Appendix B: Water Quality Modeling

Water Quality

1.1 Background

The water quality section includes a discussion of water temperatures in the Lower American River (LAR) and water quality in the Sacramento–San Joaquin River Delta (Delta). Changes in the timing and magnitude of releases resulting from modifications to the Folsom Reservoir operations could affect the freshwater inflow into the Delta and, therefore, the salinity in the Delta. Water quality in Delta is of great importance to the native fish species as well the drinking water intakes, mainly the Contra Costa Water District's (CCWD) Rock Slough intake.

Changes to the Folsom Reservoir operations as part of the Folsom Water Control Manual (WCM) Update Project could change the in-stream temperatures in the LAR, Feather, and Sacramento Rivers. Riverine temperatures are especially important in the evaluation of effects to identified fish species and their aquatic habitat. This section presents general changes in the riverine temperatures, while impacts to fish species because of the changes in riverine temperatures can be found in Chapter 7, Fisheries.

1.2 Analytical Approach

For the water quality effects evaluation of this report, Central Valley Project/State Water Project Operations Model (CalSim II) models for all the scenarios were executed for an 82-year period of record (POR) extending from water year 1921 through water year 2003. The model output parameters selected for all of water quality comparative evaluations in this document were based on either their regulatory relevance or their historical importance in characterizing effects to water quality in the Delta with respect to the Central Valley Project (CVP)/State Water Project (SWP) system.

The U.S. Bureau of Reclamation's (Reclamation's) monthly water temperature model for the Sacramento and Feather Rivers was used for the comparative evaluation of water temperatures in the Sacramento and Feather Rivers. Reclamation's temperature model has a simulation period of 81 years, extending from January 1922 to December 2002. A detailed description of this model is in Appendix 4A, Reclamation Water Temperature Model.

The U.S. Army Corps of Engineers' (USACE's) Hydrologic Engineering Center (HEC) has developed the HEC-5Q water quality model that was used previously in Reclamation's Final Environmental Impact Statement for the Coordinated Long-Term Operation of the Central Valley Project and State Water Project. For the WCM Project, daily LAR water temperatures for all the scenarios were simulated for a period of about 81 years from January 1922 to September 2002. A detailed description of this model is in Appendix 4B (under development).

1.2.1 Model Output Parameters

The model output parameters selected for the water quality effects evaluation in the Delta were based on their regulatory and operational relevance. These model output parameters are:

- **Delta Outflow**

The State Water Resources Control Board (SWRCB) Water Rights Decision 1641(D-1641) established minimum Delta outflow requirements that were proposed in the 1995 Water Quality Control Plan (WQCP). Delta outflow is an important factor in determining water quality in the Delta. A lower Delta outflow might result in a larger seawater intrusion in the Delta, which can affect the migration of estuarine species as well the salinity at drinking water intakes. The outflow objectives for February through June are based on the X2 objectives. Delta outflow objectives for July through January are presented in Table 4-1.

Table 4-1. Delta Outflow Objectives

Month	Minimum Delta Outflow (cubic feet per second)
January	4,500 (6,000 if Eight River Index[1] is > 800 thousand acre-feet)
July	8,000 for wet and above-normal water years 6,500 for below-normal water years 5,000 for dry water years 4,000 for critical water years
August	4,000 for wet, above-normal, and below-normal water years 3,500 for dry water years 3,000 for critical water years
September	3,000
October	4,000 for all except critical water years 3,000 for critical water years
November–December	4,500 for all except critical water years 3,500 for critical water years

- **Location of X2**

The location of X2 is the geographical location of two parts per thousand, near-bottom salinity isohaline, measured in kilometers (km) upstream from the Golden Gate Bridge. The location of X2 is considered significant to the biologically important entrapment zone of the estuary and native fish. X2 is an index of both Delta outflow and estuarine salinity gradient.

[1] The Eight River Index refers to the sum of the unimpaired runoff as published in the California Department of Water Resources Bulletin 120 for the following locations: Sacramento River flow at Bend Bridge, near Red Bluff; Feather River, total inflow to Oroville Reservoir; Yuba River flow at Smartville; American River, total inflow to Folsom Reservoir; Stanislaus River, total inflow to New Melones Reservoir; Tuolumne River, total inflow to Don Pedro Reservoir; Merced River, total inflow to Exchequer Reservoir; and San Joaquin River, total inflow to Millerton Lake.

D-1641 specifies that the location of X2 must remain west of the confluence of the Sacramento and San Joaquin Rivers (Collinsville, measured 81 km upstream from the Golden Gate Bridge) for February through June. The X2 compliance can be achieved in one of three ways:

1. Daily average Electrical Conductivity (EC) is less than or equal to 2.64 millimhos per centimeter (mmhos/cm) at the compliance location.
2. 14-day running average EC is less than or equal to 2.64 mmhos/cm at the compliance location.
3. Three-day running average Delta outflow is greater than or equal to minimum Delta outflow at the compliance location.

In addition, X2 compliance must be met at Chipps Island (measured 74 km upstream from the Golden Gate Bridge) and Roe Island (or Port Chicago EC Monitory Station, measured 64 km upstream from the Golden Gate Bridge), for a certain number of days each month from February through June, based on previous month's Eight River Index.

D-1641 also specifies a salinity starting condition in X2 standards, which requires the daily average or 14-day running average EC at Collinsville to be less than 2.64 mmhos/cm for at least one day between February 1 and February 14, given that the January Eight River Index is greater than 900 thousand acre-feet (TAF). For very dry January conditions (i.e., Eight River Index is less than 900 TAF), the requirement is based on the CALFED Operations group discretion.

- **Delta Export to Import (E/I) Ratio.**

The ratio of CVP/SWP exports from the Delta relative to inflow to the Delta is referred to as the export to inflow ratios or the E/I ratio. The regulatory requirement on limiting the E/I ratio was introduced in the 1995 WQCP and implemented through D-1641. Higher inflows and lower export rates provide greater protection to the estuarine species. The maximum E/I ratio as stated in D-1641 is 65 percent for July through January and is 35 percent for February through June—the months most critical for fish species.

The limit for February can be relaxed depending on the Eight River Index for January. If the index is greater than 1.5 million acre-feet per year (MAF), the E/I ratio remains at 35 percent; if the index is lower than 1.0 MAF, the limit on E/I ratio is increased to 45 percent; finally, if the index is between 1.5 MAF and 1.0 MAF, the E/I ratio is set between 35 percent and 45 percent. Delta E/I ratio is generally built into the modeling assumptions for CalSim II and, therefore, the model restricts the exports based on this limit for all months of the year.

CalSim II model outputs were tabulated for long-term average and average by 40-30-30 Sacramento Valley Index water year-type average for each of these parameters. These tables can be found in Tables 146 through 148 of each comparison in Appendix A Monthly Data Products Volume I.

1.2.2 Delta Water Quality Refined Level Evaluation

In addition to the parameters discussed above, a more refined level evaluation was completed for Delta parameters such as X2, Delta outflow, and salinity of water at the CCWD Rock Slough intake. This refined level consists of comparison of scenarios based on a consistency formulation. Interpretive thresholds were developed to define deviations from the baseline condition from this formulation. The following indices were selected:

- The February through June location of the X2 relative to river km 64 (Port Chicago), 74 (Chipps Island), and 81 (Collinsville).
- The relative X2 location and relative change in monthly position from the baseline condition. To determine consistency with the baseline condition, the following rules are applied:
  - If the magnitude of the difference in the X2 position is ever equal to or greater than 1 km, then the two models are "not consistent."
  - If the two models have greater than 5 occurrences of a less than 1 km change, then the models are "not consistent."
  - If the two models have less than or equal to 5 and greater than or equal to 2 occurrences of a less than 1 km change, then the models are "moderately consistent."
  - If the two models have less than 2 occurrences of a less than 1 km change, then the models are "consistent."
- Delta outflows were evaluated through comparison of model outputs against fall X2 standards and D-1641 outflow objectives.
- Salinity at CCWD's Rock Slough intake was evaluated through comparison of model outputs against D-1641 standards. D-1641 standards call for a minimum number of days that the mean daily chloride concentrations are less than or equal to 150 milligrams per liter (mg/L). These standards are provided in Table 4-2.

Table 4-2. D-1641 Requirements for CCWD Rock Slough Intake

	Water Year Type				
D-1641	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
Minimum Number of Days Less than 150 mg/L	240	190	175	165	155
Percent	66%	52%	48%	45%	42%

A consistency formulation for salinity at Rock Slough intake was developed as shown below:

- If the difference in count of occurrences greater than 150 mg/L is less than or equal to 1 and the difference in mg/L is greater than 3 mg/L, then the two models are "not consistent."
- If the difference in count of occurrences greater than 150 mg/L is less than or equal to 1 and the difference in mg/L is less than or equal to 3 mg/L but greater than 1 mg/L, then the two models are "moderately consistent."

- If the difference in count of occurrences greater than 150 mg/L is less than or equal to 1 and the difference in mg/L is less than or equal to 1 mg/L, then the two models are "consistent."

Counts of the X2 location occurring east of three control points (64, 74, and 81 km east of the Golden Gate Bridge) for the February through June period, for each of the 82-years, sorted by water year type are presented in Table 169 of each comparison in Appendix A Monthly Data Products Volume I.

To further refine the comparison of the models, the average, maximum, and minimum monthly X2 position was then developed for all months to compare the variability between the models, using a representation of the upper and lower boundaries of the data, and are presented in Table 170 of each comparison in Appendix A Monthly Data Products Volume I.

These maximum and minimum values discussed above present the end points in the data and do not consider changes within a given year. Therefore, the monthly shift in the X2 position was evaluated on a year-to-year basis for each month in the 82-year POR. The results are shown in Table 171 of each comparison in Appendix A Monthly Data Products Volume I.

A positive shift in the X2 location represents a condition where the alternative is farther east than the baseline, representing a poorer condition, and the magnitude of this change was derived as a final derivative of the variation between the models. Table 172 of each comparison in Appendix A Monthly Data Products Volume I shows the results of this comparison.

Delta outflow for September and October are required to maintain monthly average X2 no greater than 74 km from the Golden Gate Bridge. If the preceding spring was above normal, then the criterion is 81 km for both months. The variability of X2 values based on the complete 82-year POR, the POR delimited by water type, and differences of these parameters between each models are presented in Table 173 of each comparison in Appendix A Monthly Data Products Volume I.

The Delta outflow objectives for February through June are based on the X2 objectives which have already been discussed in earlier sections of this report. The Delta outflow objectives for July through January are defined in D-1641. Table 174 of each comparison in Appendix A Monthly Data Products Volume I shows count of months where Delta outflow is less than the objectives.

Monthly count of occurrences where salinity in CCWD's Rock Slough intake is greater than 150 mg/L is presented in Table 177 of each comparison in Appendix A Monthly Data Products Volume I.

1.2.3 Riverine Temperatures

USACE selected the model output nodes specified below for this evaluation because of their regulatory relevance, their historical importance in characterizing effects on water temperature in the CVP/SWP system, and/or because they represent locations downstream of notable accretions or depletions.

- Water temperature in the Sacramento River
  - Below Keswick Dam

- At Bend Bridge
- Below the Feather River confluence
- At Freeport

➢ Water temperature in the Feather River

- Below the Thermalito Afterbay Outlet
- At the mouth of lower Feather River

➢ Water temperature in the American River

- Below Nimbus Dam
- At Watt Avenue
- At the mouth of LAR (river mile [RM] 1)

USACE used monthly average simulated water temperatures over the entire simulation period and by water year type (based on the Sacramento Valley Index) to compare differences between the alternatives and the basis of comparison. Long-term average water temperatures for each month and monthly average water temperatures by water year type are presented in tabular format. In addition, water temperature differences were evaluated over the entire monthly exceedance distributions and over the warmest 25 percent of the monthly exceedance distributions. Water temperature exceedance distributions (or curves) illustrate the distribution of simulated water temperatures under the two compared scenarios. These data products are presented in:

➢ Tables 42 through 119 of each comparison in Appendix A Monthly Data Products Volume I;

➢ Figures 40 through 111 of each comparison in Appendix A Monthly Data Products Volume I;

➢ Tables Daily-2 through Daily-40 of each comparison in Appendix C Daily Data Products; and

➢ Figures Daily-30 through Daily-65 of each comparison in Appendix C Daily Data Products.

In general, water temperature exceedance distributions represent the probability, as a percentage of time, that modeled water temperature values would be met or exceeded at a specific location during a certain period. For the purposes of identifying general increases and decreases in water temperatures, USACE applied a metric of greater than 0.3 degree Fahrenheit (°F) in order to describe "measurable" increases and decreases in water temperatures (YCWA et al. 2007). Specifically, USACE identified measurable increases and decreases in water temperature for long-term average monthly and average monthly by water year type water temperatures for each node evaluated.

Over the monthly exceedance distributions, net measurable changes in water temperature were computed over the entire monthly distributions as well as over the warmest 25 percent of the monthly distributions for each node evaluated. Net measurable changes were calculated as a percentage of time by subtracting the percentage of time represented by measurable decreases in water temperature from the percentage of time represented by measurable increases in water temperature. Net measurable changes representing 10 percent or more of the monthly distribution evaluated are reported in this section.

While general differences in water temperatures are discussed in this section, more-detailed evaluations of water temperature exceedance distributions are presented in Chapter 7, Fisheries, to identify the effects on fish species of focused evaluation. Specifically, Chapter 7, Fisheries, evaluates differences in the probability of simulated water temperatures exceeding fish species and lifestage-specific water temperature index values with the Folsom WCM alternatives, relative to the basis of comparison.

1.3 E504 ELD Model Development

The E504 ELD CalSim II model build served as the basis of water quality effects evaluation for E504 ELD. E504 ELD incorporates the flood storage reserve requirements associated with a 400/670 TAF variable storage operation utilizing upstream storage crediting from French Meadows, Hell Hole, and Union Valley (SAFCA and Reclamation 2004). The Joint Federal Project is not part of this model build. E504 ELD represents a 2013 level of demand condition. A detailed presentation of the E504 ELD CalSim II model is found in Chapter 2, Water Supply. No modifications were made to Reclamation's monthly temperature model, other than revising the flow and storage input values from the CalSim II build for E504 ELD.

1.4 J604 FLD Model Development

J604 FLD incorporates the flood storage reserve requirements associated with a 400/670 TAF variable storage operation utilizing upstream storage crediting from French Meadows, Hell Hole, and Union Valley (SAFCA and Reclamation 2004). The Joint Federal Project auxiliary spillway is used only under emergency conditions. J604 FLD represents a 2020/2033 level of demand condition. A detailed presentation of these calculations is found in Chapter 2, Water Supply. No modifications were made to Reclamation's monthly temperature model, other than revising the flow and storage input values from the CalSim II build for J604 FLD.

1.5 Comparison of E504 ELD and J604 FLD

1.5.1 General Observations

Delta water quality model outputs indicate that, in general, these parameters show slight differences for the two scenarios. The magnitude of differences in Delta outflow is within a range of ±1.6 percent for the full simulation period average monthly outflow, with a maximum decrease of 2.5 percent in April of below-normal water years, and maximum increase of 4.4 percent in August of critical water years. The J604 FLD March through May long-term average and water year type outflows show a 0.1-percent increase for long-term and all water year types, except for a 0.3-percent increase for below-normal water years.

The long-term monthly mean E/I ratios indicate slight differences between J604 FLD and E504 ELD with a maximum absolute difference of –1.3 percent in average of all Augusts. The full simulation period differences ranges from –2.4 percent in average of all Augusts to 6.2 percent in average of all Aprils.

The long-term average monthly X2 location has a positive shift of 0.2 km in July and 0.1 km in August, November, and December. The average X2 location in May shifts negatively by 0.2 km. For all other months, there is no change in the full simulation period average monthly X2 location for the two scenarios compared. Average monthly X2 location by water year type shows a change of ±0.2 km.

1.5.2 Detailed Observations

Table 4-3. Delta Outflow, E/I Ratio, X2 Location, and Rock Slough Salinity for J604 FLD vs. E504 ELD.

Delta Outflow	**Evaluation Parameters**	**Long-term**	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
Long-term and water year type average Delta Outflow – Generally similar long-term average delta outflows and generally similar average delta outflow most of the time during all water year types (±2.5%).	Monthly Maximum Reduction	–1.4%	–1.8%	–1.3%	–2.5%	–1.3%	√
	Delta Outflow March–May	√	√	√	√	√	√
	Delta Outflow Objectives	NA	NA	NA	NA	NA	NA
E/I Ratio	**Evaluation Parameters**	**Long-term**	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
Long-term and water year type average E/I Ratio – Generally similar long-term average and generally similar most of the time during all water year types. The maximum change is seen is (±16.6%) in Critical year types.	E/I Ratio	–2.4%	–1.5%	√	√	–4.5%	–16.6%
X2 Location	**Evaluation Parameters**	**Long-term**	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
Long-term and water year type average X2 Location – Generally similar long-term average and generally similar most of the time during all water year types.	X2 Location (km)	0.2	0.2	0.2	0.1	0.1	0.1

Note: "✓"refers to same or similar values, generally representing a less than 1-percent difference in parameters.

1.5.2.1 Riverine Temperatures

Simulated monthly water temperatures at representative nodes in the rivers in the Project Area indicate that water temperatures under J604 FLD relative to E504 ELD would generally: be (1) similar most of the time during most of the year in the Sacramento River, but would be somewhat warmer more often during July and August below Keswick Dam, somewhat warmer more often during August and October at Bend Bridge, somewhat warmer more often during August and somewhat cooler more often during July below the Feather River confluence, and somewhat warmer more often during July through September at Freeport; (2) generally similar most of the time in the Feather River below the Thermalito Afterbay Outlet and at the mouth, but somewhat warmer during August below the Thermalito Afterbay Outlet; and (3) generally similar or cooler during the fall, and warmer more often during the spring and summer in the American River.

Changes in simulated water temperatures within each evaluated water body under J604 FLD relative to E504 ELD are summarized in Table 4-4 below.

Table 4-4. Riverine Water Temperatures for J604 FLD vs. E504 ELD.

<table>
<tr><th>Evaluation Parameters</th><th>Evaluation Metrics and Summary of Effects</th><th colspan="6">Results</th></tr>
<tr><th colspan="8">Water Temperature – Long-term Average and Average by Water Year Type</th></tr>
<tr><td rowspan="2">River and Location</td><td rowspan="11">Generally similar long-term average water temperatures and average water temperatures by water year type during most months at most locations, except for warmer water temperatures during the spring and summer and cooler temperatures during the fall in the American River, and warmer water temperatures during August in the Sacramento River.</td><th colspan="6">Long-term and Water Year Type Average Water Temperature</th></tr>
<tr><th>Long-term</th><th>Wet</th><th>Above Normal</th><th>Below Normal</th><th>Dry</th><th>Critical</th></tr>
<tr><td>Sacramento River below Keswick Dam</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>Warmer in Aug</td></tr>
<tr><td>Sacramento River at Bend Bridge</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>Warmer in Aug</td></tr>
<tr><td>Sacramento River at Feather River confluence</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Sacramento River at Freeport</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>Warmer in Aug</td></tr>
<tr><td>Feather River below Thermalito Afterbay Outlet</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Feather River at the mouth</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>American River below Nimbus Dam</td><td>Cooler in Dec; warmer in Aug</td><td>Cooler in Dec; warmer in Aug</td><td>✓</td><td>Cooler in Nov & Dec</td><td>Cooler in Dec & May</td><td>Cooler in Dec & Jan; warmer in Jun–Aug</td></tr>
<tr><td>American River at Watt Avenue</td><td>Cooler in Dec; warmer in May–Sep</td><td>Warmer in Jul & Aug</td><td>Warmer in May & Jul–Sep</td><td>Cooler in Dec; warmer in Apr–Jul & Sep</td><td>Warmer in Apr–Sep</td><td>Cooler in Dec; warmer in Mar–Sep</td></tr>
<tr><td>American River at the mouth</td><td>Warmer in Mar–Sep</td><td>Warmer in May–Sep</td><td>Warmer in May–Sep</td><td>Cooler in Dec; warmer in Apr–Jul & Sep</td><td>Warmer in Mar–Sep</td><td>Cooler in Dec; warmer in Mar–Sep</td></tr>
</table>

Evaluation Parameters	Evaluation Metrics and Summary of Effects	Results
Water Temperature – Net Measurable Differences over Entire Monthly Exceedance Distributions		
River and Location	Generally similar water temperatures over most of the monthly exceedance distributions, but with warmer water temperatures more often in the American River during the spring and summer and cooler temperatures during the fall.	**Entire Monthly Exceedance Distributions**
Sacramento River below Keswick Dam		✓
Sacramento River at Bend Bridge		✓
Sacramento River at Feather River confluence		✓
Sacramento River at Freeport		✓
Feather River below Thermalito Afterbay Outlet		✓
Feather River at the mouth		✓
American River below Nimbus Dam		Net measurable increases during Aug–Sep; net decreases in Nov–Dec
American River at Watt Avenue		Net measurable increases during Mar–Sep; net decreases in Nov–Dec
American River at the mouth		Net measurable increases during Mar–Sep; net decrease in Dec
Water Temperature – Net Measurable Differences over Warmest 25% of Monthly Exceedance Distributions		
River and Location	Generally similar water temperatures over most of the monthly exceedance distributions, but warmer temperatures during some months in summer in the Sacramento and Feather Rivers, and during the spring and summer in the American River, and cooler temperatures in Dec in the American River.	**Warmest 25% of the Monthly Exceedance Distributions**
Sacramento River below Keswick Dam		Net measurable increases during Jul and Aug
Sacramento River at Bend Bridge		Net measurable increases during Aug and Oct
Sacramento River at Feather River confluence		Net measurable increase during Aug and net measurable decrease during Jul
Sacramento River at Freeport		Net measurable increases during Jul–Sep
Feather River below Thermalito Afterbay Outlet		Net measurable increase during Aug
Feather River at the mouth		✓
American River below Nimbus Dam		Net measurable increases during Mar and Jun–Sep and net measurable decreases during Dec
American River at Watt Avenue		Net measurable increases during Mar–Sep and net measurable decrease during Dec
American River at the mouth		Net measurable increases during Feb–Sep and net measurable decrease during Dec

Note: "✓" refers to similar values of the evaluation metric for both scenarios.

Additional discussion of water temperature changes in the LAR is provided below.

American River below Nimbus Dam

Long-term average monthly water temperatures in the American River below Nimbus Dam would be essentially equivalent or generally similar during most months of the year, but would be measurably warmer during August and cooler during December. Monthly water temperatures by water year type would be generally equivalent or cooler during the fall and winter of most water year types, and generally similar or warmer more often during the spring and summer. Monthly water temperature exceedance probability distributions would be cooler more often during October through January, generally similar during February through May, and similar or warmer more often during June through September.

Over the entire monthly distributions, net measurable decreases in water temperature would occur over 10 percent or more of the time during November and December, and net measurable increases in water temperature would occur over 10 percent or more of the time during August and September. Over the warmest 25 percent of the monthly distributions, net measurable decreases in water temperature would occur over 10 percent or more in the distributions during December, and net measurable increases would occur over 10 percent or more in the distributions during March and June through September.

American River at Watt Avenue

Long-term average monthly water temperatures in the American River at Watt Avenue would be essentially equivalent or generally similar most of the time, but would be measurably warmer during May through August. Monthly water temperatures by water year type would be generally equivalent or cooler during the fall and winter, and generally similar or warmer during the spring and summer. Monthly water temperature exceedance probability distributions would be generally similar or cooler during October through December, similar or warmer during January and March, and warmer more often during April through September.

Over the entire monthly distributions, net measurable decreases would occur during November and December, and net measurable increases would occur during March through September. Over the warmest 25 percent of the monthly distributions, net measurable decreases in water temperature would occur during December, and net measurable increases would occur over 10 percent or more in the distributions during March through September.

American River at the Mouth

Long-term average monthly water temperatures in the American River at the mouth would be measurably warmer during March through September. Monthly water temperatures by water year type would be generally equivalent or cooler during October through February and warmer more often during March through September of most water year types. Monthly water temperature exceedance probability distributions would be generally similar during October, November and February, cooler during December through January, and warmer more often during March through September.

Over the entire monthly distributions, a net measurable decrease would occur during December, and net measurable increases would occur during March through September. Also, over the warmest 25 percent of the monthly distributions, net measurable decreases in water temperature would occur during December, and net measurable increases would occur over 10 percent or more in the distributions during February through September.

1.5.3 Evaluation of Effects

As described earlier in this chapter, no changes were made to the Folsom Reservoir operations for J604 FLD relative to E504 ELD. Therefore, this discussion of water quality effects is limited to the observations caused by other differences between E504 ELD and J604 FLD.

From the Delta water quality perspective, E504 ELD and J604 FLD show very little difference in the CalSim II model outputs. Delta outflow would change very minimally. These changes represent a percent difference of 1.6 or less. The long-term average monthly X2 location would shift by ±0.2 km for some months, while would remain the same for most months. E/I ratio shows slightly higher percentage changes but is well under the regulatory limits of 65 percent and 35 percent.

Evaluation of effects related to the river water temperatures are discussed as part of the fisheries effects evaluation in Chapter 7, Fisheries.

1.6 J602F3 ELD Model Development

J602F3 ELD was built from the E504 ELD CalSim II build. The inflow-forecast-based operations compute the required available storage level, or top-of-conservation-pool storage volumes, as a function of forecasted inflow volume. Inflow volumes are computed from runoff forecast data provided by the National Weather Service. J602F3 ELD represents a 2013 level of demand condition. A detailed description of this model is found in Chapter 2, Water Supply. No modifications were made to Reclamation's monthly temperature model, other than revising the flow and storage input values from the CalSim II build for J602F3 ELD.

1.7 Comparison of J602F3 ELD and E504 ELD

1.7.1 General Observations

Delta water quality modeling indicates that, in general, these parameters show little difference for the two scenarios compared. The magnitude of differences in Delta outflow is within a range of ±1.0 percent for the full simulation period average. A maximum reduction of 2.0 percent occurred in the monthly water year type metric in March of dry water years. Average March through May outflow shows little increase of 0.7 percent over the full simulation period with a maximum of 0.5-percent reduction observed in March through May in dry water years.

The Delta X2 location in general also shows minimal difference for the two scenarios. Long-term average and by water year type differences are typically ±0.1 km or less, with a maximum of 0.2 km positive shift in average of March of dry years. The maximum monthly change ranges from 0.2 km in September to 1.2 km in December. Minimum monthly change observed ranges from –0.1 km in August to –3.1 km in June.

Long-term average monthly E/I ratios show a maximum absolute difference of 0.2 percent for June. All other months show very little absolute difference in the range of ±0.1 percent. The relative difference ranges from –1.2 percent in average of all Aprils to 0.9 percent in average of all Junes.

The average X2 for J602F3 ELD moves east of the control point relative to E504 ELD twice: at the 74 km control point in one year in June of below-normal years, and in one year east of the 64 km control point in April of dry years. The number of months of X2 moving east of the 74 km control point for J602F3 ELD relative to E504 ELD decreases by one in May of dry water years. Results indicate that the scenarios are "consistent" with respect to the fall X2 standards. Both scenarios have X2 locations greater than those required by September standards while meeting October X2 standards. Both scenarios meet the Delta outflow objectives for July through January. The X2 for J602F3 ELD shows four instances with a greater than or equal to 1 km shift and those occurred in March, April, November, and December. With consistency-based criteria, J602F3 ELD was determined to be "not consistent" with E504 ELD.

The CCWD Rock Slough intake shows no increases in occurrences of salinity levels at greater than 150 mg/L levels. These occurrences show a one-time decrease in October of below-normal and dry water years and in September of critical water years. The maximum difference in salinity was an increase of 12.56 mg/L (from 171.79 mg/L to 184.35 mg/L) occurring in water year 1935, a below-normal water year. The difference of >3 mg/L means that J602F3 ELD is considered "not consistent" with E504 ELD based on the consistency formulation for Rock Slough salinity.

1.7.2 Detailed Observations

Table 4-5. Delta Outflow, E/I Ratio, X2 Location, and Rock Slough Salinity for J602F3 ELD vs. E504 ELD.

Delta Outflow	Evaluation Parameters	Long-term	Wet	Above Normal	Below Normal	Dry	Critical
Long-term and water year type average Delta Outflow – Generally similar long-term average delta outflows and generally similar average delta outflow most of the time during all water year types (±2.0%).	Monthly Maximum Reduction	√	–1.1%	–1.7%	–1.3%	–2.0%	√
	Delta Outflow March–May	√	√	√	√	√	√
	Delta Outflow Objectives	NA	√	√	√	√	√
E/I Ratio	**Evaluation Parameters**	**Long-term**	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
Long-term and water year type average E/I Ratio – Generally similar long-term average and generally similar most of the time during all water year types. The maximum change is seen is (±4.1%) in dry year types.	E/I Ratio	–1.2% to +0.9%	±1.9%	–1.7% to +0.8%	–1.2% to +1.1%	–1.0% to +4.1%	–1.7% to +1.0%

X2 Location	Evaluation Parameters	Long-term	Wet	Above Normal	Below Normal	Dry	Critical
Long-term and water year type average X2 Location – Generally similar long-term average and generally similar most of the time during all water year types.	X2 Location (km)	±0.1	–0.2 to +0.1	–0.2 to +0.1	–0.2 to +0.1	–0.1 to +0.2	±0.1
	X2 Location Count 81 km	NA	√	√	√	√	√
	X2 Location Count 74 km	NA	√	√	1	–1	√
	X2 Location Count 64 km	NA	√	√	√	1	√

X2 Location	Evaluation Parameters	
Long-term and water year type average X2 Location – Generally similar long-term average and generally similar most of the time during all water year types. The maximum change is seen in (±1.5 km).	Change in X2 Location Monthly Maximum Value km	0.3 west
	Change in X2 Location Monthly Minimum Value km	0.4 east
	X2 Location Relative Change km (Maximum)	1.2
	X2 Location Relative Change km (Minimum)	–3.1
	X2 Exceeding Fall Standards (Count)	√
	X2 Location Shift	**Count**
	> or = 1 km	4
	0.5–1.0 km	14
	0.25–0.5 km	27

Salinity Rock Slough	Evaluation Parameters	Long-term	Wet	Above Normal	Below Normal	Dry	Critical
Water year type Salinity at Rock Slough Intake – Generally similar long-term average and generally similar most of the time during all water year types.	Salinity Rock Slough (Change in Count >150 mg/L)	NA	√	√	o	o	o
	Salinity Rock Slough Max Change (>150 mg/L: 12.56 mg/L)						

Note: "✓"refers to same or similar values, generally representing a less than 1-percent difference in parameters.
Note: "o" refers to a decrease in the count of occurrences of greater than 150 mg/L salinity at Rock Slough.

1.7.2.1 Riverine Temperatures

Simulated monthly water temperatures at representative nodes in the rivers in the Project Area indicate that water temperatures under J602F3 ELD relative to E504 ELD would generally be: (1) equivalent or similar most of the time in the Sacramento River, but would be measurably cooler slightly more often in August, measurably warmer slightly more often in June and July below Keswick Dam, and measurably warmer slightly more often during July at Bend Bridge and below the Feather River confluence; (2) equivalent or similar most of the time in the Feather River below the Thermalito Afterbay Outlet and at the mouth; and (3) generally similar most of the time in the LAR, but with measurable reductions in water temperature during late spring, summer, and early fall months throughout the river, with measurable increases in water temperature during March and August.

Changes in simulated water temperatures within each evaluated water body under J602F3 ELD relative to E504 ELD are summarized in Table 4-10 below.

Table 4-6. Riverine Water Temperatures for J602F3 ELD vs. E504 ELD.

Evaluation Parameters	**Evaluation Metrics and Summary of Effects**	**Results**					
Water Temperature – Long-term Average and Average by Water Year Type							
River and Location		**Long-term and Water Year Type Average Water Temperature**					
		Long-term	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
Sacramento River below Keswick Dam	Generally similar long-term average water temperatures and average water temperatures by water year type during most months, with some differences during some months in the American River.	✓	✓	✓	✓	✓	✓
Sacramento River at Bend Bridge		✓	✓	✓	✓	✓	✓
Sacramento River at Feather River confluence		✓	✓	✓	✓	✓	✓
Sacramento River at Freeport		✓	✓	✓	✓	✓	✓
Feather River below Thermalito Afterbay Outlet		✓	✓	✓	✓	✓	✓
Feather River at the mouth		✓	✓	✓	✓	✓	✓
American River below Nimbus Dam		✓	✓	✓	Cooler in May	Cooler in May & Jun	✓
American River at Watt Avenue		Cooler in May	✓	Cooler in May & Jun	Cooler in May	Cooler in May & Jun	Cooler in Jul
American River at the mouth		✓	Cooler in Mar	Cooler in May & Jun	✓	Cooler in May & Jun; warmer in Mar	Cooler in Jul

<table>
<tr><th colspan="3">Water Temperature – Net Measurable Differences over Entire Monthly Exceedance Distributions</th></tr>
<tr><th>River and Location</th><td rowspan="10">Generally similar water temperatures over most of the monthly exceedance distributions, but with cooler temperatures during some months in the spring and summer below Nimbus Dam and warmer temperatures during the spring near the mouth of the American River.</td><th>Entire Monthly Exceedance Distributions</th></tr>
<tr><td>Sacramento River below Keswick Dam</td><td>✓</td></tr>
<tr><td>Sacramento River at Bend Bridge</td><td>✓</td></tr>
<tr><td>Sacramento River at Feather River confluence</td><td>✓</td></tr>
<tr><td>Sacramento River at Freeport</td><td>✓</td></tr>
<tr><td>Feather River below Thermalito Afterbay Outlet</td><td>✓</td></tr>
<tr><td>Feather River at the mouth</td><td>✓</td></tr>
<tr><td>American River below Nimbus Dam</td><td>Net measurable decreases in May & Jun</td></tr>
<tr><td>American River at Watt Avenue</td><td>Net measurable decrease in May & Jun</td></tr>
<tr><td>American River at the mouth</td><td>Net measurable decreases in May & Jun; net increase in Aug</td></tr>
</table>

<table>
<tr><th colspan="3">Water Temperature – Net Measurable Differences over Warmest 25% of Monthly Exceedance Distributions</th></tr>
<tr><th>River and Location</th><th></th><th>Warmest 25% of the Monthly Exceedance Distributions</th></tr>
<tr><td>Sacramento River below Keswick Dam</td><td rowspan="9">Generally similar water temperatures over most of the monthly exceedance distributions, but with some differences during the summer in the Sacramento and Feather rivers and differences during the spring and summer in the American River.</td><td>Net measurable decrease in Aug; net increase in Jun & Jul</td></tr>
<tr><td>Sacramento River at Bend Bridge</td><td>Net measurable increase in Jul</td></tr>
<tr><td>Sacramento River at Feather River confluence</td><td>Net measurable increase in Jul</td></tr>
<tr><td>Sacramento River at Freeport</td><td>✓</td></tr>
<tr><td>Feather River below Thermalito Afterbay Outlet</td><td>✓</td></tr>
<tr><td>Feather River at the mouth</td><td>✓</td></tr>
<tr><td>American River below Nimbus Dam</td><td>Net measurable decreases in Apr–Jul & Oct; net increase in Mar</td></tr>
<tr><td>American River at Watt Avenue</td><td>Net measurable decreases in May, Jun, & Jul</td></tr>
<tr><td>American River at the mouth</td><td>Net measurable decreases in May–Jul</td></tr>
</table>

Note: "✓" refers to similar values of the evaluation metric for both scenarios.

Additional discussion of water temperature changes in the LAR is provided below.

<u>American River below Nimbus Dam</u>

Long-term average monthly water temperatures in the American River below Nimbus Dam would be essentially equivalent during all months of the year. Monthly water temperatures by water year type would be generally similar most of the time by water year type, but would be measurably cooler during May of below-normal years and during May and June of dry water years. Monthly water temperature exceedance probability distributions would be generally similar most of the time during most months, but would be cooler during April through August and October, and warmer during March.

Over the entire monthly distributions, net measurable decreases in water temperature would occur over 10 percent or more of the time during May and June. Over the warmest 25 percent of the monthly distributions, net measurable decreases in water temperature would occur over 10 percent or more in the distributions during October and April through July, while a net measurable increase would occur during March.

American River at Watt Avenue

Long-term average monthly water temperatures in the American River at Watt Avenue would be essentially equivalent during all months of the year, except for May when temperatures would be measurably cooler. Monthly water temperatures by water year type would be generally similar during all water year types, but would be measurably cooler during May and June of above-normal and dry water years, May of below-normal water years, and July of critical water years. Monthly water temperature exceedance probability distributions would be generally similar most of the time during most months, but would be cooler during May, June, and July.

Over the entire monthly distributions, a net measurable decrease in water temperature would occur over 10 percent or more of the time during May and June. Over the warmest 25 percent of the monthly distributions, net measurable decreases in water temperature would occur over 10 percent or more in the distributions during May, June and July.

American River at the Mouth

Long-term average monthly water temperatures in the American River at the mouth (i.e., RM 1) would be essentially equivalent during all months of the year. Generally, monthly water temperatures by water year type would be similar during most months of all water year types, but would be measurably cooler during March of wet years, May and June of above-normal and dry water years, and July of critical water years, and would be measurably warmer during March of dry water years. Monthly water temperature exceedance probability distributions would be generally similar most of the time, but would be cooler during May and June and warmer during August.

Over the entire monthly distributions, net measurable increases in water temperature would occur over 10 percent or more of the time during May and June, and a net measurable increase in water temperature would occur over 10 percent or more of the time during August. Over the warmest 25 percent of the monthly distributions, net measurable decreases in water temperature would occur over 10 percent or more of the time during May through July.

1.7.3 Evaluation of Effects

The Delta water quality effects evaluation for E504 ELD and J602F3 ELD indicates that J602F3 ELD would be generally similar to E504 ELD over the full simulation period. The changes in the long-term averages for Delta outflow, X2, and E/I ratio represent a difference of 1 percent or less. Consistency-based evaluation shows that the two scenarios would be consistent for Delta outflow, but "not consistent" for X2 and salinity at Rock Slough intake.

A positive shift of greater than or equal to 1 km in X2 location occurs four times over the simulation period. Further investigation of the scenarios indicates that the X2 shifts positively by 1.2 km in December 1950, an above-normal water year. This is due in part to the change in the maximum allowable storage at Folsom Reservoir and the ability for Folsom Reservoir to store more water during this month. The X2 shifts positively by 1 km in March 1932, a dry water year, and by 1.1 km both in April 1960, a dry water year, and November 1962, a wet water year. This is due in part to the changes in the Folsom Reservoir storages and associated Folsom-Shasta reservoir storage balancing in the CalSim II model. While this change would be considered "not consistent" with the consistency-based formulation, it is rare enough that the two scenarios would still be considered generally equivalent. In addition, the consistency criteria of X2 ever shifting positively by >1 km is very rigorous and should be considered in tandem with fisheries evaluation for effects on the Delta fish population.

The salinity at Rock Slough intake increases by >3 mg/L making the two scenarios "not consistent." It should be noted that for the below-normal, dry, and critical water years, the count of occurrences of >150 mg/L decreases by one time.

1.12 References

Water Quality

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