[SCDA_207]

Appendix 5.A, CalSim II Modeling and Results

5.A CalSim II Modeling and Results

5.A.1 Introduction

This appendix summarizes the modeling methodology used to evaluate the California WaterFix Biological Assessment (CWF BA) No Action Alternative (NAA) and the Proposed Action (PA) scenarios. This appendix together with Appendix 5B and Appendix 5C describes the overall analytical framework and contains descriptions of the key analytical tools and approaches used in the quantitative evaluation of the physical conditions under the scenarios.

CWF NAA is a representation of the base Central Valley Project/State Water Project (CVP/SWP) operations and physical conditions at about year 2030. In addition to continuing the CVP/SWP operations under the NAA, CWF Proposed Action (PA) includes several main components that will affect CVP/SWP operations and the hydrologic response of the system. The PA includes construction and operation of new north Delta intakes and associated conveyance, and changes in the operation of the existing south Delta export facilities.

The CWF BA includes identifying physical and biological effects of proposed operations in comparison to the base conditions at the start of the operations of the new north Delta intake facility. In the evaluation of the NAA and the PA at about year 2030, climate change and sea level rise were assumed to be inherent. A description of the assumed climate and sea level rise projections is included in this appendix. The analytical framework and the tools described in this appendix are developed to evaluate these complex, inter-dependent, large-scale changes to the system.

The overall analytical framework used for the CWF BA effects analysis is summarized in this appendix, in addition to the description of the CalSim II modeling tool used for the operations modeling. This appendix also includes CalSim II modeling assumptions for the NAA and the CWF PA. Appendix 5B provides a summary of the tools and methods used to analyze Delta hydrodynamics and water quality effects. Appendix 5C provides a summary of the tools and methods used to analyze upstream surface water temperature effects.

5.A.2 Overview of Modeling Approach

To support the CWF BA effects analysis of the PA, numerical modeling of physical variables (or "physically based modeling") such as river flows and water temperature is required to evaluate changes to conditions affecting biological resources within the Central Valley, including the Delta. A framework of integrated analyses including hydrologic, operations, hydrodynamics, water quality, and fisheries analyses is required to provide information for the comparative biological assessment. Figure 5.A-1 shows an overall schematic of the analytical framework used for the evaluation of the NAA and the PA in the CWF BA.

As noted above the CWF BA PA includes several main components that can potentially change the CVP/SWP operations and the hydrologic response of the system. It includes construction and operation of new north Delta diversion intakes and associated conveyance, and changes in the operation of the existing south Delta export facilities. Both these operational changes and other external factors such as climate and sea level changes influence the future conditions of reservoir storage, river flow, Delta flows, exports, water temperature and water quality. Evaluation of these conditions is the primary focus of the physically based modeling analyses. The interaction between many of the elements proposed under the CWF BA required modifications to existing analytical tools or application of new analytical tools to account for these dynamic relationships.

The analytical framework in Figure 5.A-1 shows the analytical tools applied in these assessments and the relationship between these tools. Each model included in Figure 5.A-1 provides information to the next “downstream” model in order to provide various results to support the effects analyses. Changes to the historical hydrology related to the future climate are applied in the CalSim II model and combined with the assumed operations for the NAA and the PA scenarios. The CalSim II model simulates the operation of the major CVP/SWP facilities in the Central Valley and generates estimates of river flows, exports, reservoir storage, deliveries, and other parameters. The Delta boundary flows and exports from CalSim II are then used to drive the DSM2 Delta hydrodynamic and water quality models for estimating tidally-based flows, stage, velocity, and salt transport within the estuary. Particle tracking modeling uses the velocity fields generated under the hydrodynamics to emulate movement of particles throughout the Delta system. Temperature models for the primary river systems use the CalSim II reservoir storage, reservoir releases, river flows, and meteorological conditions to estimate reservoir and river temperatures under each scenario. The results from this suite of physical models are used to run numerous fisheries models and other analyses to study the effects of the two scenarios considered in the CWF BA.

5.A.3 Climate Change and Sea Level Rise

The modeling approach applied for the CWF BA integrates a suite of analytical tools in a unique manner to characterize changes to the system from “atmosphere to ocean”. Figure 5.A-2 illustrates the general flow of information for incorporating climate and sea level change in the modeling analyses. Climate and sea level can be considered the most upstream and most downstream boundary constraints on the system analyzed in the modeling for the CWF BA. However, these constraints are outside of the influence of the CWF BA and are considered external factors. The effects of these external factors are incorporated into the key models used in the analytical framework used to analyze both the NAA and the PA scenarios.

Methodology used to depict future climate and the sea level rise under the CWF BA is consistent with the Dec 2013 Public Draft Bay Delta Conservation Plan (BDCP) EIR/EIS (DWR et al. 2013) approach and is described in Appendix 5A - Attachment 1 along with the process of science review, incorporation of uncertainty, and analytical methods for selecting appropriate scenarios. For the selected future climate scenarios, regional hydrologic modeling was performed with the Variable Infiltration Capacity (VIC) hydrology model using temperature and precipitation projections of future climate. In addition to a range of hydrologic process information, the VIC model generates natural streamflows under each assumed climate condition. Appendix 5A - Attachment 2 describes the application of the macro-scale VIC hydrology model that translates the effects of future climate conditions on watershed processes ultimately affecting the timing and volume of runoff.

For evaluation the NAA and the PA in this BA, climate change and sea level rise projections for the period centered on 2025, which are assumed to represent conditions at about year 2030. The assumed climate scenario for the primary effects analysis in this BA represents central tendency (Q5 scenario) of several climate projections. A sea level rise projection of 15 cm at the Golden Gate Bridge was assumed at year 2030 for the analysis in this BA. Appendix 5A – Attachment 1 provides derivation of the climate change projections under Q5 scenario, and the basis for the 15 cm sea level rise assumption.

5.A.4 Hydrology and System Operations

The hydrology of the Central Valley and operation of the CVP/SWP systems are critical elements toward any assessment of changed conditions in the Sacramento-San Joaquin Delta. Changes to conveyance, flow patterns, demands, regulations, and/or Delta configuration will influence the operation of the CVP/SWP reservoirs and export facilities. The operations of these facilities, in turn, influence Delta flows, water quality, river flows, and reservoir storage. The interaction between hydrology, operations, and regulations is not always intuitive and detailed analysis of this interaction often results in new understanding of system responses. Modeling tools are required to approximate these complex interactions under future conditions.

This section describes in detail the methodology used to simulate hydrology and system operations for evaluating the effects of the CWF BA PA relative to the base conditions represented by the NAA. It discusses the primary tool (CalSim II) used in this process and improvements made to better simulate key components of the PA.

5.A.4.1 CalSim II Overview

CalSim II is a planning model developed by the Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation). It simulates the CVP/SWP and areas tributary to the Sacramento-San Joaquin Delta. CalSim II provides quantitative hydrologic-based information to those responsible for planning, managing and operating the State Water Project (SWP) and the federal CVP. As the official model of those projects, CalSim II is typically the system model that is used for any inter-regional or statewide analysis in California. CalSim II uses described optimization techniques to route water through a CVP/SWP system network representation.

CalSim II includes major reservoirs in the Central Valley of the California including Trinity, Lewiston, Whiskeytown, Shasta, Keswick, Oroville, Thermalito, Folsom, Natoma, San Luis, New Melones, New Don Pedro, New Exchequer and Millerton located along the Sacramento and San Joaquin Rivers and their tributaries. CalSim II also includes all the major CVP/SWP facilities including Clear Creek Tunnel, Tehama Colusa Canal, Corning Canal, Jones Pumping Plant, Delta Mendota Canal, Mendota Pool, Banks Pumping Plant, California Aqueduct, South Bay Aqueduct, North Bay Aqueduct, Coastal Aqueduct and East Branch Extension and terminal reservoirs. In addition, it also includes some of the larger, locally managed facilities such as the Glenn Colusa Canal, Contra Costa Canal and the Los Vaqueros Reservoir. Figure 5.A-3 shows most of the major reservoirs, streams and facilities included in the CalSim II model.

The CalSim II simulation model uses single time-step optimization techniques to convey water through a network of storage nodes and flow arcs based on a series of user-specified relative priorities for water allocation and storage on a monthly timestep. Physical capacities and specific regulatory and contractual requirements are input as linear constraints to the system operation using the water resources simulation language (WRESL). The process of conveying water through the channels and storing water in reservoirs is performed by a mixed integer linear programming solver. For each time step, the solver maximizes the objective function to determine a solution that delivers or stores water according to the specified priorities and satisfies all system constraints. The sequence of solved linear programming problems represents the simulation of the system over the period of analysis.

CalSim II includes an 82-year modified historical hydrology (water years 1922-2003) developed jointly by DWR and Reclamation. Water diversion requirements (demands), stream accretions and depletions, rim basin inflows, irrigation efficiencies, return flows, non-recoverable losses, and groundwater operations are components that make up the hydrology used in CalSim II. Sacramento Valley and tributary rim basin hydrologies are developed using a process designed to adjust the historical observed sequence of monthly stream flows to represent a sequence of flows at a future level of development. Adjustments to historic water supplies are determined by imposing future level land use on historical meteorological and hydrologic conditions. The resulting hydrology represents the water supply available from Central Valley streams to the system at a future level of development. Figure 5.A-4 shows the valley floor depletion regions, which represent the spatial resolution at which the hydrologic analysis is performed to produce monthly inputs to the model.

CalSim II uses rule-based algorithms for determining deliveries to north-of-Delta and south-of-Delta CVP/SWP contractors. This delivery logic uses runoff forecast information, which incorporates uncertainty and standardized rule curves. The rule curves relate storage levels and forecasted water supplies to project delivery capability for the upcoming year. The delivery capability is then translated into CVP/SWP contractor allocations which are satisfied through coordinated reservoir-export operations.

The CalSim II model utilizes a monthly time-step to route flows throughout the river-reservoir system of the Central Valley. While monthly time steps are reasonable for long-term planning analyses of water operations, at least two major components of the CWF BA PA conveyance strategy include operations that are sensitive to flow variability at scales less than monthly: operation of the modified Fremont Weir and the modeling of the proposed north Delta diversion bypass rules associated with the proposed north Delta intakes. Initial comparisons of monthly versus daily operations at these facilities indicated that weir spills were likely underestimated and diversion potential was likely overstated using a monthly time step. For these reasons, a monthly to daily flow disaggregation technique was included in the CalSim II model for the Fremont Weir, Sacramento Weir, and north Delta intakes. The technique applies historical daily patterns, based on the hydrology of the year, to transform the monthly volumes into daily flows. The procedure is described in more detail further in this document. Reclamation's 2008 Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project (2008 LTO BA) Appendix D provides more information about CalSim II (Reclamation 2008a).

5.A.4.2 Artificial Neural Network

Determination of flow-salinity relationships in the Sacramento-San Joaquin Delta is critical to both project and ecosystem management. Operation of the CVP/SWP facilities and management of Delta flows is often dependent on Delta flow needs for salinity standards. Salinity in the Delta cannot be simulated accurately by the simple mass balance routing and coarse timestep used in CalSim II. An Artificial Neural Network (ANN) has been developed (Sandhu et al. 1999) that attempts to mimic the flow-salinity relationships as simulated in DSM2 model (Appendix 5B, *DSM2 Modeling and Results*) to provide a rapid transformation of this information into a form usable by the CalSim II operations model. The ANN is implemented in CalSim II to ensure the operations of the upstream reservoirs and the Delta export pumps satisfy particular salinity requirements in the Delta. A more detailed description of the use of ANNs in the CalSim II model is provided in Wilbur and Munévar (2001).

The ANN developed by DWR (Sandhu et al. 1999, Seneviratne and Wu, 2007) attempts to statistically correlate the salinity results from a particular DSM2 model run to the various peripheral flows (Delta inflows, exports and diversions), gate operations and an indicator of tidal energy. The ANN is calibrated, or trained, on DSM2 results that may represent historical or future conditions using a full circle analysis (Seneviratne and Wu, 2007). For example, a future reconfiguration of the Delta channels to improve conveyance may significantly affect the hydrodynamics of the system. The ANN would be able to represent this new configuration by being retrained using the results from the DSM2 model representing the new configuration.

The current ANN predicts salinity at various locations in the Delta using the following parameters as input: Northern inflows, San Joaquin River inflow, Delta Cross Channel gate position, total exports and diversions, Net Delta Consumptive Use, an indicator of the tidal energy and San Joaquin River at Vernalis salinity. Northern inflows include Sacramento River at Freeport flow, Yolo Bypass flow, and combined flow from the Mokelumne, Cosumnes, and Calaveras rivers (East Side Streams) minus North Bay Aqueduct and Vallejo exports. Total exports and diversions include the SWP Banks Pumping Plant, the CVP Jones Pumping Plant, and Contra Costa Water District (CCWD) diversions including diversions to Los Vaqueros Reservoir. A total of 148 days of values of each of these parameters is included in the correlation, representing an estimate of the length of memory of antecedent conditions in the Delta. The ANN model approximates DSM2 model-generated salinity at the following key locations for the purpose of modeling Delta water quality standards: X2, Sacramento River at Emmaton, San Joaquin River at Jersey Point, Sacramento River at Collinsville, and Old River at Rock Slough. In addition, the ANN is capable of providing salinity estimates for Clifton Court Forebay, CCWD Alternate Intake Project (AIP) and Los Vaqueros diversion locations.

The ANN may not fully capture the dynamics of the Delta under conditions other than those for which it was trained. It is possible that the ANN will exhibit errors in flow regimes beyond those for which it was trained. Therefore, a new ANN is needed for any new Delta configuration or under sea level rise conditions which may result in changed flow – salinity relationships in the Delta.

5.A.4.3 Application of CalSim II to Evaluate the PA

Typical long-term planning analyses of the Central Valley system and operations of the CVP/SWP have applied the CalSim II model for analysis of system responses. CalSim II simulates future CVP/SWP project operations based on an 82-year monthly hydrology derived from the observed water years 1922-2003 period. Future land use and demands are projected for the appropriate future period. The system configuration consisting of facilities, operations, and regulations are input to the model and define the limits or preferences on operation. The configuration of the Delta, while not simulated directly in CalSim II, informs the flow-salinity relationships and several flow-related regressions for interior Delta conditions (i.e. X2 and combined Old and Middle River or OMR flow) included in the model. Each CalSim II model is a generalized simulation of a unique combination of hydrologic, facility, operations, regulations, and Delta configuration conditions. Some refinement of the CVP/SWP operations related to delivery allocations and San Luis target storage levels is generally necessary to have the model reflect suitable north-south reservoir balancing under future conditions. These refinements are generally made by experienced modelers in conjunction with project operators.

The CalSim II model produces outputs of river flows, exports, water deliveries, reservoir storage, water quality, and several derived variables such as X2, Delta salinity, OMR, and QWEST (westerly flow on the San Joaquin River approximately past Jersey Point location). The CalSim II model is most appropriately applied for comparing one alternative to another and drawing comparisons between the results. This is the method in which CalSim II is applied for the CWF BA. For the PA, a companion NAA simulation has been prepared. The No Action simulation includes the existing infrastructure, existing regulatory requirements including the recent biological opinions, future demands, climate, and sea level rise at about year 2030. The PA is compared to the NAA to evaluate areas in which the project changes conditions and the seasonality and magnitude of such changes. The change in hydrologic response or system conditions is important information that informs the effects analysis related to water-dependent resources in Sacramento-San Joaquin watersheds.

There are a number of areas in which the CalSim II model has been improved or is applied differently for the CWF BA analyses. Most of these updates were performed during or after the development of the modeling for the Bay Delta Conservation Plan DEIRS (DWR et al., 2013). Following sections briefly describes these key changes.

5.A.4.3.1 Changes to the CalSim II Model Network

The main feature of the PA that required changes to the CalSim II model network was the proposed diversion intakes in the north Delta along the Sacramento River. The intakes and associated conveyance allow for CVP/SWP diversions on the Sacramento River between Freeport and Courtland. The PA includes 3 intakes in this reach of the river with individual diversion capacity of 3,000 cfs. Since there are relatively small existing diversions and negligible inflows occurring in this reach of the Sacramento River, the CalSim II aggregates all proposed diversions into a single diversion arc (Figure 5.A-5) near Hood. This diversion arc (D400) conveys water diverted by the CVP/SWP to their respective pumping plants (either Banks PP or Jones PP) in the south Delta. Since dual conveyance – diverting from either or both north and south facilities -- is being considered, the model comingles the water at the pumping plant. Water for each project (CVP/SWP) is tracked separately.

Additional changes were made to the CalSim II network in the south Delta to allow for better estimation of the Combined Old and Middle River (OMR) flow.

The Delta island consumptive use (DICU) was applied in CalSim II at five nodes representing regions in the north, west, central, south, and San Joaquin regions of the Delta. A review of the DICU was performed in 2009 to discern if any adjustments would be necessary to best reflect the flow available at the points of diversion. The DICU was disaggregated further, into a total of seven parts, including to split out the DICU upstream and downstream of the proposed north Delta diversion, and portion of the DICU in the south Delta to improve estimates of the OMR flow.

5.A.4.3.2 Incorporation of Sacramento River Daily Variability

As described above, the operation of the modified Fremont Weir and the proposed north Delta intakes are sensitive to the daily variability of flows. Short duration, highly variable storms are likely to cause Fremont Weir spills. However, if the monthly flow volume is converted to an average monthly flow rate, it is possible to not identify any spill. Similarly, the proposed north Delta diversion bypass rules associated with operation of the north Delta intakes include variable bypass flow (flow remaining in the river downstream of the proposed intakes) requirements and pulse protection criteria. Storms as described above may permit significant diversion but only for a short period of time. Initial comparisons of monthly versus daily operations at these facilities indicated that weir spills were likely underestimated and diversion potential was likely overstated using a monthly time step.

Figure 5.A-6 shows a comparison of observed monthly averaged Sacramento River flow at Freeport and corresponding daily flow as an example. The figure shows that the daily flow exhibits significant variability around the monthly mean in the winter and spring period while remaining fairly constant in summer and fall months. Figure 5.A-7 shows the daily historical Sacramento River flow patterns at Freeport averaged by water year type. It shows that daily variability is significant in the winter-spring while the summer flows are holding fairly constant in the most water year types. Individual water years may generally show even more variability. The winter-spring daily variability is deemed important to species of concern.

In an effort to better represent the sub-monthly flow variability, particularly in early winter, a monthly-to-daily flow mapping technique is applied directly in CalSim II for the Fremont Weir, Sacramento Weir, and the north Delta intakes. The technique applies historical daily patterns, based on the hydrology of the year, to transform the monthly volumes into daily flows. Daily flow patterns are obtained from the observed DAYFLOW period of 1956-2003. In all cases, the monthly volumes are preserved between the daily and monthly flows. It is important to note that this daily mapping approach does not in any way necessarily represent the flows resulting from future operational responses on a daily time step. It is simply a technique to incorporate representative daily variability into the flows resulting from CalSim II's monthly operational decisions. It helps in refining the monthly CalSim II operations by providing a better estimate of the Fremont and Sacramento weir spills which are sensitive to the daily flow patterns and a better estimate of maximum allowable north Delta diversion in the PA.

5.A.4.3.3 Observed Daily Patterns

CalSim II hydrology is derived from historical monthly gauged flows for 1922-2003. This is the source data for monthly flow variability. DAYFLOW provides a database of daily historical Delta inflows from WY 1956 to present. This database is aligned with the current Delta infrastructure setting. Despite including the historical operational responses to varying regulatory regimes that existed over this period, in most winter and spring periods the reservoir operations and releases are governed by the inflows to the reservoirs.

Daily patterns from DAYFLOW were used directly for mapping CalSim II monthly flow volumes to daily flows for water years 1956 to 2003. For water years 1922 to 1955, daily patterns were selected from water years 1956 to 2003 based on similar total annual unimpaired Delta inflow. The daily pattern for the pre-1956 water year was assumed to be the same as the daily pattern of the identified post-1955 water year. Correlation among the various hydrologic basins is preserved by using the same post-1955 water year for all rivers flowing into the Delta, for a given year in the 1922-1955 period. Table 5.A-1 lists the selected post-1955 water years used for the water years 1922 to 1955 along with the total unimpaired annual Delta inflow.

Thus, for each month in the 82-year CalSim II simulation period, the monthly flow volume is mapped onto a daily pattern for computation of spills over the Fremont Weir and Sacramento Weir and for computing water available for diversions through the north Delta intakes. A preprocessed timeseries of daily volume fractions (the day's volume as a fraction of the month's volume), based on Sacramento River at Freeport observed flows, is input into CalSim II. The monthly volume as determined dynamically from CalSim II then is multiplied by the fractions to arrive at a daily flow sequence. The calculation of daily spills and daily diversions are thus obtained. In the subsequent cycle (but still the same month), adjustments are made to the daily river flow upstream of the Sacramento Weir and the north Delta intakes to account for differences between the monthly flows assumed in the first cycle and the daily flows calculated in subsequent cycles. For example, if no spill over Fremont was simulated using a monthly flow, but when applying a daily pattern spill does occur, then the Sacramento River flow approaching the Sacramento Weir is reduced by this amount. In this fashion, daily balance and monthly balance is preserved while adding more realism to the operation of these facilities.

5.A.4.3.4 Fremont Weir Operations

The NAA and the PA include the measure for modifying the current Fremont Weir by notching it to allow for more frequent inundation in the Yolo Bypass. Details of the Fremont Weir and Yolo Bypass Hydraulics are described in Attachment 3. The HEC-RAS modeling included in that section provides modified rating curves of the Fremont Weir for use in CalSim II. CalSim II simply includes two sets of rating curves, one with the "notch" and one without the notch. Input tables allow specification of when the notch is assumed to be operated. The amount of spill over the Fremont Weir or the notch is computed using the daily patterned Sacramento River flow at Verona and the rating curves included in the model.

5.A.4.3.5 North Delta Diversion Operations

The PA includes three intakes on the Sacramento River upstream of Sutter Slough, in the north Delta. Each intake is proposed to have 3,000 cfs maximum diversion capacity, with a total, combined intake capacity not exceeding 9,000 cfs. It is also proposed that the intakes will be screened using positive barrier fish screens to eliminate entrainment at the north Delta diversions. Water diverted at the intakes is conveyed to a new forebay in the south Delta via proposed tunnels.

The CWF BA PA includes new bypass flow rules, which govern the amount of water required to remain in the river before any diversion at the intakes can occur. Bypass rules are designed with the intent to minimize potential increased upstream tidal transport of productivity in the channels downstream of the intakes, to maintain flow supporting the migration of the salmonid and transport of pelagic species to regions of suitable habitat, to preserve shape of the natural hydrograph which may act as cue to important biological functions, to lower potential for increased tidal reversals that may occur because of the reduced net flow in the river and to provide flows to minimize predation effects downstream. The proposed bypass rules include three important components:

- initial pulse protection during which only low level pumping is allowed; low level pumping allows diversion of up to 300 cfs at each intake, with a combined maximum diversion of 900 cfs or 6% of the flow in the Sacramento River, whichever is lower, such that flow downstream of the intake is not less than 5,000 cfs

- post-pulse operations during Dec - Jun that permit a percentage of river flow above a certain threshold to be diverted (and transitioning from Level I to Level II to Level III)

- bypass flow requirements during Jul - Nov

The bypass flow rules are simulated in CalSim II using daily mapped Sacramento River flows as described above to determine the maximum potential diversion that can occur in the north Delta for each day. The simulation identifies which of the three criteria is governing, based on antecedent daily flows and season. An example of the north Delta flows and diversion is illustrated in Figure 5.A-8. As can be seen in this figure, bypass rules begin at Level I in October until the Sacramento River pulse occurs (around Dec 10th in Figure 5.A-8). During the pulse flow, the low level pumping (Level 0) is permitted, but is limited to 6% of river flow. Following the pulse protection the bypass flow requirements move to Level I post-pulse criteria (around Dec 20th in Figure 5.A-8). After sustained high flows, the bypass flow requirements move to Level II (in third week of Jan in Figure 5.A-8) and eventually to Level III (around Feb 1st in Figure 5.A-8) which permit greater potential diversion. CalSim II uses the monthly average of this daily potential diversion as one of the constraints in determining the final monthly north Delta diversion. See Section 5.A.5.2 for the complete description of the bypass rules and CalSim II modeling assumptions that incorporate these rules.

5.A.4.3.6 ANN Retraining

As noted earlier, ANNs are used for simulating flow-salinity relationships in CalSim II. They are trained on DSM2 outputs and therefore, emulate DSM2 results. ANN requires retraining whenever the flow – salinity relationship in the Delta changes. Development of a new ANN for use in the CWF BA application of the CalSim II representing the hydrodynamics and salinity conditions under projected sea level rise conditions at year 2030 is described in Section 5.B.2.3.4, *ANN Retraining*.

5.A.4.3.7 Incorporation of Climate Change Effects

Climate and sea level change are incorporated into the CalSim II model in two ways: changes to the input hydrology and changes to the flow-salinity relationship in the Delta due to sea level rise. Changes in runoff and streamflow are simulated through VIC modeling under the projected climate scenarios at 2030. These simulated changes in runoff are applied to the CalSim II inflows and downstream accretions/depletions as a fractional change from the observed inflow patterns (simulated future runoff divided by historical runoff). These fractional changes are first applied for every month of the 82-year period consistent with the VIC simulated patterns. A second order correction is then applied to ensure that the annual shifts in runoff at each location are consistent with that generated from the VIC modeling. A spreadsheet tool has been prepared to process this information and generate adjusted inflow time series records for CalSim II. Once the changes in flows have been resolved, water year types and other hydrologic indices that govern water operations or compliance requirements are adjusted to be consistent with the new hydrologic regime. Sea level rise effect on the flow-salinity response is incorporated in the respective ANN.

The following input parameters are adjusted in CalSim II to incorporate the effects of climate change:

- Inflow time series records for all major streams in the Central Valley (Appendix 5A, Attachment 8 includes the full list of CalSim II inputs modified to account for climate change effects)
- Sacramento and San Joaquin Valley water year types
- Runoff forecasts used in reservoir operations and allocation decisions
- Delta water temperature as used in triggering biological opinion smelt criteria
- Modified ANN to reflect the flow-salinity response under 15 cm sea level change

Appendix 5A - Attachments 1 and 2 provide more detailed information on the climate change and sea level rise modeling approaches, and Attachment 8 includes the full list of CalSim II inputs modified to account for climate change effects.

The CalSim II simulations do not consider future climate change adaptation which may require management of the CVP/SWP system in a different manner than today to reduce climate impacts. For example, future changes in reservoir flood control reservation to better accommodate a seasonally changing hydrograph may be considered under future programs, but are not considered under the current BA. Nor the changes in land use (crop selection) were considered under the current BA. Thus, the CalSim II modeling results represent the risks to operations, water users, and the environment in the absence of dynamic adaptation for climate change.

5.A.4.4 Output Parameters

The hydrology and system operations models produce the following key parameters on a monthly time-step:

- River flows and diversions
- Reservoir storage
- Delta flows and exports
- Delta inflow and outflow
- Deliveries to project and non-project users
- Controls on project operations

Some operations have been informed by the daily variability included in the CalSim II model for the CWF BA, and where appropriate, these results are presented. However, it should be noted that CalSim II remains a monthly model. The daily variability inputs to the CalSim II model help to better represent certain operational aspects, but the monthly results are utilized for operational decisions and water balance.

5.A.4.5 Limitations and Appropriate Use of Model Results

CalSim II is a monthly model developed for a long-term planning level analyses. The model is run for an 82-year (from 1922 to 2003) historical hydrologic period, at a projected level of hydrology and demands; and under an assumed framework of regulations. CalSim II uses historical monthly hydrology as inputs adjusted for changes in water and land use that have occurred over time or may occur in the future. With these inputs, CalSim II is not intended to simulate historical operations. The model assumes that facilities, land use, water supply contracts, and regulatory requirements are constant over 82 years, representing a fixed level of development. CalSim II provides information about would-be CVP/SWP operations for the assumed hypothetical hydrology, demand and regulatory requirements, under the 1922 – 2003 quasi-historical hydrologic sequence.

CalSim II model uses a set of pre-defined generalized balances/targets, collectively referred to as rules, which reflect the assumed regulations and are used to specify the operations of the CVP/SWP systems. These inputted rules are often specified as a function of yeartype or a prior month's simulated storage or flow condition. The model has no capability of adjusting these rules to respond to specific events that may have occurred historically, e.g., levee failures, fluctuations in barometric pressure that may have affected delta tides and salinities, facility outages, etc. The model also is not able to ensure meeting statistical performance criteria such as meeting a storage target in an assumed percentage of years unless pre-specified. These generalized rules have been developed based on historical operational trends and on limited CVP/SWP operator input and only provide a coarse representation of the project operations over the inputted hydrologic conditions. Thus, results should not be expected to exactly match what operators might do in a specific month or year within the simulation period since the latter would be informed by numerous real-time considerations. Rather, results are intended to be a reasonable representation of long-term operational trends.

Even though CalSim II relies on modified historical hydrologic inputs, and generalized representation of the operating rules, the modeling results are generally comparable to the monthly long-term historical trends. A historical comparison was conducted for CVP/SWP operations in the Historical Operations Study of water years 1975 to 1998 (DWR 2003). The documented comparison of historical and simulated records (from the early 1983 to 2003) for CalSim-II San Joaquin River Basin show the frequency of peaks and troughs coinciding from visual inspection. This information affirms water entering and leaving the system is occurring with approximately the same timing and strengthens confidence of the timing of the operational logic (DWR and Reclamation, 2007). When comparing CalSim II results to historical information, it is important to note that major changes to the system, e.g., facilities coming on line, reduced availability of Trinity Basin water and changes in regulatory requirements such as the 2008 USFWS BiOp and 2009 NMFS BiOp, have changed CVP/SWP operations significantly. Any such comparisons should involve similar conditions. Even with similar facility and regulatory conditions, differences would be expected due to specific actions specific to real-time events as mentioned above. One noteworthy difference in the current modeling is that CalSim II results show that the September releases are consistently lower in the drier years compared to the historical values. Despite detailed model inputs and assumptions, the CalSim II results may differ from real-time operations given that not all the regulatory requirements (e.g. upstream temperature requirements, reservoir release ramping rates etc) or realtime operational adjustments to the Shasta Temperature Control Device are modeled in the CalSim II. The upstream reservoir releases in real-time are determined based on many factors such as temperature control requirements, available cold water pool within the reservoirs, in-basin use including Delta flow requirements, forecasted hydrology, unforeseen demands etc. Many of the factors involve day-to-day decision-making by the CVP/SWP operators taking into account the recommendations from many of the decision-making/advisory teams such as the Sacramento River Temperature Task Group (SRTTG), Water Operations Management Team (WOMT), b2 interagency team (B2IT) and American River Operations Group, to name a few. CalSim II does not take into account all the factors identified above given the generalized representation of the likely long-term operations.

Delta exports in CalSim II are a function of many factors including physical pumping capacities, health and safety pumping requirements, south-of-Delta allocations, monthly demand patterns, available export capacities considering regulatory and operational constraints, and the assumed San Luis rule curve. San Luis rule curve is an input to CalSim II which provides a target storage each month that is dependent on the South-of-Delta allocation and upstream reservoir storage. The rule curve allows CalSim II to emulate judgement of the operators in balancing the north-of-Delta and south-of-Delta storage conditions. Assumed San Luis rule curve could differ depending on the available export capacity during winter and spring months, and the need to protect upstream carryover storage in the fall months. In the absence of any other operating criteria controlling the upstream reservoir releases or the Delta exports, different San Luis rule curves can result in differences in upstream reservoir release patterns, and Delta exports.

Under stressed water supply conditions, given the generalized nature of specified operations rules, CalSim II model results should only be considered an indicator of stressed water supply conditions, and should not necessarily be understood to reflect literally what would occur in the future under a given scenario. For example, CalSim II model can result in instances where the required minimum instream flows, or regulatory flow/salinity requirements cannot be achieved, or deliveries to senior water rights holders could be shorted due to extreme water supply conditions in the reservoirs. CalSim II does not currently reflect potential relaxations of standards that the State Water Resources Control Board in coordination with other regulatory agencies might invoke under such dry circumstances. As a result, CalSim II may tend to underestimate reservoir storages and overestimate flows during the most severe droughts. CalSim II also does not account for the compromises and temporary arrangements that are made among stakeholders during such dry circumstances. In reality the operations are managed in close coordination with various regulatory agencies and stakeholders under such extreme circumstances. In actual future operations, the project operators would continue to work in real time to satisfy legal and contractual obligations based on the water supply conditions and other information available at the time.

Appropriate use of model results is important. While there are certain components in the model that are downscaled to daily time step (simulated or approximated hydrology) such as an air-temperature based trigger for a fisheries action, the results of those daily conditions are always averaged to a monthly time step (for example, a certain number of days with and without the action is calculated and the monthly result is calculated using a day-weighted average based on the total number of days in that month); and model operational decisions based on those components are again made on a monthly basis. Therefore reporting sub-monthly results from CalSim II or from any other subsequent model that uses monthly CalSim results as an input is tenuous at best.

Because it is simulating hypothetical conditions, CalSim II is not calibrated and cannot be used in a real-time predictive manner. CalSim II results are intended to be used in a comparative manner, which allows for assessing the changes in the CVP/SWP system operations and resulting incremental effects between two scenarios. The model should be used with caution where absolute results are needed in instances such as determining effects based on a threshold, prescribing seasonal or to guide real-time operations, predicting flows or water deliveries for any real-time operations etc.

5.A.4.6 Linkages to Other Models and Analyses

The Delta boundary flows and exports from CalSim II are used to drive the DSM2 Delta hydrodynamic and water quality models for estimating tidally-based flows, stage, velocity, and salt transport within the estuary. DSM2 water quality and volumetric fingerprinting results are used to assess changes in concentration of selenium in Delta waters.

River and temperature models for the primary river systems use the CalSim II reservoir storage, reservoir releases, river flows, and meteorological conditions to estimate reservoir and river temperatures under each scenario.

Results from these temperature models are further used as an input to fisheries models (SALMOD, Reclamation Egg Mortality Model, IOS, etc.) to assess changes in fisheries habitat due to flow and temperature. CalSim II and DSM2 results are also used for fisheries models (IOS, DPM) or aquatics species survival/habitat relationships developed based on peer reviewed scientific publications.

5.A.5 CalSim II Modeling Assumptions

This section presents the assumptions used in developing the CalSim II simulations of the NAA and PA for use in the CWF BA evaluation. The assumptions were selected based on the recommentdations from the agencies involved in the Section 7 Consultation Team (SCT).

The NAA assumptions represent the continuation of existing policy and management direction at Year 2030 and include implementation of water operations components of the Reasonable and Prudent Alternative (RPA) actions specified in the 2008 Fish and Wildlife Service (FWS) and 2009 National Marine Fisheries Service (NMFS) Biological Opinions (BiOp). These assumptions are consistent with the Reclamation's 2015 Final Coordinated Long-Term Operations of the Central Valley Project and State Water Project Environmental Impact Statement (2015 LTO EIS) NAA assumptions (Reclamation 2015, Appendix 5A).

The PA will include operations of both new and existing water conveyance facilities once the new north Delta facilities are completed and become operational, thereby enabling joint management of north and south Delta diversions. Operational limits included in this PA for south Delta export facilities would supplement the south Delta operational limits currently implemented in compliance with the USFWS (2008) and NMFS (2009) BiOps as described below in Section 5.A.5.2. The proposed action also includes criteria for spring outflow and new minimum flow criteria at Rio Vista from January through August. The North Delta diversion intakes and the Head of Old River gate (HOR gate) are new facilities for the CVP/SWP and will be operated consistent with the proposed operating criteria for each of these facilities. All other criteria included in the NAA are continued in the PA. The detailed assumptions used in developing CalSim II simulations of the NAA and the PA are tabulated at the end of this section, in Table 5.A.14.

5.A.5.1 CalSim II Assumptions for the No Action Alternative

The assumptions for the NAA are consistent, where appropriate, with the 2015 LTO EIS NAA assumptions (Reclamation 2015). The NAA was developed assuming projected Year 2030 conditions. The NAA includes projected climate change and sea level rise assumptions corresponding to the Year 2030. Change in climate results in the changes in the reservoir and tributary inflows included in CalSim II. The changes associated with the assumed 15 cm sea level rise result in modified flow-salinity relationships in the Delta. The climate change and sea level rise assumptions at Year 2030 are described in detail in Appendix 5A - Attachment 1. The CalSim II simulation for the NAA does not consider any adaptation measures that would result in managing the CVP/SWP system in a different manner than today to reduce climate impacts. For example, future changes in reservoir flood control reservation to better accommodate a seasonally changing hydrograph may be considered under future programs, but are not considered under the CWF BA.

5.A.5.1.1 Hydrology

5.A.5.1.1.1 Inflows/Supplies

CalSim II model for the NAA includes the historical hydrology projected to Year 2030 considering the climate change effects.

5.A.5.1.1.2 Level of Development

CalSim II uses a hydrology which is the result of an analysis of agricultural and urban land use and population estimates. The assumptions used for Sacramento Valley land use result from an aggregation of historical survey and projected data developed for the California Water Plan Update (Bulletin 160-98). Generally, land use projections are based on Year 2020 estimates (hydrology serial number 2020D09E), however the San Joaquin Valley hydrology reflects draft 2030 land use assumptions developed by Reclamation. Where appropriate Year 2020 projections of demands associated with water rights and CVP/SWP water service contracts have been included. Specifically, projections of full build out are used to describe the American River region demands for water rights and CVP contract supplies, and California Aqueduct and the Delta Mendota Canal CVP/SWP contractor demands are set to full contract amounts.

5.A.5.1.1.3 Demands, Water Rights, CVP/SWP Contracts

CalSim II demand inputs are preprocessed monthly time series for a specified level of development (e.g. 2020) and according to hydrologic conditions. Demands are classified as CVP project, SWP project, local project or non-project. CVP/SWP demands are separated into different classes based on the contract type. A description of various demands and classifications included in CalSim II is provided in the 2008 LTO BA Appendix D (Reclamation 2008a).

Table 5.A-2 below includes the summary of the CVP/SWP project demands in thousand acre-feet (TAF) included under NAA. Detailed description of American River demands assumed under the NAA is provided in Appendix 5A - Attachment 5. For SWP contractors, full Table A demands are assumed every year. Under Article 21 of the Monterey Agreement, SWP contractors may request more than their Table A entitlements under certain water-availability conditions. Article 21 deliveries require that San Luis Reservoir be at capacity and that Banks PP

and the California Aqueduct has have available capacity to divert from the from the Delta for direct delivery. The demand assumptions are not modified for changes in climate conditions.

The detailed listing of CVP/SWP contract amounts and other water rights assumptions for the NAA are included in the delivery specification tables in Appendix 5A - Attachment 5.

5.A.5.1.2 Facilities

CalSim II includes representation of all the existing CVP/SWP storage and conveyance facilities. Assumptions regarding selected key facilities are included in Table 5.A.14 below. CalSim II also represents the flood control weirs such as the Fremont Weir located along the Sacramento River at the upstream end of the Yolo Bypass. Rating curves for the existing weir are used to model the spills over the Fremont Weir. In addition, the NAA CalSim II model assumes an operable weir notch for the Fremont Weir as modeled in the Dec 2013 Public Draft BDCP EIR/EIS (BDCP DEIRS) Alternative 4 (DWR et al. 2013). The NAA also includes the Freeport Regional Water Project, located along the Sacramento River near Freeport and the City of Stockton Delta Water Supply Project (30 mgd capacity).

A brief description of the key export facilities that are located in the Delta and included under the NAA run is provided below.

The Delta is a mostly leveed system of natural/man-made channels that serves to transport river flows and reservoir storage to the CVP/SWP facilities in the south Delta-, which export water to the Projects' contractors through two pumping plants: CVP's C.W. Jones Pumping Plant and SWP's Harvey O. Banks Pumping Plant. Jones and Banks Pumping Plants supply water to agricultural and urban users throughout parts of the San Joaquin Valley, South Lahontan, Southern California, Central Coast, and South San Francisco Bay Area hydrologic regions. The Contra Costa Canal and the North Bay Aqueduct supply water to users in the northeastern San Francisco Bay and Napa Valley areas.

5.A.5.1.2.1 Fremont Weir

Fremont Weir is a flood control structure located along the Sacramento River at the head of the Yolo Bypass. To enhance the potential benefits of the Yolo Bypass for various fish species, the Fremont Weir is assumed to be notched to provide increased seasonal floodplain inundation. It is assumed that an opening in the existing weir and operable gates are constructed at elevation 17.5 feet along with a smaller opening and operable gates at elevation 11.5 feet. Derivation of the rating curve for the elevation 17.5 feet opening used in the CalSim II model is described in Appendix 5A - Attachment 4. The modeling approach used in the CalSim II model to estimate the Fremont Weir spills using the daily patterned Sacramento River flow at Verona, is provided in Section 5.A.4.3.2.

5.A.5.1.2.2 CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity

The Jones Pumping Plant consists of six pumps including one rated at 800 cfs, two at 850 cfs, and three at 950 cfs. Maximum pumping capacity is assumed to be 4,600 cfs with the 400 cfs Delta Mendota Canal (DMC) –California Aqueduct Intertie that became operational in July 2012. As alluded to above, CalSim II does not account for maintenance outages, side flow into the DMC or other real-time phenomena that generally limits Jones to pumping rates below 4600 cfs.

5.A.5.1.2.3 SWP Banks Pumping Plant Capacity

SWP Banks pumping plant has an installed capacity of about 10,668 cfs (two units of 375 cfs, five units of 1,130 cfs, and four units of 1,067 cfs). The SWP water rights for diversions specify a maximum of 10,350 cfs, but the U. S. Army Corps' of Engineers (USACE) permit for Clifton Court Forebay Intakes allows a maximum 3-day average diversion rate of 6,680 cfs, with additional diversion possible depending on Vernalis flows such that the total diversion can go up to 8,500 cfs during December 15 – March 15. These restrictions on the Clifton Court Forebay Intake are applied to the Banks Pumping Plant in the CalSim II model. Additional capacity of 500 cfs (pumping limit up to 7,180 cfs) is allowed to reduce impact of NMFS BiOp Action 4.2.1 on the SWP.

5.A.5.1.2.4 CCWD Intakes

The Contra Costa Canal originates at Rock Slough, about four miles southeast of Oakley, and terminates after 47.7 miles at Martinez Reservoir. Historically, diversions at the unscreened Rock Slough facility (Contra Costa Canal Pumping Plant No. 1) have ranged from about 50 to 250 cfs. The canal and associated facilities are part of the CVP, but are operated and maintained by the Contra Costa Water District (CCWD). CCWD also operates a diversion on Old River and the Alternative Intake Project (AIP), the new drinking water intake at Victoria Canal, about 2.5 miles east of Contra Costa Water District's (CCWD) intake on the Old River. CCWD can divert water to the Los Vaqueros Reservoir to store good quality water when available and supply it to its customers.

5.A.5.1.3 Regulatory Standards

The regulatory standards that govern the operations of the CVP/SWP facilities under the NAA are briefly described below. Specific assumptions related to key regulatory standards are also outlined below.

5.A.5.1.3.1 D-1641 Operations

The SWRCB Water Quality Control Plan (WQCP) and other applicable water rights decisions, as well as other agreements are important factors in determining the operations of the CVP/SWP.

The December 1994 Accord committed the CVP/SWP to a set of Delta habitat protective objectives that were incorporated into the 1995 WQCP and later, were implemented by D-1641. Significant elements in D-1641 include X2 standards, export/inflow (E/I) ratios, Delta water quality standards, real-time Delta Cross Channel operation, and San Joaquin flow standards.

5.A.5.1.3.2 Coordinated Operations Agreement (COA)

The CVP/SWP use a common water supply in the Central Valley of California. Reclamation and DWR have built water conservation and water delivery facilities in the Central Valley in order to deliver water supplies to project contractors. The water rights of the projects are conditioned by the SWRCB to protect the beneficial uses of water within each respective project and jointly for the protection of beneficial uses in the Sacramento Valley and the Sacramento-San Joaquin Delta

Estuary. The agencies coordinate and operate the CVP/SWP to meet the joint water right requirements in the Delta.

The Coordinated Operations Agreement (COA), signed in 1986, defines the project facilities and their water supplies, sets forth procedures for coordination of operations, identifies formulas for sharing joint responsibilities for meeting Delta standards as they existed in SWRCB Decision 1485 (D-1485), identifies how unstored flow will be shared, sets up a framework for exchange of water and services between the Projects, and provides for periodic review of the agreement. Requirements set forth under various regulations (e.g. D-1641, BiOps) that were not in D-1485 have been shared by the CVP and SWP per informal agreements.

5.A.5.1.3.3 CVPIA (b)(2) Assumptions

The previous 2008 LTO BA modeling included a dynamic representation of the Central Valley Project Improvement Act (CVPIA) 3406(b)(2) water allocation, management and related actions (B2). The selection of discretionary actions for use of B2 water in each year was based on a May 2003 Department of the Interior policy decision. The use of B2 water is assumed to continue in conjunction with the USFWS and NMFS BiOp RPA actions. The CalSim II implementation used for the CWF BA does not dynamically account for the use of B2 water, but rather assumes pre-determined USFWS BiOp upstream fish objectives for Clear Creek, Sacramento River below Keswick Dam, and American River below Nimbus Dam, and a pulse period exports limit. Other B2 actions are assumed to be a part of USFWS and NMFS BiOp RPA actions for the American River, Stanislaus River, and Delta export restrictions, though real-time implementation does not require this.

5.A.5.1.3.4 Continued CALFED Agreements

The Environmental Water Account (EWA) was established in 2000 by the CALFED Record of Decision (ROD). The EWA was initially identified as a 4-year cooperative effort intended to operate from 2001 through 2004 but was extended through 2007 by agreement between the EWA agencies. It is uncertain, however, whether the EWA will be in place in the future and what actions and assets it may include. Because of this uncertainty, the EWA has not been included in the current CalSim II implementation, except for the Lower Yuba River Accord (LYRA) water.

In CalSim II, the LYRA Component 1 water is assumed to be transferred to South of Delta (SOD) State Water Project (SWP) contractors to help mitigate the impact of the NMFS BiOp restrictions on SWP exports during April and May. An additional 500 cfs of capacity is permitted at Banks Pumping Plant from July through September to export this transferred water.

5.A.5.1.3.5 USFWS Delta Smelt BiOp Actions

The USFWS Delta Smelt BiOp was released on December 15, 2008, in response to Reclamation’s request for formal consultation with the USFWS on the coordinated operations of the CVP/SWP. To develop CalSim II modeling assumptions for the RPA documented in this BiOp, DWR led a series of meetings that involved members of fisheries and project agencies. This group prepared the assumptions and CalSim II implementations to represent the RPA in the NAA CalSim II simulation. The following actions of the USFWS BiOp RPA have been included in the NAA CalSim II simulation:

- Action 1: Adult Delta smelt migration and entrainment (RPA Component 1, Action 1 – First Flush)
- Action 2: Adult Delta smelt migration and entrainment (RPA Component 1, Action 2)
- Action 3: Entrainment protection of larval and juvenile Delta smelt (RPA Component 2)
- Action 4: Estuarine habitat during Fall (RPA Component 3)
- Action 5: Temporary spring HOR gate and the Temporary Barrier Project (RPA Component 2)

A detailed description of the assumptions that have been used to model each action along with appropriate caveats is included in the technical memorandum “Representation of U.S. Fish and Wildlife Service Biological Opinion Reasonable and Prudent Alternative Actions for CalSim II Planning Studies”, prepared by an interagency working group under the direction of the lead agencies. This technical memorandum is included in Appendix 5A - Attachment 6.

Restoration of at least 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh required by the 2008 USFWS BiOp was not explicitly modeled in the NAA and the PA because environmental documents of the projects regarding these actions are in development.

5.A.5.1.3.6 NMFS BiOp Salmon Actions

The NMFS Salmon BiOp on long-term operations of the CVP/SWP was released on June 4, 2009. To develop CalSim II modeling assumptions for the RPA’s documented in this BiOp, DWR led a series of meetings that involved members of fisheries and project agencies. This group prepared the assumptions and CalSim II implementations to represent the RPA in the NAA CalSim II simulations for future planning studies. The following NMFS BiOp RPA’s have been included in the NAA CalSim II simulation:

- Action I.1.1: Clear Creek spring attraction flows
- Action I.4: Wilkins Slough operations
- Action II.1: Lower American River flow management
- Action III.1.4: Stanislaus River flows below Goodwin Dam
- Action IV.1.2: Delta Cross Channel gate operations
- Action IV.2.1: San Joaquin River flow requirements at Vernalis and Delta export restrictions
- Action IV.2.3: Old and Middle River flow management

For Action I.2.1, which calls for a percentage of years that meet certain specified end-of-September and end-of-April storage and temperature criteria resulting from the operation of Lake

Shasta, no specific CalSim II modeling code is implemented to simulate the performance measures identified.

A detailed description of the assumptions that have been used to model each action along with appropiate caveats is included in the technical memorandum "Representation of National Marine Fisheries Service Biological Opinion Reasonable and Prudent Alternative Actions for CalSim II Planning Studies", prepared by an interagency working group under the direction of the lead agencies. This technical memorandum resulting from this working group is included in Appendix 5A - Attachment 7. The CalSim II assumptions described in the Attachment 7 may have changed to better reflect the implementation of the RPAs in the recent years. Specifically, New Melones operations assumed in CalSim II described in Section 5.A.5.1.5.5 below override the assumptions outlined in Attachment 7.

5.A.5.1.3.7 Water Transfers

Lower Yuba River Accord (LYRA)

Acquisitions of Component 1 water under the Lower Yuba River Accord, and use of 500 cfs dedicated capacity at Banks PP during July – September, are assumed to be used to reduce the impact of the Apr – May Delta export restrictions under the 2008 and 2009 BiOps on SWP contractors as much as possible.

Phase 8 transfers

Phase 8 transfers are not included in the NAA simulation.

Short-term or Temporary Water Transfers

Short term or temporary transfers such as Sacramento Valley acquisitions conveyed through Banks PP are not included in the NAA simulation.

5.A.5.1.4 Specific Regulatory Assumptions

5.A.5.1.4.1 Lower American Flow Management

The American River Flow Management Standard (ARFMS) is included in the NAA. The flow requirements of ARFMS are further described in other sources (Reclamation 2006).

5.A.5.1.4.2 Minimum flow near Rio Vista

The minimum flow required on the Sacramento River at Rio Vista under the WQCP, SWRCB D-1641 is included. During September through December months, the flow requirement ranges from 3,000 cfs to 4,500 cfs, depending on the month and D-1641 40-30-30 index water year type.

5.A.5.1.4.3 Delta Outflow (Flow and Salinity)

SWRCB D-1641

All flow based Delta outflow requirements per SWRCB D-1641 are included in the NAA simulation. Similarly, for the February through June period the X2 standard is included in the NAA simulation.

USFWS BiOp (December, 2008) Action 4:

USFWS BiOp Action 4 requires additional Delta outflow to manage X2 in the fall months following wet and above normal water years to maintain an average X2 for September and October no greater (more eastward) than 74 kilometers following wet years and 81 kilometers following above normal years. In November, the full inflow to CVP/SWP reservoirs in the Sacramento Basin would be passed (not stored) as needed to augment Delta outflow to maintain the Sep-Oct X2 target. This action is included in the NAA.

5.A.5.1.4.4 Combined Old and Middle River Flows

The 2008 USFWS BiOp's RPA specifies minimum allowable OMR flow requirements in three of its Actions: Action 1 to protect pre-spawning adult Delta smelt from entrainment during the first flush, Action 2 to protect pre-spawning adults from entrainment and from adverse hydrodynamic conditions, and Action 3 to protect larval Delta smelt from entrainment. CalSim II simulates these actions to a limited extent by curtailing south Delta pumping.

A brief description of USFWS's 2008 BiOp's RPA Actions 1-3 is as follows: Action 1 is initiated based on a turbidity trigger that takes place during or after December. This action requires the average daily OMR flow be no more negative than -2,000 cfs for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25% of the monthly criteria). Action 1 ends after 14 days or when Action 3 is triggered based on a temperature criterion. Action 2 starts immediately after Action 1 and requires a range of net daily OMR flows to be no more negative than -1,250 to -5,000 cfs (with a 5-day running average within 25% of the monthly criteria). The Action continues until Action 3 is triggered. Action 3 also requires net daily OMR flow to be no more negative than -1,250 to -5,000 cfs based on a 14 day running average (with a simultaneous 5-day running average within 25%). Although the range is similar to Action 2, the Action implementation is different. Action 3 continues until June 30 or when water temperature reaches a certain threshold. A description of the CalSim II implementation of these actions is provided in Appendix 5A - Attachment 6.

NMFS' 2009 BiOp's RPA Action 4.2.3 requires OMR flow management to protect emigrating juvenile winter-run, yearling spring-run, and Central Valley steelhead within the lower Sacramento and San Joaquin rivers from entrainment into south Delta channels and at the export facilities in the south Delta. This action limits OMR flows to be no more negative than -2,500 to -5,000 cfs. CalSim II assumes OMR flows required in the 2009 NMFS BiOp are covered by OMR flow requirements developed for actions 1 through 3 of the 2008 USFWS BiOp as described in Appendix 5A - Attachment 7. In reality, which BiOp's RPA actions control exports (sets the least negative allowable OMR within the specified ranges) is a function of which species are present and their proximity to the export facilities. CalSim II currently has no input to reflect the fishery conditions in any particular month. Absent fish information, CalSim II sensitivity analyses have shown the above assumptions to be very reasonable.

5.A.5.1.4.5 South Delta Export-San Joaquin River Inflow Ratio

NMFS' 2009 BiOp's RPA Action 4.2.1 requires exports to be capped at a certain fraction of San Joaquin River flow at Vernalis during April and May while maintaining a minimum health and safety pumping level of 1,500 cfs. The RPA action also called for minimum flow levels at

Vernalis, but its values were predicated on upstream water rights decisions which have yet to be made. Hence, no flow augmentation for this specific RPA action is implemented.

5.A.5.1.4.6 Exports at the South Delta Intakes

Exports at Jones and Banks Pumping Plant are restricted to their permitted capacities per SWRCB D-1641 requirements and their Corps permit. In addition, the south Delta exports are subject to Vernalis flow-based export limits during April and May as required by Action 4.2.1. Additional 500 cfs pumping is allowed to reduce impact of NMFS BiOp Action 4.2.1 on SWP during the July through September period.

Under D-1641 the combined export of the CVP Tracy Pumping Plant and SWP Banks Pumping Plant is limited to a percentage of Delta inflow. The percentage ranges from 35 to 45% during February depending on the January eight river index, and is 35% during March through June months. For the rest of the months 65% of the Delta inflow is allowed to be exported.

A health and safety monthly average pumping level of 1,500 cfs is assumed from January through June as long as the OMR restrictions allow for this level of pumping.

As mentioned above, CalSim II does not account for maintenance outages, side flow into the DMC or other real-time phenomena that generally limits exports to levels below what they could otherwise theoretically be.

5.A.5.1.4.7 Delta Water Quality

The NAA simulation includes SWRCB D-1641 salinity requirements. However, not all salinity requirements are included as CalSim II is not capable of predicting salinities in the Delta. Instead, empirically based equations and models are used to relate interior salinity conditions with the flow conditions. DWR's Artificial Neural Network (ANN) trained for salinity is used to predict and interpret salinity conditions at the Emmaton, Jersey Point, Rock Slough and Collinsville stations. Emmaton and Jersey Point standards are for protecting water quality conditions for agricultural use in the western Delta and they are in effect from April 1 to August 15. The EC requirement at Emmaton varies from 0.45 mmhos/cm to 2.78 mmhos/cm, depending on the water year type. The EC requirement at Jersey Point varies from 0.45 to 2.20 mmhos/cm, depending on the water year type. The Rock Slough standard is for protecting water quality conditions for M&I use for water exported through the Contra Costa Canal. It is a year round standard that requires a certain number of days in a year with chloride concentration less than 150 mg/L. The number of days requirement is dependent upon the water year type. The Collinsville standard is applied during October through May months to protect water quality conditions for migrating fish species, and it varies between 12.5 mmhos/cm in May and 19.0 mmhos/cm in October.

The sea level rise change assumed at the Year 2030 results in a modified flow – salinity relationship in the Delta. An ANN, which is capable of emulating DSM2 results under the 15-cm sea level rise condition at the Year 2030 is used to simulate the flow-salinity relationships in CalSim II simulation for the NAA.

5.A.5.1.4.8 San Joaquin River Restoration Program

Friant Dam releases required by the San Joaquin River Restoration Program are assumed to occur in the future as currently planned and implemented under NAA. However, these releases are not modeled in the CWF NAA CalSim II model given the recapture/recirculation component is yet to be defined.

5.A.5.1.5 Operations Criteria

5.A.5.1.5.1 Fremont Weir Operations

The assumptions for the Fremont Weir are based on the BDCP DEIRS Alternative 4 (DWR et al, 2013). To provide seasonal floodplain inundation in the Yolo Bypass, the 17.5- and the 11.5-foot elevation gates are opened between December 1 and March 31. This may extend to May 15, depending on hydrologic conditions and measures to minimize land use and ecological conflicts in the bypass. As a simplification for modeling, the gates are assumed opened until April 30 in all years. The gates are operated to limit maximum spill to 6,000 cfs until the Sacramento River stage reaches the existing Fremont Weir crest elevation. When the river stage is at or above the existing Fremont Weir crest elevation, the notch gates are assumed to be closed. While desired inundation period is on the order of 30 to 45 days, gates are not managed to limit to this range, instead the duration of the event is governed by the Sacramento River flow conditions. To provide greater opportunity for the fish in the bypass to migrate upstream into the Sacramento River, the 11.5-foot elevation gate is assumed to be open for an extended period between September 15 and June 30. As a simplification for modeling, the period of operation for this gate is assumed to be September 1 to June 30. The spills through the 11.5-foot elevation gate are limited to 100 cfs.

5.A.5.1.5.2 Delta Cross Channel Gate Operations

SWRCB D-1641 DCC standards provide for closure of the DCC gates for fisheries protection at certain times of the year. From November through January, the DCC may be closed for up to 45 days. From February 1 through May 20, the gates are closed every day. The gates may also be closed for 14 days during the May 21 through June 15 time period. Reclamation determines the timing and duration of the closures after discussion with USFWS, CDFW, and NMFS.

NMFS BiOp Action 4.1.2 requires the gates to be operated as described in the BiOp based on the presence of salmonids and water quality from October 1 through December 14; and the gates to be closed from December 15 to January 31. CalSim II includes the NMFS BiOp DCC gate operations in addition to the D-1641 gate operations. When the daily flows in the Sacramento River at Wilkins Slough exceed 7,500 cfs (flow assumed to trigger the juvenile salmon migration into the Delta), the DCC is closed for a certain number of days in a month. Using historical data (1945 through 2003, USGS gauge 11390500 “Sacramento River below Wilkins Slough near Grimes, CA”), a linear relationship was obtained between average monthly flow at Wilkins Slough and the number of days in the month where the flow exceeds 7,500 cfs. This relation is used in CalSim II along with its preliminary simulated value for average monthly flow at Wilkins Slough to initially estimate the number of days with DCC gate closure for the October 1 – December 14 time period (Figure 5.A-9).

During October 1 – December 14, if the flow trigger condition is such that additional days of DCC gates closure is called for, however water quality conditions are a concern, the DCC gates remain open and the Delta exports are limited to 2,000 cfs for each day in question. Specifically, if the Rock Slough salinity standard in not met, then the gates are operated per D-1641 criteria.

The gates are also closed in any month if the monthly average Sacramento River flow upstream of the DCC is greater than 25,000 cfs.

5.A.5.1.5.3 Allocation Decisions

CalSim II includes allocation logic for determining deliveries to north-of-Delta and south-of-Delta CVP/SWP contractors. The delivery logic for both the CVP and the SWP starts by computing their respective water supplies index for the contract year. This uses runoff forecast information, which incorporates uncertainty in the hydrology. Each project then uses its own Water Supply Index versus Demand Index Curveto relate forecasted water supplies to deliverable “demand.” The deliverable “demand” is then related to delivery levels, given inputted general balancing between water available for delivery and carryover storage for each Demand Index Level. Updates of delivery levels occur monthly from January 1 through May 1 for the SWP and March 1 through May 1 for the CVP as runoff forecasts become more certain. The south-of-Delta SWP delivery is determined based on water supply parameters and operational constraints. The CVP system wide delivery and south-of-Delta delivery are determined similarly upon water supply parameters and operational constraints with specific consideration for export constraints.

5.A.5.1.5.4 San Luis Operations

CalSim II sets targets for San Luis storage each month that are dependent on the current South-of-Delta allocation and upstream reservoir storage (San Lusis rule curve). When upstream reservoir storage is high, allocations and San Luis fill targets are increased. During a prolonged drought when upstream storage is low, allocations and fill targets are correspondingly low. For the NAA simulation, the San Luis rule curve is managed to maximize filling during summer and fall months when the Delta export pumping is less constrained to minimize situations in which south-of-Delta shortages may occur due to lack of storage or exports.

5.A.5.1.5.5 New Melones Operations

In addition to flood control, New Melones is operated for four different purposes: fishery flows, water quality, Bay-Delta flow, and water supply.

5.A.5.1.5.5.1 Fishery Flows

In the NAA simulation, fishery flows refer to flow requirements of the 2009 NMFS BiOp Action III.1.3 (NMFS 2009). These flows are patterned to provide fall attraction flows in October and outmigration pulse flows in spring months (April 15 through May 15 in all years) and total up to 98.9 TAF to 589.5 TAF annually depending on the hydrological conditions based on the New Melones water supply forecast (the end-of-February New Melones Storage, plus the March - September forecast of inflow to the reservoir) (Tables 5.A-3 through 5.A-5).

5.A.5.1.5.5.2 Water Quality

Water quality releases include releases to meet the State Water Resources Control Board (SWRCB) Decision 1641 (D-1641) salinity objectives at Vernalis and the Decision 1422 (D-1422) dissolved oxygen objectives at Ripon.

The Vernalis water quality requirement (SWRCB D-1641) is an electrical conductivity (EC) requirement of 700 and 1000 micromhos/cm for the irrigation (Apr-Aug) and non-irrigation (Sep-Mar) seasons, respectively.

Additional releases are made to the Stanislaus River below Goodwin Dam if necessary, to meet the D-1422 dissolved oxygen content objective. Surrogate flows representing releases for DO requirement in CalSim II are presented in Table 5.A-6. The surrogate flows are reduced for critical years where New Melones water supply forecast (the end-of-February New Melones Storage, plus the March - September forecast of inflow to the reservoir) is less than 940 TAF. These flows are met through releases from New Melones without any annual volumetric limit.

5.A.5.1.5.5.3 Bay-Delta Flows

Bay-Delta flow requirements are defined by D-1641 flow requirements at Vernalis (not including pulse flows during the April 15 - May 16 period). These flows are met through releases from New Melones without any annual volumetric limit.

D-1641 requires the flow at Vernalis to be maintained during the February through June period. The flow requirement is based on the required location of “X2” and the San Joaquin Valley water year hydrologic classification (60-20-20 Index) as summarized in Table 5.A-7.

5.A.5.1.5.5.4 Water Supply

Water supply refers to deliveries from New Melones to water rights holders (Oakdale Irrigation District and South San Joaquin Irrigation District) and CVP eastside contractors (Stockton East Water District and Central San Joaquin Water Control District).

Water is provided to Oakdale ID and South San Joaquin ID in accordance with their 1988 Settlement Agreement with Reclamation (up to 600 TAF based on hydrologic conditions), limited by consumptive use. The conservation account of up to 200 TAF storage capacity defined under this agreement is not modeled in CalSim II.

5.A.5.1.5.5.5 Water Supply-CVP Eastside Contractors

Annual allocations are determined using New Melones water supply forecast (the end-of-February New Melones Storage, plus the March - September forecast of inflow to the reservoir) for Stockton East WD and Central San Joaquin WCD (Table 5.A-8) and are distributed throughout a year using monthly patterns.

5.A.5.2 CalSim II Assumptions for the Proposed Action

The PA is a dual conveyance alternative with three proposed intakes in the north Delta with 9,000 cfs total pumping capacity (3,000 cfs at each intake). As mentioned previously, the PA assumptions are consistent with the NAA assumptions except for a few operational changes in the Delta and the additional operations associated with the new facilities including north Delta diversion bypass flows, South Delta export operations, Head of Old River barrier operations, Spring Delta outflow and Rio Vista miminum flow requirements. CalSim II assumptions for the PA that are different from the NAA are described below.

5.A.5.2.1 Hydrology

5.A.5.2.1.1 Inflows/Supplies

Consistent with the NAA assumptions.

5.A.5.2.1.2 Level of Development

Consistent with the NAA assumptions.

5.A.5.2.1.3 Demands, Water Rights, CVP/SWP Contracts

Consistent with the NAA assumptions.

5.A.5.2.2 Facilities

5.A.5.2.2.1 Fremont Weir

Consistent with the NAA assumptions.

5.A.5.2.2.2 CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity

Consistent with the NAA assumptions.

5.A.5.2.2.3 SWP Banks Pumping Plant Capacity

Consistent with the NAA assumptions in terms of the physical capacity. SWP Banks pumping plant has an installed capacity of about 10,668 cfs (two units of 375 cfs, five units of 1,130 cfs, and four units of 1,067 cfs). The SWP water rights for diversions specify a maximum of 10,350 cfs, but the U. S. Army Corps' of Engineers (USACE) permit for Clifton Court Forebay Intakes allows a maximum 3-day average diversion rate of 6680 cfs, with additional diversion possible depending on Vernalis flows such that the total diversion can go up to 8,500 cfs during December 15 – March 15 from the south Delta channels. These restrictions on the Clifton Court Forebay Intake are applied to the Banks Pumping Plant diversions from the south Delta in the CalSim II model. Additional capacity of 500 cfs (pumping limit up to 7,180 cfs) is allowed for diversions from the south Delta consistent with the NAA.

Banks Pumping Plant physical capacity is used to constrain the maximum allowable combined SWP pumping from the south Delta channels and the proposed north Delta diversion.

5.A.5.2.2.4 CCWD Intakes

Consistent with the NAA assumptions.

5.A.5.2.2.5 Proposed Tunnels and the North Delta Diversion Intakes

The north Delta diversion intakes divert water from the Sacramento River in the north Delta near Hood and convey it through the proposed tunnels with an intermediate forebay along the way to the existing export facilities in the south Delta. The maximum conveyance capacity is assumed to be 9,000 cfs. Three separate intakes (intakes 2, 3 and 5) each capable of diverting up to 3,000 cfs are assumed along the Sacramento River near Hood, all located upstream of Sutter Slough. In the CalSim II simulation of the PA, north Delta diversion is modeled as a single diversion located along the Sacramento River at Hood.

5.A.5.2.3 Regulatory Standards

5.A.5.2.3.1 D-1641 Operations

Consistent with the NAA assumptions.

5.A.5.2.3.2 Coordinated Operations Agreement (COA)

Consistent with the NAA assumptions.

5.A.5.2.3.3 CVPIA (b)(2) Assumptions

Consistent with the NAA assumptions.

5.A.5.2.3.4 Continued CALFED Agreements

Consistent with the NAA assumptions.

5.A.5.2.3.5 USFWS Delta Smelt BiOp Actions

Consistent with the NAA assumptions.

5.A.5.2.3.6 NMFS BiOp Salmon Actions

Consistent with the NAA assumptions except for NMFS BiOp (June 2009) Action 4.2.1 as noted in Section 5.A.5.2.4.5, *South Delta Export-San Joaquin River Inflow Ratio*.

5.A.5.2.3.7 Water Transfers

Lower Yuba River Accord (LYRA)

Consistent with the NAA assumptions.

Phase 8 transfers

Consistent with the NAA assumptions.

Short-term or Temporary Water Transfers

Consistent with the NAA assumptions.

5.A.5.2.4 Specific Regulatory Assumptions

5.A.5.2.4.1 Lower American Flow Management

Consistent with the NAA assumptions.

5.A.5.2.4.2 Minimum flow near Rio Vista

The minimum flow required on the Sacramento River at Rio Vista under the WQCP, SWRCB D-1641 is included consistent with the NAA Assumptions. For January through August a minimum flow of 3,000 cfs is maintained in all years under the PA.

5.A.5.2.4.3 Delta Outflow (Flow and Salinity)

SWRCB D-1641

Consistent with the NAA assumptions.

Additional Spring Outflow Requirement

The PA includes an additional outflow requirement as an average over the March through May months to maintain Delta outflows that would occur under the NAA at the time North Delta Diversion would become operational, which for modeling purposes this is represented by the NAA model with projected climate (Q5) and sea level conditions at Year 2030. Mar–May average Delta outflows are tabulated below in Table 5.A-9 for 10% exceedances intervals based on the modeled Mar-May Delta outflow results from the NAA CalSim II simulation. Since 2009 NMFS BiOp Action IV.2.1 San Joaquin River i-e ratio constraint is a primary driver for the Apr-May Delta outflows under the NAA, this criterion was used to constrain Apr-May total Delta exports under the PA to evince desired NAA Mar-May average Delta outflows in the PA. Implicit in this approach is that spring upstream reservoir operations will not differ significantly from those in the NAA.

USFWS BiOp (December, 2008) Action 4:

Consistent with the NAA assumptions.

5.A.5.2.4.4 Combined Old and Middle River Flows

The PA requires the OMR flows to be the higher of the NAA OMR criteria and the criteria specified below in Table 5.A-10. All of the OMR modeling assumptions included in the NAA as a surrogate for the OMR criteria required by the various fish protection triggers (density, calendar, and flow based triggers) described in the 2008 USFWS and the 2009 NMFS BiOps were incorporated into the modeling of the PA. In April, May and June the PA additionally require OMR values that are dependent upon the San Joaquin River inflow as noted in the Table 5.A-11 in place of NMFS BiOp Action IV.2.1 San Joaquin River inflow to South Delta Exports ratio constraint.

In October and November, the required OMR is dependent on the timing of the SWRCB D-1641 pulse flow on the San Joaquin River. Prior to the D-1641 pulse flow, there are no OMR flow restrictions. During the pulse flows, south Delta exports are not allowed. During the two weeks following the pulse period, OMR is restricted to -5,000 cfs. For modeling purposes, the pulse is assumed to occur during the last two weeks of October (16th – 31st). The first two weeks of October (1st – 15th) are assumed to be pre-pulse period. The first two weeks in November (1st – 15th) are assumed to be post-pulse period. -5,000 cfs was used as the background OMR requirement for the two week pre-pulse period, to compute the monthly OMR requirement for October. In December, a background OMR requirement of -8,000 cfs is assumed to compute the monthly OMR requirement, except when the north Delta diversion initial pulse measured at Wilkins Slough is triggered, which limits the OMR flow requirement to -5,000 cfs. The -5,000 cfs OMR requirement is continued until either the Sacramento River initial pulse concludes or when the Delta smelt trigger (2008 USFWS RPA Action 1) occurs. Once the Delta Smelt Action 1 is triggered, OMR requirement of -2,000 cfs is assumed for the remaining days in December.

Table 5.A-12 shows the Head of Old River (HOR) gate open percentages for each month. The % values noted in the Table 5.A-12, indicate the appropriate opening for the new operable gates, to allow the specified fraction of “the flow that would have entered the Old River if the barrier were fully open”.

In computing the OMR flow in the CalSim II model, the % opening noted in Table 5.A-12 is assumed as the % of time in a month the HOR gate is open. For October, since HOR gate is required to be open 50% for 2 weeks (pre-pulse) and closed for 2 weeks (pulse), the net % open for the whole month was assumed to be 25%. Similarly, for November, since HOR gate is required to be open 50% for 2 weeks (post-pulse) and 100% open for 2 weeks, the net % open for the whole month was assumed to be 75%. Similarly, the net % open for the whole month of June was assumed to be 75% based on the values noted in the Table 5.A-12. Further, it was assumed that the salmon fry start emmigrating on January 1st, for simplification, and therefore, the net % open for the whole month of January is assumed to be 50%.

5.A.5.2.4.5 South Delta Export-San Joaquin River Inflow Ratio

NMFS BiOp (June 2009) Action 4.2.1 requires the south Delta exports are governed by this ratio in the months of April and May under the NAA. As such this action is not included in the PA. However, this action was used to constrain the total Delta exports under the PA to meet the proposed March – May average Delta outflow requirements.

5.A.5.2.4.6 Exports at the South Delta Intakes

The south Delta exports in PA are operated per SWRCB D-1641. The combined exports from the south Delta channels at the CVP Tracy Pumping Plant and SWP Banks Pumping Plant is limited to a percentage of the total Delta inflow, based on the export-inflow ratio specified under D-1641. In computing the export-inflow ratio under the PA, the diversion at the north Delta intakes is not included in the export term, and the Sacramento River inflow is defined as that occurring downstream of the North Delta Intakes.

5.A.5.2.4.7 Delta Water Quality

The PA includes SWRCB D-1641 salinity requirements consistent with the NAA. Pumping at the south Delta intakes are preferred during the July through September months up to a total pumping of 3,000 cfs to minimize potential water quality degradation in the south Delta channels. No specific intake preference is assumed beyond 3,000 cfs.

5.A.5.2.4.8 San Joaquin River Restoration Program

Consistent with the NAA assumptions.

5.A.5.2.4.9 North Delta Diversion Bypass Flows

Bypass flows requirements in the Sacramento River are specified downstream of the north Delta diversion intakes, which govern the flow required to remain in the river before any diversion can occur. The bypass rules include low level pumping at each intake during Sacramento River Pulse flow(s) period. After a pulse has ended, the allowable diversion will go to post-pulse operations through June that can transition through three levels of protection (Level I to Level II and subsequently to Level III) subject to hydrologic and fishery conditions. Minimum bypass flow requirements are specified for July through November, as noted in Table 5.A-13.

Beginning October 1st, whenever the initial Sacramento River pulse begins low level pumping allows diversions of up to 6% of Sacramento River flow flow upstream of the north Delta intakes. The low level pumping is less than or equal to 300 cfs at any one intake, with a combined limit of 900 cfs for the three intakes in the PA. The low level pumping is constrained such that the river flow never falls below 5,000 cfs.

During the initial pulse protection period low level pumping is maintained until the pulse period has ended. For modeling purposes, the initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% within a five day period and (2) Wilkins Slough flow becomes greater than 12,000 cfs. The pulse protection and the low level pumping continues until (1) Wilkins Slough returns to pre-pulse flows (flow on first day of the within-5 day increase), (2) Wilkins Slough flows decrease for five consecutive days, or (3) Wilkins Slough flows are greater than 20,000 cfs for 10 consecutive days. If the initial pulse begins and ends before December 1, the May Level 1 post-pulse criteria will go into effect after the pulse until December 1. On December 1, the post-pulse rules defined below for December through April, starting with Level 1 apply. If the initial pulse begins and ends before December 1^{st}, a second pulse period will be afforded the same protective operation.

After the pulse period has ended, the bypass flows noted in the Table 5.A-13 are maintained. After the initial pulse(s), Level I post-pulse bypass rules are applied until 15 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level II post-pulse bypass rules are applied until 30 days of bypass flows above 20,000 cfs have accrued since the pulse ended. Then Level III post-pulse bypass rules are applied. The bypass rules were applied on the mean daily river flows in the CalSim II model. Under the post-pulse operations allowable diversion will be greater of the low-level pumping or the diversion allowed by the following post-pulse bypass flow rules. In actual operations these criteria as well as fishery conditions are expected to guide allowable north Delta intake diversions as described in Section 3.3.3.1 of the BA.

In addition to the bypass flow criteria described above, a linear constraint was applied in the CalSim II PA simulation on the potential diversion at the north Delta intakes, to account for the fish screen sweeping velocity criteria of 0.4 fps based on diversion limitations from DSM2 modeling.

5.A.5.2.5 Operations Criteria

5.A.5.2.5.1 Fremont Weir Operations

Consistent with the NAA assumptions.

5.A.5.2.5.2 Delta Cross Channel Gate Operations

Consistent with the NAA assumptions.

5.A.5.2.5.3 Allocation Decisions

Consistent with the NAA assumptions.

5.A.5.2.5.4 San Luis Operations

Under the PA, the CalSim II San Luis rule curve is modified in expectation that the new north Delta diversion facility would allow capturing winter and spring excess flows and filling of the San Luis Reservoir to a greater extent than the NAA. Additional modifications to the rule curve were included to preserve upstream carryover storage conditions while minimizing south-of-Delta shortages in the fall months. Sensitivity analyses indicated that using the NAA's more aggressive rule to move water south earlier in the water year than in the PA would yield a little more delivery, but would be at the expense of upstream storage.

5.A.5.2.5.5 New Melones Operations

Consistent with the NAA assumptions.

5.A.6 CalSim II Modeling Results

This section provides monthly CalSim II model simulation results for the NAA and the PA evaluated for the CWF BA. For each parameter listed below figures and tables in various formats are included to provide the reader with tools for multiple ways of analysis. The different types of presentations are explained below:

- Long Term Average Summary and Water Year Type Based Statistics Summary Tables: These tables provide parameter values for each 10% increment of exceedance probability (rows) for each month (columns) as well as long-term and year-type averages, using the Sacramento Valley 40-30-30 Index for the Trinity, Sacramento, Feather, and American Rivers and the San Joaquin Valley 60-20-20 Index for the Stanislaus River developed by the SWRCB for projected climate at Year 2030 (under Q5 scenario) for each month.

- Probability of Exceedance Plots: Probability of exceedance plots are provided for each month over the period of record as well as monthly plots by water year type. Probability of exceedance plots provide the frequency of occurrence of values of a parameter that exceed a reference value. For this appendix, the calculation of exceedance probability is done by ranking the data. For example, for Shasta storage end of September exceedance plot, Shasta storage values at the end of September for each simulated year are sorted in ascending order. The smallest value would have a probability of exceedance of 100% since all other values would be greater than that value; and the largest value would have a probability of exceedance of 0%. All the values are plotted with probability of exceedance on the x-axis and the value of the parameter on the y-axis. Following the same example, if for one scenario, Shasta end of September of 2,000 TAF corresponds to 80% probability; it implies that Shasta end-of September storage is higher than 2,000 TAF in 80% of the years under the simulated conditions.

- Box and Whisker Plots: These plots show the monthly CalSim II results under the NAA and the PA for each month for each water year type. The plots display the distribution of data based on the following statistical summary.
    - 5th percentile that corresponds to 95% exceedance probability,
    - first quartile (25th percentile that corresponds to 75% exceedance probability),
    - median (50% exceedance probability),
    - third quartile (75th percentile that corresponds to 25% exceedance probability),
    - 95th percentile that corresponds to 5% exceedance probability, and
    - mean

End of month storage, monthly average flows, and other CalSim II results as listed below are presented in this appendix. For each of the parameter identified below a table comparing monthly temperature results, a monthly exceedance plot, and box-whisker plot by water year type are included.

5.A.6-1 Trinity Lake Storage

5.A.6-2 Whiskeytown Reservoir Storage

5.A.6-3 Shasta Lake Storage

5.A.6-4 Lake Oroville Storage

5.A.6-5 Folsom Lake Storage

5.A.6-6 New Melones Lake Storage

5.A.6-7 Trinity River below Lewiston Dam Flow

5.A.6-8 Clear Creek Tunnel Flow

5.A.6-9 Clear Creek below Whiskeytown Dam Flow

5.A.6-10 Sacramento River below Keswick Dam Flow

5.A.6-11 Sacramento River at Bend Bridge Flow

5.A.6-12 Feather River below Thermalito Diversion Dam Flow

5.A.6-13 Feather River at Sacramento River Confluence Flow

5.A.6-14 Sacramento River at Verona Flow

5.A.6-15 Fremont Weir Flow

5.A.6-16 American River below Nimbus Dam Flow

5.A.6-17 American River at Sacramento River Confluence Flow

5.A.6-18 Sacramento River at Freeport Flow

5.A.6-19 North Delta Diversion near Hood

5.A.6-20 Yolo Bypass Flow

5.A.6-21 Stanislaus River at Goodwin Flow

5.A.6-22 Stanislaus River at Mouth Flow

5.A.6-23 San Joaquin River at Vernalis Flow

5.A.6-24 Mokelumne and Cosumnes River Flow

5.A.6-25 Old and Middle River Flow

5.A.6-26 Delta Outflow

5.A.6-27 South Delta Exports

5.A.6-28 Total Delta Exports

5.A.6-29 X2 Position

5.A.6-30 San Joaquin River at Vernalis Salinity

5.A.6-31 DCC Number of Days Gates Open

5.A.6-32 DCC Flow

5.A.6-33 Total Jones Pumping Plant Exports

5.A.6-34 Total Banks Pumping Plant Exports

5.A.6-35 Sacramento River above Red Bluff Diversion Dam Flow

5.A.6-36 Sacramento River at Wilkins Slough Flow

5.A.7 References

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Attachment 1: Climate Change and Sea Level Rise Scenarios Selection

This attachment provides a summary of the approach used to develop the climate change and sea level rise projections at Year 2030 for the CWF BA. This approach and the selected climate change and sea level rise projections are identical to the projections at Year 2025 used in BDCP DEIRS (DWR et al. 2013). The attachment also summarizes the projected changes in the temperature and precipitation under each climate change scenario selected in comparison with the observed climate conditions.

Attachment 2: Regional Hydrologic Modeling

This attachment describes the approach used in modeling the projected runoff changes and the resulting hydrologic changes from the VIC model under the future climate scenarios compared to the current hydrology, which formed the basis of CalSim II’s climate-modified inputs. This approach and the resulting runoff changes under selected climate change projections are identical to those presented in the BDCP DEIRS (DWR et al. 2013).

Attachment 3: Operations Sensitivity to Climate Change Projections

This attachment summarizes the key findings from a sensitivity analysis performed to analyze operational changes considering various climate change projections under CWF BA NAA and the PA scenarios. The NAA and the PA were simulated using CalSim II under the current climate (Q0), Q5 (central tendency), Q2 (drier and more warming) and Q4 (wetter and less warming) climate change projections. The operations results from these simulations were analyzed to understand the sensitivity of incremental changes between the PA and the NAA to climate change assumptions. This section summarizes key CalSim II results for the NAA and the PA under the four climate scenarios.

Attachment 4: Fremont Weir Notch

This attachment summarizes the approach used to develop rating curves to define the amount of flow that would spill over a modified Fremont Weir based on a specific Sacramento River flow and to define the amount of inundation that would occur at the flow rate. The derived rating curves are used directly in the CalSim II model to define the monthly and daily spills over the Fremont Weir and Sacramento Weir when integrated with the system operations of the CWF BA scenarios. This attachment includes a technical memorandum previously documented for use in BDCP DEIRS (DWR et al. 2013).

Attachment 5: Summary of Demands

This attachment provides a summary of demands assumptions in the Cal Sim II modeling of the NAA and the PA for the CWF BA. The attachment includes information related to American River demand assumptions, and delivery specification tables showing the assumed CVP/SWP contract amounts, and other water rights assumptions.

Attachment 6: Representation of U.S. Fish and Wildlife Service Biological Opinion Reasonable and Prudent Alternative Actions for CalSim II Planning Studies

This attachment summarizes the CalSim II assumptions for simulating the 2008 USFWS BiOp RPAs. The information included in this attachment is consistent with what was provided to and agreed by the lead agencies in the, "*Representation of U.S. Fish and Wildlife Service Biological Opinion Reasonable and Prudent Alternative Actions for CalSim II Planning Studies*", on February 10, 2010 (updated May 18, 2010).

Attachment 7: Representation of National Marine Fisheries Service Biological Opinion Reasonable and Prudent Alternative Actions for CalSim II Planning Studies

This attachment summarizes the CalSim II assumptions for simulating the 2009 NMFS BiOp RPAs. The information included in this section is consistent with what was provided to and agreed by the lead agencies in the, "*Representation of National Marine Fisheries Service Biological Opinion Reasonable and Prudent Alternative Actions for CalSim II Planning Studies*", on February 10, 2010.

Attachment 8: Modified CalSim II Inputs for Climate Change

This attachment summarizes the list of CalSim II inputs updated to reflect the effects of climate change.

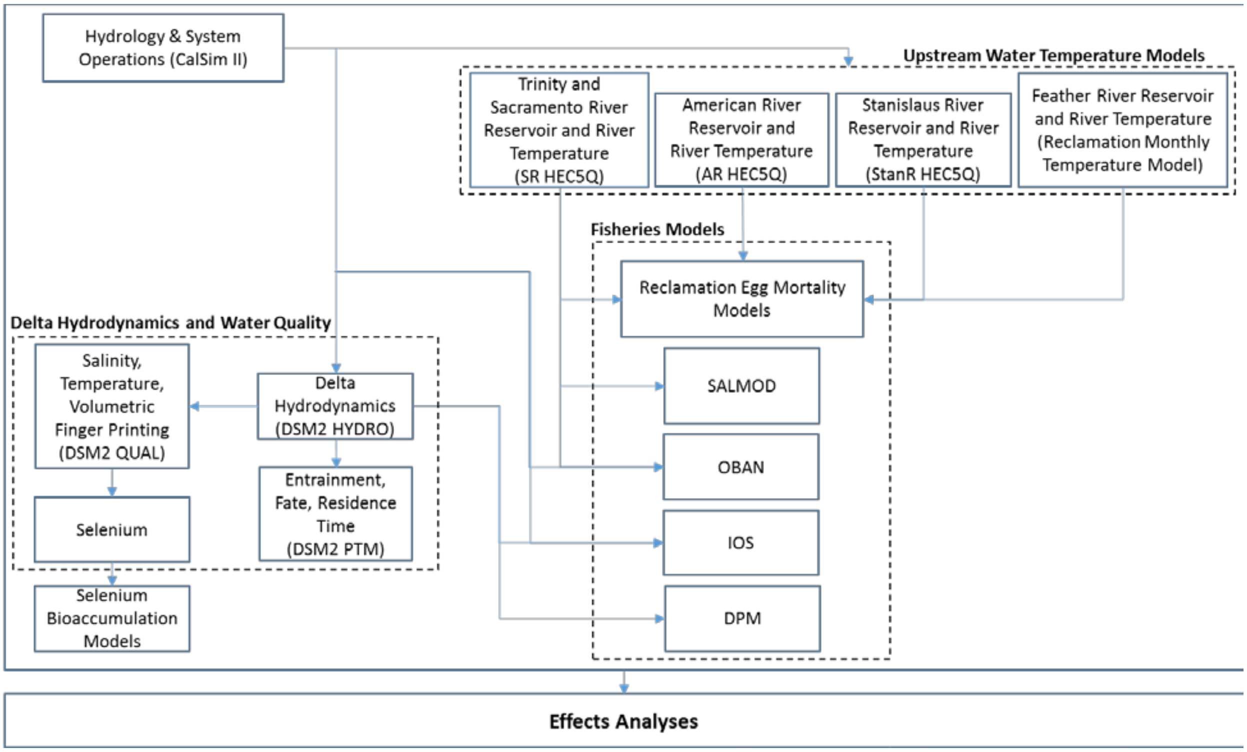
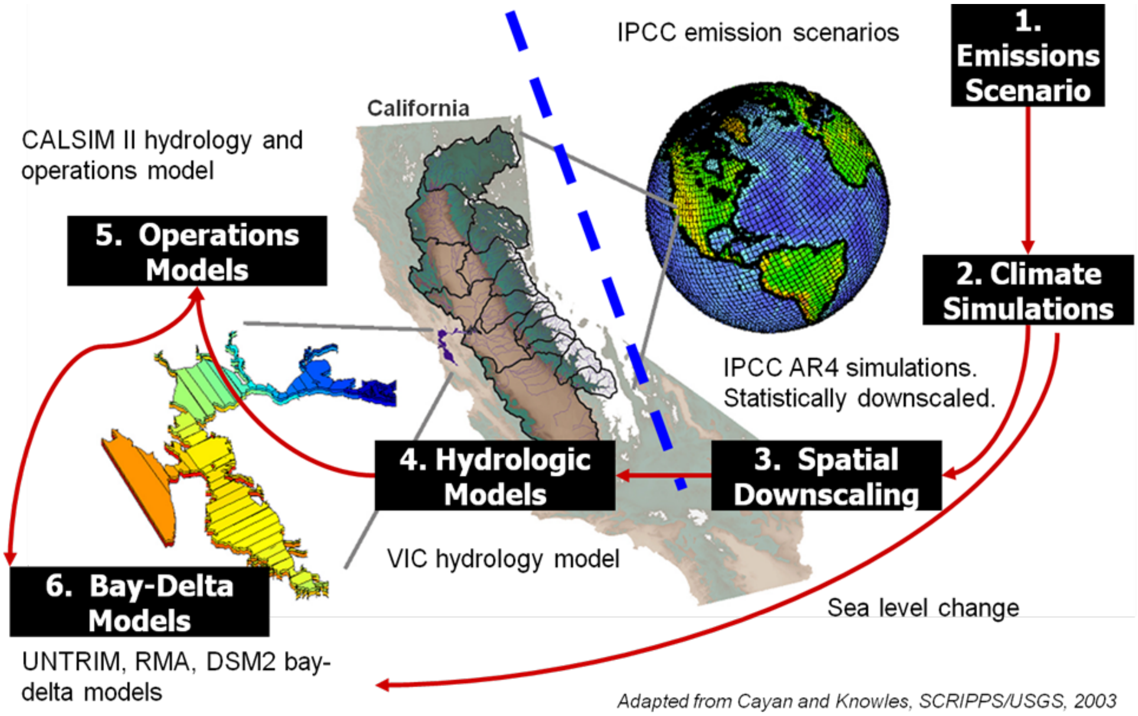


Figure 5.A-1 Analytical Framework used to Evaluate Impacts of the PA



Adapted from Cayan and Knowles, SCRIPPS/USGS, 2003

Figure 5.A-2 Characterizing Climate Impacts from Atmosphere to Oceans

Figure 5.A-3 Major Reservoirs, Streams and Facilities (both CVP/SWP) Included in the CalSim II Model

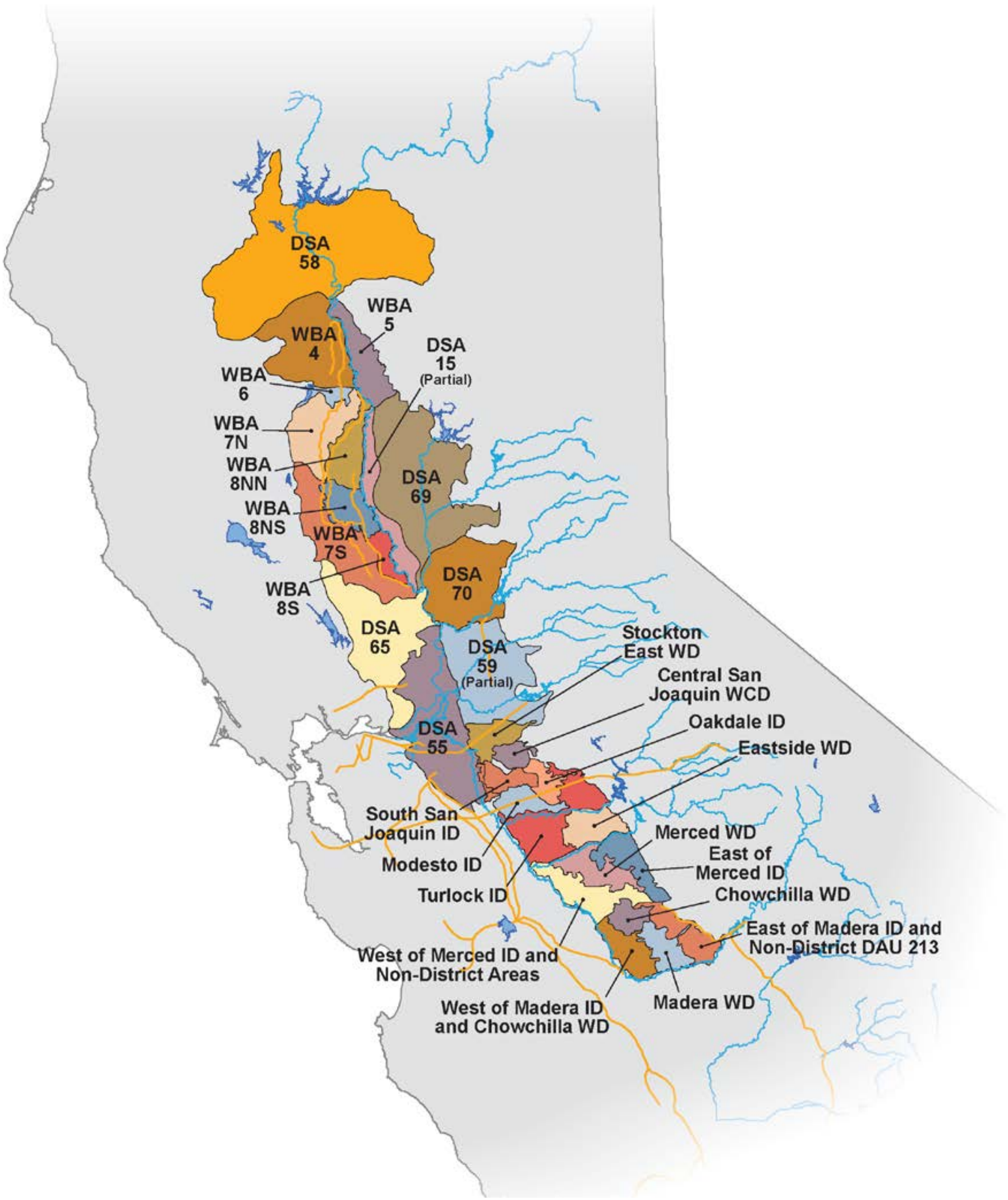


Figure 5.A-4 CalSim II Depletion Analysis Regions

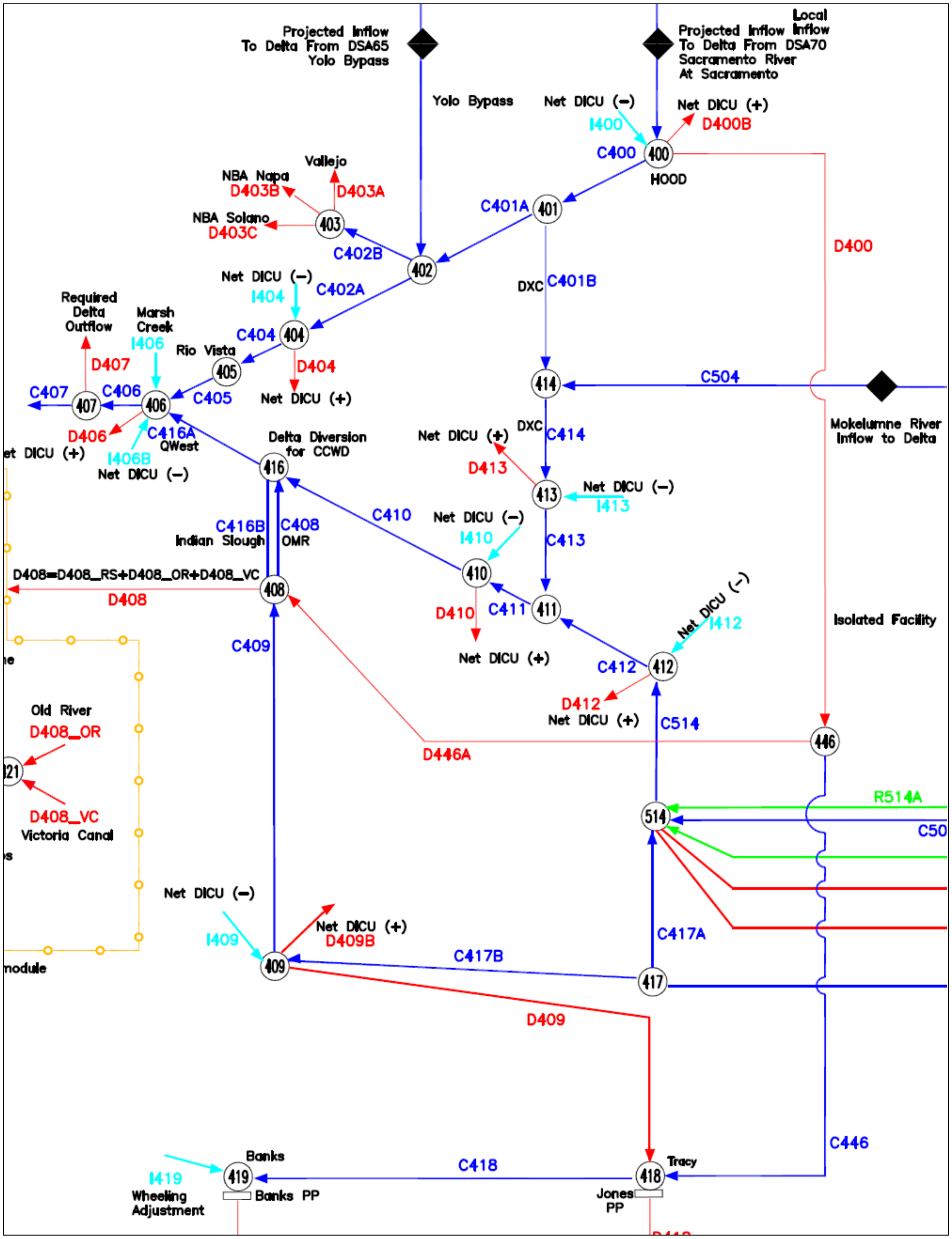


Figure 5.A-5 Updated CalSim II network for the inclusion of north Delta diversion (D400)

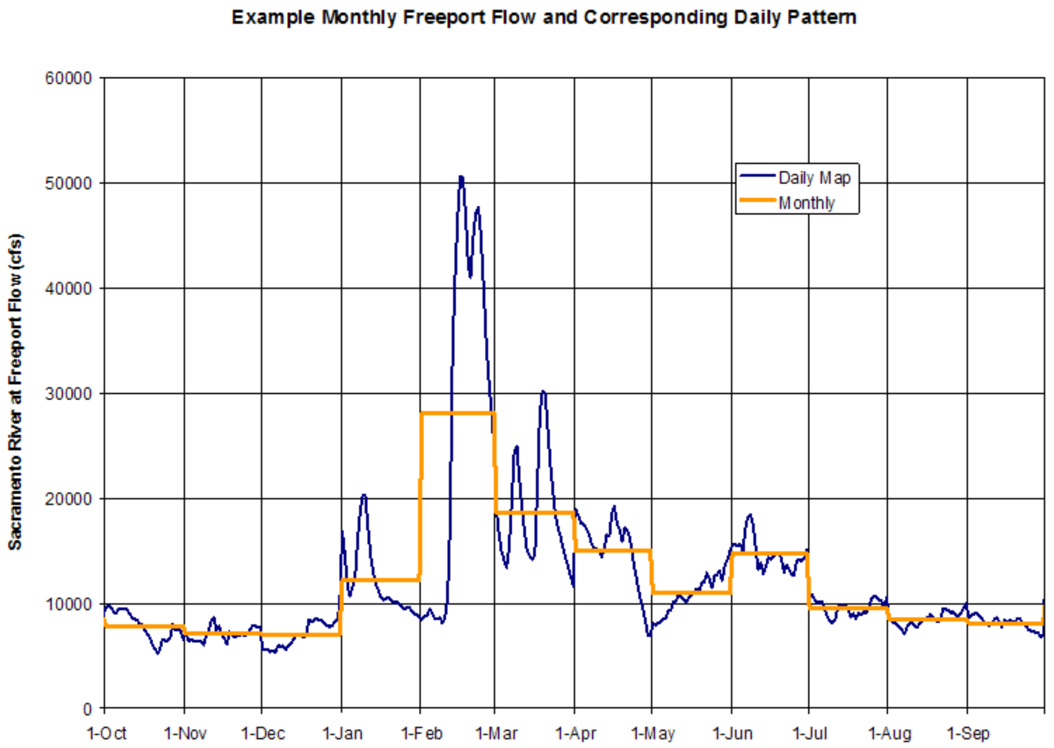


Figure 5.A-6 Example monthly-averaged and daily-averaged flow for Sacramento River at Freeport

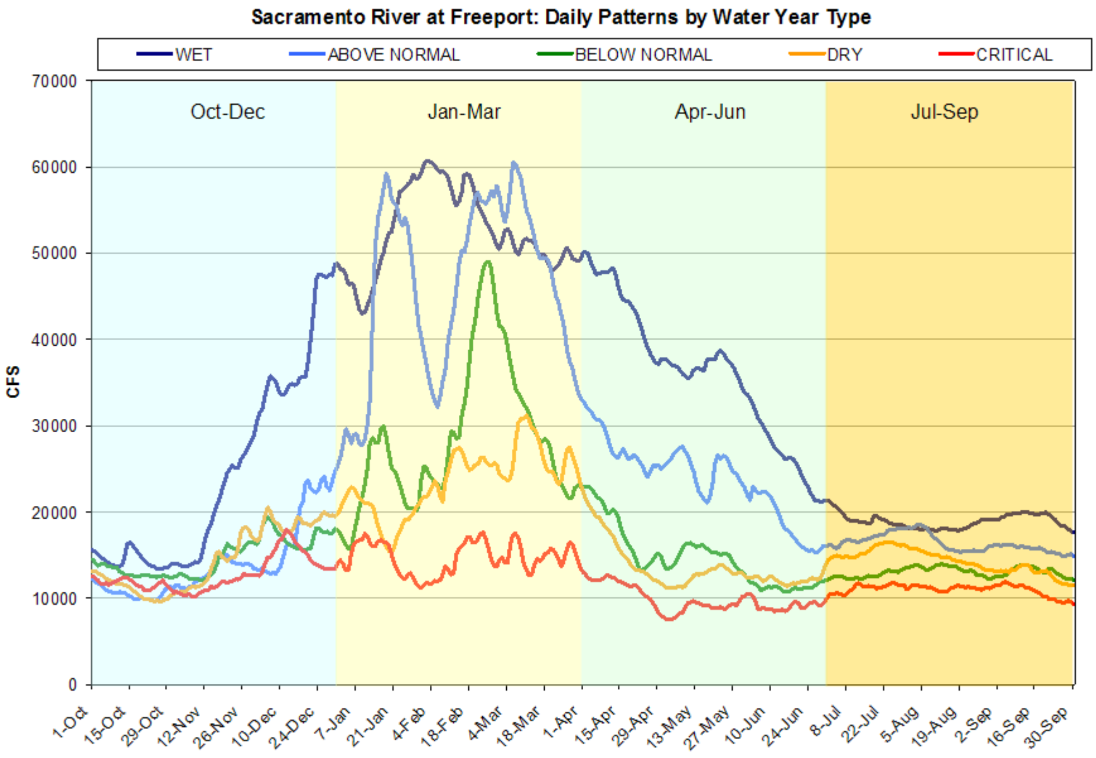


Figure 5.A-7 Mean daily flows by Water Year Type for Sacramento River at Freeport

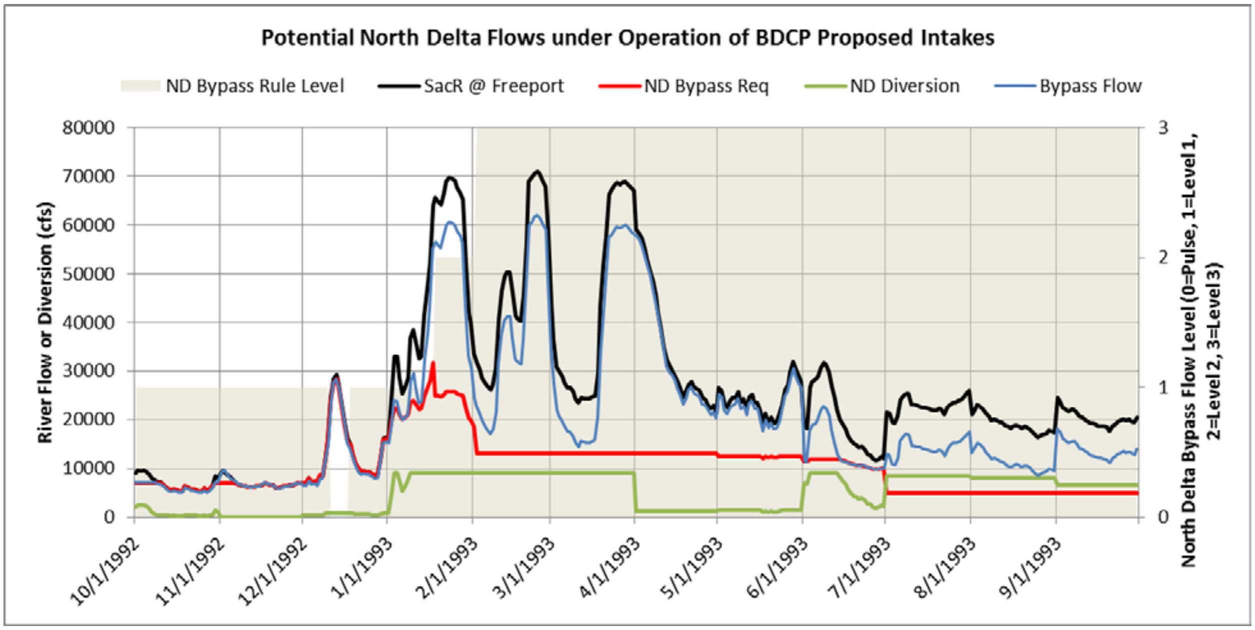


Figure 5.A-8 Example year daily patterns and operation of the north Delta intakes. Note: the grey shading indicates the active bypass rule (0=pulse/low level pumping, 1=level I, 2=level II, and 3=level III).

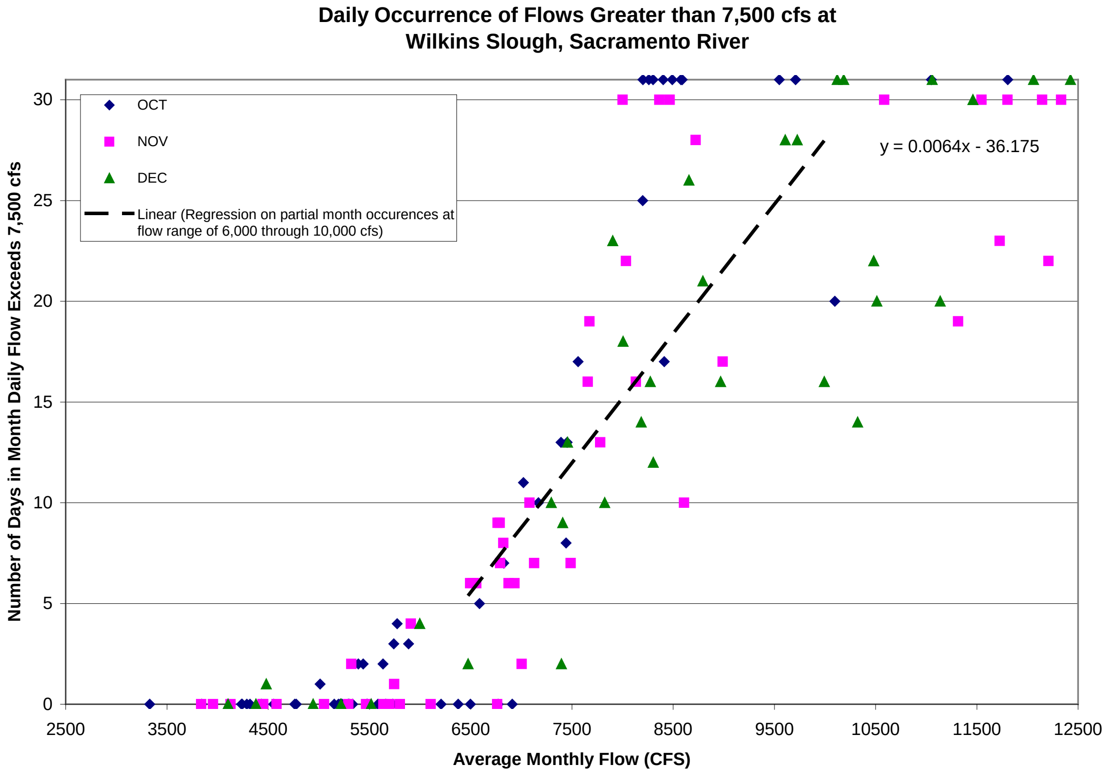


Figure 5.A-9 Relationship between monthly averages of Sacramento River flows and number of days that daily flow exceeds 7,500 cfs in a month at Wilkins Slough

Table 5.A-1 Identified "Pattern" Water Year for the Water Years 1922 to 1955 with Missing Daily Historical Flows

Water Year	Total Annual Unimpaired Delta Inflow (TAF)	Selected "Pattern" Water Year	Total Annual Unimpaired Delta Inflow (TAF)
1922	32,975	1975	31,884
1923	23,799	2002	23,760
1924	8,174	1977	6,801
1925	26,893	1962	25,211
1926	18,534	1959	17,967
1927	38,636	1984	38,188
1928	26,363	1962	25,211
1929	12,899	1994	12,456
1930	20,326	1972	19,863
1931	8,734	1977	6,801
1932	24,179	2002	23,760
1933	14,126	1988	14,019
1934	12,895	1994	12,456
1935	28,486	2003	28,228
1936	30,698	2003	28,228
1937	25,448	1962	25,211
1938	56,949	1998	56,482
1939	12,743	1994	12,456
1940	37,185	1963	36,724
1941	46,746	1986	46,602
1942	42,301	1980	41,246
1943	36,870	1963	36,724
1944	17,158	1981	17,131
1945	26,757	1962	25,211
1946	28,823	2003	28,228
1947	16,206	2001	15,460
1948	23,741	1979	22,973
1949	19,176	1960	19,143
1950	23,272	1979	22,973
1951	39,110	1984	38,188
1952	49,270	1986	46,602
1953	30,155	2003	28,228
1954	26,563	1962	25,211
1955	17,235	1981	17,131

Table 5.A-2 Summary of CVP/SWP Demands (TAF/Year) under NAA

Project Contractor Type	North-of-the-Delta	South-of-the-Delta
CVP Contractors		
Settlement/Exchange	2,194	840
Water Service Contracts	935	2,101
Agriculture	378	1,937
M&I	557	164
Refuges	189	281
SWP Contractors		
Feather River Service Area	983	
Table A	114	4,055
Agriculture	0	1,017
M&I	114	3,038

Note:
Urban demands noted above are for full build out conditions.

Table 5.A-3 Annual Fishery Flow Allocation in New Melones

New Melones Water Supply Forecast (TAF)	Fishery Flows (TAF)
0 to 1,399.9	185.3
1,400 to 1,999.9	234.1
2,000 to 2,499.9	346.7
2,500 to 2,999.9	483.7
≥3,000	589.5

Table 5.A-4 Monthly “Base” Flows for Fisheries Purposes Based on the Annual Fishery Volume

Annual Fishery Flow Volume (TAF)	Monthly Fishery Base Flows (cfs)											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr 1–15	May 16–31	Jun	Jul	Aug	Sep
98.9	110	200	200	125	125	125	250	250	0	0	0	0
185.3	577.4	200	200	212.9	214.3	200	200	150	150	150	150	150
234.1	635.5	200	200	219.4	221.4	200	500	284.4	200	200	200	200
346.7	774.2	200	200	225.8	228.6	200	1,471.4	1,031.3	363.3	250	250	250
483.7	796.8	200	200	232.3	235.7	1,521	1,614.3	1,200	940	300	300	300
589.5	841.9	300	300	358.1	364.3	1,648.4	2,442.9	1,725	1,100	429	400	400

Table 5.A-5 April 15 through May 15 "Pulse" Flows for Fisheries Purposes Based on the Annual Fishery Volume

Annual Fishery Flow Volume (TAF)	Fishery Pulse Flows (CFS)	
	April 15-30	May 1-15
185.3	687.5	666.7
234.1	1,000.0	1,000.0
346.7	1,625.0	1,466.7
483.7	1,212.5	1,933.3
589.5	925.0	2,206.7

Table 5.A-6 Surrogate flows for D-1422 DO requirement at Vernalis (TAF)

Month	Non-Critical Years	Critical Years
January	0.0	0.0
February	0.0	0.0
March	0.0	0.0
April	0.0	0.0
May	0.0	0.0
June	15.2	11.9
July	16.3	12.3
August	17.4	12.3
September	14.8	11.9
October	0.0	0.0
November	0.0	0.0
December	0.0	0.0

Table 5.A-7 Bay-Delta Vernalis Flow Objectives (average monthly cfs)

60-20-20 Index	Flow Required if X2 is West of Chipps Island	Flow required if X2 is East of Chipps Island
Wet	3,420	2,130
Above Normal	3,420	2,130
Below Normal	2,280	1,420
Dry	2,280	1,420
Critical	1,140	710

Table 5.A-8 CVP Contractor Allocations

New Melones Water Supply Forecast (TAF)	CVP Contractor Allocation (TAF)
<1,400	0
1,400 to 1,800	49
>1,800	155

Table 5.A-9 Proposed Action Additional Spring Outflow Requirement – No Action Alternative Average Mar-May Delta Outflow

Percent Exceedance	10%	20%	30%	40%	50%	60%	70%	80%	90%
Proposed Mar-May Delta Outflow Target (cfs)*:	44,500	44,500	35,000	27,900	20,700	16,800	13,500	11,500	9,100

* values based on the flow frequency of Mar – May average Delta Outflow modeled under No Action Alternative (January 27th, 2015 update of CalSim II model by Bureau of Reclamation) under Early Long-Term Q5 climate projections, without San Joaquin River Restoration Flows for this BA (Dated 4/8/2015).

Table 5.A-10 Old and Middle River Flow Criteria under the Proposed Action

	Combined Old and Middle River Flows to be No Less than Values Below[a] (cfs)				
Month	**Wet Water Year**	**Above Normal Water Year**	**Below Normal Water Year**	**Dry Water Year**	**Critical Dry Water Year**
January	0	-3,500	-4,000	-5,000	-5,000
February	0	-3,500	-4,000	-4,000	-4,000
March	0	0	-3,500	-3,500	-3,000
April[b]	see Table 5.A-12	see Table 5.A-12	see Table 5.A-12	see Table 5.A-12	see Table 5.A-12
May[b]	see Table 5.A-12	see Table 5.A-12	see Table 5.A-12	see Table 5.A-12	see Table 5.A-12
June[b]	see Table 5.A-12	see Table 5.A-12	see Table 5.A-12	see Table 5.A-12	see Table 5.A-12
July	N/A	N/A	N/A	N/A	N/A
August	N/A	N/A	N/A	N/A	N/A
September	N/A	N/A	N/A	N/A	N/A
October[c]	Based on State Water Board D-1641 pulse trigger.	Based on State Water Board D-1641 pulse trigger.	Based on State Water Board D-1641 pulse trigger.	Based on State Water Board D-1641 pulse trigger.	Based on State Water Board D-1641 pulse trigger.
November[c]	Based on State Water Board D-1641 pulse trigger.	Based on State Water Board D-1641 pulse trigger.	Based on State Water Board D-1641 pulse trigger.	Based on State Water Board D-1641 pulse trigger.	Based on State Water Board D-1641 pulse trigger.
December[d]	-5,000	-5,000	-5,000	-5,000	-5,000

[a] Values are monthly average for use in modeling. The model compares these minimum allowable OMR values to 2008 USFWS BiOp RPA OMR requirements and uses the less negative flow requirement.

[b] Based on San Joaquin inflow relationship to OMR provided Table 5.A-12.

[c] Two weeks before the D-1641 pulse (assumed to occur October 16-31 in the modeling), No OMR restrictions (for modeling purposes an OMR requirement of -5,000 cfs was assumed during this 2 week period). Two weeks during the D-1641 pulse, no south Delta exports. Two weeks after the D-1641 pulse, -5,000 cfs OMR requirement (through November).

[d] OMR restriction of -5,000 cfs for Sacramento River winter-run Chinook salmon when North Delta initial pulse flows are triggered or OMR restriction of -2,000 cfs for delta smelt when triggered. For modeling purposes (to compute a composite Dec allowable OMR), remaining days were assumed to have an allowable OMR of -8000 cfs.

Table 5.A-11 San Joaquin Inflow Relationship to Old and Middle River Flow Criteria

April and May		June	
If San Joaquin River flow at Vernalis is (cfs):	**Minimum Average OMR flows (interpolated linearly between values) (cfs)**	**If San Joaquin flow at Vernalis is the following (cfs):**	**Average OMR flows would be at least the following (no interpolation) (cfs):**
≤ 5,000	-2,000	≤ 3,500	-3,500
6,000	+1000	3,501 to 10,000	0
10,000	+2000		
15,000	+3000	10,001 to 15,000	+1000
≥30,000	+6000	>15,000	+2000

Table 5.A-12 Head of Old River Operable Barrier Operations Criteria if San Joaquin River Flows at Vernalis are Equal To or Less Than 10,000 cfs

Month	Head of Old River Gate Operations/Modeling assumptions Open Percentage[a]
Oct[b]	50% (except during the pulse)
Nov[b]	100% (except during the post-pulse period)
Dec	100%
Jan[c]	50%
Feb	50%
Mar	50%
April	50%
May	50%
Jun 1-15	50%
Jun 16-30	100%
Jul	100%
Aug	100%
Sep	100%

[a] Percent of time the HOR gate is open. Agricultural barriers are in and operated consistent with current practices. HOR gate would be open 100% whenever flows are greater than 10,000 cfs at Vernalis.

[b] Head of Old River Barrier operation is triggered based upon State Water Board D-1641 pulse trigger. For modeling assumptions only, two weeks before the D-1641 pulse, it is assumed that the Head of Old River Barrier will be open 50%.

During the D-1641 pulse (assumed to occur October 16-31 in the modeling), it is assumed the HOR gate will be closed.
For two weeks following the D-1641 pulse, it was assumed that the HOR gate will be open 50%.
Exact timing of the action will be based on hydrologic conditions.

[c] The HOR gate becomes operational at 50% when salmon fry are migrating (based on real time monitoring). This generally occurs when flood flow releases are being made. For the purposes of modeling, it was assumed that salmon fry are migrating starting on January 1.

Table 5.A-13 Post-Pulse Bypass Flow Rules and Bypass Flow Rules during July through November for the North Delta Diversion

Level I Post-Pulse Operations			**Level II Post-Pulse Operations**			**Level III Post-Pulse Operations**		
If Sacramento River at Freeport flow…			**If Sacramento River at Freeport flow…**			**If Sacramento River at Freeport flow…**		
Is over…	**But not over…**	**The bypass is…**	**Is over…**	**But not over…**	**The bypass is…**	**Is over…**	**But not over…**	**The bypass is…**
December–April								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 80% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 60% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 50% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,600 cfs plus 60% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,400 cfs plus 50% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	12,000 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	No limit	18,400 cfs plus 30% of the amount over 20,000 cfs	20,000 cfs	No limit	15,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	No limit	13,000 cfs plus 0% of the amount over 20,000 cfs
May								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 70% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 50% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 40% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,400 cfs plus 50% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,000 cfs plus 35% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	11,400 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	No limit	17,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	No limit	14,750 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	No limit	12,400 cfs plus 0% of the amount over 20,000 cfs
June								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping

Level I Post-Pulse Operations			Level II Post-Pulse Operations			Level III Post-Pulse Operations		
If Sacramento River at Freeport flow…			**If Sacramento River at Freeport flow…**			**If Sacramento River at Freeport flow…**		
Is over…	**But not over…**	**The bypass is…**	**Is over…**	**But not over…**	**The bypass is…**	**Is over…**	**But not over…**	**The bypass is…**
15,000 cfs	17,000 cfs	15,000 cfs plus 60% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 40% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 30% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,200 cfs plus 40% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	12,600 cfs plus 20% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	10,800 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	No limit	17,400 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	No limit	13,600 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	No limit	11,800 cfs plus 0% of the amount over 20,000 cfs

Bypass flow requirements in other months:		
If Sacramento River flow is over...	**But not over...**	**The bypass is...**
July–September		
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	No limit	A minimum of 5,000 cfs
October–November		
0 cfs	7,000 cfs	100% of the amount over 0 cfs
7,000 cfs	No limit	A minimum of 7,000 cfs

Table 5.A-14 CalSim II No Action Alternative and Proposed Action Inputs and Assumptions Callout Table

	No Action Alternative Assumption	Proposed Action Assumption
Planning horizon[a]	Year 2030	Same
Demarcation date[a]	February 2009 (but with operational components of 2008 USFWS and 2009 NMFS BiOp included)	Same
Period of simulation	82 years (1922-2003)	Same
Hydrology		
Inflows/Supplies	Historical with modifications for operations upstream of rim reservoirs and with changed climate at Year 2030	Same
Level of development	Projected 2030 level[b]	Same
Demands, Water Rights, CVP/SWP Contracts		
Sacramento River Region (excluding American River)		
CVP[c]	Land-use based, full build-out of contract amounts	Same
SWP (FRSA)[d]	Land-use based, limited by contract amounts	Same
Non-project or Non-CVP/SWP	Land use based, limited by water rights and SWRCB Decisions	Same
Antioch Water Works	Pre-1914 water right	Same
Federal refuges[e]	Firm Level 2 water needs	Same
Sacramento River Region - American River[f]		
Water rights	Year 2025, full water rights	Same
CVP	Year 2025, full contracts, including Freeport Regional Water Project	Same
San Joaquin River Region[g]		
Friant Unit	Limited by contract amounts, based on Friant-specific allocation policy	Same
Lower Basin	Land-use based, based on district level operations and constraints	Same
Stanislaus River	Land-use based for water rights, full contracts for CVP contractors[o]	Same

	No Action Alternative Assumption	Proposed Action Assumption
San Francisco Bay, Central Coast, Tulare Lake and South Coast Regions (CVP/SWP project facilities)		
CVP[c]	Demand based on contract amounts	Same
CCWD[i]	195 TAF/yr CVP contract supply and water rights	Same
SWP[d,j]	Demand based on Table A amounts	Same
Article 56	Based on 2001-08 contractor requests	Same
Article 21	MWD demand up to 200 TAF/month from December to March subject to conveyance capacity, KCWA demand up to 180 TAF/month and other contractor demands up to 34 TAF/month in all months, subject to conveyance capacity	Same
North Bay Aqueduct (NBA)	77 TAF/yr demand under SWP contracts, up to 43.7 cfs of excess flow under Fairfield, Vacaville and Benicia Settlement Agreement	Same
Federal refuges[e]	Firm Level 2 water needs	Same
Facilities		
North Coast Region		
Trinity Lake	2,447 TAF capacity	Same
Sacramento River Region		
Shasta Lake	4,552 TAF capacity	Same
Red Bluff Diversion Dam	Diversion dam operated with gates out all year, NMFS BiOp (Jun 2009) Action I.3.1[p]; assume permanent facilities in place	Same
Upper American River[f]	PCWA American River Pump Station	Same
Lower Sacramento River	Freeport Regional Water Project	Same
San Joaquin River Region		
Millerton Lake (Friant Dam)	520 TAF capacity	Same
New Melones Reservoir	2,420 TAF	Same
Lower San Joaquin River	City of Stockton Delta Water Supply Project, 30-mgd capacity	Same

	No Action Alternative Assumption	Proposed Action Assumption
Delta Region		
SWP Banks Pumping Plant (South Delta)	Physical capacity is 10,300 cfs but 6,680 cfs permitted capacity in all months up to 8,500 cfs during Dec 15 – Mar 15 depending on Vernalis flow conditions[l]; additional capacity of 500 cfs (up to 7,180 cfs) allowed for Jul – Sep for reducing impact of NMFS BiOp (Jun 2009) Action IV.2.1 Phase II[p] on SWP[q]	Same
CVP C.W. Bill Jones Pumping Plant (Tracy PP)	Permit capacity is 4,600 cfs in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie)	Same
Upper Delta-Mendota Canal Capacity	Full capacity of 4,600 cfs including 400 cfs Delta-Mendota Canal–California Aqueduct Intertie	Same
CCWD Intakes	Los Vaqueros storage capacity, 160 TAF; Rock Slough, Old River and Middle River intakes (Alternative Intake Project or AIP)	Same
North Delta Diversion Intakes	Not included	9,000 cfs north Delta diversion intake on the Sacramento River at Hood
Head of Old River Gate	Temporary Head of Old River Barrier installed in the fall months	Permanent Head of Old River Gate as described in Section 5.A.5.2.4.4
Fremont Weir	Spills above 54,274 cfs Sacramento River flow at Verona; Assumes an operable notch[i] in the Fremont Weir, which allows spills above 15,530 cfs Sacramento River flow at Verona of up to 6,000 cfs during Dec 1 – Apr 30. 100 cfs spills during Sep 1 – Jun 30 to support fish passage.	Same
San Francisco Bay Region		
South Bay Aqueduct (SBA)	SBA rehabilitation, 430 cfs capacity from junction with California Aqueduct to Alameda County FC&WSD Zone 7 diversion point	Same
Regulatory Standards		
North Coast Region		
<u>Trinity River</u>		

	No Action Alternative Assumption	Proposed Action Assumption
Minimum flow below Lewiston Dam	December 2000 Trinity River Record of Decision (369-815 TAF/yr)	Same
Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF as able)	Same
Sacramento River Region		
Clear Creek		
Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 Reclamation Proposal to USFWS and NPS, predetermined CVPIA 3406(b)(2) flows[m], and NMFS BiOp (Jun 2009) Action I.1.1[p]	Same
Upper Sacramento River		
Shasta Lake end-of-September minimum storage	NMFS 2004 Winter-run Biological Opinion, (1900 TAF in non-critically dry years), and NMFS BiOp (Jun 2009) Action I.2.1[p]	Same
Minimum flow below Keswick Dam	SWRCB WR 90-5, predetermined CVPIA 3406(b)(2) flows[m], and NMFS BiOp (Jun 2009) Action I.2.2[p]	Same
Feather River		
Minimum flow below Thermalito Diversion Dam	2006 Settlement Agreement (700 / 800 cfs)	Same
Minimum flow below Thermalito Afterbay outlet	1983 DWR, DFG Agreement (750-1,700 cfs)	Same
Yuba River		
Minimum flow below Daguerre Point Dam	D-1644 Operations (Lower Yuba River Accord)[n]	Same
American River		
Minimum flow below Nimbus Dam	American River Flow Management Standard as required by NMFS BiOp (Jun 2009) Action II.1[p]	Same
Minimum Flow at H Street Bridge	SWRCB D-893	Same
Lower Sacramento River		

	No Action Alternative Assumption	**Proposed Action Assumption**
Minimum flow near Rio Vista	SWRCB D-1641	Same as NAA with additional minimum flow requirement of 3,000 cfs from January to August.
North Delta Diversion Bypass Flows	Not included	Bypass flows are described in Section 5.A.5.2.9.
San Joaquin River Region		
Mokelumne River		
Minimum flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100-325 cfs)	Same
Minimum flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25-300 cfs)	Same
Stanislaus River		
Minimum flow below Goodwin Dam	Flows required for NMFS BiOp (Jun 2009) Action III.1.3[o,p]	Same
Minimum dissolved oxygen	SWRCB D-1422	Same
Merced River		
Minimum flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180-220 cfs, Nov-Mar), and Cowell Agreement	Same
Minimum flow at Shaffer Bridge	FERC 2179 (25-100 cfs)	Same
Tuolumne River		
Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94-301 TAF/yr)	Same
San Joaquin River		
San Joaquin River below Friant Dam/ Mendota Pool	San Joaquin River Restoration Program is in effect; however, Millerton releases were not included as the recapture/recirculation component is yet to be defined.	Same
Maximum salinity near Vernalis	SWRCB D-1641	Same
Minimum flow near Vernalis	SWRCB D-1641[k]	Same
Sacramento River – San Joaquin Delta Region		

	No Action Alternative Assumption	Proposed Action Assumption
Delta Outflow Index (Flow and Salinity)	SWRCB D-1641 and USFWS BiOp (Dec 2008) Action 4 (Fall X2 Requirement)	Same as NAA; In addition maintain March-May average Delta outflow under the NAA at the inititation of the dual conveyance operations in Year 2030. This additional Spring Delta Outflow requirement is described in Section 5.A.5.2.4.3
Delta Cross Channel gate operation	SWRCB D-1641 with additional days closed from Oct 1 – Jan 31 based on NMFS BiOp (Jun 2009) Action IV.1.2[s] (closed during flushing flows from Oct 1 – Dec 14 unless adverse water quality conditions)	Same
North Delta Diversion Bypass Flows	Not included	Sacramento River bypass flow requirements downstream of the proposed intakes as described in Section 5.A.5.2.4.9. In addition, a constraint on the potential diversion at the north Delta intakes, to account for the fish screen sweeping velocity criteria of 0.4 fps. The constraint was derived based on resulting diversions from the DSM2 modeling.
Minimum flow near Rio Vista	SWRCB D-1641	Same as NAA with additional minimum flow requirement of 3,000 cfs from January to August.
South Delta exports (Jones PP and Banks PP)	SWRCB D-1641. Vernalis flow-based export limits Apr 1 – May 31 as required by NMFS BiOp (Jun, 2009) Action IV.2.1[p] (additional 500 cfs allowed for Jul – Sep for reducing impact on SWP)[q]	Same as the NAA; except NMFS BiOp Action IV.2.1 is assumed to apply as an operational constraint to the total Delta exports to meet the additional Delta outflow requirement during March – May. Pumping at the south Delta intakes are preferred during the July through September months up to a total pumping of 3,000 cfs to manage water quality conditions in the south Delta channels. No specific intake preference is assumed beyond 3,000 cfs.
Combined Flow in Old and Middle River (OMR)	FWS BiOp (Dec 2008) Actions 1 through 3 and NMFS BiOp (Jun 2009) Action IV.2.3[p]	New OMR criteria described in Section 5.A.5.2.4.4 or same as the NAA, whichever results in less negative OMR flows
Head of Old River Barrier/Gate	Head of Old River Barrier (HORB) is only installed in the fall months per FWS Delta Smelt BiOp Action 5; it is assumed to be not installed in April or May.	HOR gate operations assumptions as described in Section 5.A.5.2.4.4

	No Action Alternative Assumption	Proposed Action Assumption
Operations Criteria: River-Specific		
Sacramento River Region		
Upper Sacramento River		
Flow objective for navigation (Wilkins Slough)	NMFS BiOp (Jun 2009) Action I.4[p]; 3,500 – 5,000 cfs based on CVP water supply condition	Same
American River		
Folsom Dam flood control	Variable 400/600 flood control diagram (without outlet modifications) as a surrogate for upcoming water control manual update	Same
Feather River		
Flow at Mouth of Feather River (above Verona)	Maintain CDFW/DWR flow target of 2,800 cfs for Apr – Sep dependent on Oroville inflow and FRSA allocation	Same
San Joaquin River Region		
Stanislaus River		
Flow below Goodwin Dam	NMFS BiOp (Jun 2009) Action III.1.3[o,p]	Same
San Joaquin River		
Salinity at Vernalis	Grasslands Bypass Project (full implementation)	Same
Operations Criteria: Systemwide		
CVP water allocation		
Settlement / Exchange	100% (75% in Shasta critical years)	Same
Refuges	100% (75% in Shasta critical years)	Same
Agriculture Service	100%-0% based on supply; South-of-Delta allocations are additionally limited due to D-1641, USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009) export restrictions[p]	Same
Municipal & Industrial Service	100%-50% based on supply; South-of-Delta allocations are additionally limited due to D-1641, USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009) export restrictions[p]	Same

	No Action Alternative Assumption	Proposed Action Assumption
SWP water allocation		
North of Delta (FRSA)	Contract specific	Same
South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement; allocations are additionally limited due to D-1641 and USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009) export restrictions[p]	Same
CVP/SWP coordinated operations		
Sharing of responsibility for in-basin-use	1986 Coordinated Operations Agreement (FRWP EBMUD and 2/3 of the North Bay Aqueduct diversions considered as Delta Export; 1/3 of the North Bay Aqueduct diversion as in-basin-use)	Same
Sharing of surplus flows	1986 Coordinated Operations Agreement	Same
Sharing of total allowable export capacity for project-specific priority pumping	Equal sharing of export capacity under SWRCB D-1641,USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009) export restrictions[p]	Same
Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks Pumping Plant over non-SWP users; LYRA included for SWP contractors[q]	Same
Sharing of total allowable export capacity for lesser priority and wheeling-related pumping	Cross Valley Canal wheeling (max of 128 TAF/yr), CALFED ROD defined Joint Point of Diversion (JPOD)	Same
San Luis Reservoir	San Luis Reservoir is allowed to operate to a minimum storage of 100 TAF	Same
CVPIA 3406(b)(2)[o]		
Policy Decision	Per May 2003 Dept. of Interior Decision:	Same
Allocation	800 TAF, 700 TAF in 40-30-30 dry years, and 600 TAF in 40-30-30 critical years as a function of Ag allocation	Same

	No Action Alternative Assumption	Proposed Action Assumption
Actions	Pre-determined upstream fish flow objectives below Whiskeytown and Keswick Dams, non-discretionary NMFS BiOp (Jun 2009) actions for the American and Stanislaus Rivers, and NMFS BiOp (Jun 2009) and USFWS BiOp (Dec 2008) actions leading to export restrictions[p]	Same
Accounting	Releases for non-discretionary USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009)[p] actions may or may not always be deemed (b)(2) actions; in general, it is anticipated, that accounting of these actions using (b)(2) metrics, the sum would exceed the (b)(2) allocation in many years; therefore no additional actions are considered and no accounting logic is included in the model[m]	Same
Water Management Actions		
Water Transfer Supplies (long term programs)		
Lower Yuba River Accord[q]	Yuba River acquisitions for reducing impact of NMFS BiOp export restrictions[p] on SWP	Same
Phase 8	None	Same
Water Transfers (short term or temporary programs)		
Sacramento Valley acquisitions conveyed through Banks PP[r]	Post-analysis of available capacity	Post-analysis of available capacity

[a] These assumptions have been developed under the direction of the California WaterFix Section 7 Consultation Team. Only operational components of 2008 USFWS and 2009 NMFS BiOps as of demarcation date of the NAA assumptions are included. Restoration of at least 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh required by the 2008 USFWS BiOp and restoration of at least 17,000 to 20,000 acres of floodplain rearing habitat for juvenile winter-run and spring-run Chinook salmon and Central Valley steelhead in the Yolo Bypass and/or suitable areas of the lower Sacramento River required by the NMFS 2009 BiOp are not included in the NAA assumptions because environmental documents of projects regarding these actions were not completed. Fremont Weir notch was assumed as a placeholder for Action I.6.1.

[b] The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. The Sacramento Valley hydrology used in the NAA CalSim II model reflects 2020 land-use assumptions associated with Bulletin 160-98.

[c] CVP contract amounts have been updated according to amended contracts as appropriate. Assumptions regarding CVP agricultural and M&I service contracts, exchange contract amounts, Refuge Level 2 contract amounts and Settlement Contract amounts are documented in the Delivery Specifications documented in the Appendix 5A, Attachment 5 of the CWF BA.

[d] SWP contract amounts have been updated as appropriate based on recent Table A transfers/agreements. Assumptions regarding SWP agricultural and M&I contract amounts are documented in the Delivery Specifications attachments documented in the Appendix 5A, Attachment 5 of the CWF BA.

[e] Water needs for federal refuges have been reviewed and updated as appropriate. Assumptions regarding firm Level 2 refuge water needs are documented in the Delivery Specifications attachments documented in the Appendix 5A, Attachment 5 of the CWF BA. Refuge Level 4 (and incremental Level 4) water is not analyzed.

[f] Assumptions regarding American River water rights and CVP contracts are documented in the Delivery Specifications attachments documented in the Appendix 5A, Attachment 5 of the CWF BA. The Sacramento Area Water Forum agreement, and any diversion reductions, are not included except for federal actions.

[g] The CalSim II representation of the San Joaquin River model reflects the difficulties of on-going groundwater overdraft problems. The 2030 level of development representation of the San Joaquin River Basin does not make any attempt to offer solutions to groundwater overdraft problems. In addition a dynamic groundwater simulation is not yet developed for the San Joaquin River Valley.

<table>
<tr><th></th><th>No Action Alternative Assumption</th><th>Proposed Action Assumption</th></tr>
<tr><td colspan="3">Groundwater extraction/ recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions. These limitations should be considered in the analysis of results.
[h] Fremont Weir notch assumed to represent the NMFS BO (Jun, 2009) Action I.6.1: Restoration of Floodplain Rearing Habitat action and is only for use in the modeling as a placeholder, while the proposed changes associated with this RPA are still in development under a separate multi-agency process.
[i] The actual amount diverted is operated in conjunction with supplies from the Los Vaqueros project. The Los Vaqueros storage capacity is 160 TAF and associated water rights for Delta excess flows are included.
[j] Under NAA, it is assumed that SWP Contractors demand for Table A allocations vary from 3.0 to 4.1 MAF/year. Under the NAA, it is assumed that SWP Contractors can take delivery of all Table A allocations and Article 21 supplies. Article 56 provisions are assumed and allow for SWP Contractors to manage storage and delivery conditions such that full Table A allocations can be delivered. Article 21 deliveries are limited in wet years under the assumption that demand is decreased in these conditions. Article 21 deliveries for the NBA are dependent on excess conditions only, all other Article 21 deliveries also require that San Luis Reservoir be at capacity and that Banks PP and the California Aqueduct have available capacity to divert from the Delta for direct delivery.
[k] Vernalis base flows as required by D1641 Table 3 are included in the model. D-1641 Vernalis pulse flow requirements are not included. However, pulse flows required by NMFS BO (Jun, 2009) Action III.1.3 are included in the model.
[l] USACE permit for Clifton Court Forebay Intakes (assumed for Banks PP in CalSim II) allows for an average diversion rate of 6,680 cfs in all months. Diversion rate can increase up to 1/3 of the rate of San Joaquin River flow at Vernalis during Dec 15th – Mar 15th up to a maximum diversion of 8,500 cfs, if Vernalis flow exceeds 1,000 cfs.
[m] CVPIA (b)(2) fish actions are not dynamically determined in the CalSim II model, nor is (b)(2) accounting done in the model. Since the USFWS BiOp and NMFS BiOp were issued, the Department of the Interior (Interior) has exercised its discretion to use (b)(2) in the delta by accounting some or all of the export reductions required under those biological opinions as (b)(2) actions. It is therefore assumed for modeling purposes that (b)(2) availability for other delta actions will be limited to covering the CVP's VAMP export reductions. Similarly, since the USFWS BiOp and NMFS BiOp were issued, Interior has exercised its discretion to use (b)(2) upstream by accounting some or all of the release augmentations (relative to the hypothetical (b)(2) base case) below Whiskeytown, Nimbus and Goodwin as (b)(2) actions. It is therefore assumed for modeling purposes that (b)(2) availability for other upstream actions will be limited to covering Sacramento releases, in the fall and winter. For modeling purposes, pre-determined timeseries of minimum instream flow requirements are specified below Whiskeytown and Keswick. The timeseries are based on the Aug 2008 BA Study 7.0 and Study 8.0 simulations which did include dynamically determined (b)(2) actions.
[n] D-1644 and the Lower Yuba River Accord is assumed to be implemented for the NAA and PA. The Yuba River is not dynamically modeled in CalSim II. Yuba River hydrology and availability of water acquisitions under the Lower Yuba River Accord are based on modeling performed and provided by the Lower Yuba River Accord EIS/EIR study team.
[o] The model operates the Stanislaus River by allocating water for SEWD & CSJWCD, Vernalis water quality dilution and Vernalis D1641 base flow requirements based on the New Melones Index. OID & SSJID deliveries are based on their 1988 agreement and Ripon DO requirements are represented by a static set of minimum instream flow requirements during Jun thru Sep. Instream flow requirements for fish below Goodwin are based on NMFS BiOp Action III.1.3.
[p] In cooperation with Reclamation, National Marine Fisheries Service, Fish and Wildlife Service, and Ca Department of Fish and Wildlife, the CA Department of Water Resources has developed assumptions for implementation of the USFWS BiOp (Dec 15th 2008) and NMFS BiOp (June 4th 2009) in CalSim II.
[q] Acquisitions of Component 1 water under the Lower Yuba River Accord, and use of 500 cfs dedicated capacity at Banks PP during Jul – Sep, are assumed to be used to reduce as much of the impact of the Apr – May Delta export actions on SWP contractors as possible.
[r] Only acquisitions of Lower Yuba River Accord Component 1 water are included.</td></tr>
</table>

5.A.A.1 Attachment 1: Climate Change and Sea Level Rise Scenarios Selection

This attachment provides a summary of the approach used to develop the climate change and sea level rise projections at Year 2030 for the California WaterFix Biological Assessment (CWF BA). This approach and the selected climate change and sea level rise projections are identical to the projections at Year 2025 used in the draft BDCP EIR/EIS (DWR 2013). The attachment also summarizes the projected changes in the temperature and precipitation under each climate change scenario selected in comparison with the observed climate conditions.

5.A.A.1.1 Selection of Climate Scenarios

A technical subgroup was formed with representatives from DWR, Reclamation, USFWS, and NMFS to review the technical merits of several approaches for incorporating climate change into the analytical processes. The outcome of this coordinated effort is described in detail in the BDCP EIR/EIS Appendix 5D. The issues of multi-decadal variability in the sampling of any one GCM projection and the superiority of multi-model projections over any one single projection were emphasized by the group members. These and other comments received from the group members led to the recommendation of the following criteria to guide the selection of climate scenarios:

- Select a range of scenarios to reflect the uncertainty with GCM projections and emission scenarios;

- Select scenarios that reduce the “noise” inherent with any particular GCM projection due to multi-decadal variability that often does not preserve relative rank for different locations and time periods;

- Select an approach that incorporates both the mean climate change trend and changes in variability; and

- Select time periods that are consistent with the major phases used in the BDCP planning.

- The selected approach for development of climate scenarios for the BDCP incorporates three fundamental elements. First, it relies on sampling of the ensemble of GCM projections rather than one single realization or a handful of individual realizations. Second, it includes scenarios that both represent the range of projections as well as the central tendency of the projections. Third, it applies a method that incorporates both changes to the mean climate as well as to the variability in climate. These elements are described further in the sections below.

5.A.A.1.2 Downscaled Climate Projections

A total of 112 future climate projections used in the IPCC AR4, subsequently bias-corrected and statistically downscaled (BCSD), were obtained from Lawrence Livermore National Laboratory (LLNL) under the World Climate Research Program’s (WCRP) Coupled Model Intercomparison Project Phase 3 (CMIP3). This archive of contains climate projections generated from 16 different GCMs developed by national climate centers (Table 5.A.1-1) and for SRES emission scenarios A2, A1b, and B1. Many of the GCMs were simulated multiple times for the same emission scenario due to differences in starting climate system state, thus the number of available projections is greater than simply the product of GCMs and emission scenarios. These projections have been bias corrected and spatially downscaled to 1/8th degree (~12km) resolution over the contiguous United States through methods described in detail in Wood et al. 2002, Wood et al. 2004, and Maurer 2007.

Table 5.A.A.1-1: General circulation models used in the world climate research program's (wcrp) coupled model intercomparison project phase 3 (cmip3) database

Modeling Group, Country	WCRP CMIP3 I.D.
Bjerknes Centre for Climate Research	BCCR-BCM2.0
Canadian Centre for Climate Modeling & Analysis	CGCM3.1 (T47)
Meteo-France / Centre National de Recherches Meteorologiques, France	CNRM-CM3
CSIRO Atmospheric Research, Australia	CSIRO-Mk3.0
US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, USA	GFDL-CM2.0
US Dept. of Commerce / NOAA / Geophysical Fluid Dynamics Laboratory, USA	GFDL-CM2.1
NASA / Goddard Institute for Space Studies, USA	GISS-ER
Institute for Numerical Mathematics, Russia	INM-CM3.0
Institut Pierre Simon Laplace, France	IPSL-CM4
Center for Climate System Research (The University of Tokyo), National Institute for Environmental Studies, and Frontier Research Center for Global Change (JAMSTEC), Japan	MIROC3.2 (medres)
Meteorological Institute of the University of Bonn, Meteorological Research Institute of KMA	ECHO-G
Max Planck Institute for Meteorology, Germany	ECHAM5/ MPI-OM
Meteorological Research Institute, Japan	MRI-CGCM2.3.2
National Center for Atmospheric Research, USA	CCSM3
National Center for Atmospheric Research, USA	PCM
Hadley Centre for Climate Prediction and Research / Met Office, UK	UKMO-HadCM3

5.A.A.1.3 Climate Periods

Climate change is commonly measured over a 30-year period. Changes in temperature and precipitation for any particular scenario are compared to a historical period. The historical period of 1971-2000 is selected as the reference climate since it is the currently established climate normal used by NOAA and represents the most recent time period. Corresponding to the long-term timelines of the CWF BA analysis, in which climate change is likely to be relevant, future climate periods are identified as approximately 2025 (2011-2040) [early long-term] and 2060 (2046-2075) [late long-term]. The difference in mean annual temperature and precipitation among the two future periods and historic period were identified as the climate change metric.

5.A.A.1.4 Multi-Model Ensemble and Sub-Ensembles

The recommended approach makes use of all 112 downscaled climate projections of future climate change described in the previous section. The group of multi-model, multi-emission scenario projections is termed the ensemble. Individual model-emission scenario projections are termed “members” of the ensemble. It is often useful to characterize climate change projections in terms of the simulated change in annual temperature and precipitation compared to an historical reference period. At any selected 30-yr future climatological period, each projection represents one point of change amongst the others. This is graphically depicted in Figure 5.A.A.1-1 for a region in Feather River watershed.

Since the ensemble is made up of many projections, it is useful to identify the median (50th percentile) change of both annual temperature and annual precipitation (dashed blue lines). In doing so, the state of climate change at this point in time can be broken into quadrants representing (1) drier, less warming, (2) drier, more warming, (3) wetter, more warming, and (4) wetter, less warming than the ensemble median. These quadrants are labeled Q1-Q4 in Figure 5.A.A.1-1. In addition, a fifth region (Q5) can be described that samples from inner-quartiles (25th to 75th percentile) of the ensemble and represents a central region of climate change. In each of the five regions the sub-ensemble of climate change projections, made up of those contained within the region bounds, is identified. The Q5 scenario is derived from the central tending climate projections and thus favors the consensus of the ensemble.

Through extensive coordination with the State and Federal teams involved in the CWF BA, the bounding scenarios Q1-Q4 were refined in April 2010 to reduce the attenuation of climate projection variability that comes about through the use of larger ensembles. A sensitivity analysis was prepared for the bounding scenarios (Q1-Q4) using sub-ensembles made up of different numbers of downscaled climate projections. The sensitivity analysis was prepared using a “nearest neighbor” (k-NN) approach. In this approach, a certain joint projection probability is selected based on the annual temperature change-precipitation change (i.e. 90th percentile of temperature and 90th percentile of precipitation change). From this statistical point, the “k” nearest neighbors (after normalizing temperature and precipitation changes) of projections are selected and climate change statistics are derived. Consistent with the approach applied in OCAP, the 90th and 10th percentile of annual temperature and precipitation change were selected as the bounding points. The sensitivity analysis considered using the 1-NN (single projection), 5-NN (5 projections), and 10-NN (10 projections) sub-ensemble of projections. These were compared to the original quadrant scenarios which commonly are made up of 25-35 projections and are based on the direction of change from 50th percentile statistic.

The very small ensemble sample sizes exhibited month by month changes that were sometimes dramatically different than that produced by adding a few more projections to the ensemble. The 1-NN approach was found to be inferior to all other methods for this reason. The original quadrant method produced a consensus direction of change of the projections, and thus produced seasonal trends that were more realistic, but exhibited a slightly smaller range due to the inclusion of several central tending projections. The 5-NN and 10-NN methods exhibited slightly wider range of variability than the quadrant method which was desirable from the “bounding” approach. In most cases the 5-NN and 10-NN projections were similar, although they differed at some locations in representation of season trend. The 10-NN approach (Figure 5.A.A.1-1) was found to be preferable in that it best represented the seasonal trends of larger ensembles, retained much of the “range” of the smaller ensembles, and was guaranteed to include projections from at least two GCM-emission scenario combinations (in the CMIP3 projection archive, up to 5 projections – multiple simulations – could come from one GCM-emission scenario combination). The State and Federal representatives agreed to utilize the following climate scenario selection process for CWF BA: (1) the use of the original quadrant approach for Q5 (projections within the 25th to 75th percentile bounding box) as it provides the best estimate of the consensus of climate projections, and (2) the use of the 10-NN method to developing the Q1-Q4 bounding scenarios. An automated process has been developed that generates the monthly and annual statistics for every grid cell within the Central Valley domain and identifies the members of the sub-ensemble for consideration in each of the five scenarios.

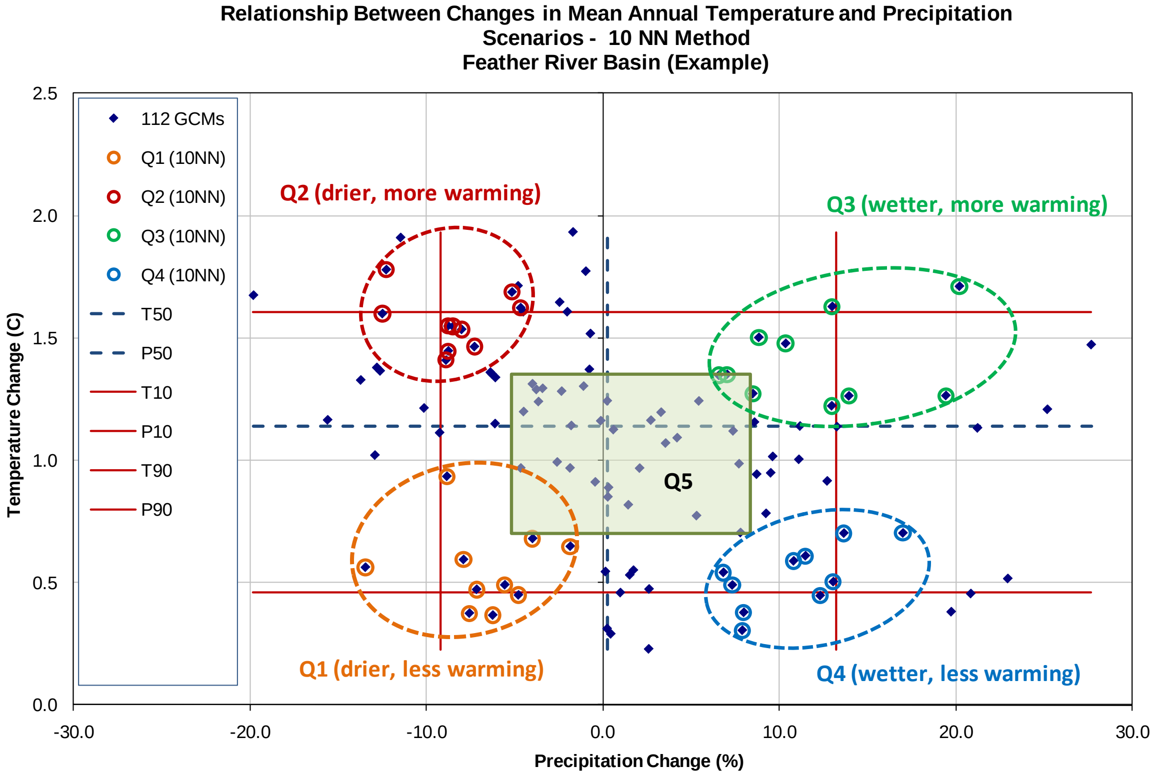


Figure 5.A.A.1-1. Example downscaled climate projections and sub-ensembles used for deriving climate scenarios (Q1-Q5), Feather River Basin at 2025. The Q5 scenario is bounded by the 25th and 75th percentile joint temperature-precipitation change. Scenarios Q1-Q4 are selected to reflect the results of the 10 projections nearest each of 10th and 90th joint temperature-precipitation change bounds. Note: the temperature and precipitation changes are normalized before determining the nearest neighbors.

5.A.A.1.5 Incorporating Changes in Mean Climate and Climate Variability

Climate is usually defined as the “average” condition of weather over a period of time. More rigorously, climate can be defined as the “statistical description” in terms of mean and variability of the relevant quantities over a period of time ranging from months to millions of years (IPCC TAR). The standard averaging period defined by the World Meteorological Organization (WMO) is 30 years. The parameters that are most often associated with the description of climate state are temperature, precipitation, and wind speed. Thus, climate change refers to a shift in the statistical properties of climate variables over extended periods of time.

One difficulty that arises in implementing climate change into long-term water resources planning is that the natural variability is often greater than the magnitude of change expected over several decades. In many water resource management areas, it is the extreme events (droughts and floods) that drive the decision-making and long-range planning efforts. Thus, there is a need to combine the climate change signal with the range of natural variability observed in the historical record.

In many current climate change analyses, only the mean state of climate change is analyzed through the use of the “delta” method. In this method, temperature and/or precipitation are adjusted by the mean shift from one future 30-year period to a historical 30-year period. However, climate change is unlikely to manifest itself in a uniform change in values. In fact, the climate projections indicate that the changes are nonlinear and shifts in the probability distributions are likely, not just the mean values. In other analyses, a transient 30-year depiction of climate is used and compared against a similar 30-year historical period. Hydrologic analyses are performed and summarized as the “mean” change between the future and base periods. This latter approach is roughly what has been applied in the OCAP and CAT processes. The difficulty with this approach is that the natural observed variability may be large and not fully present in the 30-year period, resulting in truncated variability. Also, because the sequence of variability is different under each period it is difficult to make comparisons between the resulting hydrologic variables beyond the mean response.

In order to incorporate both the climate change signal and the natural variability in the longer-term observed record, the recommended approach is to create an expanded time series which allows use of the long-term observed records. The approach is similar to that applied by the Climate Impacts Group for development of hydrologic scenarios for water planning in the Pacific Northwest (Wood et al 2002, Salathe et al 2007, Hamlet et al 2010), applied in the Lower Colorado River, Texas studies (CH2M HILL 2008), and recent Reclamation planning (USBR, 2010). The approach uses a technique called “quantile mapping” which maps the statistical properties of climate variables from one data subset with the time series of events from a different subset. In this fashion, the approach allows the use of a shorter period to define the climate state, yet maintains the variability of the longer historic record. The quantile mapping approach involves the following steps:

1. Extract a 30-year slice of downscaled climate projections based on the ensemble subset for the quadrant of interest and centered on the year of investigation (i.e. 2025 or 2060)

2. For each calendar month (i.e. January) of the future period, determine the statistical properties (cumulative distribution function, CDF) of temperature and precipitation at each grid cell

3. For each calendar month of the historical period (1971-2000 in our case), determine the statistical properties (CDFs) of temperature and precipitation at each grid cell

4. Develop quantile maps between the historic observed CDFs and the future downscaled climate CDFs, such that the entire probability distribution (including means, variance, skew, etc) at the monthly scale is transformed to reflect the climate scenario

5. Using the quantile maps, redevelop a monthly time series of temperature and precipitation over the observed period (1915 -2003) that incorporates the climate shift of the future period

6. Convert monthly time series to a daily time series by scaling monthly values to daily sequence found in the observed record

The result of the quantile mapping approach is a daily time series of temperature and precipitation that has the range of variability observed in the historic record, but also contains the shift in climate properties (both mean and expanded variability) found in the downscaled climate projection. Figure 5.A.A.1-2 provides an example of this process for a grid cell in the Feather River watershed. As shown in this figure, the precipitation change quantities are not expected to shift uniformly across all percentiles. For example, in this wetting climate scenario, the median (50th percentile) January precipitation is projected to exhibit almost no change from baseline conditions. However, for large precipitation events (i.e. the 90th percentile) January precipitation is projected to increase by almost 2 mm/day (more than 2 inches/month). That is, the climate shift is larger at higher precipitation events and lower at low precipitation events. While this may be different for each climate scenario, future period, spatial location, and month, the need to map the full range of statistic climate shift is important to characterize the projected effects of climate change. The resulting changes in the climate variables under the selected scenarios are presented in Section 5.A.A.1.8.

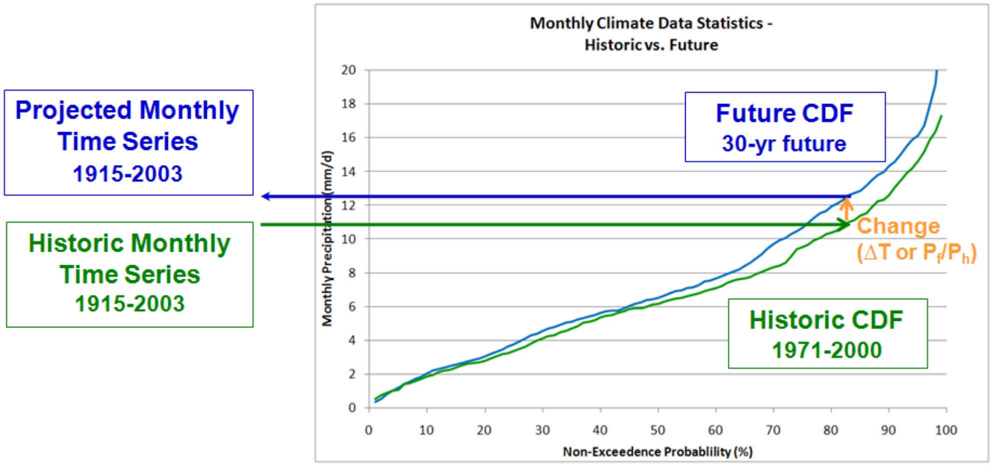


Figure 5.A.A.1-2: Historical monthly precipitation statistics for a grid cell in Feather river basin (January - example only)

5.A.A.1.6 Sea Level Rise Scenarios

In early 2007, the IPCC released their latest assessment of the scientific assessment for projections of future climate. Included in the IPCC AR4 were revised estimates of global mean sea level rise. The IPCC estimates are based on physical models that attempt to account for thermal expansion of oceans and storage changes associated with melt of land-based ice and snowfields (Healy 2007). Since their release, the IPCC AR4 sea level rise estimates have been widely criticized for their failure to include dynamic instability in the ice sheets of Greenland and Antarctica, and for their under-prediction of recent observed increases in sea level.

Due to the limitations with the current state of physical models for assessing future sea level rise, several scientific groups, including the CALFED Independent Science Board (ISB) (Healy 2007), recommend the use of empirical models for short to medium term planning purposes.

Both the CALFED ISB and CAT 2009 assessments have utilized the empirical approach developed by Ramsdorf (2007) that projects future sea level rise rates based on the degree of global warming. This method better reproduces historical sea levels and generally produces larger estimates of sea level rise than those indicated by the IPCC (2007). When evaluating all projections of global air temperature, Ramsdorf projects a mid-range sea level rise of 70 – 100 cm (28 – 40 inches) by the end of the century, and when factoring the full range of uncertainty the projected rise is 50 - 140 cm (20 – 55 inches). The CAT scenarios utilized an identical empirical approach, but limited the sea level rise estimates to the degree of warming range from 12 GCM projections selected for that study.

Using the work conducted by Ramsdorf, the projected sea level rise at the early long-term timeline for the CWF BA analysis (2025) is approximately 12 - 18 cm (5 - 7 inches). At the late long-term timeline (2060), the projected sea level rise is approximately 30 – 60 cm (12 – 24 inches).

In 2011, the United States Army Corps of Engineers (USACE) issued guidance on incorporating sea level change in civil works programs (USACE 2011). The guidance document reviews the existing literature and suggests use of a range of sea level change projections, including the “high probability” of accelerating global sea level rise. The ranges of future sea level rise were based on the empirical procedure recommended by the National Research Council (NRC, 1987) and updated for recent conditions. The three scenarios included in the USACE guidance suggest end of century sea level rise in the range of 50 to 150 centimeters (20 to 59 inches), consistent with the range of projections by Rahmstorf (2007) and Vermeer and Rahmstorf (2009). The USACE Bulletin expires in September 2013.

These sea level rise estimates are also consistent with those outlined in the USACE guidance circular for incorporating sea-level changes in civil works programs (USACE 2009). Due to the considerable uncertainty in these projections and the state of sea level rise science, it is proposed to use the mid-range of the estimates for each CWF BA timeline: 15 cm (6 inches) by 2025 and 45 cm (18 inches) by 2060. In addition, sensitivity scenarios will be prepared to consider sea level rise of up to 60 cm by 2060.

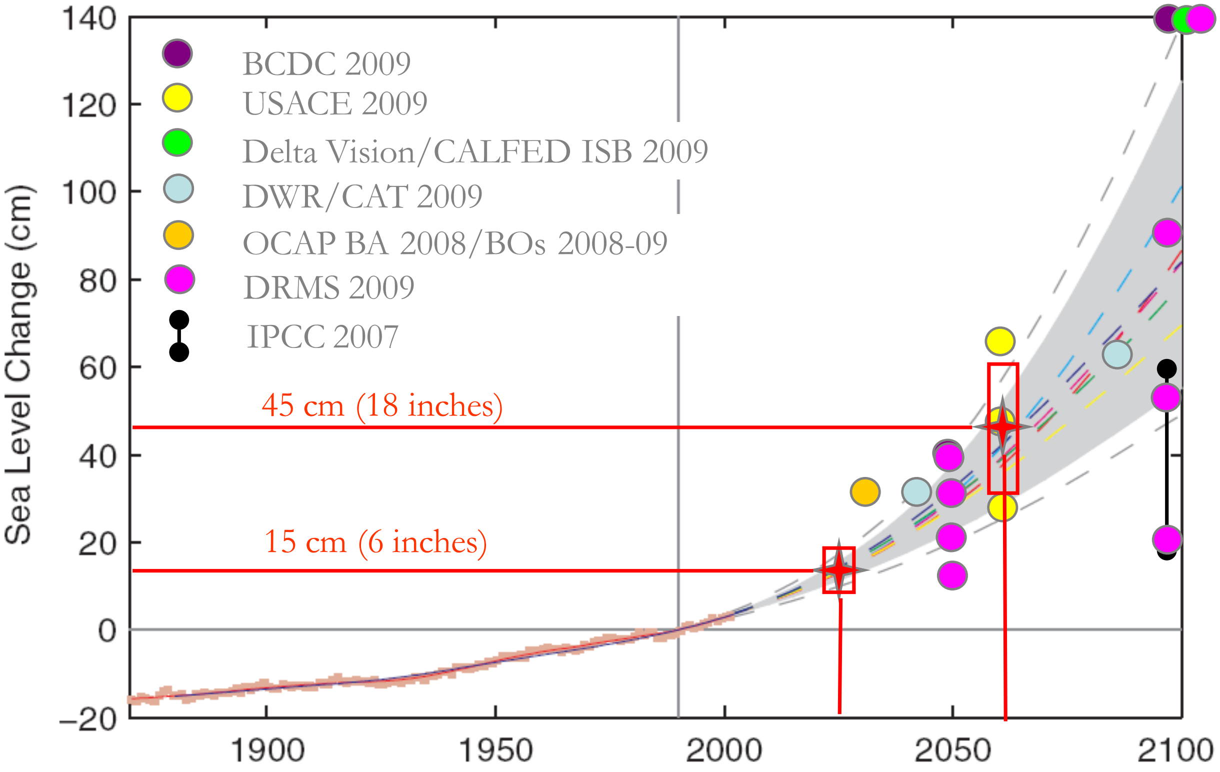


Figure 5.A.A.1-3: Historical and Projected Sea Level Change.

5.A.A.1.7 Changes in Tidal Amplitude

As discussed previously, mean sea level has been increasing across the globe and is exhibited on all U.S. coasts and almost all long-term stations. Tidal amplitude appears to be increasing, particulary in the eastern Pacific but the trend is not consistent for all stations on the West Coast. Tidal amplitude can be significantly affected by physical changes in coasts, harbors, bays, and estuaries. At long-term open-ocean stations along the California coast (La Jolla, Los Angeles, San Francisco, and Crescent City), which are less influenced by the physical changes, Flick et al. (2003) found a statistically significant increase in tidal amplitude (MHHW - MLLW), except at Crescent City which showed a slight decreasing trend. At San Francisco, the trend in tidal amplitude was found to be around 3-5% increase per century. Jay (2009) recently completed research into changes in tidal constituents, using long-term stations. Results indicated that on average tidal amplitude along the West Coast increased by about 2.2% per century. San Francisco indicated higher increases, while some stations (Alaska/Canada) were relatively constant. Jay hypothesized that global sea level rise may be influencing the location of the amphidrominc points (locations in the ocean where there are no tides) and thus affecting tidal range. However, Jay notes that it remains unclear whether rapid evolution of tidal amplitudes can be described as a symptom of global climate change.

Inland stations such as Alameda and Port Chicago showed larger increases in tidal amplitudes than open ocean stations (9% and 26%, respectively). These inland stations have both short records and may be influenced by physical changes in the Bay. The importance of long-term tide records and open-ocean stations is stressed by both Flick et al and Jay for identifying trends in tidal amplitude due to the 18.6-year periodicity and influence of physical changes. Flick et al discounts the use of these inland stations for trends in tidal amplitude. In addition, Flick et al found that other nearby stations exhibited a decreased tidal amplitude trend (Point Reyes at -12% per century and Monterey at -14% per century).

Due to the considerable uncertainty associated with the tidal amplitude increase and the evolving science relating these changes to climate change and mean sea level rise, it is recommended to include a sensitivity analysis of increased tidal amplitude. The recommendation is to evaluate the effect of an amplitude increase of 5% per century, relying on the published observed trends of Flick et al and Jay and assuming that they would continue in the future. We do not propose using the inland stations trends, adhering to guidance from Flick et al. Thus, it is proposed to include one sensitivity simulation with the UNTRIM model, which incorporates an open-ocean tidal boundary, with increased tidal amplitude of 5% per century to contribute to understanding of the relative effect of amplitude increase in comparison to mean sea level increase.

5.A.A.1.8 Climate Change Results

The projected effects of climate and sea level change are incorporated into scenarios and the analysis for the CWF BA. The use of scenarios, as described in the methodology, allows consideration of the uncertainty associated with the projections. This section describes climate change results associated with the scenarios and methods described previously. The effects of these changes on hydrology, operations, delta hydrodynamics, water quality, and other factors are described in sections specific to those analytical efforts.

5.A.8.1 Observed Climate

The Sacramento and San Joaquin River watersheds contains climate zones ranging from the alpine high sierra to the more Mediterranean climate of the valley floor and is fundamentally influenced by climate variability from seasonal to millennial scales. The water supply of the Central Valley is strongly dependent on snowmelt from high elevation portions of the watersheds. Temperature and precipitation vary considerably by season, location, and elevation as shown in Figure 1-1. Warmest temperatures in the Central Valley are in the San Joaquin and Tulare Basins in summer and coolest in the high elevation of the southern Sierra during the winter. Precipitation in most of California is dominated by extreme variability, both seasonally, annually, and over decade time scales. Precipitation is greatest in the northern Sierra, Cascade range, and north coast, and lowest in the southern San Joaquin Valley and Tulare Basin (Figure 5.A.A.1-4).

The climate of the Central Valley exhibits important spatial and seasonal variability. To illustrate this variability, monthly average temperature and precipitation are shown for representative locations in the Feather River watershed, Delta, and in the Tuolumne River watershed. These locations reflect a north-south climate regimes as well as high-low elevation changes.
As illustrated in Figure 5.A.A.1-5, the average temperature varies by over 15°C seasonally at each of the three locations and by almost 10°C across the locations within seasons. Cool winter temperatures at the higher elevation portions of the Sierra cause a considerable portion of the precipitation to fall in the form of snow. At lower elevations, warmer conditions exist and liquid

precipitation is the dominant form. The precipitation occurs primarily in the cool season (fall and winter) and contributes the majority of the annual rainfall. Precipitation is strongly dependent on elevation with valley floor precipitation less than one-third of that at higher elevations. Warmer temperatures in the late spring and summer induce snowmelt at the higher elevations. The summer precipitation tends to be short and intense at high elevations, but does not contribute a significant portion of annual total. Temperatures in the valley floor are high in the summer, although buffered by ocean breezes in regions near the Delta. Daytime high temperatures in excess of 37°C (100°F) are not uncommon in the summer.

The long-term annual statewide temperature and precipitation from 1896 to 2009 are shown in Figure 5.A.A.1-6. A significant increase in temperature is apparent in this figure although periods of cooling have occurred historically. Most importantly is the significant warming trend that has occurred since the 1970s. This warming trend is consistent with trends in both the Sacramento and San Joaquin Valleys, across the southwest, and with observed North America and global trends. Annual precipitation shows substantial variability and periods of dry and wet spells. Most notable in the precipitation record is the lack of a significant long-term annual trend, yet the annual variability appears to be increasing. The three highest annual precipitation years appear in the most recent 30-year record.

5.A.8.2 Projected Climate Change

Climate projections from over 100 General Circulation Models (GCMs) indicate a strong continued warming throughout California. The climate scenarios used in this study are derived from the full ensemble of projections as described in the Methods section. Figure 5.A.A.1-7 shows the annual temperature and precipitation changes for California derived from the central climate scenario (Q5). The Q5 scenario reflects a composite projection from the individual projections that are most close to the median change, and thus best reflect the “consensus” of projections. Figure 5.A.A.1-7 shows the changes for the period 2011-2040 (2025) and 2046-2075 (2060) as compared to the recent historical climatological period of 1971-2000. The projections indicate substantial warming with a median increase in annual temperature of about 1.1 °C by 2025 and 2.2 °C by 2060. All projections are consistent in the direction of the temperature change, but vary in terms of climate sensitivity. The projected temperature change ranges from 0.7 to 1.4 °C by 2025 and from 1.6 to 2.7 °C by 2060 in the scenarios used in the study for the delta region. Warming is projected to be generally higher the further away from the coast, reflecting a continued ocean cooling influence.

Statewide trends in annual precipitation are not as apparent as those for temperature. Roughly half of the projections at 2025 indicate a wetter future while the other half indicate drier conditions when evaluated statewide. Regional trends, however, indicate that it is more likely for the upper Sacramento Valley to experience equal or greater precipitation, while the San Joaquin Valley is likely to experience drier conditions. These trends toward a north-south transition are more pronounced in the 2060 projections than those at 2025. The changes in annual precipitation are on the order of +/- 5% (increase north, decrease south) annually under the Q5 scenario, but are greater than 10% decreases under the Q2 scenario. The north-south transition of precipitation change is likely due to the more northerly push of storm tracks caused in part by increased sea level pressure blocking systems under climate projections (Cayan et al 2008).

Figure 5.A.A.1-8 through Figure 5.A.A.1-13 summarizes projected seasonal changes in temperature and precipitation for the representative locations in the Feather River watershed, Delta, and Tuolumne River watersheds. The figures show the temperature and precipitation for the Observed (1971-2000) and five climate scenarios (Q1-Q5). Figure 5.A.A.1-8 through 5.A.A.1-10 reflect the projected changes for the 2025 period and Figures 5.A.A.1-11 through 5.A.A.1-13 reflect the changes for the 2060 period. Change in temperature is measured in degrees Celsius, while change in precipitation is measured as a percentage.

For a given season and future time period, projected changes in temperature are relatively consistent across all watersheds, with little variation throughout the basin. By 2025, temperatures are projected to increase at least 1.0°C in nearly all watersheds for all four seasons. Spring and summer show the greatest warming, with seasonal temperatures in most watersheds increasing 2°C to 4°C by 2060 depending on the scenario.

Projected changes in seasonal precipitation vary among watersheds and among seasons. On an annual basis, projected precipitation through 2060 is generally within 5% of historical precipitation, with the northern locations exhibiting positive change and the southern locations exhibiting negative change. The most significant change in precipitation occurs in spring, during which all watersheds show a decrease in precipitation for each of the future time periods.

Some general statements can be made to summarize the findings related to climate change:

Warming will continue to increase across the state with largest changes in spring and summer and larger changes further away from the coast. Annual median temperature increases are projected to be approximately 1.1 and 2.3 °C for 2025 and 2060, respectively, with less warming in winter and higher warming in summer. Summertime temperatures may increase by 4°C by 2060.

Precipitation patterns continue to be spatially and temporally complex, but trends toward drying are significant in portions of the state. Precipitation patterns are complex due to influence of oceans, storm tracks, Hadley cell expansion, and orographic considerations. A general trend towards drying is present in the south, although slight increases are projected for the Sacramento Valley. Consistent and expansive drying conditions are projected for the spring. For most of the Central Valley, drying conditions are projected in late spring and summer. Projections demonstrate a bi-modal pattern of precipitation changes between the Sacramento Valley and the San Joaquin and Tulare Basins. The hinge-point of wetter versus drier conditions in the winter moves northward with continued warming through time consistent with an expansion of the Hadley cell and more northerly storm tracks (Seager et al 2010). Areas with increases in annual precipitation are almost exclusively those that experience higher winter precipitation increases over springtime decreases.

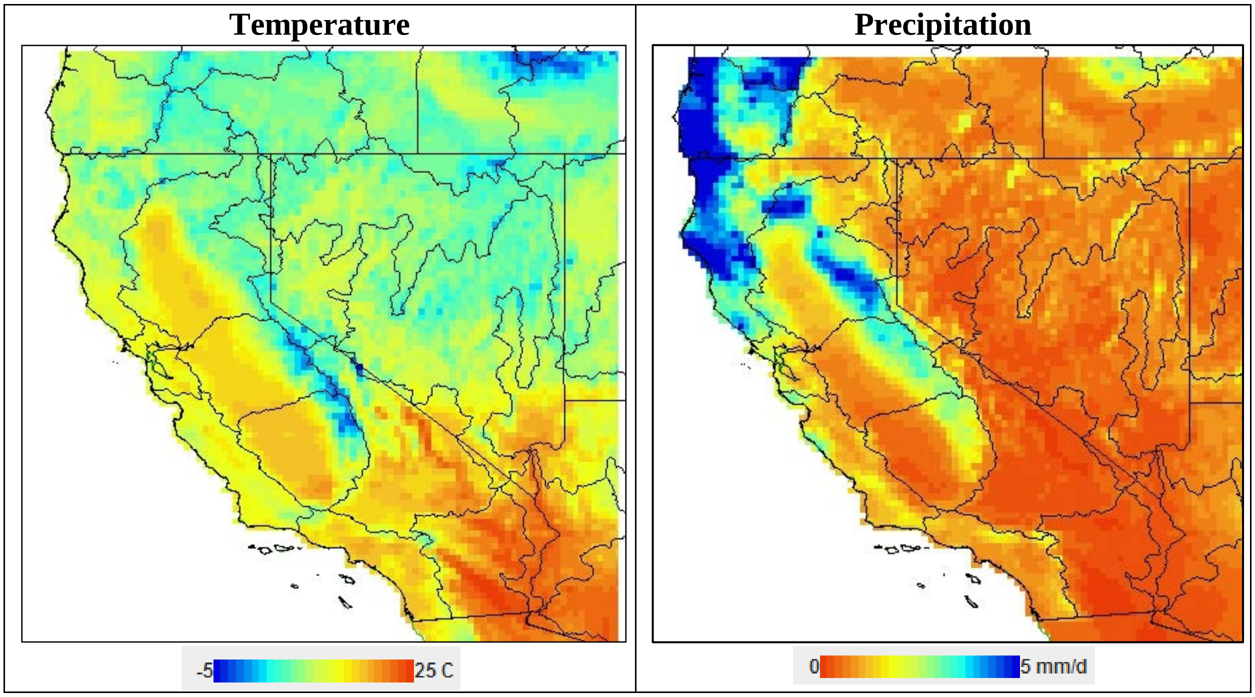
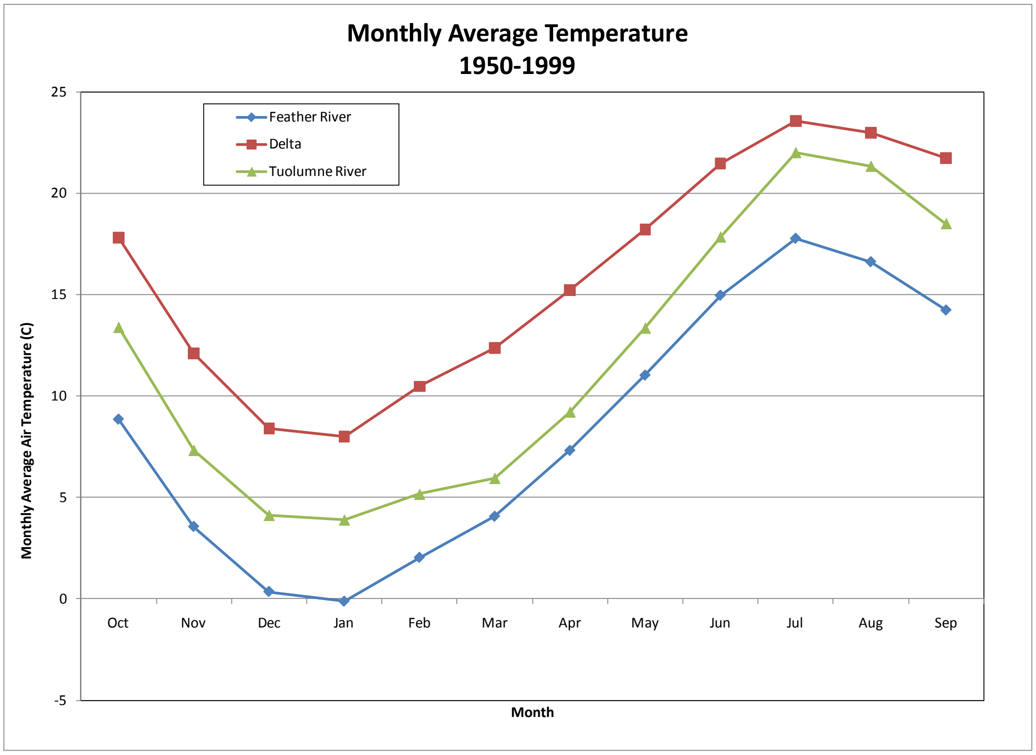


Figure 5.A.A.1-4: Average Annual Temperature (deg C) and Average Annual Precipitation (millimeters/day) for the Period 1950 to 1999 ***(Derived from Maurer (2002)***



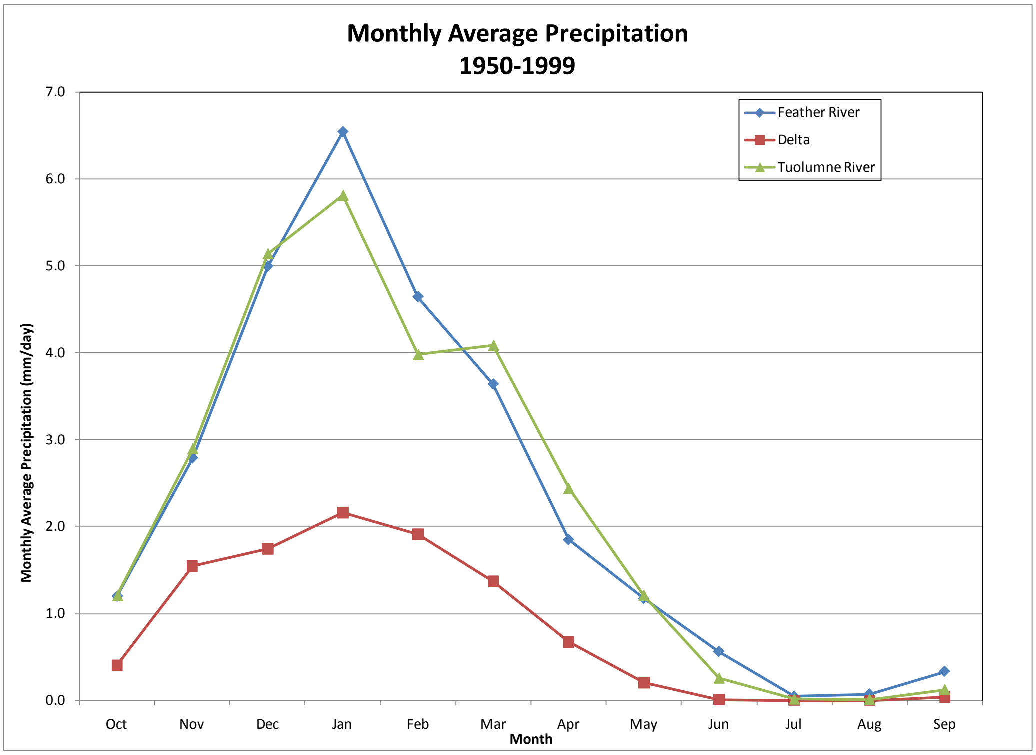
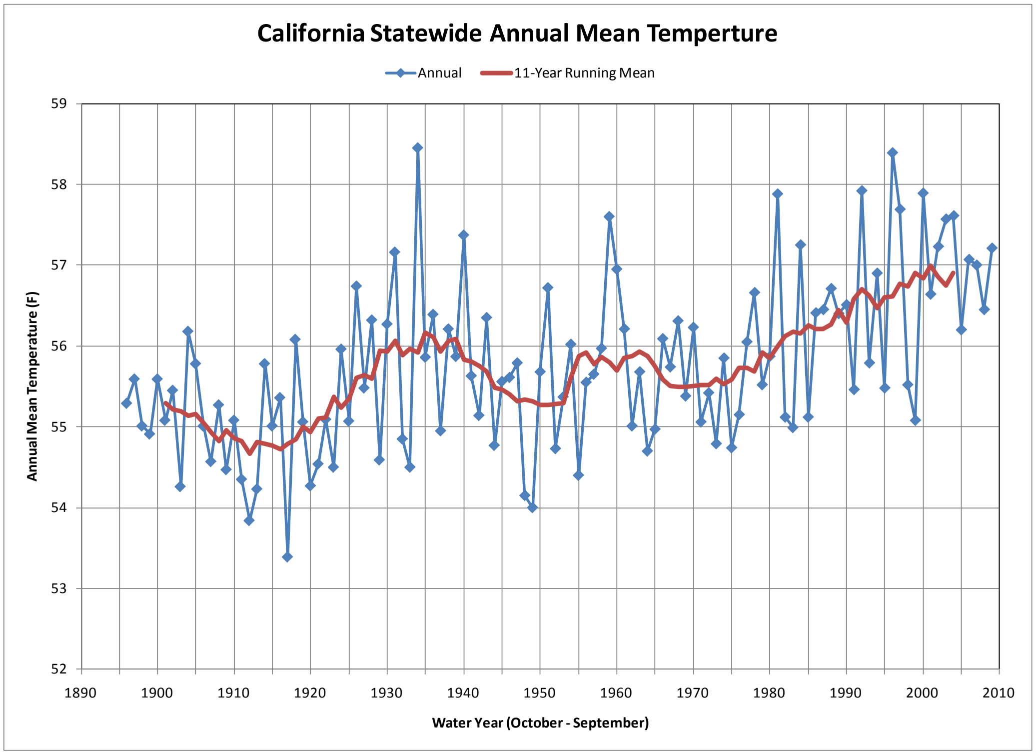


Figure 5.A.A.1-5: Monthly Average Temperature (top) and Precipitation (bottom) for Three Representative Locations in the Central Valley ***Derived from Daily Gridded Observed Meteorology (Maurer et al, 2002)***



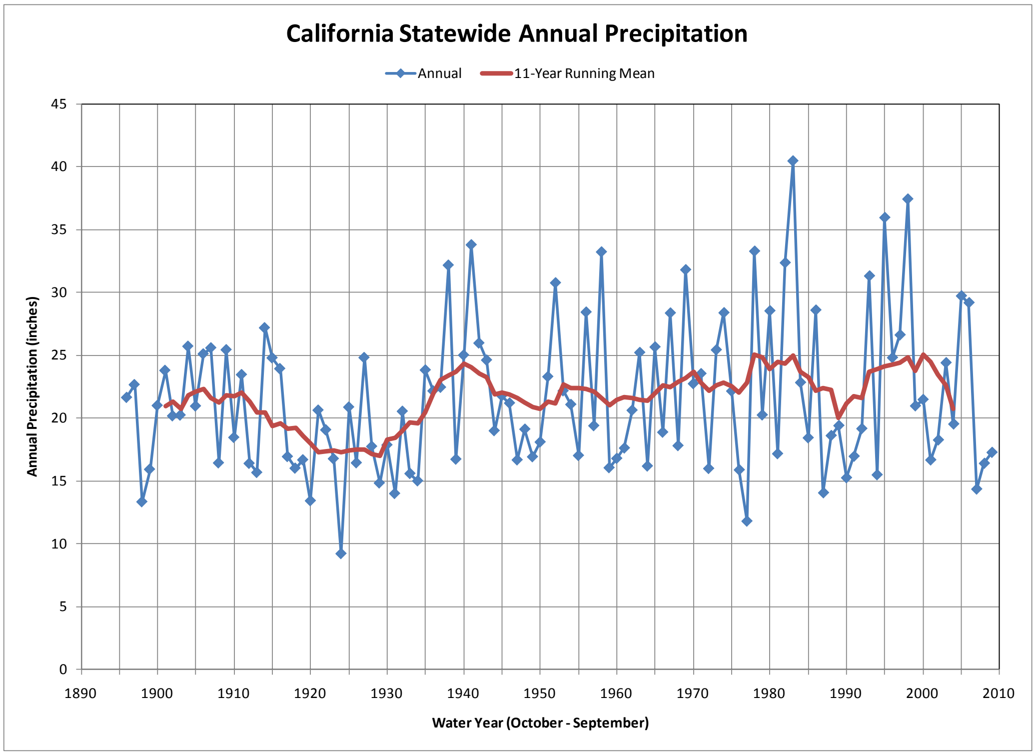
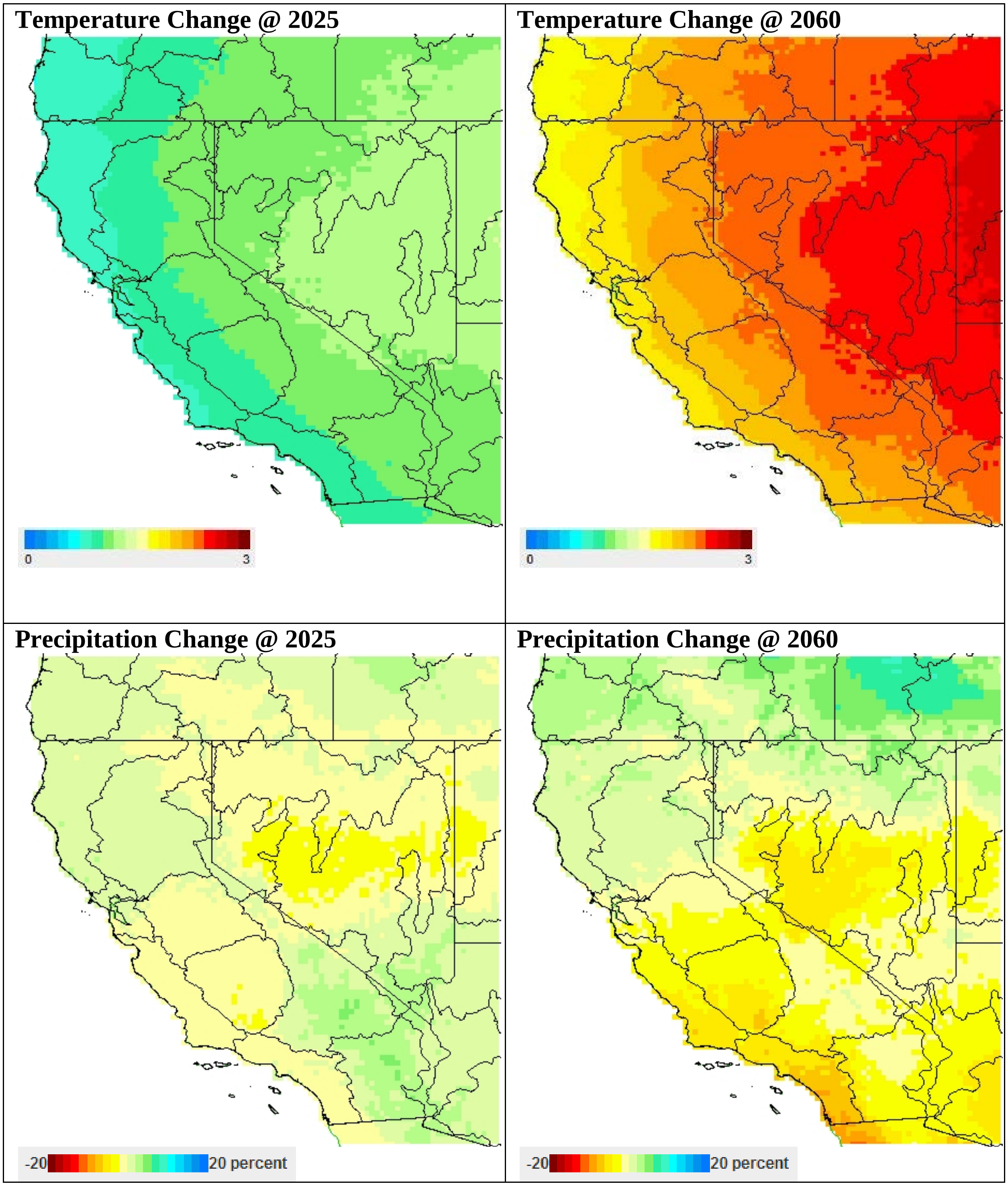


Figure 5.A.A.1-6: (Top) Statewide annual average surface air temperature, 1896-2009 and (Bottom) Annual water year average precipitation (Note: blue: annual values; red: 11-year running mean. Source: Western Regional Climate Center 2011)

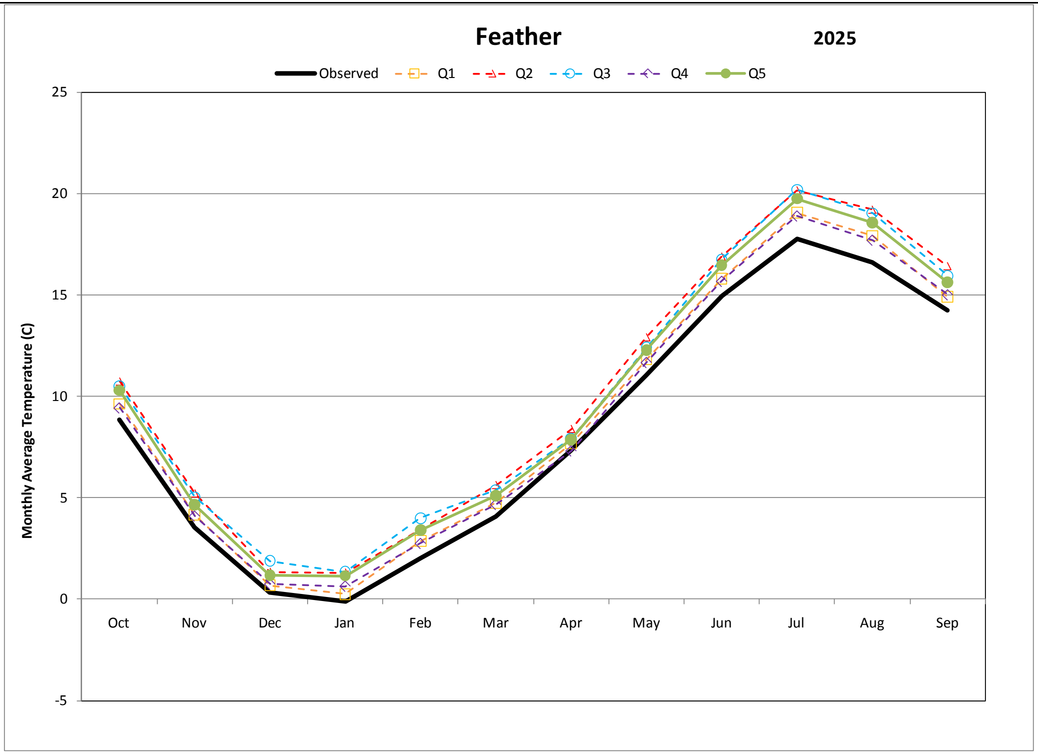

Temperature Change @ 2025

Temperature Change @ 2060

Precipitation Change @ 2025

Precipitation Change @ 2060

Figure 5.A.A.1-7: Projected Changes in Annual Temperature (top, as degrees C) and Precipitation (bottom, as percent change) for the Periods 2011-2040 (2025) and 2046-2075 (2060) as Compared to the 1971-2000 Historical Period. ***Derived from Daily Gridded Observed Meteorology (Maurer et al, 2002)***



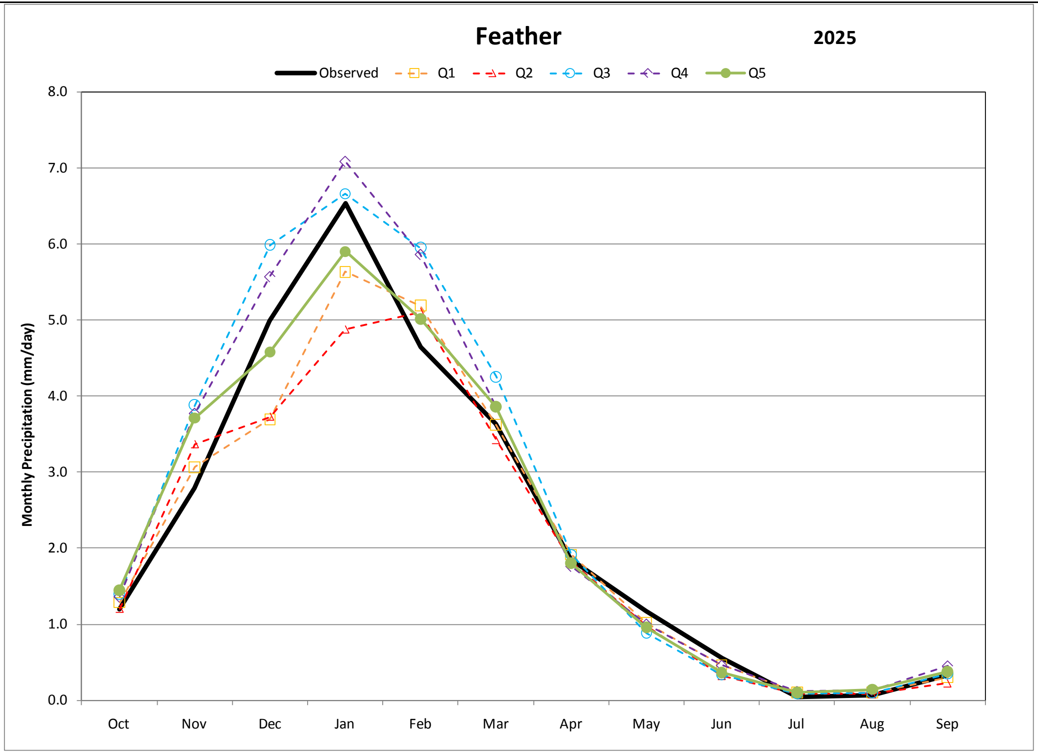
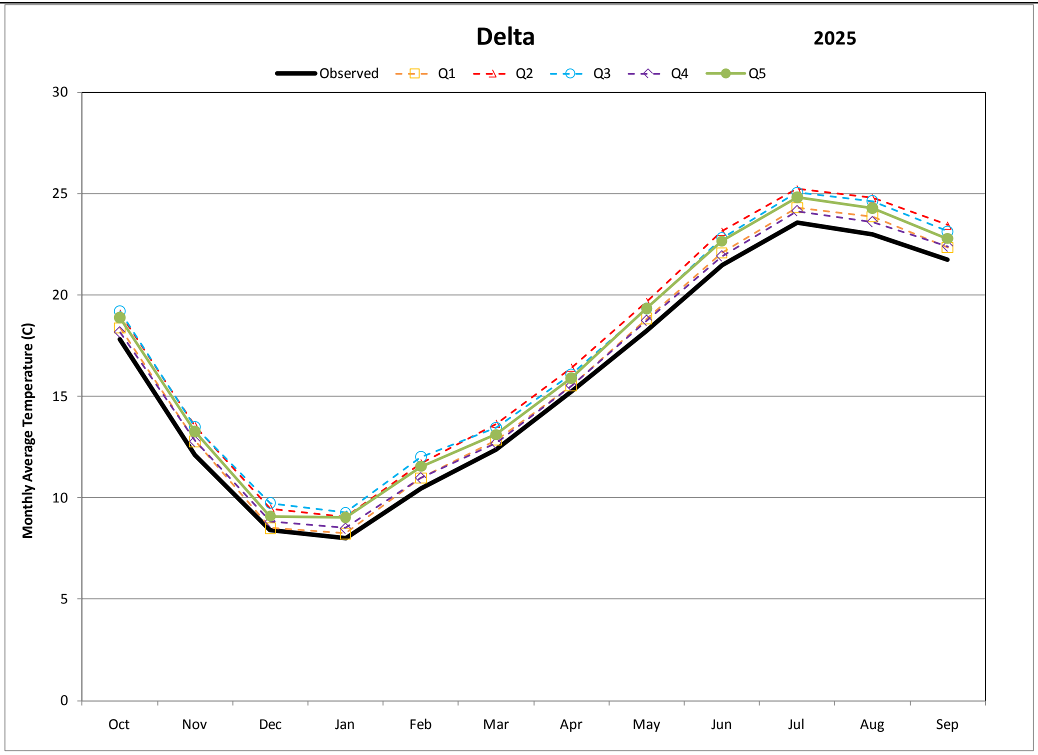


Figure 5.A.A.1-8: Projected Changes in Seasonal Temperature (top) and Precipitation (bottom) for a Grid Cell in the Feather River Basin



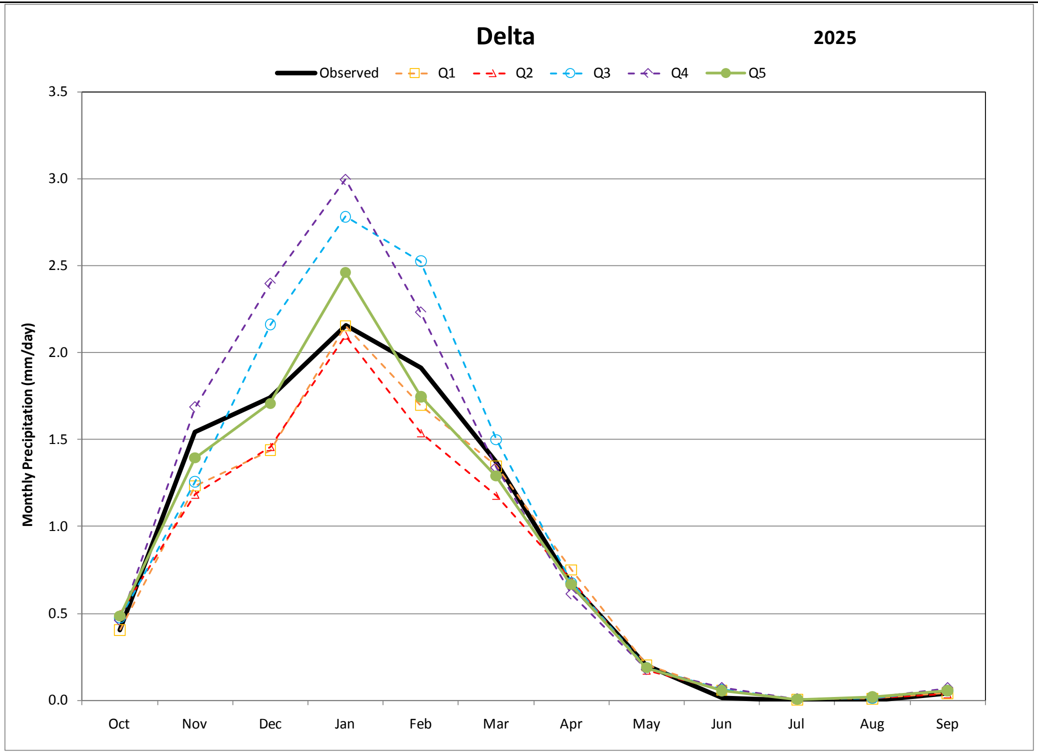


Figure 5.A.A.1-9: Projected Changes in Seasonal Temperature (top) and Precipitation (bottom) for a Grid Cell in the Delta

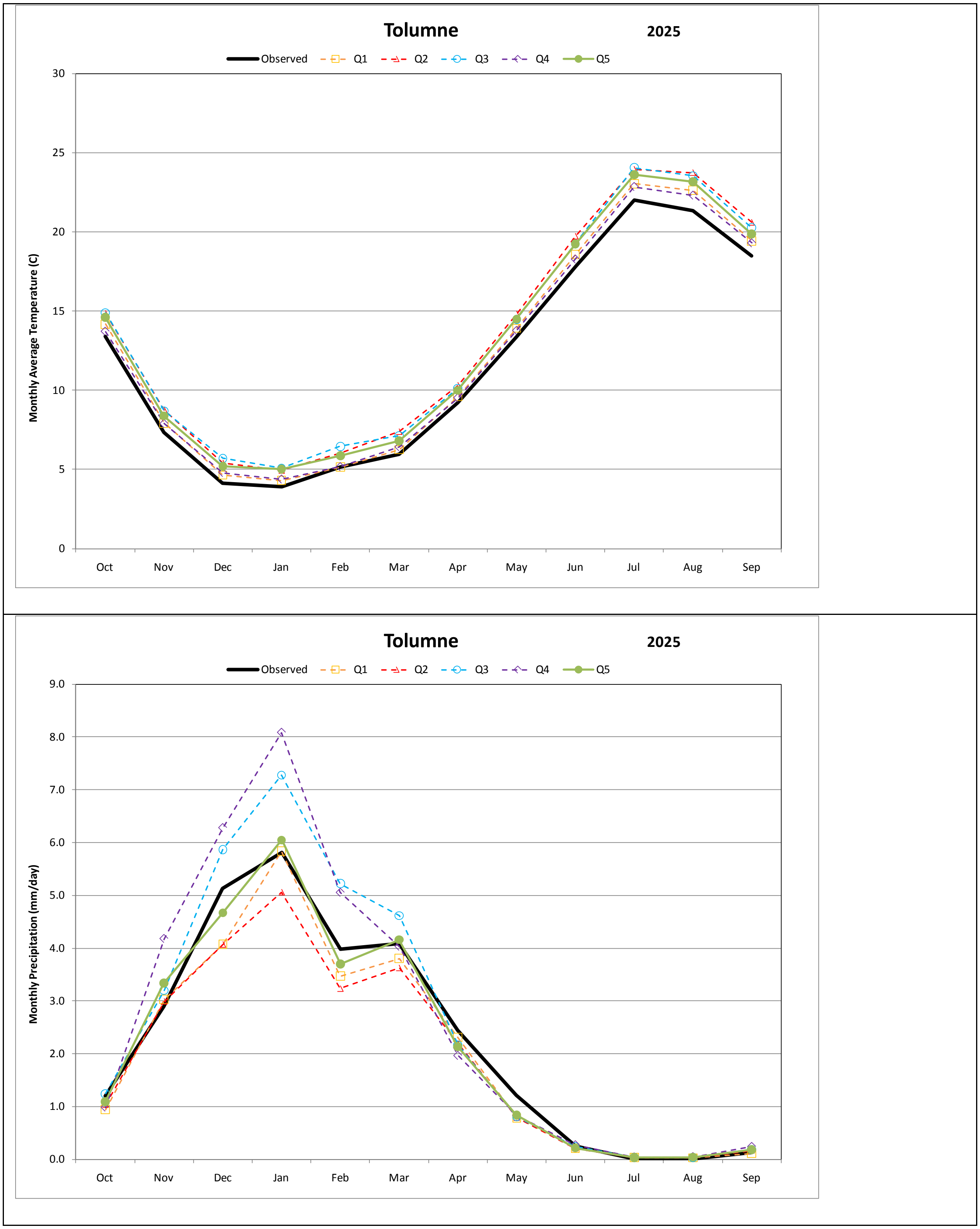


Figure 5.A.A.1-10: Projected Changes in Seasonal Temperature (top) and Precipitation (bottom) for a Grid Cell in the Tuolumne River Basin

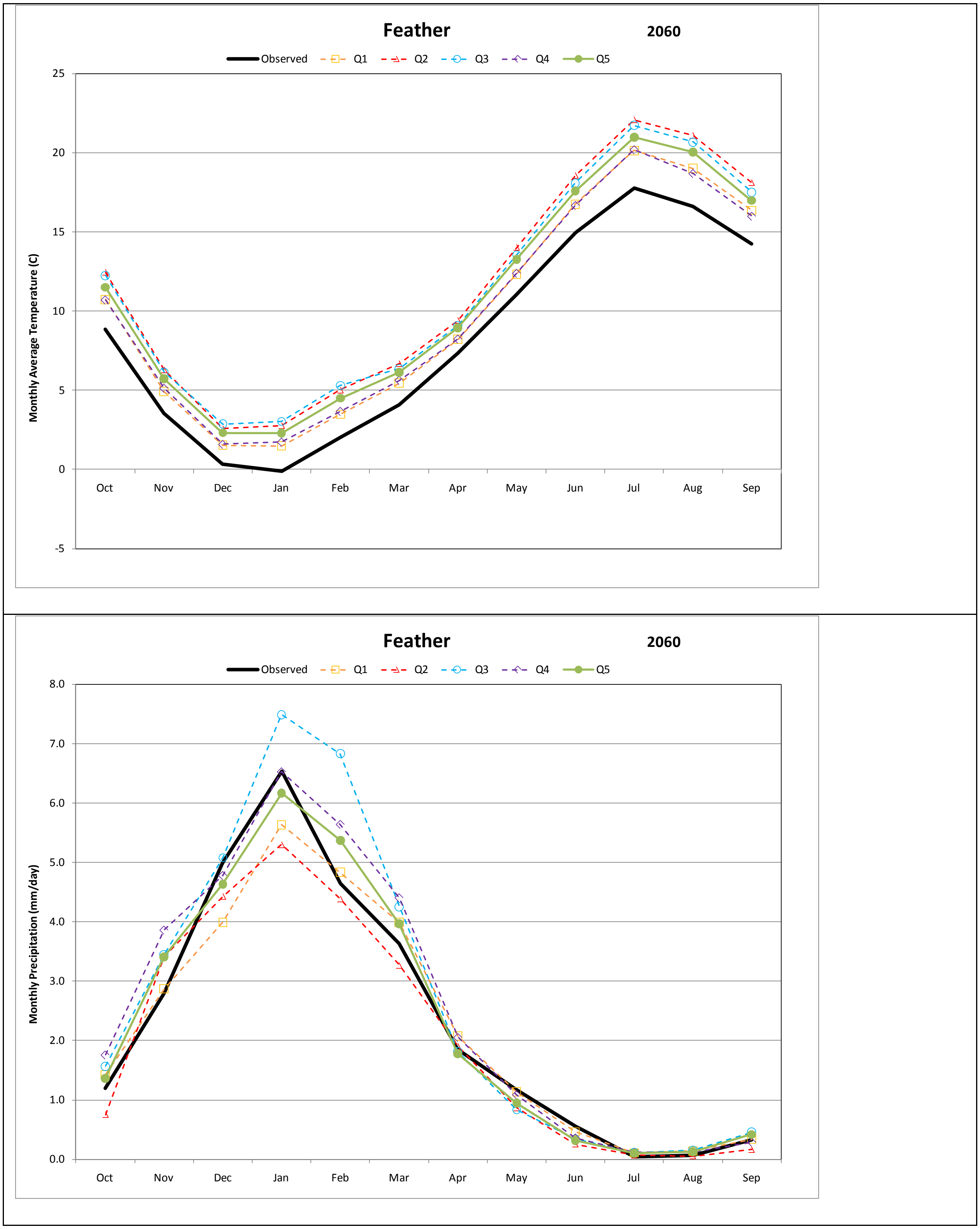


Figure 5.A.A.1-11: Projected Changes in Seasonal Temperature (top) and Precipitation (bottom) for a Grid Cell in the Feather River Basin

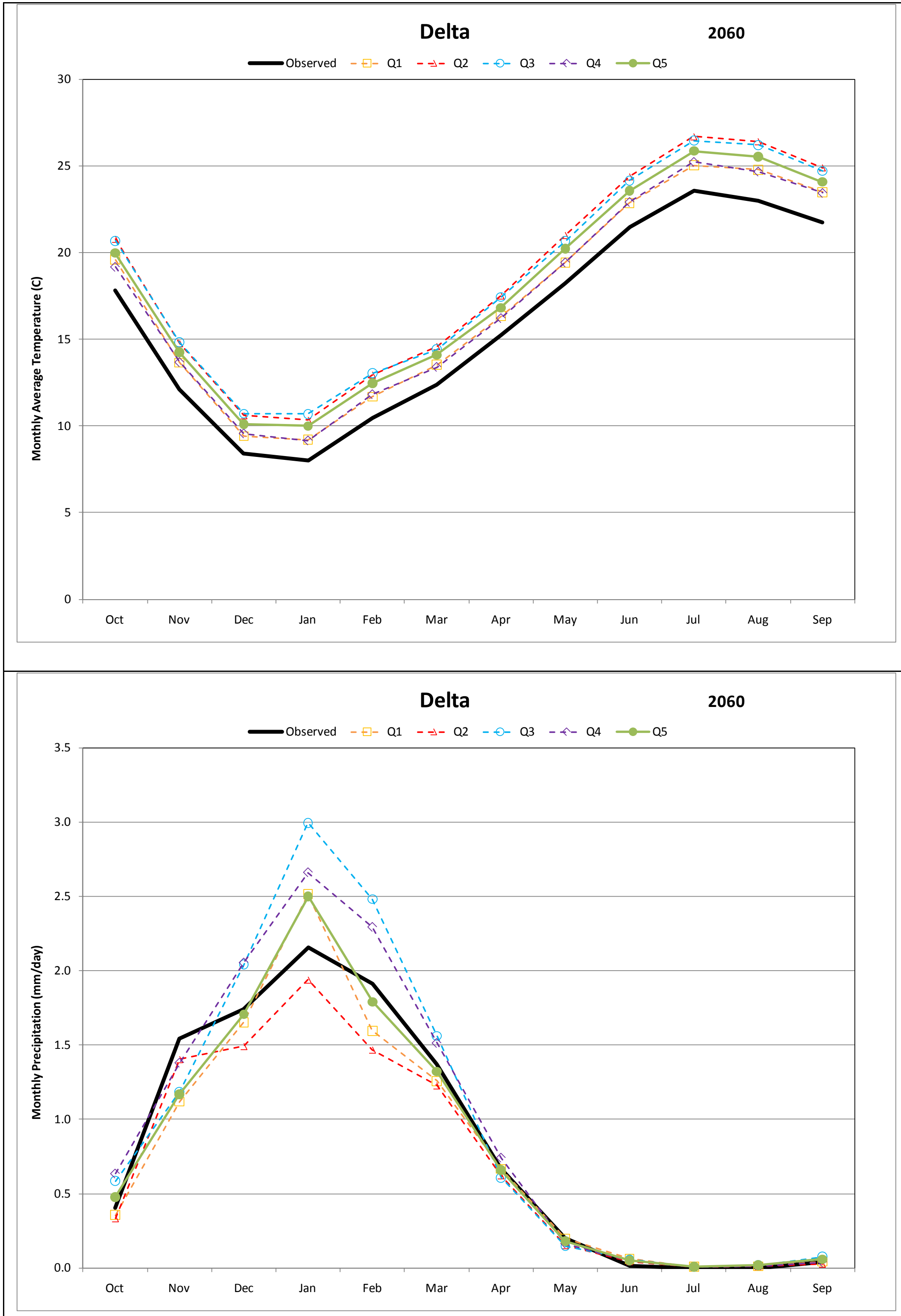
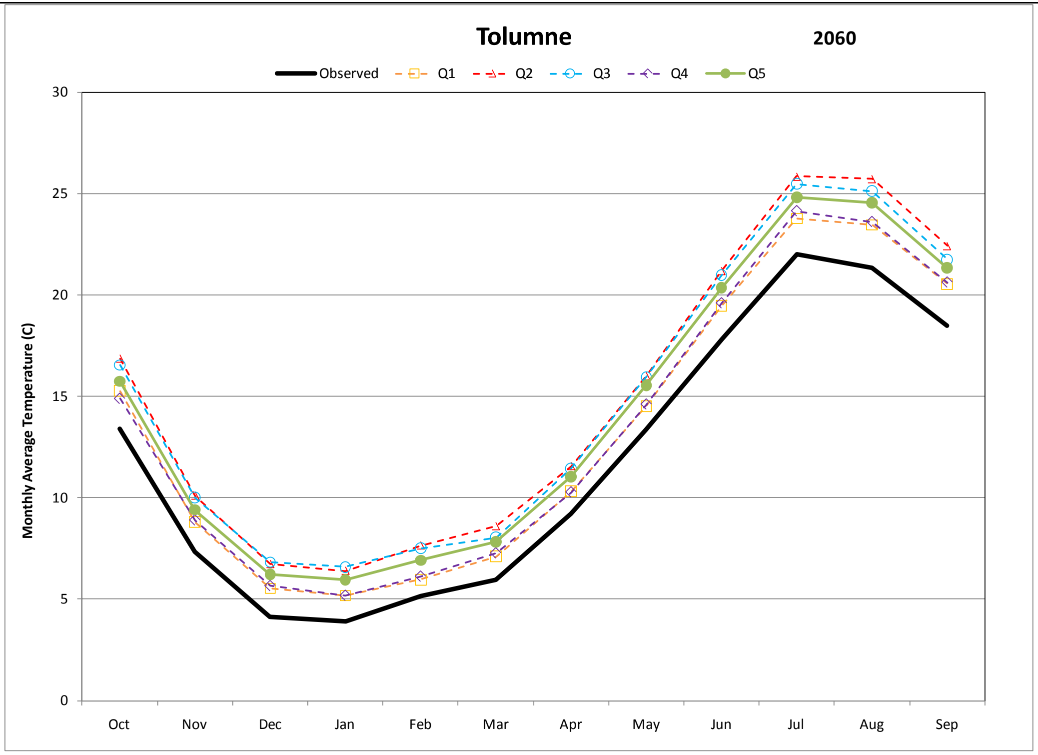


Figure 5.A.A.1-12: Projected Changes in Seasonal Temperature (top) and Precipitation (bottom) for a Grid Cell in the Delta



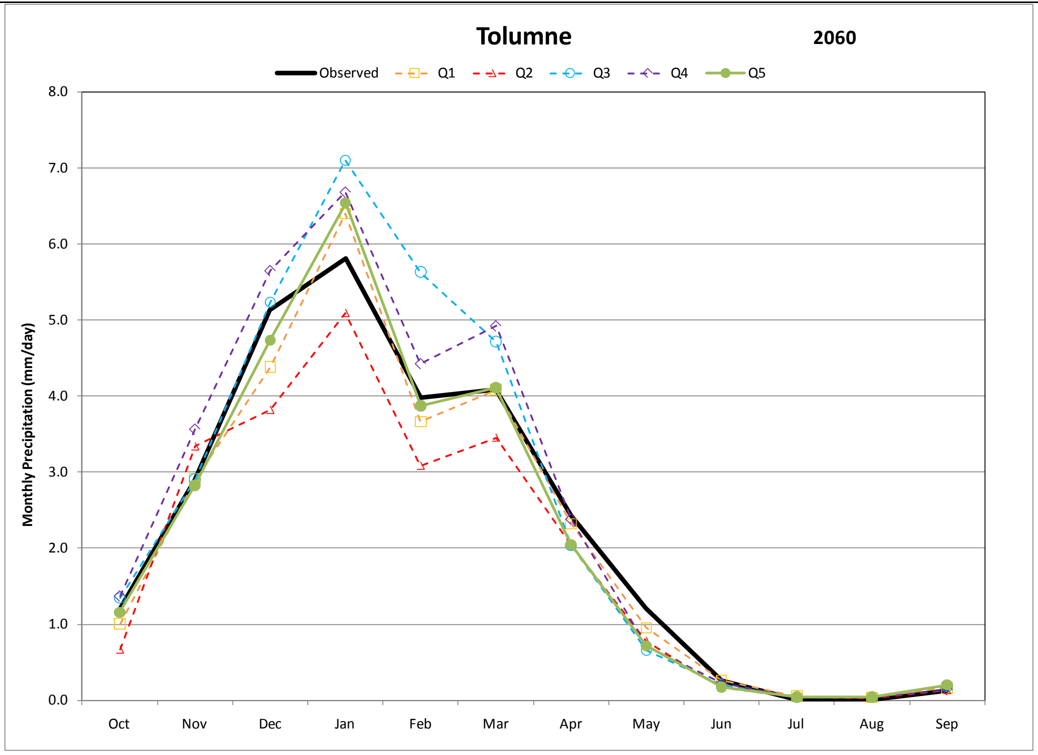


Figure 5.A.A.1-13: Projected Changes in Seasonal Temperature (top) and Precipitation (bottom) for a Grid Cell in the Tuolumne River Basin

5.A.A.1.9 References

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5.A.A.2 Attachment 2: Regional Hydrologic Modeling

This attachment describes the approach used in modeling the projected runoff changes and the resulting hydrologic changes from the VIC model under the future climate scenarios compared to the current hydrology, which formed the basis of CalSim II's climate-modified inputs. This approach and the resulting runoff changes under selected climate change projections are identical to those presented in the draft BDCP EIR/EIS (DWR 2013).

5.A.A.2.1 Regional Hydrologic Modeling

Regional hydrologic modeling is necessary to understand the watershed-scale impacts of historical and projected climate patterns on the processes of rainfall, snowpack development and snowmelt, soil moisture depletion, evapotranspiration, and ultimately changes in streamflow patterns. Future projected climate change, downscaled from global climate models (GCMs), suggests substantial warming throughout California and changes in precipitation. The effect of these changes in critical to future water management. In most prior analyses of the water resources of the Central Valley, the assumptions of hydroclimatic "stationarity", the concept that variability extends about relatively unchanging mean, have been made. Under the stationarity assumption, the observed streamflow record provides a reasonable estimate of the hydroclimatic variability. However, recent observations and future projections indicate that the climate will not be stationary, thus magnifying the need to understand the direct linkages between climate and watershed processes. Hydrologic models, especially those with strong, directly linkages to climate, enable these processes to be effectively characterized and provide estimates of changes in magnitude and timing of basin runoff with changes in climate conditions.

5.A.A.2.2 Variable Infiltration Capacity (VIC) Model

The VIC model (Liang et al. 1994; Liang et al. 1996; Nijssen et al. 1997) is a spatially distributed hydrologic model that solves the water balance at each model grid cell. The VIC model incorporates spatially distributed parameters describing topography, soils, land use, and vegetation classes. VIC is considered a macro-scale hydrologic model in that it is designed for larger basins with fairly coarse grids. In this manner, it accepts input meteorological data directly from global or national gridded databases or from GCM projections. To compensate for the coarseness of the discretization, VIC is unique in its incorporation of subgrid variability to describe variations in the land parameters as well as precipitation distribution. Parameterization within VIC is performed primarily through adjustments to parameters describing the rates of infiltration and baseflow as a function of soil properties, as well as the soil layers depths. When simulating in water balance mode, as done for this California application, VIC is driven by daily inputs of precipitation, maximum and minimum temperature, and windspeed. The model internally calculates additional meteorological forcings such short-wave and long-wave radiation, relative humidity, vapor pressure and vapor pressure deficits. Rainfall, snow, infiltration, evapotranspiration, runoff, soil moisture, and baseflow are computed over each grid cell on a daily basis for the entire period of simulation. An offline routing tool then processes the individual cell runoff and baseflow terms and routes the flow to develop streamflow at various locations in the watershed. Figure 5.A.A.2-1 shows the hydrologic processes included in the VIC model.

The VIC model has been applied to many major basins in the United States, including large-scale applications to California's Central Valley (Maurer et. al 2002; Brekke et al 2008; Cayan et al. 2009), Colorado River Basin (Christensen and Lettenmaier, 2009), Columbia River Basin (Hamlet et al 2010), and for several basins in Texas (Maurer and Lettenmaier 2003; CH2M HILL 2008). The VIC model application for California was obtained from Dan Cayan and Tapash Das at Scripps Institute of Oceanography (SIO) and is identical to that used in the recent Climate Action Team (2009) studies. The VIC model was simulated by CH2M HILL and comparisons were performed with SIO to ensure appropriate transfer of data sets. No refinements to the existing calibration was performed for the California WaterFix Biological Assessment (CWF BA) application.

5.A.A.2.3 Application of VIC Model for CWF BA Evaluations

The regional hydrologic modeling is applied to support an assessment of changes in runoff associated with future projected changes in climate. These results are intended for use in comparative assessments and serve the primary purpose of adjusting inflow records in the CalSim II long term operations model to reflect anticipated changes in climate. This section describes the regional hydrologic modeling methods used in the planning analysis for CWF BA.

The GCM downscaled climate projections (DCP) are used to adjust historical California climate for the effects of climate change for each of the climate scenarios described in Attachment 1. The resulting adjusted climate patterns, primarily temperature and precipitation fields are used as inputs to the VIC hydrology model. The VIC model is simulated for the each of the five climate scenarios at each CWF BA long-term timeline. The VIC model simulations produce outputs of hydrologic parameters for each grid cell and daily and monthly streamflows at key locations in the Sacramento River and San Joaquin River watersheds. The changes in "natural" flow at these locations between the observed and climate scenarios are then applied to adjust historical inflows to the CalSim II model.

5.A.A.2.3.1 Model Domain

The VIC application for California was originally developed by University of Washington (Wood et al, 2002), but has been subsequently refined by Ed Maurer and others (Maurer et. al 2002). The model grid consists of approximately 3000 grid cells at a 1/8th degree latitude by longitude spatial resolution. The VIC model domain is shown in Figure 5.A.A.2-2 and covers all major drainages in California.

5.A.A.2.3.2 Observed Meteorology

The VIC application for the CWF BA is run in water balance mode with inputs consisting of daily precipitation, minimum temperature, maximum temperature, and windspeed. The model internally calculates additional meteorological forcings such short-wave and long-wave radiation, relative humidity, vapor pressure and vapor pressure deficits. Daily gridded observed meteorology was obtained from the University of Washington (Hamlet and Lettenmaier 2005) for the period of 1915-2003. This data set adjusts for station inhomeniety (station length, movement, temporal trends) and is comparable to a similar observed data set developed by Maurer et. al (2002) for the 1950-99 overlapping period. The longer sequence of this observed meteorology data set allow for improved simulation techniques and integration with CalSim II model with commensurate time coverage. In addition, this observed data set is currently being applied by Cayan et al (2010) for the recent study on Southwest drought and Hamlet et al (2010) in their study of climate change in the Pacific Northwest. To better understand the sensitivity of the VIC modeling to different observed meteorology, comparative simulations using both the Hamlet data set and the Maurer data set were performed. The resulting simulated streamflows were comparable between the two data sets with relatively minor differences in individual months and years.

5.A.A.2.3.3 Daily Meteorology for Future Climate Scenarios

Scenarios of future climate were developed through methods as described in Attachment 1. These ensemble informed scenarios consist of daily time series and monthly distribution statistics of temperature and precipitation for each grid cell for the entire state of California. Historical daily time series of temperature and precipitation are converted to representative future daily series through the process of quantile mapping which applies the change in monthly statistics derived from the climate projection information onto the input time series. The result of this process (described in detail in Attachment 1) is a modified daily time series that spans the same time period as the observed meteorology (1915-2003). Daily precipitation and temperature are adjusted based on the derived monthly changes and scaled according to the daily patterns in the observed meteorology. Wind speed was not adjusted in these analyses as downscaling of this parameter was not available, nor well-translated from global climate models to local scales.

5.A.A.2.3.4 Grid Cell Characterization and Water Balance

As described previously, the VIC model was simulated in water balance mode. In this mode, a complete land surface water balance is computed for each grid cell on a daily basis for the entire model domain. Unique to the VIC model is its characterization of sub-grid variability. Sub-grid elevation bands enable more detailed characterization of snow-related processes. Five elevation bands are included for each grid cell. In addition, VIC also includes a sub-daily (1 hour) computation to resolve transients in the snow model. The soil column is represented by three soil zones extending from land surface in order to capture the vertical distribution of soil moisture. The VIC model represents multiple vegetation types as uses NASA’s Land Data Assimilation System (LDAS) databases as the primary input data set.

For each grid cell, the VIC model computes the water balance over each grid cell on a daily basis for the entire period of simulation. For the simulations performed for the CWF BA, water balance variables such as precipitation, evapotranspiration, runoff, baseflow, soil moisture, and snow water equivalent are included as output. In order to facilitate understanding of these watershed process results, nine locations throughout the in the watershed were selected for more detailed review. These locations are representative points within each of the following hydrologic basins: Upper Sacramento River, Feather River, Yuba River, American River, Stanislaus River, Tuolumne River, Merced River, and Upper San Joaquin River. The flow in these main rivers are included in the Eight River Index which is the broadest measure of total flow contributing to the Delta. A ninth location was selected to represent conditions within the Delta itself.

5.A.A.2.3.5 Routing of Streamflows

The runoff simulated from each grid cell is routed to various river flow locations using VIC's offline routing tool. The routing tool processes individual cell runoff and baseflow terms and routes the flow based on flow direction and flow accumulation inputs derived from digital elevation models (Figure 5.A.A.2-3). For the simulations performed for the CWF BA, streamflow was routed to 21 locations that generally align with long-term gauging stations throughout the watershed. For the VIC application for the CWF BA, several additional streamflow routing locations were added to ensure that all major watersheds contributing to Delta inflow were considered. The primary additions were the smaller drainages in the upper Sacramento Valley consisting of Cottonwood Creek and Bear River and the Eastside streams consisting of Cosumnes, Mokelumne, and Calaveras Rivers. Table 5.A.A.2-1 lists these 21 locations. The flow at these locations also allows for assessment of changes in various hydrologic indices used in water management in the Sacramento-San Joaquin Delta. Flows are output in both daily and monthly time steps. Only the monthly flows were used in subsequent analyses. It is important to note that VIC routed flows are considered "naturalized" in that they do not include effects of diversions, imports, storage, or other human management of the water resource.

5.A.A.2.4 Output Parameters

As discussed previously the following key output parameters are produced on a daily and monthly time-step:

- Temperature, precipitation, runoff, baseflow, evapotranspiration, soil moisture, and snow water equivalent on grid-cell and watershed basis
- Routed streamflow at major flow locations to the Sacramento Valley and San Joaquin Valley
- The results from VIC modeling for the selected climate scenarios are presented in Section 5.A.A.2.8.

5.A.A.2.5 Critical Locations for Analysis

The watershed hydrologic process information can be characterized for each of the approximately 3,000 grid cells, but the nine locations described above provide a reasonable spatial coverage of the changes anticipated in Central Valley. The routed streamflows at all 21 locations identified in Table 5.A.A.2-1 are necessary to adjust the inflow timeseries and hydrologic indices in the CalSim II model. Analysis of flows for watersheds much smaller than what is included here should be treated with caution given the current spatial discretization of the VIC model domain. The streamflows included in this analysis and used to adjust hydrology in the CalSim II model account for over 95% of the total natural inflow to the Delta.

5.A.A.2.6 Modeling Limitations

The regional hydrologic modeling described using the VIC model is primarily intended to generate changes in inflow magnitude and timing for use in subsequent CalSim II modeling. While the model contains several sub-grid mechanisms, the coarse grid scale should be noted when considering results and analysis of local scale phenomenon. The VIC model is currently best applied for the regional scale hydrologic analyses. The model is only as good as its inputs. There are several limitations to long-term gridded meteorology related to spatial-temporal interpolation and bias correction that should be considered. In addition, the inputs to the model do not include any transient trends in the vegetation or water management that may affect streamflows; they should only be analyzed from a “naturalized” flow change standpoint. Finally, the VIC model includes three soil zones to capture the vertical movement of soil moisture, but does not explicitly include groundwater. The exclusion of deeper groundwater is not likely a limiting factor in the upper watersheds of the Sacramento and San Joaquin River watersheds that contribute approximately 80-90% of the runoff to the Delta, however, in the valley floor groundwater management and surface water regulation is considerable. Water management models such as CalSim II should be utilized to characterize the heavily “managed” portions of the system.

5.A.A.2.7 Linkages to Other Physical Models

The VIC hydrology model requires input related to historic and future meteorological conditions. Long-term historical gridded datasets have been obtained to characterize past climate. Future estimates of meteorological forcings are derived from downscaled climate projections incorporating the effects of global warming. The changes in routed streamflows between historic and future VIC simulations are used to adjust inflows and hydrologic indices for use in the CalSim II model.

5.A.A.2.8 Regional Hydrologic Modeling Results

5.A.A.2.8.1 Hydrologic Processes

The hydrologic processes that describe the interaction between climate and the watershed landscape are critically important in determining water availability and the manner in which the basin response may change under future climate. The regions of greatest precipitation in the Sacramento and San Joaquin River watersheds are those are those at high elevation in the headwaters of the Sacramento, Feather, Yuba, American, Stanislaus, Tuolumne, Merced, and San Joaquin Rivers. Due to cold temperatures these areas accumulate substantial snowpack that it is critical to the total inflow to the Delta. Warming has been observed and is projected to accelerate and causes substantial changes to the timing and form of precipitation in these areas. Recent studies have assessed observed snowpack trends in the southwest. Research by Mote (2005) and Cayan (2001) indicate a general decline in April 1 snow water equivalent (SWE) for Pacific Northwest and the northern Sierra, but increasing trends in the high elevation southern Sierras. Relative losses of SWE tend to be largest at low elevations and strongly suggest a temperature-related effect.

These broad trends of April 1 SWE were generally captured over the calibration period with the VIC model as show in the right of Figure 5.A.A.2-4. The results indicate the significant influence of high elevation on the response of the watersheds. The watersheds of the northern Sierra and Cascades tend to be of lower elevation and snowfall and snowmelt are sensitive the changes in temperature; essentially causing earlier snowmelt or causing more precipitation to fall as rain rather than snow. At high elevation, the snowpack and snowmelt is not as sensitivity to small warming changes due to the presence of the majority of the watershed well above 8000 feet. Mote et al (2008) found that the changes in SWE were not linear with increasing warming trends, but that the watersheds with elevations above 2,500 meters (approximately 8,000 feet) were less sensitive to warming and more sensitive to precipitation changes.

Evapotranspiration is projected to increase substantially throughout the Central Valley. Across the watershed, increases are expected in fall, winter, and spring and substantial decreases in summer as soil moisture is depleted earlier than under historical conditions. In areas receiving increases in precipitation evapotranspiration is projected to increase in spring as higher winter precipitation and earlier snowmelt allow a higher percentage of potential evapotranspiration to be satisfied. At lower elevations, where snowpack is not significant and warmer temperatures exist, the peak increases in evapotranspiration are earlier in the year, with fall and winter being the highest. Summertime potential evapotranspiration increases significantly but in native areas without irrigation, soil moisture is the limiting factor.

Snowpack is projected to decrease as more precipitation falls as rain rather than snow and warmer temperatures cause an earlier melt. Decreases of snowpack in the fall and early winter are expected in areas where precipitation is not changed or is increased, and is caused by a greater liquid form of precipitation due to warming. Substantial decreases in spring snowpack are expected and projected to be widespread, due to earlier melt or sublimation of snowpack.

Soil moisture represents a portion of the seasonal watershed storage and buffers monthly changes in water availability and consumptive use. The interplay among precipitation, snowpack, evapotranspiration, and runoff cause changes in soil moisture conditions. In general, soil moisture is depleted earlier in the year and deficits persist longer into the late fall and early winter as compared to historical conditions. In regions with overlying snowpack, earlier melt implies earlier contribution to soil moisture storage and an earlier opportunity for evapotranspiration to consumptively use this stored water. In all regions, increased potential evapotranspiration due to warming drives greater consumptive use. However, actual evapotranspiration is governed by water availability and when such soil moisture storage is depleted actual evapotranspiration is curtailed. Overall, the watershed enters the winter season with larger soil moisture deficits and greater opportunity to store and consume winter precipitation.

Runoff (both direct and baseflow), the balance of hydrologic processes of affecting the supply and demand at the local grid-scale, is spatially diverse, but is generally projected to decrease except in some areas of the northern Sierra and Cascades during winter.

5.A.A.2.8.2 Streamflow

The VIC model simulates a daily water balance at approximately 3,000 grid cells throughout the model domain. Routing of grid cell runoff was performed for all the major rivers of the Sacramento River, San Joaquin River, and Tulare Basins. In addition, streamflow routing was performed for the Trinity River. The streamflow was routed to each of the 21 locations identified in Table 5.A.A.2-1. The flow at these locations was necessary to adjust the inflow timeseries and hydrologic indices in the CalSim II model.

VIC simulates “natural flow” conditions; that is, conditions without the regulation or diversion of river flows. The VIC model was simulated under historical meteorological conditions to represent the “no climate change” condition as described in the Methods section. Five future scenarios were then simulated using the climate adjusted meteorology representative of the Q1 through Q5 climate scenarios. Simulations were performed separately for the climate scenarios at the 2025 projections and 2060 projections.

The annual changes in streamflow at the 18 major locations (over 80% of the contributing flow to the delta) of significance are shown in Figure 5.A.A.2-6. The top figure shows the projected changes under the 2025 conditions for the five climate scenarios and the bottom figure shows the projected changes under the 2060 climate scenarios. In this figure, the locations are ordered from north to south (left to right) to depict a general trend in hydrologic response consistent with climate projections.

The green line in Figure 5.A.A.2-6 represents the results from the Q5 climate scenario (ensemble median). Changes are small in the northern watersheds, but a trend toward reduced flows is observed in the San Joaquin River basin. By 2060 under the Q5 scenario, the trend toward reduced streamflows in the south are more apparent as is a shift toward the north where the transition occurs from neutral or increased streamflow to decreased streamflows. The overall reductions in runoff are less than 10% by 2025, but up to 20% by 2060.

The streamflow changes from the Q1-Q4 climate scenarios are also shown in Figure 5.A.A.2-6 as bars. These scenarios indicate the considerable range of uncertainty that exists in climate projections. The Q1 and Q2 scenarios represent the 10th percentile of precipitation projections and result in decreased streamflows for all watersheds and are always more severe than the Q5 scenario. The Q3 and Q4 scenarios represent the 90th percentile of precipitation projections and are always wetter than the Q5 scenario. The Q5 scenario represents a median based response from the wide range of uncertainty. While the response is wide under these scenarios, it is informative to observe that even under modest increases in precipitation (as in Q5 in the north, and Q3 and Q4) the trend in through time is toward reduced streamflows and for a southerly declining trend. Even under wetter condition, increases in streamflow at 2060 are always less than the increases for the same scenario at 2025.

While annual flows show north-south differences and a general median trend toward reduced streamflow, the monthly flows exhibit a significant shift in timing. Figure 5.A.A.2-6 through Figure 5.A.A.2-15 shows the simulated mean monthly flows from the climate projections for the main eight river index locations at both 2025 and 2060 as compared to the simulated historical conditions. Commensurate with the seasonal changes in temperature, precipitation, and hydrologic processes, the peak streamflow occurs about one to two months earlier in the Trinity River, Sacramento River, Feather River, Yuba River, American River, and Stanislaus River. These changes are due to both potential increases in winter precipitation, more precipitation falling as rain rather than snow, and earlier snow melt due to warming.

The higher elevation watersheds of the San Joaquin River do not show a pronounced a shift in the timing of runoff. The Merced, Tuolumne, and Upper San Joaquin do not show this shift, but rather streamflow is sensitive to the climate scenario and the degree of change in precipitation and overall warming.

Simulations for all watersheds demonstrate a reduced late spring and summer flow patterns. It appears very likely that the hydrology of the delta drainages will exhibit a shift towards more fall-winter variability to reduced variability in the spring and summer due to climate change. Considerable uncertainty exists with respect to absolute projections of the future climate and the hydrologic response reflects this uncertainty. However, the strong trend toward seasonal shifts in runoff, decreasing streamflow in the central and southern watersheds, and expansion of variability are present in these analyses.

The flow changes simulated under the VIC hydrology model are reflected in the CalSim II model as changes in the historic inflow traces.

5.A.A.2.9 References

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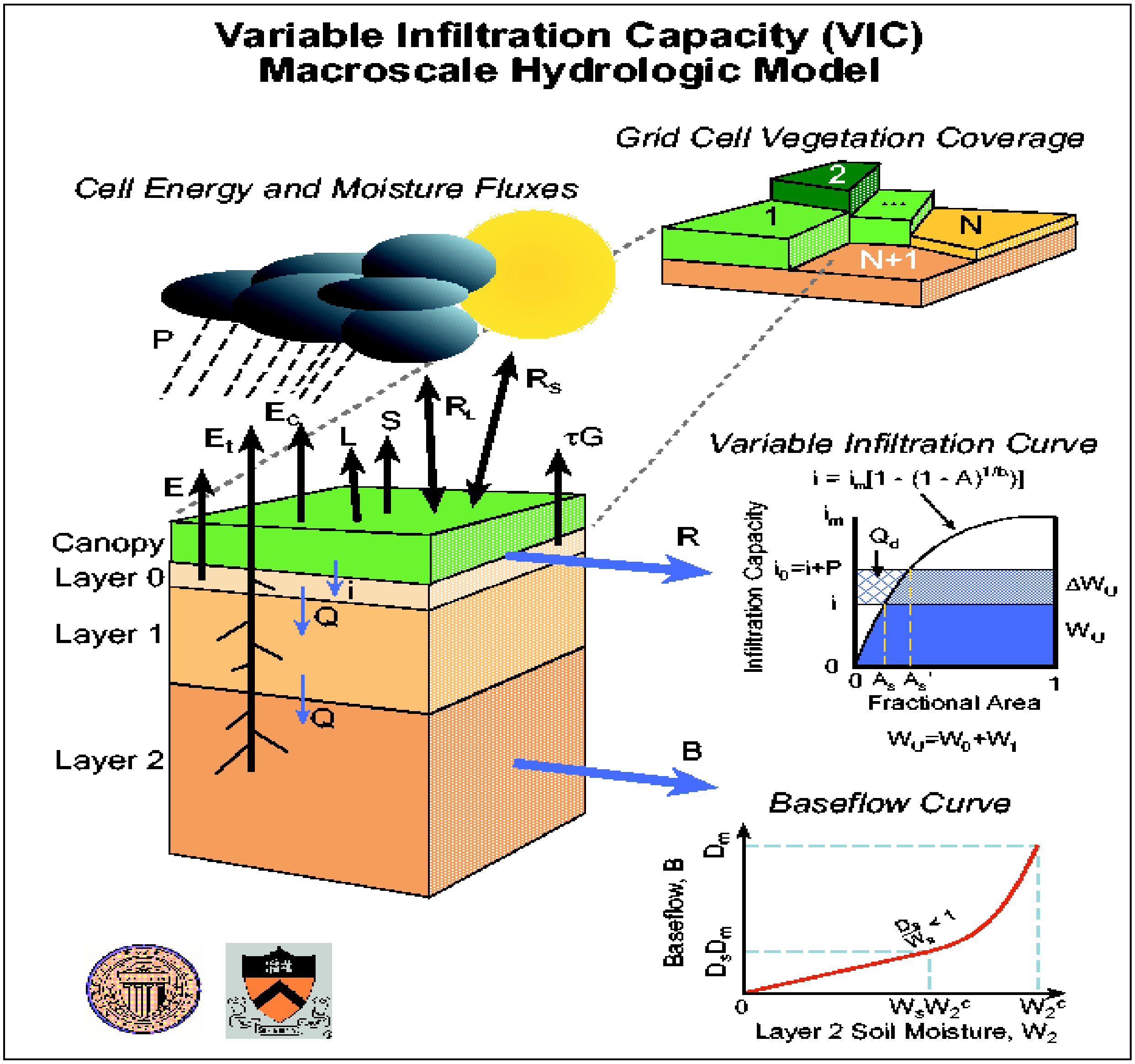


Figure 5.A.A.2-1. Hydrologic Processes Included in the VIC Model (Source: University of Washington 2010)

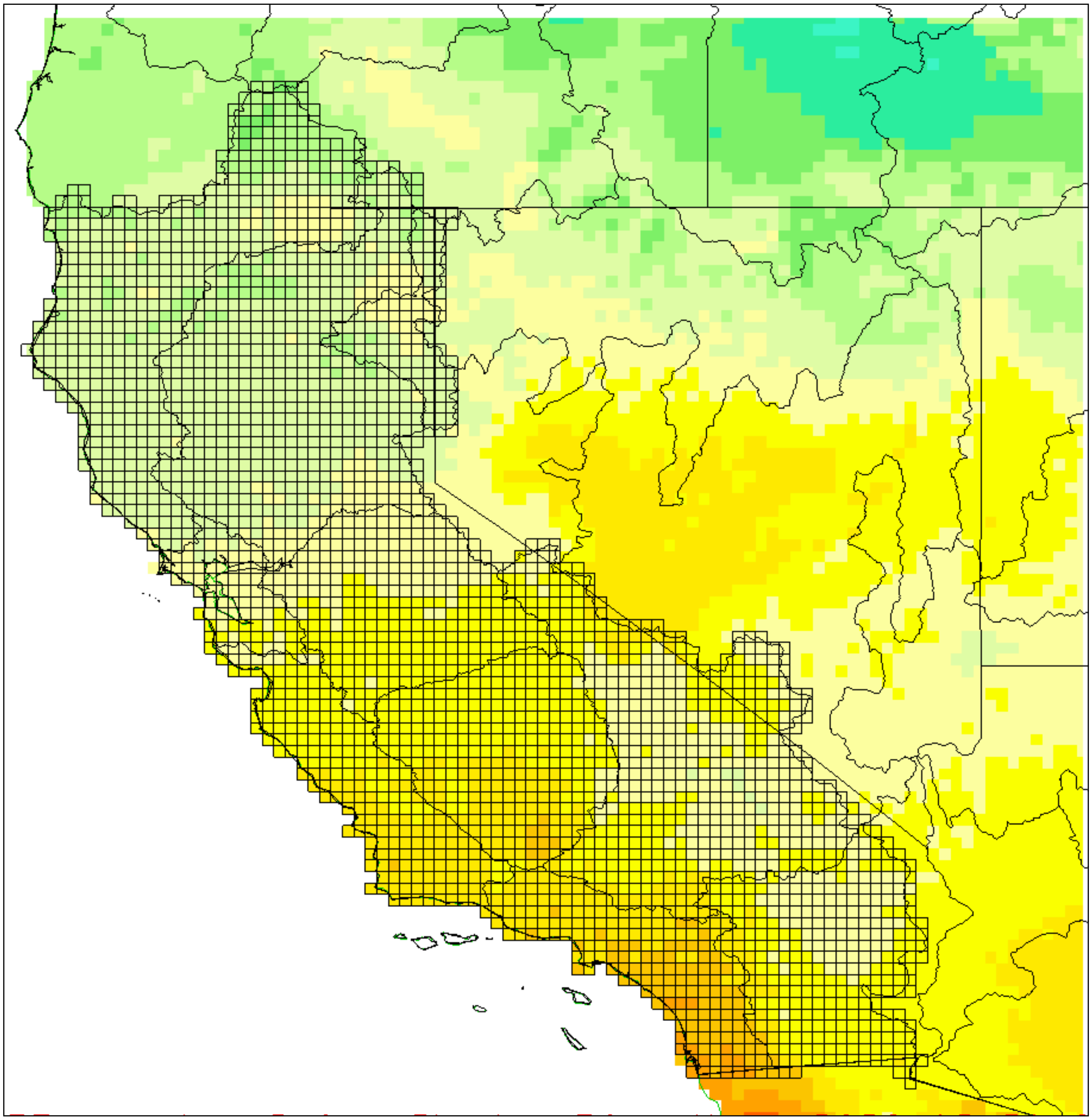


Figure 5.A.A.2-2: VIC model domain and grid as applied for the CWF BA application.

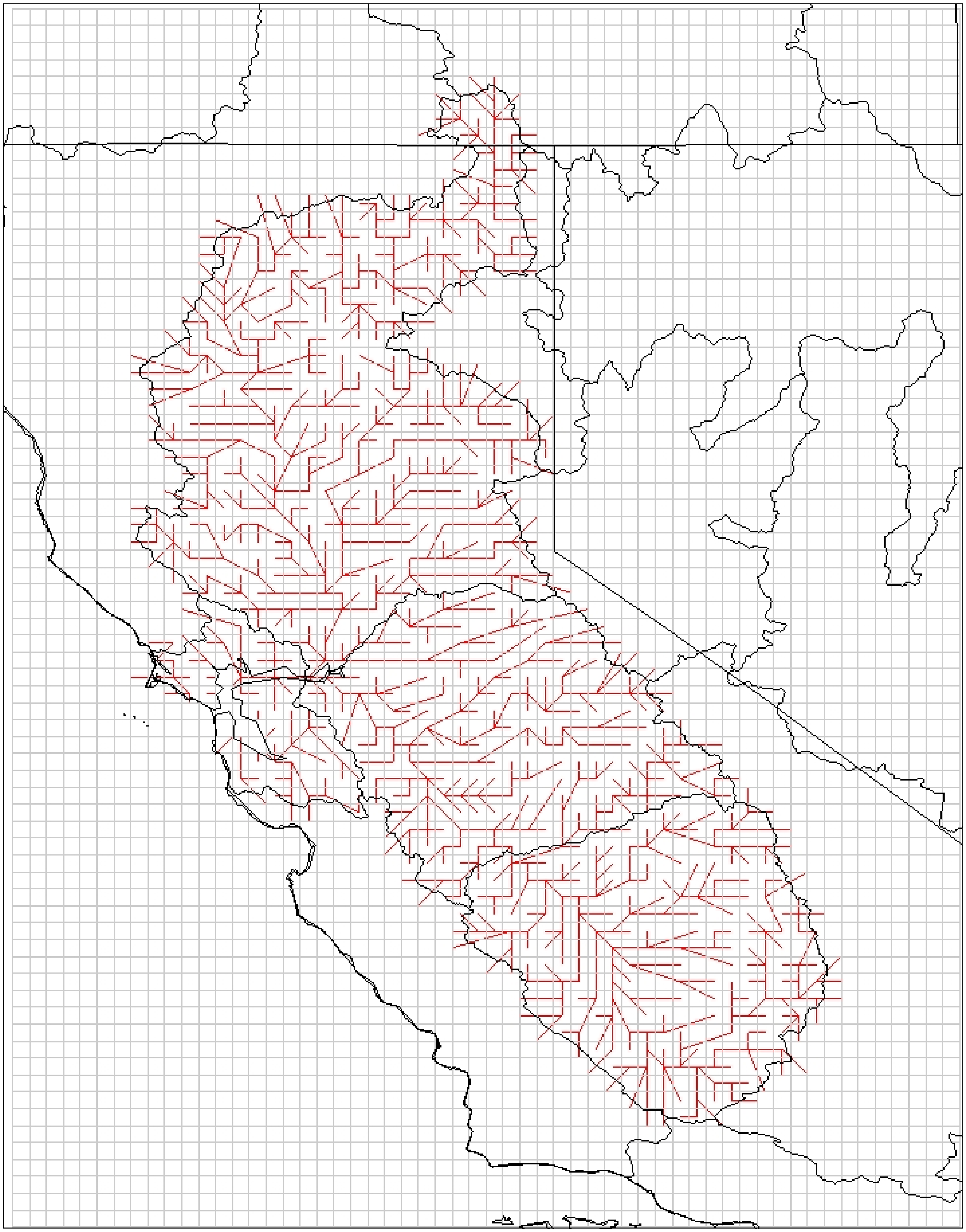


Figure 5.A.A.2-3: VIC model routing network as applied for the CWF BA application.

Table 5.A.A.2-1: Listing of flow routing locations included in the VIC modeling.

Abbr	Name	Lat	Lon	VIC Lat	VIC Lon
SMITH	Smith River at Jed Smith SP	41.7917	-124.075	41.8125	-124.063
SACDL	Sacramento River at Delta	40.9397	-122.416	40.9375	-122.438
TRINI	Trinity River at Trinity Reservoir	40.801	-122.762	40.8125	-122.813
SHAST	Sacramento River at Shasta Dam	40.717	-122.417	40.6875	-122.438
SAC_B	Sacramento River at Bend Bridge	40.289	-122.186	40.3125	-122.188
OROVI	Feather River at Oroville	39.522	-121.547	39.5625	-121.438
SMART	Yuba River at Smartville	39.235	-121.273	39.1875	-121.313
NF_AM	North Fork American River at North Fork Dam	39.1883	-120.758	39.1875	-120.813
FOL_I	American River at Folsom Dam	38.683	-121.183	38.6875	-121.188
CONSU	Cosumnes River at Michigan Bar	38.5	-121.044	38.3125	-121.313
PRD_C	Mokelumne River at Pardee	38.313	-120.719	38.3125	-120.813
N_HOG	Calaveras River at New Hogan	38.155	-120.814	38.1875	-120.813
N_MEL	Stanislaus River at New Melones Dam	37.852	-120.637	37.9375	-120.563
MERPH	Merced River at Pohono Bridge	37.7167	-119.665	37.9375	-119.563
DPR_I	Tuolumne River at New Don Pedro	37.666	-120.441	37.6875	-120.438
LK_MC	Merced River at Lake McClure	37.522	-120.3	37.5625	-120.313
MILLE	San Joaquin River at Millerton Lake	36.984	-119.723	36.9375	-119.688
KINGS	Kings River - Pine Flat Dam	36.831	-119.335	37.1875	-119.438
COTTONWOOD	Cottonwood Creek near Cottonwood	40.387	-122.239		
CLEARCREEK	Clear Creek near Igo	40.513	-122.524		
BEARCREEK	Bear River near Wheatland	39.000	-121.407		

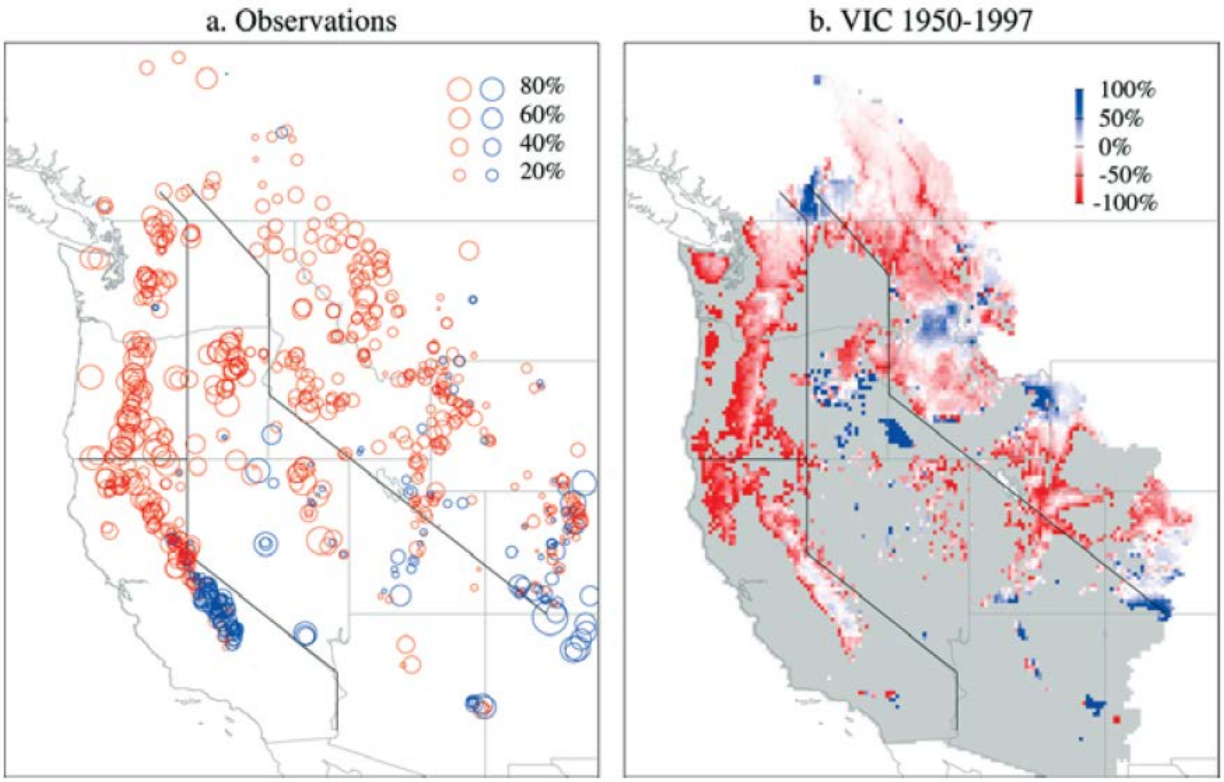
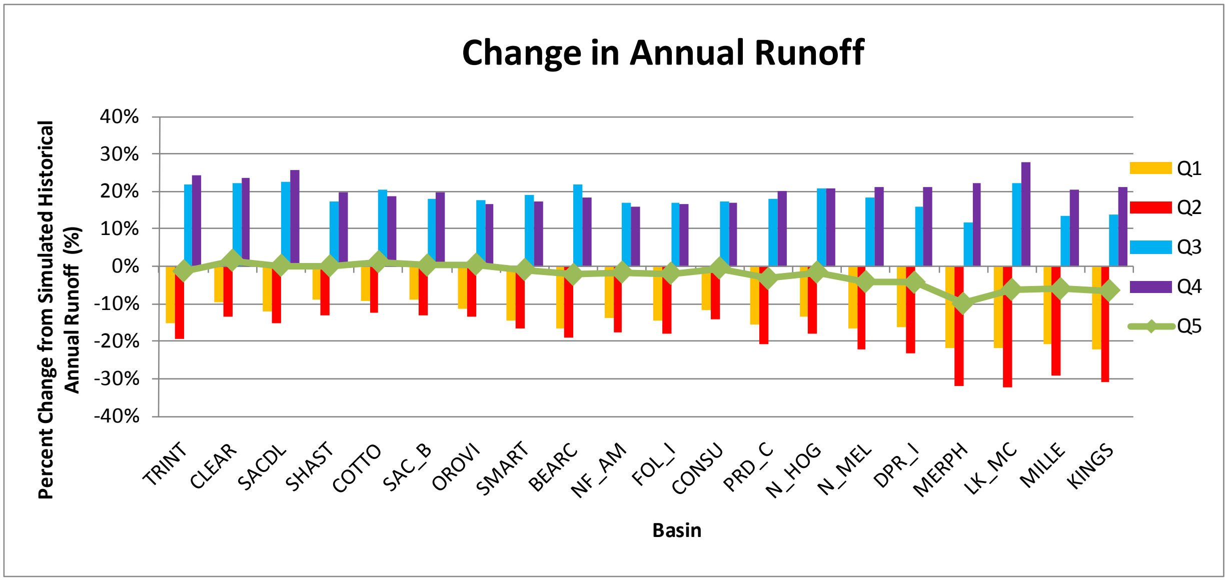


Figure 5.A.A.2-4. Left panel: Linear Trends in April 1 Snow Water Equivalent (SWE) at 824 Locations in the Western U.S. and Canada, 1950 to 1997 (Mote et al 2005)



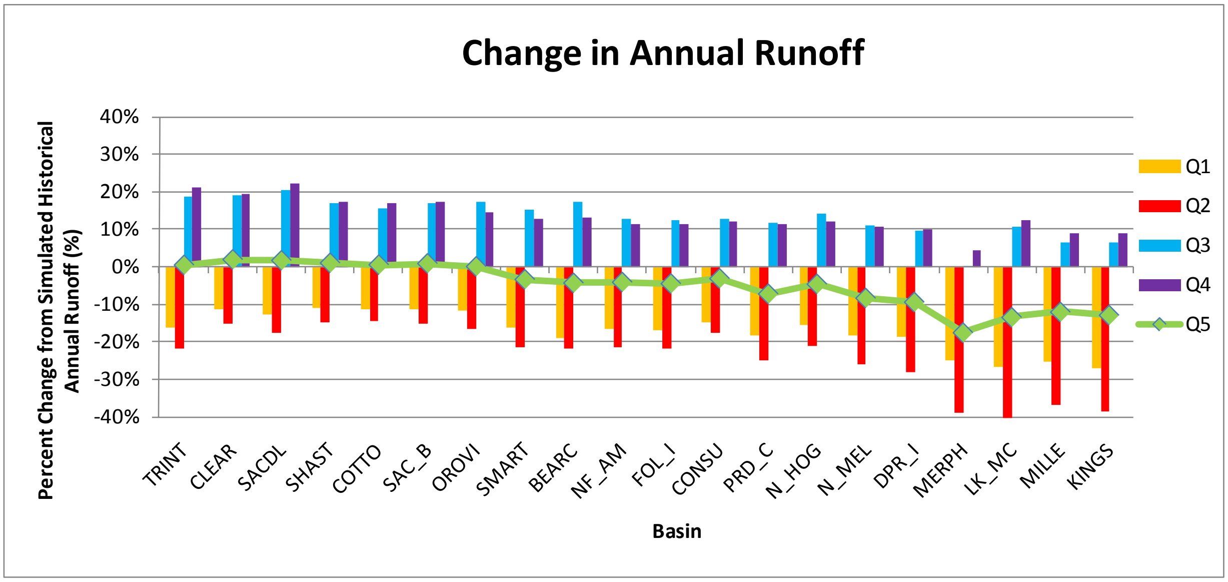
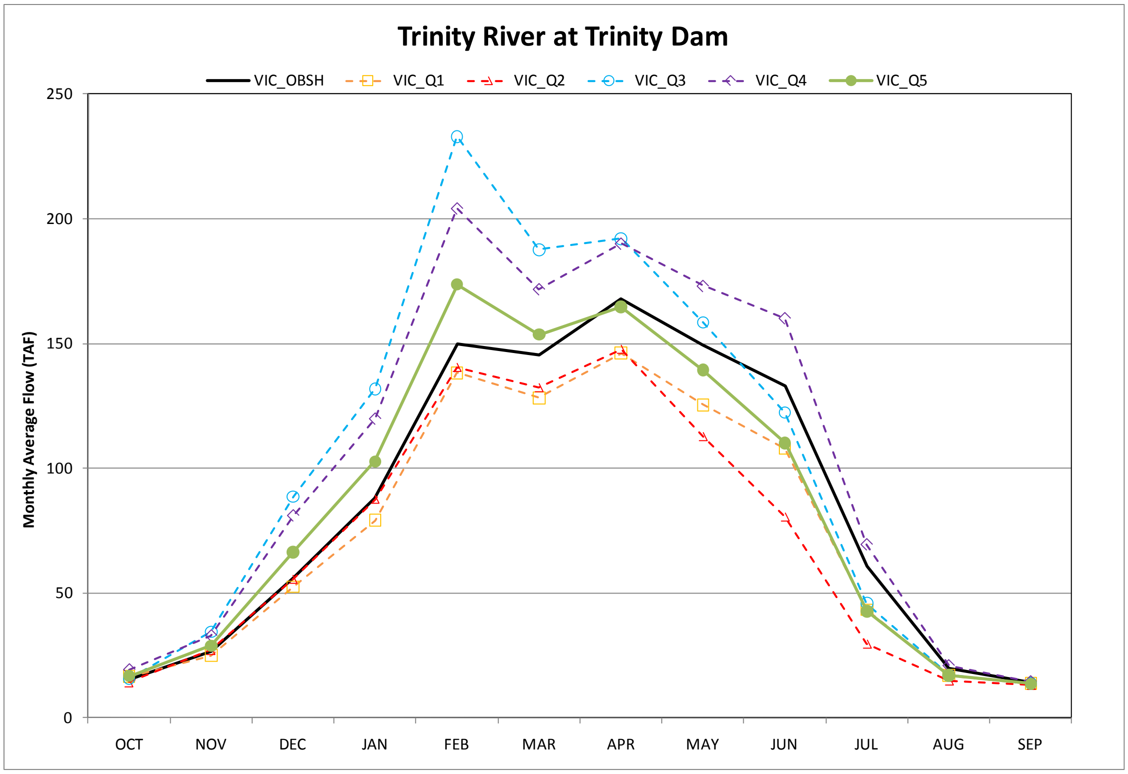


Figure 5.A.A.2-5. Simulated Changes in Natural Streamflow for Each of the VIC Simulations (top, 2025 changes; bottom, 2060 changes).



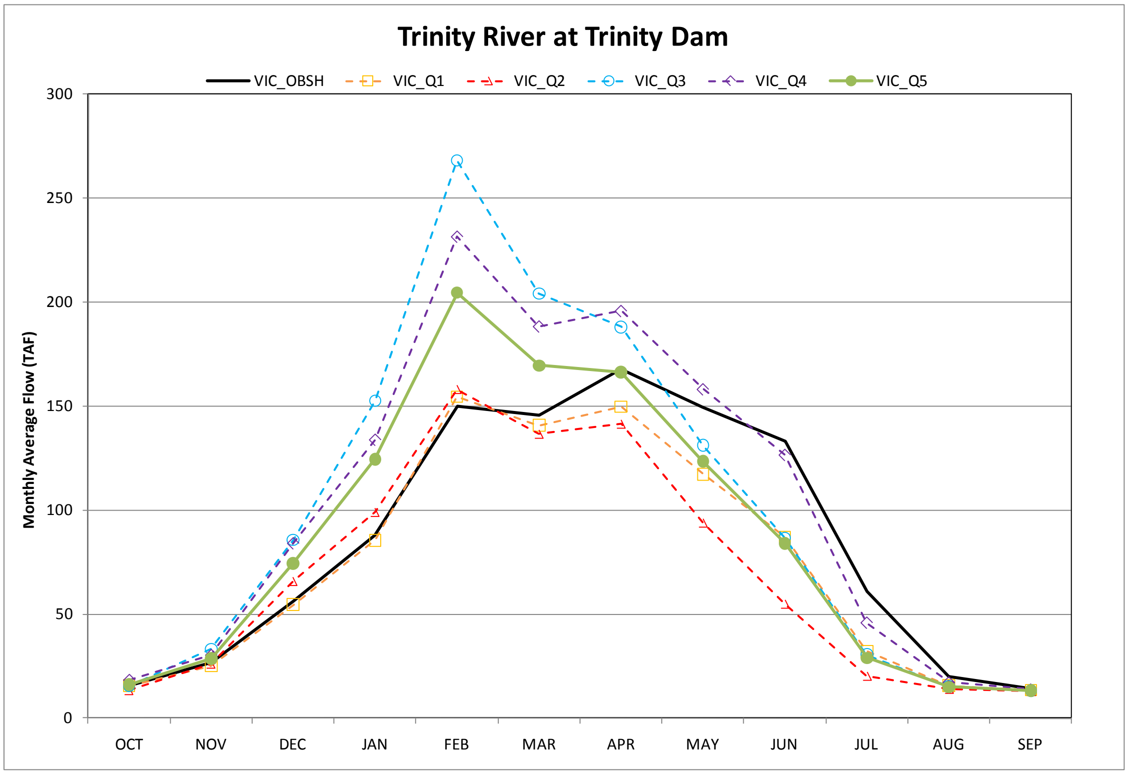
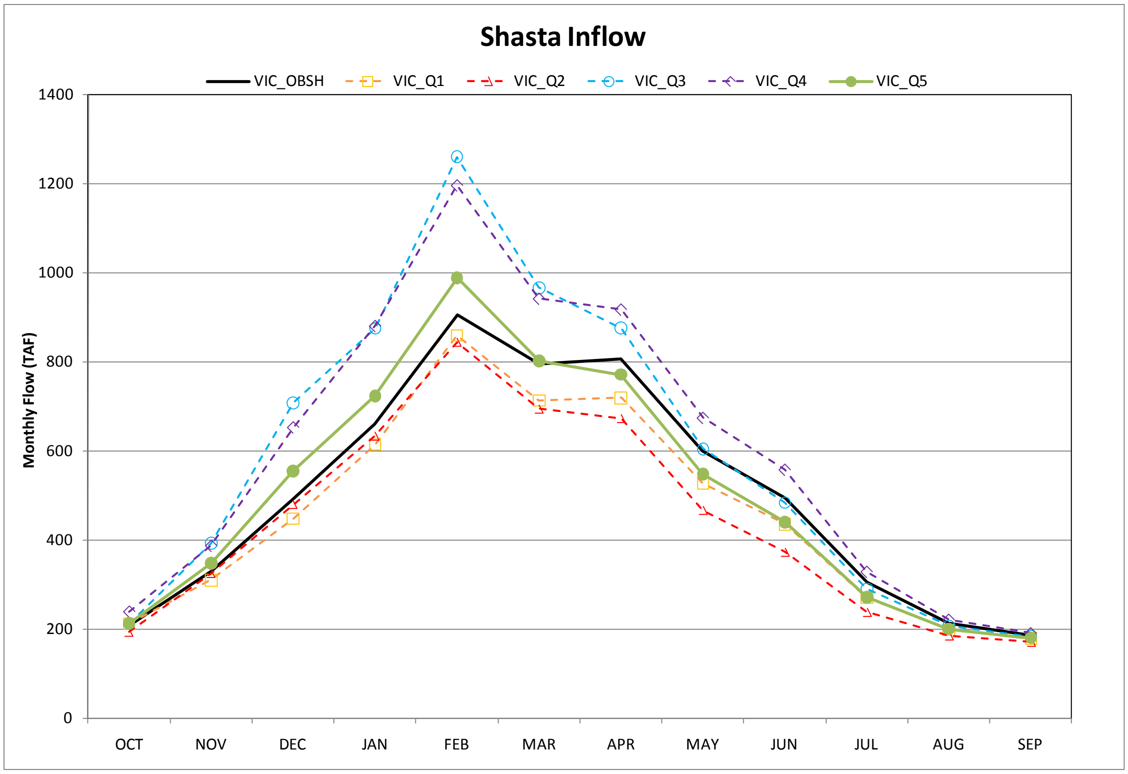


Figure 5.A.A.2-6. Simulated Changes in Monthly Natural Streamflow for Trinity River at Trinity Dam (top, 2025 changes; bottom, 2060 changes).



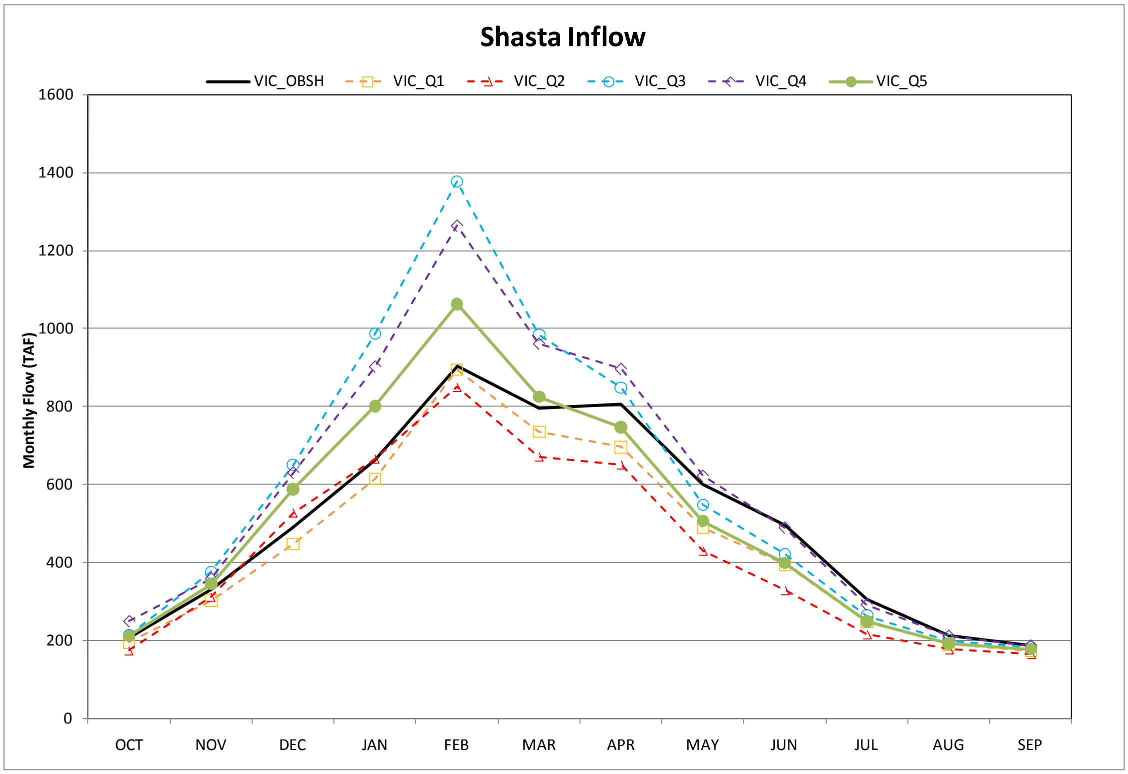
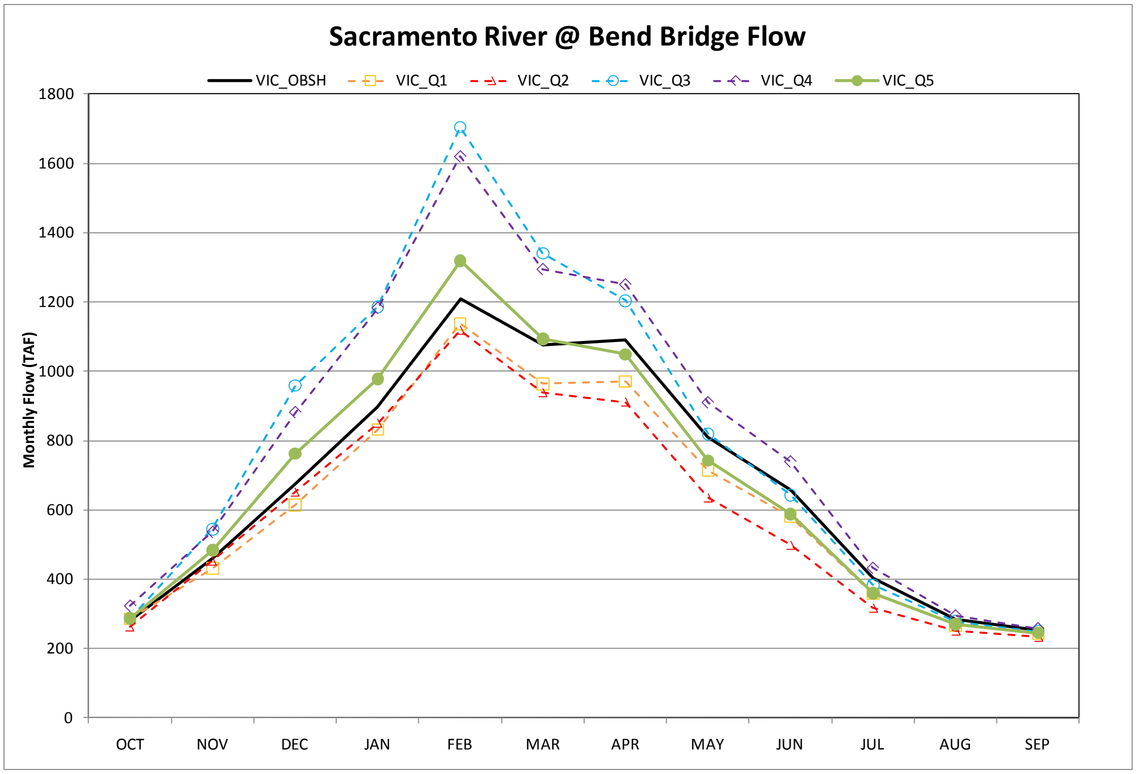


Figure 5.A.A.2-7. Simulated Changes in Monthly Natural Streamflow for Shasta Inflow (top, 2025 changes; bottom, 2060 changes).



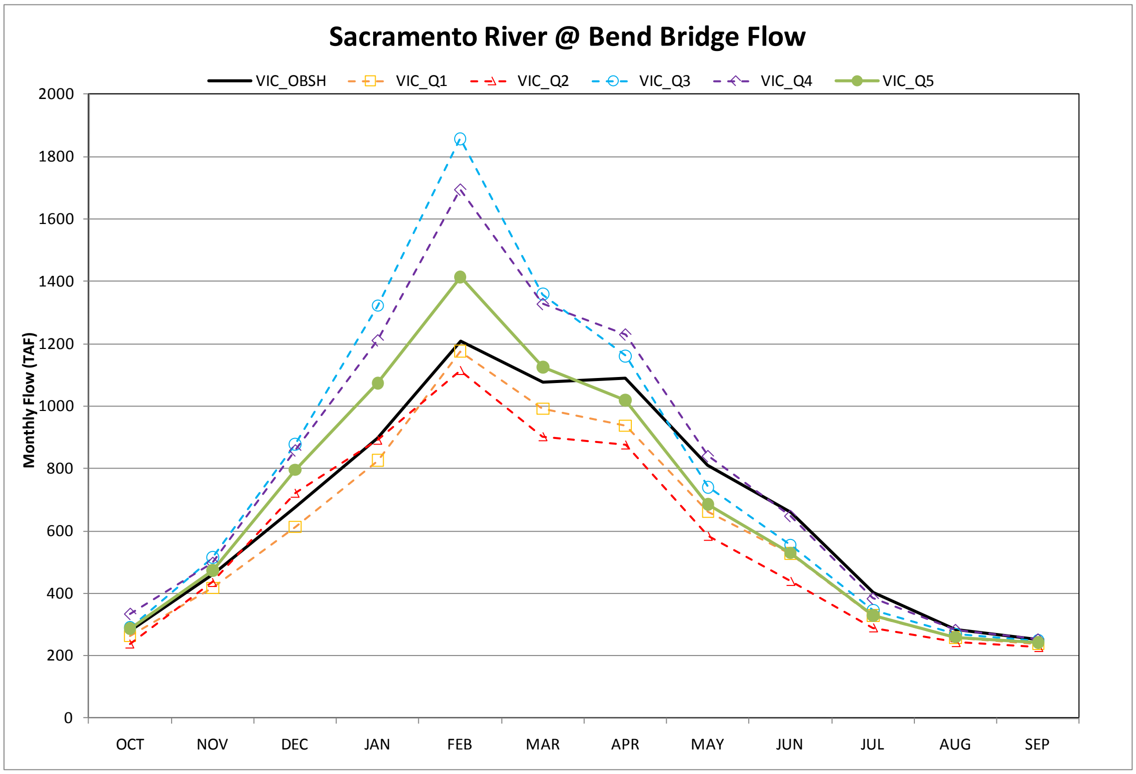
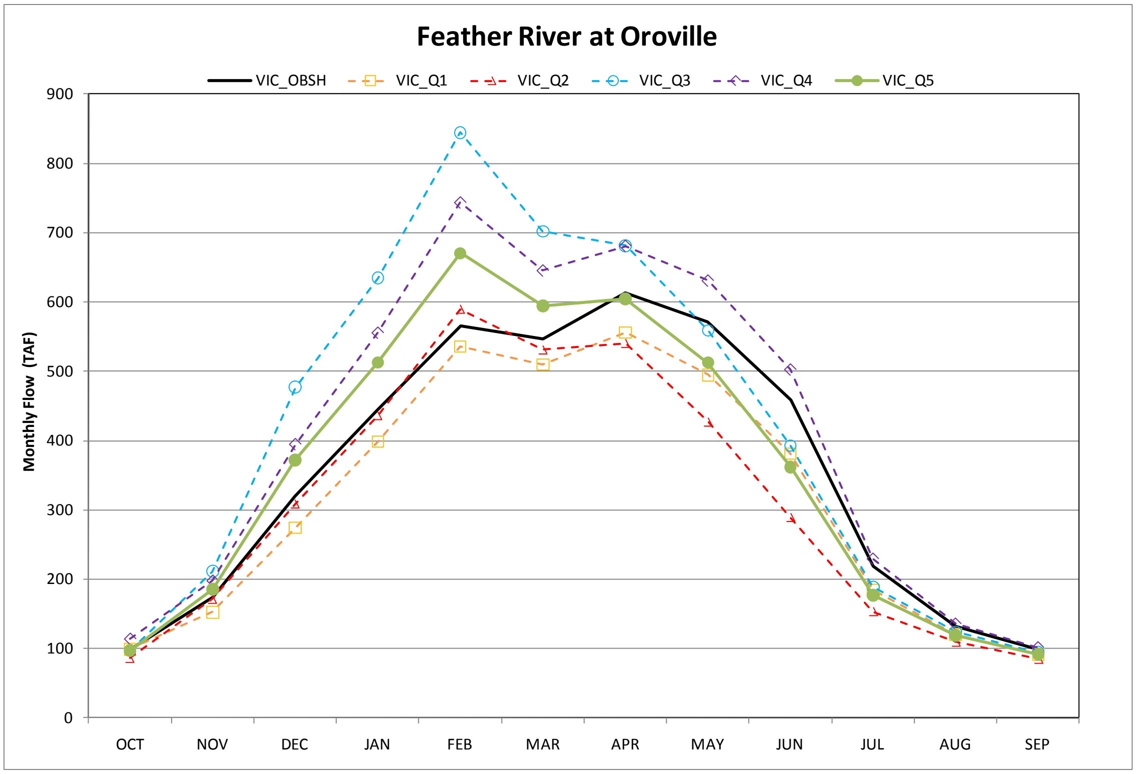


Figure 5.A.A.2-8. Simulated Changes in Monthly Natural Streamflow for Sacramento River at Bend Bridge (top, 2025 changes; bottom, 2060 changes).



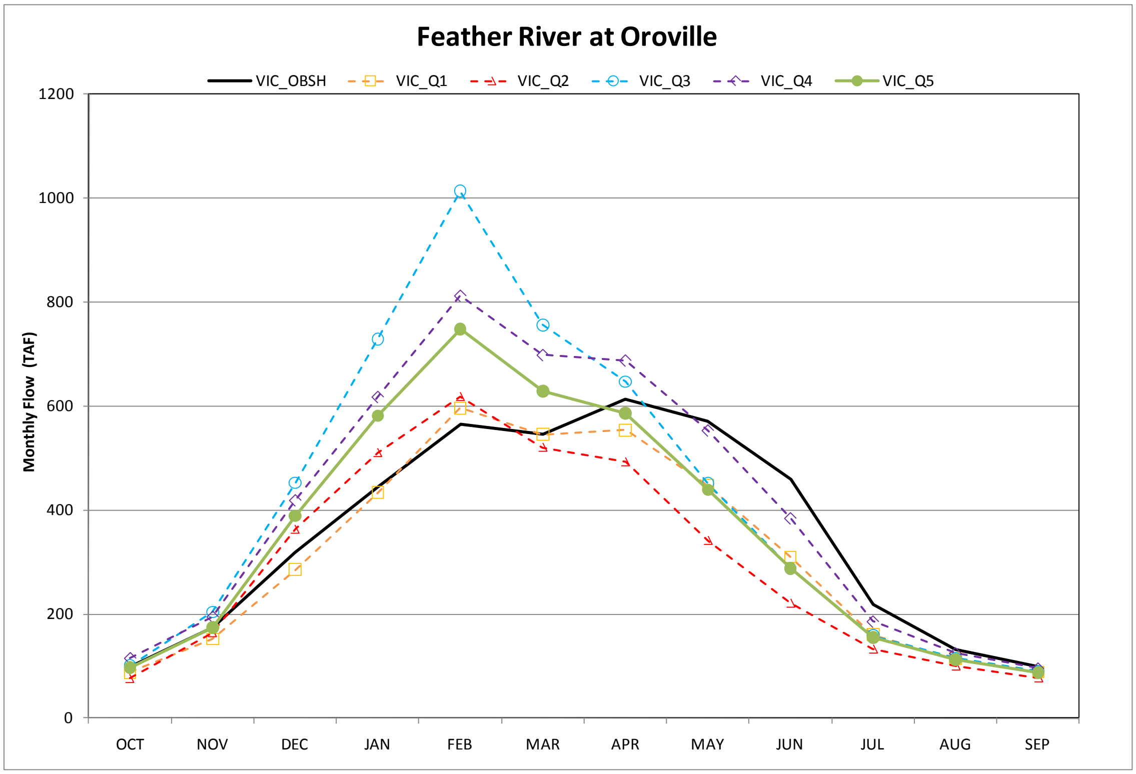
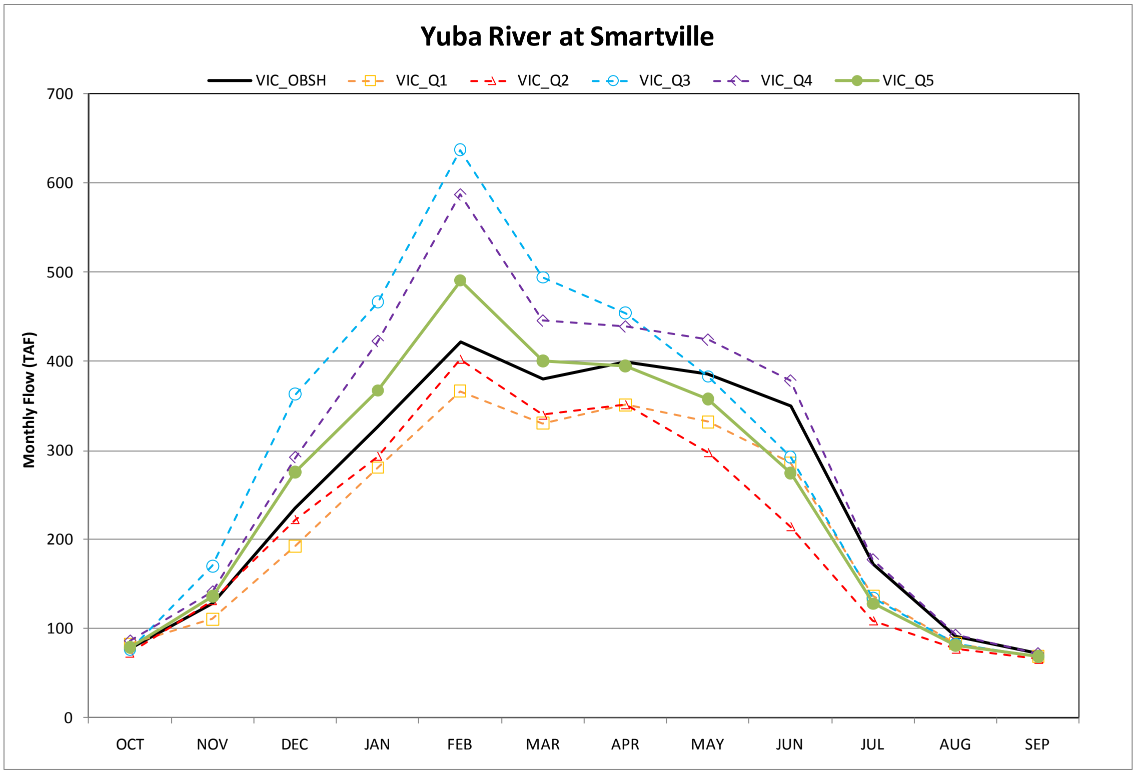


Figure 5.A.A.2-9. Simulated Changes in Monthly Natural Streamflow for Feather River at Oroville (top, 2025 changes; bottom, 2060 changes).



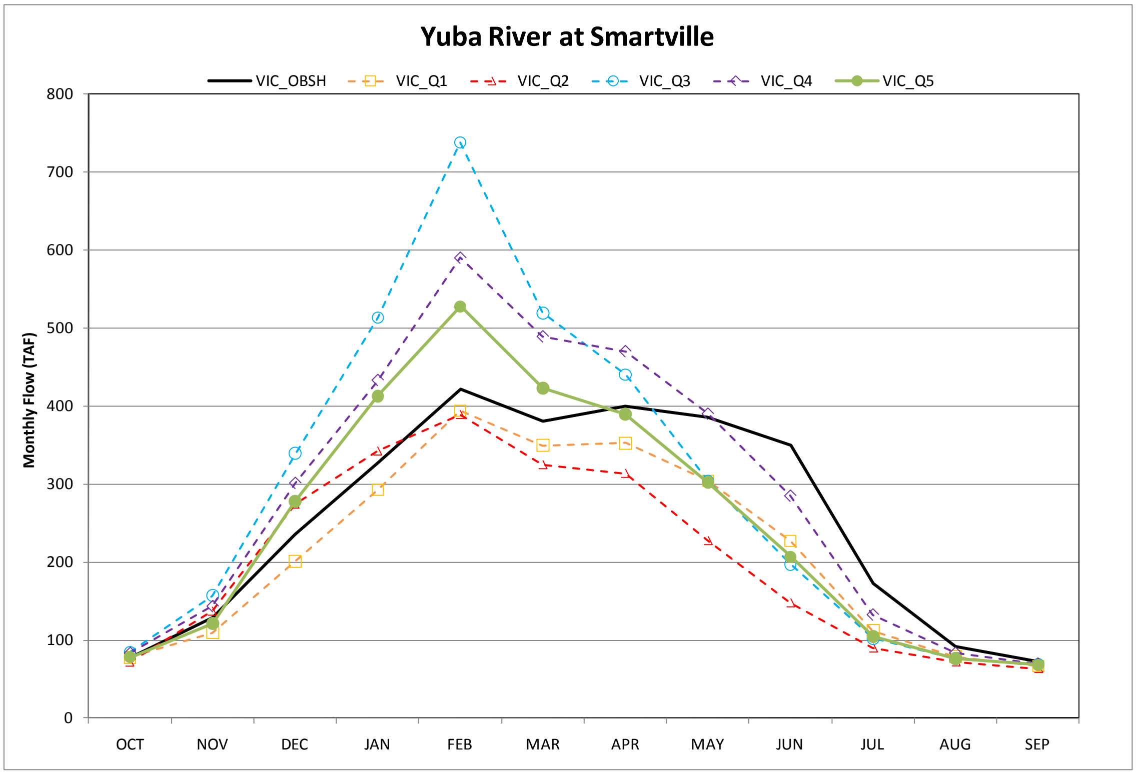
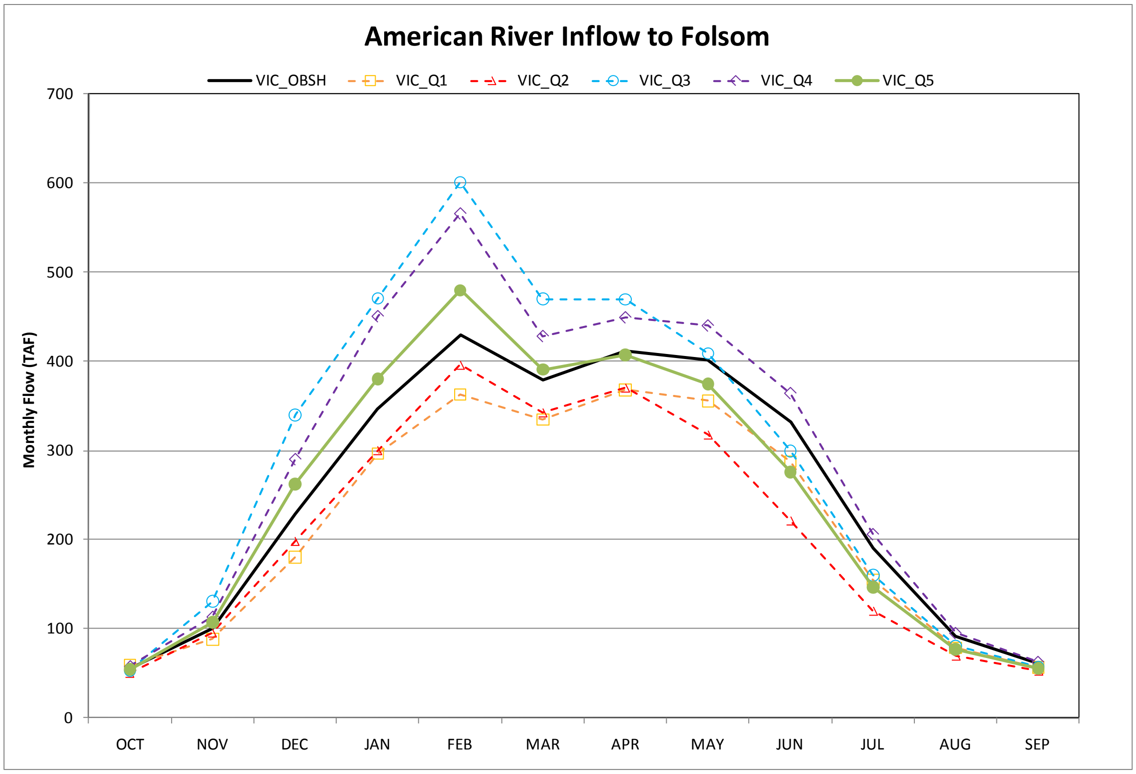


Figure 5.A.A.2-10. Simulated Changes in Monthly Natural Streamflow for Yuba River at Smartville (top, 2025 changes; bottom, 2060 changes).



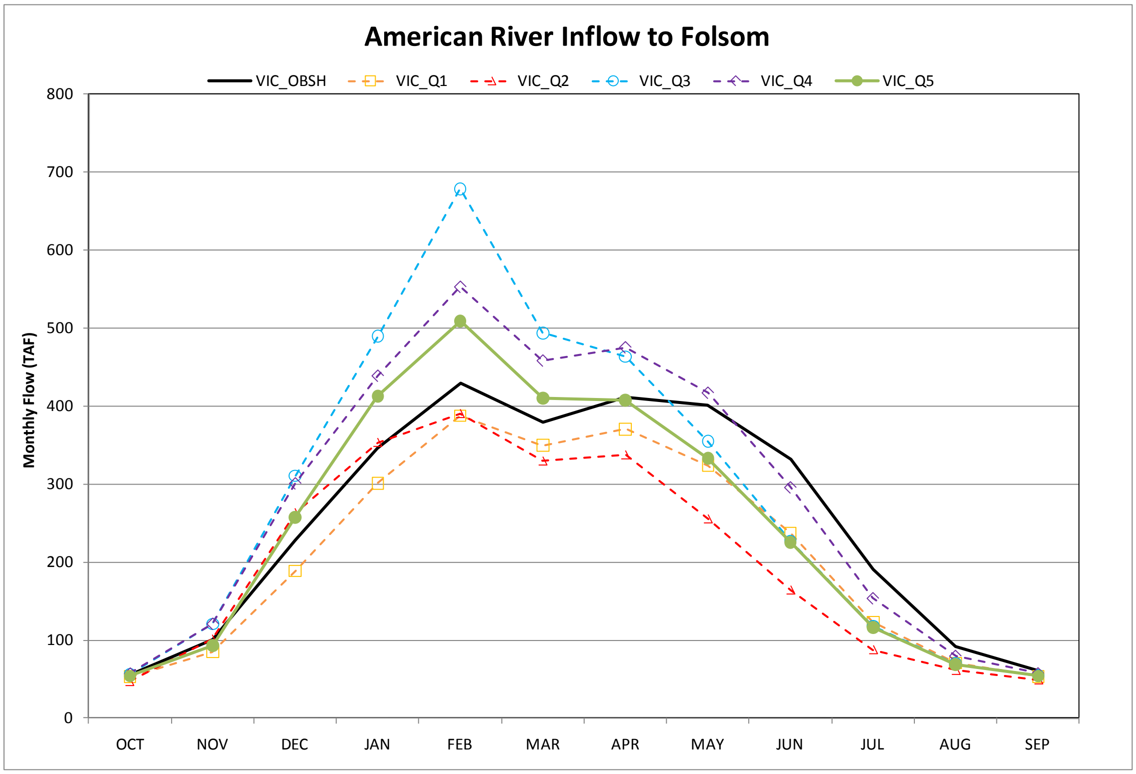
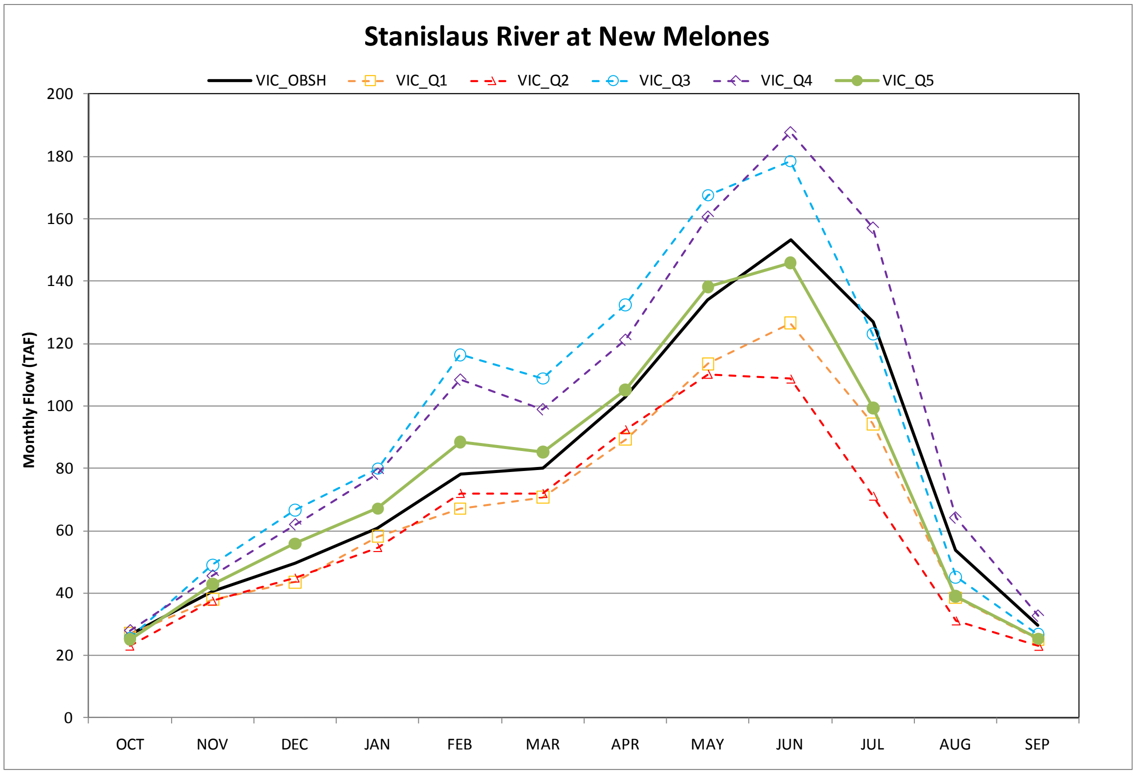


Figure 5.A.A.2-11. Simulated Changes in Monthly Natural Streamflow for American River Inflow to Folsom (top, 2025 changes; bottom, 2060 changes).



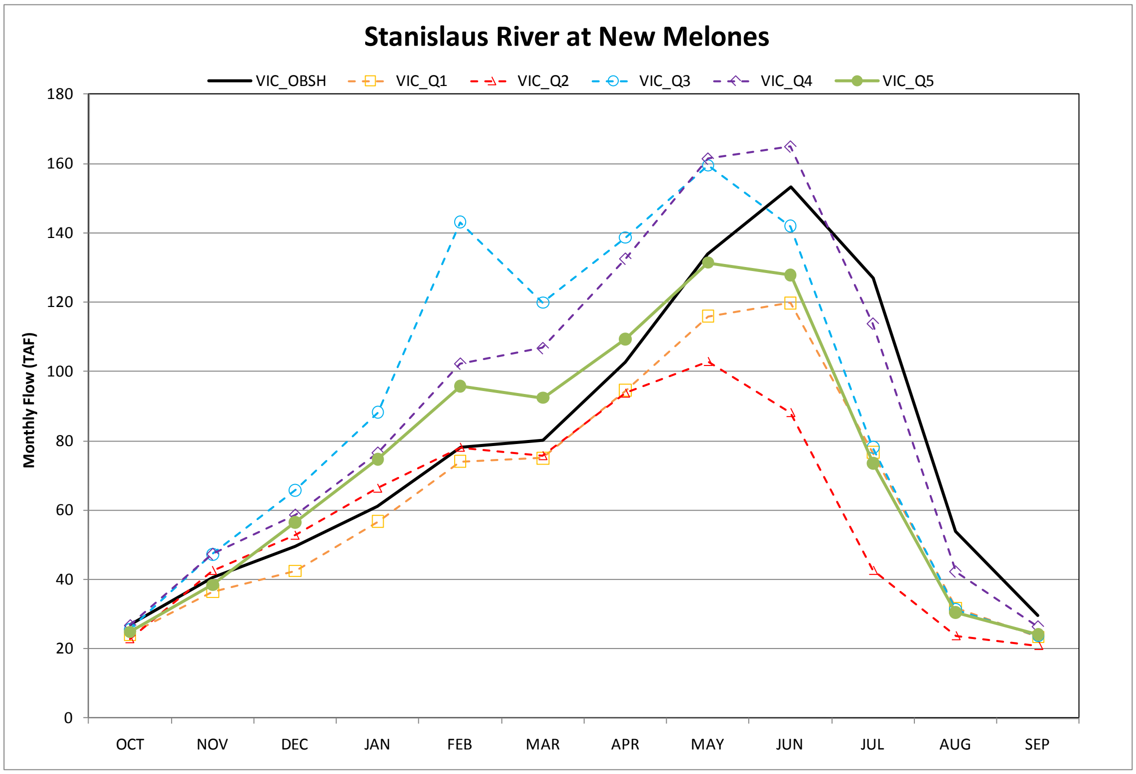
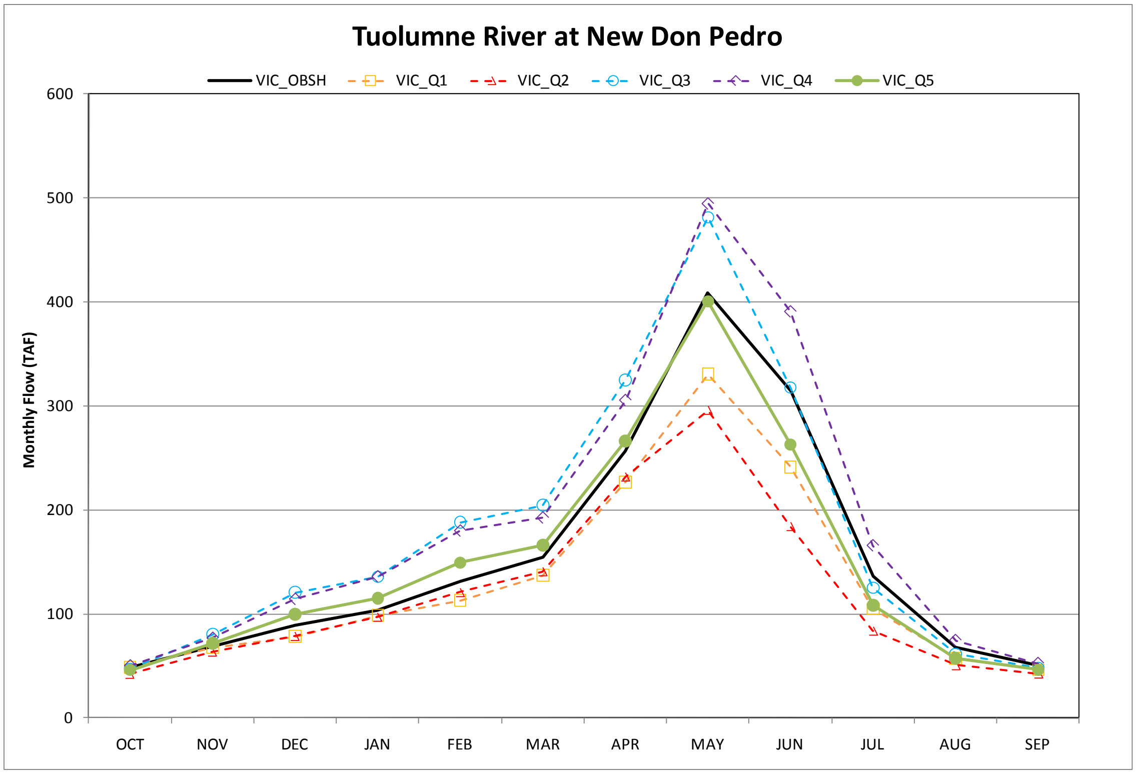


Figure 5.A.A.2-12. Simulated Changes in Monthly Natural Streamflow for Stanislaus River at New Melones (top, 2025 changes; bottom, 2060 changes).



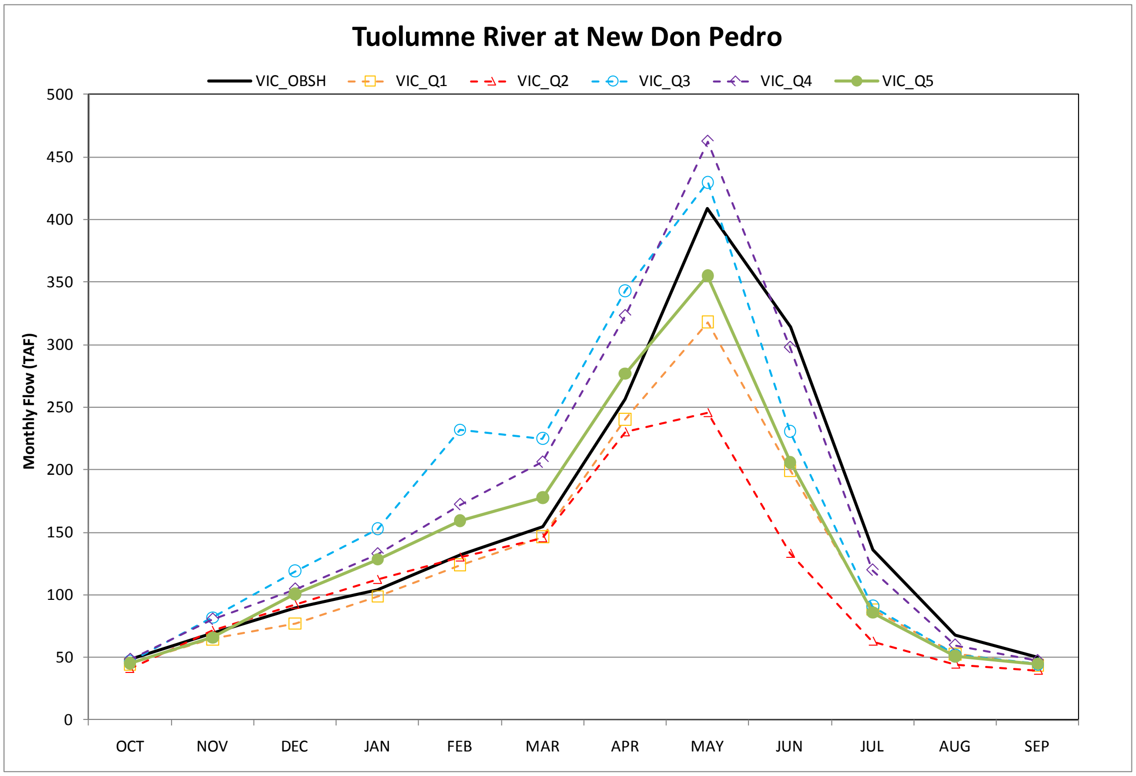
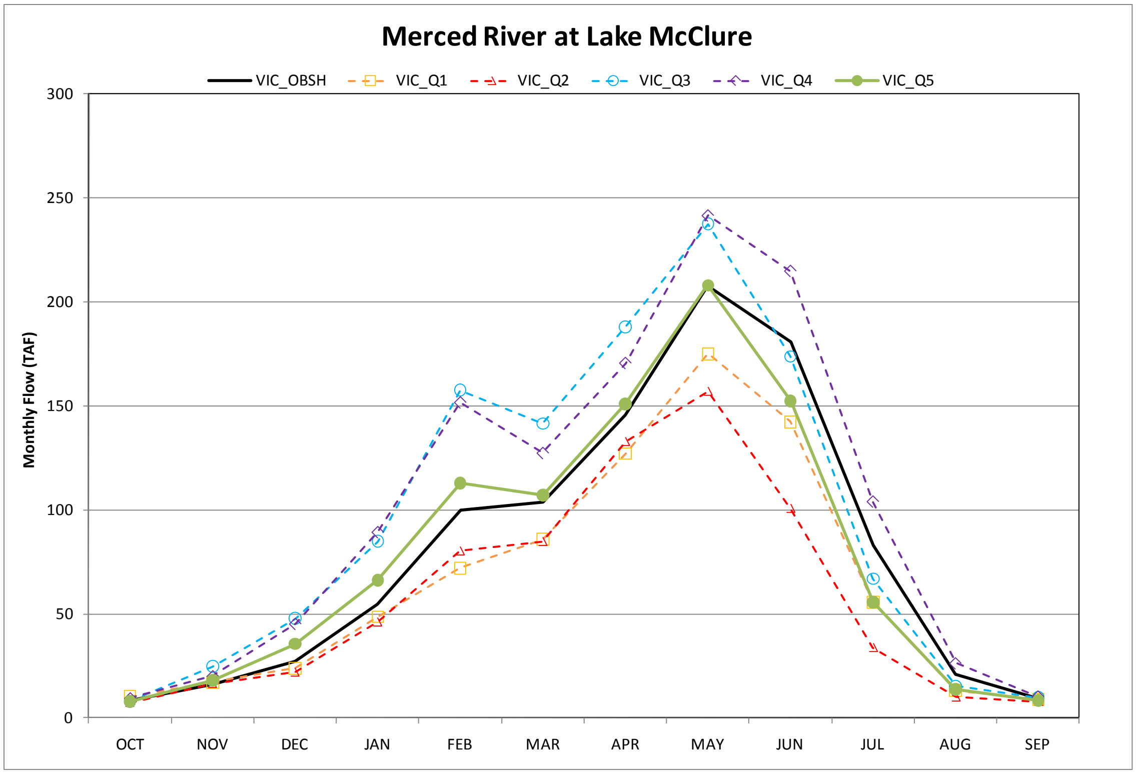


Figure 5.A.A.2-13. Simulated Changes in Monthly Natural Streamflow for Tuolumne River at New Don Pedro (top, 2025 changes; bottom, 2060 changes).



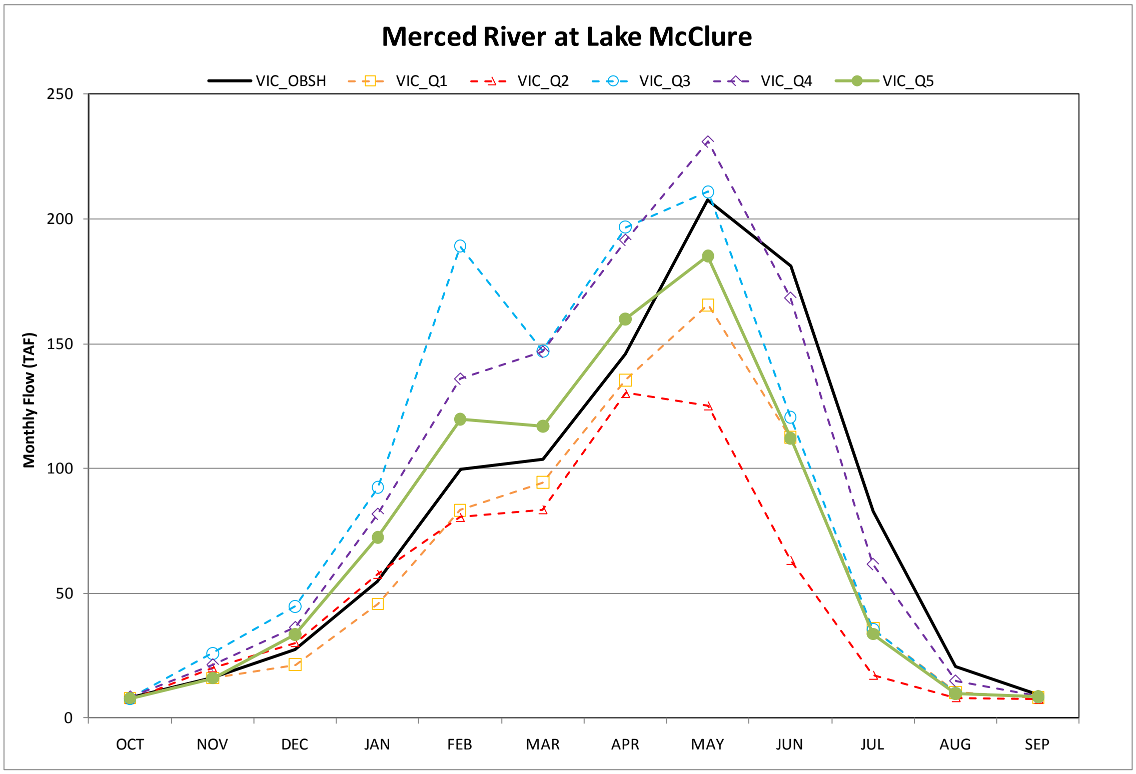
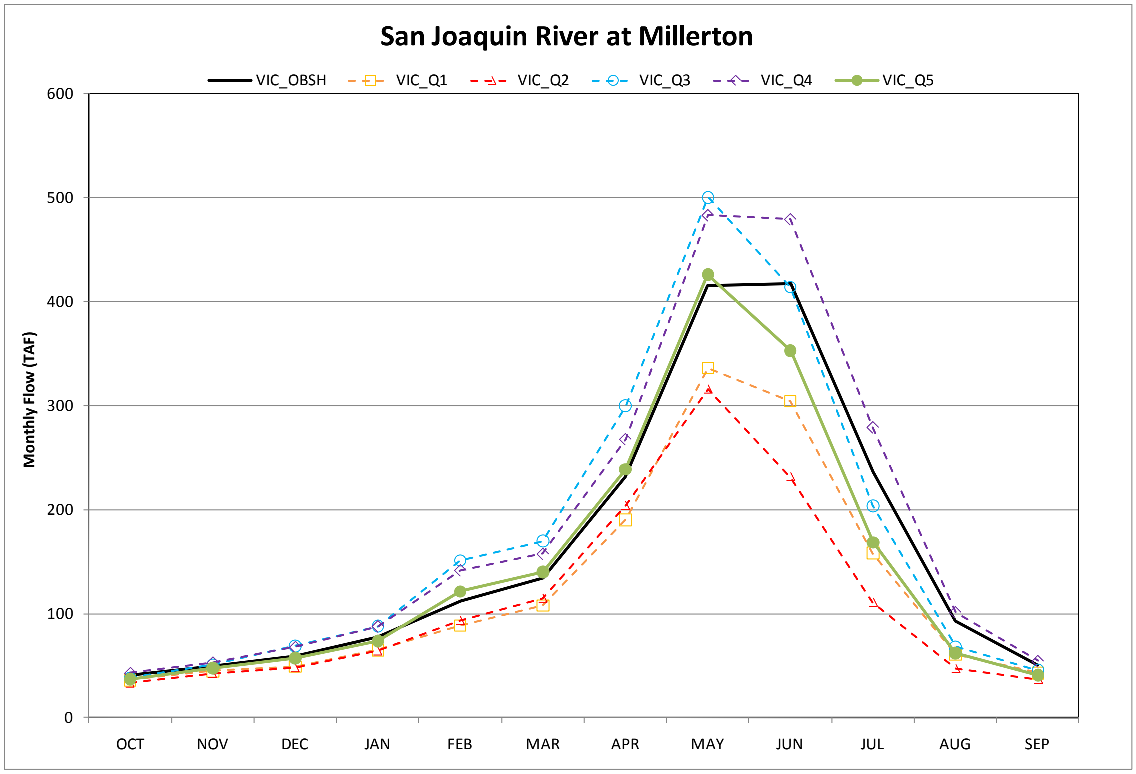


Figure 5.A.A.2-14. Simulated Changes in Monthly Natural Streamflow for Merced River at Lake McClure (top, 2025 changes; bottom, 2060 changes).



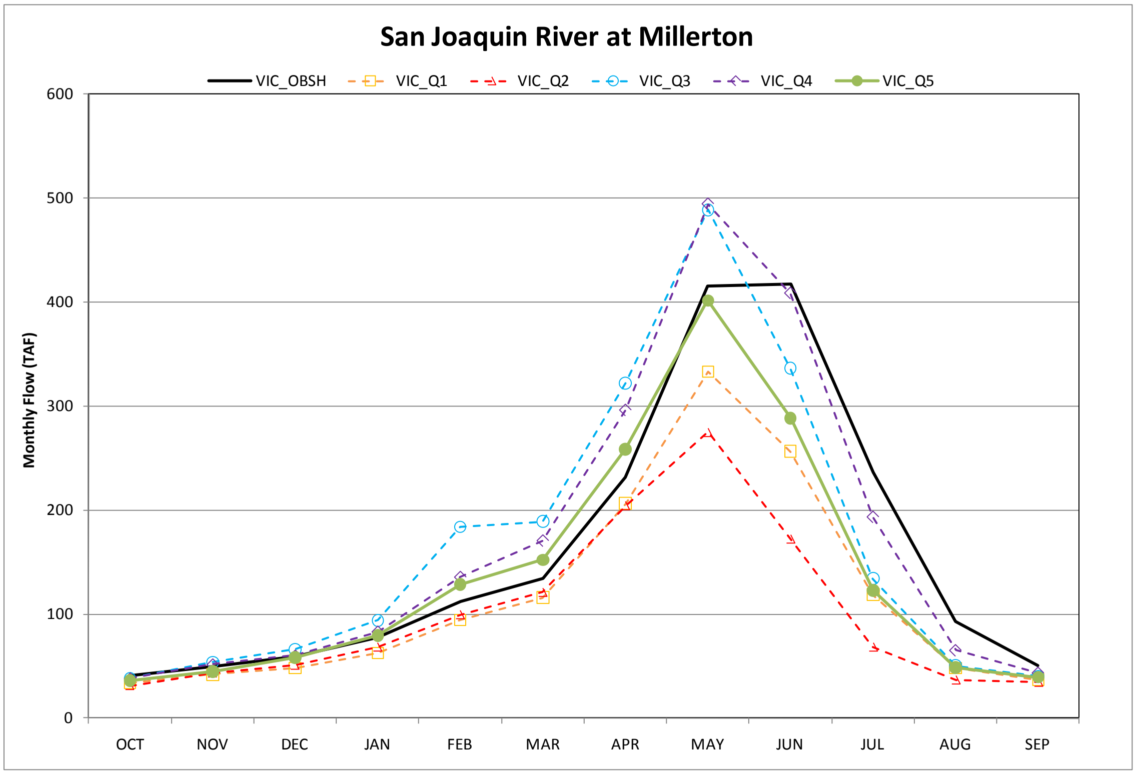


Figure 5.A.A.2-15. Simulated Changes in Monthly Natural Streamflow for San Joaquin River at Millerton (top, 2025 changes; bottom, 2060 changes).

5.A.A.3 Attachment 3: Operations Sensitivity to Climate Change Projections

This attachment summarizes the key findings from a sensitivity analysis performed to analyze operational changes considering various climate change projections under California WaterFix Biological Assessment (CWF BA) No Action Alternative (NAA) and the Proposed Action (PA) scenarios. The NAA and the PA were simulated using CalSim II under the current climate (Q0), Q5 (central tendency), Q2 (drier and more warming) and Q4 (wetter and less warming) climate change projections. The operations results from these simulations were analyzed to understand the range of uncertainty in the incremental changes between the PA and the NAA. This section summarizes key CalSim II results for the NAA and the PA under the four climate scenarios.

5.A.A.3.1.1 Study Objectives

The CalSim II model was applied to evaluate the sensitivity of the CWF BA PA to the range of future climate conditions listed above. The discussion in this section summarizes changes in the projected hydrology and system operations associated with the CWF PA at year 2030 relative to the NAA assumptions, under various climate scenarios. The CalSim II model was used for quantifying the changes in reservoir storage, river flows, delta channel flows, exports, water deliveries, and Yolo Bypass spills under conditions reflecting the operating and physical assumptions of the PA. Results from this analysis for key parameters are shown in Figures 5.A.A.3-1 through 5.A.A.3-21.

5.A.A.3.1.2 Climate Sensitivity Analyses

The NAA and the PA simulations described in the CWF BA included the projected effects under the central climate change scenario (Q5). This Q5 scenario represents the ensemble-based change from the 20 to 30 climate projections that most closely reflect the ensemble median of change in annual temperature and precipitation. Four other climate scenarios, labeled as Q1, Q2, Q3, and Q4, have also been developed as described in Appendix 5A Attachment 1. For this sensitivity analysis, PA and NAA models were generated using the modified hydrologic inputs based on the projected runoff changes under Q2 (drier and more warmer) and Q4 (wetter and less warmer) climate scenarios at Year 2030, and compared to a model run that used the hydrology under the historical climate conditions (Q0). The purpose of conducting these simulations is to help describe the sensitivity in projected CVP/SWP system operations with respect to climate uncertainty. The Q2 and Q4 simulations with projected climate changes at 2030, included the 15cm sea level rise effect, similar to the Q5 scenarios. The scenario with historical climate (Q0), did not include any sea level rise. The CalSim II simulations in this sensitivity analysis only differ in the hydrology inputs depending on the climate scenario considered and/or sea level rise effect. None of the other system parameters have been changed.

Figures 5.A.A.3-1 through 5.A.A.3-21 show the system responses for historical climate or Q0 (black lines), Q5 climate scenario (blue lines), and Q2 (green lines) and Q4 (red lines) climate scenarios. Each plot includes results from the CalSim II simulations for the NAA and the PA under the above climate scenarios. Several key observations can be made based on these simulations:

- CVP reservoir storage is very sensitive to the assumption that precipitation will remain comparable to present-day expectations. Shasta storage and operations are very sensitive to climate change assumptions and results are dependent on the climate scenario selected; Q2 (drier) scenarios result in critical low storage conditions in Shasta Lake; Shasta storage conditions under the PA are similar to the NAA under all the climate scenarios. Storage changes in Trinity Lake and Folsom Lake are similar to the changes in Shasta Lake.

- Dual conveyance appears to offer some mitigation for impacts predicted from climate change. Oroville operations are relatively less sensitive to climate scenarios than CVP reservoirs, although the increased flexibility of operations under the PA appear to respond more favorably in terms of carryover storage than the comparable NAA under climate change.

- Predicted river flows are very sensitive to the assumption that precipitation will remain comparable to present-day expectations. Substantial reductions in Sacramento River and San Joaquin River inflow to the Delta are observed under the drier climate scenarios; the seasonal shifts in runoff of the main contributing watersheds are attenuated by reservoir operations, especially in the Sacramento River.

- Under all climate scenarios, Delta outflow is lower in the winter months under the PA compared to the NAA. This model prediction reflects a predicted increase in available Delta export capacity with the new north Delta intakes.

- Changes in average springtime X2 position across Q4 (wetter) to Q2 (drier) climate scenarios is approximately 4 to 5 km, reflecting the uncertainty in the runoff estimates. The PA operations are predicted to cause a slightly eastward shift in X2 location in the spring and summer months, and a westward shift in November compared to the NAA under all climate scenarios considered.

- Old and Middle river flows are *not* very sensitive to the assumption that precipitation will remain comparable to present-day expectations. Flows that are constrained due to operational objectives or requirements such as Old and Middle River under the NAA scenarios do not show significant sensitivity to climate change futures; however, under the PA during periods in which the Old and Middle River flows are not significantly governing (e.g. January through March) uncertainty in flow estimates are on the order of 2,000 cfs; Also, the PA is always more positive or less negative than the corresponding NAA, under all the climate scenarios.

- Predicted exports are very sensitive to the assumption that precipitation will remain comparable to present-day expectations. Exports in the months that are significantly constrained under the NAA scenarios are not as sensitive to the selection of climate scenarios, but the sensitivity is increased considerably under the PA. Annual Delta exports under the PA increases compared to the NAA under all the climate scenarios by about 220 TAF/YR to 240 TAF/YR.

Overall the relative changes due to the PA operations as compared to the NAA under the range of climate futures are similar to that described under the Q5 climate scenario. However, the PA results in more flexible operations allowing the projects to export more winter runoff that tends to show greater operational response (increased upstream storage conditions, increased export variability) under the range of climate scenarios. The PA operations generally result in higher upstream storage conditions compared to the corresponding NAA scenarios, but the effects of climate change under the drier climate scenario are more significant than the improvements achieved under the PA.

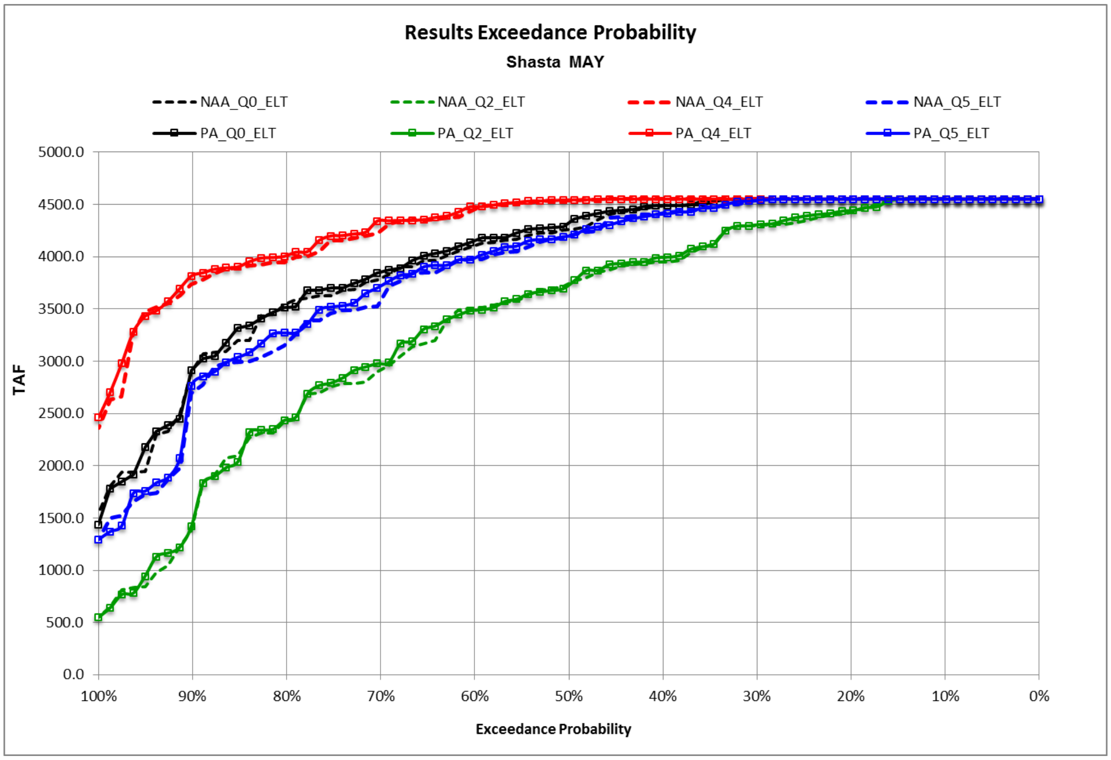


Figure 5.A.A.3-1 Shasta End of May Storage for the NAA and the PA Scenarios under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

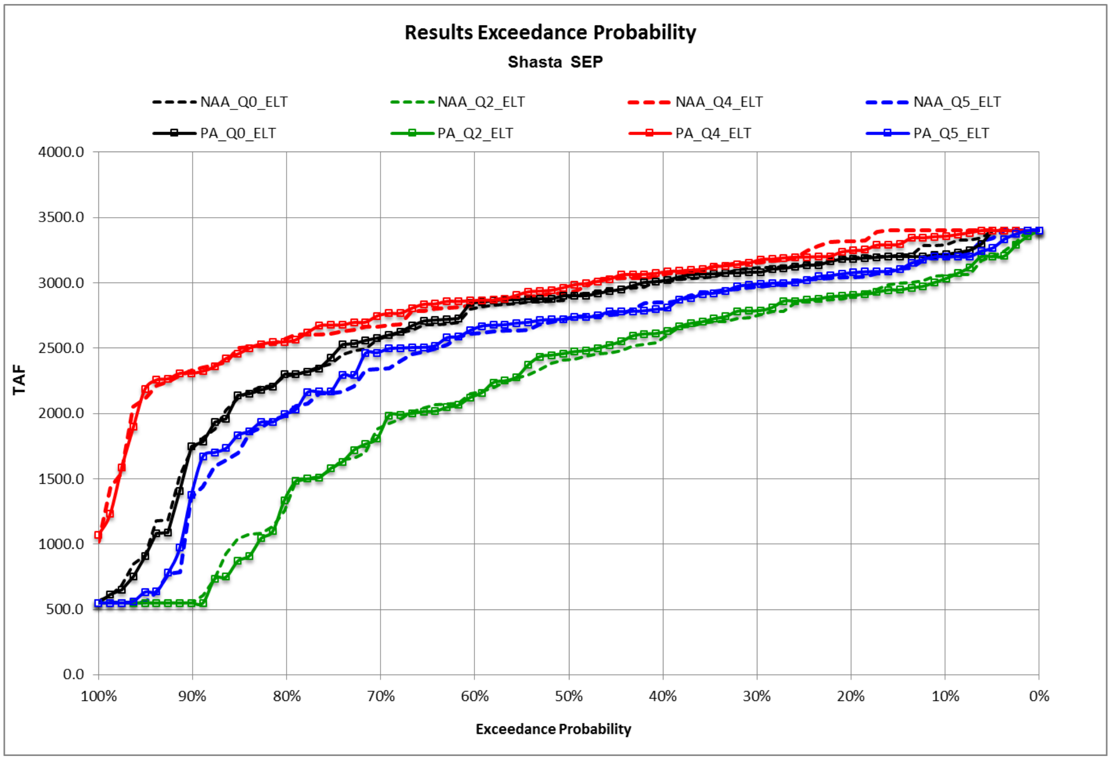


Figure 5.A.A.3-2 Shasta End of September Storage for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

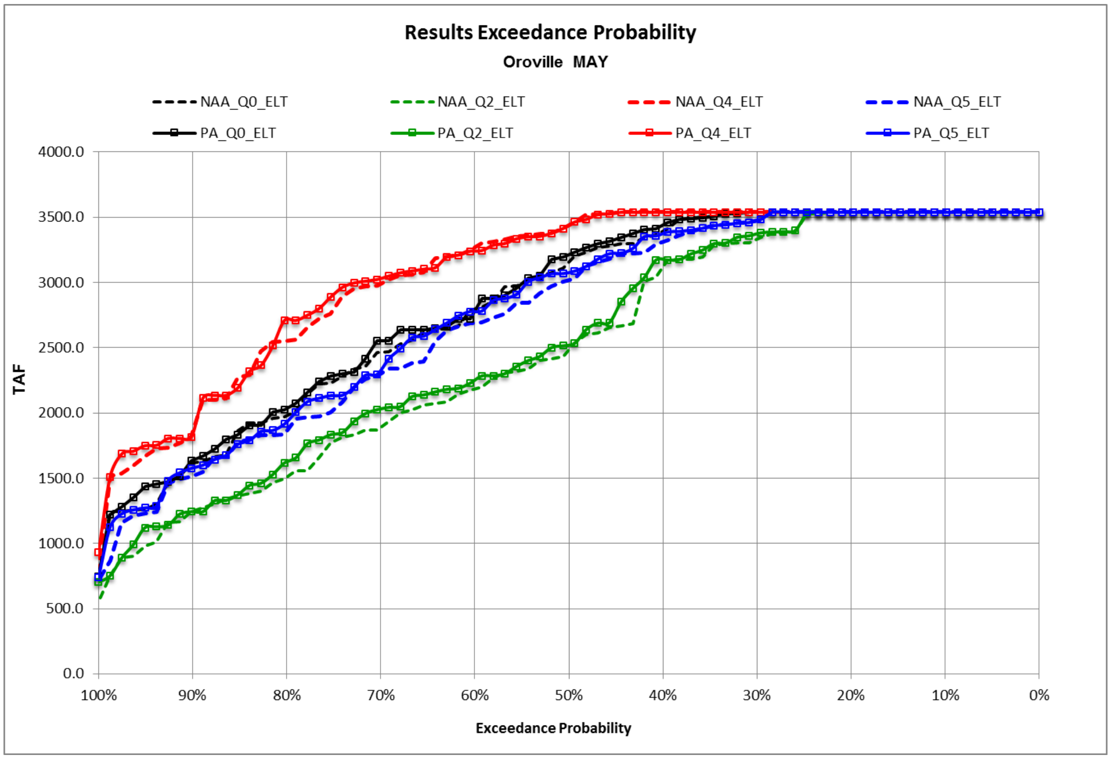


Figure 5.A.A.3-3 Oroville End of May Storage for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

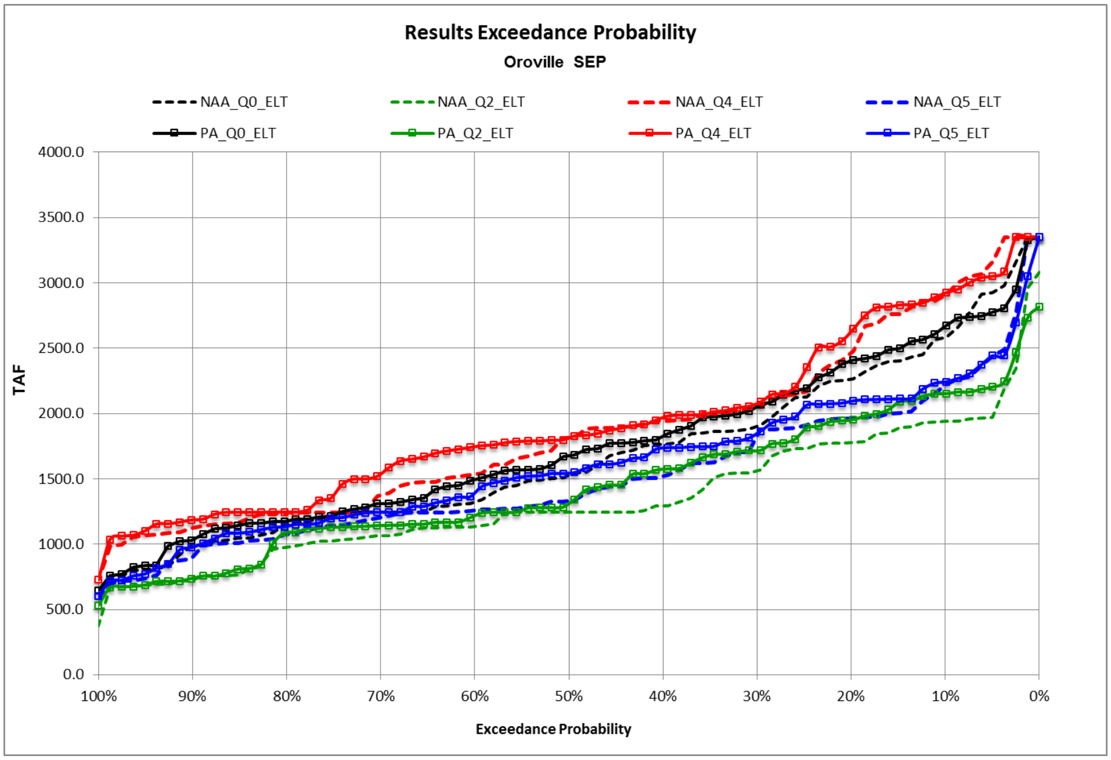


Figure 5.A.A.3-4 Oroville End of September Storage for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

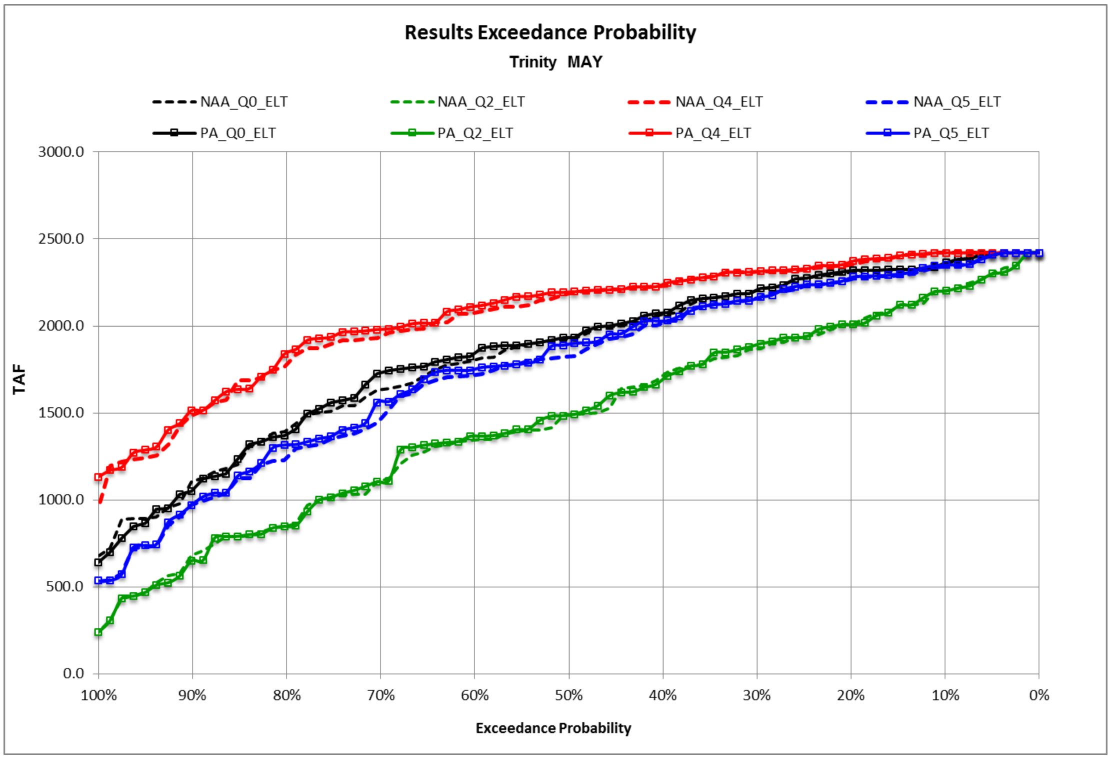


Figure 5.A.A.3-5 Trinity End of May Storage for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

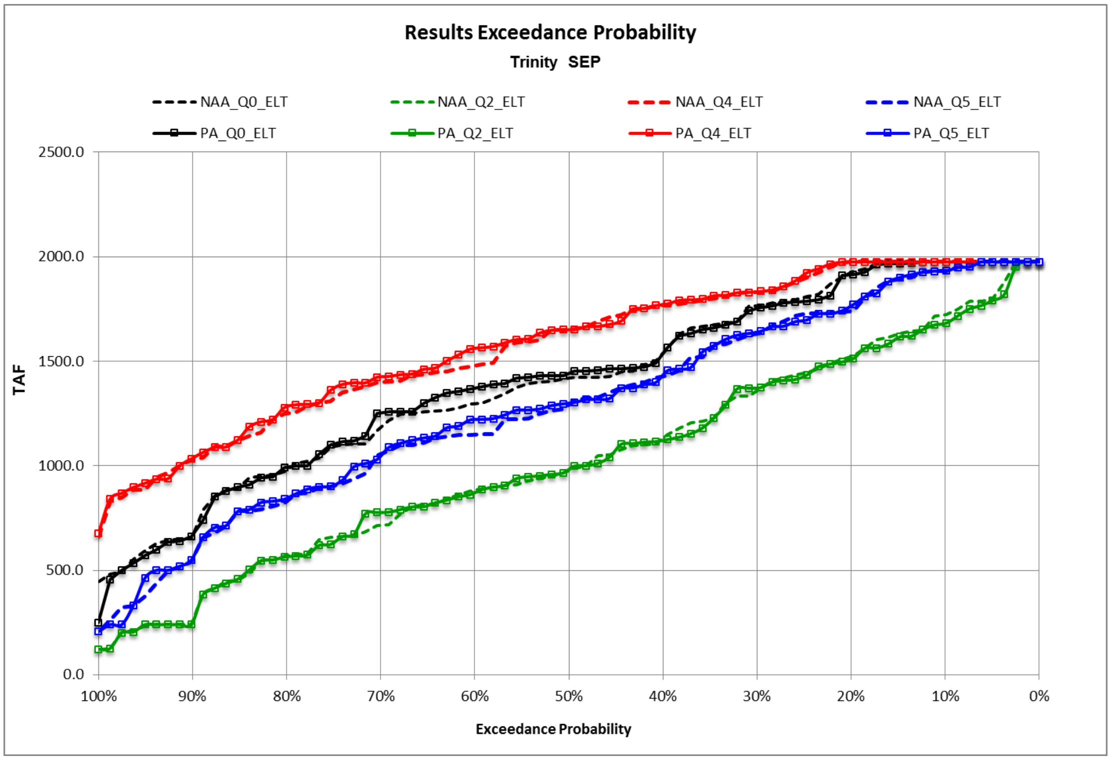


Figure 5.A.A.3-6 Trinity End of September Storage for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

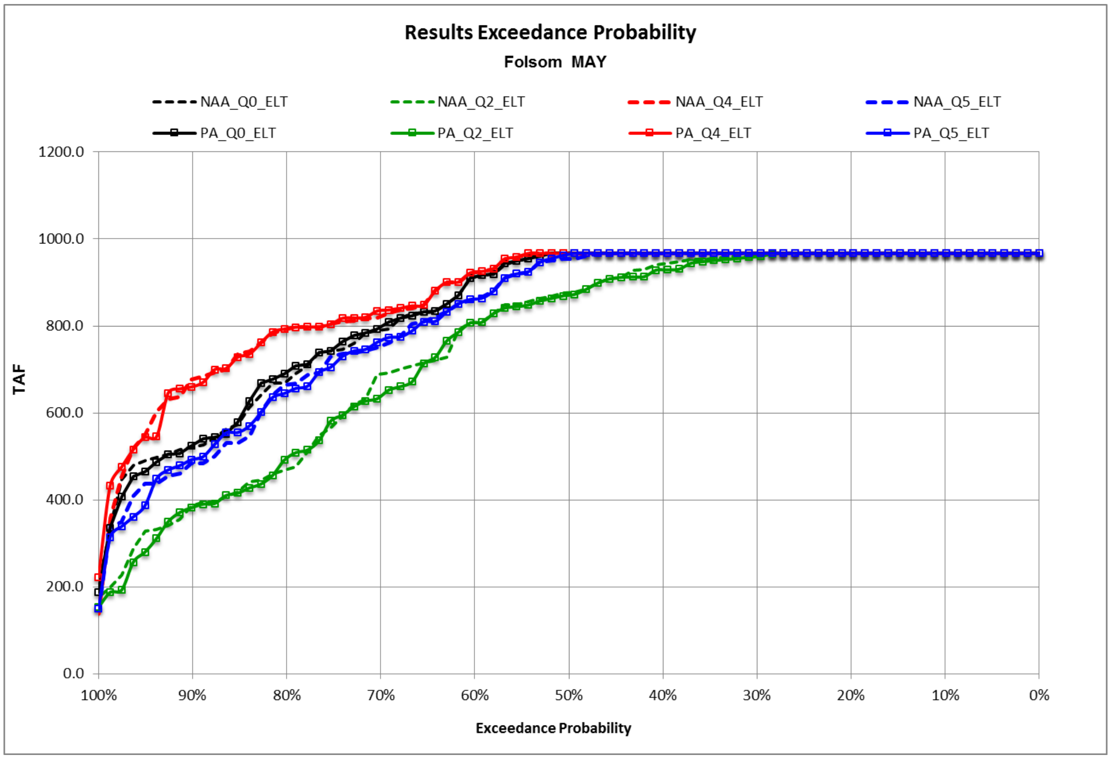


Figure 5.A.A.3-7 Folsom End of May Storage for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

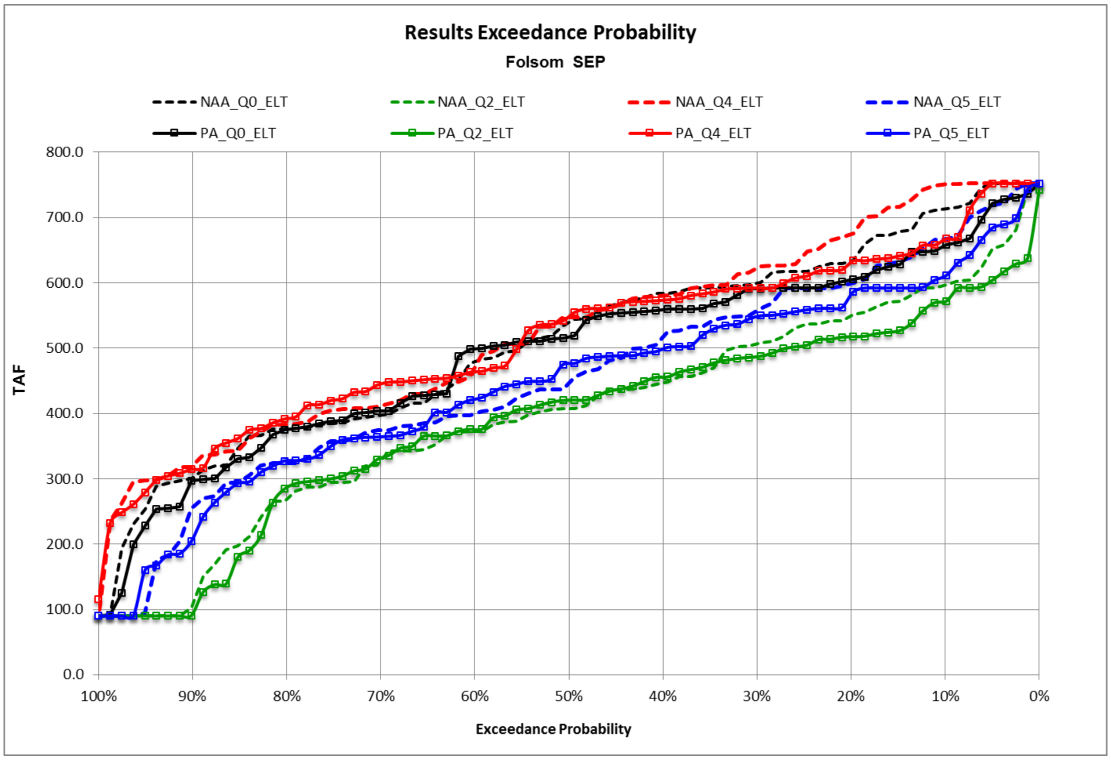


Figure 5.A.A.3-8 Folsom End of September Storage for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

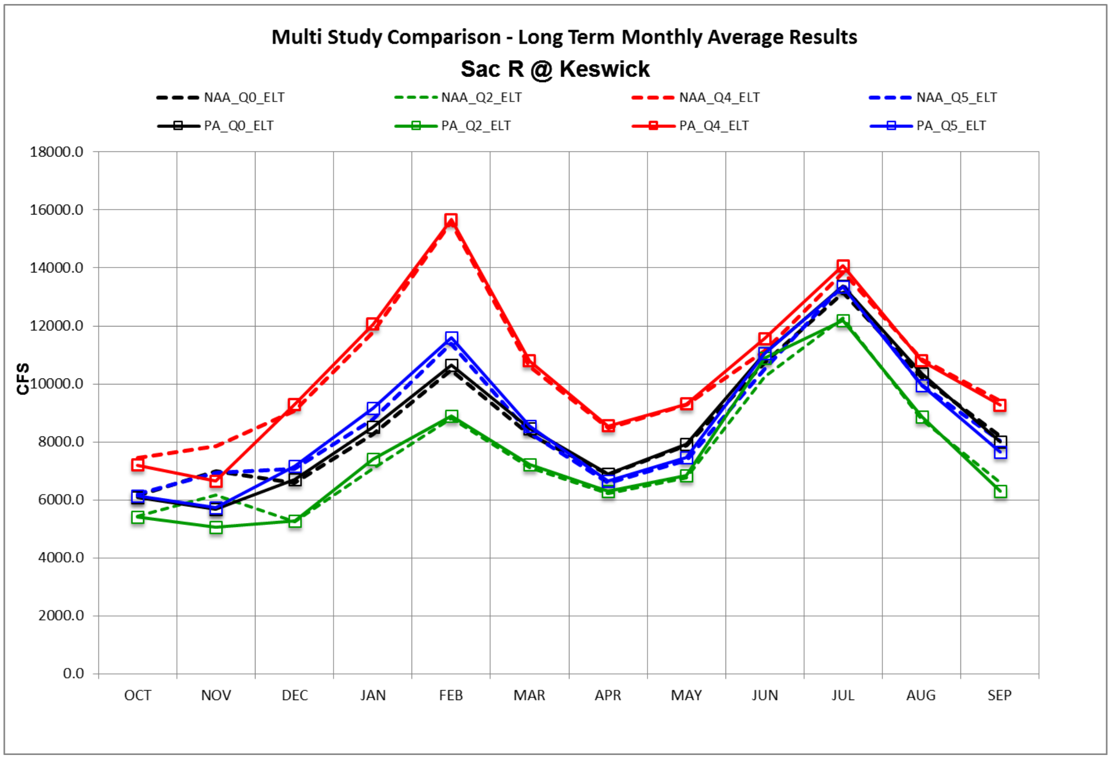


Figure 5.A.A.3-9 Sacramento River at Keswick Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

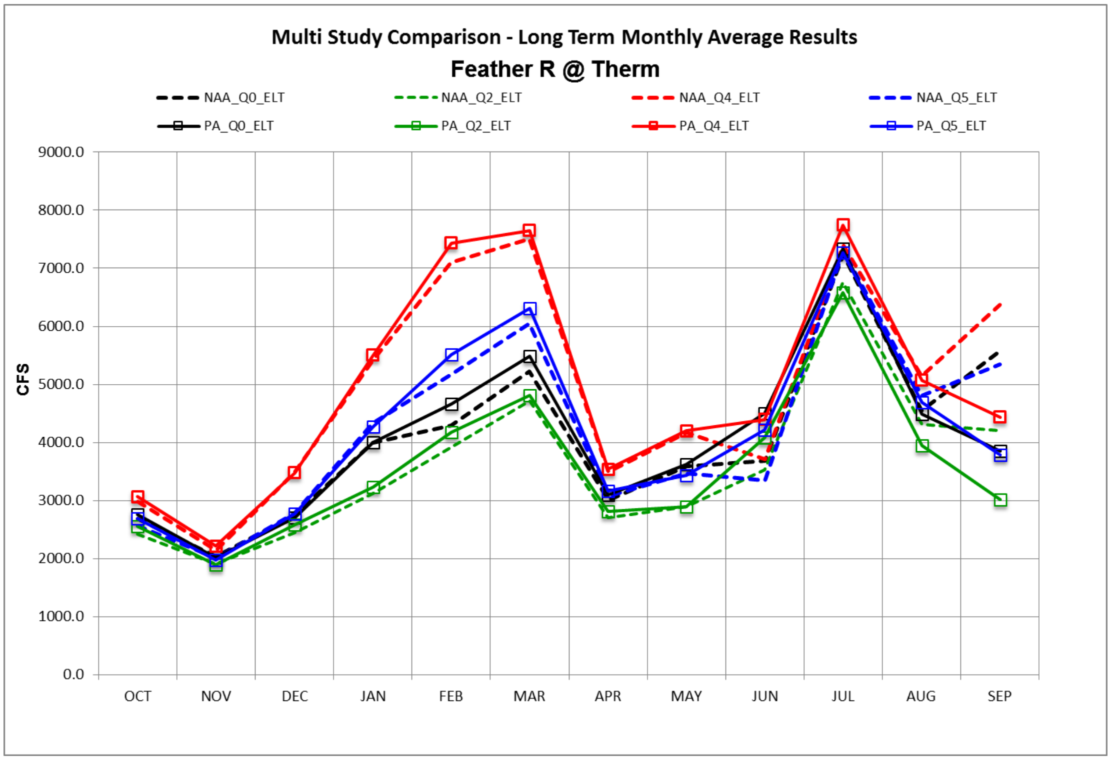


Figure 5.A.A.3-10 Feather River at Thermalito Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

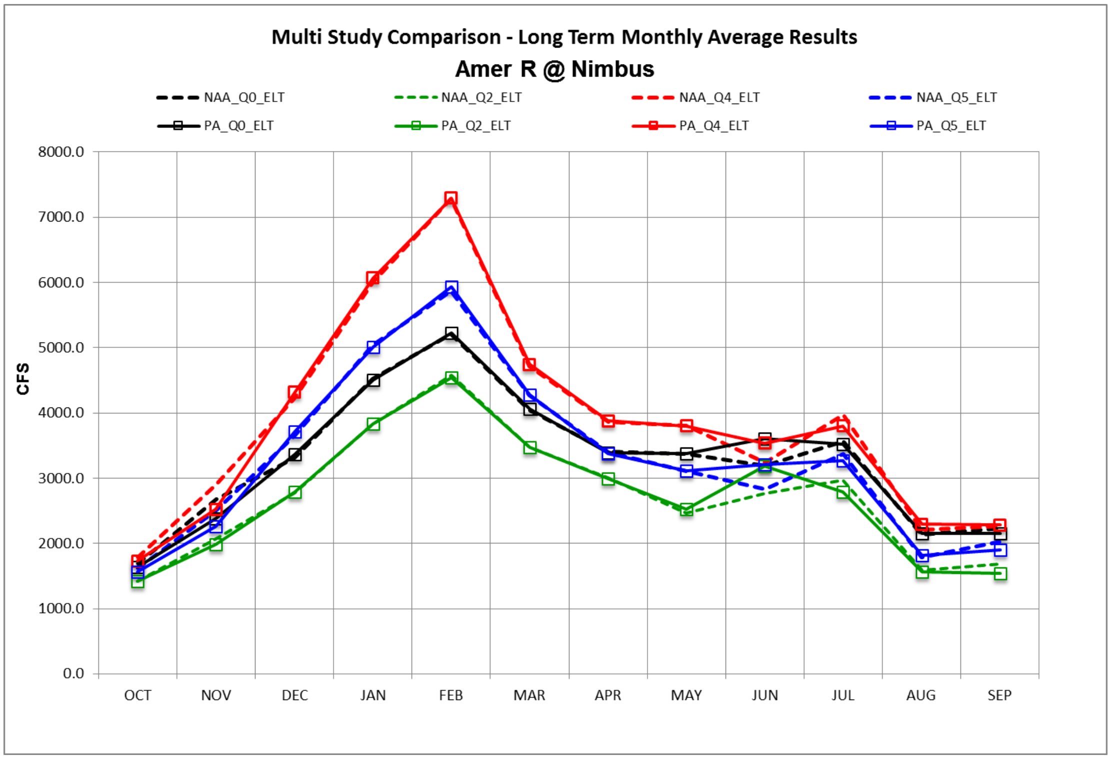


Figure 5.A.A.3-11 American River at Nimbus Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

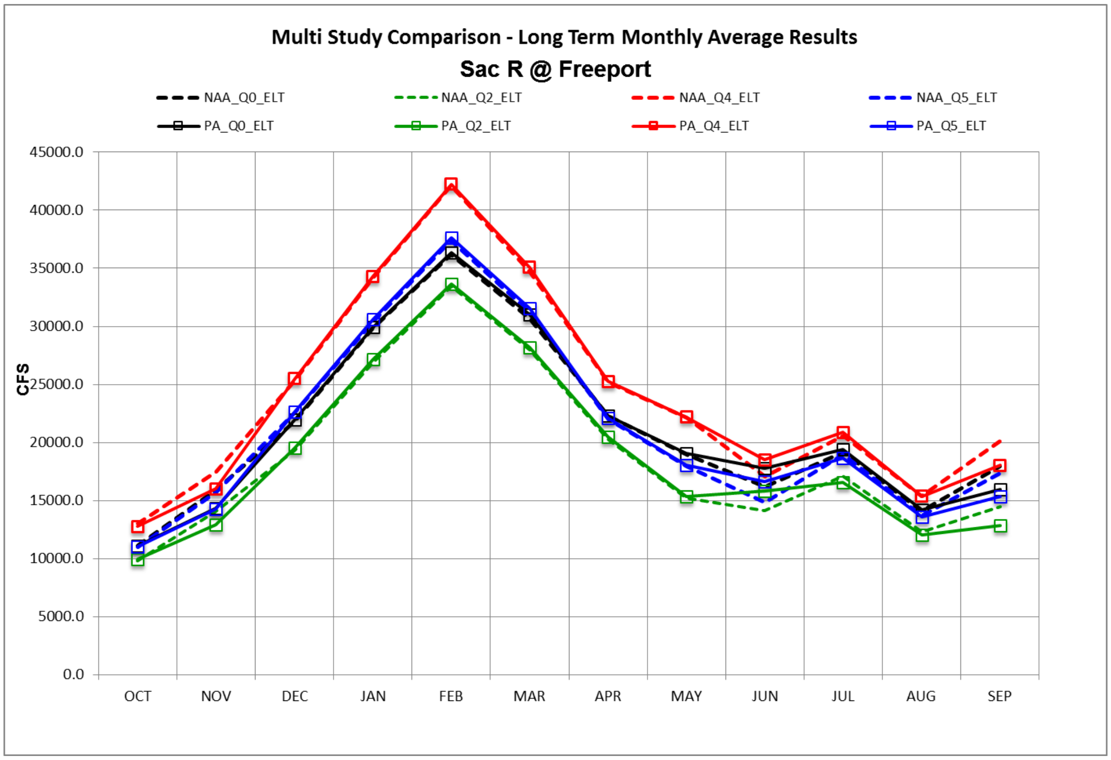


Figure 5.A.A.3-12 Sacramento River at Freeport Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

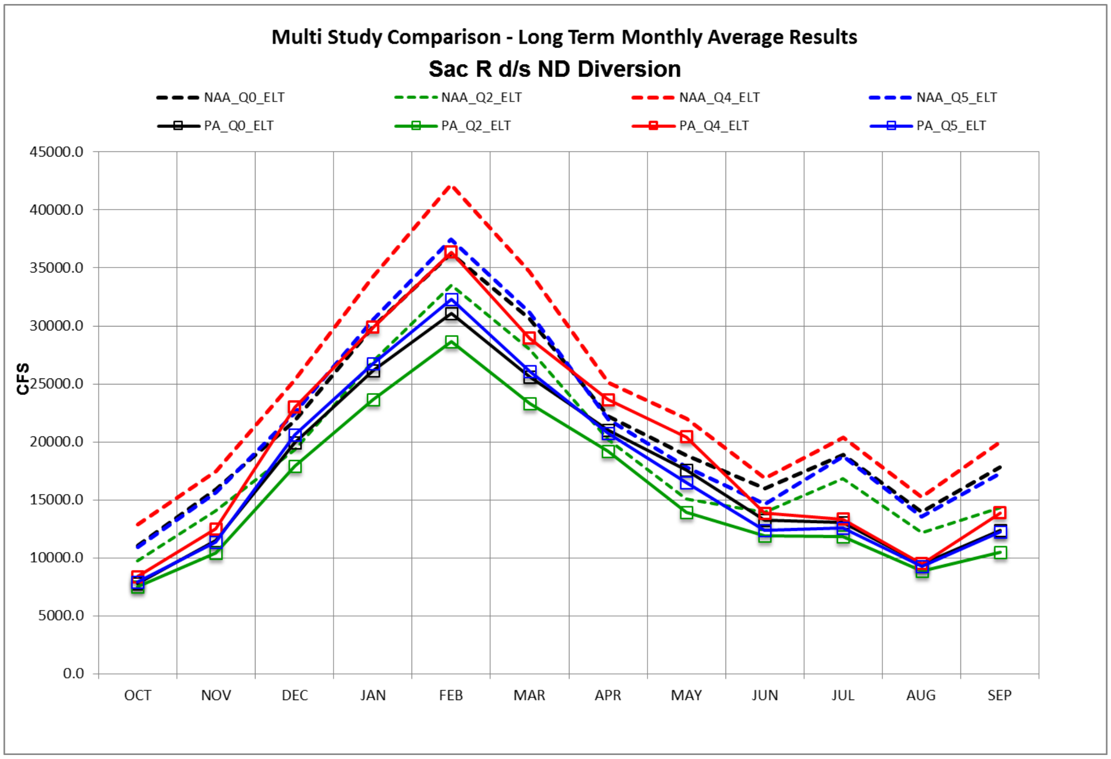


Figure 5.A.A.3-13 Sacramento River downstream of North Delta Diversion Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

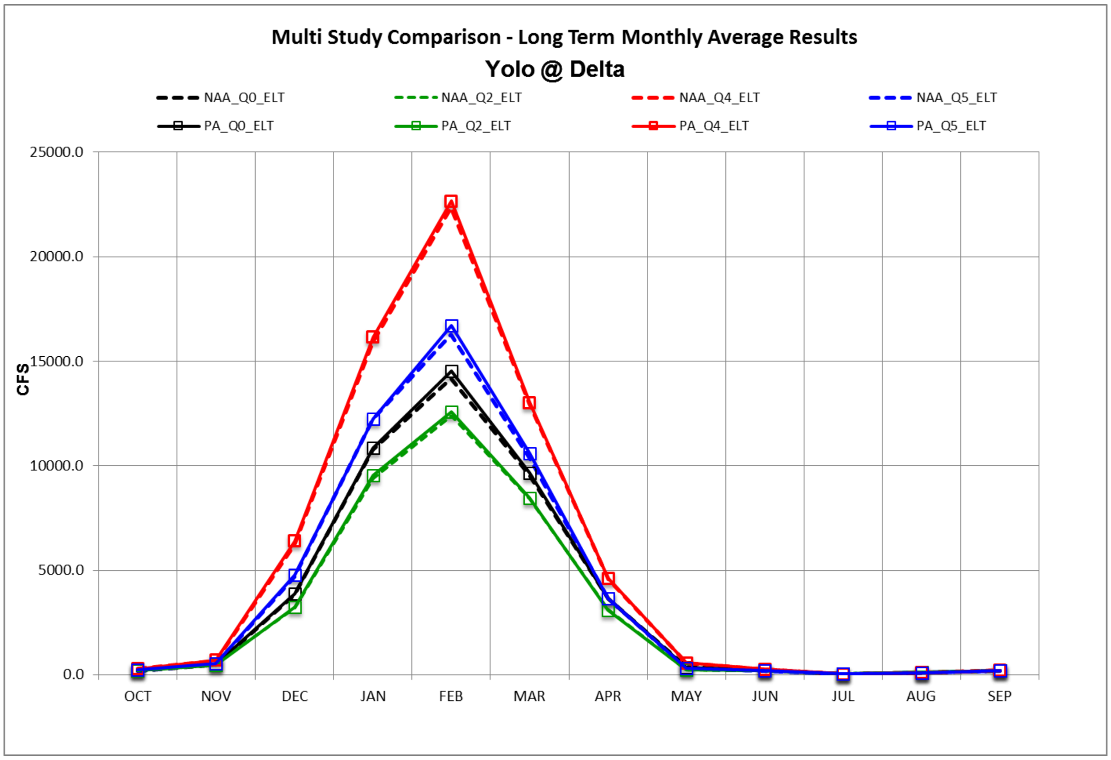


Figure 5.A.A.3-14 Yolo Bypass at the Delta Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

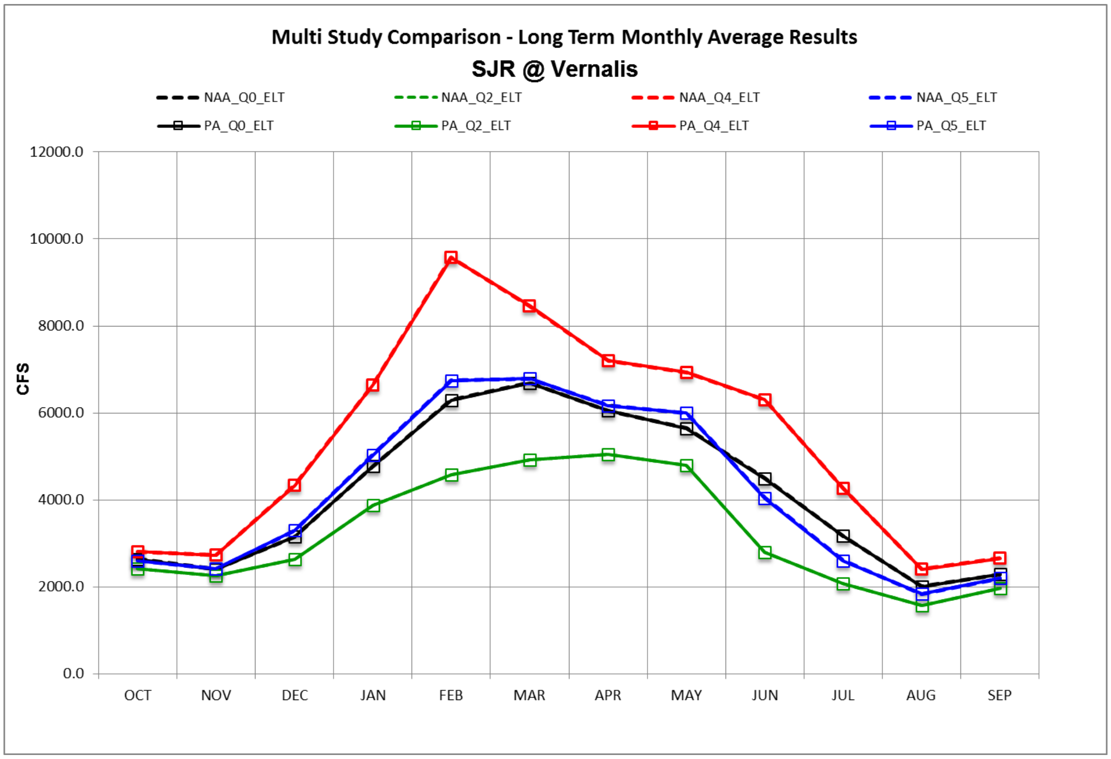


Figure 5.A.A.3-15 San Joaquin River at Vernalis Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

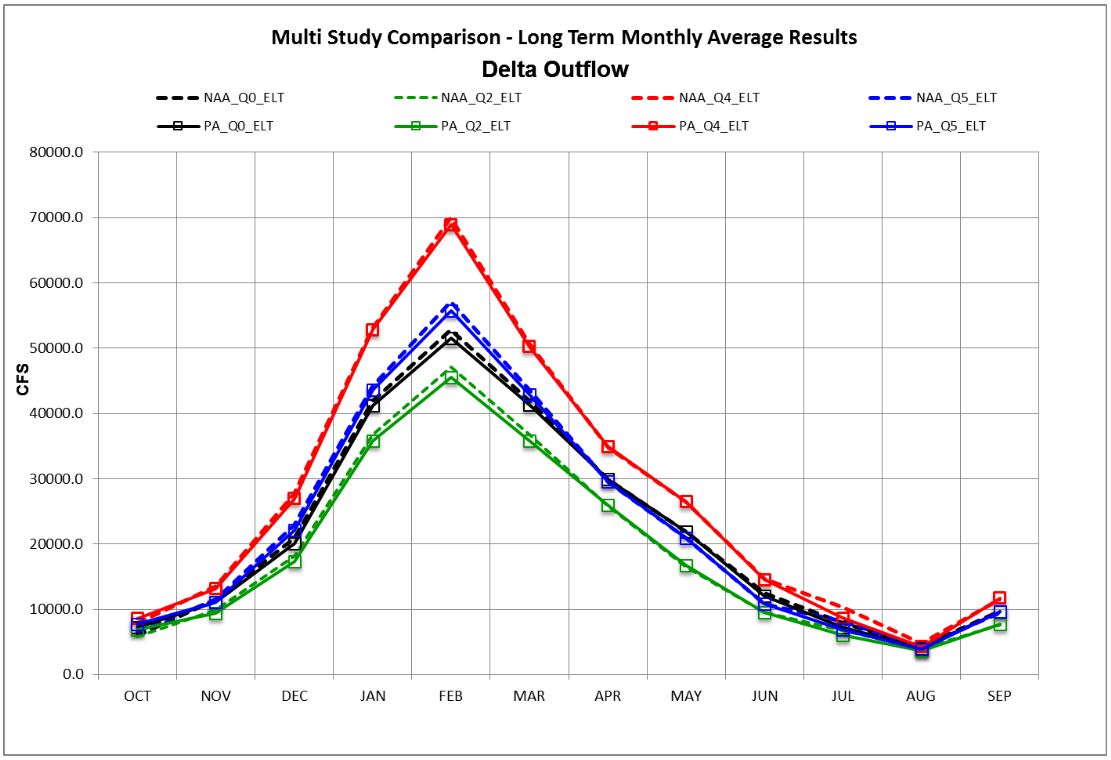


Figure 5.A.A.3-16 Monthly Delta Outflow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

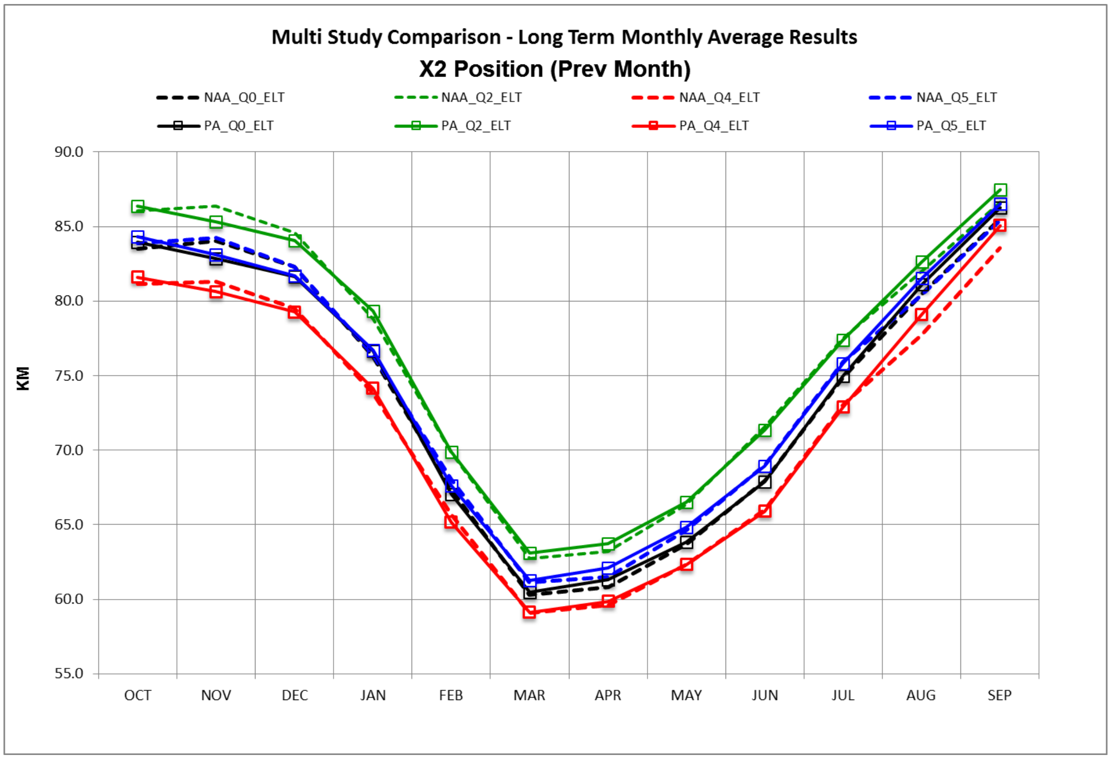


Figure 5.A.A.3-17 Previous Month X2 Position for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

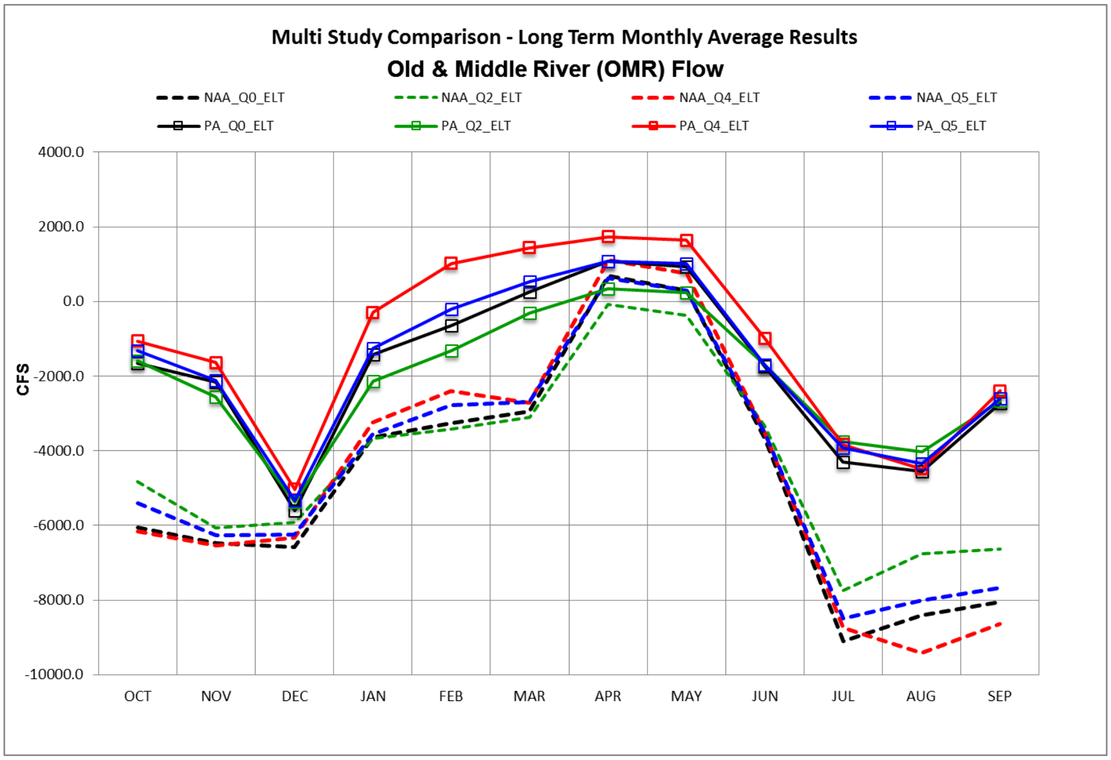


Figure 5.A.A.3-18 Combined Old and Middle River Monthly Flow for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

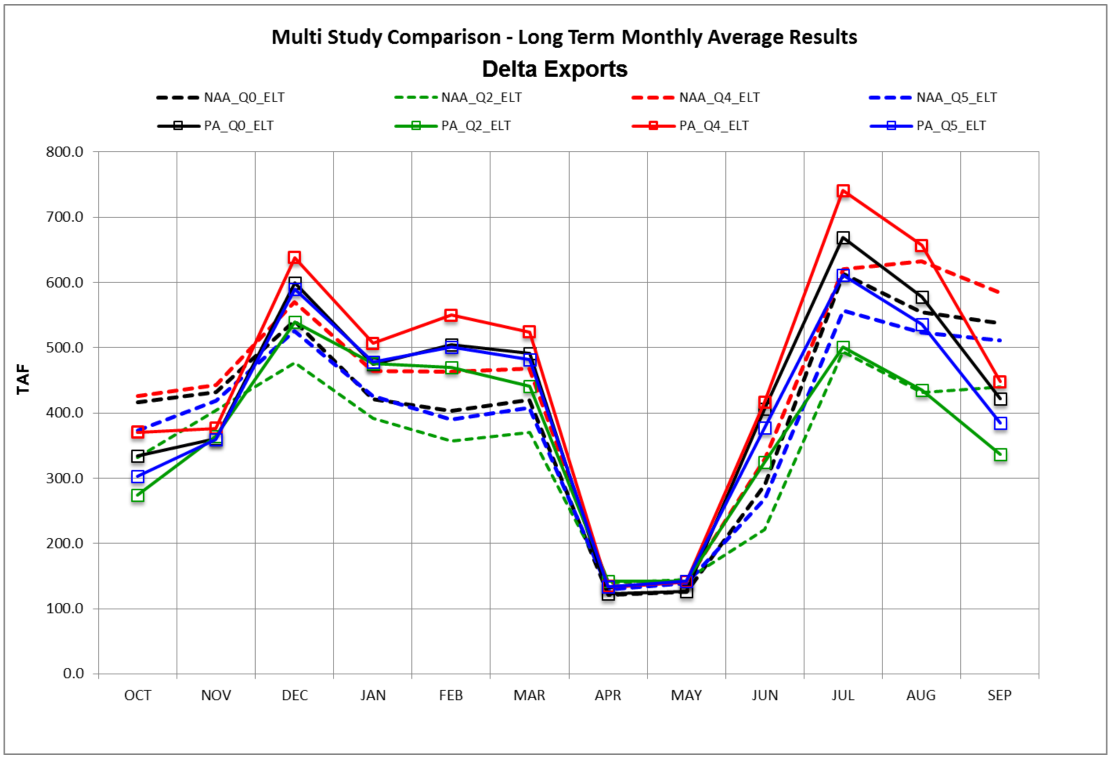


Figure 5.A.A.3-19 Monthly Delta Exports for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

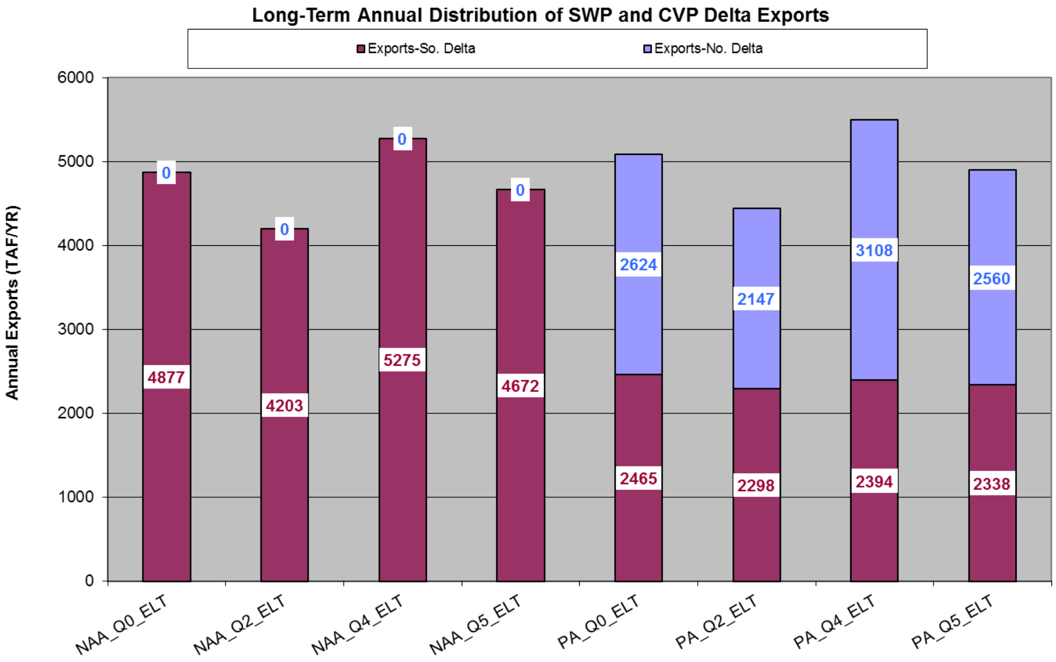


Figure 5.A.A.3-20 Long-term Average Annual Delta Exports at the North Delta Intakes and the South Delta Intakes for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

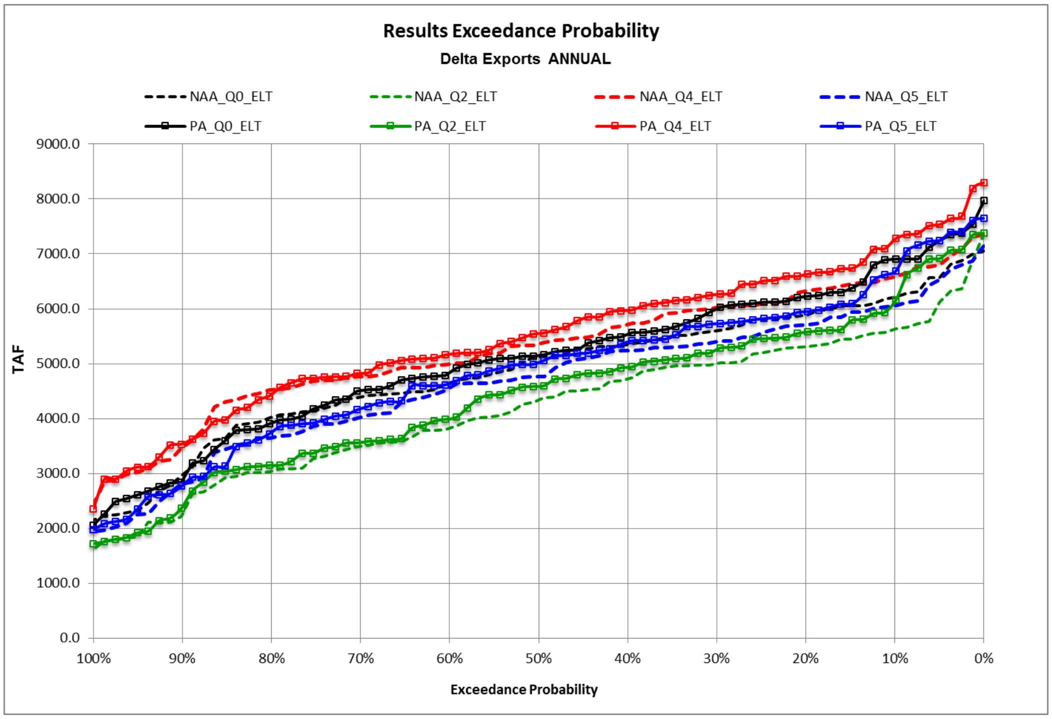


Figure 5.A.A.3-21 Annual Delta Exports for the NAA and PA under Q0, Q2, Q4 and Q5 climate scenarios at Year 2030

5.A.A.4 Attachment 4: Yolo Bypass Floodplain Hydraulics

This attachment summarizes the approach used to develop rating curves to define the amount of flow that would spill over a modified Fremont Weir based on a specific Sacramento River flow and to define the amount of inundation that would occur at the flow rate. The derived rating curves are used directly in the CalSim II model to define the monthly and daily spills over the Fremont Weir and Sacramento Weir when integrated with the system operations of the California WaterFix Biological Assessment (CWF BA) scenarios. This attachment includes a technical memorandum previously documented for use in the draft BDCP EIR/EIS (DWR 2013).

5.A.A.4.1 Introduction

The goal of the Yolo Bypass floodplain hydraulic study is to develop rating curves to define the amount of flow that would spill over a modified Fremont Weir based on a specific Sacramento River flow and to define the amount of inundation that would occur at the flow rate. The derived rating curves are used directly in the CalSim II model to define the monthly and daily spills over the Fremont Weir and Sacramento Weir when integrated with the system operations and other components of the CWF BA alternatives (NAA and PA). The assumed Fremont Weir modification in the NAA and BA are in response to the 2009 NMFS BiOp Actions Actions I.6.1 and I.7. This section describes the development of this hydraulic characterization information. In addition, an initial assessment of the inundation characteristics (area, depth, velocity, and travel time) within the Yolo Bypass was conducted. This section also includes a comparison to observed inundation areas and other multi¬ dimensional modeling efforts under assumed flow rates.

5.A.A.4.2 Description

Given that Reclamation is currently evaluating the alternatives for implementation of the 2009 NMFS BiOp Actions Actions I.6.1 and I.7, the notched Fremont Weir concept developed for the Bay Delta Conservation Plan (BDCP) was assumed to represent these NMFS RPA Actions as part of the NAA and the PA modeling under the CWF BA. This appendix provides the description of how the notch assumptions were developed. The content included in the section provides background information on the objectives for which the Fremont Weir notch assumptions were developed.

To allow increased flooding in the Yolo Bypass, the flow from the Sacramento River through a low-elevation section of the Fremont Weir needs to be conveyed downstream to the head of Tule Canal, along the current location of the Toe Drain shown on Figure 5.A.A.4-1. Preliminary hydraulic analyses were performed along with hydrologic analysis to ascertain the effectiveness of such a modification of the Weir. This section describes the data sources and methods used to develop an assessment of the frequency and duration of Fremont Weir spills under current and assumed configurations of the Fremont Weir. The characteristics of inundation (area, depth, velocity, and travel time) within the Yolo Bypass are also assessed through the development and application of a preliminary hydraulic model.

The primary objectives of this technical study are to: (1) evaluate the range of increased inundation frequency and duration of the Yolo Bypass as a result of modification to the Fremont Weir and operation, (2) summarize existing knowledge about the anticipated effects of these modifications on covered fish species both within the Yolo Bypass and elsewhere in the Delta and bays, (3) make recommendations to the BDCP Integration Team to facilitate discussion about further refining these operational parameters.

The BDCP Habitat Restoration Technical Team proposed a modification to the existing Fremont Weir to allow greater frequency of floodplain activation in the Yolo Bypass. Sacramento River flows over the weir, and into the Yolo Bypass, are often limited due to insufficient river stage as compared to the weir crest elevation. By constructing a low-elevation (“notched”) section in the Fremont Weir, lower Sacramento River flows would be necessary to provide the Yolo Bypass with a minimum flow to flood part of the bypass area and sustain inundation to benefit multiple covered fish species. This notched section and associated conveyance were evaluated and are described in this technical memorandum.

5.A.A.4.3 Overview of Yolo Bypass Floodplain Hydraulics

5.A.A.4.3.1 Relationship between Sacramento River Flow and Fremont Weir Spills

The two sets of estimated daily averages for stage and flow, Sacramento River Stage at Fremont and Fremont Weir spill flows, were used to develop a correlation between Fremont Weir spill flow and Sacramento River flow (details in section 4.5). The correlation equation was found by a polynomial regression on a filtered daily spill data set. The filtered records reflect years where the same trend was followed for a given range of river flow values. In Figure 5.A.A.4-2, the observed Fremont Weir spill data during the period 1984 to 2007 is shown as a function of the Sacramento River flows. As can be observed, for a river flow range of 50,000 to 90,000 cfs, observed records followed the same trend except from records from years: 1984, 1986, 1993, 1999 and 2006. Even though, years 1995 and 1996 follow a different trend, records from these years were considered in the polynomial regression since the divergence takes place outside the mentioned range.

Since the Sacramento River at Fremont gage only contains records from 1984 to present, it was desirable to extend the flow time series using the Sacramento River at Verona gage. The relationship between flows at these two locations for the overlapping period is shown in Figure 5.A.A.4-3. This figure indicates a strong correlation between these flows. Therefore, the equation provided on Figure 5.A.A.4-3 was developed for use in approximating Sacramento River at Fremont flows. The result of this conversion is an extended Sacramento River flow at Fremont time series that was used to evaluate the historical performance of the assumed notch in comparison with the current Fremont Weir configuration.

Using the regression equation described above, the historical Fremont Weir spills into the Yolo Bypass were reconstructed and extended to the 1929-2008 period based on Sacramento River flows at Fremont extended based on Sacramento flows at Verona vs. Sacramento flow at Fremont correlation. Figure 5.A.A.4-4 shows the correlation between the observed and simulated values for the Sacramento River flow range of 50,000 to 90,000 cfs. The R^2 of 0.9171 and the graph indicate that the regression provides a reasonable estimate of spills over the Fremont Weir. The value is not closer to 1.0 due to the outlier data values from 1984, 1986, 1993, and 1999. This analysis was done for flows below 90,000 cfs. It is important to realize that once flows get higher than that the correlations will change due to the large flows from Sacramento River into the Yolo bypass.

5.A.A.4.3.2 Range of Target Flows in the Yolo Bypass

The range of target flows in the Yolo Bypass was evaluated based on anticipated inundated area, water depth, and travel times. Based on the modeling results and comparison to previous work, it was believed that flows in the range of 3,000 to 6,000 cfs would provide sufficient surface area and water depths for desirable habitat. For these flows, the mean water depths were generally within the 2-3 foot range, velocities were less than 2.0 feet per second, and travel times were in the range of 3-4 days. The anticipated inundated area would range between 11,000 and 21,000 acres.

5.A.A.4.3.3 Modeling Tools

5.A.A.4.3.3.1 Hydraulic Model Development and Application

The inundation characteristics of Yolo Bypass were evaluated by applying a coarse-level HEC-RAS model of the Yolo Bypass from Fremont Weir to Liberty Island. The model was constructed to evaluate approximate inundated area, water depth, and velocities through the Yolo Bypass at various flow levels. The model should be considered preliminary due to limited extent of Toe Drain bathymetry and limited calibration data sets.

5.A.A.4.3.3.2 Elevation and Bathymetric Data

The initial HEC-RAS model incorporated cross-sections derived from the USGS National Elevation Dataset (NED) Digital Elevation Model (DEM) (USGS, 2006). The NED DEM represents land and water surface elevation, but does not include bathymetric data. In order to better understand the terrain and spatial influence of smaller flows in the Yolo Bypass, a new elevation dataset based on the U.S Army Corps of Engineers (USACE) Yolo Bypass RMA2 Model (USACE, 2007) was subsequently incorporated. This dataset contained bathymetry for Liberty Island. The USACE dataset was modified to incorporate surveyed cross section information provided by DWR for 14 cross sections (12 locations) between Liberty Island and I-80. The location of the survey points are shown in Figure 5.A.A.4-5. Finally, the elevation dataset was modified to estimate the Toe Drain bathymetry from I-80 to the Fremont Weir.

After converting to proper coordinates and vertical datum, a Triangulated Irregular Network (TIN) elevation surface was created with the merge of the USACE model elevation data and DWR survey points. The TIN was then used to generate cross sections of the Yolo Bypass for use in the HEC-RAS model. No cross section data was available for the Toe Drain canal from the Sacramento Weir to near the Fremont Weir. The cross-section of the region was estimated based on the available cross sections for the Toe Drain obtained from the DWR survey.

5.A.A.4.3.3.3 Boundary Conditions and Hydraulic Parameters

A HEC-RAS steady flow analysis was performed at 100, 250, 500, 1,000, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, 8,000, 9,000 and 10,000 cfs. The steady flow conditions assumed a downstream water surface elevation of 1.25 m (4.1 ft NAVD 1988), which corresponds to observed average stage data from Yolo Bypass at Liberty Island location (CDEC station LIY). The LIY CDEC station is under tidal influence and could range from 0 to 2.5 m (0 to 8.2 ft)

5.A.A.4.3.3.4 Model Calibration

A profile of the entire Yolo Bypass with the water surface elevation for 1,000, 5,000 and 10,000 cfs is presented in Figure 5.A.A.4-6. The units for elevation and cross section distances are in meters due to the HEC-HAS output data. The profile shows the lowest point of each cross section, from the Fremont Weir to Liberty Island, which represents the Toe Drain or Tule Canal profile. The profile also indicates the approximate location of the surveyed cross sections. Flows greater than 3,000 cfs are expected to begin causing inundation outside of the Toe Drain. Table 5.A.A.4-1 presents the simulated mean depth, surface area, mean velocity, and travel time for various Fremont Weir flows. The high depth and low surface area for 1,000 and 2,000 cfs flow range is due to the fact that most of the flow stays within the Toe Drain.

Initially, a single Manning’s coefficient value was assumed for all cross sections along the length of the bypass. The USACE Yolo bypass 2-D model (USACE, 2007) assumes that 70% of the land is covered by agricultural fields with Manning’s coefficient of 0.03. The remaining 30% of land has a significant percentage that is assumed to be covered by wild grassland, with a Manning’s coefficient of 0.045. This current modeling effort initially assumed a Manning’s coefficient of 0.04 for the entire Yolo Bypass. Further field observations, like the one presented on Figure 5.A.A.4-7, and historic flow-stage observations for Lisbon Weir (Figure 5.A.A.4-8), has shown that a lower Manning’s coefficient for the Toe Drain would be more appropriate. A range varying from 0.016 to 0.033 of Manning’s coefficient was initially selected from Chow (1959) based on the nature of the channel and photographs taken by DWR staff on February 18, 2009 (Figure 5.A.A.4-7). Figure 5.A.A.4-7 also shows that flows on this date, approximately 2,000 cfs, are contained within the banks of the Toe Drain at Lisbon Weir.

The historical Lisbon Weir flow versus stage measurements (Figure 5.A.A.4-8) were used to calibrate the model. Figure 5.A.A.4-8 shows water surface elevation at the Lisbon Weir cross section (HEC-RAS cross section 24842.05) as a function of Toe Drain Manning’s coefficient. Based on the field observations (Figure 5.A.A.4-7) and the data presented on Figure 5.A.A.4-8, the Manning’s coefficient of 0.022 was selected for the Toe Drain channel. A Manning’s coefficient of 0.04 was retained for the overbank areas outside of the Toe Drain.

The surface area in Table 5.A.A.4-1 represents more detailed area values then what is obtained directly from HEC-RAS results, which interpolates areas between cross sections. The areas in Table 5.A.A.4-1 were obtained by transferring the HEC-RAS model results to GIS and computing areas.

Figure 5.A.A.4-9 shows the inundated areas for various flow levels determined from the GIS mapping. Due to the topography of the Yolo Bypass, there is a dramatic increase in surface area as flow exceeds that which can be conveyed in the Toe Drain. At 6,000 cfs flow, approximately 21,500 acres are expected to be inundated, but this value is only increased to 27,100 acres at 10,000 cfs. It should be noted that the surface area values in Table 5.A.A.4-1 include approximately 3,700 acres of Liberty Island that were assumed constantly inundated. This amount should be subtracted of the total flooded area presented in Table 5.A.A.4-1 to estimate total new flooded areas. For comparative analysis this is not significant since the Liberty Island flooded area remains practically unchanged through the range of flows considered in this report.

5.A.A.4.3.3.5 Model Comparison

The results presented in previous sections were compared with results of a linear interpolation model published by Sommer et al. (2004). In Sommer et al., linear interpolation of gage elevations between stations was used to estimate water surface between gages. Figure 5.A.A.4-10 presents a comparison between the final HEC-RAS model and the model results published by Sommer et al. (2004). The comparison shows that the linear interpolation model in general overestimates areas when compared with the hydraulic HEC-RAS model. A possible explanation for the difference between the linear interpolation and the HEC-RAS model results may be due to the assumption used in the Sommer et al that the water surface elevation has a constant slope, which may not be valid at higher flows. This assumption may overestimate areas if gages are spaced apart by long distances, which is the case of the two gages used in the interpolation model that are covering the area between I-5 and Lisbon Weir. Figure 5.A.A.4-11 illustrates how possible overestimation could occur in high flows between two gages used in the linear interpolation model. It is also important to note that the HEC-RAS simulations only consider flows over the Fremont Weir and do not account for tributary flows. Although there is a significant difference between the HEC-RAS and the linear interpolation models at higher flows, both models show that the increase in inundated areas is reduced at flows greater than 5,000 cfs. It is noteworthy to mention that field measurements like the ones presented on Figure 5.A.A.4-7 and Figure 5.A.A.4-8, show that flows below 2,000 cfs are fully contained in the Toe Drain channel, therefore the change in flooded area from 0 to 2,000 cfs is minimal.

A comparison of HEC-RAS modeling results against flooded areas registered by satellite images was also performed. Four spill events with were found among several satellite images. Table 5.A.A.4-2 lists the 4 events, the estimated flows at Fremont Weir as an average for the last 7 days, and the estimated area delineated from a 300X300m resolution images. The HEC-RAS simulated area results compare well to those estimated from the images. The January 2003 and February 2006 events are included in Figure 5.A.A.4-10.

During late 2010 a separate modeling effort attempting to characterize the flow-inundation aspects of the Yolo Bypass was conducted using the MIKE21 two-dimensional model (CBEC 2010). Despite initial efforts suggesting significant differences between the two modeling approaches, the two models result in similar inundation characteristics as shown in Figure 5.A.A.4-12. The MIKE21 model was simulated using transient flows for the Fremont Weir and Westside drainages and includes a new bathymetric data set, while the HEC-RAS model was simulated as steady state conditions with the bathymetry described herein. Both model simulations produce similar inundation acreage values for flows up to 6,000 cfs but show some divergence at higher flows. Overall, the model simulations are similar for the flow range considered in the BDCP.

5.A.A.4.3.4 Modeling Methods

5.A.A.4.3.4.1 Fremont Weir Model for Current Configuration

Data Sources

The hydrologic analysis is based on the available historical records of the Sacramento River station at Fremont (FRE), managed by the Department of Water Resources (DWR). The data types used were river stage (feet) and river discharge (cfs). The FRE station has records for daily average flows from only 1996 to present date; however, hourly data river stages and river discharge flows are available since 1984. These hourly records were used to estimate daily average values for a more complete time series. Table 5.A.A.4-3 describes the stage and flow data sources used in this study. Several time series data sets were needed and the development of these time series is explained in the following section.

The conversion of hourly data to daily data was performed by the HEC-DSS Vue software function that averages the hourly data in to a daily time series. Figure 5.A.A.4-13 shows the time series of CDEC data converted from hourly to daily time step for stage in the Sacramento River at Fremont and Fremont Weir spills into the Yolo Bypass.

The longest continuous recording station applicable to this study was found for the Sacramento River at Verona USGS gage. This time series was used to compare the current and assumed configurations of the Fremont Weir over a much longer period of record than exists directly at the Fremont Weir site.

Data Development

Three time series were developed from Fremont hourly stage data and Fremont hourly spill data from CDEC. The following is a description of the process for utilizing and transforming the hourly CDEC data:

- Daily Fremont Stage: Computed from HEC-DSS Vue function that averages hourly time series into daily time series.
- Daily Sacramento River at Fremont flows: Computed using the daily Fremont stage time series and the synthetic rating curve for the Sacramento River at Fremont developed by the California Division of Flood Management (DFM) shown on Figure 5.A.A.4-14. Given the rating curve characteristics, records below 12 ft and above 45 ft were considered as missing values.
- Daily Fremont Spills: Computed from HEC-DSS Vue function that averages hourly time series into daily time series. Values described as below the rating table (BRT, code -

9998) were considered as zero values and, above rating table (ART, code -9997) as missing values.

The Sacramento River at Fremont stage (converted from USED to NAVD88) time series of daily average data is presented on Figure 5.A.A.4-15**,** Figure 5.A.A.4-16**,** and Figure 5.A.A.4-17 with the periods in which stage exceeded the Fremont Weir crest identified. The red bars on the figures represent the consecutive number of days for which there was flow over the Weir. The figures show that 28 such events were recorded between January of 1984 and December of 2007.

The computed Sacramento River at Fremont daily stage is plotted as a daily exceedance probability (Figure 5.A.A.4-18). Figure 5.A.A.4-18 shows that under historical hydrology, the daily probability of stage greater than weir crest 33.5 ft USED is approximately 17% during January-May, but only 6% when evaluated for the entire year (i.e. stage is sufficient to generate Fremont Weir spills 17% of the days within the January – May period).

Figure 5.A.A.4-19 presents Fremont Weir daily spill probability of exceedance for the entire time series period (Jan 1984-Dec-2007). The figure shows that the Fremont Weir daily flows between 0 and 10,000 cfs occur approximately 14% of the time during January through May, The information provided by the Figure 5.A.A.4-18 and Figure 5.A.A.4-19 was used to examine the frequency and magnitude of Fremont Weir spills to the Yolo Bypass. Also, the Sacramento River stage exceedance plot (Figure 5.A.A.4-18) was used to guide the selection of the bottom elevation for the assumed notch.

Assumed Modification to the Fremont Weir

Hydraulic Model Assumptions

To simulate a notch in the Fremont Weir, the HEC-RAS hydraulic model was modified to include 12 new cross sections near the Fremont Weir representing the notch. The modified Fremont Weir would need to be able to convey, by gravity, the desirable flows into the Yolo Bypass. The initial assumption was to consider a new channel with invert at 17.53 ft NAVD 88 (18 ft USED). The 17.53 ft elevation was chosen as a function of two criteria, the terrain elevation between Fremont Weir and Tule Canal, and the Sacramento River flow at Fremont.

As a reference for the first criterion, Figure 5.A.A.4-20 shows the surface profile for the cross section that represents a conservative alignment of the new structure going from Sacramento River (zero distance) to the beginning of the Tule Canal (approximately 10,000 ft) (see Figure 5.A.A.4-1). Figure 5.A.A.4-20 also shows the estimated invert of Tule Canal (11.6 ft NAVD 88) and the new channel bottom elevation (17.5 ft NAVD 88). At the time of the HEC-RAS model development, the new channel alignment and Tule Canal invert elevations were considerably uncertain. Thus, a relatively simple conceptual channel above the assumed invert was utilized in the model to reflect this uncertainty and potential backwater effects. The modeling of this notch and connecting channels should only be considered conceptual at this point of development.

Once the engineering teams further the design and biological teams better understand the requirements and limitations, a more refined weir notch and channel should be included in this modeling.

A second criterion was used to evaluate whether the notch and canal would be sufficient to convey the target flows into the Yolo Bypass with a reasonable frequency. Historical Sacramento River flows at Verona were used to estimate a range of flows that may occur in the future. According to Figure 5.A.A.4-21, daily flows exceeding the range of 20,000 to 40,000 cfs would occur around 50% of the days within the January to March time period. This flow range was used in the initial elevation setting of the assumed notch. This flow range at Verona roughly correlates to 18,000 to 28,000 cfs at Fremont and roughly 19.5 to 24.5 ft NAVD88 at Fremont Weir.

Once the elevation and flow conditions at Fremont were better understood, the cross section dimensions for the notch were approximated. Figure 5.A.A.4-22 presents the dimensions for the trapezoidal channel structure connecting the Fremont Weir to the Tule Canal. The figure shows the channel with bottom length of 225 ft, side slopes of 2:1 and top length of 287 ft. The channel dimensions were estimated to avoid channel velocities greater than 3 ft/s. It was assumed that the new structure would operate most of the time conveying flows below 10,000 cfs.

Potential Fremont Weir Notch Rating Curve

A rating curve for the modified Fremont Weir was developed from the HEC-RAS results and shown in Figure 5.A.A.4-23 and Table 5.A.A.4-4. These results are used in the CalSim II model using Sacramento Flow at Verona as a trigger for the Fremont Weir modification. The curves presented on Figure 5.A.A.4-21, show that within a defined range of Verona flows (30,000 cfs - 50,000 cfs), that represents approximately the area between the 50th and the 75th percentile of flows during February and March, will result in a flow of 1,000 cfs or greater into the Yolo Bypass.

Model Sensitivity

Since the actual design of the modified Fremont Weir is unknown and is beyond the scope of this study, an analysis was conducted to evaluate whether the frequency and magnitude of flows could be increased by enlarging the channel bottom width from 225 ft to 450 ft. Initially, it was expected that the ability to convey flow on a wider channel would increase significantly. The expected increase in channel capacity is presented in Figure 5.A.A.4-24, where T 225 ft and T 450 ft are theoretical channels with constant bottom slope, constant dimensions, same manning coefficient, and flowing at normal depth. Through greater examination of the model cross-sections, an area approximately 32,000 ft downstream from the Fremont Weir into the Yolo bypass that serves as a hydraulic constriction was identified, especially at low flows. This terrain elevation condition limits the effectiveness of a wider channel capacity to provide more flow. An improved high-resolution elevation data set would assist in identifying whether this area truly acts in this fashion. This kind of investigation, however, is beyond the scope of this study.

Comparison between Current and Assumed Fremont Weir Configurations

The two scenarios, current and assumed Fremont Weir configurations, were analyzed over a nearly 80-year (October 1929 – July 2008) reconstructed daily flow sequence using the hydrologic data sets, spill flow equations, and the rating curves described in previous sections. The correlation equations developed to extend the Sacramento River flows at Fremont are based on flows below 90,000 cfs (approximately 37,000 cfs of Fremont weir spills). The probability of occurrence of spills over the Fremont Weir significantly increases with the assumed notch. Figure 5.A.A.4-25 and Figure 5.A.A.4-26 show the exceedance plots for current and modified Fremont Weir, respectively. With the modified Fremont Weir it is expected that daily flows during the Jan-May period will exceed 3,000 cfs more than 46% of the time in contrast to less than 14% of the time with the current configuration. The months of January, February, and March will have significantly higher chances of sufficient daily flows as compared with April and May. This analysis assumed a maximum of 10,000 cfs could be passed through the modified weir.

Figure 5.A.A.4-27 through Figure 5.A.A.4-29 show the events producing discharges greater than 3,000 cfs for the existing and assumed Fremont Weir configurations. The periods greater than 30 days are indicated in the call-outs. The time series line represents stage at Sacramento River at Fremont. The bars represent when a continuous flow (up to a week no flow gap) of more than 3,000 cfs was simulated to spill into the Yolo bypass. The graphs show clearly that January through March is a critical period for spills into the bypass. The maximum number of days that continuous flows greater than 3,000 cfs would be observed with an unrestricted modified weir is 189 days in 1998. A more realistic operation of the assumed modified Weir structure (notch and gate) would only permit flows during the January 1 through April 15 period and limit notch flows up to the 3,000 - 6,000 cfs range. This operation is shown in Figure 5.A.A.4-27 through Figure 5.A.A.4-29 as green bars.

Table 5.A.A.4-5 presents a summary of the change in events that produce flows greater than 3,000 cfs over the Fremont Weir (current conditions and assumed notch). The table presents the results for the period 1984-2007 (observed flow period) and 1929-2007 (longer reconstructed flow period) and indicates that the assumed notch would more than double the number of events that are deemed biologically significant.

5.A.A.4.4 Hydrological Modeling Summary

Several broad conclusions can be made from this initial study. First, the creation of a notched low flow channel through the Fremont Weir has the potential to significantly increase the frequency of inundation of the Yolo Bypass. The frequency of providing biologically-important flows is doubled as compared to the current configuration. It appears that the increase in frequency is a more robust result than the increase in magnitude of flows. Second, the hydraulics in the upper reach are important. The profile suggests that low flows may be affected by downstream hydraulic controls. Higher resolution elevation mapping, cross-sections, and more detailed modeling would be important to better understand these conditions. Finally, the modeling has shown that sufficient velocities, depths, and general residence times could be achieved from flows in the range of 3,000-6,000 cfs. The modeling has assumed that the Yolo

Bypass would not be altered. It is likely that land use and other concerns will require that certain lands be inundated, while adjacent lands are not. When these decisions are made, it will be important to verify the hydraulic conditions to ensure that conditions both upstream and downstream are suitable for the habitats of concern.

5.A.A.4.5 Modeling Limitations

The present model is suitable for a coarse-level feasibility analysis of a modified Fremont Weir. The intent of this study is to show the range of Sacramento River flows at which a modified Fremont Weir becomes feasible and the degree and extent of increased inundation. Another major goal of this analysis was to develop an approximate rating curve for the modified Fremont Weir that could be used in other water resources models like CalLite and CalSim II. Additional study would be required to gain greater insight and begin to identify design-level conditions.

For the above mentioned goals of this study, it was acceptable to utilize the USACE elevation from the Yolo Bypass model (USACE, 2007). A detailed Yolo bypass hydraulic model would require a refinement on the number of cross sections used by the model. More cross sections would clarify possible problems like the flow on cross section at 32,000 ft downstream of the Fremont Weir (cross section 47428.85), where an apparent berm acts as a hydraulic constriction. A more refined model would also use different Manning’s coefficients as a function of land use or satellite data and would include additional low flow calibration at various locations along the Yolo Bypass.

Although a 2-D hydraulic model of the Yolo Bypass (USACE, 2007) is available from the USACE, the model was designed for high flows in the range of 343,000 cfs and 500,000 cfs. The model documentation reports that it will not reliably simulate lesser discharges. In addition to this model limitation, the computational requirements of this model and resources necessary to adapt the mesh for this analysis are beyond the scope of this task.

For the design of the modified weir, a more refined analysis on the missing flow and stage data would be desirable, a detailed survey of the area close to the weir would be necessary and more detailed assumptions would have to be defined like maximum depth and width of the channel. Coarse satellite images were used to estimate flooded areas (300x300 m resolution) and not enough time was spent on defining the correlation between Fremont Weir flows, time of travel and floodplain area inundated. However, in the future this technique could be refined and be used as a calibration tool for the model.

5.A.A.4.6 References

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Table 5.A.A.4-1: HEC-RAS model results for depth, area mean velocity and travel time for different flows at the modified Fremont Weir

Flow	Mean Depth for the Entire Yolo Bypass	Surface Area (from GIS mapping)	Mean Velocity	Travel Time
(Q) cfs	(D) ft	(A) Acres	(V) ft/s	(t) day
1,000	5.9	4,100	1.66	8.8
2,000	5.3	5,700	1.94	4.9
3,000	3.9	11,000	1.77	4.2
4,000	2.8	15,900	1.49	4.2
5,000	2.6	18,600	1.32	4.0
6,000	2.6	21,500	1.26	3.9
7,000	2.6	23,100	1.19	3.7
8,000	2.6	24,600	1.20	3.6
9,000	2.7	25,900	1.20	3.5
10,000	2.8	27,100	1.20	3.4

Table 5.A.A.4-2: Estimated flooded area from satellite images and the respective previous 7 day average of Fremont flows. Values rounded to the thousands.

Date	Flow – HEC-RAS[1] (cfs)	Area – satellite image[2] (acres)	Area – HEC-RAS (acres)
6-Mar-1998	48,000	51,000	45,000
15-Jan-2003	13,000	32,000	27,000
8-Feb-2006	14,000	36,000	31,000
13-Apr-2006	72,000	48,000	49,000

[1] Estimated flow based on Fremont Gage for the previous five days. May underestimate since tributary flow is not included.

[2] Estimated acreage based on rough delineation from 300mx300m satellite image.

Table 5.A.A.4-3. Data sources used for the Fremont Weir analysis

Location	Type of Data	Hourly Data			Daily Data		
		Source	From	To	Source	From	To
Sacramento River at Fremont	Stage (USED)	CDEC FRE	1/1/1984	Current	Computed from hourly	1/1/1984	12/31/2007
Sacramento River at Fremont	River Flow	NA	NA	NA	Computed using daily stage and DFM rating curve	1/1/1984	12/31/2007
Sacramento River at Fremont	Spill into Yolo	CDEC FRE	1/1/1984	Current	Computed from hourly	1/1/1984	12/31/2007
Sacramento River at Fremont	Spill into Yolo	NA	NA	NA	USGS 11391021	1/1/1947	9/30/1975
Sacramento River at Verona	River Flow	NA	NA	NA	USGS 11425500	10/1/1929	Current

Table 5.A.A.4-4. Summary table for the new structure diversion to be used with CalLite and Calsim II models

Sacramento River at Fremont Stage ft (NAVD 88)	Notch Flow: Unrestricted (cfs)	Notch Flow: Assumed Limits (cfs)	Sacramento River at Fremont Flow (cfs)	Sacramento River at Verona Flow (cfs)
17.5	0	0	14600	23100
18.6	100	100	17200	25700
19.2	250	250	17700	27200
19.8	500	500	18600	28600
20.7	1000	1000	20200	31000
21.8	2000	2000	22200	34100
22.7	3000	3000	24000	36500
23.4	4000	4000	25300	38500
23.9	5000	5000	26300	39900
24.5	6000	6000	27700	41600

Sacramento River at Fremont Stage ft (NAVD 88)	Notch Flow: Unrestricted (cfs)	Notch Flow: Assumed Limits (cfs)	Sacramento River at Fremont Flow (cfs)	Sacramento River at Verona Flow (cfs)
24.9	7000	6000	28900	42700
25.3	8000	6000	29900	43900
25.7	9000	6000	31000	45100
26.0	10000	6000	31900	46000

Table 5.A.A.4-5. Number of events with consecutive spills producing more than 3,000 cfs over Fremont Weir under current and assumed notch conditions

Number of events with consecutive days of spills (max 7 day gap to count as new event) that produced more than 3,000 cfs	Count of events between 1984-2007		Count of events between 1929-2007	
	Current Weir	Assumed Notch	Current Weir	Assumed Notch
Less than 30 days	18	41	48	137
Greater than 30 days	9	19	11	70
Greater than 45 days	4	11	5	46

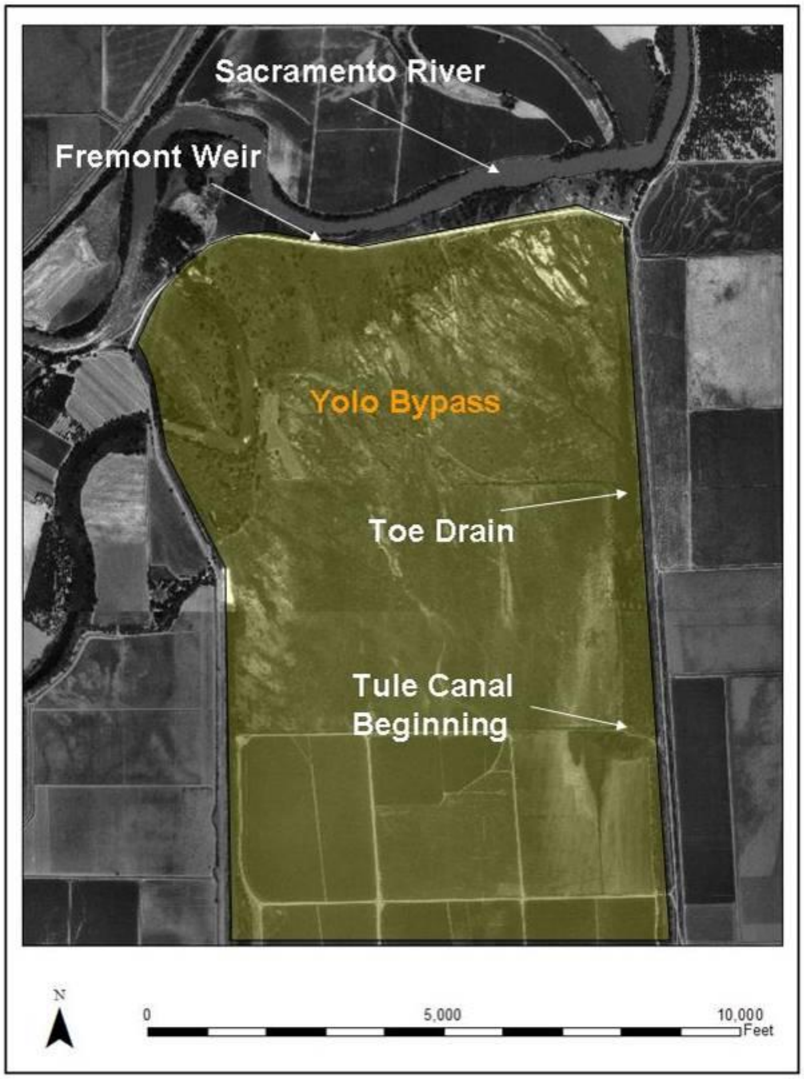


Figure 5.A.A.4-1. Aerial view of the Fremont Weir and Yolo bypass location

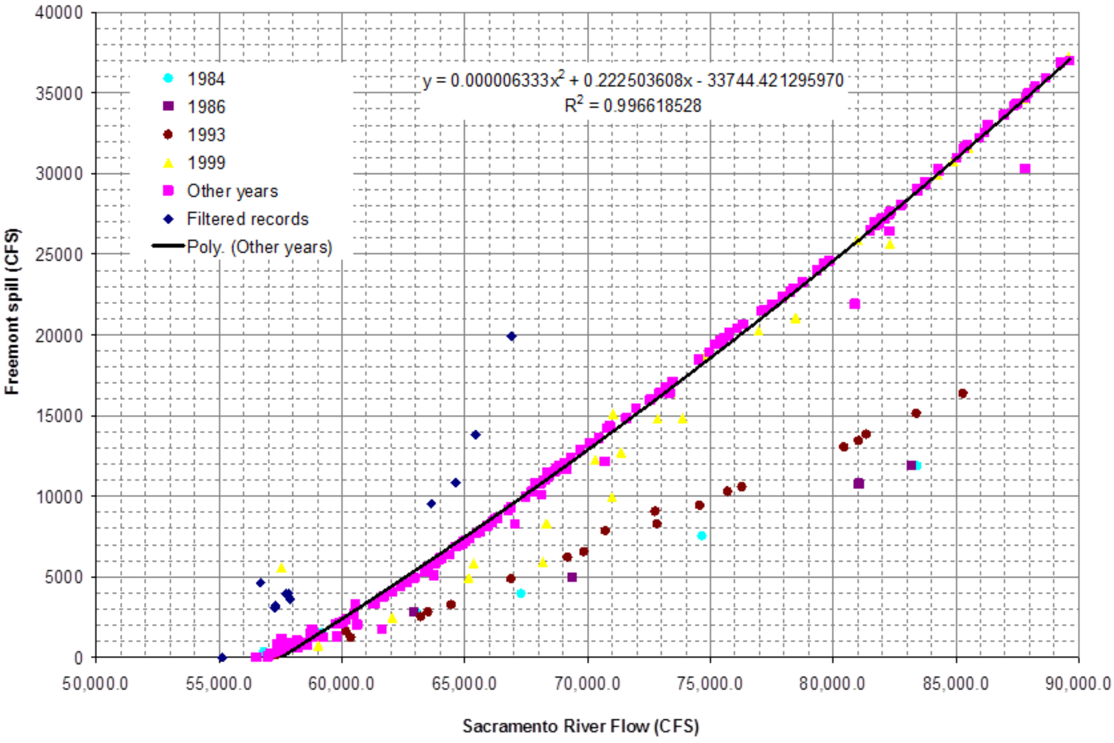


Figure 5.A.A.4-2. Fremont Weir spills curve for Sacramento flows from 50,000 to 90,000 cfs

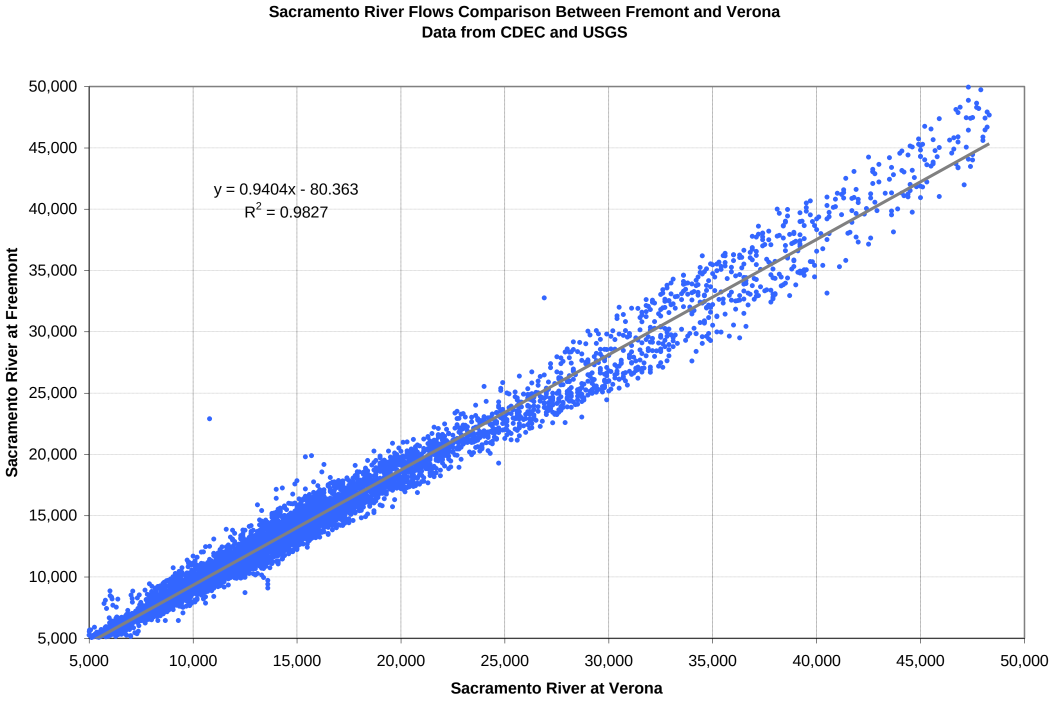


Figure 5.A.A.4-3. Correlation between Sacramento River at Verona and Sacramento River at Fremont for flows below 50,000 cfs

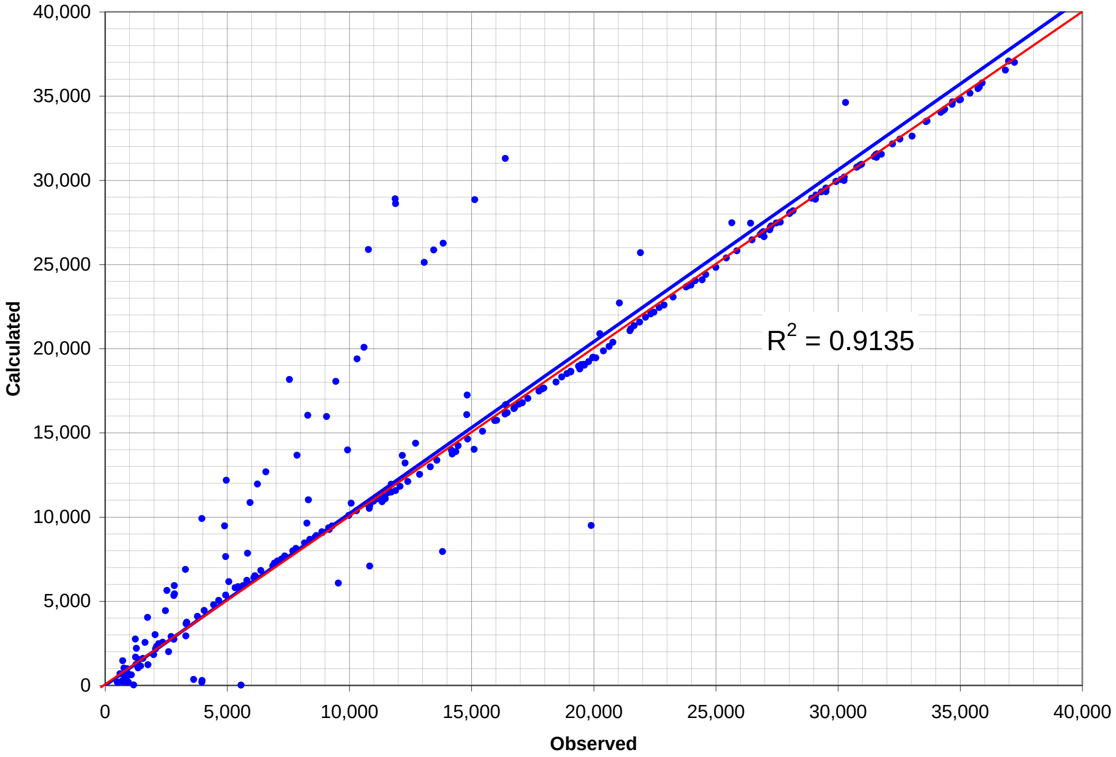


Figure 5.A.A.4-4. Observed and calculated Fremont Weir spill correlation

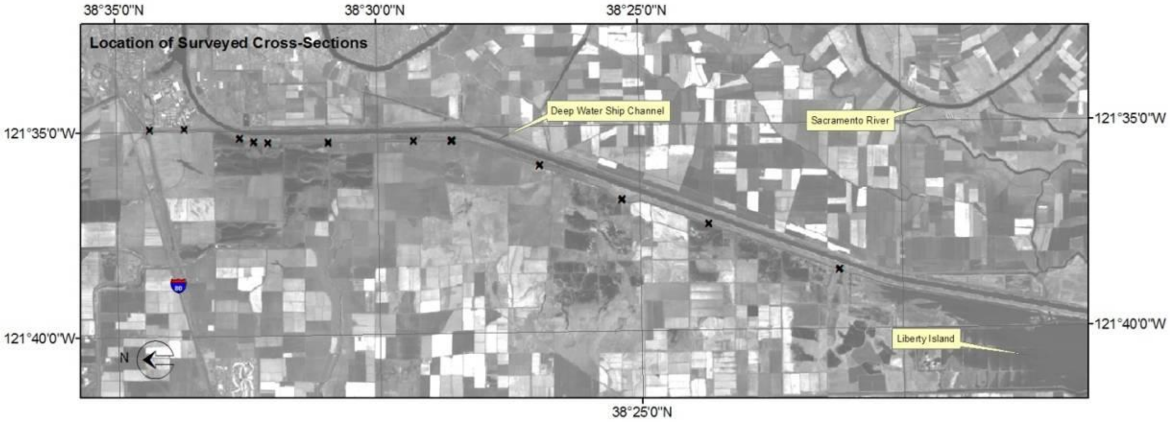


Figure 5.A.A.4-5. Location of surveyed Yolo bypass East Toe Drain cross sections (DWR unpublished data)

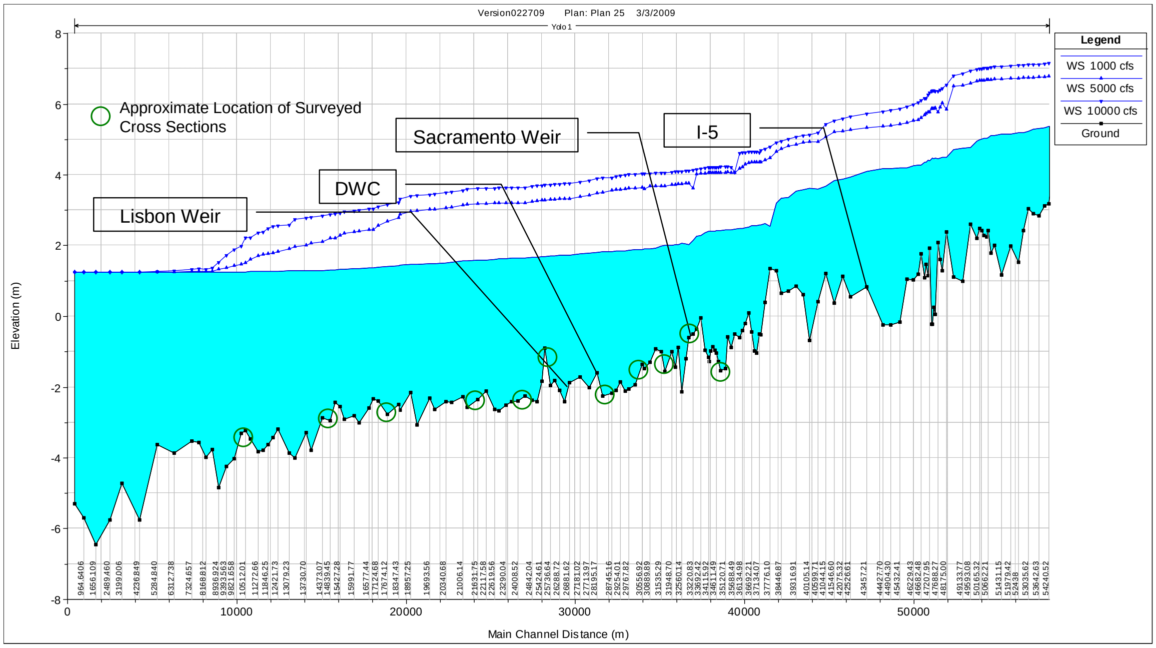


Figure 5.A.A.4-6. Yolo bypass profile for the deepest point of each cross section. Values in metric units from HEC-RAS analysis

Figure 5.A.A.4-7. Photos taken February 18 2009 between 1:45 - 2:00 pm downstream of the Lisbon Weir. Stage approx. 7.4 ft NAVD88. Flows were 1982 cfs at 13:45 and 1943 at 14:00 (DWR unpublished data)

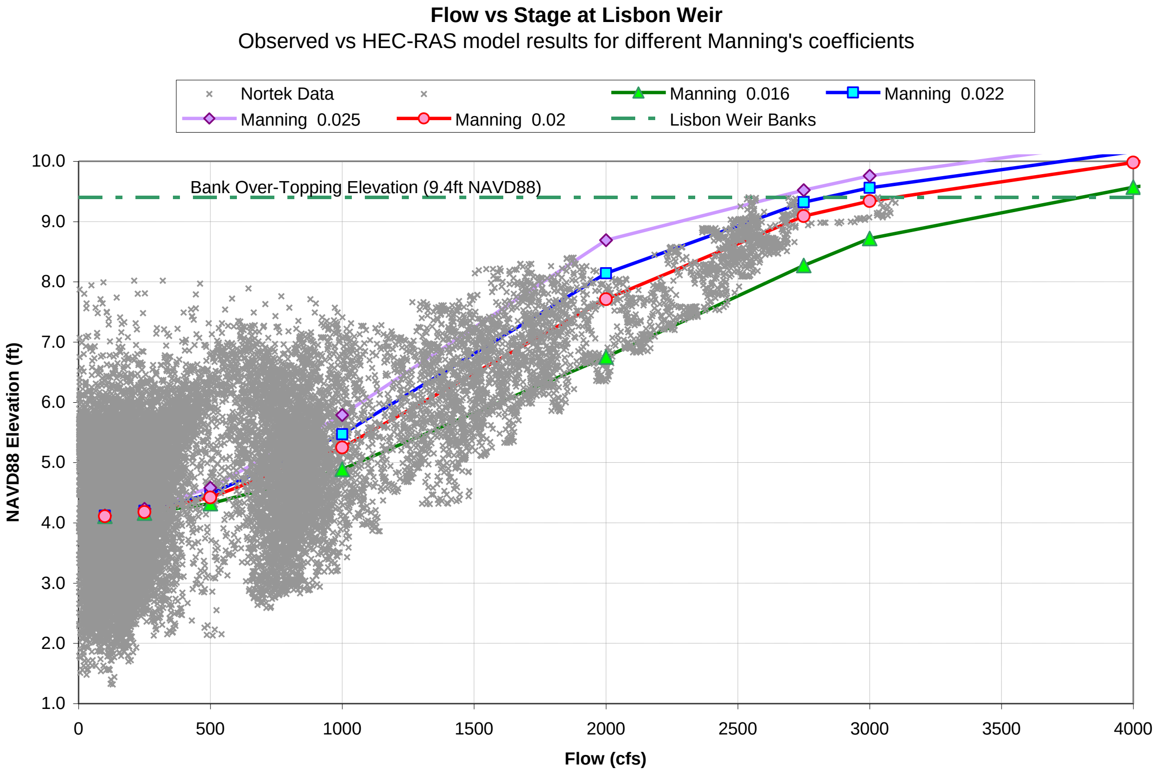
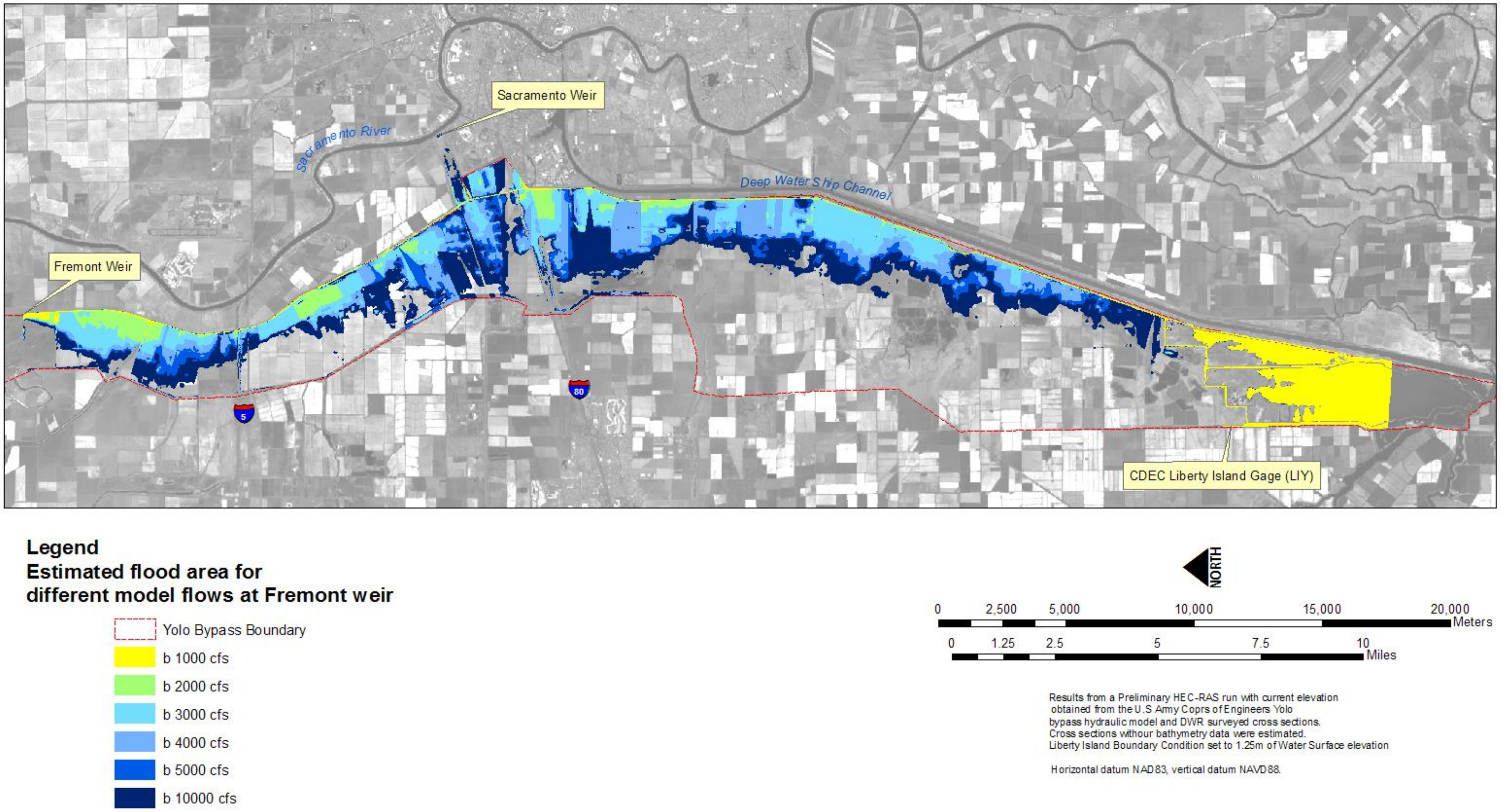


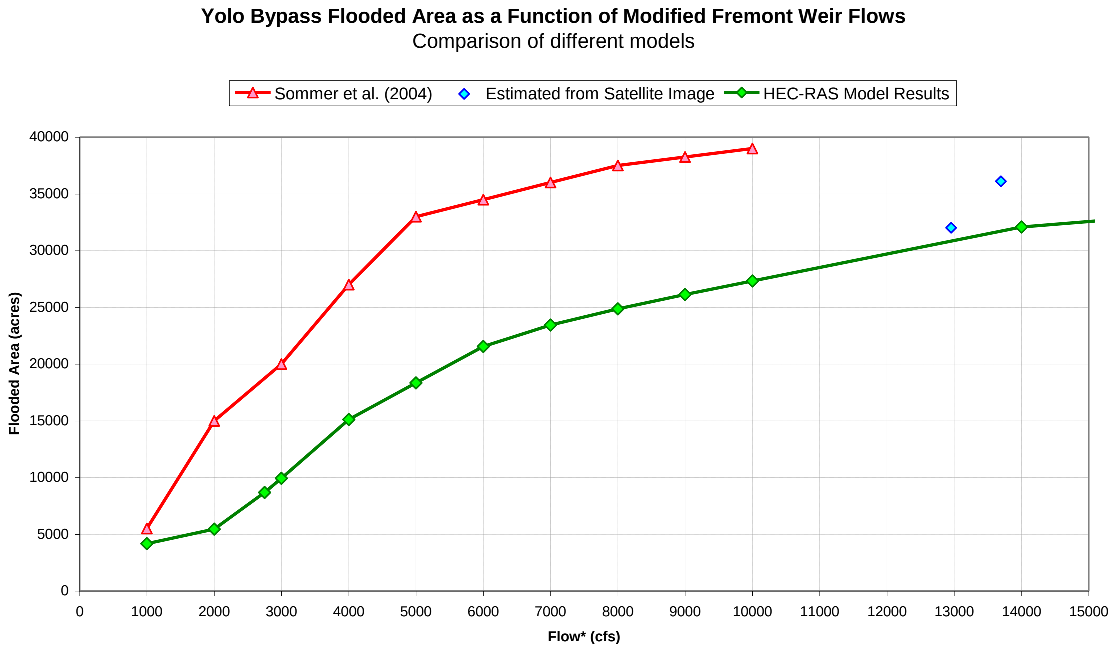
Figure 5.A.A.4-8. Historical flow vs elevation at Lisbon Weir and HEC-RAS model results at different Toe Drain Manning's coefficients. (Unpublished data from DWR)



Results from a Preliminary HEC-RAS run with current elevation obtained from the U.S Army Coprs of Engineers Yolo bypass hydraulic model and DWR surveyed cross sections. Cross sections withour bathymetry data were estimated. Liberty Island Boundary Condition set to 1.25m of Water Surface elevation

Horizontal datum NAD83, vertical datum NAVD88.

Figure 5.A.A.4-9. HEC-RAS modeling results showing flooded areas at different Fremont Weir notch flows



*HEC-RAS model assumes flows only from Fremont weir and Sommer et al.(2004)
assumes all flows that enter the Yolo Bypass

Figure 5.A.A.4-10. Comparison of flooded area for different models and models assumptions.

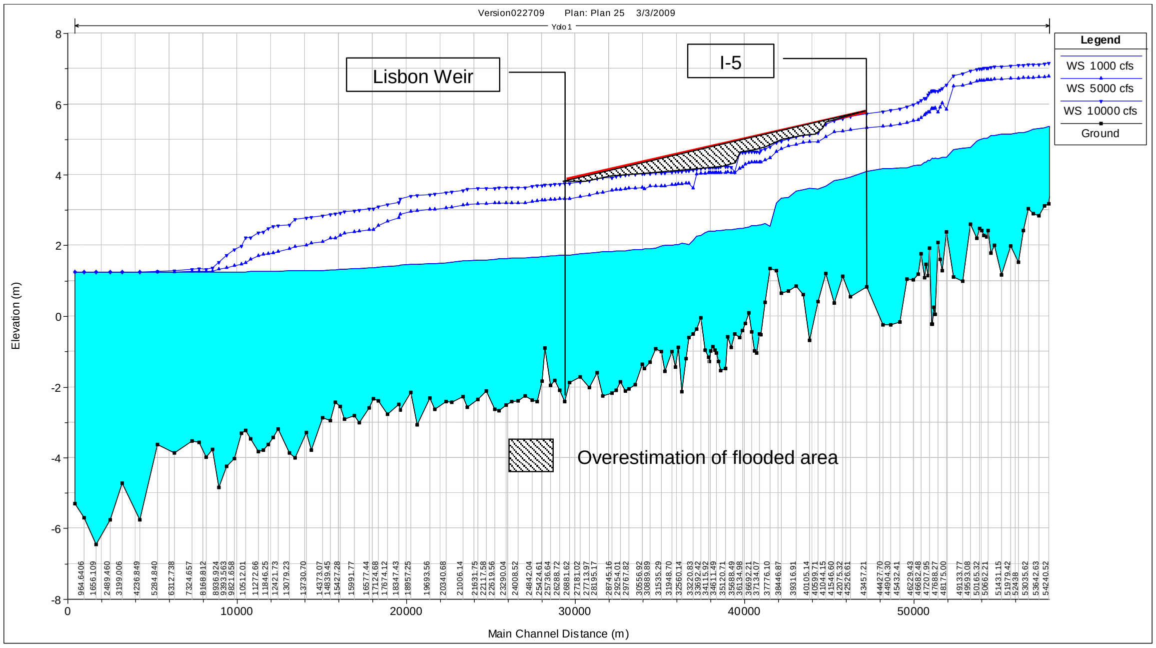


Figure 5.A.A.4-11. Possible overestimation of flooded areas using a linearization of water surface between two stations.

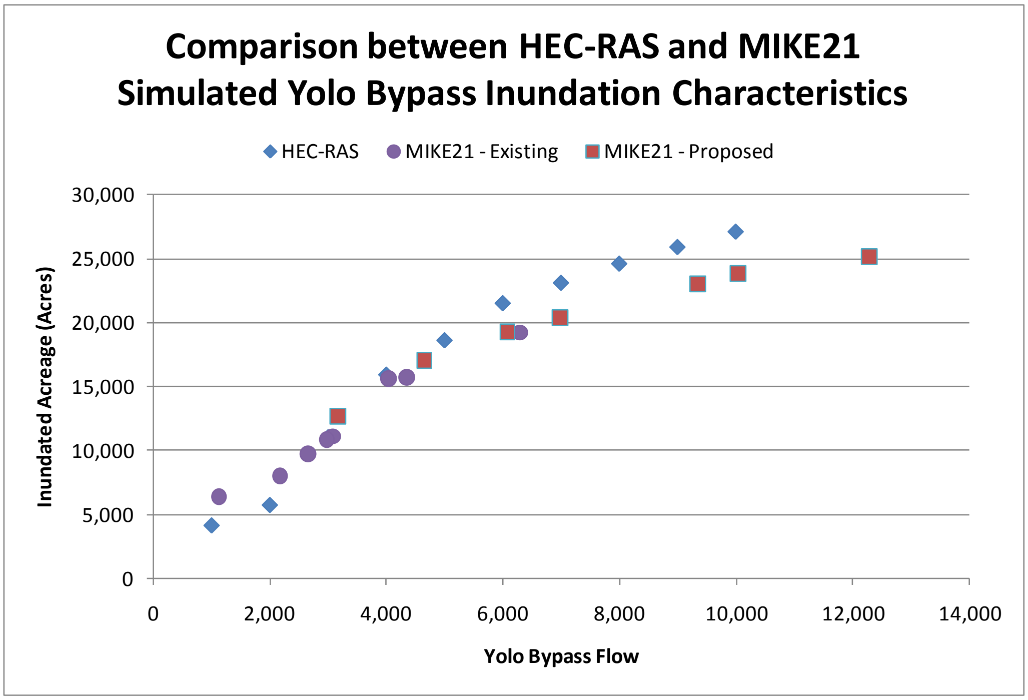


Figure 5.A.A.4-12. Comparison of HEC-RAS and MIKE21 simulated Yolo Bypass inundation characteristics.

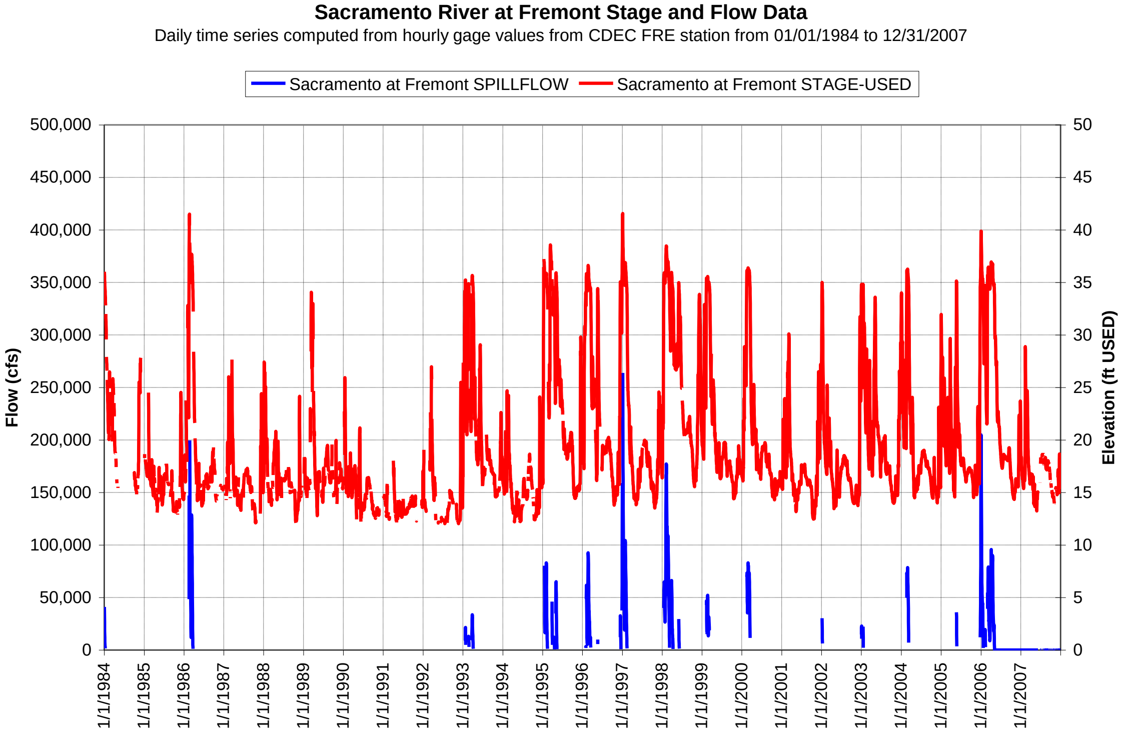


Figure 5.A.A.4-13. CDEC daily time series for stage and flow at Fremont Weir. Data converted from hourly to daily

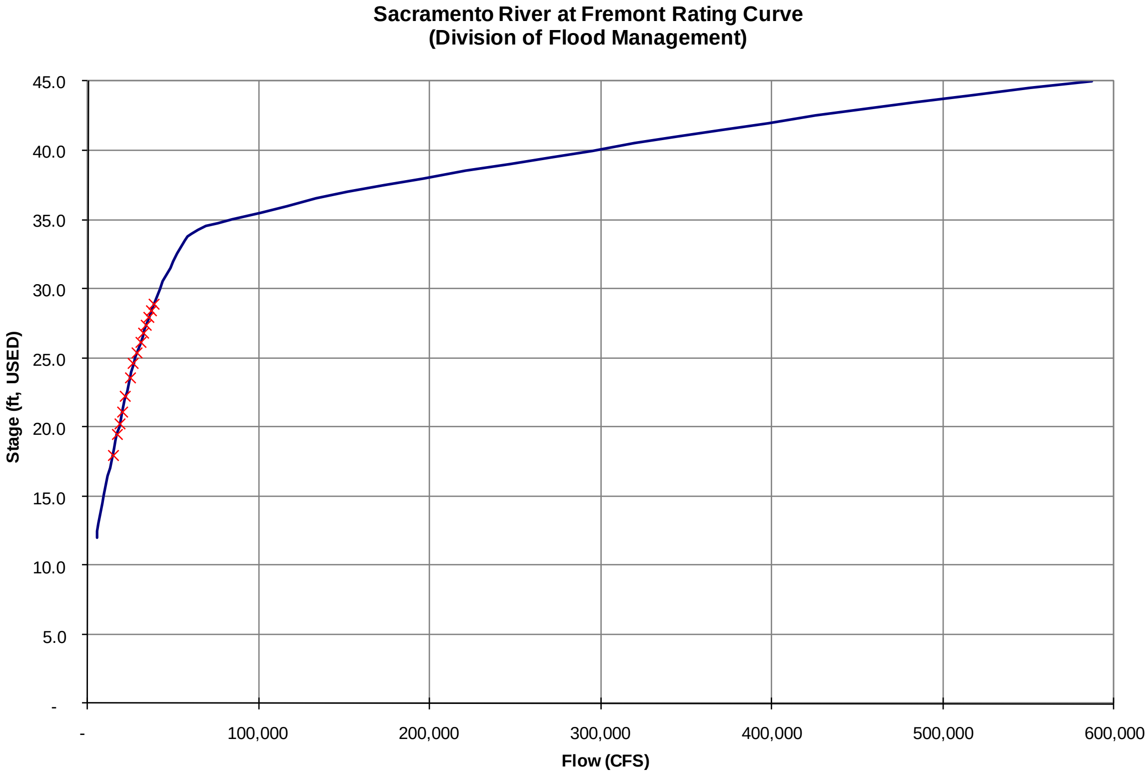


Figure 5.A.A.4-14. Sacramento River at Fremont rating curve (Source: California Division of Flood Management)

.

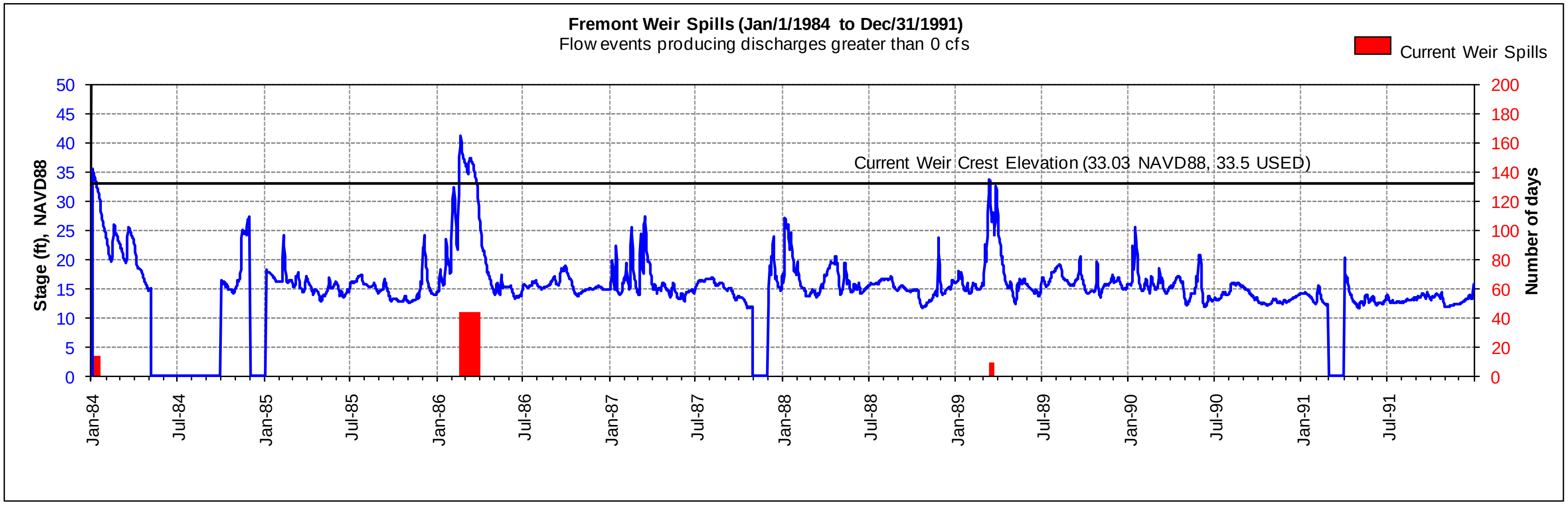


Figure 5.A.A.4-15. Observed Fremont Weir spills and duration (Jan 1984 to Dec 1991)

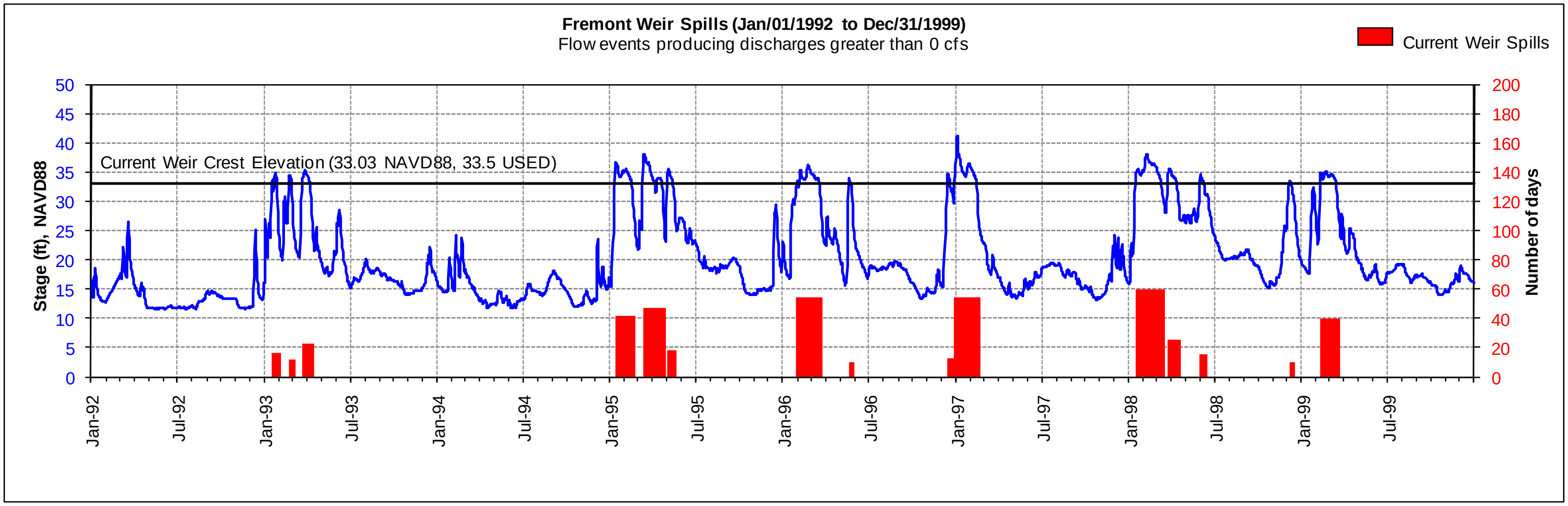


Figure 5.A.A.4-16. Observed Fremont Weir spills and duration (Jan 1992 to Dec 1999)

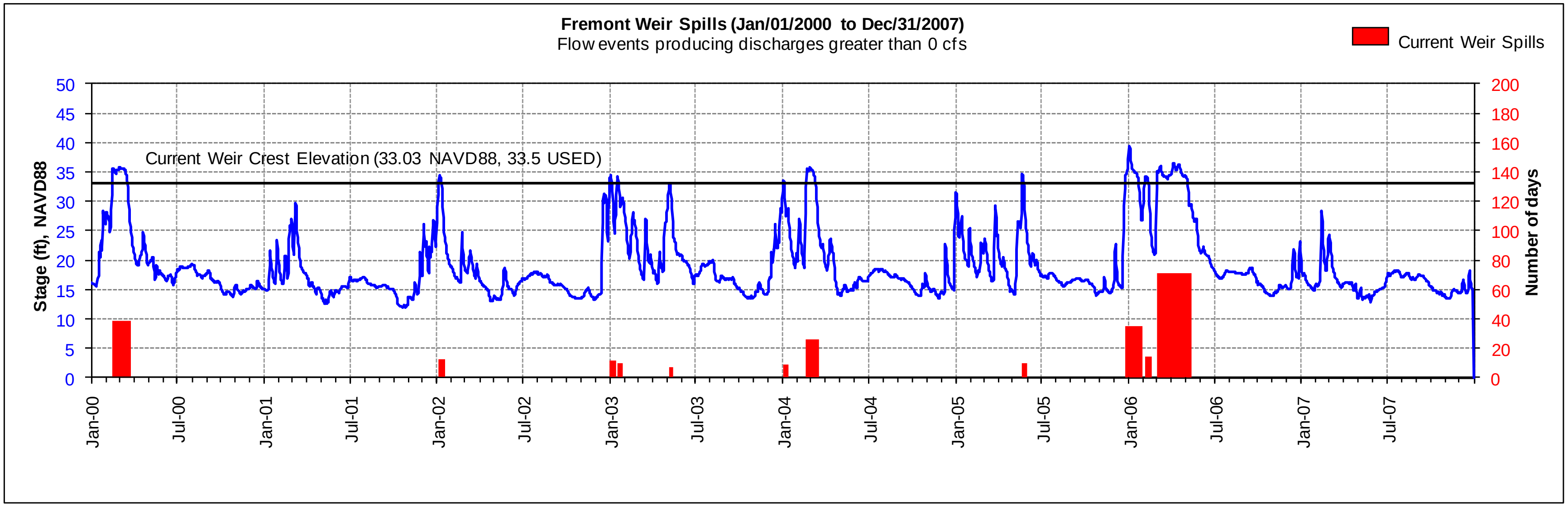


Figure 5.A.A.4-17. Observed Fremont Weir spills and duration (Jan 2000 to Dec 2007)

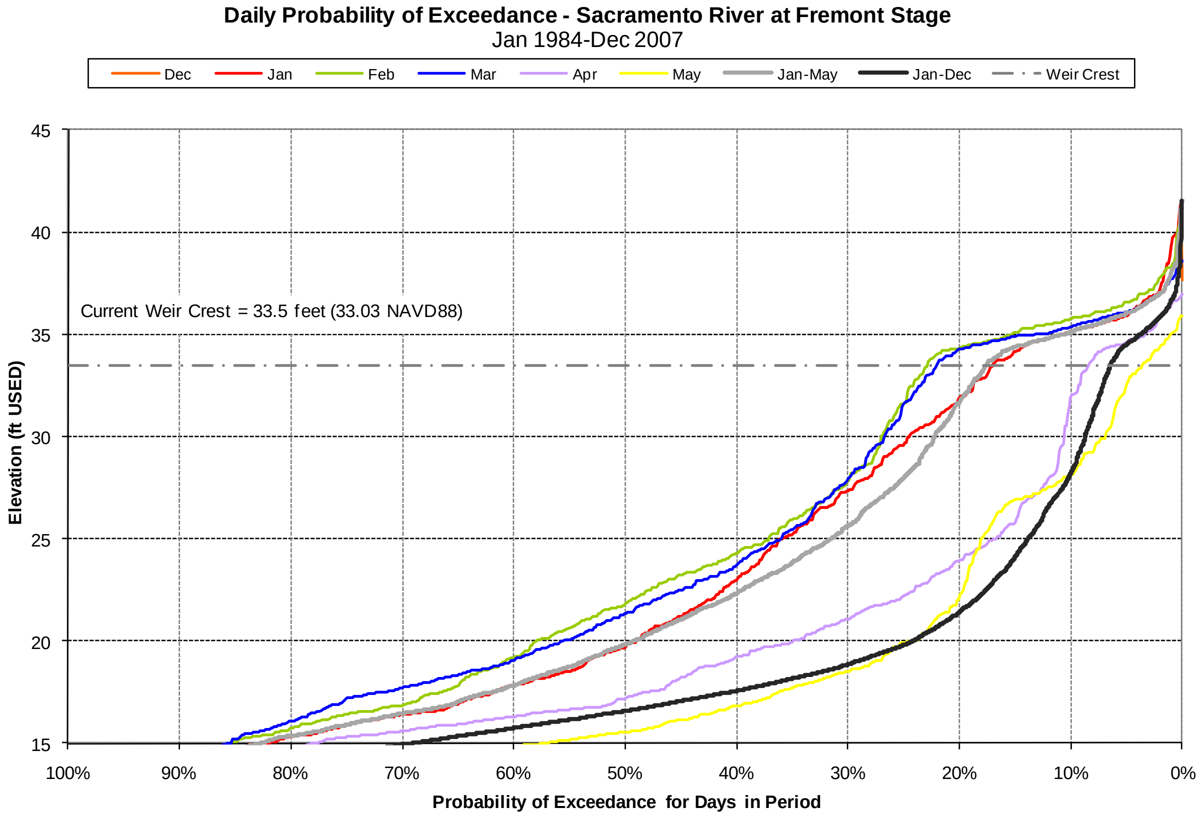


Figure 5.A.A.4-18. Sacramento River at Fremont stage probability exceedance plot, daily average (1984- 2007)

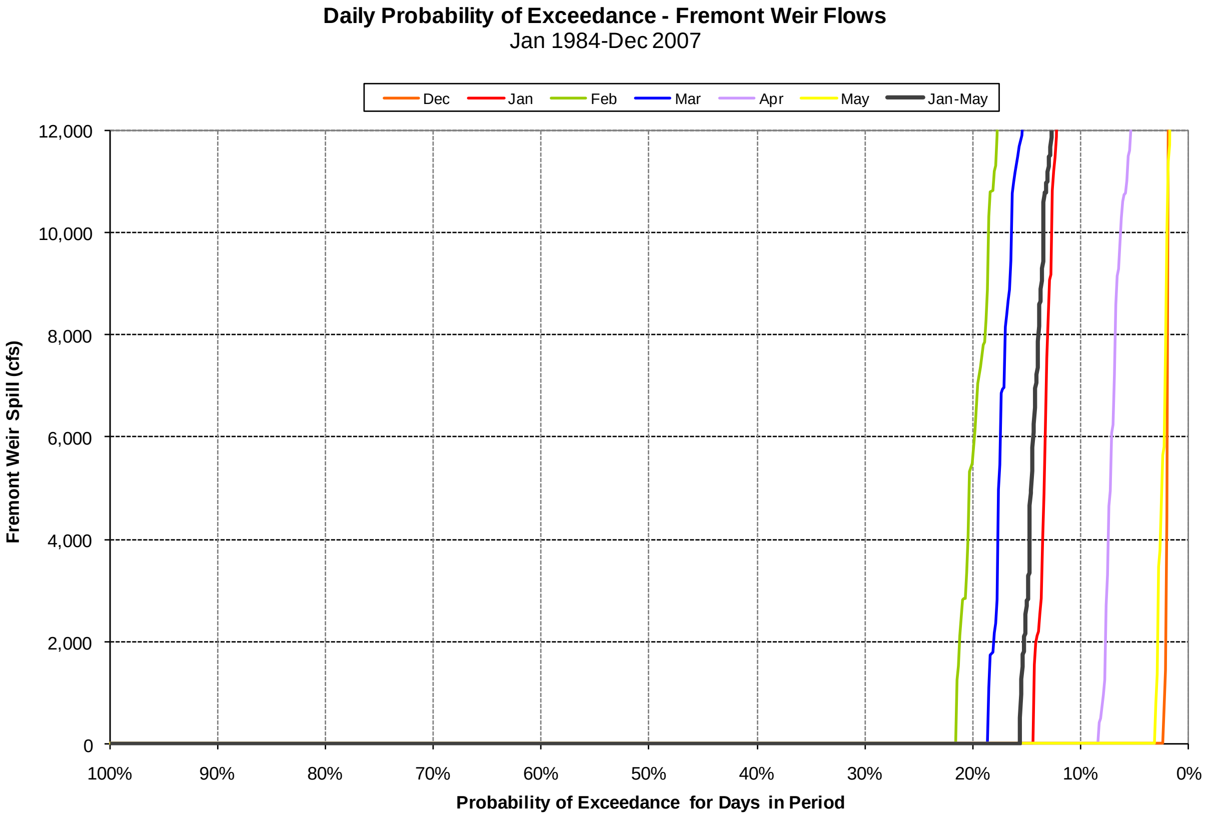


Figure 5.A.A.4-19. Fremont Weir spills probability of exceedance plot, daily average (1984-2007)

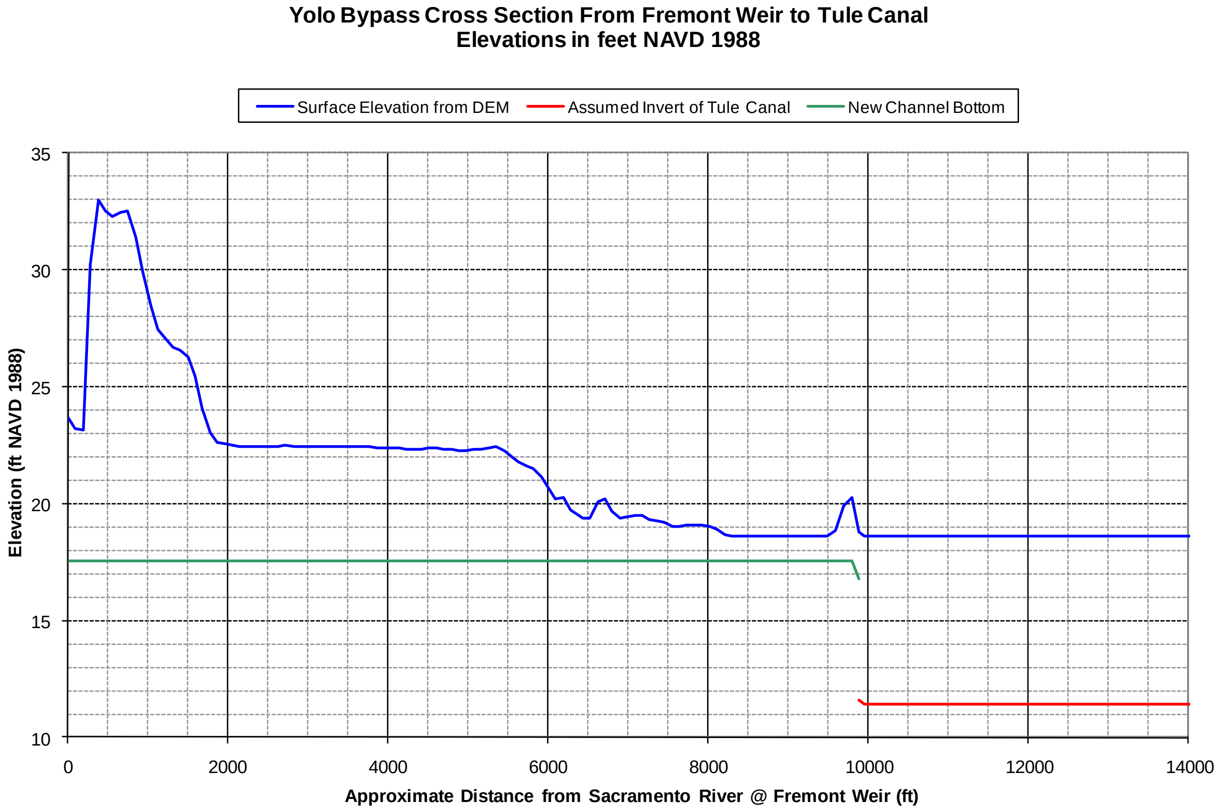


Figure 5.A.A.4-20. Yolo Bypass Profile from Sacramento River at Fremont Weir to Tule Canal

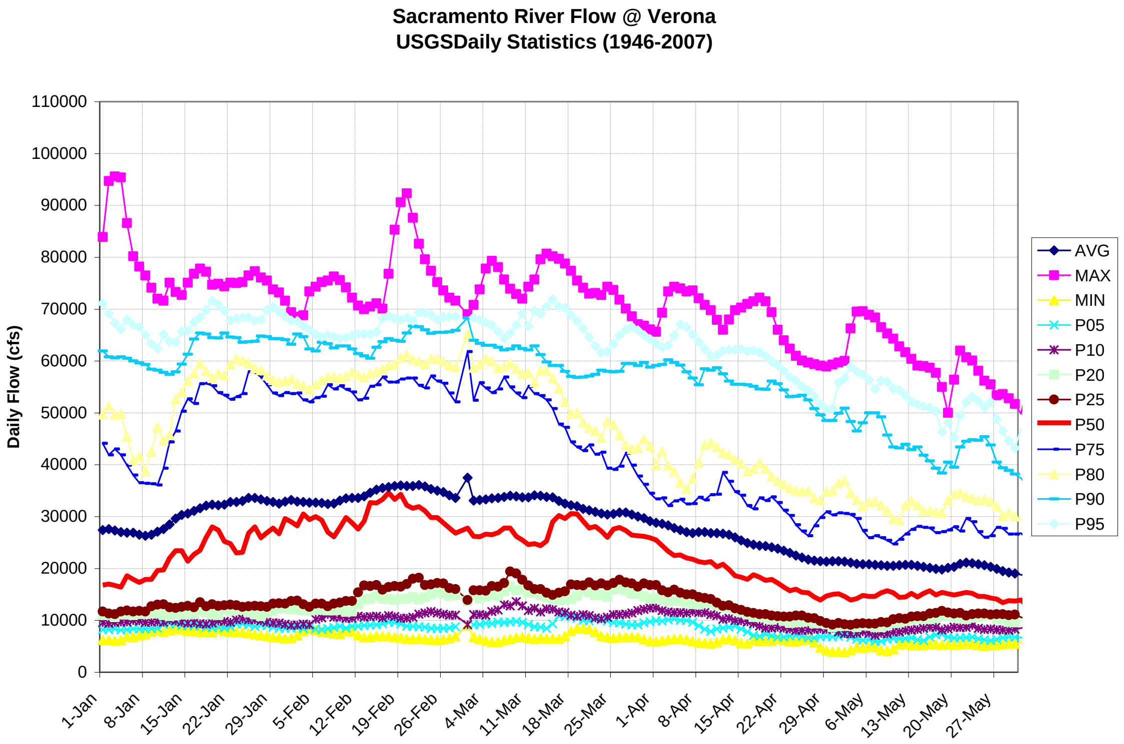


Figure 5.A.A.4-21. Daily statistics data from USGS for Sacramento River at Verona

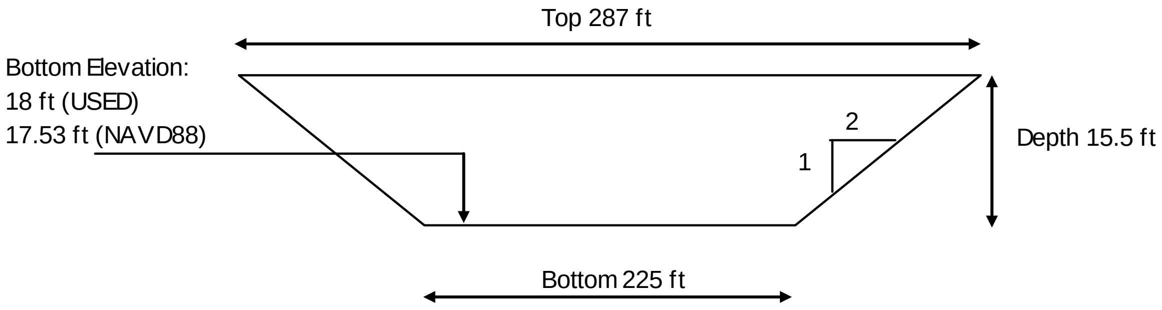


Figure 5.A.A.4-22. Dimensions for the channel connecting the Fremont Weir to the Tule Canal at the Yolo Bypass

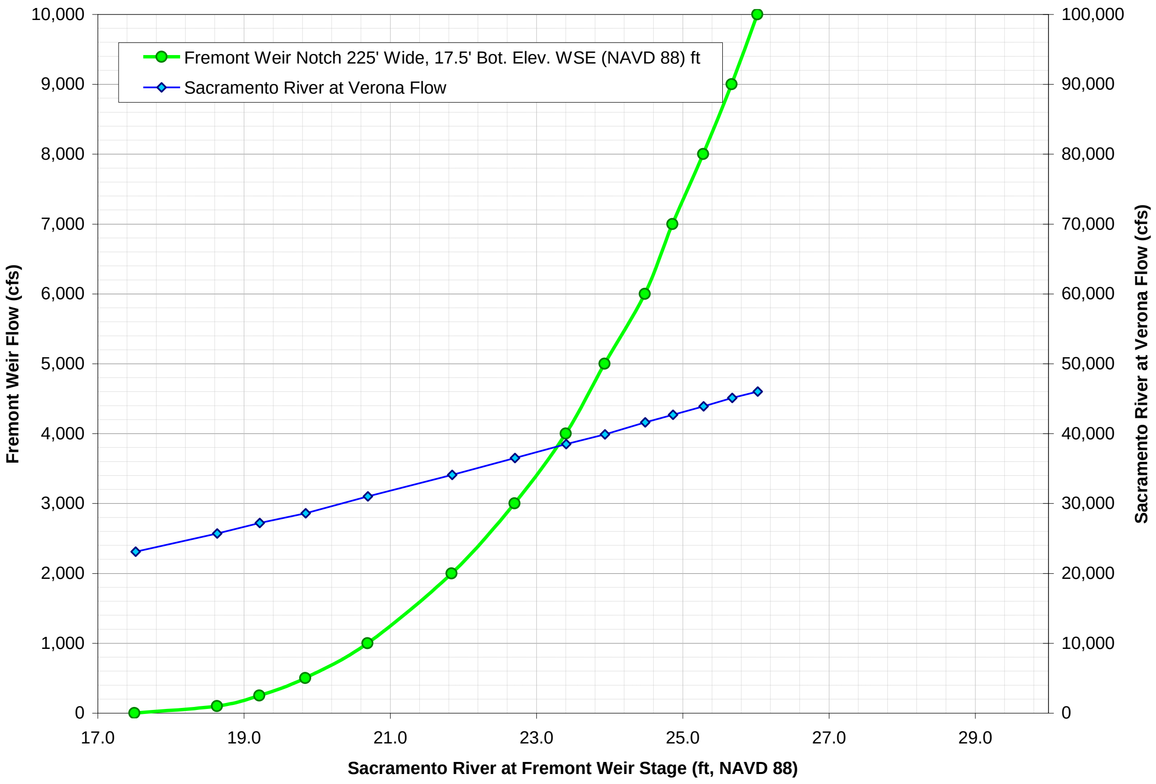


Figure 5.A.A.4-23. Rating curves for the modified Fremont Weir and Sacramento River flow at Verona

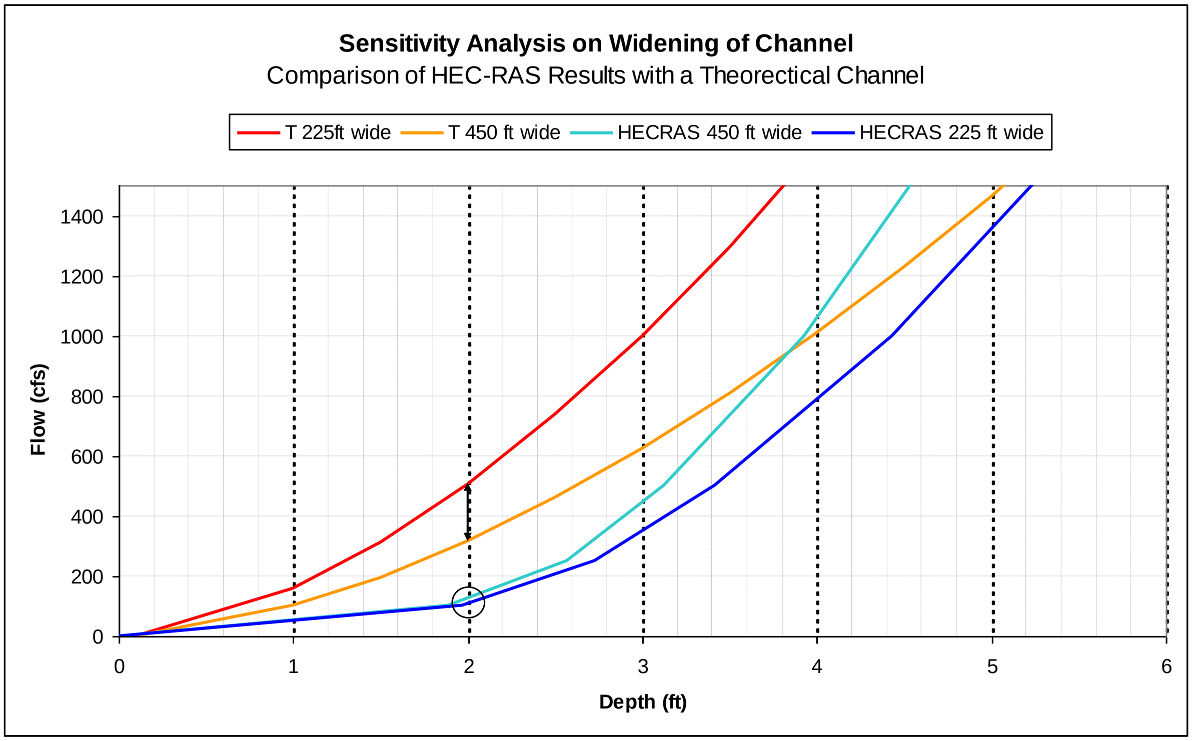


Figure 5.A.A.4-24. Sensitivity analysis on the effects of widening the spill channel

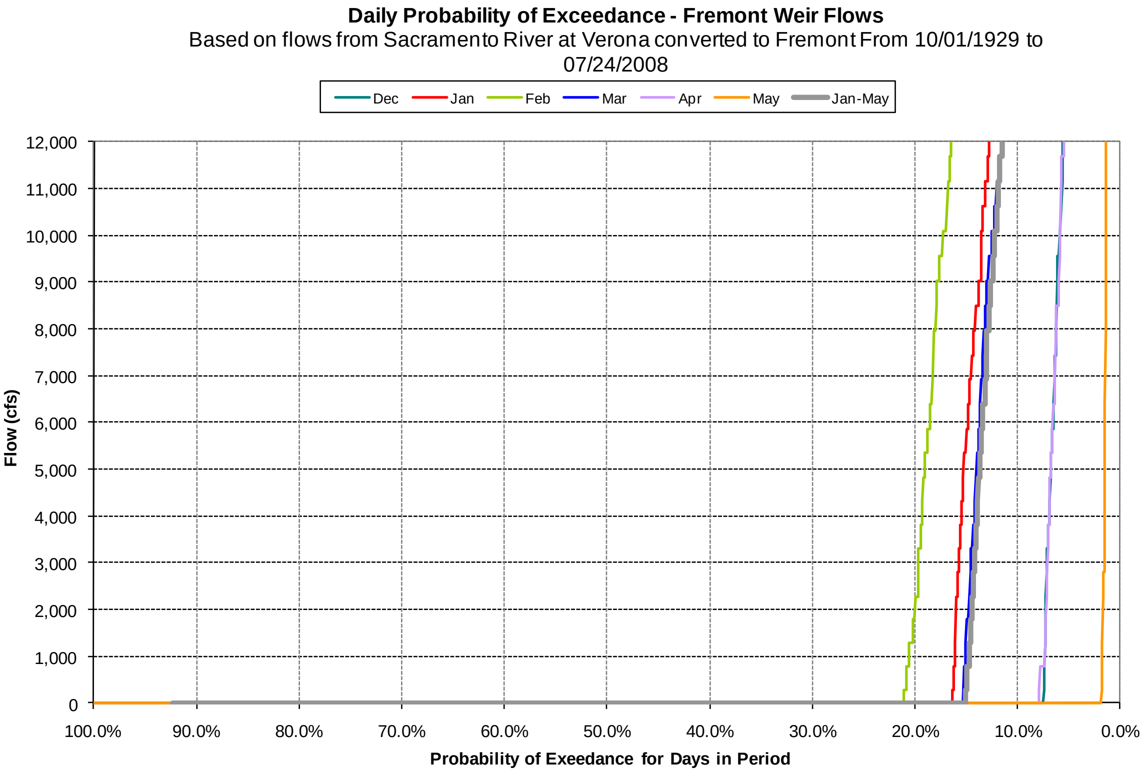


Figure 5.A.A.4-25. Exceedance plot for current Fremont Weir flows for selected months

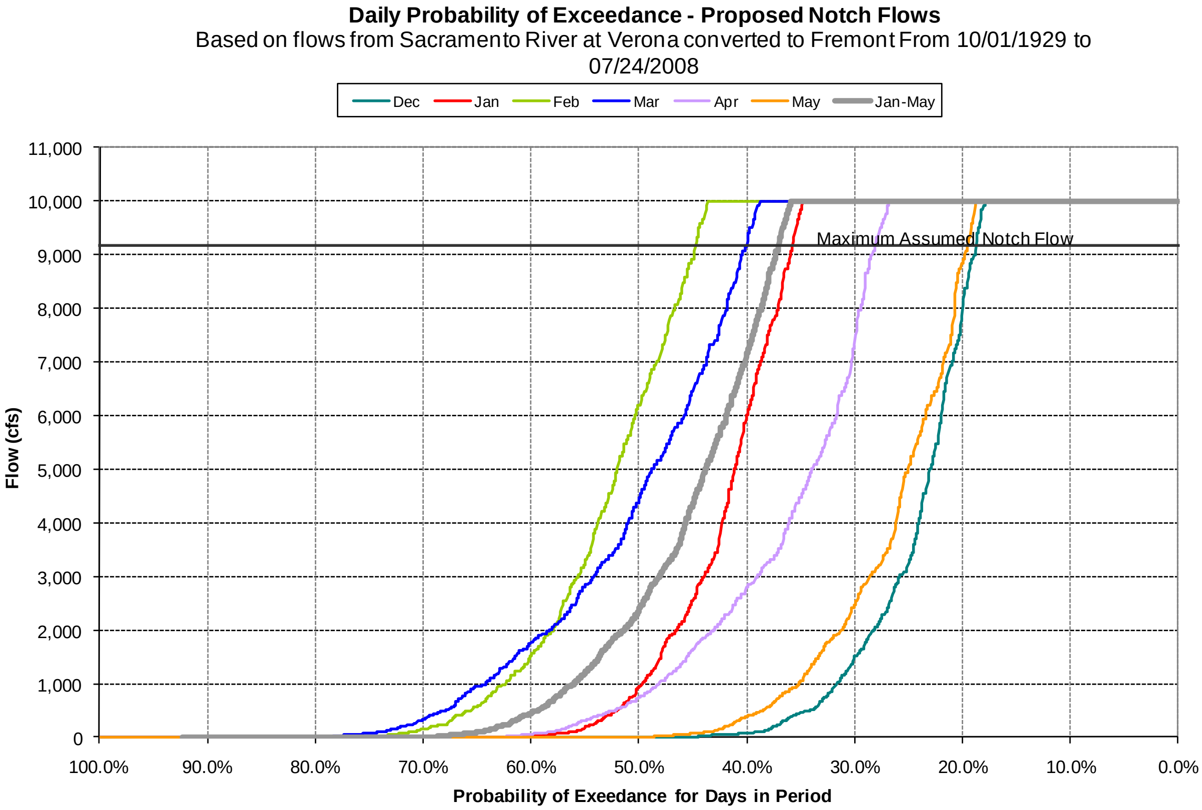


Figure 5.A.A.4-26. Exceedance plot for modified Fremont Weir for selected months

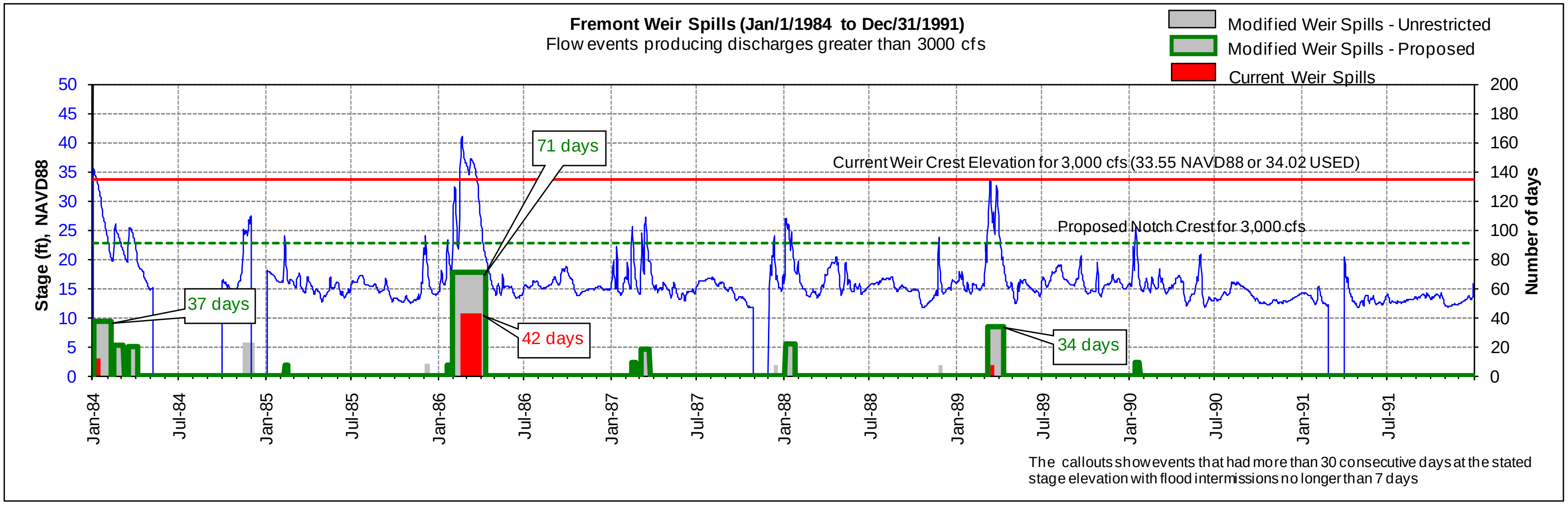


Figure 5.A.A.4-27. Events producing discharges greater than 3000 cfs for more than 30 days (1984-1991)

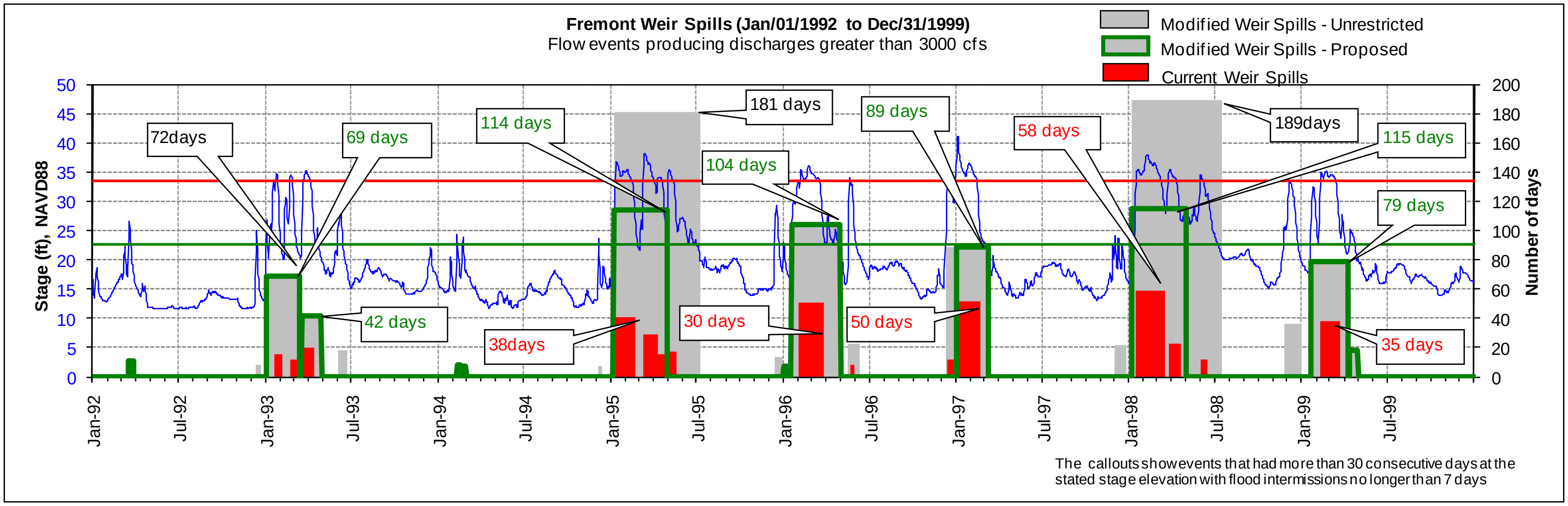


Figure 5.A.A.4-28. Events producing discharges greater than 3000 cfs for more than 30 days (1992-1999)

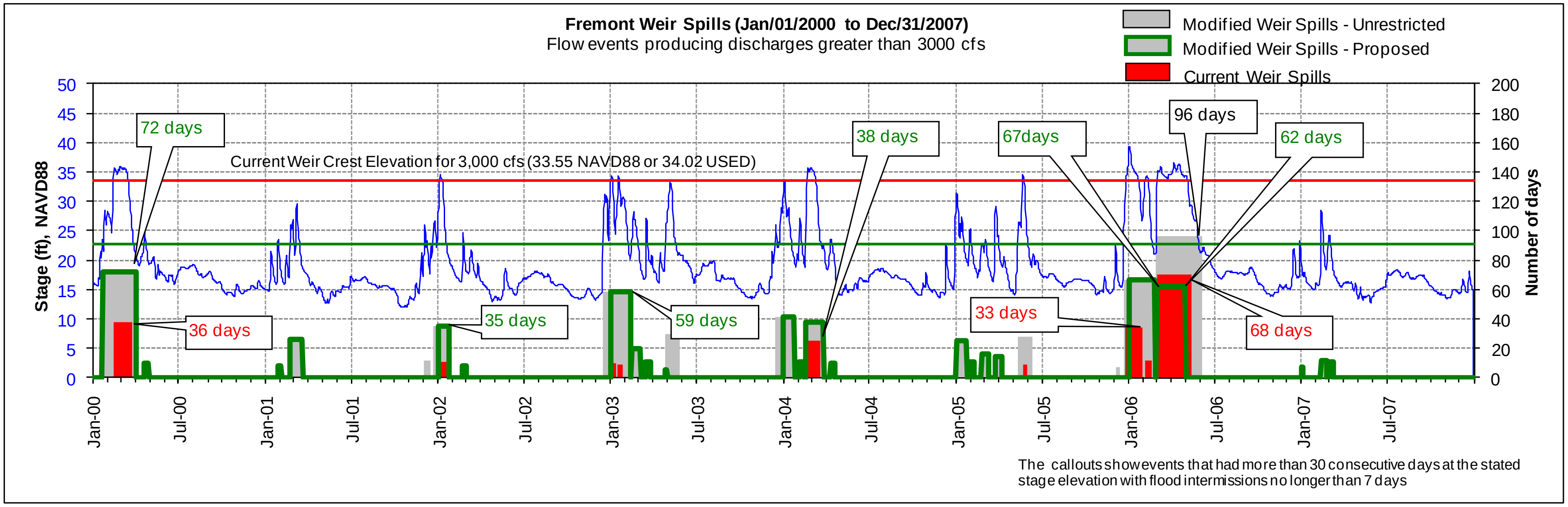


Figure 5.A.A.4-29. Events producing discharges greater than 3000 cfs for more than 30 days (2000-2007)

5.A.A.5 Attachment 5: Summary of CVP/SWP Water Supply Contract Amounts

This attachment summarizes the water supply contract amounts for the CVP/SWP assumed in the CalSim II modeling for the California WaterFix Biological Assessment (CWF BA). The first section lists the contract amounts for all the CVP/SWP contractors and other water rights holders, except for the American River users, which are listed in the next section.

5.A.A.5.1 CVP/SWP Delivery Specifications

This section lists the CVP/SWP contract amounts and other water rights assumptions used in the CWF BA No Action Alternative and Proposed Action CalSim II simulations (Tables 5.A.A.5-1 through Tables 5.A.A.5-5).

Table 5.A.A.5-1 Delta Deliveries - Future Conditions

CVP/ SWP Contractor	Geographic Location	Water Right (TAF/yr)	SWP Table A Amount (TAF)		SWP Article 21 Demand (TAF/mon)	CVP Water Service Contracts (TAF/yr)	
			Ag	M&I		AG	M&I
North Delta							
City of Vallejo	City of Vallejo						16.0
CCWD*	Contra Costa County						195.0
Napa County FC&WCD	North Bay Aqueduct			29.03	1.0		
Solano County WA	North Bay Aqueduct			47.51	1.0		
Fairfield, Vacaville and Benicia Agreement	North Bay Aqueduct	31.60					
City of Antioch	City of Antioch	18.0					
Total North Delta		**49.6**	**0.0**	**76.5**	**2.0**	**0.0**	**211.0**
South Delta							
Delta Water Supply Project	City of Stockton	32.4					
Total South Delta		**32.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Total		**82.0**	**0.0**	**76.5**	**2.0**	**0.0**	**211.0**

* The new Los Vaqueros module in CALSIM II is used to determine the range of demands that are met by CVP contracts or other water rights.

Table 5.A.A.5-2 CVP North-of-the-Delta Deliveries - Future Conditions

CVP Contractor	Geographic Location	CVP Water Service Contracts (TAF/yr)		Settlement / Exchange Contractor (TAF/yr)	Water Rights/ Non-CVP (TAF/yr)	Level 2 Refuges1 (TAF/yr)
		AG	M&I			
Anderson Cottonwood ID	Sacramento River Redding Subbasin			128.0		
Clear Creek CSD		13.8	1.5			
Bella Vista WD		22.1	2.4			
Shasta CSD			1.0			
Sac R. Misc. Users				3.4		
Redding, City of				21.0		
City of Shasta Lake		2.5	0.3			

CVP Contractor	Geographic Location	CVP Water Service Contracts (TAF/yr)		Settlement / Exchange Contractor (TAF/yr)	Water Rights/ Non-CVP (TAF/yr)	Level 2 Refuges1 (TAF/yr)
		AG	M&I			
Mountain Gate CSD			0.4			
Shasta County Water Agency		0.5	0.5			
Redding, City of/Buckeye			6.1			
Total		**38.9**	**12.2**	**152.4**		**0.0**
Corning WD	Corning Canal	23.0				
Proberta WD		3.5				
Thomes Creek WD		6.4				
Total		**32.9**	**0.0**	**0.0**		**0.0**
Kirkwood WD	Tehama-Colusa Canal	2.1				
Glide WD		10.5				
Kanawha WD		45.0				
Orland-Artois WD		53.0				
Colusa, County of		20.0				
Colusa County WD		62.2				
Davis WD		4.0				
Dunnigan WD		19.0				
La Grande WD		5.0				
Westside WD		65.0				
Total		**285.8**	**0.0**	**0.0**		**0.0**
Sac. R. Misc. Users[2]	Sacramento River			1.5		
Glenn Colusa ID	Glenn-Colusa Canal			441.5 383.5		
Sacramento NWR						53.4
Delevan NWR						24.0
Colusa NWR						28.8
Colusa Drain M.W.C.	Colusa Basin Drain			7.7 62.3		

CVP Contractor	Geographic Location	CVP Water Service Contracts (TAF/yr)		Settlement / Exchange Contractor (TAF/yr)	Water Rights/ Non-CVP (TAF/yr)	Level 2 Refuges1 (TAF/yr)
		AG	M&I			
Total		**0.0**	**0.0**	**895.0**		**106.2**
Princeton-Cordova-Glenn ID	Sacramento River			67.8		
Provident ID				54.7		
Maxwell ID				1.8		
				16.2		
Sycamore Family Trust				31.8		
Roberts Ditch IC				4.4		
Sac R. Misc. Users[2]				4.9		
				9.5		
Total		**0.0**	**0.0**	**191.2**		**0.0**
Reclamation District 108	Sacramento River			12.9		
				219.1		
River Garden Farms				29.8		
Meridian Farms WC				35.0		
Pelger Mutual WC				8.9		
Reclamation District 1004				71.4		
Carter MWC				4.7		
Sutter MWC				226.0		
Tisdale Irrigation & Drainage Co.				9.9		
Sac R. Misc. Users[2]				103.4		
				0.9		
Feather River WD export		20.0				
Total		**20.0**	**0.0**	**722.1**		**0.0**
Sutter NWR	Sutter bypass water for Sutter NWR					25.9
Gray Lodge WMA	Feather River					41.4
Butte Sink Duck Clubs						15.9

CVP Contractor	Geographic Location	CVP Water Service Contracts (TAF/yr)		Settlement / Exchange Contractor (TAF/yr)	Water Rights/ Non-CVP (TAF/yr)	Level 2 Refuges1 (TAF/yr)
		AG	M&I			
Total		**0.0**	**0.0**	**0.0**		**83.2**
Sac. R. Misc. Users[2]	Sacramento River			56.8		
City of West Sacramento				23.6		
Davis-Woodland Water Supply Project		DSA 65				
Total		**0.0**	**0.0**	**80.4**		**0.0**
Sac R. Misc. Users	Lower Sacramento River			4.8		
Natomas Central MWC				120.2		
Pleasant Grove-Verona MWC				26.3		
City of Sacramento (PCWA)			0.0		0.0	
PCWA (Water Rights)			0.0		0.0	
Total		**0.0**	**0.0**	**151.3**	**0.0**	
Total CVP North-of-Delta		**377.6**	**12.2**	**2193.8**	**0.0**	**189.4**

Notes:

[1] Level 4 Refuge water needs are not included.

[2] Refer to Table 8 for more information

Table 5.A.A.5-3 CVP South-of-the-Delta Deliveries - Future Conditions

CVP Contractor	Geographic Location	CVP Water Service Contracts (TAF/yr)		Settlement/ Exchange Contractor (TAF/yr)	Water Rights/ Non-CVP (TAF/yr)	Level 2 Refuges* (TAF/yr)	Losses (TAF/yr)
		AG	M&I				
Byron-Bethany ID	Upper DMC	20.6					
Tracy, City of			10.0				
			5.0				
			5.0				
Banta Carbona ID		20.0					
Total		**40.6**	**20.0**	**0.0**	**0.0**	**0.0**	**0.0**
Del Puerto WD	Upper DMC	12.1					

CVP Contractor	Geographic Location	CVP Water Service Contracts (TAF/yr)		Settlement/ Exchange Contractor (TAF/yr)	Water Rights/ Non-CVP (TAF/yr)	Level 2 Refuges* (TAF/yr)	Losses (TAF/yr)
		AG	M&I				
Davis WD		5.4					
Foothill WD		10.8					
Hospital WD		34.1					
Kern Canon WD		7.7					
Mustang WD		14.7					
Orestimba WD		15.9					
Quinto WD		8.6					
Romero WD		5.2					
Salado WD		9.1					
Sunflower WD		16.6					
West Stanislaus WD		50.0					
Patterson WD		16.5			6.0		
Total		**206.7**	**0.0**	**0.0**	**6.0**	**0.0**	**0.0**
Upper DMC Loss	Upper DMC						18.5
Panoche WD	Lower DMC Volta	6.6					
San Luis WD		65.0					
Laguna WD		0.8					
Eagle Field WD		4.6					
Mercy Springs WD		2.8					
Oro Loma WD		4.6					
Total		**84.4**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Central California ID	Lower DMC Volta			140.0			
Grasslands via CCID	Lower DMC Volta					81.8	
Los Banos WMA						11.2	
Kesterson NWR	Lower DMC Volta					10.5	

CVP Contractor	Geographic Location	CVP Water Service Contracts (TAF/yr)		Settlement/ Exchange Contractor (TAF/yr)	Water Rights/ Non-CVP (TAF/yr)	Level 2 Refuges* (TAF/yr)	Losses (TAF/yr)
		AG	M&I				
Freitas - SJBAP						6.3	
Salt Slough - SJBAP						8.6	
China Island - SJBAP						7.0	
Volta WMA						13.0	
Grassland via Volta Wasteway						23.2	
Total		**0.0**	**0.0**	**140.0**	**0.0**	**161.5**	**0.0**
Fresno Slough WD	San Joaquin River at Mendota Pool	4.0			0.9		
James ID		35.3			9.7		
Coelho Family Trust		2.1			1.3		
Tranquillity ID		13.8			20.2		
Tranquillity PUD		0.1			0.1		
Reclamation District 1606		0.2			0.3		
Central California ID				392.4			
Columbia Canal Co.				59.0			
Firebaugh Canal Co.				85.0			
San Luis Canal Co.				23.6			
M.L. Dudley Company					2.3		
Grasslands WD						29.0	
Mendota WMA						27.6	
Losses							101.5
Total		**55.5**	**0.0**	**560.0**	**34.8**	**56.6**	**101.5**
San Luis Canal Co.	San Joaquin River at Sack Dam			140.0			
Grasslands WD						2.3	
Los Banos WMA						12.4	
San Luis NWR						19.5	
West Bear Creek NWR						7.5	

CVP Contractor	Geographic Location	CVP Water Service Contracts (TAF/yr)		Settlement/ Exchange Contractor (TAF/yr)	Water Rights/ Non-CVP (TAF/yr)	Level 2 Refuges* (TAF/yr)	Losses (TAF/yr)
		AG	M&I				
East Bear Creek NWR						8.9	
Total		**0.0**	**0.0**	**140.0**	**0.0**	**50.6**	**0.0**
San Benito County WD (Ag)	San Felipe	35.6					
Santa Clara Valley WD (Ag)		33.1					
Pajaro Valley WD		6.3					
San Benito County WD (M&I)			8.3				
Santa Clara Valley WD (M&I)			119.4				
Total		**74.9**	**127.7**	**0.0**	**0.0**	**0.0**	**0.0**
San Luis WD	CA reach 3	60.1					
CA, State Parks and Rec		2.3					
Affonso/Los Banos Gravel Co.		0.3					
Total		**62.6**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Panoche WD	CVP Dos Amigos PP/ CA reach 4	87.4					
Pacheco WD		10.1					
Total		**97.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Westlands WD (Centinella)	CA reach 4	2.5					
Westlands WD (Broadview WD)		27.0					
Westlands WD (Mercy Springs WD)		4.2					
Westlands WD (Widern WD)		3.0					
Total		**36.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Westlands WD: CA Joint Reach 4	CA reach 4	219.0					
Westlands WD: CA Joint Reach 5	CA reach 5	570.0					
Westlands WD: CA Joint Reach 6	CA reach 6	219.0					
Westlands WD: CA Joint Reach 7	CA reach 7	142.0					

CVP Contractor	Geographic Location	CVP Water Service Contracts (TAF/yr)		Settlement/ Exchange Contractor (TAF/yr)	Water Rights/ Non-CVP (TAF/yr)	Level 2 Refuges* (TAF/yr)	Losses (TAF/yr)
		AG	M&I				
Total		**1150.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Avenal, City of	CA reach 7		3.5		3.5		
Coalinga, City of			10.0				
Huron, City of			3.0				
Total		**0.0**	**16.5**	**0.0**	**3.5**	**0.0**	**0.0**
CA Joint Reach 3 - Loss	CVP Dos Amigos PP/CA reach 3						2.5
CA Joint Reach 4 - Loss	CA reach 4						10.1
CA Joint Reach 5 - Loss	CA reach 5						30.1
CA Joint Reach 6 - Loss	CA reach 6						12.5
CA Joint Reach 7 - Loss	CA reach 7						8.5
Total		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**63.7**
Cross Valley Canal - CVP	CA reach 14						
Fresno, County of		3.0					
Hills Valley ID-Amendatory		3.3					
Kern-Tulare WD		40.0					
Lower Tule River ID		31.1					
Pixley ID		31.1					
Rag Gulch WD		13.3					
Tri-Valley WD		1.1					
Tulare, County of		5.3					
Kern NWR						11.0	
Pixley NWR						1.3	
Total		**128.3**	**0.0**	**0.0**	**0.0**	**12.3**	**0.0**
Total CVP South-of-Delta		**1937.1**	**164.2**	**840.0**	**44.3**	**281.0**	**183.7**

* Level 4 Refuge water needs are not included

Table 5.A.A.5-4 SWP North-of-the-Delta Deliveries - Future Conditions

SWP CONTRACTOR	Geographic Location	FRSA Amount (TAF)	Water Right (TAF/yr)	Table A Amount (TAF)		Article 21 Demand (TAF/mon)	Other (TAF/yr)
				Ag	M&I		
Feather River							
Palermo	FRSA		17.6				
County of Butte	Feather River				27.5		
Thermalito	FRSA		8.0				
Western Canal	FRSA	150.0	145.0				
Joint Board	FRSA	550.0	5.0				
City of Yuba City	Feather River				9.6		
Feather WD	FRSA	17.0					
Garden, Oswald, Joint Board	FRSA						
Garden	FRSA	12.9	5.1				
Oswald	FRSA	2.9					
Joint Board	FRSA	50.0					
Plumas, Tudor	FRSA						
Plumas	FRSA	8.0	6.0				
Tudor	FRSA	5.1	0.2				
Total Feather River Area		**795.8**	**186.9**	**0.0**	**37.1**		
Other							
Yuba County Water Agency	Yuba River						Variable
							333.6
Camp Far West ID	Yuba River						12.6
Bear River Exports	American R/DSA70						Variable
							95.2
Feather River Exports to American River (left bank to DSA70)	American R/DSA70		11.0				

Table 5.A.A.5-5 SWP South-of-the-Delta Deliveries - Future Conditions

SWP Contractor	Geographic Location	Table A Amount (TAF)		Article 21 Demand (TAF/mon)	Losses (TAF/yr)
		Ag	M&I		
Alameda Co. FC&WCD, Zone 7	SBA reaches 1-4		47.60	1.00	
	SBA reaches 5-6		33.02	None	
	Total		**80.62**	**1.00**	
Alameda County WD	SBA reaches 7-8		42.00	1.00	
Santa Clara Valley WD	SBA reach 9		100.00	4.00	
Oak Flat WD	CA reach 2A	5.70		None	
County of Kings	CA reach 8C	9.31		None	
Dudley Ridge WD	CA reach 8D	50.34		1.00	
Empire West Side ID	CA reach 8C	2.00		1.00	
Kern County Water Agency	CA reaches 3, 9-13B	608.86	134.60	None	
	CA reaches 14A-C	99.20		180.00	
	CA reaches 15A-16A	59.40		None	
	CA reach 31A	80.67		None	
	Total	**848.13**	**134.60**	**180.00**	
Tulare Lake Basin WSD	CA reaches 8C-8D	88.92		15.00	
San Luis Obispo Co. FC&WCD	CA reaches 33A-35		25.00	None	
Santa Barbara Co. FC&WCD	CA reach 35		45.49	None	
Antelope Valley-East Kern WA	CA reaches 19-20B, 22A-B		141.40	1.00	
Castaic Lake WA	CA reach 31A	12.70		1.00	
	CA reach 30		82.50	None	
	Total	**12.70**	**82.50**	**1.00**	
Coachella Valley WD	CA reach 26A		138.35	2.00	
Crestline-Lake Arrowhead WA	CA reach 24		5.80	None	
Desert WA	CA reach 26A		55.75	5.00	
Littlerock Creek ID	CA reach 21		2.30	None	
Mojave WA	CA reaches 19, 22B-23		82.80	None	
Metropolitan WDSC	CA reach 26A		148.67	90.70	

SWP Contractor	Geographic Location	Table A Amount (TAF)		Article 21 Demand (TAF/mon)	Losses (TAF/yr)
		Ag	M&I		
	CA reach 30		756.69	74.80	
	CA reaches 28G-H		102.71	27.60	
	CA reach 28J		903.43	6.90	
	Total		**1911.50**	**200.00**	
Palmdale WD	CA reaches 20A-B		21.30	None	
San Bernardino Valley MWD	CA reach 26A		102.60	None	
San Gabriel Valley MWD	CA reach 26A		28.80	None	
San Gorgonio Pass WA	CA reach 26A		17.30	None	
Ventura County FCD	CA reach 29H		3.15	None	
	CA reach 30		16.85	None	
	Total		**20.00**		

SWP Contractor	Geographic Location	Table A Amount (TAF)		Article 21 Demand (TAF/mon)	Losses (TAF/yr)
		Ag	M&I		
SWP Losses	CA reaches 1-2				7.70
	SBA reaches 1-9				0.60
	CA reach 3				10.80
	CA reach 4				2.60
	CA reach 5				3.90
	CA reach 6				1.20
	CA reach 7				1.60
	CA reaches 8C-13B				11.90
	Wheeler Ridge PP and CA reaches 14A-C				3.60
	Chrisman PP and CA reaches 15A-18A				1.80
	Pearblossom PP and CA reaches 17-21				5.10
	Mojave PP and CA reaches 22A-23				4.00
	REC and CA reaches 24-28J				1.40
	CA reaches 29A-29F				1.90
	Castaic PWP and CA reach 29H				3.10
	REC and CA reach 30				2.40
	Total				**63.60**
Total		**1017.10**	**3038.11**	**412.00**	**63.60**

5.A.A.5.2 American River Demand Assumptions

American River demand assumptions used for the CWF BA CalSim II modeling are consistent with the LTO EIS (Reclamation 2015). Following is a summary of the key American River assumptions used for CWF BA CalSim II modeling:

- American River Flow Management is included, as required by the NMFS Biological Opinion (Jun 2009) Action II.1
- Water rights and Central Valley Project (CVP) demands are assumed at a full “Build-out” condition with CVP contracts at full contract amounts
- Placer County Water Agency (PCWA) Pump Station is included at full demand
- Freeport Regional Water Project (FRWP) is included at full demand (EBMUD CVP contracts and SCWA CVP contract and new appropriative water rights and water acquisitions as modeled in the FRWP EIS/R)
- Sacramento River Water Reliability Project (SRWRP) is not included
- Sacramento Area Water Forum is not included (dry year “wedge” reductions and mitigation water releases are not included)

Table 5.A.A.5-6 below summarizes the water rights, CVP contract amounts, and demand amounts for each diverter in the American River system in the No Action Alternative and the Proposed Action.

Table 5.A.A.5-6 American River Diversions Assumed in the No Action Alternative and the Proposed Action

		No Action Alternative and Proposed Action (TAF/yr)		
	Diversion Location	**CVP M&I[1] Contracts (maximum[1])**	**Water Rights (maximum)**	**Diversion Limit (maximum capacity)**
Placer County Water Agency	Auburn Dam Site		65.0	65.0
Total		**0**	**65.0**	**65.0**
Sacramento Suburban Water District[2]	Folsom Reservoir		0	0
City of Folsom - includes P.L. 101-514		7	27	34
Folsom Prison			5	5
San Juan Water District (Placer County)			25	25
San Juan Water District (Sac County) - includes P.L. 101-514		24.2	33	57.2
El Dorado Irrigation District		7.55	17	24.55
City of Roseville		32	30	62.0
Placer County Water Agency		35		35
El Dorado County - P.L.101-514		15		15
Total		**120.8**	**137.0**	**257.8**
So. Cal WC/Arden Cordova WC	Folsom South Canal		5	5
California Parks and Recreation		5		5
SMUD		30	15	45
Canal Losses			1	1
Total		**35**	**21**	**56**
City of Sacramento[3]	Lower American River		225.6	225.6
Carmichael Water District			12	12
Total		**0**	**237.6**	**237.6**
Total American River Diversions		**155.8**	**460.6**	**616.4**
Sacramento River Diversions				
City of Sacramento	Lower Sacramento River		86.19	86.19
Sacramento County Water Agency		30		30
Sacramento County Water Agency - P.L. 101-514		15		15
Sacramento County Water Agency -			varies[4],	varies[4],

	Diversion Location	No Action Alternative and Proposed Action (TAF/yr)		
		CVP M&I[1] Contracts (maximum[1])	Water Rights (maximum)	Diversion Limit (maximum capacity)
water rights and acquisitions			average 32.58	average 32.58
East Bay Municipal Utilities District		133		varies[5] , average 8.2
Total Sacramento River Diversions		**178**	**118.8**	**172.0**
Total		**333.8**	**579.4**	**788.4**

Notes:

[1] When the CVP Contract quantity exceeds the quantity of the Diversion Limit minus the Water Right (if any), the diversion modeled is the quantity allocated to the CVP Contract (based on the CVP contract quantity shown times the CVP M&I allocation percentage) plus the Water Right (if any), but with the sum limited to the quantity of the Diversion Limit

[2] Diversion is only allowed if and when Mar-Nov Folsom Unimpaired Inflow (FUI) exceeds 1600 TAF

[3] When the Hodge single dry year criteria is triggered, Mar-Nov FUI falls below 400 TAF, diversion on the American River is limited to 50 TAF/yr; based on monthly Hodge flow limits assumed for the American, diversion on the Sacramento River may be increased to 223 TAF due to reductions of diversions on American River

[4] SCWA targets 68 TAF of surface water supplies annually. The portion unmet by CVP contract water is assumed to come from two sources:

(1) Delta “excess” water- averages 16.5 TAF annually, but varies according to availability. SCWA is assumed to divert excess flow when it is available, and when there is available pumping capacity.

(2) “Other” water- derived from transfers and/or other appropriated water, averaging 14.8 TAF annually but varying according remaining unmet demand.

[5] EBMUD CVP diversions are governed by the Amendatory Contract, stipulating:

(1) 133 TAF maximum diversion in any given year

(2) 165 TAF maximum diversion amount over any 3 year period

(3) Diversions allowed only when EBMUD total storage drops below 500 TAF

(4) 155 cfs maximum diversion rate

5.A.A.6 Attachment 6: Representation of U.S. Fish and Wildlife USFWS Biological Opinion Reasonable and Prudent Alternative Actions for CalSim II Planning Studies

The U.S. Fish and Wildlife Services's (USFWS) Delta Smelt Biological Opinion (BiOp) was released on December 15, 2008, in response to the U.S. Bureau of Reclamation's (Reclamation) request for formal consultation with the USFWS on the coordinated operations of the Central Valley Project (CVP) and State Water Project (SWP) in California.

To develop CalSim II modeling assumptions for reasonable and prudent alternative actions (RPA) documented in this BiOp, the California Department of Water Resources (DWR) led a series of meetings that involved members of fisheries and project agencies. The purpose for establishing this group was to prepare the assumptions and CalSim II implementations to represent the RPAs in Existing and Future Condition CalSim II simulations for future planning studies.

This memorandum summarizes the approach that resulted from these meetings and the modeling assumptions that were laid out by the group. The scope of this memorandum is limited to the December 15, 2008 BiOp. Unless otherwise indicated, all descriptive information of the RPAs is taken from Appendix B of the BiOp.

Table 5.A.A.6-1 lists the participants that contributed to the meetings and information summarized in this document.

The RPAs in the USFWS's BiOp are based on physical and biological phenomena that do not lend themselves to simulations using a monthly time step. Much scientific and modeling judgment has been employed to represent the implementation of the RPAs. The group believes the logic put into CalSim II represents the RPAs as best as possible at this time, given the scientific understanding of environmental factors enumerated in the BiOp and the limited historical data for some of these factors.

Table 5.A.A.6-1 Meeting Participants

Aaron Miller/DWR Steve Ford/DWR Randi Field/Reclamation Gene Lee/Reclamation Lenny Grimaldo/Reclamation	Derek Hilts/USFWS Steve Detwiler/USFWS Matt Nobriga/CDFW Jim White/CDFW Craig Anderson/NMFS
Parviz Nader-Tehrani/DWR Erik Reyes/DWR Sean Sou/DWR	Robert Leaf/CH2M HILL Derya Sumer/CH2M HILL
Notes: CDFW = California Department of Fish and Wildlife NMFS = National Marine Fisheries USFWS	

The simulated Old and Middle River (OMR) flow conditions and CVP/SWP Delta export operations, resulting from these assumptions, are believed to be a reasonable representation of conditions expected to prevail under the RPAs over large spans of years (refer to CalSim II modeling results for more details on simulated operations). Actual OMR flow conditions and Delta export operations will differ from simulated operations for numerous reasons, including having near real-time knowledge and/or estimates of turbidity, temperature, and fish spatial distribution that are unavailable for use in CalSim II over a long period of record. Because these factors and others are believed to be critical for smelt entrainment risk management, the USFWS adopted an adaptive process in defining the RPAs. Given the relatively generalized representation of the RPAs, assumed for CalSim II modeling, much caution is required when interpreting outputs from the model.

5.A.A.6.1 Action 1: Adult Delta Smelt Migration and Entrainment (RPA Component 1, Action 1 – First Flush)

5.A.A.6.1.1 Action 1 Summary:

Objective: A fixed duration action to protect pre-spawning adult delta smelt from entrainment during the first flush, and to provide advantageous hydrodynamic conditions early in the migration period.

Action: Limit exports so that the average daily Combined OMR flow is no more negative than -2,000 cubic feet per second (cfs) for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25%).

Timing:

Part A: December 1 to December 20 – Based upon an examination of turbidity data from Prisoner's Point, Holland Cut, and Victoria Canal and salvage data from CVP/SWP (see below), and other parameters important to the protection of delta smelt including, but not limited to, preceding conditions of X2, the Fall Midwater Trawl Survey (FMWT), and river flows; the Smelt Working Group (SWG) may recommend a start date to the USFWS. The USFWS will make the final determination.

Part B: After December 20 – The action will begin if the 3-day average turbidity at Prisoner's Point, Holland Cut, and Victoria Canal exceeds 12 nephelometric turbidity units (NTU). However the SWG can recommend a delayed start or interruption based on other conditions such as Delta inflow that may affect vulnerability to entrainment.

Triggers (Part B):

<u>Turbidity:</u> Three-day average of 12 NTU or greater at all three turbidity stations: Prisoner's Point, Holland Cut, and Victoria Canal.

OR

<u>Salvage:</u> Three days of delta smelt salvage after December 20 at either facility or cumulative daily salvage count that is above a risk threshold based upon the "daily salvage index" approach reflected in a daily salvage index value ≥ 0.5 (daily delta smelt salvage > one-half prior year FMWT index value).

The window for triggering Action 1 concludes when either off-ramp condition described below is met. These off-ramp conditions may occur without Action 1 ever being triggered. If this occurs, then Action 3 is triggered, unless the USFWS concludes on the basis of the totality of available information that Action 2 should be implemented instead.

Off-ramps:

Temperature: Water temperature reaches 12 degrees Celsius (°C) based on a three station daily mean at the temperature stations: Mossdale, Antioch, and Rio Vista

OR

Biological: Onset of spawning (presence of spent females in the Spring Kodiak Trawl Survey [SKT] or at Banks or Jones).

5.A.A.6.1.2 Action 1 Assumptions for CalSim II Modeling Purposes:

An approach was selected based on hydrologic and assumed turbidity conditions. Under this general assumption, Part A of the action was never assumed because, on the basis of historical salvage data, it was considered unlikely or rarely to occur. Part B of the action was assumed to occur if triggered by turbidity conditions. This approach was believed to tend to a more conservative interpretation of the frequency, timing, and extent of this action. The assumptions used for modeling are as follows:

Action: Limit exports so that the average daily OMR flow is no more negative than -2,000 cfs for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25% of the monthly criteria).

Timing: If turbidity-trigger conditions first occur in December, then the action starts on December 21; if turbidity-trigger conditions first occur in January, then the action starts on January 1; if turbidity-trigger conditions first occur in February, then the action starts on February 1; and if turbidity-trigger conditions first occur in March, then the action starts on March 1. It is assumed that once the action is triggered, it continues for 14 days.

Triggers: Only an assumed turbidity trigger that is based on hydrologic outputs was considered. A surrogate salvage trigger or indicator was not included because there was no way to model it.

Turbidity: If the monthly average unimpaired Sacramento River Index (four-river index: sum of Sacramento, Yuba, Feather, and American Rivers) exceeds 20,000 cfs, then it is assumed that an event, in which the 3-day average turbidity at Hood exceeds 12 NTU, has occurred within the month. It is assumed that an event at Sacramento River is a reasonable indicator of this condition occurring, within the month, at all three turbidity stations: Prisoner's Point, Holland Cut, and Victoria Canal.

A chart showing the relationship between turbidity at Hood (number of days with turbidity is greater than 12 NTU) and Sacramento River Index (sum of monthly flow at four stations on the Sacramento, Feather, Yuba and American Rivers, from 2003 to 2006) is shown on Figure 5.A.A.6-1. For months when average Sacramento River Index is between 20,000 cfs and 25,000 cfs a transition is observed in number of days with Hood turbidity greater than 12 NTU. For months when average Sacramento River Index is above 25,000 cfs, Hood turbidity was always greater than 12 NTU for as many as 5 days or more within the month in which the flow occurred. For a conservative approach, 20,000 cfs is used as the threshold value.

Salvage: It is assumed that salvage would occur when first flush occurs.

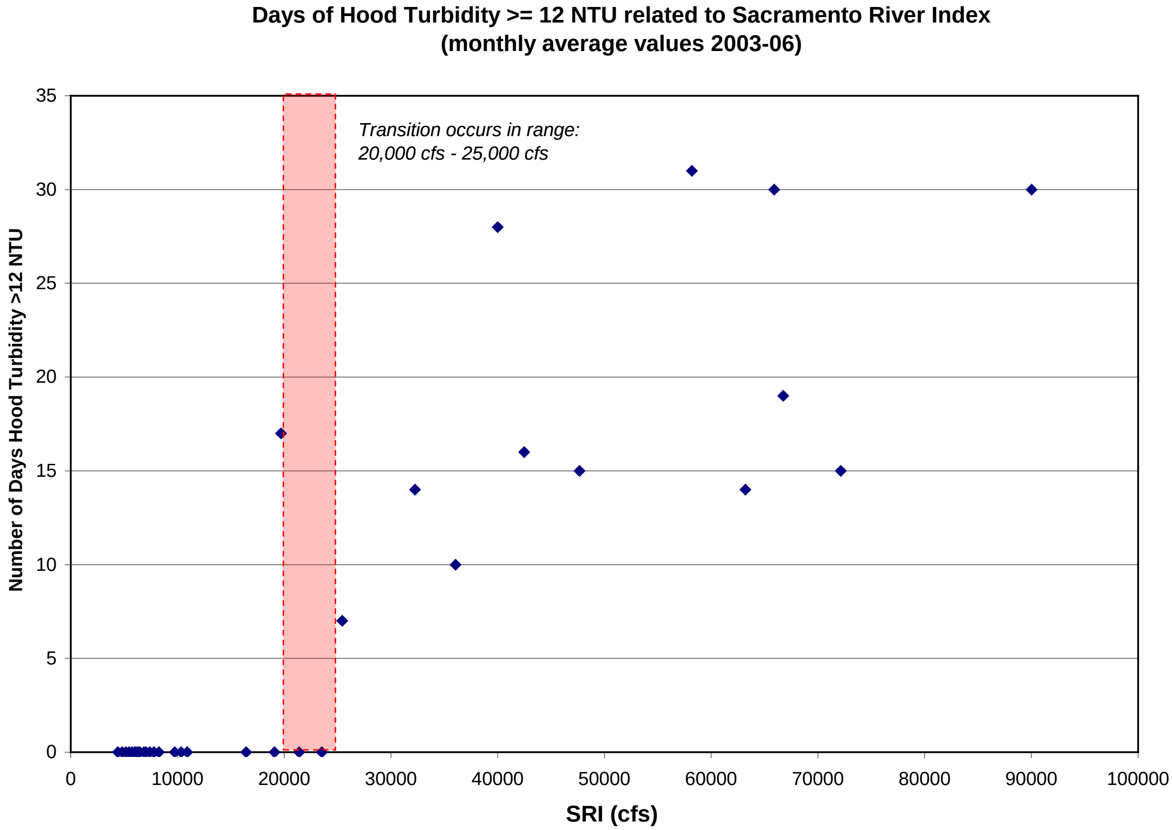


Figure 5.A.A.6-1 Relationship between Turbidity at Hood and Sacramento River Index

Off-ramps: Only temperature-based off-ramping is considered. A surrogate biological off-ramp indicator was not included.

Temperature: Because the water temperature data at the three temperature stations (Antioch, Mossdale, and Rio Vista) are only available for years after 1984, another parameter was sought for use as an alternative indicator. It is observed that monthly average air temperature at Sacramento Executive Airport generally trends with the three-station average water temperature (see Figure 5.A.A.6-2). Using this alternative indicator, monthly average air temperature is assumed to occur in the middle of the month, and values are interpolated on a daily basis to obtain daily average water temperature. Using the correlation between air and water temperature, estimated daily water temperatures are estimated from the 82-year monthly average air temperature. Dates when the three-station average temperature reaches 12°C are recorded and used as input in CalSim. A 1:1 correlation was used for simplicity instead of using the trend line equation illustrated on Figure 5.A.A.6-2.

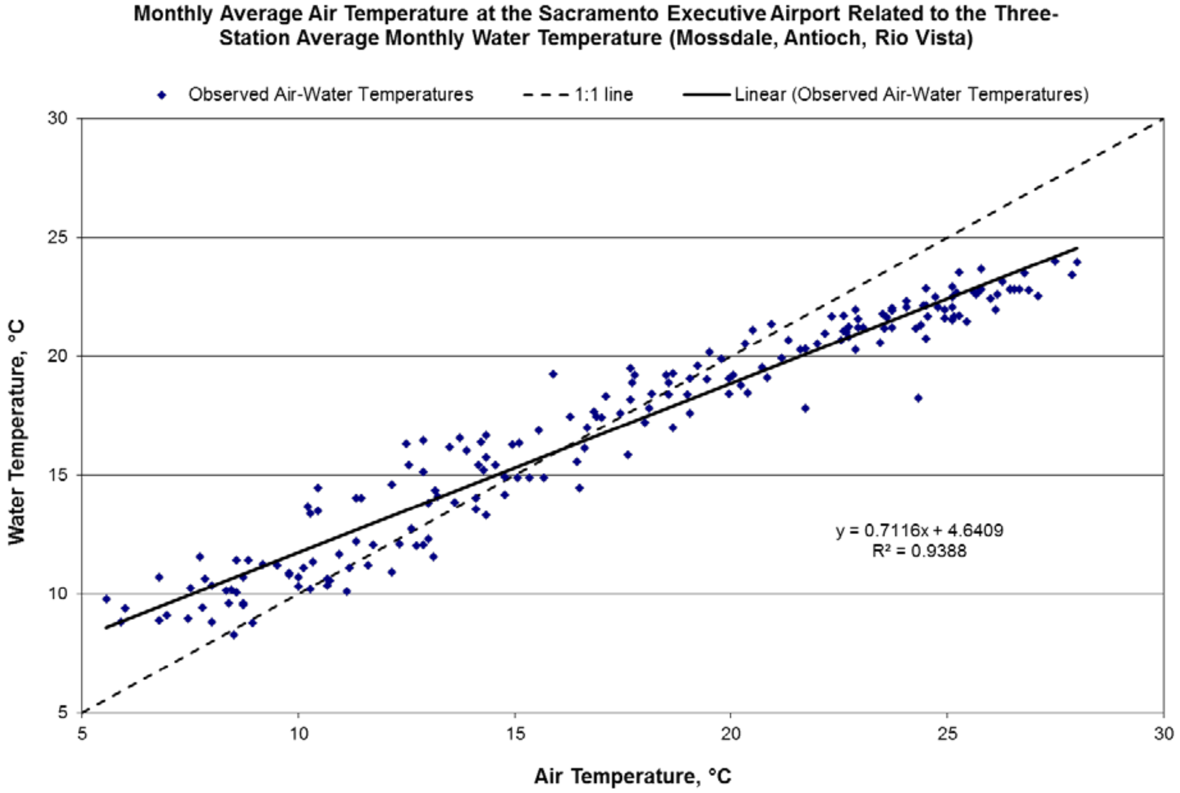


Figure 5.A.A.6-2 Relationship between Monthly Average Air Temperature at the Sacramento Executive Airport and the Three-station Average Monthly Water Temperature

Other Modeling Considerations:

In the month of December in which Action 1 does not begin until December 21, for monthly analysis, a background OMR flow must be assumed for the purpose of calculating a day-weighted average for implementing a partial-month action condition. When necessary, the background OMR flow for December was assumed to be -8,000 cfs.

For the additional condition to meet a 5-day running average no more negative than -2,500 cfs (within 25%), Paul Hutton's equation[1] is used. Hutton concluded that with stringent OMR standards (1,250 to 2,500 cfs), the 5-day average would control more frequently than the 14-day average, but it is less likely to control at higher flows. Therefore, the CalSim II implementation includes both a 14-day (approximately monthly average) and a 5-day average flow criteria based on Hutton's methodology (see Attachment 1).

Rationale: The following is an overall summary of the rationale for the preceding interpretation of RPA Action 1.

---

[1] Hutton, Paul. Metropolitan Water District of Southern California (MWDSC). Water Supply Impact Analysis of December 2008 Delta Smelt Biological Opinion, Appendix 5 (attached below). February.

December 1 to December 20 for initiating Action 1 is not considered because seasonal peaks of delta smelt salvage are rare prior to December 20. Adult delta smelt spawning migrations often begin following large precipitation events that happen after mid-December.

Salvage of adult delta smelt often corresponds with increases in turbidity and exports. On the basis of the above discussion and Figure B-2, Sacramento River Index greater than 25,000 cfs is assumed to be an indicator of turbidity trigger being reached at all three turbidity stations: Prisoner's Point, Holland Cut, and Victoria Canal. Most sediment enters the Delta from the Sacramento River during flow pulses; therefore, a flow indicator based on only Sacramento River flow is used.

The 12°C threshold for the off-ramp criterion is a conservative estimate of when delta smelt larvae begin successfully hatching. Once hatched, the larvae move into the water column where they are potentially vulnerable to entrainment.

Results: Using these assumptions, in a typical CalSim II 82-year simulation (1922 through 2003 hydrologic conditions), Action 1 will occur 29 times in the December 21 to January 3 period, 14 times in the January 1 to January 14 period, 13 times in the February 1 to February 14 period, and 17 times in the March 1 to March 14 period. In 3 of these 17 occurrences (1934, 1991, and 2001), Action 3 is triggered before Action 1 and therefore Action 1 is bypassed. Action 1 is not triggered in 9 of the 82 years (1924, 1929, 1931, 1955, 1964, 1976, 1977, 1985, and 1994), typically critically dry years. Refer to CalSim II modeling results for more details on simulated operations of OMR, Delta exports and other parameters of interest.

5.A.A.6.2 Action 2: Adult Delta Smelt Migration and Entrainment (RPA Component 1, Action 2)

5.A.A.6.2.1 Action 2 Summary:

Objective: An action implemented using an adaptive process to tailor protection to changing environmental conditions after Action 1. As in Action 1, the intent is to protect pre-spawning adults from entrainment and, to the extent possible, from adverse hydrodynamic conditions.

Action: The range of net daily OMR flows will be no more negative than -1,250 to -5,000 cfs. Depending on extant conditions (and the general guidelines below), specific OMR flows within this range are recommended by the USFWS's Smelt Working Group (SWG) from the onset of Action 2 through its termination (see Adaptive Process description in the BiOp). The SWG would provide weekly recommendations based upon review of the sampling data, from real-time salvage data at the CVP/SWP, and utilizing most up-to-date technological expertise and knowledge relating population status and predicted distribution to monitored physical variables of flow and turbidity. The USFWS will make the final determination.

Timing: Beginning immediately after Action 1. Before this date (in time for operators to implement the flow requirement) the SWG will recommend specific requirement OMR flows based on salvage and on physical and biological data on an ongoing basis. If Action 1 is not implemented, the SWG may recommend a start date for the implementation of Action 2 to protect adult delta smelt.

Suspension of Action:

Flow: OMR flow requirements do not apply whenever a 3-day flow average is greater than or equal to 90,000 cfs in Sacramento River at Rio Vista and 10,000 cfs in San Joaquin River at Vernalis. Once such flows have abated, the OMR flow requirements of the Action are again in place.

Off-ramps:

Temperature: Water temperature reaches 12°C based on a three-station daily average at the temperature stations: Rio Vista, Antioch, and Mossdale.

OR

Biological: Onset of spawning (presence of a spent female in SKT or at either facility).

5.A.A.6.2.2 Action 2 Assumptions for CalSim II Modeling Purposes:

An approach was selected based on the occurrence of Action 1 and X2 salinity conditions. This approach selects from between two OMR flow tiers depending on the previous month's X2 position, and is never more constraining than an OMR criterion of -3,500 cfs. The assumptions used for modeling are as follows:

Action: Limit exports so that the average daily OMR flow is no more negative than -3,500 or -5,000 cfs depending on the previous month's ending X2 location (-3,500 cfs if X2 is east of Roe Island, or -5,000 cfs if X2 is west of Roe Island), with a 5-day running average within 25% of the monthly criteria (no more negative than -4,375 cfs if X2 is east of Roe Island, or -6,250 cfs if X2 is west of Roe Island).

Timing: Begins immediately after Action 1 and continues until initiation of Action 3.

In a typical CalSim II 82-year simulation, Action 1 was not triggered in 9 of the 82 years. In these conditions it is assumed that OMR flow should be maintained no more negative than -5,000 cfs.

Suspension of Action: A flow peaking analysis, developed by Paul Hutton[2], is used to determine the likelihood of a 3-day flow average greater than or equal to 90,000 cfs in Sacramento River at Rio Vista and a 3-day flow average greater than or equal to 10,000 cfs in San Joaquin River at Vernalis occurring within the month. It is assumed that when the likelihood of these conditions occurring exceeds 50%, Action 2 is suspended for the full month, and OMR flow requirements do not apply. The likelihood of these conditions occurring is evaluated each month, and Action 2 is suspended for one month at a time whenever both of these conditions occur.

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[2] Hutton, Paul. MWDSC. 2009. Water Supply Impact Analysis of December 2008 Delta Smelt Biological Opinion, Appendix 4 (attached below). February.

The equations for likelihood (frequency of occurrence) are as follows:

Frequency of Rio Vista 3-day flow average > 90,000 cfs:

> 0% when Freeport monthly flow < 50,000 cfs, OR
>
> (0.00289 × Freeport monthly flow – 146)% when 50,000 cfs ≤ Freeport plus Yolo Bypass monthly flow ≤ 85,000 cfs, OR
>
> 100% when Freeport monthly flow >85,000 cfs

Frequency of Vernalis 3-day flow average > 10,000 cfs:

> 0% when Vernalis monthly flow < 6,000 cfs, OR
>
> (0.00901 × Vernalis monthly flow – 49)% when 6,000 cfs ≤ Vernalis monthly flow ≤ 16,000 cfs, OR
>
> 100% when Vernalis monthly flow >16,000 cfs

Frequency of Rio Vista 3-day flow average > 90,000 cfs equals 50% when Freeport plus Yolo Bypass monthly flow is 67,820 cfs and the frequency of Vernalis 3-day flow average > 10,000 cfs equals 50% Vernalis monthly flow is 10,988 cfs. Therefore these two flow values are used as thresholds in the model.

Off-ramps: Only temperature-based off-ramping is considered. A surrogate biological off-ramp indicator was not included.

Temperature: Because the water temperature data at the three temperature stations (Antioch, Mossdale, and Rio Vista) are only available for years after 1984, another parameter was sought for use as an alternative indicator. It is observed that monthly average air temperature at Sacramento Executive Airport generally trends with the three-station average water temperature (Figure 5.A.A.6-2). Using this alternative indicator, monthly average air temperature is assumed to occur in the middle of the month, and values are interpolated on a daily basis to obtain daily average water temperature. Using the correlation between air and water temperature, daily water temperatures are estimated from the 82-year monthly average air temperature. Dates when the three-station average temperature reaches 12°C are recorded and used as input in CalSim II. A 1:1 correlation was used for simplicity instead of using the trend line equation illustrated on Figure 5.A.A.6-2.

Rationale: The following is an overall summary of the rationale for the preceding interpretation of RPA Action 2.

Action 2 requirements are based on X2 location that is dependent on the Delta outflow. If outflows are very high, fewer delta smelt will spawn east of Sherman Lake; therefore, the need for OMR restrictions is lessened.

In the case of Action 1 not being triggered, CDFW suggested OMR > -5,000 cfs, following the actual implementation of the BiOp in winter 2009, because some adult delta smelt might move into the Central Delta without a turbidity event.

Action 2 is suspended when the likelihood of a 3-day flow average greater than or equal to 90,000 cfs in Sacramento River at Rio Vista and a 3-day flow average greater than or equal to 10,000 cfs in San Joaquin River at Vernalis occurring concurrently within the month exceeds 50%, because at extreme high flows the majority of adult delta smelt will be distributed downstream of the Delta, and entrainment concerns will be very low.

The 12°C threshold for the off-ramp criterion is a conservative estimate of when delta smelt larvae begin successfully hatching. Once hatched, the larvae move into the water column where they are potentially vulnerable to entrainment.

Results: Using these assumptions, in a typical CalSim II 82-year simulation (1922 through 2003 hydrologic conditions), Action 1, and therefore Action 2, does not occur in 11 of the 82 years (1924, 1929, 1931, 1934, 1955, 1964, 1976, 1977, 1985, 1991, 1994, and 2001), typically critically dry years. The criteria for suspension of OMR minimum flow requirements, described above, results in potential suspension of Action 2 (if Action 2 is active) 6 times in January, 11 times in February, 6 times in March (however Action 2 was not active in 3 of these 6 times), and 2 times in April. The result is that Action 2 is in effect 37 times in January (with OMR at -3,500 cfs 29 times, and at -5,000 cfs 8 times), 43 times in February (with OMR at -3,500 cfs 25 times, and at -5,000 cfs 18 times), 31 times in March (with OMR at -3,500 cfs 14 times, and at -5,000 cfs 17 times), and 80 times in April (with OMR at -3,500 cfs 46 times, and at -5,000 cfs 34 times). The frequency each month is a cumulative result of the action being triggered in the current or prior months. Refer to CalSim II modeling results for more details on simulated operations of OMR, Delta exports and other parameters of interest.

5.A.A.6.3 Action 3: Entrainment Protection of Larval and Juvenile Delta Smelt (RPA Component 2)

5.A.A.6.3.1 Action 3 Summary:

Objective: Minimize the number of larval delta smelt entrained at the facilities by managing the hydrodynamics in the Central Delta flow levels pumping rates spanning a time sufficient for protection of larval delta smelt, e.g., by using a VAMP-like action. Because protective OMR flow requirements vary over time (especially between years), the action is adaptive and flexible within appropriate constraints.

Action: Net daily OMR flow will be no more negative than -1,250 to -5,000 cfs based on a 14-day running average with a simultaneous 5-day running average within 25% of the applicable requirement for OMR. Depending on extant conditions (and the general guidelines below), specific OMR flows within this range are recommended by the SWG from the onset of Action 3 through its termination (see Adaptive Process in Introduction). The SWG would provide these recommendations based upon weekly review of sampling data, from real-time salvage data at the CVP/SWP, and expertise and knowledge relating population status and predicted distribution to monitored physical variables of flow and turbidity. The USFWS will make the final determination.

Timing: Initiate the action after reaching the triggers below, which are indicative of spawning activity and the probable presence of larval delta smelt in the South and Central Delta. Based upon daily salvage data, the SWG may recommend an earlier start to Action 3. The USFWS will make the final determination.

Triggers:

Temperature: When temperature reaches 12°C based on a three-station average at the temperature stations: Mossdale, Antioch, and Rio Vista.

OR

Biological: Onset of spawning (presence of spent females in SKT or at either facility).

Off-ramps:

Temporal: June 30;

OR

Temperature: Water temperature reaches a daily average of 25°C for three consecutive days at Clifton Court Forebay.

5.A.A.6.3.2 Action 3 Assumptions for CalSim II Modeling Purposes:

An approach was selected based on assumed temperature and X2 salinity conditions. This approach selects from among three OMR flow tiers depending on the previous month's X2 position and ranges from an OMR criteria of -1,250 to -5,000 cfs. Because of the potential low export conditions that could occur at an OMR criterion of -1,250 cfs, a criterion for minimum exports for health and safety is also assumed. The assumptions used for modeling are as follows:

Action: Limit exports so that the average daily OMR flow is no more negative than -1,250, -3,500, or -5,000 cfs, depending on the previous month's ending X2 location (-1,250 cfs if X2 is east of Chipps Island, -5,000 cfs if X2 is west of Roe Island, or -3,500 cfs if X2 is between Chipps and Roe Island, inclusively), with a 5-day running average within 25% of the monthly criteria (no more negative than -1,562 cfs if X2 is east of Chipps Island, -6,250 cfs if X2 is west of Roe Island, or -4,375 cfs if X2 is between Chipps and Roe Island). The more constraining of this OMR requirement or the VAMP requirement will be selected during the VAMP period (April 15 to May 15). Additionally, in the case of the month of June, the OMR criterion from May is maintained through June (it is assumed that June OMR should not be more constraining than May).

Timing: Begins immediately upon temperature trigger conditions and continues until off-ramp conditions are met.

Triggers: Only temperature trigger conditions are considered. A surrogate biological trigger was included.

Temperature: Because the water temperature data at the three temperature stations (Antioch, Mossdale, and Rio Vista) are only available for years after 1984, another parameter was sought to be used as an alternative indicator. It is observed that monthly average air temperature at Sacramento Executive Airport generally trends with the three-station average water temperature (Figure 5.A.A.6-2). Using this alternative indicator, monthly average air temperature is assumed to occur in the middle of the month, and values are interpolated on a daily basis to obtain daily average water temperature. Using the correlation between air and water temperature, estimated daily water temperatures are estimated from the 82-year monthly average air temperature. Dates when the three-station average temperature reaches 12°C are recorded and used as input in CalSim. A 1:1 correlation was used for simplicity instead of using the trend line equation illustrated on Figure 5.A.A.6-2.

Biological: Onset of spawning is assumed to occur no later than *May* 30.

Clarification Note: This text previously read "Onset of spawning is assumed to occur no later than April 30", where the CalSim II lookup table has May 30 as the date. Based on RPA team discussions in August 2009, it was agreed upon that onset of spawning could not be modeled in CalSim. This trigger was actually coded as a placeholder in case in future this trigger was to be used; and the date was selected purposefully in a way that it wouldn't affect modeling results. Temperature trigger for Action 3 does occur before end of April. Therefore it does not matter whether the document is corrected to read May 30 or the model lookup table is changed to April 30.

Off-ramps:

Temporal: It is assumed that the ending date of the action would be no later than June 30.

OR

Temperature: Only 17 years of data are available for Clifton Court water temperature. A similar approach as used in the temperature trigger was considered. However, because 3 consecutive days of water temperature greater than or equal to 25°C is required, a correlation between air temperature and water temperature did not work well for this off-ramp criterion. Out of the 17 recorded years, in one year the criterion was triggered in May (May 31), and in 3 years it was triggered in June (June 3, 21, and 27). In all other years it was observed in July or later. With only four data points before July, it was not possible to generate a rule based on statistics. Therefore, temporal off-ramp criterion (June 30) is used for all years.

Health and Safety: In CalSim II, a minimum monthly Delta export criterion of 300 cfs for SWP and 600 cfs (or 800 cfs depending on Shasta storage) for CVP is assumed. This assumption is suitable for dry-year conditions when allocations are low and storage releases are limited; however, minimum monthly exports need to be made for protection of public health and safety (health and safety deliveries upstream of San Luis Reservoir).

In consideration of the severe export restrictions associated with the OMR criteria established in the RPAs, an additional set of health and safety criterion is assumed. These export restrictions could lead to a situation in which supplies are available and allocated; however, exports are curtailed forcing San Luis to have an accelerated drawdown rate. For dam safety at San Luis Reservoir, 2 feet per day is the maximum acceptable drawdown rate. Drawdown occurs faster in summer months and peaks in June when the agricultural demands increase. To avoid rapid drawdown in San Luis Reservoir, a relaxation of OMR is allowed so that exports can be maintained at 1,500 cfs in all months if needed.

This modeling approach may not fit the real-life circumstances. In summer months, especially in June, the assumed 1,500 cfs for health and safety may not be sufficient to keep San Luis drawdown below a safe 2 ft/day; and under such circumstances the projects would be required to increase pumping in order to maintain dam safety.

Rationale: The following is an overall summary of the rationale for the preceding interpretation of RPA Action 3.

The geographic distribution of larval and juvenile delta smelt is tightly linked to X2 (or Delta outflow). Therefore, the percentage of the population likely to be found east of Sherman Lake is also influenced by the location of X2. The X2-based OMR criteria were intended to model an expected management response to the general increase in delta smelt's risk of entrainment as a function of increasing X2.

The 12°C threshold for the trigger criterion is a conservative estimate of when delta smelt larvae begin successfully hatching. Once hatched, the larvae move into the water column where they are potentially vulnerable to entrainment.

The annual salvage "season" for delta smelt typically ends as South Delta water temperatures warm to lethal levels during summer. This usually occurs in late June or early July. The laboratory-derived upper lethal temperature for delta smelt is 25.4°C.

Results: Action 3 occurs 30 times in February (with OMR at -1,250 cfs 9 times, at -3,500 cfs 11 times, and at -5,000 cfs 10 times), 76 times in March (with OMR at -1,250 cfs 15 times, at -3,500 cfs 27 times, and at -5,000 cfs 34 times), all times (82) in April (with OMR at -1,250 cfs 17 times, at -3,500 cfs 29 times, and at -5,000 cfs 35 times), all times (82) in May (with OMR at -1,250 cfs 19 times, at -3,500 cfs 37 times, and at -5,000 cfs 26 times), and 70 times in June (with OMR at -1,250 cfs 7 times, at -3,500 cfs 37 times, and at -5,000 cfs 26 times). Refer to CalSim II modeling results for more details on simulated operations of OMR, Delta exports and other parameters of interest. (Note: The above information is based on the August 2009 version of the model and documents the development process, more recent versions of the model may have different results.)

5.A.A.6.4 Action 4: Estuarine Habitat During Fall (RPA Component 3)

5.A.A.6.4.1 Action 4 Summary:

Objective: Improve fall habitat for delta smelt by managing of X2 through increasing Delta outflow during fall when the preceding water year was wetter than normal. This will help return ecological conditions of the estuary to that which occurred in the late 1990s when smelt populations were much larger. Flows provided by this action are expected to provide direct and indirect benefits to delta smelt. Both the direct and indirect benefits to delta smelt are considered equally important to minimize adverse effects.

Action: Subject to adaptive management as described below, provide sufficient Delta outflow to maintain average X2 for September and October no greater (more eastward) than 74 kilometers in the fall following wet years and 81 kilometers in the fall following above normal years. The monthly average X2 position is to be maintained at or seaward of these location for each individual month and not averaged over the two month period. In November, the inflow to CVP/SWP reservoirs in the Sacramento Basin will be added to reservoir releases to provide an added increment of Delta inflow and to augment Delta outflow up to the fall X2 target. The action will be evaluated and may be modified or terminated as determined by the USFWS.

Timing:

September 1 to November 30.

Triggers:

Wet and above normal water-year type classification from the 1995 Water Quality Control Plan that is used to implement D-1641.

5.A.A.6.4.2 Action 4 Assumptions for CalSim II Modeling Purposes:

Model is modified to increase Delta outflow to meet monthly average X2 requirements for September and October and subsequent November reservoir release actions in Wet and Above Normal years. No off-ramps are considered for reservoir release capacity constraints. Delta exports may or may not be reduced as part of reservoir operations to meet this action. The Action is summarized in Table 5.A.A.6-2.

Table 5.A.A.6-2. Summary of Action 4 implementation in CalSim II

Fall Months following Wet or Above Normal Years	Action Implementation
September	Meet monthly average X2 requirement (74 km in Wet years, 81 km in Above Normal years)
October	Meet monthly average X2 requirement (74 km in Wet years, 81 km in Above Normal years)
November	Add reservoir releases up to natural inflow as needed to continue to meet monthly average X2 requirement (74 km in Wet years, 81 km in Above Normal years)

Rationale: Action 4 requirements are based on determining X2 location. Adjustment and retraining of the ANN was also completed to address numerical sensitivity concerns.

Results: There are 38 September and 37 October months that the Action is triggered over the 82-year simulation period.

5.A.A.6.5 Action 5: Temporary Spring Head of Old River Barrier and the Temporary Barrier Project (RPA Component 2)

5.A.A.6.5.1 Action 5 Summary:

Objective: To minimize entrainment of larval and juvenile delta smelt at Banks and Jones or from being transported into the South and Central Delta, where they could later become entrained.

Action: Do not install the Spring Head of Old River Barrier (HORB) if delta smelt entrainment is a concern. If installation of the HORB is not allowed, the agricultural barriers would be installed as described in the Project Description. If installation of the HORB is allowed, the Temporary Barrier Project (TBP) flap gates would be tied in the open position until May 15.

Timing: The timing of the action would vary depending on the conditions. The normal installation of the spring temporary HORB and the TBP is in April.

Triggers: For delta smelt, installation of the HORB will only occur when particle tracking modeling results show that entrainment levels of delta smelt will not increase beyond 1% at Station 815 as a result of installing the HORB.

Off-ramps: If Action 3 ends or May 15, whichever comes first.

5.A.A.6.5.2 Action 5 Assumptions for CalSim II and DSM2 Modeling Purposes:

The South Delta Improvement Program (SDIP) Stage 1 is not included in the Existing and Future Condition assumptions being used for CalSim II and DSM2 baselines. The TBP is assumed instead. The TBP specifies that HORB be installed and operated during April 1 through May 31 and September 16 through November 30. In response to the USFWS BiOp, Action 5, the HORB is assumed to not be installed during April 1 through May 31.

Attachments

Appendix 4: Approach to Suspend Actions During High Flows

MEMO

Date: December 16, 2008

To: File

From: Paul Hutton

Subject: Modeling Delta Smelt High Flow Action Temporary Suspensions

This memo summarizes an approach that was developed to represent high flow periods when Delta smelt flow actions are temporarily suspended. The actions of interest include the following:

- Wanger Actions – The winter pulse flow action (on or after December 25) is temporarily suspended if the 3-day average flow at Freeport exceeds 80,000 cfs. Similarly, the pre-spawning adult flow action (January and February) is temporarily suspended if the 3-day average flow at Freeport exceeds 80,000 cfs.

- Delta Smelt Biological Opinion Actions – Action 2 is temporarily suspended if the 3-day average flows at Rio Vista and Vernalis exceed 90,000 cfs and 10,000 cfs, respectively.

Methodology

Given that (1) the actions are written in terms of 3-day flow averages and (2) typical water supply impact analyses are conducted assuming monthly average flows, a method is needed to characterize the action in terms of monthly average flows. Historical flows information from DAYFLOW was used to characterize relationships between 3-day flows and monthly flows. The desired product is to determine a frequency of exceeding the 3-day flow target as a function of a monthly flow value. This frequency will be used to proportionally reduce calculated water supply impacts in high flow months.

Results for Wanger Actions

Figure 4-1 plots the frequency that 3-day Freeport flows exceed 80,000 cfs as a function of monthly average Freeport flows (Q_F). The resulting mathematical frequency relationship (in percent units) is as follows:

0% when $Q_F < 50{,}000$ cfs

$0.0126 * \exp(0.000105*Q_F)$ when $50{,}000 \text{ cfs} \leq Q_F \leq 85{,}000$ cfs

100% when $Q_F > 85{,}000$ cfs

Results for BO Actions

Figure 4-2 plots the frequency that 3-day Rio Vista flows exceed 90,000 cfs as a function of monthly average Freeport flows (Q_F). The resulting mathematical frequency relationship (in percent units) is as follows:

0% when $Q_F < 50{,}000$ cfs

$-146 + 0.00289*Q_F$ when $50{,}000 \text{ cfs} \leq Q_F \leq 85{,}000$ cfs

100% when $Q_F > 85{,}000$ cfs

Figure 4-3 plots the frequency that 3-day Vernalis flows exceed 10,000 cfs as a function of monthly average Vernalis flows (Q_V). The resulting mathematical frequency relationship (in percent units) is as follows:

0% when $Q_V < 6{,}000$ cfs

$-49 + 0.00901*Q_V$ when $6{,}000 \text{ cfs} \leq Q_V \leq 16{,}000$ cfs

100% when $Q_V > 16{,}000$ cfs

The BO requires Rio Vista and Vernalis flows to simultaneously exceed the targets to temporarily suspend the flow action. For modeling purposes, it is assumed that these flows are statistically independent. Hence, the suspension frequency is calculated as the product of the individual frequencies. Since Rio Vista and Vernalis flows are modestly correlated, the proposed approach may somewhat understate the true suspension frequency. However, a cursory paired data evaluation suggested that the assumption will provide reasonable results.

Figure 4-1. Frequency of Wanger Freeport Flow Trigger as a Function of Monthly Freeport Flow

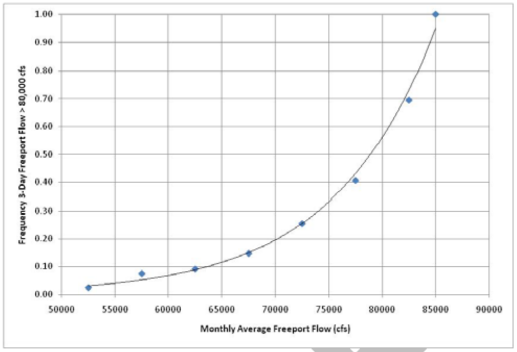


Figure 4-2. Frequency of BO Rio Vista Flow Trigger as a Function of Monthly Freeport Flow

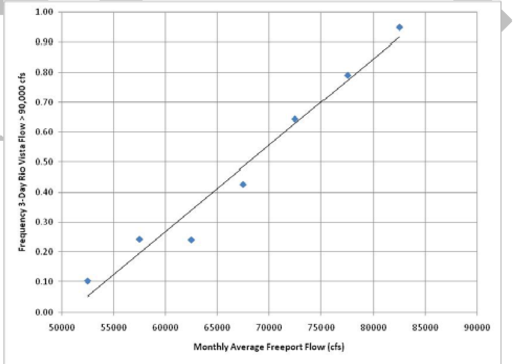
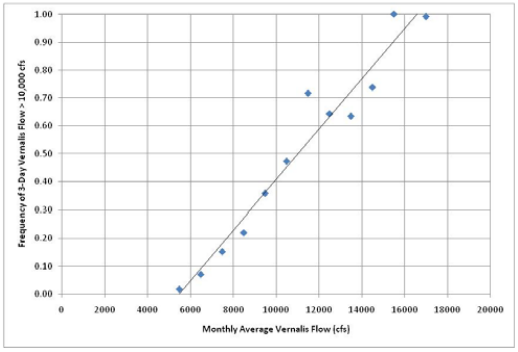


Figure 4-3. Frequency of BO Vernalis Flow Trigger as a Function of Monthly Vernalis Flow



Paul Hutton 2/2/09

Appendix 5: Approach to Relate 5-Day & 14-Day OMR Flows

MEMO

Date: January 2, 2009

To: File

From: Paul Hutton

Subject: How Frequently Will 5-Day OMR Flows (Rather than 14-Day OMR Flows) Control Project Operations Under New Delta Smelt Biological Opinion?

Background

Several flow actions specified in the December 2008 Delta Smelt biological opinion place limits on reverse flows in Old and Middle Rivers. Limits are given as 14-day averages, but the simultaneous 5-day averages are to be within 25% of the 14-day averages. This memo summarizes an investigation to answer the question "How frequently will 5-day OMR flows, rather than 14-day OMR flows, control project operations under the new Delta smelt biological opinion?"

Water supply impact studies assume the 14-day average flow controls. Such an approach would not be conservative if 5-day flows frequently control project operations. Based upon a recent meeting with SWP and CVP operators, the CVP operators believe that fishery agencies will accept violations of the 5-day flow limit provided that project operators maintain relatively stable pumping operations. Is this belief that 5-day flows will not control operations valid? Will the courts or environmental groups accept such an operation? An investigation into the potential frequency of 5-day flow control seems prudent, given that we don't know the answers to such questions.

Methods

The following methods were employed:

- Review historical Delta flow and operations data for the period between January 1990 and May 2008.
- Identify periods when (1) pumping operations were relatively stable and (2) 5-day OMR flows were more negative than 14-day OMR flows. For periods prior to

October 2006, running average OMR flows were computed from raw 24-hour USGS data. For periods after October 2006, running average OMR flows were computed from tidally filtered USGS data.

- Evaluate differences between 5-day and 14-day OMR flows. Evaluate differences between (1) average period values and (2) peak period values. The rationale for evaluating both differences is as follows. While a 5-day flow violation may be acceptable as a "peak" event, the acceptability of a flow violation over longer periods seems less likely.

Results

Fifty periods were identified when pumping operations were relatively stable and 5-day OMR flows were more negative than 14-day OMR flows. The duration of these periods was typically 7 to 9 days. These periods are summarized in Table 5-1.

Differences Between Average Period Values. For each period, the average 5-day OMR flow is plotted against average 14-day OMR flow in Figure 5-1. This graph shows a linear relationship, suggesting that differences are relatively constant over a wide range of OMR flows. This relationship further suggests that the percent difference between 14-day flows and 5-day flows will generally be greater when the absolute flow value is small. At a 50% confidence interval, 5-day OMR flows are more negative than 14-day OMR flows by nearly 400 cfs (389 cfs). At one standard error, or about 67% confidence, 5-day OMR flows are more negative than 14-day OMR flows by more than 550 cfs (389 cfs + 174 cfs = 563 cfs). At two standard errors, or about 95% confidence, 5-day OMR flows are more negative than 14-day OMR flows by more than 700 cfs (389 cfs + 2*174 cfs = 737 cfs).

By solving the Figure 5-1 regression equation for a condition when the 5-day OMR flow is 25% more negative than the 14-day OMR flow, the following limits are identified when 5-day OMR flows will control:

14-day OMR flow = -1670 cfs at a 50% confidence interval

-2420 cfs at a 67% confidence interval

-3160 cfs at a 95% confidence interval

Differences Between Peak Period Values. For each period, the peak 5-day OMR flow is plotted against peak 14-day OMR flow in Figure 5-2. This graph also shows a linear relationship, suggesting that differences are relatively constant over a wide range of OMR flows. This relationship further suggests that the percent difference between 14-day flows and 5-day flows will generally be greater when the absolute flow value is small. At a 50% confidence interval, 5-day OMR flows are more negative than 14-day OMR flows by nearly 700 cfs (679 cfs). At one standard error, or about 67% confidence, 5-day OMR flows are more negative than 14-day OMR flows by nearly 1000 cfs (679 cfs + 297 cfs = 976 cfs). At two standard errors, or about 95% confidence, 5-day OMR flows are more negative than 14-day OMR flows by nearly 1300 cfs (679 cfs + 2*297 cfs = 1273 cfs).

By solving the Figure 5-1 regression equation for a condition when the 5-day OMR flow is 25% more negative than the 14-day OMR flow, the following limits are identified when 5-day OMR flows will control:

14-day OMR flow = -2980 cfs at a 50% confidence interval
-4280 cfs at a 67% confidence interval
-5580 cfs at a 95% confidence interval

Conclusions

This memo summarizes an investigation to answer the question "How frequently will 5-day OMR flows, rather than 14-day OMR flows, control project operations under the new Delta smelt biological opinion?" An analysis of historical flow and project operations data suggests that 5-day OMR flows will often control operations when the 14-day flow target is in the most stringent range of -1500 cfs to -2500 cfs. When the projects are operating to less stringent OMR flows in the range of -3000 cfs to -5000 cfs, 5-day OMR flows will occasionally be at least 25% more negative than 14-day OMR flows and might control project operations.

If the projects are required to strictly meet the 5-day OMR flow criteria, (1) the current water supply impact assumption of 14-day OMR flow control is not conservative and (2) it would be prudent to incorporate a factor of safety to address the 5-day flow criteria.

Paul Hutton 2/2/09

Figure 5-1. Average 5d OMR flows as a function of average 14d OMR flows during periods when pumping operations were stable and 5d flows were more negative than 14d flows.

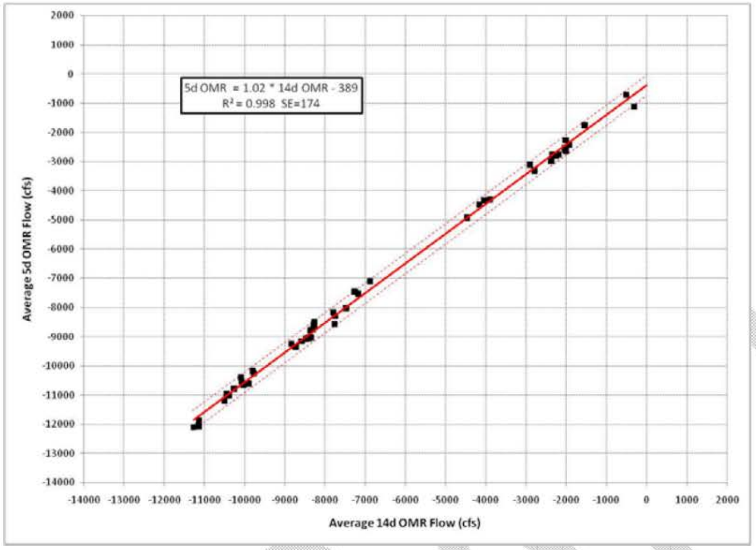
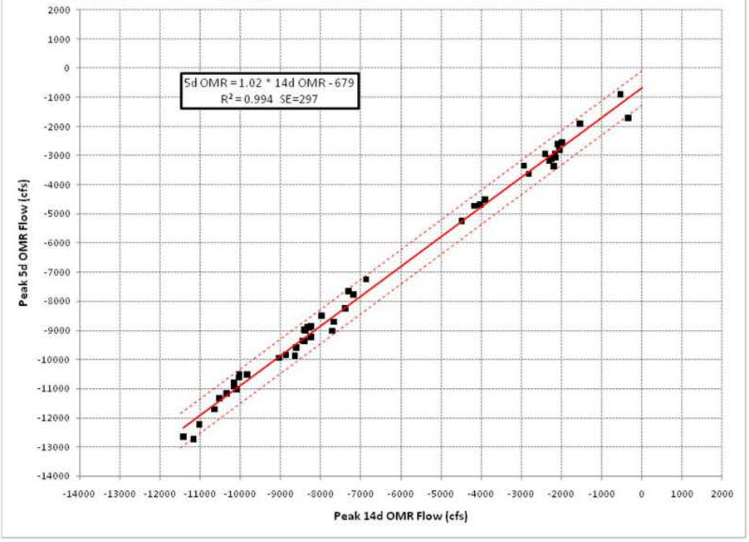


Figure 5-2. Peak 5d OMR flows as a function of peak 14d OMR flows during periods when pumping operations were stable and 5d flows were more negative than 14d flows.



Paul Hutton 2/2/09

Table 5-1. Fifty periods were identified when pumping operations were relatively stable and 5-day OMR flows were more negative than 14-day OMR flows.

Period		Duration (days)	Daily Export Range (cfs)			14d Export Range (cfs)			Average OMR Difference (cfs)				Peak OMR Difference (cfs)				
Start Date	End Date		Min	Max	Range	Min	Max	Range	14d	5d	Diff	%Diff	Date	14d	5d	Diff	%Diff
24-Jan-90	1-Feb-90	9	10000	10700	700	10400	10500	100	-8300	-8760	-460	6%	30-Jan-90	-8390	-9010	-620	7%
9-Feb-90	17-Feb-90	9	9900	10600	700	10400	10400	0	-8270	-8590	-320	4%	12-Feb-90	-8280	-8900	-620	7%
24-Feb-90	3-Mar-90	8	10000	10600	600	10400	10500	100	-8270	-8690	-420	5%	27-Feb-90	-8240	-8870	-630	8%
10-Mar-90	19-Mar-90	10	10000	10800	800	10300	10400	100	-8260	-8510	-250	3%	18-Mar-90	-8340	-8890	-550	7%
24-Mar-90	1-Apr-90	9	10300	10600	300	10300	10500	200	-8830	-9250	-420	5%	31-Mar-90	-9040	-9950	-910	10%
1-Apr-91	8-Apr-91	8	9300	10200	900	10200	10300	100	-7470	-8020	-550	7%	4-Apr-91	-7390	-8260	-870	12%
16-Mar-92	24-Mar-92	9	10000	10700	700	10300	10400	100	-8410	-9060	-650	8%	22-Mar-92	-8640	-9880	-1240	14%
20-Aug-93	27-Aug-93	8	10400	10900	500	10600	10700	100	-8730	-9350	-620	7%	24-Aug-93	-8870	-9850	-980	11%
4-Sep-93	10-Sep-93	7	10900	10900	0	10600	10700	100	-8360	-8790	-430	5%	9-Sep-93	-8420	-8990	-570	7%
18-Sep-93	23-Sep-93	6	10300	10900	600	10800	10900	100	-8370	-9030	-660	8%	20-Sep-93	-8450	-9360	-910	11%
1-Oct-93	9-Oct-93	9	10800	11100	300	10600	10900	300	-8340	-9040	-700	8%	3-Oct-93	-8240	-9240	-1000	12%
17-Oct-93	22-Oct-93	6	10800	10900	100	10900	10900	0	-7790	-8170	-380	5%	18-Oct-93	-7980	-8500	-520	7%
22-Nov-95	30-Nov-95	9	4300	4800	500	4400	4400	0	-2780	-3300	-520	19%	25-Nov-95	-2810	-3640	-830	30%
7-Dec-95	13-Dec-95	7	4200	4400	200	4300	4400	100	-2900	-3100	-200	7%	12-Dec-95	-2930	-3360	-430	15%
22-Dec-95	28-Dec-95	7	4200	4400	200	4200	4300	100	-2370	-2980	-610	26%	26-Dec-95	-2250	-3130	-880	39%
12-Aug-99	22-Aug-99	11	8700	11600	2900	10900	11300	400	-9800	-10180	-380	4%	20-Aug-99	-10040	-10630	-590	6%
28-Aug-99	5-Sep-99	9	10900	11600	700	11100	11400	300	-10260	-10790	-530	5%	1-Sep-99	-10350	-11180	-830	8%
13-Sep-99	19-Sep-99	7	11400	11500	100	11500	11500	0	-10090	-10390	-300	3%	17-Sep-99	-10030	-10530	-500	5%
3-May-00	9-May-00	7	1700	2200	500	2100	2300	200	-1930	-2410	-480	25%	8-May-00	-1980	-2560	-580	29%
5-May-01	13-May-01	9	1500	1700	200	1500	1500	0	-2000	-2630	-630	32%	11-May-01	-2190	-3380	-1190	54%
22-May-01	29-May-01	8	800	1600	800	1500	1500	0	-2020	-2590	-570	28%	27-May-01	-2140	-3080	-940	44%
22-Jul-01	29-Jul-01	8	7900	8800	900	8100	8300	200	-8580	-9160	-580	7%	25-Jul-01	-8610	-9610	-1000	12%
20-Aug-01	26-Aug-01	7	7700	8900	1200	8100	8400	300	-8470	-9080	-610	7%	23-Aug-01	-8410	-9370	-960	11%
6-Sep-01	12-Sep-01	7	7200	8300	1100	7500	7600	100	-7760	-8580	-820	11%	8-Sep-01	-7720	-9030	-1310	17%
19-Sep-01	25-Sep-01	7	7200	8200	1000	7700	7800	100	-7750	-8310	-560	7%	22-Sep-01	-7680	-8720	-1040	14%
27-Apr-02	3-May-02	7	1400	1500	100	1500	2000	500	-2190	-2750	-560	26%	30-Apr-02	-2160	-2960	-800	37%
12-May-02	18-May-02	7	1500	1500	0	1500	1500	0	-2030	-2540	-510	25%	16-May-02	-2040	-2810	-770	38%
26-May-02	31-May-02	6	1600	1600	0	1600	1600	0	-2010	-2260	-250	12%	31-May-02	-2100	-2620	-520	25%
1-May-03	7-May-03	7	1400	1500	100	1500	1500	0	-2340	-2760	-420	18%	3-May-03	-2400	-2950	-550	23%
15-May-03	22-May-03	8	1500	2300	800	1400	1700	300	-2250	-2800	-550	24%	20-May-03	-2300	-3190	-890	39%
15-Aug-03	22-Aug-03	8	11300	11600	300	11200	11400	200	-11260	-12100	-840	7%	20-Aug-03	-11430	-12670	-1240	11%
31-Aug-03	6-Sep-03	7	11200	11500	300	11400	11500	100	-11140	-12070	-930	8%	3-Sep-03	-11170	-12750	-1580	14%
13-Sep-03	21-Sep-03	9	10000	11600	1600	11200	11400	200	-11130	-11880	-750	7%	16-Sep-03	-11030	-12240	-1210	11%
25-Jul-05	31-Jul-05	7	11500	11600	100	11500	11500	0	-10020	-10670	-650	6%	28-Jul-05	-10110	-11040	-930	9%
7-Aug-05	15-Aug-05	9	10900	11700	800	11500	11600	100	-10390	-11020	-630	6%	13-Aug-05	-10530	-11350	-820	8%
22-Aug-05	28-Aug-05	7	11600	11700	100	11500	11600	100	-10500	-11190	-690	7%	25-Aug-05	-10650	-11720	-1070	10%
13-Aug-06	18-Aug-06	6	11500	11600	100	11500	11600	100	-10070	-10560	-490	5%	15-Aug-06	-10170	-10930	-760	7%
26-Aug-06	3-Sep-06	9	11300	11600	300	11500	11500	0	-9760	-10260	-500	5%	1-Sep-06	-9840	-10520	-680	7%
10-Sep-06	16-Sep-06	7	11000	11600	600	11500	11600	100	-9900	-10610	-710	7%	14-Sep-06	-10090	-11040	-950	9%
5-Nov-06	13-Nov-06	9	8600	10000	1400	9200	9400	200	-6880	-7100	-220	3%	7-Nov-06	-6870	-7260	-390	6%
15-Nov-06	23-Nov-06	9	9200	10000	800	9200	9500	300	-7260	-7460	-200	3%	20-Nov-06	-7310	-7660	-350	5%
2-Dec-06	6-Dec-06	5	8400	10200	1800	9600	9800	200	-7170	-7530	-360	5%	4-Dec-06	-7180	-7780	-600	8%
27-Jan-07	1-Feb-07	6	6300	6900	600	6500	6800	300	-3890	-4300	-410	11%	28-Jan-07	-3900	-4530	-630	16%
7-Feb-07	13-Feb-07	7	6400	6900	500	6800	6800	0	-4160	-4490	-330	8%	10-Feb-07	-4170	-4730	-560	13%
22-Feb-07	28-Feb-07	7	6600	6900	300	6800	6900	100	-4030	-4330	-300	7%	25-Feb-07	-4020	-4700	-680	17%
3-Apr-07	9-Apr-07	7	5600	7100	1500	6200	6600	400	-4460	-4920	-460	10%	7-Apr-07	-4480	-5250	-770	17%
15-May-07	20-May-07	6	1200	1500	300	1400	1500	100	-1540	-1750	-210	14%	18-May-07	-1540	-1920	-380	25%
14-Aug-07	24-Aug-07	11	11600	11600	0	11500	11600	100	-10450	-10960	-510	5%	17-Aug-07	-10160	-10810	-650	6%
3-May-08	9-May-08	7	1500	1500	0	1500	1600	100	-310	-1110	-800	258%	6-May-08	-330	-1720	-1390	421%
18-May-08	22-May-08	5	1400	1700	300	1500	1500	0	-500	-710	-210	42%	20-May-08	-530	-900	-370	70%

Paul Hutton 2/2/09

5.A.A.7 Attachment 7: Representation of National Marine Fisheries Service Biological Opinion Reasonable and Prudent Alternative Actions for CalSim II Planning Studies

The National Marine Fisheries Service's (NMFS) Biological Opinion (BiOp) on the Long-term Operations of the Central Valley Project and State Water Project was released on June 4, 2009.

To develop CalSim II modeling assumptions to represent the operations related reasonable and prudent alternative actions (RPA) required by this BiOp, the California Department of Water Resources (DWR) led a series of meetings that involved members of fisheries and project agencies. The purpose for establishing this group was to prepare the assumptions and CalSim II implementations to represent the RPAs in both Existing- and Future-Condition CalSim II simulations for future planning studies.

This memorandum summarizes the approach that resulted from these meetings and the modeling assumptions that were laid out by the group. The scope of this memorandum is limited to the June 4, 2009 BiOp. All descriptive information of the RPAs is taken from the BiOp.

Table 5.A.A.6-1 lists the participants that contributed to the meetings and information summarized in this document.

The RPAs in NMFS's BiOp are based on physical and biological processes that do not lend themselves to simulations using a monthly time step. Much scientific and modeling judgment has been employed to represent the implementation of the RPAs. The group believes the logic put into CalSim II represents the RPAs as best as possible at this time, given the scientific understanding of environmental factors enumerated in the BiOp and the limited historical data for some of these factors.

Given the relatively generalized representation of the RPAs assumed for CalSim II modeling, much caution is required when interpreting outputs from the model.

Table 5.A.A.7-1 Meeting Participants

Aaron Miller/DWR Randi Field/Reclamation Lenny Grimaldo/Reclamation Henry Wong/Reclamation	Derek Hilts/USFWS Roger Guinee/ USFWS Matt Nobriga/CDFW Bruce Oppenheim/ NMFS
Parviz Nader-Tehrani/ DWR Erik Reyes/ DWR Sean Sou/ DWR Paul A. Marshall/ DWR Ming-Yen Tu/ DWR Xiaochun Wang/ DWR	Robert Leaf/CH2M HILL Derya Sumer/CH2M HILL

Notes:
CDFW = California DWR of Fish and Wildlife
NMFS = National Marine Fisheries Service
USFWS = U.S. Fish and Wildlife Service

5.A.A.7.1 Action Suite 1.1 Clear Creek

Suite Objective: The RPA actions described below were developed based on a careful review of past flow studies, current operations, and future climate change scenarios. These actions are necessary to address adverse project effects on flow and water temperature that reduce the viability of spring-run and CV steelhead in Clear Creek.

5.A.A.7.1.1 Action 1.1.1 Spring Attraction Flows

Objective: Encourage spring-run movement to upstream Clear Creek habitat for spawning.

Action: Reclamation shall annually conduct at least two pulse flows in Clear Creek in May and June of at least 600 cfs for at least three days for each pulse, to attract adult spring-run holding in the Sacramento River main stem.

5.A.A.7.1.1.1 Action 1.1.1 Assumptions for CalSim II Modeling Purposes

Action: Model is modified to meet 600 cfs for 3 days twice in May. In the CalSim II analysis, Flows sufficient to increase flow up to 600 cfs for a total of 6 days are added to the flows that would have otherwise occurred in Clear Creek.

Rationale: CalSim II is a monthly model. The monthly flow in Clear Creek is an underestimate of the actual flows that would occur subject to daily operational constraints at Whiskeytown Reservoir. The additional flow to meet 600 cfs for a total of 6 days was added to the monthly average flow modeled.

5.A.A.7.1.2 Action 1.1.5. Thermal Stress Reduction

Objective: To reduce thermal stress to over-summering steelhead and spring-run during holding, spawning, and embryo incubation.

Action: Reclamation shall manage Whiskeytown releases to meet a daily water temperature of: (1) 60°F at the Igo gauge from June 1 through September 15; and (2) 56°F at the Igo gauge from September 15 to October 31.

5.A.A.7.1.2.1 Action 1.1.5 Assumptions for CalSim II Modeling Purposes

Action: It is assumed that temperature operations can perform reasonably well with flows included in model.

Rationale: A temperature model of Whiskeytown Reservoir has been developed by Reclamation. Further analysis using this or other temperature model is required to verify the statement that temperature operations can perform reasonably well with flows included in model.

5.A.A.7.2 Action Suite 1.2 Shasta Operations

Objectives: To address the avoidable and unavoidable adverse effects of Shasta operations on winter-run and spring-run:

- Ensure a sufficient cold water pool to provide suitable temperatures for winter-run spawning between Balls Ferry and Bend Bridge in most years, without sacrificing the potential for cold water management in a subsequent year. Additional actions to those in the 2004 CVP/SWP operations Opinion are needed, due to increased vulnerability of the population to temperature effects attributable to changes in Trinity River ROD operations, projected climate change hydrology, and increased water demands in the Sacramento River system.

- Ensure suitable spring-run temperature regimes, especially in September and October. Suitable spring-run temperatures will also partially minimize temperature effects to naturally-spawning, non-listed Sacramento River fall-run, an important prey base for endangered Southern Residents.

- Establish a second population of winter-run in Battle Creek as soon as possible, to partially compensate for unavoidable project-related effects on the one remaining population.

- Restore passage at Shasta Reservoir with experimental reintroductions of winter-run to the upper Sacramento and/or McCloud rivers, to partially compensate for unavoidable project-related effects on the remaining population.

5.A.A.7.2.1 Action 1.2.1 Performance Measures

Objective: To establish and operate to a set of performance measures for temperature compliance points and End-of-September (EOS) carryover storage, enabling Reclamation and NMFS to assess the effectiveness of this suite of actions over time. Performance measures will help to ensure that the beneficial variability of the system from changes in hydrology will be measured and maintained.

Action: To ensure a sufficient cold water pool to provide suitable temperatures, long-term performance measures for temperature compliance points and EOS carryover storage at Shasta Reservoir shall be attained. Performance measures for EOS carryover storage at Shasta Reservoir are as follows:

- 87% of years: Minimum EOS storage of 2.2 MAF

- 82% of years: Minimum EOS storage of 2.2 MAF and end-of-April storage of 3.8 MAF in following year (to maintain potential to meet Balls Ferry compliance point)

- 40% of years: Minimum EOS storage 3.2 MAF (to maintain potential to meet Jelly's Ferry compliance point in following year)

Performance measures (measured as a 10-year running average) for temperature compliance points during summer season are:

- Meet Clear Creek Compliance point 95% of time

- Meet Balls Ferry Compliance point 85% of time
- Meet Jelly's Ferry Compliance point 40% of time
- Meet Bend Bridge Compliance point 15% of time

5.A.A.7.2.1.1 Action 1.2.1 Assumptions for CalSim II Modeling Purposes

Action: No specific CalSim II modeling code is implemented to simulate the performance measures identified. System performance will be assessed and evaluated through post-processing of various model results.

Rationale: Given that the performance criteria are based on the CalSim II modeling data used in preparation of the Biological Assessment, the system performance after application of the RPAs should be similar as a percentage of years that the end-of-April storage and temperature compliance requirements are met over the simulation period. Post-processing of modeling results will be compared to various new operating scenarios as needed to evaluate performance criteria and appropriateness of the rules developed.

5.A.A.7.2.2 Action 1.2.2 November through February Keswick Release Schedule (Fall Actions)

Objective: Minimize impacts to listed species and naturally spawning non-listed fall-run from high water temperatures by implementing standard procedures for release of cold water from Shasta Reservoir.

Action: Depending on EOS carryover storage and hydrology, Reclamation shall develop and implement a Keswick release schedule, and reduce deliveries and exports as needed to achieve performance measures.

5.A.A.7.2.2.1 Action 1.2.2 Assumptions for CalSim II Modeling Purposes

Action: No specific CalSim II modeling code is implemented to simulate the Performance measures identified. Keswick flows based on operation of 3406(b)(2) releases in OCAP Study 7.1 (for Existing) and Study 8 (for Future) are used in CalSim II. These flows will be reviewed for appropriateness under this action. A post-process based evaluation similar to what has been explained in Action 1.2.1 will be conducted.

Rationale: Performance measures are set as percentage of years that the end-of-September and temperature compliance requirements are met over the simulation period. Post-processing of modeling results will be compared to various new operating scenarios as needed to evaluate performance criteria and appropriateness of the rules developed.

5.A.A.7.2.3 Action 1.2.3 February Forecast; March – May 14 Keswick Release Schedule (Spring Actions)

Objective: To conserve water in Shasta Reservoir in the spring in order to provide sufficient water to reduce adverse effects of high water temperature in the summer months for winter-run, without sacrificing carryover storage in the fall.

Action:

- Reclamation shall make its February forecast of deliverable water based on an estimate of precipitation and runoff within the Sacramento River basin at least as conservative as the 90% probability of exceedance. Subsequent updates of water delivery commitments must be based on monthly forecasts at least as conservative as the 90% probability of exceedance.

- Reclamation shall make releases to maintain a temperature compliance point not in excess of 56 degrees between Balls Ferry and Bend Bridge from April 15 through May 15.

5.A.A.7.2.3.1 Action 1.2.3 Assumptions for CalSim II Modeling Purposes

Action: No specific CalSim II modeling code is implemented to simulate the Performance measures identified. It is assumed that temperature operations can perform reasonably well with flows included in model.

Rationale: Temperature models of Shasta Lake and the Sacramento River have been developed by Reclamation. This modeling reflects current facilities for temperature controlled releases. Further analysis using this or another temperature model can further verify that temperature operations can perform reasonably well with flows included in model and temperatures are met reliably at each of the compliance points. In the future, it may be that adjusted flow schedules may need to be developed based on development of temperature model runs in conjunction with CalSim II modeled operations.

5.A.A.7.2.4 Action 1.2.4 May 15 through October Keswick Release Schedule (Summer Action)

Objective: To manage the cold water storage within Shasta Reservoir and make cold water releases from Shasta Reservoir to provide suitable habitat temperatures for winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon in the Sacramento River between Keswick Dam and Bend Bridge, while retaining sufficient carryover storage to manage for next year’s cohorts. To the extent feasible, manage for suitable temperatures for naturally spawning fall-run.

Action: Reclamation shall manage operations to achieve daily average water temperatures in the Sacramento River between Keswick Dam and Bend Bridge as follows:

- Not in excess of 56°F at compliance locations between Balls Ferry and Bend Bridge from May 15 through September 30 for protection of winter-run, and not in excess of 56°F at the same compliance locations between Balls Ferry and Bend Bridge from October 1 through October 31 for protection of mainstem spring run, whenever possible.

- Reclamation shall operate to a final Temperature Management Plan starting May 15 and ending October 31.

5.A.A.7.2.4.1 Action 1.2.4 Assumptions for CalSim II Modeling Purposes

Action: No specific CalSim II modeling code is implemented to simulate the Performance measures identified. It is assumed that temperature operations can perform reasonably well with flows included in model. During the detailed effects analysis, temperature modeling and post-processing will be used to verify temperatures are met at the compliance points. In the long-term approach, for a complete interpretation of the action, development of temperature model runs are needed to develop flow schedules if needed for implementation into CalSim II.

Rationale: Temperature models of Shasta Lake and the Sacramento River have been developed by Reclamation. This modeling reflects current facilities for temperature controlled releases. Further analysis using this or another temperature model is required to verify the statement that temperature operations can perform reasonably well with flows included in model and temperatures are met reliably at each of the compliance points. It may be that alternative flow schedules may need to be developed based on development of temperature model runs in conjunction with CalSim II modeled operations.

5.A.A.7.3 Action Suite 1.3 Red Bluff Diversion Dam (RBDD) Operations

Objectives: Reduce mortality and delay of adult and juvenile migration of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon caused by the presence of the diversion dam and the configuration of the operable gates. Reduce adverse modification of the passage element of critical habitat for these species. Provide unimpeded upstream and downstream fish passage in the long term by raising the gates year-round, and minimize adverse effects of continuing dam operations, while pumps are constructed replace the loss of the diversion structure.

5.A.A.7.3.1 Action 1.3.1 Operations after May 14, 2012: Operate RBDD with Gates Out

Action: No later than May 15, 2012, Reclamation shall operate RBDD with gates out all year to allow unimpeded passage for listed anadromous fish.

5.A.A.7.3.1.1 Action 1.3.1 Assumptions for CalSim II Modeling Purposes

Action: Adequate permanent facilities for diversion are assumed; therefore no constraint on diversion schedules is included in the Future condition modeling.

5.A.A.7.3.2 Action 1.3.2 Interim Operations

Action: Until May 14, 2012, Reclamation shall operate RBDD according to the following schedule:

•September 1 - June 14: Gates open. No emergency closures of gates are allowed.

•June 15 - August 31: Gates may be closed at Reclamation's discretion, if necessary to deliver water to TCCA.

5.A.A.7.3.2.1 Action 1.3.2 Assumptions for CalSim II Modeling Purposes

Action: Adequate interim/temporary facilities for diversion are assumed; therefore no constraint on diversion schedules is included in the No Action Alternative modeling.

5.A.A.7.4 Action 1.4 Wilkins Slough Operations

Objective: Enhance the ability to manage temperatures for anadromous fish below Shasta Dam by operating Wilkins Slough in the manner that best conserves the dam's cold water pool for summer releases.

Action: The Sacramento River Temperature Task Group (SRTTG) shall make recommendations for Wilkins Slough minimum flows for anadromous fish in critically dry years, in lieu of the current 5,000 cfs navigation criterion to NMFS by December 1, 2009. In critically dry years, the SRTTG will make a recommendation.

5.A.A.7.4.1.1 Action 1.4 Assumptions for CalSim II Modeling Purposes

Action: Current rules for relaxation of NCP in CalSim II (based on BA models) will be used. In CalSim II, NCP flows are relaxed depending on allocations for agricultural contractors. Table 5.A.A.7-2 is used to determine the relaxation.

Table 5.A.A.7-2 NCP Flow Schedule with Relaxation

CVP AG Allocation (%)	NCP Flow (cfs)
<10	3,250
10–25	3,500
25–40	4,000
40–65	4,500
>65	5,000

Rationale: The allocation-flow criteria have been used in the CalSim II model for many years. The low allocation year relaxations were added to improve operations of Shasta Lake subject to 1.9 MAF carryover target storage. These criteria may be reevaluated subject to the requirements of Action 1.2.1

5.A.A.7.5 Action 2.1 Lower American River Flow Management

Objective: To provide minimum flows for all steelhead life stages.

Action: Implement the flow schedule specified in the Water Forum's Flow Management Standard (FMS), which is summarized in Appendix 2-D of the NMFS BiOp.

5.A.A.7.5.1.1 Action 2.1 Assumptions for CalSim II Modeling Purposes

Action: The AFRMP Minimum Release Requirements (MRR) range from 800 to 2,000 cfs based on a sequence of seasonal indices and adjustments. The minimum Nimbus Dam release requirement is determined by applying the appropriate water availability index (Index Flow). Three water availability indices (i.e., Four Reservoir Index (FRI), Sacramento River Index (SRI), and the Impaired Folsom Inflow Index (IFII)) are applied during different times of the year, which provides adaptive flexibility in response to changing hydrological and operational conditions.

During some months, Prescriptive Adjustments may be applied to the Index Flow, resulting in the MRR. If there is no Prescriptive Adjustment, the MRR is equal to the Index Flow.

Discretionary Adjustments for water conservation or fish protection may be applied during the period extending from June through October. If Discretionary Adjustments are applied, then the resultant flows are referred to as the Adjusted Minimum Release Requirement (Adjusted MRR).

The MRR and Adjusted MRR may be suspended in the event of extremely dry conditions, represented by "conference years" or "off-ramp criteria". Conference years are defined when the projected March through November unimpaired inflow into Folsom Reservoir is less than 400,000 acre-feet. Off-ramp criteria are triggered if forecasted Folsom Reservoir storage at any time during the next twelve months is less than 200,000 acre-feet.

Rationale: Minimum instream flow schedule specified in the Water Forum's Flow Management Standard (FMS) is implemented in the model.

5.A.A.7.5.1.2 Action 2.2 Lower American River Temperature Management

Objective: Maintain suitable temperatures to support over-summer rearing of juvenile steelhead in the lower American River.

Action: Reclamation shall develop a temperature management plan that contains: (1) forecasts of hydrology and storage; (2) a modeling run or runs, using these forecasts, demonstrating that the temperature compliance point can be attained (see Coldwater Management Pool Model approach in Appendix 2-D); (3) a plan of operation based on this modeling run that demonstrates that all other non-discretionary requirements are met; and (4) allocations for discretionary deliveries that conform to the plan of operation.

5.A.A.7.5.1.3 Action 2.2 Assumptions for CalSim II Modeling Purposes

5.A.A.7.5.1.4 ***Action:*** *The flows in the model reflect the FMS implemented under Action 2.1. It is assumed that temperature operations can perform reasonably well with flows included in model.*

Rationale: Temperature models of Folsom Lake and the American River were developed in the 1990's. Model development for long range planning purposes may be required. Further analysis using a verified long range planning level temperature model is required to verify the statement that temperature operations can perform reasonably well with flows included in model and temperatures are met reliably

5.A.A.7.6 Action Suite 3.1 Stanislaus River / Eastside Division Actions

Overall Objectives: (1) Provide sufficient definition of operational criteria for Eastside Division to ensure viability of the steelhead population on the Stanislaus River, including freshwater migration routes to and from the Delta; and (2) halt or reverse adverse modification of steelhead critical habitat.

5.A.A.7.6.1 Action 3.1.2 Provide Cold Water Releases to Maintain Suitable Steelhead Temperatures

Action: Reclamation shall manage the cold water supply within New Melones Reservoir and make cold water releases from New Melones Reservoir to provide suitable temperatures for CV steelhead rearing, spawning, egg incubation smoltification, and adult migration in the Stanislaus River downstream of Goodwin Dam.

5.A.A.7.6.1.1 Action 3.1.2 Assumptions for CalSim II Modeling Purposes

Action: No specific CalSim II modeling code is implemented to simulate the Performance measures identified. It is assumed that temperature operations can perform reasonably well with flow operations resulting from the minimum flow requirements described in action 3.1.3.

Rationale: Temperature models of New Melones Lake and the Stanislaus River have been developed by Reclamation. Further analysis using this or another temperature model can further verify that temperature operations perform reasonably well with flows included in model and temperatures are met reliably. Development of temperature model runs is needed to refine the flow schedules assumed.

5.A.A.7.6.2 Action 3.1.3 Operate the East Side Division Dams to Meet the Minimum Flows, as Measured at Goodwin Dam

Objective: To maintain minimum base flows to optimize CV steelhead habitat for all life history stages and to incorporate habitat maintaining geomorphic flows in a flow pattern that will provide migratory cues to smolts and facilitate out-migrant smolt movement on declining limb of pulse.

Action: Reclamation shall operate releases from the East Side Division reservoirs to achieve a minimum flow schedule as prescribed in NMFS BiOp Appendix 2-E and generally described in figure 11-1. When operating at higher flows than specified, Reclamation shall implement ramping rates for flow changes that will avoid stranding and other adverse effects on CV steelhead.

5.A.A.7.6.2.1 Action 3.1.3 Assumptions for CalSim II Modeling Purposes

Action: Minimum flows based on Appendix 2-E flows (presented in Figure 5.A.A.7-1) are assumed consistent to what was modeled by NMFS (5/14/09 and 5/15/09 CalSim II models provided by NMFS; relevant logic merged into baselines models).

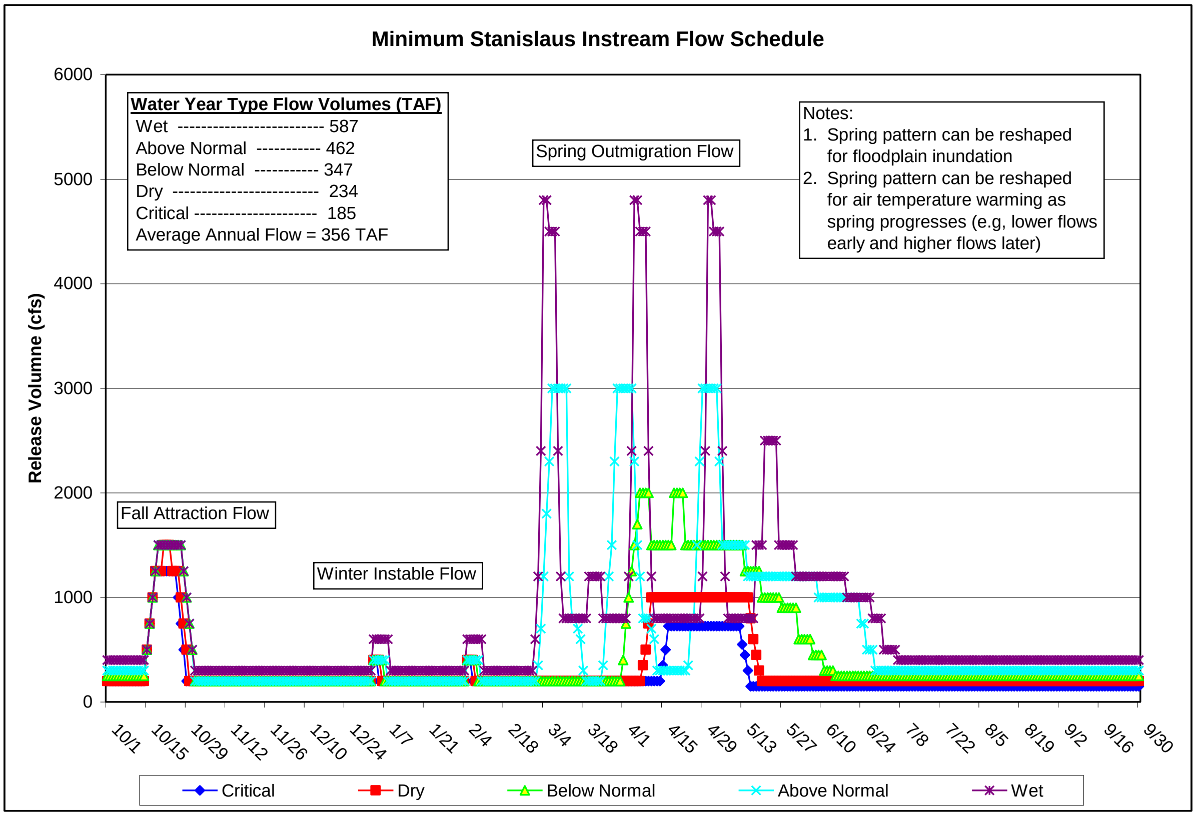


Figure 5.A.A.7-1 Minimum Stanislaus instream flow schedule as prescribed in Appendix 2-E of the NMFS BiOp (06/04/09)

Annual allocation in New Melones is modeled to ensure availability of required instream flows (Table 5.A.A.7-3) based on a water supply forecast that is comprised of end-of-February New Melones storage (in TAF) plus forecasted inflow to New Melones from March 1 to September 30 (in TAF). The “forecasted inflow” is calculated using perfect foresight in the model. Allocated volume of water is released according to water year type following the monthly flow schedule illustrated in Figure 5.A.A.7-1.

Table 5.A.A.7-3 New Melones Allocations to Meet Minimum Instream Flow Requirements

New Melones index (TAF)	Annual Allocation Required for Instream Flows (TAF)
< 1000	0 to 98.9
1,000 to 1,399	98.9
1,400 to 1,724	185.3
1,725 to 2,177	234.1
2,178 to 2,386	346.7
2,387 to 2,761	461.7
2,762 to 6,000	586.9

Rationale: This approach was reviewed by NOAA fisheries and verified that the year typing and New Melones allocation scheme are consistent with the modeling prepared for the BiOp.

5.A.A.7.7 Action Suite 4.1 Delta Cross Channel (DCC) Gate Operation, and Engineering Studies of Methods to Reduce Loss of Salmonids in Georgiana Slough and Interior Delta

5.A.A.7.7.1 Action 4.1.2 DCC Gate Operation

Objective: Modify DCC gate operation to reduce direct and indirect mortality of emigrating juvenile salmonids and green sturgeon in November, December, and January.

Action: During the period between November 1 and June 15, DCC gate operations will be modified from the proposed action to reduce loss of emigrating salmonids and green sturgeon. From December 1 to January 31, the gates will remain closed, except as operations are allowed using the implementation procedures/modified Salmon Decision Tree.

Timing: November 1 through June 15.

Triggers: Action triggers and description of action as defined in NMFS BiOp are presented in Table 5.A.A.7-4.

Table 5.A.A.7-4 NMFS BiOp DCC Gate Operation Triggers and Actions

Date	Action Triggers	Action Responses
October 1 – November 30	Water quality criteria per D-1641 are met and either the Knights Landing Catch Index (KLCI) or the Sacramento Catch Index (SCI) are greater than 3 fish per day but less than or equal to 5 fish per day.	Within 24 hours of trigger, DCC gates are closed. Gates will remain closed for 3 days.
	Water quality criteria per D-1641 are met and either the KLCI or SCI is greater than 5 fish per day	Within 24 hours, close the DCC gates and keep closed until the catch index is less than 3 fish per day at both the Knights Landing and Sacramento monitoring sites.

Date	Action Triggers	Action Responses
	The KLCI or SCI triggers are met but water quality criteria are not met per D-1641 criteria.	DOSS reviews monitoring data and makes recommendation to NMFS and WOMT per procedures in Action IV.5.
December 1 – December 14	Water quality criteria are met per D-1641.	DCC gates are closed. If Chinook salmon migration experiments are conducted during this time period (e.g., Delta Action 8 or similar studies), the DCC gates may be opened according to the experimental design, with NMFS' prior approval of the study.
	Water quality criteria are not met but both the KLCI and SCI are less than 3 fish per day.	DCC gates may be opened until the water quality criteria are met. Once water quality criteria are met, the DCC gates will be closed within 24 hours of compliance.
	Water quality criteria are not met but either of the KLCI or SCI is greater than 3 fish per day.	DOSS reviews monitoring data and makes recommendation to NMFS and WOMT per procedures in Action IV.5
December 15 – January 31	December 15 – January 31	DCC Gates Closed.
	NMFS-approved experiments are being conducted.	Agency sponsoring the experiment may request gate opening for up to 5 days; NMFS will determine whether opening is consistent with ESA obligations.
	One-time event between December 15 to January 5, when necessary to maintain Delta water quality in response to the astronomical high tide, coupled with low inflow conditions.	Upon concurrence of NMFS, DCC Gates may be opened one hour after sunrise to one hour before sunset, for up to 3 days, then return to full closure. Reclamation and DWR will also reduce Delta exports down to a health and safety level during the period of this action.
February 1 – May 15	D-1641 mandatory gate closure.	Gates closed, per WQCP criteria
May 16 – June 15	D-1641 gate operations criteria	DCC gates may be closed for up to 14 days during this period, per 2006 WQCP, if NMFS determines it is necessary.

5.A.A.7.7.1.1 Action 4.1.2 Assumptions for CalSim II Modeling Purposes

Action: The DCC gate operations for October 1 through January 31 were layered on top of the D-1641 gate operations already included in the CalSim II model. The general assumptions regarding the NMFS DCC operations are summarized in Table 5.A.A.7-5.

Timing: October 1 through January 31.

Table 5.A.A.7-5 DCC Gate Operation Triggers and Actions as Modeled in CalSim II

Date	Modeled Action Triggers	Modeled Action Responses
October 1 – December 14	Sacramento River daily flow at Wilkins Slough exceeding 7,500 cfs; flow assumed to flush salmon into the Delta	Each month, the DCC gates are closed for number of days estimated to exceed the threshold value.
	Water quality conditions at Rock Slough subject to D-1641 standards	Each month, the DCC gates are not closed if it results in violation of the D-1641 standard for Rock Slough; if DCC gates are not closed due to water quality conditions, exports during the days in question are restricted to 2,000 cfs.
December 15 – January 31	December 15-January 31	DCC Gates Closed.

Flow Trigger: It is assumed that during October 1 – December 14, the DCC will be closed if Sacramento River daily flow at Wilkins Slough exceeds 7,500 cfs. Using historical data (1945 through 2003, USGS gauge 11390500 "Sacramento River below Wilkins Slough near Grimes, CA"), a linear relationship is obtained between average monthly flow at Wilkins Slough and the number of days in month where the flow exceeds 7,500 cfs. This relation is then used to estimate the number of days of DCC closure for the October 1 – December 14 time period (Figure 5.A.A.7-2).

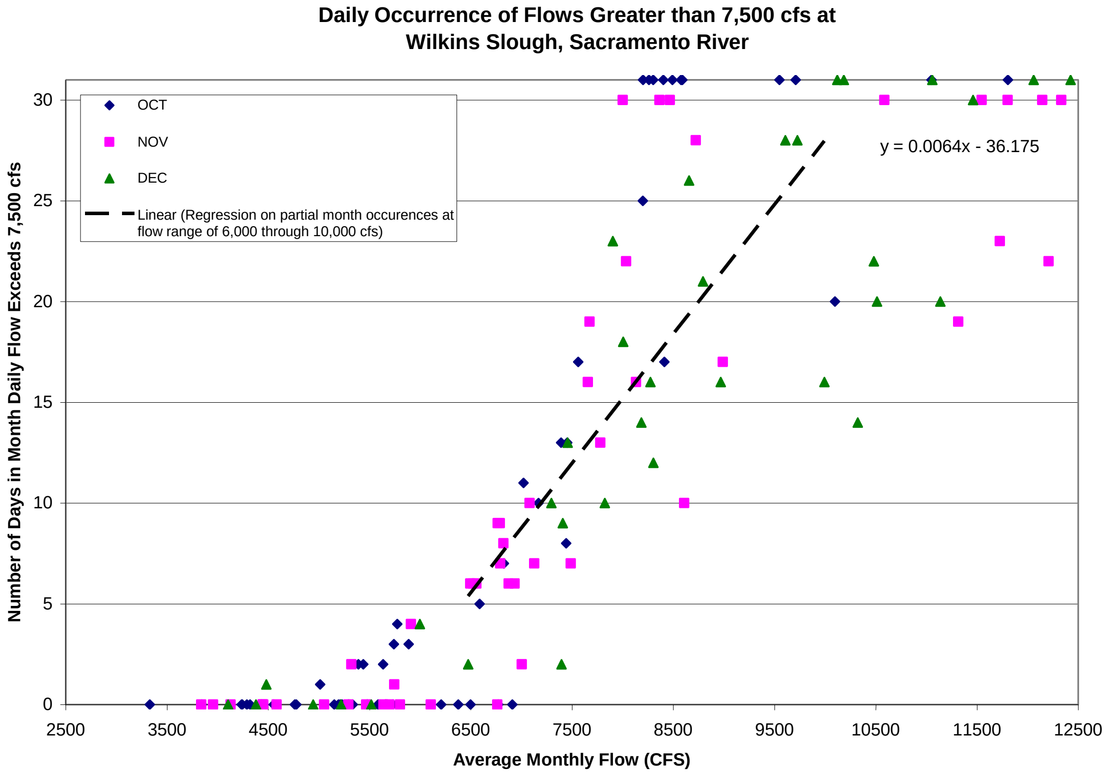


Figure 5.A.A.7-2 Relationship between monthly averages of Sacramento River flows and number of days that daily flow exceeds 7,500 cfs in a month at Wilkins Slough

It is assumed that during December 15 through January 31 that the DCC gates are closed under all flow conditions.

Water Quality: It is assumed that during October 1 – December 14 the DCC gates may remain open if water quality is a concern. Using the CalSim II-ANN flow-salinity model for Rock Slough, current month's chloride level at Rock Slough is estimated assuming DCC closure per NMFS BiOp. The estimated chloride level is compared against the Rock Slough chloride standard (monthly average). If estimated chloride level exceeds the standard, the gate closure is modeled per D1641 schedule (for the entire month).

It is assumed that during December 15 through January 31 that the DCC gates are closed under all water quality conditions.

Export Restriction: During October 1 – December 14 period, if the flow trigger condition is such that additional days of DCC gates closed is called for, however water quality conditions are a concern and the DCC gates remain open, then Delta exports are limited to 2,000 cfs for each day in question. A monthly Delta export restriction is calculated based on the trigger and water quality conditions described above.

Rationale: The proposed representation in CalSim II should adequately represent the limited water quality concerns were Sacramento River flows are low during the extreme high tides of December.

5.A.A.7.8 Action Suite 4.2 Delta Flow Management

5.A.A.7.8.1 Action 4.2.1 San Joaquin River Inflow to Export Ratio

Objectives: To reduce the vulnerability of emigrating CV steelhead within the lower San Joaquin River to entrainment into the channels of the South Delta and at the pumps due to the diversion of water by the export facilities in the South Delta, by increasing the inflow to export ratio. To enhance the likelihood of salmonids successfully exiting the Delta at Chipps Island by creating more suitable hydraulic conditions in the main stem of the San Joaquin River for emigrating fish, including greater net downstream flows.

Action: For CVP and SWP operations under this action, "The Phase II: Operations beginning is 2012" is assumed. From April 1 through May 31, 1) Reclamation shall continue to implement the Goodwin flow schedule for the Stanislaus River prescribed in Action 3.1.3 and Appendix 2-E of the NMFS BiOp); and 2) Combined CVP and SWP exports shall be restricted to the ratio depicted in table B-44 below based on the applicable San Joaquin River Index, but will be no less than 1,500 cfs (consistent with the health and safety provision governing this action.)

5.A.A.7.8.1.1 Action 4.2.1 Assumptions for CalSim II Modeling Purposes

Action: Flows at Vernalis during April and May will be based on the Stanislaus River flow prescribed in Action 3.1.3 and the flow contributions from the rest of the San Joaquin River basin consistent with the representation of VAMP contained in the BA modeling. In many years this flow may be less than the minimum Vernalis flow identified in the NOAA BiOp.

Exports are restricted as illustrated in Table 5.A.A.7-6.

Table 5.A.A.7-6. Maximum Combined CVP and SWP Export during April and May

San Joaquin River Index	Combined CVP and SWP Export Ratio
Critically dry	1:1
Dry	2:1
Below normal	3:1
Above normal	4:1
Wet	4:1

Rationale: Although the described model representation does not produce the full Vernalis flow objective outlined in the NOAA BiOp, it does include the elements that are within the control of the CVP and SWP, and that are reasonably certain to occur for the purpose of the EIS/EIR modeling.

In the long-term, a future SWRCB flow standard at Vernalis may potentially incorporate the full flow objective identified in the BiOp; and the Merced and Tuolumne flows would be based on the outcome of the current SWRCB and FERC processes that are underway.

5.A.A.7.8.2 Action 4.2.3 Old and Middle River Flow Management

Objective: Reduce the vulnerability of emigrating juvenile winter-run, yearling spring-run, and CV steelhead within the lower Sacramento and San Joaquin rivers to entrainment into the channels of the South Delta and at the pumps due to the diversion of water by the export facilities in the South Delta. Enhance the likelihood of salmonids successfully exiting the Delta at Chipps Island by creating more suitable hydraulic conditions in the mainstem of the San Joaquin River for emigrating fish, including greater net downstream flows.

Action: From January 1 through June 15, reduce exports, as necessary, to limit negative flows to -2,500 to -5,000 cfs in Old and Middle Rivers, depending on the presence of salmonids. The reverse flow will be managed within this range to reduce flows toward the pumps during periods of increased salmonid presence. Refer to NMFS BiOp document for the negative flow objective decision tree.

5.A.A.7.8.2.1 Action 4.2.3 Assumptions for CalSim II Modeling Purposes

Action: Old and Middle River flows required in this BiOp are assumed to be covered by OMR flow requirements developed for actions 1 through 3 of the FWS BiOp Most Likely scenario (Representation of U.S. Fish and Wildlife Service Biological Opinion Reasonable and Prudent Alternative Actions for CalSim II Planning Studies – DRAFT, 6/10/09).

Rationale: Based on a review of available data, it appears that implementation of actions 1 through 3 of the FWS RPA, and action 4.2.1 of the NOAA RPA will adequately cover this action within the CalSim II simulation. If necessary, additional post-processing of results could be conducted to verify this assumption.

5.A.A.7.9 References

CH2M HILL, 2009. DSM2 Recalibration. Prepared for California DWR of Water Resources, October, 2009.

DWR et al. (California Department of Water Resources, Bureau of Reclamation, U.S. Fish and Wildlife Service, and National Marine Fisheries Service). 2013. Environmental Impact Report/ Environmental Impact Statement for the Bay Delta Conservation Plan. Draft. December.

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SWRCB, 2000. Revised Water Right Decision 1641, March 15, 2000.

U.S. Bureau of Reclamation, 2006. Lower American River Flow Management Standard. Draft Report. July 31, 2006.

U.S. Bureau of Reclamation, 2008a. Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment, Appendix D CalSim-II Model, May 2008.

U.S. Bureau of Reclamation, 2008b. Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment, Appendix F DSM2 Model, May 2008.

U.S. Fish and Wildlife Service, 2008. Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the Central Valley Project (CVP) and State Water Project (SWP).

5.A.A.8 Attachment 8: Modified CalSim II Inputs for Climate Change

Updated input data due to climate change represented in CalSim II are limited to hydrologic parameters that could be estimated by the climate change modeling. The modified parameters are listed below.

Rim Basin Inflows	**Basin Floor Inflows**
Trinity Lake Inflow	Clear Creek Inflow to Sacramento River
Lewiston Lake Inflow	Cottonwood Creek Inflow to Sacramento River
Shasta Lake Inflow	Cow Creek Inflow to Sacramento River
Black Butte Lake Inflow	Battle Creek Inflow to Sacramento River
Lake Oroville Inflow	Paynes Creek Inflow to Sacramento River
Folsom Lake Inflow	Red Bank Creek Inflow to Sacramento River
New Hogan Reservoir	Antelope Creek Inflow to Sacramento River
New Melones Reservoir Inflow	Mill Creek Inflow to Sacramento River
New Don Pedro Reservoir Inflow	Deer Creek Inflow to Sacramento River
Lake McClure Inflow	Elder Creek Inflow to Sacramento River
Eastman Lake Inflow	Thomes Creek Inflow to Sacramento River
Hensley Lake Inflow	Big Chico Creek Inflow to Sacramento River
Millerton Lake Inflows	Butte Creek Spills to Sutter Bypass
	Stony Creek Inflow to Stony Gorge Reservoir
	Little Stony Creek Inflow to East Park Reservoir
	Kelly Ridge Inflow to Feather River
	Yuba River Inflow to Feather River
	Bear River Inflow to Feather River
	American River Upstream Inflow to Folsom Reservoir
	Mokelumne River Inflow to Delta
	Cosumnes River Inflow to Delta

Other
American River Runoff Forecast
Feather River Runoff Forecast
Sacramento River Runoff Forecast
Water Year Types
Sacramento River index
San Joaquin River Index
Shasta Index
Feather River Index
American River Index (D893 and 40-30-30)
Trinity Index
Delta Index
USFWS BiOp Action 3 Temperature Trigger
Unimpaired inflow to Folsom Lake from Mar to Nov
Eight River Index Forecast
SWRCB D-1641 February export-inflow ratio requirement

Several other parameters, such as demand patterns, Delta salinity standards, and flood control curves that are likely to change under future climate cannot be modeled at this time because significant uncertainty exists for the potential adaptation measures. Model assumptions regarding CVP and SWP operations in future without policy decisions by stakeholders would be deemed speculative. Therefore, CalSim II results for the NAA and the PA evaluated in the CWF BA represent the risks to operations, water users, and the environment in the absence of dynamic adaptation for climate change.

Climate change conditions are found to exacerbate dry hydrologic conditions. As noted elsewhere, under such extreme hydrologic and operational conditions where there is not enough water supply to meet all requirements, CalSim II utilizes a series of operating rules to reach a solution to allow for the continuation of the simulation. It is recognized that these operating rules are a simplified version of the very complex decision processes that SWP and CVP operators would use in actual extreme conditions. Despite detailed model inputs and assumptions, in very dry years, the model will still sometimes show dead pool conditions that may result in instances in which flow conditions fall short of minimum flow criteria, salinity conditions may exceed salinity standards, diversion conditions fall short of allocated diversion amounts, and operating agreements are not met. Such model results are anomalies that reflect the inability of the model to make real-time policy decisions under extreme circumstances, as the actual (human) operators must do. Thus, any operations simulated due to reservoir storage conditions being near dead pool should only be considered an indicator of stressed water supply conditions under that scenario, and should not necessarily be understood to reflect literally what would occur in the future. In actual future operations, as has always been the case in the past, the project operators would work in real-time to satisfy legal and contractual obligations given then current conditions and hydrologic constraints.

It should also be noted that the climate change assumptions are consistent between the CWF NAA and PA. Therefore, the incremental changes under CWF PA with respect to the NAA would provide indication of the effects related to the PA.