DRAFT

TECHNICAL MEMORANDUM 2-2:

Water Temperature Model Documentation, Calibration and Validation

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Contents

Appendices

List of Tables

List of Tables (continued)

List of Figures

List of Figures (continued)

List of Figures (continued)

Glossary

°C	degrees Celsius
Abs Err	Absolute Error (presented Figures 5-6 through 5-8, Figure 5-11 and Figure 5-12)
AFB	Air Force Base
AME	absolute mean error
cfs	cubic feet per second
CFW Temp Model	Camp Far West water temperature model
CIMIS	California Irrigation Management Information System
CVFED	Central Valley Floodplain Evaluation and Delineation Program
FERC	Federal Energy Regulatory Commission
ft	feet
fps	feet per second
GIS	Geographic Information Systems
GUI	Graphical User Interface
HEATX	Heat Exchange Program (USACE 1986)
LBR Temp Model	lower Bear River water temperature model
LIDAR	Light Detection and Ranging
LLO	low-level outlet
lower Bear River	the Bear River from the non-Project diversion dam to the Feather River confluence
m	meters
ME	mean error
mi	miles
µ	period of record average wind speed
NID	Nevada Irrigation District

Glossary (continued)

NOAA	National Oceanic and Atmospheric Administration
NPDD Temp Model	non-Project diversion dam water temperature model
NREL	National Renewable Energy Laboratory
σ	standard deviation of period of record wind speed
O&M	Operations and Maintenance
Ops Model	SSWD's water and power operations model
Project	Camp Far West Hydroelectric Project
SSWD	South Sutter Water District
Temp Models	the CFW Temp Model, the NPDD Temp Model and the LBR Temp Model, collectively
USACE	U.S. Army Corps of Engineers
WSC	wind sheltering coefficients
WSE	water-surface elevation

Executive Summary

South Sutter Water District (SSWD) developed three water temperature models (Temp Models), representing Camp Far West Reservoir (CFW Temp Model), the non-Project diversion dam (NPDD Temp Model) and the lower Bear River (LBR Temp Model). The Temp Models are a tool to examine water temperature under a variety of hydrologic and operational conditions. The Temp Models were developed to meet the following goals:

- Reasonably simulate reservoir and stream water temperatures resulting from Project operations and maintenance; that is, reproduce observed reservoir and stream water temperatures within acceptable calibration standards over a range of hydrologic conditions
- Cover a range of normal hydrologic variation of the Bear River
- Be sensitive to reservoir operations, upstream/downstream flow, and meteorological conditions

The Temp Models were developed in CE-QUAL-W2 because of the following capabilities:

- Capable of simulating multiple outlets
- Capable of simulating multiple years in a single run
- Capable of linking multiple water bodies in series (e.g. two reservoirs and a river)
- Capable of simulating on an hourly time step to characterize diurnal water temperature variability
- Capable of simulating the shading of vegetation and topography
  Freely available for download from the Portland State University website (http://www.cee.pdx.edu/w2/)

The Temps Models are designed to piggyback the SSWD water and power operations model (Ops Model). Flow output from the Ops Model are used as input to the Temp Models. A Graphical User Interface (GUI), developed in Excel, works to simplify the process of passing hydrologic data from one model to the other and to minimize user error. Concurrent with the Ops Model, the Temp Models simulate water years 1976 through 2014, and simulate water temperatures on a sub-daily time step. Water temperature output can be post processed into daily average, daily maximum, and 7-day average daily maximum water temperatures.

The Temp Models were developed, calibrated and validated with to represent historical operations, inflows and outflows. Model calibration involved an iterative process of adjusting major model parameters to achieve a reasonable match between the simulated water temperatures and the observed data. Model validation verified that parameters developed during calibration perform as expected for a secondary period of record.

The goal of temperature model calibration is to achieve a mean error of approximately 1.0°C and an absolute mean error of less than 1.0°C. Calibration and validation results met these thresholds for both the CFW and NPDD Temp Models. Results of the LBR Temp Model calibration and validation were generally not able to achieve this goal. Simulated water temperatures were typically cooler than observed water temperatures by 1.0°C or more. There are many possible reasons for this difference, including inadequate representation of accretion flows and accretion temperatures throughout the reach, and estimation of channel morphology. Results of the LBR Temp Model did show that simulated temperatures were reasonably sensitive to meteorological forcing and changes in flow resulting from upstream Project operations.

The Temp Models are intended to be used as a comparative tool rather than a predictive one to eliminate any biases. Impacts of changes in operations on temperature should be measured as the relative difference between two model runs. If used in this way, the Temp Models are appropriate for use in the Federal Energy Regulatory Commission relicensing process.

The GUI was used to develop a Base Case temperature model scenario, utilizing Base Case Ops Model output. Alternative operating scenarios can also be simulated by the GUI. Results of alternative operating scenarios can then be compared to Base Case scenario Temp Model output.

1. Introduction

South Sutter Water District's (SSWD's) operation and maintenance of the Camp Far West Hydroelectric Project, Federal Energy Regulatory Commission (FERC or Commission) Project Number 2997 (Project), affects water temperatures in stream reaches downstream from the Project. This report describes the development of water temperature models in support of SSWD's Project relicensing. As part of model development, the temperature models were calibrated and validated to historically observed water temperature data. Model calibration involved an iterative process of adjusting major model parameters to achieve a reasonable match between the simulated water temperatures and the observed data. Model validation verified that parameters developed during calibration perform as expected for a secondary period of record.

This report also describes the development of a Base Case water temperature scenario. The Base Case is representative of near-term historical operations. For the Base Case, model parameters developed during model calibration and validation were applied to a longer period of record, water years 1976 through 2014. Hydrologic input data for this scenario comes from SSWD's water and power operations model (Ops Model).

A Graphical User Interface (GUI) was created to streamline the process of performing a period of record (water years 1976 through 2014) water temperature model run. It can be used by all interested FERC relicensing participants during the relicensing to simulate water temperature conditions under potential future operations of the Project for comparison to the Base Case.

Study Goals and Objectives

The goal of Study 2-2 was to develop one or more water temperature models to supplement existing information regarding water temperature.

The objective of the study was to develop one or more water temperature models that can be used to address the study goal. The model objectives included:

- Reasonably simulate reservoir and stream water temperatures resulting from Project operation and maintenance; that is, reproduce observed reservoir and stream water temperatures within acceptable calibration standards over a range of hydrologic conditions
- Cover a range of normal hydrologic variation of the Bear River
- Be sensitive to reservoir operations, upstream/downstream flow, and meteorological conditions

Conventions

Unless noted otherwise, all elevations referenced in this Technical Memorandum use the North American Vertical Datum of 1988 expressed in feet (ft) or meters (m). All maps and spatial data products use the California State Plane, Zone II North American Datum 1983 projection. All model inflows and outflows are in metric units (cubic meters per second), while Project hydrology are in English units (cubic feet per second (cfs)). Inflow hydrology were converted from English to Metric units for use in the Temperature Models.

Statistical Metrics for Calibration and Validation

Statistical standards were used to determine how accurately the model is able to predict observed water temperatures. The two metrics used were the mean error (ME) and the absolute mean error (AME or Abs Err.), calculated as:

$$\textit{Mean Error (ME)} = \frac{\Sigma\ (\textit{Predicted Temperature} - \textit{Observed Temperature})}{\textit{number of observations}}$$

$$\textit{Absolute Mean Error (AME)} = \frac{\Sigma\ |\textit{Predicted Temperature} - \textit{Observed Temperature}|}{\textit{number of observations}}$$

These metrics provide a directly interpretable method for quantification of the quality of calibration and indication of the model performance. ME indicates the level of systematic bias in the model results; a value of 0 degrees Celsius (°C) would indicate no bias in the prediction. The goal of calibration was to minimize ME to within +/-0.5°C, indicating a small systematic bias relative to the range of temperatures being predicted. While it is also preferable for the AME value to be as close to 0°C as possible, an average error within 1.0°C represents a reasonable calibration given the range of temperatures being predicted. An AME greater than 1.0°C implies the average error is either greater than 1.0°C or less than -1.0°C.

2. Study Area Description

The Study Area, shown in Figure 2-1, is located in the Bear River watershed approximately 14 miles (mi) downstream of Lake Combie.[1] The Study Area includes both Project and non-Project facilities. Project Facilities include Camp Far West Reservoir and dam and Camp Far West Powerhouse. Non-Project facilities include the diversion dam located downstream from Camp Far West Dam, and the intake structures to SSWD's Conveyance Canal and Camp Far West Irrigation District's Canal located upstream of the diversion dam. The Study Area also includes approximately 16.9 mi of the Bear River from downstream of the non-Project diversion dam to the Feather River confluence.

Three temperature models were developed, representative of the Study Area:

- Camp Far West Dam and Reservoir (CFW Temp Model);
- The non-Project diversion dam and impoundment (NPDD Temp Model); and
- The lower Bear River from below the non-Project diversion dam to upstream of the Feather River confluence (LBR Temp Model)

[1] Lake Combie is owned and operated by Nevada Irrigation District (NID).

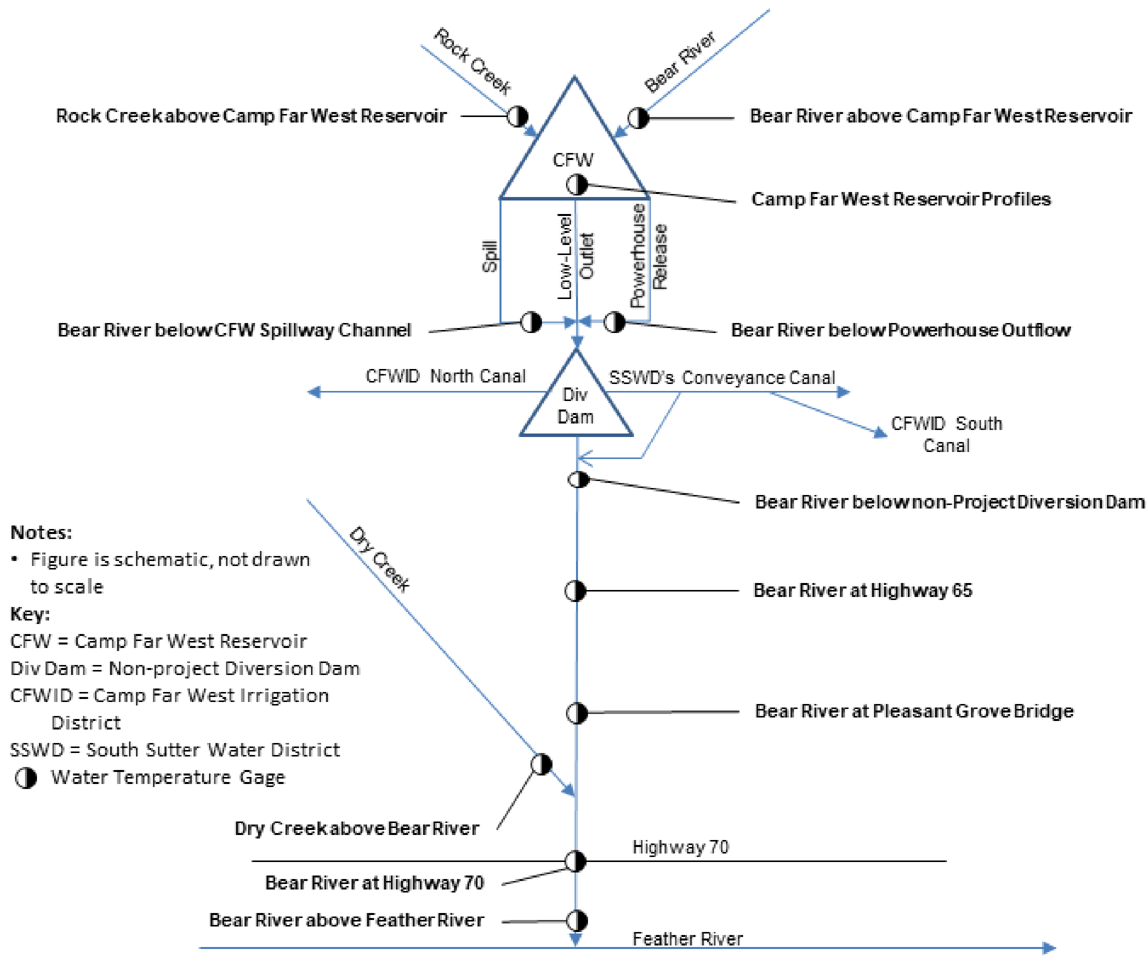

Figure 2-1. Water temperature model Study Area.

The three models are collectively referred to as the Temp Models.

Continuous water temperature data, collected by SSWD as part of Study 2-1 (SSWD 2018), were utilized to develop boundary condition input data and for comparison to model output for model calibration and validation. Table 2-1 provides a list of 10 continuous water temperature gages used for temperature model development, and their locations are shown in Figure 2-1.

Table 2-1. SSWD water temperature monitoring locations.

Location	River Mile[1]	Installation Date	Last Download	Latitude	Longitude
Upstream of Project Area					
Bear River above Camp Far West Reservoir	25.1	4/10/15	7/2/18	39.011685	-121.220506
Rock Creek above Camp Far West Reservoir	--	8/6/15	7/2/18	39.063471	-121.263205
Downstream of Project Area					
Bear River below Powerhouse Outflow	18.0	4/10/15	9/12/18	39.04898	-121.31841
Bear River below CFW Spillway Channel	17.8	9/30/15	10/25/17	39.04719	-121.31969
Bear River below diversion dam	16.9	4/10/15	9/12/18	39.04163	-121.33235
Bear River at Highway 65	11.4	4/10/15	9/12/18	38.99901	-121.40810
Bear River at Pleasant Grove Bridge	7.1	4/10/15	9/12/18	38.98561	-121.48329
Dry Creek above Bear River	--	12/1/15	9/12/18	38.99596	-121.49121
Bear River near Highway 70	3.5	4/10/15	9/12/18	38.97249	-121.54343
Bear River above Feather River Confluence	0.1	4/10/15	9/12/18	38.93906	-121.57831

[1] River miles are for locations in the Bear River only.

Table 2-2 provides a list of locations where reservoir profiles were collected approximately once per month. Reservoir profile data from all three sites showed very similar profiles to one another. Reservoir profile data from the Near Camp Far West Dam location were used to develop initial condition reservoir profiles for the entire reservoir and for comparison to model output for model calibration and validation.

Table 2-2. SSWD reservoir water temperature profile locations at Camp Far West.

Location	First Profile Date	Last Profile Date	Latitude	Longitude
Near Camp Far West Dam	4/9/15	1/30/18	39.05140	-121.31237
Rock Creek Arm of Reservoir	4/9/15	1/30/18	39.05972	-121.29323
Bear River Arm of Reservoir	4/9/15	1/30/18	39.03301	-121.27238

3. Model Platform

SSWD elected to use a single model platform, CE-QUAL-W2 (version 4.1), to develop all three models. CE-QUAL-W2, by the Waterways Experiment Station of the U.S. Army Corps of Engineers (USACE), is a two-dimensional, laterally averaged, hydrodynamic water quality model for rivers, estuaries, lakes, reservoirs, and river basin systems (Cole and Wells 2017). The model has been successfully applied to over 200 different water bodies within the United States and the world (Cole and Wells 2017). It is the reservoir model of choice for the Tennessee Valley Authority, U.S. Bureau of Reclamation, U.S. Geological Survey, USACE, and the U.S. Environmental Protection Agency (Cole and Tillman 2001).

Since the model assumes lateral homogeneity, it is best suited for relatively long and narrow water bodies exhibiting longitudinal and vertical water quality gradients. The model is capable of predicting many different variables, including water-surface elevation (WSE), velocity, and temperature at longitudinal segments and vertical layers. Positive attributes of CE-QUAL-W2 as a modeling platform for this Study include the following:

- Capable of simulating multiple outlets
- Capable of simulating multiple years in a single run
- Capable of linking multiple water bodies in series (e.g. two reservoirs)
- Capable of simulating on an hourly time step to characterize diurnal water temperature variability
- Capable of simulating the shading of vegetation and topography
  Freely available for download from the Portland State University website (http://www.cee.pdx.edu/w2/)

4. Meteorological Database

This section provides a description of the meteorological dataset development, available historical data, and methods used to create a full period of record of input meteorology.

Data Requirements

- The Temp Models were developed using CE-QUAL-W2 required hourly meteorological data types as follows:
  - Hourly air temperature (°C)
  - Hourly dew point temperature (°C)
  - Hourly wind speed, meters per second (m/sec)
  - Hourly wind direction, radians
  - Hourly cloud cover, 0 (clear) to 10 (cloudy)
  - Short wave radiation, Langleys (W) /square meter (m^2) (optional)

Meteorological input data can be input in any frequency and the frequency may vary during the simulation. Incidental short-wave radiation is optional and represents only the penetrating short-wave radiation component. CE-QUAL-W2 calculates solar radiation, if not provided, from sun angle relationships and cloud cover. The CE-QUAL-W2 model directly calculates heat transfer parameters.

Data Sources

Data from nearby weather stations were obtained from the National Oceanic and Atmospheric Administration (NOAA), the California Data Exchange Center, the California Irrigation Management Information System (CIMIS), and the National Renewable Energy Laboratory (NREL). The review of these weather station data took into consideration that meteorology data sets would need to be developed for water temperature model calibration and for the full period of record being modeled.

Beale Air Force Base (AFB) weather station was identified as the best primary meteorological weather station in the vicinity. Beale AFB, only a few miles north of the Bear River and Camp Far West Reservoir, is considered representative of the valley conditions and had a period of record covering Base Case and Calibration/Validation periods of record (October 1, 1975 through August 31, 2018).

Secondary weather stations include the CIMIS weather station at Verona, NOAA weather station at the Sacramento Executive Airport, and CIMIS weather station at Browns Valley.

Secondary gages were considered to be representative of valley conditions while also having sufficient quality and length of their historical periods of record. Secondary gage data were used to fill in missing Beale AFB data, as needed.

Weather stations sources and periods of records are listed in Table 4-1, and their geographic locations are shown in Figure 4-1.

Table 4-1. Weather stations.

Weather Station	Operating Agency	Station ID	Period of Record	Data Type[1]
Beale AFB	NOAA[3], NREL[4]	040584	7/1/1959 to Present	Air Temperature Wind Speed Wind Direction Dew Point Solar Radiation
Verona	CIMIS[2]	030	5/18/2012 to Present	Air Temperature Solar Radiation Wind Speed Wind Direction Dew Point
Sacramento Executive Airport	NOAA[3], NREL[4]	047630	1/1/1931 to Present	Air Temperature Wind Speed Wind Direction Dew Point Solar Radiation
Browns Valley	CIMIS[2]	084	4/13/1989 to Present	Solar Radiation

[1] Only includes weather station data used in the dataset creation.
[2] CIMIS - www.cimis.water.ca.gov/
[3] NOAA - www.ncdc.noaa.gov/
[4] NREL - http://www.nrel.gov/rredc/

Figure 4-1. Location of weather stations used in the Study.

Weather Station Data Review and Analysis

This section describes the review and analysis of the hourly raw data for weather stations listed in Table 4-1. Errors in the data were identified, and fixed or removed, as described below.

Beale AFB Weather Station Data Analysis

Beale AFB weather station was the primary weather station used to develop with Base Case and calibration/validation data sets. The reviewed period of record for the Beale AFB weather station was from October 1, 1975 through August 31, 2018.

Large gaps in data were observed and included June 1990 through December 1990, and January 2000 through November 2000. A second Beale AFB gage had data from 2000 through 2004; and was used to fill in the missing data from January 2000 through November 2000.

Specific issues and revisions for each of the Beale AFB weather station parameters are described below.

- **BEALE AFB WEATHER STATION AIR TEMPERATURE**
  Hourly air temperatures considered excessively high, low, or having obviously incorrectly reported temperature values were removed. Single hours of missing or bad data were filled in using an average of the preceding and following values.

- **BEALE AFB WEATHER STATION DEW POINT**
  Hours with relative humidity values greater than 100 percent were removed. Single hours of missing or bad data were filled in using an average of the preceding and following values.

- **BEALE AFB WEATHER STATION WIND SPEED**
  Individual hours of wind speed data observed to have excessively high or negative values and were removed. Single hours of missing or bad data were filled in using an average of the preceding and following values.

- **BEALE AFB WEATHER STATION WIND DIRECTION**
  Recorded hourly values of wind direction not between 0 degrees Celsius (°C) and 360 °C were removed. Single missing hours of wind direction data were not estimated by interpolation.

- **BEALE AFB WEATHER STATION SOLAR RADIATION**
  Solar radiation data were not available for download for Beale AFB from National Centers for Environmental Information. However, solar radiation values were modeled by the NREL. Further discussion of solar radiation data and the conversion process to the required cloud cover input parameter can be found later in this section.

Verona Weather Station Data Analysis

Weather station data from the Verona weather station were used to fill missing data for the calibration/validation data set based on its period of record and location relative to the Project. The reviewed period of record for the Verona weather station was from April 1, 2014 through

August 31, 2018. Specific issues and revisions for each of the Verona weather station parameters are described below.

- **VERONA WEATHER STATION AIR TEMPERATURE**
  Hourly air temperatures considered excessively low or having obviously incorrectly reported temperature values were removed. No temperatures were identified as being excessively high. Single hours of missing or bad data were filled in using an average of the preceding and following values.

- **VERONA WEATHER STATION DEW POINT**
  Hourly dew point temperatures considered excessively low or having obviously incorrectly reported temperature values were removed. No dew point temperatures were identified as being excessively high. Single hours of missing or bad data were filled in using an average of the preceding and following values.

- **VERONA WEATHER STATION WIND SPEED**
  For several days in October 2016, it was observed that many hours had wind speed values of 0 feet per second (fps) below the minimum wind speed value of 1 fps observed throughout the data set. These values of 0 fps were removed. Single hours of missing or bad data were filled in using an average of the preceding and following values.

- **VERONA WEATHER STATION WIND DIRECTION**
  All recorded hourly values of wind direction were between 0°C and 360°C.

Sacramento Executive Airport Weather Station Data Analysis

The Sacramento Executive Airport weather station was selected as the next closest weather station with all necessary data types for the full Base Case Scenario period of record and covered gaps in Beale AFB data. Errors in the data were identified, and fixed or removed in the same manner as Beale AFB.

Sacramento Executive Airport is a primary facility included in the NREL solar radiation database discussed in later in this section.

Browns Valley Weather Station Solar Radiation

Solar radiation data were used to estimate cloud cover, as described below. Hours with excessively high values were identified and removed. Single hours of missing data were calculated as the average value of the hours immediately preceding and following the missing hour.

Model Input Meteorological Dataset Development

This section describes the methodology used to develop complete input datasets as required by CE-QUAL-W2. All datasets for Calibration/Validation, and Base Case scenarios were created using reviewed hourly data, as described previously. Secondary datasets were used to fill in missing data, when required.

To best represent the historic meteorological conditions of the Project, all secondary weather station data were transformed by means of linear regression to better represent the Beale

AFB data set used during calibration and validation of the Temp Models. Cloud cover is calculated independently of the other meteorological data, as described below.

Cloud Cover

CE-QUAL-W2 requires an assessment of cloud cover represented as an integer ranging from 0, the theoretical clear sky potential solar radiation, to 10, a dark overcast day. Cloud cover was calculated by comparing the theoretical clear-sky, short-wave solar radiation to the measured value using the following formula:

$$\text{Cloud Cover} = \left(\left(1 - \left(\text{Measured Solar Radiation} / \text{Clear Sky Theoretical Solar Radiation}\right)\right) / 0.0065\right)^{0.5}$$

Theoretical clear-sky short wave solar radiation was calculated using the Heat Exchange Program (HEATX) (USACE 1986) for Beale AFB, Sacramento Executive Airport, and Browns Valley weather stations. HEATX calculates solar radiation as a function of cloud cover, project latitude, elevation, and Julian day. The clear sky theoretical solar radiation value for each day of the year was calculated by setting cloud cover to a value of 0 in HEATX. The above equation was then used to calculate cloud cover at Beale AFB, Sacramento Executive Airport, and Browns Valley weather stations. The non-linear relationship of solar radiation to cloud cover can be seen in Figure 4-2.

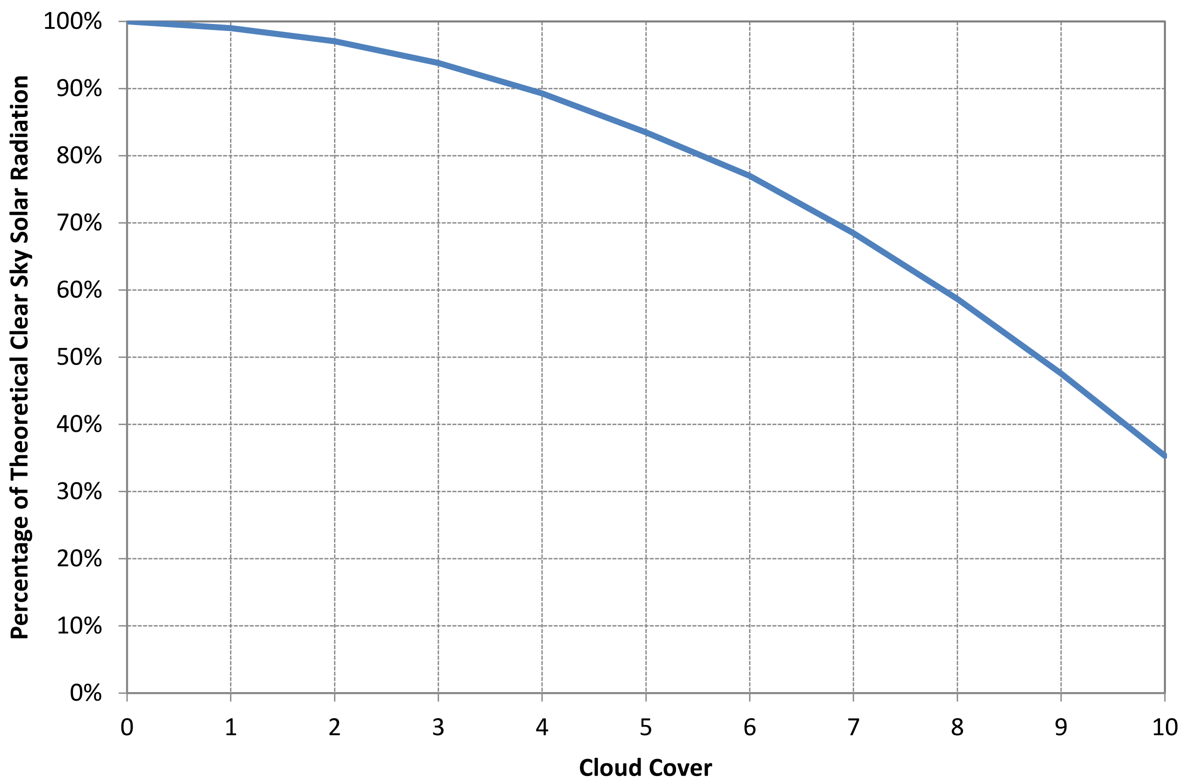

Figure 4-2. Relationship of cloud cover number to the theoretical clear-sky solar radiation.

Cloud cover for the Base Case Scenario was developed using solar radiation data from the National Solar Radiation Database developed by the NREL (NREL 2012), a laboratory of the U.S. Department of Energy. The NRSDB consists of two stages of analysis; solar radiation modeled from 1961 to 1990 performed at a limited number of sites, and solar radiation modeled from 1991 to 2010 at an expanded number of sites.

Sacramento Executive Airport was the closest weather station modeled from 1961 to 1990. Beale AFB was modeled for the second stage, from 1991 to 2010. Browns Valley was used to extend the dataset past 2010 as the closest weather station in the direct Project Vicinity with measured solar radiation data from 2010 to 2017. Table 4-2 shows cloud cover weather station data sources and periods of record. The developed dataset was used for all scenarios.

Table 4-2. Cloud cover weather stations.

Weather Station	Data Source	Used Period of Record
Sacramento Executive Airport	NREL[1]	10/1/74 to 12/31/90
Beale AFB	NREL[1]	1/1/91 to 12/31/10
Browns Valley	CIMIS[2]	1/1/11 to 10/1/17

[1] NREL - http://www.nrel.gov/rredc/
[2] CIMIS - www.cimis.water.ca.gov/

Temperature Model Dataset Development

The Beale AFB weather station was used as the primary weather station for all scenarios. For the Base Case scenario, missing Beale AFB air temperature, dew point, and wind speed were filled in using data from Sacramento Executive Airport weather station, statistically modified using linear regression techniques to represent Beale AFB meteorological conditions. The regression coefficients are listed in Table 4-3.

Table 4-3. Linear Regression Coefficients Used to Modify the Secondary Weather Station to Represent Data at the Primary Weather Station.

Primary Weather Station	Secondary Weather Station	Parameter	Coefficient A (Slope)	Coefficient B (Intercept)	R^2
Beale AFB	Sacramento Executive Airport	Wind	1.067	-0.461	0.371
		Air Temperature	1.025	0.496	0.937
		Dew Point	0.894	4.563	0.752

While air temperature and dew point linear regression variables were calculated using the typical linear regression methods, wind speed linear regression variables were calculated differently. Despite general trends observed between the two datasets (high wind speeds during storm events), there was enough hourly variability that the linear regression produced poor results. Instead, the linear coefficients were modified using the following equations, which are functions of mean-daily wind speed at a given time step (W_t), average of the data set mean-daily wind speeds (μ) and the standard deviation of the data set mean-daily wind speeds (σ):

$$W_{MODIFIED} = A\,W_t + B$$

$$A = \sigma_2 / \sigma_1$$

$$B = \mu_2 - \mu_1\,(\sigma_2 / \sigma_1)$$

Subscript 1 denotes the data being transformed (Sacramento Executive Airport). Subscript 2 denotes the data to which the modified wind speed data should statistically match (Beale AFB). The resulting modified Sacramento Executive Airport hourly wind data have the same mean wind speed and standard deviation as the Beale AFB wind data.

For the Base Case scenario, missing Beale AFB wind direction data were filled in directly from Sacramento Executive Airport weather station data. The remaining missing data were calculated using an averaged value for each hour of the day by month from Beale AFB data using the entire Base Case period of record.

For the Calibration and Validation scenarios, missing Beale AFB wind, temperature, and dew point data were estimated using interpolation for gaps up to 2 hours. Remaining missing Beale AFB wind, temperature, and dew point data were filled in directly from Verona CIMIS weather station data. All missing Beale AFB wind direction data were filled in directly from Verona CIMIS weather station data.

The resulting hourly datasets for air temperature, dew point temperature, wind speed, and wind direction were converted into metric units as required by CE-QUAL-W2. Cloud cover data did not require conversion.

5. Camp Far West Reservoir Water Temperature Model

This section describes the CFW Temp Model and presents results of calibration and validation temperature model scenarios.

Model Configuration

Model configuration included setting-up the model computational grid, initial conditions, boundary conditions, and hydrodynamic parameters for the hydrodynamic simulations. The following subsections describe the configuration and key components of the model.

Computational Grid Set up

The computational grid setup defines the process of representing the Camp Far West system in the finite difference scheme. Configuration information is provided in the main control file of the CE-QUAL-W2 model (w2_con.npt) while the computational grid is specified in the bathymetry file (bth_wb1.npt). The model requires the user to set up the bathymetry file for each branch defining the upstream and downstream segment. A bathymetry file was created, specifying the average segment width, depth, and orientation information along with bottom roughness and initial WSE for each segment. Grid geometry data development for the CFW Temp Model utilized existing Light Detection and Ranging (LIDAR) and survey data. LIDAR data were collected in 2008 by Wood Rogers for the Central Valley Floodplain Evaluation and Delineation Program (CVFED). Bathymetric survey data of the Camp Far West Reservoir were collected by GEI in 2008.

The CFW Temp Model was configured with a main branch (Bear River) and a side branch (Rock Creek). Geographic Information Systems (GIS) software was used to generate the centerline of each branch and longitudinal segments with lengths ranging from 324 m to 550 m. Each segment contains up to a maximum of eighty-three 0.61-m thick vertical layers. Model bathymetry was created up to an elevation of 96 m, 4.5 m above the current full pool elevation. Model generated volume- and surface-area-elevation curves compared well to the official curves of the reservoir developed by GEI (2009), confirming the accuracy of the model grid.

Table 5-1 provides a breakdown of branches in the CFW Temp Model. Note that each branch is bounded upstream and downstream by an inactive segment. Inactive segments divide each branch and do not have volume or surface area. The model segmentation and longitudinal profile are shown in Figure 5-1 and 5-2, respectively.

Table 5-1. CFW Temp Model grid branch summary.

Water Body	Branch Number	Branch Name	Segment Start	Segment End	Number of Active Segments	Upstream Active Segment	Downstream Active Segment
1	1	Bear River	1	20	18	2	19
	2	Rock Creek	21	30	8	22	29

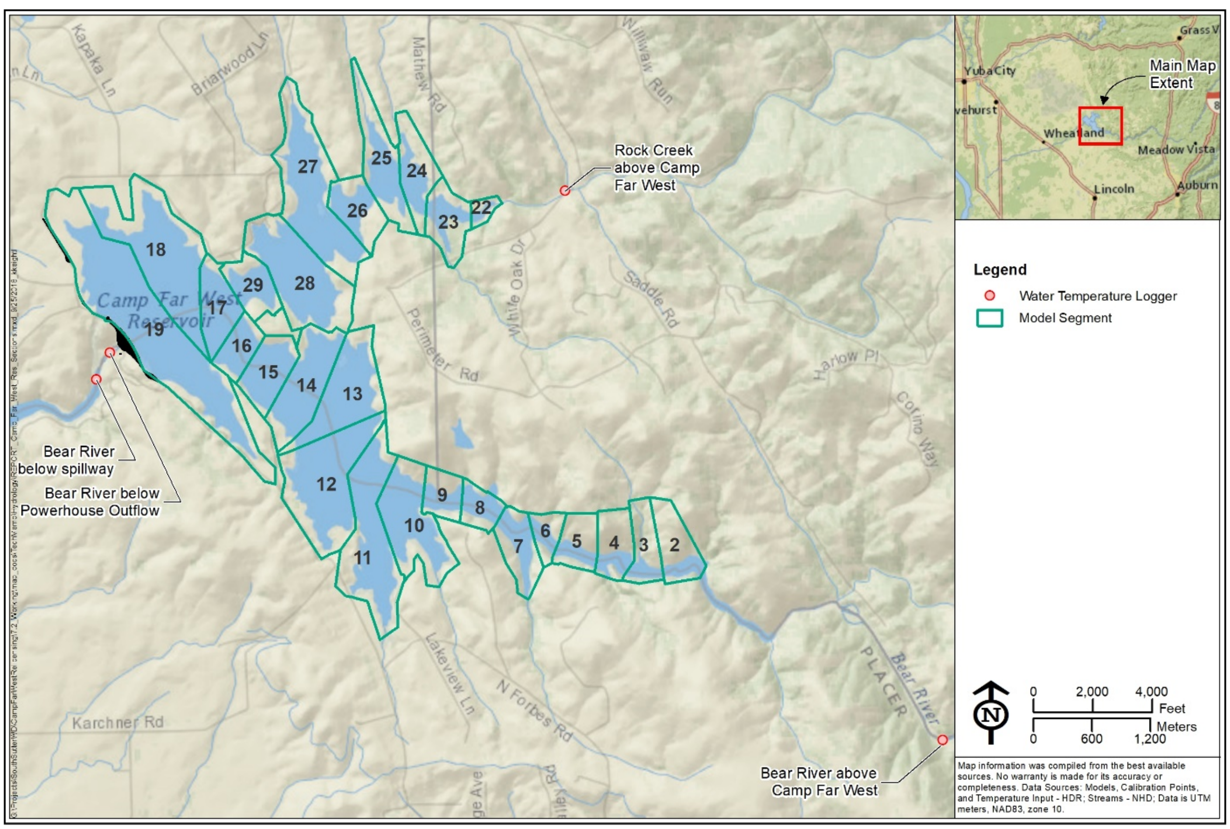

Figure 5-1. Plan view of the CFW Temp Model grid.

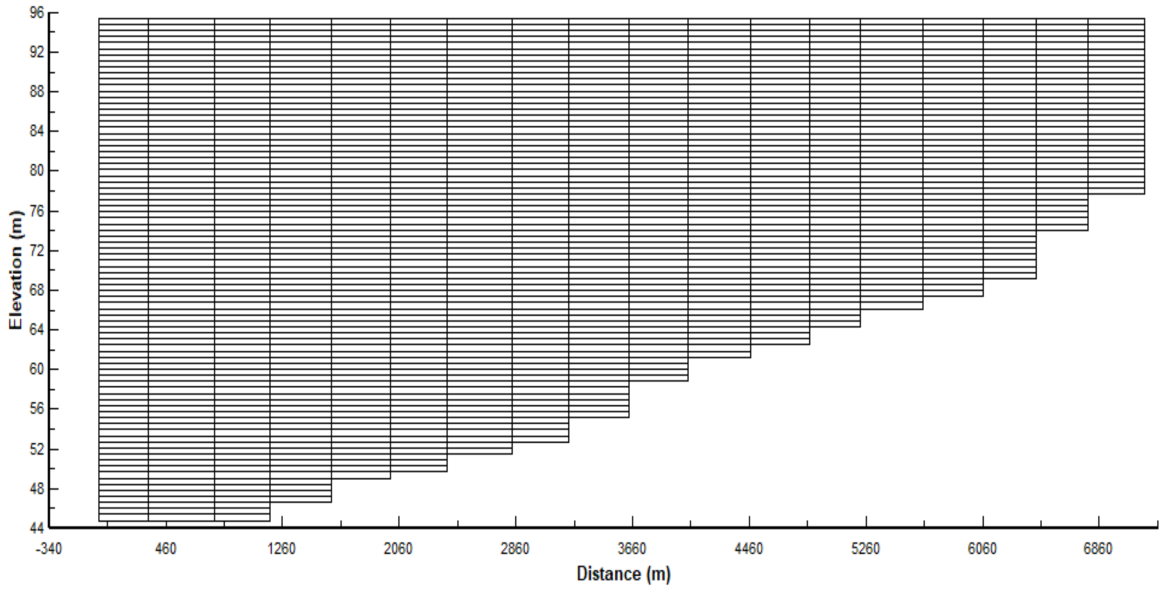

Figure 5-2. Longitudinal view of the CFW Temp Model grid for the Bear River branch, showing layer elevations.

Initial Conditions

The model was initialized with a flat free surface and a horizontally uniform water temperature profile, based on historical data, throughout Camp Far West Reservoir.

Boundary Conditions

Boundary conditions represent external contributions of water and heat sources to the water temperature model. Boundary condition inputs include inflows, inflow temperatures, outflows, and meteorological data.

The downstream boundary for the model was the Bear River below Camp Far West Dam (RM 18). The upstream boundaries for the model were on the Bear River above Camp Far West (RM 25.1) and Rock Creek above Camp Far West (Figure 5-1). Outlets from the dam include an overflow spillway at elevation 300 ft (91.4 m), a powerhouse intake at elevation 223.9 ft (68.2 m) and low-level outlet (LLO) at elevation 179 ft (54.6 m).

A time series of meteorological data including air temperature, dew point temperature, wind speed, wind direction, and cloud cover were input to the CFW Temp Model. A description of the meteorological dataset development is provided in Section 4.

For calibration and validation of the CFW Temp Model, historical Camp Far West Reservoir outflow data were used to define reservoir outlet flows, including the LLO, powerhouse intake, and spillway. See the boundary condition section for the NPDD Temp Model for additional information regarding Camp Far West Reservoir outflows. Reservoir inflows were back-calculated based on mass balance between reservoir outflows and change in reservoir storage. Calculated reservoir inflows represent the combined inflow from the Bear River and Rock Creek. Estimates of Rock Creek inflow were based on watershed area proration of synthetic Dry Creek inflows developed for the lower Bear River (see Appendix A). The difference in the calculated reservoir inflow and the synthetic Dry Creek inflow was used to represent Camp Far West Reservoir inflow from the Bear River. Inflows were averaged daily.

There were extended periods of negative Bear River inflows when evaporation exceeded reservoir inflow, which was not included in the mass balance calculation. NID is required to release 5 cfs below Lake Combie, upstream of Camp Far West Reservoir. Bear River inflow to Camp Far West was constrained to a minimum of 5 cfs, or the calculated inflow, whichever was greater. A distributed tributary file was included in the model with the remaining negative inflows to maintain water balance between reservoir inflows, outflows and storage. Figure 5-3 shows all three boundary condition inflow time series to the CFW Temp Model.

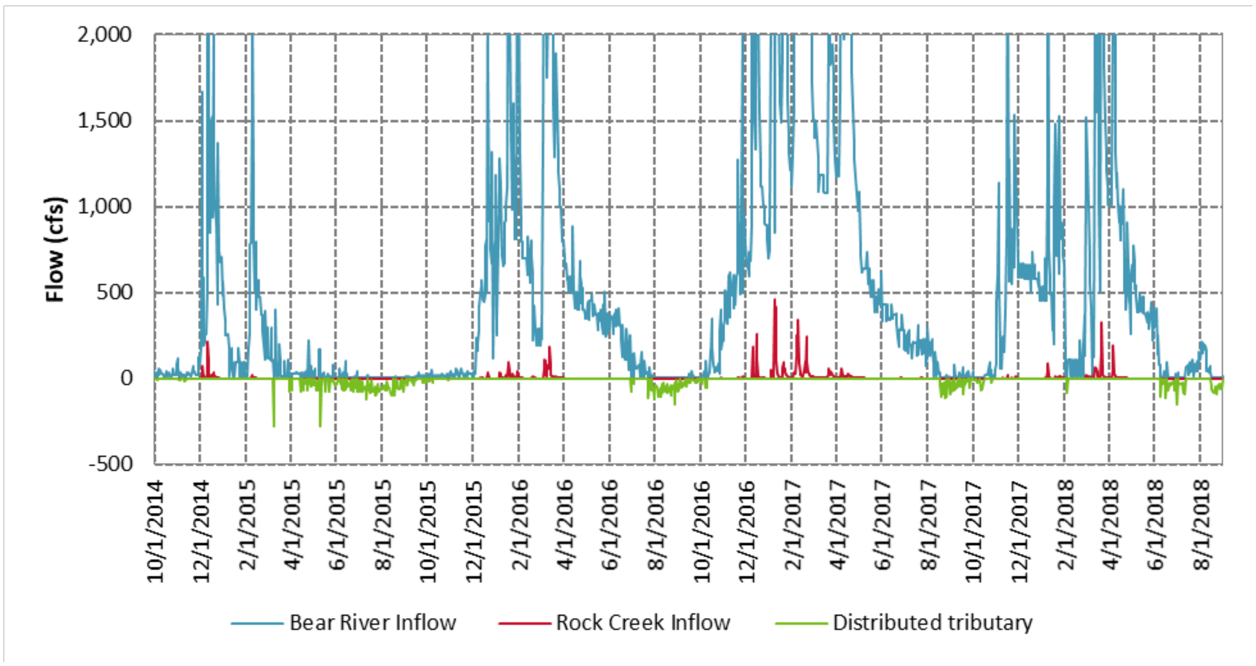

Figure 5-3. Calibration and Validation period inflows to the CFW Temp Model.

Calibration and Validation inflow temperatures for the Bear River and Rock Creek utilized hourly observed data. Figure 5-4 shows the boundary condition inflow water temperature time series for the CFW Temp Model.

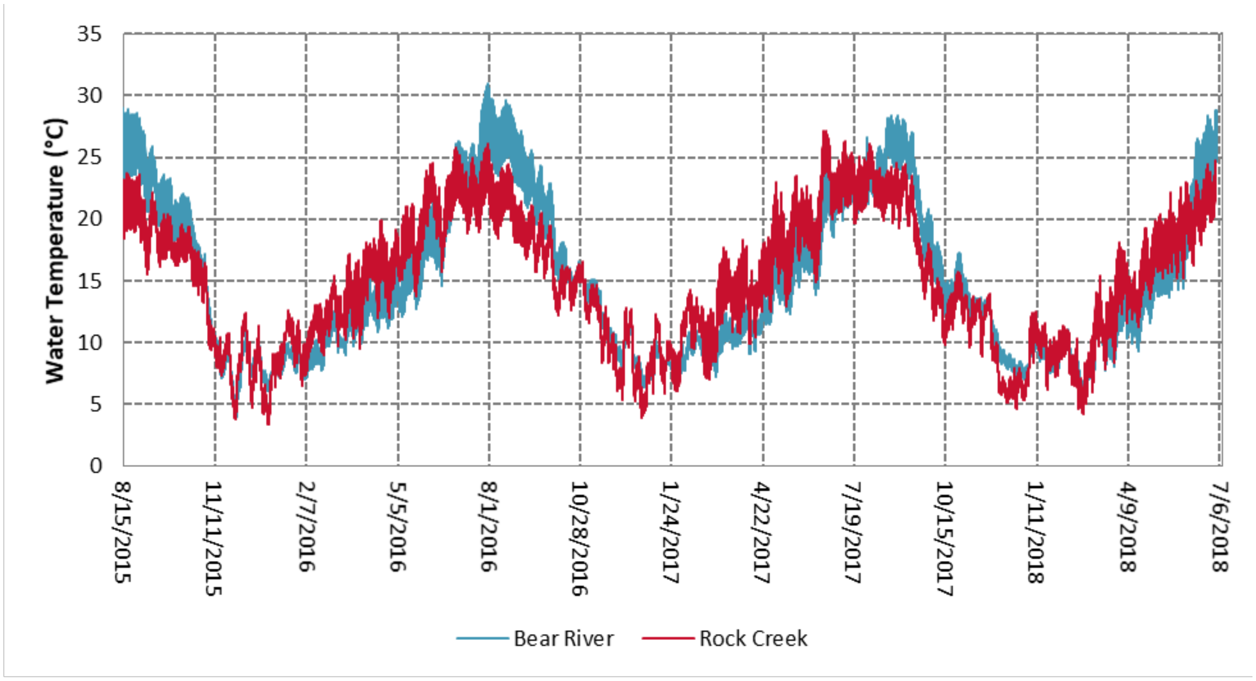

Figure 5-4. Calibration and Validation period inflow water temperatures to the CFW Temp Model.

Model Calibration

Model calibration involved an iterative process of adjusting major model parameters to achieve a reasonable match between the simulated and the observed data. Model calibration methods focused on model predictions of reservoir water levels, temperature profiles and powerhouse release temperatures. The model calibration period was from September 1, 2015 to October 31, 2017 based on available historical input information.

Water Surface Elevations

A comparison of WSE data provided by SSWD to model results is shown in Figure 5-5. WSEs were characterized by an increase during winter and spring, and a decrease throughout the summer.

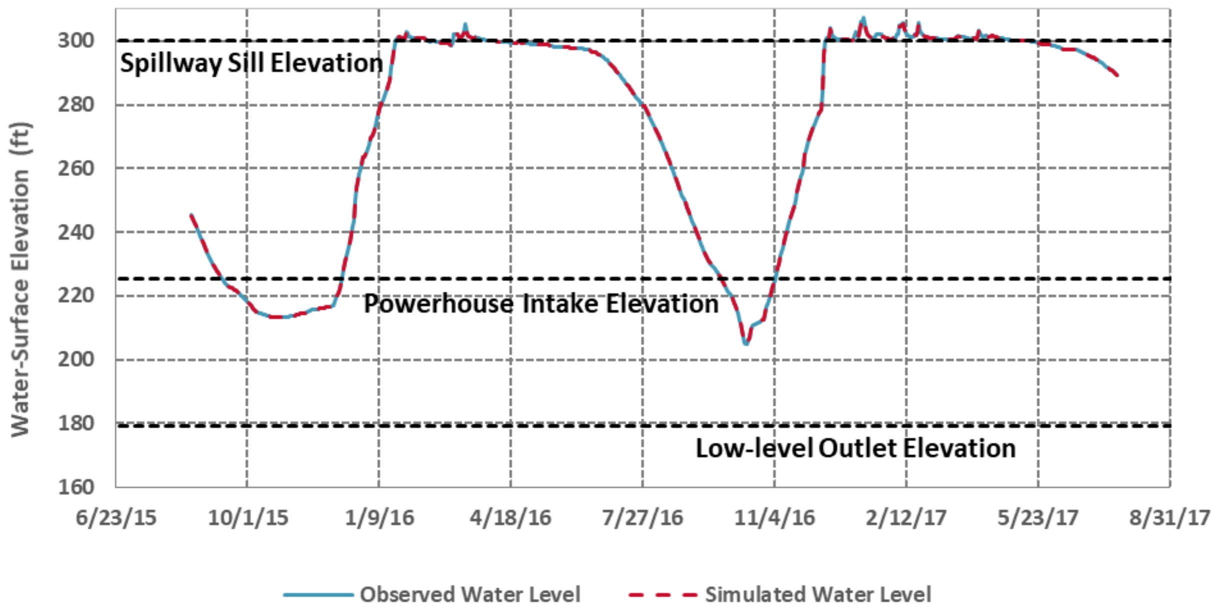

Figure 5-5. Comparison of Simulated and Historically-Measured Water Surface Elevations during CFW model calibration.

Water Temperature Profiles

The initial water temperature profile for the CFW Temp Model calibration scenario was based on the historically observed water temperature profile data collected on August 19, 2015 at Camp Far West Dam.

The calibration process involved matching of simulated reservoir temperature profiles to observed data to ensure that the model represented the mixing in the water column and reproduced the heat dynamics and thermal structure within the water column profile. Temperature data were available at three locations in the reservoir: at the dam, in the Bear River arm of the reservoir, and in the Rock Creek arm of the reservoir.

Model parameters affecting temperature calibration included surface wind sheltering coefficients, light extinction coefficients, and the accurate representation of reservoir outflows.

Wind is always a major factor governing hydrodynamic temperature simulation. In this Study, wind speed and direction were based on the meteorological data at Beale AFB, as described in Section 4. Wind sheltering coefficients (WSC) are able to scale the historically-measured wind speed values by model segment. Several sensitivity analyses were implemented to check the sensitivity of the simulated temperature profile to the WSC value, and it was found that the simulated vertical temperature profile was sensitive to the wind. The model was able to best capture the vertical mixing by setting the WSC to 0.8-in. upper segments (1-14) and to 1 in. lower segments (15-30) near the dam for the entire simulation period.

Solar radiation provides a significant heat source to the water column. The major parameter controlling the vertical distribution of light is the light extinction coefficient. A time varying light extinction coefficient was used for the entire simulation period. The light extinction coefficient values were based on Secchi disk depth data measured monthly from August 2016 to December 2017, and values ranged from 0.4 to 7.55 m^{-1}.

Figures 5-6 through 5-8 show comparisons of observed and simulated temperature profiles for various dates from 2015 through 2017 at various stations. The AME (Abs Err) for each station and date is overlaid on Figures. As shown, simulated temperatures are in good agreement with observed temperatures for all dates at all stations, resulting in an average AME of 0.55.

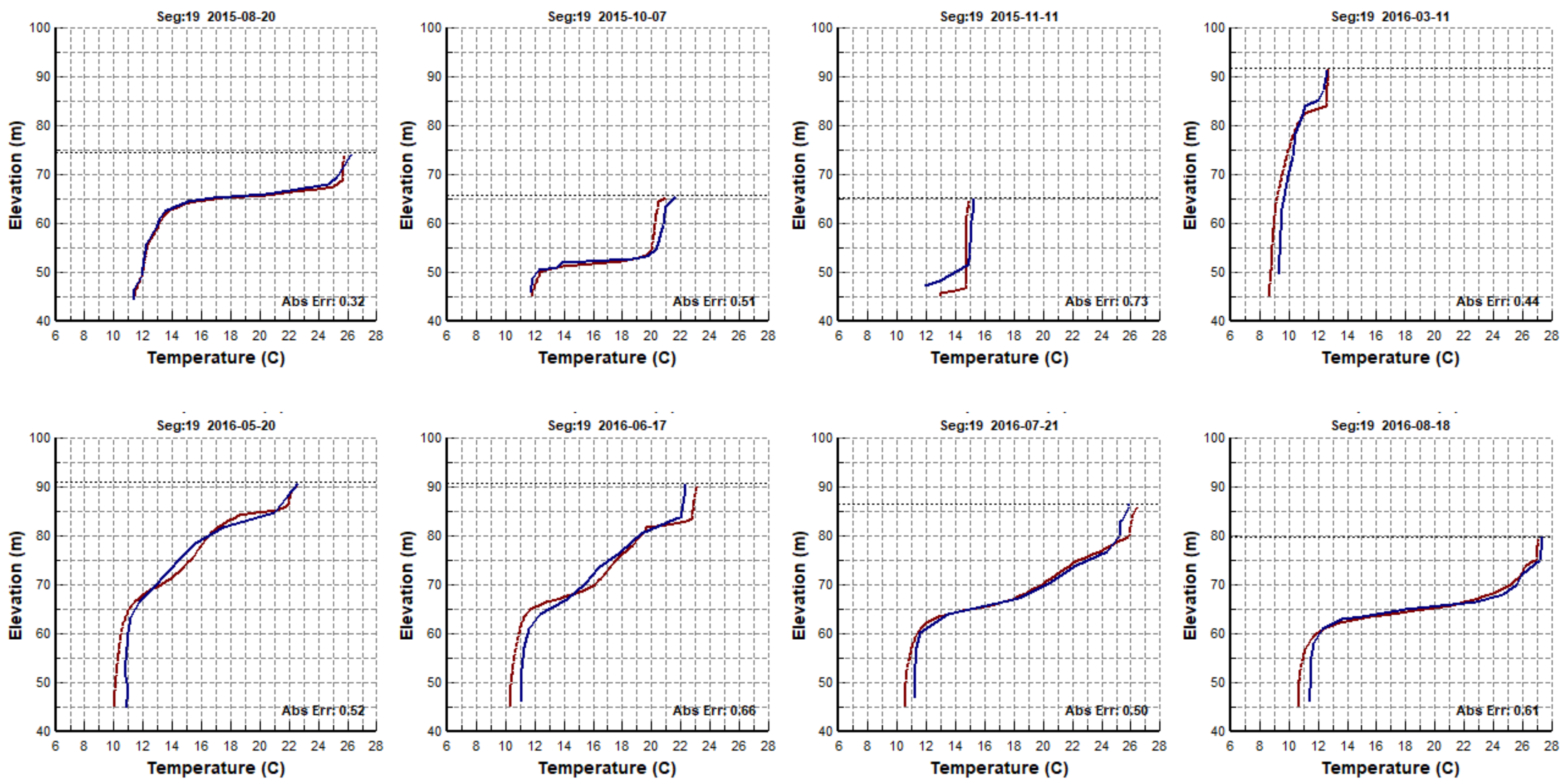

Figure 5-6. Simulated (red line) vs. Measured (blue line) temperature profiles at Camp Far West Dam (segment 19) during CFW model calibration.

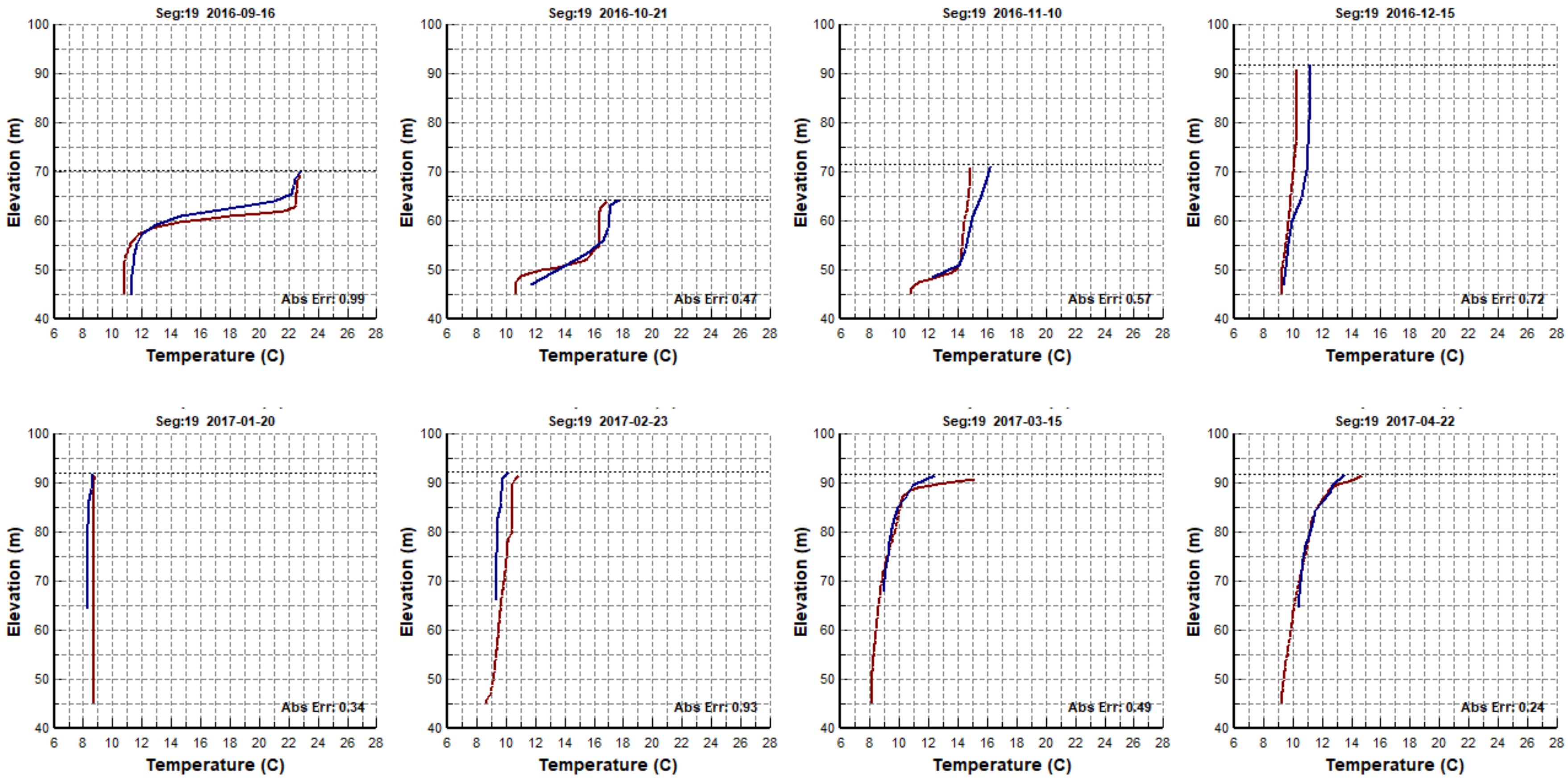

Figure 5-7. Simulated (red line) vs. measured (blue line) temperature profiles at Camp Far West Dam (segment 19) during CFW temp model calibration.

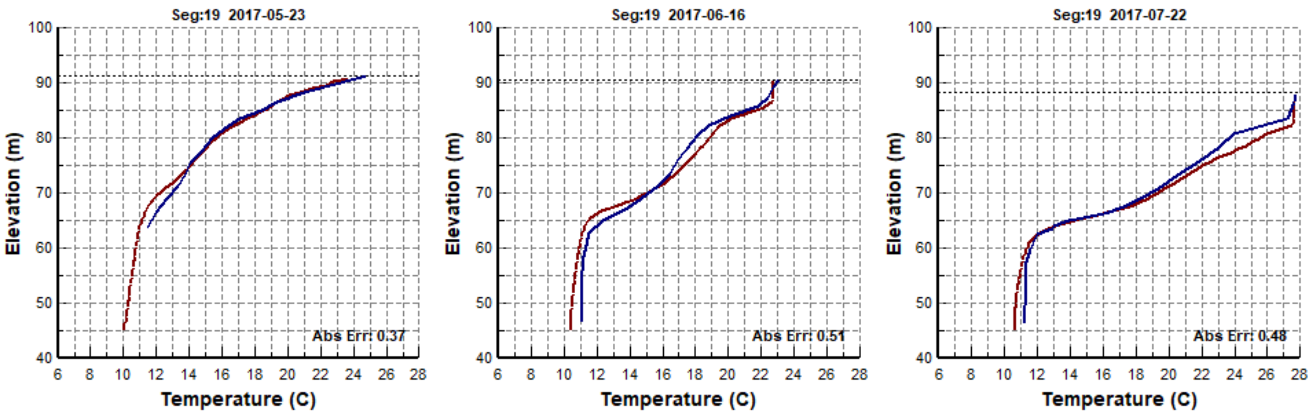

Figure 5-8. Simulated (red line) vs. measured (blue line) temperature profiles at Camp Far West Dam (segment 19) during CFW temp model calibration.

Powerhouse Release Temperatures

Historically-measured water temperatures in Bear River below the Camp Far West Powerhouse were compared with the simulated withdrawal temperatures (Figure 5-9) every 3-hours. As shown, the model successfully predicts the observed temperatures. Larger differences between the simulated and measured temperatures were seen only during peak outflows when the reservoir was spilling in 2016. The resulting ME and AME for the calibration period of record and July through October periods are shown in Table 5-2. The months of July through October were the primary focus of calibration.

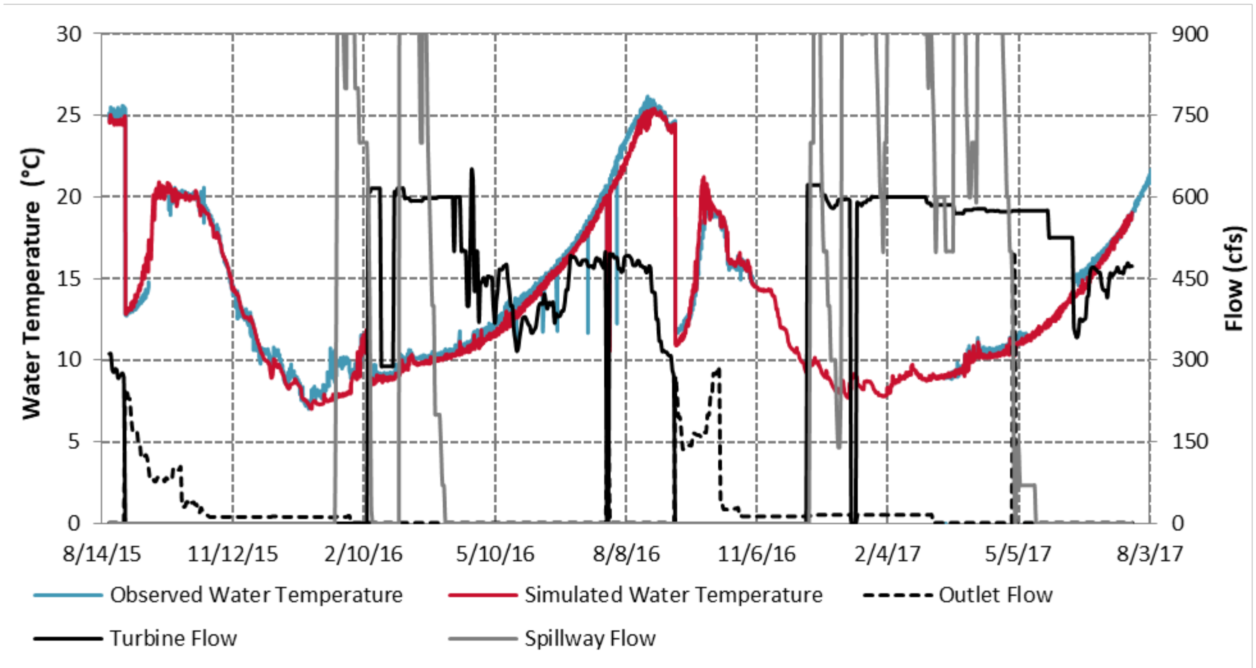

Figure 5-9. Comparison of simulated and measured Temperatures below the Powerhouse Overlaid with Camp Far West Reservoir outflows for the calibration Scenario.

Table 5-2. Calibration summary of ME and AME for the Bear River below Camp Far West Powerhouse.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.28	0.57	-0.13	0.37

Model Validation

Model validation was used to verify that the parameters developed during calibration perform as expected for a secondary period of record. The validation period for the CFW Temp Model was from January 19, 2017 to July 2, 2018, based on available historical information.

Water-Surface Elevations

WSE data provided by SSWD were compared with model results and are shown in Figure 5-10.

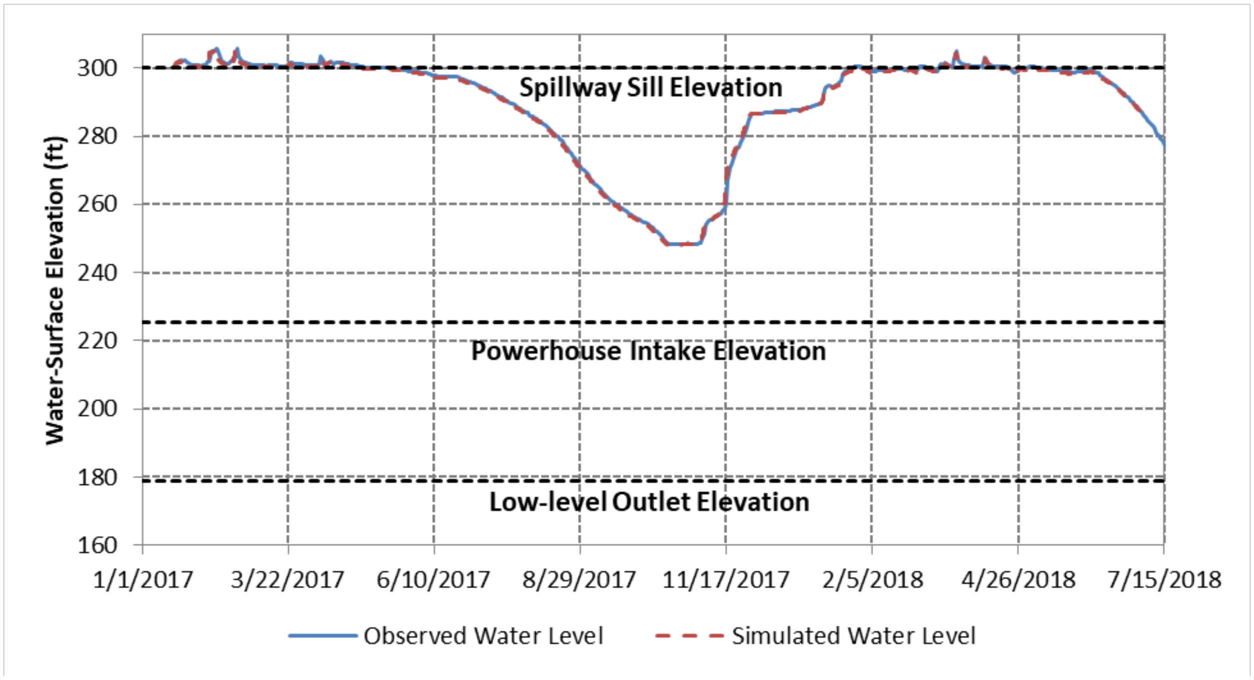

Figure 5-10. Comparison of Simulated and Historically-Measured Water Surface Elevations during CFW model calibration.

Water Temperature Profiles

The initial water temperature profile for the CFW Temp Model validation scenario was based on the historically observed profile data collected on January 19, 2017 at Camp Far West Dam.

Figures 5-11 through 5-12 show comparisons of observed and simulated temperature profiles for various dates in 2017 and January 2018 near Camp Far West Reservoir dam. Water temperature profile data collection was discontinued after January 2018. The AME (Abs Err) for each station and date is overlaid on the figures. As shown, simulated temperatures are in good agreement with observed for all dates at all stations, resulting an average AME of 0.49.

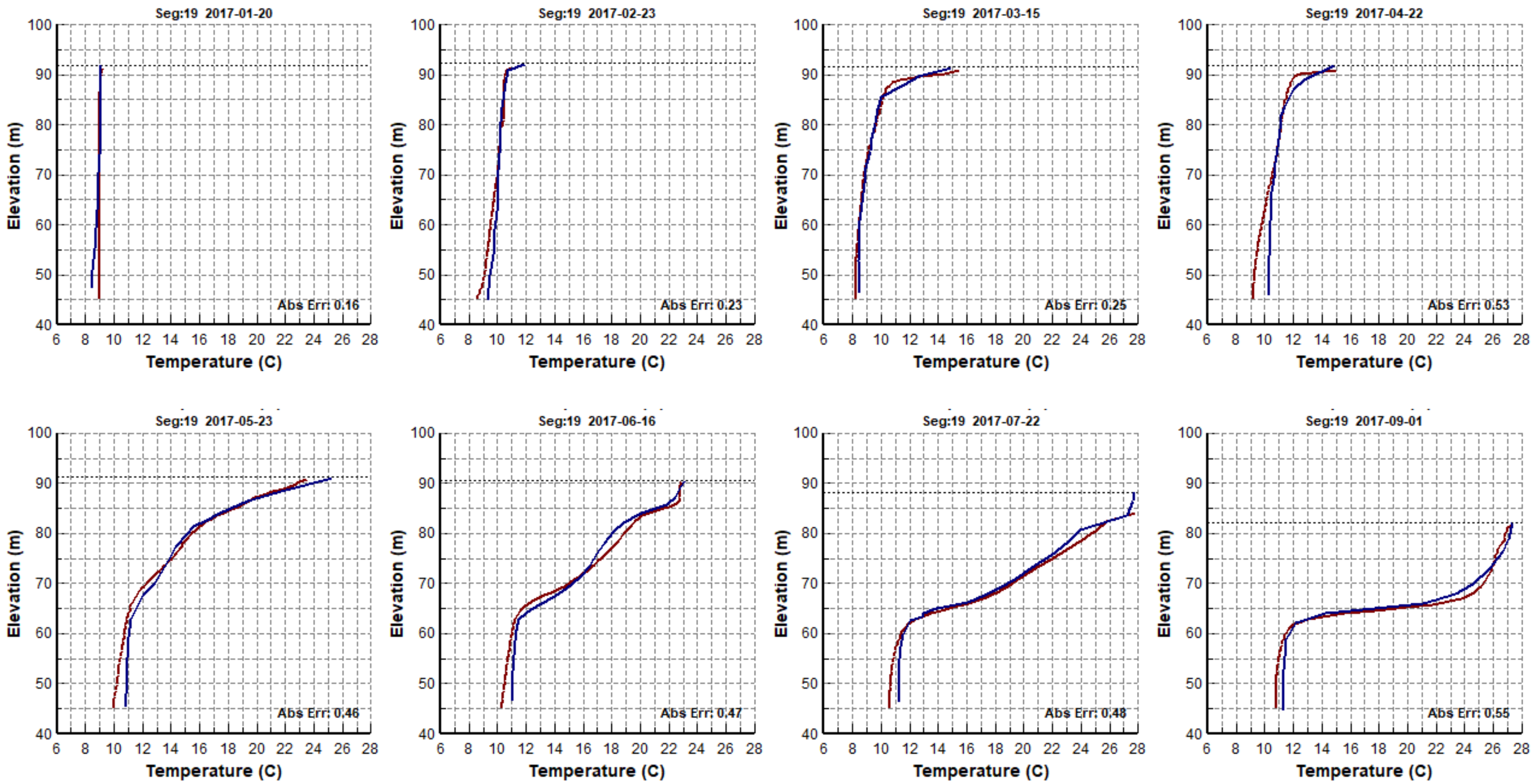

Figure 5-11. Simulated (red line) vs. Measured (blue line) temperature profiles at Camp Far West Dam (segment 19) during CFW temp model validation.

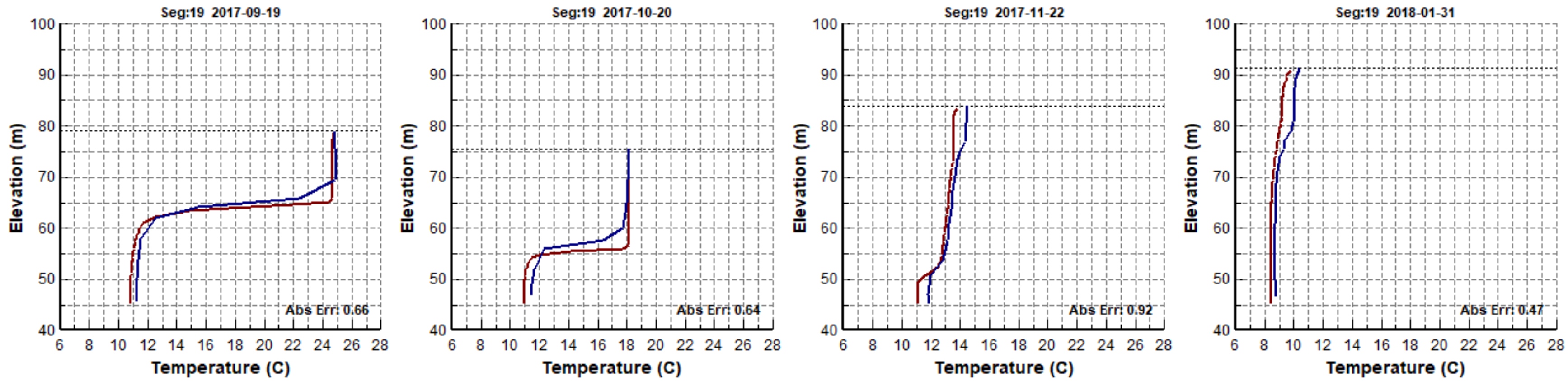

Figure 5-12. Simulated (red line) vs. Measured (blue line) temperature profiles at Camp Far West Dam (segment 19) during CFW temp model validation.

Powerhouse Release Temperatures

Historically-measured water temperatures in Bear River below the Camp Far West Powerhouse were compared with the simulated withdrawal temperatures (Figure 5-13) every 3-hours. The resulting ME and AME for the full Water Year, July through October periods of 2017 and 2018 are shown in Table 5-3.

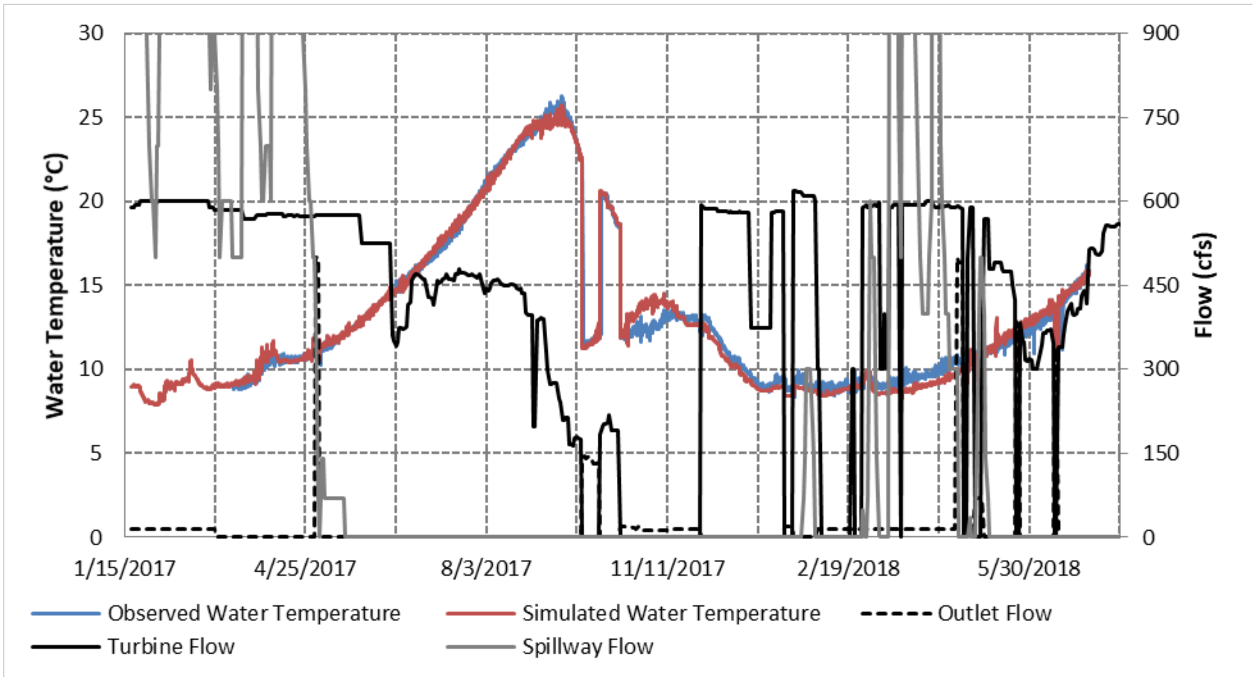

Figure 5-13. Comparison of simulated and measured Temperatures below the Powerhouse Overlaid with Camp Far West Reservoir outflows.

Table 5-3. Validation summary of ME and AME for Bear River below the Camp Far West Powerhouse.

Model Scenario	Water Year (Oct-Sep)		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Validation	-0.08	0.41	0.08	0.43

6. Non-Project Diversion Dam Water Temperature Model

This section describes the NPDD Temp Model and presents results of the calibration and validation temperature model scenarios.

Model Configuration

Model configuration included setting up the model computational grid, initial conditions, boundary conditions, and hydrodynamic parameters for the hydrodynamic simulations. The following subsections describe the configuration and key components of the model.

Computational Grid Set up

Similar to the CFW Temp Model, a bathymetry file was created that specified the average segment width, depth and orientation. Grid geometry data development for the NPDD model utilized existing LIDAR and survey data. LIDAR data were collected in 2008 by Wood Rogers for CVFED. Bathymetric survey data were collected by HDR in October 2017.

The NPDD was configured as a single branch made up of seven active segments. Note that each branch is bounded upstream and downstream by an inactive segment. Inactive segments divide each branch and do not have volume or surface area. Longitudinal segment lengths ranged from 156 m to 379 m. Each segment contains up to a maximum of forty-three 0.30-m thick vertical layers. No storage-capacity curves exist for the diversion dam for comparison to NPDD Temp Model generated curves.

Table 6-1 provides a breakdown of branches in the NPDD Temp Model. Model segmentation and the longitudinal profile are shown in Figures 6-1 and 6-2, respectively.

Table 6-1. NPDD Temp Model grid branch summary.

Water Body	Branch Number	Branch Name	Segment Start	Segment End	Number of Active Segments	Upstream Active Segment	Downstream Active Segment
2	1	Bear River	31	39	7	32	38

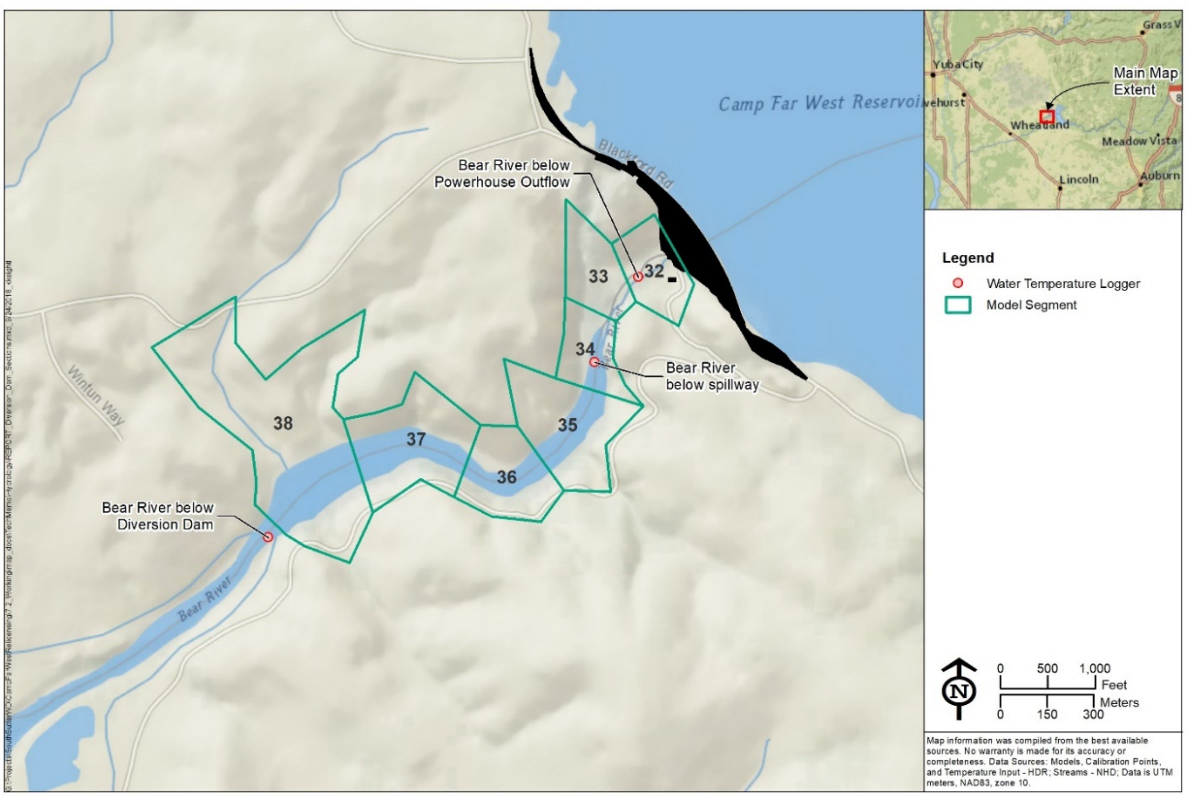

Figure 6-1. Plan view of the NPDD Temp Model grid.

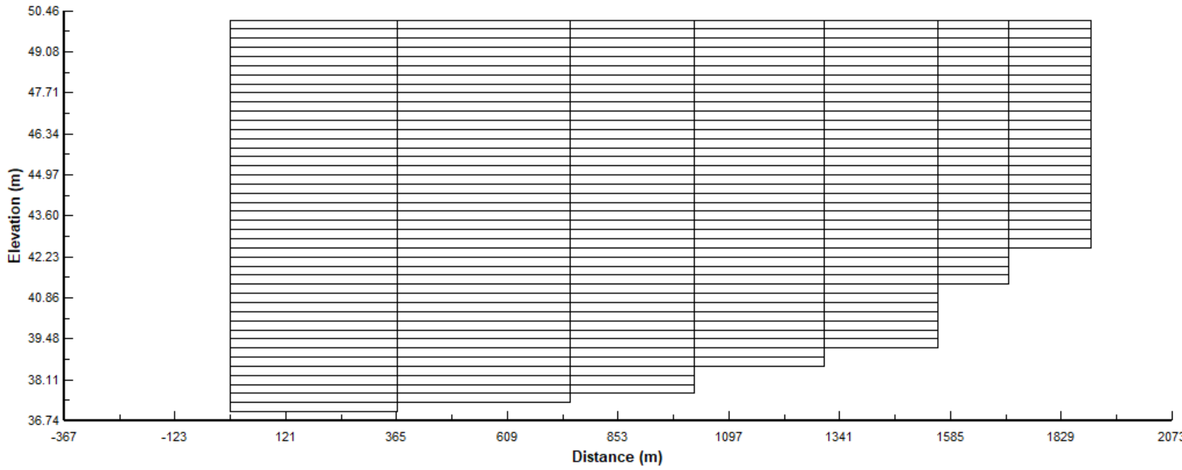

Figure 6-2. Longitudinal view of the NPDD Temp Model grid, showing layer elevations.

Initial Conditions

The model was initialized with a flat free surface at an elevation of 137.8 ft (42 m) and a uniform water temperature was applied throughout the NPDD water body.

Boundary Conditions

Boundary condition inputs include inflows and inflow temperatures, outflows, and meteorological data. The upstream boundary of the model was Camp Far West Dam at RM 18. Downstream boundaries were outflows from the non-Project diversion dam, including an overflow spillway at an elevation of 130.5 ft (39.8 m), a diversion outlet to the SSWD Conveyance Canal at an elevation of 127.9 ft (39.0 m), and a diversion outlet to the Camp Far West Irrigation District North Canal at an elevation of 129.1 ft (39.3 m). Inflow and outflow data were obtained from SSWD.

Time series of meteorological input data including air temperature, dew point temperature, wind speed, wind direction, and cloud cover were developed for the NPDD Temp Model. A description of the meteorological dataset development is provided in Section 4.

Initial runs of the NPDD Temp Model using historical flow data failed because water levels in the NPDD Temp Model were going so low that it wasn't able to make releases properly. Daily mass balance calculations of historical inflows and outflows indicated a number of days where there was an imbalance between inflows and outflows as shown in Figure 6-3. Diversion dam inflows (Camp Far West Reservoir outflows) and outflows were modified as needed to constrain inflow to equal outflow. Non-Project diversion dam spill flow was modified first, if the diversion dam was spilling. Secondly, Camp Far West Powerhouse flow (Figure 6-4) and Camp Far West outlet flow (Figure 6-5) were modified to balance inflow and outflow. These outflows were used to simulate releases and back-calculate reservoir inflow for the CFW Temp Model for the calibration and validation scenarios.

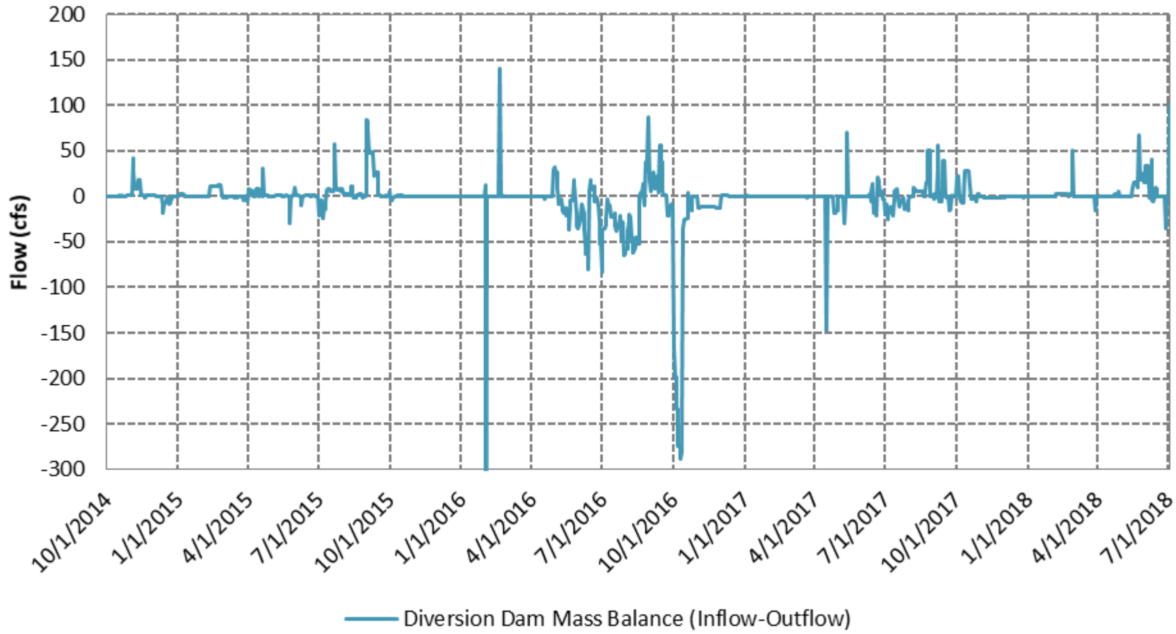

Figure 6-3. Mass balance between observed inflows and outflows to the non-Project diversion dam.

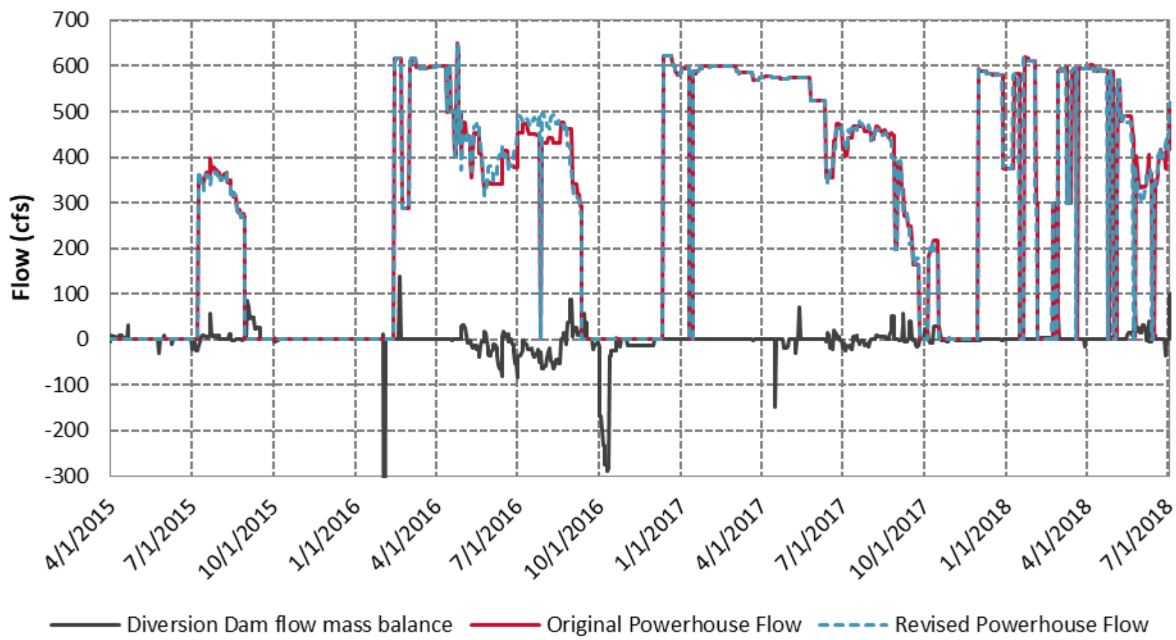

Figure 6-4. Calibration and validation period powerhouse releases before and after the mass balance adjustment to non-Project diversion dam inflows and outflows.

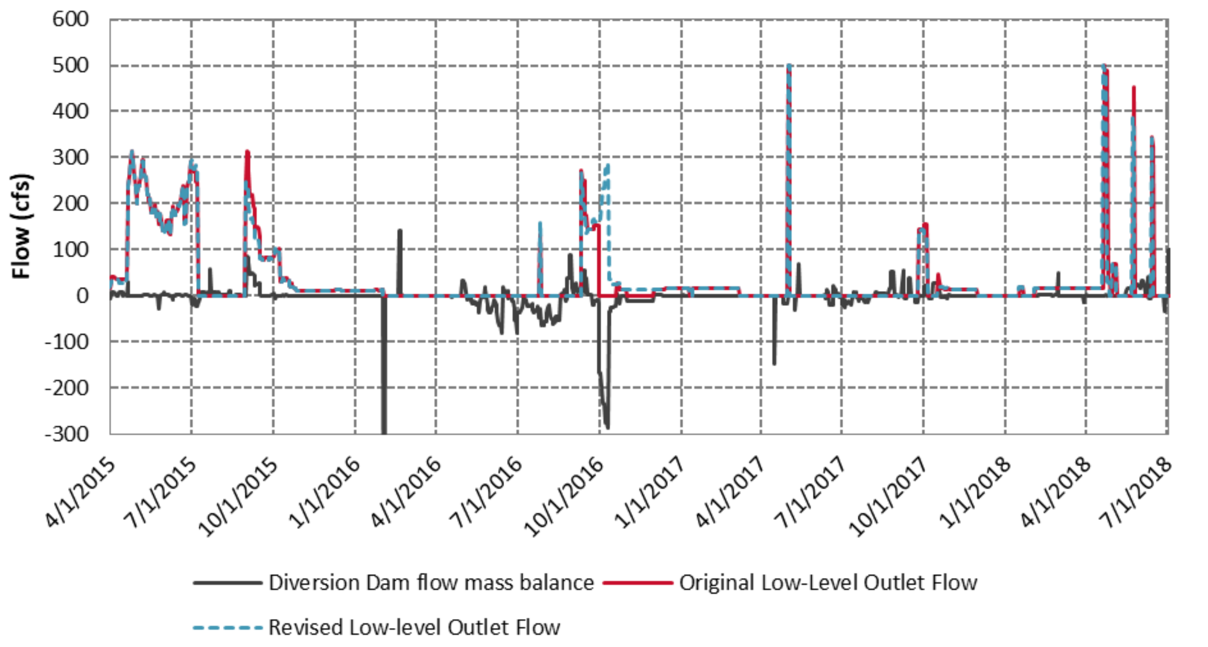

Figure 6-5. Calibration and validation period Camp Far West outlet releases before and after the mass balance adjustment to non-Project diversion dam inflows and outflows.

Revised Camp Far West Reservoir outflows were used to back-calculate reservoir inflow, as described in Section 5. A comparison of Camp Far West Reservoir inflows before (original) and after (revised) the mass balance adjustment to the non-Project diversion dam inflows and outflows is shown in Figure 6-6. Camp Far West Reservoir calibration results improved using revised reservoir inflows and outflows.

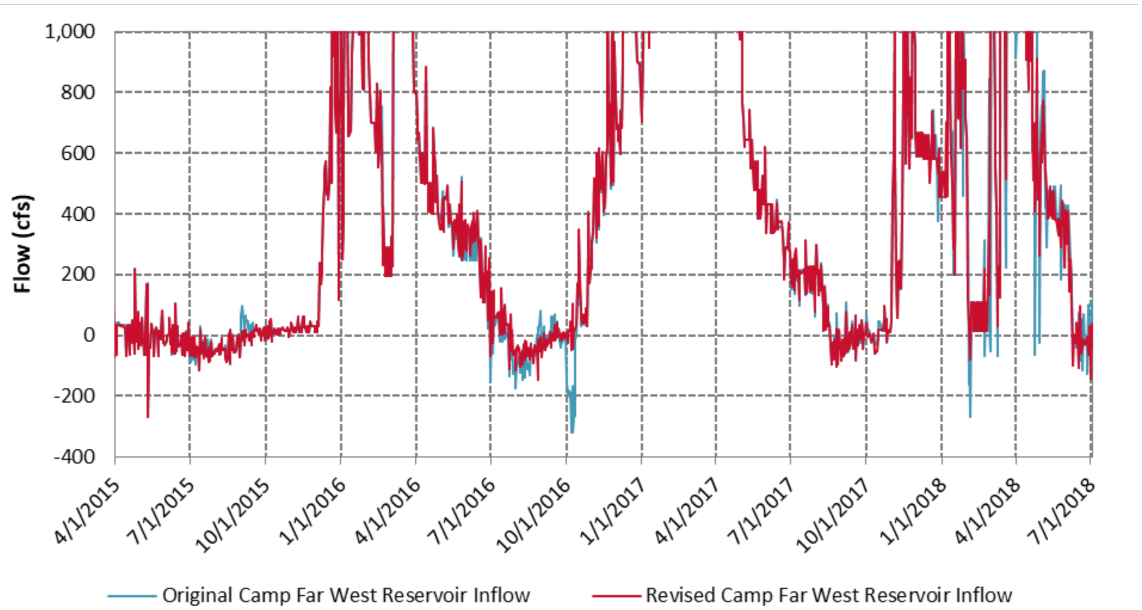

Figure 6-6. Calibration and validation period Camp Far West Reservoir inflows before and after the mass balance adjustment to non-Project diversion dam inflows and outflows.

Calibration inflow temperatures to the NPDD Temp model used hourly observed data from the Bear River below the powerhouse outflow gage. This gage captured release temperatures from both the powerhouse and the LLO, and to a minor extent, experienced backwater temperature effects when Camp Far West Reservoir was spilling. Figure 6-7 shows the boundary condition inflow time series for the CFW Temp Model. Validation inflow temperatures used outflows temperatures from the CFW Temp Model validation scenario.

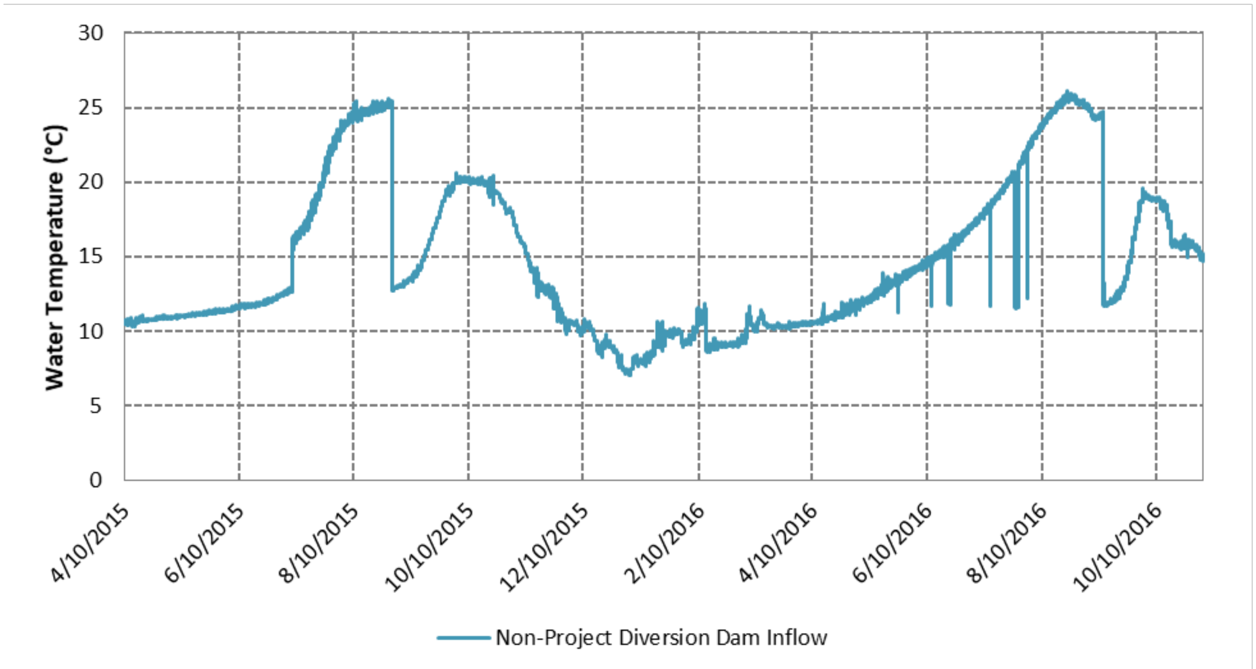

Figure 6-7. Calibration period non-Project diversion dam inflow water temperature.

Model Calibration

Model calibration involved an iterative process of adjusting major model parameters to achieve a reasonable match between the simulated and observed data. The model calibration effort focused on model predictions of water temperature in the Bear River below the non-Project diversion dam. Water temperature profile data were not available. The model calibration period was from April 11, 2015 to November 2, 2016, based on available historical input information.

Historical water-level data were not available for the diversion dam impoundment for the calibration period. A constant WSE of 42 m (137.8 ft) was maintained throughout the calibration scenario.

The wind sheltering coefficient was the primary variable used to calibrate the NPDD Temp Model. A constant value of 0.5 was used for each segment.

Bear River Release Temperatures

Historically-measured water temperatures in the Bear River below the non-Project diversion dam were compared with the simulated withdrawal temperatures on an hourly basis, as shown in Figure 6-8. Post processing of model output was necessary to calculate a flow weighted average of fish flow releases out of SSWD's Conveyance Canal to the Bear River and diversion dam spill releases to the Bear River. Simulated temperatures compared very well to observed temperatures in the Bear River below the diversion dam. The resulting ME and AME for the calibration period of record and July through October periods are shown in Table 6-2.

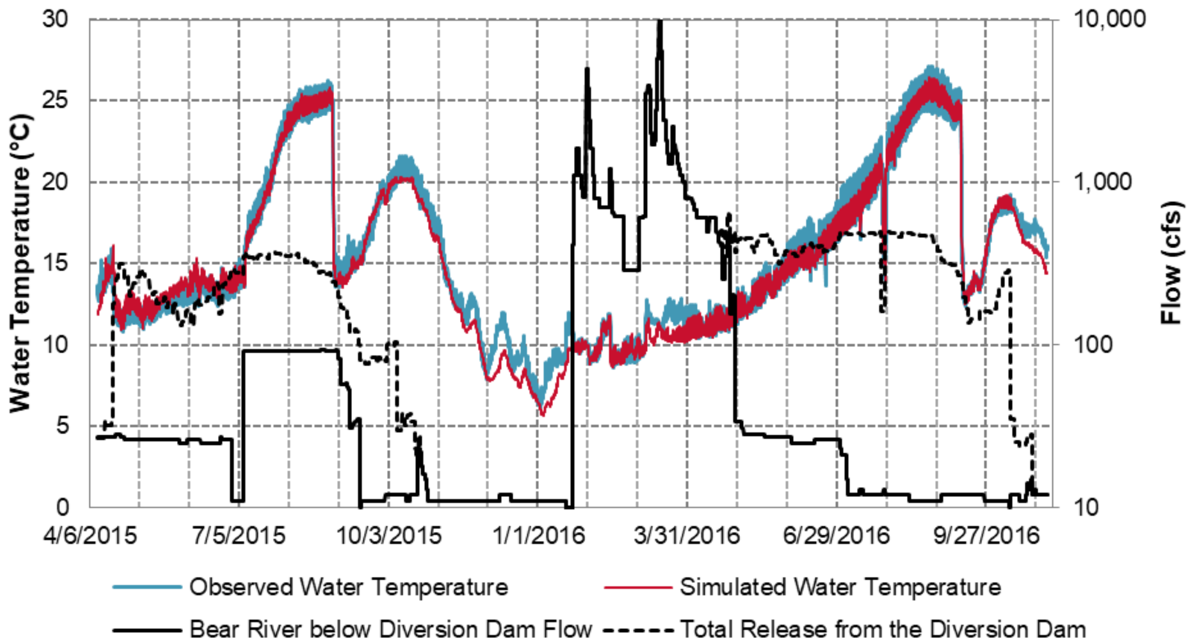

Figure 6-8. Comparison of simulated and measured Temperatures below the Powerhouse Overlaid with Camp Far West Reservoir outflows for the calibration scenario.

Table 6-2. Calibration summary of ME and AME for the Bear River below the non-Project Diversion Dam.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.24	0.53	-0.19	0.46

Model Validation

Model validation was used to verify that the parameters developed during the calibration perform as expected for a secondary period of record. The validation period for the NPDD Temp Model was from January 19, 2017 to July 2, 2018. Inflow and inflow water temperature boundary condition data were provided by the CFW Temp Model validation scenario.

Historical water-level data were not available for the diversion dam impoundment for the validation period. A constant WSE of 42 m was maintained throughout the calibration scenario.

Bear River Release Temperatures

Historically-measured water temperatures in Bear River below the non-Project diversion dam were compared with the simulated withdrawal temperatures on an hourly basis, as shown in Figure 6-9. The resulting ME and AME for the full Water Year and July through October periods of 2017 and 2018 are shown in Table 6-3. ME and AME statistics for the validation scenario were similar to the calibration scenario.

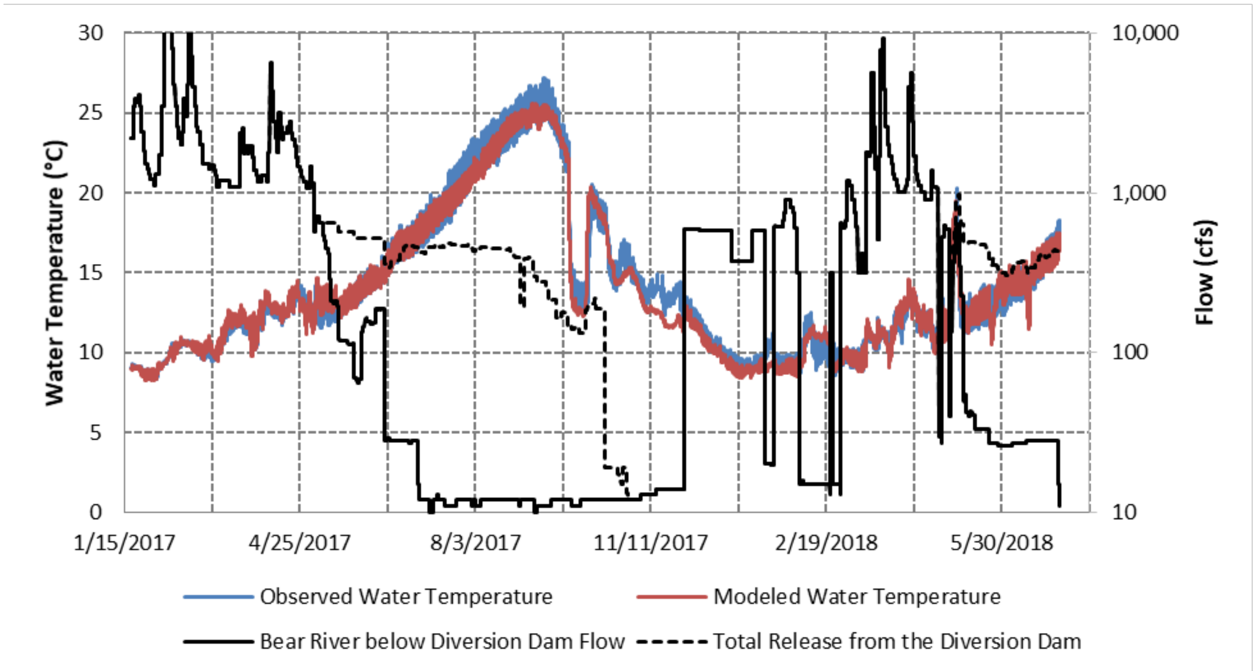

Figure 6-9. Comparison of simulated and measured temperatures below the powerhouse overlaid with Camp Far West Reservoir outflows for the calibration scenario.

Table 6-3. Validation summary of ME and AME for the Bear River below the non-Project Diversion Dam.

Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Validation	-0.08	0.48	-0.12	0.56

7. Lower Bear River Water Temperature Model

This section describes the LBR Temp Model and presents results of the calibration and validation temperature model scenarios. The domain of the LBR Temp Model is from the non-Project diversion dam to the confluence with the Feather River.

Model Configuration

Model configuration included setting up the model computational grid, initial conditions, boundary conditions, and hydrodynamic parameters for the hydrodynamic simulations. The following subsections describe the configuration and key components of the model.

Computational Grid Set up

The computational grid setup defines the process of representing the Bear River in the finite difference scheme. Configuration information is provided in the main control file of the CE-QUAL-W2 model while the computational grid is specified in the bathymetry file. A bathymetry file was created, specifying the average segment width, depth, and orientation information, along with bottom roughness and initial WSE for each segment. Table 7-1 provides a breakdown of segments in the LBR Temp Model. Note that each branch is bounded upstream and downstream by an inactive segment. Inactive segments divide each branch and do not have volume or surface area. Figure 7-1 shows a plan view of the model grid. Grid geometry data development for the LBR Temp Model utilized existing LIDAR data and survey data. LIDAR data were collected in 2008 by Wood Rogers for CVFED. Stream channel survey data were collected by HDR in 2018 as part of SSWD's relicensing Instream Flow Study of the lower Bear River (Study 3.3). LIDAR data provide channel geometry information in the portion of the channel that was out of water at the time of the survey. Survey data were used to define segment geometry below water.

Table 7-1. NPDD Temp Model grid branch summary.

Water Body	Branch Number	Branch Name	Segment Start	Segment End	Number of Active Segments	Upstream Active Segment	Downstream Active Segment
3	1	lower Bear River	1	36	34	2	35

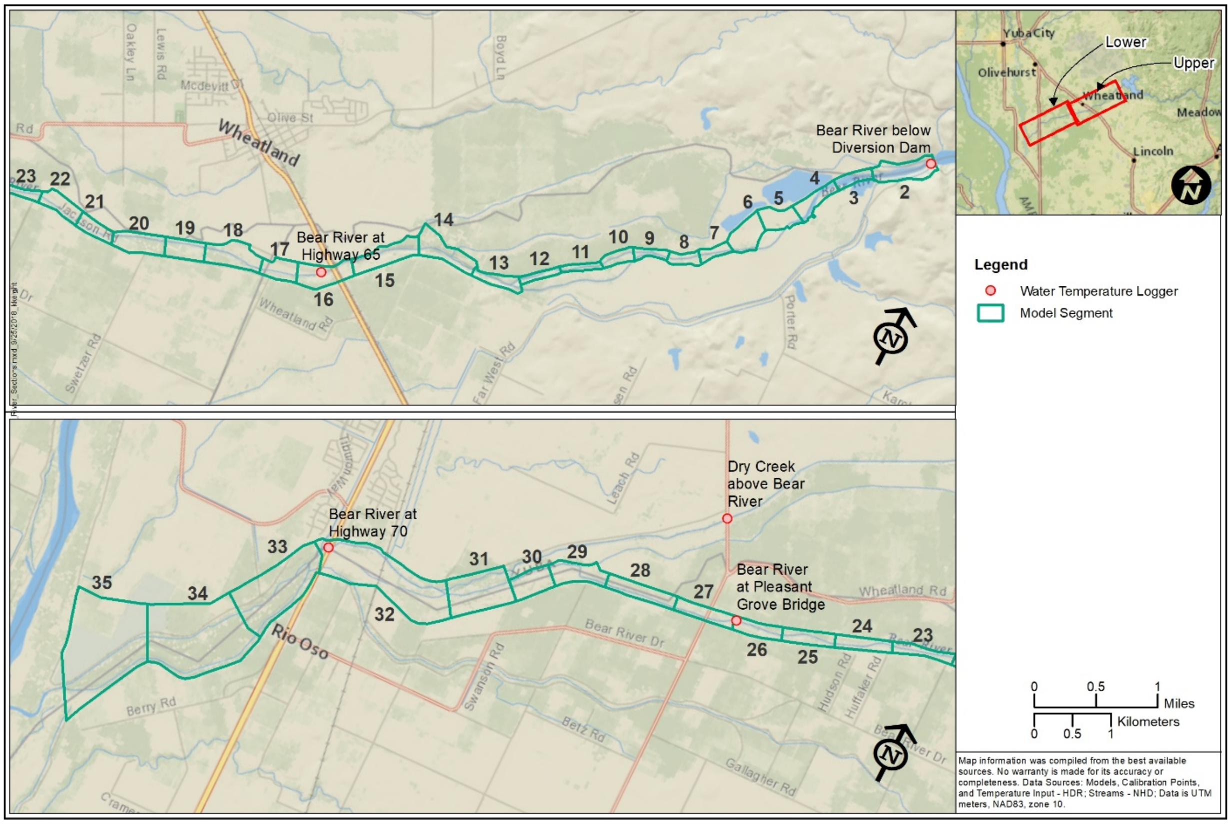

Figure 7-1. Plan view of the LBR model grid.

Bear River transect and habitat data from the SSWD's relicensing Instream Flow Study were utilized for LBR Temp Model channel characterization in the CE-QUAL-W2 model. The lower Bear River was surveyed to identify different habitat types such as glide, lateral scour pool, low-gradient riffle, mid-channel pool, and run. The habitat survey provided an estimate as to the prevalence or frequency of each habitat type by model segment. Transect data were collected as part of the Instream Flow Study along two river reaches, each approximately 1 mi long, for various habitat types. Using GIS, LIDAR transects were exported at the same location as the surveyed transects, like the example shown in Figure 7-12. Survey transect data below the LIDAR water level were used to estimate channel bathymetry in the wetted area of the channel.

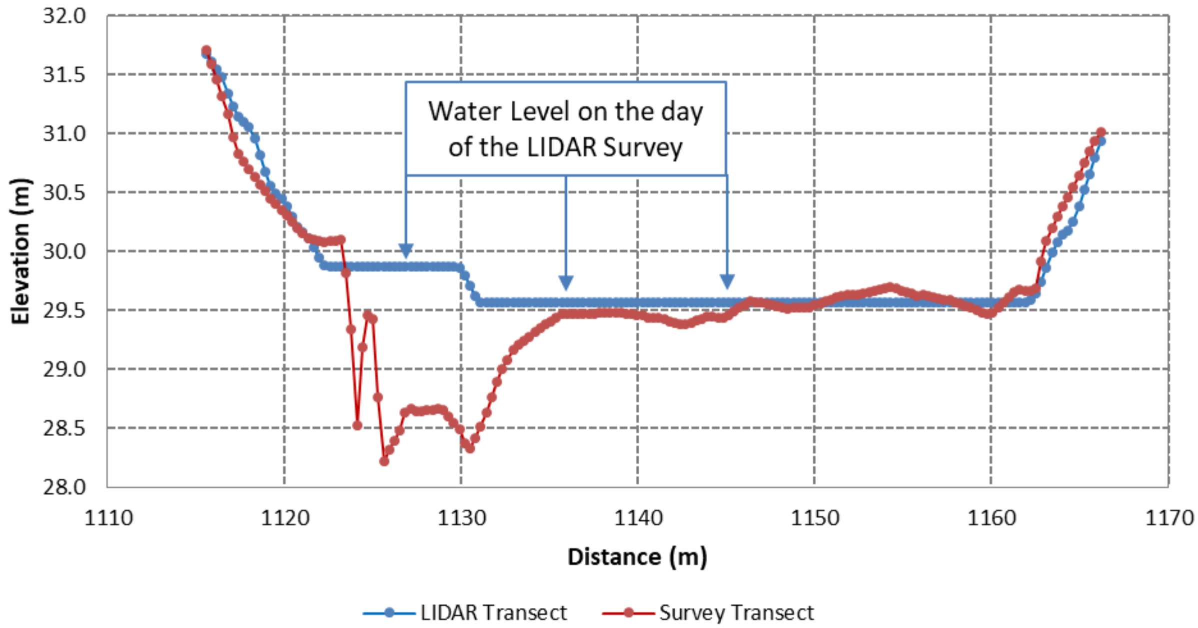

Figure 7-2. Example of LIDAR and survey transect data for a lateral scour pool (LAP) habitat type.

In order to establish a representative cross section for each habitat type below the water surface, an average was taken of all the below water level transect data for each habitat type. A total of 45 transects were used to develop low-flow channel bathymetry. The representative transects were converted into the CE-QUAL-W2 bathymetric input format, specifically, average width by elevation (depth below the LIDAR water level).

The percentage of each habitat type within each model segment was calculated using GIS. A percentage weighted average width below the LIDAR water surface was calculated for each model segment, representing the low-flow channel. Again using GIS, LIDAR data were used to develop average channel widths by elevation for each LBR model transect, representing the high-flow channel. High-flow and low-flow segment bathymetry were combined to represent the bathymetry for each model segment.

An average channel slope of 0.011-ft/ft was calculated for the lower Bear River. The resulting longitudinal channel profile is shown in Figure 7-3.

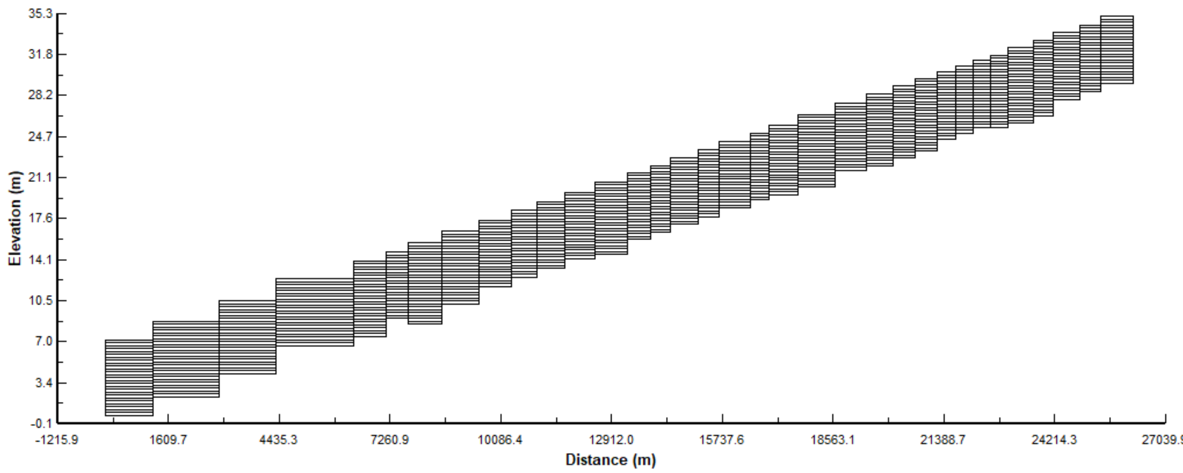

Figure 7-3. Longitudinal view of the LBR model grid, showing layer elevations.

Initial Conditions

The initial WSE was based on the normal depth of the river as computed by CE-QUAL-W2. This allows the model to run more smoothly from the start and eliminates trying to estimate an initial WSE for each segment. A uniform water temperature was applied throughout the lower Bear River water body.

Boundary Conditions

Boundary condition inputs include inflows and inflow temperatures at the head of the reach and from Dry Creek, and meteorological data from historical records. An artificial spillway was included at the downstream end of the model to represent the Feather River for model stability.

Time series of meteorological data including air temperature, dew point temperature, wind speed, wind direction, and cloud cover were developed for the LBR Temp Model. A description of the meteorological dataset development is provided in Section 4.

For calibration and validation of the LBR Temp Model, historical operations data were used to define inflow to the Bear River, including fish flow releases for SSWD Conveyance Canal and non-Project diversion dam spill. Spill was modified as needed to balance inflows to and outflows from the non-Project diversion dam, as described in Section 6. The Ops Model includes an annual repeated time series of monthly average reach accretion and depletion between the diversion dam and Bear River at Wheatland flow gage (SSWD 2016). Ops Model output will be used to define period of record inflow boundary conditions, as described in Section 9. These accretion flows were also included in the calibration and validation scenarios. Figure 7-4 shows boundary condition inflows below the non-Project diversion dam and accretion/depletion flows upstream of the Wheatland gage (Highway 65). Synthetic inflow hydrology for Dry Creek was developed as part of this temperature modeling study. The methodology is documented in Appendix A. Figure 7-5 shows inflows to the lower Bear River from Dry Creek.

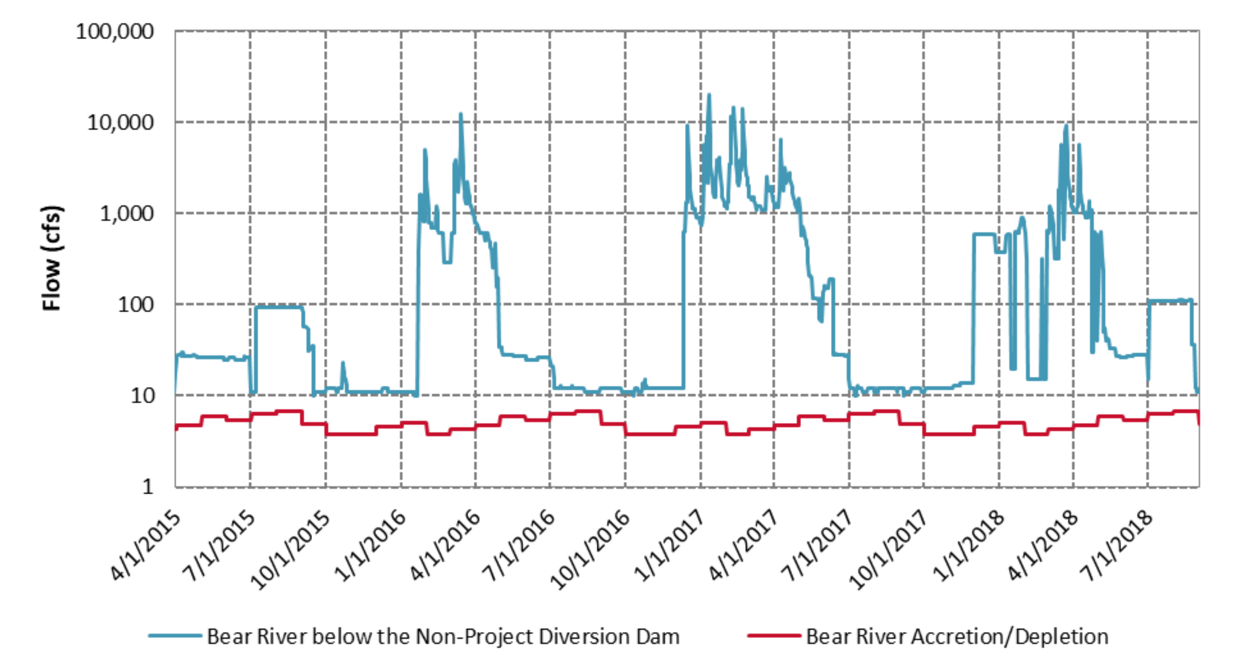

Figure 7-4. Calibration and validation scenario inflows to the LBR Temp Model below the non-Project diversion dam and from reach accretion/depletion upstream of the Wheatland flow gage.

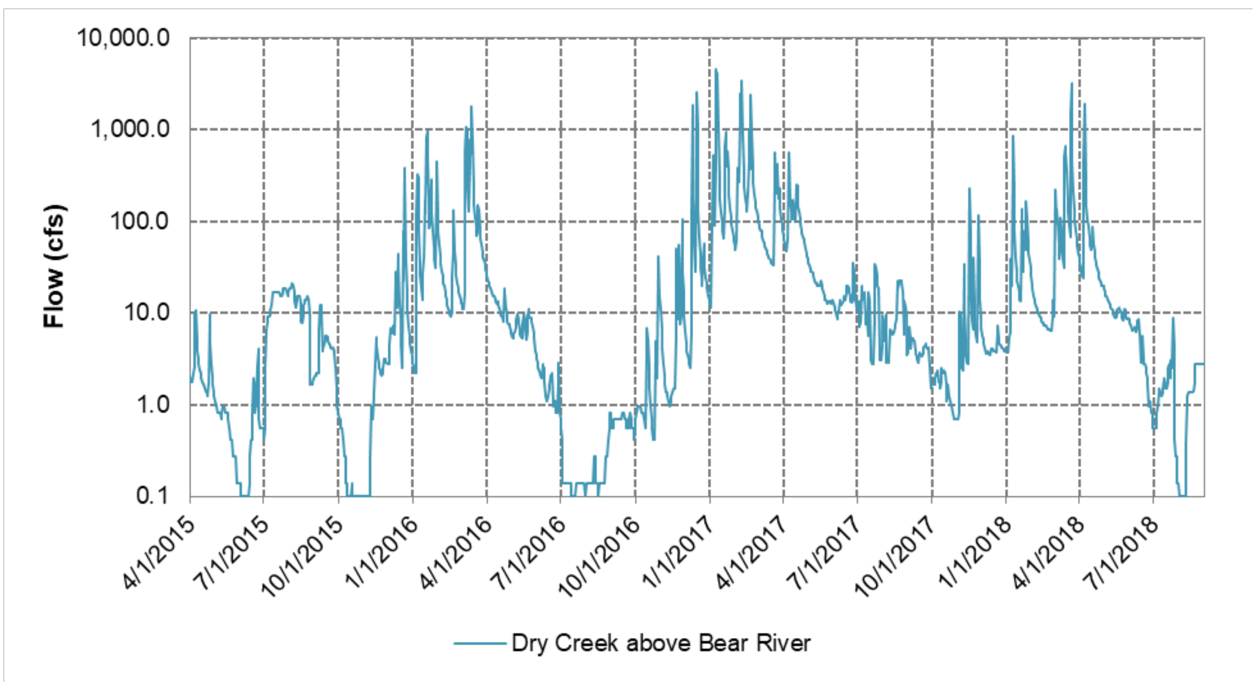

Figure 7-5. Calibration and validation scenario inflows to the LBR Temp Model from Dry Creek.

Calibration inflow temperatures for the lower Bear River utilized hourly observed data. Figure 7-6 shows the boundary condition inflow time series for the LBR Temp Model at the head of the reach. Validation inflow temperatures used outflow temperatures from the NPDD Temp Model validation scenario.

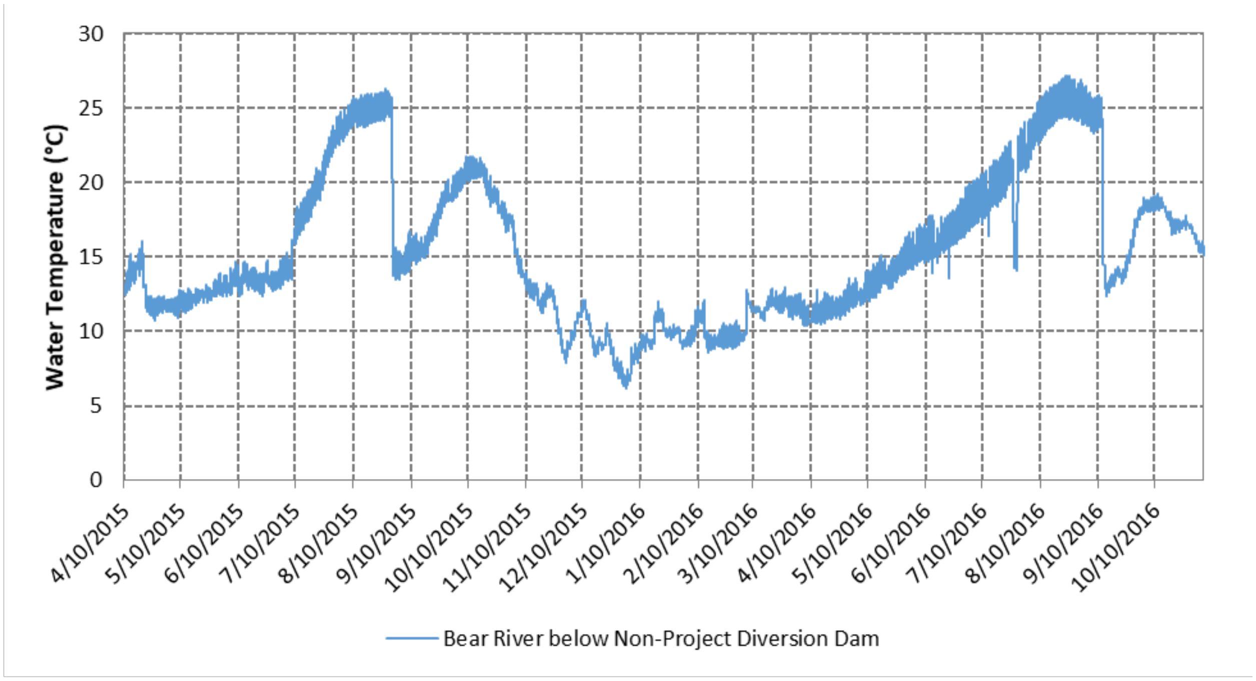

Figure 7-6. Calibration period inflow water temperatures to the LBR Temp Model at the head of the reach.

The Dry Creek water temperature gage above the Bear River had a limited period of record: September 13, 2016 through November 3, 2016 and June 23, 2017 through September 12, 2018. Data from June 23, 2017 through June 22, 2018 were repeated for calibration periods with missing data. The resulting calibration and validation boundary condition water temperatures for Dry Creek above the Bear River are shown in Figure 7-7. Dry Creek temperatures were also used to represent Bear River accretion/depletion temperatures upstream of the Wheatland flow gage.

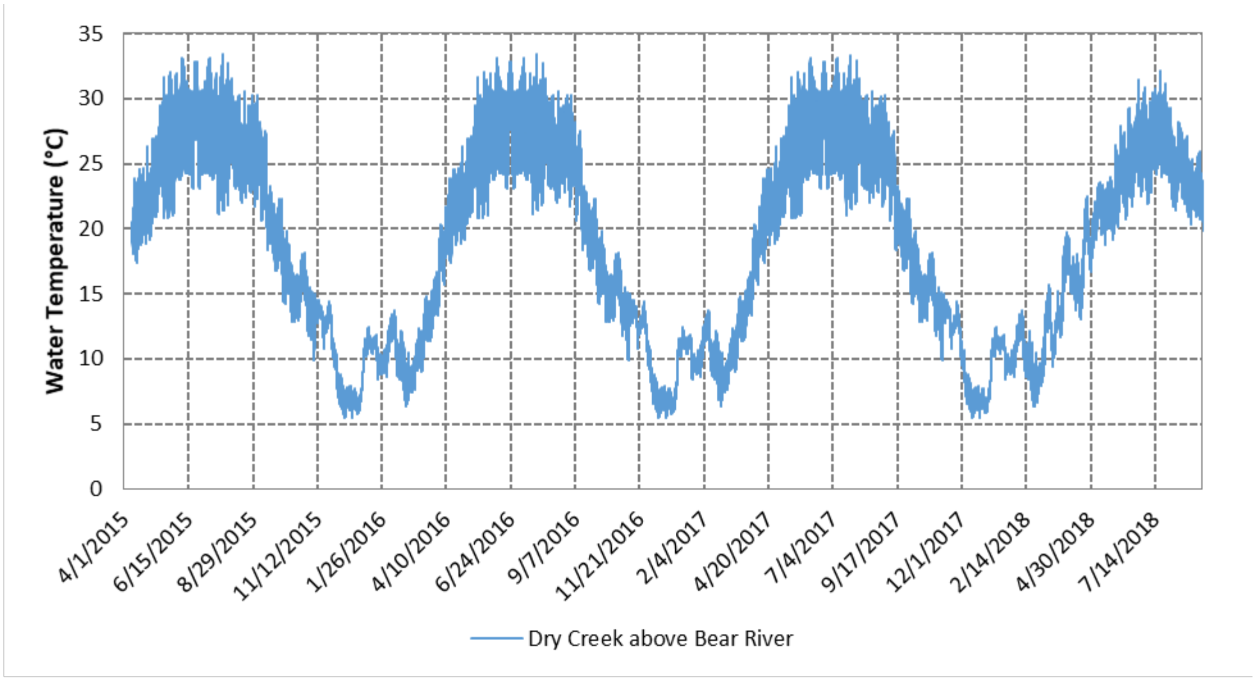

Figure 7-7. Calibration period inflow water temperatures to the LBR Temp Model at the head of the reach.

Model Calibration

Model calibration involved an iterative process of adjusting major model parameters to achieve a reasonable match between the simulated and the observed data. Model calibration effort focused on model predictions of water temperature at three locations along the lower Bear River: at Highway 65 (RM11.4), at Pleasant Grove Bridge (RM 7.1), and near Highway 70 (RM 3.5). Water temperature was also measured at RM 0.1 above the Feather River confluence. These data were not used for model calibration because of backwater temperature effects from the Feather River. The model calibration period was from April 10, 2015 to November 4, 2016, based on available historical data.

Calibration of the LBR Temp Model focused primarily on shading parameters. Dynamic shading was used to quantify the effects of topographic and vegetative shading for each model segment. Topographic shading was minimized to be representative of valley conditions. Vegetation shade inputs included vegetation elevation, distance to vegetation from the center of the channel, and a shade reduction factor representing the fraction of incoming short-wave solar radiation to reach the water surface for both the right and left banks. Shade reduction factors were defined for two periods of the year, representing leaf-on conditions during summer and leaf-off periods during winter. Vegetation elevation and distance to vegetation were calculated using GIS. Shade reduction factors of 100 percent in summer months and 0 percent in winter months produced the best results during calibration.

Bear River at Highway 65 Temperatures

Historically-measured water temperatures in the Bear River at the Highway 65 crossing were compared with the simulated temperatures. Comparison of daily average temperatures are shown in Figure 7-8. Comparison of daily maximum temperatures are shown in Figure 7-9.

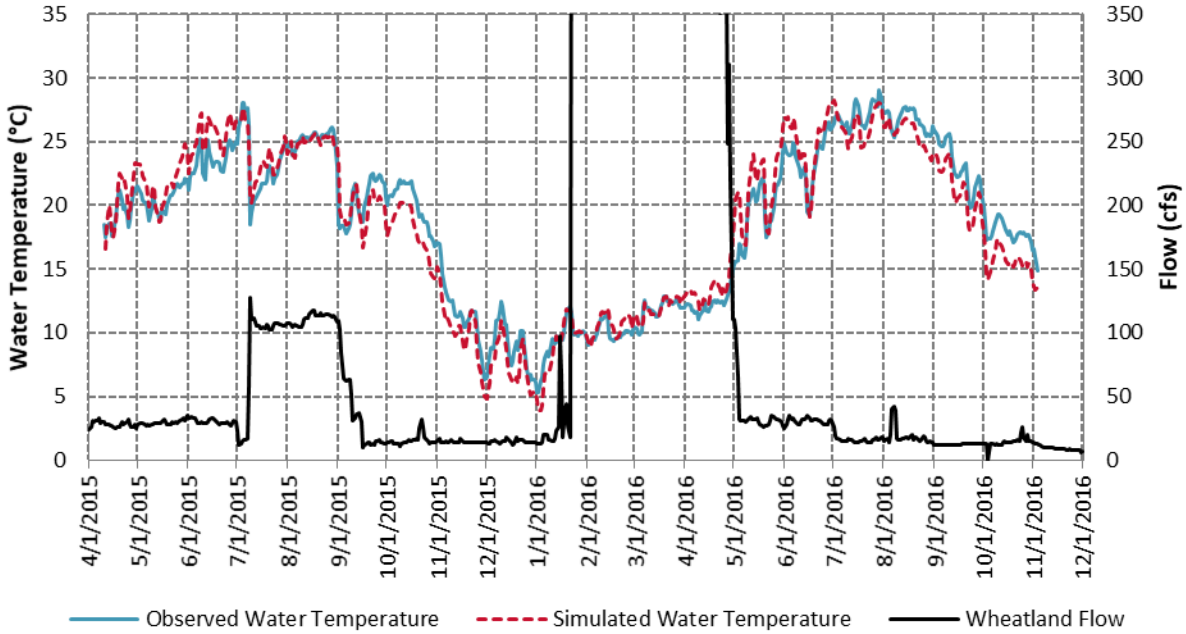

Figure 7-8. Comparison of simulated and measured daily average water temperatures in the Bear River at Highway 65 with Bear River at Wheatland flow.

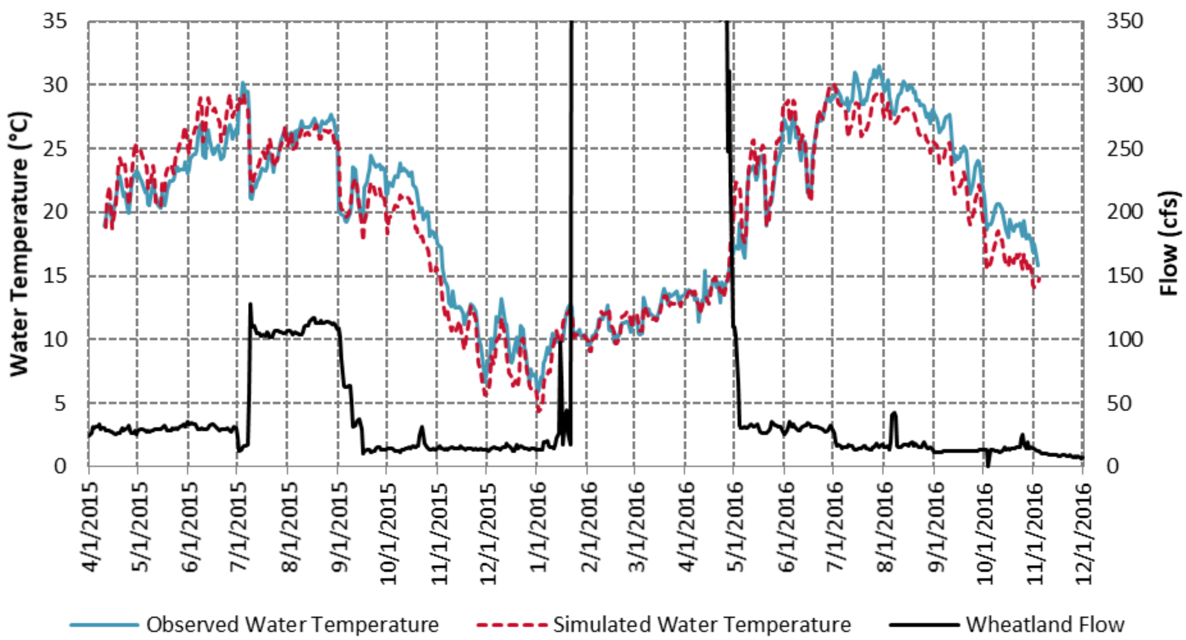

Figure 7-9. Comparison of simulated and measured daily maximum water temperatures in the Bear River at Highway 65 with Bear River at Wheatland flow.

Tables 7-2 and 7-3 summarize the ME and AME for the daily average temperature comparison and daily maximum temperature comparison, respectively, for the calibration period of record and July through October periods.

Table 7-2. Calibration summary of Daily Average ME and AME for the Bear River at Highway 65.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.17	1.26	-0.99	1.34

Table 7-3. Calibration summary of Daily Maximum ME and AME for the Bear River at Highway 65.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.55	1.39	-1.50	1.73

Bear River at Pleasant Grove Bridge Temperatures

Historically-measured water temperatures in the Bear River at the Pleasant Grove Bridge crossing were compared with the simulated temperatures. Comparison of daily average temperatures are shown in Figure 7-10. Comparison of daily maximum temperatures are shown in Figure 7-11.

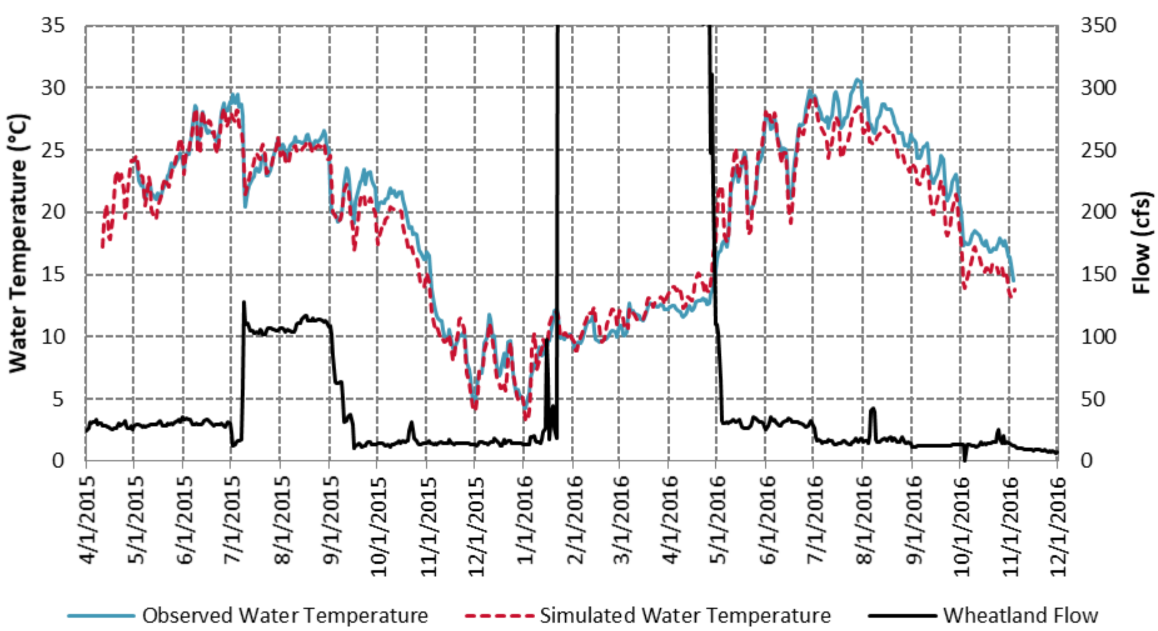

Figure 7-10. Comparison of simulated and measured daily average water temperatures in the Bear River at Pleasant Grove Bridge with Bear River at Wheatland flow.

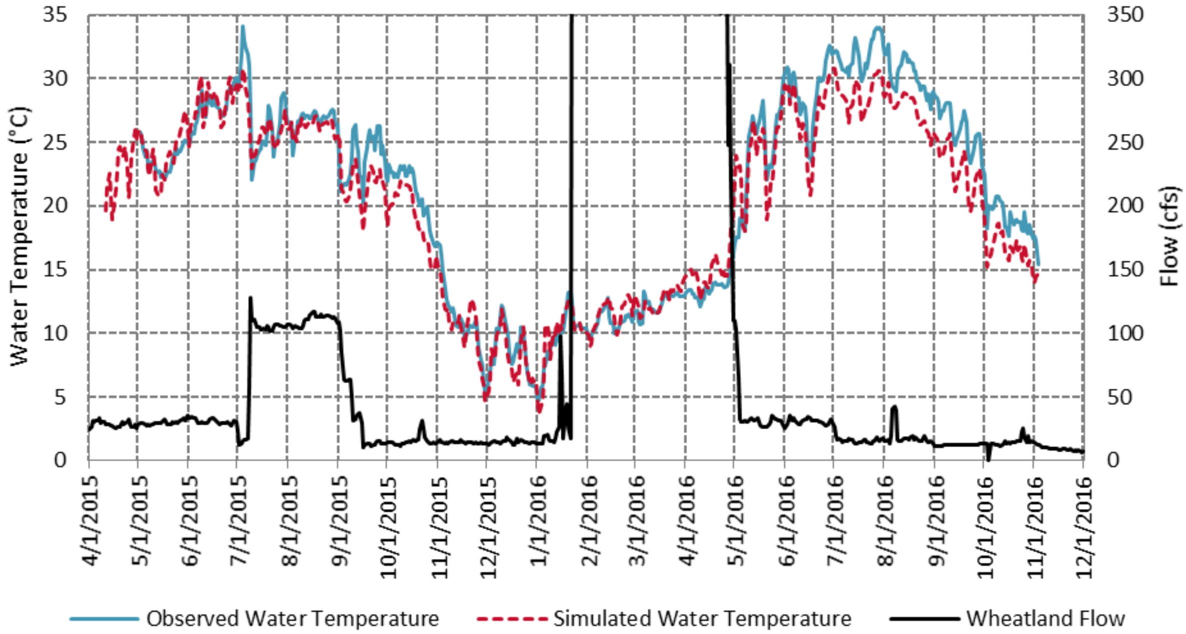

Figure 7-11. Comparison of simulated and measured daily maximum water temperatures in the Bear River at Pleasant Grove Bridge with Bear River at Wheatland flow.

Tables 7-4 and 7-5 summarize the ME and AME for the daily average temperature comparison and daily maximum temperature comparison, respectively, for the calibration period of record and July through October periods.

Table 7-4. Calibration summary of Daily Average ME and AME for the Bear River at Pleasant Grove Bridge.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.56	1.14	-1.38	1.54

Table 7-5. Calibration summary of Daily Maximum ME and AME for the Bear River at Pleasant Grove Bridge.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.95	1.56	-2.08	2.20

Bear River at Highway 70 Temperatures

Historically-measured water temperatures in the Bear River at the Highway 70 crossing were compared with the simulated temperatures. Comparison of daily average temperatures are shown in Figure 7-12. Comparison of daily maximum temperatures are shown in Figure 7-13.

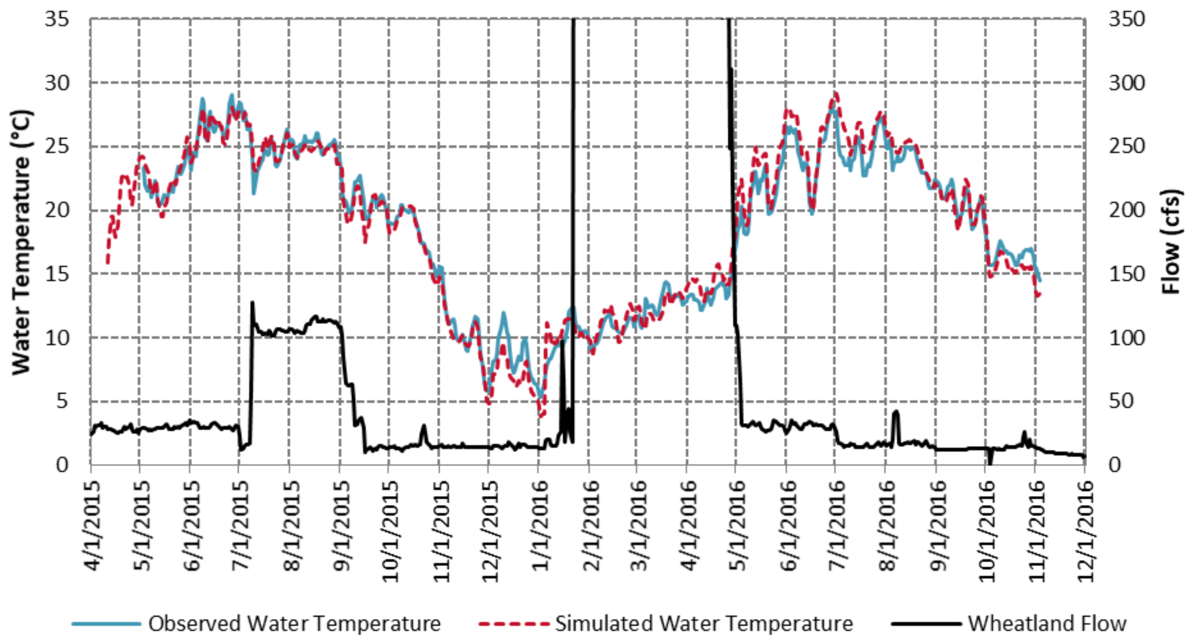

Figure 7-12. Comparison of simulated and measured daily average water temperatures in the Bear River at Highway 70 with Bear River at Wheatland flow.

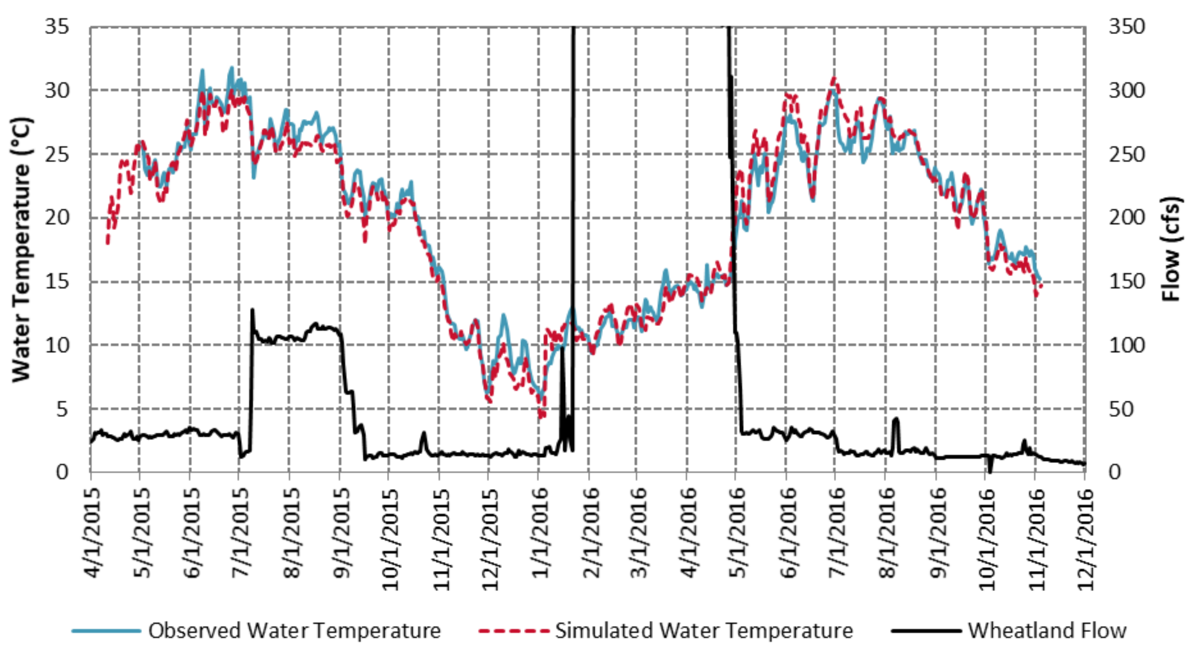

Figure 7-13. Comparison of simulated and measured daily maximum water temperatures in the Bear River at Highway 70 with Bear River at Wheatland flow.

Tables 7-6 and 7-7 summarize the ME and AME for the daily average temperature comparison and daily maximum temperature comparison, respectively, for the calibration period of record and July through October periods.

Table 7-6. Calibration summary of Daily Average ME and AME for the Bear River at Highway 70.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	0.10	0.79	0.05	0.68

Table 7-7. Calibration summary of Daily Maximum ME and AME for the Bear River at Highway 70.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.13	0.89	-0.33	0.83

Model Validation

Model validation was used to verify that the parameters developed during the calibration perform as expected for a secondary period of record. The validation period for the LBR temp model was from January 19, 2017 to August 31, 2018. Inflow and inflow water temperature boundary condition data were provided by the NPDD Temp Model validation scenario through July 2, 2018. Observed flow and water temperature boundary condition data were utilized for July 3, 2018 through August 31, 2018.

Bear River at Highway 65 Temperatures

Historically-measured water temperatures in the Bear River at the Highway 65 crossing were compared with the simulated temperatures. Comparison of daily average temperatures are shown in Figure 7-14. Comparison of daily maximum temperatures are shown in Figure 7-15.

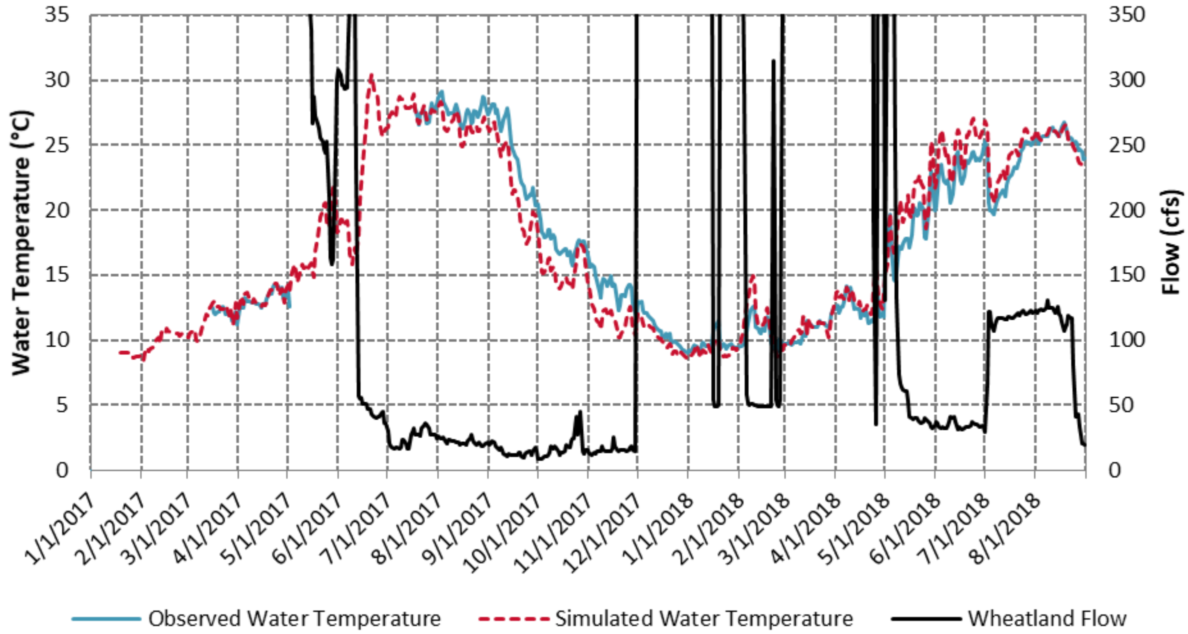

Figure 7-14. Comparison of simulated and measured daily average water temperatures in the Bear River at Highway 65 with Bear River at Wheatland flow.

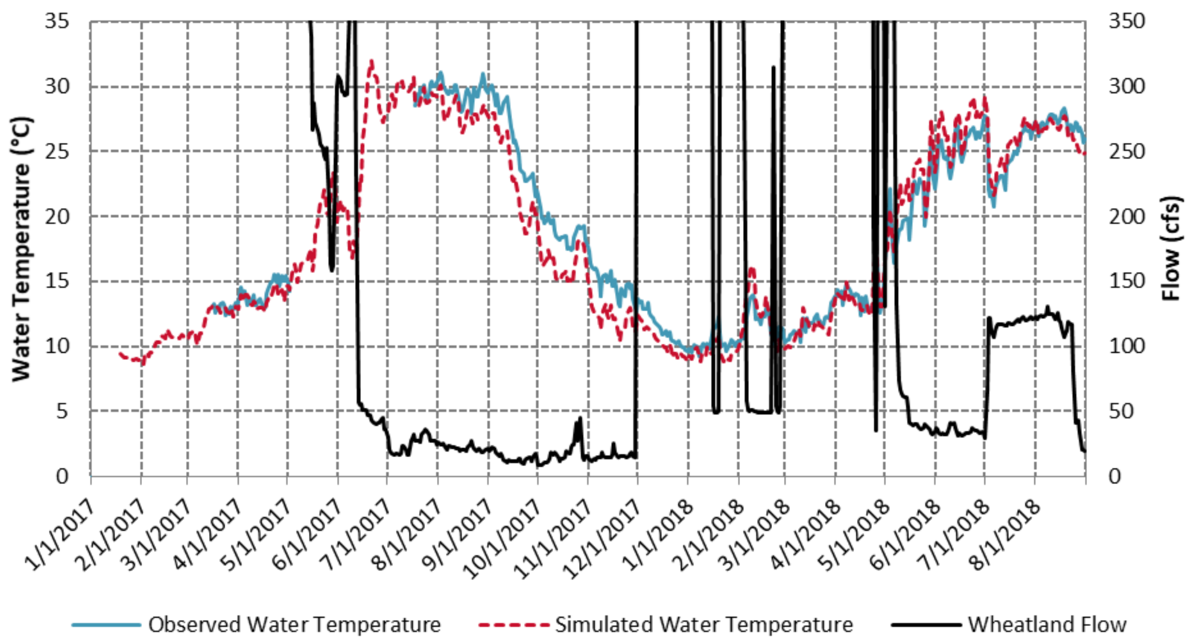

Figure 7-15. Comparison of simulated and measured daily maximum water temperatures in the Bear River at Highway 65 with Bear River at Wheatland flow.

Tables 7-8 and 7-9 summarize the ME and AME for the daily average temperature comparison and daily maximum temperature comparison, respectively, for the calibration period of record and July through October periods.

Table 7-8. Validation summary of Daily Average ME and AME for the Bear River at Highway 65.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.18	1.12	-0.82	1.29

Table 7-9. Validation summary of Daily Maximum ME and AME for the Bear River at Highway 65.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.63	1.24	-1.26	1.57

Bear River at Pleasant Grove Bridge Temperatures

Historically-measured water temperatures in the Bear River at the Pleasant Grove Bridge crossing were compared with the simulated temperatures. Comparison of daily average temperatures are shown in Figure 7-16. Comparison of daily maximum temperatures are shown in Figure 7-17.

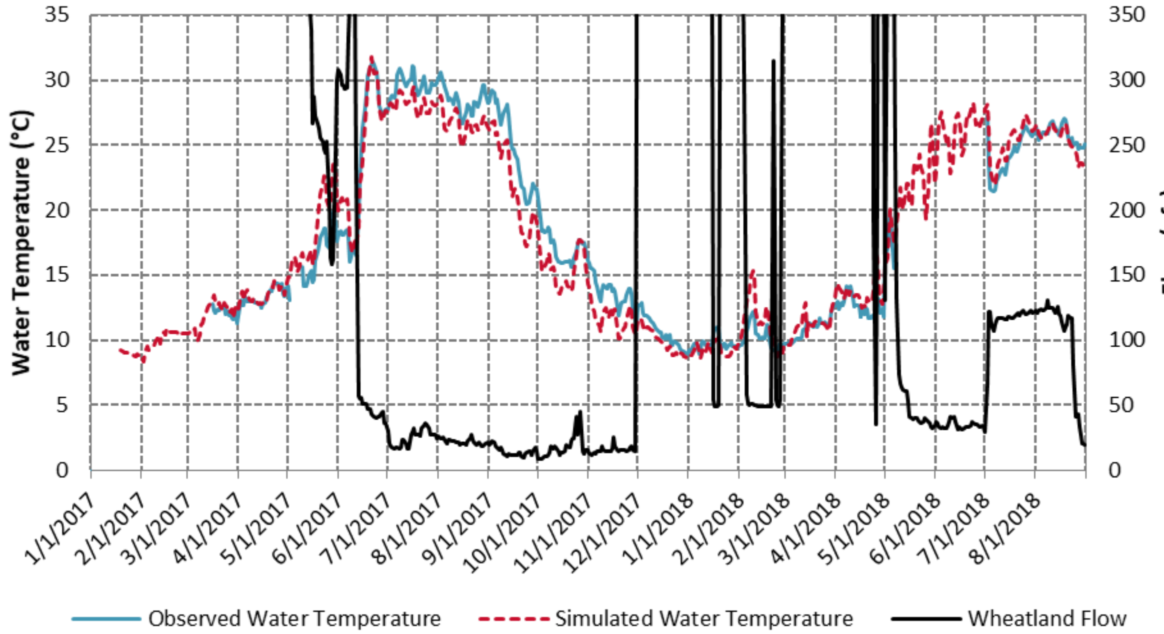

Figure 7-16. Comparison of simulated and measured daily average water temperatures in the Bear River at Pleasant Grove Bridge with Bear River at Wheatland flow.

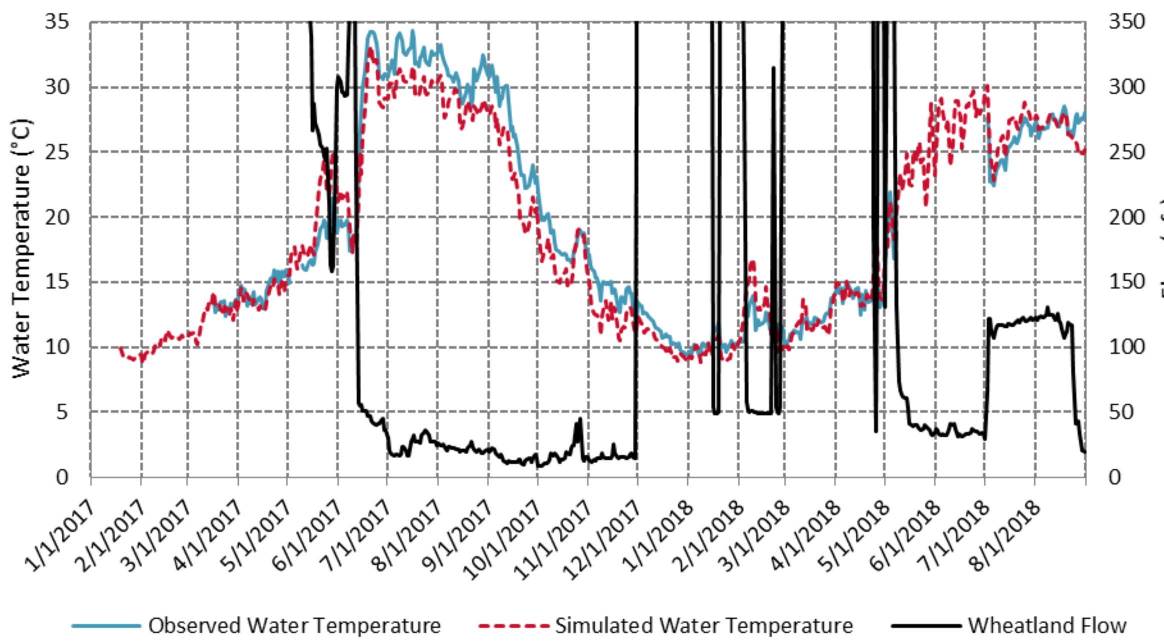

Figure 7-17. Comparison of simulated and measured daily maximum water temperatures in the Bear River at Pleasant Grove Bridge with Bear River at Wheatland flow.

Tables 7-10 and 7-11 summarize the ME and AME for the daily average temperature comparison and daily maximum temperature comparison, respectively, for the calibration period of record and July through October periods.

Table 7-10. Validation summary of Daily Average ME and AME for the Bear River at Pleasant Grove Bridge.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.35	1.19	-1.18	1.51

Table 7-11. Validation summary of Daily Maximum ME and AME for the Bear River at Pleasant Grove Bridge.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.69	1.40	-1.41	1.85

Bear River at Highway 70 Temperatures

Historically-measured water temperatures in the Bear River at the Highway 70 crossing were compared with the simulated temperatures. Comparison of daily average temperatures are shown in Figure 7-18. Comparison of daily maximum temperatures are shown in Figure 7-15.

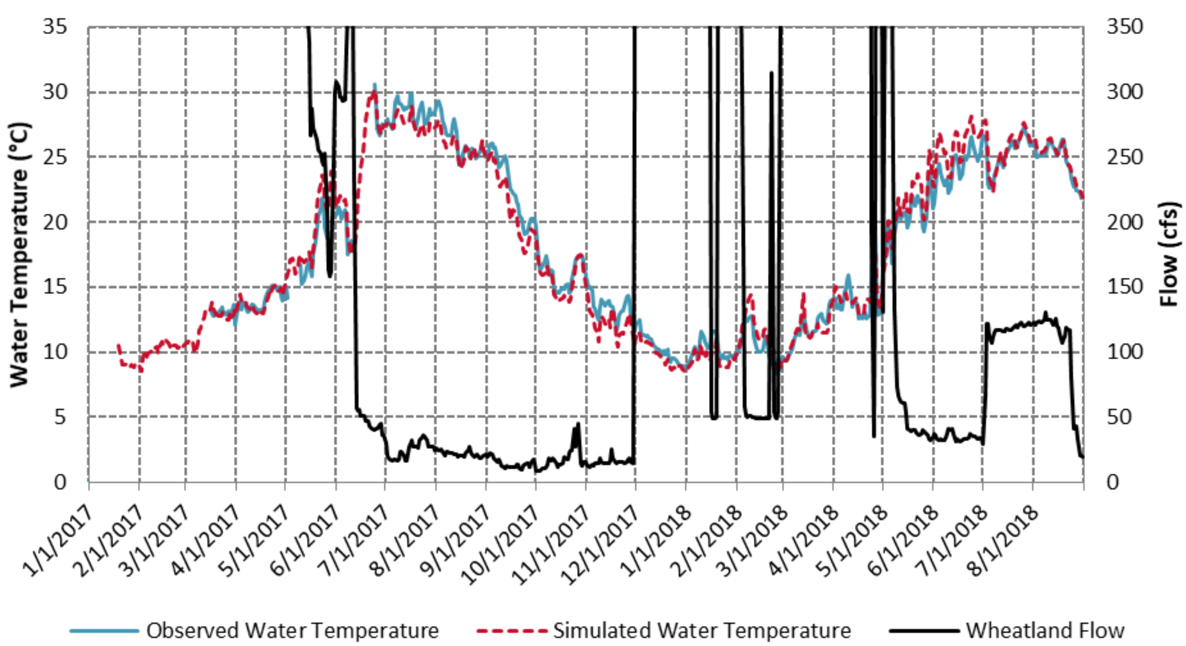

Figure 7-18. Comparison of simulated and measured daily average water temperatures in the Bear River at Highway 70 with Bear River at Wheatland flow.

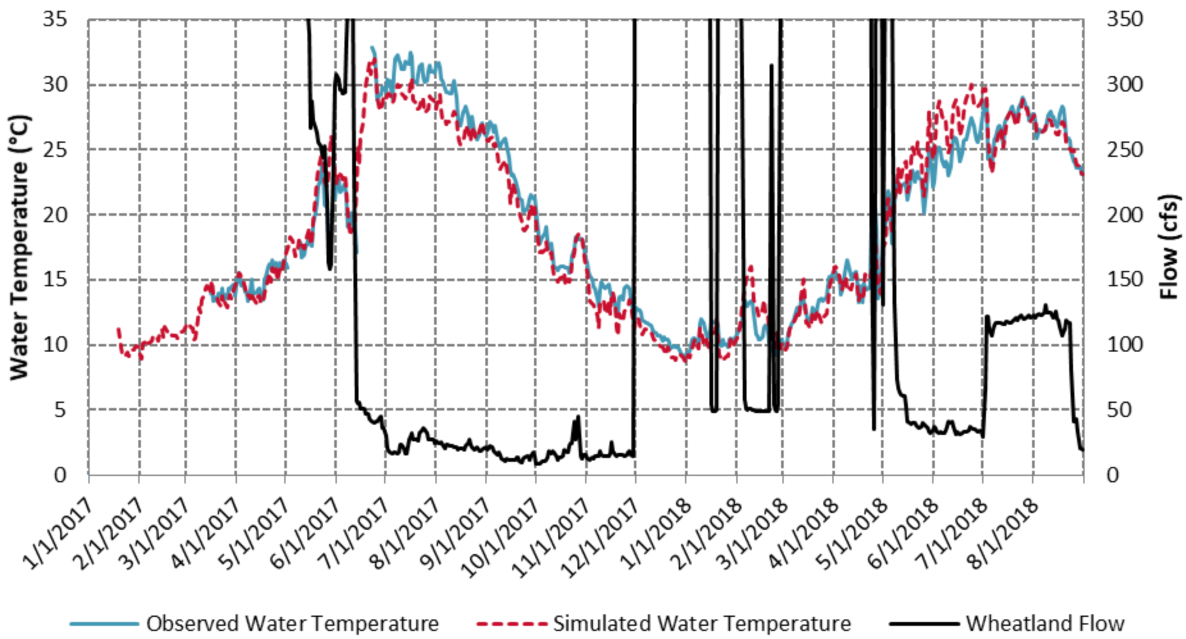

Figure 7-19. Comparison of simulated and measured daily maximum water temperatures in the Bear River at Highway 70 with Bear River at Wheatland flow.

Tables 7-12 and 7-13 summarize the ME and AME for the daily average temperature comparison and daily maximum temperature comparison, respectively, for the calibration period of record and July through October periods.

Table 7-12. Validation summary of Daily Average ME and AME for the Bear River at Highway 70.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.05	0.77	-0.43	0.69

Table 7-13. Validation summary of Daily Maximum ME and AME for the Bear River at Highway 70.

Model Scenario	Full Period		Summer Months (Jul-Oct)	
	ME (°C)	**AME (°C)**	**ME (°C)**	**AME (°C)**
Calibration	-0.28	1.03	-0.97	1.07

8. Graphical User Interface (GUI)

A GUI was created to streamline the process of performing a period of record (water years 1976 through 2014) temperature model run, which takes Ops Model output and runs in series:

- The CFW Temp Model
- The NPDD Temp Model
- The LBR Temp Model

The GUI works to simplify the process and minimize user error. The GUI:

- Identifies and assembles boundary condition input data
- Passes temperature output from each upstream Temp Model to the downstream Temp Model to run the models in series
- Converts from English to metric units between the Ops Model and the Temp Models
- QCs Temp Model output after each model is run

The SSWD Temp Model GUI was developed as a Microsoft Excel spreadsheet, *SSWD Temp Model GUI.xlsb*. The control sheet is the main user interface for setting up and running the Temp Models. The control sheet contains a set of 8 steps to be performed in sequence by the model user. These steps are:

- Step 1 – Identify the Ops Model HEC-DSS output file, and the starting elevation of Camp Far West Reservoir
- Step 2 – Create or Identify the HEC-DSS Temp Model output file, where Temp Model output data will be written
- Step 3 – Import boundary input data from HEC-DSS files identified in Step 1 to the Flow Data worksheet (Optional)
- Step 4 – Run the CFW and NPDD Temp Models in series
- Step 5 – Perform CFW Temp Model and NPDD Temp Model output QA/QC
- Step 6 – Run CE-QUAL-W2 water balance application if QA/QC of Camp Far West Reservoir water levels is not satisfactory
- Step 7 – Run the LBR Temp Model
- Step 8 – Perform LBR Temp Model QA/QC
- Step 9 – Export Temp Model output to HEC-DSS

Set up of Input and Output Files – Steps 1 through 3

Figure 8-1 shows a screen shot of Steps 1 through 3 on the Control worksheet of the SSWD Temp Model GUI.

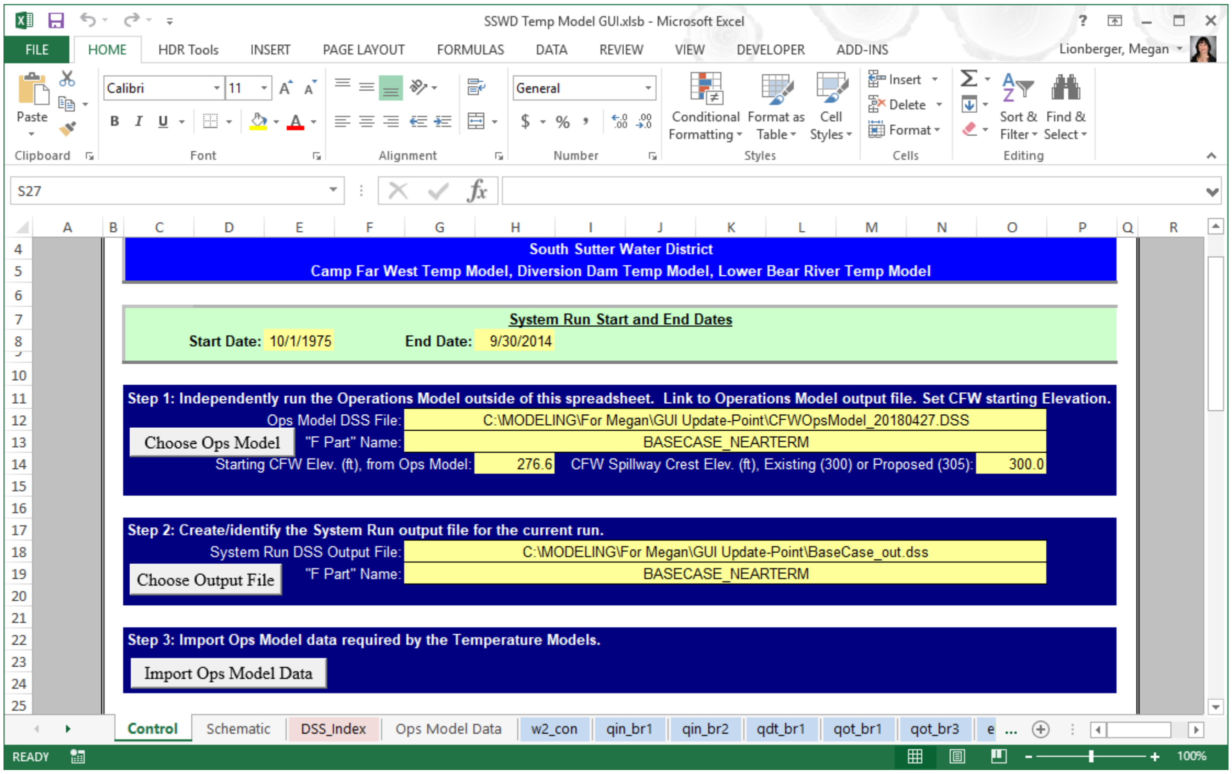

Figure 8-1. Screen shot of Steps 1 through 3 on the Control sheet of the SSWD Temp Model GUI.

Step 1 identifies the location of the Ops Model HEC-DSS output file, which is run independently from and prior to running the Temp Models. Pressing the 'Choose Ops Model File' button in Step 1 prompts an open-file dialog box for the user to browse and select the Water Balance/Operations Model output file. The Ops Model DSS File pathname box is automatically updated after the Water Balance/Operations Model output file is identified. It is up to the user to enter the Ops Model HEC-DSS F Part Name, the initial condition Camp Far West Reservoir WSE, and the Camp Far West Reservoir spillway crest elevation. The initial WSE should be consistent with the initial conditions defined in the Ops Model. The spillway crest elevation is selected by the user from a drop down list. The existing spillway crest elevation is 300 ft, and the proposed Project spillway crest elevation is 305 ft. The selected spillway crest elevation should be consistent with the Ops Model.

Pressing the 'Choose Output File' button in Step 2 opens a yes/no dialog box with the question 'Do you want to create a new Output file?' To use an existing HEC-DSS file as the file that the Temp Model output is written to, select no. To create a new file to write Temp Model output to, select yes. An open-file dialog box will appear for the user to link to an existing file or create a new one. The user must also enter a HEC-DSS F Part Name to be associated with output written to the Temp Model output file.

Step 3 can be performed automatically by the GUI, or manually by the user. To do so automatically, click the 'Copy Input Data' button. Data needed to run the Temp Models are copied from the Ops Model HEC-DSS file into the Flow Data worksheet in the SSWD Temp Model GUI. If the pathname for the Ops Model output file is incorrect, an error box will appear, as shown in Figure 8-2. After the user clicks the OK button, the SSWD Temp Model GUI file automatically closes.

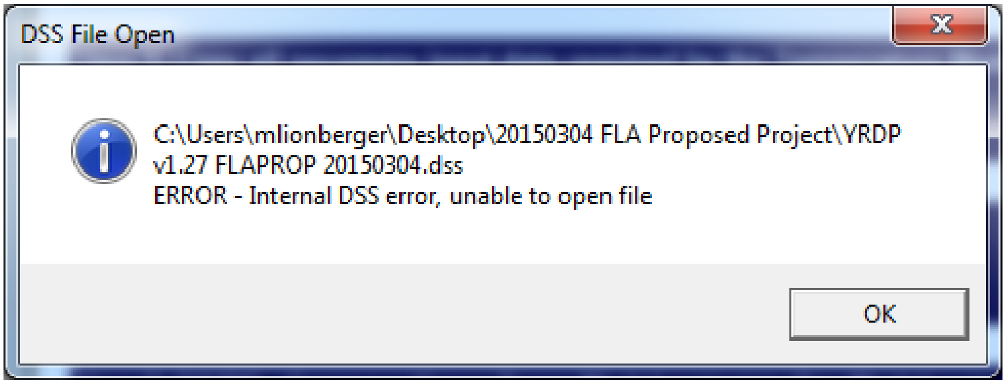

Figure 8-2. Error box that appears when Ops Model file pathname is incorrect.

If the pathname is entered correctly, yet the F Part is entered incorrectly in Step 1, data will not load correctly to the Flow Data worksheet when the user clicks the 'Copy Input Data' button in Step 5. It is good practice to check this worksheet to see that data have been copied in correctly. If not, the data columns will be filled with -902 values.

To perform Step 3 manually, copy data from the Ops Model and paste into the Temp Model user by completing the following steps:

- Step 1 – Open the Ops Model
- Step 2 – Click on the *To_DSS_Archive* worksheet
- Step 3 – Click the button at the top of column A that says **Copy Data for Temp Model** to automatically copy the data needed by the Temp Model
- Step 4 – Open the Temp Model
- Step 5 – Click on the *Flow Data* worksheet
- Step 6 – Click the button at the top of column A that says **Paste Ops Model Data** to automatically paste the copied data from the Ops Model

Running the CFW Temp Model and NPDD Temp Model – Steps 4 through 6

Figure 8-3 shows a screen shot of Steps 4 through 6 on the Control worksheet of the SSWD Temp Model GUI.

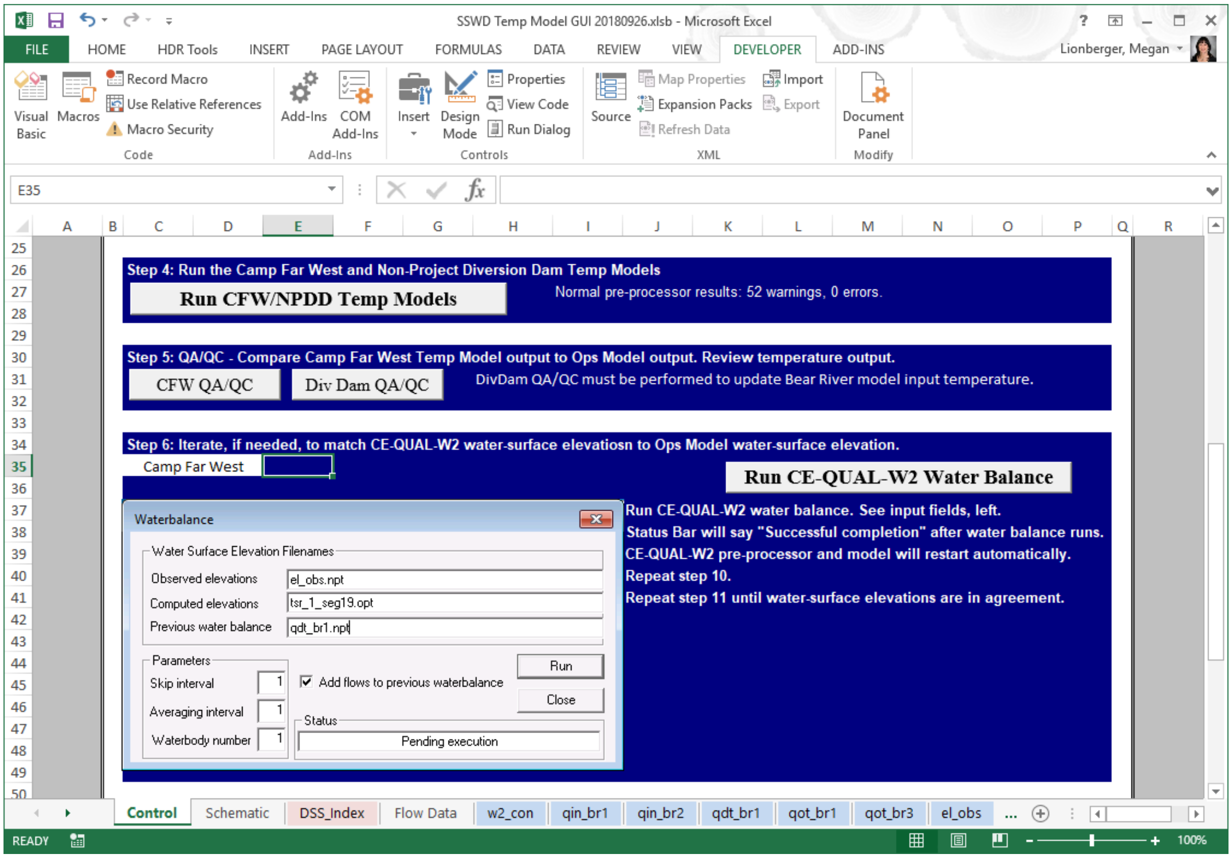

Figure 8-3. Screen shot of Steps 4 through 6 on the Control sheet of the SSWD Temp Model GUI.

Pressing the *Run CFW/NPDD Temp Models* button in Step 4 calls a macro to export the seven worksheets in the workbook associated with the CFW and NPDD Temp Models as fixed-width ASCII files. Before the files are exported, a dialog box opens, as shown in Figure 8-4, to check that the models are being run for the first time for this scenario. The branch 1 distributed tributary file (qdt_br1.npt) is used by the water balance program when iterating to match the Temp Model WSE to the Ops Model WSE. The distributed tributary file is overwritten when the model user clicks yes. If iterating, click no and proceed to step 6.

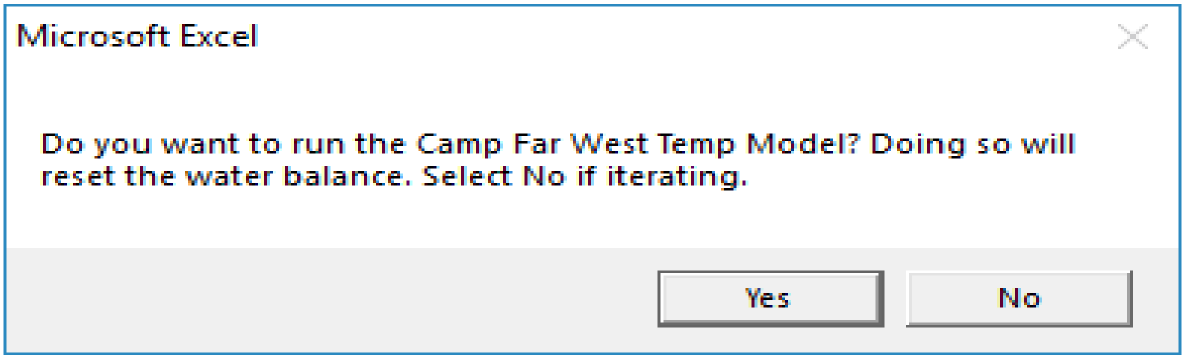

Figure 8-4. Screen shot of the dialog box that opens when the *Run CFW/NPDD Temp Models* button is clicked.

Model files are exported to a subfolder within the folder location of the SSWD Temp Model GUI called 'CFW_DivDam.' This folder must already exist and cannot be renamed. Once the files have been exported, a windows batch file is used to call and run the CE-QUAL-W2 preprocessor. The purpose of the preprocessor is to check the control file and input files for errors. The preprocessor executable file (preW2-37_64.exe) produces several output files including:

- A file that echoes all the control inputs (pre.opt),
- A file that summarizes any potential problems/warnings with the input data (pre.wrn), and
- A file that summarizes any serious problems with the input data that could prevent the model from running or running incorrectly (pre.err). Note that this file is only generated if there are errors identified by the preprocessor.

Running the preprocessor for the combined CFW and NPDD Temp Models typically produces 44 warnings and 0 errors when running the Base Case. CE-QUAL-W2 will run if warnings are detected, and will not run if errors are detected. If additional warning or errors are encountered by the preprocessor than are expected, do not initiate the model run. See the pre.wrn and/or the pre.err files for more information. Closing the preprocessor window once it finishes running prompts a dialog box, as shown in Figure 8-5. Pressing yes will initiate CE-QUAL-W2, and will activate a run status window, as shown in Figure 8-6. Running the CFW and NPDD Temp Models for the period of record (water year 1976 through 2014) takes multiple hours.

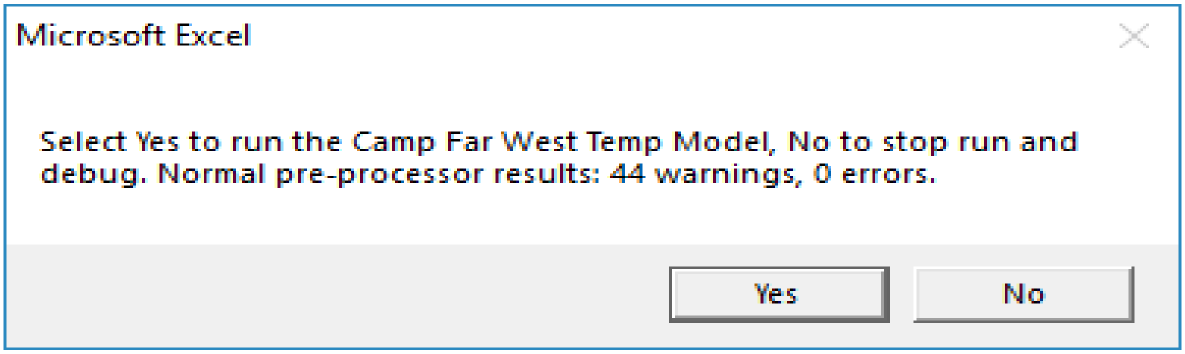

Figure 8-5. Screen shot of the dialog box after the CE-QUAL-W2 preprocessor is run for the CFW and NPDD Temp Models.

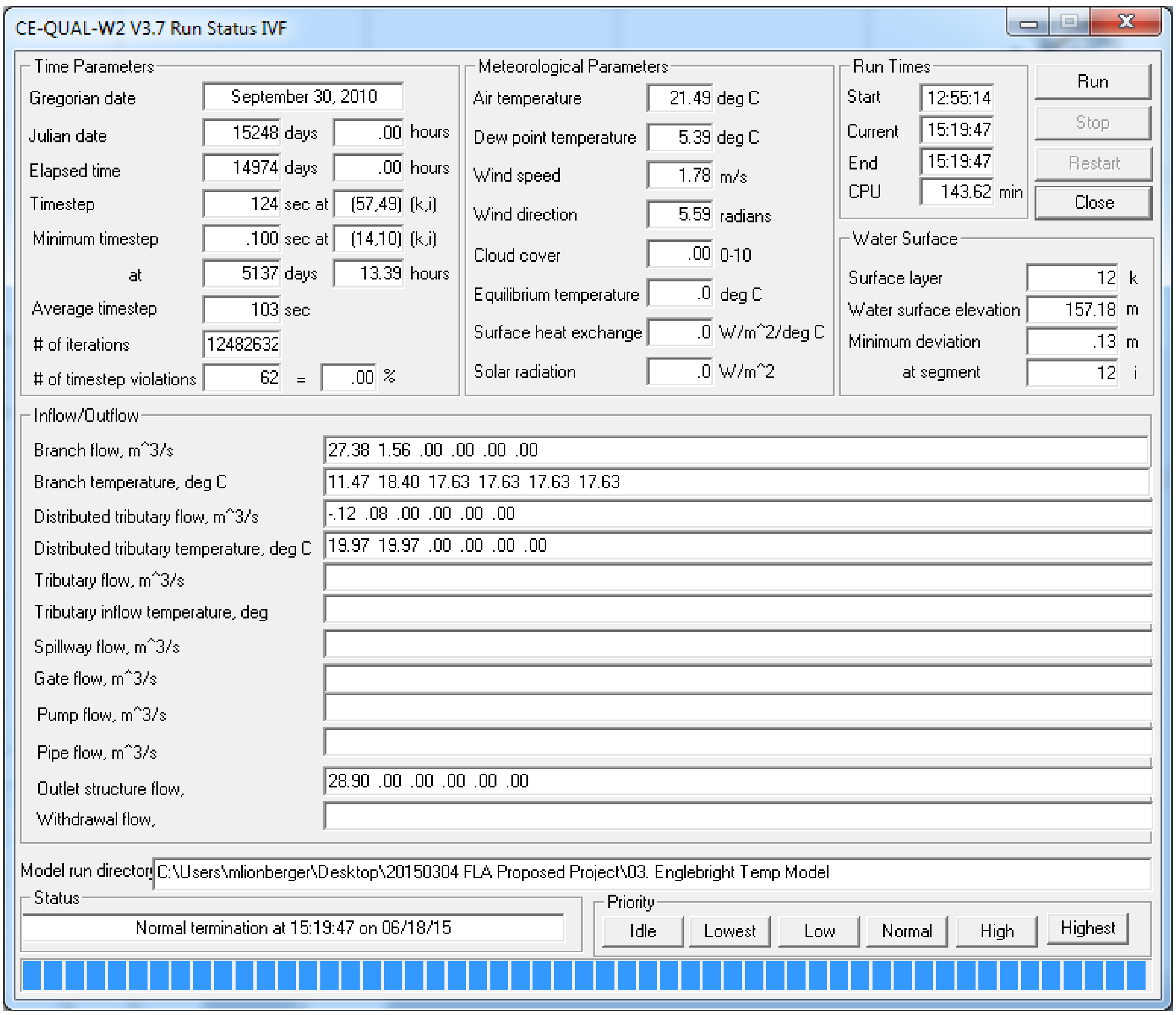

Figure 8-6. Screen shot of the CE-QUAL-W2 run status window.

Table 8-1 lists executable files used by the SSWD Temp Model GUI to run the CFW and NPDD Temp Models. These files must be located in the 'CFW_DivDam' subfolder. Note that these executable files are for a 64-bit PC, and are backwards compatible with 32-bit PCs.

Table 8-1. Englebright Temp Model executable files and descriptions.

File Type	File Name	Description
Executable files	preW2-v4_64.exe	64-Bit CE-QUAL-W2 Preprocessor
	w2_v4_64.exe	64-Bit CE-QUAL-W2 Executable
	waterbal_ivf_4.exe	Water-balance Utility

Pushing the *CFW QA/QC* button in Step 5 imports Camp Far West Reservoir WSE data from the CFW Temp Model and allows the user to compare it to Ops Model output. Pushing the *NPDD QA/QC* button in Step 5 imports non-Project diversion dam Reservoir WSE data from the NPDD Temp Model and allows the user to compare it to the assumed static WSE of 138 ft (42 m).

WSEs simulated by the CFW Temp Model may not exactly match the Ops Model the first time the Temp Model is run because of small differences in the storage capacity curves between the Ops Model and the CFW Temp Model. Iteration of the CFW Temp Model may be necessary to produce agreement between the two models. Step 6 iterates the CFW Temp Model by first running the water balance utility and then rerunning the model. The water balance utility computes the difference in flow necessary to reproduce Ops Model WSEs. The flow difference is applied to the branch 1 distributed tributary file qdt_br1.npt. Figure 8-7 shows a screen shot of the water balance utility.

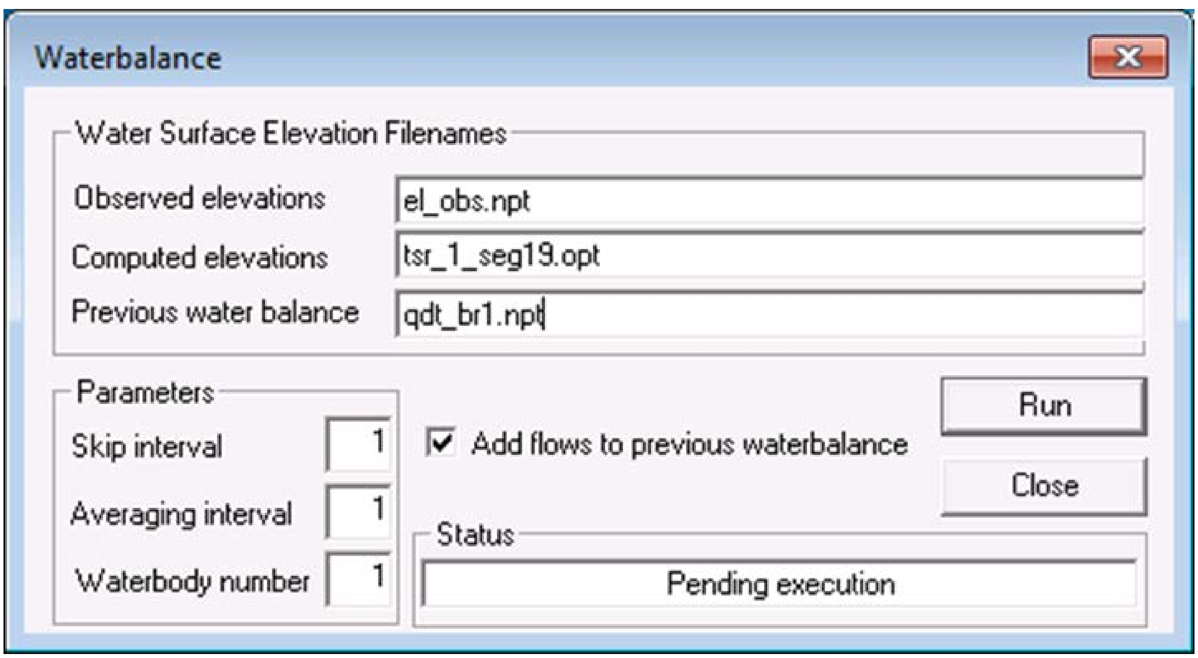

Figure 8-7. Screen shot of the CE-QUAL-W2 water balance utility.

Repeat Step 5 each time the CFW and NPDD Temp Models are run (Steps 4 or 6). The QA/QC buttons must be clicked for both CFW and NPDD prior to running the LBR Temp Model to pass output data from the NPDD Temp Model to the LBR Temp Model correctly.

Running the LBR Temp Model – Steps 7 and 8

Figure 8-8 shows a screen shot of Steps 7 and 8 on the Control worksheet of the SSWD Temp Model GUI.

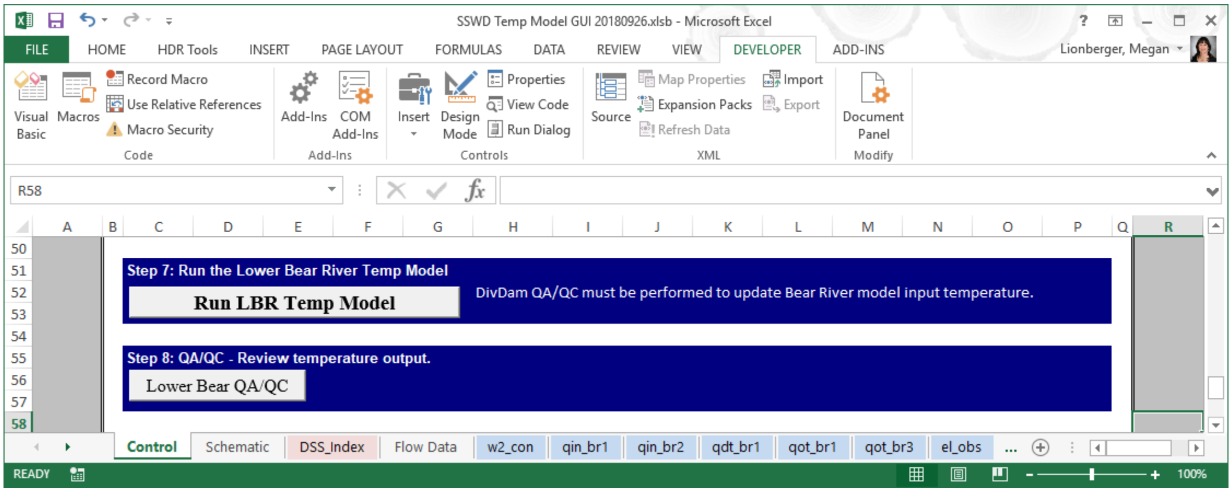

Figure 8-8. Screen shot of Steps 7 and 8 on the Control sheet of the SSWD Temp Model GUI.

Because of the way NPDD Temp Model releases are configured it is necessary to post-process NPDD Temp Model release output temperatures to develop the input temperature time series to the LBR Temp Model. A portion of the diversion to SSWD's Conveyance Canal is returned to meet the minimum instream flow requirement below the non-Project diversion dam. A flow-weighted average of minimum instream flow releases and diversion dam spill releases is used to develop hourly LBR Temp Model inflow temperatures, which is done within the SSWD Temp Model GUI by pressing the *NPDD QA/QC* button (step 5).

Pressing the *Run LBR Temp Model* button in Step 7 calls a macro to export five worksheets in the SSWD Temp Model GUI associated with the LBR Temp Models as fixed-width ASCII files. Model files are exported to a subfolder within the folder location of the SSWD Temp Model GUI called 'Bear.' This folder must already exist and cannot be renamed. Once the files have been exported, a windows batch file is used to call and run the CE-QUAL-W2 preprocessor. Running the preprocessor for the LBR Temp Model typically produces 52 warnings and 0 errors when running the Base Case. Closing the preprocessor window once it finished running prompts a dialog box, as shown in Figure 8-9. Pressing yes will initiate CE-QUAL-W2 and will activate a run status window (see Figure 8-7). Running the LBR Temp Model for the period of record (water year 1976 through 2014) takes multiple hours.

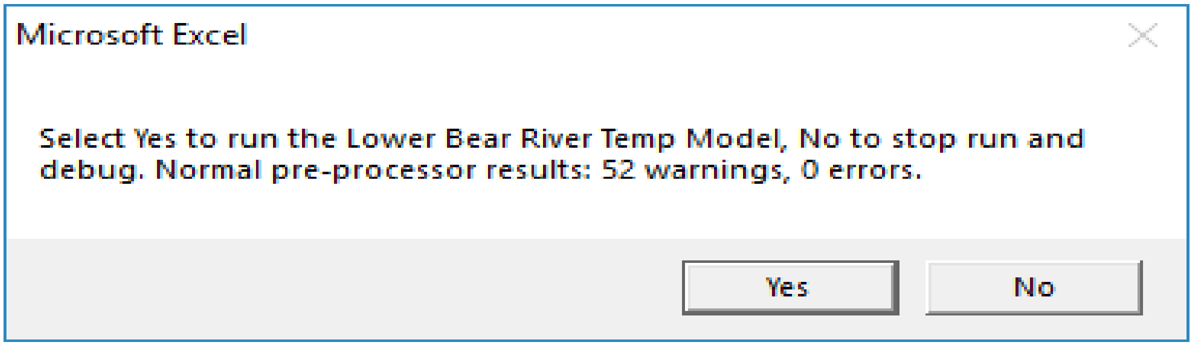

Figure 8-9. Screen shot of the dialog box after the CE-QUAL-W2 preprocessor is run for the LBR Temp Model.

Pushing the *LBR QA/QC* button in Step 8 imports water temperature output data from the LBR Temp Model at three locations: at the Highway 65 crossing, at the Pleasant Grove Bridge crossing, and at the Highway 70 crossing. The purpose of this step is make sure the output are reasonable. Output temperatures typically range between 0 and 30 degrees Celsius.

Exporting Temp Model Output to HEC-DSS – Step 9

Figure 8-10 shows a screen shot of Step 9 on the Control worksheet of the SSWD Temp Model GUI.

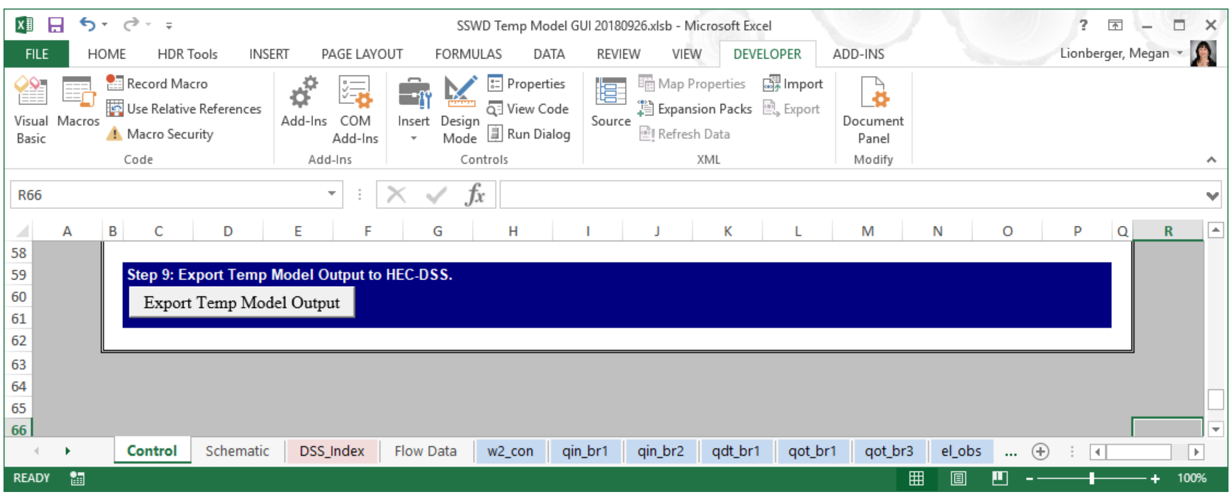

Figure 8-10. Screen shot of Step 9 on the Control sheet of the SSWD Temp Model GUI.

Pushing the *Export Temp Model Output* button in Step 9 imports hourly water temperature output data at the terminal end of all three water bodies and exports these data to the HEC-DSS file selected in Step 2. Ops Model Data imported to the Temp Model in Step 3 is also exported to the HEC-DSS output file. Exported Temp Model data include Camp Far West Reservoir release temperatures, non-Project diversion dam release temperatures and lower Bear River temperatures at the Feather River confluence. Time-series water-temperature data for each segment in the LBR Temp Model, 2 through 35, are imported to the LBR_Segment_T worksheet. A separate tool is under development to transform these data into hourly values and for subsequent export to HEC-DSS. The size of this data set prohibits doing do so within Excel.

9. Base Case Scenario

For the Base Case the Temp Models were setup and run in series using the SSWD Temp Model GUI for the relicensing period of record, October 1, 1975 through September 30, 2014. Inflow and outflow boundary conditions are provided by the Ops Model. Synthetic water temperature boundary conditions were developed for the period of record, and are described below. Meteorological boundary conditions were described in Section 4.

Hydrologic Boundary Conditions

Flow and reservoir water level output from the Ops Model (SSWD 2016) are imported by the SSWD Temp Model GUI to define flow boundary conditions and for quality control checks of Temp Model output. The time step of the Ops Model output is daily. Daily average inflow to Camp Far West from the Ops Model is a single time series and must be split between Bear River and Rock Creek. Rock Creek unimpaired hydrology was developed as part of the unimpaired hydrology data set for the Project. Bear River inflow is calculated by the Temp Model GUI as the difference between the Ops Model inflow to Camp Far West Reservoir and the inflow from Rock Creek. Figure 9-1 shows the Base Case inflows to Camp Far West Reservoir for the Bear River and Rock Creek.

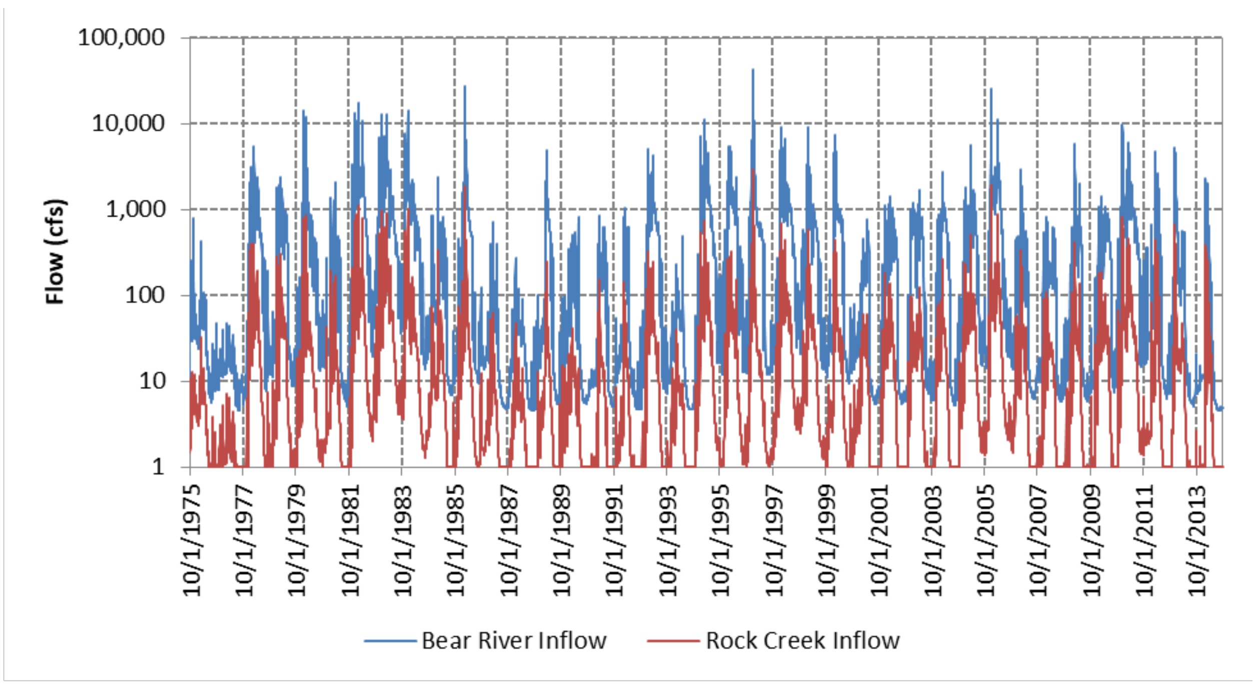

Figure 9-1. Base Case inflows to Camp Far West Reservoir for the Bear River and Rock Creek.

Synthetic inflow hydrology for Dry Creek was developed as part of this temperature modeling study. The methodology is documented in Appendix A. Figure 9-2 shows the time series of inflows to the lower Bear River from Dry Creek.

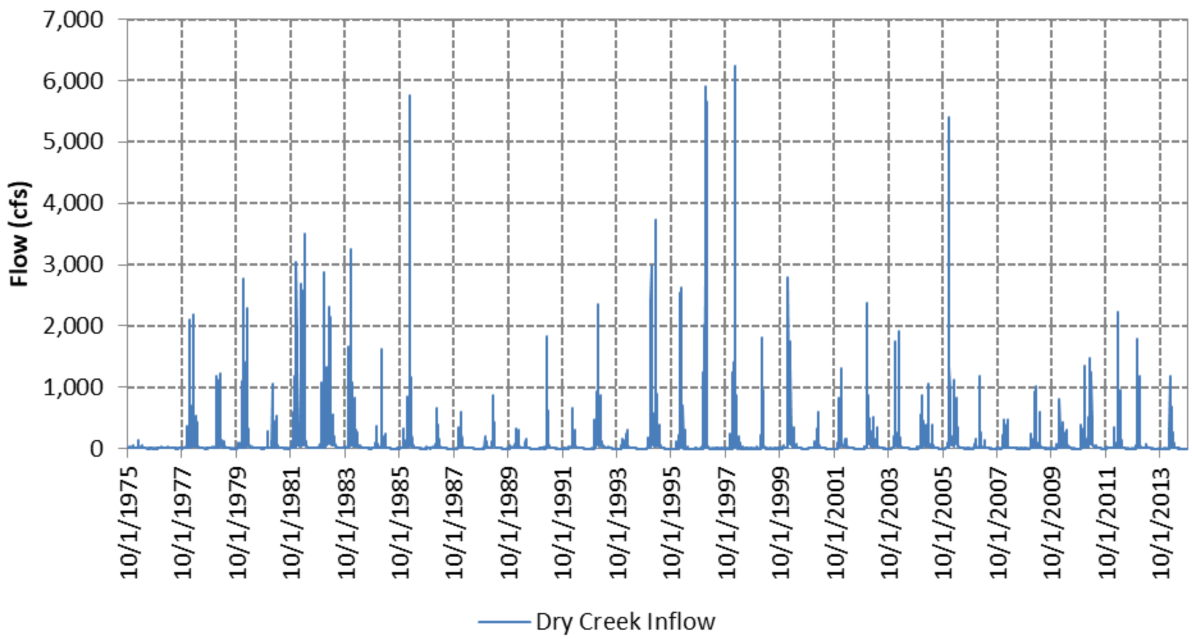

Figure 9-2. Base Case inflows to the Lower Bear River from Dry Creek.

Water Temperature Boundary Conditions

Synthetic water temperature data were developed for inflow locations. These locations include:

- Bear River inflow to Camp Far West Reservoir
- Rock Creek inflow to Camp Far West Reservoir
- Accretion in the lower Bear River between the non-Project diversion dam and the Wheatland Gage (Highway 65)
- Dry Creek inflow to the lower Bear River

Bear River Inflow to Camp Far West Reservoir

Temperature collected as part of relicensing Study 2-1, Water Temperature Monitoring, were used to develop boundary condition inflow temperatures in the Bear River above Camp Far West Reservoir. Air temperatures and Bear River inflows developed during calibration and validation, described in Sections 4 and 5, were used to develop a regression to estimate inflow temperatures. Results of the regression were very poor.

Alternatively, an annual time series of representative daily average inflow temperatures was developed by water year type, as shown in Figure 9-3. The available period of record was April 10, 2015 through July 2, 2018. According to the Smartsville water year type index[2], water year 2015 was classified as Critically Dry, 2016 was classified as Above Normal, 2017 was classified as Wet, and 2018 was classified as Below Normal. Temperatures were similar in all years from approximately September through March. Averages from all years in the period of record were used for this period. From April through August, historical data were

[2] As proposed in the new licenses for NID's Yuba-Bear Hydroelectric Project (NID 2011).

used directly, based on the Smartsville index water year type for that year. The historical period of record was missing a representative Dry year. A Dry year time series was developed by averaging the Below Normal and Critically Dry year type data.

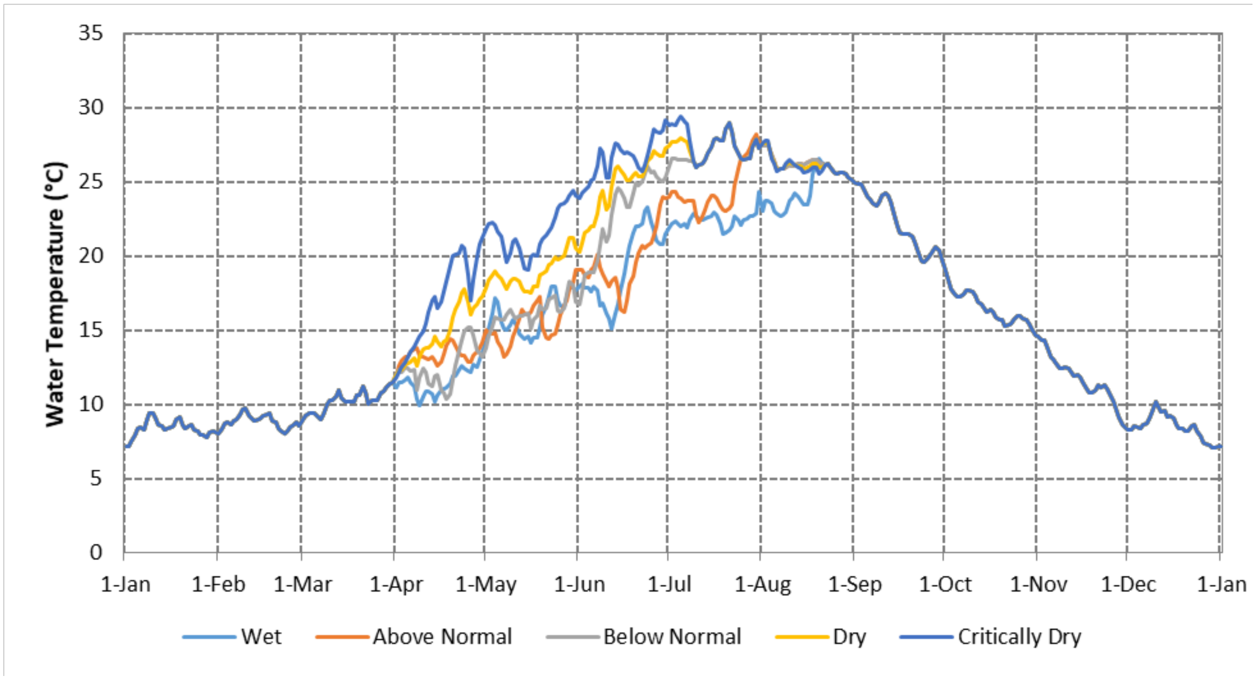

Figure 9-3. Water-year type dependent boundary condition water temperature for Bear River inflow to Camp Far West Reservoir.

The water year type dependent time series were applied to the full period of record, based on the historical Smartsville Index. This time series is shown in Figure 9-4.

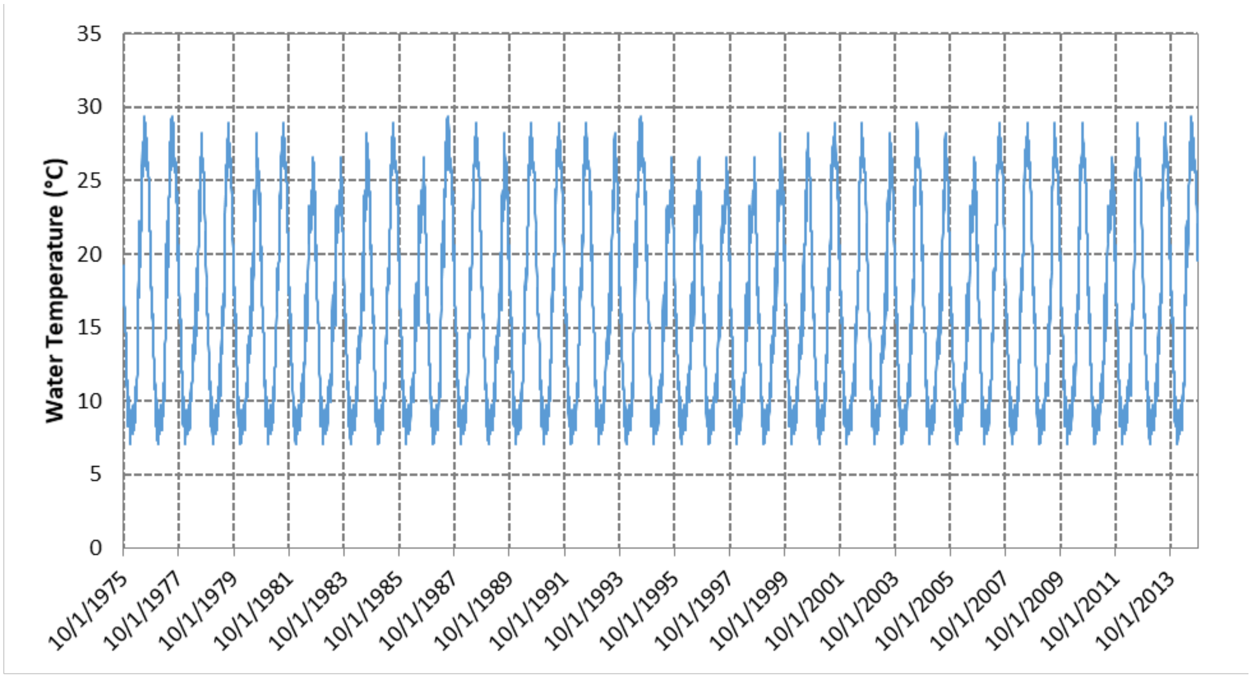

Figure 9-4. Period of record (water years 1976 through 2014) boundary condition water temperature for the Bear River inflow to the Camp Far West Reservoir.

Rock Creek Inflow to Camp Far West Reservoir

Temperature data collected as part of Relicensing Study 2-1, Water Temperature Monitoring, were used to develop boundary condition inflow temperatures in the Rock Creek above Camp Far West Reservoir. Regression-based inflow temperatures were developed based on Rock Creek inflows and air temperature. Two regressions were developed, one for the months of November through April, and the other for May through October. It was apparent in the data that there was a lag in water temperature response to changes in air temperature. A moving 3-day average significantly improved regression results in both seasons. Linear regression coefficients were developed using the Solver add-in for Excel, and are summarized in Table 9-1. Figure 9-5 shows a comparison of regression-based (predicted) water temperatures and historically observed water temperatures. The resulting period of record inflow time series is shown in Figure 9-6.

Table 9-1. Seasonal regression coefficients used to develop Rock Creek Inflow temperatures to Camp Far West Reservoir.

Regression Period	Regression Coefficients					R^2
	Rock Creek Flow (cfs)		Air Temperature (°C)		Intercept	
November-April	Log (Q)	0.656	3-day Average	0.865	0.5562	0.9642
May-October	Q	0.673	3-day Average	0.584	5.3902	

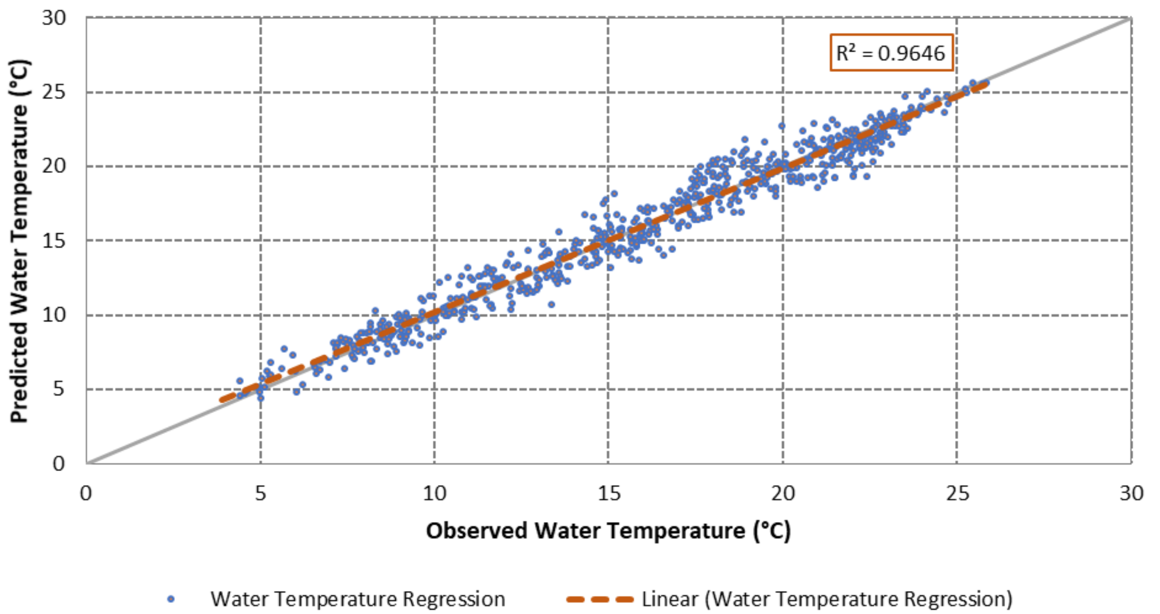

Figure 9-5. Regression results of water temperature for Rock Creek inflow to the Camp Far West Reservoir.

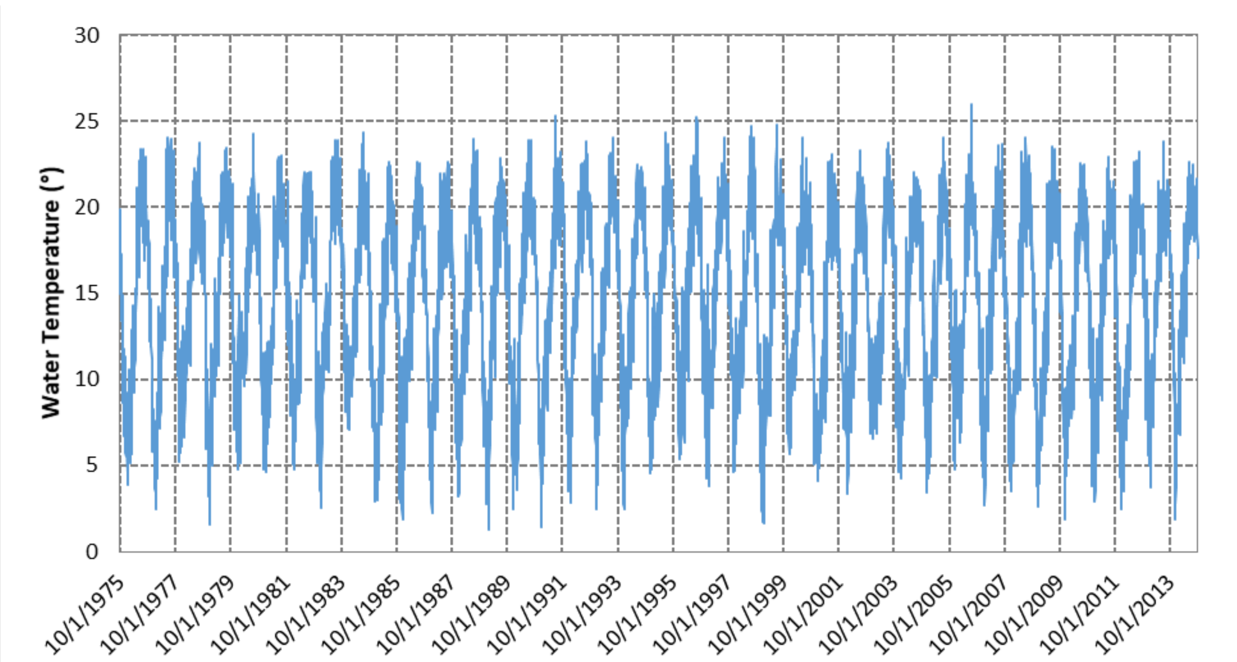

Figure 9-6. Period of record (water years 1976 through 2014) boundary condition water temperature for the Rock Creek inflow to the Camp Far West Reservoir.

Accretion in the Lower Bear River

Accretion temperatures were assumed to be similar to Dry Creek inflow temperatures. Data developed for Dry Creek, discussed below, were used to also represent accretion inflow temperatures.

Dry Creek Inflow to the Lower Bear River

As part of the Dry Creek/Best Slough Baseline habitat Assessment prepared by the U.S. Fish and Wildlife Service (2016), a water temperature model was developed using SNTEMP to simulate stream temperatures in Dry Creek. Daily average water temperature output in Dry Creek above the Bear River from this model was used as boundary condition inflow temperatures in the LBR Temp Model. Period of record water temperatures representing Dry Creek inflows to the Bear River are shown in Figure 9-7.

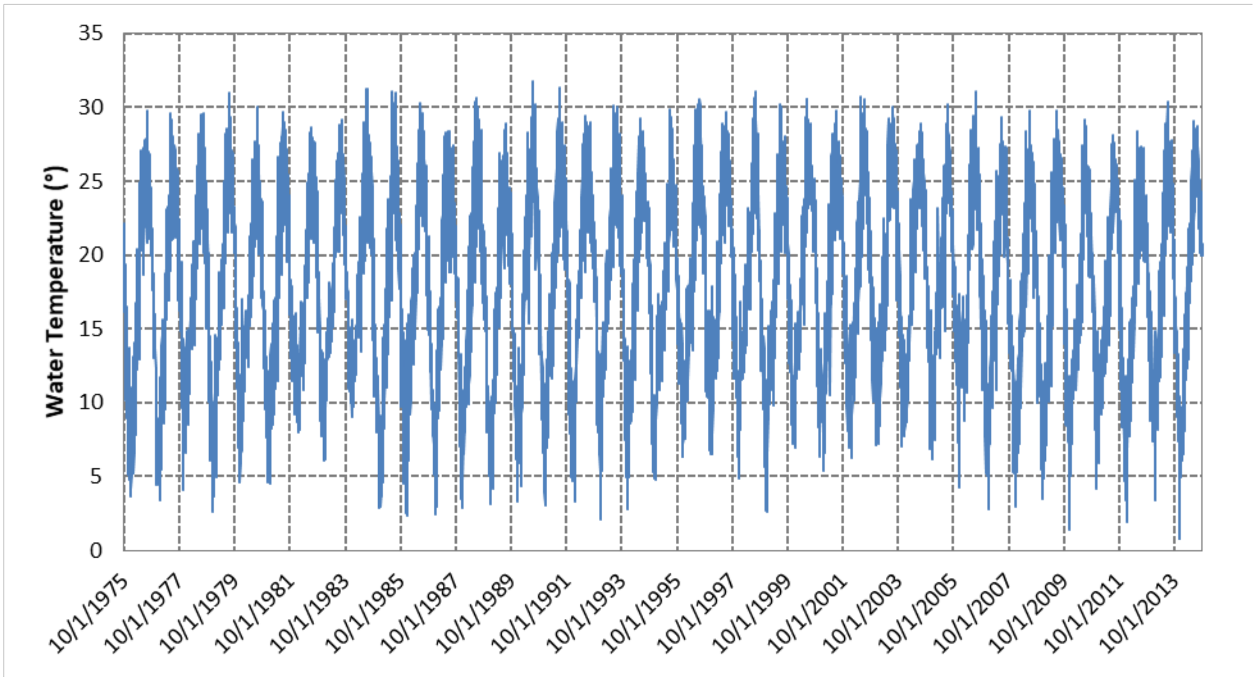

Figure 9-7. Period of record (water years 1976 through 2014) boundary condition water temperatures for Dry Creek inflow above Bear River.

10. References

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Appendix A – Bear River Hydrology Methods Memo
Appendix B – Temp Model Calibration and Validation Files
Appendix C – Temp Model GUI Configured for the Base Case