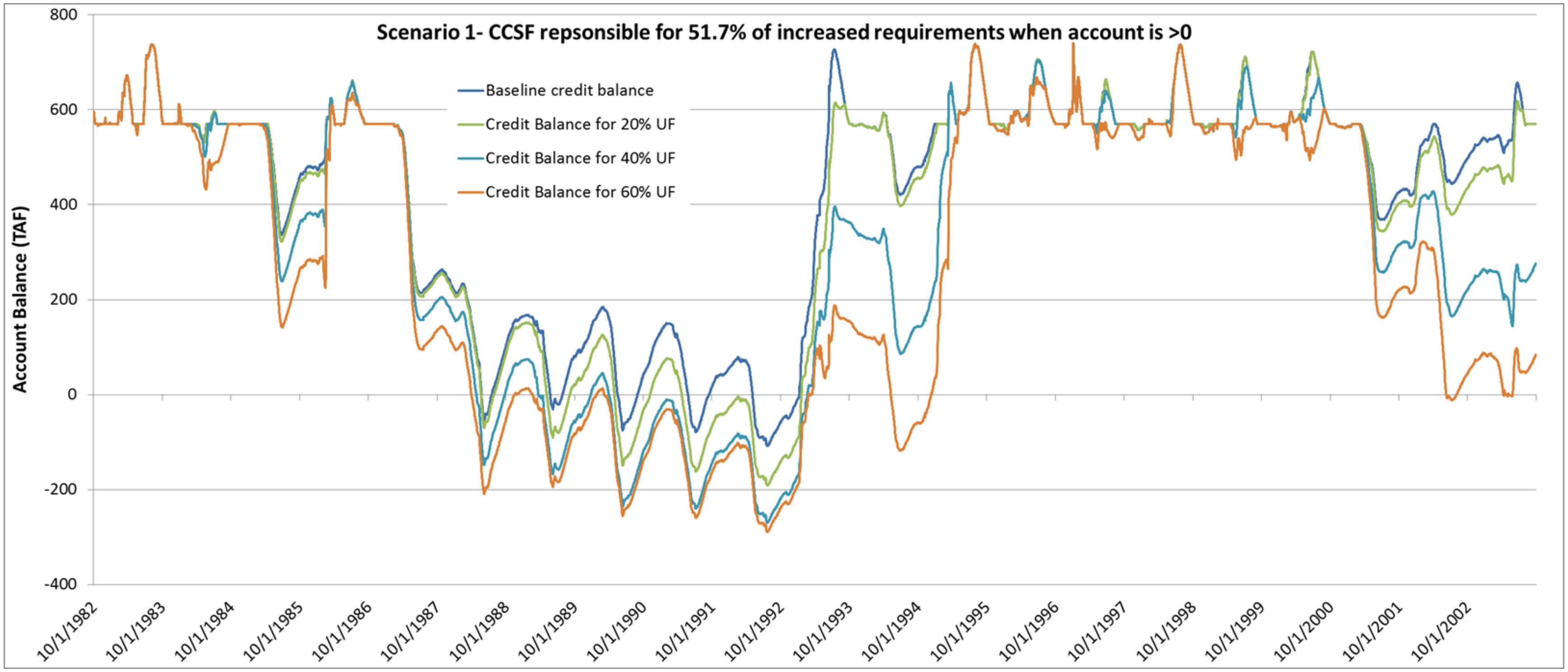

Figure L.4-2. CCSF's Water Bank Account Balance Assuming Scenario 1 (City is Responsible for 51.7% of Increased Flow Requirement Only When Balance is Positive.)

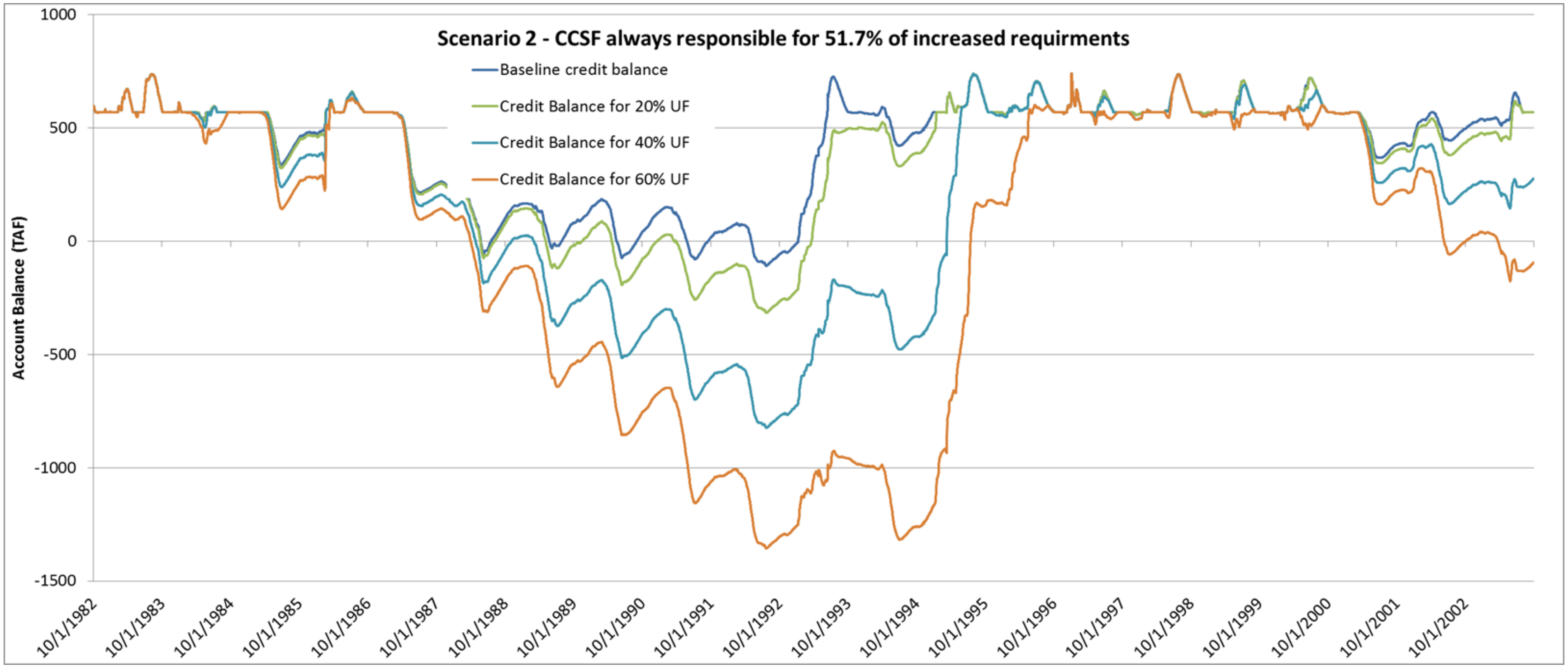

Figure L.4-3. CCSF's Water Bank Account Balance Assuming Scenario 2 **(City is Always Responsible for 51% of Increased Flow Requirement)**

The results show that increased instream flow requirements on the Lower Tuolumne River potentially required as a result of water quality certification associated with FERC relicensing would primarily affect SFPUC water supply during a drought. Reductions in the water bank account balance are replenished in average years; however, the results show that during multi-year droughts the balance is further diminished under the LSJR the alternatives.

SFPUC currently delivers an annual average of 238 mgd (SFPUC 2013). About 15 percent of the supply is from the Alameda and Peninsula Watersheds and 85 percent of the supply is from the Tuolumne River. However during drought periods, the Hetch Hetchy project can supply nearly 93 percent of the total supply delivered (SFPUC 2013). The SFPUC has undertaken a multi-year capital water supply improvement program, the Water System Improvement Program (WSIP), to upgrade its water supply systems; some of the projects within the WSIP are underway and some projects are nearing completion (SFPUC 2006) (see Chapter 16, *Evaluation of Other Indirect and Additional Actions*, and Section L.5, *Potential Actions to Meet Water Supply Demand*, for a description of several of these projects). These projects are meant to bolster the base supply to meet the service area's growing demands, as well as to provide reliability and supply during a drought (SFPUC 2006). Current supplies are adequate to meet current demand under annual average precipitation patterns. Increased future demands would be met through the WSIP. Under average annual precipitation patterns the bank account balance remains positive throughout the year; therefore, there is no effect to CCSF. During prolonged annual sequences of less than average precipitation, drought operations are invoked and LSJR alternatives could further reduce available supply.

Drought operations include a design maximum of 20 percent retail rationing per year, groundwater conjunctive use and agricultural water transfers. The 20 percent rationing is not uniform across all customers, some wholesale customers may receive up to 40 percent reductions (SFPUC 2013). It should be noted that these annual retail rationing considerations during drought operations were developed before Executive Order EO B-29-15, State of Emergency Due to Severe Drought Conditions, was implemented in May 2015, which directs urban water agencies to achieve mandatory water conservation goals; as a result, changes in the rationing design assumptions have likely changed since the SFPUC 2013 report was published. The Regional Groundwater Storage and Recovery project would yield over 60 TAF per drought cycle and is currently being constructed. Remaining design drought demand is met through transfers from irrigation districts. Historically, transfers have occurred from MID and TID to the SFPUC. However, in 2012, the MID Board of Directors rejected a proposal for long-term transfers to SFPUC. This rejection makes future temporary drought transfers uncertain. Negotiations are ongoing between neighboring Oakdale Irrigation District (OID) and the SFPUC. A transfer from OID would involve a wheeling deal with MID, but would not require any new infrastructure.

The decrease in water bank account balance below zero is considered bank account deficit, which can be interpreted as drought shortage from the Tuolumne River Watershed (Table L.4-1). The increase in deficit from baseline, in severe drought periods represented by the years 1987–1992, ranges from 14 to 30 TAF/y under Scenario 1 and from 35 to 208 TAF/y under Scenario 2 (Table L.4-2). This is the assumed water supply that would need to be replaced to meet the demand of the SFPUC service area. SFPUC has a variety of water supply options that may be employed to replace the drought supplies, which are discussed elsewhere in this document (Chapter 13, *Service Providers*, Chapter 16, *Evaluation of Other Indirect and Additional Actions,* and summarized in Section L.5, *Potential Actions to Meet Water Supply Demand*).

While the above results, and the annual average of 1987–1992 "severe drought year" increased deficits from baseline (i.e., additional supplemental water needed as a result of project alternatives), are expressed here and in the following Section L.6, *Regional Economic and Ratepayer Effects on Water Supply Changes*, and Chapter 20, *Economic Analyses*, as the annual average basis for severe drought years only, these deficits can also be expressed as a longer-term annual average, as shown in Table L.4-3.

Table L.4-2. Annual Average CCSF Water Bank Deficit for 6-Year Drought Period (1987–1992)

	Scenario 1		Scenario 2	
	Annual Average Deficit (TAF)	Increase from Baseline (TAF)	Annual Average Deficit (TAF)	Increase from Baseline (TAF)
Baseline Account Deficit	18		18	
Deficit for LSJR Alternative 2 (20% UF)	32	14	53	35
Deficit for LSJR Alternative 3 (40% UF)	45	27	137	119
Deficit for LSJR Alternative 4 (60% UF)	48	30	226	208

TAF = thousand acre-feet
UF = unimpaired flow

Table L.4-3. Annual Average CCSF Water Bank Deficit for 21-Year Period of Record (1983–2003)[a]

	Scenario 1		Scenario 2	
	Annual Average Deficit (TAF)	Increase from Baseline (TAF)	Annual Average Deficit (TAF)	Increase from Baseline (TAF)
Baseline Account Deficit	5		5	
Deficit for LSJR Alternative 2 (20% UF)	9	4	15	10
Deficit for LSJR Alternative 3 (40% UF)	13	8	39	34
Deficit for LSJR Alternative 4 (60% UF)	14	9	76	71

TAF = thousand acre-feet
UF = unimpaired flow
[a] This 21-year period of record corresponds to available data from CCSF Form 173 and 174 hydrologic operations data and reported Raker Act balances (CCSF 2011a, 2011b) that overlap with the WSE model period of record up to 2003.

L.5 Potential Actions to Meet Water Supply Demand

This section summarizes the actions SFPUC could take to meet water supply demand to make up any reductions in water supply resulting from the flow requirements. The extent to which CCSF's water supply diversions from the Tuolumne River Watershed would be reduced by the flow requirements is uncertain. It would depend on a number of factors, including the assignment of responsibility to the CCSF or the irrigation districts to meet the flow requirements through a proceeding amending water rights or FERC relicensing, the interpretation of the Fourth Agreement, whether CCSF pays the irrigation districts to release water to meet the flow requirement, and any future agreement between the irrigation districts and CCSF. It is reasonable to assume, however, that CCSF's water supply from the Tuolumne River could be reduced because (1) SFPUC would have less available water supply to divert under CCSF's water rights, or (2) more flows would be released to comply with the irrigation districts' FERC license, potentially leaving SFPUC with less water. With these caveats, the analysis in Section L.4, *Water Bank Account Modeling*, quantifies a potential reduction in the SFPUC water supply during a drought under each of the LSJR alternatives (Table L.4-2).

Because of these unknown factors, SFPUC's potential response(s) to meeting the unimpaired flow requirements of the LSJR alternatives are difficult to predict and could involve implementing multiple actions concurrently or consecutively. As a result, analyzing and disclosing the economic and environmental effects of such actions is complex, and impacts cannot be precisely determined. The following are potential actions SFPUC could take to replace reductions in water supply resulting under the LSJR alternatives.

- Water transfer
- In-Delta diversion(s)
- Water supply Desalination Project

The resource chapters of this recirculated SED disclose the possible environmental effects of water transfers, and Section L.6, *Regional Economic and Ratepayer Effects of Water Supply Changes*, discloses the economic effects of water transfers. The cost and environmental evaluation of constructing and operating an in-delta diversion or desalination plant are provided in Chapter 16, *Evaluation of Other Indirect and Additional Actions*. It is unlikely that either in-Delta diversion or desalination could replace all of the water supply no longer available for diversion under the LSJR alternatives, particularly LSJR Alternatives 3 and 4, given the amount of water that may be reduced in drought conditions under these two alternatives, and depending on the scenario applied (Table L.4-2). Because these actions include publicly-owned facilities and discretionary actions by a public agency (i.e., SFPUC), they would be subject to CEQA and would undergo the project-level CEQA review at the time they are proposed. Following is a summary of these actions.

L.5.1 Water Transfer

For the purposes of the economic analysis in Section L.6, *Regional Economic and Ratepayer Effects of Water Supply Changes,* it is assumed that SFPUC would enter into a water transfer agreement the irrigation districts and pay for the volume of water needed to meet its demand. A possible water transfer between SFPUC and irrigation districts relies on numerous unknown variables (e.g., willingness of irrigation districts to enter into a transfer agreement, the price of the water, and the volume of water needed). If a water transfer were to occur, the Bay Area would experience a regional economic effect because additional dollars would be spent in the SFPUC service provider region for some portion of their needed water supply. The plan area would experience a reduction in economic activity because the volume of water transferred to CCSF likely would no longer be used for farming in the plan area. This economic effect is described in the agricultural economic analysis in Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results.* The analysis assumes that agricultural resources would not receive their total water supply to meet needed demand under each of the LSJR alternatives. Appendix G does not evaluate the impacts on other water supply uses, such as municipal uses, which are evaluated in Chapter 20, *Economic Analysis*. A water transfer, however, would also result in an offsetting (at least partially) positive economic benefit to the plan area because compensating income would come from the Bay Area to the plan area. The extent to which the compensating income from the water transfer would offset the negative economic effects associated with the reduction of water supply needed for farming is uncertain because the value of the water to be transferred is not known.

The SFPUC WSO report was developed in support of the SFPUC WSIP prepared by SFPUC to increase reliability of the regional water system that provides water to San Francisco and neighboring communities (SFPUC 2008a). In the 2008 WSIP Draft Programmatic Environmental Impact Report (PEIR), SFPUC included an proposed water transfer between SFPUC and MID and TID for 25 mgd during drought years (BAWSCA 2016). The final WSIP PEIR reduced the water transfer to 2 mgd during droughts and (SFPUC 2008b and BAWSCA 2016). While neither 25 mgd nor 2 mgd are not enough to potentially compensate for the potential need under the LSJR alternatives described in Section L4, *Water Bank Account Modeling*, this information is useful because it provides context for the potential to transfer water and the types of impacts associated with the transfer of water. It was described that construction and operation of new infrastructure would not be needed for the type of transfer (SFPUC 2008b). It is expected this type of transfer would transfer water that would otherwise be directly diverted or stored by the irrigation districts (SFPUC 2012a). Furthermore, and assumed that the irrigation districts would maintain the same level of canal diversions (SFPUC 2012a). Under the water transfer, as described in the WSIP PEIR, impacts would be less than significant to the following resources on the Tuolumne River: streamflow and reservoir water levels; geomorphology; surface water quality; surface water supplies; groundwater; fisheries; terrestrial biological resources; recreational and visual resources and energy resources. Impacts on terrestrial biological resources could be mitigated to a level of less than significance (SFPUC 2008b, SFPUC 2012a, and ESA+Orion Joint Venture 2012).

Similar to the water transfer described by the WSIP PEIR the type of water transfer that could occur under the LSJR alternatives likely would not require the construction or operation of new infrastructure, given that the Hetch Hetchy aqueduct can accommodate the delivery of water to the existing Tesla Portal treatment plant near the city of Tracy. It would also likely transfer water that would otherwise be directly diverted or stored by the irrigation districts. Nonetheless, because a water transfer would involve a discretionary action by a public agency (i.e., SFPUC, the irrigation districts, or the State Water Board), it would be subject to CEQA and would undergo the project-level CEQA review at the time it is proposed. A larger water transfer under the LSJR alternatives between SFPUC and the irrigation districts could result in indirect environmental impacts on several resources as a result of the potential reduced surface water supply in the Central Valley (i.e., surface water supply going to SFPUC would not go to Central Valley surface water users). As discussed in Chapter 9, *Groundwater Resources*, Chapter 11, *Agricultural Resources*, Chapter 13, *Service Providers*, and Chapter 14, *Energy and Greenhouse Gases*, and Chapter 16, *Evaluation of Other Indirect and Additional Actions*, reductions in surface water supply to various end users in the Central Valley could result in significant and unavoidable impacts, particularly under the higher unimpaired flow alternatives.

L.5.2 In-Delta Diversion

As described in SFPUC documents, specifically the WSO report (SFPUC 2007), SFPUC has several options for augmenting or increasing their water supply, including diverting water from the Sacramento-San Joaquin Delta. The SFPUC WSO report was developed in support of the SFPUC WSIP prepared by SFPUC to increase reliability of the regional water system that provides water to San

Francisco and neighboring communities (SFPUC 2008a). In the 2008 WSIP PEIR, SFPUC concluded that the in-Delta diversion option was infeasible, in part, because it would not achieve consistent year-round diversions due to uncertainties regarding the availability of water supplies and pumping capacities (SFPUC 2008a). Nonetheless, a discussion of this option has been included in light of the changing circumstances since 2008 (e.g., Pelagic Organism Decline, climate change, California WaterFix, and the State Water Board's Delta Flow Criteria Report [State Water Board 2010]). Thus, it is discussed as a possible option available to the SFPUC that may be explored in the future in light of the changing circumstances.

Constructing and operating an in-Delta diversion with a design capacity of 28,000 AF/y at the Tesla Portal near the City of Tracy is estimated to cost about $306.1 million for capital cost, $7.8 million for annual operation and maintenance costs, for $357.1 million in lifecycle costs (SFPUC 2007). This project would include a new Delta intake and pumping plant, a new pipeline, a new Delta Water Treatment Plant and a new blending facility at Tesla Portal. For a project of 28,000 AF/y, this results in approximately $255 per AF over the 50-year lifecycle period. The cost per AF of additional water from a delta diversion for a larger project could be less than $255 per AF because of the economies of scale (i.e., the larger infrastructure projects are, the less they typically cost per unit per year). These costs do not include the cost of purchasing the water from willing sellers to supply the diversion project. This, or other in-Delta diversions, may be able to divert water that was left in the Tuolumne River as a result of increased instream flows under LSJR Alternatives 2, 3, or 4. The water rights and contractual obligations of SFPUC and other water right holders would need to be determined. If purchased, the purchase cost would vary depending on market conditions, entities selling the water, and water-year conditions (i.e., drought), but could range from about $50–$600 per AF, which could result in costs of $1.4 million to $16.8 million per year (PPIC 2011; Maven 2015).

The construction and operation of an in-Delta diversion could result in potentially significant environmental impacts on various resources, as disclosed in Chapter 16, *Evaluation of Other Indirect and Additional Actions,* including: aesthetics, agriculture, air quality, biological resources, cultural resources, geology and soils, greenhouse gas emissions, hazards and hazardous materials, hydrology and water quality, land use and planning, noise, transportation and traffic, and utilities and service systems. The significance determination ultimately would depend on the location of the Delta intake and the route of the pipeline to deliver the water to the existing Tesla Portal, both of which are currently unknown. As disclosed in Chapter 16, the SFPUC identified a number of mitigation measures that could be applied to reduce potentially significant impacts to a less-than-significant level, including many related to air quality, biological resources, cultural resource, geology and soils, greenhouse gas emissions, hazards and hazardous materials, hydrology and water quality, noise, and transportation and traffic applied during construction and design of the facility, should it be constructed.

L.5.3 Water Supply Desalination Project

The WSO report (SFPUC 2007) addressed potential challenges or issues associated with constructing and operating a year-round desalination facility (capacity of 28,000 AF/y) near the existing Oceanside Water Pollution Control Plant in San Francisco. In the WSIP PEIR (SFPUC 2008b), the Oceanside site, along with two other alternative locations, was identified as a potential site for desalination in drought years as part of the Bay Area Regional Desalination Program. SFPUC included the Bay Area Regional Desalination Program (BARDP) in the WSIP PEIR analysis as part of a “variant” of the WSIP. A desalinization project would provide a reliable water supply regardless of the water year type or other surface water supplies used by SFPUC. A desalinization project would likely need to be larger than analyzed in the WSO report, or the BARDP feasibility studies, for LSJR Alternatives 3 and 4. Therefore, costs and environmental impacts associated with the Claude "Bud" Lewis Carlsbad Desalination Plant (Carlsbad Desalination Plant) in Carlsbad, California, which has a larger capacity, are summarized below.

Desalination projects currently under development or completed in the past 5 years in California have estimated costs between $1,000 and $3,000 per AF (WaterReuse 2012; SDCWA 2015). SFPUC estimated that the capital cost for a BARDP desalination facility that would use 28,000 AF/y of feedwater to produce approximately 22,175 AF/y of treated water, including the intake and pipeline for conveyance to the existing conveyance system, would be $168 million, or approximately $8.50 per gallon per day. This includes contingencies and planning, permitting, engineering, and administrative costs. The annual operating cost was estimated at approximately $10.5 million (MWH 2010). The BARDP would require the use of existing infrastructure, including the use of Mallard Slough Pump Station and associated water rights, conveyance to and from Los Vaqueros Reservoir, and Los Vaqueros Reservoir (for storage); the estimated total costs for using these facilities would translate into about $173 - $226 per AF of delivered water (CCWD 2014)

Poseidon Resources currently owns and operates the Carlsbad Desalination Plant, which has been operating since December 2015. However, the County of San Diego has the option to purchase the plant in 30 years. The County of San Diego has agreed to pay $2,131 to $2,367 per acre-foot of desalinated water, which includes the cost of conveying water to the San Diego County Water Authority’s aqueduct (Carlsbad Desalination Project 2015).

As part of the WSIP PEIR, SFPUC prepared a conceptual-level, generalized impact analysis of the BARDP, which, at the time of the analysis, was based on limited, preliminary information regarding project design and operation, and site location. The construction and operation of BARDP could result in potentially significant environmental impacts on various resources, as disclosed in Chapter 16, *Evaluation of Other Indirect and Additional Actions.* Because of this limited project-specific information, it was generally determined that most of the potential impacts associated with construction and operation of a desalination plant and associated facilities would be potentially significant for the following resources: land use; visual quality; geology, soils, and seismicity; water quality and hydrology; air quality; biological resources; cultural resources; greenhouse gas emissions; hazards; noise and vibration; energy resources; traffic, transportation, and circulation; public services and utilities; recreational resources; and agricultural resources. This is similar to the resources affected by the construction and operation of the existing Carlsbad Desalination Project. While there are many geographic differences between San Francisco and Carlsbad that could influence the significance of an impact on an environmental resource, the analysis for the Carlsbad facility identified significant and unavoidable impacts only for the cumulative regional impact associated with air quality; all other impacts on resources were either mitigated to levels of less than significant (cultural, hazards and hazardous materials, land use and planning and transportation and circulation) or were less than significant (City of Carlsbad 2015).

L.6 Regional Economic and Ratepayer Effects of Water Supply Changes

Based on the assessment of SFPUC's water bank balance in New Don Pedro Reservoir over a 21-year historical sequence (Section L.4, *Water Bank Account Modeling*), the regional effects of the three LSJR alternatives on the four-county Bay Area regional economy (Alameda, San Francisco, San Mateo, Santa Clara Counties) and ratepayers were evaluated under the two scenarios. As discussed in Section L.4, the assessment shows that under both scenarios, the water bank account would reach zero during drought years, indicating that changes in flow objectives on the Lower Tuolumne River may affect the ability of SFPUC to supply water to its retail and wholesale customers under drought conditions.

L.6.1 Methodology

Water Replacement Costs Assumptions

For purposes of assessing water shortage impacts on the four-county Bay Area regional economy, it was assumed that the SFPUC would meet its water demands during drought periods by purchasing water from MID and TID. Other water supply options are summarized above in Section L.5, *Potential Actions to Meet Water Supply Demand*, and discussed in Chapter 16, *Evaluation of Other Indirect and Additional Actions*. While is likely that SFPUC would employ a suite of water supply actions to meet its water demands, the specific combination of actions at any given time cannot be predicted.

It is reasonable to assume that SFPUC would purchase and transfer additional water supplies from the Tuolumne River Watershed to its service area to offset water shortages during drought periods. Such purchases would be expected to result in substantially lower estimates of regional impacts than if SFPUC would cut back its water deliveries (i.e., impose shortages) to its retail and wholesale customers, particularly for impacts related to commercial and industrial water users. See Sunding 2014 for an assessment of impacts on SFPUC due to assumed imposition of water shortages, as opposed to the water replacement approach used in this analysis, within the Hetch Hetchy Regional Water System Service Area.

Under the assumption that SFPUC would purchase replacement water supplies from MID and TID, water costs to SFPUC were calculated based on the predicted annual average shortages under the LSJR alternatives during severe drought years (represented by 1987–1992), relative to baseline conditions. The estimated annual average costs to SFPUC to replace the reduced water supplies were then calculated based on the following assumptions.

- During drought periods, SFPUC would replace reductions in water supplies under the LSJR alternatives by purchasing water at $1,000 per AF; the $1,000 per AF assumes a cost higher than the $50–$600 per AF documented in PPIC, 2011 and Maven 2015.
- No other costs to SFPUC would be required to wheel, treat, or distribute the purchased water beyond existing costs for Hetch Hetchy water. (Note that if the transferred water comes from Cherry or Eleanor Reservoirs instead of passing through Hetch Hetchy Reservoir, the water would need to be filtered, potentially resulting in additional cost.)
- SFPUC operations and maintenance costs to produce water from the Hetch Hetchy water system do not vary based on the amount of water annually delivered by the system. As a result, SFPUC

water-production costs do not appreciably decline when less water is delivered during drought conditions. (System facilities still need to be operated and maintained regardless of the amount of water delivered through the system.) Because of this, 100 percent of the $1,000 per AF cost to replace reduced water supplies would be added to overall SFPUC costs to provide water from the Hetch Hetchy system.

Based on these assumptions, average annual water-shortage replacements costs for SFPUC are estimated in Table L.6-1a and L.6-1b. Annual severe drought-period costs for the LSJR alternatives are estimated to range from about $14 million to $30 million under Scenario 1, and from about $35 million to $208 million under Scenario 2.

Table L.6-1a. Estimated Annual SFPUC Replacement Water Purchase Costs under the LSJR Alternatives (Annual average within severe 6-year drought period represented by years 1987–1992)

	Scenario 1		Scenario 2	
Alternative	Required Water Transfer (TAF)	Estimated Purchase Cost	Required Water Transfer (TAF)	Estimated Purchase Cost
LSJR Alternative 2	14	$14,000,000	35	$35,000,000
LSJR Alternative 3	27	$27,000,000	119	$119,000,000
LSJR Alternative 4	30	$30,000,000	208	$208,000,000

TAF = thousand acre –feet

Long-term average costs depend on the return period of droughts of the magnitude and duration used in this analysis of SFPUC replacement water costs. The 6-year drought used in this analysis, 1987–1992, occurred within a 21-year analysis period, 1983–2003, that is hydrologically consistent with[3] the 94-year, 1922–2015, period of record analyzed in Chapter 21, *Drought Evaluation*. This 6-year drought is the driest 6-year period on record with regard to Tuolumne River flows, and has a return frequency of 1 in 94 years. Assuming a "worst-case" return period of one severe 6-year drought every 21 years, the mean annual cost to purchase replacement water in drought years shown in Table L.6.1a would be spread over 21 years, instead of over only 6 drought years. The mean annual reduction in water supply compared to baseline would range from 4 to 9 TAF per year under scenario 1, to 10 to 71 TAF per year under scenario 2 (table L.6-1b). The distributed costs would be similarly reduced--longer-term annual average costs for the LSJR alternatives are estimated to range from about $4 million to $9 million under scenario 1 and from about $10 million to $71 million under scenario 2.

It should be noted, however, that the estimated costs to be incurred by SFPUC and its wholesale agencies due to a water supply reduction during a severe drought would not be expected to occur evenly over a defined period, either 6 years or 21 years, as suggested by the calculation of an average annual value, based either on the example 1987–1992 drought or on the available 21-year period of record used for assessing water bank deficits. Consequently, while the calculation of an

[3] Median, 75th, and 90th percentile exceedence unimpaired flows for the Tuolumne River at New Don Pedro Reservoir were 1665 TAF, 1094 TAF, and 820 TAF, respectively, for the WY 1922–2015 period of record, and 1626 TAF, 1033 TAF, and 834 TAF, respectively, for the WY 1983–2003 period of record (DWR 2007a, updated with DWR 2016 and CDEC records). The specific order of the 1987–1992 sequence of below-average flows resulted in the significance of that particular 6-year drought, while the overall probability distribution of annual unimpaired flow in any water year is similar for both periods of record compared (1983–2003 and 1922–2015).

average annual cost is useful for evaluating potential effects (both cost and regional economic effects) relative to ongoing budgetary conditions, the temporal accuracy of calculating an average annual cost is somewhat uncertain.

Table L.6-1b. Estimated Mean Annual SFPUC Replacement Water Purchase Costs under the LSJR Alternatives (Annual average over longer period of record represented by years 1983-2003).

	Scenario 1		Scenario 2	
Alternative	Required Water Transfer (TAF)	Estimated Purchase Cost	Required Water Transfer (TAF)	Estimated Purchase Cost
LSJR Alternative 2	4	$4,000,000	10	$10,000,000
LSJR Alternative 3	8	$8,000,000	34	$34,000,000
LSJR Alternative 4	9	$9,000,000	71	$71,000,000

TAF = thousand acre -feet

For the assessment of regional economic effects of the water supply impacts, the costs in Table L.5-1 were distributed to SFPUC water users by agency and user category as follows.

- Replacement water and related costs were distributed to water agencies in proportion to 2010 water deliveries, as reported in SFPUC's 2010 Urban Water Management Plan for CCSF, excluding SFPUC's retail groundwater customers. According to this distribution, 34 percent of the water would be delivered to the retail service area and 66 percent would be delivered to the wholesale service area (Table L.3-1). Within the wholesale service area, distributions to the 27 agencies receiving SFPUC water would be proportional to SFPUC water deliveries in 2010.

Replacement water costs were allocated among end-use water customer categories (i.e., residential, commercial and industrial, government and other, and dedicated irrigation uses) according to 2010 water deliveries, as shown in Table L.3-2. For the SFPUC retail service area, reported delivery allocations among user categories include 55.2 percent residential, 32.1 percent commercial and industrial, and 12.7 percent government and other. (For the SFPUC retail service area, dedicated city irrigation demands are met using groundwater supplies, which have been excluded from the assessment.) Across the wholesale service area, delivery allocations among user categories include 58.5 percent residential, 20.8 percent commercial and industrial, 11.4 percent government and other, and 9.3 percent dedicated irrigation uses.

Based on these methods, the costs of replacement water under each LSJR alternative were allocated to agencies and user categories, and were then compiled by county for each scenario.

Regional Impact Assessment

As discussed in Section L.4, *Water Bank Account Modeling*, implementation of the LSJR alternatives could result in water shortages in the SFPUC retail and wholesale service areas during drought periods. As discussed previously, it was assumed that SFPUC would purchase water to offset water shortages during the drought periods. It was also assumed that SFPUC would pass along the additional cost to its retail customers in the form of a temporary rate surcharge and to its wholesale customers in the form of higher wholesale water rates. In turn, wholesale customers would be expected to pass along their higher costs to their retail customers through a temporary rate surcharge. As higher water costs filter through the four-county Bay Area region, less discretionary income would be available to water customers to spend on goods and services, resulting in reductions in output (sales) and employment throughout the region. Under 2010 baseline conditions, industrial output within the Bay Area region totaled $645.3 billion, led by $278.1 billion in industrial output in Santa Clara County. This level of output supported almost 3.2 million jobs within the regional economy.

The regional economic effects of rate surcharges would largely be determined by the reactions of end-use customers to temporarily higher water rates, including the actions taken by residential customers, commercial and industrial customers, government water users, and dedicated irrigation water users. For example, faced with higher water costs during drought years, residential customers could decrease their water use in response to water price increases or they could decrease their spending on other goods and services to compensate for higher water utility bills. However, if rate increases are relatively small, households may not change their spending habits at all or may maintain current spending levels by reducing savings and/or investments by charging purchases using credit cards or by borrowing.

For commercial and industrial water customers, the situation is more complex. These water customers could react in several ways, including temporarily incurring reduced profits, purchasing less water and/or decreasing production levels, raising product/service prices, or changing their mix of production inputs to reduce non-water-related costs. In reality, businesses would likely take implement a combination of these actions, depending on the proportion of a business's overall costs that are attributable to water, the magnitude of rate increases, and a business's ability to raise prices in its individual market environment.

For institutional water users primarily composed of government agencies, the cause-and-effect response to water prices would not be the same as for households or commercial and industrial customers. While agencies could lay off staff or reduce spending on other operational inputs in response to temporarily higher water costs, the need for agencies to maintain staffing and service levels set through agency budgeting suggests that temporary economic effects of higher water costs would be limited. Additionally, government agencies are often reluctant to reduce payroll or staff levels, and may be more likely to run temporary budget deficits or to seek a temporary budget augmentation to offset cost increases.

The IMPLAN input-output economic model was used to analyze SFPUC water-replacement cost effects on the regional economy. The model was used to estimate the indirect and induced economic activity associated with direct changes in water costs to customers within SFPUC's retail and wholesale service areas. IMPLAN is the most widely used economic input-output model for assessing regional economic impacts of regulatory and policy actions. Using 2010 IMPLAN county-level data files, individual IMPLAN models were constructed for Alameda, San Francisco, San Mateo, and Santa Clara Counties, and water costs were input to the models, as discussed below, to generate estimates of direct, indirect, and induced effects on industrial output and employment. Refer to Appendix G, *Agricultural Economic Effects of the Lower San Joaquin River Flow Alternatives: Methodology and Modeling Results,* for additional details concerning the IMPLAN model. Due to the complexities of predicting how the various classes of water customers would react to temporarily higher water rates, and due to the limitations of the IMPLAN input-output modeling tool to assess cost-related impacts, several assumptions were made to simplify the modeling approach for assessing the regional economic effects of the LSJR alternatives, including the following.

- For the SFPUC retail service area and the 27 water agencies that purchase wholesale water from SPFUC, it is assumed that the increased water costs would be passed along to customers. As a result, no reductions in output values or employment levels would be expected for water agencies, although demand for water may fall while rate surcharges are in effect. This assumption appears reasonable both due to the temporary nature of water cost increases during drought years and due to the need for agencies to maintain operating capacity, even when water demand temporarily decreases.

- Households would react to temporarily higher water costs by reducing their discretionary spending on other goods and services within the four-county Bay Area region. Note that this assumption may result in overestimating regional economic impacts because households are likely to react to higher water costs by cutting water use, which would have limited effects on the regional economy, as well as by reducing spending on other goods and services, some of which would occur outside of the region.
- Due to the temporary nature of potential water cost increases during drought years, commercial and industrial users would react to higher water costs by absorbing reduced levels of profits rather than by cutting production or raising prices. With production (or unit sales) remaining stable, there would be no change in the demand for goods and services from a business's suppliers and no employee layoffs would occur. Similarly, with no increase in product prices, there would be no related change in costs to a business's customers. The effect, therefore, would be on the discretionary personal income of business owners and those who receive corporate profit distributions, such as shareholders, resulting in lowered consumer spending in the region. To the extent that business owners and shareholders reside in the four-county Bay Area region, the reduced spending would cause reduced economic activity in the region. It is unlikely, however, that all or most business owners and shareholders reside in the region. However, for the purposes of this assessment, all business owners and shareholders are assumed to reside within the region. Note that this assumption may lead to an overestimate of regional impacts, particularly because many corporate shareholders likely reside outside of the region.
- For government agencies, a temporary increase in water costs would represent an increase in operating costs. Government agencies were assumed to react by decreasing spending on labor and other goods and services required for agency operations. Note that this assumption may lead to an overestimate of regional impacts because some agencies may not respond by decreasing spending.
- For dedicated irrigation users, who include both public and private entities irrigating large or high water-use sites, a temporary increase in water costs would result in a decrease in discretionary spending by private water users (e.g., multi-family residential complexes, commercial and industrial landscaped areas) and a decrease in operational spending on goods and services by government water users.

Based on the assumptions discussed above, the following methods were used to model effects for the four major customer categories served by affected water agencies.

- For residential water users, increased water costs were treated as a decrease in discretionary income. The regional economic impacts of a change in water costs to households were modeled by importing an "institutional" spending pattern for households from the IMPLAN model's library, editing the spending pattern as needed (e.g., removing expenditures that would not likely change because of increased water spending), and inputting the decrease in discretionary income due to increased water costs under each LSJR alternative. Water costs were allocated across the nine IMPLAN household income categories based on the existing percentage distribution of household demand for IMPLAN commodity No. 3033 (which includes water, sewage treatment, and other utility services) in each county, as indicated by IMPLAN county-level data files.

- For commercial and industrial water customers, increased water costs were treated as a decrease in discretionary personal income for proprietors and corporate shareholders based on the assumption that these water users would absorb temporary reductions in profits rather than decrease production and/or increase prices to consumers. As a result, regional economic impacts were modeled as reductions in household income, using the same modeling methods employed for residential water users.
- For government agencies, increased water costs were treated as an increase in government agency operating costs, which would cause a reduction in spending on other operational inputs. The regional impacts of a change in water costs to government was modeled by importing "institutional" spending patterns for four government sectors from the model's library and inputting the increased water costs under each LSJR alternative. Water costs were allocated across the four government sectors (i.e., federal government non-defense, federal government defense, state and local government non-education, and state and local government education) based on the existing percentage distribution of demand by each government sector for IMPLAN commodity 3033 (water, sewage treatment, and other utility services) in each county, as indicated by IMPLAN county-level data files.
- Some water agencies have separate customer accounts for large- or high-water-use landscapes (e.g., parks, multi-family residential lawn areas, business landscaping). These accounts are often connected to dedicated irrigation water meters and may be enrolled in an agency's water conservation landscape program. As such, data on water used by these customers, which include both public and private users, is compiled separately from other residential, commercial and industrial, and government accounts. No information is readily available concerning the allocation of dedicated irrigation water use among these customer categories. As a result, for dedicated irrigation water users, it was assumed that half of the cost increases assigned to dedicated irrigation uses would be attributable to multi-family, commercial, and industrial users and half would be attributable to government users. Based on this assumption, half of the costs estimated for dedicated irrigation customers was assigned to residential, commercial, and industrial users, and half was assigned to government users, with regional impacts modeled as described above for each customer category.

Using these methods, water-replacement costs for each customer category were input to the county-level IMPLAN models, and the resulting estimates of direct, indirect, and induced effects on output and employment were compiled for each LSJR alternative by county.

Ratepayer Effects Assumptions

As discussed previously, under drought conditions, implementation of the LSJR alternatives is predicted to result in water supply reductions within the SFPUC retail service area and within the service areas of the 27 agencies in Alameda, San Mateo, and Santa Clara Counties that purchase wholesale water from SFPUC. Under the LSJR alternatives, SFPUC is assumed to meet its water demands during drought periods by buying water from MID and TID. SFPUC would then presumably pass along the additional cost to its retail customers in the form of a temporary rate surcharge and to its wholesale customer in the form of a higher wholesale water rate. In turn, wholesale agencies would presumably pass along their higher costs to their retail customers through a temporary rate surcharge based on water usage.

Effects of water purchases on SFPUC service area rates were evaluated based on the relative increase in overall SFPUC budget costs attributable to replacement water purchases under each alternative. Existing water rates that are annually established for both the retail and wholesale service areas reflect operating costs, debt service costs, capital costs, programmatic project costs, and reserve considerations. The ratepayer assessment used the total SFPUC Water Enterprise and Hetch Hetchy Water budgets for fiscal year 2013–2014 as baselines for the assessment. These budgets account for the cost of producing, conveying, filtering, treating, and distributing water within the SFPUC service areas, as well as to defray the costs of past, current, and future projects.

For purposes of evaluating ratepayer effects, increases in budgetary costs to SFPUC to replace water under drought conditions was assumed to result in proportional rate increases in SFPUC's retail and wholesale water rates, relative to the existing rates shown in Table L.3-4.

L.6.2 Regional Economic Effects of the LSJR Alternatives

Under Scenario 1 (the City is only responsible for 51.7 percent of the increased flow requirement when the New Don Pedro Reservoir bank account balance is positive), decreased spending on goods and services resulting from increased water costs for residential, commercial, industrial, and institutional water users would result in industrial output declining throughout the Bay Area region during severe drought periods. These reductions during severe drought years (e.g. 1987–1992) are estimated to range from $16.2 million under LSJR Alternative 2 to $35.3 million under LSJR Alternative 4 (Table L.6-2). While large, these reductions during drought periods would be relatively small in the context of the regional economy, ranging from 0.03 to 0.05 percent of total output.

Table L.6-2. Estimated Average Annual Water Supply Effects (Direct, Indirect, and Induced) during Severe Drought Years on Economic Output in the Bay Area Region Associated with the LSJR Alternatives 2, 3, and 4: Scenario 1[a]

		Change from Baseline by LSJR Alternative Under Scenario 1[a]		
Economic Effects (2010 Dollars)	2010 Baseline	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Alameda County				
Total County Output ($ Millions)	143,450.6	-2.8	-5.5	-6.2
% of Output	*100*	*-0.02*	*-0.04*	*-0.04*
San Francisco County				
Total County Output ($ Millions)	124,678.1	-5.6	-10.9	-12.2
% of Output	*100*	*-0.04*	*-0.09*	*-0.10*
San Mateo County				
Total County Output ($ Millions)	99,088.3	-4.4	-8.5	-9.5
% of Output	*100*	*-0.04*	*-0.09*	*-0.10*
Santa Clara County				
Total County Output ($ Millions)	278,082.8	-3.4	-6.6	-7.4
% of Output	*100*	*-0.01*	*-0.02*	*-0.03*
Bay Area Region				
Total Region Output ($ Millions)	645,299.8	-16.2	-31.4	-35.3
% of Output	*100*	*-0.03*	*-0.05*	*-0.05*

Source: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.

[a] The City is only responsible for 51.7% of the increased flow requirement when the New Don Pedro Reservoir bank account balance is positive

The total regional effects of the LSJR alternatives on jobs under Scenario 1 are similar, in relative terms, to the effects on economic output. During drought periods, average annual jobs within the region are predicted to decrease by 117 (0.01 percent) under LSJR Alternative 2 compared to baseline (Table L.6-3). Under LSJR Alternatives 3 and 4, jobs are predicted to decrease by 226 (0.01 percent) and 254 (0.01 percent), respectively. Job losses under LSJR Alternative 4 are predicted to be largest in San Francisco County (84 jobs) and San Mateo County (71 jobs).

Table L.6-3. Estimated Average Annual Water Supply Effects (Direct, Indirect, and Induced) during Severe Drought Years on Jobs in the Bay Area Region Associated with LSJR Alternatives: Scenario 1[a]

		Change from Baseline by LSJR Alternative Under Scenario 1		
Economic Effects	2010 Baseline	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Alameda County				
Total County Jobs	872,636	-21	-41	-46
% of Jobs	100	<-0.01	<-0.01	-0.01
San Francisco County				
Total County Jobs	734,063	-39	-75	-84
% of Jobs	100	-0.01	-0.01	-0.01
San Mateo County				
Total County Jobs	464,194	-33	-64	-71
% of Jobs	100	-0.01	-0.01	-0.02
Santa Clara County				
Total County Jobs	1,112,308	-24	-47	-53
% of Jobs	100	<-0.01	<-0.01	<-0.01
Bay Area Region				
Total Region Jobs	3,183,201	-117	-226	-254
% of Jobs	100	<-0.01	<-0.01	<-0.01

Source: 2010 IMPLAN county data file, and IMPLAN model runs for LSJR alternatives.

[a] The City is only responsible for 51.7% of the increased flow requirement when the New Don Pedro Reservoir bank account balance is positive.

Under Scenario 2 (the City is always responsible for 51.7 percent of the increased flow requirement)) output and job losses during drought periods are predicted to be substantially higher than under Scenario 1 because replacement water needs and related costs to customers would be much larger. Annual output reductions are estimated to range from $40.5 million to $243.6 million under LSJR Alternatives 2, 3, and 4 (Table L.6-4). In the context of the overall Bay Area region economy, these reductions would represent less than 0.01 percent of total output. Similarly, job losses would be relatively small, ranging from an estimated 292 to 1,756 jobs, representing up to 0.06 percent of all regional jobs, across LSJR Alternatives 2, 3, and 4 (Table L.6-5).

Table L.6-4. Estimated Average Annual Water Supply Effects (Direct, Indirect, and Induced) during Severe Drought Years on Economic Output in the Bay Area Region Associated with the LSJR Alternatives 2, 3, and 4: Scenario 2[a]

Economic Effects (2010 Dollars)	2010 Baseline	Change from Baseline by LSJR Alternative Under Scenario 2[a]		
		LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Alameda County				
Total County Output ($ Millions)	143,450.6	-7.1	-24.5	-43.0
% of Output	100	-0.05	-0.17	-0.30
San Francisco County				
Total County Output ($ Millions)	124,678.1	-14.0	-48.2	-84.2
% of Output	100	-0.11	-0.39	-0.68
San Mateo County				
Total County Output ($ Millions)	99,088.3	-10.9	-37.6	-65.5
% of Output	100	-0.11	-0.38	-0.66
Santa Clara County				
Total County Output ($ Millions)	278,082.8	-8.5	-29.2	-51.0
% of Output	100	-0.03	-0.11	-0.18
Bay Area Region				
Total Region Output ($ Millions)	645,299.8	-40.5	-139.5	-243.6
% of Output	100	-0.06	-0.22	-0.38

Source: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.

[a] The City is always responsible for 51.7% of the increased flow requirement.

Table L.6-5. Estimated Average Annual Water Supply Effects (Direct, Indirect, and Induced) during Severe Drought Years on Jobs in the Bay Area Region Associated with LSJR Alternatives 2, 3, and 4: Scenario 2[a]

		Change from Baseline by LSJR Alternative Under Scenario 2[a]		
Economic Effects	2010 Baseline	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Alameda County				
Total County Jobs	872,636	-53	-181	-318
% of Jobs	100	-0.01	-0.02	-0.04
San Francisco County				
Total County Jobs	734,063	-97	-334	-583
% of Jobs	100	-0.01	-0.05	-0.08
San Mateo County				
Total County Jobs	464,194	-82	-282	-491
% of Jobs	100	-0.02	-0.06	-0.11
Santa Clara County				
Total County Jobs	1,112,308	-61	-209	-364
% of Jobs	100	-0.01	-0.02	-0.03
Bay Area Region				
Total Region Jobs	3,183,201	-292	-1,005	-1,756
% of Jobs	100	-0.01	-0.03	-0.06

Source: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives.
[a] The City is always responsible for 51.7% of the increased flow requirement.

L.6.3 Ratepayer Effects of the LSJR Alternatives

As discussed previously, the SFPUC Water Enterprise and Hetch Hetchy Water budgets account for the cost of producing, conveying, filtering, treating, and distributing water within the SFPUC service areas, as well as providing funds to defray the costs of past, current, and future projects. The adopted fiscal year 2013–2014 budgets totaled $483.2 million (Table L.3-3). Existing water rates for SFPUC's retail and wholesale customers, which are largely driven by these budget costs, are shown in Table L.3-4.

The budget effects of purchasing replacement water during severe drought periods (e.g., 1987–1992) under the LSJR alternatives are shown in Tables L.6-6 and L.6-7. Compared to adopted fiscal year 2013–2014 SFPUC budget costs of $483.2 million, water replacement costs under Scenario 1 (the City is only responsible for 51.7 percent of the increased flow requirement when the New Don Pedro Reservoir bank account balance is positive) would represent increases in overall costs ranging from 3 to 6 percent (Table L.6-6). These severe drought-period increases would presumably result in rate surcharges within the retail and wholesale service areas of about the same percentage relative to existing water rates. For example, the drought-period rate surcharge in the SFPUC retail service area could cause existing rates for a single-family residential customer to rise by about 3 percent under LSJR Alternative 2, and by about 6 percent under LSJR Alternatives 3 and 4. Existing rates charged by SFPUC to its wholesale customers could increase by similar percentages.

Table L.6-6. Estimated SFPUC Budget Effects of Purchasing Replacement Water Supplies during Severe Drought Periods Associated with LSJR Alternatives 2, 3, and 4: Scenario 1[a]

	Baseline[a]	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Average Annual Water Replacement Costs ($ Millions)	--	14	27	30
Water Budget with Replacement Costs ($ Millions)	483.2	497.2	510.2	513.2
Percentage Change in Water Budget Expenditures	--	2.9%	5.6%	6.2%

Scenario 1: The City is only responsible for 51.7% of the increased flow requirement when the New Don Pedro Reservoir bank account balance is positive

[a] Represents combined Adopted Water Enterprise and Hetch Hetchy Water budgets for fiscal year 2013–2014.

Table L.6-7. Estimated SFPUC Budget Effects of Purchasing Replacement Water Supplies during Severe Drought Periods Associated with LSJR Alternatives 2, 3, and 4: Scenario 2[a]

	Baseline[a]	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Average Annual Water Replacement Costs ($ Millions)	--	35	119	208
Water Budget with Replacement Costs ($ Millions)	483.2	518.2	602.2	691.2
Percentage Change in Water Budget Expenditures	--	7.2%	24.6%	43.1%

Scenario 2: The City is always responsible for 51.7% of the increased flow requirement

[a] Represents combined Adopted Water Enterprise and Hetch Hetchy Water budgets for fiscal year 2013–2014.

Under Scenario 2 (the City is always responsible for 51.7 percent of the increased flow requirement), estimated increases in SFPUC budget expenditures to purchase and transfer water to offset shortages during severe drought periods under the LSJR alternatives would be much higher than under Scenario 1, with increases ranging from about 7 to 43 percent (Table L.6-7). As a result, water rate increases during severe drought periods would be expected to be substantially higher than under Scenario 1. Under Scenario 2, the severe drought-period rate surcharge in the SFPUC retail service area could cause existing rates for a single-family residential customers to rise by about 7 percent under LSJR Alternative 2, by about 25 percent under LSJR Alternative 3, and by about 43 percent under LSJR Alternative 4. Existing rates charged by SFPUC to its wholesale customers could be expected to increase by similar percentages.

Using a longer-term period of record (1983–2003), the annual average water replacement costs (as derived in Table L.6.1b) are much less than the costs within the severe drought period (1987 to 1992) described above. Under Scenario 1, estimated longer-term increases in budget expenditures range from 0.8 to 1.9 percent (Table L.6-8). Under Scenario 2, estimated longer-term increases in budget expenditures range from 2.1 to 14.7 percent (Table L.6-9).

Table L.6-8. Estimated Longer-term SFPUC Budget Effects of Purchasing Replacement Water Supplies during Severe Drought Periods Associated with LSJR Alternatives 2, 3, and 4: Scenario 1[a]

	Baseline[a]	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Average Annual Water Replacement Costs ($ Millions)	--	4	8	9
Water Budget with Replacement Costs ($ Millions)	483.2	487.2	491.2	492.2
Percentage Change in Water Budget Expenditures	--	0.8%	1.7%	1.9%

Scenario 1: The City is only responsible for 51.7% of the increased flow requirement when the New Don Pedro Reservoir bank account balance is positive

[a] Represents combined Adopted Water Enterprise and Hetch Hetchy Water budgets for fiscal year 2013–2014.

Table L.6-9. Estimated Longer-term SFPUC Budget Effects of Purchasing Replacement Water Supplies during Severe Drought Periods Associated with LSJR Alternatives 2, 3, and 4: Scenario 2[a]

	Baseline[a]	LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Average Annual Water Replacement Costs ($ Millions)	--	10	34	71
Water Budget with Replacement Costs ($ Millions)	483.2	493.2	517.2	554.2
Percentage Change in Water Budget Expenditures	--	2.1%	7.0%	14.7%

Scenario 2: The City is always responsible for 51.7% of the increased flow requirement

[a] Represents combined Adopted Water Enterprise and Hetch Hetchy Water budgets for fiscal year 2013–2014.

For the 27 individual water agencies that purchase wholesale water from SFPUC, the actual drought surcharges levied on their retail water customers (e.g., residential, commercial and industrial) would be expected to vary depending on the percentage of each district's overall water demand met by purchases from SFPUC. As shown in Table L-3-1, 19 of the water agencies served by SFPUC purchased at least 90 percent of their total water supply from SFPUC in 2010. Within the service areas of those agencies (e.g., the Cities of Hayward, East Palo Alto, Menlo Park), percentage increases in drought-period rates would likely be similar to increases in wholesale water rates under the LSJR alternatives. For water agencies that rely less on SFPUC water deliveries (e.g., the Cities of Santa Clara, Sunnyvale, and San Bruno), the rate surcharges attributable to the LSJR alternatives would presumably be lower. Additionally, rate increases for customer classifications within each agency would vary based on the rate-setting policies of each agency.

L.6.4 Sensitivity Analysis

The results described above are based on an assumed cost of $1000 per AF of water for purchases from irrigation districts (i.e., MID and TID). This assumed price is key to the analysis, and was derived based on a review of recent water purchases, involving both MID and TID, as well as by other agricultural districts in California. Although this assumption is considered reasonable for the analysis, a case also can be made for assuming either a higher or lower average cost per AF, given the many site- and time-specific factors that affect water transaction prices.

One important factor is that water transfers in California, particularly agricultural-to-urban water district transfers, are often constrained by the availability of facilities to transport water between areas. A second important factor is that some irrigation districts prohibit, restrict or, at a minimum, discourage water transfers from districts (or individual farmers) to urban water districts (Aredas 2015). These factors, however, are not considered limiting for assessing water purchases (under certain conditions) by CCSF from MID or TID; consequently, the assumed water transfers appear reasonably feasible, although highly dependent on the amount of water to be transferred and other considerations.

As presented in Table L.4-2, the amount of water to be transferred varies under the LSJR alternatives and implementation scenarios. As shown, the two implementation scenarios would have a substantially different effect on the need for water. Under Scenario 1 (the City is only responsible for 51.7 percent of the increased flow requirement when the New Don Pedro Reservoir bank account balance is positive), the estimated amount of water needed by CCSF ranges from 14 TAF to 30 TAF annually during severe drought periods. Under Scenario 2 (the City is always responsible for 51.7 percent of the increased flow requirement), the amount of water needed ranges from 35 TAF to 208 TAF. Because these amounts are based on average annual conditions over a 6-year severe drought period similar to 1987–1992, the availability of water for purchase from sources other than MID and TID should be assumed to be limited, thereby putting upward pressure on the price of water.

In its 2012 report to the SFPUC Commission, the SFPUC staff estimated that 2 million gallons of water per day (see Table 1 of that report)[4] would be purchased from MID/TID at a cost of $700 per AF (in 2018 dollars) (SFPUC 2012b). Obtaining these water supplies from MID/TID for the 2011–2012 water year was considered “water supply projects in planning and environmental review.” Based on supply and demand conditions during extended drought periods, it can reasonably be assumed that the cost of water would likely be higher during the later years of this period.

A limited review of relevant information concerning the cost of water in recent water purchase transactions suggests that a reasonable cost range for agricultural-to-urban water transfers is $500 to $2000 per AF, depending importantly on underlying supply and demand conditions (Carr pers. comm.). Although many factors influence the relationship between the price of water per AF and the extent of associated regional economic effects, assuming that this relationship is linear provides an order-of-magnitude approximation of potential effects of assuming different average water prices.

Approximate impacts on total economic output and employment in the four-county Bay Area region (San Francisco, Alameda, San Mateo, and Santa Clara Counties) using water transfer prices of $500, $1000, and $2000 per AF are shown in Tables L.6-8 and L.6-9 under Scenarios 1 and 2 for the LSJR alternatives. “Severe drought periods” refer to the 1987–1992 drought used as a basis for calculated deficits (see Sections L.4 and L.5).

[4] This amount of water is equivalent to 6 AF/y.

Table L.6-8. Estimated Average Annual Water Supply Effects on Economic Output during Severe Drought Periods in the Four-County Bay Area Region under LSJR Alternatives 2, 3, and 4 for Different Water Transfer Prices

Scenario	Water Transfer Price ($/AF)	Total Region Output ($ Millions)[c]			
		2010 Baseline	Change from Baseline under LSJR Alternative		
			LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Scenario 1[a]	500	645,300	-8.1	-15.7	-17.7
	1000	645,300	-16.2	-31.4	-35.3
	2000	645,300	-32.4	-62.8	-70.6
Scenario 2[b]	500	645,300	-20.3	-69.8	-121.8
	1000	645,300	-40.5	-139.5	-243.6
	2000	645,300	-81	-279	-487.2

Source: 2010 IMPLAN county data files and IMPLAN model runs for LSJR alternatives; Appendix L, Table L.6-2 and L.6-4.

$/AF = dollars per acre-foot

[a] Scenario 1 is defined in Appendix L as: storage credits would be reallocated only if CCSF has a positive credit balance in the water bank account.

[b] Scenario 2 is defined in Appendix L as: storage credits would be reallocated even if CCSF has a negative balance in the water bank account.

[c] Region consists of the four Bay Area counties: San Francisco, Alameda, San Mateo, and Santa Clara.

Table L.6-9. Estimated Average Annual Water Supply Effects on Employment in the Four-County Bay Area Region during Severe Drought Periods under LSJR Alternatives 2, 3, and 4 Assuming Different Water Transfer Prices

Scenario	Water Transfer Price ($/AF)	Total Region Employment (# of Jobs)[c]			
		2010 Baseline	Change from Baseline under LSJR Alternative		
			LSJR Alternative 2	LSJR Alternative 3	LSJR Alternative 4
Scenario 1[a]	500	3,183,201	-58.5	-113	-127
	1000	3,183,201	-117	-226	-254
	2000	3,183,201	-234	-452	-508
Scenario 2[b]	500	3,183,201	-146	-502.5	-878
	1000	3,183,201	-292	-1005	-1756
	2000	3,183,201	-584	-2010	-3512

Source: 2010 IMPLAN county data files (baseline conditions) and IMPLAN model runs for LSJR alternatives; Appendix L, Table L.6-3 and L.6-5.

$/AF = dollars per acre-foot.

[a] Scenario 1 is defined as: storage credits would be reallocated only if CCSF has a positive credit balance in the water bank account.

[b] Scenario 2 is defined as: storage credits would be reallocated even if CCSF has a negative balance in the water bank account.

[c] Region consists of the four Bay Area counties: San Francisco, Alameda, San Mateo, and Santa Clara.

In summary, the results presented in Tables L.6-2 through L.6-5 are considered reasonable estimates of regional economic impacts based on an assumed average cost of $1000 per AF. The amount of economic output lost associated with an assumed average price of water ranging from $500 to $2,000/AF could range from $8.1 to $70.6 million annually under Scenario 1, and $20.3 to $487.2 million annually under Scenario 2. The number of jobs lost associated with an assumed average price of water ranging from $500 to $2,000/AF could range from 59 to 508 annually under Scenario 1, and 146 to 3,512 annually under Scenario 2.

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Appendix M

Summary of Public Comments on 2012 Draft SED

Phase I Substitute Environmental Document

Summary of Public Comments on the 2012 Draft SED

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Contents

Acronyms and Abbreviations

AFRP	Anadromous Fish Restoration Program
BDCP	Bay Delta Conservation Plan
CAISO	California Independent System Operator
CCSF	City and County of San Francisco
CDFW	California Department of Fish and Wildlife
COG	coordinated operations group
CSJWCD	Central San Joaquin Water Conservation District
CVP	Central Valley Project
CVPIA-AFRP	Central Valley Project Improvement Act – Anadromous Fish Restoration Program
DFG	Department of Fish and Game
DO	dissolved oxygen
DWR	California Department of Water Resources
DWR Reliability Study	Department of Water Resources State Water Project Reliability Study
EC	electro-conductivity
FERC	Federal Energy Regulatory Commission
ILRP	Irrigated Lands Regulatory Program
ITP	Incidental Take Permit
LSJR	Lower San Joaquin River
MID	Modesto Irrigation District
NMFS BiOp	National Marine Fisheries Service's Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project
NOP	Notice of Preparation
OCAP	Operations Criteria and Plan
OID	Oakdale Irrigation District
PKD	proliferative kidney disease
POD	Pelagic Organism Decline
POI	program of implementation
Reclamation or USBR	U.S. Bureau of Reclamation
RPA	Reasonable and Prudent Alternative
RSWSP	Regional Surface Water Supply Project

SED	Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the San Francisco Bay-Sacramento/San Joaquin Delta Estuary: San Joaquin River Flows and Southern Delta Water Quality
SEWD	Stockton East Water District
SJR	San Joaquin River
SJR basin	San Joaquin River basin
SJRRP	San Joaquin River Restoration Program
SJTA	San Joaquin Tributaries Authority
SMART	Specific, Measurable, Achievable, Relevant, and Time-fixed
SSJID	South San Joaquin Irrigation District
State Water Board	State Water Resources Control Board
SWP	State Water Project
TMDL	Total Maximum Daily Load
USEPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
VAMP	Vernalis Adaptive Management Plan
WSE	Water Supply Effect Model
WSE Model	Water Supply Evaluation Model

Introduction and Overview

This document is a summary of public comment received by the State Water Resources Control Board (State Water Board) regarding the *Substitute Environmental Document in Support of Potential Changes to the Water Quality Control Plan for the San Francisco Bay-Sacramento/San Joaquin Delta Estuary: San Joaquin River Flows and Southern Delta Water Quality* (2012 Draft SED). The comment period ran from December 31, 2012, to March 29, 2013. The State Water Board received approximately 4000 responses. Of these, the State Water Board identified and selected 119 responses that covered the range of substantive comments; this summary only covers the comments in those 119 responses.

A response is a single, whole submission that may take the form of a letter, email, fax, or presentation at an organization-sponsored or other type of public meeting. Each response may contain anywhere from one to several hundred comments.[1] Many of the responses received were original responses submitted by individuals, agencies, and organizations, and some of the responses were form letters. The State Water Board intends to revise and recirculate the SED and therefore is not required to respond to all of the comments on this version of the SED. However, to assist in the revision of the SED prior to recirculation, the State Water Board has selected and analyzed the letters that cover the range of substantive comments. No out-of-scope letters were analyzed. This Summary of Public Comment on 2012 Draft SED is a narrative analysis of concerns raised in the responses. Material in quotation marks was selected from responses that reflect the tenor and type of a number of comments.

Although this analysis attempts to capture the full range of concerns raised, it should be used with caution. The respondents are self-selected; therefore, their comments do not necessarily represent the sentiments of the entire population. This analysis attempts to provide fair representation of the wide range of views submitted but makes no attempt to treat input as if it were a vote or a statistical sample. In addition, respondents' reasons for voicing these viewpoints are varied, subtle, or detailed. In an effort to provide a succinct summary of all of the concerns raised, many subtleties are not conveyed in this summary.

This Summary of Public Comment on 2012 Draft SED is divided into the following sections:

- Introduction and Overview
- Content Analysis Process
- Summary of Comments

Content Analysis Process

The goals of this content analysis process are to:

- Ensure that every selected response is considered.
- Identify the concerns raised by all selected respondents.

[1] *Responses* refer to single, whole submissions from respondents (e.g., letters, emails, faxes, presentations at public meetings). *Comments* refer to identifiable expressions of concern made within responses.

- Represent the breadth and depth of the public's viewpoints and concerns as fairly as possible.
- Present those concerns in such a way as to facilitate the Managing Agencies' consideration of comments.

Content analysis employs both qualitative and quantitative approaches. It is a systematic process designed to provide a mailing list of respondents, extract topics from each letter, evaluate similar topics from different responses, and identify specific topics of concern. The process also provides a relational database capable of reporting various types of information while linking comments to the original letters.

Throughout the content analysis process, the team strives to identify all relevant concerns, not just those represented by the majority of respondents. Breadth and depth of comment are important. In addition to capturing relevant factual input, the process identifies the relative emotion and strength of public sentiment behind particular viewpoints.

The Summary of Public Comment on 2012 Draft SED attempts to capture all significant concerns related to a project. However, it is only a summary. Content analysis summaries and reports are not intended to replace original letters.

Summary of Comments

The following summary of the comments received on the SED reflects respondents' sentiment on a variety of issues both diverse and interrelated regarding the proposed changes to management of the Bay-Delta. These issues range in nature from the strictly procedural to the technically specific. Public comment on these issues demonstrates the interest, feelings, and concern Californians have regarding the management of water resources in California. These comments reflect respondents' convictions about California waters, the use of those waters, and how the State Water Board should best manage these resources.

This section begins with a general analysis and proceeds with identification and discussion of respondents' main areas of concern. It is divided into the following sections:

- General Analysis
- Decision-Making Process, Public Involvement, and Coordination
- Substitute Environmental Document, Alternatives, and Analysis
- Proposed Water Quality Control Plan
- Natural Resources Management
- Recreation
- Socio-Economic Concerns
- Methods of Compliance Evaluation

General Analysis

Respondents express their belief that the State Water Board has "failed to carry out its Public Trust responsibilities;" they assert that the plan will not provide for the restoration of fisheries, the protection of the Delta ecosystem, the remediation of water quality violations, or restoration of salmon and steelhead populations in the San Joaquin River.

Decision-Making Process, Public Involvement, and Coordination

Public Involvement

Respondents assert that the proposed project is “unlawful” on several grounds related to noticing. They argue that neither the 2009 Notice of Preparation (NOP) nor the 2011 revised NOP indicates that the State Water Board would be developing a new LSJR flow objective even though the SED asserts that it is in fact analyzing a “new LSJR flow objective.” Similarly, they argue that the State Water Board did not provide adequate notice of the intent to revise the narrative objective. Some argue that the noticing related to the salmon narrative objective was also lacking.

Respondents also complain that the State Water Board did not adequately involve the regulated community in the development of the SED. They note that the SED does not analyze information provided in writing and at workshops and assert that this failure is contrary to the legal requirements of CEQA. Specifically, respondents complain that the SED does not “include information provided by the San Joaquin Tributaries Authority (SJTA).” They ask that the SED be revised to “evaluate” this information.

Some ask that the SED specify a “process for response to public comment on the Technical Report,” and that it explain how the State Water Board “will respond to public comments and deficiencies in the Technical Report.”

Others complain that the public notice appears to contradict the requirement of CEQA to “include all comments, even late submittals, in the administrative record.”

Coordination with Other Agencies and Governments

Some respondents assert that the State Water Board did not comply with CEQA requirements to consult with responsible agencies because it did not consult with the irrigation districts regarding “the extent or content of environmental review.” Some insist that the SED “must be revised to identify local agencies and irrigation districts” with which the State Water Board will consult and to include a schedule for this consultation. Respondents also argue that the SED is internally inconsistent on the question of responsible agencies; they note that the SED states that the State Water Board is the “only agency with responsibility for approving and implementing the plan” but later notes that “local irrigation districts and other public agencies will determine how best to comply with the plan.” They ask that the SED either “identify local agencies as responsible agencies…or analyze each method of how the State Water Board will implement the plan.”

Respondents suggest that the WQCP be revised to not require consensus of the coordinated operations group (COG)[2] of the adaptive management[3] plan; they suggest that consensus should be a goal but not a requirement and ask instead that a “dispute resolution process” be incorporated.

The California Department of Fish and Wildlife (CDFW) specifically requests that if the management actions in the adaptive management plan are intended to “benefit or may negatively affect a

[2] In the recirculated SED, the COG is referred to as the *STM Working Group*.

[3] In the recirculated SED, adaptive management is referred to as *adaptive implementation*.

sensitive species and/or its habitat" then the Executive Director "will consult with the regulatory agency" with jurisdiction before making a "determination regarding approval of the plan." CDFW also takes issue with the assertion that it should "develop and implement improvements to its anadromous fish hatcheries." The comment notes that a process for review and change has been underway for some time and while the recommendations will be evaluated at the "next policy team meeting" and "CDFW does not know whether the Team will recommend policy changes."

Contra Costa County complains that their "detailed scoping comments" were "ignored."

Compliance with CEQA

A number of respondents assert that the SED does not meet the requirements of CEQA. Several request that the State Water Board revise the SED and recirculate it for public comment. Specifically, respondents ask that the SED be revised such that it provides "a sufficient degree of analysis to provide decision makers with information" to make an informed decision. Additionally, they argue that the SED does not identify or describe the "secondary effects of the proposal," including inducing "agricultural operations to rely more heavily on groundwater" and the resulting increase in air pollution for increased use of diesel engines to "pump groundwater."

Several respondents assert that the State Water Board is effectively "piecemealing" the project in contravention of CEQA requirements. They note that the State Water Board must evaluate the "whole of an action" including those parts that would "cause direct or reasonably foreseeable indirect physical environmental changes." These respondents assert that the division the Phase I components (San Joaquin River flow and South Delta salinity objectives) from the Phase II components (review and update of the 2006 Bay-Delta Water Quality Control Plan) "constitutes piecemealing" of the "project description." They argue that the State Water Board should be "considering Phase I and Phase II as an integrated whole." Respondents note that the connection between the two phases is "inextricable" and that the SWRCB "intends to reintegrate the segmented pieces." Others note that CCR 23 § 3777 "requires a single SED be performed for each basin plan amendment" and does "not provide or otherwise allow for multiple SEDs for a single basin plan amendment."

Some respondents complain that the SED does not include a "stable and finite project description" and therefore does not comply with requirements of CEQA. They argue that the call for "an adaptive management process" is "too vague with regard to what standards are to be used" which makes it "impossible to determine what effects the proposed objective and implementation plan may have on the environment."

Further, some respondents argue that separating "the analysis of the San Joaquin River from the Sacramento River has resulted in a disjointed depiction of the conditions in the Delta" and that the State Water Board has not explained this phased approach sufficiently, which "frustrates the public disclosure goals of CEQA."

Respondents suggest that the following objectives may change and are reasonably foreseeable and so should be included in the analysis: water quality objectives for Sacramento River inflows, changes to export/inflow ratios, Delta Cross Channel closure objectives, Suisun Marsh objectives, Old and Middle River reverse flow objectives, and "other changes to water quality objectives that are reasonably foreseeable from Phase II proceedings to date."

Some argue that the State Water Board cannot legally "adopt a statement of overriding considerations" without "substantial evidence that [the] project will confer benefits"; they note that "[g]eneral benefits are not sufficient." According to these respondents, the State Water Board "must explicitly find the fish and wildlife benefit outweighs the significant impacts to groundwater, agriculture, water supply, service providers, and the economy."

Others assert that the SED fails to comply with CEQA because the "determinations are not supported by substantial evidence."

Compliance with Water Rights Laws

Some respondents complain that the plan includes "language assigning responsibility for portions of the WQCP to specific parties, including DWR [California Department of Water Resources]" and that such assignments should properly "be reserved for the water rights hearing." They therefore ask that all such language be removed from the SED and proposed WQCP. Respondents note that the Board has conflated its legislative authority with the adjudicative water rights authority by pre-determining many of the water rights conditions. They argue that this is illegal and "fails to provide the targeted water rights holders with the procedural protections and due process provided by an adjudicative water right proceeding."

Several respondents assert that the SED "conflicts" with water rights laws by "ignoring the water right priority system and the relevant protective statutes." They note that under the priority system "any required reductions of Delta or tributary water use must first be borne by exporters before any Delta tributary water rights holders are affected." Some also note that the SED "burdens senior water right [holders] without first impacting more junior water right holders." Additionally, they are concerned that by "including only the Stanislaus, Tuolumne, and Merced Rivers in the objectives, the Board ignores other possible sources of water to satisfy the narrative objectives." Some ask that the SED "explicitly acknowledge" the "potential for water rights holders to obtain compensation though transfer agreements with export water users" and that such transfers "could help fund water efficiency and other measures to reduce impacts." Respondents also assert that the Board's plan violates the Delta Reform Act of 2009 "because the Appendix K flow objective threatens to impair the prior water rights of major service providers."

Several respondents argue that the proposed changes in the South Delta salinity objectives would "injure water rights of …beneficial users" and would violate the "federal Clean Water Act's antidegradation policy and the Board's own 1968 resolution protecting against degradation of the state's waters."

Respondents assert that there are several errors in the SED related to water rights, including the following:

- The City and County of San Francisco (CCSF) is incorrectly characterized as "a contracting water district with the Districts as the primary water rights holders and surface water diverters." The "CCSF holds its own water rights to the Tuolumne River and does not receive water under contract with the Districts."
- The SED describes CCSF's storage allocation under the Fourth Agreement as a "740-TAF water right": however, it is "not a water right but rather a water bank account in Don Pedro Reservoir that allows CCSF to satisfy the District's entitlement to daily natural flow."

- The Stockton East Water District (SEWD) "does not use water diverted pursuant to SSJID [South San Joaquin Irrigation District] or OID [Oakdale Irrigation District] water rights."
- The SED incorrectly describes the water diversions of OID and SSJID. These districts "hold water right separate and distinct from the 1988 Agreement and Stipulation with" USBR.
- SED incorrectly describes "senior water rights holders as 'contractors' to the U.S. Bureau of Reclamation (Reclamation or USBR)".

Additionally, some respondents complain that the State Water Board overstates its authority to implement the water quality objectives. They note that the State Water Board's "jurisdiction and authority over" water rights actions, FERC [Federal Energy Regulatory Commission] hydropower licensing processes, other water quality actions or actions by other entities "is limited" even though these are the primary ways the State Water Board intends to implement the changes to the water quality objectives. Similarly, respondents argue that the State Water Board has overstated its authority to implement the flow objectives. For example, while the State Water Board has the authority to amend water rights permits, "this authority to reserve jurisdiction only applies to permits: it does not extend to water rights secured by license." Respondents go on to note that the majority of water diverted in the geographic scope of the proposed project is diverted "pursuant to licensed or pre-1914 water rights." Respondents also complain that the "SED fails to evaluate how much water in the plan area is diverted pursuant" to such rights. Without this analysis, they note that "it is not clear whether there is sufficient water over which the State Water Board had jurisdiction to implement the LSJR Flow Objective."

Respondents also note that while the State Water Board has the right to "curtail water use that is wasteful or unreasonable," it must make a determination of fact that the use is unreasonable. Further, respondents assert that the State Water Board "should be careful not to equate the power to curtail a specific use of water with the authority to require the reallocation of water to a different beneficial use." Some respondents argue that the Board should reconsider the choice to not "include an accurate description" of the water rights diverters on the Stanislaus River until the next phase. They specifically complain that the analysis in regards to the New Melones Reservoir is flawed in the SED and they request that the Board correct this in a revised SED.

Some respondents are concerned that the plan of implementation could redirect effects to the Sacramento Valley and note that because the adaptive management plan is not fully described in the SED they cannot determine whether or not this would be the case. They note that if the plan would require additional flows from the Sacramento Valley and enable increased Delta exports, this would "violate the fundamental principles of the water right priority system and the area of origin statutes."

Compliance with Other Regulations

Some respondents assert that the proposed project is "unlawful" because the State Water Board "does not have jurisdiction to set minimum stream flows on the Stanislaus, Tuolumne, and Merced Rivers below Federal Energy Regulatory Commission (FERC) licensed facilities."

Plan Development and Revision

Respondents ask that the section of the plan called "Action by other Agencies" be revised "to establish the schedule, expected results, and other specifics required by Water Code section 13244 to establish accountability for performance." Further they ask that the plan "establish a procedure for an annual informational workshop where other agencies submit written reports, and discuss the consequences of their reports, for implementation of their responsibilities under the plan update." Some suggest that such specifics are needed to increase the State Water Board's ability to compel action by other agencies.

Substitute Environmental Document, Alternatives, and Analysis

Adequacy of the Analysis

Some respondents complain that the SED "relies on inaccurate assumptions, flawed modeling, and data that is often either erroneous or not representative of the actual area at issue." Others criticize the SED for combining the effects of "all the tributaries together," arguing that this "masks the impacts" and that the "analysis must be redone and each tributary's impact should stand alone." Some complain about the failure of the SED "to evaluate and disclose the lessons of the failed Vernalis Adaptive Management Plan (VAMP) experiment." Some complain that the SED does not include analysis of effects in "dry and consecutive dry years." Additionally, some assert that the SED "relies in part upon incomplete and out-of-date scientific information." Others complain that the SED "presents a confusing analysis" instead "of presenting the evidence and logic underlying the assumptions made in the impact analysis."

Many respondents ask that the SED be revised and recirculated for a wide variety of reasons, including inappropriate project description, inappropriate baseline, inadequate analysis of impacts, inadequate consideration of mitigation measures, and an inadequate range of alternatives.

Respondents complain that the SED does not actually contain a program-level analysis in spite of claiming to do so. They ask that the SED be revised to "disclose the level of detail and analysis required by a program-level analysis and conduct such analysis."

Others complain that the SED omits "any account of the known hydrodynamic fate of San Joaquin River flows in the presence of Delta export pumping." They note that these hydraulic relationships "affect the dynamic size of the low salinity zone…[and] the volume of Delta outflow, rates of fish entrainment and death at the export pumps, survival of migrating salmon smolts and the survival of sensitive open water (pelagic) fish."

Respondents criticize the SED for failing to identify areas of known controversy or dispute.

Some assert that the Board is "required to analyze implementation and set for a plan of implementation in the SED." They object to the creation of the Implementation Workgroup and suggest that having this group develop the implementation plan in place of the Board is "unlawful." Others ask that the SED analyze the impacts of the adaptive management plan.

Others comment that in spite of promises "that the Water Quality Control Plan would include a full CEQA examination and consideration of alternatives," the SED fails to do so.

Project Description

Respondents criticize the SED for lacking a legally "adequate project description." They assert that nowhere in the SED "is there a clear concise description which sets forth the objectives of the proposed project and measurable benefits that will be achieved by implementation of the proposed project." Some also criticize the project description because it "fails to describe the program of implementation in sufficient detail to conduct a legally adequate evaluation of the environmental impacts." Further, they are concerned that the project description "excludes from the Plan area the

Upper San Joaquin River above Merced River." They note that the Board "cannot legally exclude" this area because it contributes "nearly 35% of the unimpaired flow of the entire San Joaquin River basin." Respondents similarly complain about the exclusion of upstream rim reservoirs on the Upper San Joaquin River from the plan area.

Respondents assert that the SED "fails to explain why certain areas are included and others are excluded." Further, they complain that the "SED fails to explain how the departure from the geographic scope of the 2006 Bay Delta Plan is supported."

Some complain that the SED didn't "describe the upstream facilities of the SFPUC [San Francisco Public Utilities Commission] in adequate detail and excluded the SFPUC's service area from consideration." They protest that the project description "incorrectly assumes that the SFPUC's operations will not be affected or modified" and so the SED "fails to consider the impacts of reduced water supply on the SFPUC… and the resulting economic impacts on the Bay Area."

Some respondents request that the SED include "consideration of future action to restore Hetch Hetchy Valley in Yosemite National Park."

Baseline

The baseline is of concern to several respondents. Some ask that the baseline be recast to "assume 100% compliance with the standards" and that the alternatives should be designed to completely comply with those standards. Some point to the use of the 2009 Department of Water Resources State Water Project Reliability Study (DWR Reliability Study) as "the inputs into the Water Supply Evaluation Model (WSE Model)" as a fundamental flaw in the analysis. They complain that this study "grossly misrepresents operations of the New Melones Project on the Stanislaus River" and conclude that use of the study "as the input assumptions to the WSE Model results in an erroneous depiction of conditions and cannot be the basis of comparison for alternatives." They also note that inclusion of the June 2009 National Marine Fisheries Service's Biological Opinion and Conference Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (NMFS BiOp) Reasonable and Prudent Alternative 3.1.3 (June 2009 BiOp Appendix 2-E flow schedule)" is problematic because the "June 2009 BiOp flows have been set aside by a Federal Court." They suggest that including the BiOp in the baseline is therefore a "prejudicial error." Others argue that the SED should include the Operations Criteria and Plan (OCAP) Table 2E requirements "that have been in place since 2009" to ensure a more accurate baseline.

Others complain that the SED omits "flows from the San Joaquin River Restoration Program (SJRRP)" and since this agreement "existed at the time of the NOP" it "ought to have been included in the environmental setting and baseline." In a related vein, several respondents criticize the inclusion of the VAMP in the baseline because doing so "mischaracterizes the existing physical environment."

Other items that respondents argue should be included in the baseline are:

- D-1641 Vernalis flow requirements met by the Central Valley Project (CVP)
- D-1641 Vernalis water quality requirements met by the State Water Project (SWP)/CVP
- Ripon dissolved oxygen (DO) requirement
- NMFS Biological Opinion (BiOp) instream flow requirements (Table 2E)
- NMFS BiOp interim temperature objectives
- NMFS BiOp Vernalis April/May flow requirements

- OID/SSJID entitlement diversions
- SEWD/Central San Joaquin Water Conservation District (CSJWCD) CVP contractor deliveries
- Baseline of southern Delta diversions
- Quality and quantity of water contribution from land to the west of the San Joaquin River.

Some make the more general comment that the baseline does not meet minimum legal requirements because “[w]ithout explanation it omits relevant aspects of the existing physical environment while contemporaneously adding other features that were not part of the existing physical environment.” This results in an “inaccurate baseline that contaminates the SED’s study of environmental effects.”

Several respondents complain that the baseline does not “describe existing physical conditions.” Some ask why the baseline was not adjusted to “reflect the change in the Board’s regulatory approach” as reflected in the revised NOP issued in 2012.

Mitigation Measures

A number of respondents complain that the SED “fails to identify and evaluate all feasible mitigation measures.” They note that both flow and non-flow mitigation must be considered and cannot be “summarily” dismissed. Some point out that there are a variety of flow measures that could be discussed including “pulse flows, highly variable flow regimes, outmigration flows, and flow regimes by water year type.” Additionally, respondents argue that the SED must consider non-flow mitigation measures such as predator suppression. Further, the SED must provide analysis to support conclusions that measures are infeasible. Respondents note that to comply with CEQA the SED must “identify feasible mitigation measures for each significant environmental impact.”

Some also assert that the “export projects” should be required to “fully mitigate the impacts…on fisheries” before others are asked to mitigate the effects.

Antidegradation Analysis

The Antidegradation Analysis is of concern to several respondents. They argue that it does not provide the economic or social analysis that is required. As a result, they assert that the salinity objectives should not be approved. Some argue that the “export areas served by the Central Valley Project and the State Water Project have “never [been] designated as a beneficial use for purposes of Delta water quality planning” and therefore cannot be considered as areas of “important economic or social development” in the State Water Board’s analysis. Several respondents assert that a full antidegradation analysis must be completed as required by state and federal law and should be available for public review and comment before the release of the final SED. Some argue to postponing the antidegradation analysis until the implementation phase violates CEQA.

Some respondents note that the SED “fails to analyze what environmental impacts the proposed project will have on the Bay Delta Estuary despite no longer protecting those beneficial uses.” They note that this “threatens to violate the state’s Antidegradation Policy without any analysis or explanation.”

Development and Range of Alternatives

Respondents note that the SED does not include alternatives that would meet the requirements of the "rules for evaluation of alternatives" that it sets out, and complain that the SED does not provide legally sufficient information or reasons as to why the State Water Board eliminated other alternatives from analysis.

Some respondents argue that the SED should include alternatives that would provide reasonable protection of fish and wildlife beyond just the unimpaired flow alternatives analyzed. Others are concerned that the SED provides inadequate explanation for why some alternatives were considered but not analyzed. Some note that the Board is required to consider "a much broader set of alternatives" including "non-flow alternatives." They suggest that pulse flows, improving riparian habitat, gravel enhancement and augmentation, and reduced ocean harvest could also be considered in the alternatives. Some respondents go on to say that the alternatives presented are not actually separate alternatives, but are "simply gradations of the same alternative." Some ask that the Board "analyze reasonable alternatives to 'mimicking the natural hydrograph'" and alternatives to the "draft narrative flow objective." They note that the SED "fails to analyze whether there are flow alternatives that would support native fish populations and that could potentially reduce the significant impacts to water supply."

Proposals for New Alternatives

Several respondents suggest that the State Water Board should provide an alternative that "includes a comprehensive land retirement program that would greatly reduce the discharge of salts."

Respondents suggest that the SED "needs to evaluate the USFWS [U.S. Fish and Wildlife Service] proposed alternative from the 2005 Anadromous Fish Restoration Program [AFRP] Report." Some specifically ask for the inclusion of an alternative that is "consistent with the AFRP doubling flows and is based mostly, but not solely, on percent of unimpaired flow."

Some ask that the SED include an alternative that "considers flow contribution from the upper SJR." Additionally, respondents ask that the SED include an alternative that "includes contributions from Friant flows."

Several respondents ask that the Board include "analysis of a predation alternative because it would mitigate significant impacts arising out of the existing alternatives."

Respondents also ask for the analysis of "other reasonable flow alternatives" including unimpaired flow for a shorter time frame (February through May rather than February through June), pulse flows, and one that tailors "specific flow regimes for each tributary based upon different flow functionality goals." Some ask for the Board to include an alternative that "analyzed the reservoir rule curves as currently modeled in the SED" as an alternative for reservoir operations (a "minimum impact to storage alternative"). At minimum, they assert, the SED should "have developed a suite of alternatives for reservoir operations and analyzed the impacts of flow alternatives under these different reservoir operation scenarios."

Respondents ask that the SED include an alternative that "applies the same objective to Vernalis and the South Delta in order to compare water costs and effectiveness with the baseline."

Alternative Selection

Respondents criticize the analysis for failing to "disclose the evidence-based reasoning that led [the Board] from the alternatives" to their preferred alternative. Further, some argue that the SED does not provide sufficient evidence to "support the conclusion that there are no feasible alternatives to the Preferred LSJR Alternative." They also argue that "[n]one of the LSJR flow alternatives are feasible because there is no real-time data that would enable water suppliers to manage their diversions on a 14-day running average percentage of unimpaired flow." Others are concerned that the SED does not "provide any analysis of the potential environmental effects of the range of possible flow patterns the Executive Director may order in the future."

Respondents ask that the Board evaluate "whether there are less costly alternatives that would be equally effective in achieving environmental protection" and they note that doing so is required by Health and Safety Code section 57005. Others ask that the SED include an "evaluation of alternatives for how to get the most good from use of the limited water available."

LSJR Alternatives

Some respondents complain that the range of LSJR alternatives is problematic. They argue that the selection criteria are "not rooted in CEQA and fail to demonstrate a connection with the project objectives." Further, they note that since the central objective is to "adopt a standard that is protective of native fish populations" and since 60% flows have been identified as the "level necessary to restore migratory fish populations," 60% flows should "set the floor, not the ceiling in shaping alternatives" to be analyzed.

Respondents also note that the SED incorrectly refers to "existing LSJR Flow Objectives;" they note that there is a San Joaquin River Flow Objective and ask that the SED "be revised to address the change in geographic scope and provide support for such a change."

Respondents complain that because the program of implementation "provides no numeric or otherwise measurable requirement, a water right proceeding or 401 certification cannot implement" the narrative objective.

Several respondents object to the 14-day running average and suggest that a shorter time frame is more conducive to creating a natural hydrograph. Some prefer a 3-day running average and others suggest a 3- to 5-day running average. Some also suggest that these shorter running average periods be combined with "no limit on maximum flows" to "achieve a more natural hydrograph that is needed for a healthy river ecosystem."

Narrative Objective

Many respondents ask for "additional specificity" in the narrative objective and ask for clearer definitions of terms including "viable, reasonably controllable measures" and "conditions that reasonably contribute toward maintaining fish populations." Respondents also ask for the inclusion of "explicit, measurable objectives." Some ask for clarification on the relationship between the narrative objective and the numeric flow objectives. They note that the "existing Salmon Narrative Objective and the San Joaquin River Flow Objective are two separate objectives." Further, they note that the Board "did not provide public notice" that it was reviewing the Salmon Narrative Objective even though the Board refers to a "single narrative flow objective." They complain that the SED does not analyze the "effects of changing the Salmon Narrative

Objective." Some also assert that the SED "fails to provide a legally or scientifically sufficient analytical link between the proposed narrative objective and implementation flows, and potential flow-derived benefits for salmonids."

Some express concern that the SED does not "disclose or evaluate the environmental impacts from changing the narrative objective." Additionally, some ask that the SED evaluate whether the "protection offered by the new Narrative Objective is more or less protective than the previous salmon doubling objective." Some ask that the Board provide a "redline/strikeout version of the Bay-Delta WQCP to show that the narrative salmon doubling objective will remain as an objective in the Bay-Delta WQCP after this update."

LSJR Alternative 1 – No-Project Alternative

Several respondents argue that the no-project alternative does not accurately describe the actual circumstances that would exist if the State Water Board took no action. For example, they assert that the SED misrepresents the seniority of water rights to OID and SSJID and therefore makes inaccurate conclusions about water delivery reductions. Some note that the no-project alternative must include the NMFS BO Action IV.2.1 "which requires the irrigation districts to provide minimum flows at Vernalis between April 1 [and] May 31."

Respondents note that the WSE Model, which is used to estimate the effects of the no-project alternative, "assumes water delivery and reservoir storage constraints that do not exist and would not exist if the State Water Board took no action" and therefore the WSE Model "skews the no-project analysis and misrepresents the environmental impacts." Others note that this alternative "is not viable and will result in the New Melones Reservoir emptying in dry years." Some assert that the analysis "does not accurately analyze the impacts of the no-project alternative on aquatic resources."

LSJR Alternatives 2–4

Several respondents support the 60% flow alternative and assert that these flows are needed to protect "viable salmonid populations." On the other hand, some respondents are concerned that the 60% flow alternative "does not adequately protect or account for other competing needs."

LSJR Preferred Alternative

Confused about which alternative is the preferred alternative, some respondents inaccurately complain that the "State Water Board has not adequately explained why Alternative 2 was selected when the SED explicitly acknowledges that this alternative would result in 'significant and unavoidable impacts' to wastewater service providers that would be unable to reliably meet new NPDES effluent limitations."

Respondents note that because the Board has identified Alternative 3 as the Environmentally Superior Alternative it must "provide an explanation" as to why it is not feasible. Further, they note that the preferred alternative does not "meet the objective of water quality standards that protect sensitive beneficial uses" and so cannot be selected over the Environmentally Superior Alternative.

Others complain that the SED "relegates too many critical factors to the implementation phase," which results in the SED providing "insufficient information to determine whether the preferred alternative is the environmentally superior alternative." In this vein, some respondents request that the SED provide "clear standards or [an] explicit decision making framework…to support the recommendation."

Respondents note that both NMFS and the U.S. Environmental Protection Agency (USEPA) have "posited that a standard of 35% of unimpaired flows is simply insufficient." Therefore they assert that the proposal of 35% is not a "justifiable standard."

Respondents request that the SED include a figure showing the "effect of using a 14-day running average as compared to using daily unimpaired flow values."

SDWQ Alternatives

Some respondents object to the inclusion of "just two options that would be different from the salinity objectives included in the existing 2006 Bay-Delta Plan." They argue that the Board should expand their alternatives to include one with salinity objectives "between those advanced in SDWQ Alternative 2 and Alternative 3." They believe that such an alternative would "offer a superior environmental alternative." Respondents also more specifically criticize the SED because it "did not consider alternative salinity levels between 1.0 and 1.4 dS/m." Other respondents oppose the preferred alternative because they believe it does not incorporate "adequate mitigation for the 'significant and unavoidable impacts' to wastewater service providers." These respondents make several suggestions for mitigation that could be added, such as the following:

- Different or additional averaging periods
- Mixing zones
- Site-specific objectives
- Revised permit implementation language

Respondents criticize the no-project alternative because it assumes full compliance with "flow and water quality objectives in the 2006 Bay-Delta Plan," noting that the "clear, uninterrupted and unchanging history of the southern Delta salinity objectives is one of non-compliance."

Technical and Editorial

The following editorial changes are requested by respondents:

- Clarification that the Grant Line Canal is not "two parallel canals." The Fabian and Bell Canal is a separate canal and is "a single channel, not two." (page. 2-32, Section 2.6.1)
- Use "rivers" instead of "streams" in Section 7-13.
- Correct the boundaries of the Stockton East Water District in Figure 2-5
- Consistent use of the terms San Joaquin River (SJR), San Joaquin River basin (SJR basin) and Lower San Joaquin River (LSJR) to eliminate potential confusion.
- Clarification that the Stockton East Water District owns one-third of the Goodwin Dam (page 2-2).
- Clarification that the Stockton East Water District is a water conservation district (page 2-3).
- Clarification that the Stockton East Water District has 95,400 irrigated acres (Table 9-5).
- Clarification that the Stockton East Water District's groundwater management plan was approved on May 9, 2006.

- Precisely give the percentage difference between the median and average flows (pages 2-15, 2-20, and 2-27).
- Revise Chapter 7 to include more of the background information to "adequately present the needed technical foundation to evaluate the assessment results."
- Include all the alternatives (including the no-project alternatives) in Table 8-1 to allow for "side-by-side comparisons."
- Addition of subheadings in the impact analysis.
- Include the Central Valley Project Improvement Act in the "Relevant federal programs, policies, plans or regulations" (Section 7.3.1).

Proposed Water Quality Control Plan

Many respondents are concerned about the adaptive management plan. Some ask for clarification as to whether the adaptive management plan can change the LSJR Flow Objective and whether this is "creating a different avenue to revise the water quality objective."

A number of respondents ask for clarification on the adaptive management plan. These requests include the following:

- Increased detail on the annual and longer-term adaptive management.
- Clearly defined resource objectives.
- Clarification of the roles, responsibilities and authorities of the Implementation Workgroup and COG.
- Clarification of the structure and function of the decision-making process.
- Definition of the specific criteria that will be used to trigger management actions.
- Definition of timing requirements.
- Clarification of the role of the Executive Director.
- Clarification of the membership of the COG.
- Clarification of the relationship between the adaptive management plan and the flow objective.
- Definition of annual specific and measurable objectives that the Board is attempting to achieve.
- Definition of specific and measurable long-term objectives.
- Evaluation of how "scientific rigor…can be obtained when management actions are changed on an annual basis."
- Clarification as to how adaptive management and monitoring will be funded.
- Definition of the term "real-time adaptive management" and how it differs from annual adaptive management.
- Clarification as to who will conduct the monitoring and at what level of precision.
- Inclusion of an "adequate process for implementing and evaluating higher flows."
- Inclusion of independent science review and advice.

Respondents are concerned that the program of implementation (POI) does not provide sufficient detail to support a determination that it will be capable of achieving the LSJR fish and wildlife narrative objectives. Others complain that the POI is "not clear regarding whether it intends to implement the LSJR Flow Objective, the Narrative Objective, or both." They also note that because the POI "does not include implementation measures for the LSJR Flow Objective, the proposed project violates the Porter-Cologne Act." Some ask that the State Water Board "used the three phase (nine-step) adaptive management process described in Appendix A of the Final Draft Delta Plan… as an ongoing framework." Others note that the State Water Board must include actions in the POI that would "incentivize compliance" and that without these the Board "cannot implement its plan." Some argue that the role of the Implementation Workgroup "must be limited" and that the "program of implementation and SED should make clear that the State Water Board members will make an independent determination of the appropriate balancing of beneficial uses." Others insist that the POI be "altered to clearly state that the USBR and DWR obligations for meeting the southern Delta water quality objectives remain unless and until the to-be-conducted water rights proceeding determines and assigns otherwise."

Some respondents ask that the State Water Board "elevate the role of independent science within the adaptive management plan." They also suggest that independent scientific review be required for "reviews of project operation and review of proposals to modify management actions." Some ask that the adaptive management plan "follow a true scientific model of monitoring, special studies, and hypotheses testing."

Respondents also suggest that the "wide latitude provided to the COG undermines the SED analysis and public disclosure" and as such "amounts to an unlawful delegation and violates other periodic review requirements in the Water Code." Further, NMFS notes that it "may be difficult for NMFS to participate in the Board's adaptive management process such as the COG…[because] NMFS currently has limited staffing and our resources are already full." Therefore, they ask that the Board "provide the staffing."

Respondents ask for clarification of how the Board intends "to improve the quality, quantity and access to floodplain habitat in the LSJR and its major salmon bearing tributaries with either (1) significantly higher flow to inundate the floodplain or (2) extensive restoration projects to provide habitat at lower flows." Others ask for clarification as to "what the benefit of the new requirements…would be and how they would improve upon coordination, operations, and actions that are already in place and working well."

Plan Development

Respondents argue that the Board should have "identified… the various water demands" for beneficial uses and then should identify "which of the beneficial uses are the most sensitive, so that it can comply with the federal Clean Water Act requirement that requires the most sensitive beneficial uses be protected." Because the Board did not follow this path, these respondents assert that the plan does not comply with the Clean Water Act. Further some respondents assert that the Board must "weigh and balance the beneficial uses against each other and demonstrate a rational connection between the proposed project and the benefit to fish and wildlife." They note that such an analysis is not included in the SED. Others assert that this lack of an analysis of the balancing of beneficial interests "fails to meet the Board's obligations under the Public Trust." Additionally, some respondents assert that the Board "needs to determine the amount of water available for appropriation" and then determine the "volumes of water needed…[to] protect (and sustain) the beneficial uses and …the public's interest in that beneficial use." Some criticize the SED for not containing "any explanation of what balancing factors were taken into account to arrive at the proposed objective." Further, they are concerned that the balancing factors "were not equally weighted;" they note that impacts on the agricultural sector and water supply "were determined using worst-case scenario assumptions" while the impacts on fish and wildlife resources "were determined using best-case scenario assumptions."

Some respondents are concerned that the "proposed timelines associated with developing the adaptive management process…and Implementation Plan…are extremely aggressive." Further, they note that given the "complexity and level of effort" associated with developing an adaptive management plan, the Board should not delay these steps until after the Office of Administrative Law approves the plan.

Other respondents are concerned that the phasing approach to the planning process will extend the process into 2015 or farther. Since they are revising the 2006 Bay-Delta Plan, this means that the process will take 9 years or more. These respondents ask whether the Board "has legal authority to undertake" such a lengthy process. Some ask that the Board "pursue a comprehensive solution that is consistent with the timing of the overall comprehensive Delta planning process and which takes into account the potential impact on hydroelectric energy generation."

Respondents express concern that the proposed project "delegates duties to the Executive Director in violation of Resolution 2012-0061."

Relationship to Other Programs/Policies

Respondents ask that the Board "disclose the vital role of federal Clean Water Act policies and regulations with which the State Water Resources Control Board must comply." They note that the intent of the CWA is for water quality control plans to "be used to improve water quality, not merely maintain it." Additionally, some note that the Board appears "to have also shaved the science-based 60% flow figure down to the flawed 35% flow through a misplaced reliance on Porter-Cologne …rather than protecting the most sensitive beneficial use as required by the CWA." Additionally, respondents note that the Water Code requires that the program of implementation must "include a description of the actions which are necessary to achieve the objectives;" since development of the POI has been deferred, this information is not available and "is an impermissible failure to analyze the whole project under CEQA." Some respondents argue that because the "draft POI would effectively allow for amendments of the water quality control plan through an adaptive management program," it fails to comply with "the procedural requirements of Porter-Cologne and the APA that are applicable to the promulgation of [a] water quality control plan."

Respondents note that "existing federal and state law…requires the doubling of the natural production of Chinook salmon, from the 1967–1991 average." Given this, the respondents are concerned that the SED "proposes a narrative objective for salmon that is significantly weaker than the existing objective."

Some respondents are concerned that the plan area is problematic. They note that the Bay Delta Plan covers a specific geographic area and that the proposed project "seeks to regulate waters outside the scope of the Bay Delta Plan." They assert that this change to the geographic scope is "unlawful" because the Board did not provide notice of the changes and because Water Code prohibits regulation of waters outside the plan area as part of a review of the plan. Others assert that because the plan area no longer spans more than one basin, the "LSJR Flow objective is in reality a localized basin plan that is the responsibility of the Central Valley Regional Water Quality Control Board."

Respondents also assert that the plan "conflicts with the Legislature's mandate for a comprehensive Delta Plan under SBX7-7, which has been in progress for over three years by the Delta Stewardship Council." They also argue that the proposal conflicts with the Bay Delta Conservation Plan (BDCP) (now referred to as the California Water Fix). Others ask that the SED be revised to "include the relevant information and analysis developed by the BDCP." Some also ask for clarification as to how the plan development will be "coordinated with the Board's review of the change petition for BDCP."

Respondents complain that the policies in the Delta Protection Acts of 1959 and 1992 and the Watershed Protection Act are not included in the regulatory setting. Others ask that the description of the California Water Fix be corrected to note that the "remanded biological opinions will not be in operation until the 'new water conveyance infrastructure identified in the Plan becomes operational.'"

Others note that salinity objectives "should be met without disproportionately burdening New Melones and consistent with federal law, HR 2828 (Public Law 108-361), which mandates a reduction in reliance on New Melones to meet the water quality objectives."

Respondents also assert that the proposed project is "unlawful because the State Water Board failed to fully implement the 2006 Water Quality Control Plan." These respondents note that "failure to fully implement the objectives amounts to a de facto amendment without complying with the procedural requirements for amending a water quality control plan." They also specifically note that the Board failed to implement the non-flow measures in the plan even though they were identified as being "needed to achieve the protection of beneficial uses." They argue that since the Board failed to previously implement the non-flow measures in its earlier plans, the Board "is precluded from revising the flow measures to require increased flow from the San Joaquin River."

Some respondents express concern over the plan's reliance on the FERC relicensing process. They note that if the State Water Board "intends to rely on FERC proceedings to build a scientific basis for informing the development of instream flow objectives, continual oversight will be necessary to ensure an adequate record." Further, they note that the "FERC proceedings on the Merced and Tuolumne Rivers cannot be relied upon to inform development of flow objectives at downstream points within the southern Delta itself, such as Vernalis or the Stockton Deep Water Ship Channel." Others assert that "to the extent the State Water Board wishes to use the FERC proceedings to implement the LSJR Flow Objective, the State Board must first establish that the project undergoing relicensing is preventing the achievement of the LSJR Flow Objective." They further note that "the State Water Board has not made this finding and the SED does not provide sufficient information upon which such a finding could be made." Some also note that the State Water Board does not "have the authority to control FERC operations" and so "does not have the jurisdiction to control the Irrigation Districts reservoirs."

CDFW notes that the SED references Fish and Game Code sections 6430-6439 and that these sections were "repealed in 2004." They ask that the SED reference the correct sections of the Fish and Game Code and the California Code of Regulations.

Additionally, some respondents note the "analysis of the SDWQ Alternatives …is deeply flawed because it assumes under baseline conditions there will be egregious violations of the existing southern Delta EC objectives." Further, they take issue with the fact that the Draft SED "concludes that relaxing [the] objectives under the SDWQ alternatives will not have any significant impacts on water quality because relaxing them will be similar to the situation where there is no effort whatsoever to meet the existing objectives." Some also assert that the proposed relaxation of the salinity objectives is not "consistent with the Board's antidegradation policy" or "with the requirements of the federal Clean Water Act."

Respondents ask that the Board clarify the nature of the "tributary rule" as referenced in Section 5.2, provide a citation for and explanation of the rule, and explain how it "could apply to the LSJR Flow Objective." Others ask for the SED to be revised to "clarify the relationship between the proposed project, SJR flows, and the X-2 requirement."

Respondents also note that the Board must "comply with the Delta Reform Act" and that the "Board has reversed the logical order of policy making" by lagging behind the "progress of the DSC's [Delta Stewardship Council's] Delta Plan." Others ask that the SED explain how the proposed project will comply with the Raker Act. Some assert that the draft salinity objectives "fail to adequately consider" Water Code section 13241 factors. Some also ask for the SED to be revised to include a discussion of the federal Endangered Species Act, federal reclamation law, and other federal laws that "affect water supply, surface hydrology and water quality, either directly or indirectly."

Respondents insist that the SED should include discussion of US PL 108-361 (HR 2828) as part of the regulatory setting. Others ask that the following be included in the regulatory setting section:

- Central Valley Project Improvement Act – Anadromous Fish Restoration Program (CVPIA-AFRP)
- Interim Biological Opinions for USFWS and NMFS
- Current update of the USFWS Native Delta Fish Recovery Plan
- Recognition of the development of a Central Valley salmonid recovery plan by NMFS
- The CDFW Incidental Take Permit (ITP) for SWP export operations
- Development of the BDCP (now the California Water Fix)
- Discussion of Essential Fish Habitat management under NMFS
- Central Valley Regional Water Board's Irrigated Lands Regulatory Program (ILRP)
- The Grasslands Bypass Project

Salinity Objectives

Respondents request that "any changes to the salinity objectives be delayed until the South Delta Water Agency and U.C. Cooperative Extension Office's study is complete and the State Water Board has thoroughly reviewed the resulting report." Others ask that the Board "analyze the potential impacts of relaxing the salinity objectives on hydrodynamics" because currently "water is sometimes released by the U.S. Bureau of Reclamation to achieve the existing salinity objective and any change in this objective would therefore, ultimately impact flows, temperature, and pollutant concentrations in the south Delta."

Several respondents note that "water exportation from the Delta has not been a designated beneficial use" and note that in D-1641 the "Board placed responsibility for meeting South Delta salinity objectives to protect South Delta agricultural beneficial uses on the shoulders of the U.S. Bureau of Reclamation and the California Department of Water Resources, the exporters themselves." Several also ask for clarification of why the Board is revising the salinity objective at all. Respondents assert that it appears that the Board "dislikes having to enforce salinity objectives on the Bureau and Department…in part because the violations are nearly continuous at times." Respondents argue that the Board is trying to reduce these violations by relaxing the salinity objectives rather than "by improving water quality." In a similar vein, some respondents point out that the analysis seems to assume that the State Water Board "will adopt water quality objectives but not enforce them." They argue that this is "in direct conflict with the requirement to provide a program of implementation."

Others assert that the use of "temporary barriers or low-lift pumping stations" is not needed to protect agricultural uses in the southern Delta and ask that they be removed as a "potential 'method of compliance.'"

Some assert that the State Water Board does not appear to have "adequately considered alternatives to the three proposed salinity objectives." These respondents also note that there was "little to no analysis or discussion as to why a 'maximum 30-day running average of mean daily EC' is being maintained." They further point out that several scientific reports "recognized that the agricultural beneficial use and other beneficial uses are 'affected more by longer term salinity averages.'"

Others note that "the western San Joaquin Valley tributaries cause most of the underlying salinity problems" and assert that the Board should "deal with the reality that irrigating those salty lands with water imported from the tidally-influenced Delta is an unreasonable use of water."

Flow Objectives

Respondents argue that the proposed project is "unlawful because flow is not a water quality constituent that can be regulated through a water quality control plan," and that flow is not a water quality "constituent or characteristic" of the water itself. Therefore, the Board "cannot regulate flow pursuant to the Clean Water Act."

Other respondents ask that the SED either include an analysis of the effects of the proposed changes to the October pulse flows or else remove the changes from the plan. Some assert that "the program of implementation suggests that the State Water Board intends to change the responsibility for meeting the October flow objective." However, they note that the Board "makes no mention of this reallocation in its environmental analysis." They argue that this omission means that the "SED is deficient."

Some respondents also ask that the State Water Board "begin at 45 percent of unimpaired flow… and allow for adaptation to lesser levels if and when populations are trending towards recovery and survival rates have dramatically improved." Further, they note that in 2010, "the Board issued a final report called the Development of Flow Criteria for the Sacramento-San Joaquin Delta Ecosystem" and that the report "determined that 60 percent of unimpaired flow from the San Joaquin River from February through June is needed in order to preserve the attributes of a natural variable Delta system to which native fish species are adapted." These respondents ask the Board to clarify how they determined that a 35% unimpaired flow would be sufficient. Some suggest that the 35% unimpaired flow would fail to meet the Board's public trust requirements to protect fishery resources. Others suggest that the percentage unimpaired flow proposed in the plan is "significantly lower than flow standards resulting from the use of the UF [unimpaired flow] approach elsewhere." They note that "actions below an 80% UF threshold 'will likely result in moderate to major changes in natural structure and ecosystem functions.'" Others note that the FWS recommended "76%, 86%, and 97% UF for the Tuolumne, Merced and Stanislaus Rivers." Some ask that the Board implement unimpaired flows of 50% on each tributary.

Several respondents express concern that the Board is "proposing a flow that is below current baseline conditions in the Stanislaus River." They note that the "Reasonable and Prudent Alternative (RPA) actions in the NMFS BiOp flow schedules are the minimum necessary to avoid jeopardy and are implemented as part of a suite of actions to manage year-round conditions of temperature, flow, and habitat to avoid jeopardy." Further, they assert that "setting a standard that merely avoids jeopardy is unlikely to achieve the doubling goal of the Bay-Delta Plan." Respondents also ask that the Board "make the salmon-doubling goal an explicit part" of the flow objective.

Several respondents also express concern that the limited range of flows (+/- 10%) may not allow for "a sufficiently broad range of flows." They note that this constraint "may inhibit the ability to implement management actions/experiments designed to address key uncertainties regarding the role of flows." Respondents also ask that the Board clarify whether the term "total quantity of flow" is "based on the preferred alternative amount (35% unimpaired flow) or the adaptive management range (+/- 10%) encompassing the preferred alternative."

NMFS "recommends adopting the NMFS and US Fish and Wildlife Service interim protective flows developed for the New Don Pedro FERC relicensing 2009 Administrative Law Judge hearings as interim measures subject to the Board's adaptive management process." They note that these measures "are necessary to improve the quantity, suitability, and consistency of the aquatic habitat for all life stages of salmon and steelhead in the Tuolumne River." They also ask for a "year-round flow schedule" for the Merced River. Further, they ask that the Board adopt the minimum flows for Vernalis that are found in the NMFS RPA. Some also ask that the Board clarify whether "adaptive management is individual to each Tributary or whether the adaptive management is for all Tributaries combined."

Others note that the "1000 cfs [cubic feet per second] minimum flow standard is not adequate to provide even minimal fish passage between the Delta and sections of the San Joaquin watersheds upstream of the Delta." Some respondents complain that the Board had failed to define the location of all four compliance points and note that because of this omission "it is unclear who is 'directly affected' by the regulation."

Additionally, respondents express concern that the proposed flows "will not provide essential ecological functions such as adequate variability of flows, magnitude of flows, and tributary baseflows that a natural hydrograph can provide." They particularly note that a "great deal of the variability is lost when one moves from a 3-day average to a 14-day average." Respondents also note that the caps on flow proposed in the SED "limit the benefits of high water years to aquatic life including the flushing of gravels used for spawning, and the creation of nursery habitat for juveniles in floodplains." They ask that the caps be reevaluated "because they allow for the delivery of less than 35% UF in the rivers at times when there is not risk of flooding." Some also note that "flows are needed year round, not just the February to June period, to support all CV steelhead life history stages and their habitat needs." Some assert that the unimpaired flow objective should "provide geomorphic function and allow for inundation of floodplain habitat"; they also note that "habitat restoration alone cannot make up for lack of flow."

Some respondents ask for clarification that the "maximum monthly flows are just that, maximum monthly flows, and not intended to represent maximum daily flows."

Others point out that the "unimpaired flow criteria are not well suited for real-time operations." Some also assert that the SED "is inadequate in its analysis as to how unimpaired flow standards produce the benefits expected, and if balanced against the economic impacts of foregone water storage and use, whether the non-flow options such as habitat restoration can more efficiently achieve the reasonable protection of beneficial uses." Some also note that a "more balanced approach would be to implement non-flow related actions first before considering additional in-stream flows."

Some respondents also ask that the flow objective include "a measurable, quantitative target." They suggest that the Board establish objectives that are "SMART (Specific, Measurable, Achievable, Relevant, and Time-fixed)" and that these objectives "reflect the intended outcome of the actions." Some also ask that the Board "clearly define unimpaired flow" and indicate that it is not synonymous with "natural flows."

Some respondents ask that the Board first identify "the various water demands for beneficial uses, which of the beneficial uses are the most sensitive, the increment of flows available for riparian and appropriative consumptive use, and then [propose] flow objectives in accordance with those findings." Additionally, some respondents ask that the Board consider "reduction or cessation of Delta pumped exports to allow instream flows to facilitate fish migration and turbid open water conditions needed by Delta smelt."

Respondents also ask that the State Water Board ensure that Section 5937 be enforced and ensure that the flow below Friant Dam be increased sufficiently to "sustain fish populations."

Natural Resources Management

Biological Resources (Fish and Wildlife)

Several respondents complain that the SED provides "no evidence" that the "proposed alternative will protect fish and wildlife." They note that the SED does not describe the "method and extent to which the proposed project protects the beneficial use of fish and wildlife," "the specific fish species for which the Lower San Joaquin River Flow Objective is supposed to protect," or "the quality or quantity of protection the LSJR Flow Objective will offer or how this protection will be measured." Some also complain that the SED "does not include an initial assessment of water available to protect fish and wildlife beneficial uses."

Some respondents complain that the SED relies on the Technical Report; they note that the SED misrepresents the conclusions of the report and also note that the report itself is "not supported by the best available science."

Some respondents ask that the SED explain the change in the purpose of the LSJR Flow Objective; they note that previously the objective "sought to protect fish and wildlife migrating through the Delta" but that the new purpose is "to protect fish and wildlife beneficial uses in the LSJR watershed and the eastside tributaries." Some complain that the SED defines fish and wildlife beneficial uses as "including San Joaquin River Basin fall-run Chinook salmon and other important ecosystem processes;" these respondents note that "'other important ecosystem processes' are outside the beneficial use of fish and wildlife" and "if the State Water Board would like to develop an objective to provide protection to ecosystems, it must notice a new process and develop a new objective." Several respondents ask that the SED's "aquatic impacts analysis be expanded to include significant impacts that occur as a result of implementing a LSJR alternative outside of the February through June window;" these respondents note that "aquatic resources are present in the Bay-Delta and eastside tributaries year round and thus [are] subject to flow impacts year round."

Some respondents note that the SED provides "no discussion or rationale… to support the 10% threshold of significance" used in the analyses. They note that the "BDCP Effects Analysis applied a 5% significance threshold" and argue that the 10% threshold "may underestimate impacts." Therefore they ask that the SED provide "technical support and transparency regarding how the 10% threshold was established" and a justification for "departing from the 5% threshold that is used in other EIR analyses of impacts to sensitive aquatic resources in the Delta."

Respondents complain that the SED "does not estimate the level of protection the proposed project will provide to fish and wildlife." Respondents note that the "assumption of benefit is not the same as a judgment of reasonable protection." Some also assert that "the proposed project will not provide flows that are more 'natural' than currently exist" and therefore "the proposed project cannot be said to provide reasonable protection to fish and wildlife."

Respondents note that the impacts of selenium can be significant to aquatic organisms and ask that the analysis address these issues more thoroughly. Respondents note that the "35% unimpaired flow level proposed for the Stanislaus River is not consistent with the riparian preservation and conservation policies for the state."

Some ask that CDFW policies be added under the heading BIO-1. They specifically reference Department of Fish and Game (DFG) Code Section 1389 Preservation and Enhancement and DFG Section 1385, California Riparian Habitat Conservation Act. Respondents also ask that the SED be revised to "include relevant information and analysis developed by the San Joaquin River Restoration Program (SJRRP)."

Wildlife

Respondents complain that the SED "fails to analyze effects as they related to freshwater invertebrates." They particularly notice the failure to analyze the effects of salinity on zooplankton. In this vein, some complain that the SED does not consider "phytoplankton, zooplankton, and micro-organisms that are much more sensitive to flow compared to fish." Respondents complain that the SED fails to adequately consider the potential effects of the plan on special-status terrestrial species. They suggest that many species' survival is "directly tied to agricultural landscapes" and that because the Preferred Alternative would result "in the fallowing of more than 100,000 acres of agricultural lands within the San Joaquin Basin" these effects could be significant. Others ask that the conclusion in BIO-4 that "there would be a significant impact on special-status animals resulting from the loss of riparian vegetation on the Stanislaus River" be "supported by a full description of the impacts on each affected special-status species."

Several respondents ask that the SED evaluate potential effects from selenium on the following species: San Joaquin kit fox, kangaroo rats, blunt-nosed lizards, giant garter snake, and California least terns.

Fish

Respondents express concern about the analysis of effects on fish species and note that many sections "such as those describing species life histories and stressors are poorly documented and many of the findings are not supported by either references or analyses."

Some complain that the SED does not contain sufficient information that "suggests February flows will benefit or otherwise protect fish species." Some also note that "[b]ecause there are few, if any, fish migrating through the system and flow requirements in June are responsible for such a large portion of the adverse impacts, June flows do not provide reasonable protection to salmon." Some also complain that the SED's "preferred alternative fails to adequately demonstrate any measurable benefits for salmon with respect to improving critical life functions and thereby improving salmon populations." Further, some respondents argue that the SED must be revised such that it considers all possible alternatives and to avoid a "decision that is arbitrary and capricious and in violation of the law."

Several respondents assert that the analysis of the 20% alternative is flawed. They note that the "conclusion that the 20 percent alternative will have significant impacts to aquatic resources is not supported." Further they note that the adoption of the 20% alternative would "not actually reduce flow on the Stanislaus River" in spite of the SED's assertion to the contrary. Further, they note that "having lower flows than currently exist does not alone support the conclusion that there will be insufficient flows for outmigration" and they note that the SED does not "identify the quantity of flow needed" to improve flow for outmigrating salmonids. Additionally, respondents note that the SED makes the "unsupported" conclusion that "predation is correlated with flow." They additionally note that the SED "provides no citation or scientific support for the conclusion" that the "20 percent unimpaired flow requirement would result in significant impacts to disease risk on the Stanislaus River." Finally, they note that the SED does not provide adequate support for the assertion that the "20 percent unimpaired flow requirement would result in significant impacts to transport on the Stanislaus River."

Respondents express concern that the SED does "not adequately consider how water management may impact the amount of flow actually available for fish." They are concerned as well that the SED "does not consider whether the adaptive management process would make available the maximum amount of unimpaired flow for fish." Others express concern over the use of the DFG Salmon Model; they assert that the model is "not the best available science," that it is "not an accepted statistical modeling approach," that it "is not robust and its conclusions can change drastically from minor changes in the fitting data," that "it has little predictive value," and it does not take into consideration "other stressors" beyond "measured flow." Others assert that the DFG Salmon Model simply "does not support the proposed project" and note that the SED "failed to run the DFG Salmon Model …for any of its proposed alternatives." Respondents also complain that the SED offers no "analysis of velocity and stage in the San Joaquin River system and the Delta on salmon." Additionally, some respondents note that the SED's own analysis is inconclusive and contradictory as it relates to the impact of higher flows on contaminants.

Respondents ask that the SED be revised to correct the analysis of project impacts on the "coldwater pool in Lake McClure." They assert that "[m]odeling performed as part of the FERC process on the Merced River shows that the coldwater pool will be dramatically reduced as a result of the proposed project" and ask that the SED be revised to analyze the "impact on coldwater fisheries accordingly." Some respondents further note that even though the San Joaquin, Stanislaus, Tuolumne, and Merced Rivers have been "listed as impaired water bodies due to elevated temperatures…there are no proposed objectives in the SED to protect the identified beneficial uses of cold fresh water habitat; migration of aquatic organisms; spawning, reproduction and/or early development of fish; and rare, threatened, or endangered species' habitat from elevated temperatures." They suggest this results in a failure to comply with the CWA.

Respondents are concerned about the apparent over-reliance on increased flows to address fish species population concerns. They note that there "is no consideration of restoration alternatives such as gravel replenishment and physical cleaning" even though these "alternative approaches will result in a benefit to salmon and do so without jeopardizing agricultural beneficial uses or other species' habitats."

The low dissolved oxygen and "other degraded water quality conditions in the Stockton Deepwater Ship Channel" are of concern to other respondents. They note that these conditions "can effectively close this migratory corridor for anadromous fishes." They note that flows of 2000 cfs would be required year-round at Vernalis "to avoid low dissolved oxygen conditions." Respondents who express concern about the temperature in the lower San Joaquin River and its effects on juvenile and adult salmonids' migration note that "based on the best available evidence…, flows of ≥5,000 cfs during the spring at Vernalis would be necessary." Additionally, they note that "when flows average ≥5, 000 cfs from March–June, population growth occurs the vast majority of the time."

Some note that the "SED fails to recognize the lack of consensus by regulatory agencies on the appropriateness of the HORB [Head of Old River Barrier]." They point out that "recent data suggests that an effort routing migrating smolts through Old River to the CVP pumps may prove to be a better option."

Several respondents are concerned that the SED does not pay sufficient attention to the issue of predation. Several note that the predation rates in the south Delta are extremely high "(greater than 95%)" and must be addressed in order for the increased flows to have the expected benefits to fish. Some suggest that the omission of 2012 Predation Study undertaken by the Modesto Irrigation District (MID) and the Turlock Irrigation District as part of the FERC relicensing process is "arbitrary and capricious in violation of the law and skews the entire analysis." Others note that because of the high predation rate "turbidity within the water column becomes a very important factor." However, they note that the "SED concludes the Preferred Alternative will not create turbidity;" therefore the preferred alternative "provides no measurable benefit to salmon through the creation of turbidity and does nothing to decrease the single biggest threat salmon face throughout the system." Additionally some note that the SED does not rely on the best available science and that there are "volumes of more recent and credible predations studies on the tributaries and the LSJR" than those relied on in the SED.

Some respondents ask that the "inadequate fish export facilities in the South Delta be addressed" and suggest that the Board should "require export agencies to replace the 1950 technology screens." Respondents also ask that the SED include "mitigation measures dealing with the impact of Delta diversions on aquatic species" to address that "small unscreened Delta diversions have the 'potential to directly remove fish from the channels and alter local movement patterns.'"

Respondents also ask that the analysis be updated to include more recent information on habitat conditions on the Merced River, discussion of the current hatchery review process, the development of hatchery management plans by CDFW for Central Valley salmonids, and "current disease investigations and assessments that have been conducted as part of the VAMP survival studies."

Some respondents ask that the SED address "how the proposed salinity changes might affect aquatic life" particularly how they might "affect striped bass and any other fish or aquatic plant species." Respondents ask for the State Water Board to clarify how the "threshold of one-foot per month [was] determined to weigh impacts to redds." They also suggest that "evaluating the effects of redd dewatering and fish stranding losses base on average monthly flow does not accurately capture the effects on aquatic species."

Respondents note that the SED does not sufficiently analyze potential impacts on the following fisheries: existing spring-run Chinook salmon populations in the Tuolumne and Stanislaus Rivers, steelhead, green sturgeon, white sturgeon, Sacramento splittail, or any of the Bay-Delta's native resident species.

Respondents ask that the SED evaluate and discuss potential impacts from selenium on the following species: Sacramento splittail, Chinook salmon, Delta smelt, rainbow trout, white sturgeon, greater and lesser scaup, and surf and black scoters.

The description of rainbow trout is of concern to some respondents, who note that the "sections describing rainbow trout/steelhead [do] not correctly describe rainbow trout." Several mention the need to "clearly define rainbow trout and steelhead classification" and avoid blurring "the lines between resident and anadromous rainbow trout in anadromous waters, and rainbow trout located above rim dams." Some ask that the SED be revised "to analyze the extent to which the proposed project protects steelhead populations."

Commenters recommended a number of revisions and corrections in the SED related to fish, such as the following:

- Include the San Joaquin River as part of the location for green sturgeon.
- Clarify the habitat description for green sturgeon to indicate that 8–14 degrees centigrade is the spawning temperature range and that adult habitat temperature can be as high as 22 degrees centigrade.
- Update the description of Delta smelt habitat to indicate that they occur both in the low salinity zone and in freshwater areas.
- Acknowledge that there is a recreational fishery for Sacramento splittail and update the habitat description.
- Include the San Joaquin River in the white sturgeon location.
- Include the Yuba, American and Feather Rivers in the American shad location.
- Acknowledge that there is a population of spring-run Chinook salmon on the Sacramento River and Butte Creek.
- Correct information about timing of Delta smelt migration to acknowledge that migration coincides with first flush, and update spawning information to include the north Delta and Cache Slough Complex.
- Update the description of Delta smelt diet.
- Acknowledge that longfin smelt are also found throughout the legal Delta including the Yolo Bypass and Cache Slough Complex.
- Update description of the Sacramento splittail diet.
- Update the distribution description for striped bass.
- Acknowledge that striped bass are a "major source of mortality to fishes throughout the delta, not just at the SWP."
- Include the Red Hills roach and Kern Brook lamprey in the special-status fish species table (Table 7-2). Both are state species of concern.

- Improve the analysis of green and white sturgeon.
- Reconsider the statement that none of the steelhead populations are considered to be viable, since current data do not support this conclusion.
- Correct references to Sacramento pikeminnow to reflect that pikeminnow is a native species.
- Correctly acknowledge that there are "no spring-run Chinook in the plan area."
- Correctly acknowledge that the population of Central Valley fall-run Chinook salmon has "been deemed by NMFS to be 'rebuilt.'"
- Include Delta and longfin smelt as Pelagic Organism Decline (POD) species.
- Update description of Delta smelt to acknowledge that "downstream transport [of larvae] is not an obligate life history trait."
- Include information about the effect of introduced species on native fish species.
- Evaluate entrainment of fish species by the SWP and CVP in the Bay-Delta estuary.
- Include a complete working salmonid life cycle for the LSJR basin.
- Acknowledge that it "is only a hypothesis that pumping may confuse outmigrating salmonids" and that there "are no studies that have established this hypothesis."

Additionally, some respondents ask that the Hatchery Operations section be revised to reflect that both the Merced River Hatchery and the Mokelumne River Fish Hatchery are considered part of the San Joaquin River Basin system.

Respondents also ask that the section on diseases be revised to include proliferative kidney disease (PKD) and to clarify that Ceratomyxa shasta is a myxosporidian.

Respondents ask that impacts AQUA-1 and AQUA-2 be revised "to reanalyze the impact of reservoir habitat without the assumption that reservoir levels will remain unchanged." These respondents note that "there is no support for the assumption that the proposed project will not affect reservoir operations." Some respondents note that the threshold of significance in AQUA-1 should be revisited to ensure it is "sensitive to the species habitat requirements and habitat preferences."

The analysis in AQUA-3 concerns respondents who assert that it "is not supported and is incorrect." They note that the "needs of spawning, rearing and migration habitat are not always the same… and the SED must be revised to separate the analysis and evaluate the environmental impacts of spawning, rearing and migration habitat separately." They also ask that the SED "be revised to include the flow and temperature "modeling results from Merced Irrigation District." Further, they ask that "migration habitat" be defined and that a "baseline for migration habitat" be established.

Respondents ask that the analysis in AQUA-4 be revised to include a "discussion of the source of information used in developing the incipient lethal threshold criterion." They also ask that the analysis "address the temperature tolerance of juvenile fall-run Chinook salmon that may be oversummering in the rivers." Respondents ask that the analysis be revised to analyze the "impacts of the proposed project on the USEPA temperature criteria." They note that the analysis should address "which temperature levels can be controlled with flow."

Some respondents assert that AQUA-5's "analysis of exposure to pollutants is inadequate and does not support a conclusion that water quality will be significantly changed." They further note that no data is provided "on existing pollutant levels in the water column versus in sediments on which to draw any conclusion regarding whether increased flow would have a positive or negative effect on water quality."

Respondents complain that the analysis in AQUA-6 "contradicts other analysis in the SED." They ask that the analysis is AQUA-6 be revised to reflect the analysis in Chapter 6, which "concludes the proposed project will result in little, if any mobilization."

Respondents take issue with the analysis in AQUA-7, noting that it "does not provide a baseline for existing dewatering or stranding" and without the baseline "the SED cannot properly determine the impact of the proposed project on stranding." They also note that "stranding and dewatering is an issue very specific to each tributary and specific reaches within each tributary" and ask that the SED be revised to "provide analysis of dewatering and stranding by reach." Others complain that the analysis is inadequate because "it is based on median monthly flow," which can "obscure meaningful changes in flows that occur in specific months under specific hydrologic conditions." Also addressing flow, some note that the use of median monthly flow "fails to properly analyze potential adverse impacts that are most stressful in dry and critically dry hydrologic conditions."

Some respondents are concerned that the analysis in AQUA-8 is problematic because the "conclusions regarding effects of the LSJR flow alternatives on spawning habitat quality are not supported by substantial evidence."

Respondents find that the analysis in AQUA-9 is problematic because the "SED does not provide a baseline for existing food web support." Further, they contend that the "SED does not analyze the impact of the food web on fish populations" and "does not analyze what food is currently available [and] which food sources could be increased." Others note that the analysis "lacks the support of substantial evidence."

Respondents similarly find that AQUA-10 does not provide a baseline for existing predation and "drastically underestimates the baseline impact of predation by stating predation 'pressures' are 'considerable.'" They also complain that the SED "does not analyze the extent to which prey vulnerability results in increased mortality from predation." Further, they note that while the "SED surmises that increased water temperature and increased prey vulnerability may be responsible for increased mortality due to predation" the "SED fails to compare predation and prey mortality rates in areas that meet and do not meet temperature standards." They assert that without this analysis the "SED cannot conclude that temperature affects predation."

Respondents also complain about AQUA-11. They note that the "SED does not provide a baseline for existing disease" and that without a baseline "the SED cannot properly determine the impact of the proposed project on disease." Further they suggest that the SED's analysis of disease must include other factors beyond temperature including "age, health, food, toxins, genetic variance and other factors."

Respondents criticize AQUA-12 because it "assumes that decreased travel time to and through the Delta will benefit fish," but the "SED does not analyze the impact of reduced travel time or provide scientific support for this assumption." They also note that the SED does not include the fact that "salmon smolts are volitional swimmers and swim faster than the velocity of flow in the LSJR and the Tributaries" in its analysis.

Some respondents ask that the analysis in AQUA-13 "be supplemented with Delta passage modeling results."

Hydrology and Water Quality

Respondents ask for clarification as to whether the "significance threshold of reducing baseline instream flow by 5 percent or more" applies to tributaries, the SJR or the Delta. Respondents note that the analyses in the Groundwater chapter and the Agricultural Resources chapter contradict each other. They note that the groundwater analysis "assumes that any and all surface water diversions no longer available from the tributary streams will be replaced with groundwater pumping." However, the Agricultural analysis assumes that "the loss of surface water diversions [will lead] farmers to taking …irrigated land out of production." They note that this results in "essentially double counting of impacts."

Some note that if flows on the Tuolumne are not available to the Regional Surface Water Supply Project (RSWSP), the three cities will use groundwater pumping "to keep up with the demand of providing potable water to existing and future residences and businesses."

Several respondents fault the SED for not adequately examining changes in reservoir operations that result from the various alternatives. They suggest that the "SED should have analyzed each of the storage operations scenarios, in turn, with each of the flow alternatives…to fulfill the role of the SED in helping decision makers balance impacts and benefits."

Respondents ask the State Water Board to "further evaluate reliance on median flows… to characterize seasonal runoff patterns." They suggest that the current reliance on median flows does not always provide accurate estimates of the seasonal runoff patterns.

Respondents ask for the SED to provide the reasoning behind using the range of 1984–2009 for unimpaired flow analysis. Some ask that the SED be revised to "disclose the historic amount of flow the tributaries contribute to the San Joaquin River" and to clarify what contributions are existing and which are historic.

Some respondents are concerned that the analysis of the 35% unimpaired flow "overstate[s] its equivalence to flows recommended by fishery agencies and conservation organizations."

Respondents also ask that the SED be revised to "correctly describe the system." Their specific requests include the following:

- Correct where water released at New Don Pedro Dam is regulated.
- Correctly acknowledge that Goodwin Tunnel is gravity fed.
- Acknowledge that water pumped at Jones Pumping Plant is "almost entirely SJR flow."
- Acknowledge that "very little, if any, San Joaquin River water [makes] it to the Delta."
- Correctly identify the upstream dams.

Hydrologic and Water Quality Modeling

Several respondents criticize the modeling used in the SED. They assert that the modeling is "so fundamentally flawed" that "it renders the entire document arbitrary and capricious." Respondents criticize the use of the Water Supply Effect Model (WSE) and note that the "assumptions built into the WSE have no basis in actual conditions and render the results virtually useless." Respondents suggest that the SED "need[s] to either use CALSIM II for all of its alternatives and modeling runs, or completely revise the WSE before it can be utilized." Respondents also complain that the SED "applied different models to different aspects of the SED which results in non-comparable results and erroneous evaluation of the environmental impacts." Respondents assert that all the conclusions in the SED that are based on the WSE must be reconsidered because the WSE is so flawed that no decisions can reasonably be based on the results.

Flaws respondents identified in the WSE include:

- Inaccurate representation of reservoir operations.
- Baseline and no-project alternative are not reflective of current operations.
- Inaccurate description of existing water rights.
- Application of a single-purpose reservoir rule curve.
- Inconsistent applications of existing ESA requirements.
- Incorrect description of water operations.
- Reduced deliveries to Stockton East Water District.
- Use of static reservoir operations.
- Inaccurate representation of the water available at New Melones for spring pulse flows.
- Insufficient estimates of agricultural return flow quantity and quality.
- Failure to check "whether the dissolved oxygen requirement on the Stanislaus is met."
- The use of CALSIM EC data that are not consistent with historical data.

Other modeling concerns include:

- The failure to describe the interaction between the proposed flow objectives and the NMFS BiOP RPA flow and temperature requirements on the Stanislaus River.
- The failure to fully consider and analyze existing monitoring data.

Water Resources

Some respondents complain that the SED "fails to assess how much water in the plan areas is diverted pursuant to riparian rights and how the SED proposed to regulate water diverted pursuant to a riparian right." Respondents also ask that the SED include estimates of in-Delta diversions.

Some respondents ask that the SED recognize that farming operations in the Delta increase water quantity because "wild vegetation consumes more water than farming operations." Others ask that the SED thoroughly evaluate and mitigate "impacts to groundwater quantity and quality…along with the impacts to those that rely upon the groundwater and the resulting economic impacts to the communities it serves."

Others ask that the SED be revised to include "the upstream reservoirs in the environmental analysis."

Some complain that the effect of the flow objectives on the Stanislaus River on "the availability of water to the County [Count of San Joaquin and San Joaquin County Flood Control and Water Conservation District] water districts is neither adequately nor specifically described."

Several respondents express concern regarding the adequacy of the groundwater impacts analysis. They ask that the suggested impacts be quantified in order to "fully disclose to SWRCB members the serious and grave impacts before a decision can be made." Some note that groundwater overdraft is an issue in San Joaquin County and ask that the SED include the direct and indirect effects of "a reduction in the provision of surface water and the corresponding impact to the groundwater basin and agricultural resources." Others are concerned that the SED "does not analyze the proposed project's impact to groundwater recharge." Respondents also note that the long-term groundwater overdraft has contributed to "intrusion of highly saline water into the Basin," which has resulted in the abandonment of several municipal and irrigation wells. They ask that the SED include discussion of the degradation of water quality "due to saline migration."

Respondents argue that the proposed project is "an unreasonable use of water" because the proposed project would have significant effects on agriculture, water supply, groundwater, and recreation without any demonstrable beneficial effects on fish and wildlife.

Some respondents feel that water levels should not be an objective of the WQCP "either as a numeric or narrative objective" because "[w]ater depth or, more specifically, water volume in a channel is a better indicator." Further they note that "imposing water level performance goals for the purposes of addressing water quality would be unreasonable because the barriers are not designed to be operable in real-time." These respondents also ask that "flow direction and magnitude, i.e., 'circulation,' should not be an objective of the WQCP" because "circulation in the South Delta is a complex and ever-changing sum of inflows from upstream sources" and therefore "the instantaneous flow at a given location changes rapidly … and is difficult to predict."

Respondents also ask that the SED be revised to correct information about the operation and effect of "the export and temporary barriers." Others ask that Appendix H of the SED be revised "to include an assessment of the potential impacts of new surface water supply projects in the southern Delta" and identify "potentially feasible mitigation measures to address any potentially significant impacts."

Some respondents ask that the SED be corrected to more accurately describe the water levels above and below the Old River barrier and the effect of the barrier on flow.

Water Quality

Respondents take issue with the analysis of water quality in the SED. For example, they note that the analysis of "water levels… is inappropriate as water levels do not affect water quality." Some also ask that the SED "explicitly identify the efforts on the part of the Central Valley Water Board to design and implement a regional monitoring program for contaminants in the Delta." Respondents also complain that the SED does not identify the "specific pollutants" that it expects will be affected by increased flow or how much those pollutants will be diluted.

Respondents are concerned that the compliance stations are not appropriate; specifically they note that the Old River at Tracy Boulevard Bridge should not be a compliance station because historically "this station poorly reflects the water quality being supplied to the South Delta…[because] exceedances at this station are adversely impacted by local high salinity discharges."

Some express concern about the analysis regarding water temperature and complain that the SED "fails to identify the criteria used to compare the alternatives' impacts on water temperature." Some are concerned that the time frame used for the analysis of impacts is inappropriate and that the analysis should address year-round effects on water quality. They also note that the SED does not support the conclusions regarding temperature with "substantial evidence." Respondents also contend that the SED does not provide sufficient support for the threshold of significance for temperature impacts. Some are concerned that "monthly average temperature is a rather coarse review of the temperature regime" and suggest that weekly maximum temperature is an "important consideration to protect against acute effects."

The relaxation of salinity objectives concerns several respondents. They are concerned about the potential negative effects on agriculture and ask that the decision be delayed until the "South Delta Water Agency study is complete." Respondents note that the San Joaquin River "is currently the only means of drainage of salinity imported into the San Joaquin drainage basin" and that such drainage is necessary "to maintain production of food." They ask that the SED examine the "environmental impacts of Regional Board and SWRCB programs for curtailing drainage flows and the cumulative impacts." Many criticize the SED for failing to "adequately disclose or analyze the effects of salt loading on the west side of the San Joaquin valley and how salt run-off from those areas contributes to the degradation of water quality in the Delta." Some also note that the SED should include an improved analysis of selenium issues in the Delta. They note that the "larger the salt load, the larger the selenium load." Further they point out that at elevated levels "selenium becomes actively poisonous" and threatens "many species, including salmon, white sturgeon, green sturgeon, and migratory birds." Some respondents also note that researchers "have not undertaken yet to model the potential impacts of climate change for the forecasting and handling of toxic contaminants like selenium in the state's water quality regulation and policy frameworks;" they ask that the Board "seek such research as soon as possible." Some note that the SED analysis "lacks any meaningful discussion of the substantial reductions in selenium and salt loads resulting from drainage management actions on the west side of the San Joaquin Valley." Others complain that the SED does not disclose the "violation of the currently existing salinity standard during April–August." Several respondents are concerned that the project could contribute to increasing salinity levels in groundwater and ask that the SED analyze the potential impacts from this increased salinity on drinking water treatment, agriculture, and increased groundwater demand.

Several respondents express concern over the analysis of electro-conductivity (EC) levels. Some are concerned that the use of monthly averages is inappropriate because it "masks the impacts of high salinity events/times" and because it does not "adequately describe what is happening in the null zones." Additionally, some are concerned that the timeframe of 1993–2009 "is too short" for the EC analysis and they note that "much more extensive data exists."

Respondents are also concerned that the SED does not analyze "the effects of the proposed flows and salinity objective on achieving existing objectives in impaired downstream river segments, e.g., attaining the dissolved oxygen objective in Old and Middle Rivers and meeting the load allocations in the Lower San Joaquin River Dissolved Oxygen Total Maximum Daily Load (TMDL)"

Some respondents ask that the SED analyze the potential changes in water quality in the Delta that could occur if "the water users in the San Joaquin Basin utilize more groundwater to offset the loss of surface water supplies."

Some ask that the State Water Board clarify the potential effects of increased flow on wastewater treatment plants along the rivers.

Respondents complain that requiring Reclamation "to provide assimilative capacity or to require Reclamation and DWR to install, operate and maintain barriers, conduct the specified monitoring, and conduct the specified studies" is "inconsistent with the goal of the Preferred SDWQ Alternative [and] unreasonable and unlawful." Many are concerned that the SED's analysis does not accurately reflect the various factors that influence salinity in the southern Delta. As a result, these respondents believe that the SED inappropriately assigns mitigation to the various parties based on the inaccurate assessment of responsibility for salinity contributions. For example, they note that "DWR does not cause degradation of water quality in the south Delta through manipulation of water levels and flows" and is not a source of saline discharges. However, the State Water Board still is "proposing to make DWR responsible for assimilative capacity for local sources and evapo-concentration of salinity in the south Delta."

Several respondents argue that the SED fails to adequately analyze and disclose adverse impacts on urban drinking water quality, including levels of organic carbon or bromide. Some respondents assert that the threshold used in the SED to assess impacts on water quality for municipal drinking water purposes is inappropriate and request that the threshold be "set to the WQCP's own water quality standard for protection of municipal and industrial uses of 1.0 EC."

Respondents also ask that the SED provide a more robust analysis of the potential effects from changes in operation of the Don Pedro Hydroelectric Project on the "water supply reliability for the Bay Area Water Supply and Conservation Agency's wholesale customer communities.

Hydropower and Energy

A number of respondents express concern about the analysis of potential effects on hydropower generation. Some note that the SED assumes that "reservoir carryover storage" would be "similar to the baseline" and that this assumption is "fundamentally flawed as increased flow requirements will necessarily reduce the water left in the reservoirs and thus carryover storage will be altered." Further, some note that some hydropower is generated by irrigation releases during the summer months and that "reduced reservoir releases for irrigation would reduce power generation when demand is at its peak." Respondents also ask that the SED be revised to include an analysis of energy demand as part of the impact analysis.

Some commenters ask that all the alternatives be analyzed on a year-round basis for their potential effects on hydropower, while others are concerned that the analysis is based on the WSE Model that incorrectly assumes that reservoir storage will remain unaffected by the proposed project.

Respondents complain that the SED does not evaluate the costs of replacement energy that would be required because of the proposed project's "shift of hydropower generation from summer to spring." They also complain that the SED "fails to analyze the impact …on the reliability of energy statewide," and note that unlike other renewable energy sources, hydropower "can be dispatched within minutes," which allows it to compensate for "over-stressed peak load hours." Respondents also ask that the SED evaluate the "hydropower impacts on the Governor's Clean Energy Jobs Plan."

Respondents ask that the SED include an analysis of the environmental effects from increased groundwater pumping that would result from the proposed project, including the increased use of energy.

Some respondents complain that the analysis "incorrectly assumes regional economic effects due to hydropower loss are 'virtually imperceptible' when compared to annual statewide electricity production." They assert that the impacts of the project "will be much more substantial and concentrated to the project area" and that the SED must analyze the regional hydropower impacts. Additionally, some respondents ask that the analysis be revised "to analyze the proposed project's impact to hydropower in dry and consecutive dry years."

Other Physical Elements

Respondents are concerned about the analysis of flooding, sediment, and erosion. Some ask that the SED specify the "point at which unimpaired flow requirements will be suspended" to allow for an adequate analysis of the impacts of flooding. Further, some complain that the flood risk analysis is based on the WSE Model that incorrectly assumes that reservoir storage will remain unaffected by the proposed project. Some also ask that the SED confirm that the "proposed project will not result in floodplain inundation" or increased turbidity. Some also ask that the SED provide "adequate analysis" for the assertion that the flow objective would not "expose people or structures to a significant risk of loss, injury or death involving flooding," particularly in wet years when "flooding is more likely and damage is more severe." Some respondents ask that the SED include an analysis of potential seepage issues resulting from the proposed project.

Some ask that the SED be revised to acknowledge the beneficial effect flooding and sedimentation will have on food production and availability. Others ask for the SED to analyze the "effects of additional siltation occurring if greater fishery flows are required."

Some note that recent flood events "especially 1995, indicated that the capacity at Vernalis was substantially less than the design capacity" and ask that the SED acknowledge this.

Air Quality

Respondents ask that the SED analyze the potential effects on air quality from increased use of diesel pumps for the pumping of groundwater. They ask that this analysis include the potential effects on human health and ask that mitigation measures be incorporated into the SED to address the air quality impacts.

Climate Change

Respondents ask that the SED be revised to address environmental changes as a result of climate change, including habitat changes, temperature, and sea-level rise. Additionally, they complain that failure to analyze the impacts on global warming is a "serious deficiency" and "conflicts with various state policies." Some note that the threshold of significance used in the SED for contributions to climate change and greenhouse gases lacks "an identifiable, quantitative, qualitative or performance level and is therefore insufficient for CEQA purposes."

Respondents note that climate change is likely to result in seal-level rise and that this will have effects on the rate at which surface flows drain into the Delta. This may also slow the escape of subsurface flow and "contribute to rising water table elevations" which may "disrupt agricultural production." They ask that the SED consider these potential effects of climate change in its analysis of the proposed project.

Several respondents complain that the SED does not address the project's cumulative effect on climate change, particularly as it relates to increases in greenhouse gas (GHG) emissions.

Others note that with climate change will come increased drought and as a result they ask for the Board to set minimum flows higher (some suggest 2,000 cfs at Vernalis year round) to ensure that flows are "sufficient to maintain fish and wildlife, water quality and recreational opportunities."

Service Providers

Several respondents note that the "CVP and SWP diversions from the Delta are the major cause of harm to fisheries and, accordingly, the CVP and SWP should mitigate all past, present, and future damage." Respondents complain that the SED's Preferred Alternative "fails to adequately implement or evaluate the principle that the CVP and SWP must mitigate for the impacts caused by export operations." Others ask that the SED "analyze what, if any, water quality impacts would occur to water exported by the CVP and the SWP."

Respondents complain that the SED fails to "evaluate the significant effects of the reduction of surface water supplies …within SEWD [Stockton East Water District]." Others ask that the SED evaluate the "potential water quality impacts of the proposed alternatives" at Contra Costa Water District's intakes. Some complain that the SED does not include San Francisco Public Utilities Commission's Hetch Hetchy Project facilities upstream of the Don Pedro Project and the SFPUC's service area in the plan area. Further they complain that the SED's conclusion that "the water supply, operations and water infrastructure of CCSF [City and County of San Francisco] will not be affected…is not supported by substantial evidence." In fact the "SFPUC's analysis... shows there would be dramatic and significant impacts on the SFPUC's diversions from the Hetch Hetchy Project…and the Bay Area economy assuming …that revised water release requirements ordered by FERC" could occur. Additionally, they complain that the SED does not recognize the potential effect of reducing water supply from the Tuolumne River to SFPUC.

Respondents complain that due to the "inaccurate project description," the SED fails to analyze the "reasonably foreseeable potential impacts to the SFPUC and the BAWSCA [Bay Area Water Supply Conservation Agency] member agencies and their service areas." They note that this failure "extends to the cumulative impacts … [and] the economic analysis."

Water supply to the city of Tracy is of concern to some; they note that the city "receives approximately 70% of its potable water supply from the Stanislaus River" and that the proposed unimpaired flows "will result in shortages during dry years." They ask the Board to "adopt more reasonable and attainable standards." They also ask that the Board "remember that the flow objectives being proposed may affect the salinity levels of Tracy's wastewater discharge" because the city may need to "return to using higher salinity groundwater in greater quantities."

Respondents also complain that the SED ascribes responsibility for salinity in the Delta to "municipal discharges" and note that these "findings are not consistent with the findings of the 2012 Technical Report and DWR Modeling Study of NPDES dischargers." Further, they complain that the cost estimates in the SED for construction of a reverse osmosis plant to desalinate water are too low "and inadequately estimate the full costs of constructing, operating, and maintaining reverse osmosis treatment, including brine disposal." Others complain that the SED assumes that development of reverse osmosis is a "reasonable" option. They ask that the SED consider other options that would help reduce the need for service providers to resort to reverse osmosis.

Some respondents complain that the SED does not "specify what specific actions municipal dischargers will be expected to take, if any, to implement the salinity objectives."

Others ask that the SED correct the description of service providers and the system, including the following:

- Correctly identify that the Oakdale Irrigation District and South San Joaquin Irrigation District sell hydropower to the California Independent System Operator (CAISO).
- Disclose that water is impounded at Goodwin Dam for diversion to SEWD and Central San Joaquin Water Conservation District.
- Acknowledge that OID and SSJID are not CVP customers or settlement contractors.
- Include analysis of how the proposed project will impact local irrigation districts.
- Acknowledge that Reclamation does not contract to deliver water to OID/SSJID.
- Include a more complete and accurate description of the contract between MID and the City of Modesto.
- Include analysis of the proposed project's impact on service provider pricing.
- Ensure the list of water suppliers is complete.
- Include analysis of impacts on water suppliers under a range of water year types.

Agricultural Resources

Respondents complain that the "Board ignores conscious [sic] Delta farming practices that manage salt and sustain their lands' fertility." Respondents also complain that the SED fails to discuss the data that is available on the effect of salinity on Delta agriculture.

They also complain that the SED misrepresents the water practices of agriculture and assert that irrigation district customers "make every effort to ensure the water is used efficiently." Some observe that while "agricultural uses have improved water use efficiency across California over the past several decades, it is clear that there are still substantial gains to be achieved and that improvements in agricultural water use efficiency can reduce the impacts of reduced water diversions." These respondents ask that the SED include an analysis of the impacts of improving water use efficiency.

Some respondents ask that the SED acknowledge that "water transfers can constitute a beneficial use of water that helps optimize water use throughout the state," noting that if existing and recent water transfers out of the basin are not considered, the "SED likely overestimates potential agricultural impacts."

Some respondents suggest that the SED's preferred alternative "will result in the loss of thousands of acres of agricultural land, including agricultural lands that are prime or [of] statewide or local importance." Further, they assert that the project will "result in the cancellation of untold Williamson Act contracts." They note that the SED therefore "violates" many local general plans, yet fails to analyze these impacts.

Respondents note that in the Turlock Irrigation District, there are very few acres of crops that could be temporarily left fallow as most acres are either permanent crops or dairy-related crops. They ask that the impacts on agriculture be fully analyzed, including the effect on the dairy industry of fallowing crops. Others note that the assumption that farmers will "fallow only low value crops…is problematic." They note that it is "contrary to local policies and rules on water shortage…and is contrary to the rules of water right priority."

Respondents also note that many acres in the region are orchards and that these crops both represent a significant investment and can be significantly affected by even 1 year of insufficient water. Respondents also ask that the SED include an analysis of the impacts from seepage from the Stanislaus River on agriculture, specifically on orchards.

Several respondents criticize the use of the WSE Model and the SWAP Model to support the agricultural resources analysis. They note that the SWAP Model is "driven by the water supply effects of the WSE Model" and "therefore the defects of the WSE Model are embedded into the SWAP Model." Further, they note that the SWAP Model inappropriately dilutes the local regional economic agricultural effect.

Cumulative Effects

A number of respondents are concerned that the SED does not sufficiently analyze cumulative impacts. They note that the SED does not "analyze whether the combined effects of the proposed project and other projects will result in significant adverse environmental impacts." Some also complain that the cumulative impacts section on aquatic resources make "no mention of the SJRRP" or the California Water Fix. They also note that the SED "fails to determine whether the proposed project's incremental effects are cumulatively considerable."

Recreation

Respondents assert that the SED analysis on economic losses from recreation is inaccurate and ask that the SED be revised to analyze the proposed project's impacts on recreation. They note that the analysis is based on the WSE Model that inaccurately assumes that reservoir operations will not be affected by the proposed project. They note that the proposed project may have "potentially significant impacts to boating and aesthetics at New Melones Reservoir."

Socio-Economic Concerns

Economic Effects

Respondents complain that while the Board "considers economic factors and competing beneficial uses of water in determining the reasonable protection of beneficial uses and the extent to which protection of Public Trust resources is feasible," the Board does not "consider the ability and need to develop alternative water supplies, including recycled water, to meet other beneficial uses, such as municipal and agricultural uses." Respondents note that increased costs "associated with investments in alternative water supplies, like improved water use efficiency, do not demonstrate that Public Trust protections are infeasible."

Others note that the economic analysis "assumes little to no elasticity in water use" and that "it does not take into account more efficient use of water through improvements in technology, better groundwater management, and changes in cropping patterns."

Social and Economic Issues

Respondents criticize the economic analysis and suggest that it "does not include a sufficient range of economic sectors that may be affected." They note that the analysis "does not analyze the economic effects that would occur when the doubling goal is achieved, nor the impact to fisheries, recreation and related economic sectors that would occur under the status quo of declining salmonid runs." Others note that the SED fails to analyze the "economic and employment benefits of increased flow alternatives, including recreational and commercial fishing and non-market economic benefits." Respondents complain that the SED overly relies on the IMPLAN economic model and that the model "overestimates ripple effects on the regional economy from changes in agricultural revenue."

Respondents ask that the SED include an analysis of the proposed project's "impact on the cost of treated water." They note that since "less water is being treated, the costs of delivered water will go up to cover capital costs so [that] the bonds can be repaid."

Others ask that the economic analysis include the following:

- The project's effect on stranded capital costs.
- The economic effects in dry or consecutive dry years.
- Calibration of the SWAP Model area with the plan area.
- Localized economic impacts in the plan area.
- The economic impacts from increased groundwater pumping.
- The costs associated with loss in energy revenue.
- Economic benefits from increased flows including recreational activities such as boating, hunting, hiking, bird watching and camping.

Methods of Compliance Evaluation

Respondents complain that the SED fails to consider reasonably foreseeable methods of compliance. They note that instead of "disclosing and analyzing all reasonable methods of compliance, the SED assumes a single method of compliance and analyzed only this single method." Further, they assert that "the method of compliance assumed by the SED is not reasonable." Some also note that the SED must be revised to "identify and evaluate the environmental impacts of all reasonable methods of compliance."