Appendix 6B, Section A

Surface Water Temperature Modeling

This appendix provides 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. The appendix also provides temperature model results and interpretation methods used for the impacts analysis and descriptions. Additional information pertaining to the development of the analytical tools, incorporating climate change, and the use of input data from other models, is also provided. 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.A.1 Surface Water Temperature Modeling Methodology

This section summarizes the surface water temperature modeling methodology used for the No Action Alternative, Second Basis of Comparison, and other alternatives. It describes how temperature modeling fits into the overall analytical framework and contains descriptions of the key analytical and numerical tools and approaches used in the quantitative evaluation of the alternatives.

In the evaluation of the No Action Alternative, Second Basis of Comparison, and other alternatives, climate change assumptions at the Year 2030 are used to develop modified climate input files for the temperature models. The modeling assumptions are provided in Section 6B.A.2.

6B.A.1.1 Overview of the Modeling Approach

To support the water quality and aquatic resources impact analyses of the alternatives, modeling of surface water temperature in the Central Valley is necessary to evaluate changes to conditions affecting surface water temperatures in rivers that are affected by SWP and CVP operations. Two different surface water temperature modeling tools were used for the analysis. The HEC-5Q model simulated daily temperatures for the Trinity River (downstream of Lewiston Dam), Sacramento River (from Keswick Dam to the Feather River confluence), American River (from Nimbus Dam to Sacramento River confluence), and Stanislaus River (from New Melones Dam to the confluence with San Joaquin River). The Reclamation Temperature Model was used for simulating monthly temperatures for the Feather and Lower Sacramento (from the Feather River confluence to Freeport) rivers. Both models used CalSim II outputs as stream flow and reservoir storage inputs. The results from these models are used to inform the understanding of effects on the surface water temperature of each individual alternative considered in the EIS.

6B.A.1.1.1 HEC-5Q

Over the past 15 years, various temperature models were developed to simulate temperature conditions on the rivers affected by CVP and SWP operations (Sacramento River Water Quality Model [SRWQM], San Joaquin River HEC-5Q model) (Reclamation 2008). Recently, these models were compiled and updated into a single modeling package hereafter referred to as the HEC-5Q model. Further updates were performed under the EIS modeling that included improved meteorological data and subsequent validation of the Sacramento and American River models, implementation of the Folsom Temperature Control Devices and low-level outlet, implementation of the Trinity River auxiliary outlet, improved temperature targeting for the Shasta and Folsom Dams, as well as improved documentation and streamlining of the models as well as improved integration with the CalSim II model.

Section 6B.C.4 of this appendix is consistent with the technical memorandum submitted to Reclamation that documented changes in the HEC-5Q compilation and updates for the temperature models.

The HEC-5Q model contains three separate models that simulate reservoir and river temperatures:

- The Trinity River from Trinity Dam to below Lewiston Dam and the Sacramento River from Shasta Dam to the Feather River confluence. Reservoir temperatures are simulated for Trinity Lake, Lewiston Reservoir, Shasta Lake, Keswick Reservoir, and Black Butte Reservoir (see Figure 6B.A.1 for a schematic of the Trinity-Sacramento River HEC-5Q model).

- The American River from Folsom Dam to the confluence with the Sacramento River. Reservoir temperatures were simulated for Folsom Lake and Lake Natoma (see Figure 6B.A.2 for a schematic of the American River HEC-5Q model).
- The Stanislaus River from upstream of New Melones Reservoir to the confluence with the San Joaquin River and the lower San Joaquin River from the Stanislaus River confluence to below Vernalis. Reservoir temperatures were simulated for New Melones Reservoir (see Figure 6B.A.3 for a schematic of the Stanislaus River HEC-5Q model).

The HEC-5Q model was developed using integrated HEC-5 and HEC-5Q models. The HEC-5 component of the model simulates daily reservoir and river flow operations from monthly CalSim II data that are disaggregated to daily data. The HEC-5Q component simulates mean daily reservoir and river temperatures based on the daily flow inputs and meteorological parameters specified on a 6-hour time step.

6B.A.1.1.2 Reclamation Temperature Model

The Reclamation Temperature Model includes reservoir and stream temperature models that simulate monthly reservoir and stream temperatures used for evaluating the effects of CVP and SWP project operations on mean monthly water temperatures in the basin (Reclamation 2008). The model simulates temperatures in seven major reservoirs (Trinity Lake, Whiskeytown Reservoir, Shasta Lake, Oroville Reservoir, Folsom Lake, New Melones Reservoir, and Tulloch Reservoir), four downstream regulating reservoirs (Lewiston, Keswick, and Goodwin reservoirs; Lake Natoma), and five main river systems (Trinity, Sacramento, Feather, American, and Stanislaus rivers). The river component of the Reclamation Temperature Model calculates temperature changes in the regulating reservoirs, below the main reservoirs. With regulating reservoir release temperature as the initial river temperature, the river model computes temperatures at several locations along the rivers. The calculation points for river temperatures generally coincide with tributary inflow locations. The model is one-dimensional in the longitudinal direction and assumes fully mixed river cross sections. The effect of tributary inflow on river temperature is computed by mass balance calculation. The river temperature calculations are based on regulating reservoir release temperatures, river flows, and climatic data.

For the EIS, the Reclamation Temperature Model was used for the Feather River and Lower Sacramento River from the Feather River confluence to Freeport. Sacramento, Trinity, American, and Stanislaus rivers temperature effects were analyzed using the daily HEC-5Q models described in the previous section.

For more information on the Reclamation Temperature Model, see Appendix H of the Reclamation's 2008 Operation Criteria and Plan (OCAP) Biological Assessment (BA) (Reclamation 2008).

6B.A.2 Surface Water Temperature Modeling Simulations and Assumptions

This section describes the assumptions for the HEC-5Q and Reclamation Temperature Model monthly temperature simulations of the No Action Alternative, Second Basis of Comparison, and other alternatives.

The following model simulations were performed as the basis of evaluating the impacts of the other alternatives:

- No Action Alternative
- Second Basis of Comparison

The following model simulations of other alternatives were performed:

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

Assumptions for each of these alternatives were developed with the surface water modeling tools and are described in Appendix 5A, Section B.

Alternative 1 modeling assumptions are the same as the Second Basis of Comparison and Alternative 2 modeling assumptions are the same as the No Action Alternative; therefore, the assumptions for those alternatives are not discussed separately in this document.

The general modeling assumptions described below pertain to the No Action Alternative, Second Basis of Comparison, and other alternatives model runs.

6B.A.2.1 Input Storage and Streamflow

6B.A.2.1.1 HEC-5Q

Monthly flows simulated by the CalSim II model for an 82-year period (water years 1922 through 2003) are used as input to HEC-5Q. Temporal downscaling is performed on the CalSim II monthly average tributary flows to convert them to daily average flows for HEC-5Q input using a pre-processing tool (see Tables 6B.A.1 to 6B.A.3 for a list of all of the CalSim II inputs).

Table 6B.A.1 CalSim II Input Mapping with Trinity-Sacramento River HEC-5Q Model

HEC-5Q Control Point Number	HEC-5Q Control Point Name	Input Types	CalSim II Node
340	Trinity Reservoir	Storage Inflow Outflow Evaporation	S1 I1 C1+F1 E1
330	Lewiston Reservoir	Inflow Diversion	I100 D100
240	Whiskeytown Reservoir	Storage Inflow Outflow Evaporation	S3 I3 C3+F3 E3
220	Shasta Reservoir	Storage Inflow Outflow Evaporation	S4 I4 C4+F4 E4
200	Keswick Reservoir	Evaporation	E5
180	Sacramento River below Clear Creek Confluence	Diversion	C5-C104
178	Sacramento River below Cow Creek Confluence	Inflow	C10801
176	Sacramento River below Cottonwood Creek Confluence	Inflow	C10802
172	Sacramento River below Battle Creek Confluence	Inflow	C10803
170	Sacramento River at Bend Bridge	Inflow Diversion	I109+R109 D109
160	Sacramento River above Red Bluff Diversion Dam	Inflow Diversion	C11001+I112 D112
150	Sacramento River below Woodson Bridge	Inflow Diversion	C11305+C11301+R113+R114A+R114B+R114C D113A+D113B
140	Sacramento River at GCID	Diversion	D114
1136	Black Butte Reservoir	Storage Inflow Outflow Diversion	S42 I42+C41 C42+F42 E42+D42

HEC-5Q Control Point Number	HEC-5Q Control Point Name	Input Types	CalSim II Node
1134	Stony Creek Diversions	Diversion	C42-C142A
1132	Stony Creek Confluence	Inflow	C11501
132	Sacramento River at Ord Ferry	Diversion	D117
130	Sacramento River at Butte City	Inflow Diversion	I118 I118+C115-C118-D117
128	Sacramento River above Moultin Weir	Inflow Diversion	I123+c17603 C118+I123+C17603-C124
126	Sacramento River at Moultin Weir	Diversion	D124
120	Sacramento River at Colusa Weir	Diversion	D125
116	Sacramento River at Tisdale Weir	Diversion	D126
114	Sacramento River above Knights Landing	Diversion	C126-C129
112	Sacramento River at Knights Landing	Diversion	C129-C134
365	Butte Creek BP3	Diversion	C136B-R137-R135A-R135B-C217A

Table 6B.A.2 CalSim II Input Mapping with American River HEC-5Q Model

HEC-5Q Control Point Number	HEC-5Q Control Point Name	Input Types	CalSim II Node
590	Folsom Reservoir	Storage Inflow Outflow Diversion	S8 C300+I8 C8+F8 E8+D8
580	Natoma Reservoir	Storage Diversion	S9 D9+E9-I9
572	American River above City of Sacramento Diversion	Diversion	GS66-I302
570	American River at City of Sacramento Diversion	Diversion	D302

Table 6B.A.3 CalSim II Input Mapping with Stanislaus River HEC-5Q Model

HEC-5Q Control Point Number	HEC-5Q Control Point Name	Input Types	CalSim II Node
240	New Melones Reservoir	Storage Inflow Outflow Evaporation	S10 I10 C10+F10 E10
220	Tulloch Reservoir	Storage Inflow Diversion	S76 I76 E76
200	Goodwin Reservoir	Inflow Diversion	I520 C76-C520
160	Stanislaus River at Knights Ferry	Diversion	C520-C528
150	Stanislaus River at Orange Blossom Bridge	Diversion	C520-C528
140	Stanislaus River at Oakdale Highway 120 Bridge	Diversion	C520-C528
130	Stanislaus River at Riverbank Bridge	Diversion	C520-C528
120	Stanislaus River at McHenry Bridge	Diversion	C520-C528
110	Stanislaus River at Ripon Gage	Diversion	C520-C528
400	San Joaquin River above Stanislaus River Confluence Dummy Reservoir	Diversion	C620+C545+C528-C644
98	San Joaquin River at Vernalis	Diversion	C620+C545+C528-C644

6B.A.2.1.2 Reclamation Temperature Model

Monthly flows that were simulated by the CalSim II model for an 81-year period (January 1922 to December 2002) are used as input to the model. Because of the CalSim II model's complex structure, where applicable, flow arcs were combined at the appropriate temperature nodes to ensure compatibility with the Reclamation Temperature Model.

6B.A.2.2 Climate Change Assumptions

When simulating alternatives with climate change, some of the inputs to the temperature models must be modified. This section presents the assumptions and approaches used for modifying meteorological and inflow temperatures in the temperature models. For the alternative simulations, climate assumptions were established around Year 2030. Therefore, to be consistent with the other water supply and economics models, the climate input data for HEC-5Q and Reclamation Temperature Model were modified to represent approximate conditions at Year 2030.

6B.A.2.2.1 HEC-5Q

HEC-5Q requires meteorological inputs specified in the form of equilibrium temperatures, exchange rates, shortwave radiation and wind speed. The exchange rates and equilibrium temperatures are computed from hourly observed data at the Gerber gauging station. Considering the uncertainties associated with climate change impacts, it was assumed that the equilibrium temperature inputs derived from observed data would be modified by the change in daily average air temperature projected under the climate change scenarios.

The inflow temperatures in HEC-5Q are specified as seasonal curve fit values with diurnal variations superimposed as a function of heat exchange parameters. The seasonal temperature values are derived based on the observed flows and temperatures for each inflow. HEC-5Q superimposes diurnal variations on the seasonal values specified using the heat exchange parameter inputs. The diurnal variations are superimposed by adjusting the equilibrium temperature to reflect the inflow location environment and scaling it based on the heat exchange rate scaling factor and the weighting factor for emphasis on the seasonal values specified. In this fashion, any climate change effects accounted for in the equilibrium temperature are translated to the changes in inflow temperatures in the HEC-5Q. Therefore, for the climate change scenarios, only the equilibrium temperatures were adjusted for the projected change in temperature, and these influence the inflow temperatures; however, independent inflow temperature inputs were not changed.

6B.A.2.2.2 Reclamation Temperature Model

The Reclamation Temperature Model requires mean monthly meteorological inputs of air and equilibrium temperature and heat exchange rates. The heat exchange rates and equilibrium temperatures are computed from the mean monthly air temperature data and long-term estimates of solar radiation, relative humidity, wind speed, cloud cover, solar reflectivity, and river shading. Considering the uncertainties associated with climate change impacts, it was assumed that the equilibrium temperature and heat exchange rate inputs would be modified by the change in mean monthly air temperature in the climate change scenarios.

Reservoir inflow temperatures were derived from the available record of observed data and averaged by month. The mean monthly inflow temperatures are then repeated for each study year. For alternatives modeled with climate change, the inflow temperatures were modified based on the projected long-term average change in mean annual air temperature for each month.

6B.A.3 Reference

Reclamation (Bureau of Reclamation). 2008. *2008 Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment, Appendix H Reclamation Temperature Model and SRWQM Temperature Model.*

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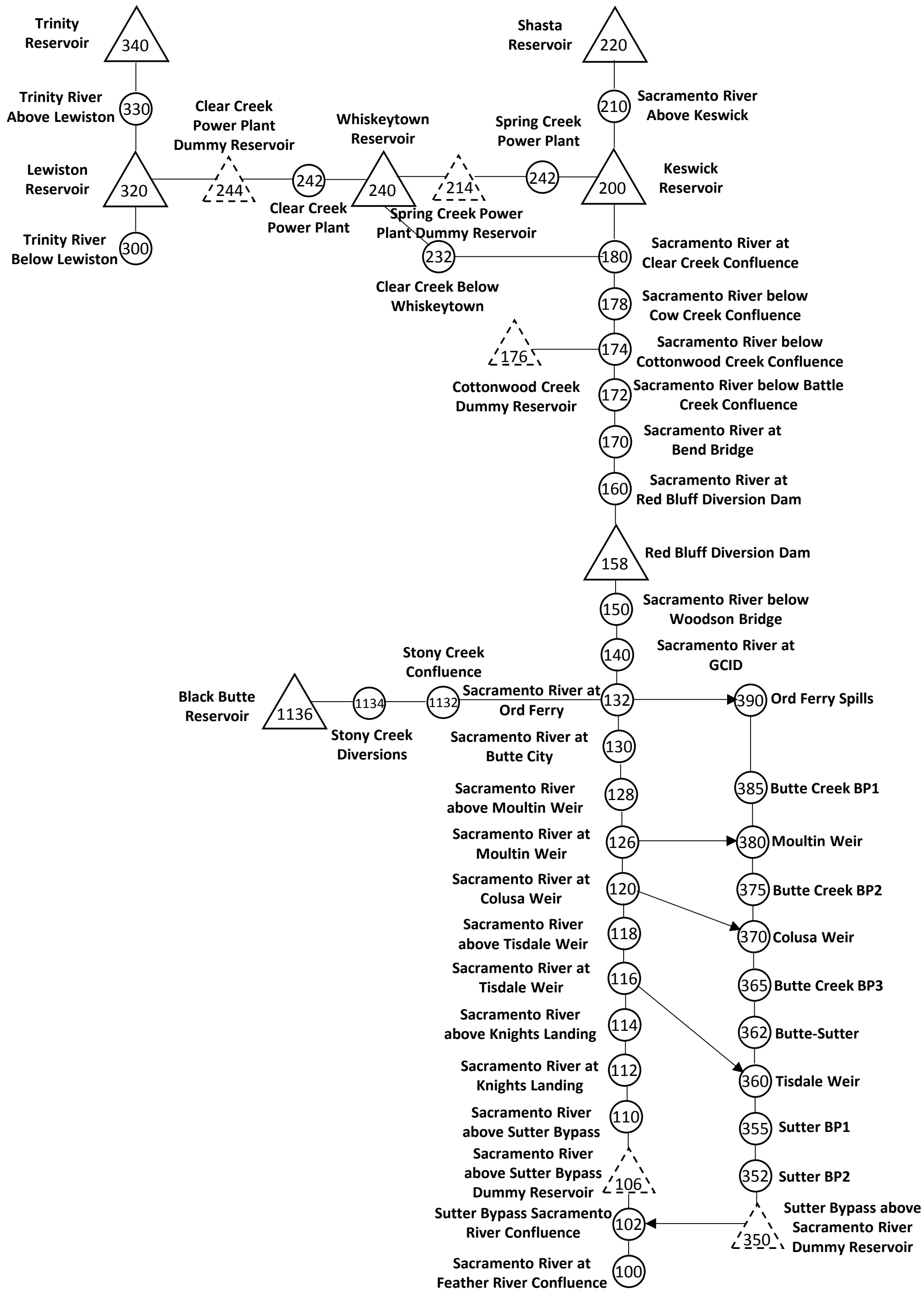

Figure 6B.A.1 Schematic of Trinity-Sacramento River HEC-5Q Model

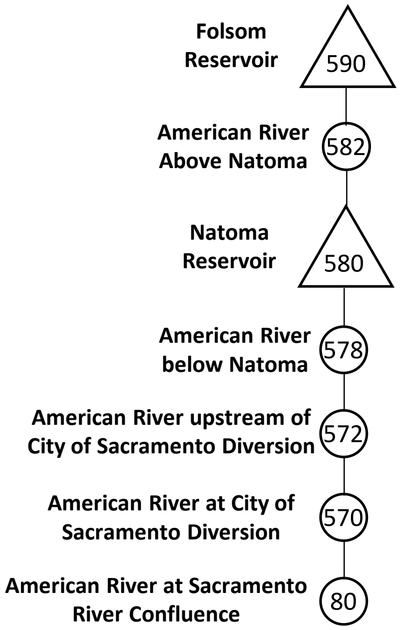

Figure 6B.A.2 Schematic of American River HEC-5Q Model

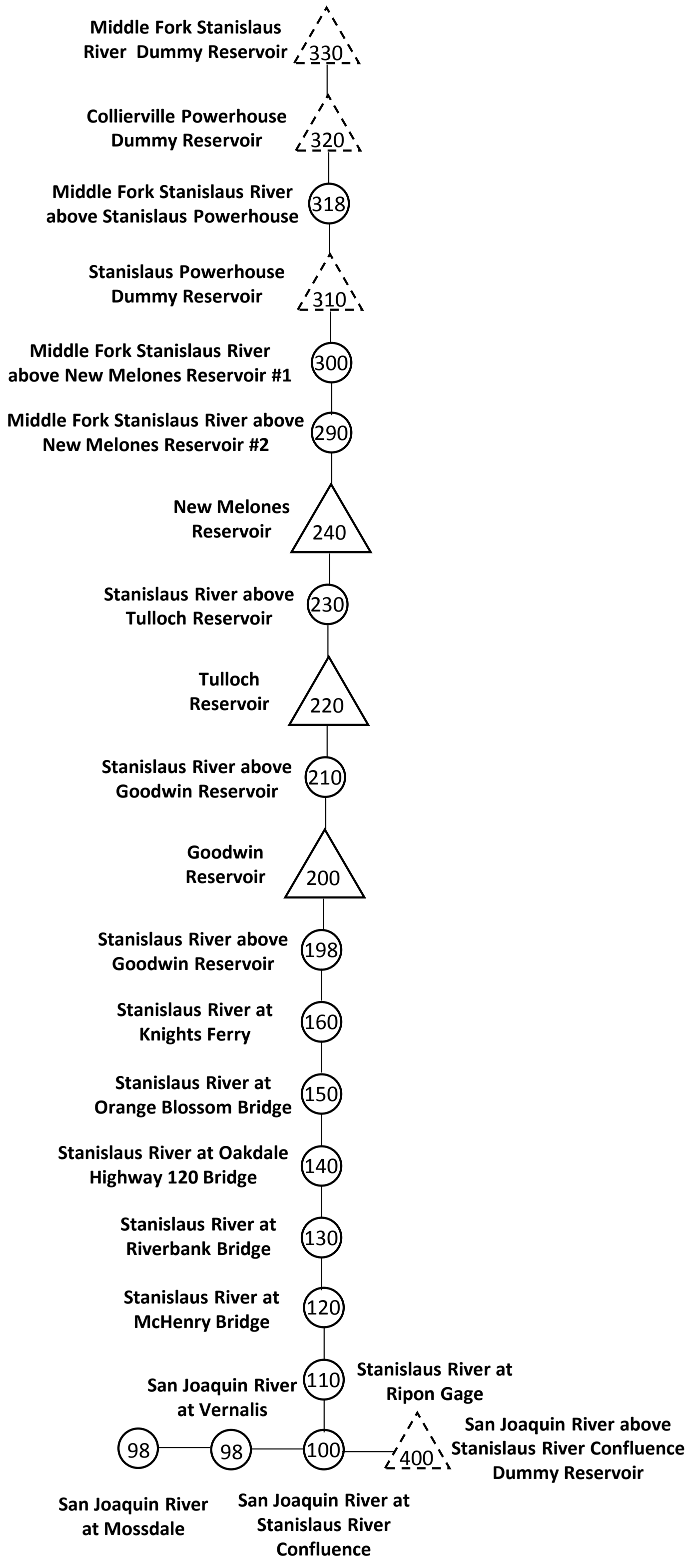

Figure 6B.A.3 Schematic of Stanislaus River HEC-5Q Model

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