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APPENDIX 5A, SECTION D
MODELING TECHNICAL APPENDIX – WATER
TEMPERATURE MODELING RESULTS

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Appendix 5A, Section D

Modeling Technical Appendix – Water Temperature Modeling Results

D.1 Introduction

This section provides a summary of modeling performed to simulate water temperatures on the Trinity, Sacramento, and American Rivers for the Delta Conveyance Project Final Environmental Impact Report (EIR). It includes a description of the Trinity-Sacramento River and American River HEC5Q models. The presentation of the modeling methodology includes a general description of the models, model inputs, selective withdrawal descriptions where applicable, and limitations of each of the models. Appendix 5A, *Modeling Technical Appendix*, Section D, Attachments 1 and 2 present results of the HEC5Q modeling for the existing condition and future (2040) conditions, respectively, in various tabular and graphical formats.

D.2 HEC5Q

D.2.1 Overview of Reservoir and River Temperature Modeling Using HEC5Q

HEC5Q is a modeling tool that simulates reservoir and river water temperatures based on input storage, flow, and meteorological data. The HEC5Q modeling tool consists of two model components, HEC5 and HEC5Q. HEC5 is the daily flow simulation component of the model, in which daily storage and flows are simulated at specific nodes (HEC 1998). HEC5Q is the temperature simulation component of the model, where 6-hour input meteorological data (equilibrium temperatures, exchange rates, shortwave radiation, and wind speed) are applied to the simulated storage and flows from the HEC5 model to simulate water temperatures at specified locations (RMA 1998). The HEC5Q component is a cross-sectional based model and has a higher spatial resolution in comparison to the HEC5 component. The HEC5Q modeling tool is often used for long-term planning analyses and has been applied to numerous rivers across the United States.

The HEC5Q models used in the Delta Conveyance Project EIR were previously used in Reclamation's Biological Assessment under the 2019 Re-initiation of Consultation on the Coordinated Long-Term Operation of the CVP and SWP (Reclamation 2019) but have been updated to use CalSim 3 outputs and simulate the same 94-year period as CalSim 3. For this EIR, HEC5Q was applied to the Trinity, Sacramento, and American Rivers. Monthly CalSim 3 outputs, from October 1921 to September 2015, were downscaled to daily timeseries and then used to prescribe HEC5's storage and flow data for use in the HEC5Q model. 6-hour meteorological data used in the models were derived from observed data from the Gerber and Nicolaus CIMIS (California Irrigation Management Information System) stations.

D.2.2 Trinity-Sacramento River HEC5Q Model

D.2.2.1 Description of the Model

The Trinity-Sacramento River HEC5Q model was developed by Reclamation to simulate water temperature in the Trinity and Sacramento rivers and the CVP reservoirs that operate on these rivers, with a focus in simulating the temperature impacts of changes in water management at Lake Shasta and flows in the upper Sacramento River between Keswick Dam and Knights Landing. Figure 5A-D.1 shows a schematic of the Trinity-Sacramento River HEC5Q model and shows all of the reservoir and river control points where temperatures are simulated. The model was developed using the integrated HEC5 and HEC5Q model framework developed by the Army Corps of Engineers (ACOE) Hydrologic Engineering Center (HEC). The HEC5 component is used to simulate daily flow operations, and the HEC5Q component is used to simulate mean daily reservoir and river temperatures. The reservoirs included in the model are Shasta Lake and Trinity Lake, and the Lewiston, Whiskeytown, Keswick, and Black Butte reservoirs. Streams included in the model are Clear Creek, the Trinity River, the upper Sacramento River from Shasta to Knights Landing, and Stony Creek.

The Trinity-Sacramento River HEC5Q model simulates changes in water temperature based on the flow and meteorological parameters on a 6-hour timestep. The model was customized to simulate the operations of the selective withdrawal temperature control device (TCD) at Shasta Dam and also the Trinity Dam auxiliary outlet. The model was calibrated for 1998-2003 based on the observed water temperatures in the reservoirs and the upper Sacramento River (RMA 2003). A limited validation was also performed in 2015 to incorporate additional meteorological data collected through 2012 (see Appendix 6B, Section C of the 2015 LTO EIS (Reclamation 2015)).

D.2.2.2 Model Inputs

Model inputs to the Trinity-Sacramento River HEC5Q model include initial storage levels, reservoir and tributary inflows, reservoir outflows, diversions, and reservoir evaporation derived from CalSim 3 outputs. Table 5A-D.1 lists the CalSim 3 outputs used in the derivation of inputs to the Trinity-Sacramento River HEC5Q model.

The CalSim 3 Existing Conditions model represents SWP and CVP operations to comply with the regulatory environment as of 2020. The CalSim 3 model for the No Project Alternative represents projected year 2040 conditions in the absence of the Proposed Project or Project Alternatives. In general, the No Project Alternative (2040) model includes facilities and programs that are represented in the Existing Conditions model. However, water supplies and water demands differ from Existing Conditions in order to represent projected changes in land use and urban growth, climate change and sea level rise. For additional description of the CalSim 3 model used for the analysis see Appendix 5A, *Modeling Technical Appendix*, Section B.

The daily downscaled CalSim 3 timeseries used as inputs to the Trinity-Sacramento River HEC5Q model assume a constant (uniform) daily flow over each month of the 94-year CalSim 3 simulation period. An exception to this is the inflow timeseries to Trinity and Shasta Lakes, where monthly average inflows are downscaled to a daily timestep by fitting to a cubic-spline. This allows the simulation of a daily varying inflow into the reservoirs with a smooth transition between the individual months, while assuming the same monthly volume of inflow consistent with CalSim 3 outputs.

1 As mentioned previously, 6-hour meteorological inputs for the model were derived from observed
2 Gerber and Nicolaus CIMIS data and then were adjusted to reflect the projected climate change at
3 about year 2020 for the Existing Conditions and 2040 for the No Project Alternative. Considering the
4 uncertainties associated with climate change projections, it was assumed that the equilibrium
5 temperature inputs derived from observed data would be modified by the projected change in daily
6 average air temperature under the climate scenario to reflect the effect of the climate change.

7 HEC5Q estimates the 6-hour inflow water temperatures based on the specified seasonal water
8 temperature values with diurnal variations superimposed as a function of inputted location-specific
9 heat exchange parameters. The seasonal water temperature values are derived based on the
10 observed flows and water temperatures for each inflow. HEC5Q superimposes diurnal variations on
11 the specified seasonal temperature values using the heat exchange parameter inputs. The diurnal
12 variations are superimposed by adjusting the equilibrium temperature to reflect the inflow location
13 environment and scaling it based on the heat exchange rate scaling factor and the weighting factor
14 for emphasis on the seasonal values specified (RMA 1998). In this fashion, any climate change
15 effects accounted for in the equilibrium temperature are translated to the changes in inflow
16 temperatures in HEC5Q. Therefore, for simulating water temperatures using HEC5Q under the
17 scenarios with climate change, only the equilibrium temperatures were adjusted for the projected
18 change in temperature, and these influence the inflow temperatures, however, the seasonal inflow
19 temperatures and the location-specific heat exchange inputs for the inflows were not changed.

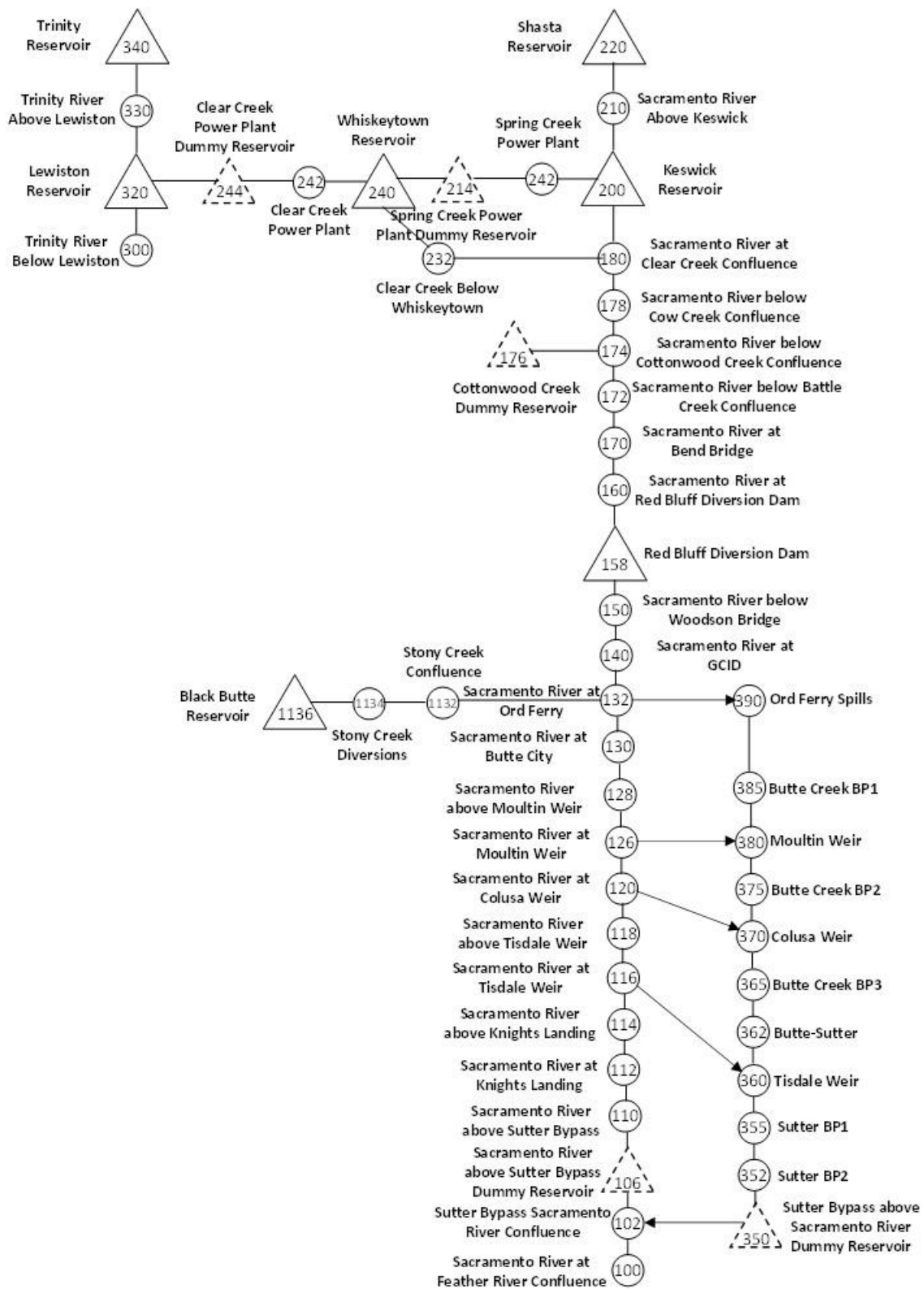


Figure 5A-D.1. Schematic of Trinity-Sacramento River HEC5Q Model

1 **Table 5A-D.1. CalSim 3 inputs to the Trinity-Sacramento River HEC5Q Model**

HEC5Q Control Point Number	HEC5Q Control Point Name	Input Types	CalSim 3 Node
340	Trinity Reservoir	Storage	S_TRNTY
		Inflow	I_TRNTY
		Outflow	C_TRNTY
		Evaporation	E_TRNTY
330	Lewiston Reservoir	Inflow	I_LWSTN
		Diversion	D_LWSTN_CCT011
240	Whiskeytown Reservoir	Storage	S_WKYTN
		Inflow	I_WKYTN
		Outflow	C_WKYTN
		Evaporation	E_WKYTN
220	Shasta Reservoir	Storage	S_SHSTA
		Inflow	I_SHSTA
		Outflow	C_SHSTA + D_WKYTN_SPT003
		Evaporation	E_WKYTN + D_WKYTN_WTPCSD + D_WKYTN_02_PU + D_WKYTN_WTPBUK
200	Keswick Reservoir	Evaporation	E_KSWCK
180	Sacramento River below Clear Creek Confluence	Diversion	C_KSWCK – C_SAC289
178	Sacramento River below Cow Creek Confluence	Inflow	C_SAC277 – C_SAC289 – C_WKYTN
176	Sacramento River below Cottonwood Creek Confluence	Inflow	C_SAC271 – C_SAC277
172	Sacramento River below Battle Creek Confluence	Inflow	C_SAC269 – C_SAC271
170	Sacramento River at Bend Bridge	Inflow	Positive values of C_SAC257 – C_SAC269
		Diversion	Negative values of C_SAC257 – C_SAC269
160	Sacramento River above Red Bluff Diversion Dam	Inflow	C_SAC240 - C_SAC257 + D_SAC240_TCC001 + D_SAC240_05_NA
		Diversion	D_SAC240_TCC001 + D_SAC240_05_NA
150	Sacramento River below Woodson Bridge	Inflow	C_SAC217 – C_SAC240 + D_SAC224_04_NA
		Diversion	D_SAC224_04_NA
140	Sacramento River at GCID	Diversion	D_SAC207_GCC007

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1 **Table 5A-D.1. CalSim 3 inputs to the Trinity-Sacramento River HEC5Q Model (continued)**

HEC5Q Control Point Number	HEC5Q Control Point Name	Input Types	CalSim 3 Node
1136	Black Butte Reservoir	Storage	S_BLKBT
		Inflow	I_BLKBT + C_SGRGE
		Outflow	C_BLKBT - D_STN026_06_PA
		Diversion	E_BLKBT + D_STN026_06_PA
1134	Stony Creek Diversions	Diversion	C_BLKBT - D_STN026_06_PA - C_STN004
1132	Stony Creek Confluence	Inflow	C_SAC195 - C_SAC217 + D_SAC207_GCC007
132	Sacramento River at Ord Ferry	Diversion	D_SAC185_08N_NA + D_SAC185_09_NA + SP_SAC193_BTC003 + SP_SAC188_BTC003
130	Sacramento River at Butte City	Inflow	Positives of C_SAC169 + D_SAC185_08N_NA + D_SAC185_09_NA + SP_SAC193_BTC003 + SP_SAC188_BTC003 - C_SAC195 - C_STN004
		Diversion	Negatives of C_SAC169 + D_SAC185_08N_NA + D_SAC185_09_NA + SP_SAC183_BTC003 + SP_SAC188_BTC003 - C_SAC195 - C_STN004
128	Sacramento River above Moulton Weir	Inflow	Positives of C_SAC162 - C_SAC169
		Diversion	Negatives of C_SAC162 - C_SAC169
126	Sacramento River at Moulton Weir	Diversion	C_SAC169 - C_SAC159
120	Sacramento River at Colusa Weir	Diversion	C_SAC159 - C_SAC146
116	Sacramento River at Tisdale Weir	Diversion	C_SAC146 - C_SAC122
114	Sacramento River above Knights Landing	Diversion	C_SAC122 - C_SAC099
112	Sacramento River at Knights Landing	Diversion	C_SAC099 - C_SAC091
365	Butte Creek BP3	Diversion	SP_SAC193_BTC003+SP_SAC188_BTC003+SP_SAC178_BTC003 + SP_SAC159_BTC003 + SP_SAC148_BTC003 + SP_SAC122_SBP021 - C_SSL001

2 **D.2.2.3 Model Outputs**

3 The Sacramento-Trinity HEC5Q model generates daily reservoir and river temperatures throughout
4 the CalSim 3 94-year simulation period. It also can provide the temperature profiles for Shasta,
5 Trinity, and other selected reservoirs included in the model.

1 **D.2.2.4 Simulation of Selective Withdrawal**

2 The Trinity-Sacramento River HEC5Q model has the capability of simulating the selective
3 withdrawal capabilities at Shasta Dam and Trinity Dam in order to meet specified tailwater
4 temperature targets.

5 **Shasta Selective Withdrawal**

6 Shasta Dam has a TCD that allows water to be released from different elevations of the reservoir
7 pool to produce a specified tailwater temperature target that is intended to meet a downstream
8 temperature objective, particularly during the summer months. The TCD allows the extraction of
9 water from four different depths. This grants access to colder water at lower depths and the
10 opportunity to blend water extracted from different depths. Blending allows operators to meet
11 temperature regulations while conserving cold water pool for future use.

12 Shasta Dam is operated to meet temperature objectives under the four-tiered strategy outlined in
13 the 2019 National Marine Fisheries Service Biological Opinion (BiOp), which range from 53.5°F to
14 56°F with a compliance location on the Sacramento River above Clear Creek (NMFS 2019). Specific
15 temperature objectives vary within this range depending on storage and hydrologic conditions. Cold
16 water management using this four-tiered strategy allows for strategically selected temperature
17 objectives, based on projected total storage and cold-water pool, meteorology, Delta conditions, and
18 habitat suitability for incoming fish population size and location. This approach recognizes that cold
19 water is a scarce resource that can be managed to achieve desired water temperature for fisheries
20 objectives.

21 The closer Shasta Lake is to being full by the end of May, the greater the likelihood of being able to
22 meet downstream water temperature objectives throughout the entire temperature control season.
23 If storage is high enough to use the TCD upper shutters by the end of May (above 3.66 MAF), the
24 operators can maximize the cold-water pool potential. Historical relationships suggest that a storage
25 of 4 MAF on May 1st generally provides enough storage to continue operating through the upper
26 gates and develop a sufficient cold-water pool to meet a 53.5°F temperature objective on the
27 Sacramento River above Clear Creek. This temperature is sufficient for Winter-Run Chinook Salmon
28 spawning and egg incubation with minimal risks of higher temperatures in the late summer and fall.

29 The Trinity-Sacramento HEC5Q temperature model features a Fortran implementation of the TCD in
30 its simulations of Shasta Dam operations (RMA 2003 Reclamation, 2008). The model requires a
31 timeseries input of target Shasta Dam outlet temperatures, which it then meets as closely as possible
32 using blending between different elevations. The model determines which configuration of the TCD
33 gates will produce a release temperature that best meets the monthly temperature target. The
34 process of developing the temperature targets is as follows.

35 Initial temperature operations are developed at a monthly scale. Impacts of Sacramento River
36 temperatures are then assessed using the Martin and Anderson temperature-dependent egg
37 mortality models, which calculate egg mortality for Sacramento River Winter run Chinook salmon.
38 See Section E, *Salmonid Population and Mortality Modeling*, of this Modeling Appendix for a
39 description of the Martin and Anderson models. A spreadsheet tool is then used to facilitate daily-
40 scale temperature targeting for each tier. The spreadsheet calculates the warming from Shasta Dam
41 to the Sacramento River below Clear Creek, which is the location for temperature compliance. To
42 minimize the number of variables changing between iterations, the warming between the locations
43 in the monthly-scale run is used for all iterations. Daily-scale Shasta Dam tailwater targets are then

back-calculated using daily warming values from Shasta releases to the Sacramento River below Clear Creek location.

Late-season violations typically result from depleted cold-water pool. Monthly-scale temperature targeting attempts to address this issue by setting warmer temperature targets (while still maintaining 56°F or 53.5°F as appropriate) at the beginning of the season. Theoretically, warmer early-season temperature targets would preserve cold water pool volume, reducing major violations later in the season. Daily-scale temperature targeting employed this same technique at a more refined scale.

Trinity Selective Withdrawal

Trinity Dam has no specific TCD but includes an auxiliary outlet that allows access to the reservoir pool that cannot be accessed by the power outlets. This auxiliary outlet is only used in actual operations under emergency situations to control temperatures in the Trinity River when they exceed specific targets in the summer/fall months. The HEC5Q model uses a tailwater temperature target of 49°F between August 15th and October 31st when temperature management is most important. If release temperatures from the power outlets exceed this temperature target during this period, the auxiliary outlet is operated to blend with the releases from the power outlets to achieve the temperature target. More detail is provided in the Appendix 6B, Section C of the 2015 LTO EIS (Reclamation 2015).

D.2.3 American River HEC5Q Model

D.2.3.1 Description of the Model

The American River HEC5Q model simulates water temperatures for the Lower American River (below Folsom Dam to the confluence of Sacramento River). Figure 5A-D.2 shows a schematic of the American River HEC5Q model and shows all of the reservoir and river control points where temperatures are simulated. The model uses inputs from CalSim 3 that have been temporally downscaled to daily timeseries and 6-hour meteorological data. The American River model was last fully calibrated in 2013, using a calibration period of 2003 to 2011 (RMA and WCI 2013). A validation procedure was performed in 2015 to incorporate additional logic in the model for the Folsom Water Supply Treatment Control Device (WSTCD), which is described in Appendix 6B, Section C of the 2015 LTO EIS (Reclamation 2015). For the 2015 validation equilibrium temperature scaling factors in the HEC5Q inputs were adjusted to match the simulated temperatures with 2013 calibration results. The 2015 validation process used the hydrology and meteorological boundary condition data from the 2013 calibration.

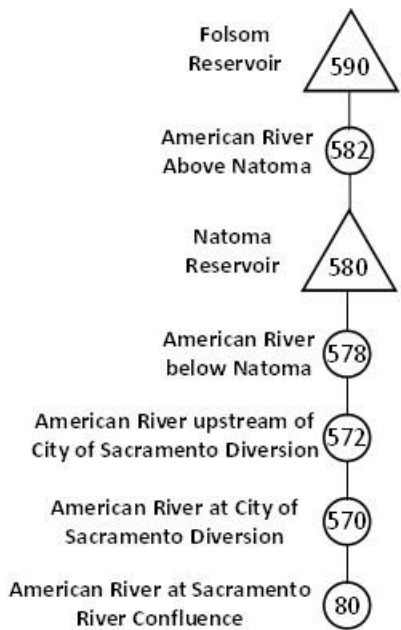


Figure 5A-D.2. Schematic of American River HEC5Q Model

D.2.3.2 Model Inputs

Model inputs to the American River HEC5Q model include initial storage levels, reservoir and tributary inflows, reservoir outflows, diversions, and reservoir evaporation derived from CalSim 3 outputs. Table 5A-D.2 lists the CalSim 3 outputs used in the derivation of inputs to the American River HEC5Q model.

The daily downscaled CalSim 3 timeseries all assume a constant (uniform) daily flow over each month of the 94-year CalSim 3 simulation period. 6-hour meteorological inputs to the model were derived from observed Nicolaus CIMIS data and then were adjusted for the 2020 for the Existing Conditions and 2040 for the No Project Alternative. The same note about the climate change adjustments to the meteorological inputs and inflow temperatures in the Trinity-Sacramento River model applies to the American River HEC5Q model.

D.2.3.3 Model Outputs

The American River HEC5Q model generates daily reservoir and river temperatures throughout the CalSim 3 94-year simulation period. It can also provide the temperature profiles for Folsom Lake.

D.2.3.4 Simulation of Selective Withdrawal

Folsom Dam has multiple TCDs. There is a main temperature control shutter device, which allows water to come from different elevations of the reservoir pool to go through the power outlets. There is a low-level outlet that allows access to the reservoir pool below the power outlets. These are operated in combination to meet a specified tailwater temperature target, particularly during the summer and fall months. The model also includes a WSTCD mentioned previously, which pulls water from specified levels and temperature ranges of the reservoir pool for the local water supply diversion from the Folsom Lake.

1 **Table 5A-D.2. CalSim 3 inputs to the American River HEC5Q Model**

HEC5Q Control Point Number	HEC5Q Control Point Name	Input Types	CalSim 3 Node
590	Folsom Lake	Storage	S_FOLSM
		Inflow	C_NFA011+C_SFA011+I_FOLSM+CT_FAIROAKS
		Outflow	C_FOLSM+SG374_FOLSM_66
		Diversion	E_FOLSM+D_FOLSM_WTPRSV+D_FOLSM_WTPSJP+D_FOLSM_26S_PU3+D_FOLSM_26S_NU4+D_FOLSM_WTPFOL+D_FOLSM_WTPEDH
580	Lake Natoma	Storage	S_NTOMA
		Diversion	D_NTOMA_FSC003+E_NTOMA-SR_26N_NTOMA-SR_26S_NTOMA-SG375_NTOMA_66
572	American River above City of Sacramento Diversion	Diversion	D_AMR017_WTPBJM-SG376_AMR020_66-R_RFS26S_AMR020-SG377_AMR015_66-SG378_AMR009_66-SR_26S_AMR007
570	American River at City of Sacramento Diversion	Diversion	D_AMR007_WTPFBN

2 Annual schedules of monthly tailwater temperature targets for Folsom Dam are specified based on a
3 combination of end-of-May Folsom Lake storage and June to September inflow volume to Folsom
4 Lake, an indicator of the available cold-water pool, for each year of the CalSim 3 simulation period.
5 The annual schedules were developed for different tiers of volume of cold water pool (Folsom end-
6 of-May storage plus June to September inflow), with each tier corresponding to a specific
7 temperature target schedule for the year. A representative subset of the Automated Temperature
8 Selection Procedure (ATSP) temperature target schedules specified in the 2009 NMFS BiOp were
9 used in the selection procedure for use in the HEC5Q model. Table 5A-D.3 shows the annual
10 temperature target schedules for the different Folsom end-of-May storage plus June to September
11 inflow volume tiers. As can be seen from the table, the schedules only vary for the May-November
12 period. A description of the annual temperature target schedules development is provided in
13 Appendix 6B, Section C of the 2015 LTO EIS (Reclamation 2015). Based on the tailwater target
14 temperature schedule timeseries, the model determines which configuration of the shutters and
15 low-level outlet will produce a release temperature that best meets the monthly temperature target.
16 The low-level outlet with a maximum release capacity of 700 cfs, is allowed to operate from
17 September 15th to November 30th. The WSTCD included in the American River HEC5Q model is
18 operated to withdraw stored water within the temperature range of 63°F – 65°F, and an elevation
19 range of 320 feet to 460 feet. Appendix 6B, Section C of the 2015 LTO EIS (Reclamation 2015)
20 provides a complete description of the Folsom Dam TCD operating logic in the American River
21 HEC5Q model.

1 **Table 5A-D.3. Final Temperature Targeting Schedules for Folsom Dam**

Schedule Number	Folsom End-of-May Storage plus Jun-Sep Inflow (TAF)	Folsom Dam Release Temperature Target (Deg-F)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
22	<=600	52.0	52.0	52.0	59.0	66.8	66.0	66.0	63.0	67.5	68.0	60.5	56.0
21	700	52.0	52.0	52.0	59.0	66.8	66.0	66.0	63.0	67.5	68.0	60.5	56.0
20	750	52.0	52.0	52.0	59.0	65.9	65.2	66.2	63.3	66.7	68.1	60.6	56.0
19	850	52.0	52.0	52.0	59.0	66.3	65.6	65.6	62.9	67.0	67.3	59.7	56.0
18	900	52.0	52.0	52.0	59.0	65.6	65.0	66.0	63.5	66.3	67.5	59.8	56.0
17	950	52.0	52.0	52.0	59.0	65.8	65.2	65.2	62.8	66.4	66.6	58.8	56.0
16	1,050	52.0	52.0	52.0	59.0	65.0	64.4	65.4	63.1	65.6	66.7	58.9	56.0
15	1,100	52.0	52.0	52.0	59.0	65.2	64.6	64.6	62.4	65.7	65.8	57.9	56.0
14	1,200	52.0	52.0	52.0	59.0	64.3	63.8	64.8	62.7	64.9	65.9	58.0	56.0
13	1,250	52.0	52.0	52.0	59.0	64.5	64.0	64.0	62.0	65.0	63.0	58.0	56.0
12	1,350	52.0	52.0	52.0	59.0	63.7	63.2	64.2	62.3	64.2	63.1	58.1	56.0
11	1,400	52.0	52.0	52.0	59.0	63.7	63.2	63.2	61.3	64.2	63.1	58.1	56.0
10	1,500	52.0	52.0	52.0	59.0	62.9	62.4	63.4	61.6	63.3	63.2	58.1	56.0
9	1,550	52.0	52.0	52.0	59.0	62.9	62.4	62.4	60.6	63.3	63.2	58.1	56.0
8	1,650	52.0	52.0	52.0	59.0	61.9	61.4	62.4	60.6	62.3	63.2	58.1	56.0
7	1,700	52.0	52.0	52.0	59.0	62.0	61.6	61.6	59.9	62.5	58.3	57.2	56.0
6	1,800	52.0	52.0	52.0	59.0	61.0	60.6	61.6	59.9	61.5	58.3	57.2	56.0
5	1,850	52.0	52.0	52.0	59.0	61.0	60.6	60.6	58.9	61.5	58.3	57.2	56.0
4	1,950	52.0	52.0	52.0	59.0	60.0	59.6	60.6	58.9	60.5	58.3	57.2	56.0
3	2,000	52.0	52.0	52.0	59.0	60.0	59.6	59.6	57.9	60.5	58.3	56.2	56.0
2	2,100	52.0	52.0	52.0	59.0	59.0	58.6	59.6	57.9	59.5	57.3	56.2	56.0
1	2,150	52.0	52.0	52.0	59.0	59.0	58.6	58.6	56.9	59.5	56.3	55.2	56.0

2 **D.2.4 Model Limitations**

3 There are several limitations to the HEC5Q models and the simulated water temperatures, both in
4 their capability to simulate observed water temperatures and as applied in this EIR. Calibration of
5 the HEC5Q model was focused on simulating daily average observed temperatures, primarily in the
6 warmer periods, and the model adequately represents the thermal responses to the hydrologic and
7 meteorological changes. Even though the HEC5Q models simulate water temperatures on a sub-
8 monthly timescale, given that they are driven by the monthly CalSim 3 results as inputs, the use of
9 modeled temperatures should generally be limited to monthly average values, even though short-
10 term fluctuations may be real and important to biological resources. If sub-monthly results are to be
11 used, it is important to understand that the HEC5Q models adhere to the CalSim 3 monthly volumes
12 of reservoir storage, releases, and diversions resulting from monthly operational decisions. HEC5Q
13 models do not alter operations (other than temperature control device gate settings) to meet a
14 temperature objective downstream in the river, and there is no feedback to CalSim 3 to alter storage
15 or release volumes.

For Folsom Dam, a simplified procedure is used to specify the annual temperature target schedules based on end-of-May storage and June-September inflow, and the targets are not altered dynamically in a given year. If the cold water pool estimate is slightly above or below the threshold used for a tier, a different temperature schedule will be selected that can greatly affect the temperature results. For Shasta Dam, a more sophisticated iterative method based on salmonid egg mortality modeling is used to select temperature targets, but the accuracy of these targets is still affected by limitations of the egg mortality models used. Lastly, given that the inputs to the HEC5Q models are from CalSim 3, all the limitations of CalSim 3 should be considered when using the water temperature results.

D.3 Appropriate Use of Model Results

The physical models developed and applied here are generalized and simplified representations of a complex water resources system. A brief description of appropriate use of the model results to compare two scenarios or to compare against threshold values or standards is presented below.

D.3.1 Absolute vs. Relative Use of the Model Results

The models, as applied in this study, are not predictive of actual operations and resulting water temperatures. Therefore, the results cannot be considered as absolute with and within a quantifiable confidence interval unless the hypothetical storage levels and assumed uniform release rates were to occur.

D.3.2 Appropriate Reporting Timestep

Because the water temperature models are driven by the long-term hypothetical operations simulated in CalSim 3 on a monthly time step, typically the temperature results from HEC5Q are presented on a monthly time step. Monthly flow and water temperature results are unlikely to address the daily variability in river temperatures but reflect changes in the monthly means. The daily variability, around a changed mean, could be added to the monthly temperature results by scaling the historical daily temperature patterns to reflect the monthly means. However, this approach of incorporating daily variability does not account for the uncertainty associated with the daily flow conditions resulting from daily operational decisions that are not included in the boundary flows used by the temperature models. Thus, while the models generate daily results, they need to be interpreted with the understanding that the monthly changes are the most appropriate use of the modeling results.

D.3.3 Statistical Comparisons are Preferred

Absolute differences computed at a point in time between model results from an alternative and a baseline to evaluate impacts is a tenuous use of model results (e.g., computing differences between the results from a baseline and an alternative for a particular day or month and year within the period of simulation). Likewise, computing absolute differences between an alternative (or a baseline) and a specific threshold value (or a standard) is a tenuous use of model results. Statistics computed based on the absolute differences at a point in time (e.g., average of monthly differences) is a tenuous use of model results. Computing the absolute differences in this way disregards the

possibility that operators would react differently than the model to the conditions in individual scenarios and this may distort the evaluation of impacts.

Reporting seasonal patterns from long-term averages and water year type averages will avoid the short-term predictive unrealities alluded to above. Statistics computed based on long-term and water year type averages are an appropriate use of model results for the same reason. Similarly, computing differences between long-term or water year type averages of model results from two scenarios is appropriate. Care should be taken to use the appropriate water year type for presenting water year type average statistics of model results (e.g., D1641 Sacramento River 40-30-30 or San Joaquin River 60-20-20 based on CalSim 3 inflow forecasts).

The most appropriate presentation of monthly and annual model results is in the form of probability distributions and comparisons of probability distributions (e.g., cumulative probabilities) for the reasons discussed above. If necessary, comparisons of model results against threshold or standard values should be limited to comparisons based on cumulative probability distributions.

D.4 Linkages to Other Models and Analyses

Various fisheries models use the outputs from the HEC5Q and Reclamation Temperature Model for their inputs. These include the SALMOD model, which incorporates the daily flow and temperature outputs from the HEC5Q model, the arguments above notwithstanding, to calculate production and mortality of different species and life-stages of Chinook salmon in the upper Sacramento River. The Martin and Anderson Egg Mortality Models use daily temperature outputs from the Trinity-Sacramento HEC5Q model to estimate temperature-dependent egg mortality for Sacramento River Winter run Chinook salmon. The simulated temperatures are used in numerous other individual analyses to analyze the upstream effects on the listed species.

D.5 Presentation of Results

Water temperature results are included in 5A Modeling Technical Appendix, Section D, Attachment 1 for the 2020 level of development and Attachment 2 for the future (2040) level of development. Absolute water temperatures are presented for existing conditions, proposed project, and project alternatives. Water temperatures for the proposed project and project alternatives are compared to existing conditions and the No Project Alternative.

The 5A Modeling Technical Appendix, Section D Attachment 1 and Attachment 2 also include the estimated volume of the cold water pool in Shasta Lake at different temperatures. Reservoir temperature profiles for each month of the simulation period were output from the Trinity-Sacramento HEC5Q model. These temperature profiles show temperatures at different elevations in the reservoir pool. The elevation that corresponded to certain temperatures was converted to a volume. This calculation yielded the reservoir pool volume that has a temperature below the selected temperature. Sections provided for each parameter include figures and tables in various formats to provide the reader with tools for multiple ways of analysis. Different types of presentations are explained below:

- Long Term Average Summary and Water Year Type Based Statistics Summary Tables: These tables provide parameter values for each 10% increment of exceedance probability (rows) for

each month (columns) as well as long-term and water year type averages, using the Sacramento Valley 40-30-30 Index for the Trinity, Sacramento, Feather, and American Rivers for each month.

- Probability of Exceedance Plots: Probability of exceedance plots are provided for each month over the simulation period as well as monthly plots by water year type. Probability of exceedance plots provide the frequency of occurrence of values of a parameter that exceed a reference value. For this appendix, the calculation of exceedance probability is done by ranking the data. For example, for Sacramento River below Keswick September temperature exceedance plot, monthly temperature values for September for each simulated year are sorted in ascending order. The smallest value would have a probability of exceedance of 100% since all other values would be greater than that value; and the largest value would have a probability of exceedance of 0%. All the values are plotted with probability of exceedance on the x-axis and the value of the parameter on the y-axis. Following the same example, if for one scenario, a Sacramento River below Keswick September temperature of 60°F corresponds to 10% probability; it implies that Sacramento River below Keswick September temperature is lower than 60°F in 90% of the years.
- Box and Whisker Plots: These plots show the monthly averaged water temperature results under the No Action Alternative and the Proposed Action for each month for each water year type. The plots display the distribution of data based on the following statistical summary.
 - 5th percentile that corresponds to 95% exceedance probability,
 - First quartile (25th percentile that corresponds to 75% exceedance probability).
 - Median (50th exceedance probability),
 - Third quartile (75th percentile that corresponds to 25% exceedance probability),
 - 95th percentile that corresponds to 5% exceedance probability, and
 - Mean

Monthly averaged water temperature results for the following locations on the Trinity, Sacramento, and American Rivers are presented in 5A Modeling Technical Appendix, Section D Attachment 1 and Attachment 2. For each of the locations identified below a table comparing monthly temperature results, a monthly exceedance plot, and box-whisker plot by water year type are included.

- American River above Confluence
- American River below Folsom Dam
- American River below Nimbus Dam (Hazel Avenue)
- American River Watt Avenue
- American River William Pond Park
- Clear Creek above Sacramento
- Clear Creek at Clear Creek Tunnel
- Clear Creek at Igo

- 1 • Clear Creek at Spring Creek Tunnel
- 2 • Clear Creek at Whiskeytown
- 3 • Sacramento River at Balls Ferry
- 4 • Sacramento River at Bend Bridge
- 5 • Sacramento River below Clear Creek
- 6 • Sacramento River below Keswick
- 7 • Sacramento River below Shasta
- 8 • Sacramento River at Butte City
- 9 • Sacramento River at Cottonwood Creek
- 10 • Sacramento River at Cow Creek
- 11 • Sacramento River at Glenn Colusa Irrigation District
- 12 • Sacramento River at Hamilton City
- 13 • Sacramento River at Jelly's Ferry
- 14 • Sacramento River at Red Bluff Dam
- 15 • Sacramento River below Red Bluff
- 16 • Sacramento River at Stony Creek
- 17 • Sacramento River at Tehama Colusa Irrigation District
- 18 • Sacramento River at Woodson Bridge
- 19 • Stony Creek above Sacramento
- 20 • Stony Creek below Black Butte
- 21 • Trinity River above Lewiston
- 22 • Trinity River below Lewiston
- 23 • Trinity River below Trinity Dam

24 Estimated cold water pool volumes for selected temperatures of 48°F, 50°F, 52°F, 54°F, 56°F and
25 58°F are reported for Shasta Lake for the months of April to October in 5A Modeling Technical
26 Appendix, Section D Attachment 1 for existing conditions and project alternatives at the 2020 level
27 of development, and 5A Modeling Technical Appendix, Section D Attachment 2 for project
28 alternatives at the 2040 level of development, including the No Project Alternative.

D.6 References Cited

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