Appendix 6B, Section C

Surface Water Temperature Modeling – HEC-5Q Model Update

Information about the methods and assumptions used for the Coordinated Long-Term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS) analysis on surface water temperature is provided in this appendix. This appendix is organized into three sections that are briefly described below:

- Appendix 6B, Section A: Surface Water Temperature Modeling Methodology, Simulations, and Assumptions
  - The water quality impacts analysis uses the HEC-5Q and Reclamation Monthly Temperature models to assess and quantify effects of the alternatives on the environment. This section provides information about the overall analytical framework linkages with other models.
  - This section provides a brief description of the assumptions for the surface water temperature model simulations of the No Action Alternative, Second Basis of Comparison, and other alternatives.
- Appendix 6B, Section B: Surface Water Temperature Modeling Results
  - This section provides model outputs and a description of the model simulation output formats used in the analysis and interpretation of modeling results for the alternatives impacts assessment.
- Appendix 6B, Section C: HEC-5Q Model Update for Surface Water Temperature Modeling
  - This section provides a detailed description of the compilation and updates of the HEC-5Q models performed during development of the EIS for the Trinity-Sacramento, American, and Stanislaus Rivers.

6B.C.1 Introduction

This section describes tasks that were undertaken to update the Trinity-Sacramento River, American River, and San Joaquin River HEC-5Q models. The work performed was for the Bureau of Reclamation (Reclamation). Four tasks were performed as part of this update:

- A housekeeping task where all existing work prior to the updates was compiled, organized, and modified to create a base version from which all future work would be based from.
- A validation task where the Trinity-Sacramento and American River models were modified to better match observed data.

- A flow mapping task where improvements to the input flows coming from CalSim II were made where necessary.
- A temperature targeting and selective withdrawal task where the logic used to define temperature targets major reservoirs operate as well as the withdrawal logic used to meet those targets was refined.

The following sections in this appendix describe the background for the model updates, the five tasks, and the quality assurance/quality control (QA/QC) process used to ensure the quality of the work.

6B.C.2 Background

In January and February of 2014, there were three separate HEC-5Q modeling toolkits for Trinity-Sacramento, American, and San Joaquin River systems specifically for the EIS and based on CalSim II inputs. These toolkits were developed from models that Don Smith of Resource Management Associates (RMA) had delivered to Reclamation previously. Various issues began to arise with the model output results that resulted in a need to update the model files for several projects. This produced project-specific model versions that were different from the model versions delivered by RMA. After new issues continued to arise, it became apparent that there was a need to implement additional logic to the HEC-5Q model as well as provide organization and documentation for the models.

6B.C.3 Housekeeping Task

This section describes the Housekeeping Task, during which the initial work of compiling the Toolkit took place.

The goal of the Housekeeping Task was to lay out, structure, and compile an initial temperature model toolkit (Toolkit) that would serve to organize all of the existing work for the San Joaquin River, Trinity-Sacramento River, and American River HEC-5Q models as well provide improvements necessary to create a foundation for future improvements to the temperature models. The Housekeeping Task consisted of deciding on the contents of the Toolkit; laying out its structure; and compiling its contents, testing, improvements, and documentation.

The Housekeeping Task first identified the contents of the Toolkit and how it would be structured. It was recommended that there be one central HEC-5Q Toolkit that would contain an individual folder for the San Joaquin River, the Trinity-Sacramento Rivers, and the American River models. Within each river folder, there would be a complete application model (files, data, protocol document, and QA/QC tools) based on CalSim II inputs and that could support climate change scenarios. The river folders would also contain a complete calibration model from which the application model was developed. The Toolkit would support running the model through a batch process, which is the process through which the previous toolkits were run, as well as through the graphical user interface (GUI). Both the batch process and the GUI would utilize the same model files in order to eliminate redundant files. The models would run on the same executables, contained in a folder separate from the river folders (labeled bin). There would also be a folder for the GUI, which would include all the files required to run the GUI and a protocol document. There would also be a central reference document library and a version control folder that would track the source and changes of all the files contained within the Toolkit over the course of the updates.

The reference document library is a compilation of documents that were deemed necessary or useful as references for the user of the Toolkit. Included with the reference document library was the development of an HEC-5Q Quick Start Guide that was requested by Reclamation as part of the updates. This quick start guide provides an overview of how the all the model components work.

The file structure was designed to be compatible with either the use of the Batch Process or the GUI to run the models and to be consistent with the file structure used for the modeling for EIS. Ideally, the use of the GUI would fit within this structure. However, after some investigation into how the GUI locates the required input files, it was determined that using the GUI within the file structure and using only one set of model files for both the Batch Process and the GUI would require code changes to the GUI itself. Therefore, a decision was made to not fully implement the GUI into the Toolkit but to include it anyway.

After identifying the contents of the Toolkit and laying out the structure, the next task was to compile the contents. This involved reconciling different versions of the model files. Table 6B.C.1 shows the model versions that were reconciled for each river.

Table 6B.C.1 HEC-5Q Model Toolkits Reconciled during the Housekeeping Task

River	Models	Toolkits
Trinity-Sacramento	SRWQM** Extension (October 2013)	Remand_SRWQM_Toolkit (January 24, 2014)
San Joaquin	CDFW* SJR Model (June 2013)	Remand_SJR_HEC5Q_Toolkit (February 21, 2014)
American	SRWQM Extension (October 2013)	Remand_FAST_HEC5Q_Toolkit (February 18, 2014)

a. California Department of Fish and Wildlife

b. Sacramento River Water Quality Model

There were substantial differences between the versions of the Trinity-Sacramento River model. The SRWQM model (January 2014) was originally developed in 2002 and modeled only the Trinity River (to below Lewiston Dam) and the Sacramento River (to below Knights Landing). The SRWQM Extension (October 2013) extended the SRWQM model to include the Feather River (from Oroville Reservoir), the American River (from Folsom Reservoir), the Sutter

Bypass, and the lower Sacramento River (to below Freeport). The SRWQM Extension included new meteorological data that the Feather and American River extensions of the model were calibrated to. However, the older Trinity-Sacramento River section of the model was not recalibrated to the new meteorological data.

During compilation of the Toolkit, it was recommended that the Trinity and Sacramento River sections of the SRWQM Extension be the versions used moving forward. Those sections represented the latest modeling logic and nodal layout, including the Sutter Bypass. However, changes had to be made to the SRWQM Extension files before it could be incorporated. First, the Feather River was removed completely from the model files, as well as the lower Sacramento River (from the Feather River confluence to below Freeport) because it receives inputs from the Feather River. Second, a validation procedure was undertaken to adjust the necessary model parameters in order to incorporate the updated Gerber California Irrigation Management Information System (CIMIS) station meteorological data. A detailed description of this validation procedure is described below.

The San Joaquin River and American River versions were mostly consistent between the versions. Changes had been made on the Stanislaus River primarily for consistency with CalSim II. During the Housekeeping Task, an increase in the Tulloch power plant outflow capacity was implemented in the Toolkit. It should be noted that the previous versions of the San Joaquin River model included Electrical Conductivity as an additional output parameter of the model. This capability was removed for the Toolkit.

The American River version had a spreadsheet that computed downstream temperature targets for Folsom Outflow and Watt Avenue and two file changes for consistency with CalSim II. The spreadsheet and file changes were included in the Toolkit. During the Housekeeping Task, implementation of the Folsom Water Supply Intake Temperature Control Device (Folsom TCD) was included. Implementing the logic for the Folsom TCD required a validation run of the American River, which is described in detail below.

Compilation of the Toolkit into the agreed upon file structure included the need to change the reconciled files. These changes included changing path names in the batch files and renaming files so that there was a consistent naming convention across the three different river models. Also, among the changes was the implementation of common executables for the CalSim II pre-processor and HEC-5Q for each of the three models. This would eliminate redundant files and make changes to the CalSim II pre-processor and HEC-5Q codes easier, as code changes would only occur in one file. Also among the changes was the implementation of common executables for the CalSim II pre-processor and HEC-5Q.

In addition to the elements required for the models, model files and data from previous work that were part of the development of the models were compiled. These included the 2002 Sacramento River calibration (RMA 2003), the 2013

American River calibration (RMA 2013), the 2013 Stanislaus River calibration, and the Sacramento River and American River validations described below.

6B.C.4 Validation

This section describes the validation procedures and required updates to the model for the Trinity-Sacramento and American River models.

6B.C.4.1 Trinity-Sacramento River

The Trinity-Sacramento River model was originally developed and calibrated in 2002, using meteorological data from the Gerber CIMIS station (RMA 2003). Since that 2002 calibration, the model code has changed and there are updated meteorological data from the Gerber CIMIS station. During the Housekeeping Task, it was recommended that the Trinity-Sacramento River model incorporate the updated meteorological data from the Gerber CIMIS station. Fully incorporating the updated Gerber meteorological data would require a full recalibration of the model, which was beyond the scope of this project. Instead, a validation task was conducted to produce temperature results similar to the 2002 calibration. The validation task assumed the following conditions:

- 1981-2002 hydrology from the 2002 calibration
- Ambient temperature data that were used in 2002
- Revised meteorology developed in 2012
- Control point configuration consistent with CalSim II
- Bypasses included in the model representation

During the validation process, equilibrium temperature scaling factors for the reservoirs, reaches, reservoir inflows, and tributary inflows were adjusted to match observed data. The scaling factors were adjusted to compensate for higher equilibrium temperatures of the updated Gerber meteorology data. The equilibrium temperatures of the updated Gerber meteorology were higher than the 2002 Gerber meteorology because the updated data were computed without a wind speed scaling factor assumption, while the 2002 data had been computed with an assumed wind speed scaling factor.

Several comparison plots and tables from select locations that are representative of the computed versus observed temperature results of the Trinity-Sacramento River validation are contained in Appendix 6B, Section A. Comparison plots and tables at additional locations can be found in the document titled *Trinity Sacramento River 2014 Validation Plots* included in the file set for this report. In general, the validation task resulted in computed temperatures that had good agreement with observed data. Table 6B.C.2 shows the average computed and observed temperature at select locations in the Trinity-Sacramento River model.

Table 6B.C.2 Average Computed and Observed Temperatures at Select Locations Resulting from the Validation of the Trinity-Sacramento River Model

Location	Average Computed Temperature (^{0}F)	Average Observed Temperature (^{0}F)
Trinity River below Lewiston Dam	48.3	47.9
Sacramento River below Shasta Dam	49.8	58.6
Sacramento River below Keswick Dam	51.0	51.1
Sacramento River below Clear Creek	51.8	51.6
Sacramento River at Balls Ferry	52.7	52.7
Sacramento River at Bend Bridge	53.3	53.8
Sacramento River at Red Bluff	53.8	54.1
Sacramento River at Tehama	54.2	54.2
Sacramento River at Woodson Bridge	55.1	55.1
Sacramento River at Butte City	57.8	57.9
Sacramento River above Colusa Drain	59.4	58.8

6B.C.4.2 American River

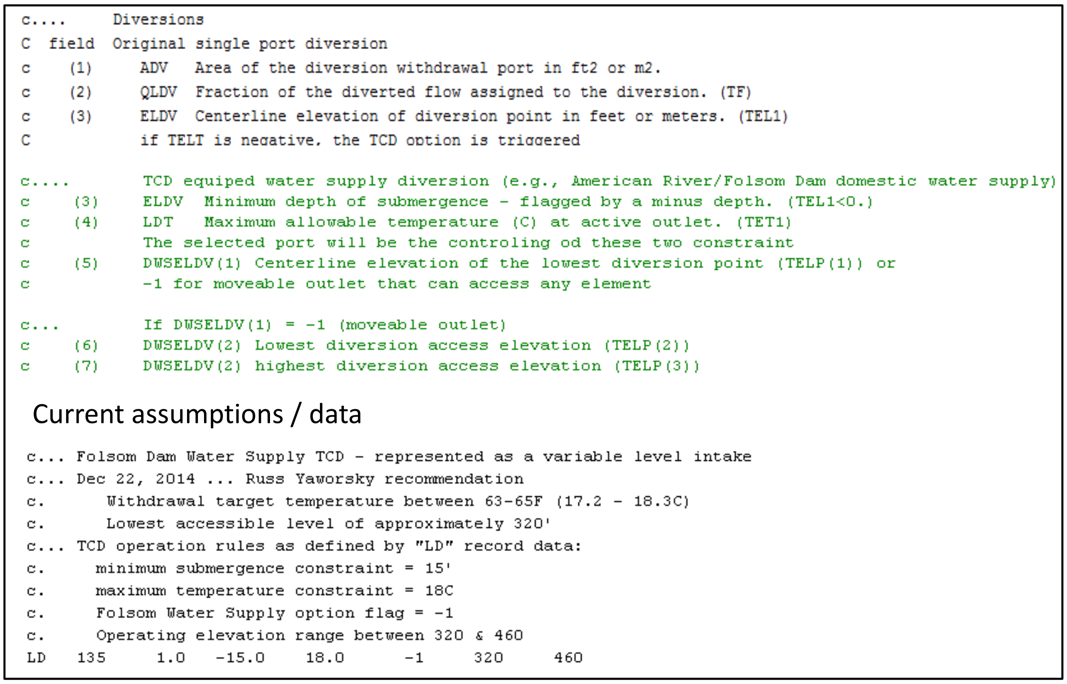
The American River HEC-5Q model was developed in 2013 as part of the SRWQM Extension (RMA 2013). Subsequent to this initial development, the model shortcomings listed below were identified and addressed. Implementing the fixes required for these shortcomings required a validation of the American River HEC-5Q model data to make sure they still matched observed data.

6B.C.4.2.1 Folsom Water Supply Temperature Control Device

The Folsom Water Supply Intake Temperature Control Device (Folsom TCD) was not properly represented in the 2013 calibration model, resulting in withdrawal of cold water at depth. The model was modified to represent the withdrawal as a movable port that can move based on the following operating objectives and constraints:

- Minimum submergence limit of 15 feet. The negative value indicates the variable level output as opposed to a fixed port representation that was original envisioned.
- Maximum temperature constraint of 18^{0}C. The outlet will be lowered to access this or a lower temperature when constrained by the minimum submergence requirement.
- Operating elevation range between 320 feet and 460 feet.

The LD record in Figure 6B.C.1 shows the change in the American River HEC-5Q data file implemented for the Folsom TCD.



```
c....     Diversions
C  field  Original single port diversion
c    (1)     ADV   Area of the diversion withdrawal port in ft2 or m2.
c    (2)     QLDV  Fraction of the diverted flow assigned to the diversion. (TF)
c    (3)     ELDV  Centerline elevation of diversion point in feet or meters. (TEL1)
C            if TELT is negative, the TCD option is triggered

c....        TCD equiped water supply diversion (e.g., American River/Folsom Dam domestic water supply)
c     (3)    ELDV  Minimum depth of submergence - flagged by a minus depth. (TEL1<0.)
c     (4)    LDT   Maximum allowable temperature (C) at active outlet. (TET1)
c            The selected port will be the controling od these two constraint
c     (5)    DWSELDV(1) Centerline elevation of the lowest diversion point (TELP(1)) or
c            -1 for moveable outlet that can access any element

c...         If DWSELDV(1) = -1 (moveable outlet)
c     (6)    DWSELDV(2) Lowest diversion access elevation (TELP(2))
c     (7)    DWSELDV(2) highest diversion access elevation (TELP(3))
```

Current assumptions / data

```
c... Folsom Dam Water Supply TCD - represented as a variable level intake
c... Dec 22, 2014 ... Russ Yaworsky recommendation
c.      Withdrawal target temperature between 63-65F (17.2 - 18.3C)
c.      Lowest accessible level of approximately 320'
c... TCD operation rules as defined by "LD" record data:
c.     minimum submergence constraint = 15'
c.     maximum temperature constraint = 18C
c.     Folsom Water Supply option flag = -1
c.     Operating elevation range between 320 & 460
LD   135     1.0   -15.0    18.0      -1     320     460
```

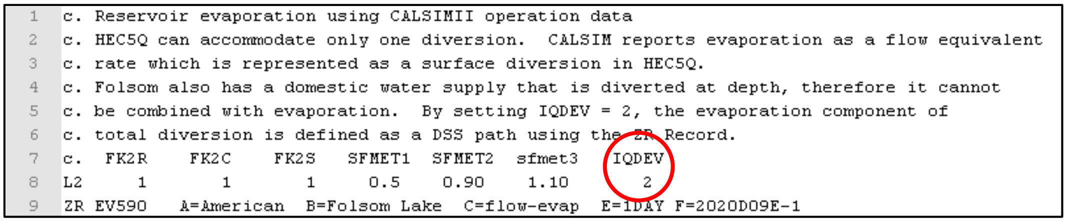
Figure 6B.C.1 Change in the American River HEC-5Q Data File for the Folsom Water Supply Intake Temperature Control Device

6B.C.4.2.2 Folsom Inflow Temperatures

Inflow temperatures were lowered relative to observed data in the 2013 calibration model to compensate for the low level extraction of cold water by the fixed depth domestic water supply outlet. These inflow temperatures were increased relative to the 2013 calibration model temperatures with the implementation of the new Folsom TCD logic.

6B.C.4.2.3 Folsom Evaporation

A change in the L2 record (see Figure 6B.C.2) was made to account for the separation of evaporation in CalSim II. The standard version of HEC-5Q will only accommodate a single diversion; however, CalSim II reports evaporation as a flow equivalent rate (E8) which is represented as a surface diversion in HEC-5Q while the Folsom Lake domestic water supply diversion (D8) is diverted at depth. Therefore, these two rates cannot be combined for accurate temperature simulation. From a flow accounting perspective (HEC5), the total flow diverted from the lake is E8+D8. By setting IQDEV = 2, the evaporation component of total diversion is defined as a DSS path using the ZR Record and subtracted from E8+D8 in HEC-5Q.



```
c. Reservoir evaporation using CALSIMII operation data
c. HEC5Q can accommodate only one diversion.  CALSIM reports evaporation as a flow equivalent
c. rate which is represented as a surface diversion in HEC5Q.
c. Folsom also has a domestic water supply that is diverted at depth, therefore it cannot
c. be combined with evaporation.  By setting IQDEV = 2, the evaporation component of
c. total diversion is defined as a DSS path using the ZR Record.
c.  FK2R    FK2C    FK2S   SFMET1  SFMET2  sfmet3   IQDEV
L2     1       1       1     0.5    0.90    1.10      2
ZR EV590   A=American  B=Folsom Lake  C=flow-evap  E=1DAY F=2020D09E-1
```

Figure 6B.C.2 Change in the American River HEC-5Q Data File to Separate Evaporation from Total Diversion at Folsom Dam

6B.C.4.2.4 River Mile Correction

The river mile location of Nimbus and Folsom Dams were improperly defined in the 2013 calibration model. A half-mile reach was inserted below Nimbus Dam to match the river mile locations of Nimbus and Folsom Dams in the HEC-RAS model. The Nimbus Dam went from river mile 22 to 22.5 and Folsom Dam went from river mile 28.7 to 29.2. This change affects temperature results.

In general, the validation resulted in good agreement between computed and observed temperatures. The average computed and observed temperatures at select locations in the American River model are shown in Table 6B.C.3.

Table 6B.C.3 Average Computed and Observed Temperatures at Select Locations Resulting from the Validation of the Trinity-Sacramento River Model

Location	Average Computed Temperature (^{0}F)	Average Observed Temperature (^{0}F)
American River below Nimbus Dam	56.5	56.7
American River at William Pond Park	57.7	57.7
American River at Watt Avenue	58.5	58.3

6B.C.5 Flow/Boundary Condition Mapping

HEC-5Q receives flow inputs from CalSim II through the CalSim II_HEC-5Q pre-processing executable. Monthly CalSim II flow and storage time series outputs are read into the executable where they are combined and mapped to nodes in the HEC-5Q model based on specifications in the [River model]_CS.dat (e.g. SR_CS.dat) file, converted to daily time series, and stored in the HEC-5Q input DSS file (CalSim II_HEC5Q.DSS). In the case of the storage time series, a daily patterning procedure is applied. As part of the temperature model updates, several modifications were made to improve the flow mapping of CalSim II to HEC-5Q. Additionally, HEC-5Q provides flow and temperature inputs to several fisheries models. These modifications are described below.

6B.C.5.1 Sutter Bypass Boundary Conditions Mapping

During modifications of the SRWQM Extension model files for the Trinity-Sacramento River model, it was determined that there was some incorrect mapping with the CalSim II schematic at Butte Creek. Specifically, there was double-counting of the Butte Creek Inflow at the Knights Landing control point. In CalSim II, Butte Creek inflow is input into the Sutter Bypass. However, in the SRWQM Extension, that inflow was added directly into the Sacramento River, causing higher flows in the Sacramento River at Knights Landing in the HEC-5Q model as compared to CalSim II. The Butte City inflow record (specifically IN118 in the SR_CS.dat file) was removed in the SR_5CS.dat file for the final Trinity-Sacramento River model.

6B.C.5.2 American River Flow Mapping Change

The control point resolution below Nimbus Dam was inadequate in the 2013 calibration model to properly allocate the City of Sacramento withdrawal. This lack of resolution presented a problem in relating HEC-5Q flows to CalSim II flows. The additional control point that localizes the City of Sacramento withdrawal is shown on Figure 6B.C.3. The additional control point (CP) #572 results in the depletions / accretions being distributed uniformly between CP 572 and CP 578 (mile 7.5 to mile 22.0). The City of Sacramento diversion is applied at CP 570. This change only has a small impact on temperature (it reduces temperatures at Watt Avenue up to +/- 0.5^{0}F).

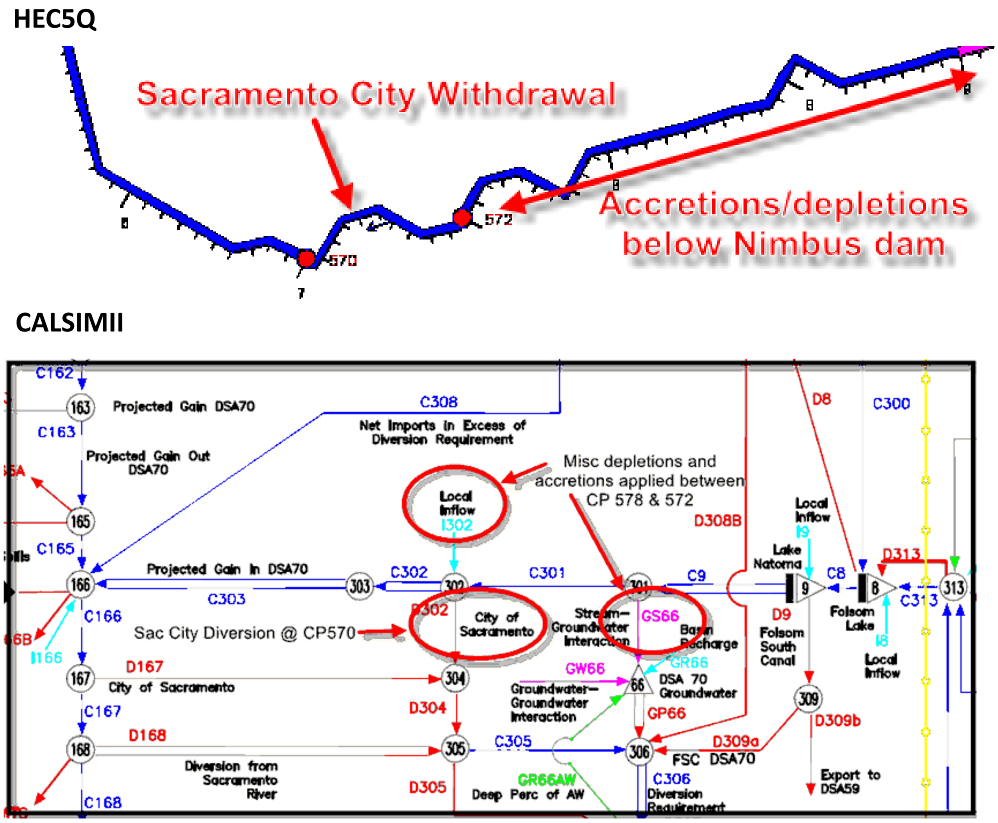


Figure 6B.C.3 Schematics of HEC-5Q and CalSim II Models with Additional Control Point 572

6B.C.5.3 Stanislaus River

The flow mapping between CalSim II and HEC-5Q in the Delta-Mendota Canal section of the San Joaquin River model is currently inadequate and results in serious flow differences. To fully address this requires a modification to the CalSim II schematic, which is beyond the scope of the work to update the temperature models. Since the EIS only focuses on temperature effects from Reclamation operations on the Stanislaus and Lower San Joaquin Rivers, the San Joaquin River model was reduced to only include the Stanislaus River and the San Joaquin River from the Stanislaus River confluence to the head of Old River. A requirement of this model to run and simulate temperatures at Vernalis was to develop a boundary condition time series of inflow temperature at the San Joaquin River above the Stanislaus River confluence. This time series would incorporate all the upstream temperature effects due to water operations above this point in the San Joaquin River basin (including Friant, Mendota Pool, and the Tuolumne and Merced Rivers). This time series was generated with the February 21, 2014 San Joaquin River HEC-5Q model using the EIS No Action Alternative Q5 CalSim II results for inputs.

6B.C.5.4 Mapping to Fisheries Models

The capability of mapping HEC-5Q flow and temperature outputs with three fisheries models was added to the Sacramento River model, including SALMOD, Reclamation Mortality model, and Cramer Fish Sciences models.

6B.C.6 Temperature Target, Selective Withdrawal, and Operational Outputs

This section describes the temperature targeting and/or selective withdrawal changes and procedures for the Trinity, Shasta, and Folsom Dams. These changes were completed after the validation was deemed appropriate because the temperature targets do not affect the matching of the observed temperatures; the validation period of record occurred when the Trinity Dam auxiliary outlet and Folsom Dam low-level outlets were not used.

6B.C.6.1 Trinity River

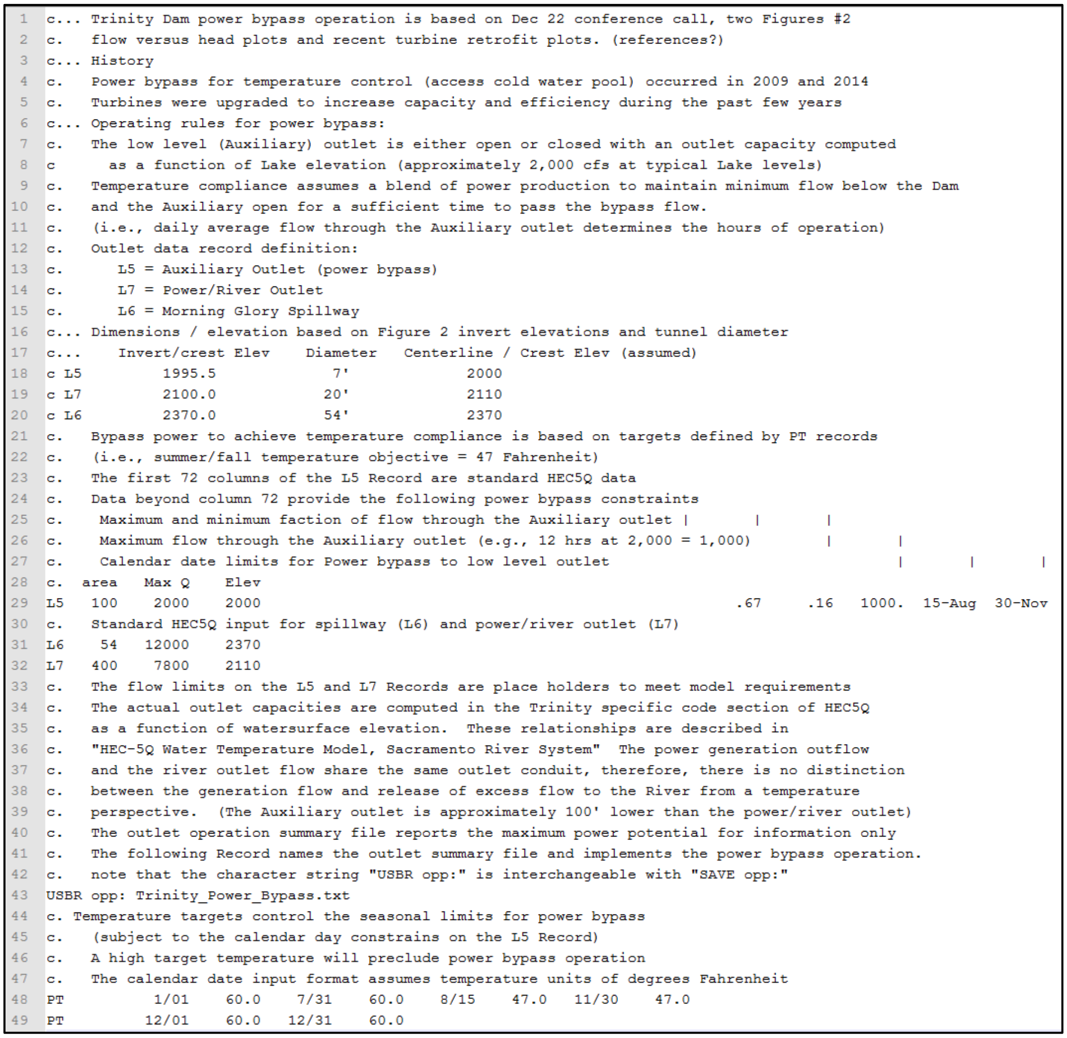
6B.C.6.1.1 Seasonal Temperature Target Schedule

A simplistic approach for seasonal temperature targets was implemented for the Trinity River. The seasonal targets are shown in Table 6B.C.4. The temperature targets of importance are the 49^{0}F temperatures between August and November when temperature management is the most crucial on the Trinity River and the auxiliary outlet (described in the next section) is allowed to operate. The 60^{0}F temperature target was implemented to force power generation in the model.

Table 6B.C.4 Seasonal Temperature Targets for Trinity Dam to Operate to in the HEC-5Q Model

Date	Temperature Target
January 1	60^{0} F
July 31	60^{0} F
August 15	49^{0} F
November 30	49^{0} F
December 1	60^{0} F
December 31	60^{0} F

Trinity Dam has a low-level (auxiliary) outlet, a morning glory spillway, and a single-level power intake that doubles as a high capacity river outlet. The relevant input data for Trinity Dam in the Trinity-Sacramento HEC-5Q data file are shown on Figure 6B.C.4. (Note that the line numbers are for reference only and are not line numbers in the Trinity-Sacramento HEC5Q data file.) Additional diagrams that were used as the basis for the improvements to Trinity Dam selective withdrawal logic in the Trinity-Sacramento River model are included in later portions of this appendix.



```
 1 c... Trinity Dam power bypass operation is based on Dec 22 conference call, two Figures #2
 2 c.   flow versus head plots and recent turbine retrofit plots. (references?)
 3 c... History
 4 c.   Power bypass for temperature control (access cold water pool) occurred in 2009 and 2014
 5 c.   Turbines were upgraded to increase capacity and efficiency during the past few years
 6 c... Operating rules for power bypass:
 7 c.   The low level (Auxiliary) outlet is either open or closed with an outlet capacity computed
 8 c      as a function of Lake elevation (approximately 2,000 cfs at typical Lake levels)
 9 c.   Temperature compliance assumes a blend of power production to maintain minimum flow below the Dam
10 c.   and the Auxiliary open for a sufficient time to pass the bypass flow.
11 c.   (i.e., daily average flow through the Auxiliary outlet determines the hours of operation)
12 c.   Outlet data record definition:
13 c.      L5 = Auxiliary Outlet (power bypass)
14 c.      L7 = Power/River Outlet
15 c.      L6 = Morning Glory Spillway
16 c... Dimensions / elevation based on Figure 2 invert elevations and tunnel diameter
17 c...    Invert/crest Elev    Diameter   Centerline / Crest Elev (assumed)
18 c L5         1995.5             7'             2000
19 c L7         2100.0            20'             2110
20 c L6         2370.0            54'             2370
21 c.   Bypass power to achieve temperature compliance is based on targets defined by PT records
22 c.   (i.e., summer/fall temperature objective = 47 Fahrenheit)
23 c.   The first 72 columns of the L5 Record are standard HEC5Q data
24 c.   Data beyond column 72 provide the following power bypass constraints
25 c.    Maximum and minimum faction of flow through the Auxiliary outlet |       |       |
26 c.    Maximum flow through the Auxiliary outlet (e.g., 12 hrs at 2,000 = 1,000)        |       |
27 c.    Calendar date limits for Power bypass to low level outlet                                |       |       |
28 c.  area   Max Q    Elev
29 L5   100    2000    2000                                                     .67     .16   1000.  15-Aug  30-Nov
30 c.   Standard HEC5Q input for spillway (L6) and power/river outlet (L7)
31 L6    54   12000    2370
32 L7   400    7800    2110
33 c.   The flow limits on the L5 and L7 Records are place holders to meet model requirements
34 c.   The actual outlet capacities are computed in the Trinity specific code section of HEC5Q
35 c.   as a function of watersurface elevation.  These relationships are described in
36 c.   "HEC-5Q Water Temperature Model, Sacramento River System"  The power generation outflow
37 c.   and the river outlet flow share the same outlet conduit, therefore, there is no distinction
38 c.   between the generation flow and release of excess flow to the River from a temperature
39 c.   perspective.  (The Auxiliary outlet is approximately 100' lower than the power/river outlet)
40 c.   The outlet operation summary file reports the maximum power potential for information only
41 c.   The following Record names the outlet summary file and implements the power bypass operation.
42 c.   note that the character string "USBR opp:" is interchangeable with "SAVE opp:"
43 USBR opp: Trinity_Power_Bypass.txt
44 c. Temperature targets control the seasonal limits for power bypass
45 c.   (subject to the calendar day constrains on the L5 Record)
46 c.   A high target temperature will preclude power bypass operation
47 c.   The calendar date input format assumes temperature units of degrees Fahrenheit
48 PT          1/01    60.0    7/31    60.0    8/15    47.0   11/30    47.0
49 PT         12/01    60.0   12/31    60.0
```

Figure 6B.C.4 Input Data Relevant to the Trinity Dam Selective Withdrawal Procedure in the Trinity-Sacramento HEC-5Q Data File

As the auxiliary outlet and power intake are at a fixed elevation, the only available temperature control option is to bypass power generation and divert colder temperature flows to the auxiliary outlet. The allocation between the auxiliary (power bypass) and power flows is designed to meet the seasonal temperature targets described earlier based on the Trinity-specific data described below.

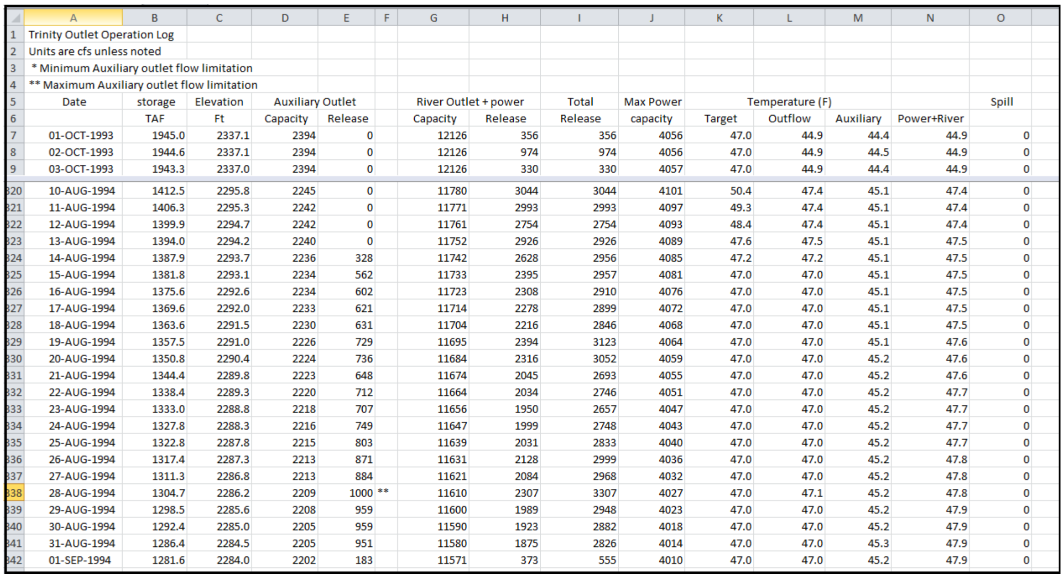
The Line 29 (L5) defines the auxiliary outlet characteristics and serves as the power bypass outlet. The first 72 columns are standard inputs while the additional data beyond column 72 constrain operation rules for power bypass to the auxiliary outlet. The constraints imply that the auxiliary outlet can be throttled to a specified flow rate. In reality, the auxiliary outlet is fully open or completely closed. Therefore, the fraction of the total outflow translates to a time period when the auxiliary outlet is fully open. Power flows would provide the minimum flow requirement for the river above Lewiston Lake. Mixing within Lewiston Lake is assumed to blend the flows of different temperatures.

- Col 73-80: Maximum fraction of the total out flow allowed through the auxiliary outlet (power bypass)
- Col 81-88: Minimum fraction of the total outflow required for bypass through the auxiliary outlet
- Col 89-96: Maximum flow through the auxiliary outlet in cubic feet per second (cfs)
- Col 97-112: Calendar date limits for power bypass to the low-level outlet. These dates override the limits set by the "PT" record.

Lines 31 and 32 (L6 and L7) are standard inputs defining the spillway crest length and power intake area as well as the flow capacity and elevation. The maximum flow for both the auxiliary (L5) and power intake (L7) serve as placeholder data. The actual flow rates are defined within the code as a function of lake elevation. When the flow and elevation conditions fall within the constraints seen in Figure 6B.C.3, the generation flow is added to the river outlet capacity seen in Figure 6B.C.2. From a temperature simulation perspective, there is no difference between power flow and river release flows as they share the same outlet conduit. The power production only adds to the total flow capacity of the common outlet tunnel.

6B.C.6.1.2 Trinity Dam Operations Output

A single comma-delimited output file is generated by the Trinity Dam-specific option. This file is named on the "USBR_OPP " record that triggers the power bypass option. This comma-delimited file ("Trinity Power Bypass.txt") when imported into Excel produces a file that summarizes the outlet operation and other pertinent data. The file includes daily lake storage and elevation, flow capacity and allocation to the auxiliary and power outlets, total outflow (release), target and outflow temperature, and spill information. The screen capture shown in Figure 6B.C.5 is an example of the resulting Excel file. There are two flags that indicate constraints on the bypass flow. In the example, August 28 is the day that is constrained by the maximum daily flow limit.



Trinity Outlet Operation Log
Units are cfs unless noted
 * Minimum Auxiliary outlet flow limitation
** Maximum Auxiliary outlet flow limitation

Date	storage	Elevation	Auxiliary Outlet			River Outlet + power		Total	Max Power	Temperature (F)				Spill
	TAF	Ft	Capacity	Release		Capacity	Release	Release	capacity	Target	Outflow	Auxiliary	Power+River	
01-OCT-1993	1945.0	2337.1	2394	0		12126	356	356	4056	47.0	44.9	44.4	44.9	0
02-OCT-1993	1944.6	2337.1	2394	0		12126	974	974	4056	47.0	44.9	44.5	44.9	0
03-OCT-1993	1943.3	2337.0	2394	0		12126	330	330	4057	47.0	44.9	44.4	44.9	0
10-AUG-1994	1412.5	2295.8	2245	0		11780	3044	3044	4101	50.4	47.4	45.1	47.4	0
11-AUG-1994	1406.3	2295.3	2242	0		11771	2993	2993	4097	49.3	47.4	45.1	47.4	0
12-AUG-1994	1399.9	2294.7	2242	0		11761	2754	2754	4093	48.4	47.4	45.1	47.4	0
13-AUG-1994	1394.0	2294.2	2240	0		11752	2926	2926	4089	47.6	47.5	45.1	47.5	0
14-AUG-1994	1387.9	2293.7	2236	328		11742	2628	2956	4085	47.2	47.2	45.1	47.5	0
15-AUG-1994	1381.8	2293.1	2234	562		11733	2395	2957	4081	47.0	47.0	45.1	47.5	0
16-AUG-1994	1375.6	2292.6	2234	602		11723	2308	2910	4076	47.0	47.0	45.1	47.5	0
17-AUG-1994	1369.6	2292.0	2233	621		11714	2278	2899	4072	47.0	47.0	45.1	47.5	0
18-AUG-1994	1363.6	2291.5	2230	631		11704	2216	2846	4068	47.0	47.0	45.1	47.5	0
19-AUG-1994	1357.5	2291.0	2226	729		11695	2394	3123	4064	47.0	47.0	45.1	47.6	0
20-AUG-1994	1350.8	2290.4	2224	736		11684	2316	3052	4059	47.0	47.0	45.2	47.6	0
21-AUG-1994	1344.4	2289.8	2223	648		11674	2045	2693	4055	47.0	47.0	45.2	47.6	0
22-AUG-1994	1338.4	2289.3	2220	712		11664	2034	2746	4051	47.0	47.0	45.2	47.7	0
23-AUG-1994	1333.0	2288.8	2218	707		11656	1950	2657	4047	47.0	47.0	45.2	47.7	0
24-AUG-1994	1327.8	2288.3	2216	749		11647	1999	2748	4043	47.0	47.0	45.2	47.7	0
25-AUG-1994	1322.8	2287.8	2215	803		11639	2031	2833	4040	47.0	47.0	45.2	47.7	0
26-AUG-1994	1317.4	2287.3	2213	871		11631	2128	2999	4036	47.0	47.0	45.2	47.8	0
27-AUG-1994	1311.3	2286.8	2213	884		11621	2084	2968	4032	47.0	47.0	45.2	47.8	0
28-AUG-1994	1304.7	2286.2	2209	1000	**	11610	2307	3307	4027	47.0	47.1	45.2	47.8	0
29-AUG-1994	1298.5	2285.6	2208	959		11600	1989	2948	4023	47.0	47.0	45.2	47.9	0
30-AUG-1994	1292.4	2285.0	2205	959		11590	1923	2882	4018	47.0	47.0	45.2	47.9	0
31-AUG-1994	1286.4	2284.5	2205	951		11580	1875	2826	4014	47.0	47.0	45.3	47.9	0
01-SEP-1994	1281.6	2284.0	2202	183		11571	373	555	4010	47.0	47.0	45.2	47.9	0

Figure 6B.C.5 Example Trinity Outlet Operations File Generated when Running the Model (The file is titled “Trinity Power Bypass.txt after the Trinity-Sacramento River model is run”)

6B.C.6.2 Shasta Dam

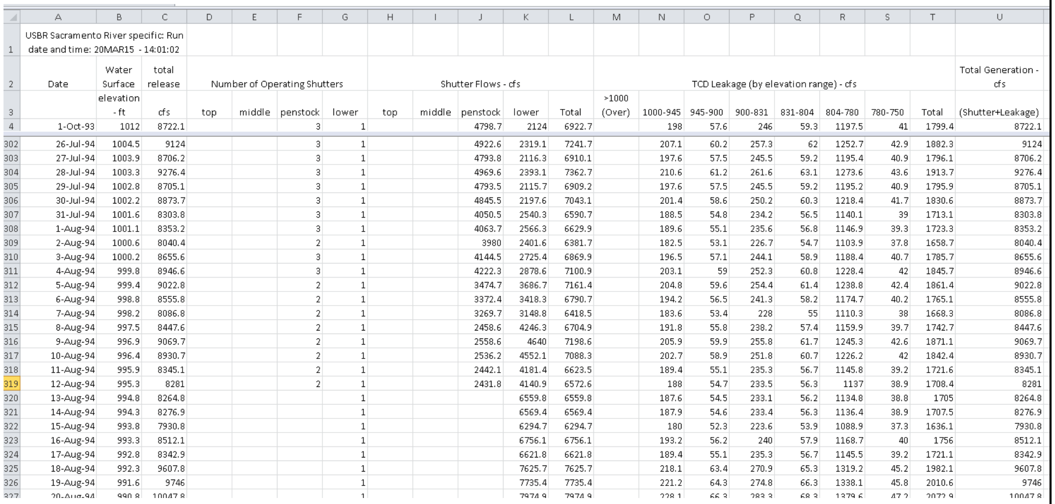
6B.C.6.2.1 Seasonal Temperature Target Schedule

A Shasta Dam release temperature target scheduling spreadsheet for the Trinity-Sacramento River model was developed using logic that was derived from the National Marine Fisheries Service 2009 Biological Opinion on the Long-Term Operations of the Central Valley Project and State Water Project (NMFS BO) and actual temperature management operations provided by Reclamation. The spreadsheet generates a PT record that is referenced at line 580 in the Trinity-Sacramento HEC-5Q data file.

6B.C.6.2.2 Shasta Operations Output File

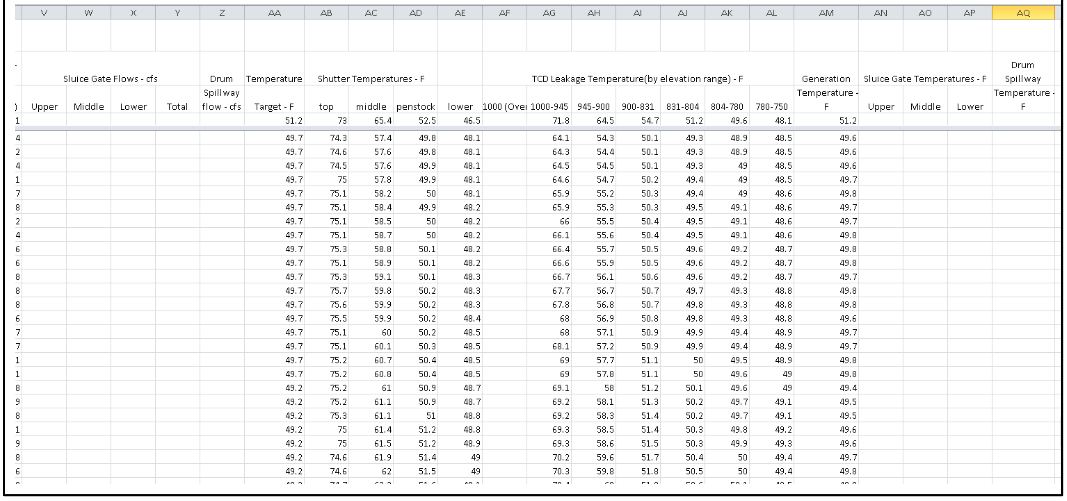
Two comma-delimited files (*.2xl) are produced that summarize the Shasta TCD operation. Both files provide similar information; however, the file "TCD_xx.log0.2xl" contains zeros while "TCD_xx.log.2xl" contains blanks in the computed flows and temperatures columns. The blank-filled file is easier to read but precludes arithmetic manipulation. Figure 6B.C.6 is an example Excel file generated by the “TCD_xx.log0.2xl” text file. This figure separated into two parts for ease of reading.

Columns A - U



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U
1	USBR Sacramento River specific: Run date and time: 20MAR15 - 14:01:02																				
2	Date	Water Surface	total release	Number of Operating Shutters				Shutter Flows - cfs					TCD Leakage (by elevation range) - cfs								Total Generation - cfs
3		elevation - ft	cfs	top	middle	penstock	lower	top	middle	penstock	lower	Total	>1000 (Over)	1000-945	945-900	900-831	831-804	804-780	780-750	Total	(Shutter+Leakage)
4	1-Oct-93	1012	8722.1			3	1			4798.7	2124	6922.7		198	57.6	246	59.3	1197.5	41	1799.4	8722.1
302	26-Jul-94	1004.5	9124			3	1			4922.6	2319.1	7241.7		207.1	60.2	257.3	62	1252.7	42.9	1882.3	9124
303	27-Jul-94	1003.9	8706.2			3	1			4793.8	2116.3	6910.1		197.6	57.5	245.5	59.2	1195.4	40.9	1796.1	8706.2
304	28-Jul-94	1003.3	9276.4			3	1			4969.6	2393.1	7362.7		210.6	61.2	261.6	63.1	1273.6	43.6	1913.7	9276.4
305	29-Jul-94	1002.8	8705.1			3	1			4793.5	2115.7	6909.2		197.6	57.5	245.5	59.2	1195.2	40.9	1795.9	8705.1
306	30-Jul-94	1002.2	8873.7			3	1			4845.5	2197.6	7043.1		201.4	58.6	250.2	60.3	1218.4	41.7	1830.6	8873.7
307	31-Jul-94	1001.6	8303.8			3	1			4050.5	2540.3	6590.7		188.5	54.8	234.2	56.5	1140.1	39	1713.1	8303.8
308	1-Aug-94	1001.1	8353.2			3	1			4063.7	2566.3	6629.9		189.6	55.1	235.6	56.8	1146.9	39.3	1723.3	8353.2
309	2-Aug-94	1000.6	8040.4			2	1			3980	2401.6	6381.7		182.5	53.1	226.7	54.7	1103.9	37.8	1658.7	8040.4
310	3-Aug-94	1000.2	8655.6			3	1			4144.5	2725.4	6869.9		196.5	57.1	244.1	58.9	1188.4	40.7	1785.7	8655.6
311	4-Aug-94	999.8	8946.6			3	1			4222.3	2878.6	7100.9		203.1	59	252.3	60.8	1228.4	42	1845.7	8946.6
312	5-Aug-94	999.4	9022.8			2	1			3474.7	3686.7	7161.4		204.8	59.6	254.4	61.4	1238.8	42.4	1861.4	9022.8
313	6-Aug-94	998.8	8555.8			2	1			3372.4	3418.3	6790.7		194.2	56.5	241.3	58.2	1174.7	40.2	1765.1	8555.8
314	7-Aug-94	998.2	8086.8			2	1			3269.7	3148.8	6418.5		183.6	53.4	228	55	1110.3	38	1668.3	8086.8
315	8-Aug-94	997.5	8447.6			2	1			2458.6	4246.3	6704.9		191.8	55.8	238.2	57.4	1159.9	39.7	1742.7	8447.6
316	9-Aug-94	996.9	9069.7			2	1			2558.6	4640	7198.6		205.9	59.9	255.8	61.7	1245.3	42.6	1871.1	9069.7
317	10-Aug-94	996.4	8930.7			2	1			2536.2	4552.1	7088.3		202.7	58.9	251.8	60.7	1226.2	42	1842.4	8930.7
318	11-Aug-94	995.9	8345.1			2	1			2442.1	4181.4	6623.5		189.4	55.1	235.3	56.7	1145.8	39.2	1721.6	8345.1
319	12-Aug-94	995.3	8281			2	1			2431.8	4140.9	6572.6		188	54.7	233.5	56.3	1137	38.9	1708.4	8281
320	13-Aug-94	994.8	8264.8				1				6559.8	6559.8		187.6	54.5	233.1	56.2	1134.8	38.8	1705	8264.8
321	14-Aug-94	994.3	8276.9				1				6569.4	6569.4		187.9	54.6	233.4	56.3	1136.4	38.9	1707.5	8276.9
322	15-Aug-94	993.8	7930.8				1				6294.7	6294.7		180	52.3	223.6	53.9	1088.9	37.3	1636.1	7930.8
323	16-Aug-94	993.3	8512.1				1				6756.1	6756.1		193.2	56.2	240	57.9	1168.7	40	1756	8512.1
324	17-Aug-94	992.8	8342.9				1				6621.8	6621.8		189.4	55.1	235.3	56.7	1145.5	39.2	1721.1	8342.9
325	18-Aug-94	992.3	9607.8				1				7625.7	7625.7		218.1	63.4	270.9	65.3	1319.2	45.2	1982.1	9607.8
326	19-Aug-94	991.6	9746				1				7735.4	7735.4		221.2	64.3	274.8	66.3	1338.1	45.8	2010.6	9746
327	20-Aug-94	990.8	10047.8				1				7974.9	7974.9		228.1	66.3	283.3	68.3	1379.6	47.2	2072.9	10047.8

Columns V-AG



	V	W	X	Y	Z	AA	AB	AC	AD	AE	AF	AG	AH	AI	AJ	AK	AL	AM	AN	AO	AP	AQ
	Sluice Gate Flows - cfs				Drum	Temperature	Shutter Temperatures - F				TCD Leakage Temperature(by elevation range) - F							Generation	Sluice Gate Temperatures - F			Drum Spillway
)	Upper	Middle	Lower	Total	Spillway flow - cfs	Target - F	top	middle	penstock	lower	1000 (Over	1000-945	945-900	900-831	831-804	804-780	780-750	Temperature - F	Upper	Middle	Lower	Temperature - F
1						51.2	73	65.4	52.5	46.5		71.8	64.5	54.7	51.2	49.6	48.1	51.2				
4						49.7	74.3	57.4	49.8	48.1		64.1	54.3	50.1	49.3	48.9	48.5	49.6				
2						49.7	74.6	57.6	49.8	48.1		64.3	54.4	50.1	49.3	48.9	48.5	49.6				
4						49.7	74.5	57.6	49.9	48.1		64.5	54.5	50.1	49.3	49	48.5	49.6				
1						49.7	75	57.8	49.9	48.1		64.6	54.7	50.2	49.4	49	48.5	49.7				
7						49.7	75.1	58.2	50	48.1		65.9	55.2	50.3	49.4	49	48.6	49.8				
8						49.7	75.1	58.4	49.9	48.2		65.9	55.3	50.3	49.5	49.1	48.6	49.7				
2						49.7	75.1	58.5	50	48.2		66	55.5	50.4	49.5	49.1	48.6	49.7				
4						49.7	75.1	58.7	50	48.2		66.1	55.6	50.4	49.5	49.1	48.6	49.8				
6						49.7	75.3	58.8	50.1	48.2		66.4	55.7	50.5	49.6	49.2	48.7	49.8				
6						49.7	75.1	58.9	50.1	48.2		66.6	55.9	50.5	49.6	49.2	48.7	49.8				
8						49.7	75.3	59.1	50.1	48.3		66.7	56.1	50.6	49.6	49.2	48.7	49.7				
8						49.7	75.7	59.8	50.2	48.3		67.7	56.7	50.7	49.7	49.3	48.8	49.8				
8						49.7	75.6	59.9	50.2	48.3		67.8	56.8	50.7	49.8	49.3	48.8	49.8				
6						49.7	75.5	59.9	50.2	48.4		68	56.9	50.8	49.8	49.3	48.8	49.6				
7						49.7	75.1	60	50.2	48.5		68	57.1	50.9	49.9	49.4	48.9	49.7				
7						49.7	75.1	60.1	50.3	48.5		68.1	57.2	50.9	49.9	49.4	48.9	49.7				
1						49.7	75.2	60.7	50.4	48.5		69	57.7	51.1	50	49.5	48.9	49.8				
1						49.7	75.2	60.8	50.4	48.5		69	57.8	51.1	50	49.6	49	49.8				
8						49.2	75.2	61	50.9	48.7		69.1	58	51.2	50.1	49.6	49	49.4				
9						49.2	75.2	61.1	50.9	48.7		69.2	58.1	51.3	50.2	49.7	49.1	49.5				
8						49.2	75.3	61.1	51	48.8		69.2	58.3	51.4	50.2	49.7	49.1	49.5				
1						49.2	75	61.4	51.2	48.8		69.3	58.5	51.4	50.3	49.8	49.2	49.6				
9						49.2	75	61.5	51.2	48.9		69.3	58.6	51.5	50.3	49.9	49.3	49.6				
8						49.2	74.6	61.9	51.4	49		70.2	59.6	51.7	50.4	50	49.4	49.7				
6						49.2	74.6	62	51.5	49		70.3	59.8	51.8	50.5	50	49.4	49.8				

Figure 6B.C.6 Example Shasta Outlet Operations File Generated in the Model (The file is titled “TCD_xx.log.2xl after the Trinity-Sacramento River model is run”)

Columns D-K list the number of shutters and flow allocation to the top, middle, penstock and lower levels. Columns M-S list the leakage flows by elevation ranges. (Note that these leakage flows may have changed due to shutter maintenance and modification.)

Column C equals columns L+T (total release and power flow components) and are identical except when the power flow capacity is exceeded. When the total release exceeds the allowable power flow, the excess is allocated to the sluice gate with the temperature nearest the temperature objective. Use of the spillway occurs only after the power and sluice gate are fully utilized. Columns V-Z list the sluice gate and spillway flows.

The remaining columns report water temperatures. The shutter temperatures (AB-AE) are reported for all possible levels even though there may be no flow.

Temperatures for all possible leakage levels appear in columns AF-AL. Columns AA and AM report the temperature object and the power flow temperature respectively. The remaining columns report the sluice and spillway temperatures only when there is flow.

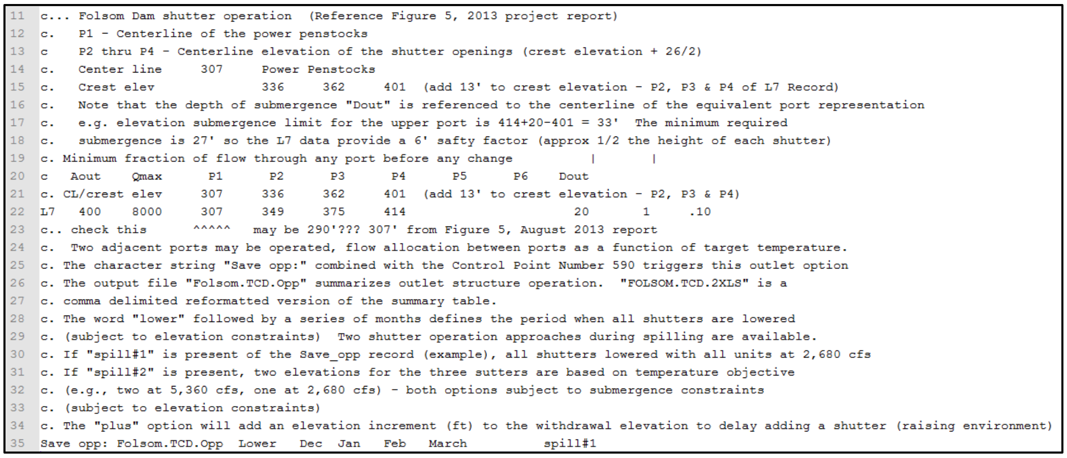
6B.C.6.3 Folsom Dam

6B.C.6.3.1 Seasonal Temperature Target Schedule

A Folsom Dam release temperature target scheduling procedure for the American River model was developed using logic that was derived from the NMFS BO and actual temperature management operations provided by Reclamation. The spreadsheet generates a PT record that is referenced at line 262 in the American River HEC-5Q data file.

6B.C.6.3.2 Selective Withdrawal Operations

The shutter position and power bypass are set to meet the temperature targets based on the Folsom-specific data described below. Figure 6B.C.7 shows the relevant input data for Folsom Dam in the American River HEC-5Q data file and has additional comments that supplement this text. (Note that the line numbers are for reference only and are not line numbers in the American River HEC-5Q data file.)



```
11 c... Folsom Dam shutter operation  (Reference Figure 5, 2013 project report)
12 c.   P1 - Centerline of the power penstocks
13 c    P2 thru P4 - Centerline elevation of the shutter openings (crest elevation + 26/2)
14 c.   Center line     307     Power Penstocks
15 c.   Crest elev              336     362     401  (add 13' to crest elevation - P2, P3 & P4 of L7 Record)
16 c.   Note that the depth of submergence "Dout" is referenced to the centerline of the equivalent port representation
17 c.   e.g. elevation submergence limit for the upper port is 414+20-401 = 33'  The minimum required
18 c.   submergence is 27' so the L7 data provide a 6' safty factor (approx 1/2 the height of each shutter)
19 c. Minimum fraction of flow through any port before any change          |       |
20 c   Aout    Qmax      P1      P2      P3      P4      P5      P6    Dout
21 c. CL/crest elev     307     336     362     401  (add 13' to crest elevation - P2, P3 & P4)
22 L7   400     8000    307     349     375     414                      20       1     .10
23 c.. check this      ^^^^^   may be 290'??? 307' from Figure 5, August 2013 report
24 c.  Two adjacent ports may be operated, flow allocation between ports as a function of target temperature.
25 c. The character string "Save opp:" combined with the Control Point Number 590 triggers this outlet option
26 c. The output file "Folsom.TCD.Opp" summarizes outlet structure operation.  "FOLSOM.TCD.2XLS" is a
27 c. comma delimited reformatted version of the summary table.
28 c. The word "lower" followed by a series of months defines the period when all shutters are lowered
29 c. (subject to elevation constraints)  Two shutter operation approaches during spilling are available.
30 c. If "spill#1" is present of the Save_opp record (example), all shutters lowered with all units at 2,680 cfs
31 c. If "spill#2" is present, two elevations for the three sutters are based on temperature objective
32 c. (e.g., two at 5,360 cfs, one at 2,680 cfs) - both options subject to submergence constraints
33 c. (subject to elevation constraints)
34 c. The "plus" option will add an elevation increment (ft) to the withdrawal elevation to delay adding a shutter (raising environment)
35 Save opp: Folsom.TCD.Opp  Lower   Dec  Jan   Feb   March          spill#1
```

Figure 6B.C.7 Input Data Relevant to the Folsom Dam Selective Withdrawal Procedure in the American River HEC-5Q Data File

Line 19 (L5) defines the low level outlet characteristics that serves as the power bypass outlet. The first 72 columns are standard inputs while the additional data beyond column 72 control operation of the power bypass. The following three inputs provide limit on flow and date limits for power bypass.

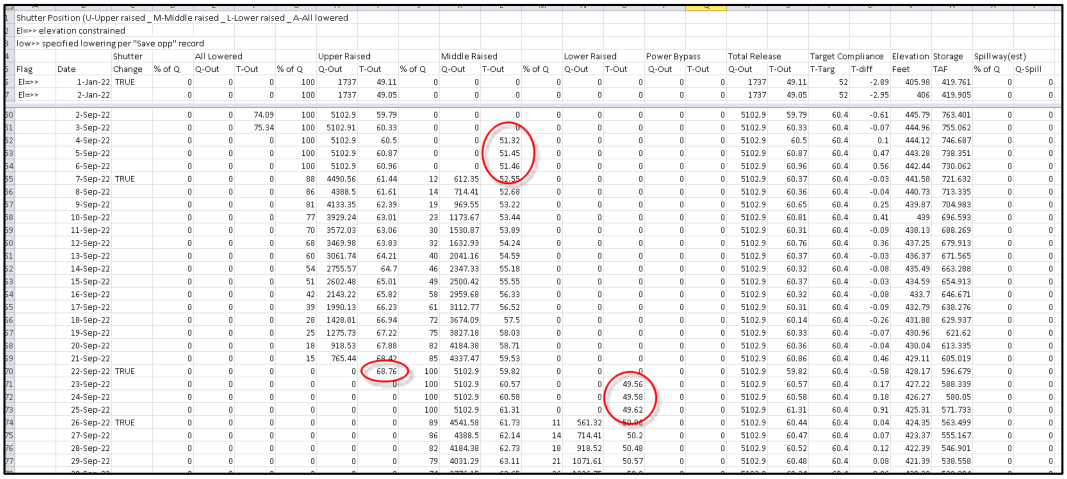
- Col 73-80: Maximum fraction of flow through the low level power bypass
- Col 81-88: Minimum fraction of flow through the low level power bypass
- Col 89-96: Maximum flow through the low level power bypass
- Col 97-112: Calendar date limits for power bypass to the low level outlet

Line 29 (L7) is a standard input for representing a multi-port withdrawal structure. For the Folsom Lake TCD (shutters) option, the standard inputs are used to define the penstock (all shutters raised) and three possible shutter elevations and the shutter submergence criteria. The value defined in columns 81-88 (.10) is the threshold fraction of the total flow required for a shutter change.

Line 36 initiates the Folsom Dam-specific option. The character string "Save opp:" (“USBR_opp” is an alternate flag) combined with the control point number 590 triggers this outlet operation option. Two adjacent shutters are operated and flow is allocation between shutters to provide an outflow that approximates the target temperature. Following the file naming, a series of months (e.g., December thru March) may be included to specify that shutters be set in the lowered position. During tainter gate operation, the shutters are operated to meet the temperature objective after correcting for the temperature of the spill. Including “SPILL#1” following the months will force the outflow at the highest possible level, thus conserving the cold water resource.

6B.C.6.3.3 Folsom Dam Operations Output

There are two output files generated by the Folsom-specific option. The "Folsom.TCD.Opp" is a text file that is produced as the simulation progresses. This text file is reformatted to produce a file with a “2xls” file extension upon completion of the temperature simulation (this file will not be created if the run ends prematurely). This comma-delimited file, when imported into Excel, produces a file that summarizes the Folsom shutter operation and power bypass. The file includes daily flow allocation, outflow temperature, temperature compliance, lake elevation and storage information. An example of the resulting Excel file is shown on Figure 6B.C.8. There are two flags in column A that indicate operation constrained by lake elevation or specified shutter lowering. Shutter changes are indicated by “TRUE” in column C. Shutter changes are indicated when a shutter level is discontinued and when a new shutter level is added. In reality, the two shutter changes indicated on September 22 and 26 would actually be one change in which the “middle raised” shutter (one or two shutter bays) would remain unchanged while both remaining shutters in the “upper raised” position would be removed to move from the “upper raised” condition to the “lower raised” condition. The number of shutter bays at the indicated level is not considered in the flow allocation. Therefore, the total generation flow for a shutter level may exceed the capacity of a single penstock. Power bypass assumes that all shutters are raised and the power bypass fraction is indicated only by flow. There are temperatures circled in red in the sample output that have no corresponding flow. These temperatures indicate that a shutter change would have occurred if not for the minimum flow requirement.

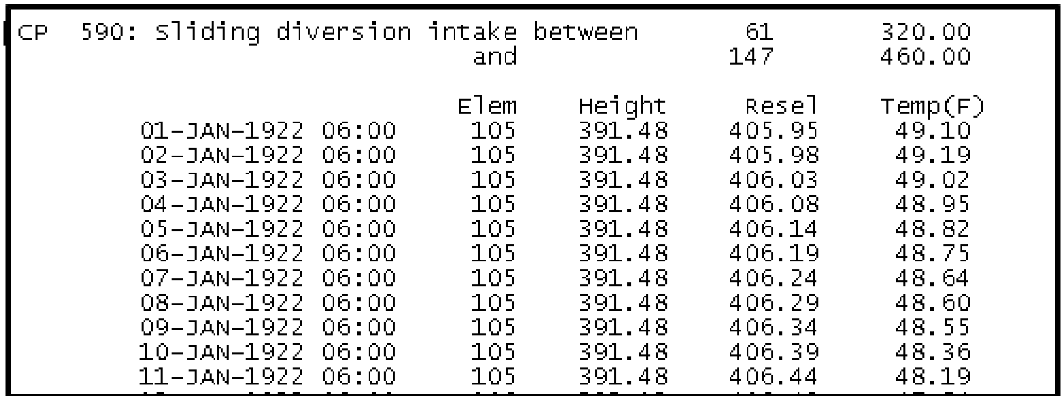


Shutter Position (U-Upper raised _ M-Middle raised _ L-Lower raised _ A-All lowered
El=>> elevation constrained
low>> specified lowering per "Save opp" record

		Shutter		All Lowered			Upper Raised			Middle Raised			Lower Raised		Power Bypass		Total Release		Target Compliance		Elevation	Storage	Spillway(est)	
Flag	Date	Change	% of Q	Q-Out	T-Out	% of Q	Q-Out	T-Out	% of Q	Q-Out	T-Out	% of Q	Q-Out	T-Out	Q-Out	T-Out	Q-Out	T-Out	T-Targ	T-diff	Feet	TAF	% of Q	Q-Spill
El=>>	1-Jan-22	TRUE	0	0	0	100	1737	49.11	0	0	0	0	0	0	0	0	1737	49.11	52	-2.89	405.98	419.761	0	0
El=>>	2-Jan-22		0	0	0	100	1737	49.05	0	0	0	0	0	0	0	0	1737	49.05	52	-2.95	406	419.905	0	0
	2-Sep-22		0	0	74.09	100	5102.9	59.79	0	0	0	0	0	0	0	0	5102.9	59.79	60.4	-0.61	445.79	763.401	0	0
	3-Sep-22		0	0	75.34	100	5102.91	60.33	0	0	0	0	0	0	0	0	5102.9	60.33	60.4	-0.07	444.96	755.062	0	0
	4-Sep-22		0	0	0	100	5102.9	60.5	0	0	51.32	0	0	0	0	0	5102.9	60.5	60.4	0.1	444.12	746.687	0	0
	5-Sep-22		0	0	0	100	5102.9	60.87	0	0	51.45	0	0	0	0	0	5102.9	60.87	60.4	0.47	443.28	738.351	0	0
	6-Sep-22		0	0	0	100	5102.9	60.96	0	0	51.46	0	0	0	0	0	5102.9	60.96	60.4	0.56	442.44	730.062	0	0
	7-Sep-22	TRUE	0	0	0	88	4490.56	61.44	12	612.35	52.55	0	0	0	0	0	5102.9	60.37	60.4	-0.03	441.58	721.632	0	0
	8-Sep-22		0	0	0	86	4388.5	61.61	14	714.41	52.68	0	0	0	0	0	5102.9	60.36	60.4	-0.04	440.73	713.335	0	0
	9-Sep-22		0	0	0	81	4133.35	62.39	19	969.55	53.22	0	0	0	0	0	5102.9	60.65	60.4	0.25	439.87	704.983	0	0
	10-Sep-22		0	0	0	77	3929.24	63.01	23	1173.67	53.44	0	0	0	0	0	5102.9	60.81	60.4	0.41	439	696.593	0	0
	11-Sep-22		0	0	0	70	3572.03	63.06	30	1530.87	53.89	0	0	0	0	0	5102.9	60.31	60.4	-0.09	438.13	688.269	0	0
	12-Sep-22		0	0	0	68	3469.98	63.83	32	1632.93	54.24	0	0	0	0	0	5102.9	60.76	60.4	0.36	437.25	679.913	0	0
	13-Sep-22		0	0	0	60	3061.74	64.21	40	2041.16	54.59	0	0	0	0	0	5102.9	60.37	60.4	-0.03	436.37	671.565	0	0
	14-Sep-22		0	0	0	54	2755.57	64.7	46	2347.33	55.18	0	0	0	0	0	5102.9	60.32	60.4	-0.08	435.49	663.288	0	0
	15-Sep-22		0	0	0	51	2602.48	65.01	49	2500.42	55.55	0	0	0	0	0	5102.9	60.37	60.4	-0.03	434.59	654.913	0	0
	16-Sep-22		0	0	0	42	2143.22	65.82	58	2959.68	56.33	0	0	0	0	0	5102.9	60.32	60.4	-0.08	433.7	646.671	0	0
	17-Sep-22		0	0	0	39	1990.13	66.23	61	3112.77	56.52	0	0	0	0	0	5102.9	60.31	60.4	-0.09	432.79	638.276	0	0
	18-Sep-22		0	0	0	28	1428.81	66.94	72	3674.09	57.5	0	0	0	0	0	5102.9	60.14	60.4	-0.26	431.88	629.937	0	0
	19-Sep-22		0	0	0	25	1275.73	67.22	75	3827.18	58.03	0	0	0	0	0	5102.9	60.33	60.4	-0.07	430.96	621.62	0	0
	20-Sep-22		0	0	0	18	918.53	67.88	82	4184.38	58.71	0	0	0	0	0	5102.9	60.36	60.4	-0.04	430.04	613.335	0	0
	21-Sep-22		0	0	0	15	765.44	68.42	85	4337.47	59.53	0	0	0	0	0	5102.9	60.86	60.4	0.46	429.11	605.019	0	0
	22-Sep-22	TRUE	0	0	0	0	0	68.76	100	5102.9	59.82	0	0	0	0	0	5102.9	59.82	60.4	-0.58	428.17	596.679	0	0
	23-Sep-22		0	0	0	0	0	0	100	5102.9	60.57	0	0	49.56	0	0	5102.9	60.57	60.4	0.17	427.22	588.339	0	0
	24-Sep-22		0	0	0	0	0	0	100	5102.9	60.58	0	0	49.58	0	0	5102.9	60.58	60.4	0.18	426.27	580.05	0	0
	25-Sep-22		0	0	0	0	0	0	100	5102.9	61.31	0	0	49.62	0	0	5102.9	61.31	60.4	0.91	425.31	571.733	0	0
	26-Sep-22	TRUE	0	0	0	0	0	0	89	4541.58	61.73	11	561.32	50.06	0	0	5102.9	60.44	60.4	0.04	424.35	563.499	0	0
	27-Sep-22		0	0	0	0	0	0	86	4388.5	62.14	14	714.41	50.2	0	0	5102.9	60.47	60.4	0.07	423.37	555.167	0	0
	28-Sep-22		0	0	0	0	0	0	82	4184.38	62.73	18	918.52	50.48	0	0	5102.9	60.52	60.4	0.12	422.39	546.901	0	0
	29-Sep-22		0	0	0	0	0	0	79	4031.29	63.11	21	1071.61	50.57	0	0	5102.9	60.48	60.4	0.08	421.39	538.558	0	0

Figure 6B.C.8 Example Folsom Outlet Operations File Generated when Running the Model (The file is titled "Folsom.TCD.Opp.txt after the American River model is run")

The other Folsom operations output (Figure 6B.C.9) is a text file that summarizes the Folsom TCD operation. The file is named "WS_TCD.txt" and includes the operational information seen below. The output is daily except when the reservoir element location changes and there is an additional line of output during that day.



```
CP  590: sliding diversion intake between        61        320.00
                                    and         147        460.00

                                   Elem     Height      Resel      Temp(F)
          01-JAN-1922 06:00         105     391.48     405.95       49.10
          02-JAN-1922 06:00         105     391.48     405.98       49.19
          03-JAN-1922 06:00         105     391.48     406.03       49.02
          04-JAN-1922 06:00         105     391.48     406.08       48.95
          05-JAN-1922 06:00         105     391.48     406.14       48.82
          06-JAN-1922 06:00         105     391.48     406.19       48.75
          07-JAN-1922 06:00         105     391.48     406.24       48.64
          08-JAN-1922 06:00         105     391.48     406.29       48.60
          09-JAN-1922 06:00         105     391.48     406.34       48.55
          10-JAN-1922 06:00         105     391.48     406.39       48.36
          11-JAN-1922 06:00         105     391.48     406.44       48.19
```

Figure 6B.C.9 Example Folsom TCD Operations File Generated when Running the Model (The file is titled "WS_TCD.txt after the American River model is run")

6B.C.7 Quality Assurance/Quality Control

This section describes two different elements of the QA/QC process used to ensure the quality for the Toolkit. The first section describes the update and review process for the Toolkit. The second section describes the spreadsheets that were developed to perform a QA/QC process on application model runs from the Toolkit.

6B.C.7.1 Update and Review Process

Three QA/QC spreadsheet tools were also developed as part of the updates to the Toolkit. The spreadsheet tools are designed to be used for a QA/QC process of all application model runs from the Toolkit.

6B.C.7.1.1 CalSim II and HEC-5Q Comparison Spreadsheet

The first spreadsheet tool HEC5Q_CalSim II_QA/QC_[River Model]_rev06_011615_Template_NAA_Example compares CalSim II storages and flows with HEC-5Q storages and flows to ensure that storages and flows are translating correctly. A procedure for performing a QA/QC of CalSim II and HEC-5Q flows and storages is described in the spreadsheet. Minor differences between CalSim II input flows and HEC-5Q output flows are expected because HEC-5Q storages and flows are modified to meet downstream temperature targets. In addition, not all HEC-5Q output locations map well with CalSim II nodes, which can cause significant flow differences. The flow mapping task reduced this issue but additional changes to CalSim II are required. Expected differences for each HEC-5Q location are described in the spreadsheet and deviations from those expected results are recommended to be investigated for potential issues.

6B.C.7.1.2 HEC-5Q Alternative Comparison Spreadsheet

The second spreadsheet tool HEC-5Q_AltCompare_[River Model]_rev03_012715_Template_Example compares HEC5Q storages, flows, and temperatures between two alternatives to ensure that temperature results make logical sense based on flow and storage differences. A procedure for performing a temperature comparison procedure is described in the spreadsheet. This spreadsheet assumes that a comparison procedure of flows and storages differences has been already been completed as part of review of CalSim II results and that the flow and storage differences are accurate. Use of this spreadsheet requires the user to have performed a prior HEC-5Q and CalSim II QA/QC procedure with the tool described previously for both alternatives. It also requires the user to have a prepared expectation of temperature differences based on their knowledge of the differences between the alternatives.

6B.C.7.1.3 Operation Diagnostic Spreadsheets

The third spreadsheet tool is an operation diagnostic tool [Reservoir] _Operations_Diagnostic_rev01_030515. There is one for Shasta, Trinity, and Folsom Dams. The purpose of the tool is to graphically display the flows and temperatures through the various temperature control structures and outlets for Shasta, Trinity, and Folsom Dams to view how the reservoirs are operating to meet downstream temperature targets.

6B.C.8 Trinity-Sacramento River Model Validation

This section provides comparisons between observed temperature data and computed temperature results from the validation task for the Trinity-Sacramento

River. Figures 6B.C.10 through 6B.C.42 present geographic locations used in the HEC-5Q Model and comparisons of observed and computed data at these locations. Observed results are from Reclamation, Department of Water Resources (DWR), and U.S. Geological Survey (USGS) data. The results indicate overall good agreement between computed and observed data.

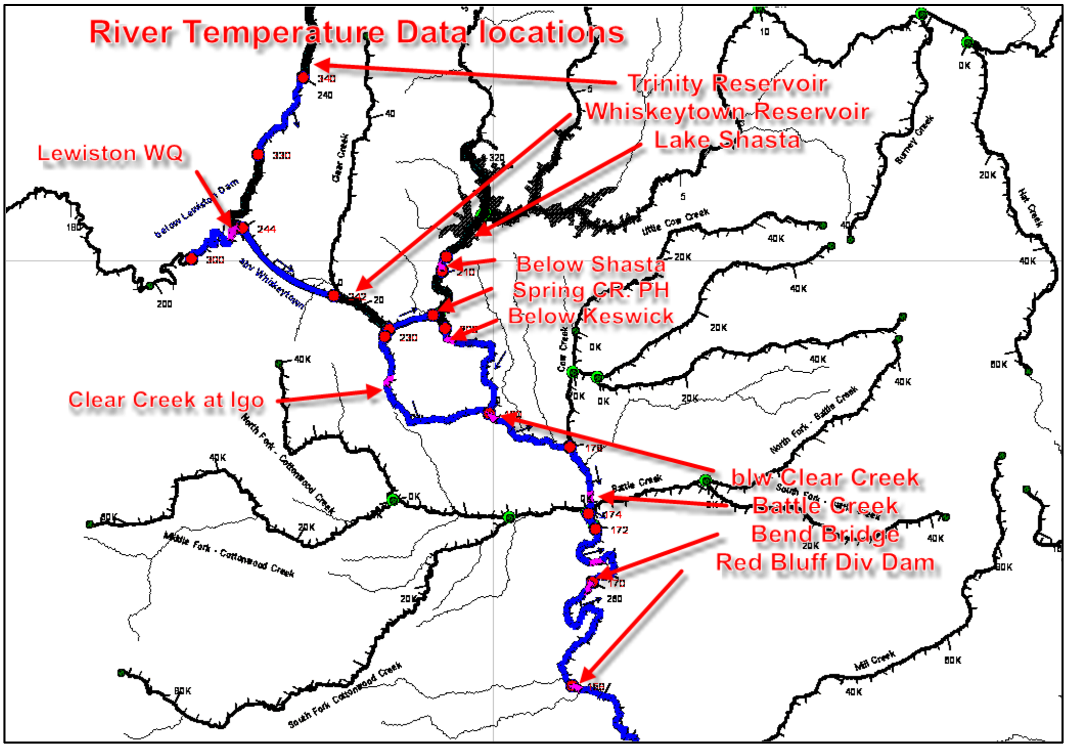


Figure 6B.C.10 Schematic of the Trinity-Sacramento River HEC-5Q Model Upstream of Red Bluff Diversion Dam Location

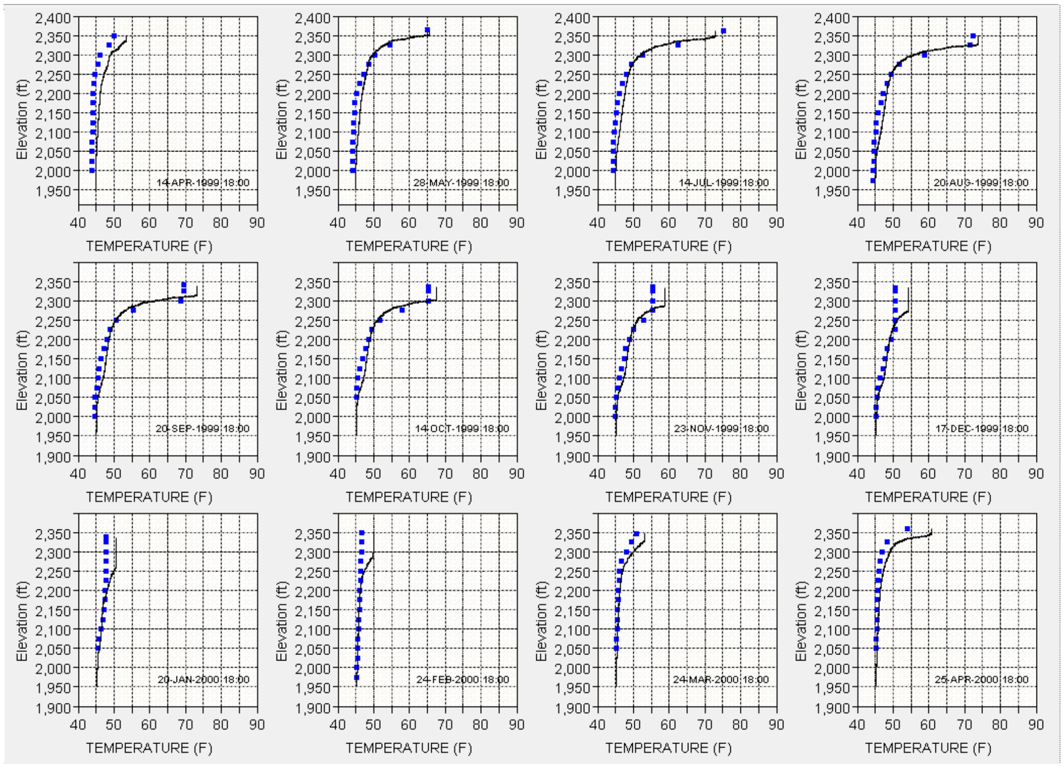


Figure 6B.C.11 Trinity Lake Observed (blue dots) and Computed (black line) Temperature Profiles Resulting from the Trinity-Sacramento River Validation

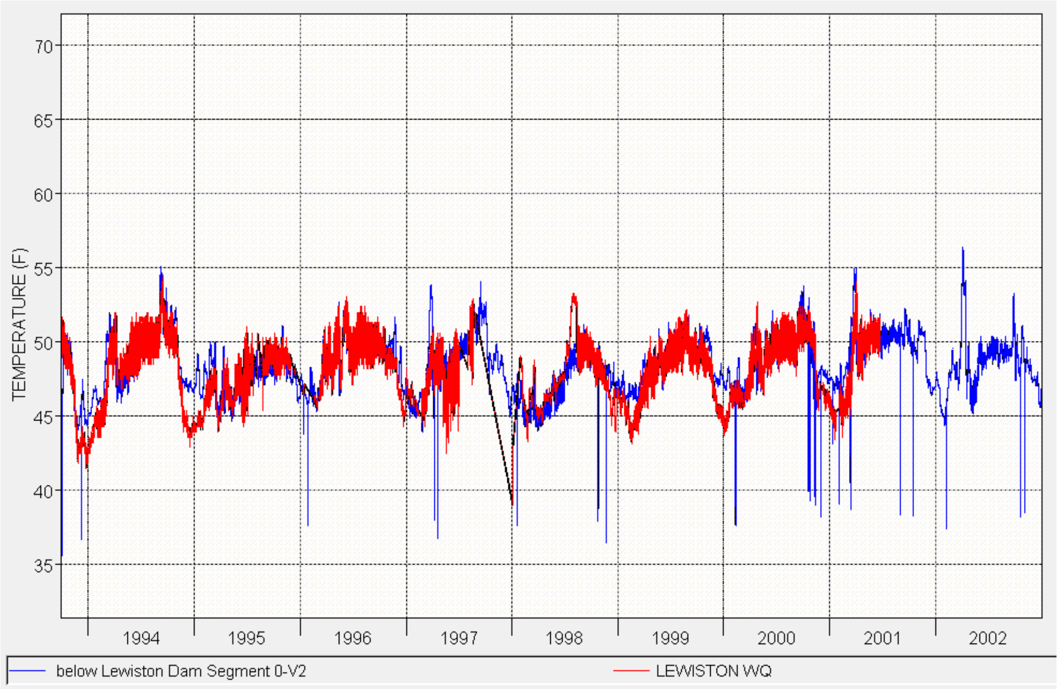


Figure 6B.C.12 Trinity River below Lewiston Dam Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

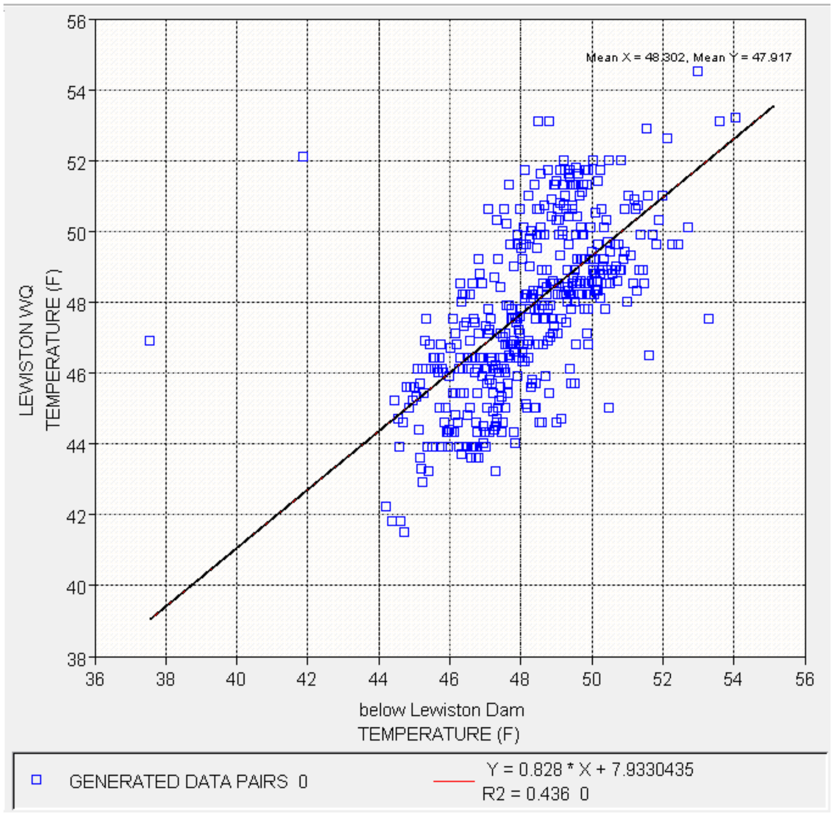


Figure 6B.C.13 Trinity River below Lewiston Dam Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.5 Trinity River below Lewiston Dam Computed and Observed Statistical Comparison

Period	Values	Computed (oF)	Observed (oF)	Bias (oF)	RMS Differences (oF)	Mean Differences (oF)
Jan	356	46.60	45.23	1.37	2.04	1.77
Feb	394	46.59	45.60	1.00	1.73	1.37
Mar	468	47.99	46.99	1.00	2.04	1.57
Apr	468	47.79	48.06	-0.27	1.77	1.31
May	490	48.08	48.16	-0.08	1.47	1.12
Jun	452	48.71	48.91	-0.20	1.73	1.42
Jul	336	49.24	49.82	-0.58	1.96	1.72
Aug	344	49.68	50.21	-0.53	1.98	1.72
Sep	356	49.85	49.97	-0.12	1.49	1.22
Oct	366	49.64	49.47	0.16	1.68	1.16
Nov	354	48.58	48.01	0.57	1.58	1.15

Period	Values	Computed (oF)	Observed (oF)	Bias (oF)	RMS Differences (oF)	Mean Differences (oF)
Dec	296	47.29	45.48	1.81	2.01	1.82
Jan-Mar	1218	47.13	46.02	1.11	1.94	1.56
Apr-Jun	1410	48.19	48.37	-0.18	1.66	1.28
Jul-Sep	1036	49.60	50.00	-0.40	1.82	1.55
Oct-Dec	1016	48.58	47.80	0.79	1.75	1.35
Average Year	4680	48.31	48.00	0.31	1.79	1.43

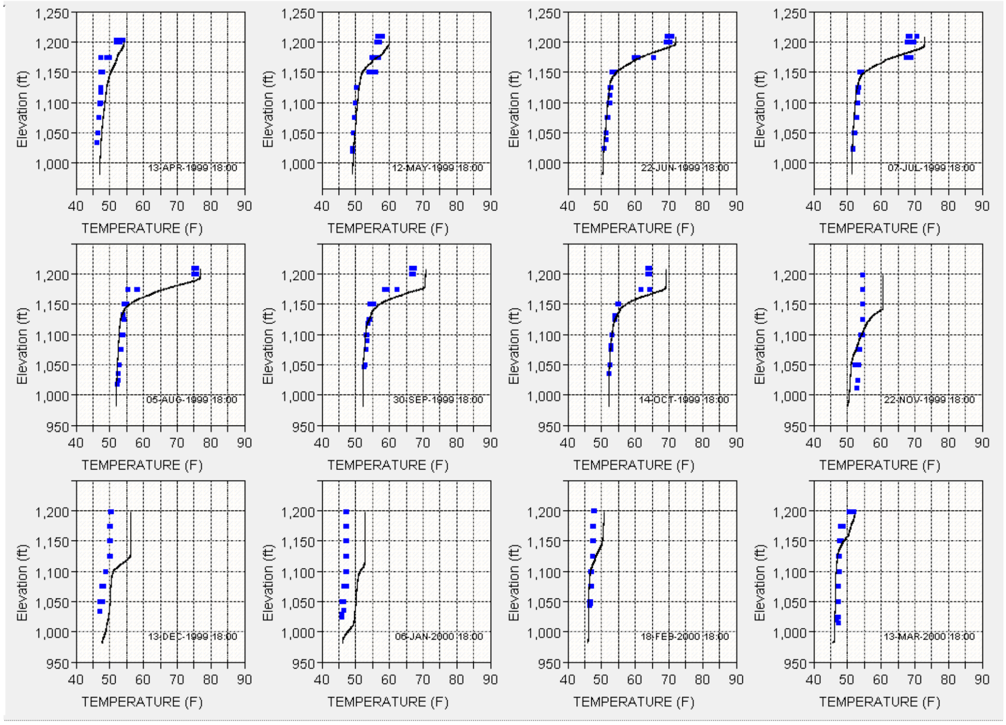


Figure 6B.C.14 Whiskeytown Lake Observed (blue dots) and Computed (black line) Temperature Profiles Resulting from the Trinity-Sacramento River Validation

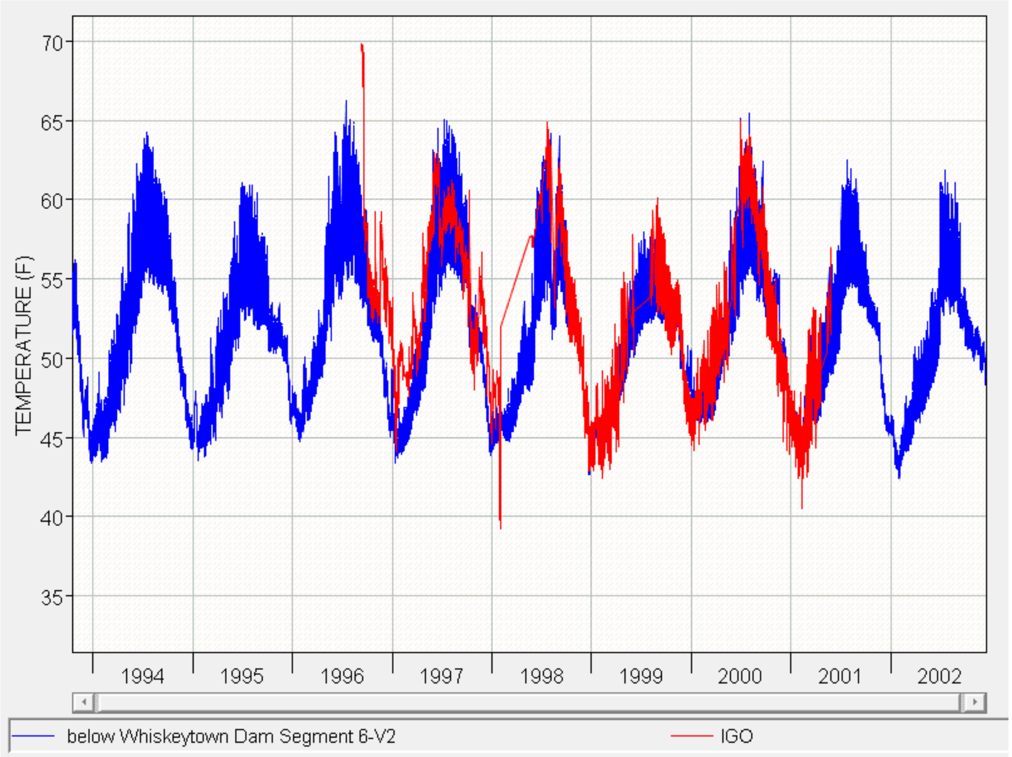


Figure 6B.C.15 Clear Creek below Whiskeytown Lake Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

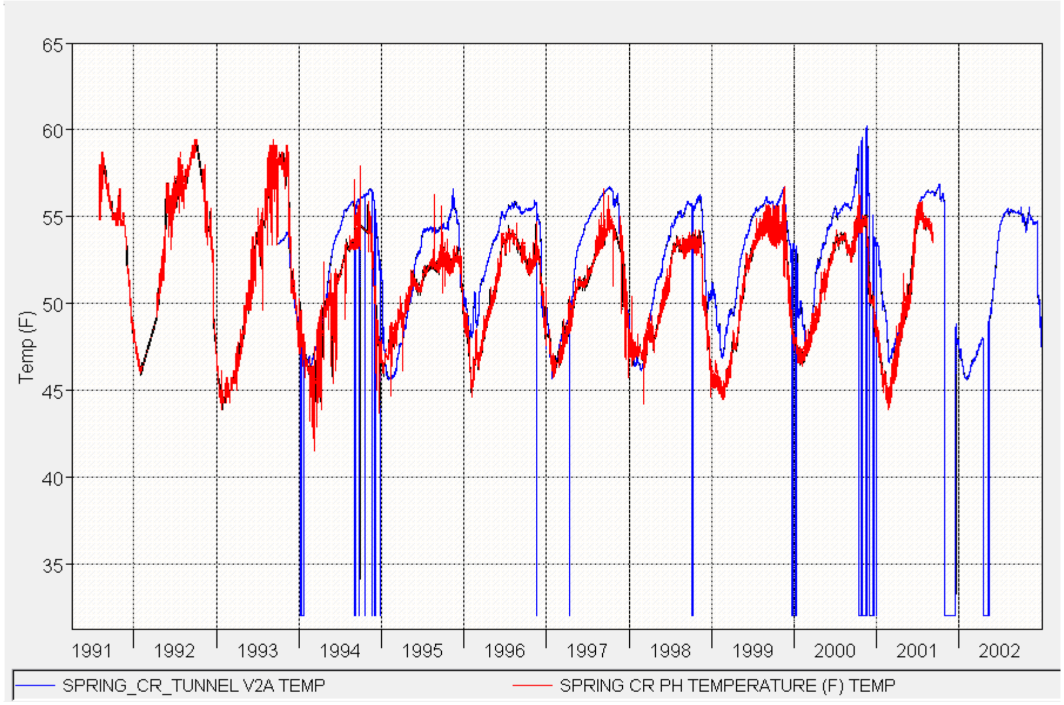


Figure 6B.C.16 Spring Creek Powerhouse Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

Table 6B.C.6 Clear Creek below Whiskeytown Computed and Observed Statistical Comparison

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Jan	458	47.11	47.07	0.05	5.17	3.15
Feb	432	47.22	46.37	0.85	1.99	1.64
Mar	464	47.95	47.31	0.64	1.75	1.46
Apr	444	49.43	48.76	0.67	2.16	1.34
May	480	50.89	50.44	0.45	0.97	0.79
Jun	458	52.36	51.93	0.43	1.03	0.75
Jul	460	53.23	53.19	0.04	0.74	0.58
Aug	474	53.57	53.57	0.00	0.50	0.36
Sep	418	53.01	53.54	-0.52	3.81	1.22
Oct	326	52.59	53.55	-0.97	6.01	2.44
Nov	352	51.37	53.14	-1.77	8.04	4.06
Dec	414	48.47	49.72	-1.25	6.63	3.82
Jan-Mar	1354	47.43	46.93	0.50	3.37	2.09
Apr-Jun	1382	50.91	50.40	0.51	1.47	0.95
Jul-Sep	1352	53.28	53.43	-0.15	2.18	0.70
Oct-Dec	1092	50.64	51.97	-1.33	6.95	3.48
Average Year	5180	50.56	50.61	-0.05	3.87	1.72

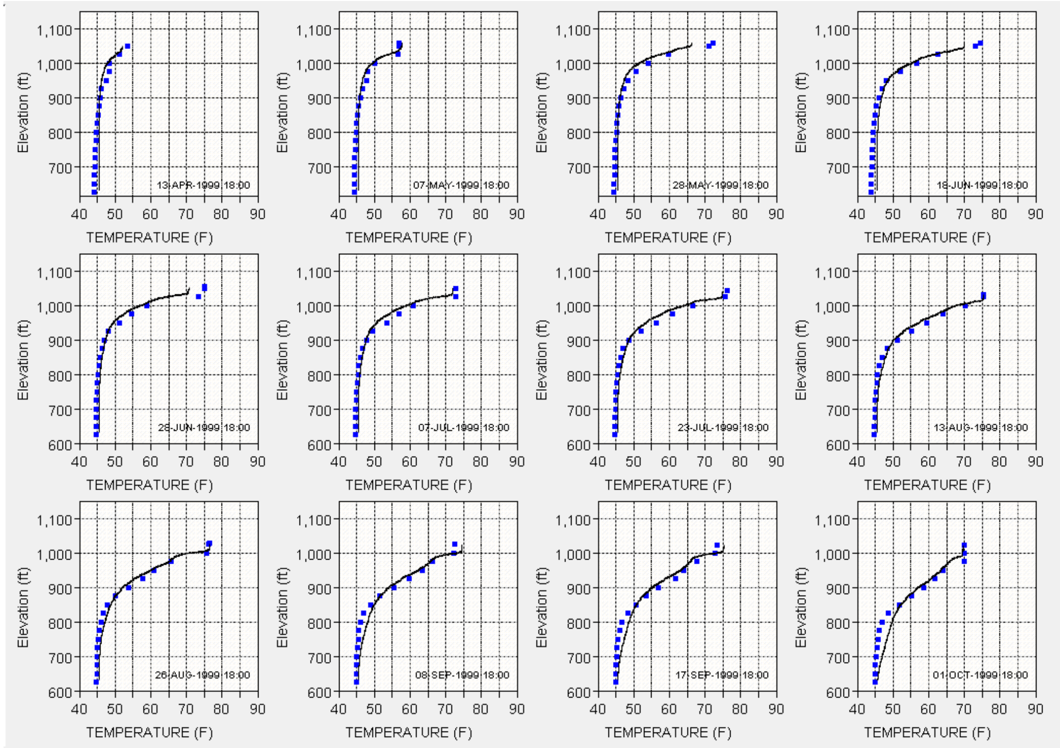


Figure 6B.C.17 Shasta Lake Observed (blue dots) and Computed (black line) Temperature Profiles Resulting from the Trinity-Sacramento River Validation

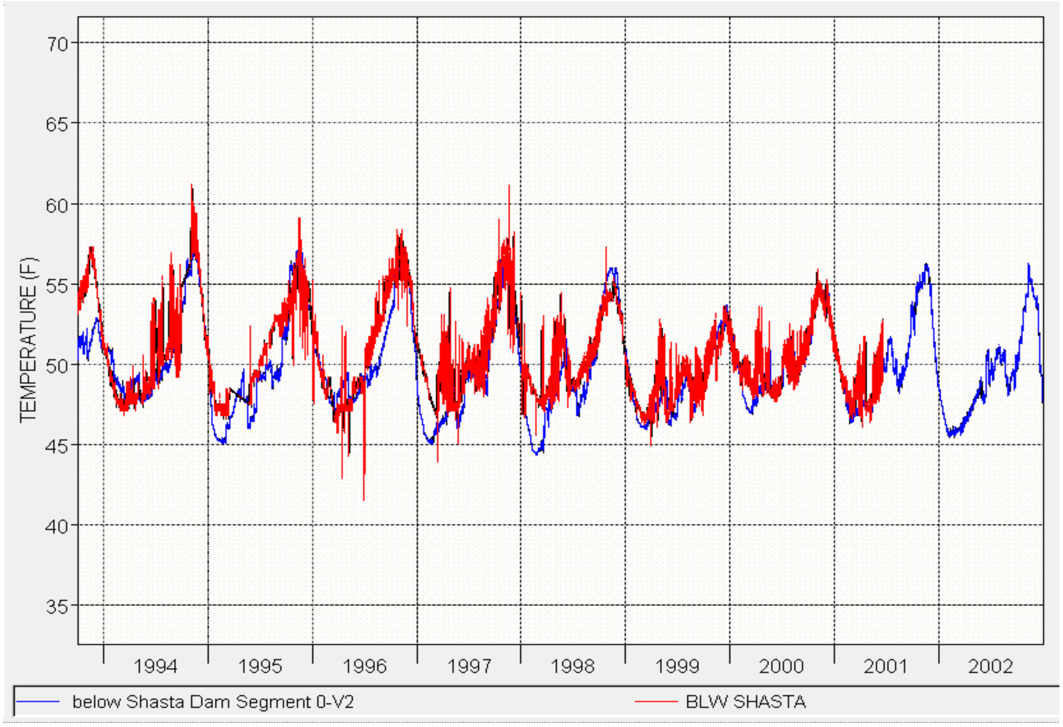


Figure 6B.C.18 Sacramento River below Shasta Lake Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

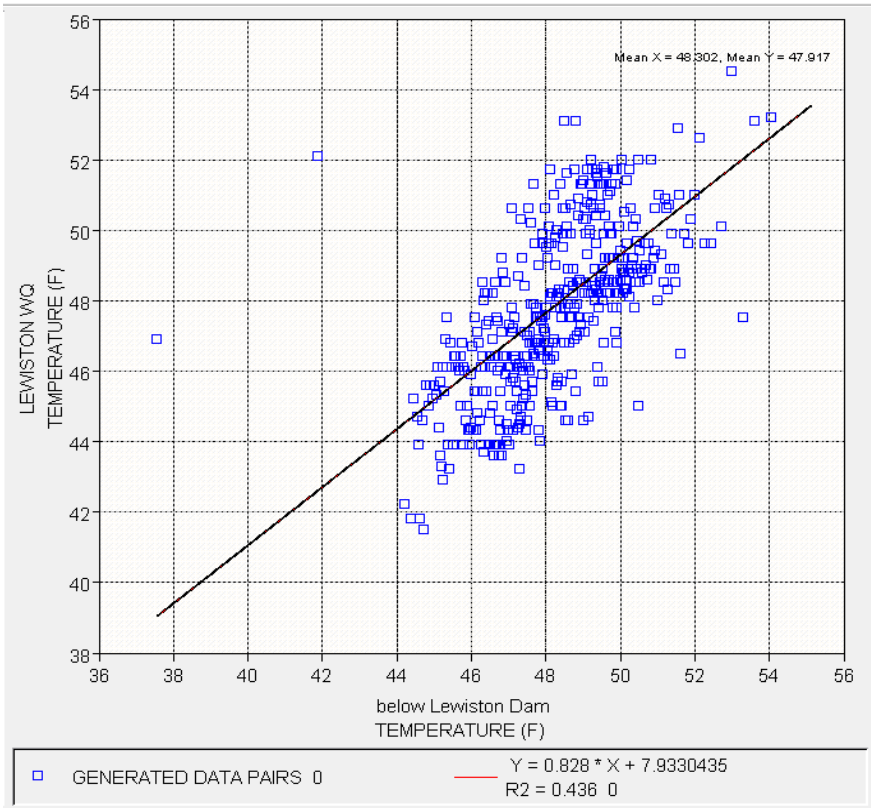


Figure 6B.C.19 Sacramento River below Shasta Lake Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.7 Sacramento River below Shasta Lake Computed and Observed Statistical Comparison

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Jan	424	49.16	49.82	-0.66	1.69	1.21
Feb	404	47.04	48.19	-1.15	1.92	1.54
Mar	384	46.81	47.89	-1.08	1.83	1.39
Apr	364	47.77	48.74	-0.97	2.12	1.62
May	386	48.27	48.81	-0.54	1.62	1.18
Jun	428	48.46	49.03	-0.56	1.54	1.09
Jul	374	49.19	50.03	-0.84	1.59	1.23
Aug	408	49.40	50.79	-1.39	2.11	1.72
Sep	410	50.80	51.70	-0.90	1.73	1.35
Oct	318	53.10	53.39	-0.28	1.34	1.06
Nov	360	55.27	55.00	0.27	1.49	1.09

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Dec	318	53.05	53.14	-0.09	1.16	0.86
Jan-Mar	1212	47.71	48.66	-0.96	1.81	1.38
Apr-Jun	1178	48.19	48.87	-0.68	1.77	1.28
Jul-Sep	1192	49.81	50.86	-1.05	1.83	1.44
Oct-Dec	996	53.87	53.89	-0.03	1.34	1.01
Average Year	4578	49.72	50.43	-0.71	1.71	1.29

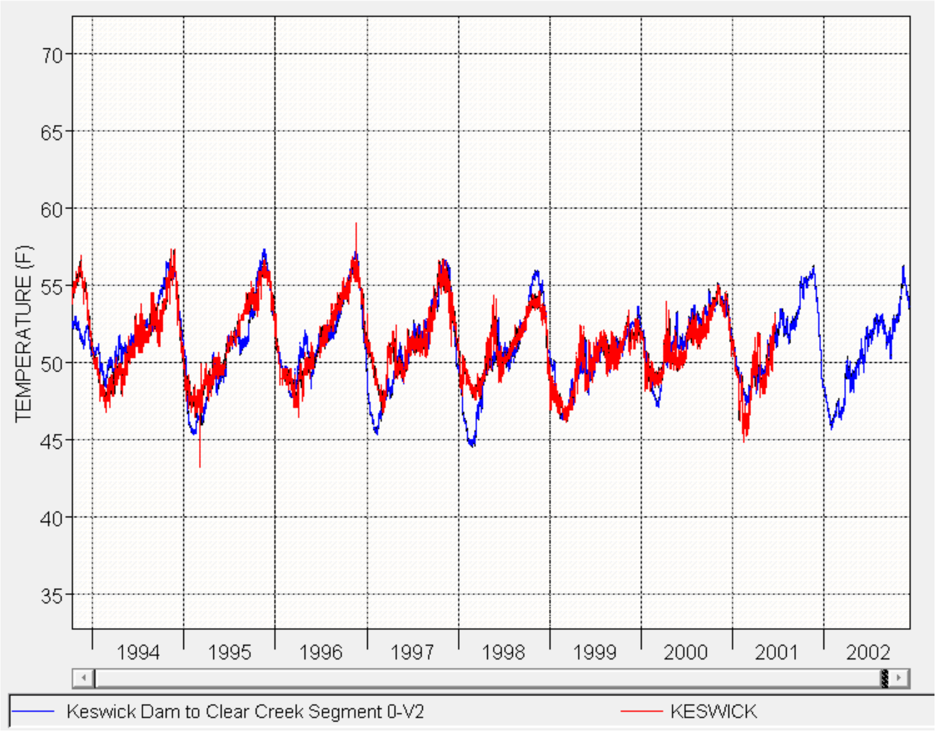


Figure 6B.C.20 Sacramento River below Keswick Dam Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

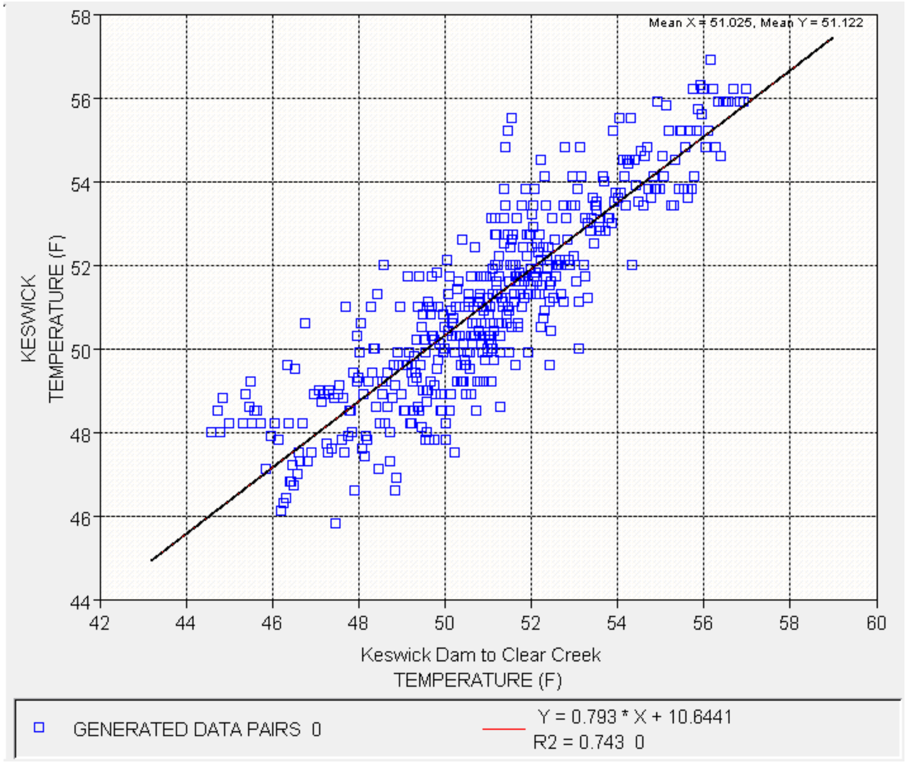


Figure 6B.C.21 Sacramento River below Keswick Dam Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.8 Sacramento River below Keswick Dam Computed and Observed Statistical Comparison

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Jan	468	49.22	49.52	-0.29	1.85	1.40
Feb	434	47.35	48.08	-0.72	1.89	1.52
Mar	496	47.90	48.25	-0.36	1.41	1.17
Apr	466	49.53	49.65	-0.12	1.43	1.19
May	486	50.20	50.06	0.14	1.22	0.98
Jun	400	50.73	50.47	0.26	0.89	0.71
Jul	402	51.47	51.38	0.09	0.65	0.52
Aug	430	51.68	51.89	-0.21	0.97	0.78
Sep	414	52.62	52.65	-0.03	1.11	0.85
Oct	428	54.20	53.82	0.37	0.95	0.75
Nov	418	55.21	54.69	0.53	0.99	0.82
Dec	426	52.83	52.72	0.11	0.90	0.73

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Jan-Mar	1398	48.17	48.62	-0.45	1.72	1.36
Apr-Jun	1352	50.13	50.04	0.09	1.21	0.97
Jul-Sep	1246	51.92	51.98	-0.05	0.93	0.72
Oct-Dec	1272	54.07	53.74	0.33	0.95	0.77
Average Year	5268	50.99	51.02	-0.03	1.26	0.97

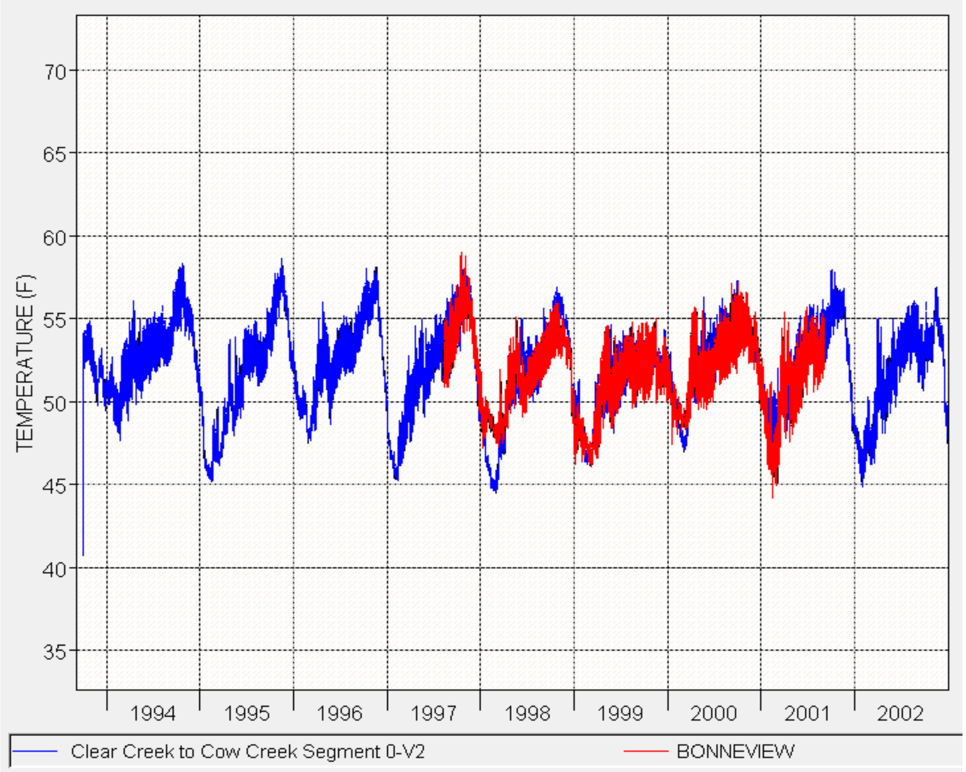


Figure 6B.C.22 Sacramento River below Clear Creek Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

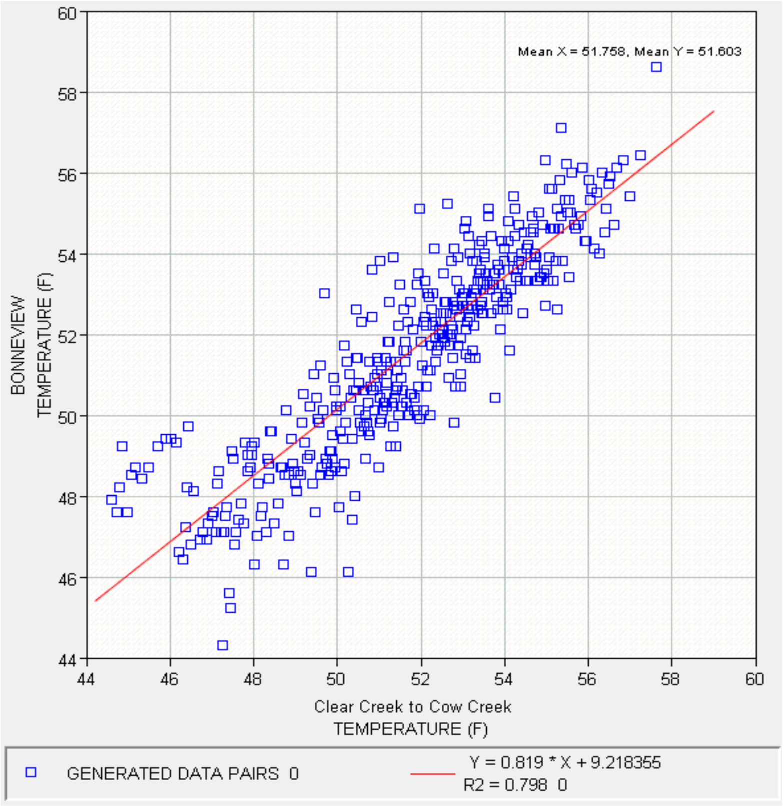


Figure 6B.C.23 Sacramento River below Clear Creek Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.9 Sacramento River below Clear Creek Computed and Observed Statistical Comparison

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Jan	248	49.39	49.27	0.12	1.41	1.08
Feb	226	47.33	48.08	-0.75	1.98	1.57
Mar	248	48.24	48.80	-0.57	1.36	1.06
Apr	240	50.40	50.93	-0.53	1.29	1.00
May	248	51.56	51.38	0.18	1.44	1.16
Jun	236	52.14	51.39	0.75	1.31	1.11
Jul	242	52.88	52.52	0.36	0.87	0.66
Aug	292	53.11	52.69	0.42	0.85	0.68
Sep	252	53.62	53.41	0.21	0.84	0.66
Oct	248	54.17	54.24	-0.07	0.98	0.77
Nov	240	54.48	53.93	0.55	1.07	0.88

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Dec	246	52.25	52.14	0.11	0.94	0.79
Jan-Mar	722	48.35	48.74	-0.39	1.60	1.23
Apr-Jun	724	51.37	51.24	0.13	1.35	1.09
Jul-Sep	786	53.20	52.87	0.34	0.85	0.67
Oct-Dec	734	53.63	53.43	0.19	0.99	0.81
Average Year	2966	51.68	51.60	0.07	1.23	0.94

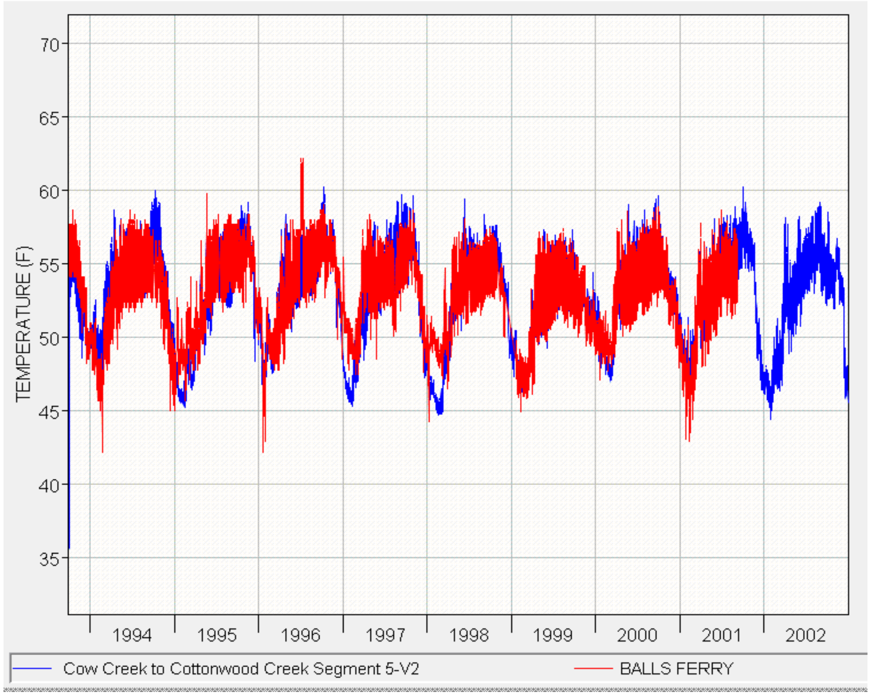


Figure 6B.C.24 Sacramento River at Balls Ferry Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

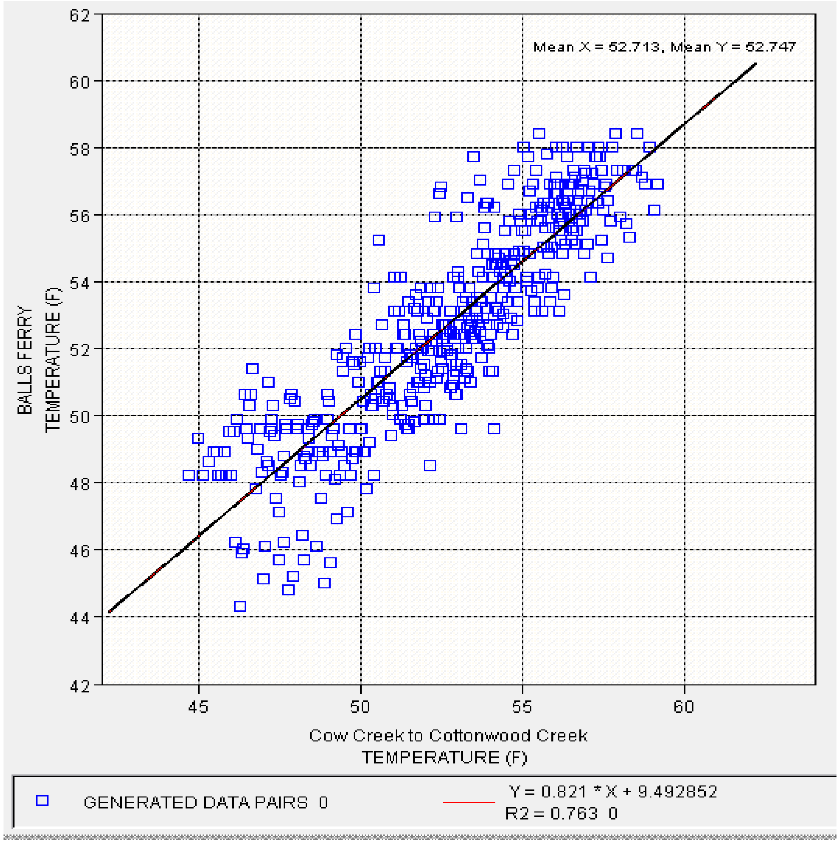


Figure 6B.C.25 Sacramento River at Balls Ferry Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.10 Sacramento River at Balls Ferry Computed and Observed Statistical Comparison

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Jan	442	48.25	49.31	-1.05	2.42	1.93
Feb	432	47.51	48.49	-0.98	2.20	1.79
Mar	496	49.42	50.25	-0.83	1.73	1.43
Apr	452	52.06	52.50	-0.44	1.74	1.41
May	472	53.08	53.34	-0.25	1.51	1.21
Jun	446	53.81	54.10	-0.29	1.48	1.17
Jul	452	54.59	54.76	-0.17	1.44	0.99
Aug	464	54.54	54.62	-0.08	1.34	1.05
Sep	426	55.23	55.08	0.15	1.20	0.97
Oct	410	55.54	54.96	0.59	1.27	0.99
Nov	392	54.50	54.06	0.44	1.08	0.85

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Dec	374	51.29	51.44	-0.15	1.52	1.21
Jan-Mar	1370	48.44	49.39	-0.95	2.12	1.70
Apr-Jun	1370	52.98	53.31	-0.33	1.58	1.26
Jul-Sep	1342	54.77	54.81	-0.04	1.33	1.01
Oct-Dec	1176	53.84	53.54	0.30	1.30	1.01
Average Year	5258	52.45	52.72	-0.27	1.63	1.26

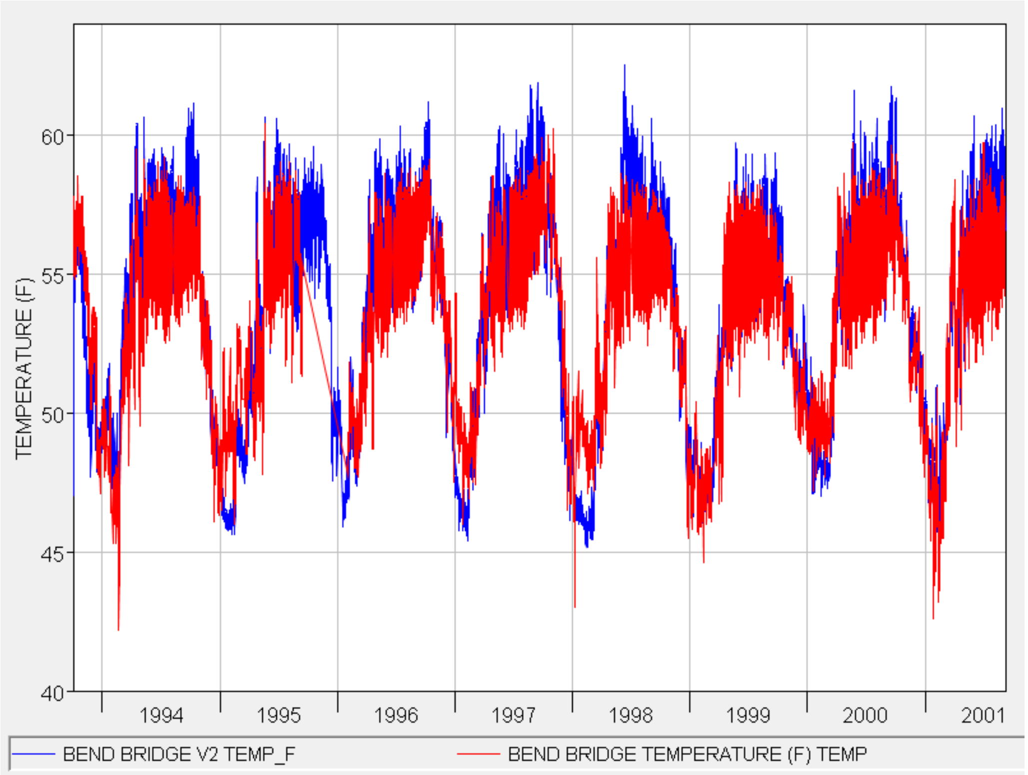


Figure 6B.C.26 Sacramento River at Bend Bridge Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

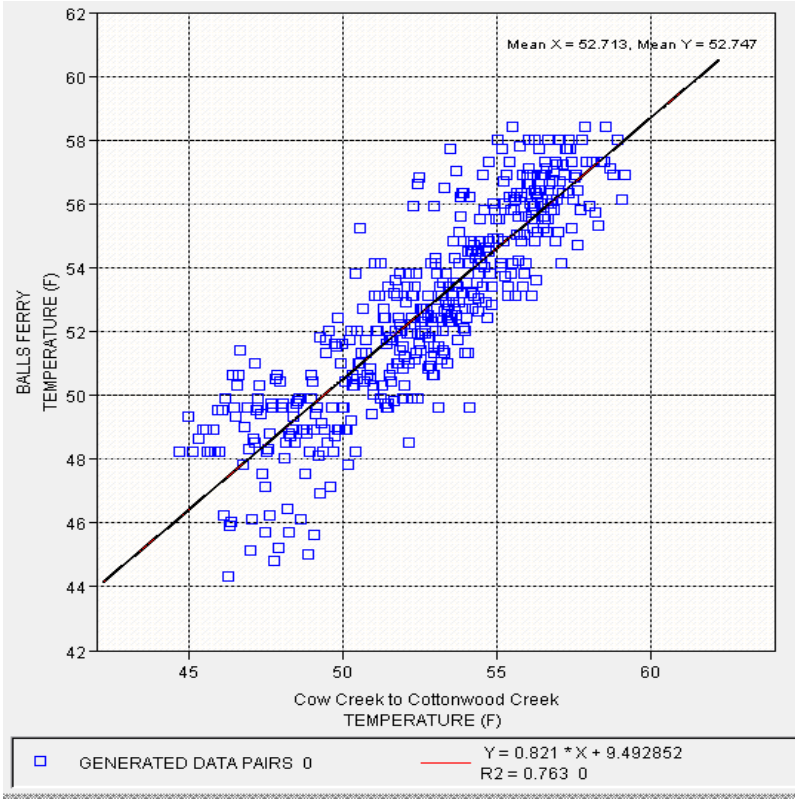


Figure 6B.C.27 Sacramento River at Bend Bridge Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.11 Sacramento River at Balls Ferry Computed and Observed Statistical Comparison

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Jan	406	47.53	48.79	-1.26	2.25	1.76
Feb	446	47.51	48.45	-0.94	1.95	1.60
Mar	472	50.40	51.08	-0.69	1.52	1.20
Apr	472	53.76	53.64	0.12	1.60	1.29
May	486	55.45	54.74	0.71	1.48	1.18
Jun	432	56.32	55.33	1.00	1.70	1.30
Jul	474	56.72	55.74	0.98	1.42	1.18
Aug	466	56.53	55.81	0.72	1.32	1.11
Sep	390	56.99	56.14	0.85	1.42	1.12
Oct	366	56.25	55.80	0.45	1.17	0.95
Nov	360	53.45	53.70	-0.25	1.16	0.90

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Dec	366	50.03	50.36	-0.33	1.33	1.04
Jan-Mar	1324	48.55	49.49	-0.95	1.91	1.51
Apr-Jun	1390	55.15	54.55	0.60	1.59	1.26
Jul-Sep	1330	56.73	55.88	0.85	1.39	1.14
Oct-Dec	1092	53.24	53.29	-0.04	1.22	0.97
Average Year	5136	53.45	53.32	0.13	1.56	1.23

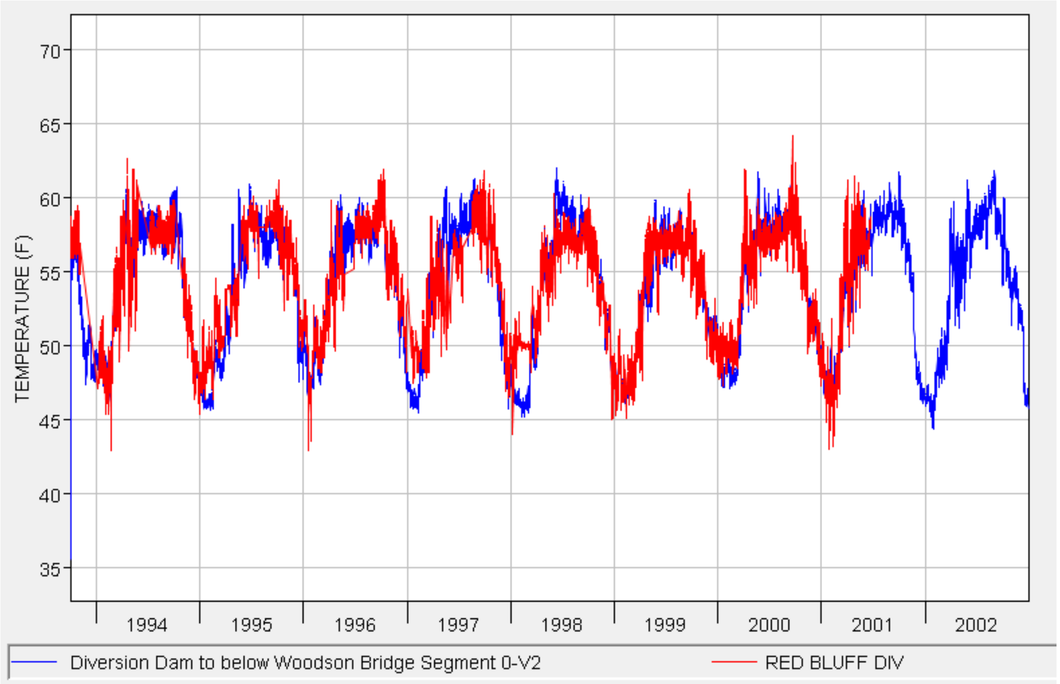


Figure 6B.C.28 Sacramento River at Red Bluff Dam Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

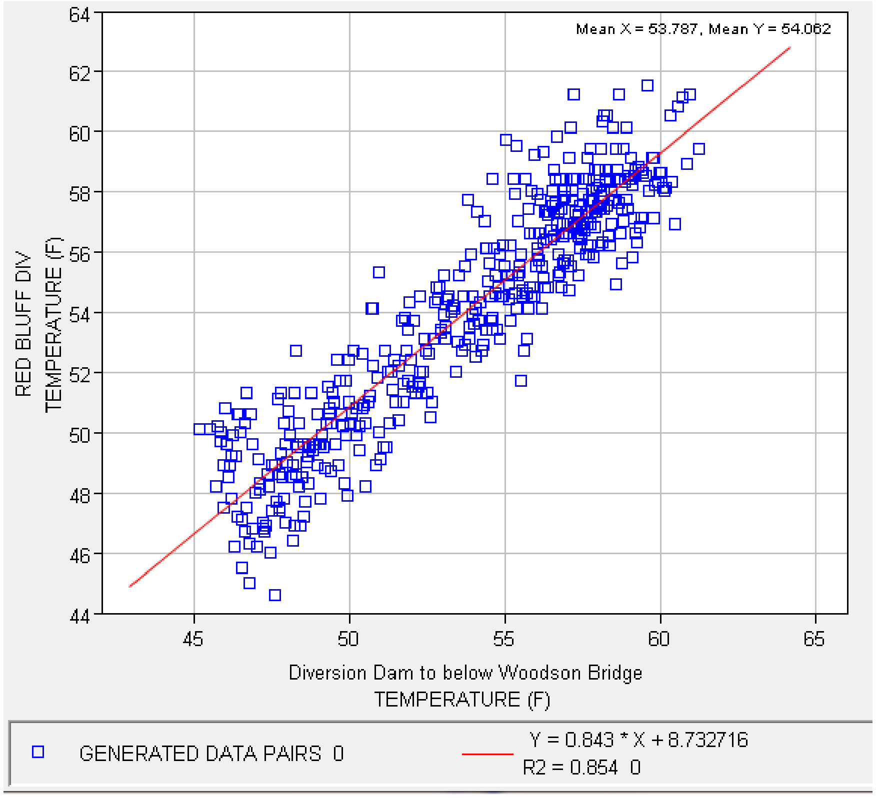


Figure 6B.C.29 Sacramento River at Red Bluff Dam Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.12 Sacramento River at Red Bluff Dam Computed and Observed Statistical Comparison

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Jan	448	47.72	48.76	-1.04	2.09	1.65
Feb	434	47.63	48.95	-1.32	2.29	1.83
Mar	485	50.71	51.68	-0.97	1.71	1.38
Apr	460	54.30	54.51	-0.21	1.97	1.57
May	402	56.22	55.77	0.45	1.81	1.39
Jun	312	57.73	56.92	0.81	1.62	1.25
Jul	346	58.09	57.48	0.61	1.19	0.91
Aug	366	57.83	57.65	0.18	1.07	0.86
Sep	416	58.14	58.08	0.07	1.35	1.11
Oct	357	56.70	56.86	-0.16	1.08	0.88
Nov	408	53.97	54.22	-0.25	1.20	0.95

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Dec	430	50.09	50.62	-0.54	1.55	1.20
Jan-Mar	1367	48.75	49.86	-1.11	2.04	1.61
Apr-Jun	1174	55.87	55.58	0.29	1.82	1.42
Jul-Sep	1128	58.03	57.76	0.27	1.21	0.96
Oct-Dec	1195	53.39	53.72	-0.33	1.30	1.02
Average Year	4864	53.76	54.02	-0.26	1.65	1.27

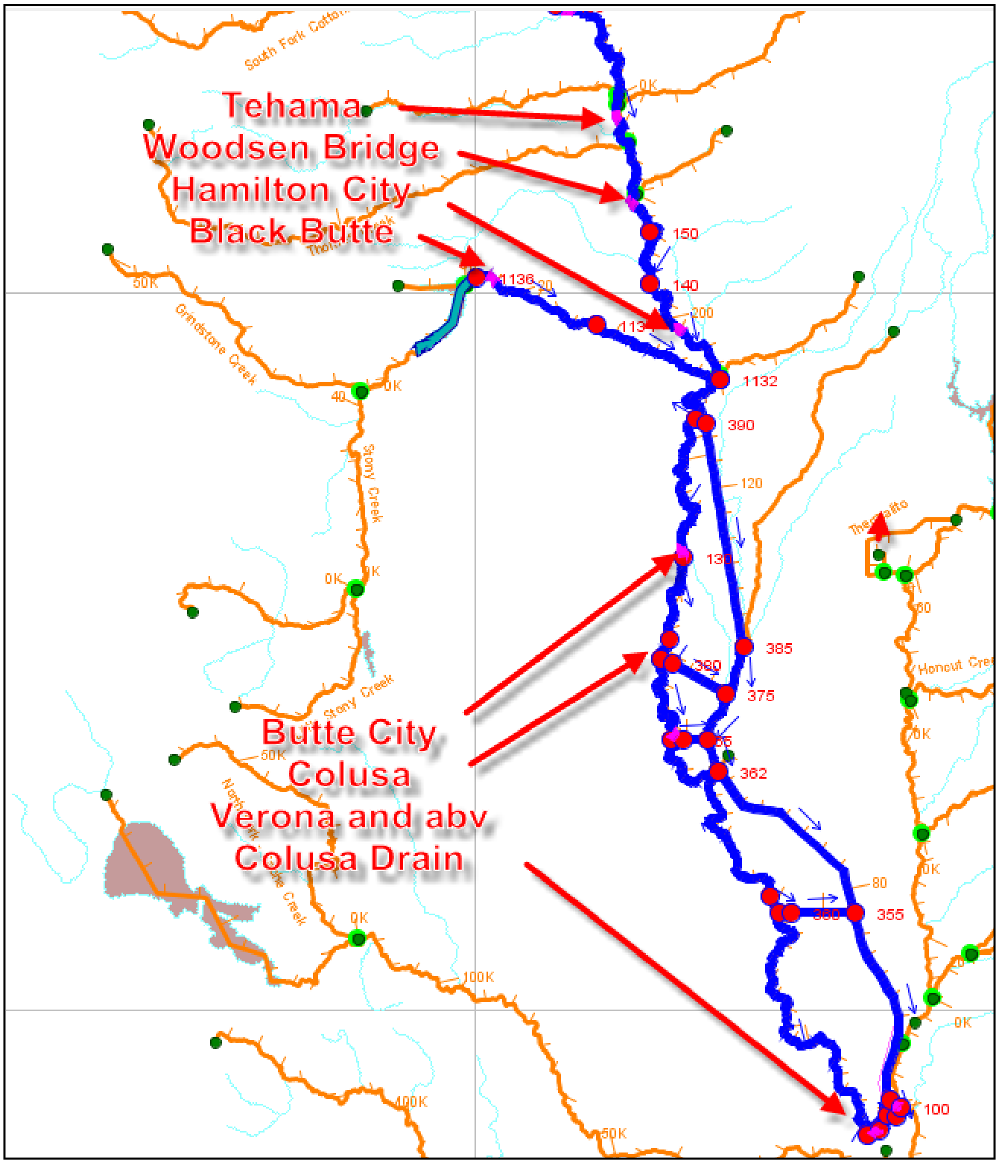


Figure 6B.C.30 Schematic of the Trinity-Sacramento River HEC-5Q Model Downstream of the Tehama Colusa Canal

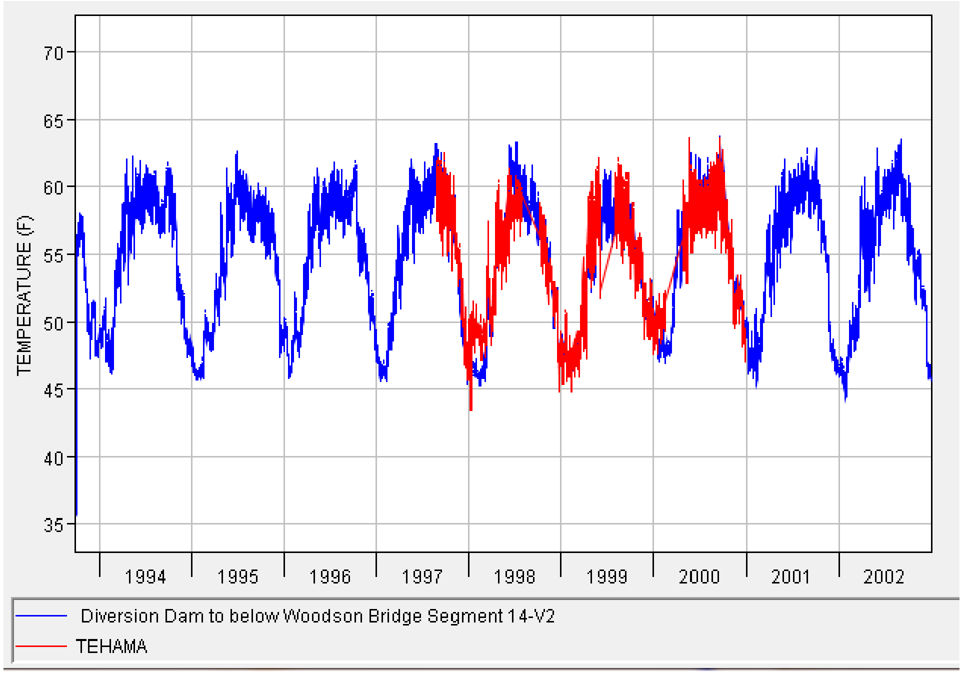


Figure 6B.C.31 Sacramento River at Tehama Colusa Canal Observed (red) and Computed (blue) temperature Time Series Resulting from the Trinity-Sacramento River Validation

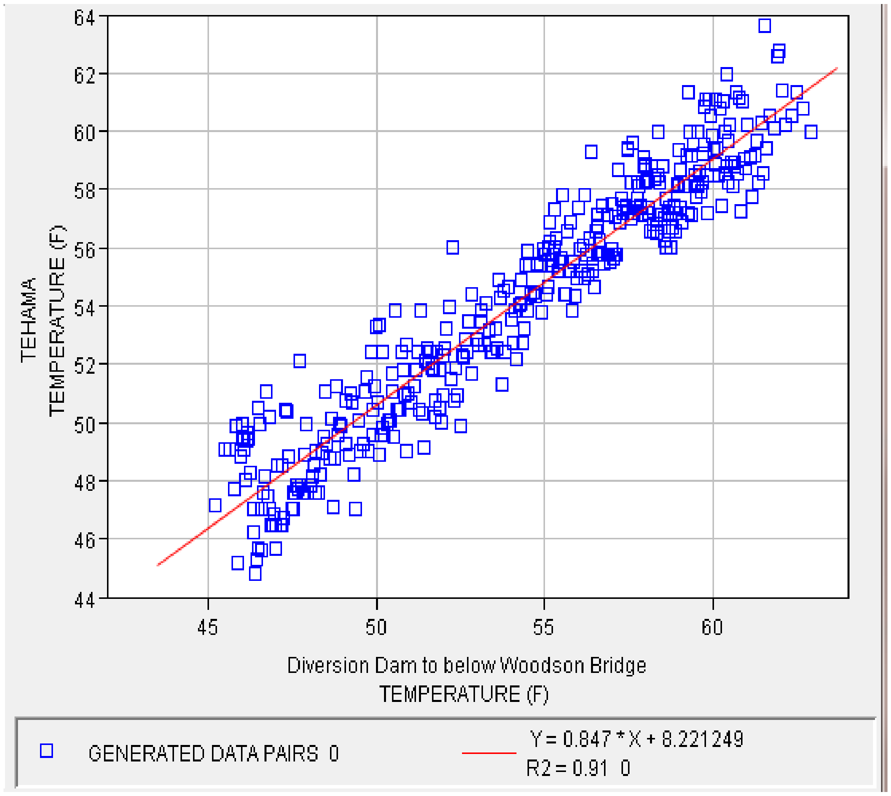


Figure 6B.C.32 Sacramento River at Tehama Colusa Canal Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.13 Sacramento River at Tehama Colusa Canal Computed and Observed Statistical Comparison

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Jan	448	47.72	48.76	-1.04	2.09	1.65
Feb	434	47.63	48.95	-1.32	2.29	1.83
Mar	485	50.71	51.68	-0.97	1.71	1.38
Apr	460	54.30	54.51	-0.21	1.97	1.57
May	402	56.22	55.77	0.45	1.81	1.39
Jun	312	57.73	56.92	0.81	1.62	1.25
Jul	346	58.09	57.48	0.61	1.19	0.91
Aug	366	57.83	57.65	0.18	1.07	0.86
Sep	416	58.14	58.08	0.07	1.35	1.11
Oct	357	56.70	56.86	-0.16	1.08	0.88
Nov	408	53.97	54.22	-0.25	1.20	0.95
Dec	430	50.09	50.62	-0.54	1.55	1.20
Jan-Mar	1367	48.75	49.86	-1.11	2.04	1.61
Apr-Jun	1174	55.87	55.58	0.29	1.82	1.42
Jul-Sep	1128	58.03	57.76	0.27	1.21	0.96
Oct-Dec	1195	53.39	53.72	-0.33	1.30	1.02
Average Year	4864	53.76	54.02	-0.26	1.65	1.27

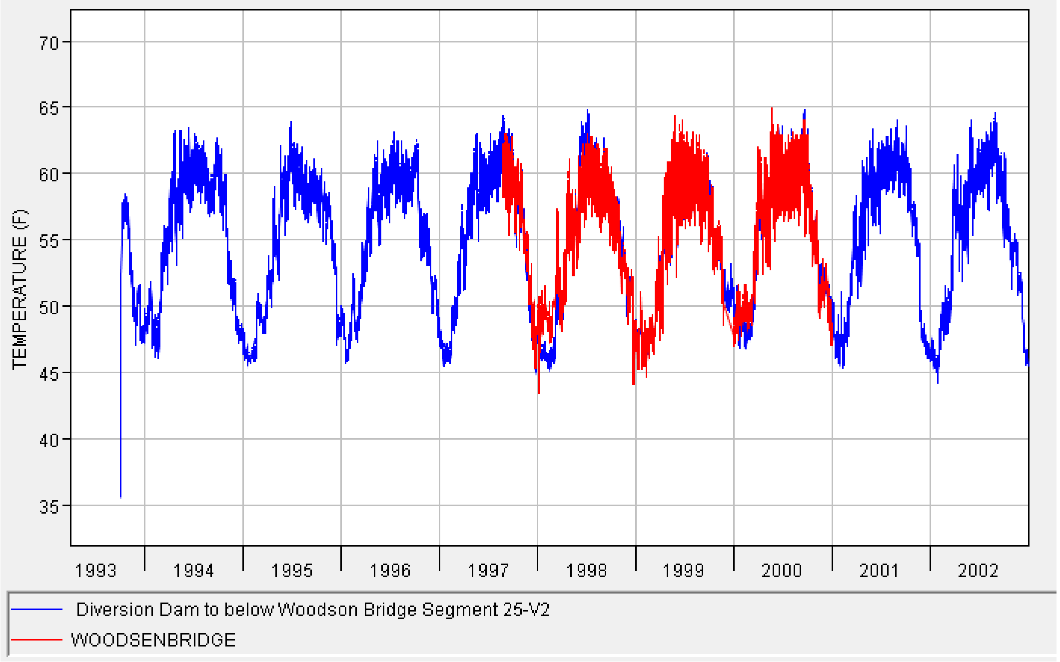


Figure 6B.C.33 Sacramento River below Woodson Bridge Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

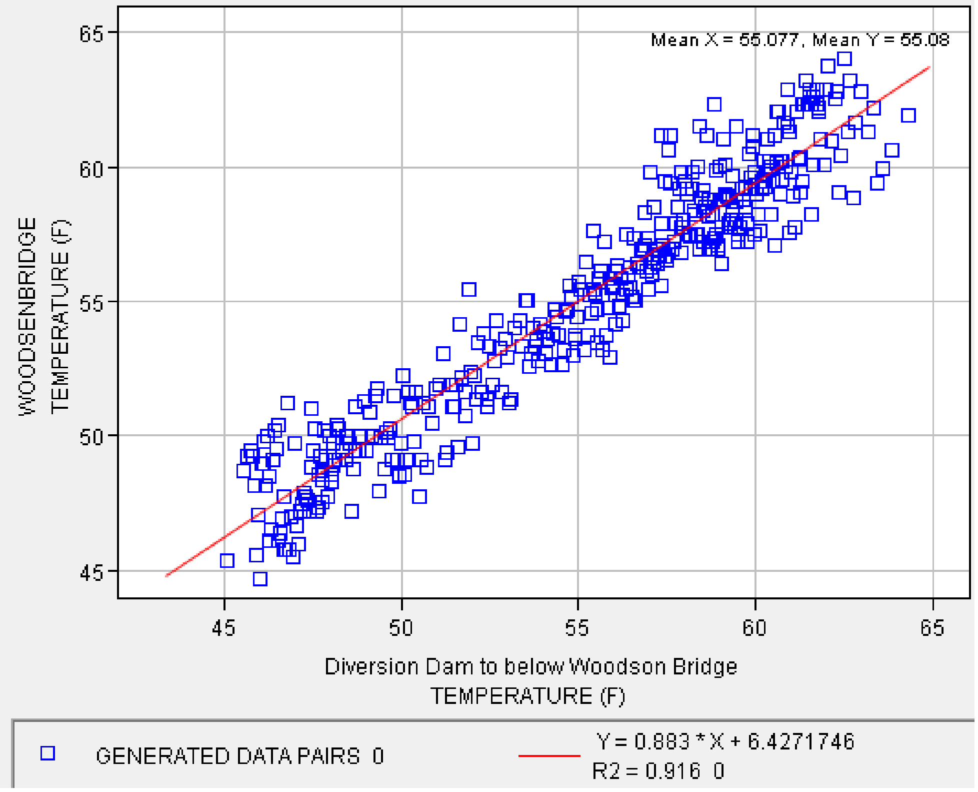


Figure 6B.C.34 Sacramento River below Woodson Bridge Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.14 Sacramento River below Woodson Bridge Computed and Observed Statistical Comparison

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Jan	279	47.71	48.54	-0.84	1.90	1.48
Feb	255	47.14	48.65	-1.51	1.96	1.62
Mar	249	50.06	51.08	-1.02	1.58	1.25
Apr	270	54.74	55.37	-0.63	1.52	1.21
May	279	57.27	57.31	-0.04	1.52	1.21
Jun	270	59.93	59.11	0.82	2.07	1.72
Jul	279	59.92	59.53	0.39	1.55	1.22
Aug	300	59.84	59.49	0.35	1.18	0.97
Sep	360	59.92	59.20	0.72	1.26	1.03
Oct	372	57.11	56.88	0.23	0.80	0.63
Nov	339	53.82	53.57	0.24	1.19	0.95
Dec	279	49.42	49.49	-0.06	1.13	0.90
Jan-Mar	783	48.27	49.38	-1.11	1.82	1.45
Apr-Jun	819	57.32	57.26	0.05	1.72	1.38
Jul-Sep	939	59.89	59.39	0.50	1.33	1.07
Oct-Dec	990	53.82	53.67	0.15	1.04	0.82
Average Year	3531	55.01	55.07	-0.06	1.48	1.15

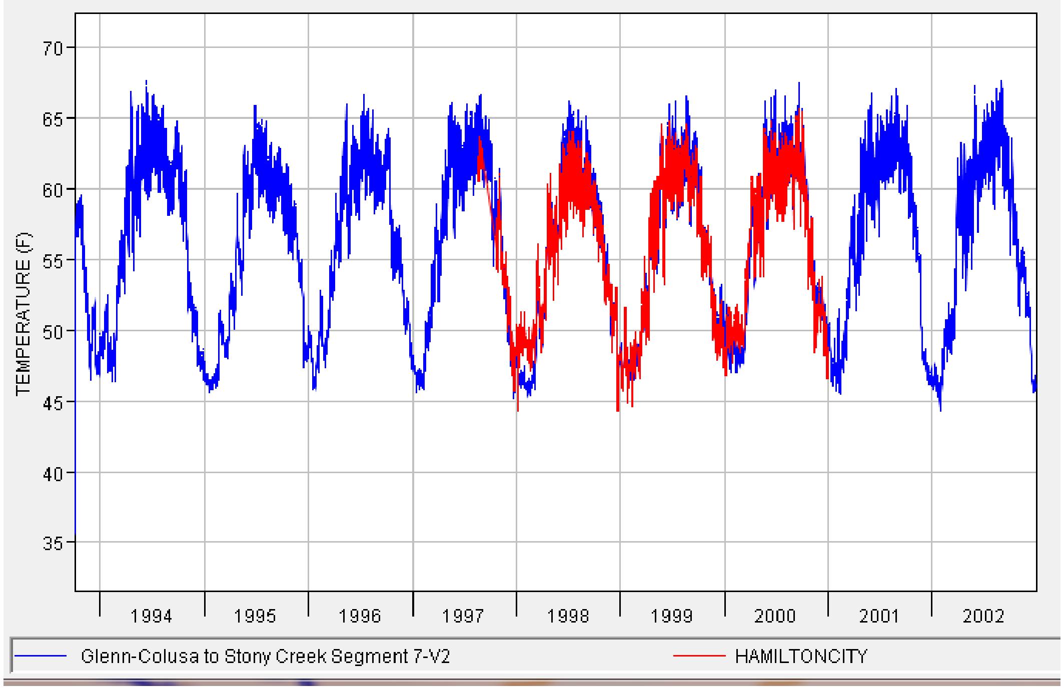


Figure 6B.C.35 Sacramento River at Hamilton City Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

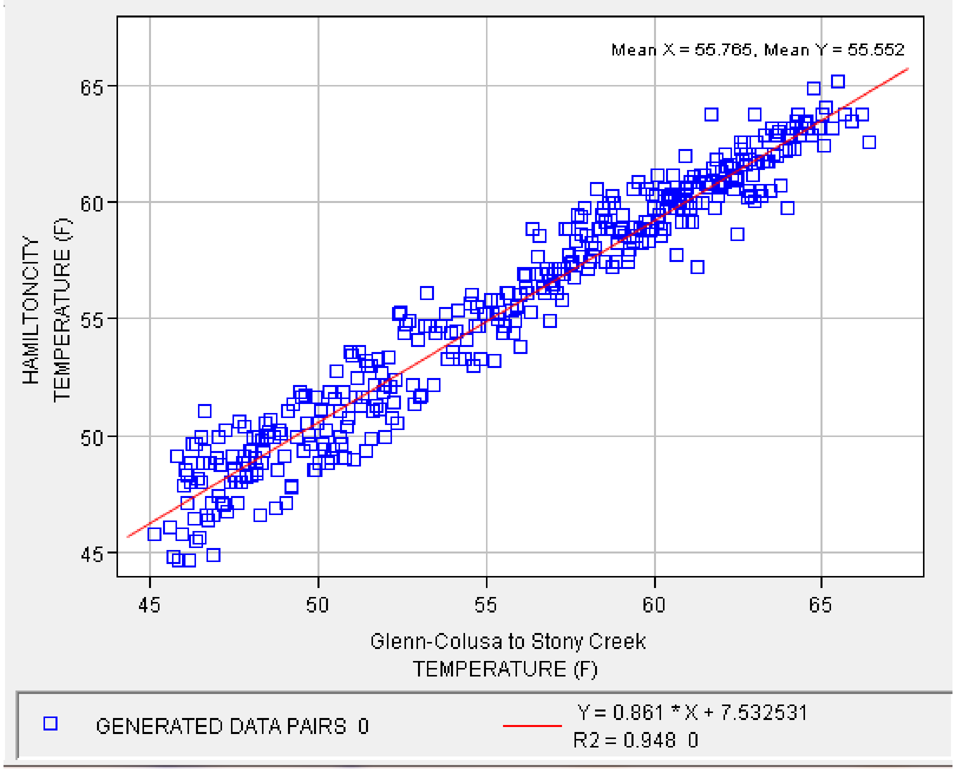


Figure 6B.C.36 Sacramento River at Hamilton City Observed (Y-Axis) as Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.15 Sacramento River at Hamilton City Computed and Observed Statistical Comparison

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Jan	279	47.71	48.54	-0.84	1.90	1.48
Feb	255	47.14	48.65	-1.51	1.96	1.62
Mar	249	50.06	51.08	-1.02	1.58	1.25
Apr	270	54.74	55.37	-0.63	1.52	1.21
May	279	57.27	57.31	-0.04	1.52	1.21
Jun	270	59.93	59.11	0.82	2.07	1.72
Jul	279	59.92	59.53	0.39	1.55	1.22
Aug	300	59.84	59.49	0.35	1.18	0.97
Sep	360	59.92	59.20	0.72	1.26	1.03
Oct	372	57.11	56.88	0.23	0.80	0.63
Nov	339	53.82	53.57	0.24	1.19	0.95
Dec	279	49.42	49.49	-0.06	1.13	0.90
Jan-Mar	783	48.27	49.38	-1.11	1.82	1.45
Apr-Jun	819	57.32	57.26	0.05	1.72	1.38
Jul-Sep	939	59.89	59.39	0.50	1.33	1.07
Oct-Dec	990	53.82	53.67	0.15	1.04	0.82
Average Year	3531	55.01	55.07	-0.06	1.48	1.15

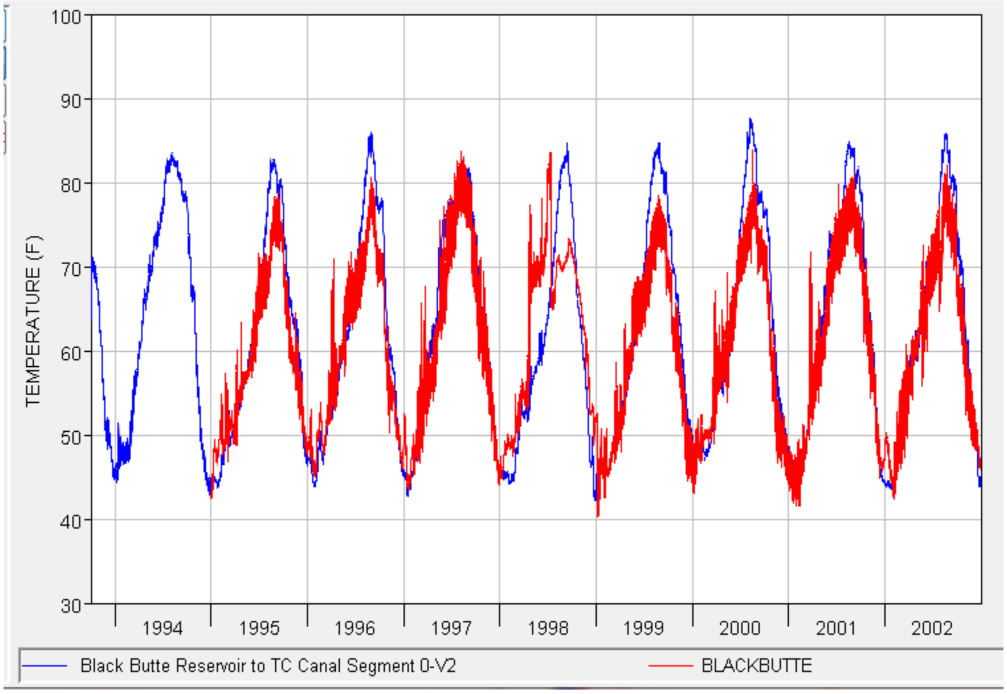


Figure 6B.C.37 Stony Creek below Black Butte Dam Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

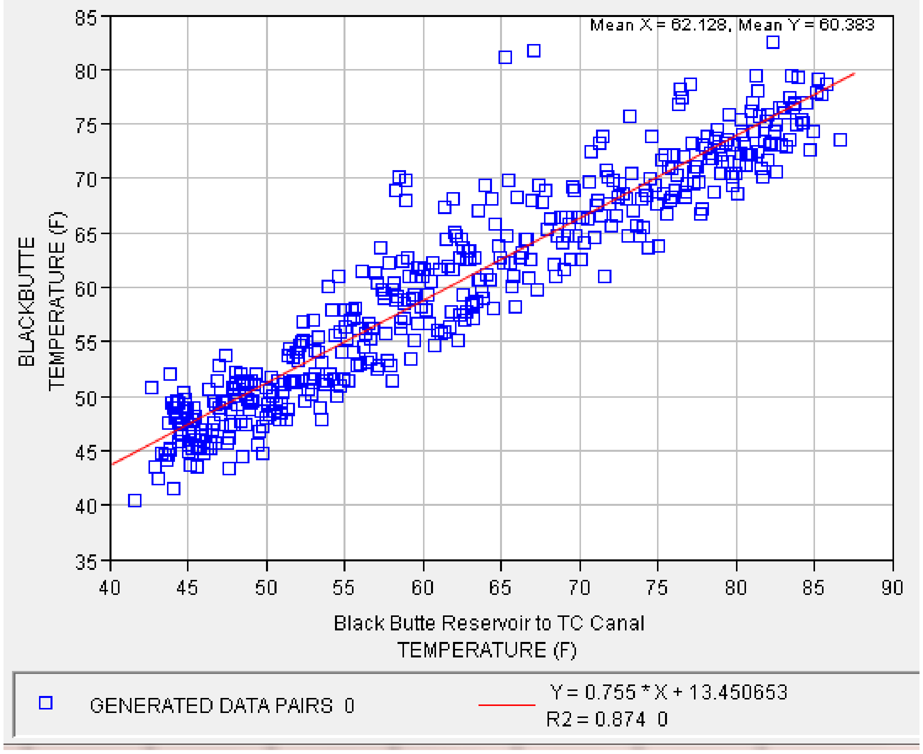


Figure 6B.C.38 Stony Creek below Black Butte Dam Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.16 Stony Creek below Black Butte Dam Computed and Observed Statistical Comparison

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Jan	279	47.71	48.54	-0.84	1.90	1.48
Feb	255	47.14	48.65	-1.51	1.96	1.62
Mar	249	50.06	51.08	-1.02	1.58	1.25
Apr	270	54.74	55.37	-0.63	1.52	1.21
May	279	57.27	57.31	-0.04	1.52	1.21
Jun	270	59.93	59.11	0.82	2.07	1.72
Jul	279	59.92	59.53	0.39	1.55	1.22
Aug	300	59.84	59.49	0.35	1.18	0.97
Sep	360	59.92	59.20	0.72	1.26	1.03
Oct	372	57.11	56.88	0.23	0.80	0.63
Nov	339	53.82	53.57	0.24	1.19	0.95
Dec	279	49.42	49.49	-0.06	1.13	0.90
Jan-Mar	783	48.27	49.38	-1.11	1.82	1.45
Apr-Jun	819	57.32	57.26	0.05	1.72	1.38
Jul-Sep	939	59.89	59.39	0.50	1.33	1.07
Oct-Dec	990	53.82	53.67	0.15	1.04	0.82
Average Year	3531	55.01	55.07	-0.06	1.48	1.15

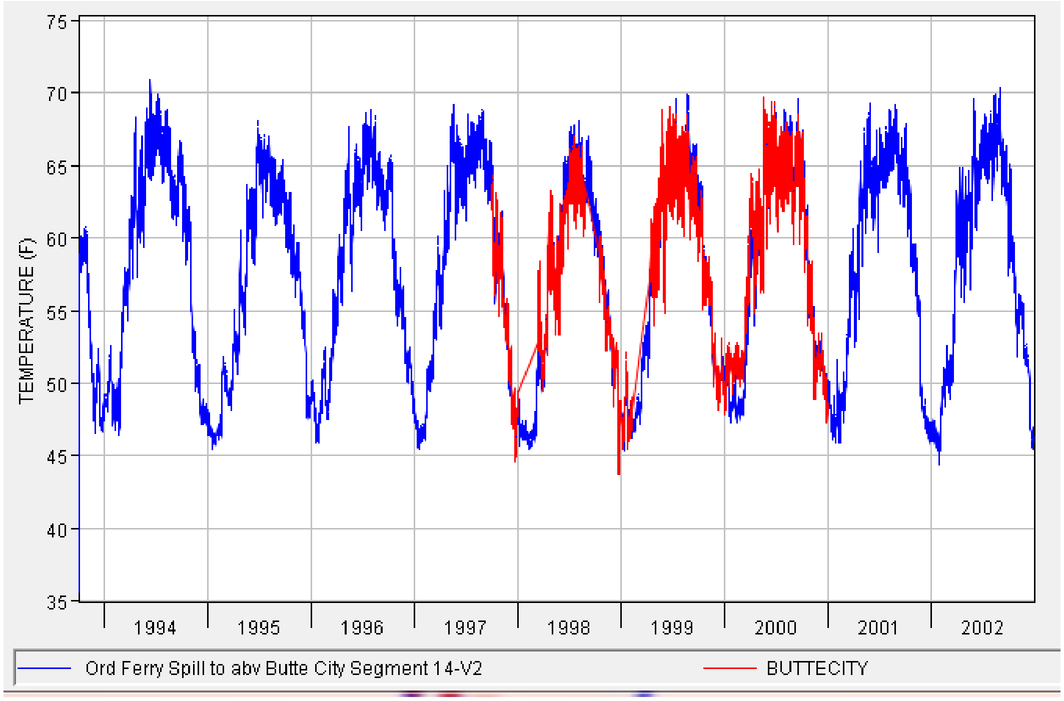


Figure 6B.C.39 Sacramento River at Butte City Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

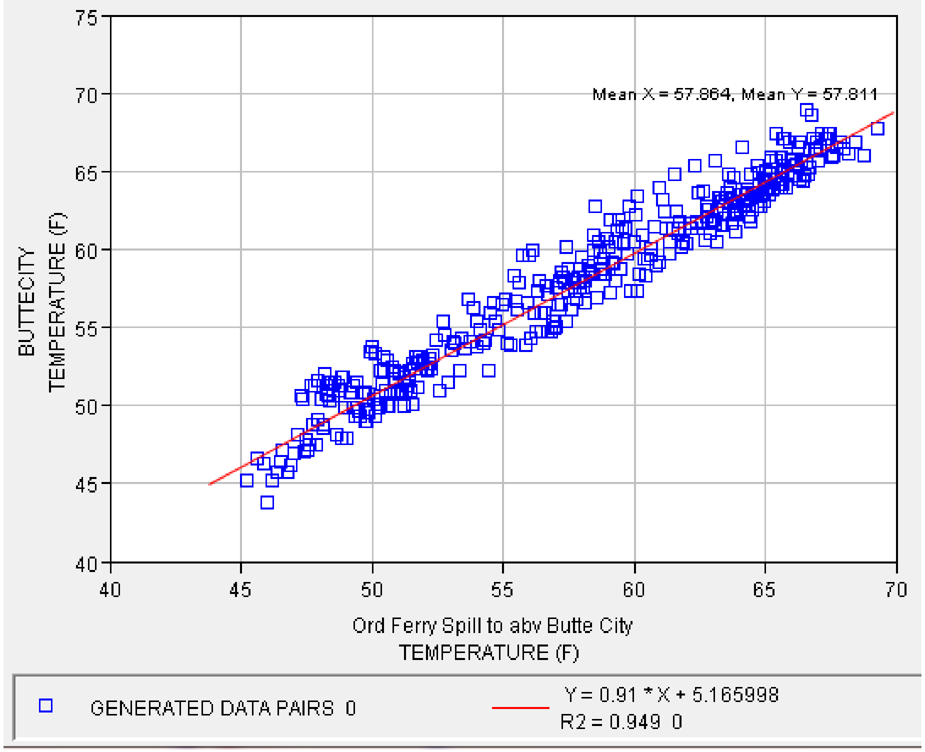


Figure 6B.C.40 Sacramento River at Butte City Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

1 **Table 6B.C.17 Sacramento River at Butte City Computed and Observed Statistical**
2 **Comparison**

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Jan	279	47.71	48.54	-0.84	1.90	1.48
Feb	255	47.14	48.65	-1.51	1.96	1.62
Mar	249	50.06	51.08	-1.02	1.58	1.25
Apr	270	54.74	55.37	-0.63	1.52	1.21
May	279	57.27	57.31	-0.04	1.52	1.21
Jun	270	59.93	59.11	0.82	2.07	1.72
Jul	279	59.92	59.53	0.39	1.55	1.22
Aug	300	59.84	59.49	0.35	1.18	0.97
Sep	360	59.92	59.20	0.72	1.26	1.03
Oct	372	57.11	56.88	0.23	0.80	0.63
Nov	339	53.82	53.57	0.24	1.19	0.95
Dec	279	49.42	49.49	-0.06	1.13	0.90
Jan-Mar	783	48.27	49.38	-1.11	1.82	1.45
Apr-Jun	819	57.32	57.26	0.05	1.72	1.38
Jul-Sep	939	59.89	59.39	0.50	1.33	1.07
Oct-Dec	990	53.82	53.67	0.15	1.04	0.82
Average Year	3531	55.01	55.07	-0.06	1.48	1.15

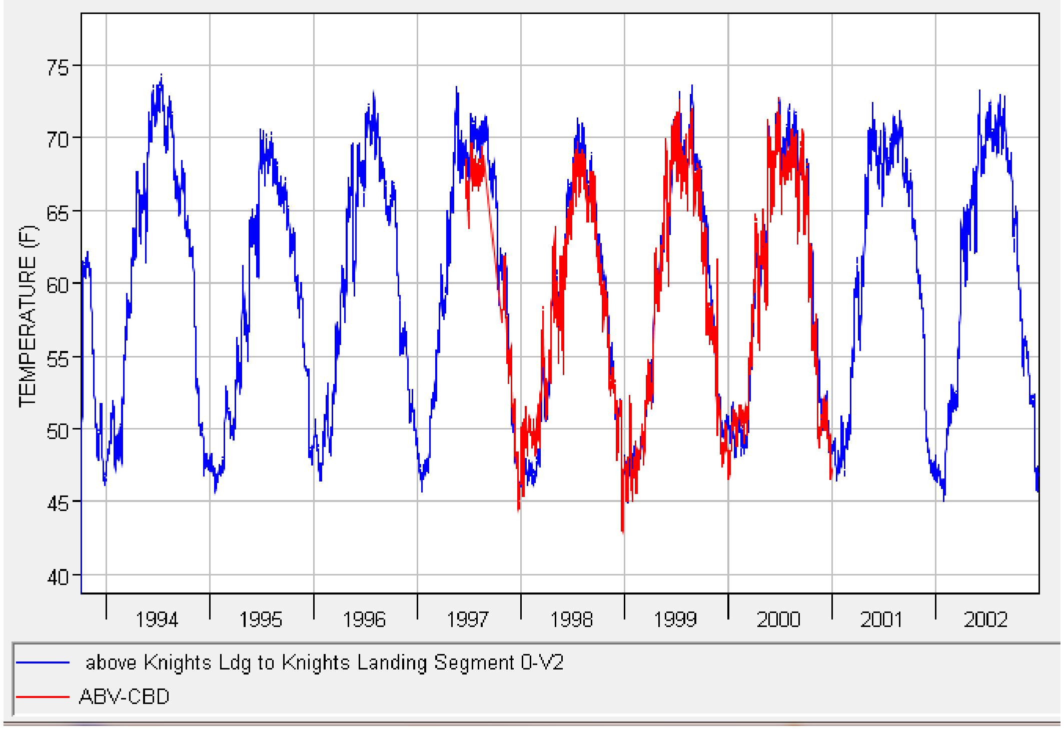


Figure 6B.C.41 Sacramento River above the Colusa Drain Observed (red) and Computed (blue) Temperature Time Series Resulting from the Trinity-Sacramento River Validation

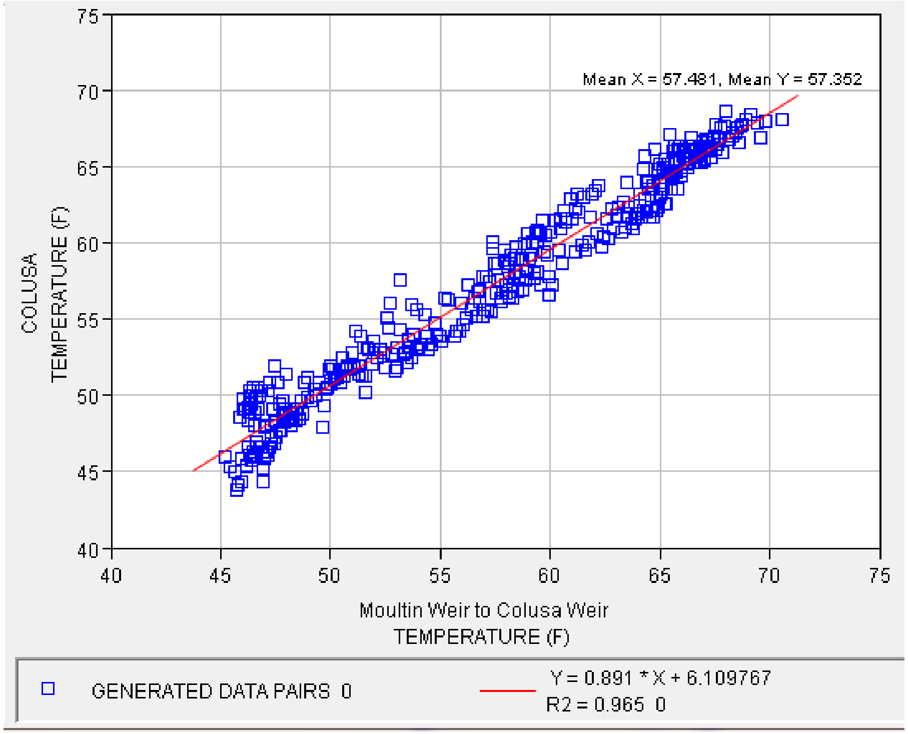


Figure 6B.C.42 Sacramento River above the Colusa Drain Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the Trinity-Sacramento River Validation

Table 6B.C.18 Sacramento River above the Colusa Drain Computed and Observed Statistical Comparison

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Jan	279	48.27	48.70	-0.43	1.84	1.48
Feb	243	48.16	49.29	-1.13	1.72	1.41
Mar	273	51.55	52.63	-1.08	1.62	1.33
Apr	270	57.76	58.08	-0.32	1.12	0.89
May	279	62.57	62.12	0.45	1.39	1.03
Jun	303	67.25	66.42	0.83	1.49	1.27
Jul	372	69.51	67.90	1.61	1.84	1.63
Aug	342	69.61	68.08	1.53	1.80	1.54
Sep	270	67.27	65.88	1.38	1.93	1.47
Oct	288	62.42	60.14	2.28	2.93	2.39
Nov	360	55.52	54.39	1.13	2.03	1.61
Dec	372	49.60	48.96	0.64	1.30	1.05
Jan-Mar	795	49.36	50.23	-0.87	1.73	1.41
Apr-Jun	852	62.71	62.37	0.34	1.35	1.07
Jul-Sep	984	68.93	67.41	1.52	1.85	1.56
Oct-Dec	1020	55.31	54.03	1.28	2.12	1.62
Average Year	3651	59.41	58.76	0.66	1.80	1.43

6B.C.9 American River Model Validation

Comparisons between observed temperature data and computed temperature results from the validation task for the American River are provided in this section. Figures 6B.C.43 through 6B.C.50 present geographic locations used in the HEC-5Q model and comparisons of observed and computed data at these locations. Observed results are from Reclamation, DWR, and USGS data. The results indicate overall good agreement between computed and observed data.

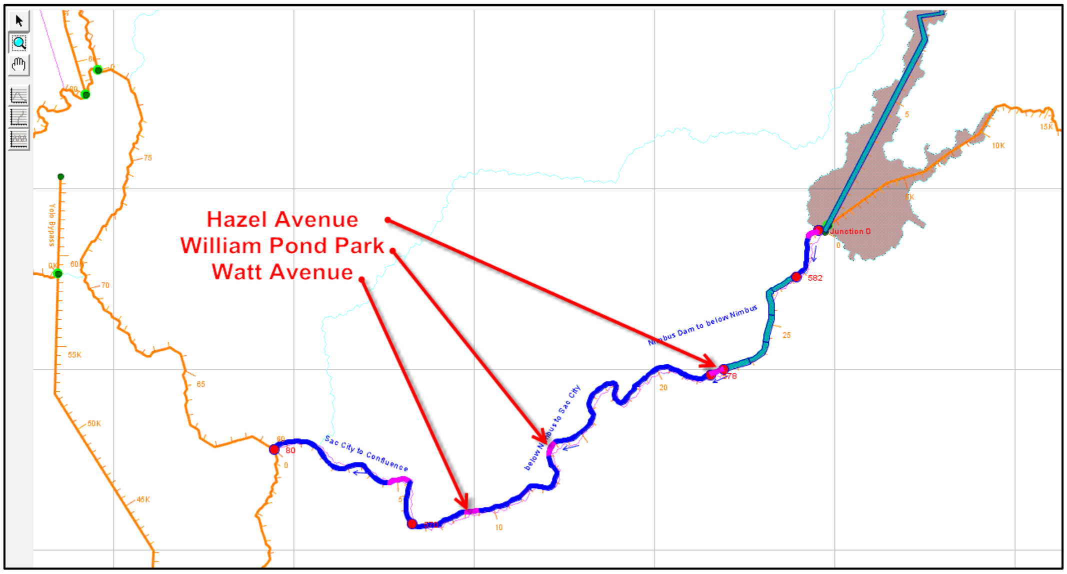


Figure 6B.C.43 Schematic of the American River HEC-5Q Model

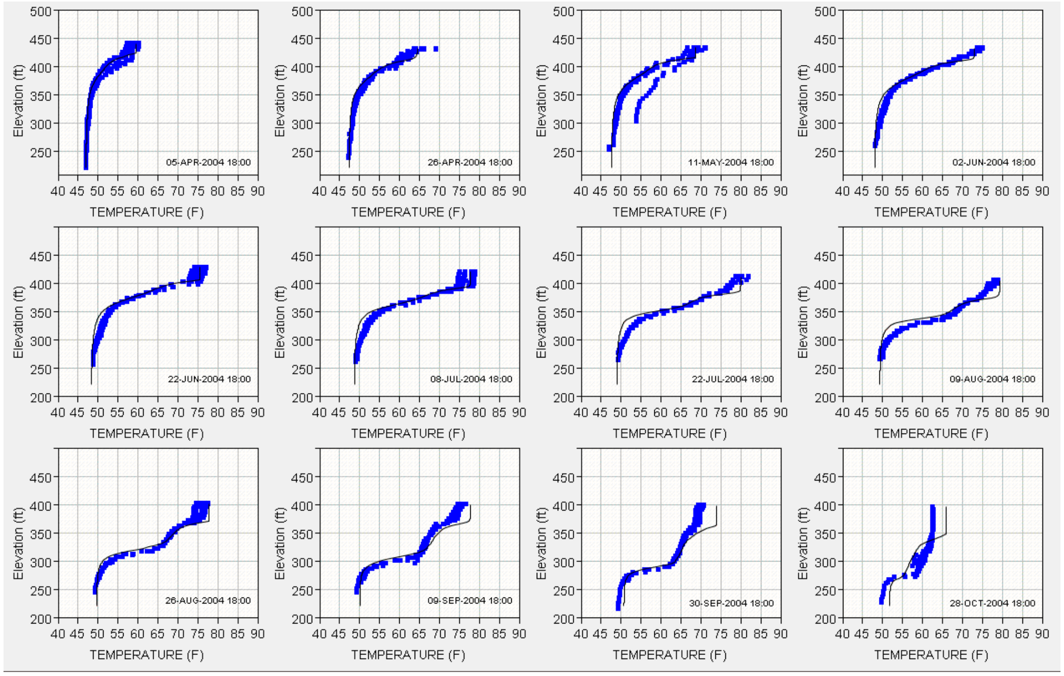


Figure 6B.C.44 Folsom Lake Observed (blue dots) and Computed (black line) Temperature Profiles Resulting from the American River Validation

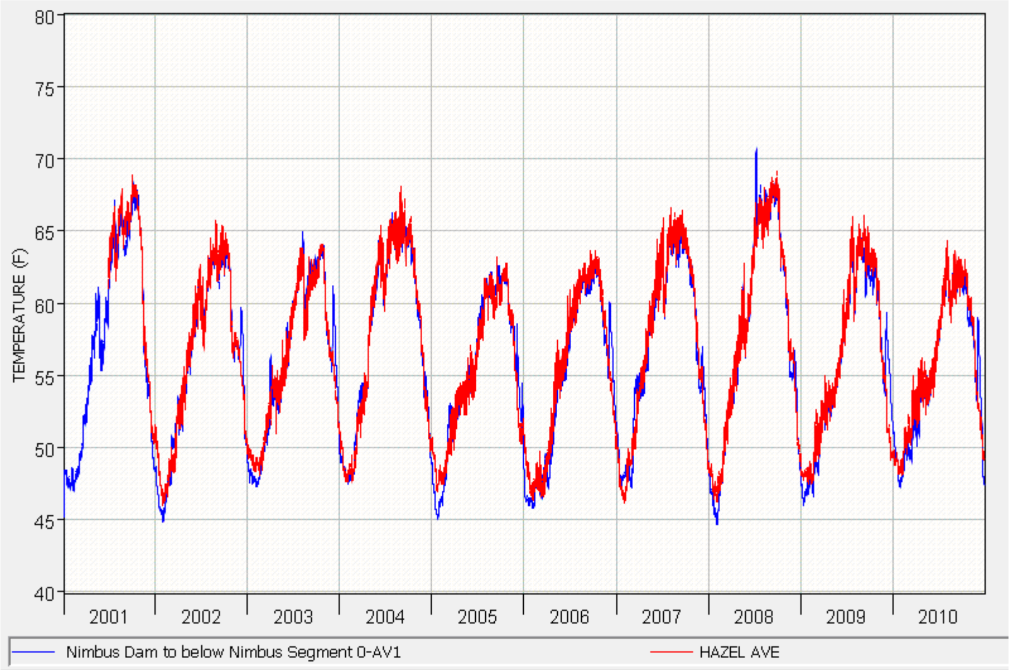


Figure 6B.C.45 American River below Nimbus Dam Observed (red) and Computed (blue) Temperature Time Series Resulting from the American River Validation

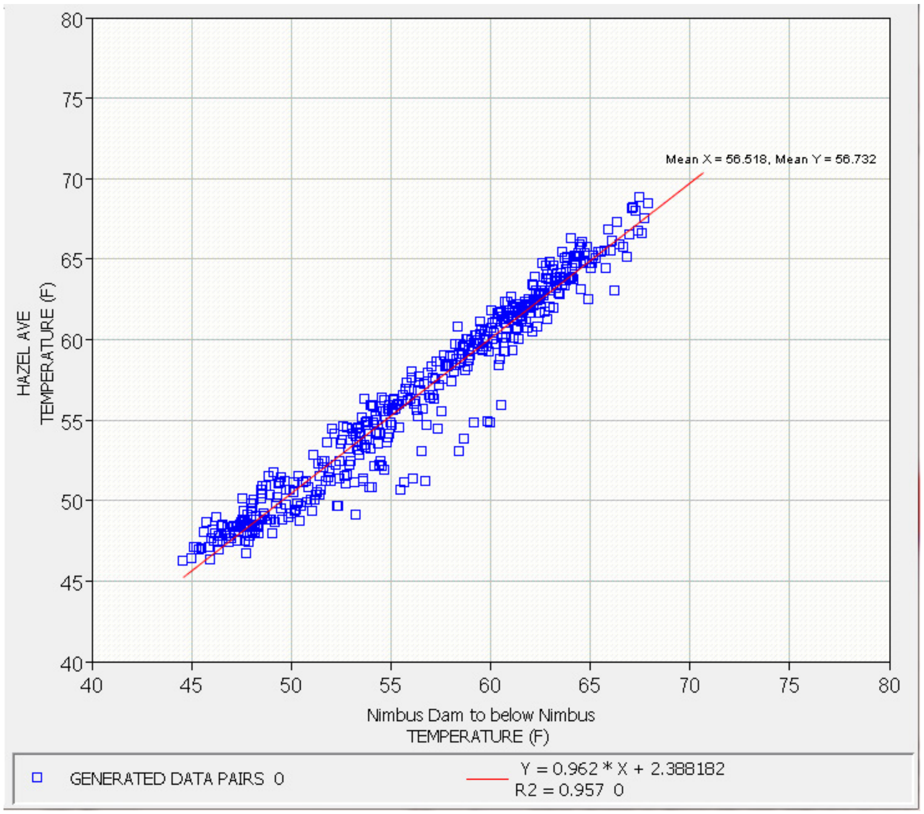


Figure 6B.C.46 American River below Nimbus Dam Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the American River Validation

Table 6B.C.19 American River below Nimbus Dam Computed and Observed Statistical Comparison

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Jan	1108	47.54	48.53	-1.00	1.40	1.14
Feb	1016	47.71	48.21	-0.49	0.83	0.68
Mar	1116	51.03	50.71	0.32	1.29	1.05
Apr	1064	53.07	53.57	-0.50	0.96	0.78
May	1093	55.83	56.12	-0.29	0.90	0.69
Jun	1075	58.56	58.67	-0.11	0.84	0.66
Jul	1199	61.91	61.88	0.04	0.93	0.72
Aug	1192	63.08	63.08	0.00	0.89	0.68
Sep	1164	63.26	63.68	-0.42	0.99	0.82
Oct	1240	62.82	63.26	-0.44	0.66	0.56
Nov	1200	57.69	58.27	-0.58	1.05	0.88
Dec	1236	53.28	52.39	0.89	2.00	1.56
Jan-Mar	3240	48.79	49.18	-0.39	1.20	0.97
Apr-Jun	3232	55.83	56.13	-0.30	0.90	0.71
Jul-Sep	3555	62.75	62.87	-0.12	0.94	0.74
Oct-Dec	3676	57.94	57.97	-0.04	1.36	1.00
Average Year	13703	56.53	56.73	-0.20	1.12	0.86

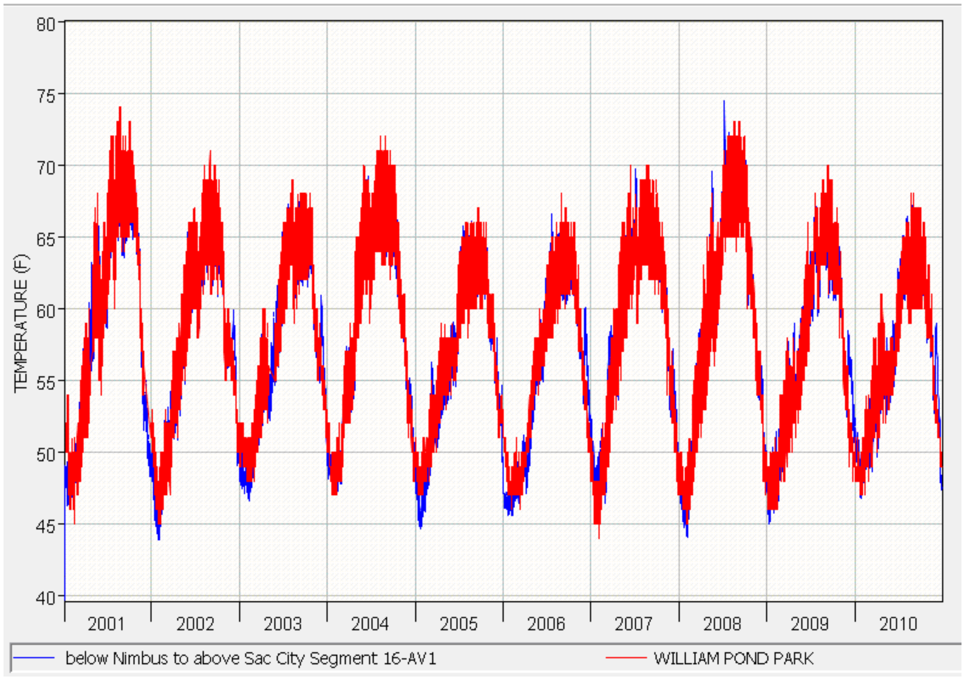


Figure 6B.C.47 American River at William Pond Park Observed (red) and Computed (blue) Temperature Time Series Resulting from the American River Validation

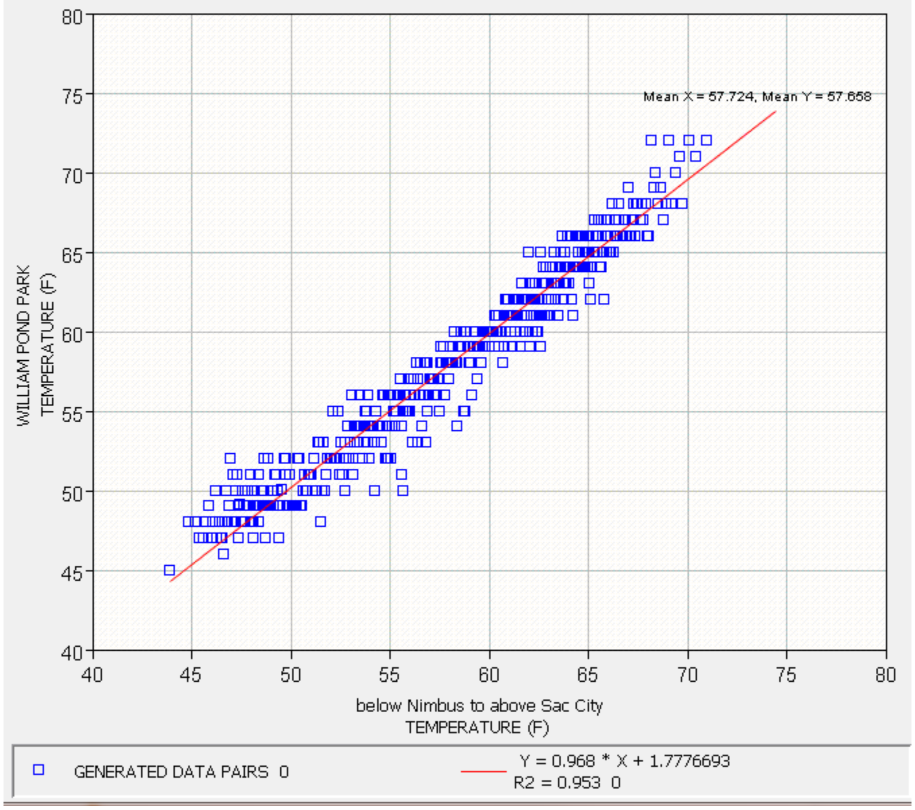


Figure 6B.C.48 American River at William Pond Park Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the American River Validation

Table 6B.C.20 American River at William Pond Park Computed and Observed Statistical Comparison

Period	Values	Computed (ºF)	Observed (ºF)	Bias (ºF)	RMS Differences (ºF)	Mean Differences (ºF)
Jan	1198	47.78	48.68	-0.91	1.63	1.29
Feb	1121	48.51	48.75	-0.23	1.05	0.85
Mar	1219	52.35	51.80	0.54	1.39	1.12
Apr	1157	54.59	54.83	-0.24	1.16	0.92
May	1131	58.36	58.25	0.12	1.13	0.89
Jun	1196	60.62	60.27	0.34	1.07	0.84
Jul	1236	63.93	63.38	0.55	1.14	0.88
Aug	1232	65.15	64.94	0.22	1.09	0.86
Sep	1200	64.79	65.18	-0.39	1.17	0.93
Oct	1240	63.24	63.76	-0.52	0.98	0.78
Nov	1200	57.70	58.26	-0.56	1.13	0.90
Dec	1113	53.24	52.24	0.99	1.84	1.43
Jan-Mar	3538	49.58	49.78	-0.19	1.38	1.09
Apr-Jun	3484	57.88	57.81	0.08	1.12	0.88
Jul-Sep	3668	64.63	64.49	0.13	1.13	0.89
Oct-Dec	3553	58.24	58.30	-0.06	1.35	1.02
Average Year	14243	57.65	57.66	-0.01	1.25	0.97

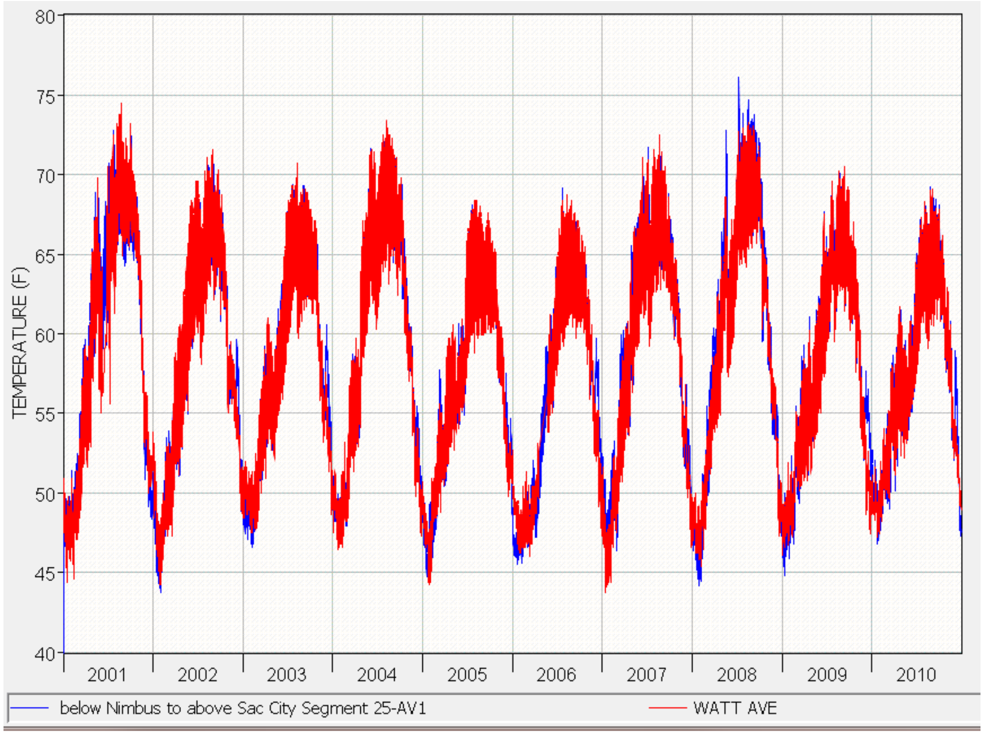


Figure 6B.C.49 American River at Watt Avenue Observed (red) and Computed (blue) Temperature Time Series Resulting from the American River Validation

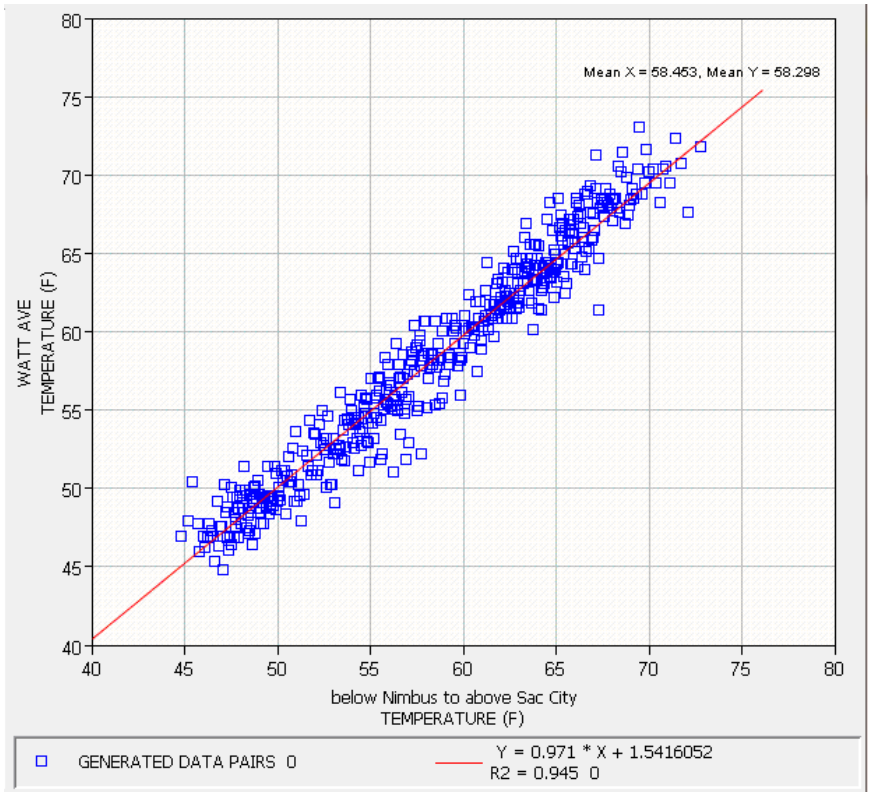


Figure 6B.C.50 American River at Watt Avenue Observed (Y-Axis) and Computed (X-axis) Temperature Data Pairs Resulting from the American River Validation

Table 6B.C.21 American River at Watt Avenue Computed and Observed Statistical Comparison

Period	Values	Computed (°F)	Observed (°F)	Bias (°F)	RMS Differences (°F)	Mean Differences (°F)
Jan	1223	47.91	48.48	-0.57	1.45	1.09
Feb	1128	49.14	49.11	0.02	1.02	0.83
Mar	1224	53.40	52.77	0.63	1.44	1.17
Apr	1153	55.98	55.99	0.00	1.26	1.02
May	1151	59.88	59.52	0.36	1.37	1.08
Jun	1200	62.20	61.43	0.77	1.89	1.35
Jul	1240	65.51	64.67	0.84	1.75	1.25
Aug	1236	66.64	66.42	0.22	1.40	1.16
Sep	1196	65.96	66.32	-0.36	1.38	1.14
Oct	1240	63.58	64.03	-0.46	1.01	0.84
Nov	1188	57.72	58.06	-0.35	1.05	0.83
Dec	1232	52.76	51.95	0.81	1.91	1.57
Jan-Mar	3575	50.18	50.15	0.02	1.33	1.04
Apr-Jun	3504	59.39	59.01	0.38	1.54	1.15
Jul-Sep	3672	66.04	65.80	0.24	1.52	1.18
Oct-Dec	3660	58.04	58.03	0.01	1.39	1.08
Average Year	14411	58.46	58.29	0.16	1.45	1.11

6B.C.10 Trinity River Outlet Diagrams

Diagrams that were used to simulate the Trinity Dam selective withdrawal procedure and the associated updates to the Trinity Dam outlets in the Trinity-Sacramento HEC-5Q model are presented in this section. Figure 6B.C.51 shows a schematic of the Trinity Dam outlets. Figure 6B.C.52 shows outlet capacity curves for the different Trinity Dam outlets. Figure 6B.C.53 shows the operational and flow vs. head (0 feet head at 1,900 feet lake elevation) characteristics of the Trinity Dam retrofitted turbine.

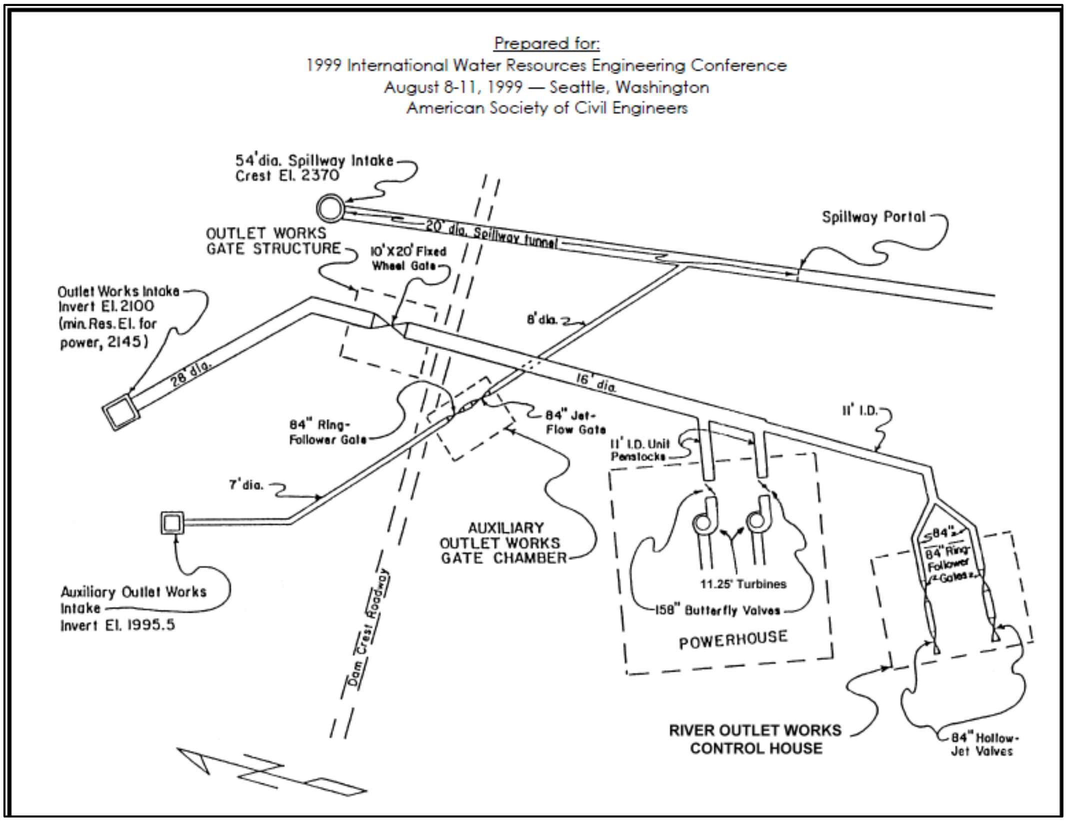


Figure 6B.C.51 Schematic of Trinity Dam Outlets (Wahl and Cohen 1999)

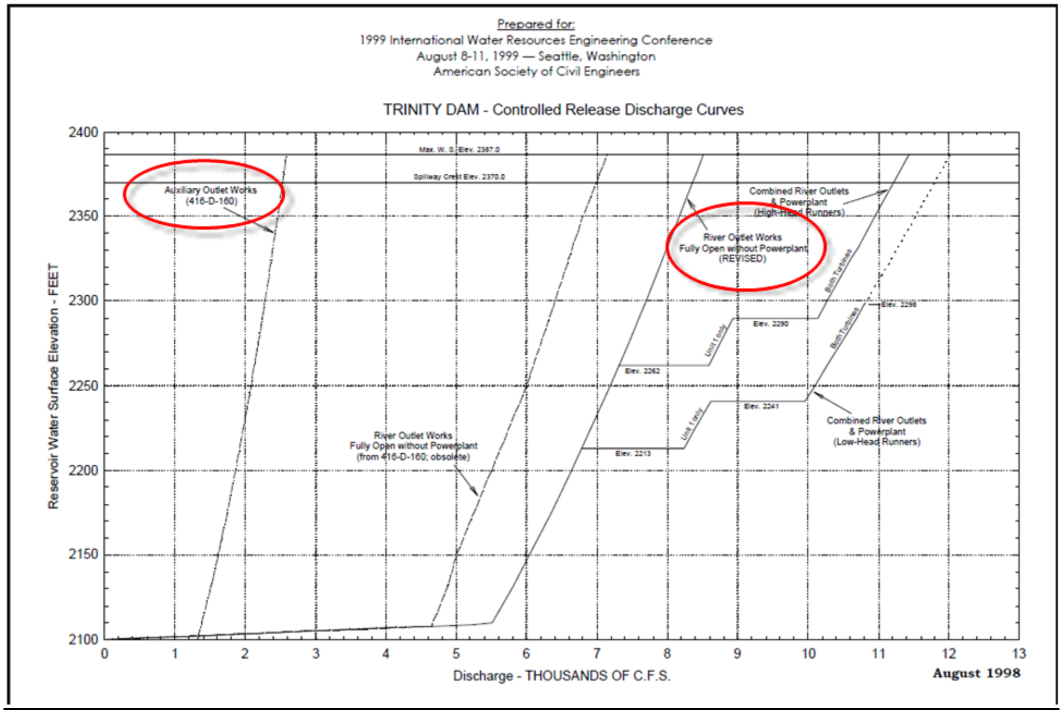


Figure 6B.C.52 Outlet Capacity Curves for Trinity Dam Outlets (Wahl and Cohen 1999)

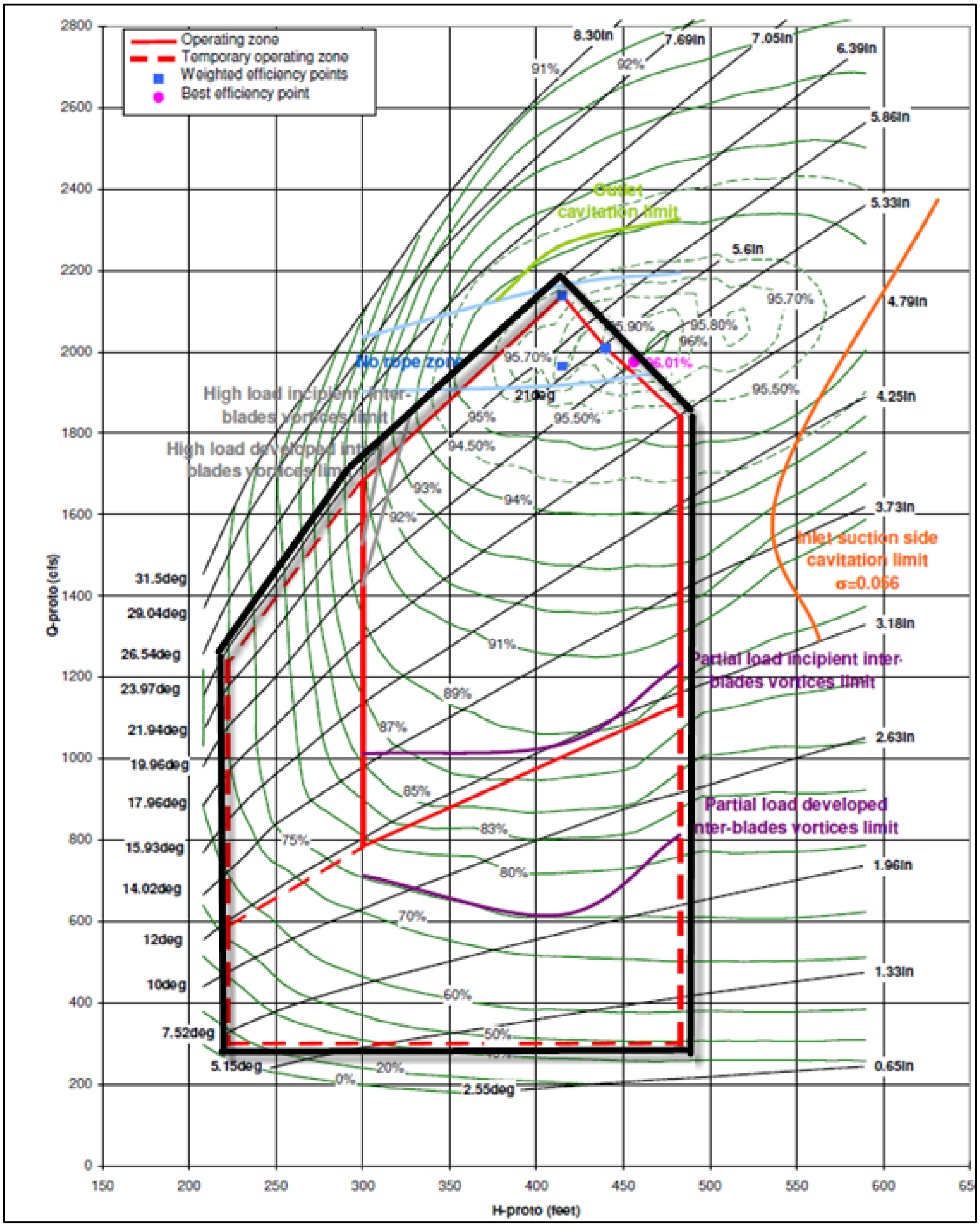


Figure 6B.C.53 Operational and Flow Compared to Total Head (with 0 feet head at 1,900 feet lake elevation) Characteristics of the Trinity Dam Retrofitted Turbine

6B.C.11 Shasta Release Temperature Target Schedules Spreadsheet Development

An approach to setting Shasta Dam release temperature target schedules in accordance with the 2009 NMFS BO, current management of the temperature target locations, and the spreadsheet tool SacR_Temp_Sel_Tool_rev05_FULL_FINAL_3-3-15.xlsm are presented in this section.

6B.C.11.1 Background

The SWRCB Water Rights Order 90-05 and NMFS BO include water temperature criteria in Sacramento River downstream of Shasta Dam. The NMFS BO Reasonable and Prudent Alternative (RPA) I.2.1 sets forth temperature compliance percentages for the summer season at specified locations on the Sacramento River (Table 6B.C.22) for not exceeding 56^{0}F at the specified location. These compliance percentages do not apply during extended drought periods.

Table 6B.C.22 Compliance Percentage for Not Exceeding 56^{0}F at Select Locations on the Sacramento River in the NMFS BO

Location	Compliance Percentage in NMFS BO (based on 10-year moving average)
Clear Creek	95 percent of Time
Balls Ferry	85 percent of Time
Jelly's Ferry	40 percent of Time
Bend Bridge	15 percent of Time

Shasta Lake releases are operated to not exceed 56^{0}F at the compliance locations, to the extent possible. The Sacramento River Temperature Task Group (SRTTG) meets once a month from April to October to discuss temperature compliance actions, as described in Appendix 3A.

Historically, initial compliance locations have been correlated to End-of-April storage, as summarized in Table 6B.C.23.

Table 6B.C.23 Compliance Location Based Upon End-of-April Storage

Compliance Location	End-of-April Storage (TAF)
Clear Creek	<3600
Balls Ferry	3600 – 4000
Jelly's Ferry	4000 – 4400
Bend Bridge	>4400

Figure 6B.C.54 shows the temperature compliance from 1996 to 2014 based on monthly Sacramento River Temperature Reports (Reclamation 2015). Shasta

Dam releases were operated under SWRCB Water Rights Order 90-05 during this entire time period. Operations under the NMFS BO were initiated in 2009.

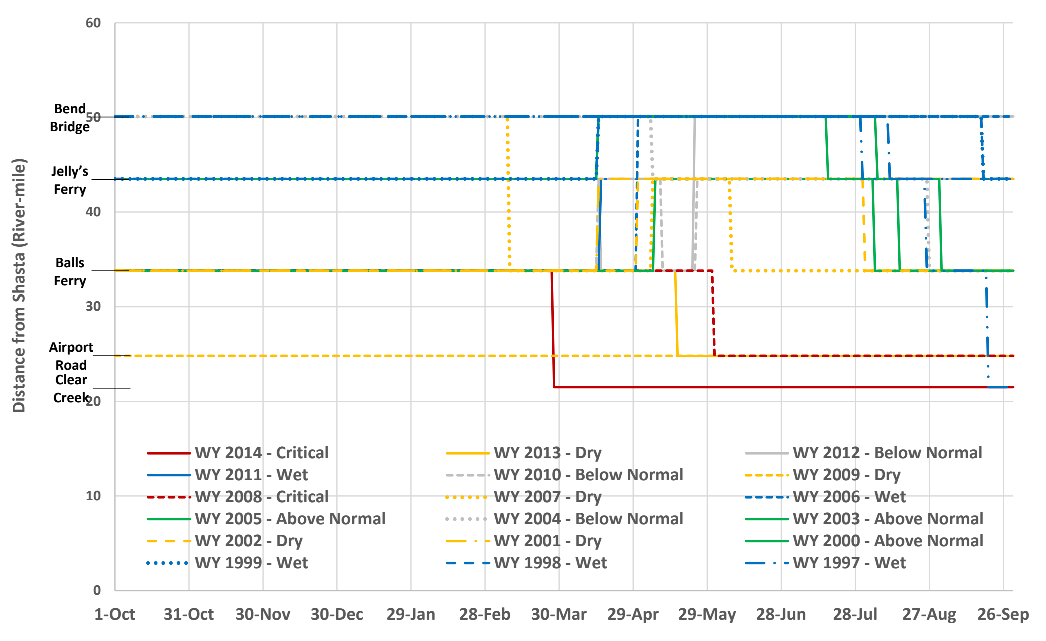


Figure 6B.C.54 Temperature Compliance Locations from 1996 through 2014

As shown in Figure 6B.C.54, the compliance location often changed multiple times in a year as Shasta storage, meteorology, tributary, and fisheries conditions changed through the year. No specific procedure could be identified for when locations were changed. In some years, such as 2007, the location would start further downstream (Bend Bridge), then move upstream (Balls Ferry), then move downstream (Jelly's Ferry), and then back upstream (Balls Ferry). In other years (e.g., 2004), the location would progressively move upstream.

Two general trends were identified. First, the compliance locations tended to be at Balls Ferry, Airport Road, and/or Clear Creek in dryer years (when Shasta Lake storage was low with less cold-water), and at Jelly's Ferry and Bend Bridge in wetter years. Second, the compliance location tended to move closer to Shasta Dam later in the year (as the cold-water pool became more depleted and meteorological conditions became warmer). These two trends, combined with the general operations used by Reclamation to set the initial annual compliance location, were used to help develop the temperature scheduling logic described below.

6B.C.11.2 Temperature Target Spreadsheet Development

This section describes the development of the Sacramento River Temperature Targeting Spreadsheet SacR_Temp_Sel_Tool_rev05_FULL_FINAL_3-3-15.xlsm.

Shasta storage data from the CalSim II EIS No Action Alternative Q5 run dated January 27, 2015 was loaded into the spreadsheet. This storage data set the compliance location for each year of the CalSim II simulation period and the data remain unchanged throughout the temperature schedule development. April storage was chosen as the parameter from which to choose the compliance location because it was specified as the indicator of cold-water pool storage in the NMFS BO. April storage was divided into five tiers, each tier representing a different compliance location based on Reclamation's rule-of-thumb approach for Shasta End-of-April storage shown in Table 6B.C.23. (Note that the storage tier for compliance with Jelly's Ferry is at 4,425 TAF in this procedure instead of 4,400 TAF.)

The four compliance locations (see Table 6B.C.22) were given an annual temperature schedule of monthly Shasta release temperature targets. These targets were developed using the following logic.

- **Step 1:** For each month individually, the difference between the modeled temperature at the compliance location and the modeled temperature below Shasta Dam was calculated for each year.
- **Step 2:** The difference value calculated in Step 1 that represented a specified exceedance for each month was then calculated for all compliance locations. This helped characterize the warming that occurred between Shasta release temperatures and each compliance location. For example, September at Bend Bridge was given a 5 percent exceedance. This exceedance says that only 5 percent of years had a September temperature difference higher than this difference value (e.g. 11.2^{0}F). In other words, warming that occurred between Shasta and Bend Bridge in September for the previous model run was 11.2^{0}F or lower for 95 percent of years.
- **Step 3:** The value calculated in Step 2 was then subtracted from 56^{0}F and this became the Shasta release temperature target for that compliance location in that month. This step assumes that the Shasta release temperature target will meet 56^{0}F or lower at the compliance location for the exceedance percentage number of years. For example, a Shasta release temperature target of 44.8^{0}F in September will meet 56^{0}F or lower at Bend Bridge for 95 percent of years.

The Sacramento River HEC-5Q model was run, using the January 13, 2015 version delivered to Reclamation and the CalSim II data described in previously, and the temperature output was loaded into the spreadsheet. The compliance performance was checked by calculating the percentage of years, over the 81-year simulation period, each compliance location exceeded 56^{0}F for each month and the difference between that percentage and the compliance percentage listed in Table 6B.C.22. Then, using an initial set of exceedance percentages (described in Step 2) and the latest Sacramento River HEC-5Q model code (March 3, 2015) to set the new temperature schedules, the Sacramento River HEC-5Q model was re-run and the temperature output reloaded in the spreadsheet. An iterative process was then performed where the exceedance percentages were adjusted, the Sacramento River HEC-5Q model was re-run and the temperature output was reloaded, and the compliance performance was checked until the compliance performance was deemed satisfactory. The final exceedance percentages (June to December) are listed in Table 6B.C.24.

Table 6B.C.24 Exceedance Percentages for June through December at the Four Temperature Compliance Locations

	June	July	August	September	October	November	December
Clear Creek	75.00	50.00	15.00	5.00	25.00	40.00	50.00
Balls Ferry	75.00	50.00	15.00	5.00	25.00	40.00	50.00
Jelly’s Ferry	75.00	50.00	15.00	5.00	25.00	40.00	50.00
Bend Bridge	75.00	50.00	15.00	5.00	25.00	40.00	50.00

January through May were not given exceedance percentages as temperature management during those months is generally not an issue. Instead, January, February, and March were given a constant temperature target of 60.8^{0}F, which is the average temperature above the thermocline in Lake Shasta. Shasta Lake generally does not stratify during those months so the temperature at the top of the thermocline is assumed to be consistent through the entire depth of Shasta Lake (Rettig and Bortleson 1983). April and May were given a constant temperature of 53.6^{0}F, which is the average temperature below the thermocline in Shasta Lake. Stratification starts to occur in April and May and it is assumed that there is enough storage in Shasta Lake to conserve the cold-water pool. The final Shasta release temperature targets used in the spreadsheet for each compliance location are shown in Table 6B.C.25.

Table 6B.C.25 Final Shasta Lake Release Temperature Targets Used in the Temperature Targeting Spreadsheet

Location	Shasta Storage (TAF)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
None	<2000	60.8	60.8	60.8	53.6	53.6	52.6	52.6	51.8	50.8	54.6	56.0	56.2
Clear Creek	<3600	60.8	60.8	60.8	53.6	53.6	52.6	52.6	51.8	50.8	54.6	56.0	56.2
Balls Ferry	<4000	60.8	60.8	60.8	53.6	53.6	51.2	51.5	50.4	49.3	54.1	56.3	56.9
Jelly’s Ferry	<4425	60.8	60.8	60.8	53.6	53.6	49.6	50.1	48.7	47.7	53.6	56.7	57.6
Bend Bridge	<9999	60.8	60.8	60.8	53.6	53.6	48.5	49.0	47.4	46.6	53.4	56.9	58.1

This modeling approach does not dynamically change the compliance location that in reality changes throughout the year based on the SRTTG recommendations. While the temperature release targets would not change using for the year with this modeling logic, the logic recognizes that those temperature release targets will not be possible to meet in each year due to changes in Shasta Lake storage and meteorological conditions. If modeled Shasta Lake releases are lower than the temperature target, then it could be considered that the compliance location was moved downstream. In addition, if Shasta Lake releases are higher than the temperature target, then it could be considered that the compliance location was moved upstream.

As an example, the End-of-April Storage from the CalSim II run in Year 1940 is 4,140 TAF. The compliance location is therefore set to be Jelly's Ferry and the temperature schedule in Table 6B.C.25 is for Jelly's Ferry. Using those temperature targets, the HEC-5Q model run produces Shasta Lake outflow temperatures that do not meet those temperature targets and thus result in temperatures that do not meet 56^{0}F at Jelly's Ferry, due to Shasta Lake storage and downstream meteorological conditions. For instance, in July the Shasta Lake outflow was 48.6^{0}F, even though the release target was 50.1^{0}F. This is because Shasta Lake storage was still relatively high to preserve more cold water in the reservoir pool and meteorological conditions were cooler than were typical for July. Thus the release temperature was cooler than the temperature target and as a result, 56^{0}F was met at Bend Bridge. In September, Shasta Lake outflow was 53.7^{0}F, even though the temperature target was 47.7^{0}F. This is because meteorological conditions were warmer than were typical for September. Thus the release temperature was warmer than the temperature target and as result, 56^{0}F could only be met at Clear Creek. A full illustration of modeled Year 1940 and the compliance location changes based on Shasta release temperatures are presented on Figure 6B.C.55.

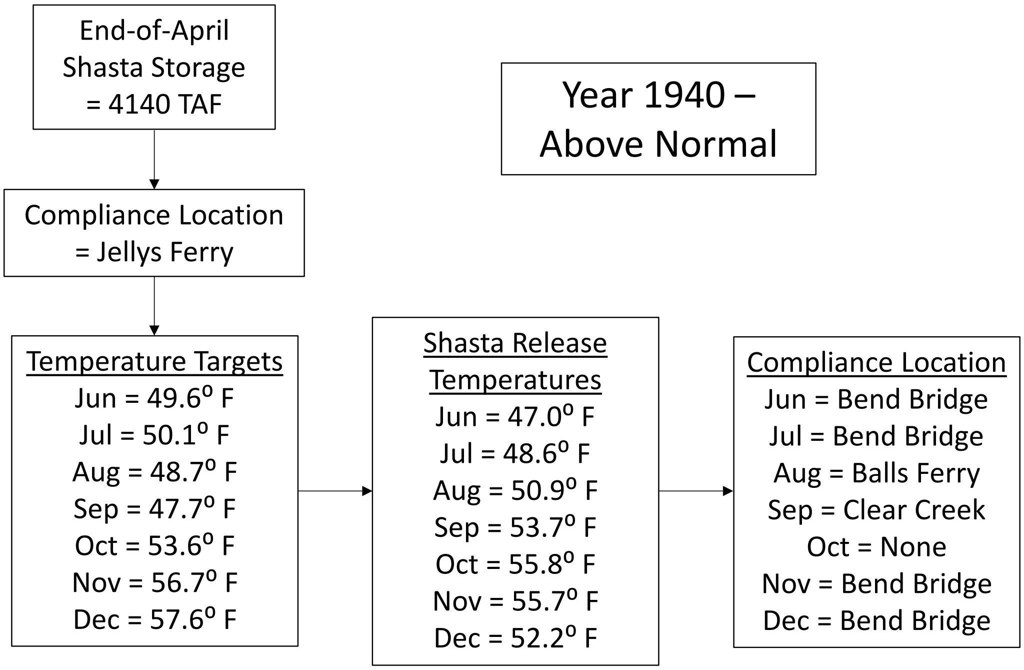
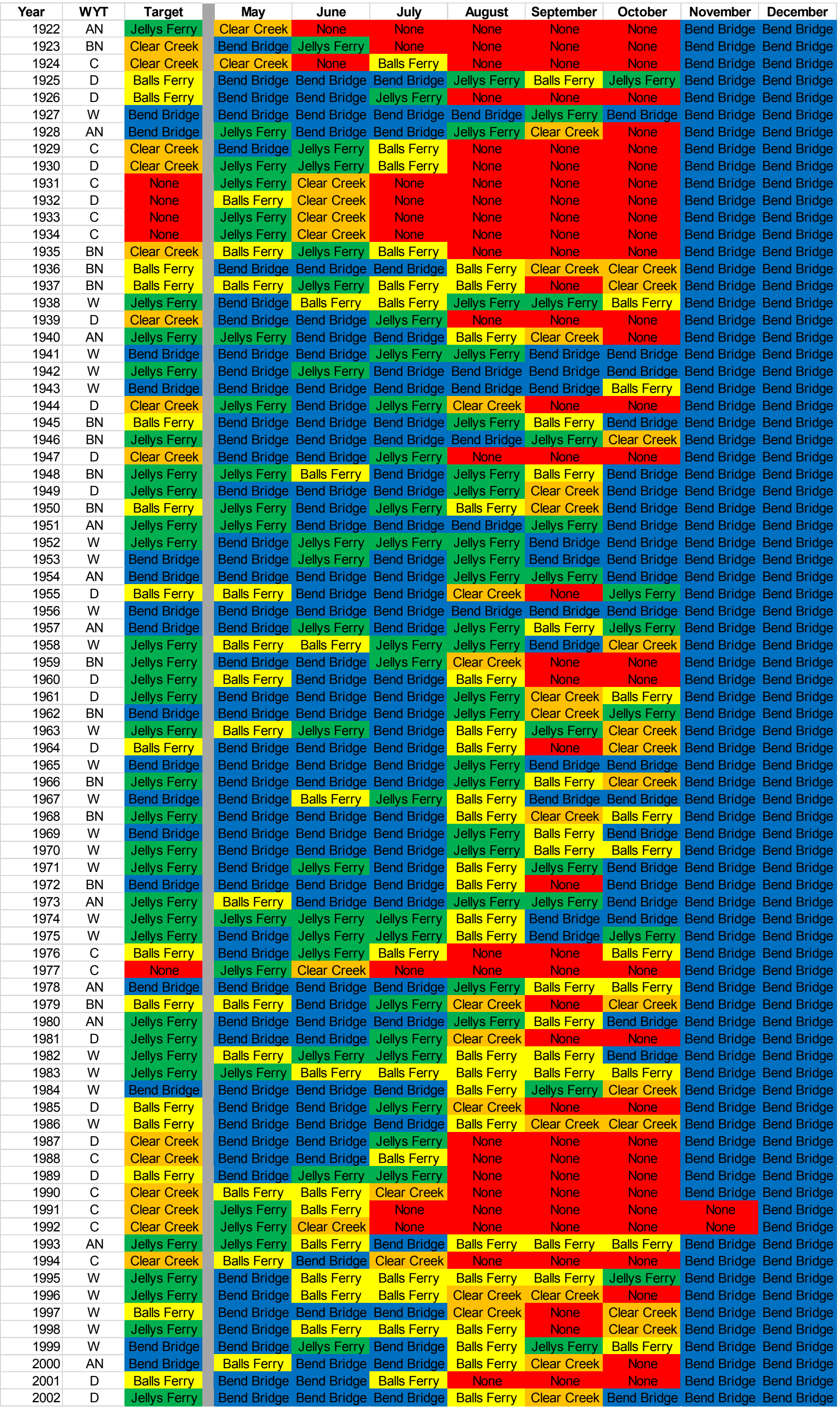


Figure 6B.C.55 Changes in Compliance Location Based on Shasta Lake Release Temperatures for Year 1940

While during all months the temperature target was set based on a compliance location of Jelly's Ferry, the actual compliance location changed. Thus the model passively mimics the SRTTG changing the compliance location based on Shasta Lake storage conditions and downstream meteorological conditions.

The chosen compliance location based on End-of-April storage and the actual compliance location achieved over the 81-year simulation period are shown on Figure 6B.C.56.



Year	WYT	Target	May	June	July	August	September	October	November	December
1922	AN	Jellys Ferry	Clear Creek	None	None	None	None	None	Bend Bridge	Bend Bridge
1923	BN	Clear Creek	Bend Bridge	Jellys Ferry	None	None	None	None	Bend Bridge	Bend Bridge
1924	C	Clear Creek	Clear Creek	None	Balls Ferry	None	None	None	Bend Bridge	Bend Bridge
1925	D	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Balls Ferry	Jellys Ferry	Bend Bridge	Bend Bridge
1926	D	Balls Ferry	Bend Bridge	Bend Bridge	Jellys Ferry	None	None	None	Bend Bridge	Bend Bridge
1927	W	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1928	AN	Bend Bridge	Jellys Ferry	Bend Bridge	Bend Bridge	Jellys Ferry	Clear Creek	None	Bend Bridge	Bend Bridge
1929	C	Clear Creek	Bend Bridge	Jellys Ferry	Balls Ferry	None	None	None	Bend Bridge	Bend Bridge
1930	D	Clear Creek	Jellys Ferry	Jellys Ferry	Balls Ferry	None	None	None	Bend Bridge	Bend Bridge
1931	C	None	Jellys Ferry	Clear Creek	None	None	None	None	Bend Bridge	Bend Bridge
1932	D	None	Balls Ferry	Clear Creek	None	None	None	None	Bend Bridge	Bend Bridge
1933	C	None	Jellys Ferry	Clear Creek	None	None	None	None	Bend Bridge	Bend Bridge
1934	C	None	Jellys Ferry	Clear Creek	None	None	None	None	Bend Bridge	Bend Bridge
1935	BN	Clear Creek	Balls Ferry	Jellys Ferry	Balls Ferry	None	None	None	Bend Bridge	Bend Bridge
1936	BN	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Balls Ferry	Clear Creek	Clear Creek	Bend Bridge	Bend Bridge
1937	BN	Balls Ferry	Balls Ferry	Jellys Ferry	Balls Ferry	Balls Ferry	None	Clear Creek	Bend Bridge	Bend Bridge
1938	W	Jellys Ferry	Bend Bridge	Balls Ferry	Balls Ferry	Jellys Ferry	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge
1939	D	Clear Creek	Bend Bridge	Bend Bridge	Jellys Ferry	None	None	None	Bend Bridge	Bend Bridge
1940	AN	Jellys Ferry	Jellys Ferry	Bend Bridge	Bend Bridge	Balls Ferry	Clear Creek	None	Bend Bridge	Bend Bridge
1941	W	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge
1942	W	Jellys Ferry	Bend Bridge	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge
1943	W	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Balls Ferry	Bend Bridge	Bend Bridge
1944	D	Clear Creek	Jellys Ferry	Bend Bridge	Jellys Ferry	Clear Creek	None	None	Bend Bridge	Bend Bridge
1945	BN	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1946	BN	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Clear Creek	Bend Bridge	Bend Bridge
1947	D	Clear Creek	Bend Bridge	Bend Bridge	Jellys Ferry	None	None	None	Bend Bridge	Bend Bridge
1948	BN	Jellys Ferry	Jellys Ferry	Balls Ferry	Bend Bridge	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1949	D	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Clear Creek	Bend Bridge	Bend Bridge	Bend Bridge
1950	BN	Balls Ferry	Jellys Ferry	Bend Bridge	Jellys Ferry	Balls Ferry	Clear Creek	Bend Bridge	Bend Bridge	Bend Bridge
1951	AN	Jellys Ferry	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1952	W	Jellys Ferry	Bend Bridge	Jellys Ferry	Jellys Ferry	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge
1953	W	Bend Bridge	Bend Bridge	Jellys Ferry	Bend Bridge	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge
1954	AN	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1955	D	Balls Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Clear Creek	None	Jellys Ferry	Bend Bridge	Bend Bridge
1956	W	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge
1957	AN	Bend Bridge	Bend Bridge	Jellys Ferry	Bend Bridge	Jellys Ferry	Balls Ferry	Jellys Ferry	Bend Bridge	Bend Bridge
1958	W	Jellys Ferry	Balls Ferry	Balls Ferry	Jellys Ferry	Jellys Ferry	Bend Bridge	Clear Creek	Bend Bridge	Bend Bridge
1959	BN	Jellys Ferry	Bend Bridge	Bend Bridge	Jellys Ferry	Clear Creek	None	None	Bend Bridge	Bend Bridge
1960	D	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Balls Ferry	None	None	Bend Bridge	Bend Bridge
1961	D	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Clear Creek	Balls Ferry	Bend Bridge	Bend Bridge
1962	BN	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Clear Creek	Jellys Ferry	Bend Bridge	Bend Bridge
1963	W	Jellys Ferry	Balls Ferry	Jellys Ferry	Bend Bridge	Balls Ferry	Jellys Ferry	Clear Creek	Bend Bridge	Bend Bridge
1964	D	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Balls Ferry	None	Clear Creek	Bend Bridge	Bend Bridge
1965	W	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge
1966	BN	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Balls Ferry	Clear Creek	Bend Bridge	Bend Bridge
1967	W	Bend Bridge	Bend Bridge	Balls Ferry	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge
1968	BN	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Balls Ferry	Clear Creek	Balls Ferry	Bend Bridge	Bend Bridge
1969	W	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1970	W	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Balls Ferry	Balls Ferry	Bend Bridge	Bend Bridge
1971	W	Jellys Ferry	Bend Bridge	Jellys Ferry	Bend Bridge	Balls Ferry	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1972	BN	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Balls Ferry	None	Bend Bridge	Bend Bridge	Bend Bridge
1973	AN	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Jellys Ferry	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1974	W	Jellys Ferry	Jellys Ferry	Jellys Ferry	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge
1975	W	Jellys Ferry	Bend Bridge	Jellys Ferry	Jellys Ferry	Balls Ferry	Bend Bridge	Jellys Ferry	Bend Bridge	Bend Bridge
1976	C	Balls Ferry	Bend Bridge	Jellys Ferry	Balls Ferry	None	None	Balls Ferry	Bend Bridge	Bend Bridge
1977	C	None	Jellys Ferry	Clear Creek	None	None	None	None	Bend Bridge	Bend Bridge
1978	AN	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Balls Ferry	Balls Ferry	Bend Bridge	Bend Bridge
1979	BN	Balls Ferry	Balls Ferry	Bend Bridge	Jellys Ferry	Clear Creek	None	Clear Creek	Bend Bridge	Bend Bridge
1980	AN	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1981	D	Jellys Ferry	Bend Bridge	Bend Bridge	Jellys Ferry	Clear Creek	None	None	Bend Bridge	Bend Bridge
1982	W	Jellys Ferry	Balls Ferry	Jellys Ferry	Jellys Ferry	Balls Ferry	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge
1983	W	Jellys Ferry	Jellys Ferry	Balls Ferry	Balls Ferry	Balls Ferry	Balls Ferry	Balls Ferry	Bend Bridge	Bend Bridge
1984	W	Bend Bridge	Bend Bridge	Bend Bridge	Bend Bridge	Balls Ferry	Jellys Ferry	Clear Creek	Bend Bridge	Bend Bridge
1985	D	Balls Ferry	Bend Bridge	Bend Bridge	Jellys Ferry	Clear Creek	None	None	Bend Bridge	Bend Bridge
1986	W	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Balls Ferry	Clear Creek	Clear Creek	Bend Bridge	Bend Bridge
1987	D	Clear Creek	Bend Bridge	Bend Bridge	Jellys Ferry	None	None	None	Bend Bridge	Bend Bridge
1988	C	Clear Creek	Bend Bridge	Bend Bridge	Balls Ferry	None	None	None	Bend Bridge	Bend Bridge
1989	D	Balls Ferry	Bend Bridge	Jellys Ferry	Jellys Ferry	None	None	None	Bend Bridge	Bend Bridge
1990	C	Clear Creek	Balls Ferry	Balls Ferry	Clear Creek	None	None	None	Bend Bridge	Bend Bridge
1991	C	Clear Creek	Jellys Ferry	Balls Ferry	None	None	None	None	None	Bend Bridge
1992	C	Clear Creek	Jellys Ferry	Clear Creek	None	None	None	None	None	Bend Bridge
1993	AN	Jellys Ferry	Jellys Ferry	Balls Ferry	Bend Bridge	Balls Ferry	Balls Ferry	Balls Ferry	Bend Bridge	Bend Bridge
1994	C	Clear Creek	Balls Ferry	Bend Bridge	Clear Creek	None	None	None	Bend Bridge	Bend Bridge
1995	W	Jellys Ferry	Bend Bridge	Balls Ferry	Balls Ferry	Balls Ferry	Balls Ferry	Jellys Ferry	Bend Bridge	Bend Bridge
1996	W	Jellys Ferry	Bend Bridge	Balls Ferry	Balls Ferry	Clear Creek	Clear Creek	None	Bend Bridge	Bend Bridge
1997	W	Balls Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Clear Creek	None	Clear Creek	Bend Bridge	Bend Bridge
1998	W	Jellys Ferry	Bend Bridge	Balls Ferry	Balls Ferry	Balls Ferry	None	Clear Creek	Bend Bridge	Bend Bridge
1999	W	Bend Bridge	Bend Bridge	Jellys Ferry	Bend Bridge	Balls Ferry	Jellys Ferry	Balls Ferry	Bend Bridge	Bend Bridge
2000	AN	Bend Bridge	Balls Ferry	Bend Bridge	Bend Bridge	Balls Ferry	Clear Creek	None	Bend Bridge	Bend Bridge
2001	D	Balls Ferry	Bend Bridge	Bend Bridge	Balls Ferry	None	None	None	Bend Bridge	Bend Bridge
2002	D	Jellys Ferry	Bend Bridge	Bend Bridge	Bend Bridge	Balls Ferry	Clear Creek	Bend Bridge	Bend Bridge	Bend Bridge

Figure 6B.C.56 Simulated Compliance Location Target and Achievement for Each Year over the 81-Year CalSim II Period

6B.C.11.3 Temperature Compliance Performance

As shown in Table 6B.C.26, the compliance location achieved during each month for each year over the 81-year simulation period mimics the general trends described previously. During dry periods (e.g., 1985 to 1992), the compliance location generally starts out at the upstream locations Clear Creek and Balls Ferry. Over the course of each year, the compliance location moves progressively upstream.

Table 6B.C.26 shows the percentage of years the HEC-5Q model (using the CalSim II data described earlier and the temperature targets shown in Table 6B.C.25) met 56^{0}F at each compliance location and the years short of meeting the compliance percentage.

Table 6B.C.26 Compliance Performance of the Final Temperature Targets

Location and Percentage of Years Required for Compliance	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	Percentage of Years 56^{0}F Was Met at Each Compliance Location (N=81 Years)						
Clear Creek (95 percent of years)	98	89	72	57	62	91	100
Balls Ferry (85 percent of years)	90	86	62	42	47	93	100
Jelly's Ferry (40 percent of years)	75	69	33	26	33	91	98
Bend Bridge (15 percent of years)	54	47	7	14	26	95	98
	Number of Years Short of Compliance						
Clear Creek (95 percent of years)	-	5	19	31	27	3	-
Balls Ferry (85 percent of years)	-	-	19	35	31	-	-
Jelly's Ferry (40 percent of years)	-	-	5	11	5	-	-
Bend Bridge (15 percent of years)	-	-	6	1	-	-	-

6B.C.12 Folsom Release Temperature Target Schedules Spreadsheet Development

An approach to setting Folsom Dam release temperature target schedules for temperature management on the Lower American River based on NMFS BO and is an accompanying document to the spreadsheet tool AmerR_Temp_Sel_Tool_rev15_FULL_FINAL_3-16-15.xlsm is presented in this section.

6B.C.12.1 Background

The NMFS BO RPA II.2 sets forth a temperature requirement for the Lower American River at the Watt Avenue Bridge to not exceed 65^0F from May 15 to October 31.

In order to meet the NMFS BO temperature requirement, Reclamation manages Folsom Dam release temperatures based on temperature schedules set forth in Appendix 2-D of the NMFS BO. These schedules set monthly temperatures at Watt Avenue for Folsom Dam to operate to from May to October (temperature management season) based on forecasted Folsom storage and inflow. The initial temperature schedule for each year is determined based on an operations plan developed by Reclamation and approved by the American River Operations Group (ARG). However, these schedules are based on forecasted conditions. As conditions actually happen throughout the temperature management season, due to changes in Folsom Lake storage and inflow, current meteorological conditions, and/or the state of fisheries in the river, the Watt Avenue temperature target schedule is adjusted based on recommendations from the ARG.

It was possible to model the initial annual temperature target schedule for Folsom Lake to operate to for the year because storage and forecasted inflow are known quantities in CalSim II. However, modeling the dynamic adjustment of the Watt Avenue temperature target based on current storage and meteorological conditions was not going to be possible. Thus logic was developed to create a temperature target selection procedure that set a specific schedule for each year that remained unchanged. This logic is described in the following section.

6B.C.12.2 Temperature Target Spreadsheet Development

The development of the Sacramento River Temperature Targeting Spreadsheet AmerR_Temp_Sel_Tool_rev15_FULL_FINAL_3-16-15.xlsm is described in this section.

Folsom storage and inflow data from the CalSim II EIS No Action Alternative Q5 run dated January 27, 2015 was loaded into the spreadsheet. This CalSim II data remained unchanged throughout the temperature schedule development. May Folsom Storage plus June to September average inflow to Folsom (storage plus inflow) was calculated in the spreadsheet. This was a simplification of the forecasting approach that is used to set the actual temperature targets, as it only took into account June through September inflow.

Appendix 2-D of the NMFS BO lists 72 different temperature target schedules for May through October. Each schedule changed the temperature target for one month only. It was deemed unnecessary to incorporate all 72 schedules due to the simplified forecasting approach described above that only focused on June to September inflow. This reduced the 72 schedules to schedules that focused primarily on temperature management during June through September. Ultimately the 72 schedules were reduced to 22 schedules as these schedules were deemed to adequately represent the variance in temperature targets during June through September.

Then, using an initial set of storage plus inflow tiers assigned to each temperature schedule number, the schedule number for each year of the CalSim II period of record was calculated. Then the average storage plus inflow for each tier was calculated. For example, there were 8 years over the simulation period that had a schedule number of 11 and the average storage plus inflow was 1,415 TAF. The average storage plus inflow calculated for each tier was plotted versus the schedule number, as shown in Figure 6B.C.57.

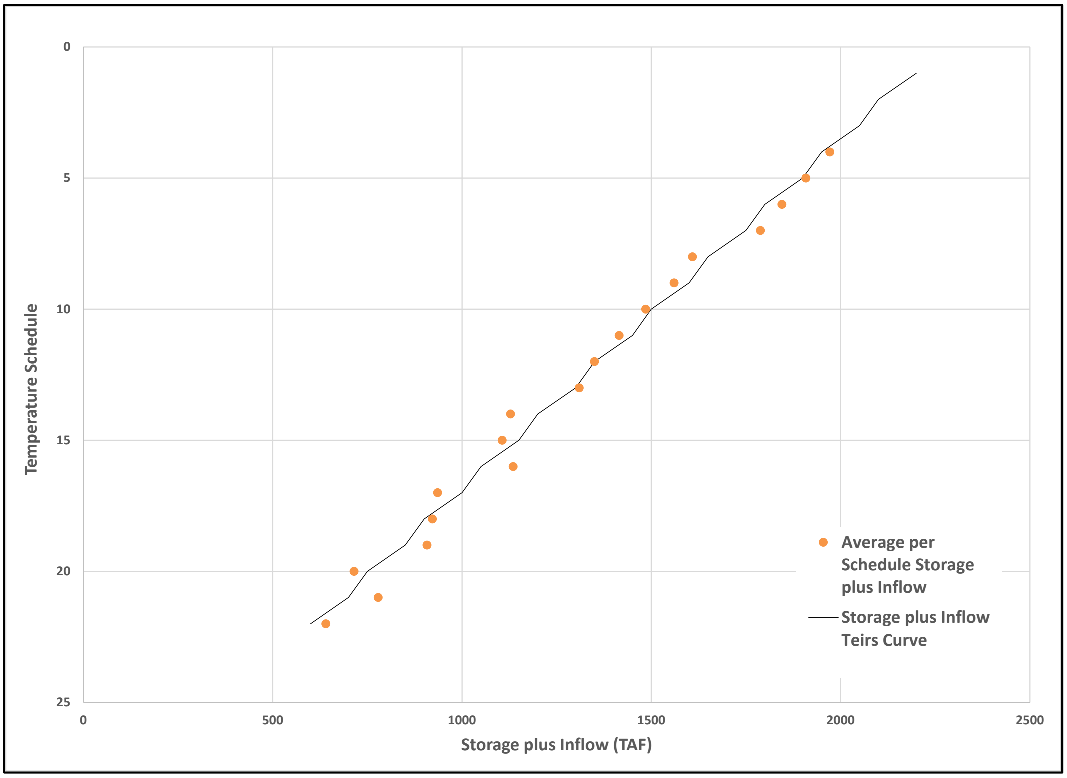


Figure 6B.C.57 Temperature Schedule Number and Average Folsom Lake Storage plus June-September Inflow for each Schedule Number

The schedule shown in the plot was used to calculate the final storage plus inflow tiers used in the spreadsheet.

Using the regression equation shown in Figure 6B.C.57, the final storage plus inflow tiers to be used for the spreadsheet were calculated (see Table 6B.C.27).

Table 6B.C.27 Final Watt Avenue Temperature Target Schedules (Yellow highlighted cells indicate a change from the previous schedule)

Schedule	Storage plus June-Sept. Inflow	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	56	56	56	63	61	61	62	62	61	57	56	56
2	600	56	56	56	63	62	62	62	62	62	58	56	56
3	700	56	56	56	63	62	62	63	63	62	59	57	56
4	750	56	56	56	63	63	63	63	63	63	60	57	56
5	850	56	56	56	63	63	63	64	64	63	60	58	56
6	900	56	56	56	63	64	64	64	64	64	60	58	56
7	1000	56	56	56	63	64	64	65	65	64	60	58	56
8	1050	56	56	56	63	65	65	65	65	65	60	58	56
9	1150	56	56	56	63	65	65	66	66	65	65	59	56
10	1200	56	56	56	63	66	66	66	66	66	65	59	56
11	1300	56	56	56	63	66	66	67	67	66	65	59	56
12	1350	56	56	56	63	67	67	67	67	67	65	59	56
13	1450	56	56	56	63	67	67	68	68	67	65	59	56
14	1500	56	56	56	63	68	68	68	68	68	65	59	56
15	1600	56	56	56	63	68	68	69	69	68	68	59	56
16	1650	56	56	56	63	69	69	69	69	69	68	59	56
17	1750	56	56	56	63	69	69	70	70	69	69	60	56
18	1800	56	56	56	63	70	70	70	70	70	69	60	56
19	1900	56	56	56	63	70	70	71	71	70	70	61	56
20	1950	56	56	56	63	71	71	71	71	71	70	61	56
21	2050	56	56	56	63	71	71	72	72	71	71	62	56
22	2100	56	56	56	63	72	72	72	72	72	71	62	56

January, February, March and December were given temperature targets of 56^0F for all temperature schedules as a default. During these months, temperature management is generally not an issue. April was given a temperature target of 63^0F to conserve cold water in the reservoir pool at the start of the temperature management season.

Establishing the temperature target schedule sets the temperature targets at Watt Avenue. However, Folsom Dam can only actually operate to release temperatures, with the goal that those release temperatures will ultimately meet the Watt Avenue temperature target after ambient warming occurs. To calculate the Folsom release temperatures, the following logic was developed.

- **Step 1:** The American River HEC-5Q Model was run using the January 13, 2015 version delivered to Reclamation, the CalSim II data described previously, and an initial Watt Avenue and Folsom Dam temperature target schedules. The temperature output from that HEC-5Q model run was loaded into the spreadsheet.

- **Step 2:** For each month individually, the difference (shift) between the modeled temperature at Watt Avenue and the modeled temperature below Folsom Dam was calculated for each year.
- **Step 3:** The annual shift calculated in Step 2 that represented a specified exceedance for each month was then calculated. This helped characterize the warming that occurred between Folsom release temperatures and Watt Avenue. For example, September was given a 50 percent exceedance. This exceedance says that 50 percent years had a September temperature shift higher than this shift value (e.g., 0.6^0F). Therefore, warming that occurred between Folsom Dam and Watt Avenue in September for the previous model run was 0.6^0F or lower for 95 percent of years.
- **Step 4:** The exceedance shift value calculated in step iii was then divided by the average annual June to September shift value. This calculated a shift factor that was used in the final temperature shift calculations.
- **Step 5:** The average June to September shift value for each schedule number was then calculated. For example, schedule number 11 was the schedule for eight years over the simulation period and the average June to September shift was 4.6^0F.
- **Step 6:** The average June to September shift value calculated in Step v was plotted versus its temperature schedule number, as shown in Figure 6B.C.58.
- **Step 7:** Average June to September shifts for each schedule number were then calculated using the regression equation in Figure 6B.C.58.
- **Step 8:** The shift values calculated in step vii were then multiplied by the shift factor calculated in step vii and was subtracted from the temperature target value in Table 6B.C.27. This created the Folsom Dam release temperature target schedules.
- **Step 9:** An iterative process where the Folsom Dam temperature target schedules developed using the initial temperature target schedules described in step 1 were then used in the next HEC5Q model run and then reloaded into the spreadsheet. The process was repeated until the Folsom Dam release temperature target schedules were deemed acceptable based on modeled temperature results. The final Folsom Dam release temperature target schedules are shown in Table 6B.C.28.

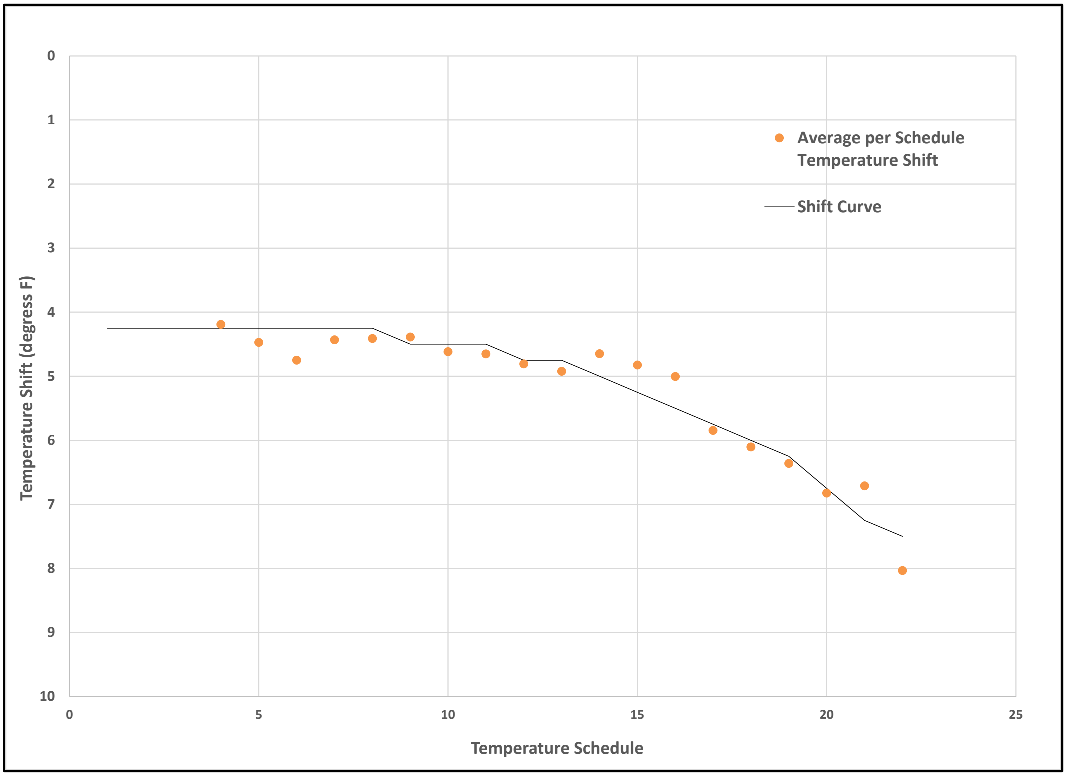


Figure 6B.C.58 Average Temperature Shift between Modeled Folsom Lake Release Temperatures and Watt Avenue Temperatures for each Schedule Number after Multiple Iterations

The shift curve shown in the plot was used to calculate the final temperature shifts used in the spreadsheet.

Table 6B.C.28 Final Folsom Dam Lake Release Temperature Targets in the Spreadsheet (Yellow highlighted cells indicate a change from the previous schedule)

Schedule	Storage plus Jun-Sep Inflow	Jan	Feb	Mar	Apr	Shift Factors							
						0.7	0.8	0.8	1.2	0.6	0.4	0.2	0
						May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	52	52	52	59	66.8	66.0	66.0	63.0	67.5	68.0	60.5	56
2	600	52	52	52	59	66.8	66.0	66.0	63.0	67.5	68.0	60.5	56
3	700	52	52	52	59	65.9	65.2	66.2	63.3	66.7	68.1	60.6	56
4	750	52	52	52	59	66.3	65.6	65.6	62.9	67.0	67.3	59.7	56
5	850	52	52	52	59	65.6	65.0	66.0	63.5	66.3	67.5	59.8	56
6	900	52	52	52	59	65.8	65.2	65.2	62.8	66.4	66.6	58.8	56
7	1000	52	52	52	59	65.0	64.4	65.4	63.1	65.6	66.7	58.9	56
8	1050	52	52	52	59	65.2	64.6	64.6	62.4	65.7	65.8	57.9	56
9	1150	52	52	52	59	64.3	63.8	64.8	62.7	64.9	65.9	58.0	56
10	1200	52	52	52	59	64.5	64.0	64.0	62.0	65.0	63.0	58.0	56
11	1300	52	52	52	59	63.7	63.2	64.2	62.3	64.2	63.1	58.1	56
12	1350	52	52	52	59	63.7	63.2	63.2	61.3	64.2	63.1	58.1	56

Schedule	Storage plus Jun-Sep Inflow	Jan	Feb	Mar	Apr	Shift Factors							
						0.7	0.8	0.8	1.2	0.6	0.4	0.2	0
						May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
13	1450	52	52	52	59	62.9	62.4	63.4	61.6	63.3	63.2	58.1	56
14	1500	52	52	52	59	62.9	62.4	62.4	60.6	63.3	63.2	58.1	56
15	1600	52	52	52	59	61.9	61.4	62.4	60.6	62.3	63.2	58.1	56
16	1650	52	52	52	59	62.0	61.6	61.6	59.9	62.5	58.3	57.2	56
17	1750	52	52	52	59	61.0	60.6	61.6	59.9	61.5	58.3	57.2	56
18	1800	52	52	52	59	61.0	60.6	60.6	58.9	61.5	58.3	57.2	56
19	1900	52	52	52	59	60.0	59.6	60.6	58.9	60.5	58.3	57.2	56
20	1950	52	52	52	59	60.0	59.6	59.6	57.9	60.5	58.3	56.2	56
21	2050	52	52	52	59	59.0	58.6	59.6	57.9	59.5	57.3	56.2	56
22	2100	52	52	52	59	59.0	58.6	58.6	56.9	59.5	56.3	55.2	56

January through April were not given shift factors and instead were given a constant 4^0F shift as a default for the same reason described for those months for the Watt Avenue temperature target schedules.

6B.C.12.3 Temperature Performance

Figure 6B.C.59 shows box and whisker plots of modeled temperatures at Watt Avenue in the completed spreadsheet.

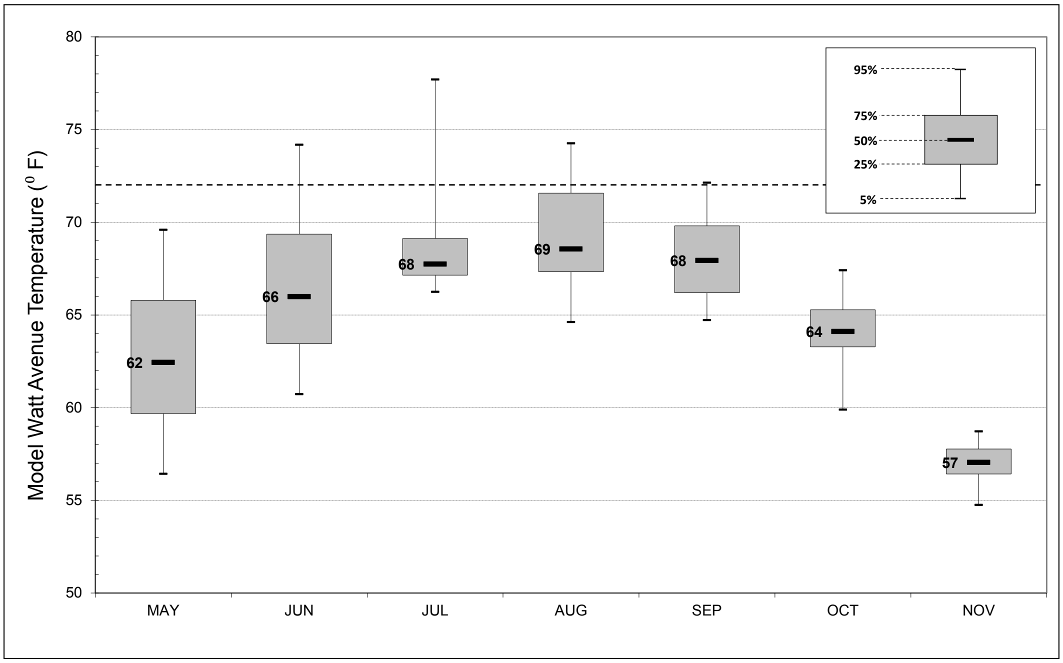


Figure 6B.C.59 Modeled Watt Avenue temperatures in Final Spreadsheet

The figure shows the expected pattern where temperatures are higher in the summer but the Watt Avenue target temperature for each month were met in majority of the years. The maximum temperature target (72^0F) was not exceeded in approximately 75 percent of years for all months. The years where the temperatures exceeded the maximum 72^{0}F target were during dry periods, when meeting the Watt Avenue temperature targets are not possible to meet due to low storage in Folsom Lake.

6B.C.13 References

RMA (Resource Management Associates). 2003. *Upper Sacramento River Water Quality Modeling with HEC-5Q: Model Calibration and Validation*.

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Appendix 6C

Methylmercury Model Documentation

This appendix provides information about the methods, modeling tools, and assumptions used for the Coordinated Long-term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS) analysis. It also provides information pertaining to the development of the analytical tools and the use of input data as well as model result processing and interpretation methods used for the impacts analysis and descriptions.

This appendix is organized into three main sections that are briefly described below:

- **Section 6C.1: Modeling Methodology.** The methylmercury impacts analysis used CalSim II, the Delta Simulation Model II (DSM2), and the Central Valley Regional Water Quality Control Board (Central Valley RWQCB) Total Maximum Daily Load (TMDL) model (RWQCB Model) to assess and quantify effects of the alternatives on the long-term operations of the CVP and SWP and on the environment. This section provides information about the overall analytical framework and how some of the model input information obtained from other models was processed through the use of analytical tools.
- **Section 6C.2: Modeling Simulations and Assumptions.** This section provides a brief description of the assumptions for the RWQCB Model simulations of the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.
- **Section 6C.3: Modeling Results.** This section provides a description of the model simulation output formats used in the analysis and interpretation of modeling results for the alternatives impacts assessment.

6C.1 Modeling Methodology

This section summarizes the methylmercury modeling methodology used for the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5. It describes the overall analytical framework and contains descriptions of the key analytical and numerical tools and approaches used in the quantitative evaluation of the alternatives. The alternatives include several major components that will have significant effects on SWP and CVP operations and minor effects on the water quality of the system.

6C.1.1 Overview of the Modeling Approach and Objectives

Modeling of physical and biological methylmercury processes in the Delta is necessary to evaluate changes related to the implementation of alternatives that could affect the health of humans and wildlife consuming fish in the Delta. It has been recognized that fish tissue concentrations are the best indicator of mercury contamination in the Delta as described in the RWQCB Model (Central Valley RWQCB 2011). The RWQCB Model, an empirical tissue concentration model, was based on the concentration averages of fish mercury and water concentrations of methylmercury over broad areas of the Delta (Wood 2010). The RWQCB Model is used to estimate fish tissue mercury concentrations from concentrations of dissolved methylmercury in water.

CalSim II, DSM2 (water), and the RWQCB Model (fish tissue) were used in sequence to estimate the effects of CVP and SWP operations on water and fish tissue quality in the Delta. CalSim II simulates flow in the waterways, and DSM2 simulates one-dimensional hydrodynamics in the Delta, as discussed in Chapter 5, Surface Water Resources and Water Supplies. One of the three DSM2 modules, QUAL, simulates one-dimensional source tracking in the Delta. Results from DSM2 proportioned by source area were multiplied by average source concentrations and added to determine annual average aqueous methylmercury concentrations in the Delta for all year types and dry years for specific model nodes. The RWQCB Model is based on a power curve that uses the DSM2 output to simulate aqueous methylmercury concentrations to estimate total mercury concentrations in the fish fillets of standard 350-mm-long Largemouth Bass.

Figure 6C.1 shows the modeling tools applied in the methylmercury impacts assessment and the relationship between these tools. Each model included in Figure 6C.1 provides information to the next “downstream” model in order to provide various results to support the impacts analysis.

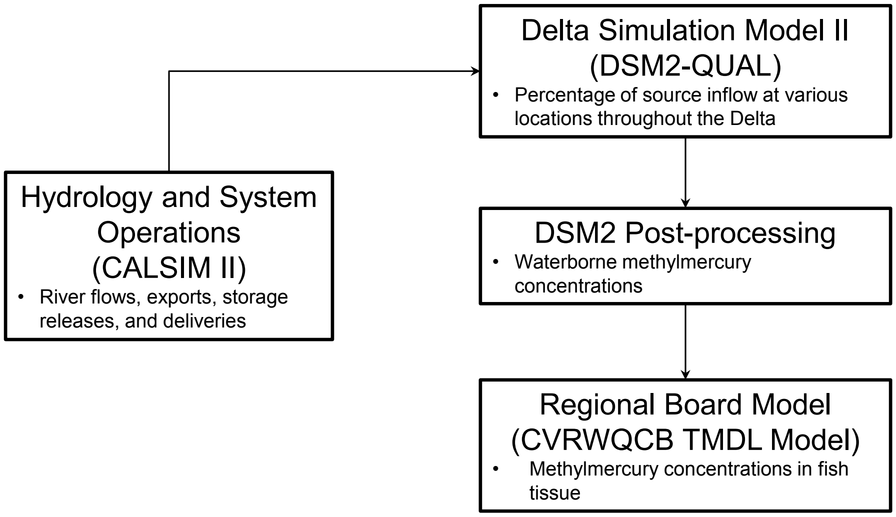

Figure 6C.1. Relationships among the Different Predictive Modeling Tools

6C.1.1.1 Modeling Objectives

Impacts on methylmercury resources in the Delta SWP and CVP Service Areas were evaluated for each alternative as part of the EIS development. Modeling objectives included the evaluation of the following:

- Percent changes in fish tissue mercury concentrations
- Exceedances of human and fish and wildlife thresholds

6C.1.2 Key Components of the Methylmercury Modeling

A calibrated regional flow model was used to provide a regional framework to be used for modeling of waterborne methylmercury concentrations. An additional model was used to translate waterborne methylmercury concentrations to total mercury concentrations in fish tissue.

6C.1.2.1 DSM2 Postprocessing

Dissolved methylmercury data were available for six inflow locations to the Delta (Table 6C.1):

- Sacramento River at Freeport (mainstem flow to Delta)
- San Joaquin River at Vernalis (mainstem flow to Delta)
- Mokelumne and Calaveras rivers (for Eastside tributaries)
- Various Delta locations (for Delta agriculture)
- Suisun Bay (for San Francisco Bay)

Table 6C.1. Modeled Methylmercury Concentrations in Water

Location	Period*	Period Average Concentration (ng/L)			
		No Action Alternative	Alternative 1	Alternative 3	Alternative 5
Delta Interior					
San Joaquin River at Stockton	All	0.16	0.16	0.16	0.16
	Drought	0.16	0.16	0.17	0.16
Turner Cut	All	0.15	0.15	0.15	0.15
	Drought	0.14	0.14	0.14	0.14
San Joaquin River at San Andreas Landing	All	0.12	0.11	0.11	0.12
	Drought	0.11	0.11	0.11	0.11
San Joaquin River at Jersey Point	All	0.11	0.11	0.11	0.11
	Drought	0.11	0.10	0.10	0.11
Victoria Canal	All	0.14	0.14	0.14	0.14
	Drought	0.14	0.13	0.14	0.14
Western Delta					
Sacramento River at Emmaton	All	0.10	0.10	0.10	0.10
	Drought	0.10	0.10	0.10	0.10
San Joaquin River at Antioch	All	0.10	0.10	0.10	0.10
	Drought	0.09	0.09	0.09	0.10

Location	Period*	Period Average Concentration (ng/L)			
		No Action Alternative	Alternative 1	Alternative 3	Alternative 5
Montezuma Slough at Hunter Cut/ Beldon's Landing	All	0.08	0.08	0.08	0.08
	Drought	0.07	0.07	0.07	0.07
Major Diversions (Pumping Stations)					
North Bay Aqueduct at Barker Slough Pumping Plant	All	0.11	0.11	0.11	0.11
	Drought	0.11	0.11	0.11	0.11
Contra Costa Pumping Plant #1	All	0.13	0.13	0.13	0.13
	Drought	0.12	0.12	0.12	0.13
Banks Pumping Plant	All	0.14	0.13	0.13	0.14
	Drought	0.13	0.13	0.13	0.13
Jones Pumping Plant	All	0.14	0.14	0.14	0.14
	Drought	0.14	0.13	0.14	0.14

Notes:

ng/L = nanogram per liter

* “All” water years 1922-2003 represent the 82-year period modeled using DSM2; “drought” represents a 5-consecutive-year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore model results for Second Basis of Comparison and Alternative 4 are not presented separately.

Model results for Alternative 2 and No Action Alternative are the same, therefore model results for Alternative 2 are not presented separately.

For DSM2 output locations, the geometric mean methylmercury concentrations from the inflow locations were combined with the modeled daily average percent inflow for each DSM2 output location to estimate waterborne methylmercury concentrations at those locations. The annual average mix of water from the six inflow sources (Table 6C.1) was calculated from daily percent inflows provided by the DSM2-QUAL model output. The daily waterborne methylmercury concentrations at DSM2 locations were calculated using the following equation:

$$C_{water\ quarterly} = [(I_1 * C_1)+(I_2 * C_2)+ (I_3 * C_3)+ (I_4 * C_4)+ (I_5 * C_5)+ (I_6 * C_6)]/100$$

Where:

- $C_{water\ daily}$ = daily average methylmercury concentration in water (micrograms/liter [µg/L]) at a DSM2 output location
- $I_{1\text{-}6}$ = modeled daily inflow from each of the six sources of water to the Delta for each DSM2 output location (percentage)
- $C_{1\text{-}6}$ = methylmercury concentration in water (µg/L) from each of the six inflow sources to the Delta (1-6)

The annual average waterborne methylmercury concentrations for the DSM2 output locations are shown in Table 6C.1.

6C.1.2.2 Regional Board Fish Tissue Model

The RWQCB Model predicts methylmercury concentration in 350-millimeter normalized Largemouth Bass fillet tissue from methylmercury in water. The Central Valley RWQCB developed an empirical power curve model based on measured Largemouth Bass fillet concentrations as averaged over large areas of the Delta compared to average methylmercury concentrations in water for those same areas and time periods (Central Valley RWQCB 2011):

$$\text{Fish mercury (milligrams/kilogram, wet weight)} = 20.365 \times (\text{methylmercury in water, ng/L})^{1.6374}$$

$$(\text{with } r^2 = 0.910, \text{ and } P \text{ less than } 0.05)$$

The goal of the RWQCB Model was to establish the linkage between the 0.24 milligram per kilogram (mg/kg) tissue mercury TMDL target to a waterborne goal of 0.066 ng methylmercury/L. The RWQCB Model results are presented with the recognition of the imprecision of predicting fish tissue concentrations from estimates of methylmercury concentrations for specific Delta locations, but with the knowledge that Largemouth Bass are probably the best indicator of fish tissue contamination (see Section 6C.1.2.3). Results provide an estimated mean tissue concentration as would be expected by location and alternative. The model provides a Delta-specific, empirical estimate of the relationship between waterborne methylmercury and bioaccumulated fish tissue mercury.

The overall construction and calibration of the RWQCB Model were unchanged for this EIS analysis.

6C.1.2.3 Model Development

The RWQCB Model is based on unfiltered aqueous methylmercury data from March to October 2000 and Largemouth Bass fillet concentration data from September/October 2000. Largemouth Bass samples were chosen close in time and space to water collections. The paired samples, averaged over broad Delta areas, provided the framework for the nonlinear empirical model. Data were grouped by subareas of the Delta such as Sacramento River, Mokelumne River, Central Delta, San Joaquin River, and West Delta.

Largemouth Bass are excellent indicators of mercury contamination because they have a relatively high level of mercury compared to other species, are piscivorous, are abundantly distributed throughout the Delta, are popular gamefish, and have high site fidelity. Largemouth Bass are therefore representative of spatial patterns of tissue mercury concentrations throughout the aquatic food web, including exposure to humans.

The RWQCB Model was used to convert DSM2 estimated waterborne methylmercury concentrations to fish tissue mercury concentrations. The toxicity benchmark used to assess impacts of alternatives was the Central Valley RWQCB TMDL tissue concentration goal of 0.24 mg/kg wet weight (ww) of mercury for normalized 350-mm total length Largemouth Bass tissue (Central Valley RWQCB 2011).

6C.2 Modeling Simulations and Assumptions

This section describes the assumptions for the RWQCB Model simulations of the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5. Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore model results for Second Basis of Comparison and 4 are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore model results for Alternative 2 are not presented separately. A description of DSM2 model assumptions is presented in Appendix 5A.

6C.2.1 Location Assumptions

The Central Valley RWQCB developed a nonlinear model based on Largemouth Bass as grouped in large regions of the Delta (rather than specific locations) compared to average methylmercury concentrations in water for those same, general regions (Central Valley RWQCB 2011). As such, the model provides a Delta-specific, general, long-term average relationship between co-located waterborne methylmercury concentrations and total mercury concentrations in Largemouth Bass fillets.

6C.2.2 Normalization and Tissue Type Assumptions

As discussed above, Largemouth Bass are excellent indicators of long-term average mercury exposure, risk, and the spatial pattern for both ecological and human health effects. A fish tissue mercury dataset was available for Largemouth Bass from locations across the Delta. However, the Largemouth Bass tissue mercury concentrations were presented as edible fillet concentrations for fish normalized to 350 mm in total length (SFEI 2010). It is important to standardize concentrations to the same length fish for establishment of the model and for model predictions because of the well-established positive relationship between fish length and age and tissue mercury concentrations (e.g., Alpers et al. 2008). This same normalization technique was used by the Regional Board for their model (Central Valley RWQCB 2011). The 350-mm size fish is an appropriate size representative of human health consumption and risk. The standardized size allows the best comparison among locations and alternatives. The fillet concentrations predicted by the model are expected to be slightly different from whole-body fish concentrations as consumed by wildlife, but comparisons among locations and alternatives and to the Regional Board benchmark will allow an evaluation of relative impacts to fish and wildlife as well as most accurately estimating impacts to human consumers.

6C.2.3 Model Application Methodology

To evaluate differences between the No Action Alternative, Second Basis of Comparison, and other alternatives for impact assessment, modeled methylmercury concentrations were compared directly (for percent change) and to the 0.24-mg/kg wet weight tissue threshold benchmark.

Results of comparisons to these benchmarks are expressed as exceedance quotients (EQs) in some of the tables and figures. Annual average methylmercury concentrations in water did not exceed the unfiltered aqueous methylmercury goal (0.06 µg/L) or the California Toxic Rule criterion for the consumption of water at the organism (0.050 µg/L) and of the organism only (0.051 µg/L), so no EQs were calculated for waterborne concentrations.

6C.2.3.1 No Action Alternative and Second Basis of Comparison Model Runs

The overall purpose of the models is to provide a set of conditions for the No Action Alternative and the Second Basis of Comparison to be used for comparison with the forecasts of the alternatives to determine whether the implementation of the alternatives is likely to result in substantial impacts to methylmercury, thereby affecting biological resources. Modeling for the No Action Alternative and the Second Basis of Comparison was completed for five Delta interior locations, three western Delta locations, and four locations near major water diversions. DSM2 postprocessing output provided estimates of the waterborne methylmercury concentration at each of those 12 locations (Table 6C.1). The RWQCB Model was then used to estimate methylmercury tissue concentrations in 350-mm Largemouth Bass. The modeled tissue methylmercury concentrations and the EQs (based on comparisons to thresholds) both served as a basis for comparison of other alternatives to identify potential impacts.

6C.2.3.2 Alternatives 1 through 5 Model Runs

For model simulations of Alternatives 1 through 5, the same procedure as described for the No Action Alternative and the Second Basis of Comparison was used with similar assumptions.

6C.3 Modeling Results

The postprocessing tool that presents the results from the RWQCB Model is an Excel-based spreadsheet tool. The general preprocessing and input files development are described in the modeling data assumptions sections above. This section focuses on data analysis and results interpretation for the impacts descriptions.

6C.3.1 Postprocessing and Results Analysis: Delta-wide Model

Output data resulting from the RWQCB Model simulations for each alternative were processed to provide a tabular depiction of potential impacts to methylmercury resources (Tables 6C.2 – 6C.4). As discussed previously, outputs from the RWQCB Model used in this analysis are annual average fish tissue mercury concentrations for all year types and separately presented for the subset of dry years.

All annual average concentrations exceed the TMDL target goal of 0.24 mg/kg tissue mercury at all locations modeled in the Delta for all years both as measured and modeled. Results are shown in Tables 6C.2 – 6C.4 and Figures 6C.2 and 6C.3. Table 6C.1 presents the period-average waterborne methylmercury concentrations by location and water year type as used to model fish tissue concentrations (Tables 6C.2 – 6C.4).

The differences in fish tissue mercury concentrations over long-term average conditions were reduced or similar (5 percent or less) under Alternatives 1 through 5 as compared to the No Action Alternative, and under the No Action Alterantive and Alternatives 1 through 4 as compared to the Second Basis of Comparison , as shown in Tables 6C.2 – 6C.4. Fish tissue mercury concentrations over long-term average conditions are greater than 5 percent under Alternative 5 as compared to the Second Basis of Comparison in the Suisun Marsh (Montezuma Slough at Hunter Cut/Beldon’s Landing), and near Delta water intakes (San Joaquin River at Antioch, Contra Costa Pumping Plant Number 1, Banks Pumping Plant, and Jones Pumping Plant).

Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore model results for Alternative 4 are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore model results for Alternative 2 are not presented separately.

6C.3.2 Model Limitations and Applicability

Although it is impossible to predict future hydrology, land use, and water use with certainty, the RWQCB Model and DSM2 were used to forecast impacts on fish that could result from implementation of the alternatives. Mathematical models like DSM2 can only approximate processes of physical systems. Models are inherently inexact because the mathematical description of the physical system is imperfect and the understanding of interrelated physical processes is incomplete. However, the RWQCB Model is a powerful tool that, when used carefully, can provide useful insight into processes of the physical system. Methylmercury concentrations for inflow sources to the Delta (e.g., agriculture in the Delta, Yolo Bypass, Eastside Tributaries) also caused uncertainty in the modeling because of limited data. For the Sacramento River and the San Joaquin River, about 90 data points (Chapter 6, Table 6.58; Table 6D.1) were used to estimate the mean methylmercury concentrations for these inflow sources, whereas the mean methylmercury concentrations for other inflow sources to the Delta had many fewer data points, ranging from 14 to no data points (concentrations for the Eastside Tributaries were assumed).

6C.4 References

Alpers, C. N., C. Eagles-Smith, C. Foe, S. Klasing, M. C. Marvin-DiPasquale, D. G. Slotton, and L. Windham-Meyers. 2008. *Sacramento–San Joaquin Delta Regional Ecosystem Restoration Implementation Plan, Ecosystem Conceptual Model. Mercury*. January 24.

Central Valley RWQCB (Central Valley Regional Water Quality Control Board). 2011. *Sacramento–San Joaquin Delta Estuary TMDL for Methylmercury. Final EPA Approval of Basin Plan Amendment.* Oct. 20.

SFEI (San Francisco Estuary Institute). 2010. Regional Data Center. Site accessed April 13,2010. http://www.sfei.org/data

Wood, M., C. Foe, J. Cooke, and L. Stephen. 2010. *Sacramento–San Joaquin Delta Estuary TMDL for Methylmercury, Final Staff Report*. April. Prepared for California Regional Water Quality Control Board: Central Valley Region, Rancho Cordova, CA.

Table 6C.2. Summary Table for Methylmercury Concentrations in 350-mm Largemouth Bass Fillets for No Action Alternative, Second Basis of Comparison, and Alternative 1

Location	Period[a]	Estimated Concentrations of Methylmercury (mg/kg ww) No Action Alternative	Estimated Concentrations of Methylmercury (mg/kg ww) Second Basis of Comparison and Alternative 1	% Change In Methylmercury Concentrations[b] Alternative 1 compared to No Action Alternative	% Change In Methylmercury Concentrations[b] No Action Alternative compared to Second Basis of Comparison	Exceedance Quotients[c] No Action Alternative	Exceedance Quotients[c] Second Basis of Comparison and Alternative 1
Delta Interior							
San Joaquin River at Stockton	All	1.00	0.99	0	0	4.2	4.1
	Drought	1.06	1.06	0	0	4.4	4.4
Turner Cut	All	0.89	0.87	-3	3	3.7	3.6
	Drought	0.84	0.81	-4	4	3.5	3.4
San Joaquin River at San Andreas Landing	All	0.59	0.58	-3	3	2.5	2.4
	Drought	0.54	0.53	-3	3	2.3	2.2
San Joaquin River at Jersey Point	All	0.57	0.54	-4	5	2.4	2.3
	Drought	0.52	0.50	-4	4	2.2	2.1
Victoria Canal	All	0.85	0.82	-4	4	3.6	3.4
	Drought	0.82	0.76	-6	7	3.4	3.2
Western Delta							
Sacramento River at Emmaton	All	0.50	0.49	-2	2	2.1	2.0
	Drought	0.48	0.47	-2	2	2.0	2.0
San Joaquin River at Antioch	All	0.50	0.47	-6	7	2.1	2.0
	Drought	0.43	0.41	-5	5	1.8	1.7

Location	Period[a]	Estimated Concentrations of Methylmercury (mg/kg ww) No Action Alternative	Estimated Concentrations of Methylmercury (mg/kg ww) Second Basis of Comparison and Alternative 1	% Change In Methylmercury Concentrations[b] Alternative 1 compared to No Action Alternative	% Change In Methylmercury Concentrations[b] No Action Alternative compared to Second Basis of Comparison	Exceedance Quotients[c] No Action Alternative	Exceedance Quotients[c] Second Basis of Comparison and Alternative 1
Montezuma Slough at Hunter Cut/Beldon's Landing	All	0.35	0.32	-6	7	1.4	1.4
	Drought	0.28	0.26	-5	5	1.1	1.1
Major Diversions (Pumping Stations)							
North Bay Aqueduct at Barker Slough Pumping Plant	All	0.56	0.56	-1	1	2.4	2.3
	Drought	0.59	0.57	-2	2	2.4	2.4
Contra Costa Pumping Plant #1	All	0.73	0.68	-6	6	3.0	2.8
	Drought	0.67	0.62	-7	8	2.8	2.6
Banks Pumping Plant	All	0.79	0.75	-5	5	3.3	3.1
	Drought	0.75	0.69	-7	8	3.1	2.9
Jones Pumping Plant	All	0.83	0.79	-4	4	3.5	3.3
	Drought	0.82	0.77	-6	7	3.4	3.2

Notes:

mg/kg = milligram per kilogram

ww = wet weight

a. "Al": water years (1922-2003) represent the 82-year period modeled using DSM2. "Drought" Represents a 5-consecutive-year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

b. % change indicates a negative change (increased concentrations) relative to No Action Alternative or Second Basis of Comparison when values are positive and a positive change (lowered concentrations) relative to No Action Alternative or Second Basis of Comparison when values are negative.

c. Concentrations greater than 0.24 mg/kg ww mercury exceed the TMDL guidance concentration.

1 **Table 6C.3 Summary Table for Methylmercury Concentrations in 350-mm Largemouth Bass Fillets for Alternative 3**

Location	Period[a]	Estimated Concentrations of Methylmercury (mg/kg, ww) Alternative 3	% Change In Methylmercury Concentrations[b] No Action Alternative	% Change In Methylmercury Concentrations[b] Second Basis of Comparison	Exceedance Quotients[c] Alternative 3
Delta Interior					
San Joaquin River at Stockton	All	1.00	1	1	4.2
	Drought	1.07	1	1	4.5
Turner Cut	All	0.88	-2	1	3.7
	Drought	0.82	-3	1	3.4
San Joaquin River at San Andreas Landing	All	0.58	-3	0	2.4
	Drought	0.53	-2	1	2.2
San Joaquin River at Jersey Point	All	0.55	-4	1	2.3
	Drought	0.51	-2	2	2.1
Victoria Canal	All	0.83	-2	2	3.5
	Drought	0.79	-3	3	3.3
Western Delta					
Sacramento River at Emmaton	All	0.49	-2	0	2.0
	Drought	0.47	-1	0	2.0
San Joaquin River at Antioch	All	0.48	-6	1	2.0
	Drought	0.42	-3	2	1.7
Montezuma Slough at Hunter Cut/Beldon's Landing	All	0.33	-6	1	1.4
	Drought	0.27	-3	2	1.1

Location	Period[a]	Estimated Concentrations of Methylmercury (mg/kg, ww) Alternative 3	% Change In Methylmercury Concentrations[b] No Action Alternative	% Change In Methylmercury Concentrations[b] Second Basis of Comparison	Exceedance Quotients[c] Alternative 3
Major Diversions (Pumping Stations)					
North Bay Aqueduct at Barker Slough Pumping Plant	All	0.56	-1	0	2.3
	Drought	0.58	-1	2	2.4
Contra Costa Pumping Plant #1	All	0.69	-5	1	2.9
	Drought	0.64	-4	4	2.7
Banks Pumping Plant	All	0.77	-3	2	3.2
	Drought	0.72	-4	4	3.0
Jones Pumping Plant	All	0.81	-3	2	3.4
	Drought	0.80	-3	4	3.3

Notes:

mg/kg = milligram per kilogram

ww = wet weight

a. “Al”: water years (1922-2003) represent the 82-year period modeled using DSM2. “Drought” Represents a 5-consecutive-year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

b. % change indicates a negative change (increased concentrations) relative to No Action Alternative or Second Basis of Comparison when values are positive and a positive change (lowered concentrations) relative to No Action Alternative or Second Basis of Comparison when values are negative.

c. Concentrations greater than 0.24 mg/kg ww mercury exceed the TMDL guidance concentration.

Table 6C.4. Summary Table for Methylmercury Concentrations in 350-mm Largemouth Bass Fillets for No Action Alternative, Second Basis of Comparison, and Alternative 5

Location	Period[a]	Estimated Concentrations of Methylmercury (mg/kg, ww) Alternative 5	% Change In Methylmercury Concentrations[b] No Action Alternative	% Change In Methylmercury Concentrations[b] Second Basis of Comparison	Exceedance Quotients[c] Alternative 5
Delta Interior					
San Joaquin River at Stockton	All	1.00	0	0	4.1
	Drought	1.05	0	0	4.4
Turner Cut	All	0.89	0	3	3.7
	Drought	0.85	1	4	3.5
San Joaquin River at San Andreas Landing	All	0.60	1	4	2.5
	Drought	0.55	2	4	2.3
San Joaquin River at Jersey Point	All	0.57	1	5	2.4
	Drought	0.53	2	5	2.2
Victoria Canal	All	0.85	0	4	3.6
	Drought	0.82	0	7	3.4
Western Delta					
Sacramento River at Emmaton	All	0.50	0	3	2.1
	Drought	0.49	1	3	2.0
San Joaquin River at Antioch	All	0.51	1	7	2.1
	Drought	0.44	2	7	1.8
Montezuma Slough at Hunter Cut/Beldon's Landing	All	0.35	1	7	1.5
	Drought	0.28	1	7	1.2

Location	Period[a]	Estimated Concentrations of Methylmercury (mg/kg, ww) Alternative 5	% Change In Methylmercury Concentrations[b] No Action Alternative	% Change In Methylmercury Concentrations[b] Second Basis of Comparison	Exceedance Quotients[c] Alternative 5
Major Diversions (Pumping Stations)					
North Bay Aqueduct at Barker Slough Pumping Plant	All	0.56	0	1	2.4
	Drought	0.58	0	2	2.4
Contra Costa Pumping Plant #1	All	0.74	2	8	3.1
	Drought	0.70	5	13	2.9
Banks Pumping Plant	All	0.79	0	5	3.3
	Drought	0.74	-1	7	3.1
Jones Pumping Plant	All	0.83	0	5	3.5

Notes:

mg/kg = milligram per kilogram

ww = wet weight

a. “Al”: water years (1922-2003) represent the 82-year period modeled using DSM2. “Drought” Represents a 5-consecutive-year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

b. % change indicates a negative change (increased concentrations) relative to No Action Alternative or Second Basis of Comparison when values are positive and a positive change (lowered concentrations) relative to No Action Alternative or Second Basis of Comparison when values are negative. Changes of 10% or more are shaded.

c. Concentrations greater than 0.24 mg/kg ww mercury exceed the TMDL guidance concentration.

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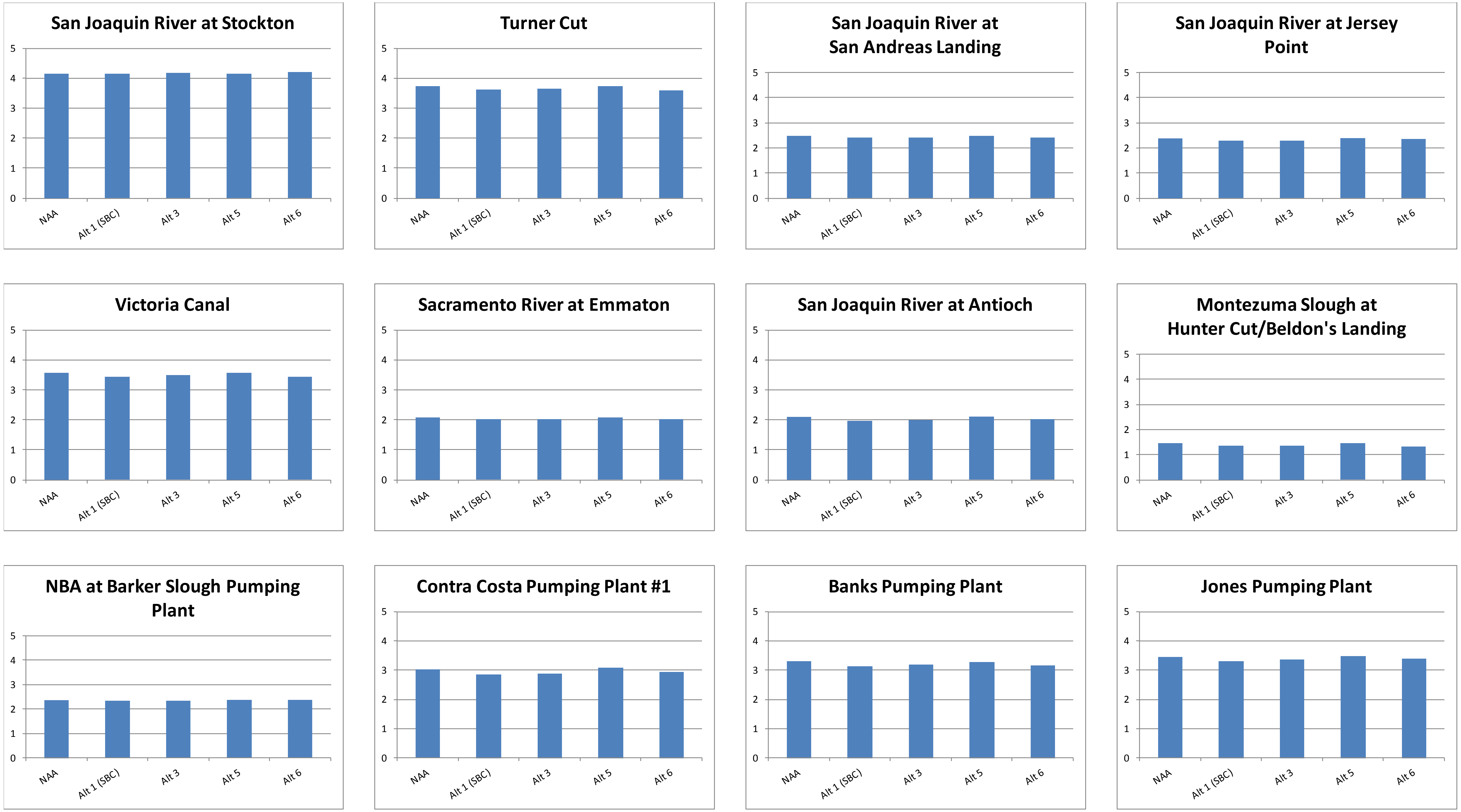
San Joaquin River at Stockton

Turner Cut

San Joaquin River at San Andreas Landing

San Joaquin River at Jersey Point

Victoria Canal

Sacramento River at Emmaton

San Joaquin River at Antioch

Montezuma Slough at Hunter Cut/Beldon's Landing

NBA at Barker Slough Pumping Plant

Contra Costa Pumping Plant #1

Banks Pumping Plant

Jones Pumping Plant

Figure 6C.2 Level of Concern Exceedance Quotients for Mercury Concentrations in 350-mm Largemouth Bass Fillets for All Years

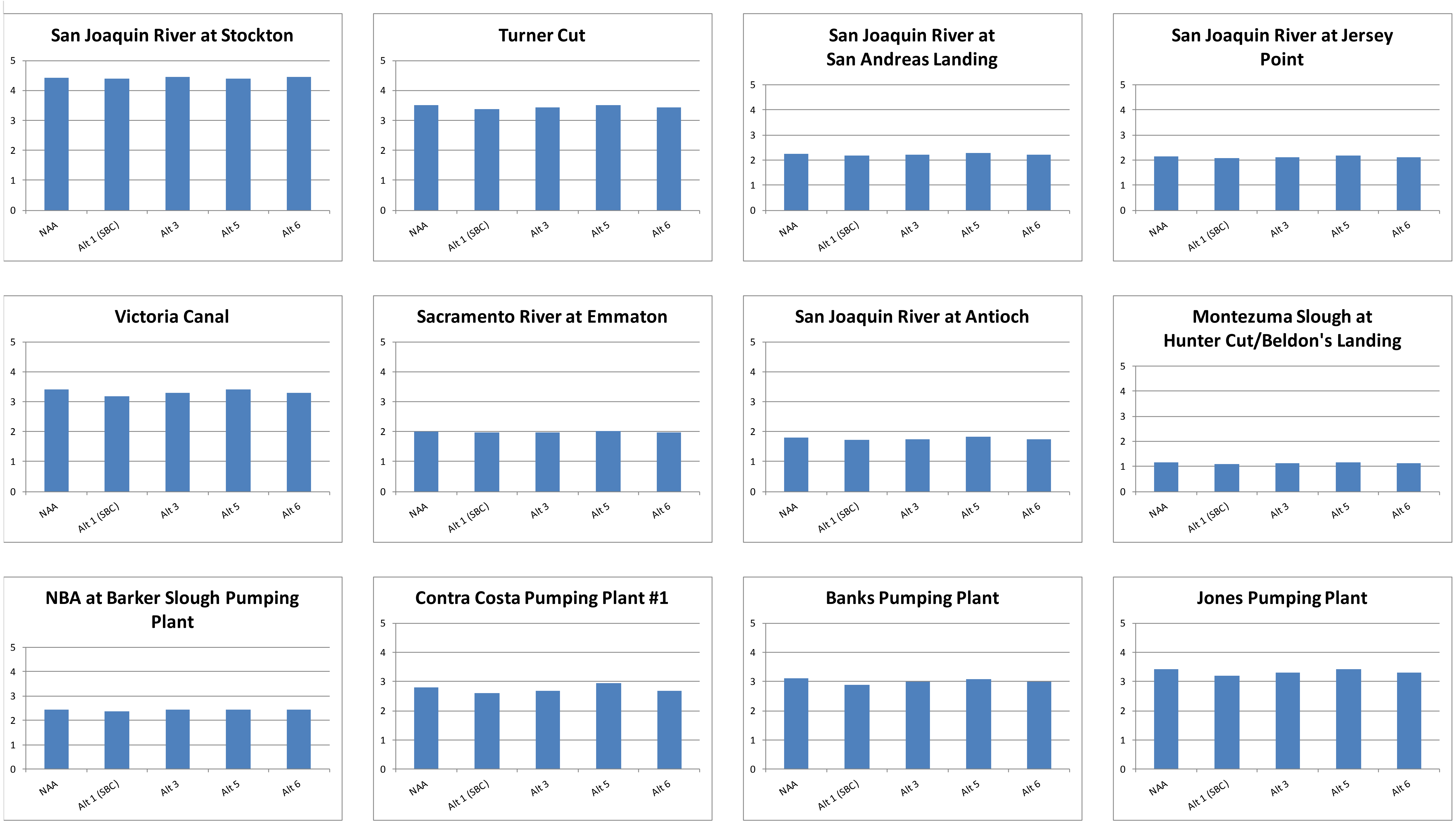

Figure 6C.3. Level of Concern Exceedance Quotients for Mercury Concentrations in 350-mm Largemouth Bass Fillets for Drought Years

Appendix 6D

Selenium Model Documentation

This appendix provides information about the methods, modeling tools, and assumptions used for the Coordinated Long Term Operation of the Central Valley Project (CVP) and State Water Project (SWP) Environmental Impact Statement (EIS) analysis. This appendix also provides information pertaining to the development of the analytical tools and the use of input data as well as model result processing and interpretation methods used for the impacts analysis and descriptions.

This appendix is organized into three main sections:

- Section 6D.1: Modeling Methodology
  - The selenium impacts analysis uses CalSim II, the Delta Simulation Model II (DSM2), and Delta-specific selenium bioaccumulation modeling to assess and quantify effects of the alternatives on the long-term operation and the environment. This section provides information about the development and calibration of a Delta-wide bioaccumulation model for selenium in fish, use of outputs from that model to estimate bioaccumulation in bird eggs and fish fillets, and modeling of selenium bioaccumulation in sturgeon living in the western Delta using inputs from other models.
- Section 6D.2: Modeling Simulations and Assumptions
  - This section provides a brief description of the assumptions for the selenium model simulations of the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.
- Section 6D.3: Modeling Results
  - This section provides a description of the model simulation output formats used in the analysis and interpretation of modeling results for the alternatives impacts assessment.

6D.1 Modeling Methodology

This section summarizes the selenium modeling methodology used for the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5. It describes the overall analytical framework and development and use of bioaccumulation models. This section also contains descriptions of the key analytical and numerical tools and approaches used in the quantitative evaluation of the alternatives. The project alternatives include changes to CVP and SWP operation that would cause subsequent effects on the water quality of the system relative to selenium. Those changes in waterborne selenium concentrations would propagate to changes in selenium concentrations in fish and bird eggs throughout the Delta.

6D.1.1 Overview of the Modeling Approach and Objectives

Modeling of flows, hydrodynamics, and selenium bioaccumulation in the Delta is necessary to support the selenium impact analysis of alternatives. Impact analysis focuses on evaluation of changes to selenium concentrations in tissues that affect the health of fish as well as wildlife and humans consuming fish in the Delta.

CalSim II, DSM2, and bioaccumulation modeling were used in sequence to estimate the effects of CVP and SWP operations on water quality relative to selenium in the Delta. CalSim II, which simulates flow in California's waterways, and DSM2, which simulates one-dimensional hydrodynamics in California's Delta, are discussed in detail in Appendix 5A. One of the three DSM2 modules, QUAL, simulates one-dimensional source tracking in the Delta. Results from DSM2 were multiplied by source concentrations (shown in Table 6D.1) to determine annual average waterborne selenium concentrations in the Delta for all year types and drought years.

Operations-related changes in waterborne selenium concentrations in the Delta may result in increased selenium bioaccumulation or toxicity (or both) to aquatic and semi-aquatic receptors using the Delta. Historical fish tissue data from 2000, 2005, and 2007 (Foe 2010a) and measured (for Sacramento River below Knights Landing and for San Joaquin River at Vernalis) or DSM2-modeled (other locations) waterborne selenium concentrations for selected locations in 2000, 2005, and 2007 were used to model water-to-tissue relationships. This modeling generally followed procedures described by Presser and Luoma (2010a, 2010b). Implementation of the Grassland Bypass Project (GBP) has led to a 60 percent decrease in selenium loads from the Grassland Drainage Area compared to pre-project conditions (San Francisco Bay Regional Water Quality Control Board 2008). These changes are reflected in data for the San Joaquin River at Vernalis, where water quality is monitored frequently because the river is a primary source of selenium to the Delta. Vernalis water data for 2 years (1999-2000, 2004-2005, and 2006-2007) were used for each year when fish data were available because of the GBP-related changes and because the lag time for selenium bioaccumulation in the piscivorous Largemouth Bass (*Micropterus salmoides*, the species for which the Delta-wide bioaccumulation model was calibrated) may be more than 1 year (Beckon 2014).

Output from the DSM2-QUAL model (expressed as percentage of inflow from different sources) was used in combination with the available measured waterborne selenium concentrations (Table 6D.1) to model concentrations of selenium at locations throughout the Delta. These modeled waterborne selenium concentrations were used in the relationship model to estimate bioaccumulation of selenium in whole-body fish and in bird eggs. Selenium concentrations in fish fillets were then estimated from those in whole-body fish. The following sections provide detailed information about the modeling approach for selenium.

Table 6D.1 Selenium Concentrations in Water at Inflow Sources to the Delta

Delta Sources	Representative Inflow Site	GM Se Concentration in Water (µg/L)[a]	Years	Source
Delta Agriculture	Mildred Island, Center	0.11	2000	Lucas and Stewart 2007
East Delta Tributaries	Mokelumne, Calaveras, and Cosumnes Rivers	0.10[b]	None	None
Martinez/Suisun Bay	San Joaquin River near Mallard Island	0.10	02/2000–08/2008	SFEI 2014
Sacramento River	Sacramento River at Freeport	0.09	11/2007–07/2014	USGS 2014
San Joaquin River	San Joaquin River at Vernalis (Airport Way)	0.45 [c]	11/2007-08/2014	USGS 2014
San Joaquin River	San Joaquin River at Vernalis (Airport Way)	0.83 [d]	1999-2000	SWAMP 2009
		0.85	2004-2005	SWAMP 2009
		0.58	2006-2007	SWAMP 2009
Yolo Bypass	Sacramento River below Knights Landing	0.23[e]	2004, 2007, 2008	DWR 2009

Notes:

a. Selenium concentrations are in dissolved fraction unless otherwise noted.

b. Dissolved selenium concentration is assumed to be 0.1 µg/L due to lack of available data and lack of sources that would be expected to result in concentrations greater than 0.1 µg/L.

c. Data used to represent conditions for comparison of alternatives.

d. Not specified whether total or dissolved selenium; data for 1999-2000 used for bioaccumulation by bass in 2000; data for 2004-2005 for bass in 2005; and data for 2006-2007 for bass in 2007.

e. Total selenium concentration in water.

µg/L = microgram(s) per liter
GM = geometric mean
Se = selenium

In addition to the Delta-wide modeling for fish and birds (calibrated with data for Largemouth Bass), selenium uptake and food-chain transfer information from the ecosystem-scale selenium model for the San Francisco Bay-Delta Regional Ecosystem Restoration Implementation Plan (Presser and Luoma 2013) informed the selenium bioaccumulation model for the western Delta. The Largemouth Bass has lower selenium bioaccumulation rates than those observed for sturgeon (Green Sturgeon [*Acipenser medirostris]* and White Sturgeon, [*A. transmontanus]*) and is not an appropriate model species that would be protective of sturgeon. Sturgeon differ by feeding, in part, on Overbite Clams (*Corbula* [*Potamocorbula*] *amurensis*) in Suisun Bay and may do so in the western portion of the Delta under future conditions. Therefore, DSM2-modeled waterborne selenium concentrations from three western-most locations in the Delta (Sacramento River at Emmaton, San Joaquin River at Antioch, and

Montezuma Slough at Hunter Cut/Beldon's Landing) were used to model selenium bioaccumulation for sturgeon at those three locations to supplement the modeling done for Largemouth Bass.

The results from this suite of physical and biological models are used to inform the understanding of effects of each alternative considered in this EIS on selenium. Modeling objectives included evaluation of the following:

- Percent changes in waterborne selenium concentrations under the alternatives as compared to the No Action Alternative and the Second Basis of Comparison
- Exceedances of fish, wildlife, or human thresholds for selenium effects

6D.1.2 Key Components of the Selenium Modeling

To fulfill the objectives of the selenium modeling effort, DSM2 output data were used in combination with source water concentrations to estimate waterborne selenium concentrations at representative locations throughout the Delta (Tables 6D.2 through 6D.4, located at end of this appendix). Waterborne selenium concentrations were then used to estimate tissue selenium concentrations in Largemouth Bass (as a representative higher trophic-level fish) throughout the Delta and in sturgeon in the western Delta. Estimation of concentrations in Largemouth Bass throughout the Delta included the development and calibration of a bioaccumulation model using measured concentrations in bass (Foe 2010a). In contrast, modeling for sturgeon in the western Delta relied on literature-based model parameters (Presser and Luoma 2013), because data were not available to further calibrate the model.

6D.1.2.1 DSM2 Post-processing

Dissolved or total selenium data were available for six inflow locations to the Delta (Table 6D.1):

- Sacramento River below Knights Landing (just upstream of Yolo Bypass, representing the Bypass source)
- Sacramento River at Freeport (mainstem flow to Delta)
- San Joaquin River at Vernalis (Airport Way) (mainstem flow to Delta)
- Mokelumne, Calaveras, and Cosumnes Rivers (for East Delta tributaries)
- Mildred Island, Center (for Delta Agriculture)
- San Joaquin River near Mallard Island (for Martinez/Suisun Bay)

Both dissolved and total selenium data were considered suitable for purposes of the modeling conducted for the Delta, because they typically do not differ greatly. Statements related to waterborne selenium concentrations in this appendix would be applicable to either dissolved or total concentrations.

Whole-body Largemouth Bass data for selenium were available from the following DSM2 output locations:

- Big Break
- Cache Slough Ryer
- Franks Tract
- Middle River Bullfrog
- Old River Near Paradise Cut
- Sacramento River Mile (RM) 44
- San Joaquin River Potato Slough

Largemouth Bass data also were available from the Veterans Bridge on the Sacramento River and from Vernalis on the San Joaquin River, but DSM2 data were not available for those locations; therefore, historical data for selenium concentrations in water collected nearby (Table 6D.1) were used to represent quarterly averages. The geometric mean of total selenium concentrations in water collected from the Sacramento River below Knights Landing in 2004, 2007, and 2008 (DWR 2009) were used to represent quarterly averages of selenium concentrations in water for Veterans Bridge in all years. The geometric means of selenium concentrations (total or dissolved was not specified) in water collected from 1999–2000, 2004-2005, and 2006-2007 (SWAMP 2009) were used to represent quarterly averages for selenium concentrations in water at Vernalis during 2000, 2005, and 2007, respectively.

For DSM2 output locations, the geometric mean selenium concentrations from the inflow locations were combined with the modeled quarterly average percent inflow for each DSM2 output location to estimate waterborne selenium concentrations at those locations. The quarterly average mix of water from the six inflow sources (Table 6D.1) was calculated from daily percent inflows provided by the DSM2 model output for the DSM2 output locations for which fish data were available. The quarterly waterborne selenium concentrations at DSM2 locations were calculated using Equation 1:

$$C_{water\ quarterly} = ([I_1*C_1] + [I_2*C_2] + [I_3*C_3] + [I_4*C_4] + [I_5*C_5] + [I_6*C_6])/100$$

Where:

- $C_{water\ quarterly}$ = quarterly average selenium concentration in water (micrograms/liter [µg/L]) at a DSM2 output location
- $I_{1\text{-}6}$ = modeled quarterly inflow from each of the six sources of water to the Delta for each DSM2 output location (percentage)
- $C_{1\text{-}6}$ = selenium concentration in water (µg/L) from each of the six inflow sources to the Delta (1-6)

Example Calculation: Modeled Selenium Concentration at Franks Tract Year 2000, First Quarter:

> (43.94 [% inflow from Sacramento River water source at Franks Tract] × 0.09 µg/L [selenium concentration at Sacramento River at Freeport]) + (11.56 [% inflow from East Delta Tributaries water source at Franks Tract] × 0.10 µg/L [selenium concentration at Mokelumne, Calaveras, and Cosumnes Rivers]) + (15.79 [% inflow from San Joaquin River water source at Franks Tract] × 0.83 µg/L [selenium concentration at San Joaquin River at Vernalis]) + (0.02 [% inflow from Martinez/Suisun Bay water source at Franks Tract] × 0.10 µg/L [selenium concentration at San Joaquin River near Mallard Island]) + (0.32 [% inflow from Yolo Bypass water source at Franks Tract] × 0.23 µg/L [selenium concentration at Sacramento River below Knights Landing]) + (5.06 [% inflow from Delta Agriculture water source at Franks Tract] × 0.11 µg/L [selenium concentration at Mildred Island, Center])/100 = 0.19 µg/L

The quarterly and average annual waterborne selenium concentrations for the DSM2 output locations are shown in Table 6D.2 (Year 2000), Table 6D.3 (Year 2005), and Table 6D.4 (Year 2007).

6D.1.2.2 Delta-wide Selenium Model Development

Selenium concentrations in whole-body fish and in bird eggs were calculated using ecosystem-scale models developed by Presser and Luoma (2010a, 2010b, 2013). The models were based on biogeochemical and physiological factors from laboratory and field studies; loading rates, chemical speciation, and transformation to particulate material; bioavailability; bioaccumulation in invertebrates; and trophic transfer to predators. Important components of the methodology included (1) empirically determined environmental partitioning factors between water and particulate material that quantify the effects of dissolved speciation and phase transformation; (2) concentrations of selenium in living and non-living particulates at the base of the food web that determine selenium bioavailability to invertebrates; and (3) selenium biodynamic food web transfer factors that quantify the physiological potential for bioaccumulation from particulate matter to consumer organisms and from prey to their predators.

6D.1.2.2.1 Selenium Concentration in Particulates

Phase transformation reactions from dissolved to particulate selenium are the primary form by which selenium enters the food web. Presser and Luoma (2010a, 2010b, 2013) used field observations to quantify the relationship between particulate material and dissolved selenium as indicated in Equation 2.

$$C_{particulate} = K_d * C_{water\ column}$$

Where:

- $C_{particulate}$ = selenium concentration in particulate material (micrograms/kilogram, dry weight [µg/kg dw])
- K_d = particulate/water ratio
- $C_{water\ column}$ = selenium concentration in water column (µg/L)

The K_d (also called an “enrichment factor”) describes the particulate/water ratio at the moment the sample was taken and should not be interpreted as an equilibrium constant (as it sometimes is mistaken to be). It can vary widely among hydrologic environments and potentially among seasons (Presser and Luoma 2010a, 2010b, 2013; Young et al. 2010). In addition, other factors such as selenium speciation, water residence time, and particle type affect K_d. Selenium typically enters a stream primarily as selenate. If the stream flows into a wetland and the water is retained there with sufficient residence time, recycling of selenium may occur. This results in generation of particulate selenium and conversion to more bioaccumulative selenite and organo-selenium from the less-bioaccumulative dissolved selenate. Residence time of water containing selenium is usually the most influential factor on the conditions in the receiving aquatic environment. Short water residence times (such as in streams and rivers) limit partitioning of selenium into particulate material. Conversely, longer residence times (such as in sloughs, lakes, and estuaries) allow greater uptake by plants, algae, and microorganisms. Furthermore, environments in downstream portions of a watershed can receive cumulative contributions of upstream recycling in a hydrologic system. Because of its high variability, K_d is a large source of uncertainty in any selenium model where extrapolations from selenium concentrations in the water column to those in aquatic organism tissues, or from tissue to waterborne concentrations, are necessary.

In developing the Delta-wide bioaccumulation model for bass, the particulate selenium concentration initially was estimated using Equation 2 and a default K_d of 1,000 (Presser and Luoma 2010a). Because the K_d is typically much more variable than other steps in the bioaccumulation model, the K_d was then adjusted to calibrate the model so that the modeled concentrations for fish approximated the measured concentrations in bass for normal and wet years (2000 and 2005) and for drought years (2007), as described in more detail in Section 6D.1.2.3.

6D.1.2.2.2 Selenium Concentrations in Invertebrates

Trophic transfer factors (TTFs) for transfer of selenium from particulates to prey and to predators were developed using data from laboratory experiments and field studies (Presser and Luoma 2010a, 2010b, 2013). TTFs are species-specific, but the range of TTFs for freshwater invertebrates was found to be similar to TTFs for marine invertebrates determined in laboratory experiments.

TTFs for estimating selenium concentrations in invertebrates were calculated using Equation 3:

$$TTF_{invertebrate} = (C_{invertebrate})/(C_{particulate})$$

Where:

- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate
- $C_{invertebrate}$ = concentration of selenium in invertebrate (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)

An average aquatic insect TTF was calculated from TTFs for aquatic insect species with similar bioaccumulative potential, including Mayfly (*Baetidae; Heptageniidae; Ephemerellidae*), Caddisfly (*Rhyacophilidae; Hydropsychidae*), Crane Fly (*Tipulidae*), Stonefly (*Perlodidae*/*Perlidae*; *Chloroperlidae*), Damselfly (*Coenagrionidae*), Corixid (*Cenocorixa* sp.), and Chironomid (*Chironomus* sp.) aquatic life stages. Species-specific TTFs ranged from 2.1 to 3.2; the average TTF of 2.8 was used in the Delta-wide model.

6D.1.2.2.3 Selenium Concentrations in Whole-body Fish

The mechanistic equation for modeling of selenium bioaccumulation in fish tissue is similar to that for invertebrates if whole-body concentrations are the endpoint (Presser and Luoma 2010a, 2010b, 2013), as shown in Equation 4:

$$TTF_{fish} = C_{fish} / C_{invertebrate}$$

where:

$$C_{invertebrate} = C_{particulate} * TTF_{invertebrate}$$

therefore:

$$C_{fish} = C_{particulate} * TTF_{invertebrate} * TTF_{fish}$$

Where:

- C_{fish} = concentration of selenium in fish (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- $C_{invertebrate}$ = *concentration of selenium in invertebrate (µg/g dw)*
- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate
- TTF_{fish} = trophic transfer factor from invertebrate to fish

Modeling selenium bioaccumulation into a particular fish species considers organism physiology and its preferred foods. However, variability in fish tissue selenium concentrations for present modeling purposes is driven more by dietary choices and their respective levels of bioaccumulation (that is, TTFinvertebrate) than by differences in fish physiology or the dietary transfer to the fish (TTFfish). A diet of mixed prey (including invertebrates or other fish) can be modeled as shown in Equation 5:

$$C_{fish} = TTF_{fish} * ([C_1 * F_1] + [C_2 * F_2] + [C_3 * F_3])$$

Where:

- C_{fish} = concentration of selenium in fish (µg/g dw)
- TTF_{fish} = trophic transfer factor for fish species
- $C_{1\text{-}3}$ = concentration of selenium in invertebrate or fish prey items 1, 2, and 3 (µg/g dw)
- $F_{1\text{-}3}$ = fraction of diet composed of prey items 1, 2, and 3

Modeling of selenium concentrations in longer food webs with higher trophic levels (for example, predator fish such as bass consuming forage fish) can be completed by incorporating additional TTFs, as shown in Equation 6:

$$C_{predatorfish} = C_{particulate} * TTF_{invertebrate} * TTF_{foragefish} * TTF_{predatorfish}$$

Where:

- $C_{predatorfish}$ = concentration of selenium in fish (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate
- $TTF_{foragefish}$ = trophic transfer factor for invertebrates to foraging fish species
- $TTF_{predatorfish}$ = trophic transfer factor for forage fish to predator species

The fish TTFs reported in Presser and Luoma (2010a) ranged from 0.5 to 1.6, so the average fish TTF of 1.1 was used for all trophic levels of fish in the Delta-wide model.

Modeled selenium concentrations in whole-body fish were used to estimate selenium concentrations in fish fillets, as described in Section 6D.1.2.2.5.

6D.1.2.2.4 Selenium Concentrations in Bird Eggs

Selenium concentrations in bird tissues can be estimated, but the transfer of selenium into bird eggs is more meaningful for evaluating reproductive endpoints (Presser and Luoma 2010a; Ohlendorf and Heinz 2011). Examples of models for selenium transfer to bird eggs are as shown in Equations 7 and 8:

$$C_{birdegg} = C_{particulate} * TTF_{invertebrate} * TTF_{birdegg}$$

(this equation is based on birds, such as shorebirds, eating invertebrates)

or:

$$C_{birdegg} = C_{particulate} * TTF_{invertebrate} * TTF_{fish} * TTF_{birdegg}$$

(this equation is based on birds, such as herons or terns, feeding on small fish)

Where:

- $C_{birdegg}$ = concentration of selenium in bird egg (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate
- TTF_{fish} = trophic transfer factor from invertebrate to fish
- $TTF_{birdegg}$ = trophic transfer factor from invertebrate or fish (depending on diet) to bird egg

Presser and Luoma (2010b, 2013) reviewed the available data for selenium bioaccumulation from diet to bird eggs and concluded that the mean $TTF_{birdegg}$ = 2.6 was most appropriate for modeling. This TTF was based on laboratory studies in which Mallards (*Anas platyrhynchos*) were fed selenium-fortified diets to evaluate reproductive effects. Mallards are considered a sensitive species to selenium based on reproductive endpoints. In their previous evaluation of those data, Presser and Luoma (2010a) concluded that a $TTF_{birdegg}$ = 1.8 was appropriate. The form of selenium included in the Mallard diet (selenomethionine) has been used as a surrogate in many laboratory studies to represent exposure of fish and birds under field conditions. Other laboratory studies were conducted with Black-crowned Night-herons (*Nycticorax*

nycticorax) by Smith et al (1988), for Eastern Screech-owls (*Otus asio)* by Wiemeyer and Hoffman (1996), and for American Kestrels (*Falco sparverius)* by Santolo et al. (1999). In each of these studies, the experimental groups also received supplemental selenium in the form of selenomethionine. Transfer factors for the selenium-supplemented birds varied from approximately 1.0 to 2.2, with a mean of 1.5.

In field studies conducted at Kesterson Reservoir and the Volta Wildlife Area reference site, extensive sampling of food-chain biota and bird eggs was conducted from 1983 through 1985, and birds were collected to determine qualitatively the kinds of aquatic organisms they had eaten (Saiki and Lowe 1987; Hothem and Ohlendorf 1989; Schuler et al. 1990; Ohlendorf and Hothem 1995). Based on the kinds of food items found in each of the sampled species and the mean selenium concentrations in those kinds of organisms, a mean selenium concentration was estimated for each species at each site during each nesting season. In contrast to the findings with selenomethionine-supplemented diets in the laboratory, TTFs from diet to eggs were almost always less than 2.0. At the Volta Wildlife Area, where diet and egg selenium concentrations were representative of "background" conditions, transfer factors ranged from 0.63 to 2.0, with a mean of 1.35. At Kesterson, the transfer factors ranged from less than 0.2 to 0.48.

Because selenomethionine in the Mallard diet is probably more readily transferred to eggs than are the selenium forms in field-collected food-chain biota, the $TTF_{birdegg}$ = 1.8 value from Presser and Luoma (2010a) was used in the bioaccumulation model.

6D.1.2.2.5 Selenium Concentrations in Fish Fillets

Selenium concentrations in whole-body fish from the bioaccumulation model were converted to selenium concentrations in skinless fish fillets for evaluation of potential human health effects. The regression equation provided in Saiki et al. (1991) for Largemouth Bass from the San Joaquin River system was considered to be the most representative of fish in the Delta and was used for the conversion of these selenium concentrations as shown in Equation 9:

$$SF = (-0.388) + (1.322 * WB)$$

Where:

- SF = selenium concentration in skinless fish fillet (µg/g dw)
- WB = selenium concentration in whole-body fish (µg/g dw)

For the impact assessment in this EIS, fish fillet data were compared to the Advisory Tissue Level (2.5 micrograms per gram [µg/g]) in wet weight (ww) (OEHHA 2008); therefore, wet-weight concentrations were estimated from dry-weight concentrations using the equation provided by Saiki et al. (1991) as shown in Equation 10:

$$WW = DW * (100 - Moist)/100$$

Where:

- WW = selenium concentration in wet weight (µg/g ww)
- DW = selenium concentration in dry weight (µg/g dw)
- $Moist$ = mean moisture content of the species

Because moisture content in fish varies among species, sample handling, and locations, the mean moisture content of 70 percent used by Foe (2010b) was used as an assumed approximation for fish in the Delta. The final equation used to estimate selenium concentration in skinless fish fillets (wet weight) from selenium concentration in whole-body fish (dry weight) is as shown in Equation 11:

$$SF = ([-0.388] + [1.322 * WB]) * 0.3$$

Where:

- SF = selenium concentrations in skinless fish fillet (µg/g ww)
- WB = selenium concentration in whole-body fish (µg/g dw)

6D.1.2.3 Delta-wide Selenium Model Calibration

Several models were evaluated and refined to estimate selenium uptake in fish and in bird eggs from waters in the Delta. Input parameters to the model (K_ds and the number of trophic levels) were varied among the models as refinements were made. Data for Largemouth Bass collected in the Delta from areas near DSM2 output locations were used to calculate the geometric mean selenium concentration in whole-body fish (Foe 2010a). The ratio of the estimated (modeled) selenium concentration in fish to measured selenium in whole-body bass was used to evaluate each fish model and to focus refinements of the model. These Delta-wide models are presented in the following subsections.

Characteristics of water flow in the Delta affect selenium bioaccumulation and the model refinements, because longer residence time for the water can be expected to increase bioaccumulation by increasing K_d. Foe (2010a) reported the water year type for 2000 as “above normal” for both the Sacramento River and San Joaquin River watersheds. It came after “wet” water years and was followed by “dry” water years. Year 2005 was wetter than 2000, was reported as “above normal” for the Sacramento River watershed and “wet” for the San Joaquin River watershed. Year 2005 occurred between periods of wet water years. Water Year 2007 was reported as “dry” (Sacramento River watershed) and “critically dry” (San Joaquin River watershed). It came after wet water years and was followed by critically dry water years.

There was no difference in bass selenium concentrations in the Sacramento River at Rio Vista in comparison to the San Joaquin River at Vernalis in 2000, 2005, and 2007 (Foe 2010a). The lack of a difference in bioaccumulated selenium between the two river systems was unexpected because the San Joaquin River is considered a significant source of selenium to the Delta. There were differences among years, however, that were related to hydrology and water flow through the Delta. Year 2005 selenium concentrations in bass were comparatively lower than those estimated for Year 2000. As expected in a wet water year, the water residence time was shorter, resulting in less selenium recycling, lower K_d values, and lower concentrations of selenium entering the food web. The dry water year (2007) resulted in a longer water residence time, higher K_d values, greater selenium recycling, and higher concentrations of bioavailable selenium entering the food web. These differences among years were considered when refining the selenium bioaccumulation model.

6D.1.2.3.1 Bioaccumulation in Whole-body Fish

Models estimating whole-body selenium concentrations in fish were refined by modifying dietary composition and input parameters to closely represent measured conditions in the Delta. Each model is described in this section.

Model 1 was a basic representative of uptake by a forage fish, while Model 2 calculated sequential bioaccumulation in a more complex food web that included predatory fish eating forage fish, as shown below:

Model 1: Trophic level 3 (TL-3) fish eating invertebrates (Equation 12):

$$C_{fish} = C_{particulate} * TTF_{invertebrate} * TTF_{fish}$$

Model 2: Trophic level 4 (TL-4) fish eating TL-3 fish (Equation 13):

$$C_{predatorfish} = C_{particulate} * TTF_{invertebrate} * TTF_{foragefish} * TTF_{predatorfish}$$

Where:

- C_{fish} = concentration of selenium in fish (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- $TTF_{invertebrate}$ = Trophic transfer factor from particulate material to invertebrate
- TTF_{fish} = Trophic transfer factor from invertebrate to forage fish or forage fish to predator fish

Equation 12 is the same as Equation 4 and Equation 13 is the same as Equation 6 that were described previously for the generalized model. In both Models 1 and 2, the particulate selenium concentration was estimated using Equation 2 and a default K_d of 1,000. The average TTFs for invertebrates (2.8) and fish (1.1) were used in each model. The outputs of estimated selenium concentrations and the ratios of predicted-to-observed bass selenium concentrations for Models 1 and 2 are presented in Table 6D.5 and Figure 6D.1 (all figures are provided at the end of this appendix).

Models 1 and 2 tended to substantially underestimate the whole-body selenium concentrations in fish compared to bass data reported in Foe (2010a). This was partly because Model 1 was estimating selenium concentration in a forage fish (TL-3), whereas bass are a predatory fish with expected higher dietary exposure. Consequently, Model 1 was not further developed as the selenium bioaccumulation model to represent fish in the Delta.

Model 2 is representative of predatory fish, but Model 2 was very similar to Model 1 in distribution of data and in underestimating bass data, even though an additional trophic-level transfer was included in the model. As noted in Section 6D.1.2.2.1 and described in much greater detail by Presser and Luoma (2010a, 2010b, 2013), the K_d values for uptake from water are far more variable than the

TTFs for invertebrates or fish. Models 1 and 2 also apparently reflect the tendency of selenium (as an essential nutrient) to be more bioaccumulative when waterborne concentrations are low (as described by Stewart et al. [2010]), which they were for the DSM2-modeled concentrations (that is, 0.09 to 0.85 µg/L). Available K_d values from various sampling efforts in the Delta provided by Presser and Luoma (2010b) were reviewed for potential applicability in the modeling effort. Those values varied on the basis of locations within the Delta and Suisun Bay and also by water year and flow characteristics (often greater than 5,000 and sometimes exceeding 10,000). However, efforts to incorporate various selected K_d values (for example, 2,000 or 3,000) into the model uniformly for different DSM2 locations failed to produce ratios of modeled-to-measured fish selenium concentrations that approximated 1 (they either over- or underestimated fish selenium concentrations because of variability in site conditions).

The available bass data and the assumed TTFs for invertebrates (2.8) and fish (1.1) were used to back-calculate a location and sample-specific K_d. It is recognized that some of the variability in bioaccumulation may be associated with the TTFs, but there were no reasonable assumptions for selection of alternative values to plug into the model.

When TTFs were held constant, back-calculation of K_d values revealed a concentration-related influence on the values. For waterborne selenium concentrations in the range of 0.09 to 0.13 µg/L (N = 50), the median was 5,575; when waterborne selenium concentrations were in the range of 0.14 to 0.40 µg/L (N = 19), the median K_d was 2,431; for waterborne selenium concentrations in the range of 0.41 to 0.85 µg/L (N = 19), the median K_d was 748. These observations are consistent with an inverse relationship between waterborne selenium concentrations and bioaccumulation in aquatic organisms (Stewart et al. 2010).

Figure 6D.2 shows the log-log regression relation of K_d to waterborne selenium concentration when all years are included and the TTFs are held constant, while Figure 6D.3 shows the relationship for normal/wet years (2000 and 2005) and Figure 6D.4 shows the regression for dry years (2007), when the K_ds were generally higher.

Model 3 is based on Model 2 (with TTFs as described previously) but includes the K_d estimated from the log-log regression relation for all years (Figure 6D.2). This produced a median ratio of predicted-to-observed whole-body selenium in bass that slightly exceeded 1 (Figure 6D.1); details are provided in Table 6D.6. Because of the noticeable differences between 2007 (the dry year) and the other 2 years, the next step in modeling was to evaluate 2007 separately from 2000 and 2005.

Model 4 was developed using the log-log relationship between K_d and water selenium concentrations for 2000 and 2005 (Figure 6D.3). Model 5 was developed using log-log relationship between K_d and water selenium concentrations for 2007 (Figure 6D.4 and Table 6D.7). These two models produced ratios of predicted-to-observed whole-body selenium in bass approximating 1, as shown in Figure 6D.1.

As expected in a large, complex, and diverse ecological habitat such as the Delta, variations in the data distribution and in the outputs of the models are not surprising. However, it should be noted that the estimated K_d values for Model 3 (674-6,060; Table 6D.6), Model 4 (651-4,997; Table 6D.7), and Model 5 (1,206-8,064; Table 6D.7) are consistent with those summarized by Presser and Luoma (2010b) for the Delta.

Figures 6D.5 and 6D.6 illustrate the distribution of data for selenium concentrations in Largemouth Bass (Foe 2010a) relative to the measured or DSM2-modeled waterborne selenium concentrations (Tables 6D.1 through 6D.4) and Models 3, 4, and 5 to complement the boxplots shown in Figure 6D.1. There is notably more variability in selenium concentrations in bass between 0.09 and 0.13 µg/L than at higher waterborne selenium concentrations (as shown in both Figures 6D.5 and 6D.6); most of the higher values are from 2007 and most of the lower ones are from 2005.

Figure 6D.5 shows the available data for 2000, 2005, and 2007 plotted with the Model 3 prediction of selenium concentrations. As noted previously in text and in Figure 6D.1, the model slightly over-predicts the median concentrations in fish on the basis of waterborne selenium concentrations. This effect is reflected in Figure 6D.1 by the outliers above the 90th percentile bar (that is, the higher over-predictions for fish, which are those from 2000 and 2005). However, overall, the model is within 1 µg/g for all values less than the prediction, and within approximately 1.2 µg/g for the values greater than the prediction (Figure 6D.5).

Because of the notable differences between data for 2007 compared to combined 2000 and 2005 data, Model 4 was developed for 2000 and 2005 and Model 5 was developed for 2007, Figure 6D.6 shows those model predictions compared to the data. These two models improved the predictions; although the figure shows more differences between data and the models at the lower waterborne concentrations (that is, less than 0.30 µg/L) than at higher ones, the divergence is generally less than 0.5 µg/g at the higher waterborne concentrations. The outliers for Model 4 are mostly above the 90th percentile (that is, over-predicting concentrations in fish), rather than below, as shown in Figure 6D.1. For Model 5, the predictions are "tighter" with just a few outliers above or below the 90th percentile.

Evaluation of water-year effects on selenium concentration in bass concluded that Model 4 was relatively predictive of selenium concentration in whole-body bass during normal to wet water years. Model 5 was considered predictive for dry water years (such as 2007). Model 3 incorporates the varying bioaccumulation when all years are considered (that is, 2000, 2005, and 2007). Although Model 3 tends to slightly overestimate selenium bioaccumulation (Table 6D.6 and Figure 6D.1), it was used for estimating selenium concentrations in whole-body fish in the impact assessment for "All" years, and Model 5 was used for "Drought" years.

6D.1.2.3.2 Selenium Bioaccumulation in Bird Eggs

The K_d, invertebrate TTF, and fish TTFs developed for use in fish bioaccumulation Models 4 and 5 were also used to estimate selenium uptake into bird eggs using the following two bird egg models (Table 6D.8):

Bird Egg: Uptake from invertebrates (Equation 14):

$$C_{birdegg} = C_{particulate} * TTF_{invertebrate} * TTF_{birdegg}$$

where:

$$C_{particulate} = K_d * C_{water}$$

Bird Egg: Uptake from fish (Equation 15):

$$C_{birdegg} = C_{particulate} * TTF_{invertebrate} * TTF_{fish} * TTF_{fish} * TTF_{birdegg}$$

where:

$$C_{particulate} = K_d * C_{water}$$

Where:

- $C_{birdegg}$ = concentration of selenium in bird egg (µg/g dw)
- $C_{particulate}$ = concentration of selenium in particulate material (µg/g dw)
- C_{water} = selenium concentration in water column (µg/L)
- K_d = particulate/water ratio
- $TTF_{invertebrate}$ = trophic transfer factor from particulate material to invertebrate
- TTF_{fish} = trophic transfer factor from invertebrate or fish to fish
- $TTF_{birdegg}$ = trophic transfer factor from invertebrate or fish (depending on diet) to bird egg

Equation 14 is the same as Equation 7, but Equation 15 differs from Equation 8 in that it assumes birds are eating larger predatory fish such as bass.

6D.1.2.4 Western Delta Sturgeon Model

Presser and Luoma (2013) determined K_d values for San Francisco Bay (including Carquinez Strait – Suisun Bay) during “low flow” conditions (5,986) and “average” conditions (3,317). These values were used to model selenium concentrations in particulates in bioaccumulation modeling for sturgeon under “Drought” and “All” year conditions at the three locations in the western Delta. (By comparison, calibration of the Delta-wide model for two western-most location from which bass had been collected [Big Break] resulted in an average K_d = 3,736 for 2000/2005 [Model 4, normal/wet years] and average K_d = 7,166 for 2007 [Model 5, dry year].)

Sturgeon in the western Delta, Carquinez Strait, and Suisun Bay typically prey on a mix of clams including *Corbula amurensis*, which is known to be an efficient bioaccumulator of selenium (Stewart et al. 2010) and crustaceans. Presser and Luoma (2013) assumed a sturgeon diet of 50 percent clams and 50 percent amphipods and other crustaceans in their model. Based on this diet, the authors reported a TTF of 9.2 (identified as TTF_{prey} in Table 1 of Presser and Luoma [2013]). This TTF was used to calculate concentrations in sturgeon invertebrate prey for the Sacramento River at Emmaton, San Joaquin River at Antioch, and Montezuma Slough at Hunter Cut/Beldon's Landing locations under the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5.

A TTF of 1.3 from diet to fish (identified as $TTF_{predator}$) was reported for sturgeon in Presser and Luoma (2013) and was used to calculate concentrations of selenium in sturgeon for the three western Delta locations.

Modeling for sturgeon at the three western Delta locations did not require refinement because it relied on recent data provided by Presser and Luoma [2013]) and because data to refine the model were not available.

6D.2 Modeling Simulations and Assumptions

As described in Section 6D.1, selenium modeling was performed for evaluation of the alternatives. This section describes the assumptions for the selenium model simulations of the No Action Alternative, Second Basis of Comparison, and other alternatives. A description of DSM2 model assumptions is in Appendix 5A.

The following model simulations were used as the basis of evaluating the impacts of Alternatives 1 through 5 as compared to the No Action Alternative, and the No Action Alternative and Alternatives 1 through 5 as compared to the Second Basis of Comparison:

- No Action Alternative
- Second Basis of Comparison

The following selenium model simulations of other alternatives were performed:

- Alternative 1 – for selenium simulation purposes, considered the same as Second Basis of Comparison
- Alternative 2 – for selenium simulation purposes, considered the same as No Action Alternative
- Alternative 3
- Alternative 4 – for selenium simulation purposes, considered the same as Second Basis of Comparison.
- Alternative 5

The general selenium modeling assumptions described in the following subsection pertain to all the model runs.

6D.2.1 Delta-wide Assumptions

The calibrated Delta-wide selenium bioaccumulation models (Models 3, 4, and 5) are considered representative of conditions in the Delta under current and likely future conditions, because they incorporate realistic concentrations of waterborne selenium and they predict selenium concentrations in predatory fish that approximate measured concentrations in Largemouth Bass. The calibrated models take into account the variable nature of selenium bioaccumulation in relation to waterborne concentrations, which is reflected in the generally inverse relationship between the K_d and waterborne selenium concentration.

Models are not available to quantitatively estimate the level of changes in selenium bioaccumulation as related to residence time, but the effects of residence time are incorporated in the bioaccumulation modeling for selenium that was based on higher K_d values for drought years in comparison to wet, normal, or all years. If increases in fish tissue or bird egg selenium were to occur, the increases would likely be of concern only where fish tissues or bird eggs are already elevated in selenium to near or above thresholds of concern. That is, where biota concentrations are currently low and not approaching thresholds of concern (which is the case throughout the Delta, except for sturgeon in the western Delta), changes in residence time alone would not be expected to cause them to then approach or exceed thresholds of concern. In consideration of this factor, although the Delta as a whole is a Clean Water Act (CWA) Section 303(d)-listed waterbody for selenium (SWRCB 2011), and although monitoring data of fish tissue or bird eggs in the Delta are sparse, the most likely areas in which biota tissue selenium concentrations would be high enough that additional bioaccumulation due to increased residence time from restoration areas would be a concern are the western Delta and Suisun Bay (discussed below for sturgeon), and the south Delta in areas that receive San Joaquin River water.

The South Delta receives elevated selenium loads from the San Joaquin River. In contrast to Suisun Bay and possibly the western Delta in the future, the south Delta lacks the Overbite Clam (*Corbula* [*Potamocorbula*] *amurensis*), which is considered a key driver of selenium bioaccumulation in Suisun Bay because of its high bioaccumulation of selenium and its role in the benthic food web that includes long-lived sturgeon. The south Delta does have *Corbicula fluminea*, another bivalve that bioaccumulates selenium, but it is not as invasive as the Overbite Clam and thus likely makes up a smaller fraction of sturgeon diet. Also, nonpoint sources of selenium in the San Joaquin Valley that contribute selenium to the Delta will be controlled through a Total Maximum Daily Load (TMDL) developed by the Central Valley Regional Water Quality Control Board (Central ValleyRWQCB) for the lower San Joaquin River, established limits for the Grassland Bypass Project, and Basin Plan objectives (Central Valley RWQCB 2001, 2010; SWRCB 2010a, 2010b) that are expected to result in decreasing discharges of selenium from the San Joaquin River to the Delta. Further, if selenium levels in the San Joaquin River are not sufficiently reduced by these efforts, it is expected that the SWRCB and Central Valley RWQCB would initiate additional TMDLs to further control nonpoint sources of selenium.

6D.2.2 Western Delta Sturgeon Assumptions

Modeling for selenium bioaccumulation by sturgeon in the western Delta is considered to be based on the most appropriate uptake factors available, which were published recently by Presser and Luoma (2013) specifically for sturgeon in northern San Francisco Bay estuary. The disparity between larger estimated changes for sturgeon and smaller changes for other biota (that is, whole-body fish, bird eggs, and fish fillets) is attributable largely to differences in modeling approaches, as described previously. The model for most biota was calibrated to encompass the varying concentration-dependent uptake from waterborne selenium concentrations (expressed as the K_d, which is the ratio of selenium concentrations in particulates [as the lowest level of the food chain] relative to the waterborne concentration) that was exhibited in data for Largemouth Bass in 2000, 2005, and 2007 at various locations across the Delta. In contrast, the modeling for sturgeon could not be similarly calibrated at the three western Delta locations and used literature-derived uptake factors and TTFs for the estuary from Presser and Luoma (2013). There was a significant negative log-log relationship of K_d to waterborne selenium concentration that reflected the greater bioaccumulation rates for bass at low waterborne selenium than at higher concentrations. There was no difference in bass selenium concentrations in the Sacramento River at Rio Vista compared to the San Joaquin River at Vernalis in 2000, 2005, and 2007 (Foe 2010a), despite a nearly 10-fold difference in waterborne selenium concentrations. It is unknown whether this might also occur in the sturgeon food web. Thus, there is more confidence in the site-specific modeling based on the Delta-wide model that was calibrated for bass data than in the estimates for sturgeon based on “fixed” K_d values for all years and for drought years without regard to waterborne selenium concentration at the three locations in different time periods.

The western Delta and Suisun Bay receive elevated selenium loads from North San Francisco Bay (including San Pablo Bay, Carquinez Strait, and Suisun Bay) and from the San Joaquin River. Point sources of selenium in North San Francisco Bay (that is, refineries) that contribute selenium to Suisun Bay are expected to be reduced through a TMDL under development by the San Francisco Bay Regional Water Quality Control Board (San Francisco Bay RWQCB 2012) that is expected to result in decreasing discharges of selenium. Nonpoint sources of selenium in the San Joaquin Valley that contribute selenium to the San Joaquin River, and thus the Delta and Suisun Bay, will be controlled through a TMDL developed by the Central Valley RWQCB (2001) for the lower San Joaquin River, established limits for the GBP, and Basin Plan objectives (Central Valley RWQCB 2010; SWRCB 2010a, 2010b) that are expected to result in decreasing discharges of selenium from the San Joaquin River to the Delta. If selenium levels are not sufficiently reduced via these efforts, it is expected that the SWRCB and the San Francisco Bay and Central Valley regional Water Quality Control Boards would initiate additional actions to further control sources of selenium.

6D.2.3 Model Application Methodology

To evaluate differences in the impact assessment, modeled whole-body fish, bird egg or fish fillet data were compared directly (for percent change) and to the following threshold effect benchmarks:

- Whole-body fish for the Delta-wide model were compared to the Level of Concern (4 milligrams per kilogram [mg/kg] dw; Beckon et al. 2008) and the Toxicity Level (8.1 mg/kg dw; USEPA 2014) for fish tissue.

- Modeled bird egg selenium concentrations were compared to Level of Concern (6 mg/kg dw) and Toxicity Level (10 mg/kg dw) values from Beckon et al. (2008).
- Fish fillet data were compared to the Advisory Tissue Level (2.5 µg/g ww) for human consumption of fish (OEHHA 2008).
- Whole-body selenium concentrations in sturgeon were compared to Low Effect (5 mg/kg dw) and High Effect (8 mg/kg dw) guidelines from Presser and Luoma (2013).

Results of comparisons to these benchmarks are expressed as Exceedance Quotients (EQs) in some of the tables and figures. Annual average selenium concentrations in water did not exceed the 5.0 µg/L(4-day average) or 20 µg/L (1-hour average) criterion, so no EQs were calculated.

6D.2.3.1 No Action Alternative and Second Basis of Comparison Models

The purpose of the No Action Alternative and the Second Basis of Comparison for comparison with the forecasts of the alternative models was to determine whether the implementation of the proposed alternatives is likely to result in substantial impacts to selenium, thereby affecting biological resources. The No Action Alternative and the Second Basis of Comparison models were completed for five Delta interior, three western Delta, and four major Delta diversion locations. DSM2 post-processing output provided estimates of the waterborne selenium concentration at each of those 12 locations (Table 6D.9). The Delta-specific selenium bioaccumulation model that was calibrated using Largemouth Bass data from the Delta was then used to estimate selenium concentrations in whole-body fish and then in bird eggs and fish fillets. Selenium concentrations in sturgeon inhabiting the western Delta (represented by three locations) were estimated using recently published literature parameters. Modeled selenium concentrations in whole-body fish (predatory fish throughout the Delta or sturgeon in the western Delta), bird egg or fish fillet data were compared to the threshold effect benchmarks listed previously. The modeled tissue selenium concentrations themselves and the EQs (based on comparisons to thresholds) both served as a basis for comparison of other alternatives to identify potential impacts.

6D.2.3.2 Alternative Models

For each of the alternative model simulations, the same procedure as described for the No Action Alternative and the Second Basis of Comparison models was used, with similar assumptions, to estimate waterborne selenium concentrations and selenium concentrations in fish and bird eggs. Each alternative model simulation for each type of biota (whole-body fish [either using the Delta-wide model for bass or the western Delta sturgeon model], bird eggs, or fish fillets) was compared to both the No Action Alternative and the Second Basis of Comparison to determine potentially significant impacts.

6D.3 Modeling Results

The post-processing tool is Excel-based. The general pre-processing and input files development are described in the modeling data assumptions sections above. This section focuses on data analysis and results interpretation for the impact assessment.

6D.3.1 Post-processing and Results Analysis: Delta-wide Model

Output data resulting from the model simulations for each alternative are processed to provide a tabular depiction of potential impacts to fish and wildlife (Tables 6D.13 through 6D.15). As discussed previously, outputs from the post-processing model used in this analysis are annual average selenium fish tissue concentrations for all year types and separately presented for the subset of drought years.

The variation in concentrations between the No Action Alternative, Second Basis of Comparison, and Alternatives 1 through 5 was less than 5 percent (Tables 6D.13 through 6D.15). Annual average concentrations do not exceed the selenium thresholds at all locations modeled in the Delta for all years and drought years both as measured and as modeled. Results are shown in Tables 6D.9 through 6D.15 and Figures 6D.7 through 6D.10. Table 6D.9 presents the period-average waterborne selenium concentrations by location and water year type that were used to model fish tissue (whole-body and fillet) and bird egg concentrations (Tables 6D.10 through 6D.12).

All estimated selenium concentrations in water and biota (whole-body fish, bird eggs, and fish fillets) were below the benchmarks used for evaluation (presented in Section 6D.2.4). The highest estimated selenium concentrations were for Alternative 1 in the San Joaquin River at San Andreas Landing and Sacramento River at Emmaton, and Alternative 3 in the North Bay Aqueduct at Barker Slough in drought years (Tables 6D.10 through 6D.12). Changes in estimated selenium concentrations for Alternatives 3 and 5 compared to the No Action Alternative and Alternative 1 were less than 4 percent (Tables 6D.14 and 6D.15).

6D.3.2 Post-processing and Results Analysis: Western Delta Sturgeon Model

Output data resulting from the sturgeon model simulations for each alternative at the three western Delta locations were processed to provide a tabular depiction of potential impacts to sturgeon. Table 6D.16 presents the period-average waterborne selenium concentrations by location and water year type that were used to model fish tissue concentrations (Table 6D.17). As discussed previously, outputs from the post-processing model used in this analysis are annual average selenium concentrations in whole-body sturgeon for all year types and separately presented for the subset of drought years.

The expected variations in whole-body sturgeon selenium concentrations between the No Action Alternative, the Second Basis of Comparison, and Alternatives 1 through 5 were less than 1 mg/kg dw (Table 6D.17). The highest estimated selenium concentrations were for drought years at all three locations with little difference among alternatives. Annual average sturgeon concentrations slightly exceeded the low selenium thresholds for all locations and alternatives for drought years, but not for all years. Results of comparisons to the thresholds are shown in Table 6D.18 and Figure 6D.11. Estimated selenium concentrations did not exceed high thresholds.

Changes in estimated selenium concentrations compared to the No Action Alternative and Second Basis of Comparison are less than 5 percent for all years and for drought years (Table 6D.19). The largest predicted changes were a small decrease under Alternative 3 relative to the No Action Alternative for the San Joaquin River at Antioch in all years and a small increase predicted for Alternative 5 relative to Second Basis of Comparison at that location in all years. Both of these predicted changes were less than 5 percent. However, as noted previously, even the expected changes for the San Joaquin River at Antioch for Alternatives 3 and 5 as compared to the No Action Alternative or the Second Basis of Comparison were less than 1 mg/kg dw. It is not likely that such small changes in whole-body selenium concentrations would be detectable under field conditions.

6D.3.3 Model Limitations and Applicability

Although it is impossible to predict future hydrology, land use, and water use with certainty, the selenium model and DSM2 were used to forecast impacts to fish and wildlife that could result from implementation of the alternatives. The selenium model for sturgeon has greater uncertainty than the selenium model for bass because the sturgeon model was not as finely calibrated for varying K_d relative to waterborne selenium concentrations throughout the Delta, as discussed in Section 6D.2.2. Mathematical models like DSM2 can only approximate processes of physical systems. Models are inherently inexact because the mathematical description of the physical system is imperfect and the understanding of interrelated physical processes is incomplete. However, the selenium models are powerful tools that, when used carefully, can provide useful insight into processes of the physical system. Selenium concentrations for inflow sources to the Delta (for example, agriculture in the Delta, Yolo Bypass, Eastside Tributaries) also caused uncertainty in the modeling because of limited data. For the Sacramento River and the San Joaquin River, approximately 90 data points (Chapter 6, Table 6.58; Table 6D.1) were used to estimate the mean selenium concentrations for these inflow sources, whereas the mean selenium concentrations for other inflow sources to the Delta had many fewer (0 to 14) data points (concentrations for the Eastside Tributaries were assumed).

6D.4 References

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Table 6D.2 Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2000

		First Quarter Inflow Percentage						Second Quarter Inflow Percentage						Third Quarter Inflow Percentage						Fourth Quarter Inflow Percentage						Estimated Waterborne Selenium Concentrations (μg/L)				
	Inflow Source ➔	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**					
	Inflow Location ➔	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	**1st Quarter**	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
DSM2 Output	**Selenium (μg/L) ➔**	0.11	0.10	0.09	0.83	0.10	0.23	0.11	0.10	0.09	0.83	0.10	0.23	0.11	0.10	0.09	0.83	0.10	0.23	0.11	0.10	0.09	0.83	0.10	0.23					
Water Location	**Location ID**																													
Big Break	BIGBRK_MID	2.94	6.88	53.15	6.59	0.18	5.70	2.95	6.37	73.59	13.55	0.27	3.12	3.13	0.45	85.63	0.44	4.15	6.12	2.13	0.20	84.85	0.02	8.76	3.96	0.13	0.20	0.10	0.10	0.13
Cache Slough	CACHS_LEN	1.46	0	53.38	0	0	31.91	1.24	1.5E-05	85.07	2.5E-05	0	13.25	1.66	4.7E-07	85.95	4.3E-07	5.9E-07	12.23	1.32	2.8E-06	89.83	1.1E-07	2.3E-05	8.67	0.12	0.11	0.11	0.10	0.11
Cache Slough Ryer	CACHSR_MID	2.88	0	54.86	0	0	20.48	3.36	9.8E-07	79.75	1.9E-06	0	16.25	1.90	9.3E-08	84.53	1.8E-07	9.2E-12	13.38	1.81	1.0E-07	89.45	6.2E-10	3.0E-06	8.54	0.10	0.11	0.11	0.10	0.11
Cosumnes R.	COSR_LEN	8.1E-06	98.82	0	0	0	0	0	100.00	0	0	0	0	0	100.00	0	0	0	0	0	100.00	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Franks Tract	FRANKST_MID	5.06	11.56	43.94	15.79	0.02	0.32	4.17	9.42	61.16	23.89	0.01	1.22	4.04	0.57	90.34	0.41	0.80	3.78	2.76	0.62	91.38	0.12	2.42	2.64	0.19	0.27	0.10	0.10	0.16
Little Holland Tract	LHOLND_L0	72.35	0	5.06	0	0	6.50	23.38	8.2E-07	63.10	1.6E-06	0	13.03	18.48	2.2E-07	68.67	4.2E-07	7.2E-13	12.68	19.63	2.6E-09	72.79	0	0	7.42	0.10	0.11	0.11	0.10	0.11
Middle R Bullfrog	MIDRBULFRG_LEN	10.54	13.07	18.37	32.20	1.9E-03	3.2E-03	5.49	9.19	14.96	70.17	4.2E-04	0.10	7.81	6.43	69.63	14.94	0.12	1.02	4.86	6.31	59.79	27.84	1	0.68	0.31	0.61	0.20	0.30	0.36
Mildred Island	MILDDRISL_MID	7.47	14.31	22.79	30.23	2.4E-03	1.8E-03	4.77	10.05	18.48	66.48	6.7E-04	0.13	6.57	4.57	83.28	4.14	0.15	1.25	4.50	6.63	71.28	16.13	0.61	0.82	0.29	0.58	0.12	0.21	0.30
Mok. R. below Cosum.	MOKBCOS_LEN	2.07	96.19	0	0	0	0	1.65	98.35	0	0	0	0	7.23	92.77	4.7E-09	0	0	0	2.47	97.53	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Mok. R. downstream Cosum.	MOKDCOS_MID	2.07	96.43	0	0	0	0	1.68	98.32	0	0	0	0	7.08	92.92	0	0	0	0	2.34	97.66	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Old R near Paradise Cut	OLDRNPARADSEC_MID	6.24	0	0	87.26	0	0	14.40	1.67	5.21	78.66	1.2E-05	0.04	10.56	3.9E-05	1.3E-04	89.44	8.8E-28	3.0E-07	2.50	1.1E-04	3.5E-04	97.50	2.8E-20	1.7E-07	0.73	0.68	0.75	0.81	0.74
Paradise Cut	PARADSECUT_LEN	4.69	0	0	91.37	0	0	2.62	0.06	0.15	97.16	1.5E-07	1.1E-03	3.43	0	0	96.57	0	0	0.96	0	0	99.04	0	0	0.76	0.81	0.81	0.82	0.80
Port of Stockton	PORTOSTOCK_L0	1.67	0	0	18.85	0	0	2.22	0	0	60.73	0	0	3.09	0	0	81.32	0	0	2.70	0	0	89.89	0	0	0.16	0.51	0.68	0.75	0.52
Sac. R. at Isleton	SACRISLTON_L0	0.33	0	95.77	0	0	0	0.31	0.00	99.60	0	0	5.5E-05	0.44	0	99.55	0	0	1.3E-05	0.28	0	99.72	0	0	1.1E-03	0.09	0.09	0.09	0.09	0.09
Sac River RM 44	SACR44_L0	0.14	0	97.93	0	0	0	0.11	0	99.81	0	0	0	0.13	0	99.86	0	0	0	0.05	0	99.94	0	0	0	0.09	0.09	0.09	0.09	0.09
Sandmound Sl.	SANDMND_MID	6.36	10.51	43.82	12.90	0.03	0.57	5.22	8.81	63.78	20.40	0.03	1.63	5.24	0.61	87.78	0.49	1.22	4.59	3.31	0.43	89.58	0.06	3.44	3.11	0.17	0.25	0.10	0.10	0.15
Sherman Island	SHERMNILND_L0	1.64	3.45	52.71	3.93	0.60	12.10	2.48	4.95	76.80	10.96	0.96	3.67	2.60	0.40	81.69	0.46	8.21	6.56	1.77	0.11	77.64	0.01	16.46	3.94	0.11	0.18	0.10	0.10	0.12
SJR Bowman	SJRBOWMN_MID	1.40	0	0	94.03	0	0	1.52	0	0	98.48	0	0	3.00	0	0	97.00	0	0	0.33	0	0	99.67	0	0	0.78	0.82	0.81	0.83	0.81
SJR N Hwy4	SJRNHWY4_MID	3.49	0	0	89.96	0	0	1.87	0	0	98.13	0	0	3.91	0	0	96.09	0	0	0.72	0	0	99.28	0	0	0.75	0.82	0.80	0.82	0.80
SJR Naval st	SJRNAVLST_L0	8.89	12.70	0.00	65.44	0	0	2.69	6.26	0	90.94	0	0	5.98	10.89	0	83.00	0	0	2.02	3.10	0.00	94.84	0	0	0.57	0.76	0.71	0.79	0.71
SJR Potato Slough	SJRPOTSL_MID	3.15	12.62	55.38	12.40	0.01	0.06	3.05	10.32	65.93	19.73	0.01	0.86	2.63	0.35	93.54	0.20	0.45	2.79	2.06	0.80	93.46	0.06	1.47	2.11	0.17	0.24	0.10	0.09	0.15
SJR Turner	SJRTURNR_MID	8.81	9.28	2.55	56.31	5.3E-05	1.0E-05	3.33	5.77	0.41	90.39	6.3E-06	2.4E-03	8.69	13.75	17.87	59.41	0.01	0.16	3.23	4.83	7.34	84.49	0.03	0.05	0.49	0.76	0.53	0.72	0.62
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	1.92	4.35	55.13	4.50	0.44	10.23	2.45	4.72	77.70	10.28	0.76	3.91	2.64	0.35	83.38	0.38	6.66	6.52	1.82	0.12	80.54	0.01	13.33	4.11	0.12	0.17	0.10	0.10	0.12
Suisun Bay	SUISNB_LEN	0.81	1.22	45.93	1.24	16.49	15.94	0.92	1.66	49.51	3.61	41.10	2.95	0.80	0.23	27.56	0.40	68.55	2.42	0.60	0.03	28.62	0.01	69.16	1.54	0.11	0.13	0.10	0.10	0.11
Sycamore Slough	SYCAMOR_MID	6.50	50.69	15.18	0	0	0	5.89	76.86	16.89	2.8E-07	0	0	5.04	14.29	80.66	1.2E-31	0	0	4.23	31.10	64.66	0	0	0	0.07	0.10	0.09	0.09	0.09
White Slough	WHITESL_L0	22.32	11.88	17.97	25.51	1.7E-08	6.0E-11	16.54	12.10	16.87	54.46	3.7E-09	6.1E-05	9.89	7.76	82.34	3.8E-03	3.0E-05	5.3E-04	11.19	12.92	75.64	0.24	4.2E-04	6.4E-04	0.26	0.50	0.09	0.10	0.24
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	14.83	22.63	29.02	22.45	5.4E-08	0	12.45	13.97	21.21	52.32	2.2E-09	2.3E-04	8.74	7.78	83.47	2.4E-03	4.0E-05	5.6E-04	5.28	14.84	79.82	0.05	5.0E-04	7.3E-04	0.25	0.48	0.09	0.09	0.23

Table 6D.3 Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2005

		First Quarter Inflow Percentage						Second Quarter Inflow Percentage						Third Quarter Inflow Percentage						Fourth Quarter Inflow Percentage						Estimated Waterborne Selenium Concentrations (μg/L)				
	Inflow Source ➔	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**					
	Inflow Location ➔	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***					
DSM2 Output Water Location	**Selenium (μg/L) ➔**	0.11	0.10	0.09	0.85	0.10	0.23	0.11	0.10	0.09	0.85	0.10	0.23	0.11	0.10	0.09	0.85	0.10	0.23	0.11	0.10	0.09	0.85	0.10	0.23	**1st Quarter**	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
	Location ID																													
Big Break	BIGBRK_MID	5.87	7.57	83.73	2.41	0.24	0.18	2.90	17.21	52.77	26.69	1.6E-03	0.43	3.31	2.21	88.77	1.70	3.98	0.03	2.39	0.24	90.17	0.01	6.48	0.70	0.11	0.30	0.10	0.09	0.15
Cache Slough	CACHS_LEN	4.89	2.2E-07	93.64	8.E-07	3.8E-07	1.47	1.48	7.1E-07	94.13	8.0E-07	1.1E-08	4.38	1.94	1.7E-05	98.02	1.0E-05	1.6E-06	0.05	2.30	1.2E-05	92.72	4.6E-07	0.00	4.98	0.09	0.10	0.09	0.10	0.09
Cache Slough Ryer	CACHSR_MID	8.13	3.0E-07	91.14	1.2E-06	1.3E-06	0.73	3.74	2.5E-08	91.89	1.0E-07	2.9E-08	4.38	2.15	5.6E-07	97.77	2.6E-07	4.5E-09	0.08	2.66	8.8E-07	96.37	1.9E-08	7.6E-06	0.97	0.09	0.10	0.09	0.09	0.09
Cosumnes R.	COSR_LEN	0	100.00	0	0	0	0	0.00	100.00	0.00	0	0	0	0	100	0	0	0	0	1.2E-04	100.00	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Franks Tract	FRANKST_MID	8.65	11.65	72.50	7.E+00	0.19	0.05	4.63	16.63	26.97	51.74	1.1E-04	0.03	4.27	3.20	89.93	1.81	0.77	0.02	3.17	0.81	94.16	0.06	1.74	0.05	0.15	0.49	0.11	0.09	0.21
Little Holland Tract	LHOLND_L0	97.11	3.2E-09	2.88	9.E-09	3.9E-09	0.01	44.12	6.5E-09	53.25	2E-08	1.2E-08	2.63	18.61	5.6E-07	81.24	0.00	0.00	0.16	46.22	6.1E-08	53.77	2.8E-08	2.6E-09	0.01	0.11	0.10	0.09	0.10	0.10
Middle R Bullfrog	MIDRBULFRG_LEN	13.67	9.76	28.26	48.24	0.08	0.01	5.55	5.64	2.70	86.11	7.1E-05	8.4E-04	7.43	12.50	53.07	26.88	0.12	3.1E-03	5.54	8.75	65.65	19.67	0.39	1.1E-03	0.46	0.75	0.30	0.24	0.44
Mildred Island	MILDDRISL_MID	12.36	11.39	32.28	43.87	8.4E-02	0.01	4.81	6.98	2.78	85.43	3.6E-05	6.7E-04	6.73	12.68	65.46	14.98	0.15	3.9E-03	4.81	7.16	77.85	9.71	0.47	1.8E-03	0.43	0.74	0.21	0.17	0.38
Mok. R. below Cosum.	MOKBCOS_LEN	2.18	97.82	0	0.00	0	0	0.53	99.47	0	0	0	0	3.05	96.95	0	0	0	0	3.00	97.00	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Mok. R. downstream Cosum.	MOKDCOS_MID	2.22	97.78	0	0.00	0	0	0.53	99.47	0	0	0	0	3.05	96.95	0	0	0	0	2.93	97.07	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Old R near Paradise Cut	OLDRNPARADSEC_MID	8.95	4.7E-05	1.5E-03	91.05	1.4E-05	1.4E-06	1.43	1.7E-07	1.6E-05	98.57	1.7E-08	3.5E-10	6.64	0	5.E-09	93.36	0	0	14.49	0.24	3.16	82.09	0.02	8.1E-05	0.78	0.84	0.80	0.72	0.79
Paradise Cut	PARADSECUT_LEN	10.28	1.6E-07	6.8E-07	89.72	1.6E-11	1.7E-08	0.82	0	0	99.18	0	0	2.39	0	0	97.61	0	0	1.08	0	0	98.92	0	0	0.77	0.84	0.83	0.84	0.82
Port of Stockton	PORTOSTOCK_L0	4.70	0	0	95.30	0	0	2.83	0	0	97.16	0	0	2.20	0	0	97.80	0	0	2.20	0	0	97.79	0	0	0.82	0.83	0.83	0.83	0.83
Sac. R. at Isleton	SACRISLTON_L0	0.55	0	99.45	0.00	0	0	0.18	0	99.82	0.00	0	0	0.45	0	99.55	0.00	0	0	0.41	0	99.59	0	0	8.2E-08	0.09	0.09	0.09	0.09	0.09
Sac River RM 44	SACR44_L0	0.21	0	99.79	0.00	0	0	0.07	0	99.93	0.00	0	0	0.14	0	99.86	0.00	0	0	0.17	0	99.83	0	0	0	0.09	0.09	0.09	0.09	0.09
Sandmound Sl.	SANDMND_MID	10.51	10.17	74.35	4.65	0.25	0.07	5.35	18.03	32.15	44.41	1.5E-04	0.06	5.61	3.13	87.97	2.10	1.17	0.02	3.93	0.55	92.97	0.03	2.45	0.07	0.13	0.43	0.11	0.09	0.19
Sherman Island	SHERMNILND_L0	4.89	5.04	87.74	1.52	0.56	0.23	2.43	14.17	61.17	21.31	0.03	0.89	2.76	1.84	86.03	1.72	7.62	0.04	1.95	0.11	84.69	0.01	11.76	1.48	0.10	0.26	0.10	0.09	0.14
SJR Bowman	SJRBOWMN_MID	1.10	0	0.00	98.90	0	0	0.45	0	0	99.55	0	0	2.06	0	0	97.94	0	0	0.80	0	0	99.20	0	0	0.84	0.85	0.83	0.84	0.84
SJR N Hwy4	SJRNHWY4_MID	1.89	0	0.00	98.11	0	0	0.59	0	0	99.41	0	0	2.64	0	0	97.36	0	0	1.94	0.00	0	98.06	0	0	0.84	0.85	0.83	0.84	0.84
SJR Naval st	SJRNAVLST_L0	4.70	5.45	0.00	89.85	0	0	1.06	5.10	0	93.84	0	0	4.11	9.43	0	86.46	0	0	4.97	12.46	0	82.57	0	0	0.77	0.80	0.75	0.72	0.76
SJR Potato Slough	SJRPOTSL_MID	6.24	16.03	71.18	6.45	0.07	0.03	2.65	23.15	38.61	35.59	1.1E-05	0.01	2.75	2.58	93.40	0.83	0.42	0.01	2.16	1.30	95.35	0.02	1.04	0.13	0.14	0.36	0.10	0.09	0.17
SJR Turner	SJRTURNR_MID	6.75	4.55	1.37	87.31	0.01	0	1.49	3.20	0.00	95.31	0	0	6.05	11.77	4.90	77.27	0.01	8.4E-05	5.55	16.96	10.99	66.44	0.06	7.4E-05	0.76	0.81	0.68	0.60	0.71
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	4.87	5.29	87.53	1.67	0.37	0.27	2.37	13.56	62.61	20.61	0.02	0.84	2.82	1.68	87.76	1.46	6.24	0.03	2.05	0.14	86.70	0.01	9.68	1.42	0.10	0.25	0.10	0.09	0.14
Suisun Bay	SUISNB_LEN	2.63	1.36	66.87	0.33	28.58	0.23	1.35	6.21	59.91	8.33	22.38	1.82	0.83	0.82	31.47	1.16	65.65	0.07	0.68	0.05	32.01	0.03	66.56	0.68	0.10	0.16	0.11	0.10	0.11
Sycamore Slough	SYCAMOR_MID	14.41	68.02	17.57	8.8E-17	0	3.5E-29	3.66	95.02	1.31	1.E-18	0	3.9E-33	4.79	40.41	54.81	2.9E-20	0	1.1E-32	5.24	32.04	62.72	2.6E-18	7.7E-14	1.0E-30	0.10	0.10	0.09	0.09	0.10
White Slough	WHITESL_L0	47.62	12.39	33.06	6.93	8.2E-04	2.7E-06	15.95	8.06	2.95	73.04	1.4E-05	1.5E-07	10.03	26.20	63.17	0.61	3.0E-05	8.1E-08	9.32	12.33	78.34	0.01	4.6E-04	4.6E-08	0.15	0.65	0.10	0.09	0.25
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	20.77	29.09	44.03	6.11	2.4E-04	3.6E-06	14.40	8.89	3.00	73.72	7.9E-06	0	9.10	26.19	64.27	0.45	3.1E-05	0	6.26	14.39	79.35	1.9E-03	6.8E-04	0	0.14	0.65	0.10	0.09	0.25

Table 6D.4 Calculation of Quarterly Average Selenium Concentrations for DSM2 Output Locations Based on Percentage of Flow at Each Location from Different Sources: Year 2007

		First Quarter Inflow Percentage						Second Quarter Inflow Percentage						Third Quarter Inflow Percentage						Fourth Quarter Inflow Percentage						Estimated Waterborne Selenium Concentrations (µg/L)				
	Inflow Source →	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**	**Delta Ag.**	**East Delta Tributaries**	**Sac. R.**	**San Joaq. R.**	**Martinez/ Suisun Bay**	**Yolo Bypass**					
	Inflow Location →	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	***Mildred Island, Center***	***Mokelumne Calaveras Cosumnes Rivers***	***Freeport***	***Vernalis***	***San Joaq. R. near Mallard Island***	***Sac. R. below Knights Landing***	**1st Quarter**	**2nd Quarter**	**3rd Quarter**	**4th Quarter**	**Annual**
	Selenium (µg/L) →	0.11	0.10	0.09	0.58	0.10	0.23	0.11	0.10	0.09	0.58	0.10	0.23	0.11	0.10	0.09	0.58	0.10	0.23	0.11	0.10	0.09	0.58	0.10	0.23					
DSM2 Output Water Location	**Location ID**																													
Big Break	BIGBRK_MID	2.66	1.75	93.01	0.07	2.30	0.21	4.40	3.10	84.13	4.24	1.24	2.89	3.58	0.32	81.60	0.79	9.45	4.27	2.60	0.11	84.06	0.04	8.53	4.65	0.09	0.12	0.10	0.10	0.10
Cache Slough	CACHS_LEN	1.86	1.4E-05	97.14	2.2E-07	2.8E-05	1.01	1.99	5.1E-04	88.84	8.8E-04	1.6E-05	9.17	1.92	9.1E-06	89.20	1.9E-05	1.6E-06	8.88	1.64	1.9E-05	91.73	8.5E-06	5.1E-04	6.62	0.09	0.10	0.10	0.10	0.10
Cache Slough Ryer	CACHSR_MID	2.85	1.8E-06	96.46	4.7E-08	1.5E-05	0.68	2.66	1.2E-04	88.76	1.8E-04	1.4E-06	8.58	2.16	1.5E-05	88.35	3.1E-05	3.1E-07	9.49	1.96	4.5E-06	90.83	2.8E-06	1.9E-04	7.21	0.09	0.10	0.10	0.10	0.10
Cosumnes R.	COSR_LEN	0.00	100.00	0	0	0	0.00	0.01	99.99	0	0	0	0	0.09	99.91	0	0	0	0	0	100.00	0	0	0	0.00	0.10	0.10	0.10	0.10	0.10
Franks Tract	FRANKST_MID	3.85	4.08	90.69	0.32	0.94	0.11	6.16	5.35	77.86	9.10	0.16	1.38	4.86	0.34	88.03	0.84	2.96	2.98	3.19	0.32	91.15	0.17	2.23	2.95	0.09	0.14	0.10	0.10	0.11
Little Holland Tract	LHOLND_L0	29.80	0.00	69.38	1.2E-07	5.3E-05	0.81	22.80	8.0E-05	71.18	1.1E-04	5.2E-06	6.02	18.52	2.4E-05	73.18	0.00	4.9E-07	8.30	21.64	5.2E-07	71.72	1.4E-06	4.9E-05	6.64	0.10	0.10	0.11	0.10	0.10
Middle R Bullfrog	MIDRBULFRG_LEN	8.32	10.69	59.08	21.39	0.48	0.04	9.69	10.67	38.75	40.64	0.03	0.22	8.41	3.92	81.16	4.51	0.87	1.14	5.81	4.90	72.42	15.36	0.57	0.94	0.20	0.29	0.12	0.17	0.19
Mildred Island	MILDDRISL_MID	7.42	11.13	68.24	12.63	0.54	0.04	8.53	10.39	42.57	38.23	0.03	0.25	6.49	1.12	88.25	1.83	1.00	1.30	4.91	4.55	80.81	7.99	0.66	1.08	0.15	0.28	0.10	0.13	0.17
Mok. R. below Cosum.	MOKBCOS_LEN	1.46	98.54	0	0	0	0	6.32	93.68	6.5E-04	0	0	0	15.09	84.81	0.10	6.2E-35	0	0	2.30	97.70	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Mok. R. downstream Cosum.	MOKDCOS_MID	1.46	98.54	0	0	0	0	6.42	93.58	0	0	0	0	15.19	84.81	3.2E-04	0	0	0	2.27	97.73	0	0	0	0	0.10	0.10	0.10	0.10	0.10
Old R near Paradise Cut	OLDRNPARADSEC_MID	3.95	5E-12	3E-06	96.05	1.7E-16	2.5E-17	15.73	1.81	12.66	69.68	0.02	0.10	10.18	1.9E-05	1.6E-04	89.82	6.9E-08	6.5E-07	2.31	9.2E-04	0.01	97.68	0	9.7E-05	0.56	0.43	0.53	0.57	0.52
Paradise Cut	PARADSECUT_LEN	1.91	0	0	98.09	0	0	4.98	0.11	0.61	94.29	6.7E-04	3.7E-03	7.14	0	0	92.86	0	0	1.24	4.1E-03	0.05	98.71	4.1E-04	4.5E-04	0.57	0.55	0.55	0.57	0.56
Port of Stockton	PORTOSTOCK_L0	1.48	0	0	98.52	0	0	2.29	0	0	97.71	0	0	6.32	0.04	0	93.64	0	0	7.16	0.05	0	92.78	0	0	0.57	0.57	0.55	0.55	0.56
Sac. R. at Isleton	SACRISLTON_L0	0.45	0	99.55	0	0	2.1E-06	0.63	8.8E-05	99.36	5.7E-08	0	0.01	0.49	0	99.51	0	0	2.9E-04	0.39	1.0E-08	99.61	0	6.7E-07	0.01	0.09	0.09	0.09	0.09	0.09
Sac River RM 44	SACR44_L0	0.20	0	99.80	0	0	0	0.30	0	99.70	0	0	0	0.15	0	99.85	0	0	0	0.11	0	99.89	0	0	0	0.09	0.09	0.09	0.09	0.09
Sandmound Sl.	SANDMND_MID	4.47	3.23	90.83	0.17	1.17	0.13	7.20	4.64	79.23	6.98	0.23	1.71	6.15	0.39	84.96	0.98	4.06	3.46	3.79	0.22	89.26	0.10	3.11	3.51	0.09	0.13	0.10	0.10	0.10
Sherman Island	SHERMNILND_L0	2.14	0.95	92.16	0.04	4.49	0.23	3.69	2.31	83.94	2.94	4.01	3.11	2.99	0.32	77.36	0.77	14.22	4.34	2.22	0.06	75.89	0.03	17.11	4.68	0.09	0.11	0.10	0.10	0.10
SJR Bowman	SJRBOWMN_MID	0.88	0	0	99.12	0	0	3.52	0	0	96.48	0	0	8.49	2.5E-04	0	91.51	0	0	0.91	0	0	99.09	0	0	0.58	0.56	0.54	0.58	0.56
SJR N Hwy4	SJRNHWY4_MID	1.82	2.8E-08	0	98.18	0	0	4.35	1.4E-07	0	95.65	0	0	12.54	0.08	4.0E-26	87.39	0	0	1.89	1.3E-04	0	98.11	0	0	0.57	0.56	0.52	0.57	0.56
SJR Naval st	SJRNAVLST_L0	4.83	6.83	0	88.35	0	0	5.86	11.12	1.3E-06	83.02	0	0	12.06	40.15	3.4E-03	47.78	6.2E-07	6.3E-06	4.73	6.37	2.5E-04	88.90	5.4E-09	7.0E-09	0.52	0.50	0.33	0.53	0.47
SJR Potato Slough	SJRPOTSL_MID	2.91	5.22	91.00	0.15	0.61	0.10	4.89	5.67	79.70	8.49	0.10	1.16	3.16	0.19	91.86	0.46	1.88	2.44	2.37	0.33	93.43	0.10	1.44	2.33	0.09	0.13	0.10	0.09	0.10
SJR Turner	SJRTURNR_MID	7.22	10.11	10.82	71.76	0.08	0.01	7.49	11.95	7.23	73.31	2.9E-03	0.02	11.09	11.29	65.50	11.02	0.46	0.63	6.16	6.57	36.18	50.55	0.19	0.35	0.44	0.45	0.15	0.34	0.35
SJR/Pt. Antioch/fish pier	ASRANTFSH_MID	2.17	1.01	92.90	0.04	3.62	0.26	3.74	2.30	84.37	3.04	3.24	3.31	3.00	0.27	79.62	0.65	12.05	4.40	2.27	0.07	78.73	0.03	14.08	4.82	0.09	0.11	0.10	0.10	0.10
Suisun Bay	SUISNB_LEN	0.87	0.23	46.77	0.01	51.97	0.14	0.94	0.51	31.58	0.43	65.55	0.98	0.84	0.16	21.30	0.36	76.08	1.25	0.59	0.02	21.39	0.01	76.63	1.36	0.10	0.10	0.10	0.10	0.10
Sycamore Slough	SYCAMOR_MID	10.20	72.58	17.22	5.1E-10	9.7E-14	4.3E-29	13.62	50.90	35.47	0.01	4.0E-09	1.1E-07	5.33	3.90	90.77	1.9E-16	3.8E-25	1.1E-22	3.69	20.36	75.95	6.0E-19	1.1E-37	2.4E-31	0.10	0.10	0.09	0.09	0.10
White Slough	WHITESL_L0	20.35	16.73	61.67	1.25	4.8E-03	2.4E-04	33.31	13.41	23.49	29.78	3.9E-04	3.2E-03	15.53	1.33	83.05	0.09	1.2E-03	2.0E-03	9.35	8.62	81.98	0.04	3.7E-04	7.1E-04	0.10	0.24	0.09	0.09	0.13
White Slough DS Disappointment Sl.	WHTSLDISPONT_LEN	10.09	24.12	65.07	0.71	4.1E-03	1.9E-04	17.00	13.60	32.29	37.10	1.4E-03	0.01	7.70	1.46	90.83	1.5E-03	1.3E-03	2.2E-03	5.21	9.69	85.06	0.03	9.7E-04	2.1E-03	0.10	0.28	0.09	0.09	0.14

Table 6D.5 Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Models 1 and 2

	Year 2000								Year 2005								Year 2007							
	Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio		Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio		Concentration					Whole-body Bass[a]	Fish-to-Bass Ratio	
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish		Model 1	Model 2	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish		Model 1	Model 2	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish		Model 1	Model 2
	First Quarter								First Quarter								First Quarter							
Sacramento River RM 44	0.09	0.09	0.25	0.27	0.30	2.6	0.10	0.11	0.09	0.09	0.25	0.28	0.31	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.31	1.8	0.15	0.17
Cache Slough Ryer[b]	0.10	0.10	0.28	0.31	0.34	1.5	0.21	0.23	0.09	0.09	0.26	0.29	0.31	1.7	0.17	0.18	0.09	0.09	0.26	0.28	0.31	2.5	0.11	0.12
San Joaquin River Potato Slough	0.17	0.17	0.47	0.52	0.57	1.4	0.38	0.42	0.14	0.14	0.40	0.44	0.48	1.3	0.33	0.37	0.09	0.09	0.26	0.28	0.31	2.5	0.11	0.13
Franks Tract	0.19	0.19	0.53	0.58	0.64	1.6	0.35	0.39	0.15	0.15	0.41	0.45	0.49	1.1	0.39	0.43	0.09	0.09	0.26	0.29	0.32	3.0	0.10	0.11
Big Break	0.13	0.13	0.35	0.39	0.43	1.6	0.25	0.28	0.11	0.11	0.31	0.34	0.37	1.0	0.33	0.37	0.09	0.09	0.26	0.28	0.31	2.8	0.10	0.11
Middle River Bullfrog	0.31	0.31	0.86	0.95	1.05	NA	NA	NA	0.46	0.46	1.29	1.42	1.56	1.9	0.7	0.8	0.20	0.20	0.55	0.61	0.67	2.1	0.3	0.3
Old River near Paradise Cut[c]	0.73	0.73	2.05	2.25	2.48	NA	NA	NA	0.78	0.78	2.19	2.41	2.66	2.4	1.0	1.1	0.56	0.56	1.57	1.73	1.90	NA	NA	NA
Knights Landing[d]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[e]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82
	Second Quarter								Second Quarter								Second Quarter							
Sacramento River RM 44	0.09	0.09	0.25	0.28	0.30	2.6	0.11	0.12	0.09	0.09	0.25	0.28	0.30	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.31	1.8	0.15	0.17
Cache Slough Ryer[b]	0.11	0.11	0.32	0.35	0.38	1.5	0.23	0.26	0.10	0.10	0.27	0.30	0.33	1.7	0.17	0.19	0.10	0.10	0.29	0.32	0.35	2.5	0.12	0.14
San Joaquin River Potato Slough	0.24	0.24	0.67	0.74	0.81	1.4	0.54	0.60	0.36	0.36	1.02	1.12	1.23	1.3	0.86	0.94	0.13	0.13	0.38	0.42	0.46	2.5	0.17	0.18
Franks Tract	0.27	0.27	0.76	0.83	0.92	1.6	0.51	0.56	0.49	0.49	1.36	1.50	1.65	1.1	1.31	1.44	0.14	0.14	0.39	0.43	0.47	3.0	0.14	0.16
Big Break	0.20	0.20	0.55	0.60	0.66	1.6	0.39	0.43	0.30	0.30	0.83	0.91	1.00	1.0	0.89	0.98	0.12	0.12	0.33	0.36	0.39	2.8	0.13	0.14
Middle River Bullfrog	0.61	0.61	1.71	1.88	2.07	NA	NA	NA	0.75	0.75	2.09	2.30	2.53	1.9	1.2	1.3	0.29	0.29	0.82	0.90	0.99	2.1	0.4	0.5
Old River near Paradise Cut[c]	0.68	0.68	1.89	2.08	2.29	NA	NA	NA	0.84	0.84	2.35	2.59	2.84	2.4	1.1	1.2	0.43	0.43	1.22	1.34	1.47	NA	NA	NA
Knights Landing[d]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[e]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82
	Third Quarter								Third Quarter								Third Quarter							
Sacramento River RM 44	0.09	0.09	0.25	0.28	0.30	2.6	0.11	0.12	0.09	0.09	0.25	0.28	0.31	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.31	1.8	0.15	0.17
Cache Slough Ryer[b]	0.11	0.11	0.31	0.34	0.37	1.5	0.22	0.25	0.09	0.09	0.25	0.28	0.31	1.7	0.16	0.18	0.10	0.10	0.29	0.32	0.35	2.5	0.13	0.14
San Joaquin River Potato Slough	0.10	0.10	0.27	0.30	0.32	1.4	0.22	0.24	0.10	0.10	0.27	0.30	0.33	1.3	0.23	0.25	0.10	0.10	0.27	0.30	0.33	2.5	0.12	0.13
Franks Tract	0.10	0.10	0.28	0.31	0.34	1.6	0.19	0.20	0.11	0.11	0.29	0.32	0.36	1.1	0.28	0.31	0.10	0.10	0.28	0.31	0.34	3.0	0.10	0.11
Big Break	0.10	0.10	0.29	0.32	0.35	1.6	0.20	0.22	0.10	0.10	0.29	0.32	0.35	1.0	0.31	0.35	0.10	0.10	0.28	0.31	0.34	2.8	0.11	0.12
Middle River Bullfrog	0.20	0.20	0.57	0.63	0.69	NA	NA	NA	0.30	0.30	0.83	0.91	1.01	1.9	0.5	0.5	0.12	0.12	0.32	0.36	0.39	2.1	0.2	0.2
Old River near Paradise Cut[c]	0.75	0.75	2.11	2.32	2.55	NA	NA	NA	0.80	0.80	2.24	2.47	2.71	2.4	1.0	1.1	0.53	0.53	1.49	1.64	1.80	NA	NA	NA
Knights Landing[d]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[e]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82

	Year 2000								Year 2005								Year 2007							
	Concentration						Fish-to-Bass Ratio		Concentration						Fish-to-Bass Ratio		Concentration						Fish-to-Bass Ratio	
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish	Whole-body Bass[a]	Model 1	Model 2	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish	Whole-body Bass[a]	Model 1	Model 2	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 1 Fish	Model 2 Fish	Whole-body Bass[a]	Model 1	Model 2
	Fourth Quarter								Fourth Quarter								Fourth Quarter							
Sacramento River RM 44	0.09	0.09	0.25	0.28	0.30	2.6	0.11	0.12	0.09	0.09	0.25	0.28	0.31	1.5	0.19	0.21	0.09	0.09	0.25	0.28	0.30	1.8	0.15	0.17
Cache Slough Ryer[b]	0.10	0.10	0.29	0.31	0.35	1.5	0.21	0.23	0.09	0.09	0.26	0.28	0.31	1.7	0.16	0.18	0.10	0.10	0.28	0.31	0.34	2.5	0.12	0.13
San Joaquin River Potato Slough	0.09	0.09	0.26	0.29	0.32	1.4	0.21	0.23	0.09	0.09	0.25	0.28	0.31	1.3	0.21	0.24	0.09	0.09	0.26	0.29	0.32	2.5	0.12	0.13
Franks Tract	0.10	0.10	0.27	0.29	0.32	1.6	0.18	0.20	0.09	0.09	0.26	0.28	0.31	1.1	0.25	0.27	0.10	0.10	0.27	0.30	0.32	3.0	0.10	0.11
Big Break	0.10	0.10	0.27	0.30	0.33	1.6	0.19	0.21	0.09	0.09	0.26	0.28	0.31	1.0	0.28	0.31	0.10	0.10	0.27	0.30	0.33	2.8	0.11	0.12
Middle River Bullfrog	0.30	0.30	0.84	0.92	1.01	NA	NA	NA	0.24	0.24	0.68	0.74	0.82	1.9	0.4	0.4	0.17	0.17	0.47	0.52	0.57	2.1	0.2	0.3
Old River near Paradise Cut[c]	0.81	0.81	2.27	2.50	2.75	NA	NA	NA	0.72	0.72	2.01	2.21	2.43	2.4	0.9	1.0	0.57	0.57	1.59	1.75	1.93	NA	NA	NA
Knights Landing[d]	0.23	0.23	0.64	0.71	0.78	NA	NA	NA	0.23	0.23	0.64	0.71	0.78	2.2	0.3	0.4	0.23	0.23	0.64	0.71	0.78	NA	NA	NA
Vernalis[e]	0.83	0.83	2.32	2.56	2.81	1.7	1.50	1.65	0.85	0.85	2.38	2.62	2.88	1.9	1.38	1.52	0.58	0.58	1.62	1.79	1.97	2.4	0.74	0.82

Notes:

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Models 1 and 2 used the default K_d (1000) and the average selenium trophic transfer factors to aquatic insects (2.8) and fish (1.1 for all trophic levels).

Model 1 = TL-3 Fish Eating Invertebrates

Model 2 = TL-4 Fish Eating TL-3 Fish

Invert. = invertebrate

K_d = particulate concentration/water concentration ratio

µg/g, dw = micrograms per gram, dry weight

NA = not available; bass not collected here

RM = river mile

TL = trophic level

a. Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010a).

b. Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

c. Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

d. Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calcula mean whole-body largemouth bass and ratios.

e. Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999–2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and ye 2007 were used for Year 2007 estimates.

Table 6D.6 Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Model 2 with Estimated K_d from All Years Regression for Model 3

	Year 2000							Year 2005							Year 2007						
	Concentration						Fish-to-Bass Ratio	Concentration						Fish-to-Bass Ratio	Concentration						Fish-to-Bass Ratio
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 3 Fish	K_d	Whole-body Bass[a]	Model 3	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 3 Fish	K_d	Whole-body Bass[a]	Model 3	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 3 Fish	K_d	Whole-body Bass[a]	Model 3
	First Quarter							First Quarter							First Quarter						
Sacramento River RM 44	0.09	0.54	1.50	1.81	6060	2.6	0.69	0.09	0.54	1.50	1.81	5945	1.5	1.25	0.09	0.54	1.50	1.81	5946	1.8	0.98
Cache Slough Ryer[b]	0.10	0.54	1.50	1.82	5389	1.5	1.22	0.09	0.54	1.50	1.82	5783	1.7	1.05	0.09	0.54	1.50	1.81	5852	2.5	0.71
San Joaquin River Potato Slough	0.17	0.55	1.53	1.85	3229	1.4	1.36	0.14	0.54	1.52	1.84	3824	1.3	1.41	0.09	0.54	1.50	1.81	5819	2.5	0.73
Franks Tract	0.19	0.55	1.53	1.85	2904	1.6	1.13	0.15	0.54	1.52	1.84	3724	1.1	1.61	0.09	0.54	1.50	1.82	5762	3.0	0.61
Big Break	0.13	0.54	1.51	1.83	4295	1.6	1.18	0.11	0.54	1.51	1.82	4873	1.0	1.79	0.09	0.54	1.50	1.81	5850	2.8	0.64
Middle River Bullfrog	0.31	0.56	1.56	1.88	1801	NA	NA	0.46	0.56	1.57	1.90	1221	1.9	1.0	0.20	0.55	1.53	1.86	2773	2.1	0.87
Old River near Paradise Cut[c]	0.73	0.57	1.60	1.93	780	NA	NA	0.78	0.57	1.60	1.94	729	2.4	0.8	0.56	0.57	1.58	1.92	1007	NA	NA
Knights Landing[d]	0.23	0.55	1.54	1.87	2394	NA	NA	0.23	0.55	1.54	1.87	2394	2.2	0.8	0.23	0.55	1.54	1.87	2394	NA	NA
Vernalis[e]	0.83	0.57	1.60	1.94	689	1.7	1.14	0.85	0.57	1.60	1.94	674	1.9	1.02	0.58	0.57	1.59	1.92	976	2.4	0.80
	Second Quarter							Second Quarter							Second Quarter						
Sacramento River RM 44	0.09	0.54	1.50	1.81	5952	2.6	0.69	0.09	0.54	1.50	1.81	5947	1.5	1.25	0.09	0.54	1.50	1.81	5944	1.8	0.98
Cache Slough Ryer[b]	0.11	0.54	1.51	1.83	4777	1.5	1.22	0.10	0.54	1.50	1.82	5538	1.7	1.05	0.10	0.54	1.50	1.82	5241	2.5	0.72
San Joaquin River Potato Slough	0.24	0.55	1.54	1.87	2309	1.4	1.38	0.36	0.56	1.56	1.89	1537	1.3	1.45	0.13	0.54	1.52	1.84	4020	2.5	0.74
Franks Tract	0.27	0.55	1.55	1.87	2048	1.6	1.14	0.49	0.56	1.58	1.91	1159	1.1	1.67	0.14	0.54	1.52	1.84	3921	3.0	0.61
Big Break	0.20	0.55	1.53	1.86	2800	1.6	1.20	0.30	0.55	1.55	1.88	1876	1.0	1.84	0.12	0.54	1.51	1.83	4645	2.8	0.64
Middle River Bullfrog	0.61	0.57	1.59	1.92	928	NA	NA	0.75	0.57	1.60	1.93	764	1.9	1.0	0.29	0.55	1.55	1.88	1896	2.1	0.9
Old River near Paradise Cut[c]	0.68	0.57	1.59	1.93	842	NA	NA	0.84	0.57	1.60	1.94	682	2.4	0.8	0.43	0.56	1.57	1.90	1291	NA	NA
Knights Landing[d]	0.23	0.55	1.54	1.87	2394	NA	NA	0.23	0.55	1.54	1.87	2394	2.2	0.8	0.23	0.55	1.54	1.87	2394	NA	NA
Vernalis[e]	0.83	0.57	1.60	1.94	689	1.7	1.14	0.85	0.57	1.60	1.94	674	1.9	1.02	0.58	0.57	1.59	1.92	976	2.4	0.80
	Third Quarter							Third Quarter							Third Quarter						
Sacramento River RM 44	0.09	0.54	1.50	1.81	5947	2.6	0.69	0.09	0.54	1.50	1.81	5946	1.5	1.25	0.09	0.54	1.50	1.81	5946	1.8	0.98
Cache Slough Ryer[b]	0.11	0.54	1.51	1.82	4942	1.5	1.22	0.09	0.54	1.50	1.81	5914	1.7	1.05	0.10	0.54	1.51	1.82	5184	2.5	0.72
San Joaquin River Potato Slough	0.10	0.54	1.50	1.82	5592	1.4	1.34	0.10	0.54	1.50	1.82	5523	1.3	1.39	0.10	0.54	1.50	1.82	5557	2.5	0.73
Franks Tract	0.10	0.54	1.50	1.82	5412	1.6	1.10	0.11	0.54	1.51	1.82	5121	1.1	1.59	0.10	0.54	1.50	1.82	5393	3.0	0.61
Big Break	0.10	0.54	1.50	1.82	5227	1.6	1.17	0.10	0.54	1.51	1.82	5159	1.0	1.79	0.10	0.54	1.50	1.82	5291	2.8	0.64
Middle River Bullfrog	0.20	0.55	1.54	1.86	2688	NA	NA	0.30	0.55	1.55	1.88	1868	1.9	1.0	0.12	0.54	1.51	1.83	4656	2.1	0.86
Old River near Paradise Cut[c]	0.75	0.57	1.60	1.93	757	NA	NA	0.80	0.57	1.60	1.94	714	2.4	0.8	0.53	0.56	1.58	1.91	1061	NA	NA
Knights Landing[d]	0.23	0.55	1.54	1.87	2394	NA	NA	0.23	0.55	1.54	1.87	2394	2.2	0.8	0.23	0.55	1.54	1.87	2394	NA	NA
Vernalis[e]	0.83	0.57	1.60	1.94	689	1.7	1.14	0.85	0.57	1.60	1.94	674	1.9	1.02	0.58	0.57	1.59	1.92	976	2.4	0.80

DSM2 Delta Water Location	Year 2000							Year 2005							Year 2007						
	Concentration				K_d	Whole-body Bass[a]	Fish-to-Bass Ratio	Concentration				K_d	Whole-body Bass[a]	Fish-to-Bass Ratio	Concentration				K_d	Whole-body Bass[a]	Fish-to-Bass Ratio
	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 3 Fish			Model 3	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 3 Fish			Model 3	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 3 Fish			Model 3
	Fourth Quarter							Fourth Quarter							Fourth Quarter						
Sacramento River RM 44	0.09	0.54	1.50	1.81	5948	2.6	0.69	0.09	0.54	1.50	1.81	5946	1.5	1.25	0.09	0.54	1.50	1.81	5947	1.8	0.98
Cache Slough Ryer[b]	0.10	0.54	1.50	1.82	5261	1.5	1.22	0.09	0.54	1.50	1.81	5830	1.7	1.05	0.10	0.54	1.50	1.82	5345	2.5	0.71
San Joaquin River Potato Slough	0.09	0.54	1.50	1.82	5704	1.4	1.34	0.09	0.54	1.50	1.81	5885	1.3	1.39	0.09	0.54	1.50	1.82	5678	2.5	0.73
Franks Tract	0.10	0.54	1.50	1.82	5621	1.6	1.10	0.09	0.54	1.50	1.81	5859	1.1	1.59	0.10	0.54	1.50	1.82	5596	3.0	0.61
Big Break	0.10	0.54	1.50	1.82	5534	1.6	1.17	0.09	0.54	1.50	1.82	5809	1.0	1.78	0.10	0.54	1.50	1.82	5470	2.8	0.64
Middle River Bullfrog	0.30	0.55	1.55	1.88	1859	NA	NA	0.24	0.55	1.54	1.87	2283	1.9	1.0	0.17	0.55	1.53	1.85	3241	2.1	0.87
Old River near Paradise Cut[c]	0.81	0.57	1.60	1.94	704	NA	NA	0.72	0.57	1.60	1.93	795	2.4	0.8	0.57	0.57	1.58	1.92	994	NA	NA
Knights Landing[d]	0.23	0.55	1.54	1.87	2394	NA	NA	0.23	0.55	1.54	1.87	2394	2.2	0.8	0.23	0.55	1.54	1.87	2394	NA	NA
Vernalis[e]	0.83	0.57	1.60	1.94	689	1.7	1.14	0.85	0.57	1.60	1.94	674	1.9	1.02	0.58	0.57	1.59	1.92	976	2.4	0.80

Notes:

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Model 3 used the average selenium trophic transfer factors to aquatic insects (2.8) and fish (1.1 for all trophic levels).

Model 3 = Model 2 (TL-4 Fish Eating TL-3 Fish) with K_d estimated using all years regression (log K_d = 2.76-0.97(logDSM2))

Invert. = invertebrate

K_d = particulate concentration/water concentration ratio

µg/g, dw = micrograms per gram, dry weight

NA = not available; bass not collected here

RM = river mile

TL = trophic level

a. Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010a).

b. Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

c. Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

d. Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calc geometric mean whole-body largemouth bass and ratios.

e. Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999-2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 200 2007 were used for Year 2007 estimates.

Table 6D.7 Selenium Bioaccumulation from Water (µg/L) to Particulates and Fish (µg/g, dw) Using Model 2 with Estimated K_d from Normal/Wet Years Regression for Model 4 and Dry Years Regression for Model 5

	Year 2000							Year 2005							Year 2007						
	Concentration						Fish-to-Bass Ratio	Concentration						Fish-to-Bass Ratio	Concentration						Fish-to-Bass Ratio
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d	Whole-body Bass[a]	Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d	Whole-body Bass[a]	Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 5 Fish	K_d	Whole-body Bass[a]	Model 5
	First Quarter							First Quarter							First Quarter						
Sacramento River RM 44	0.09	0.44	1.24	1.49	4997	2.6	0.57	0.09	0.44	1.24	1.50	4909	1.5	1.03	0.09	0.73	2.03	2.46	8063	1.8	1.33
Cache Slough Ryer[b]	0.10	0.45	1.25	1.51	4481	1.5	1.01	0.09	0.44	1.24	1.50	4784	1.7	0.87	0.09	0.73	2.03	2.46	7929	2.5	0.97
San Joaquin River Potato Slough	0.17	0.47	1.32	1.59	2786	1.4	1.17	0.14	0.46	1.30	1.57	3260	1.3	1.20	0.09	0.73	2.03	2.46	7883	2.5	0.99
Franks Tract	0.19	0.48	1.33	1.61	2525	1.6	0.98	0.15	0.46	1.30	1.57	3181	1.1	1.37	0.09	0.73	2.03	2.46	7802	3.0	0.82
Big Break	0.13	0.46	1.28	1.55	3630	1.6	1.00	0.11	0.45	1.26	1.53	4082	1.0	1.50	0.09	0.73	2.03	2.46	7926	2.8	0.87
Middle River Bullfrog	0.31	0.50	1.40	1.69	1621	NA	NA	0.46	0.52	1.46	1.76	1130	1.9	0.9	0.20	0.71	2.00	2.42	3616	2.1	1.14
Old River near Paradise Cut[c]	0.73	0.55	1.53	1.85	745	NA	NA	0.78	0.55	1.54	1.86	700	2.4	0.8	0.56	0.70	1.96	2.37	1247	NA	NA
Knights Landing[d]	0.23	0.49	1.36	1.64	2111	NA	NA	0.23	0.49	1.36	1.64	2111	2.2	0.7	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis[e]	0.83	0.55	1.55	1.87	665	1.7	1.10	0.85	0.55	1.55	1.87	651	1.9	0.99	0.58	0.70	1.96	2.37	1206	2.4	0.99
	Second Quarter							Second Quarter							Second Quarter						
Sacramento River RM 44	0.09	0.44	1.24	1.50	4914	2.6	0.57	0.09	0.44	1.24	1.50	4910	1.5	1.03	0.09	0.73	2.03	2.46	8061	1.8	1.33
Cache Slough Ryer[b]	0.11	0.45	1.27	1.53	4007	1.5	1.03	0.10	0.45	1.25	1.51	4596	1.7	0.87	0.10	0.72	2.03	2.45	7061	2.5	0.96
San Joaquin River Potato Slough	0.24	0.49	1.36	1.65	2041	1.4	1.22	0.36	0.51	1.42	1.72	1399	1.3	1.32	0.13	0.72	2.02	2.44	5343	2.5	0.98
Franks Tract	0.27	0.49	1.38	1.67	1826	1.6	1.02	0.49	0.52	1.46	1.77	1077	1.1	1.55	0.14	0.72	2.02	2.44	5204	3.0	0.82
Big Break	0.20	0.48	1.34	1.62	2441	1.6	1.04	0.30	0.50	1.39	1.69	1683	1.0	1.65	0.12	0.72	2.02	2.45	6220	2.8	0.86
Middle River Bullfrog	0.61	0.54	1.50	1.81	876	NA	NA	0.75	0.55	1.53	1.85	732	1.9	1.0	0.29	0.71	1.99	2.40	2424	2.1	1.1
Old River near Paradise Cut[c]	0.68	0.54	1.51	1.83	801	NA	NA	0.84	0.55	1.55	1.87	658	2.4	0.8	0.43	0.70	1.97	2.38	1617	NA	NA
Knights Landing[d]	0.23	0.49	1.36	1.64	2111	NA	NA	0.23	0.49	1.36	1.64	2111	2.2	0.7	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis[e]	0.83	0.55	1.55	1.87	665	1.7	1.10	0.85	0.55	1.55	1.87	651	1.9	0.99	0.58	0.70	1.96	2.37	1206	2.4	0.99
	Third Quarter							Third Quarter							Third Quarter						
Sacramento River RM 44	0.09	0.44	1.24	1.50	4910	2.6	0.57	0.09	0.44	1.24	1.50	4910	1.5	1.03	0.09	0.73	2.03	2.46	8064	1.8	1.33
Cache Slough Ryer[b]	0.11	0.45	1.26	1.53	4135	1.5	1.02	0.09	0.44	1.24	1.50	4885	1.7	0.87	0.10	0.72	2.03	2.45	6980	2.5	0.96
San Joaquin River Potato Slough	0.10	0.44	1.25	1.51	4637	1.4	1.11	0.10	0.45	1.25	1.51	4584	1.3	1.15	0.10	0.72	2.03	2.46	7510	2.5	0.99
Franks Tract	0.10	0.45	1.25	1.51	4499	1.6	0.92	0.11	0.45	1.26	1.52	4274	1.1	1.33	0.10	0.72	2.03	2.45	7276	3.0	0.82
Big Break	0.10	0.45	1.25	1.52	4356	1.6	0.98	0.10	0.45	1.26	1.52	4304	1.0	1.49	0.10	0.72	2.03	2.45	7131	2.8	0.87
Middle River Bullfrog	0.20	0.48	1.34	1.63	2350	NA	NA	0.30	0.50	1.39	1.69	1677	1.9	0.9	0.12	0.72	2.02	2.45	6235	2.1	1.15
Old River near Paradise Cut[c]	0.75	0.55	1.53	1.85	725	NA	NA	0.80	0.55	1.54	1.86	687	2.4	0.8	0.53	0.70	1.96	2.37	1317	NA	NA
Knights Landing[d]	0.23	0.49	1.36	1.64	2111	NA	NA	0.23	0.49	1.36	1.64	2111	2.2	0.7	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis[e]	0.83	0.55	1.55	1.87	665	1.7	1.10	0.85	0.55	1.55	1.87	651	1.9	0.99	0.58	0.70	1.96	2.37	1206	2.4	0.99

DSM2 Delta Water Location	Year 2000							Year 2005							Year 2007						
	Concentration				K_d	Whole-body Bass[a]	Fish-to-Bass Ratio	Concentration				K_d	Whole-body Bass[a]	Fish-to-Bass Ratio	Concentration				K_d	Whole-body Bass[a]	Fish-to-Bass Ratio
	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish			Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish			Model 4	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 5 Fish			Model 5
	Fourth Quarter							Fourth Quarter							Fourth Quarter						
Sacramento River RM 44	0.09	0.44	1.24	1.50	4911	2.6	0.57	0.09	0.44	1.24	1.50	4909	1.5	1.03	0.09	0.73	2.03	2.46	8064	1.8	1.33
Cache Slough Ryer[b]	0.10	0.45	1.25	1.52	4383	1.5	1.02	0.09	0.44	1.24	1.50	4820	1.7	0.87	0.10	0.72	2.03	2.45	7209	2.5	0.96
San Joaquin River Potato Slough	0.09	0.44	1.24	1.50	4723	1.4	1.11	0.09	0.44	1.24	1.50	4862	1.3	1.15	0.09	0.73	2.03	2.46	7682	2.5	0.99
Franks Tract	0.10	0.44	1.24	1.51	4660	1.6	0.91	0.09	0.44	1.24	1.50	4843	1.1	1.31	0.10	0.73	2.03	2.46	7564	3.0	0.82
Big Break	0.10	0.45	1.25	1.51	4593	1.6	0.97	0.09	0.44	1.24	1.50	4804	1.0	1.47	0.10	0.72	2.03	2.46	7386	2.8	0.87
Middle River Bullfrog	0.30	0.50	1.40	1.69	1669	NA	NA	0.24	0.49	1.37	1.65	2020	1.9	0.9	0.17	0.72	2.01	2.43	4260	2.1	1.14
Old River near Paradise Cut[c]	0.81	0.55	1.54	1.87	678	NA	NA	0.72	0.54	1.52	1.84	759	2.4	0.8	0.57	0.70	1.96	2.37	1229	NA	NA
Knights Landing[d]	0.23	0.49	1.36	1.64	2111	NA	NA	0.23	0.49	1.36	1.64	2111	2.2	0.7	0.23	0.71	1.99	2.41	3098	NA	NA
Vernalis[e]	0.83	0.55	1.55	1.87	665	1.7	1.10	0.85	0.55	1.55	1.87	651	1.9	0.99	0.58	0.70	1.96	2.37	1206	2.4	0.99

Notes:

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Models 4 and 5 used the average selenium trophic transfer factors to aquatic insects (2.8) and fish (1.1 for all trophic levels).

Model 4 = Model 2 (TL-4 Fish Eating TL-3 Fish) with K_d estimated using normal/wet years regression (log K_d = 2.75-0.90(logDSM2))

Model 5 = Model 2 (TL-4 Fish Eating TL-3 Fish) with K_d estimated using dry years (2007) regression (log K_d = 2.84-1.02(logDSM2))

Invert. = invertebrate

K_d = particulate concentration/water concentration ratio

µg/g, dw = micrograms per gram, dry weight

NA = not available; bass not collected here

RM = river mile

TL = trophic level

a. Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010a).

b. Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

c. Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

d. Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calc geometric mean whole-body largemouth bass and ratios.

e. Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999-2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 200 2007 were used for Year 2007 estimates.

Table 6D.8 Selenium Bioaccumulation from Water (µg/L) to Particulates, Whole-body Fish (µg/g, dw), and Bird Eggs (µg/g, dw) Using Model 2 with Estimated K_d from Normal/Wet Years Regression for Model 4 and Dry Years Regression for Model 5

	Year 2000									Year 2005									Year 2007								
	Concentration					Whole-	Fish-to-Bass Ratio	Bird Eggs		Concentration					Whole-	Fish-to-Bass Ratio	Bird Eggs		Concentration					Whole-	Fish-to-Bass Ratio	Bird Eggs	
DSM2 Delta Water Location	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d	body Bass[a]	Model 4	From Invert.	From Fish	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d	body Bass[a]	Model 4	From Invert.	From Fish	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 5 Fish	K_d	body Bass[a]	Model 5	From Invert.	From Fish
	First Quarter									First Quarter									First Quarter								
Sacramento River RM 44	0.09	0.44	1.24	1.49	4997	2.6	0.57	2.22	2.69	0.09	0.44	1.24	1.50	4909	1.5	1.03	2.23	2.70	0.09	0.73	2.03	2.46	8063	1.8	1.33	3.66	4.43
Cache Slough Ryer[b]	0.10	0.45	1.25	1.51	4481	1.5	1.01	2.25	2.72	0.09	0.44	1.24	1.50	4784	1.7	0.87	2.23	2.70	0.09	0.73	2.03	2.46	7929	2.5	0.97	3.66	4.43
San Joaquin River Potato Slough	0.17	0.47	1.32	1.59	2786	1.4	1.17	2.37	2.87	0.14	0.46	1.30	1.57	3260	1.3	1.20	2.33	2.82	0.09	0.73	2.03	2.46	7883	2.5	0.99	3.66	4.43
Franks Tract	0.19	0.48	1.33	1.61	2525	1.6	0.98	2.40	2.90	0.15	0.46	1.30	1.57	3181	1.1	1.37	2.34	2.83	0.09	0.73	2.03	2.46	7802	3.0	0.82	3.66	4.42
Big Break	0.13	0.46	1.28	1.55	3630	1.6	1.00	2.30	2.79	0.11	0.45	1.26	1.53	4082	1.0	1.50	2.27	2.75	0.09	0.73	2.03	2.46	7926	2.8	0.87	3.66	4.43
Middle River Bullfrog	0.31	0.50	1.40	1.69	1621	NA	NA	2.52	3.05	0.46	0.52	1.46	1.76	1130	1.9	0.9	2.62	3.17	0.20	0.71	2.00	2.42	3616	2.1	1.14	3.60	4.36
Old River near Paradise Cut[c]	0.73	0.55	1.53	1.85	745	NA	NA	2.75	3.32	0.78	0.55	1.54	1.86	700	2.4	0.8	2.77	3.35	0.56	0.70	1.96	2.37	1247	NA	NA	3.53	4.27
Knights Landing[d]	0.23	0.49	1.36	1.64	2111	NA	NA	2.45	2.96	0.23	0.49	1.36	1.64	2111	2.2	0.7	2.45	2.96	0.23	0.71	1.99	2.41	3098	NA	NA	3.59	4.34
Vernalis[e]	0.83	0.55	1.55	1.87	665	1.7	1.10	2.78	3.37	0.85	0.55	1.55	1.87	651	1.9	0.99	2.79	3.37	0.58	0.70	1.96	2.37	1206	2.4	0.99	3.53	4.27
	Second Quarter									Second Quarter									Second Quarter								
Sacramento River RM 44	0.09	0.44	1.24	1.50	4914	2.6	0.57	2.23	2.70	0.09	0.44	1.24	1.50	4910	1.5	1.03	2.23	2.70	0.09	0.73	2.03	2.46	8061	1.8	1.33	3.66	4.43
Cache Slough Ryer[b]	0.11	0.45	1.27	1.53	4007	1.5	1.03	2.28	2.76	0.10	0.45	1.25	1.51	4596	1.7	0.87	2.24	2.72	0.10	0.72	2.03	2.45	7061	2.5	0.96	3.65	4.42
San Joaquin River Potato Slough	0.24	0.49	1.36	1.65	2041	1.4	1.22	2.46	2.97	0.36	0.51	1.42	1.72	1399	1.3	1.32	2.56	3.10	0.13	0.72	2.02	2.44	5343	2.5	0.98	3.63	4.39
Franks Tract	0.27	0.49	1.38	1.67	1826	1.6	1.02	2.49	3.01	0.49	0.52	1.46	1.77	1077	1.1	1.55	2.64	3.19	0.14	0.72	2.02	2.44	5204	3.0	0.82	3.63	4.39
Big Break	0.20	0.48	1.34	1.62	2441	1.6	1.04	2.41	2.91	0.30	0.50	1.39	1.69	1683	1.0	1.65	2.51	3.04	0.12	0.72	2.02	2.45	6220	2.8	0.86	3.64	4.40
Middle River Bullfrog	0.61	0.54	1.50	1.81	876	NA	NA	2.70	3.26	0.75	0.55	1.53	1.85	732	1.9	1.0	2.75	3.33	0.29	0.71	1.99	2.40	2424	2.1	1.1	3.57	4.32
Old River near Paradise Cut[c]	0.68	0.54	1.51	1.83	801	NA	NA	2.73	3.30	0.84	0.55	1.55	1.87	658	2.4	0.8	2.79	3.37	0.43	0.70	1.97	2.38	1617	NA	NA	3.55	4.29
Knights Landing[d]	0.23	0.49	1.36	1.64	2111	NA	NA	2.45	2.96	0.23	0.49	1.36	1.64	2111	2.2	0.7	2.45	2.96	0.23	0.71	1.99	2.41	3098	NA	NA	3.59	4.34
Vernalis[e]	0.83	0.55	1.55	1.87	665	1.7	1.10	2.78	3.37	0.85	0.55	1.55	1.87	651	1.9	0.99	2.79	3.37	0.58	0.70	1.96	2.37	1206	2.4	0.99	3.53	4.27
	Third Quarter									Third Quarter									Third Quarter								
Sacramento River RM 44	0.09	0.44	1.24	1.50	4910	2.6	0.57	2.23	2.70	0.09	0.44	1.24	1.50	4910	1.5	1.03	2.23	2.70	0.09	0.73	2.03	2.46	8064	1.8	1.33	3.66	4.43
Cache Slough Ryer[b]	0.11	0.45	1.26	1.53	4135	1.5	1.02	2.27	2.75	0.09	0.44	1.24	1.50	4885	1.7	0.87	2.23	2.70	0.10	0.72	2.03	2.45	6980	2.5	0.96	3.65	4.41
San Joaquin River Potato Slough	0.10	0.44	1.25	1.51	4637	1.4	1.11	2.24	2.71	0.10	0.45	1.25	1.51	4584	1.3	1.15	2.24	2.72	0.10	0.72	2.03	2.46	7510	2.5	0.99	3.65	4.42
Franks Tract	0.10	0.45	1.25	1.51	4499	1.6	0.92	2.25	2.72	0.11	0.45	1.26	1.52	4274	1.1	1.33	2.26	2.74	0.10	0.72	2.03	2.45	7276	3.0	0.82	3.65	4.42
Big Break	0.10	0.45	1.25	1.52	4356	1.6	0.98	2.26	2.73	0.10	0.45	1.26	1.52	4304	1.0	1.49	2.26	2.74	0.10	0.72	2.03	2.45	7131	2.8	0.87	3.65	4.42
Middle River Bullfrog	0.20	0.48	1.34	1.63	2350	NA	NA	2.42	2.93	0.30	0.50	1.39	1.69	1677	1.9	0.9	2.51	3.04	0.12	0.72	2.02	2.45	6235	2.1	1.15	3.64	4.40
Old River near Paradise Cut[c]	0.75	0.55	1.53	1.85	725	NA	NA	2.76	3.33	0.80	0.55	1.54	1.86	687	2.4	0.8	2.77	3.35	0.53	0.70	1.96	2.37	1317	NA	NA	3.53	4.27
Knights Landing[d]	0.23	0.49	1.36	1.64	2111	NA	NA	2.45	2.96	0.23	0.49	1.36	1.64	2111	2.2	0.7	2.45	2.96	0.23	0.71	1.99	2.41	3098	NA	NA	3.59	4.34
Vernalis[e]	0.83	0.55	1.55	1.87	665	1.7	1.10	2.78	3.37	0.85	0.55	1.55	1.87	651	1.9	0.99	2.79	3.37	0.58	0.70	1.96	2.37	1206	2.4	0.99	3.53	4.27

DSM2 Delta Water Location	Year 2000									Year 2005									Year 2007								
	Concentration					Whole-	Fish-to-Bass Ratio	Bird Eggs		Concentration					Whole-	Fish-to-Bass Ratio	Bird Eggs		Concentration					Whole-	Fish-to-Bass Ratio	Bird Eggs	
	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d	body Bass[a]	Model 4	From Invert.	From Fish	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 4 Fish	K_d	body Bass[a]	Model 4	From Invert.	From Fish	DSM2 Water	Particulate from Water	Invert. from Particulate	Model 5 Fish	K_d	body Bass[a]	Model 5	From Invert.	From Fish
	Fourth Quarter									Fourth Quarter									Fourth Quarter								
Sacramento River RM 44	0.09	0.44	1.24	1.50	4911	2.6	0.57	2.23	2.70	0.09	0.44	1.24	1.50	4909	1.5	1.03	2.23	2.70	0.09	0.73	2.03	2.46	8064	1.8	1.33	3.66	4.43
Cache Slough Ryer[b]	0.10	0.45	1.25	1.52	4383	1.5	1.02	2.26	2.73	0.09	0.44	1.24	1.50	4820	1.7	0.87	2.23	2.70	0.10	0.72	2.03	2.45	7209	2.5	0.96	3.65	4.42
San Joaquin River Potato Slough	0.09	0.44	1.24	1.50	4723	1.4	1.11	2.24	2.71	0.09	0.44	1.24	1.50	4862	1.3	1.15	2.23	2.70	0.09	0.73	2.03	2.46	7682	2.5	0.99	3.66	4.42
Franks Tract	0.10	0.44	1.24	1.51	4660	1.6	0.91	2.24	2.71	0.09	0.44	1.24	1.50	4843	1.1	1.31	2.23	2.70	0.10	0.73	2.03	2.46	7564	3.0	0.82	3.65	4.42
Big Break	0.10	0.45	1.25	1.51	4593	1.6	0.97	2.24	2.72	0.09	0.44	1.24	1.50	4804	1.0	1.47	2.23	2.70	0.10	0.72	2.03	2.46	7386	2.8	0.87	3.65	4.42
Middle River Bullfrog	0.30	0.50	1.40	1.69	1669	NA	NA	2.51	3.04	0.24	0.49	1.37	1.65	2020	1.9	0.9	2.46	2.98	0.17	0.72	2.01	2.43	4260	2.1	1.14	3.61	4.37
Old River near Paradise Cut[c]	0.81	0.55	1.54	1.87	678	NA	NA	2.78	3.36	0.72	0.54	1.52	1.84	759	2.4	0.8	2.74	3.32	0.57	0.70	1.96	2.37	1229	NA	NA	3.53	4.27
Knights Landing[d]	0.23	0.49	1.36	1.64	2111	NA	NA	2.45	2.96	0.23	0.49	1.36	1.64	2111	2.2	0.7	2.45	2.96	0.23	0.71	1.99	2.41	3098	NA	NA	3.59	4.34
Vernalis[e]	0.83	0.55	1.55	1.87	665	1.7	1.10	2.78	3.37	0.85	0.55	1.55	1.87	651	1.9	0.99	2.79	3.37	0.58	0.70	1.96	2.37	1206	2.4	0.99	3.53	4.27

Notes:

Equations from Presser and Luoma (2010a, 2010b) were used to calculate selenium concentrations for fish. Models 4 and 5 used the average selenium trophic transfer factors to aquatic insects (2.8), fish (1.1 for all trophic levels) and bird eggs (1.8).

Model 4 = Model 2 (TL-4 Fish Eating TL-3 Fish) with K_d estimated using normal/wet years regression (log K_d = 2.75-0.90(logDSM2))

Model 5 = Model 2 (TL-4 Fish Eating TL-3 Fish) with K_d estimated using dry years (2007) regression (log K_d = 2.84-1.02(logDSM2))

Invert. = invertebrate

K_d = particulate concentration/water concentration ratio

µg/g, dw = micrograms per gram, dry weight

NA = not available; bass not collected here

RM = river mile

TL = trophic level

a. Geometric mean calculated from whole-body largemouth bass data presented in Foe (2010a).

b. Fish data collected at Rio Vista (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

c. Fish data collected at Old River near Tracy (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

d. Geometric mean of total selenium concentrations in water collected from years 2004, 2007, and 2008 (DWR Website 2009) was used to estimate selenium concentrations in particulates and biota (DSM2 data were not available). Fish data collected from Sacramento River at Veterans Bridge (Foe 2010a) were used to calculate geometric mean whole-body largemouth bass and ratios.

e. Geometric mean of selenium concentrations (total or dissolved was not specified) in water collected from years 1999-2000 (SWAMP Website 2009) was used to estimate Year 2000 selenium concentrations in particulates and biota (DSM2 data were not available); years 2004-2005 were used for Year 2005 estimates; and years 2006-2007 were used for Year 2007 estimates.

Table 6D.9 Modeled Annual Average Selenium Concentrations in Water for No Action Alternative and Alternatives 1 (Second Basis of Comparison), 3, and 5

Location	Period *	Period Average Concentration (µg/L) No Action Alternative	Period Average Concentration (µg/L) Second Basis of Comparison	Period Average Concentration (µg/L) Alternative 3	Period Average Concentration (µg/L) Alternative 5
Delta Interior					
San Joaquin River at Stockton	ALL	0.42	0.42	0.42	0.42
	DROUGHT	0.40	0.40	0.39	0.39
Turner Cut	ALL	0.28	0.27	0.27	0.29
	DROUGHT	0.22	0.21	0.21	0.24
San Joaquin River at San Andreas Landing	ALL	0.11	0.10	0.10	0.11
	DROUGHT	0.10	0.09	0.09	0.10
San Joaquin River at Jersey Point	ALL	0.12	0.11	0.11	0.12
	DROUGHT	0.10	0.10	0.10	0.10
Victoria Canal	ALL	0.23	0.22	0.21	0.24
	DROUGHT	0.17	0.16	0.16	0.21
Western Delta					
Sacramento River at Emmaton	ALL	0.10	0.10	0.10	0.11
	DROUGHT	0.10	0.10	0.10	0.10
San Joaquin River at Antioch	ALL	0.11	0.11	0.11	0.12
	DROUGHT	0.10	0.10	0.10	0.10
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	0.11	0.11	0.11	0.11
	DROUGHT	0.10	0.10	0.10	0.10
Major Diversions (Pumping Stations)					
North Bay Aqueduct at Barker Slough Pumping Plant	ALL	0.11	0.11	0.11	0.11
	DROUGHT	0.10	0.10	0.10	0.10
Contra Costa Pumping Plant #1	ALL	0.14	0.13	0.13	0.15
	DROUGHT	0.11	0.10	0.10	0.13
Banks Pumping Plant	ALL	0.21	0.19	0.19	0.22
	DROUGHT	0.16	0.14	0.15	0.18
Jones Pumping Plant	ALL	0.28	0.25	0.27	0.29
	DROUGHT	0.26	0.21	0.24	0.26

Notes:

* All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index)

µg/L = microgram per liter

Table 6D.10 Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative and Second Basis of Comparison

Location	Period [a]	Estimated Concentrations of Selenium (mg/kg, dw[b])							
		Whole-body Fish NAA	Whole-body Fish Alt. 1 (SBC)	Bird Eggs (Invertebrate Diet) NAA	Bird Eggs (Invertebrate Diet) Alt. 1 (SBC)	Bird Eggs (Fish Diet) NAA	Bird Eggs (Fish Diet) Alt. 1 (SBC)	Fish Fillets (ww) NAA	Fish Fillets (ww) Alt. 1 (SBC)
Delta Interior									
San Joaquin River at Stockton	ALL	1.90	1.90	2.83	2.83	3.42	3.42	0.64	0.64
	DROUGHT	2.39	2.39	3.55	3.55	4.30	4.30	0.83	0.83
Turner Cut	ALL	1.88	1.87	2.79	2.79	3.38	3.37	0.63	0.63
	DROUGHT	2.42	2.42	3.59	3.60	4.35	4.35	0.84	0.84
San Joaquin River at San Andreas Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.66	4.42	4.42	0.86	0.86
San Joaquin River at Jersey Point	ALL	1.83	1.83	2.72	2.72	3.29	3.29	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Victoria Canal	ALL	1.87	1.86	2.78	2.77	3.36	3.35	0.62	0.62
	DROUGHT	2.43	2.43	3.61	3.62	4.37	4.38	0.85	0.85
Western Delta									
Sacramento River at Emmaton	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
San Joaquin River at Antioch	ALL	1.83	1.83	2.72	2.72	3.29	3.29	0.61	0.61
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.45	2.45	3.65	3.65	4.42	4.42	0.86	0.86
Major Diversions (Pumping Stations)									
North Bay Aqueduct at Barker Slough Pumping Plant	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61
	DROUGHT	2.45	2.45	3.65	3.65	4.42	4.42	0.86	0.86
Contra Costa Pumping Plant #1	ALL	1.84	1.83	2.74	2.73	3.31	3.30	0.61	0.61
	DROUGHT	2.45	2.45	3.64	3.65	4.41	4.42	0.85	0.86
Banks Pumping Plant	ALL	1.86	1.86	2.77	2.76	3.35	3.34	0.62	0.62
	DROUGHT	2.43	2.44	3.62	3.63	4.38	4.39	0.85	0.85

Location	Period [a]	Estimated Concentrations of Selenium (mg/kg, dw[b])							
		Whole-body Fish NAA	Whole-body Fish Alt. 1 (SBC)	Bird Eggs (Invertebrate Diet) NAA	Bird Eggs (Invertebrate Diet) Alt. 1 (SBC)	Bird Eggs (Fish Diet) NAA	Bird Eggs (Fish Diet) Alt. 1 (SBC)	Fish Fillets (ww) NAA	Fish Fillets (ww) Alt. 1 (SBC)
Jones Pumping Plant	ALL	1.88	1.87	2.79	2.78	3.38	3.37	0.63	0.63
	DROUGHT	2.41	2.42	3.58	3.60	4.33	4.35	0.84	0.84

Notes:
a. All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index)
b. Dry weight, except as noted for fish fillets

Alt. = alternative
dw = dry weight
mg/kg = milligram per kilogram
NAA = No Action Alternative
SBC = Second Basis of Comparison
“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.
Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.
ww = wet weight

Table 6D.11 Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative, Second Basis of Comparison, and Alternative 3

Location	Period [a]	Estimated Concentrations of Selenium (mg/kg, dw[b])											
		Whole-body Fish NAA	Whole-body Fish Alt. 1 (SBC)	Whole-body Fish Alt. 3	Bird Eggs (Invertebrate Diet) NAA	Bird Eggs (Invertebrate Diet) Alt. 1 (SBC)	Bird Eggs (Invertebrate Diet) Alt. 3	Bird Eggs (Fish Diet) NAA	Bird Eggs (Fish Diet) Alt. 1 (SBC)	Bird Eggs (Fish Diet) Alt. 3	Fish Fillets (ww) NAA	Fish Fillets (ww) Alt. 1 (SBC)	Fish Fillets (ww) Alt. 3
Delta Interior													
San Joaquin River at Stockton	ALL	1.90	1.90	1.90	2.83	2.83	2.83	3.42	3.42	3.42	0.64	0.64	0.64
	DROUGHT	2.39	2.39	2.39	3.55	3.55	3.55	4.30	4.30	4.30	0.83	0.83	0.83
Turner Cut	ALL	1.88	1.87	1.87	2.79	2.79	2.79	3.38	3.37	3.37	0.63	0.63	0.63
	DROUGHT	2.42	2.42	2.42	3.59	3.60	3.60	4.35	4.35	4.35	0.84	0.84	0.84
San Joaquin River at San Andreas Landing	ALL	1.82	1.82	1.82	2.71	2.71	2.71	3.28	3.28	3.28	0.61	0.61	0.61
	DROUGHT	2.46	2.46	2.46	3.65	3.66	3.66	4.42	4.42	4.42	0.86	0.86	0.86
San Joaquin River at Jersey Point	ALL	1.83	1.83	1.82	2.72	2.72	2.77	3.29	3.29	3.35	0.61	0.61	0.62
	DROUGHT	2.46	2.46	2.46	3.65	3.65	3.62	4.42	4.42	4.38	0.86	0.86	0.85
Victoria Canal	ALL	1.87	1.86	1.86	2.78	2.77	2.77	3.36	3.35	3.35	0.62	0.62	0.62
	DROUGHT	2.43	2.43	2.43	3.61	3.62	3.62	4.37	4.38	4.38	0.85	0.85	0.85
Western Delta													
Sacramento River at Emmaton	ALL	1.82	1.82	1.82	2.71	2.71	2.71	3.28	3.28	3.28	0.61	0.61	0.61
	DROUGHT	2.46	2.46	2.46	3.65	3.65	3.65	4.42	4.42	4.42	0.86	0.86	0.86
San Joaquin River at Antioch	ALL	1.83	1.83	1.82	2.72	2.72	2.71	3.29	3.29	3.28	0.61	0.61	0.61
	DROUGHT	2.46	2.46	2.46	3.65	3.65	3.65	4.42	4.42	4.42	0.86	0.86	0.86
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	1.82	1.82	2.71	2.71	2.71	3.28	3.28	3.28	0.61	0.61	0.61
	DROUGHT	2.45	2.45	2.46	3.65	3.65	3.65	4.42	4.42	4.42	0.86	0.86	0.86
Major Diversions (Pumping Stations)													
North Bay Aqueduct at Barker Slough Pumping Plant	ALL	1.82	1.82	1.82	2.71	2.71	2.71	3.28	3.28	3.28	0.61	0.61	0.61
	DROUGHT	2.45	2.45	2.45	3.65	3.65	3.65	4.42	4.42	4.42	0.86	0.86	0.86
Contra Costa Pumping Plant #1	ALL	1.84	1.83	1.83	2.74	2.73	2.72	3.31	3.30	3.30	0.61	0.61	0.61
	DROUGHT	2.45	2.45	2.45	3.64	3.65	3.65	4.41	4.42	4.41	0.85	0.86	0.86

		Estimated Concentrations of Selenium (mg/kg, dw[b])											
Location	**Period [a]**	**Whole-body Fish NAA**	**Whole-body Fish Alt. 1 (SBC)**	**Whole-body Fish Alt. 3**	**Bird Eggs (Invertebrate Diet) NAA**	**Bird Eggs (Invertebrate Diet) Alt. 1 (SBC)**	**Bird Eggs (Invertebrate Diet) Alt. 3**	**Bird Eggs (Fish Diet) NAA**	**Bird Eggs (Fish Diet) Alt. 1 (SBC)**	**Bird Eggs (Fish Diet) Alt. 3**	**Fish Fillets (ww) NAA**	**Fish Fillets (ww) Alt. 1 (SBC)**	**Fish Fillets (ww) Alt. 3**
Banks Pumping Plant	ALL	1.86	1.86	1.86	2.77	2.76	2.76	3.35	3.34	3.34	0.62	0.62	0.62
	DROUGHT	2.43	2.44	2.44	3.62	3.63	3.62	4.38	4.39	4.39	0.85	0.85	0.85
Jones Pumping Plant	ALL	1.88	1.87	1.87	2.79	2.78	2.79	3.38	3.37	3.37	0.63	0.63	0.63
	DROUGHT	2.41	2.42	2.41	3.58	3.60	3.59	4.33	4.35	4.34	0.84	0.84	0.84

Notes:
a. All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index)
b. Dry weight, except as noted for fish fillets
Alt. = alternative
dw = dry weight
mg/kg = milligram per kilogram
NAA = No Action Alternative
SBC = Second Basis of Comparison
“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.
ww = wet weight

Table 6D.12 Summary Table for Annual Average Selenium Concentrations in Biota for No Action Alternative, Second Basis of Comparison, and Alternative 5

Location	Period [a]	Estimated Concentrations of Selenium (mg/kg, dw[b])											
		Whole-body Fish NAA	Whole-body Fish Alt. 1 (SBC)	Whole-body Fish Alt. 5	Bird Eggs (Invertebrate Diet) NAA	Bird Eggs (Invertebrate Diet) Alt. 1 (SBC)	Bird Eggs (Invertebrate Diet) Alt. 5	Bird Eggs (Fish Diet) NAA	Bird Eggs (Fish Diet) Alt. 1 (SBC)	Bird Eggs (Fish Diet) Alt. 5	Fish Fillets (ww) NAA	Fish Fillets (ww) Alt. 1 (SBC)	Fish Fillets (ww) Alt. 5
Delta Interior													
San Joaquin River at Stockton	ALL	1.90	1.90	1.90	2.83	2.83	2.83	3.42	3.42	3.42	0.64	0.64	0.64
	DROUGHT	2.39	2.39	2.39	3.55	3.55	3.55	4.30	4.30	4.30	0.83	0.83	0.83
Turner Cut	ALL	1.88	1.87	1.88	2.79	2.79	2.79	3.38	3.37	3.38	0.63	0.63	0.63
	DROUGHT	2.42	2.42	2.41	3.59	3.60	3.59	4.35	4.35	4.34	0.84	0.84	0.84
San Joaquin River at San Andreas Landing	ALL	1.82	1.82	1.82	2.71	2.71	2.71	3.28	3.28	3.28	0.61	0.61	0.61
	DROUGHT	2.46	2.46	2.45	3.65	3.66	3.65	4.42	4.42	4.42	0.86	0.86	0.86
San Joaquin River at Jersey Point	ALL	1.83	1.83	1.83	2.72	2.72	2.78	3.29	3.29	3.36	0.61	0.61	0.62
	DROUGHT	2.46	2.46	2.45	3.65	3.65	3.60	4.42	4.42	4.35	0.86	0.86	0.84
Victoria Canal	ALL	1.87	1.86	1.87	2.78	2.77	2.78	3.36	3.35	3.36	0.62	0.62	0.62
	DROUGHT	2.43	2.43	2.42	3.61	3.62	3.60	4.37	4.38	4.35	0.85	0.85	0.84
Western Delta													
Sacramento River at Emmaton	ALL	1.82	1.82	1.82	2.71	2.71	2.71	3.28	3.28	3.28	0.61	0.61	0.61
	DROUGHT	2.46	2.46	2.45	3.65	3.65	3.65	4.42	4.42	4.42	0.86	0.86	0.86
San Joaquin River at Antioch	ALL	1.83	1.83	1.83	2.72	2.72	2.72	3.29	3.29	3.29	0.61	0.61	0.61
	DROUGHT	2.46	2.46	2.45	3.65	3.65	3.65	4.42	4.42	4.42	0.86	0.86	0.86
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	1.82	1.82	2.71	2.71	2.71	3.28	3.28	3.28	0.61	0.61	0.61
	DROUGHT	2.45	2.45	2.45	3.65	3.65	3.65	4.42	4.42	4.42	0.86	0.86	0.86
Major Diversions (Pumping Stations)													
North Bay Aqueduct at Barker Slough Pumping Plant	ALL	1.82	1.82	1.82	2.71	2.71	2.71	3.28	3.28	3.28	0.61	0.61	0.61
	DROUGHT	2.45	2.45	2.45	3.65	3.65	3.65	4.42	4.42	4.42	0.86	0.86	0.86
Contra Costa Pumping Plant #1	ALL	1.84	1.83	1.84	2.74	2.73	2.74	3.31	3.30	3.32	0.61	0.61	0.61
	DROUGHT	2.45	2.45	2.44	3.64	3.65	3.63	4.41	4.42	4.39	0.85	0.86	0.85
Banks Pumping Plant	ALL	1.86	1.86	1.86	2.77	2.76	2.77	3.35	3.34	3.35	0.62	0.62	0.62
	DROUGHT	2.43	2.44	2.43	3.62	3.63	3.61	4.38	4.39	4.37	0.85	0.85	0.85

Location	Period [a]	Estimated Concentrations of Selenium (mg/kg, dw[b])											
		Whole-body Fish NAA	Whole-body Fish Alt. 1 (SBC)	Whole-body Fish Alt. 5	Bird Eggs (Invertebrate Diet) NAA	Bird Eggs (Invertebrate Diet) Alt. 1 (SBC)	Bird Eggs (Invertebrate Diet) Alt. 5	Bird Eggs (Fish Diet) NAA	Bird Eggs (Fish Diet) Alt. 1 (SBC)	Bird Eggs (Fish Diet) Alt. 5	Fish Fillets (ww) NAA	Fish Fillets (ww) Alt. 1 (SBC)	Fish Fillets (ww) Alt. 5
Jones Pumping Plant	ALL	1.88	1.87	1.88	2.79	2.78	2.79	3.38	3.37	3.38	0.63	0.63	0.63
	DROUGHT	2.41	2.42	2.41	3.58	3.60	3.58	4.33	4.35	4.33	0.84	0.84	0.84

Notes:

a. All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index)

b. Dry weight, except as noted for fish fillets

Alt. = alternative
dw = dry weight
mg/kg = milligram per kilogram
NAA = No Action Alternative
SBC = Second Basis of Comparison
“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.
ww = wet weight

Table 6D.13 Summary Table for Selenium Concentrations in Biota, and Comparisons for No Action Alternative and Second Basis of Comparison to Benchmarks

Location	Period [a]	Estimated Concentrations of Selenium (mg/kg, dw[b])								Exceedance Quotients[c]													
		Whole-body Fish		Bird Eggs (Invertebrate Diet)		Bird Eggs (Fish Diet)		Fish Fillets (ww)		Whole-body Fish				Bird Eggs (Invertebrate Diet)				Bird Eggs (Fish Diet)				Fish Fillets (ww)	
										Level of Concern[d]		Toxicity Level[e]		Level of Concern[f]		Toxicity Level[g]		Level of Concern[f]		Toxicity Level[g]		Advisory Tissue Level[h]	
		NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)
Delta Interior																							
San Joaquin River at Stockton	ALL	1.90	1.90	2.83	2.83	3.42	3.42	0.64	0.64	0.47	0.47	0.23	0.23	0.47	0.47	0.28	0.28	0.57	0.57	0.34	0.34	0.25	0.25
	DROUGHT	2.39	2.39	3.55	3.55	4.30	4.30	0.83	0.83	0.60	0.60	0.29	0.29	0.59	0.59	0.36	0.36	0.72	0.72	0.43	0.43	0.33	0.33
Turner Cut	ALL	1.88	1.87	2.79	2.79	3.38	3.37	0.63	0.63	0.47	0.47	0.23	0.23	0.47	0.46	0.28	0.28	0.56	0.56	0.34	0.34	0.25	0.25
	DROUGHT	2.42	2.42	3.59	3.60	4.35	4.35	0.84	0.84	0.60	0.60	0.30	0.30	0.60	0.60	0.36	0.36	0.72	0.73	0.43	0.44	0.34	0.34
San Joaquin River at San Andreas Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61	0.46	0.46	0.23	0.22	0.45	0.45	0.27	0.27	0.55	0.55	0.33	0.33	0.24	0.24
	DROUGHT	2.46	2.46	3.65	3.66	4.42	4.42	0.86	0.86	0.61	0.61	0.30	0.30	0.61	0.61	0.37	0.37	0.74	0.74	0.44	0.44	0.34	0.34
San Joaquin River at Jersey Point	ALL	1.83	1.83	2.72	2.72	3.29	3.29	0.61	0.61	0.46	0.46	0.23	0.23	0.45	0.45	0.27	0.27	0.55	0.55	0.33	0.33	0.24	0.24
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86	0.61	0.61	0.30	0.30	0.61	0.61	0.37	0.37	0.74	0.74	0.44	0.44	0.34	0.34
Victoria Canal	ALL	1.87	1.86	2.78	2.77	3.36	3.35	0.62	0.62	0.47	0.47	0.23	0.23	0.46	0.46	0.28	0.28	0.56	0.56	0.34	0.34	0.25	0.25
	DROUGHT	2.43	2.43	3.61	3.62	4.37	4.38	0.85	0.85	0.61	0.61	0.30	0.30	0.60	0.60	0.36	0.36	0.73	0.73	0.44	0.44	0.34	0.34
Western Delta																							
Sacramento River at Emmaton	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61	0.46	0.46	0.22	0.22	0.45	0.45	0.27	0.27	0.55	0.55	0.33	0.33	0.24	0.24
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86	0.61	0.61	0.30	0.30	0.61	0.61	0.37	0.37	0.74	0.74	0.44	0.44	0.34	0.34
San Joaquin River at Antioch	ALL	1.83	1.83	2.72	2.72	3.29	3.29	0.61	0.61	0.46	0.46	0.23	0.23	0.45	0.45	0.27	0.27	0.55	0.55	0.33	0.33	0.24	0.24
	DROUGHT	2.46	2.46	3.65	3.65	4.42	4.42	0.86	0.86	0.61	0.61	0.30	0.30	0.61	0.61	0.37	0.37	0.74	0.74	0.44	0.44	0.34	0.34
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61	0.46	0.46	0.23	0.23	0.45	0.45	0.27	0.27	0.55	0.55	0.33	0.33	0.24	0.24
	DROUGHT	2.45	2.45	3.65	3.65	4.42	4.42	0.86	0.86	0.61	0.61	0.30	0.30	0.61	0.61	0.37	0.37	0.74	0.74	0.44	0.44	0.34	0.34
Major Diversions (Pumping Stations)																							
North Bay Aqueduct at Barker Slough Pumping Plant	ALL	1.82	1.82	2.71	2.71	3.28	3.28	0.61	0.61	0.46	0.46	0.23	0.23	0.45	0.45	0.27	0.27	0.55	0.55	0.33	0.33	0.24	0.24
	DROUGHT	2.45	2.45	3.65	3.65	4.42	4.42	0.86	0.86	0.61	0.61	0.30	0.30	0.61	0.61	0.37	0.37	0.74	0.74	0.44	0.44	0.34	0.34
Contra Costa Pumping Plant #1	ALL	1.84	1.83	2.74	2.73	3.31	3.30	0.61	0.61	0.46	0.46	0.23	0.23	0.46	0.45	0.27	0.27	0.55	0.55	0.33	0.33	0.25	0.24
	DROUGHT	2.45	2.45	3.64	3.65	4.41	4.42	0.85	0.86	0.61	0.61	0.30	0.30	0.61	0.61	0.36	0.36	0.73	0.74	0.44	0.44	0.34	0.34
Banks Pumping Plant	ALL	1.86	1.86	2.77	2.76	3.35	3.34	0.62	0.62	0.47	0.46	0.23	0.23	0.46	0.46	0.28	0.28	0.56	0.56	0.33	0.33	0.25	0.25
	DROUGHT	2.43	2.44	3.62	3.63	4.38	4.39	0.85	0.85	0.61	0.61	0.30	0.30	0.60	0.60	0.36	0.36	0.73	0.73	0.44	0.44	0.34	0.34
Jones Pumping Plant	ALL	1.88	1.87	2.79	2.78	3.38	3.37	0.63	0.63	0.47	0.47	0.23	0.23	0.47	0.46	0.28	0.28	0.56	0.56	0.34	0.34	0.25	0.25
	DROUGHT	2.41	2.42	3.58	3.60	4.33	4.35	0.84	0.84	0.60	0.60	0.30	0.30	0.60	0.60	0.36	0.36	0.72	0.73	0.43	0.44	0.34	0.34

Notes:

a. All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).
b. Dry weight, except as noted for fish fillets.
c. Exceedance Quotient = tissue concentration/benchmark
d. Level of Concern for fish tissue (lower end of range) = 4 mg/kg dw (Beckon et al. 2008)
e. Toxicity Level for fish tissue = 8.1 mg/kg dw (USEPA 2014)
f. Level of Concern for bird eggs (lower end of range) = 6 mg/kg dw (Beckon et al. 2008)
g. Toxicity Level for bird eggs = 10 mg/kg dw (Beckon et al. 2008)
h. Advisory Tissue Level = 2.5 mg/kg ww (OEHHA 2008)

Alt. = Alternative
dw = dry weight
mg/kg = milligram per kilogram
NAA = No Action Alternative
SBC = Second Basis of Comparison
“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.
Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.
ww = wet weight

Table 6D.14 Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 3 to No Action Altenative and Second Basis of Comparison Conditions and Benchmarks

Location	Period [a]	Estimated Concentrations of Selenium (mg/kg, dw[b])				% Change In Selenium Concentrations Compared to NAA and Alternative 1 (Second Basis of Comparison)[c]								Exceedance Quotients[d]						
		Whole-body Fish	Bird Eggs (Invert. Diet)	Bird Eggs (Fish Diet)	Fish Fillets (ww)	Whole-body Fish		Bird Eggs (Invert. Diet)		Bird Eggs (Fish Diet)		Fish Fillets (ww)		Whole-body Fish		Bird Eggs (Invert. Diet)		Bird Eggs (Fish Diet)		Fish Fillets (ww)
		Alt. 3	Alt. 3	Alt. 3	Alt. 3	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	LOC[e]	TL[f]	LOC[g]	TL[h]	LOC[g]	TL[h]	ATL[i]
Delta Interior																				
San Joaquin River at Stockton	ALL	1.90	2.83	3.42	0.64	0	0	0	0	0	0	0	0	0.47	0.23	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.39	3.55	4.30	0.83	0	0	0	0	0	0	0	0	0.60	0.29	0.59	0.36	0.72	0.43	0.33
Turner Cut	ALL	1.87	2.79	3.37	0.63	0	0	0	0	0	0	0	0	0.47	0.23	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.42	3.60	4.35	0.84	0	0	0	0	0	0	0	0	0.60	0.30	0.60	0.36	0.73	0.44	0.34
San Joaquin River at San Andreas Landing	ALL	1.82	2.71	3.28	0.61	0	0	0	0	0	0	0	0	0.46	0.22	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.66	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Jersey Point	ALL	1.82	2.77	3.35	0.62	0	0	2	2	2	2	2	2	0.46	0.23	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.46	3.62	4.38	0.85	0	0	-1	-1	-1	-1	-1	-1	0.61	0.30	0.60	0.36	0.73	0.44	0.34
Victoria Canal	ALL	1.86	2.77	3.35	0.62	0	0	0	0	0	0	0	0	0.47	0.23	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.43	3.62	4.38	0.85	0	0	0	0	0	0	0	0	0.61	0.30	0.60	0.36	0.73	0.44	0.34
Western Delta																				
Sacramento River at Emmaton	ALL	1.82	2.71	3.28	0.61	0	0	0	0	0	0	0	0	0.46	0.22	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Antioch	ALL	1.82	2.71	3.28	0.61	0	0	0	0	0	0	0	0	0.46	0.23	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	2.71	3.28	0.61	0	0	0	0	0	0	0	0	0.46	0.23	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.46	3.65	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
Major Diversions (Pumping Stations)																				
North Bay Aqueduct at Barker Slough Pumping Plant	ALL	1.82	2.71	3.28	0.61	0	0	0	0	0	0	0	0	0.46	0.23	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.45	3.65	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
Contra Costa Pumping Plant #1	ALL	1.83	2.72	3.30	0.61	0	0	0	0	0	0	0	0	0.46	0.23	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.45	3.65	4.41	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.36	0.74	0.44	0.34
Banks Pumping Plant	ALL	1.86	2.76	3.34	0.62	0	0	0	0	0	0	0	0	0.46	0.23	0.46	0.28	0.56	0.33	0.25
	DROUGHT	2.44	3.62	4.39	0.85	0	0	0	0	0	0	0	0	0.61	0.30	0.60	0.36	0.73	0.44	0.34
Jones Pumping Plant	ALL	1.87	2.79	3.37	0.63	0	0	0	0	0	0	0	0	0.47	0.23	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.41	3.59	4.34	0.84	0	0	0	0	0	0	0	0	0.60	0.30	0.60	0.36	0.72	0.43	0.34

Notes:

a. All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

b. Dry weight, except as noted for fish fillets.

c. % change indicates a negative change (increased concentrations) relative to the No Action Alternative and Second Basis of Comparison when values are positive and a positive change (lowered concentrations) relative to the No Action Alternative and Second Basis of Comparison when values are negative.

d. Exceedance Quotient = tissue concentration/benchmark

e. Level of Concern for fish tissue (lower end of range) = 4 mg/kg dw (Beckon et al. 2008)

f. Toxicity Level for fish tissue = 8.1 mg/kg dw (USEPA 2014)

g. Level of Concern for bird eggs (lower end of range) = 6 mg/kg dw (Beckon et al. 2008)

h. Toxicity Level for bird eggs = 10 mg/kg dw (Beckon et al. 2008)

i. Advisory Tissue Level = 2.5 mg/kg ww (OEHHA 2008)

Notes (continued):
Alt. = alternative
dw = dry weight
Invert. = invertebrate
mg/kg = milligram per kilogram
NAA = No Action Alternative
SBC = Second Basis of Comparison
“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.
ww = wet weight

Table 6D.15 Summary Table for Selenium Concentrations in Biota, and Comparisons for Alternative 5 to No Action Alternative and Second Basis of Comparison Conditions and Benchmarks

Location	Period ^{a}	Estimated Concentrations of Selenium (mg/kg, dw^b)				% Change In Selenium Concentrations Compared to NAA and Alternative 1 (Second Basis of Comparison)^c								Exceedance Quotients^d						
		Whole-body Fish	Bird Eggs (Invert. Diet)	Bird Eggs (Fish Diet)	Fish Fillets (ww)	Whole-body Fish		Bird Eggs (Invert. Diet)		Bird Eggs (Fish Diet)		Fish Fillets (ww)		Whole-body Fish		Bird Eggs (Invert. Diet)		Bird Eggs (Fish Diet)		Fish Fillets (ww)
		Alt. 5	Alt. 5	Alt. 5	Alt. 5	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	NAA	Alt. 1 (SBC)	LOC^e	TL^f	LOC^g	TL^h	LOC^g	TL^h	ATL^i
Delta Interior																				
San Joaquin River at Stockton	ALL	1.90	2.83	3.42	0.64	0	0	0	0	0	0	0	0	0.47	0.23	0.47	0.28	0.57	0.34	0.25
	DROUGHT	2.39	3.55	4.30	0.83	0	0	0	0	0	0	0	0	0.60	0.29	0.59	0.36	0.72	0.43	0.33
Turner Cut	ALL	1.88	2.79	3.38	0.63	0	0	0	0	0	0	0	0	0.47	0.23	0.47	0.28	0.56	0.34	0.25
	DROUGHT	2.41	3.59	4.34	0.84	0	0	0	0	0	0	0	0	0.60	0.30	0.60	0.36	0.72	0.43	0.34
San Joaquin River at San Andreas Landing	ALL	1.82	2.71	3.28	0.61	0	0	0	0	0	0	0	0	0.46	0.23	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.45	3.65	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Jersey Point	ALL	1.83	2.78	3.36	0.62	0	0	2	2	2	2	3	3	0.46	0.23	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.45	3.60	4.35	0.84	0	0	-1	-2	-1	-2	-2	-2	0.61	0.30	0.60	0.36	0.73	0.44	0.34
Victoria Canal	ALL	1.87	2.78	3.36	0.62	0	0	0	0	0	0	0	0	0.47	0.23	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.42	3.60	4.35	0.84	0	0	0	0	0	0	0	-1	0.60	0.30	0.60	0.36	0.73	0.44	0.34
Western Delta																				
Sacramento River at Emmaton	ALL	1.82	2.71	3.28	0.61	0	0	0	0	0	0	0	0	0.46	0.23	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.45	3.65	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
San Joaquin River at Antioch	ALL	1.83	2.72	3.29	0.61	0	0	0	0	0	0	0	0	0.46	0.23	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.45	3.65	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	1.82	2.71	3.28	0.61	0	0	0	0	0	0	0	0	0.46	0.23	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.45	3.65	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
Major Diversions (Pumping Stations)																				
North Bay Aqueduct at Barker Slough Pumping Plant	ALL	1.82	2.71	3.28	0.61	0	0	0	0	0	0	0	0	0.46	0.23	0.45	0.27	0.55	0.33	0.24
	DROUGHT	2.45	3.65	4.42	0.86	0	0	0	0	0	0	0	0	0.61	0.30	0.61	0.37	0.74	0.44	0.34
Contra Costa Pumping Plant #1	ALL	1.84	2.74	3.32	0.61	0	1	0	1	0	1	0	1	0.46	0.23	0.46	0.27	0.55	0.33	0.25
	DROUGHT	2.44	3.63	4.39	0.85	0	-1	0	-1	0	-1	0	-1	0.61	0.30	0.61	0.36	0.73	0.44	0.34
Banks Pumping Plant	ALL	1.86	2.77	3.35	0.62	0	0	0	0	0	0	0	0	0.47	0.23	0.46	0.28	0.56	0.34	0.25
	DROUGHT	2.43	3.61	4.37	0.85	0	0	0	0	0	0	0	-1	0.61	0.30	0.60	0.36	0.73	0.44	0.34
Jones Pumping Plant	ALL	1.88	2.79	3.38	0.63	0	0	0	0	0	0	0	0	0.47	0.23	0.47	0.28	0.56	0.34	0.25
	DROUGHT	2.41	3.58	4.33	0.84	0	0	0	0	0	0	0	-1	0.60	0.30	0.60	0.36	0.72	0.43	0.34

Notes:

a. All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5 consecutive year (water years 1987-1991) drought period consisting of dry and critical water year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

b. Dry weight, except as noted for fish fillets.

c. % change indicates a negative change (increased concentrations) relative to the No Action Alternative and Second Basis of Comparison when values are positive and a positive change (lowered concentrations) relative to the No Action Alternative and Second Basis of Comparison when values are negative.

d. Exceedance Quotient = tissue concentration/benchmark

e. Level of Concern for fish tissue (lower end of range) = 4 mg/kg dw (Beckon et al. 2008)

f. Toxicity Level for fish tissue = 8.1 mg/kg dw (USEPA 2014)

g. Level of Concern for bird eggs (lower end of range) = 6 mg/kg dw (Beckon et al. 2008)

h. Toxicity Level for bird eggs = 10 mg/kg dw (Beckon et al. 2008)

i. Advisory Tissue Level = 2.5 mg/kg ww (OEHHA 2008)

Notes (continued):
Alt. = alternative
dw = dry weight
Invert. = invertebrate
mg/kg = milligram per kilogram
NAA = No Action Alternative
SBC = Second Basis of Comparison
“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.
ww = wet weight

Table 6D.16 Modeled Selenium Concentrations in Water for No Action Alternative and Alternatives 1 (Second Basis of Comparison), 3, and 5

Location	Period *	Period Average Concentration (µg/L) No Action Alternative	Period Average Concentration (µg/L) Alternative 1 (SBC)	Period Average Concentration (µg/L) Alternative 3	Period Average Concentration (µg/L) Alternative 5
Sacramento River at Emmaton	ALL	0.10	0.10	0.10	0.11
	DROUGHT	0.10	0.10	0.10	0.10
San Joaquin River at Antioch	ALL	0.11	0.11	0.11	0.12
	DROUGHT	0.10	0.10	0.10	0.10
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	0.11	0.11	0.11	0.11
	DROUGHT	0.10	0.10	0.10	0.10

Notes:

* All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5-consecutive-year (Water Years 1987-1991) drought period consisting of dry and critical water-year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.

Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately.
Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.

µg/L = microgram per liter

SBC = Second Basis of Comparison

Table 6D.17 Summary of Annual Average Selenium Concentrations in Whole-body Sturgeon

Location	Period *	Estimated Concentrations of Selenium in Whole-body Sturgeon (mg/kg, dw) No Action Alternative	Estimated Concentrations of Selenium in Whole-body Sturgeon (mg/kg, dw) Alternative 1 (SBC)	Estimated Concentrations of Selenium in Whole-body Sturgeon (mg/kg, dw) Alternative 3	Estimated Concentrations of Selenium in Whole-body Sturgeon (mg/kg, dw) Alternative 5
Sacramento River at Emmaton	ALL	4.16	4.11	4.08	4.20
	DROUGHT	6.96	6.92	6.91	7.09
San Joaquin River at Antioch	ALL	4.56	4.40	4.34	4.61
	DROUGHT	7.06	6.99	6.97	7.23
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	4.33	4.27	4.24	4.35
	DROUGHT	7.10	7.07	7.06	7.16

Notes:

* All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5-consecutive-year (Water Years 1987-1991) drought period consisting of dry and critical water-year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

"Alt. 1 (SBC)" is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.

Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately.

Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.

dw = dry weight

mg/kg = milligram per kilogram

SBC = Second Basis of Comparison

Table 6D.18 Comparison of Annual Average Selenium Concentrations in Whole-body Sturgeon to Toxicity Thresholds[a]

Location	Period [b]	No Action Alternative Low	No Action Alternative High	Second Basis of Comparison Low	Second Basis of Comparison High	Alternative 3 Low	Alternative 3 High	Alternative 5 Low	Alternative 5 High
Sacramento River at Emmaton	ALL	0.83	0.52	0.8	0.51	0.8	0.51	0.8	0.52
	DROUGHT	1.4	0.87	1.4	0.86	1.4	0.86	1.4	0.9
San Joaquin River at Antioch	ALL	0.9	0.57	0.9	0.55	0.9	0.54	0.9	0.6
	DROUGHT	1.4	0.88	1.4	0.87	1.4	0.87	1.4	0.9
Montezuma Slough at Hunter Cut/ Beldon's Landing	ALL	0.87	0.54	0.85	0.53	0.85	0.53	0.9	0.54
	DROUGHT	1.4	0.89	1.4	0.88	1.4	0.88	1.4	0.9

Notes:

a. Toxicity thresholds are those reported in Presser and Luoma (2013): Low = 5 mg/kg, dw and High = 8 mg/kg, dw

b. All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5-consecutive-year (Water Years 1987-1991) drought period consisting of dry and critical water-year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternatives 1 and 4 results are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.

dw = dry weight

mg/kg = milligram per kilogram

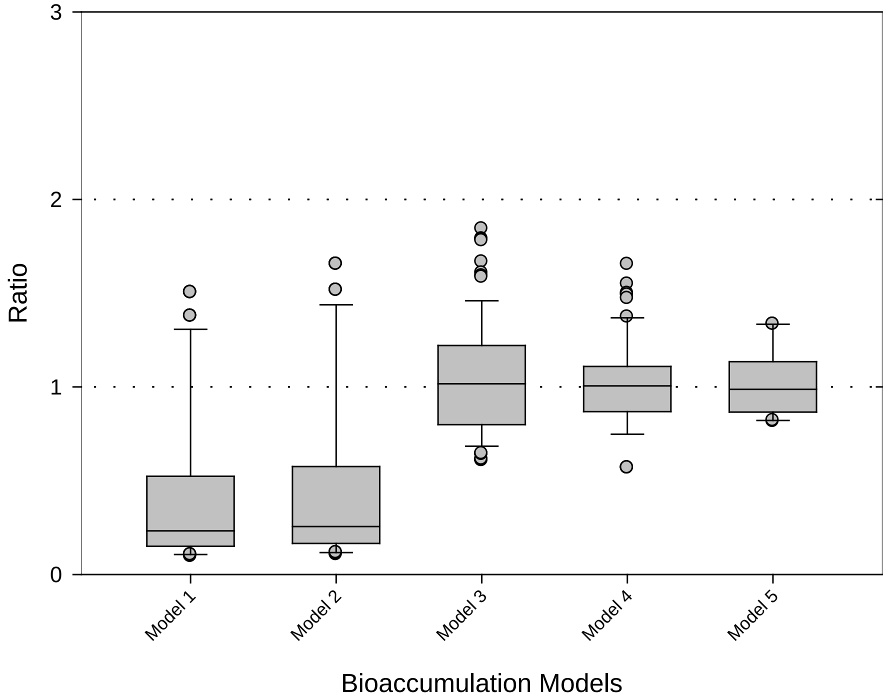
SBC = Second Basis of Comparison

Table 6D.19 Percent Change in Selenium Concentrations Relative to No Action Alternative and Second Basis of Comparison

Location	Period *	Alternative 3 NAA	Alternative 3 Alt1 (SBC)	Alternative 5 NAA	Alternative 5 Alt 1 (SBC)
Sacramento River at Emmaton	ALL	-2.0	-0.7	0.9	2.2
	DROUGHT	-0.8	-0.1	1.8	2.5
San Joaquin River at Antioch	ALL	-4.7	-1.3	1.2	4.8
	DROUGHT	-1.2	-0.2	2.5	3.5
Montezuma Slough at Hunter Cut/Beldon's Landing	ALL	-2.2	-0.7	0.5	2.1
	DROUGHT	-0.5	-0.1	0.8	1.2

Notes:
* All: Water years 1922-2003 represent the 82-year period modeled using DSM2. Drought: Represents a 5-consecutive-year (Water Years 1987-1991) drought period consisting of dry and critical water-year types (as defined by the Sacramento Valley 40-30-30 water year hydrologic classification index).

"Alt. 1 (SBC)" is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.
Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately.
Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.
dw = dry weight
mg/kg = milligram per kilogram
SBC = Second Basis of Comparison



For Models 1 and 2, default values (K_d = 1000, TTF_{invert} = 2.8, TTF_{fish} = 1.1) were used in calculations as follows:

Model 1=Trophic level 3 (TL-3) fish eating invertebrates
Model 2= TL-4 fish eating TL-3 fish

Model 3=Model 2 with K_d estimated using all years regression (log Kd = 2.76-0.97(logDSM2))
Model 4=Model 2 with K_d estimated using normal/wet years (2000/2005) regression (log Kd = 2.75-0.90(logDSM2))
Model 5=Model 2 with K_d estimated using dry years (2007) regression (logKd = 2.84-1.02(logDSM2))

Figure 6D.1 Ratios of Predicted Selenium Concentrations in Fish Models 1 through 5 to Observed Selenium Concentrations in Largemouth Bass

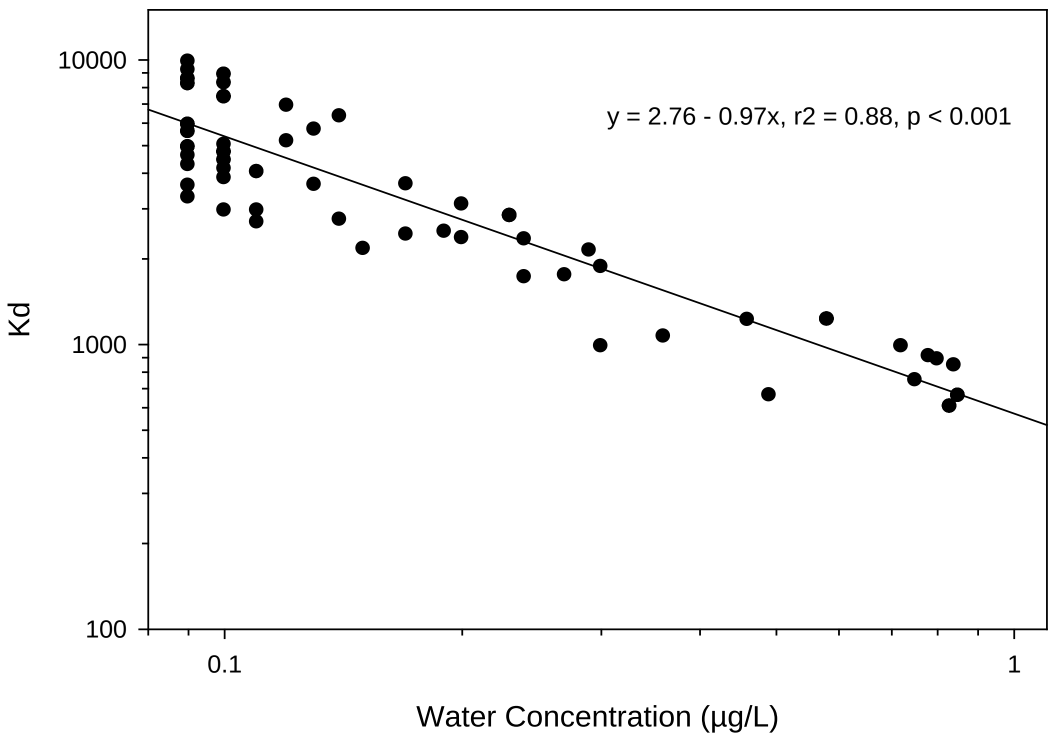


Figure 6D.2 Log-log Regression Relation of Estimated K_d to Waterborne Selenium Concentration for Model 3 in All Years (Based on Years 2000, 2005, and 2007)

To predict the K_d (y) from water concentrations using the regression equation, take the log of the water concentration (x), multiply it by the slope (-0.97), which gives a positive number for x<1 (i.e., waterborne selenium concentrations less than 1 µg/L); then add this number to the intercept (2.76) and take the antilog.

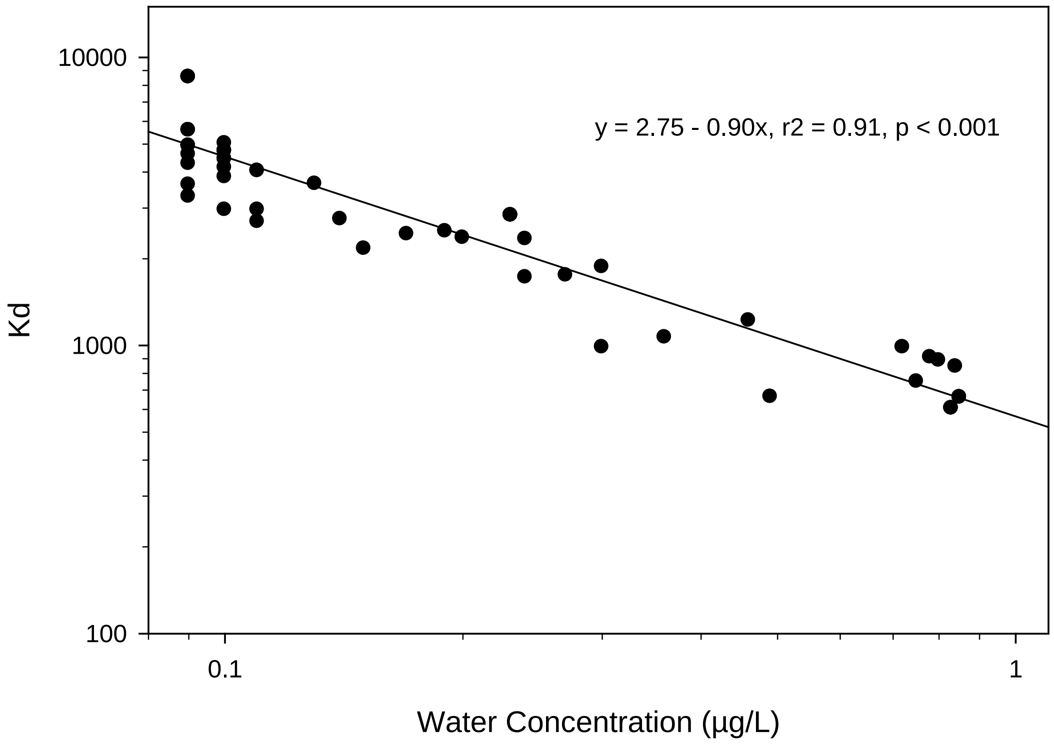


Figure 6D.3 Log-log Regression Relation of Estimated K_d to Waterborne Selenium Concentration for Model 4 in Normal/Wet Years (Based on Years 2000 and 2005)

To predict the K_d (y) from water concentrations using the regression equation, take the log of the water concentration (x), multiply it by the slope (-0.90), which gives a positive number for x<1 (i.e., waterborne selenium concentrations less than 1 µg/L); then add this number to the intercept (2.75) and take the antilog.

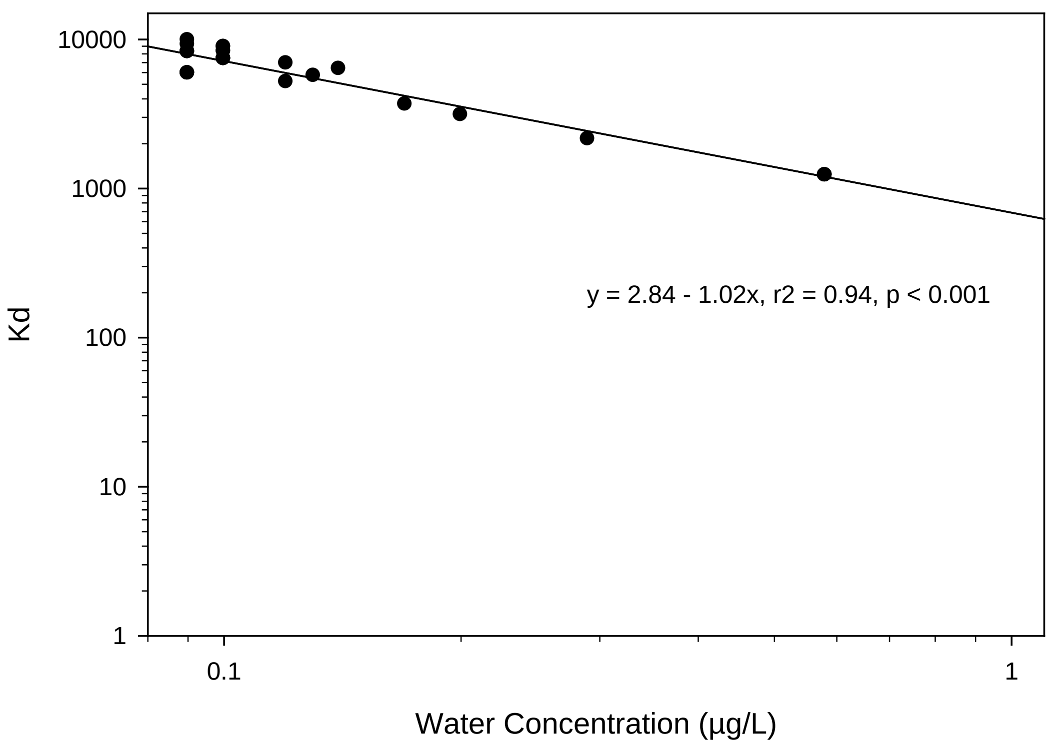
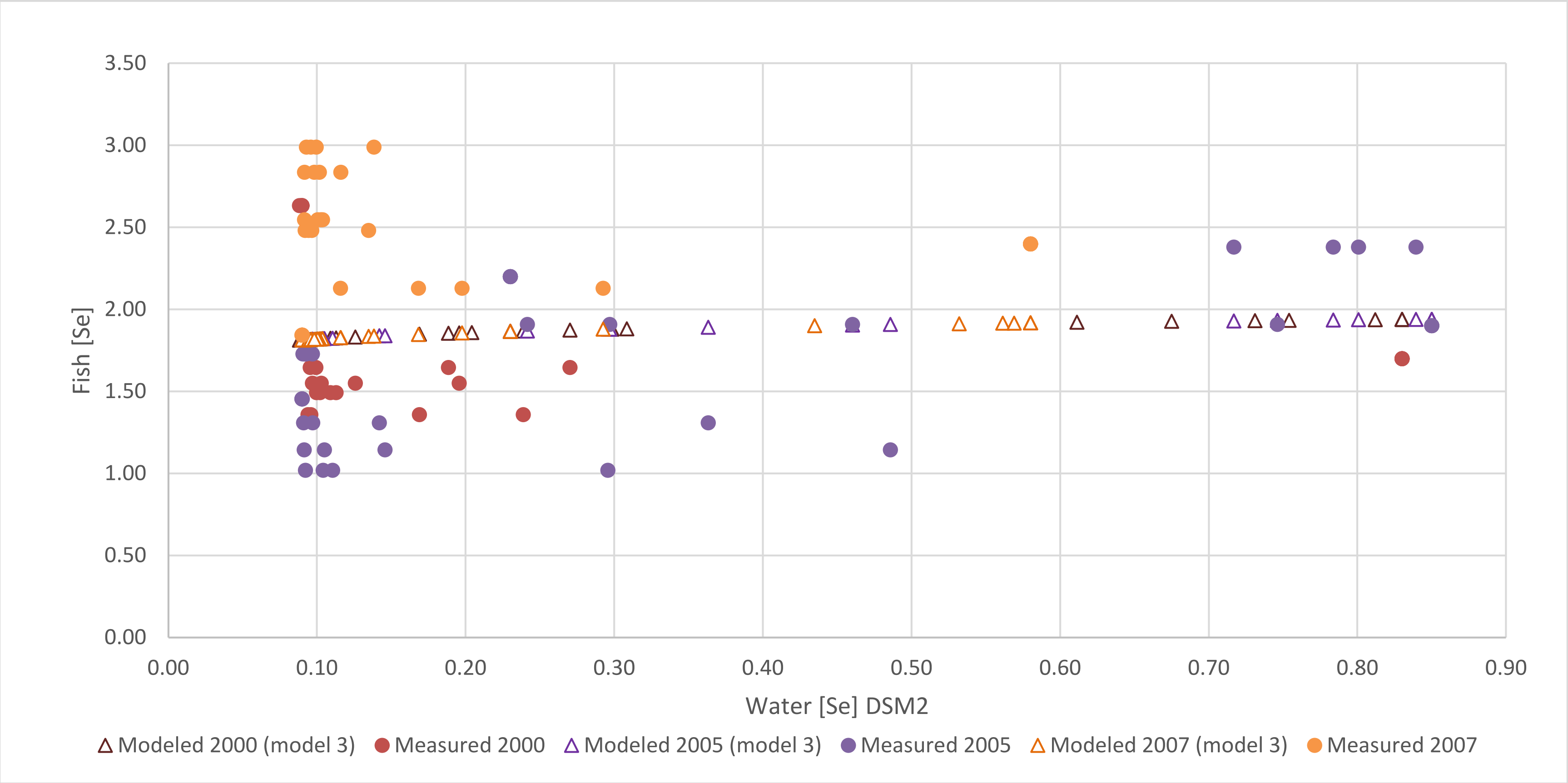


Figure 6D.4 Log-log Regression Relation of Estimated K_d to Waterborne Selenium Concentration for Model 5 in Dry Years (Based on Year 2007)

To predict the K_d (y) from water concentrations using the regression equation, take the log of the water concentration (x), multiply it by the slope (-1.02), which gives a positive number for x<1 (i.e., waterborne selenium concentrations less than 1 µg/L); then add this number to the intercept (2.84) and take the antilog.



1

2 Figure 6D.5 Distribution of Data for Selenium Concentrations in Largemouth Bass Relative to Waterborne Selenium for Model 3

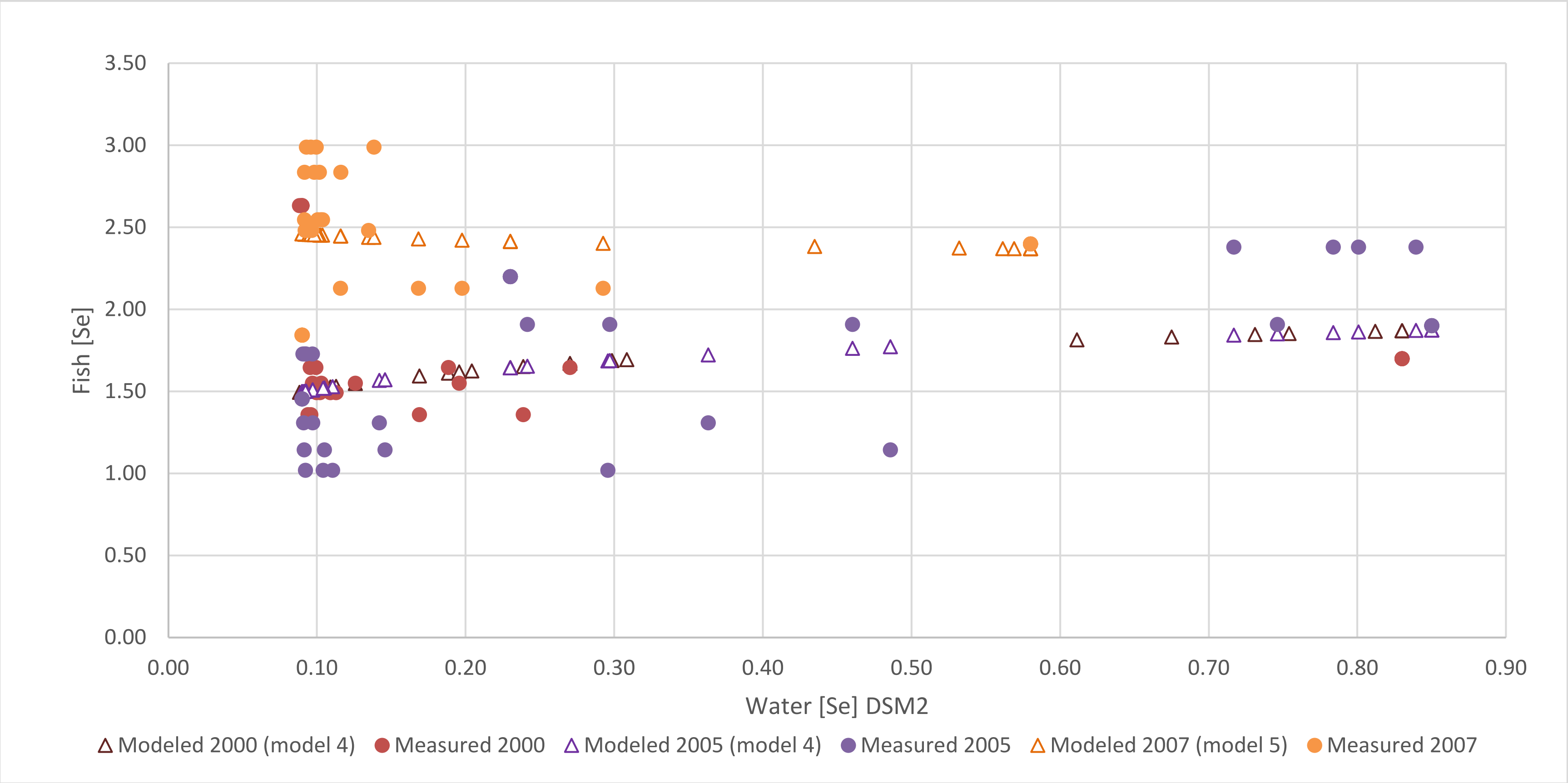
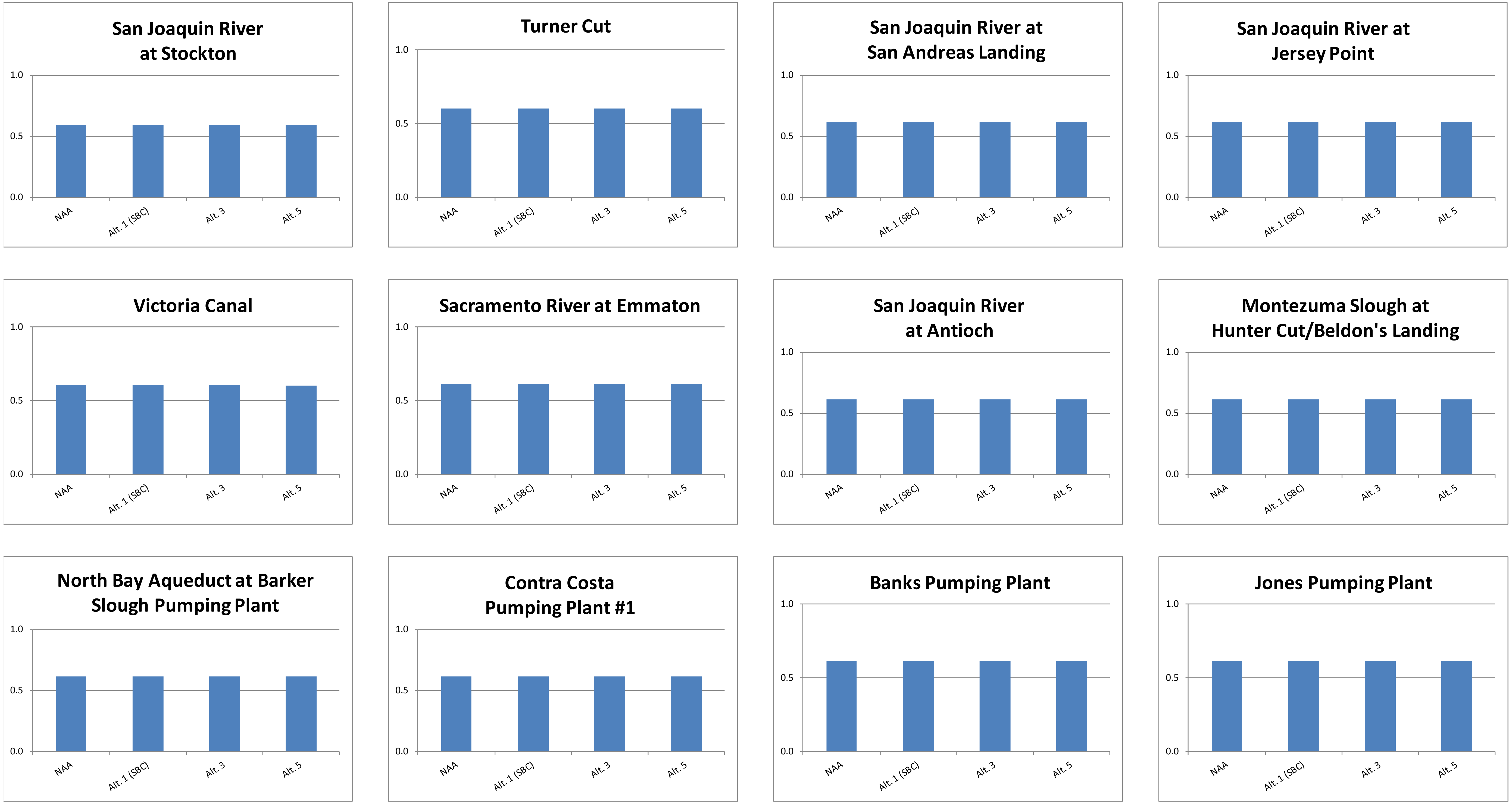


Figure 6D.6 Distribution of Data for Selenium Concentrations in Largemouth Bass Relative to Waterborne Selenium for Model 4 and Model 5



San Joaquin River at Stockton

Turner Cut

San Joaquin River at San Andreas Landing

San Joaquin River at Jersey Point

Victoria Canal

Sacramento River at Emmaton

San Joaquin River at Antioch

Montezuma Slough at Hunter Cut/Beldon's Landing

North Bay Aqueduct at Barker Slough Pumping Plant

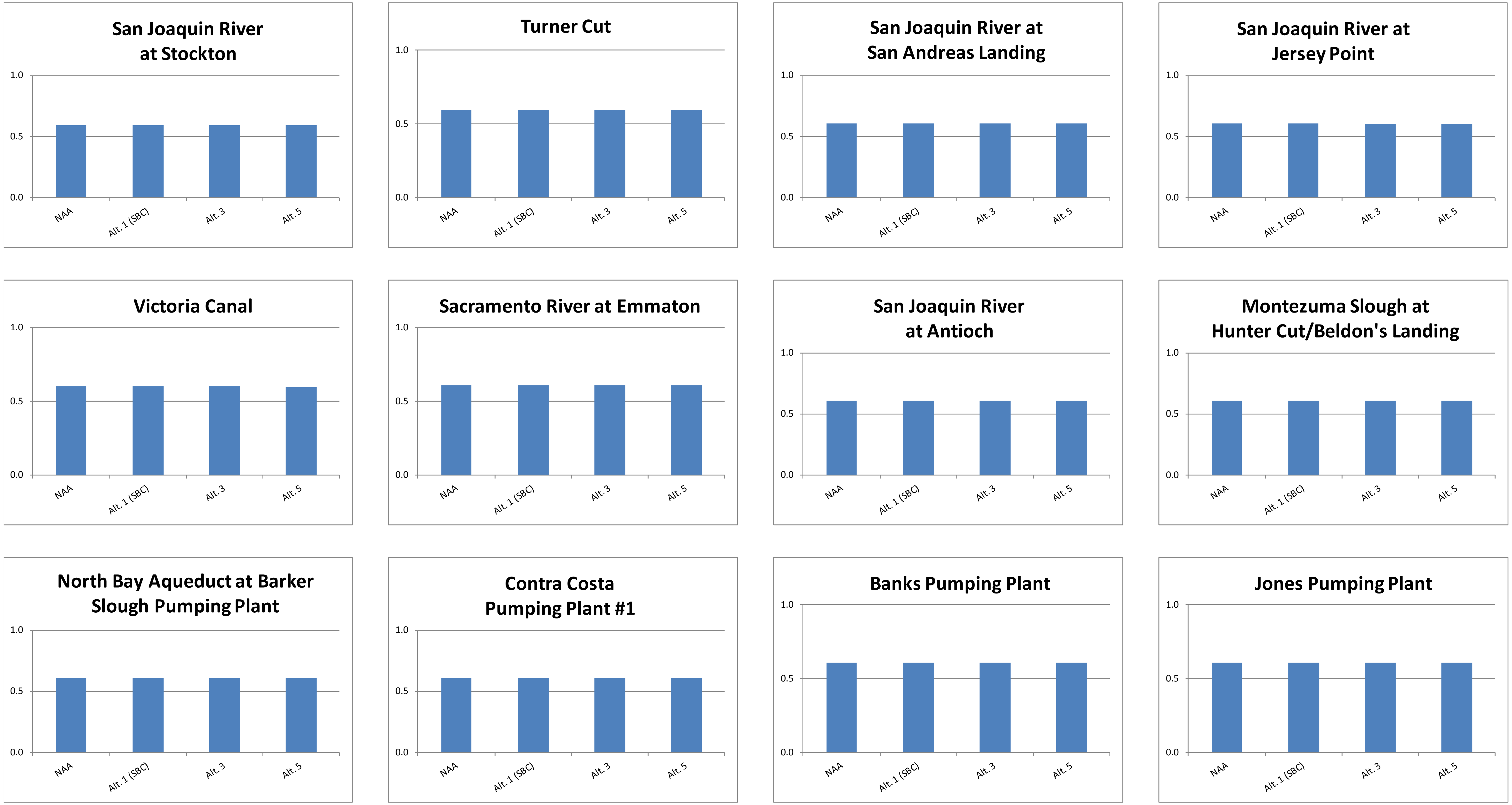
Contra Costa Pumping Plant #1

Banks Pumping Plant

Jones Pumping Plant

Figure 6D.7 Level of Concern Exceedance Quotients for Selenium Concentrations in Whole-Body Fish for Drought Years

"Alt. 1 (SBC)" is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1. Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.


San Joaquin River at Stockton

Turner Cut

San Joaquin River at San Andreas Landing

San Joaquin River at Jersey Point

Victoria Canal

Sacramento River at Emmaton

San Joaquin River at Antioch

Montezuma Slough at Hunter Cut/Beldon's Landing

North Bay Aqueduct at Barker Slough Pumping Plant

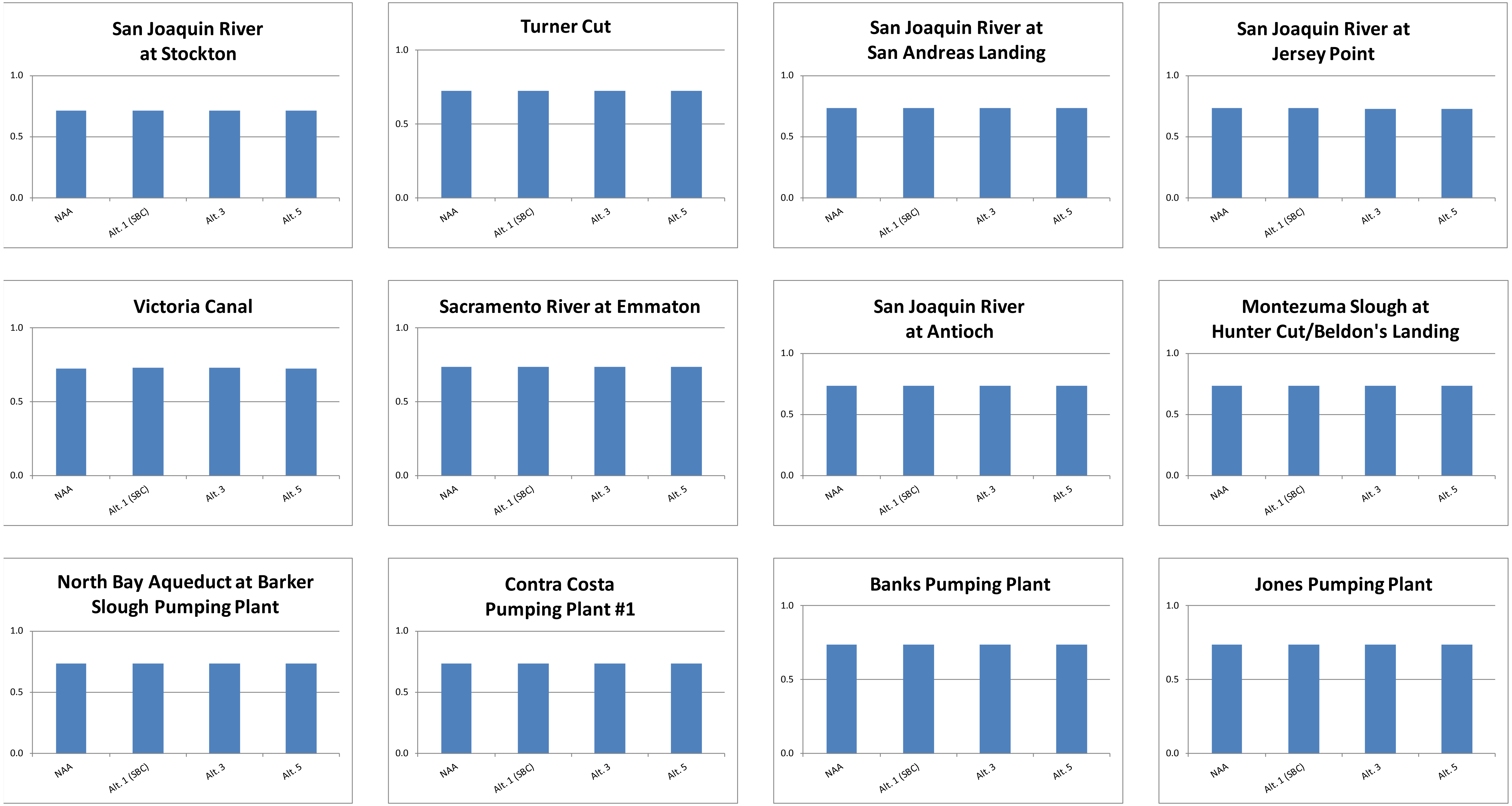
Contra Costa Pumping Plant #1

Banks Pumping Plant

Jones Pumping Plant

Figure 6D.8 Level of Concern Exceedance Quotients for Selenium Concentrations in Bird Eggs (Invertebrate Diet) for Drought Years

“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1. Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.



San Joaquin River at Stockton

Turner Cut

San Joaquin River at San Andreas Landing

San Joaquin River at Jersey Point

Victoria Canal

Sacramento River at Emmaton

San Joaquin River at Antioch

Montezuma Slough at Hunter Cut/Beldon's Landing

North Bay Aqueduct at Barker Slough Pumping Plant

Contra Costa Pumping Plant #1

Banks Pumping Plant

Jones Pumping Plant

Figure 6D.9 Level of Concern Exceedance Quotients for Selenium Concentrations in Bird Eggs (Fish Diet) for Drought Years

"Alt. 1 (SBC)" is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1. Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.

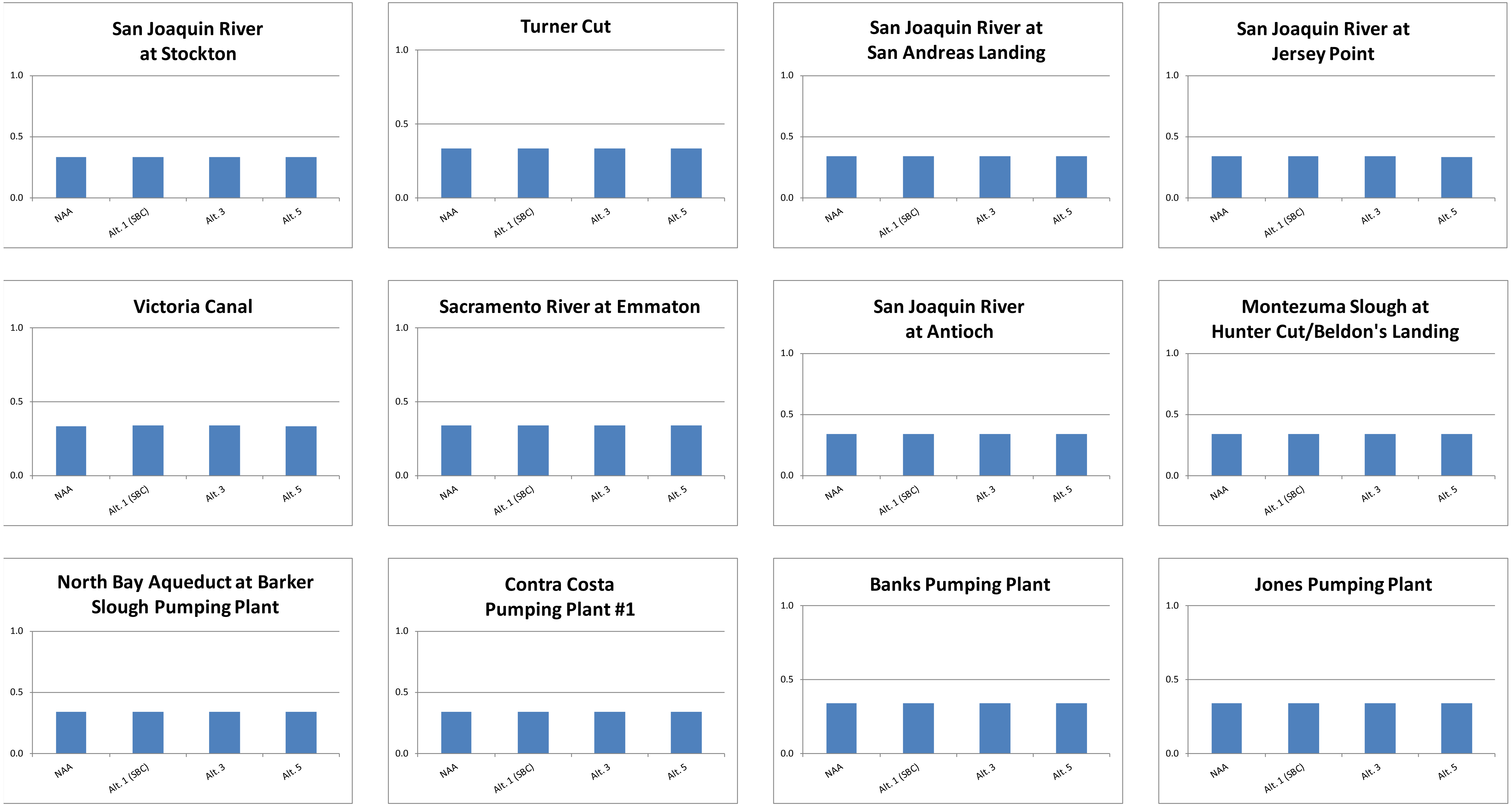


Figure 6D.10 Level of Concern Exceedance Quotients for Selenium Concentrations in Fish Fillets (wet weight) for Drought Years

“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1. Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately. Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.

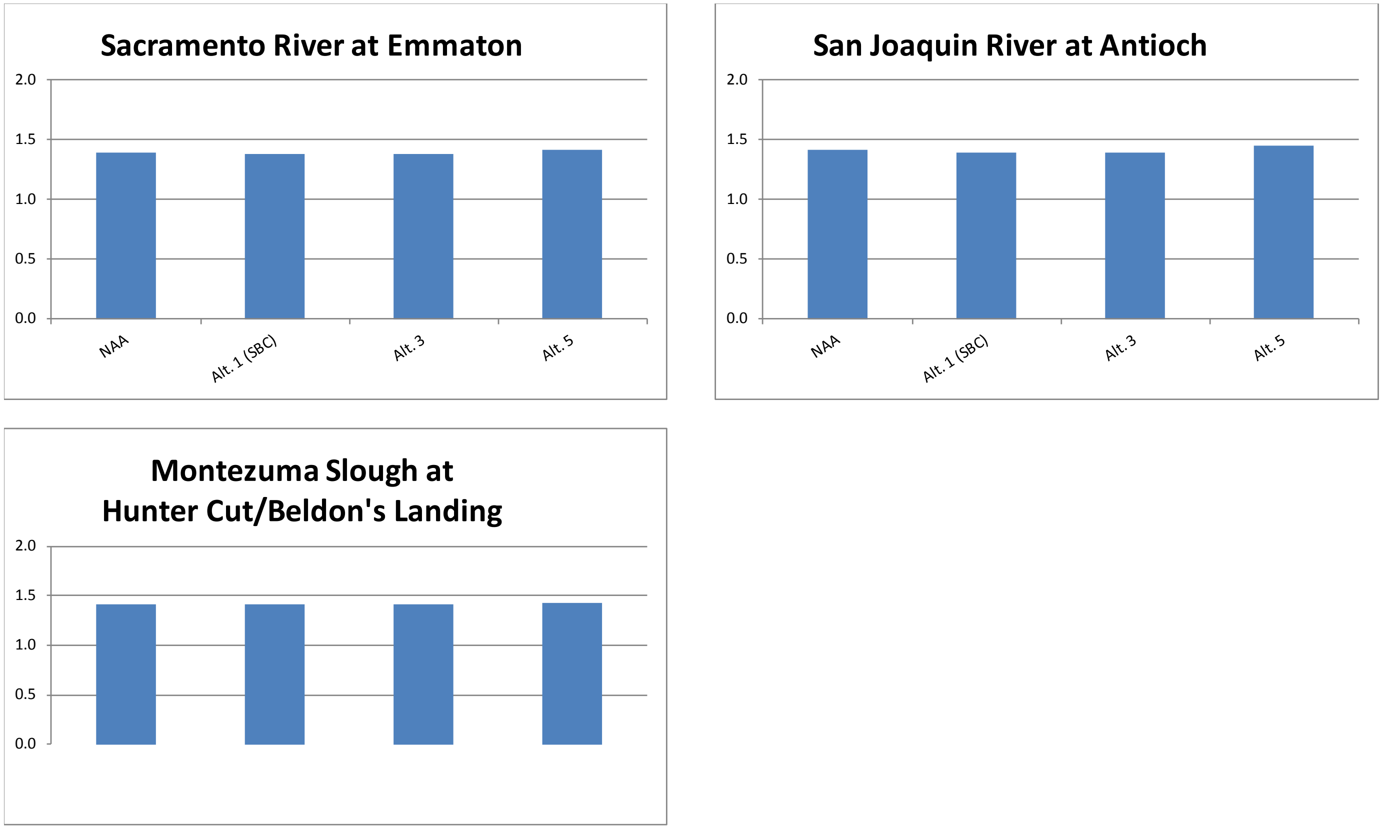


Figure 6D.11 Low Toxicity Threshold Exceedance Quotients for Selenium Concentrations in Whole-body Sturgeon for Drought Years

“Alt. 1 (SBC)” is the same as Second Basis of Comparison. This nomenclature was used in this appendix to be consistent with the model run output for the model run that represents both Second Basis of Comparison and Alternative 1.
Model results for Alternatives 1, 4, and Second Basis of Comparison are the same, therefore Alternative 4 results are not presented separately.
Model results for Alternative 2 and No Action Alternative are the same, therefore Alternative 2 results are not presented separately.

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