

STUDY DESCRIPTION WR-2
Water Temperature Model of Project-Affected Reaches
and in New Spicer Meadow Reservoir
July 28, 2026

This Study Description was developed to inform information gaps identified by Calaveras County Water District (CCWD) for the relicensing of its North Fork Stanislaus River Hydroelectric Project (Project).¹

This Study will use the United States Army Corps of Engineers' (USACE) Hydrologic Engineering Center HEC-5Q (USACE 1998), which is part of a modeling suite developed by USACE as a companion to its HEC-5 flood control and conservation system model. HEC-5Q is designed to simulate water temperature in reservoirs and rivers. California Department of Fish and Wildlife and CCWD's modelers agreed HEC-5Q Model is adequate to reliably model New Spicer Meadows Reservoir. Model output will be average daily temperature and, if maximum daily temperatures are needed, these will be post-processed. For New Spicer Meadow Reservoir, model output will be at various locations, including the intake tower. For stream reaches, model output nodes will include the head and tail of each reach, at Big Trees State Park, and at the Avery stream gage, and at additional locations, if needed. The model output will be provided in HEC-DSS format.

STUDY AREA

The Study Area includes the following reservoirs/impoundments and river reaches:

- Reservoirs/Impoundments
 - North Fork Diversion Impoundment
 - New Spicer Meadow Reservoir.
 - McKays Point Diversion Impoundment.
 - Beaver Creek Diversion Impoundment.
- River Reaches
 - Highland Creek downstream of New Spicer Meadow Dam to confluence with North Fork Stanislaus River (NFSR).
 - NFSR from North Fork Diversion Dam to confluence with Highland Creek.
 - NFSR from confluence with Highland Creek to normal maximum water surface elevation of McKays Point Reservoir.
 - Beaver Creek from Beaver Creek Diversion Dam to confluence with NFSR.

¹ In addition to the details provided in this study description, study implementation will also follow the "*Concepts and Practices Applicable to All Relicensing Studies*" developed by CCWD.

- NFSR from McKays Point Diversion Dam to confluence with Beaver Creek.
- NFSR from confluence with Beaver Creek to confluence with Middle Fork Stanislaus River (MFSR).
- Stanislaus River from the confluence of NFSR and MFSR to Collierville Powerhouse Tailrace.

Figure 1 shows a model schematic representing the Study Area.

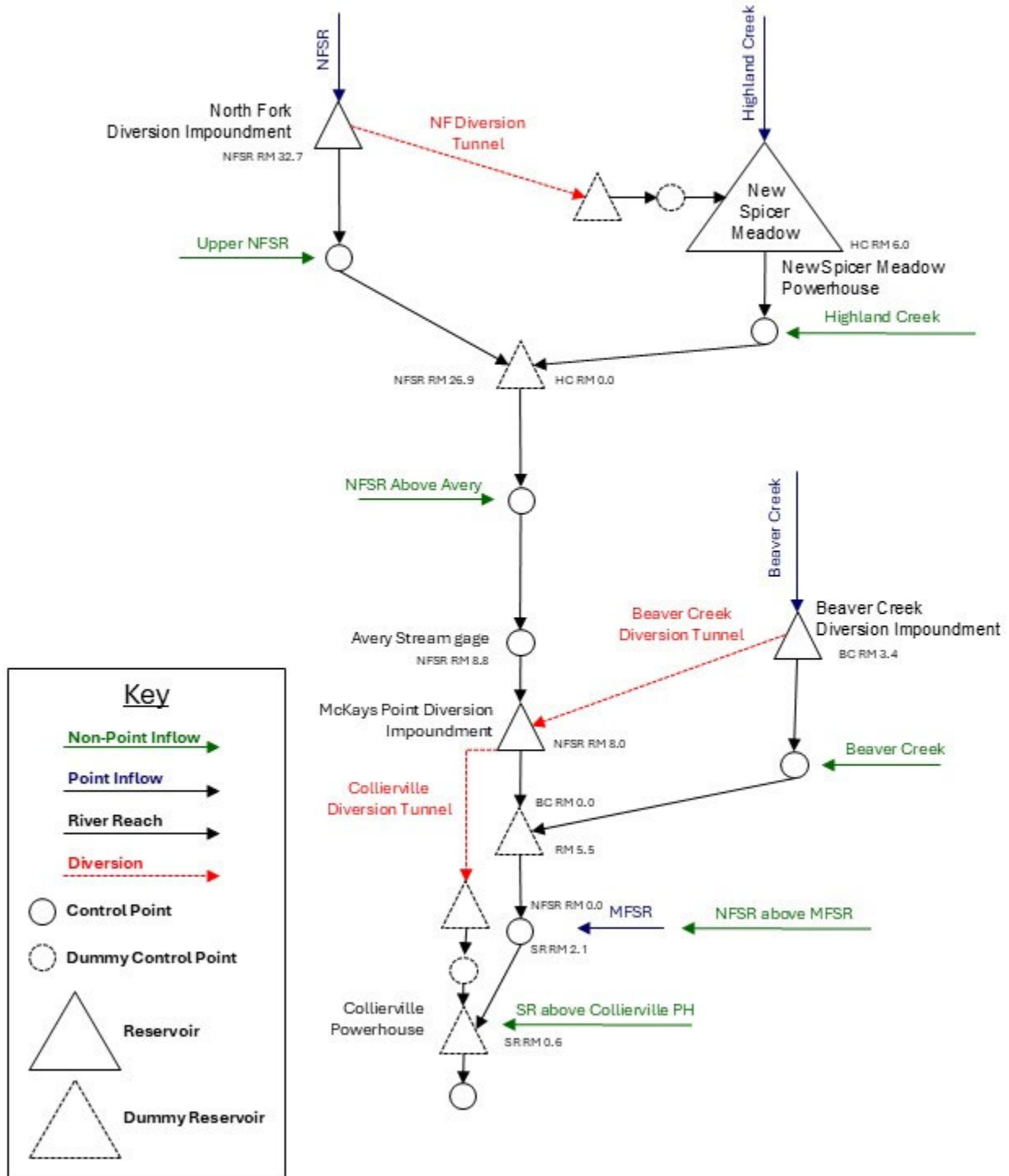


Figure 1. HEC-5Q Water Temperature Model Schematic.

For this Study description and the above schematic, the following definitions apply:

- Non-Point Inflow: accretion inflow to a reach that is not attributable to a single source or location.
- Point Inflow: inflow to a reach or reservoir/impoundment that is attributable to a single source. Reservoirs/impoundments must be accompanied by a point inflow.
- River Reach: one of the seven river reaches listed above.
- Diversion: a redirection of water from one of three impoundments.
- Control Point: used to identify the beginning or end of a reach where there is no reservoir/impoundment. Used to report flow and temperature within a reach.
- Dummy Control Point: used to report flow and temperature on a diversion.
- Reservoir: one of four impoundments listed above.
- Dummy Reservoir: the most upstream location on a tributary must be a reservoir/impoundment. If no reservoir/impoundment exists, a dummy reservoir/impoundment is used. A dummy reservoir/impoundment is also needed at the confluence of two or more river reaches. A dummy reservoir/impoundment has no storage.

STUDY METHODS

Excluding Data Summary Development (i.e., Reporting), the Study consists of the following six steps: 1) Develop HEC-5 Module Framework; 2) Collect Channel Cross-Section Data; 3) Develop HEC-5Q Module Framework; 4) Calibrate HEC-5Q Model; 5) Validate HEC-5Q Model; and 6) Develop Baseline Scenario. Each step is described below.

Step 1 - Develop HEC-5 Module Framework

The HEC-5Q model consists of two modules, one to simulate water quantity (HEC-5) and one to simulate water quality (HEC-5Q). The HEC-5Q module utilizes the flow simulation capabilities of HEC-5 module. For the Study, the HEC-5 module will run using a daily average time step.

All hydrologic inputs to the HEC-5 module will come from the relicensing OASIS Operations Model (Ops Model).² A spreadsheet tool or python script will be developed to pre-process Ops Model output for input to the HEC-5Q water temperature module. Pre-processing will include:

- Conversion of Ops Model output from hourly average flow to daily average flow.
- Distribution of lumped multi-reach non-point inflow into individual reach non-point inflows using watershed area proration.

² CCWD will include in the Pre-Application Document (PAD) a description of the Ops Model, a calibration and validation reports, and the Ops Model configured in the baseline scenario.

The following list summarizes the hydrologic inputs to be included in the HEC-5 module and as shown in Figure 1:

- NFSR inflow to North Fork Diversion Dam.
- Diverted flow out of North Fork Diversion Dam into North Fork Diversion Tunnel.
- Highland Creek inflow to New Spicer Meadow Reservoir.
- Incremental accretion in NFSR between North Fork Diversion Dam and confluence with Highland Creek.
- Incremental accretion in Highland Creek below New Spicer Meadow Dam and confluence with NFSR.
- Incremental accretion between the NFSR-Highland Creek confluence and Avery stream gage.
- Beaver Creek inflow to Beaver Creek Diversion Dam.
- Diverted flow out of Beaver Creek Diversion Dam into Beaver Creek Diversion Tunnel.
- Beaver Creek Diversion Dam release to Beaver Creek.
- Diverted flow out of McKay's Point Diversion Dam into Collierville Diversion Tunnel.
- Incremental accretion in Beaver Creek from Beaver Creek Diversion Dam to NFSR confluence.
- MFSR flow into NFSR.
- Incremental accretion in NFSR from NFSR-Beaver Creek confluence to NFSR-MFSR confluence.
- Incremental accretion in Stanislaus River from NFSR-MFSR confluence to Collierville PH tailrace.

The HEC-5Q Model will use the New Spicer Meadow Reservoir area-capacity curve from the draft Exhibit B in the PAD, which is the same area-capacity curve used in the Ops Model.

Step 2 - Collect Channel Cross-Section Data

For river reaches, the HEC-5Q module cross-section geometry inputs include flow area, hydraulic radius, and water surface top width as a function of elevation for each transect. A minimum of one cross section is needed for each HEC-5Q control point. At control points marking the confluence of a tributary river branch, a cross-section must be provided for both the mainstream and the terminus of the tributary river branch. Cross-sections at intermediate locations within the stream branch may be furnished. The energy grade line slope is also a required input for each channel cross-section.

Channel cross-section data will be collected as part of this Study since there are no existing data sets that can be used to develop channel geometry input data. Accessibility in the Study area is challenging due to the remote nature of much of the Study area, which limits the ability to take

transect measurements in most Study reaches. In some cases, transect data will be collected in one reach location and repeated at other locations within the reach where similar conditions exist. At a minimum, cross sections will be collected for this Study at the following locations:

- In Highland Creek below New Spicer Meadow Dam (HC RM 5.6).
- In NFSR below North Fork Diversion Dam (NFSR RM 32.5).
- In NFSR above Highland Creek (NFSR RM 27.8).
- In NFSR below Highland Creek (NFSR RM 26.8).
- In NFSR at Boards Crossing (NFSR RM 16.2).
- In NFSR at Big Trees State Park (NFSR RM 11.0).
- In NFSR below McKays Point Diversion Dam (NFSR RM 7.8).
- In Beaver Creek below Beaver Creek Diversion Dam (BC RM 3.4).
- In NFSR at Candy Rock Recreation access (NFSR RM 4.25) or Blue Streak Recreation access (NFSR RM 5.0).
- In Stanislaus River above the Collierville Powerhouse Tailrace (SR RM 1.0).

Light Detection and Ranging information from November 2021 will be used to inform energy grade lines for repeated transect locations.

Step 3 - Develop HEC-5Q Module Framework

The HEC-5Q module computes the distribution of water temperature either vertically or longitudinally in reservoirs and longitudinally in riverine reaches. New Spicer Meadow Reservoir will be simulated as a one-dimensional vertically segmented reservoir. The New Spicer Meadow Powerhouse intake will be simulated as a wet well with multiple port elevations³ to enable selective withdrawal. North Fork Diversion, Beaver Creek Diversion, and McKays Point Diversion impoundments will be simulated as longitudinally stratified reservoirs with no storage capacity for model stability. Channel geometry input data will be developed from channel cross-section data collected under Step 2.

The following list summarizes daily average water temperature inputs to accompany point inflows and non-point inflows in the HEC-5Q module:

- Point inflow water temperatures to:
 - NFSR at North Fork Diversion Dam.
 - Highland Creek at New Spicer Meadow Reservoir.

³ The New Spicer Meadows Intake includes three ports (see draft Exhibits A and B for additional information regarding the intake).

- Beaver Creek at Beaver Creek Diversion Dam.
- MFSR at NFSR.
- Non-point inflow water temperatures to:
 - NFSR between North Fork Diversion Dam and confluence with Highland Creek.
 - Highland Creek below New Spicer Meadow Dam and confluence with NFSR.
 - NFSR between the NFSR-Highland Creek confluence and Avery stream gage.
 - Beaver Creek from Beaver Creek Diversion Dam to the NFSR confluence.
 - NFSR from NFSR-Beaver Creek confluence to the NFSR-MFSR confluence.
 - NFSR from NFSR-MFSR confluence to the Collierville Powerhouse tailrace.

HEC-5Q requires daily meteorological input data consisting of the following parameters:

- Coefficient of surface heat exchange, British Thermal Units (BTU)/square-foot (ft²)/day/degree Fahrenheit (°F).
- Equilibrium temperature (°F).
- Short-wave solar radiation BTU/ft²/day.
- Wind speed, miles per hour (mph).

Coefficient of heat exchange and equilibrium temperature are not directly recorded meteorological parameters and are calculated using the Heat Exchange Program (HEATX) developed by the USACE (USACE 1972). The HEATX model directly calculates the required inputs to the HEC-5Q model as described above. Mean-daily input parameters for HEATX include:

- Cloud cover based on a 0 to 10 scale, with 0 being clear and 10 being completely overcast.
- Wind speed (mph).
- Air temperature (°F).
- Dew point temperature (°F).

Cloud cover and dew point temperature are not typically measured. Cloud Cover will be estimated based on observed daily short-wave solar radiation relative to the theoretical daily maximum solar radiation. Dew point temperature will be calculated from air temperature and relative humidity observations. Available data from nearby weather stations are summarized in Table 1.

Table 1. Summary of available meteorological data from weather stations located in the vicinity of the Study Area.

Gage (Source, Gage ID)	Gage Elevation (feet)	Available Data	Available Period of Record
Highland Meadow (CDEC, HHM)	8,700	Air Temperature Relative Humidity Wind Speed Solar Radiation	9/2/1999-present
Stanislaus Meadow (CDEC, SLM)	7,750	Air Temperature	10/11/1999-present
Bloods Creek (CDEC, BLD)	7,200	Air Temperature	9/15/1998-present
Upper Met (CDEC, UMT)	7,920	Air Temperature Relative Humidity Wind Speed Solar Radiation	3/1/2018-8/26/2021
Lower Met (CDEC LMT)	7,063	Air Temperature Relative Humidity Wind Speed Solar Radiation	3/1/2018-present
Black Springs (CDEC, BLS)	6,500	Air Temperature	9/8/1998-present
Big Trees (CDEC, ARN)	4,700	Air Temperature Relative Humidity Wind Speed Solar Radiation	5/8/2026-present
Calaveras Ranger Station (CDEC, CVS)	3,360	Air Temperature	9/8/1998-present
Stanislaus Powerhouse (CDEC, SPW)	1,060	Air Temperature Relative Humidity	11/8/2007-present 10/1/2015-present
Columbia Airport (NOAA NCEI, USW00000206)	2,120	Air Temperature Dew Point Temperature Wind Speed Solar Radiation Sky Condition	7/31/2014-8/25/2025
Mount Elizabeth (CDEC, MTE)	4,933	Air Temperature Relative Humidity Wind Speed Solar Radiation	7/19/1999-present

Selection of meteorological data for developing water temperature model inputs will be based on the available period of record and data quality. If possible, two zones will be used within the HEC-5Q model representing conditions in the upper watershed and lower watershed, respectively. A consistent data set will be developed across all simulation periods, as described in Steps 4, 5, and 6.

Step 4 - Calibrate HEC-5Q Model

The calibration scenario will simulate one year, starting June 1, 2026, for comparison with observed water temperature profiles in New Spicer Meadow Reservoir and point measurements taken hourly of water temperature that will be collected throughout the Study Area. The calibration

scenario will be used to adjust model parameters from upstream to downstream and reach by reach to minimize the error between model simulated daily average water temperature and observed daily average water temperature. Two methods will be used to quantify the error of the simulation (Cole and Wells 2011). These two methods are:

- Mean Error (ME). The daily ME, or difference between historical and simulated data, will be averaged for the period of record. The goal of calibration is to have this value as close to 0°F as possible; a value of 0°F would indicate no systematic bias in the prediction. For calibration, the ME should be within +/-0.5°F to indicate any systematic bias was relatively small compared to the range of temperatures being predicted.
- Absolute Mean Error (AME). The AME indicates how far off the predicted water temperatures are, on average, regardless of whether the predictions are too high or too low. The absolute value of the error for each day is averaged for the period of record. While a value of 0°F was preferable, calibrated AME should be below 1.0°F.

Point inflow water temperatures will be represented by historical water temperature data measured concurrently by CCWD for the calibration simulation period. Non-point inflow water temperatures are less easy to define because the source is often unknown. Adjustment of non-point inflow water temperature may be used as a calibration factor if observed data is inadequate.

Calibration locations will include the following locations, from upstream to downstream, assuming there are available water temperature observations to do so:

- Hobart Creek downstream of confluence with North Fork Tunnel Outlet.
- Highland Creek below New Spicer Meadow Dam (HC RM 5.6).
- Highland Creek upstream of NFSR confluence (HC RM 0.1).
- NFSR upstream of confluence with Highland Creek (NFSR RM 27.8).
- NFSR downstream of confluence with Highland Creek (NFSR RM 26.8).
- NFSR at Boards Crossing (NFSR RM 16.2).
- NFSR at Big Trees State Park (NFSR RM 11.0).
- NFSR at the Avery stream gage (NFSR RM 8.8).
- NFSR below McKays Point Diversion Dam (NFSR RM 7.9).
- NFSR at the Candy Rock Recreation access (NFSR RM 4.25) or Blue Streak Recreation access (NFSR RM 5.0).
- NFSR upstream of confluence with MFSR (NFSR RM 0.1).
- Stanislaus River upstream of Collierville Tailrace (SR RM 1.0).
- Collierville Tailrace.

All hydrologic inputs for the calibration scenario will come from the Ops Model. Selective withdrawal operations information for the New Spicer Meadow Powerhouse intake will be provided by CCWD.

Step 5 - Validate HEC-5Q Model

The validation scenario will be developed to test the adequacy of the model calibration by simulating a period of time independent of the calibration period, likely beginning in May or June 2027. Like the calibration scenario, ME and AME statistics will be used to assess model error. If validation scenario ME is greater than $\pm 0.5^{\circ}\text{F}$ or AME is greater than 1.0°F at any location with adequate gage data, model parameters will be readjusted in both the model calibration and validation scenarios until both ME and AME statistics fall within an acceptable range under both scenarios and no further improvement is possible.

Point inflow water temperatures will be represented by historical water temperature data measured concurrently by CCWD for the validation simulation period. Adjustment of non-point inflow water temperature, if needed, will conform to methods used for the calibration scenario.

All hydrologic inputs for the validation scenario will come from the Ops Model. Selective withdrawal operations information for the New Spicer Meadow Powerhouse intake will be provided by CCWD.

Step 6 - Develop Baseline Scenario

The baseline scenario (i.e., operation of the Project under existing conditions) will use calibrated model parameters to simulate current operations under historical hydrologic conditions from Water Year (WY) 2014 to WY 2025. Results from the baseline scenario will serve as reference for comparison with additional scenarios developed during the relicensing process to evaluate water temperature under alternative Project operating conditions.

All inflows to the baseline scenario and Project operation data will come directly from the Ops Model. General guidelines for selective withdrawal operations at New Spicer Meadow Powerhouse intake will be implemented based on guidance provided by CCWD.

Point measurements of historical inflow water temperature are not available for the baseline period of record. Therefore, inflow water temperatures will be synthesized by repeating historical water temperatures used for calibration and/or validation on an annual basis, or a more robust regression will be developed based on flow and meteorological conditions if there is adequate data to do so.

Simulated water temperature output at the head and tail of each reach, at Big Trees State Park, and at the Avery stream gage will be exported to a model output file in HEC-DSS format. Additional output locations will be added as needed.

Step 7 – Data Summary Development

A Study report that includes a description of model development, calibration results, validation results, and the model configured in baseline scenario setup will be provided.⁴

SCHEDULE

CCWD anticipates the schedule for completion of Study tasks as follows:

Step 1: Develop HEC-5 Model Framework	January – March 2027
Step 2: Collect Channel Cross-Section Data	June – October 2027
Step 3: Develop HEC-5Q Model Framework	January– October 2027
Step 4: Calibrate HEC-5Q Model	October – December 2027
Step 5: Validate HEC-5Q Model	November 2027 – February 2028
Step 6: Develop Baseline Scenario	March – April 2028
Step 7: Data Summary Development	January – June 2028

REFERENCES

- Cole, T.M., and S.A. Wells. 2011. “CE-QUAL-W2: A two-dimensional, laterally averaged, Hydrodynamic and Water Quality Model, Version 3.7,” Department of Civil and Environmental Engineering, Portland State University, Portland, OR.
- United States Army Corps of Engineers (USACE), Hydrologic Engineering Center (HEC). 1998. Users’ Manual, Simulation of Flood Control and Conservation Systems, Appendix on Water Quality Analysis. August 1998.
- _____. 1972. HEATX: Thermal Analysis Program. U.S. Army Corps of Engineers, Baltimore District.

⁴ In addition to the details provided in this section, reporting will also follow the "*Concepts and Practices Applicable to All Relicensing Studies*" developed by CCWD.

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