Appendix G: Water Quality Model Calibration & Scenario Reports

North Umpqua Subbasin Temperature Model Configuration and Calibration Report - Draft

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PRESENTED TO

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TETRA TECH

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1.0 INTRODUCTION

Tetra Tech is assisting USEPA Region 10 with technical and modeling activities to support the development of total maximum daily loads (TMDLs) for the North and South Umpqua River and Main Stem Umpqua River. These TMDLs are part of a group of 15 Oregon temperature TMDLs that cumulatively address over 700 temperature impaired segments, all of which are being replaced pursuant to a court order and judgement issued October 4, 2019. The TMDLs must be replaced over an eight-year period. For the 2006 Umpqua Basin TMDL, models were developed for periods in July 2001 and July 2002 (during the summer period) and did not coincide with the salmon and steelhead spawning use designation period. Tetra Tech is assisting USEPA Region 10 and Oregon Department of Environmental Quality (DEQ) with technical and modeling activities to support the development of TMDLs for spawning temperature impairments in the North Umpqua River Watershed.

The North Umpqua River Basin covers approximately 1,350 square miles (mi^2) and is part of the Umpqua River Basin in western Oregon. The North Umpqua River originates from Maidu Lake at an elevation of 5,998 feet (1,828 meters) at the western most portion of the watershed. It flows westward through steep canyons, going through the Umpqua National Forest, over Toketee Falls, and three impoundments along its course. The river joins the South Umpqua River to form the main Umpqua River just northwest of Roseburg. Major tributaries to the North Umpqua River include the Clearwater River, Fish Creek, Canton Creek, Steamboat Creek, Little River, and Rock Creek.

The waterbodies identified for model development, based on data availability, for the spawning period included: Canton Creek, Clearwater River, Lake Creek, North Umpqua River (riverine portions below Lemolo Lake, Toketee Lake, and Soda Springs Dam), Rock Creek, and Steamboat Creek. Figure 1-1 shows the locations of the waterbodies modeled.

During 2022, Oregon DEQ developed a Quality Assurance Project Plan (QAPP) which summarized the modeling approach used for the temperature TMDL replacement project applicable within the North Umpqua Subbasin (17100301). The QAPP (DEQ 2022) detailed the spatial and temporal extents of the water quality impairments, provided a modeling approach, identified data sources for defining and creating inputs, and outlined scenarios for evaluating management strategies. The modeling approach described in this document follows the approach described in the QAPP. This report briefly describes the technical approach used to develop the models for various waterbodies within the North Umpqua River watershed, summarizes available data and methods used to estimate model inputs, and serves as documentation of the model configuration and calibration for the North Umpqua mainstem and its tributaries.

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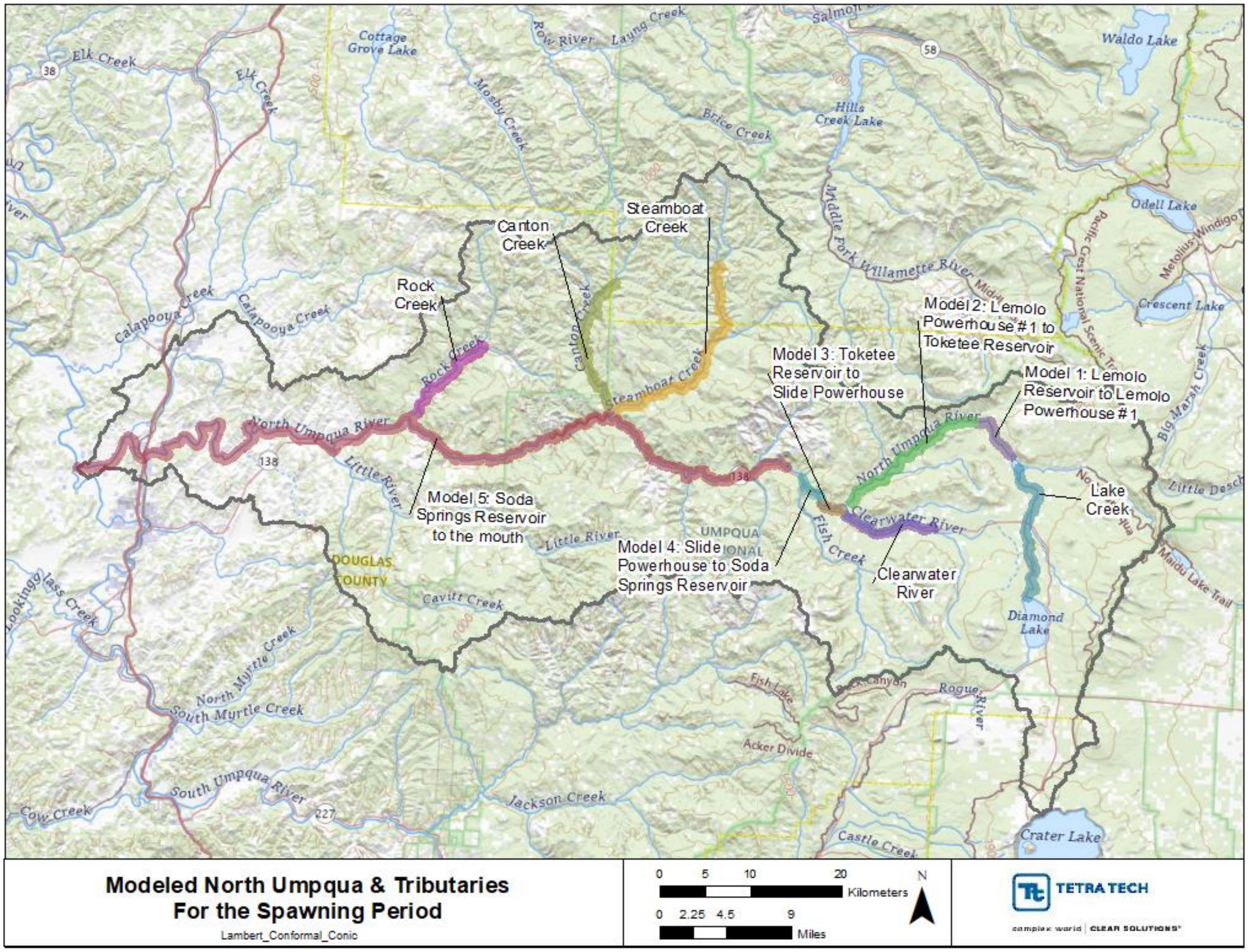

Figure 1-1 Heat Source Models developed in the North Umpqua watershed to support spawning temperature impairment analysis.

2.0 TECHNICAL APPROACH

The original setup and calibration of several North Umpqua models was completed by DEQ during the 2006 TMDL and documented in the Little River Watershed TMDL (DEQ, 2002) and Umpqua Basin TMDL and WQMP (DEQ, 2006). The models were developed using Heat Source Model version 7 (HS7). These models focused on the summer period during July 2001 and July 2002. Due to the number of TMDLs to be replaced and the mandated schedule, EPA and DEQ agreed that the approach to completing these TMDLs will rely on previously completed technical work as much as possible and rely on existing data.

New models were developed for the North Umpqua River and select tributaries to address spawning period listings using the summer models as the basis. The spawning period is usually defined from September 1 to June 15. The models were developed for the period from August 1 through October 15, 2009, based on the best available data that covered the warmest days in the spawning period from September 1 through October 15. Updating the Heat Source models mainly involved the determination of inflows, water temperatures, and weather conditions. Channel morphology and shading information were left unchanged from the original models. Shading is a critical controlling factor for the water temperature change along the river and is determined by both topography and vegetation. Shading information has been incorporated in the Heat Source models. It is assumed that the topography remains the same and vegetation does not change dramatically from July to the fall spawning season and was not changed in the model. The majority of trees in the North Umpqua are conifers, and the remaining deciduous trees will retain their leaves through the spawning model period, since deciduous trees in Oregon do not reach peak fall color change until mid-October (DEQ 2022).

Flow data were limited for the tributaries based on the preliminary review of the existing data. In the case of limited availability of flow data, flow scaling with the gaged drainage area or other approaches were considered. In 2009 DEQ collected continuous stream temperature (and a grab flow data at select locations) to support temperature model development for the spawning period. In addition to the DEQ data, temperature data were also collected by other organizations such as the U.S. Forest Service (USFS) and U.S. Department of Interior, Bureau of Land Management (BLM) during 2009 and were used to support spawning period model development on major tributaries to the North Umpqua River and calibration. In addition, the model includes two point source inputs that were not modeled previously in the HS7 model. The point source inputs include the Glide-Idleyld Sanitary District wastewater point source input to the North Umpqua River and the Rock Creek Hatchery input to Rock Creek.

The segmentations of the models are unchanged from the original models, and the existing spatial resolution of 50 meters was applied for all the models.

The newly developed models are based on the Heat Source version 8 (HS8) model. The improvements of HS8 from HS7 are discussed in the following section.

2.1 HEAT SOURCE MODEL VERSION 8

The HS8 models are based on HS7 models developed for the summer of 2001/2002. Stream morphology and vegetation parameters were unchanged from the HS7 summer models to HS8 spawning period models. HS8 requires channel bottom width specification. Therefore, the bankfull widths in HS7 models were converted to bottom widths for use in the HS8 models.

The model parameters for HS8 are similar to HS7. HS8 provides several improvements over HS7. Some of the notable improvements are listed below. Additional details on the HS8 are documented in the North Umpqua River TMDL QAPP (DEQ 2022).

- The major difference is that the model code is now written in Python 2.5 and C rather than Excel Visual Basic Application (DEQ 2008). Excel is used as the interface in HS8;
- HS8 can simulate an unlimited number of days, compared to a 21-day simulation in HS7;
- HS8 channel geometry uses the channel bottom width as the starting point while HS7 uses the channel bankfull width as the starting point of the channel geometry calculation;
- HS8 specifies bed conduction inputs including hyporheic exchange parameters;
- The shading calculation has been improved from HS7.

2.2 CONVERSION FROM HS7 TO HS8 AND GENERAL SETUP

Heat Source model development involved using the Heat Source models built using HS7 and converting them to HS8. The model input spatial resolution (dx) is 50 meters. Outputs are generated every 100 meters. The model time step (dt) is set between 0.3 and 2 minutes, depending on the model, to maintain stability, and outputs are generated every hour. The dx of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream and is consistent with the HS7 summer models.

All channel hydraulics related inputs such as stream gradient, elevation, side slope angle, and Manning’s n were retained (i.e., kept the same as the HS7 models). The only exception being the channel widths. The stream channel within Heat Source is represented as a trapezoidal cross-section. Unlike HS7 where the bank full width is an input into the model, the version HS8 model requires input of the channel bottom width. A separate macro (provided by DEQ) that utilizes the methodology from HS7 was used to calculate the channel bottom width. The macro uses the bank full width, the width to depth ratio and channel angle from HS7 model to calculate the bottom width.

The existing vegetation from the summer period HS7 models was used in the HS8 models. Vegetation was assumed to be largely unchanged from July to the fall spawning season, and the vegetation (and the topographic shade angles) were left unchanged in the models. The existing vegetation data includes four transverse vegetation samples taken in each of the seven cardinal directions, with the distance between samples taken as fifteen meters.

As part of model morphology input setup, the HS8 model also requires setting the bed conduction related parameters. These inputs include hyporheic zone thickness, percent hyporheic exchange, and porosity. Bottom width and side slope angle also affect these inputs by controlling the wetted perimeter of the channel (i.e., the portion or lateral length of the channel bed in direct contact with the stream). These stream morphological characteristics largely govern heat and mass transfer across the stream bed. Typically, information on the waterbody sediment size class (e.g., bedrock, gravel, sand, silt) is used as the basis for selecting literature values for these inputs. Sediment thermal conductivity and diffusivity were set at default values, which were based on an average of multiple sediment types, at 1.57 W/m/°C, and 0.0064 cm^2/sec, respectively.

The following sections discuss the model development and calibration for each of the waterbodies that were modeled.

3.0 CANTON CREEK

3.1 MODEL TIME PERIOD AND EXTENT

The model was developed for the period from August 01, 2009, to October 15, 2009. The extent of the model domain is Canton Creek from just above the confluence of Pass Creek (River kilometer [RKM] 16.95) to the mouth of Canton Creek at the confluence of Steamboat Creek. The extent of the Canton Creek Heat Source model is shown in Figure 3-1.

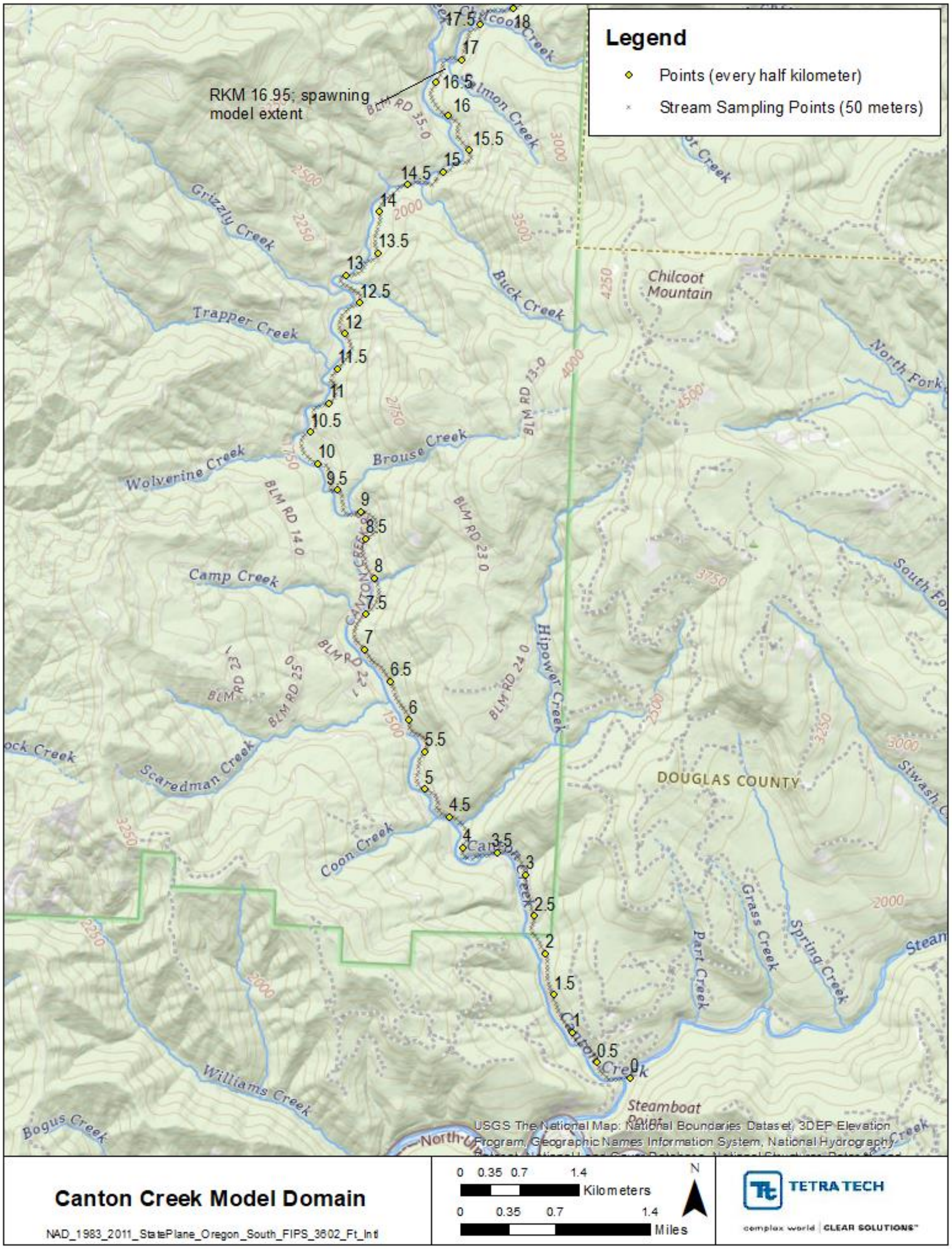

Figure 3-1. Extent of Canton Creek modeling domain

3.2 HEAT SOURCE MODEL INPUT – CANTON CREEK

In the Canton Creek model, the model time step (dt) was set at 2 minutes. Remaining general set up is consistent with the description in Section 2.2. The channel bottom widths used in the model ranged from 2.7 meters to 25.5 meters, with a mean of 11.9 meters. Figure 3-2 and Figure 3-3 show the computed stream channel elevation and gradient, respectively, and Figure 3-4 shows the calculated channel bottom widths for Canton Creek. Figure 3-5 shows the Manning's n values used in the model. The flow and water temperature inputs are discussed in the following sections.

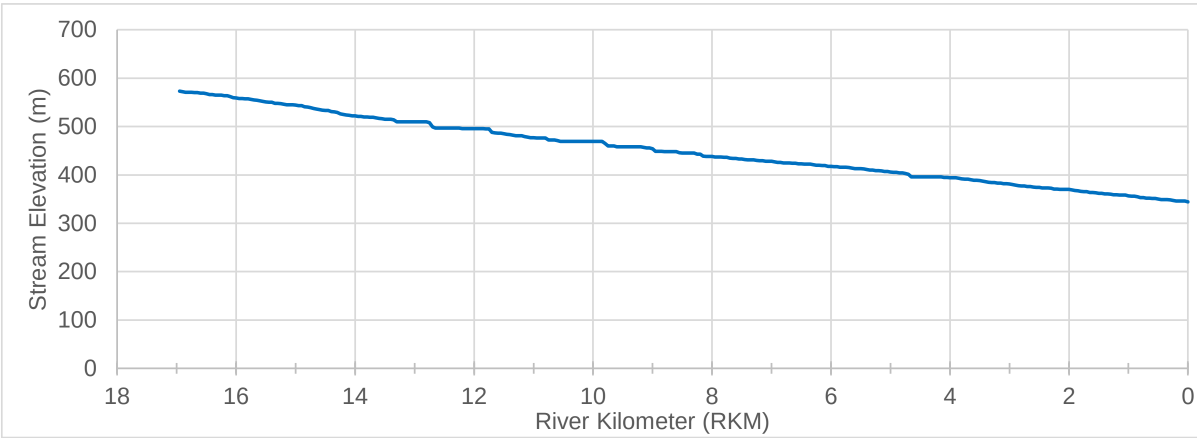

Figure 3-2. Canton Creek elevation.

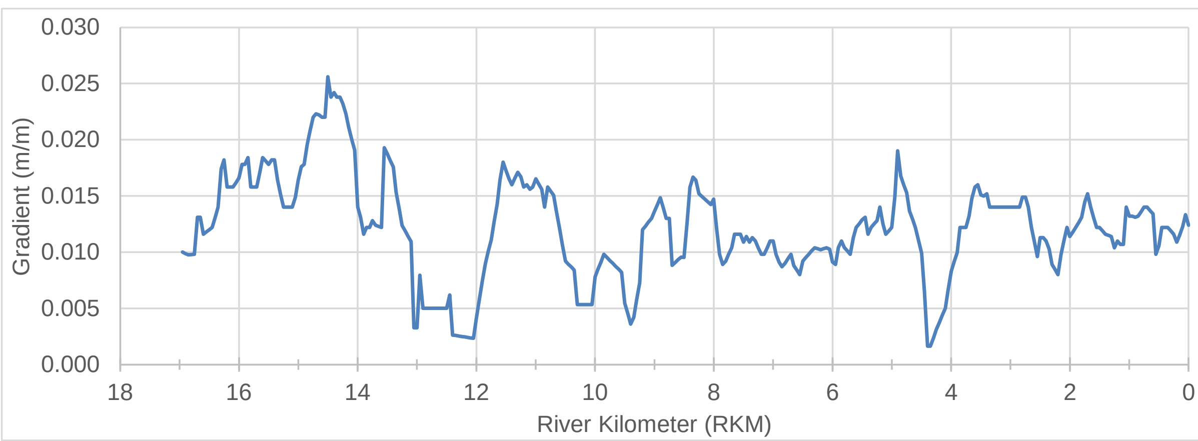

Figure 3-3. Canton Creek gradient.

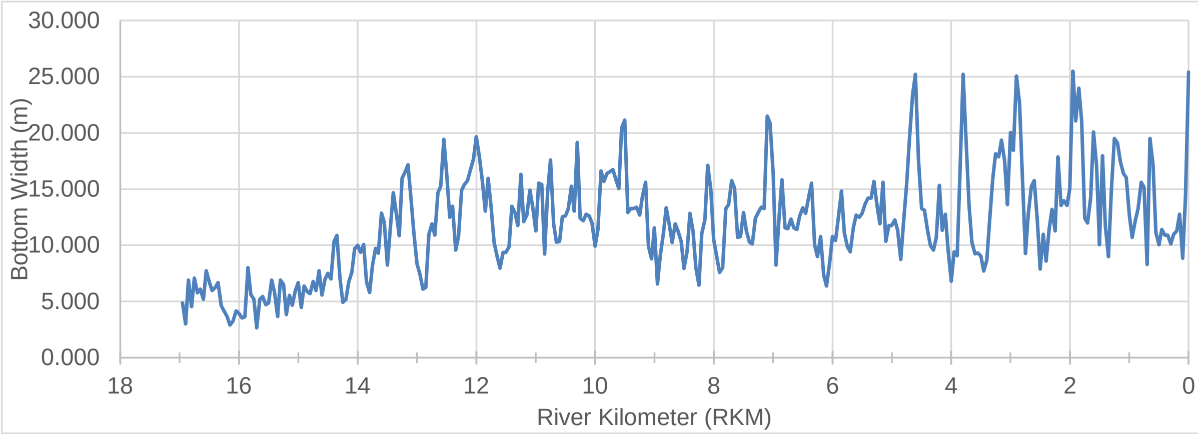

Figure 3-4. Canton Creek calculated bottom width.

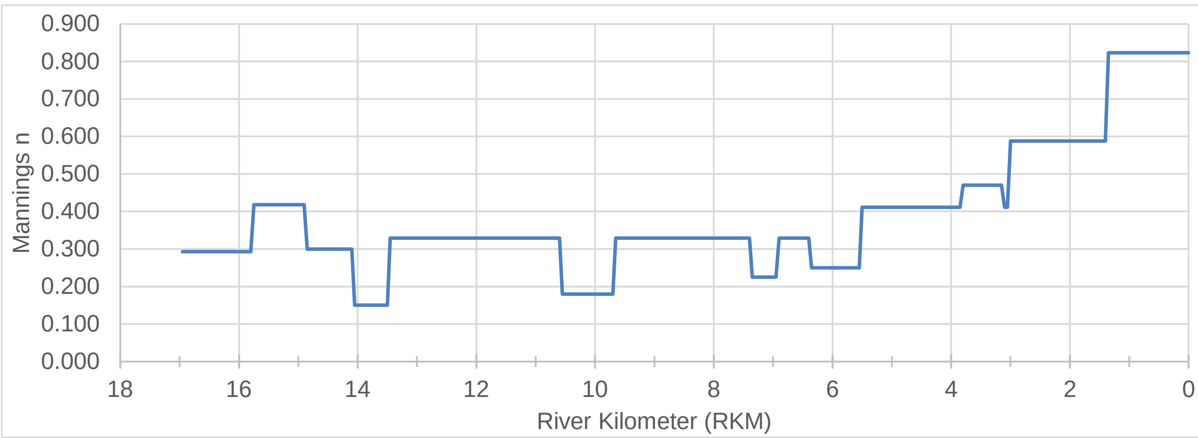

Figure 3-5. Canton Creek assigned Manning's n values.

3.3 FLOW INPUTS – CANTON CREEK

There are no flow data available for Canton Creek or any of its tributaries for 2009. The nearest flow gauge available was U.S. Geological Survey (USGS) 14316700 - Steamboat Creek near Glide, which was used as a reference gage for flow estimation (Figure 3-10). Table 3-1 shows an inventory of the model inputs to Canton Creek. The flow estimation is discussed in the next section.

Table 3-1. Inventory of available flow data in the Canton Creek watershed used in the Heat Source Model.

Station ID	Model location (Km)	Source	Type	Notes
Canton Creek	16.77	Derived data	Boundary condition	Estimated using 2002 model, using the ratio of the tributary flow to total flow at downstream end
Pass Creek	16.75	Derived data	Tributary	Estimated using 2002 model, using the ratio of the tributary flow to total flow at downstream end
Spring at model kilometer 13.2	13.2	Derived data	Tributary	Estimated using 2002 model, using the ratio of the tributary flow to total flow at downstream end
Trapper Creek	11.6	Derived data	Tributary	Estimated using 2002 model, using the ratio of the tributary flow to total flow at downstream end

Station ID	Model location (Km)	Source	Type	Notes
Wolverine Creek	10.2	Derived data	Tributary	Estimated using 2002 model, using the ratio of the tributary flow to total flow at downstream end
Brouse Creek	9.1	Derived data	Tributary	Estimated using 2002 model, using the ratio of the tributary flow to total flow at downstream end
Hipower Creek	4.25	Derived data	Tributary	Estimated using 2002 model, using the ratio of the tributary flow to total flow at downstream end

3.3.1 Flow Estimation – Canton Creek

Due to the lack of flow data on Canton Creek in 2009, stream flows had to be estimated to configure the model at all locations. Flows from the 2002 model were used in the estimation of flows. In the 2002 model the flows were set as a constant for the entire modeling period from July 12 to July 31 for each of the tributaries (Figure 3-6).

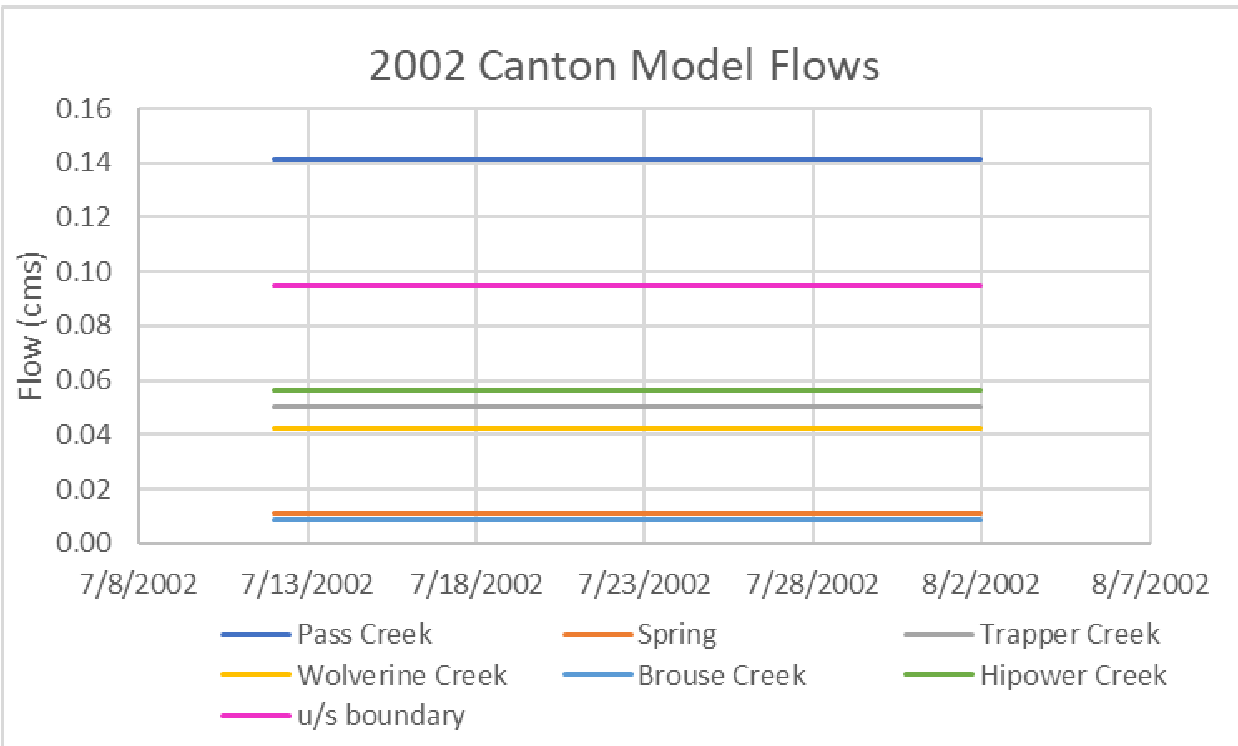

Figure 3-6. Flow inputs in the 2002 Canton Creek model.

Flow ratios were calculated for each of the tributaries using the constant flow and total flow at the downstream of Canton Creek. Figure 3-7 shows the distribution of flows during 2002. The majority of flows entering the system come from the upstream boundary of Canton Creek and Pass Creek.

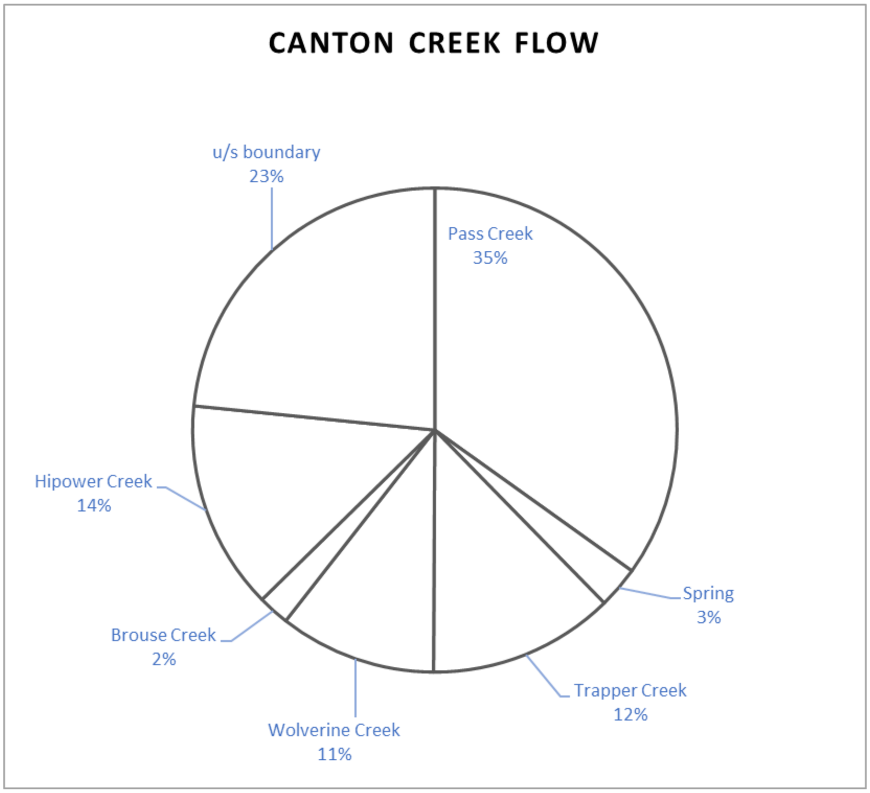

Figure 3-7. Distributions of tributary flow inputs in Canton Creek model (2002).

Next, the 2002 flows for Canton Creek in the Steamboat Creek model were regressed with the observed 2002 flows at USGS 14316700-Steamboat Creek near Glide. Figure 3-8 shows the regression relationship between Canton Creek and Steamboat Creek during 2002.

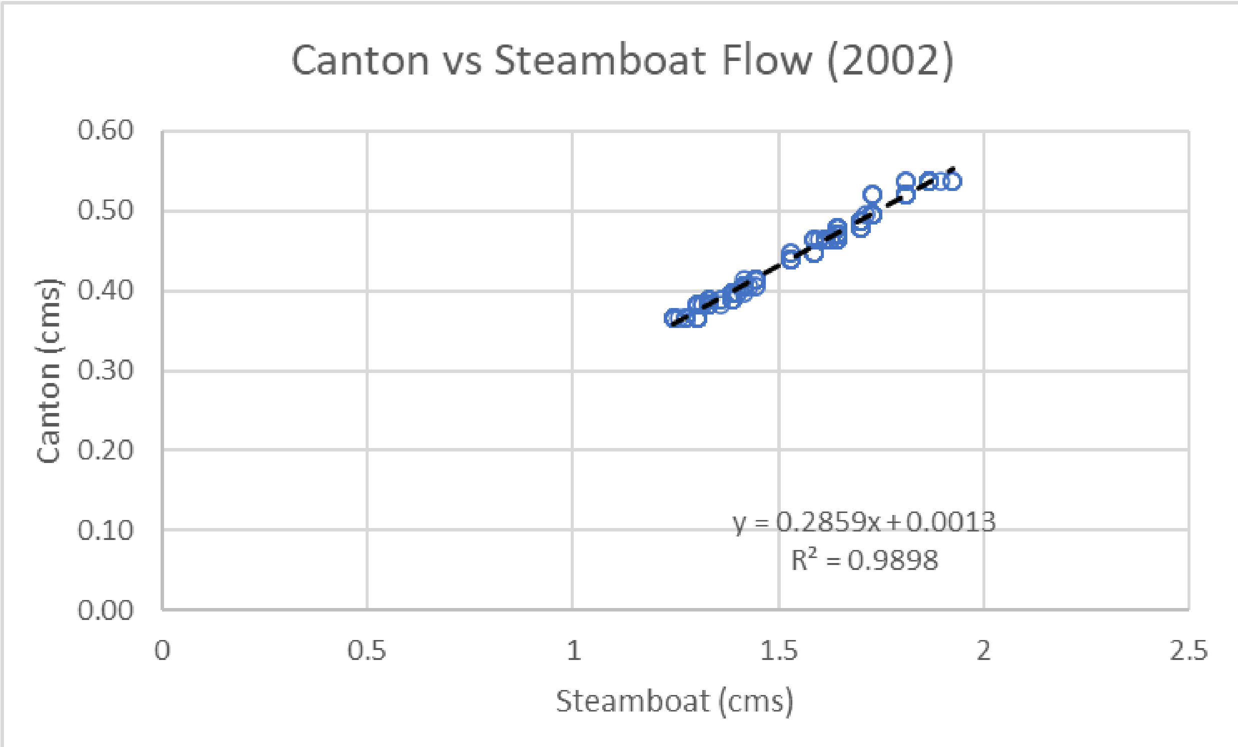

Figure 3-8. Canton Creek flows in Steamboat Creek model versus observed Steamboat Creek flows (2002).

The flows at Canton Creek for 2009 were then estimated using this regression relationship with the observed 2009 flows at the Steamboat near Glide USGS station. The calculated ratios for each tributary were then multiplied by the estimated Canton Creek 2009 flows to estimate each of the flow inputs for the 2009 Canton Creek model. During model calibration the calculated upstream boundary flow estimates were further adjusted (by doubling the estimated flows) to improve model prediction of water temperatures. Figure 3-9 shows the estimated flows for the upstream boundary and the various tributaries in the Canton Creek model. Note that the total flow estimated for Canton Creek at the most downstream end is used as tributary input for the Steamboat Creek model.

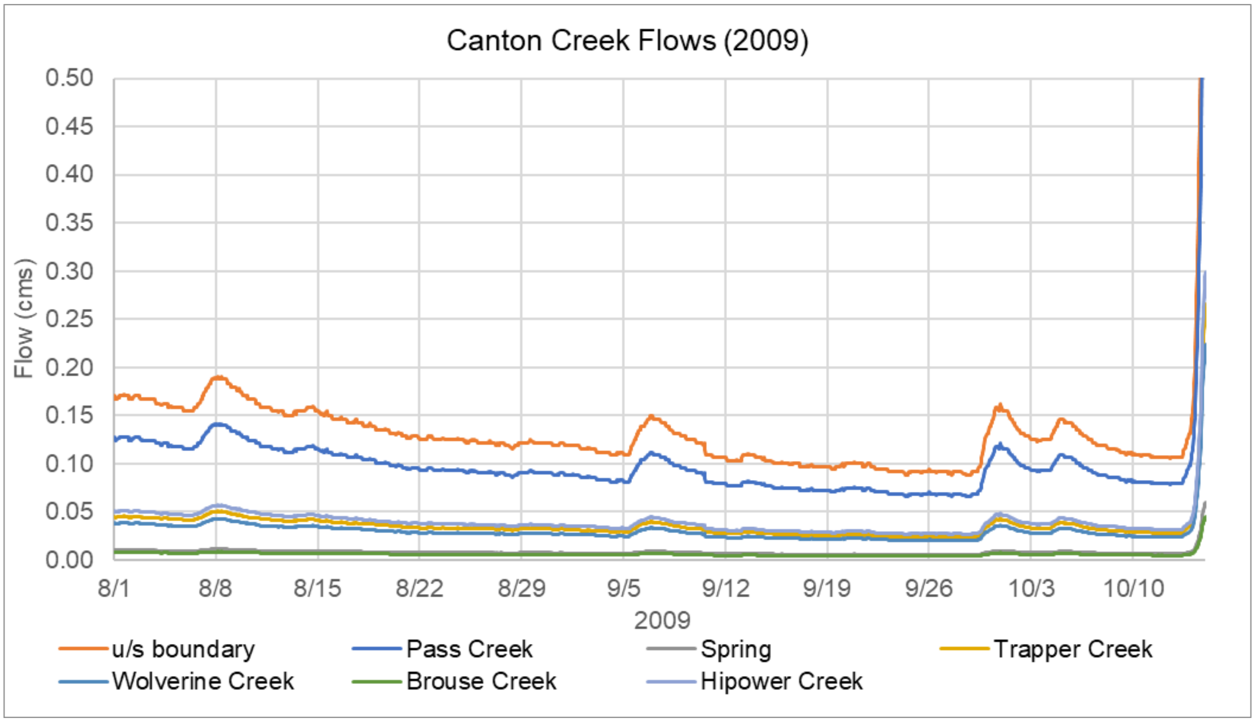

Figure 3-9. Estimated flows for the upstream boundary and tributaries of Canton Creek.

3.4 WATER TEMPERATURE INPUTS – CANTON CREEK

Temperature data were available from two BLM stations – Pass Creek above the confluence with Canton Creek (PASS) and Canton Creek above the confluence with Pass Creek (CAPA). Figure 3-10 shows the locations of the stream temperature monitoring stations that were used as boundary conditions to configure the model and for calibration. Table 3-2 provides an inventory of the water temperature data used in the model development.

Observed hourly timeseries from both BLM stations covered the entire modeling period. Figure 3-11 and Figure 3-12 show the observed hourly stream temperature data. Observed hourly stream temperatures from the CAPA station were used as the upstream boundary. The PASS station was used to configure the Pass Creek tributary input and for deriving temperatures for other tributaries. Relationships were developed with Pass Creek using the 2002 model inputs for each of the tributaries in the model as follows:

- Trapper Creek (Pass Creek minus 0.29 °C)
- Wolverine Creek (Pass Creek minus 1.19 °C)
- Brouse Creek set the same as Trapper Creek
- Hipower Creek (Pass Creek minus 2.29 °C)
- The spring was set to be the same as that in 2002 (i.e., at 18 °C)

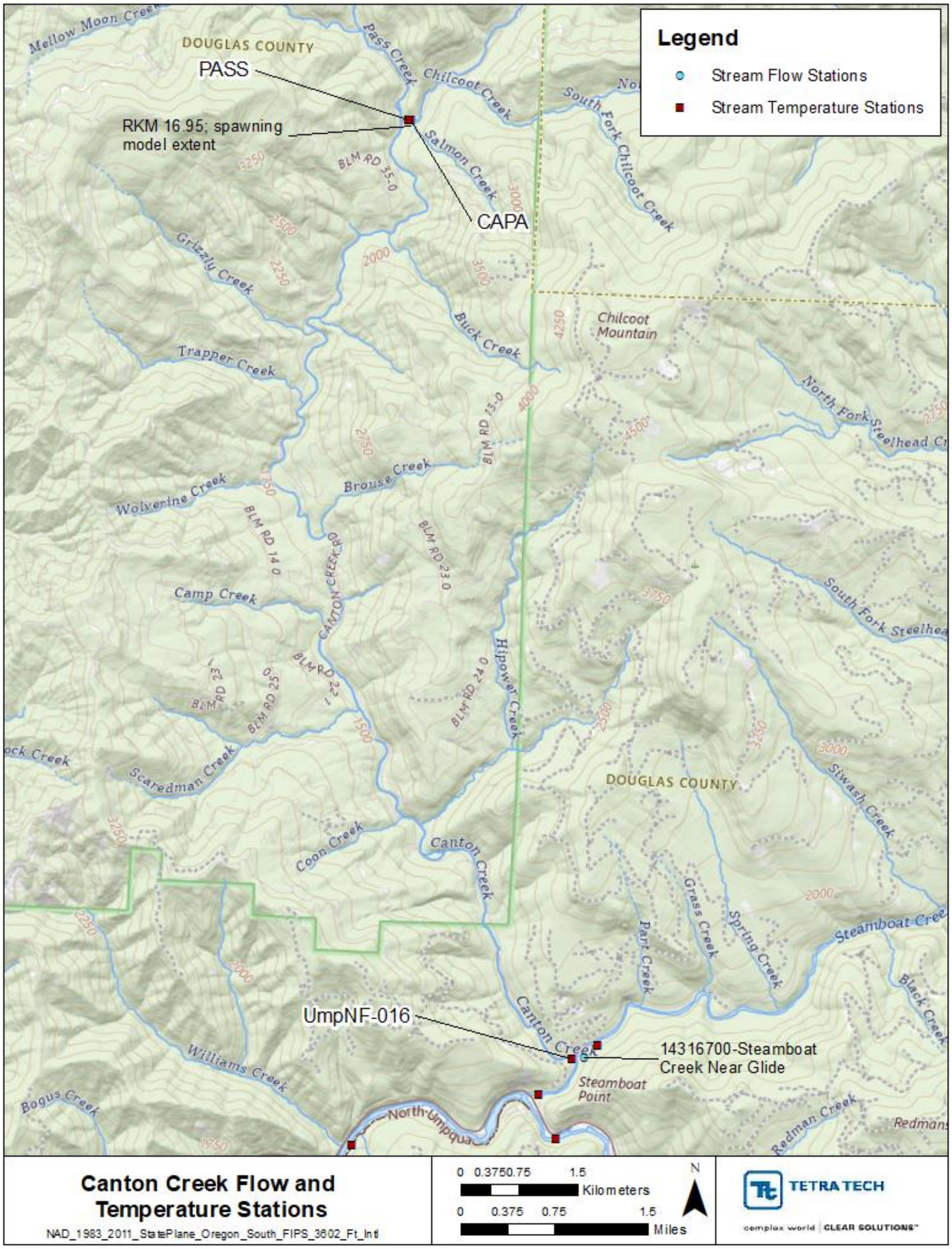

Figure 3-10 Canton Creek observed stream water temperature locations.

Table 3-2. Inventory of available water temperature data locations used to configure the Canton Creek model.

Station ID	Model location (Km)	Source	Type	Notes
Canton Creek above Pass Creek (CAPA) 40181-BLM	16.85	BLM	Boundary Condition	
Pass Creek (PASS) 42408-BLM	16.75	BLM	Tributary	
Spring at model kilometer 13.2	13.2	Derived data	Tributary	Constant 18 °C (same as in 2002 model)
Trapper Creek	11.6	Derived data	Tributary	Relationship derived from 2002 model.
Wolverine Creek	10.2	Derived data	Tributary	Relationship derived from 2002 model.
Brouse Creek	9.1	Derived data	Tributary	Same surrogate relationship as in 2002 model.
Hipower Creek	4.25	Derived data	Tributary	Relationship derived from 2002 model

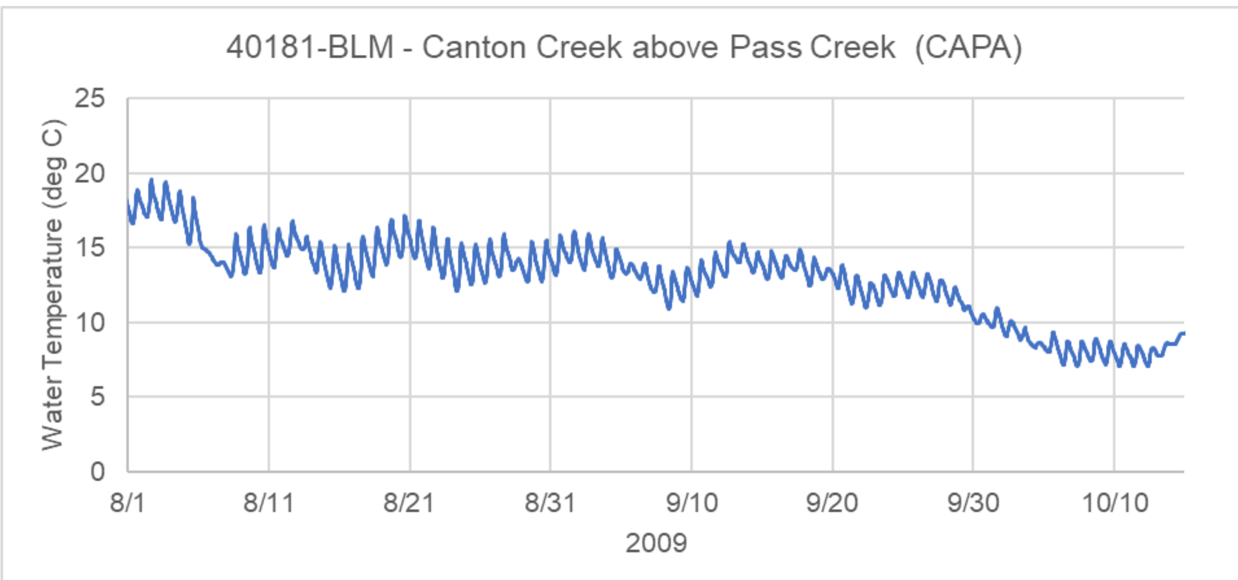

Figure 3-11. Observed water temperature at Canton Creek above Pass Creek (CAPA).

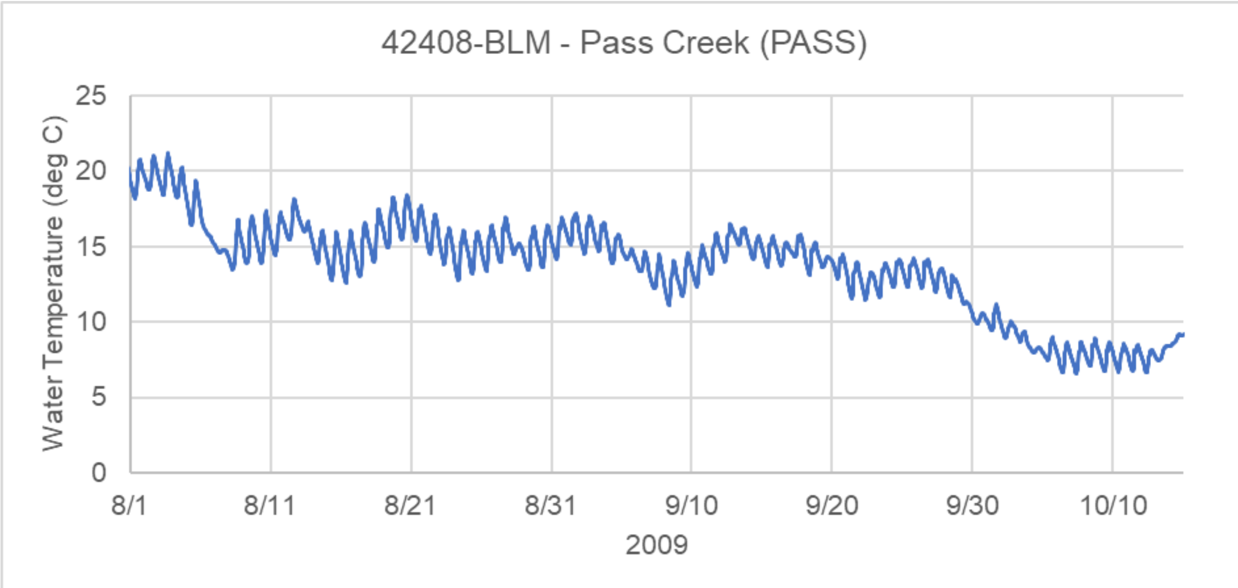

Figure 3-12. Observed water temperature at Pass Creek (PASS).

3.5 METEOROLOGICAL DATA – CANTON CREEK

Hourly meteorology inputs into the model include air temperature, relative humidity, and wind speed.

Table 3-3 lists the available meteorological data along the Canton Creek model subdomain with relevant data for the model simulation time period.

Air temperatures were specified using data from the station 23894-ORDEQ (North Umpqua upstream of Steamboat Creek) that was specifically collected by DEQ during 2009 to support the calibration. The 23894-ORDEQ station had missing data for the month of August and during October (from October 12 onwards). These missing air temperature data were filled using the air temperature data from Roseburg Regional Airport meteorological station, after applying an adiabatic lapse rate adjustment and further refinement during calibration. Figure 3-14 shows the hourly air temperatures timeseries used in the model. Relative humidity and cloud cover were taken from the National Climatic Data Center (NCDC) Roseburg station (NOAA 2005). The Roseburg station provided descriptive sky cover information, which was converted to tenths from 0 to 1 for input in the Heat Source Model. Wind speed data were taken from the Grandad Remote Automatic Weather Station (RAWS) station and adjusted during calibration. The wind speed was reduced by 35% except for the first four days. For the first four days the wind speed was increased 50%, this was done to better match the calibration during the first week of August. Figure 3-14 shows the hourly meteorological inputs used for the Canton Creek model.

Table 3-3. Inventory of available Meteorological Station Data for Canton Creek

Station ID	Station Name	Elevation (m)	Latitude/ Longitude	Frequency	Available Met Data	Source	Notes
23894-ORDEQ	North Umpqua Upstream of Steamboat Creek	366	43.3403°/ -122.733	Hourly	Air Temperature	DEQ	Air Temperature used. Missing data estimated using Roseburg Air Temperature
WBAN 24231	NCDC – LCD station Roseburg Regional Airport	152.9	43.23367 °/ -123.3578 °	Hourly	Air Temperature, Relative Humidity, Cloud cover, Wind Speed	NCDC - LCD	Relative Humidity and Cloud Cover used
GDFO3	Grandad	884.15	43.41583 / -122.577	Hourly	Air Temperature, Relative Humidity, Wind Speed	RAWS	Wind Speed used after adjustment

Figure 3-13 Canton Creek Meteorological Stations

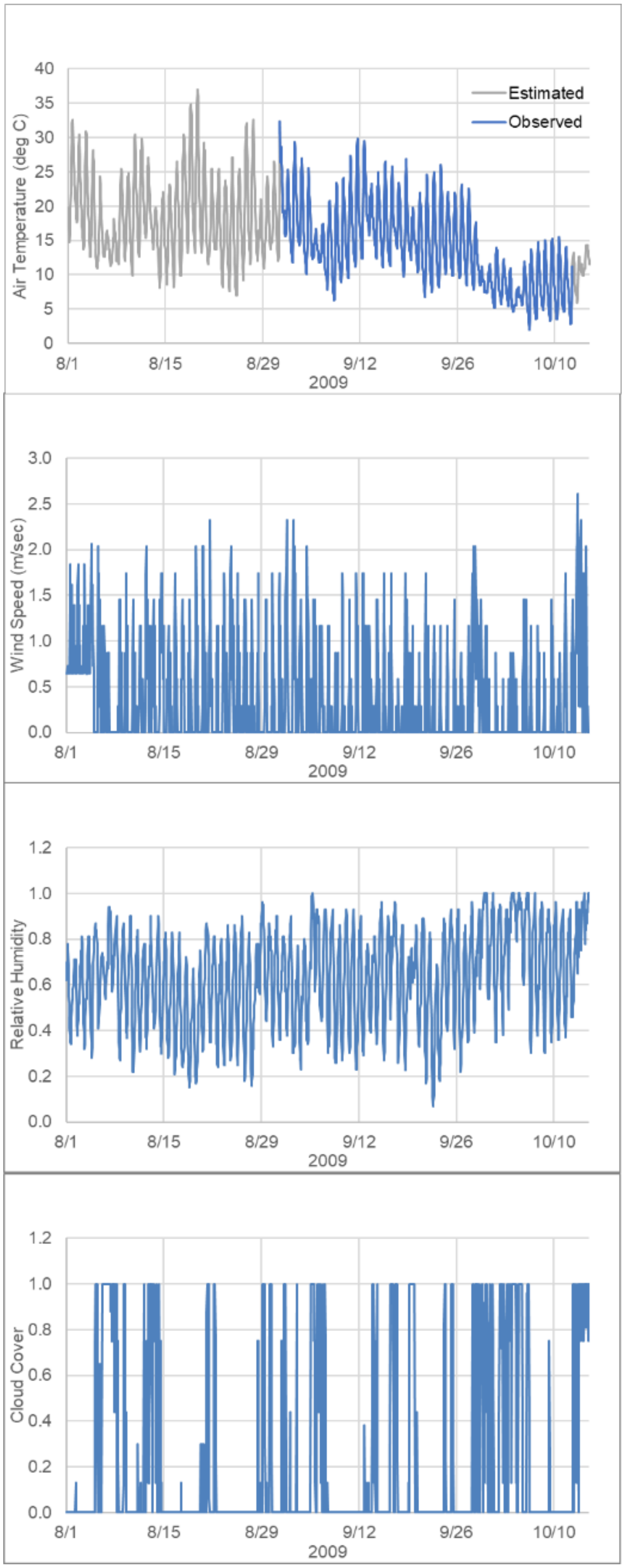

Figure 3-14 Meteorological input specified in the Canton Creek model.

3.6 MODEL CALIBRATION – CANTON CREEK

The Canton Creek HS8 model was simulated for the time period from August 1, 2009, to October 15, 2009. It covers the 16.95-kilometer study area from just above the confluence of Pass Creek to the mouth. No flow data are available for calibration of flow. The model outputs were generated hourly, every 100 meters.

The model was calibrated against observed water temperature data from a USFS station at the mouth. Model calibration refers to the comparison of observed data to modeled values. Table 3-4 shows the observed water temperature station used in the Canton Creek Heat Source model calibration. The model location in the table below describes the distance of the calibration site from the most downstream model node. The location of the water temperature calibration station used can be found in Figure 3-10.

Table 3-4. Calibration site used in the Canton Creek Heat Source Model Calibration

Station ID	Description	Model location (km)	Data Type	Source
UmpNF-016	Canton Creek at Mouth	1.25	Hourly Water Temperature	USFS

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A combination of visual and computed error statistics was used to assess the model calibration. The goodness of fit for the Heat Source model was summarized using the mean error (ME), average absolute mean error (MAE), root mean square error (RMSE), and the Nash-Sutcliffe efficiency coefficient (NSE) as measures of the deviation of model-predicted water temperatures from the measured values. Detailed explanation on each of the statistics can be found in the QAPP for this project (DEQ 2022). These model performance measures were calculated as follows:

$$ME = \frac{1}{n}\sum(P - O)$$

$$MAE = \frac{1}{n}\sum|P - O|$$

$$RMSE = \sqrt{\frac{1}{n}\sum(P - O)^2}$$

$$NSE = 1 - \frac{\sum(P - O)^2}{\sum(O - \bar{O})^2}$$

where,

P = model predicted values

O = observed values

$\bar{O}$ = the mean of observed values

n = number of samples

3.7 TEMPERATURE CALIBRATION – CANTON CREEK

Hourly temperature observations were compared at the Canton Creek at mouth station. The model captures the overall seasonal trends well. The model tends to overestimate the diurnal trends during August, especially the first week of August and tends to overestimate the daily minimum as seen in Figure 3-15. In general, the modeled daily maximum temperatures (Figure 3-16) agree well with data with some overestimation seen during the first week of August.

Channel morphology related inputs were retained from the HS7 model during calibration. The sediment heat exchange parameters, i.e., sediment thermal conductivity and diffusivity, and wind function coefficients, were applied at their HS8 default values.

Several adjustments were made during calibration to improve model prediction of water temperature. These included adjustments of the wind speeds which were discussed in the meteorological data section. The adjustments to wind speed were necessary to improve the model prediction of daily maximum water temperatures. Flow data were limited for Canton Creek and flow adjustments to the upstream boundary flows were also done by increasing the flows to improve the predicted temperatures along the system. This was discussed in the flow estimation section. Finally, hyporheic flow was also specified to better capture observed hourly temperatures. The addition of hyporheic flows helped reduce the diurnal variation. The observed data showed reduced diurnal variation starting around September, and the hyporheic flow adjustments helped improve the results. A final value of 50 percent hyporheic exchange throughout the system was arrived at during calibration.

Table 3-5 shows the hourly and daily maximum water temperature calibration statistics. The overall calculated model calibration error statistics showed a ME, MAE and RMSE of less than 1 ºC for the hourly and daily maximum water temperatures. The NSE for the hourly and daily maximum water temperatures were 0.73 and 0.87 respectively.

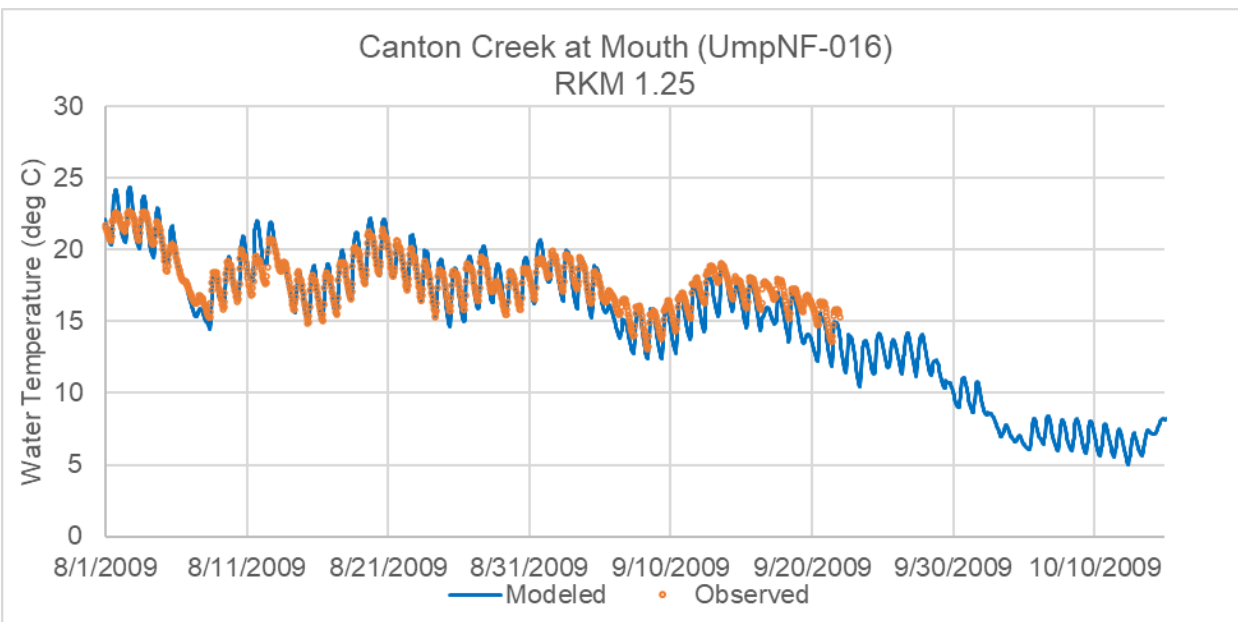

Figure 3-15. Observed versus Modeled Hourly Water Temperature – Canton Creek at Mouth (UmpNF-016)

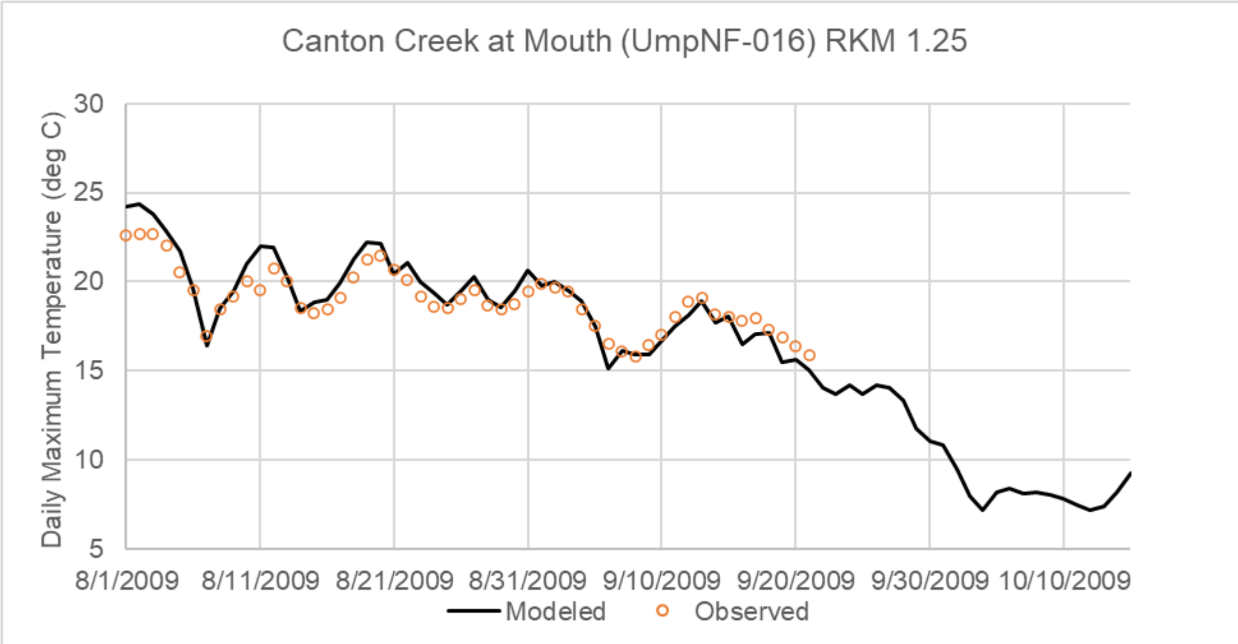

Figure 3-16. Observed versus Modeled Daily Maximum Water Temperature – Canton Creek at Mouth (UmpNF-016)

Table 3-5. Hourly and Daily Maximum Water Temperature calibration statistics for Canton Creek (August 1 to September 21, 2009)

Statistic	**Canton Creek at Mouth (UmpNF-016) RKM 1.25**
Hourly Temperature Statistics	
ME	-0.35
MAE	0.77
RMSE	0.97
NSE	0.73
Count	1,248
Daily Maximum Temperature Statistics	
ME	0.25
MAE	0.66
RMSE	0.84
NSE	0.87
Count	52

4.0 CLEARWATER RIVER

4.1 MODEL TIME PERIOD AND EXTENT

The model was developed for the period from August 01, 2009, to October 15, 2009. The Clearwater River is a tributary to the North Umpqua River at Toketee Reservoir. The river is part of the Pacific Power hydroelectric project area. Flow below Stump Lake has been reduced by hydroelectric water diversion. The extent of the spawning model domain is from Clearwater River below Diversion 1 (RKM 12.4) to the mouth. The model extent of the Clearwater River Heat Source Model is shown in Figure 4-1.

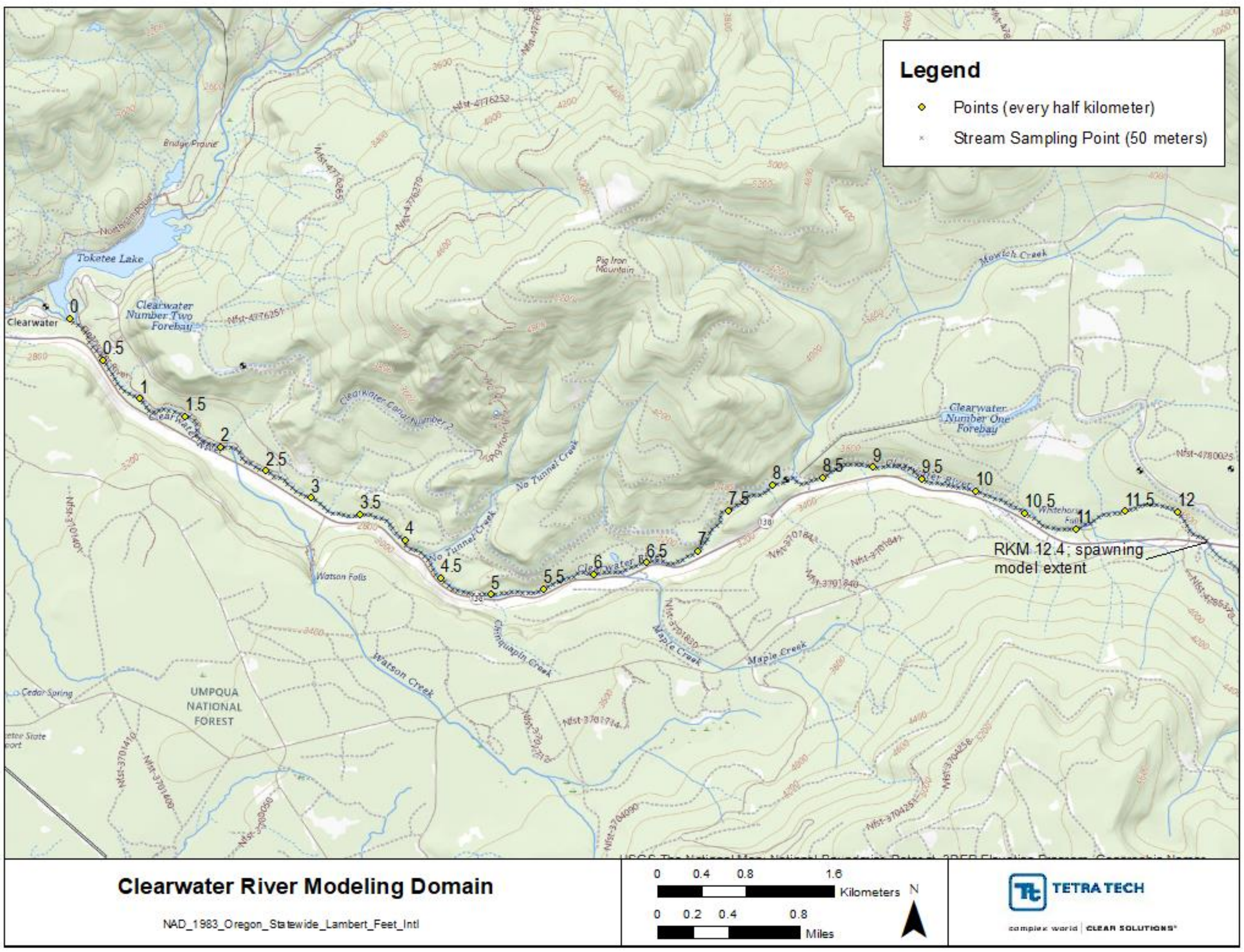

Figure 4-1. Extent of the Clearwater River modeling domain

4.2 HEAT SOURCE MODEL INPUT – CLEARWATER RIVER

In the Clearwater River model, the model time step (dt) was set at 1 minute. Remaining general set up is consistent with the description in Section 2.2. The channel bottom widths used in the Clearwater River model ranged from 5.2 meters to 17.8 meters, with a mean of 10.4 meters. Figure 4-2 and Figure 4-3 show the computed stream channel elevation and gradient, respectively, and Figure 4-4 shows the calculated channel bottom widths for the Clearwater River. Figure 4-5 shows the Manning's n values used in the model. The flow and water temperature inputs are discussed in the following sections.

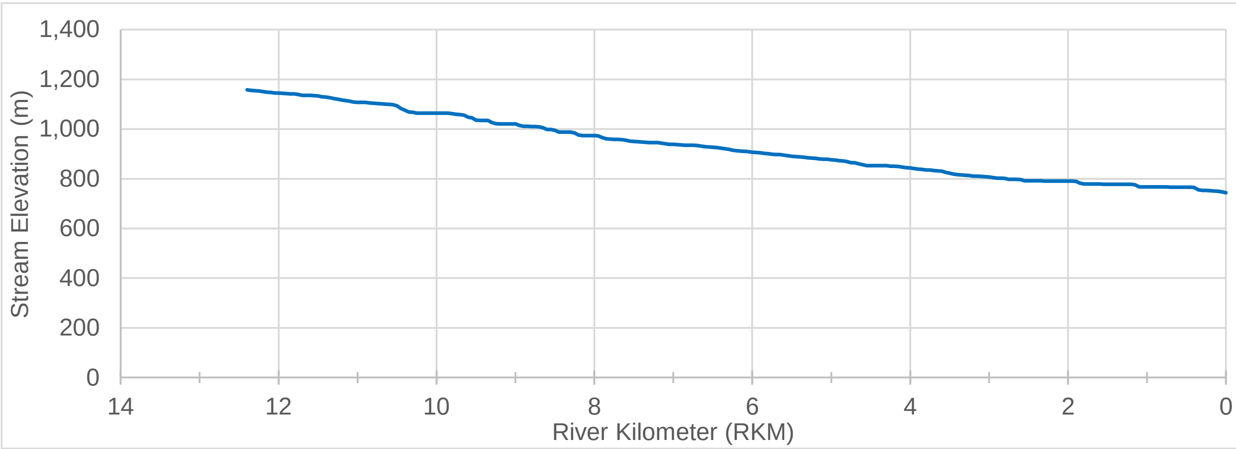

Figure 4-2. Clearwater River elevation.

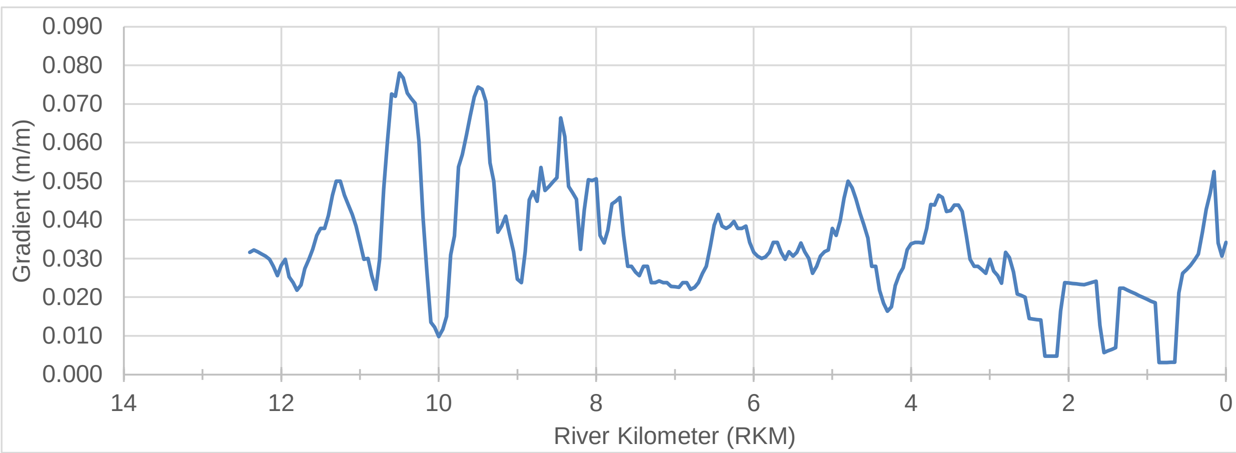

Figure 4-3. Clearwater River gradient.

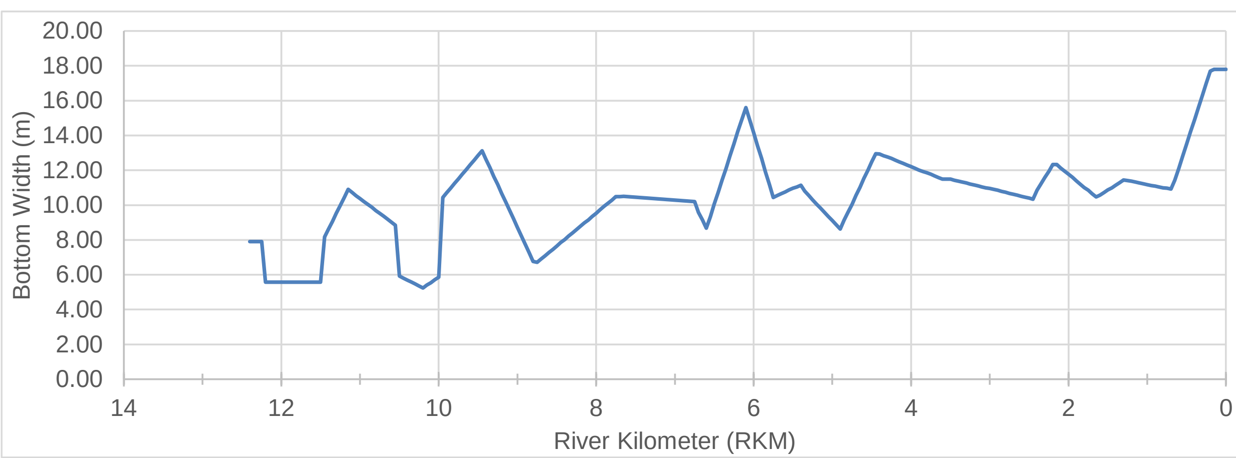

Figure 4-4. Clearwater River calculated bottom width.

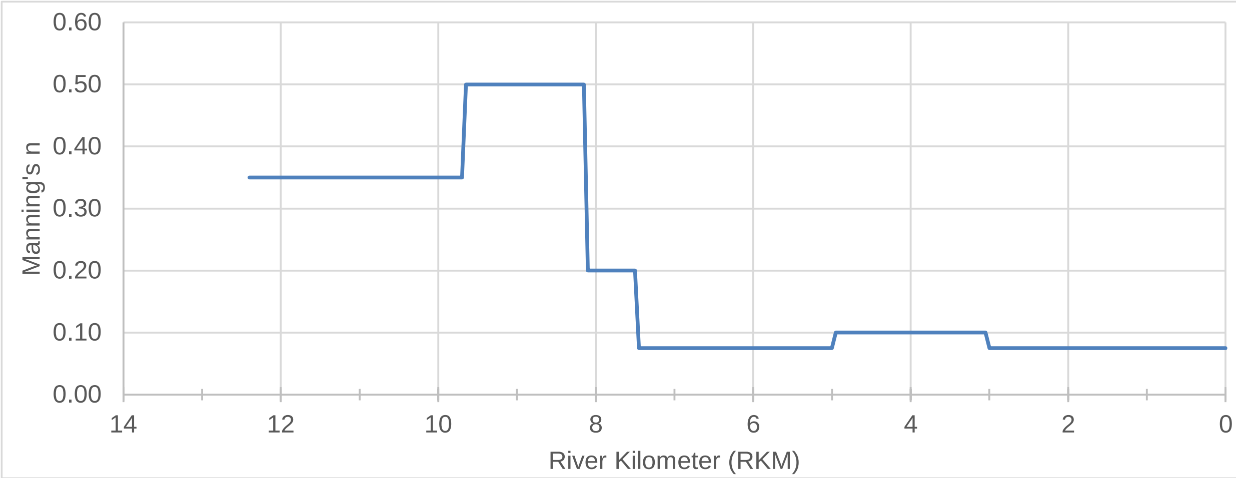

Figure 4-5. Clearwater River assigned Manning's n values.

4.3 FLOW INPUTS – CLEARWATER RIVER

Limited flow data were available for configuring the Clearwater River model. Available flow data included a gage at the upstream boundary with partial flow records that started from October 1, 2009, and grab sample measurements taken during September 2009, by DEQ at Mowich Creek and Watson Creek. Table 4-1 shows an inventory of the available flow data and notes how they were used. Model development for the Clearwater River relies upon deriving flow rates for Powerhouse #1 at the upstream boundary, Mowich Creek, and Watson Creek. Unknowns include withdrawals at Powerhouse #2, which was derived during modeling.

Table 4-1. Inventory of available flow data in the Clearwater River watershed used in the Heat Source Model development.

Station ID	Model location (Km)	Source	Type	Notes
Clearwater River below Diversion 1 (14314500)	12.4	USGS	Boundary condition	Period of record from 10/1/1988 to current. Missing data in 2009. Only available from 10/1/2009 onwards. Estimated using drainage area relationship
Mowich Creek	8.2	Derived data	Tributary	Derived for other periods using drainage area relationship.
Powerhouse 1 outlet	8.1	Derived data	Tributary	Estimated using flow balance
Watson Creek	2.1	Derived data	Tributary	Measured instantaneous flow for 9/10/2009. Derived for other periods using drainage area relationship.

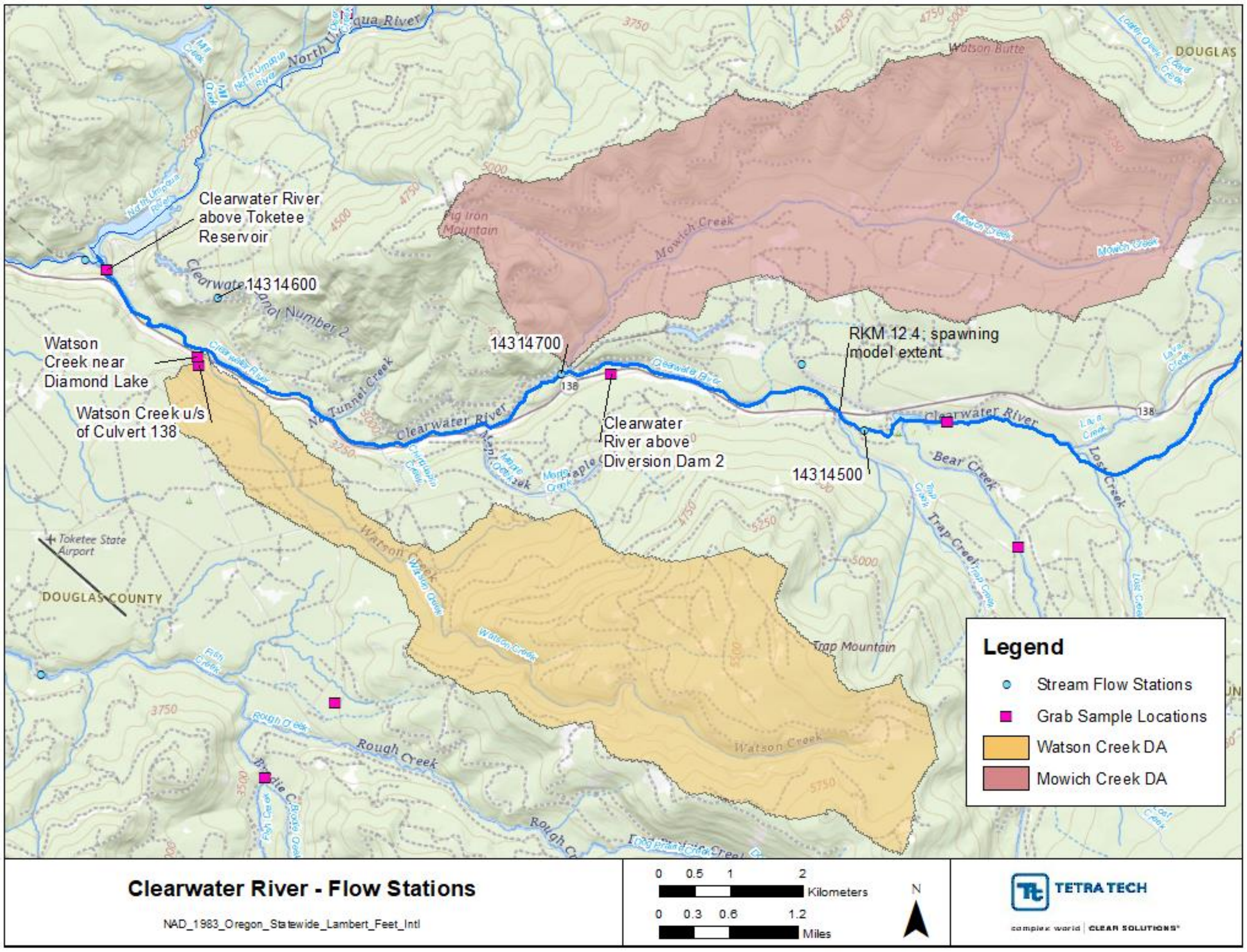

Figure 4-6. Clearwater River observed stream flow and drainage area locations for estimated streams.

4.3.1 Flow Estimation – Clearwater River

The upstream boundary below Powerhouse #1 diversion were defined using flows from USGS 14314500 Clearwater River above Trap Creek near Toketee Falls. The flow data at this gage start from October 1, 2009. Missing flows prior to October 1 were derived using a drainage area relationship with USGS 14314700-Clearwater River below Mowich Creek near Toketee Falls. The observed flows at USGS 14314500 starting October 2009 were used as a guide during estimation, and the exponent in the drainage area equation was adjusted to better match the observed flows. Figure 4-7 shows the estimated flows at USGS 14314500 that were used to define the upstream boundary in the Clearwater River model. Note that the estimated flows prior to 2009 were appended to the observed flows from October 2009 onwards and specified in the model.

$Q_u = Q_g\left(A_u/A_g\right)^a$ Equation 1

Q_u = the estimated discharge for the ungagged watershed

Q_g = observed discharge for the gaging station

A_u= the area of the ungaged watershed (USGS 14314500 reported drainage area of 41.6 mi^2)

A_g = the area of the gaged watershed (USGS 14324700 reported drainage area of 60.4 mi^2)

a = the exponent of area (0.3 – arrived at using flow balance).

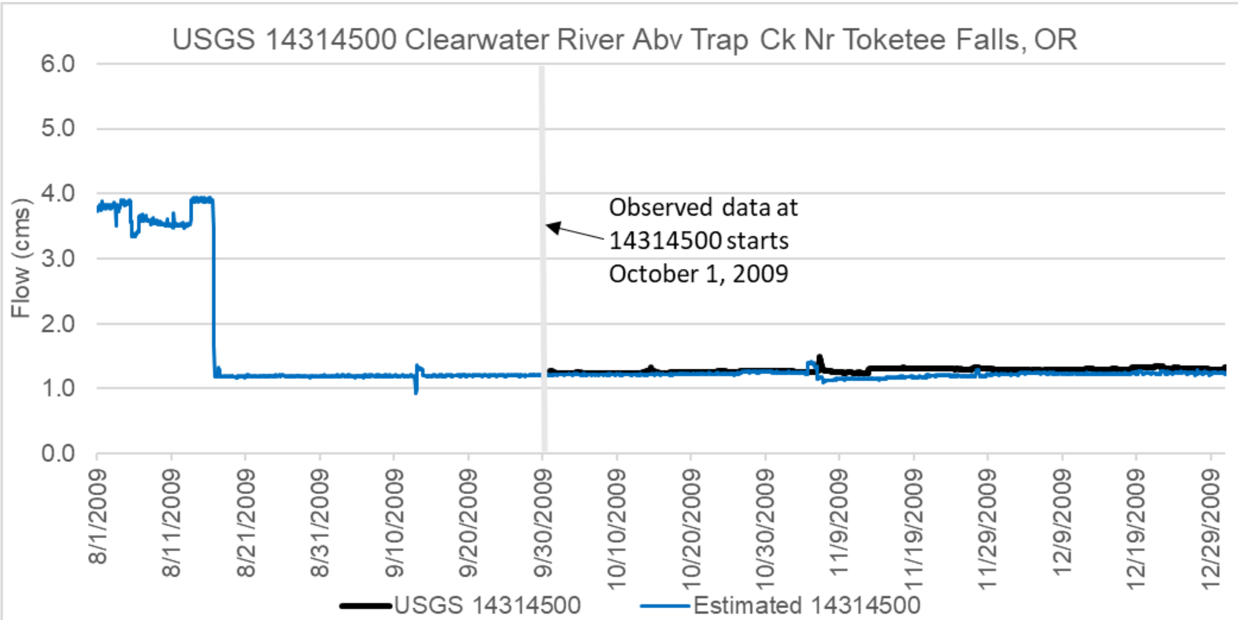

Figure 4-7. Estimated flows at USGS 14314500 (Clearwater River upstream boundary)

Mowich Creek flows into Clearwater River at RKM 8.2 just downstream of where the Powerhouse #1 outlet goes into Clearwater River at RKM 8.1. Flows for Mowich Creek were derived using the drainage area ratio method using USGS 14314700 (Clearwater River below Mowich Creek near Toketee Falls, OR). Figure 4-6 shows the drainage area for Mowich Creek. The Mowich Creek drainage area calculated using the USGS Stream Stats program was determined to be 11.1 mi^2, and the drainage area for USGS 14314700 was 60.4 mi^2. An exponent of 1.2 was used to refine the flow estimates using the one flow estimate for Mowich as a guide. Figure 4-8 shows the estimated flows for Mowich Creek. Note that the one Mowich flow estimate shown in Figure 4-8 was calculated using observed flow collected by DEQ for Watson Creek (0.136 cms on September 10. 2009). The flow was scaled using their drainage areas ([11.1 mi^2/8.76 mi^2] x 0.136 cms = 0.172 cms).

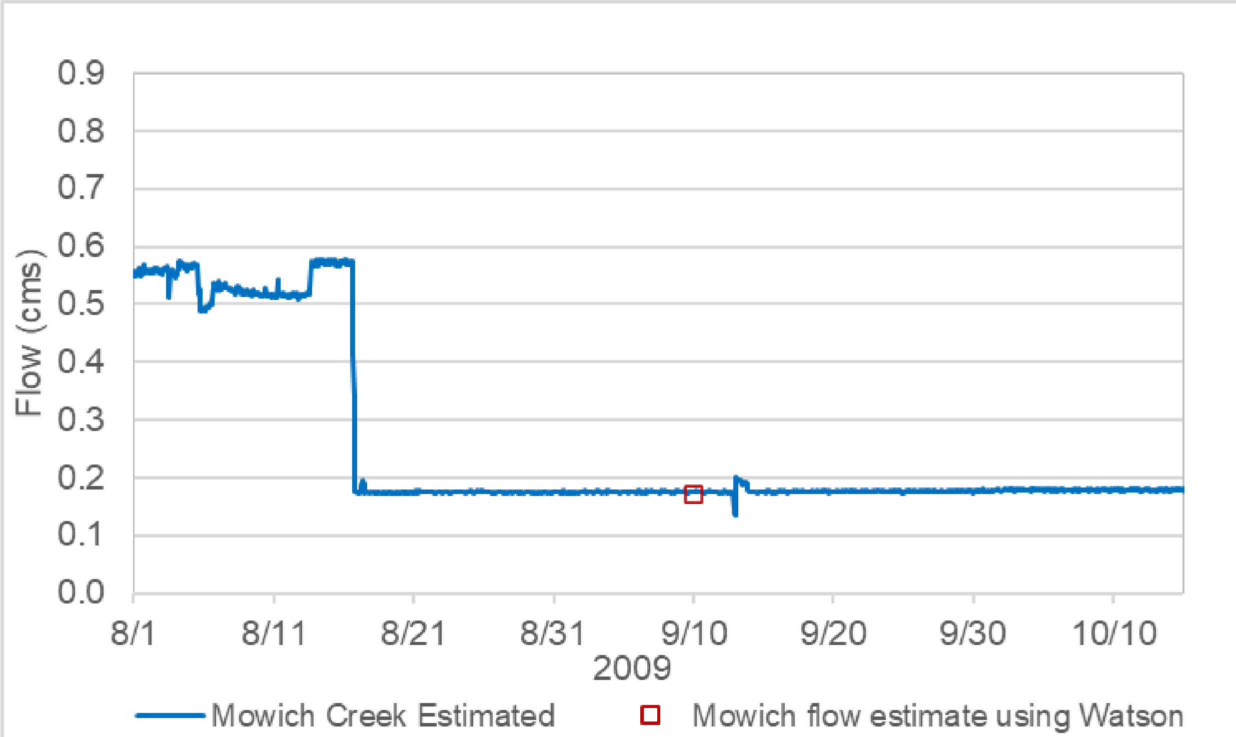

Figure 4-8. Estimated flows at Mowich Creek

The USGS gage 14314700 is located at RKM 8.05 and includes contributions from Mowich Creek and Powerhouse #1. In addition, the gage also accounts for the Powerhouse #2 withdrawal that occurs just upstream of the gage. A flow balance was calculated at 14314700 Clearwater River below Mowich Creek near Toketee Falls, taken as the sum of flows from 14314500, Mowich Creek and net flows from Powerhouse#1 and Powerhouse #2. Figure 4-9 shows the estimated flows for Mowich Creek and the gages upstream and downstream of Mowich Creek, used for flow balance. As can be seen in Figure 4-9 the calculated Mowich Creek flows approximately account for the deficit (~0.15 cms) seen in the flows between stations 14314500 and 14314700. This results in a net deficit between Powerhouse #1 and #2 estimated to zero to complete the flow balance.

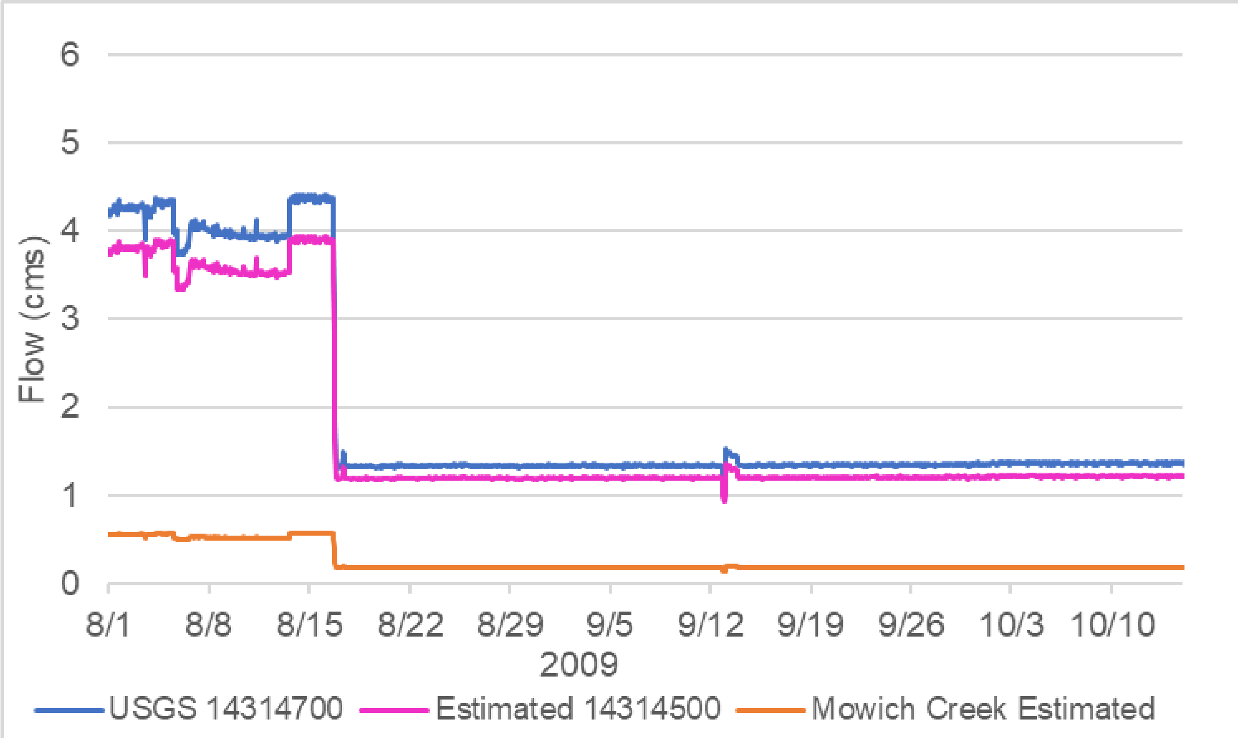

Figure 4-9. Flows upstream and downstream of Mowich along Clearwater River and at Mowich

Flows from the Powerhouse #2 withdrawal were available from USGS 14314600 - Clearwater No. 2 Power Canal near Toketee Falls, OR (Figure 4-6). Figure 4-10 shows the observed flows at Powerhouse #2.

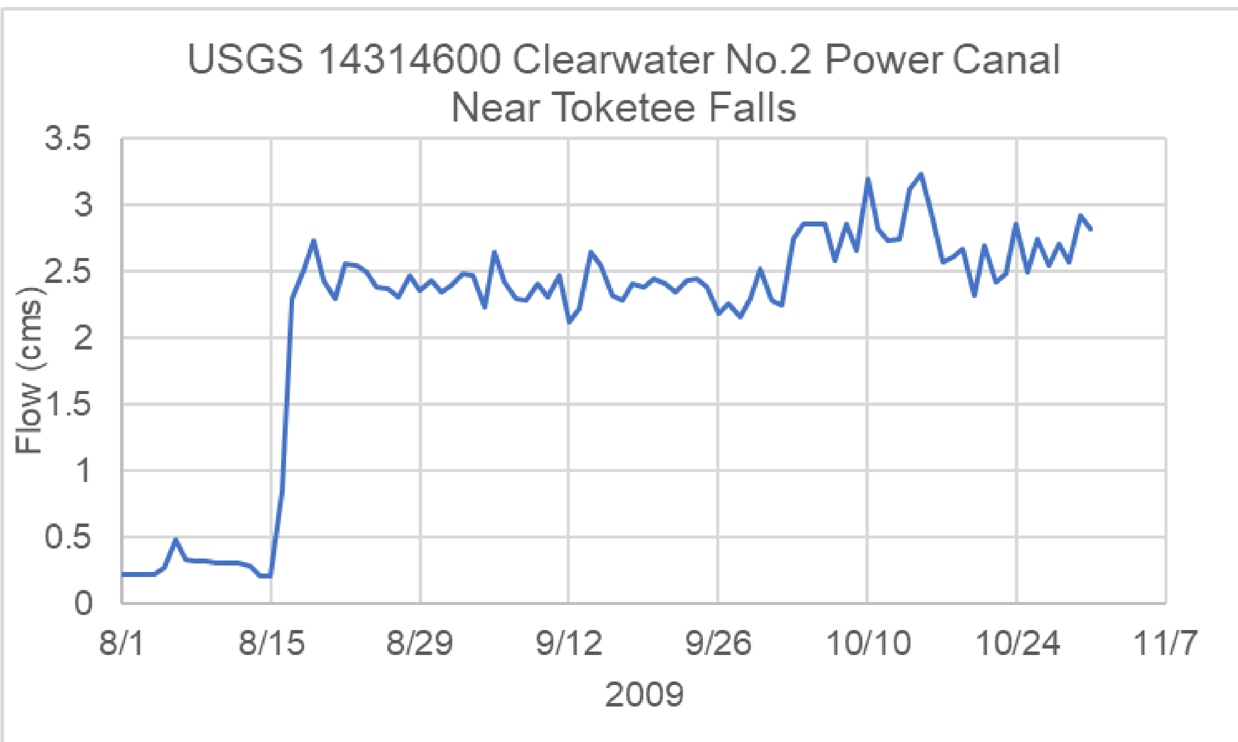

Figure 4-10. Clearwater Powerhouse #2 flows

Withdrawals within the model are assigned spatially as a constant flow. A calculated median flow of 2.42 cms (calculated for the period from August through October 2009) using the flows from the 14314600 USGS gage was assigned in the model at RKM 8.10 as the Clearwater No. 2 withdrawal. Since the flow balance indicated that the net flow deficit between the powerhouse inflow and withdrawal was zero, the Powerhouse #1 flows were set equal to a constant 2.42 cms in the model equal to the Powerhouse #2 withdrawal.

Flows for Watson Creek tributary were estimated using the drainage area ratio method between Mowich Creek and Watson Creek. The Watson Creek drainage area calculated using the USGS Stream Stats program was calculated to be 8.76 mi^2, and the drainage area for Mowich Creek as reported previously was 11.1 mi^2. The flows were further refined using flow data collected by DEQ on August 31 and September 10,2009 at Watson Creek near Diamond Lake and at Watson Creek u/s of Culvert 138, respectively (Figure 4-6). An exponent of 0.7 was used to refine the flow estimates based on the grab flows.

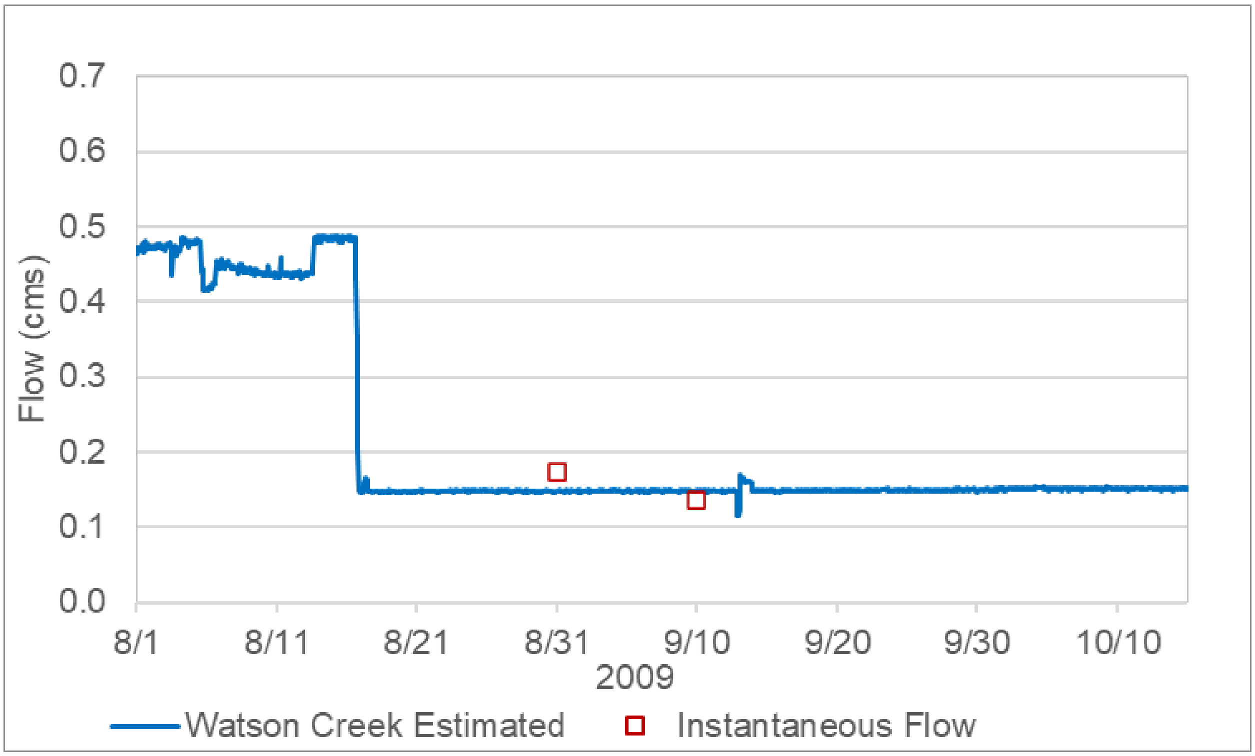

Figure 4-11. Estimated flows for Watson Creek.

Flow data were collected at the downstream end of the Clearwater River above Toketee Reservoir on two occasions: September 1, 2009 with a flow of 3.84 cms and September 10, 2009 with a flow of 3.82 cms. The flows were nearly identical. A flow balance was constructed from Clearwater River below Mowich Creek (14314700) to the mouth using these flow data. The net flow was calculated using the flow at the downstream end of the Clearwater River above Toketee Reservoir minus the sum of the flows from Watson Creek (0.14 cms) and the upstream flow at 14314700 on September 10, 2009 (1.34 cms). The net flow which accounts for the flows from the surrounding drainage area was estimated to be 2.34 cms and was assigned as accretion in the model from RKM 5.35 to RKM 2.40.

4.4 WATER TEMPERATURE INPUTS – CLEARWATER RIVER

Water temperature data were available at the upstream boundary (Clearwater River below Diversion 1) and from the two tributary inputs – Mowich Creek and Watson Creek. Table 4-2 provides an inventory of the water temperature data used in the model development. The locations of the various stream temperature monitoring locations that were used as boundary conditions to configure the model or for calibration are shown in Figure 4-12. The observed data at the Clearwater River below Diversion 1 and Watson Creek had missing data in the first two weeks of August and during the last week of September. Regression relationships were developed at these two locations with data from Mowich Creek that had a complete dataset with no missing data. Figure 4-13 shows the regression developed at the two locations.

Table 4-2. Inventory of available water temperature data locations used to configure the Clearwater River model.

Station ID	Model location (Km)	Source	Type	Notes
Clearwater River below Diversion 1 (25711-ORDEQ)	12.4	DEQ	Boundary Condition	Missing data from August 1 to 18 & from September 17 to 23 & October 14 to 15.
Mowich Creek (UmpNF-064)	8.2	USFS	Tributary	
Powerhouse 1 outlet	8.1	Derived data	Tributary	Derived using 2001 summer model inputs
Watson Creek (36085-ORDEQ)	2.1	DEQ	Tributary	Missing data from August 1 to 18 & from September 18 to 24 & October 14 to 15.

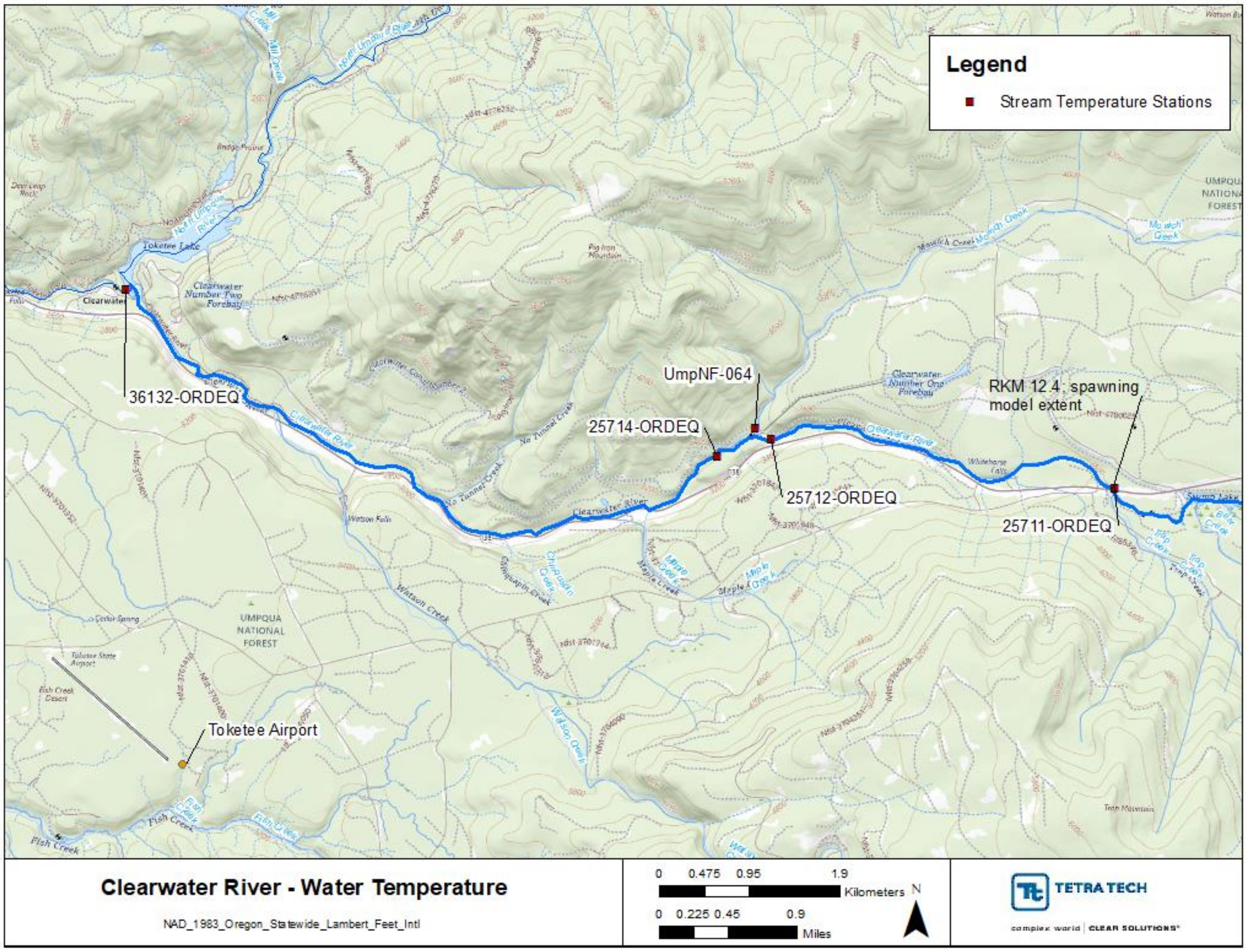

Figure 4-12 Clearwater River stream water temperature locations.

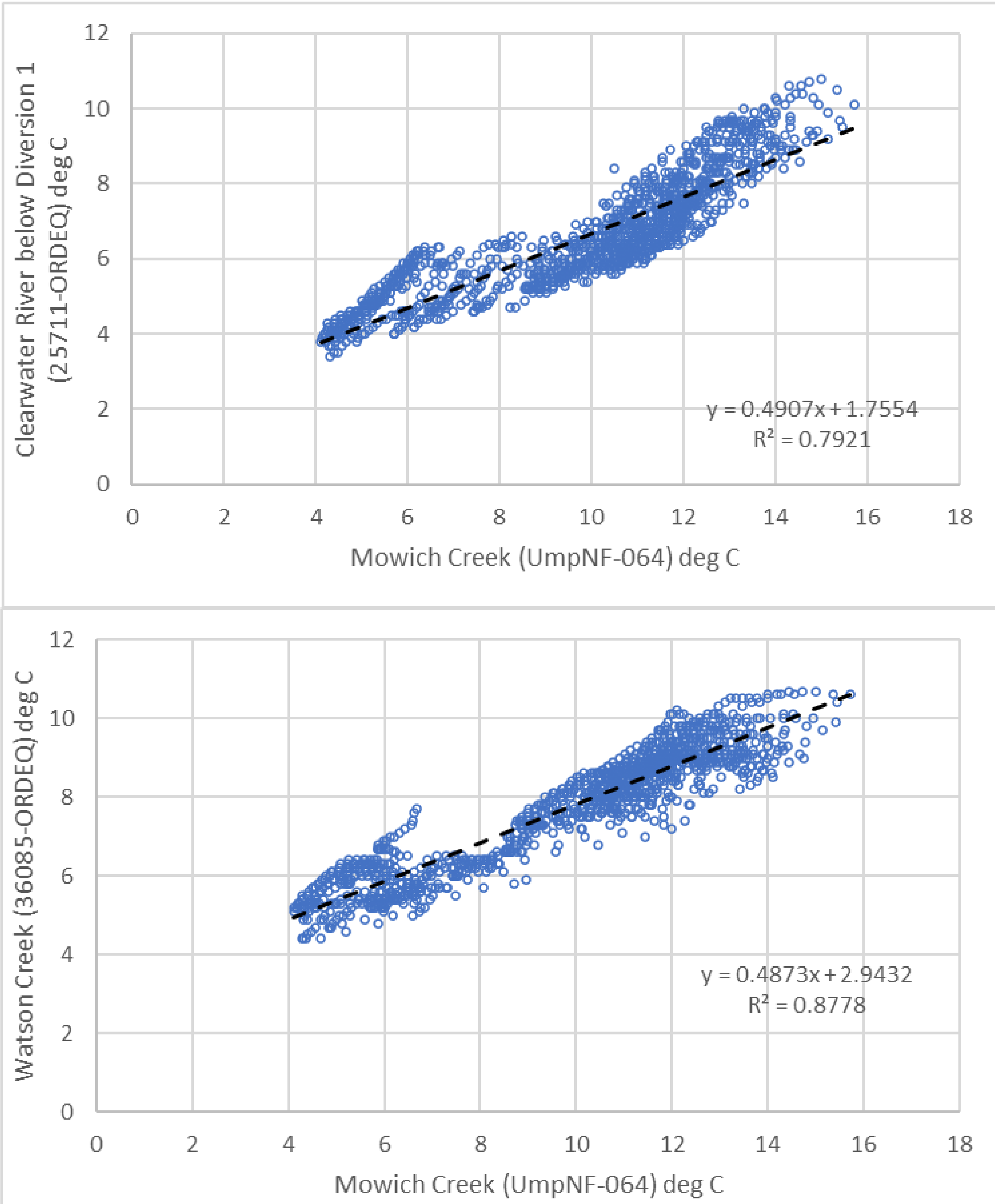

Figure 4-13. Regression between water temperature at Clearwater River below Div.1 & Watson Creek with Mowich Creek.

Figure 4-14 through Figure 4-16 show the observed stream temperature time series data for the upstream boundary and tributaries used in the model. The figures also show the missing data that were estimated using the regression relationships that were developed.

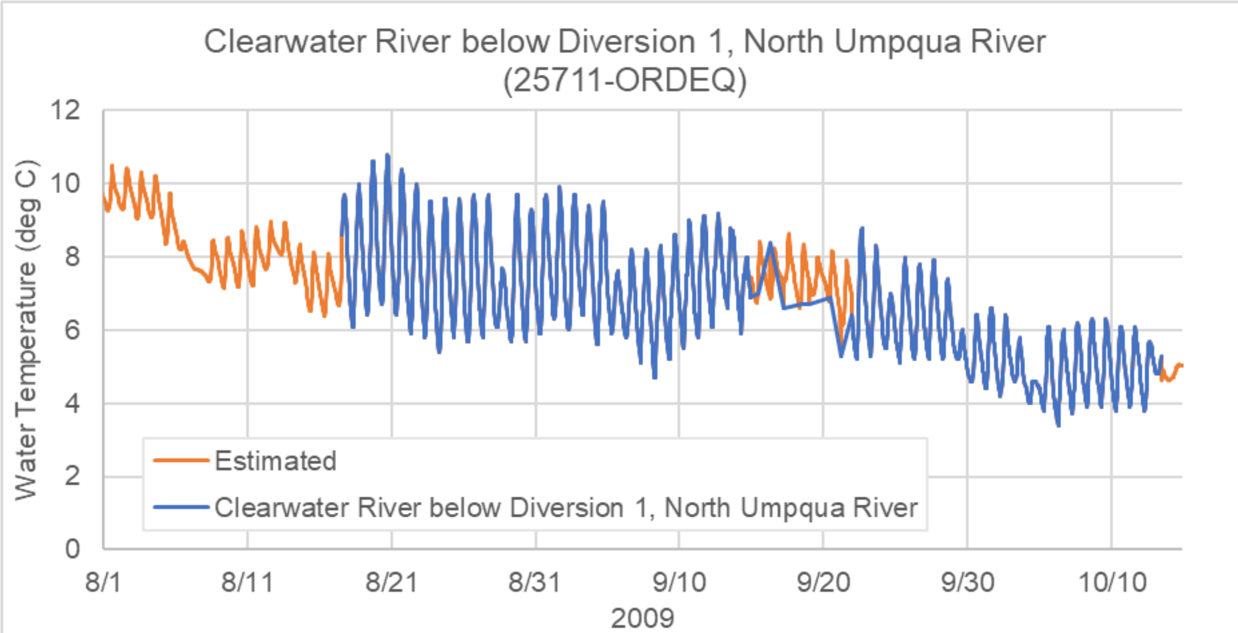

Figure 4-14. Hourly water temperature at the upstream boundary in the Clearwater River model.

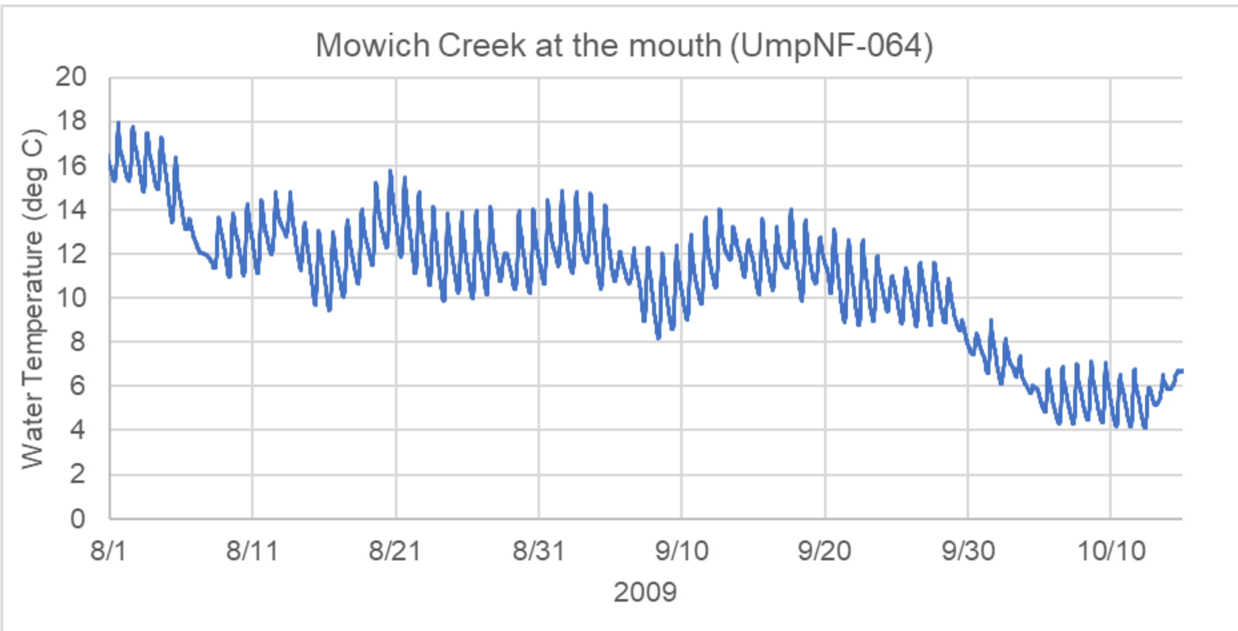

Figure 4-15. Hourly water temperature at Mowich Creek at the mouth in the Clearwater River model.

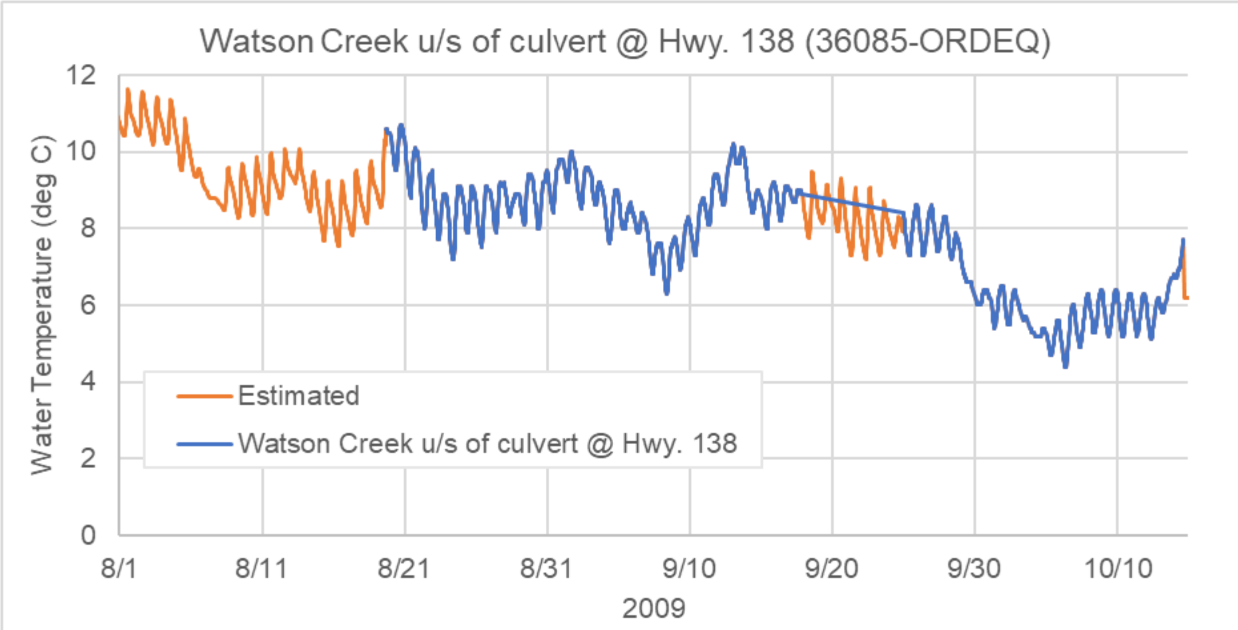

Figure 4-16. Hourly water temperature at Watson Creek in the Clearwater River model.

Water temperature data were not available for Powerhouse #1 for 2009, so they were estimated using temperatures from the summer model. Water temperature data for Powerhouse #1 were available for four days from July 8 to July 11 in the 2001 summer Heat Source model. Figure 4-17 shows the water temperature during 2001 that were available from the summer model.

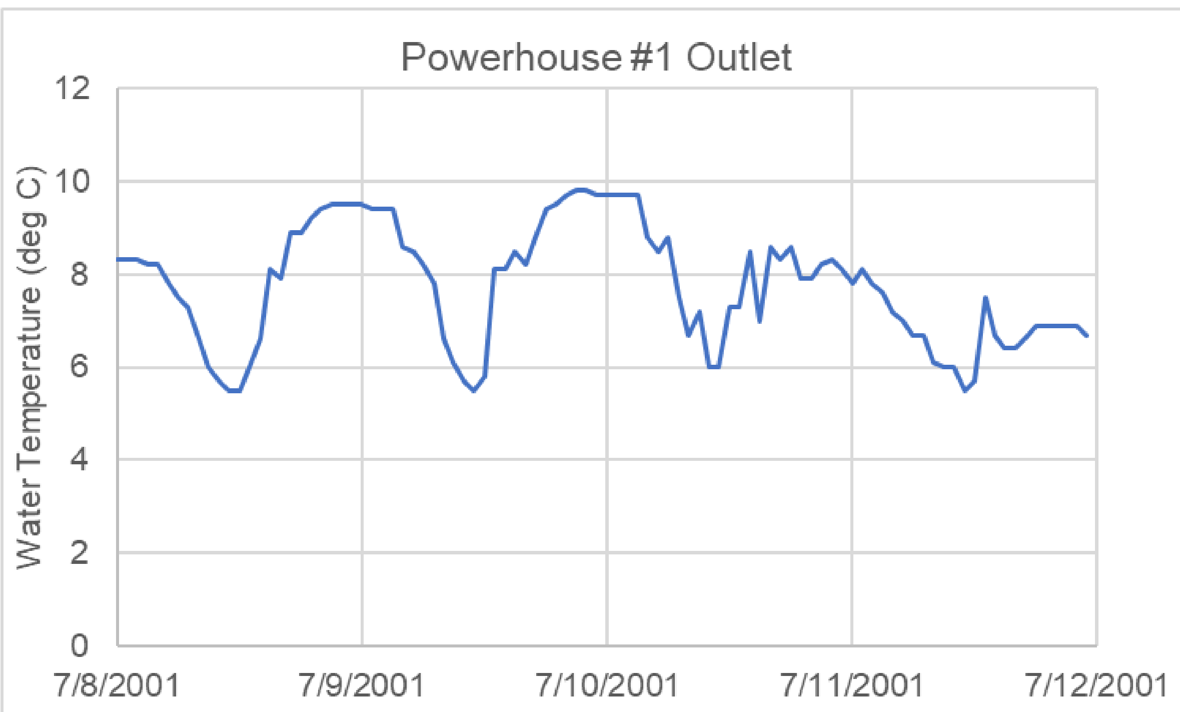

Figure 4-17. Powerhouse #1 discharge temperatures to Clearwater Creek 7/8/2001 to 7/11/2001 (Summer Model)

In the absence of Powerhouse #1 data for 2009, the 2001 data from July 8 to July 11 was used and repeated over the entire modeling time period. During calibration, the Powerhouse #1 water temperatures were further refined to improve model performance on temperature simulation in Clearwater River below the Clearwater 2 diversion. The Powerhouse #1 water temperatures were refined by incorporating both the warmer July 8 and cooler July 11 temperatures for October. Further adjustments included scaling the water temperature by increasing it by 1 ºC in August and reducing it by 0.7 ºC in October. These refinements were made to improve the calibration at the most downstream station location. Figure 4-18 shows the water temperature inputs for the Powerhouse #1 specified in the model.

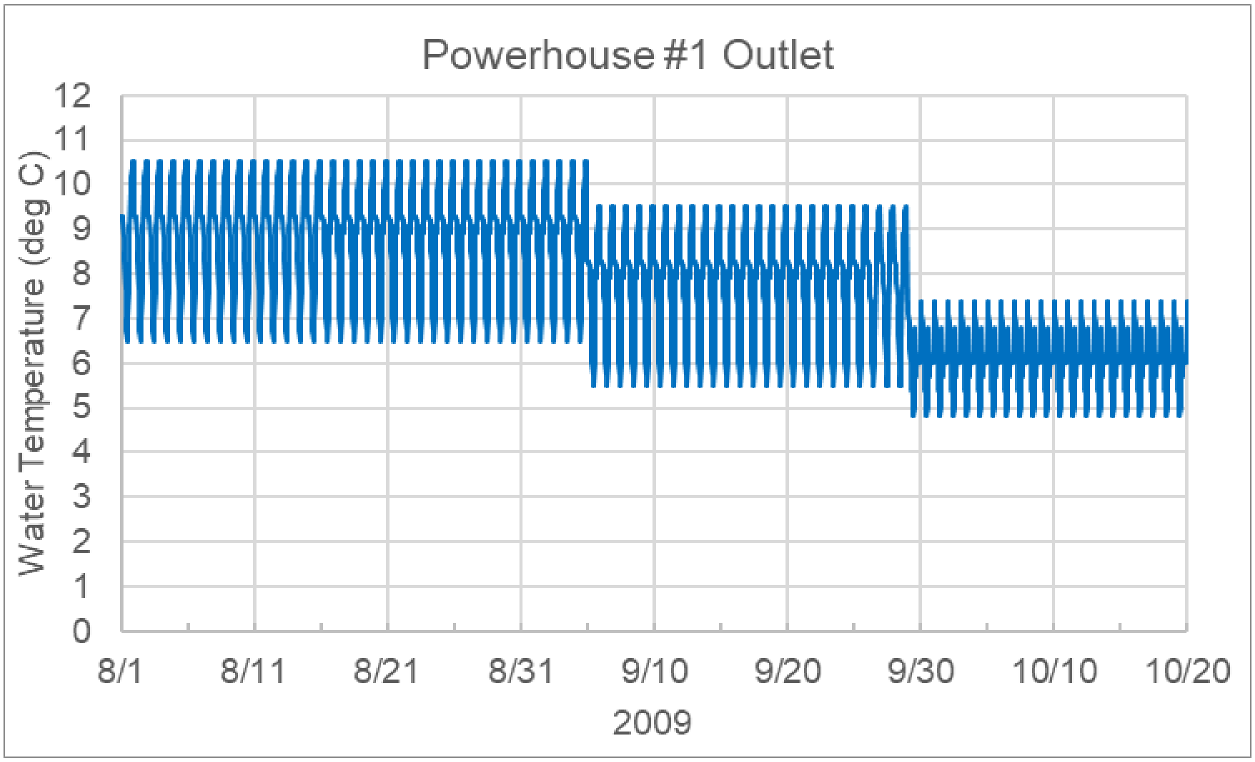

Figure 4-18. Powerhouse #1 outlet water temperature to Clearwater Creek used in spawning model (2009)

4.5 METEOROLOGICAL DATA – CLEARWATER RIVER

Meteorological inputs for Clearwater River were configured using data from the Toketee Airport weather station (Table 4-3). The Toketee Airport is in close proximity just south of the Clearwater River. The hourly meteorological input time series data at the Toketee Airport can be found in Figure 4-19. Cloud cover data are not available at the Toketee Airport station and were calculated based on cloud cover descriptive information reported at the Roseburg Regional Airport (Refer to Section 5, Figure 5-13 for more information on cloud cover).

Table 4-3. Inventory of available Meteorological Station Data in the Clearwater River watershed

Station ID	Station Name	Elevation (m)	Frequency	Available Met Data	Source
TOFO3	Toketee Airport	1024.39	43.2186°/-122.413°	Hourly	Air Temperature, Relative Humidity, Wind Speed

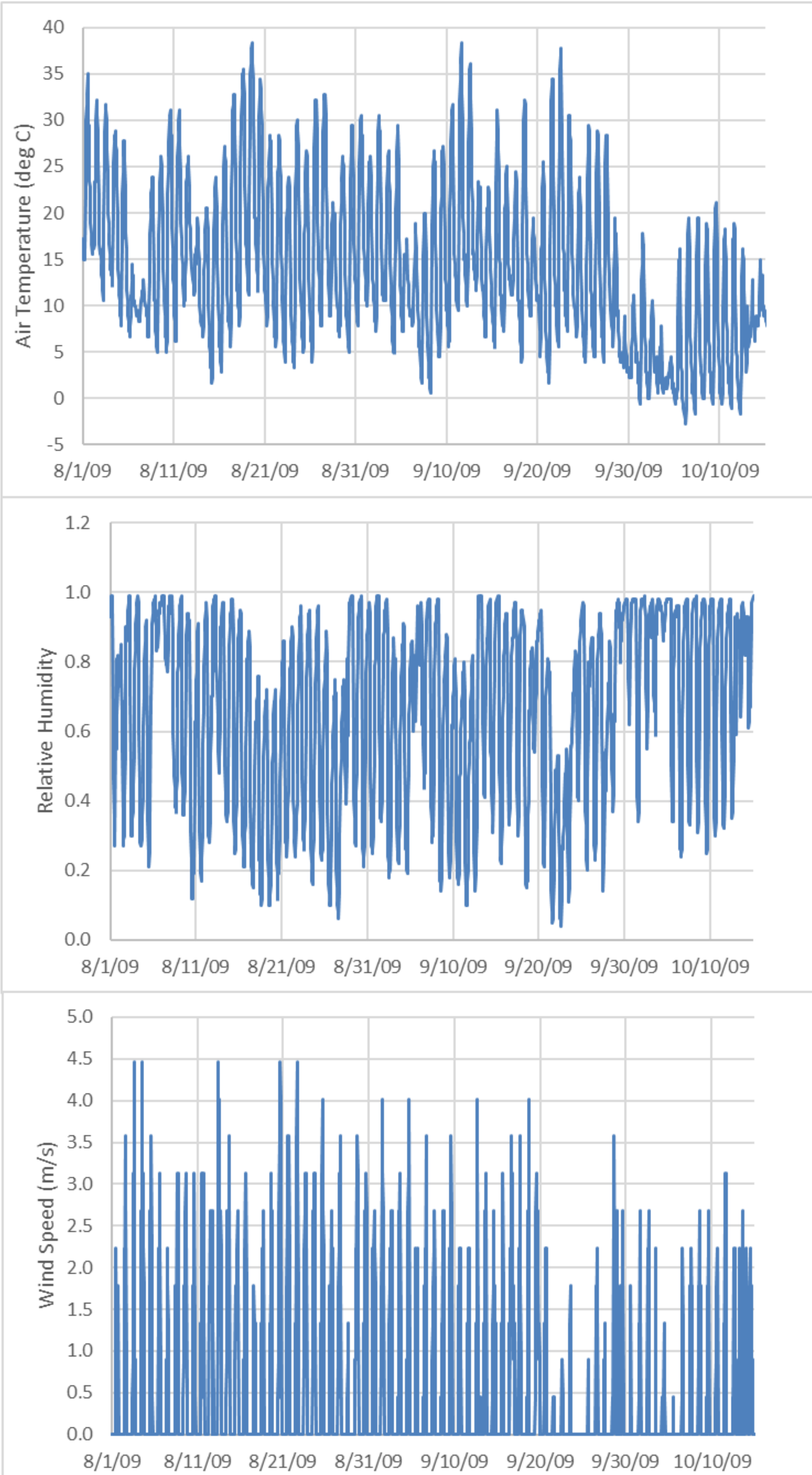

Figure 4-19. Air temperature, Relative Humidity and Wind Speed at Toketee Airport Station (MesoWest)

4.6 MODEL CALIBRATION – CLEARWATER RIVER

The Clearwater River Heat Source model was simulated for the time period from August 1, 2009, to October 15, 2009, over the 12.4-kilometer study area from the Clearwater River below the Powerhouse #1 diversion to the mouth. The model was calibrated against observed flow and water temperature data. Model calibration refers to the comparison of observed data to modeled values. Table 4-4 shows the observed flow and water temperature stations used in the Clearwater River Heat Source model calibration. The location of the observed flow calibration station can be found in Figure 4-6 and the observed water temperature stations used can be found in Figure 4-12. The model outputs were generated hourly, every 100 meters. The modeled stream flows were calibrated first, followed by stream temperature.

The model calibration sites and data sources for the Clearwater River are summarized in Table 4-4. The model location in the table below describes the distance of each calibration site from the most downstream model node.

Table 4-4. Calibration sites used in the Clearwater River Heat Source Model Calibration

Station ID	Description	Model RKM	Data Type	Source
Hourly Flow				
14314700	Clearwater R Below Mowich Creek, Nr Toketee Falls	8.05	Flow	USGS
Hourly Water Temperature				
25712-ORDEQ	Clearwater River above Clearwater 2 Diversion	8.40	Water Temperature	DEQ
25714-ORDEQ	Clearwater River below Clearwater 2 Diversion	7.60	Water Temperature	DEQ
36132-ORDEQ	Clearwater River near Mouth (upstream of diversion)	0.10	Water Temperature	DEQ

A combination of visual and computed error statistics was used to assess the model calibration. Summary statistics (ME, MAE, RMSE, and NSE) followed the calculations described in Section 3.6.

4.7 FLOW CALIBRATION – CLEARWATER RIVER

Hourly flow values at the Clearwater River below Mowich Creek near Toketee Falls, OR (14314700) were compared to the simulated flow at the same gage for the simulation time-period (Figure 4-20). Table 4-5 shows the flow calibration statistics.

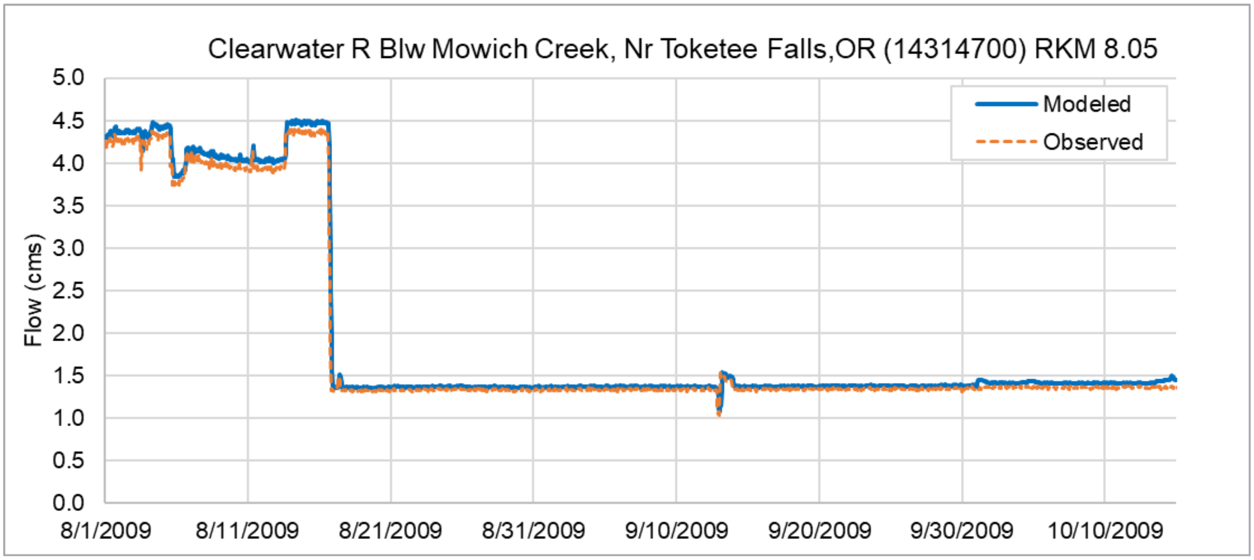

Figure 4-20. Clearwater River below Mowich Creek near Toketee Falls, OR (USGS 14314700).

Table 4-5. Flow calibration statistics for the Clearwater River

Flow (cms)	Clearwater River below Mowich Creek near Toketee Falls (USGS 14314700) RKM 8.05
ME	0.06
MAE	0.06
RMSE	0.09
NSE	1.00
Count	1,884

4.8 TEMPERATURE CALIBRATION – CLEARWATER RIVER

Hourly and daily maximum modeled temperatures were compared with data from each of the stream temperature calibration monitoring stations (Figure 4-21 and Figure 4-22) in Table 4-4. The modeled stream temperature at the most upstream calibration location, Clearwater River above Clearwater 2 Diversion consistently underpredicted the daily maximum values. This location is about 4 kilometers downstream of the upstream boundary with no tributaries coming into the system. During calibration sensitivity adjustments were made to the cloud cover by decreasing the cloud cover and decreasing the wind speed to attempt to improve the predicted maximum temperatures. These adjustments did improve the water temperatures but were ultimately not used. DEQ field sheets during 2009 for this site noted that there was rock on top of the sensor. This indicated that the stream temperatures at this location may not be entirely reliable, hence no further adjustments were made to match the observed data at this site.

Channel morphology related inputs were retained from the HS7 model during calibration. The sediment heat exchange parameters, i.e., sediment thermal conductivity and diffusivity, and wind function coefficients, were applied at their HS8 default values.

The stream temperature calibration at the Clearwater River below Clearwater 2 Diversion was guided primarily by flow balance and by adjustments to the Powerhouse #1 water temperatures (which were unknown) to improve the calibration. The model is able to reproduce the sudden drop in stream temperatures starting October 1. The details of the creation and refinements to the Powerhouse #1 temperature input are discussed in Section 4.4.

The adjustments to Powerhouse #1 also helped improve the predicted water temperatures at the mouth. The addition of accretion flows from RKM 5.35 to RKM 2.40 to meet the flow balance at the downstream end, discussed previously in the flow estimation section, also helped improve the predicted stream temperatures at the mouth. Further improvements at this station were achieved by reducing the accretion water temperature by 0.5 ºC from 7 ºC to 6.5 ºC. Finally, hyporheic flow was also specified to better capture observed hourly temperatures. The addition of hyporheic flows helped reduce the diurnal variation downstream. A final value of 30 percent hyporheic exchange was arrived at during calibration.

Table 4-6 shows the hourly and daily maximum water temperature calibration statistics. The overall calculated model calibration error statistics showed a ME, MAE and RMSE of less than 1 ºC for the hourly and daily maximum water temperatures for all stations. The NSE for the hourly and daily maximum water temperatures was greater than 0.8 for all stations, except for the daily maximum at Clearwater River above Clearwater 2 Diversion which had a NSE of 0.78.

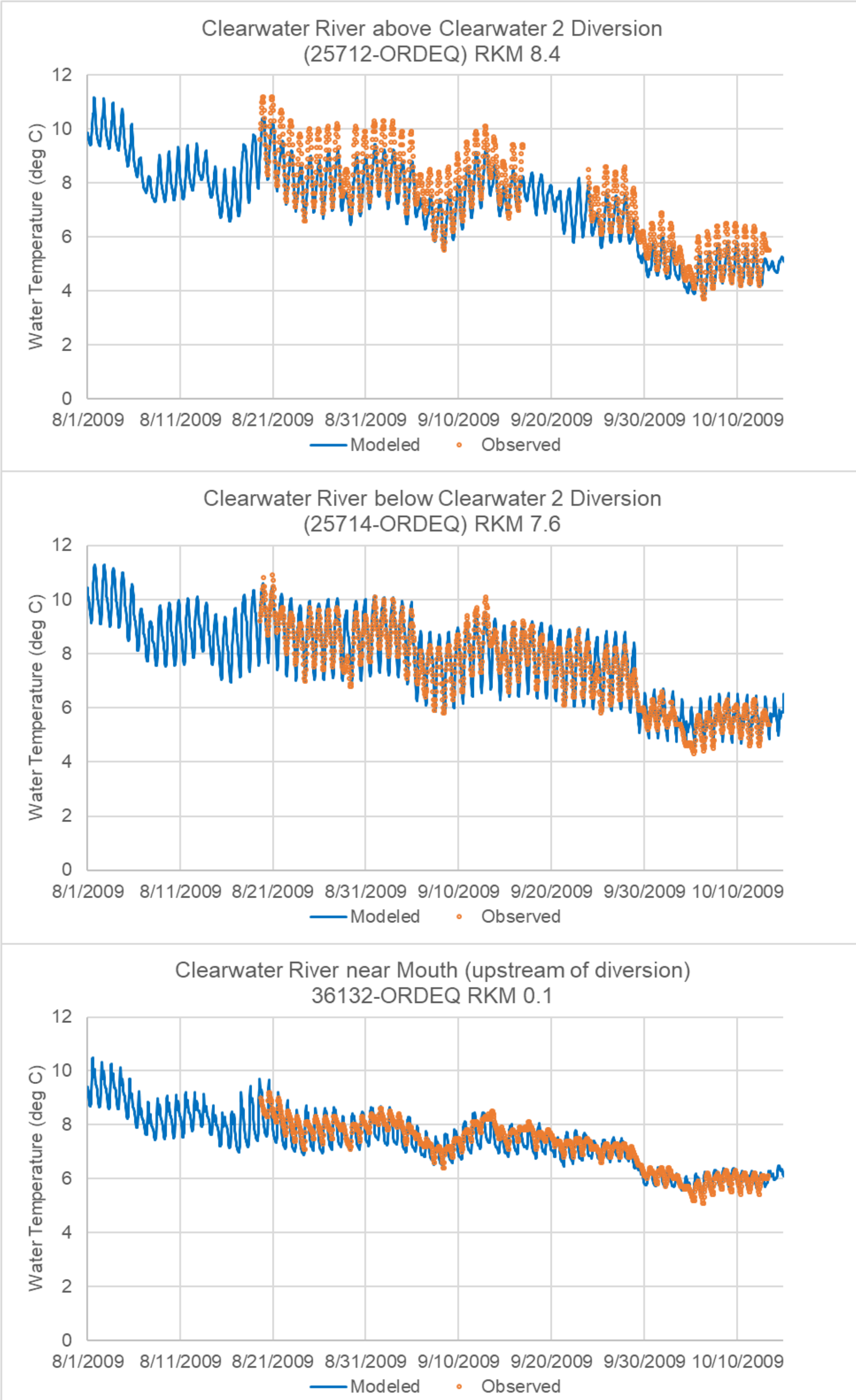

Figure 4-21. Observed versus Modeled Hourly Water Temperature – Station 25712 ORDEQ (top), Station 25714 ORDEQ (middle), and Station 36132 ORDEQ (bottom).

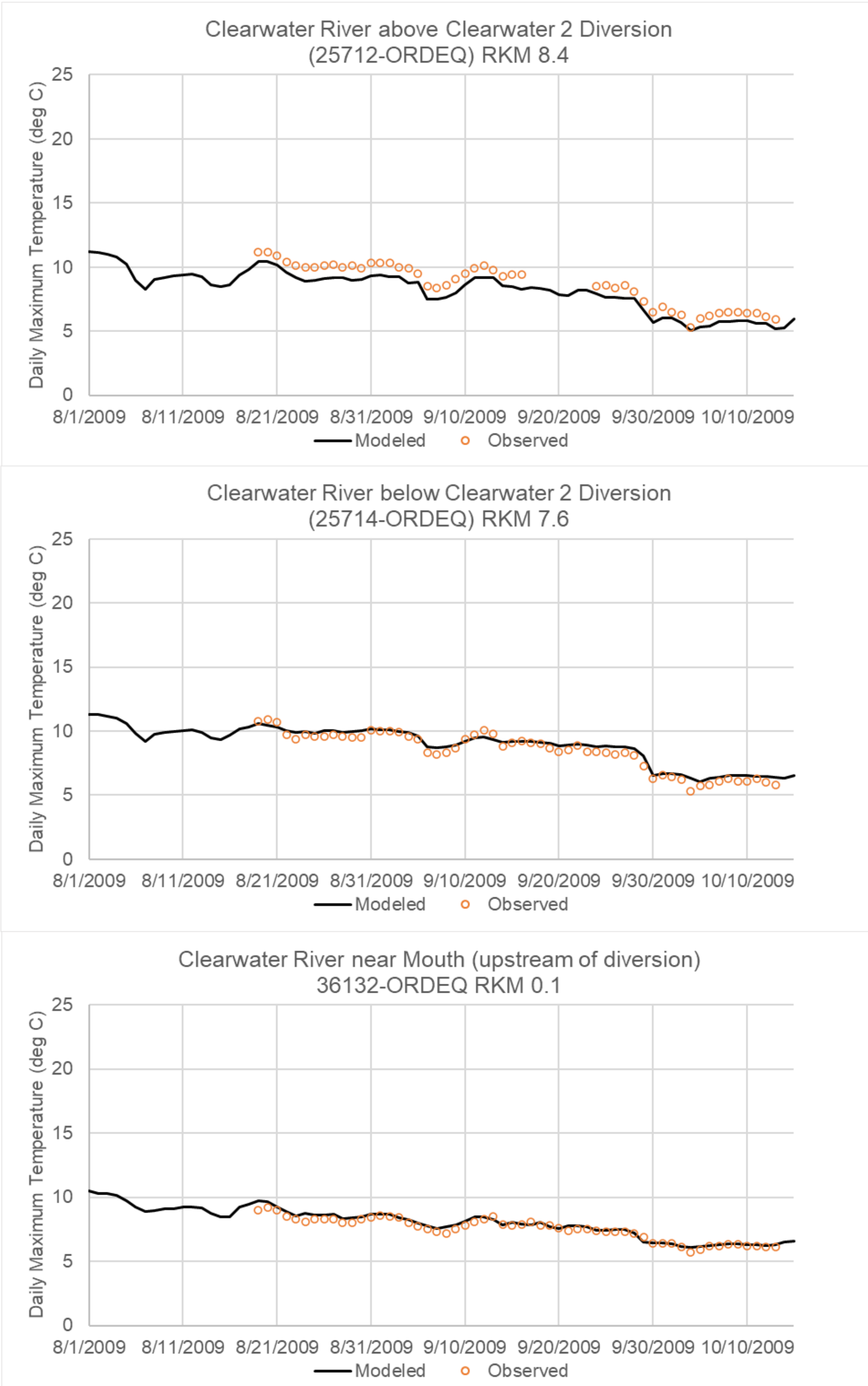

Figure 4-22. Observed versus Modeled Daily Max Water Temperature– Station 25712 ORDEQ (top), Station 25714 ORDEQ (middle), and Station 36132 ORDEQ (bottom).

Table 4-6. Hourly and Daily Maximum Stream Temperature calibration statistics for Clearwater River (August 1 to October 15, 2009)

Statistic	Clearwater River above Clearwater 2 Diversion (25712 ORDEQ)[a]	Clearwater River below Clearwater 2 Diversion (25714 ORDEQ)[b]	Clearwater River near Mouth (upstream of diversion) (36132 ORDEQ)[b]
Hourly Temperature Statistics			
ME	-0.57	0.09	-0.15
MAE	0.59	0.42	0.32
RMSE	0.72	0.51	0.37
NSE	0.82	0.87	0.82
Count	1,149	1,317	1,313
Daily Maximum Temperature Statistics			
ME	-0.82	0.26	0.18
MAE	0.82	0.35	0.22
RMSE	0.84	0.40	0.27
NSE	0.78	0.92	0.93
Count	49	56	46

a: Period of Record (POR) from August 19 to October 13, 2009 (N/A from 9/17 to 9/23); b: POR from August 19 to October 13, 2009

5.0 LAKE CREEK

5.1 MODEL TIME PERIOD AND EXTENT

The model was developed for the period from August 01, 2009, to October 15, 2009. This period corresponded to the period when hourly water temperature data were collected by DEQ, as listed in the QAPP (DEQ, 2022). Hourly stream temperature data were collected at several major tributaries and locations along Lake Creek, which were used for model boundary configuration and calibration purposes respectively.

Lake Creek generally flows in the northernly direction. The extent of the model domain is the same as that of the summer period Lake Creek model which is from Diamond Lake to the mouth of Lake Creek at the confluence of the North Umpqua River. The model extent of the Lake Creek Heat Source Model is shown in Figure 5-1.

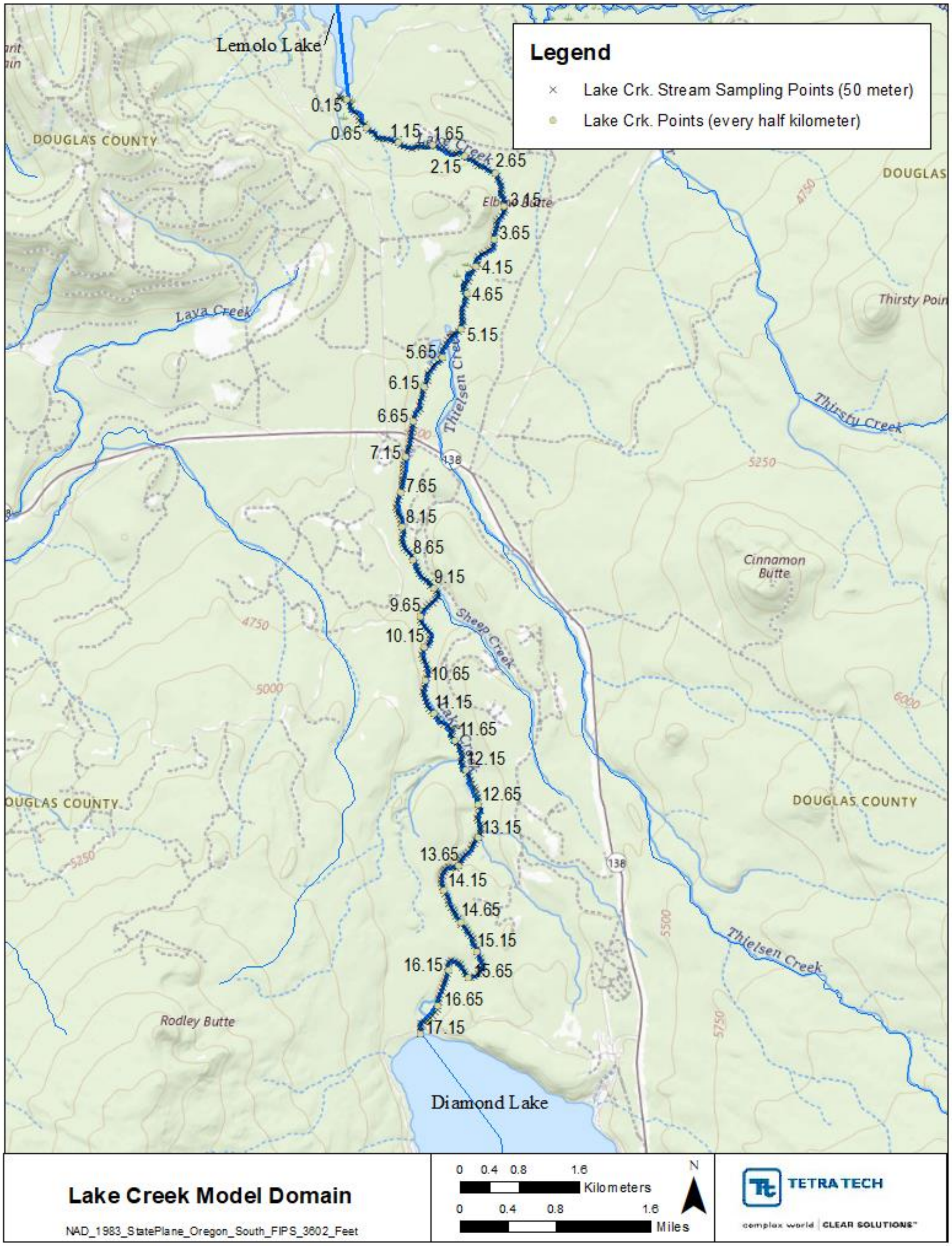

Figure 5-1. Extent of the Lake Creek modeling domain

5.2 HEAT SOURCE MODEL INPUT – LAKE CREEK

In the Lake Creek model, the model time step (dt) was set at 1 minute. Remaining general set up is consistent with the description in Section 2.2. The channel bottom widths used in the model ranged from 2.2 meters to 9.9 meters, with a mean of 5.14 meters. Figure 5-2 and Figure 5-3 show the computed stream channel elevation and gradient, respectively, and Figure 5-4 shows the calculated channel bottom widths for Lake Creek. Figure 5-5 shows the Manning's n values used in the model. The flow and water temperature inputs are discussed in the following sections.

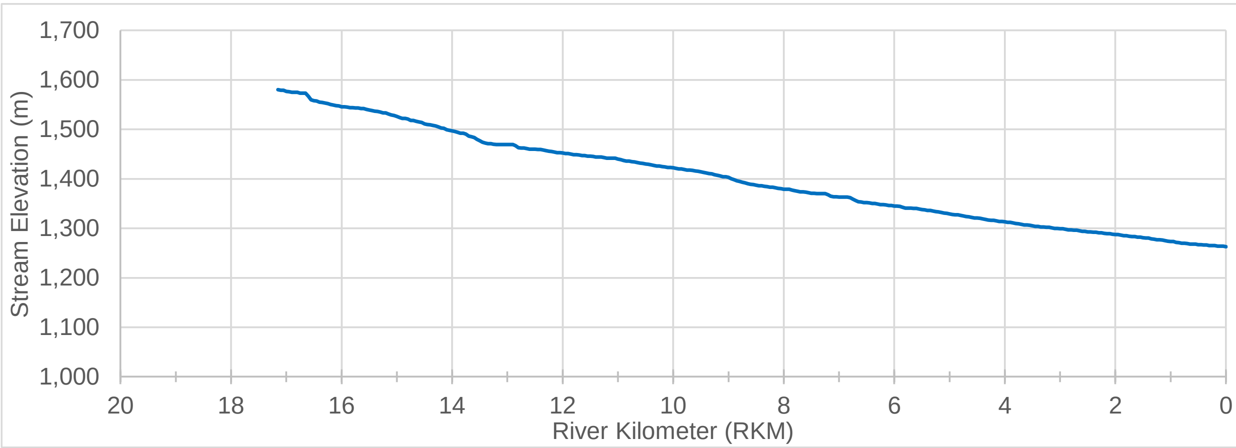

Figure 5-2. Lake Creek elevation.

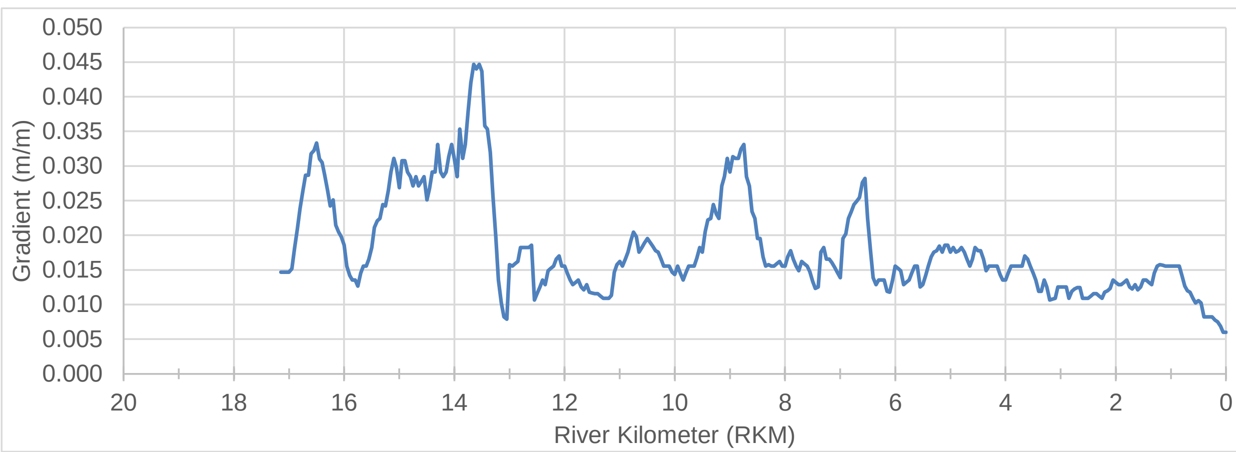

Figure 5-3. Lake Creek gradient.

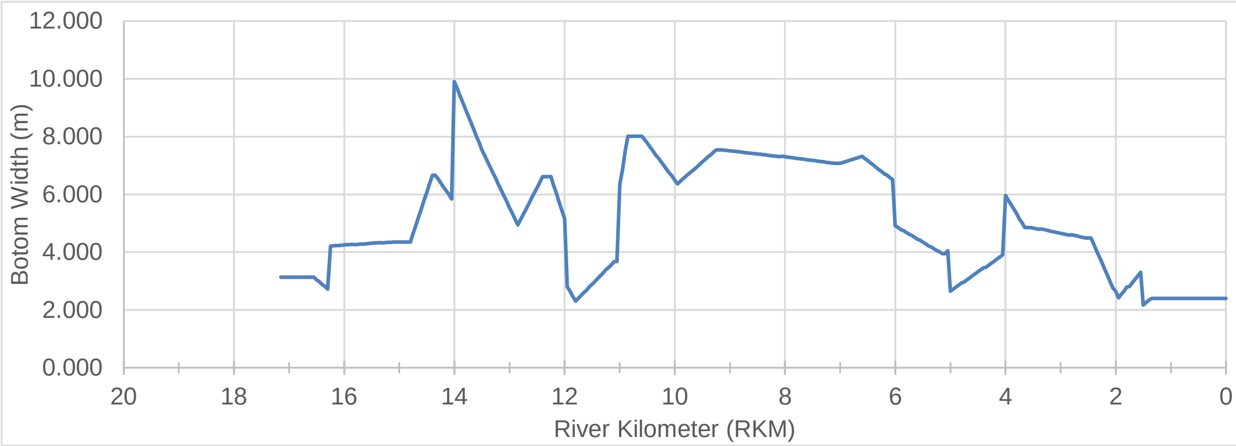

Figure 5-4. Lake Creek calculated bottom width.

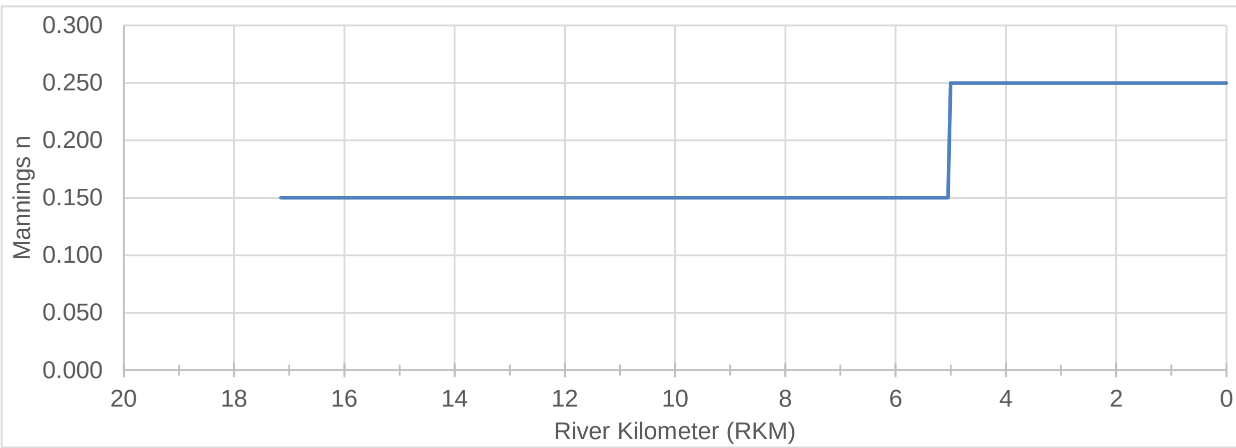

Figure 5-5. Lake Creek assigned Manning's n values.

5.3 FLOW INPUTS – LAKE CREEK

Flow data for Lake Creek are available at USGS station 14312500 (Lake Creek near Diamond Lake, OR) and were used to configure the upstream boundary condition. The flow data at this station were available as 15-minute data and were converted to hourly and specified in the model. Two tributaries were also included in the configuration of the spawning season model. Thielsen Creek and Sheep Creek were excluded from the Lake Creek summer HS7 model due to lack of flow; however, Thielsen Creek and Sheep Creek do have flow during the spawning period in 2009. Flows were estimated for Sheep Creek and Thielson Creek using the drainage area ratio method and were scaled using flows from USGS 14312500 - Lake Creek near Diamond Lake, OR (Figure 5-6). Figure 5-6 shows drainage areas for the Sheep Creek and Thielsen Creek. The drainage areas were estimated using USGS StreamStats and were as follows: Sheep Creek - 1 mi^2 and Thielsen Creek - 21.8 mi^2. The reported drainage area for USGS 14312500 was 51.6 mi^2. The generalized drainage area relationship as reported by the USGS (Cooper 2005) is as follows:

$$Q_u = Q_g\left(A_u/A_g\right)^a$$

Qu = the estimated discharge for the ungaged watershed,

Qg = discharge for the gaging station,

Au = the area of the ungaged watershed (Sheep Creek - 1 $mi^2$and Thielsen Creek - 21.8 mi^2), Ag = the area of the gaged watershed (USGS 14312500 - 51.6 mi^2), and

a = the exponent of area (1 for Sheep Creek and 2 for Thielsen , which were obtained through flow balance analysis).

Table 5-1shows an inventory of the available flow data and notes how they were used. The hourly flow data are shown for lake Creek near Diamond Lake (USGS 14312500) and estimated flows for Thielson and Sheep creeks can be found in Figure 5-7 and Figure 5-8, respectively.

Table 5-1. Inventory of available flow data in the Lake Creek watershed used in the Heat Source Model development.

Station ID	Model location (Km)	Source	Type	Notes
Lake Creek near Diamond Lake, OR (14312500)	17.15	USGS	Boundary Condition	
Sheep Creek	9.30	Derived data	Tributary	Drainage area ratio method
Thielson Creek	5.25	Derived data	Tributary	Drainage area ratio method

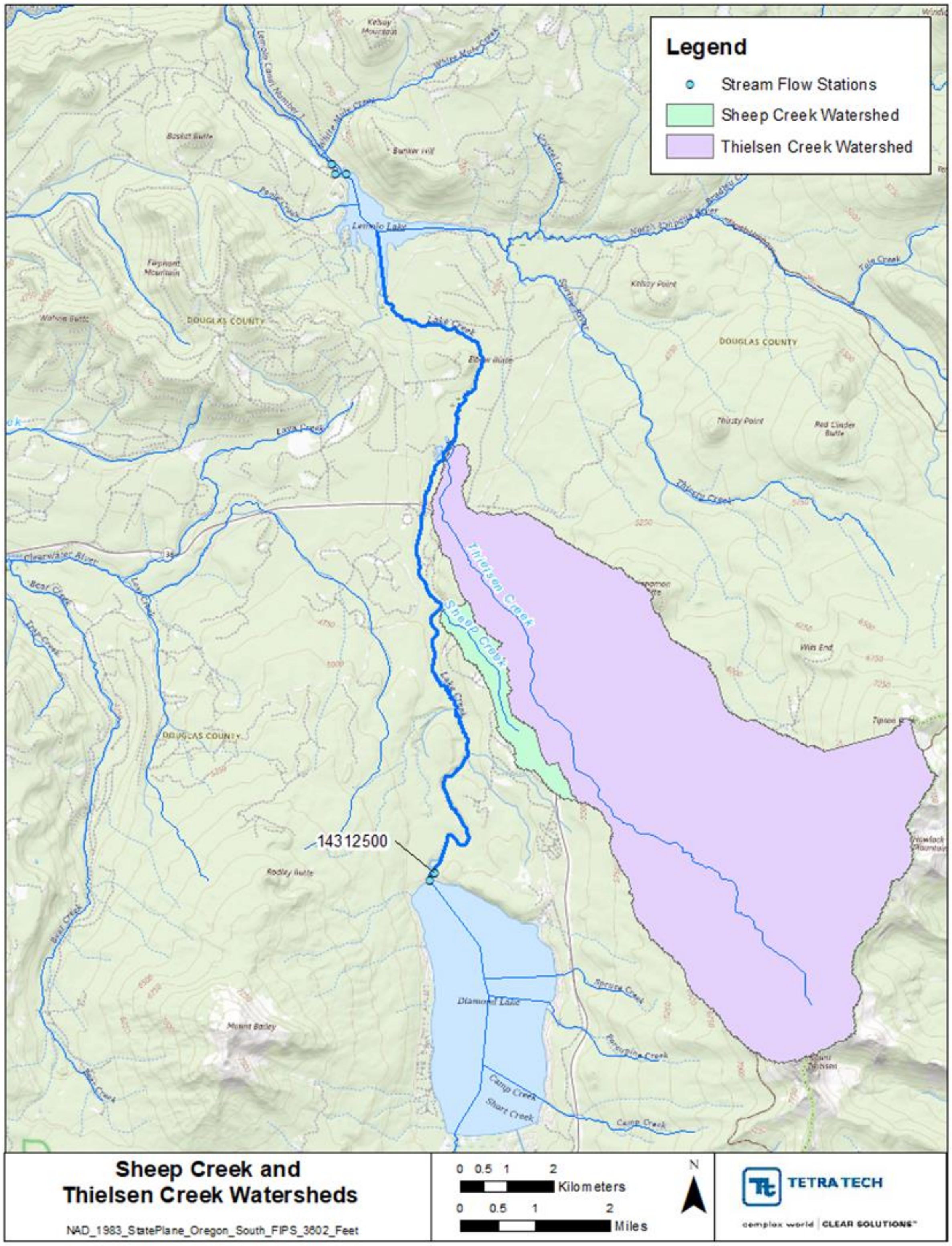

Figure 5-6. Lake Creek observed stream flow and drainage area locations for estimated streams.

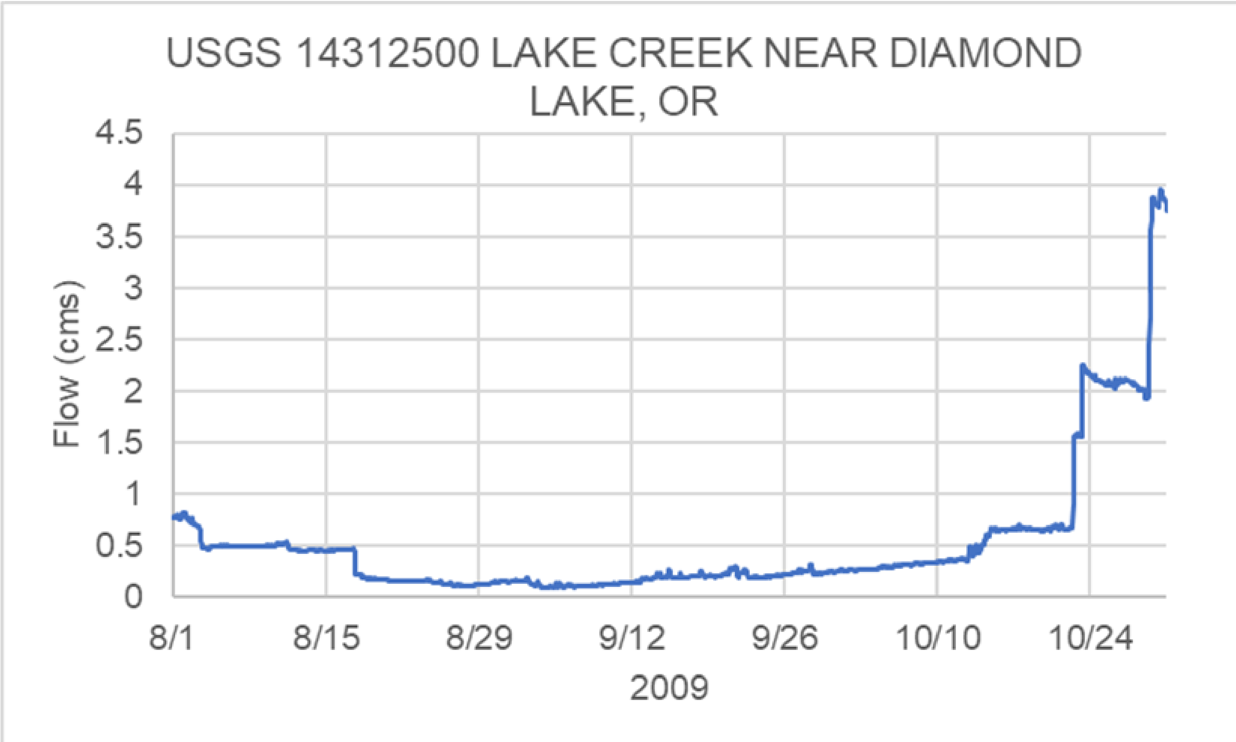

Figure 5-7. Observed hourly flow data at USGS station 14312500 (Lake Creek near Diamond Lake, OR).

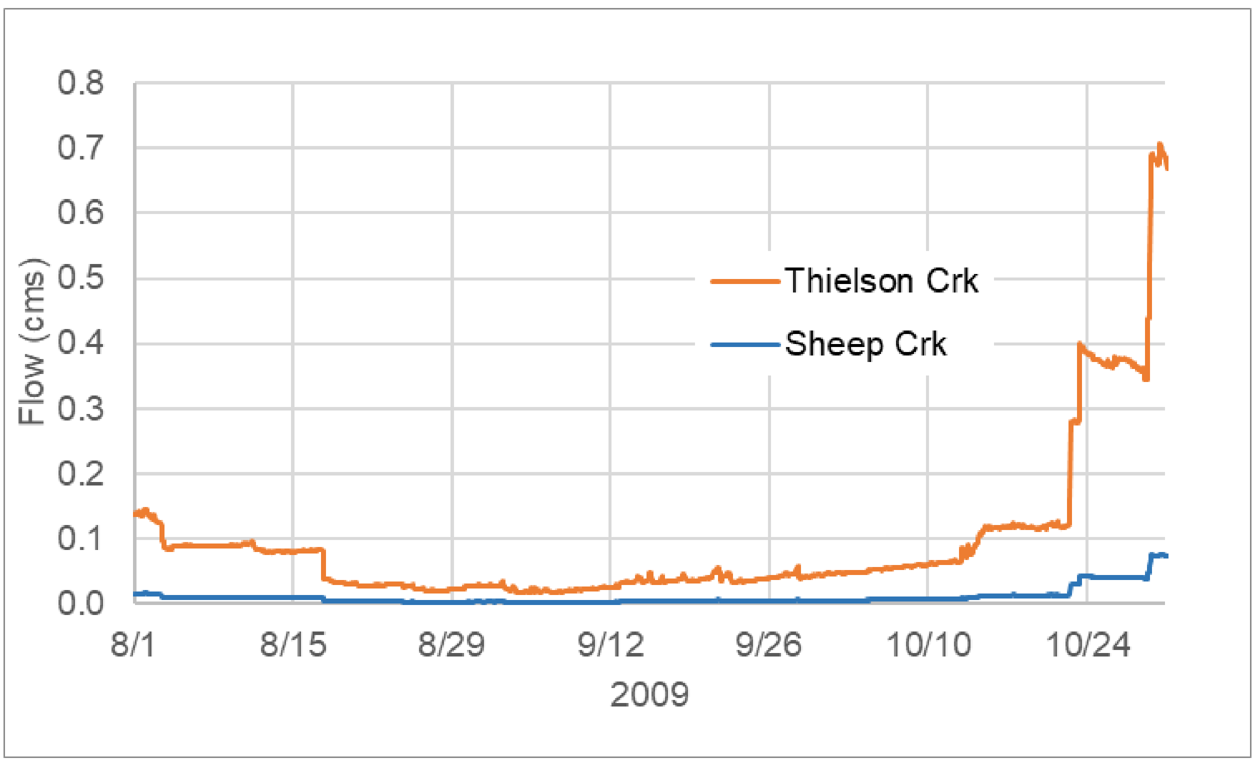

Figure 5-8. Estimated hourly flow data at Thielson Creek and Sheep Creek.

Measured flow rates and flow balance calculations were used to estimate additional flows from tributaries and accretion. Instantaneous flow measurements were collected on September 9, 2009, at Lake Creek at Road 138 (old USGS station 14312600 location) and Lake Creek at the mouth. Figure 5-9 shows the location of the flow measurement locations. Estimated flows for Thielson Creek and Sheep Creek along with upstream flows were used estimate the flow deficit at Lake Creek at Road 138. The flow balance showed that an additional 0.0987 cms was needed to make the flow balance at Lake Creek at Road 138 (RKM 7.45). This additional flow was added as accretion in the model. The 0.0987 cms flow was distributed evenly from RKM 17.15 to RKM 7.45 (195 segments) which resulted in a flow of 0.0005 cms assigned to each segment in the model.

5.4 WATER TEMPERATURE INPUTS – LAKE CREEK

The upstream boundary of Lake Creek was specified using hourly water temperature data from USFS station Lake Creek below Diamond Lake (UmpNF-053). The 30-minute temperature data were converted to hourly and specified in the model. Thielson Creek and Sheep Creek were also included in the configuration of the spawning season model. Tributary temperature was assigned to Sheep Creek and Thielson Creek using a surrogate station from an adjacent watershed (UmpNF-064 - Mowich Creek at Mouth) (as shown in Figure 5-9).

Table 5-2 provides an inventory of the water temperature data used in the model development for configuring the model tributary boundary conditions. Figure 5-9 shows the locations of the various stream temperature monitoring locations that were used as boundary conditions to configure the model or for calibration. Figure 5-10 shows the observed stream temperature time series data for August through October 2009 used for the upstream boundary assignment.

Table 5-2. Inventory of available water temperature data locations used to configure the Lake Creek model.

Station ID	Model location (Km)	Source	Type	Notes
Lake Creek below Diamond Lake_LTWT (UmpNF-053)	17.15	USFS	Boundary Condition	
Thielson Creek	9.30	Derived data	Tributary	Direct surrogate using UmpNF-064 - Mowich Creek at Mouth
Sheep Creek	5.25	Derived data	Tributary	Direct surrogate using UmpNF-064 - Mowich Creek at Mouth

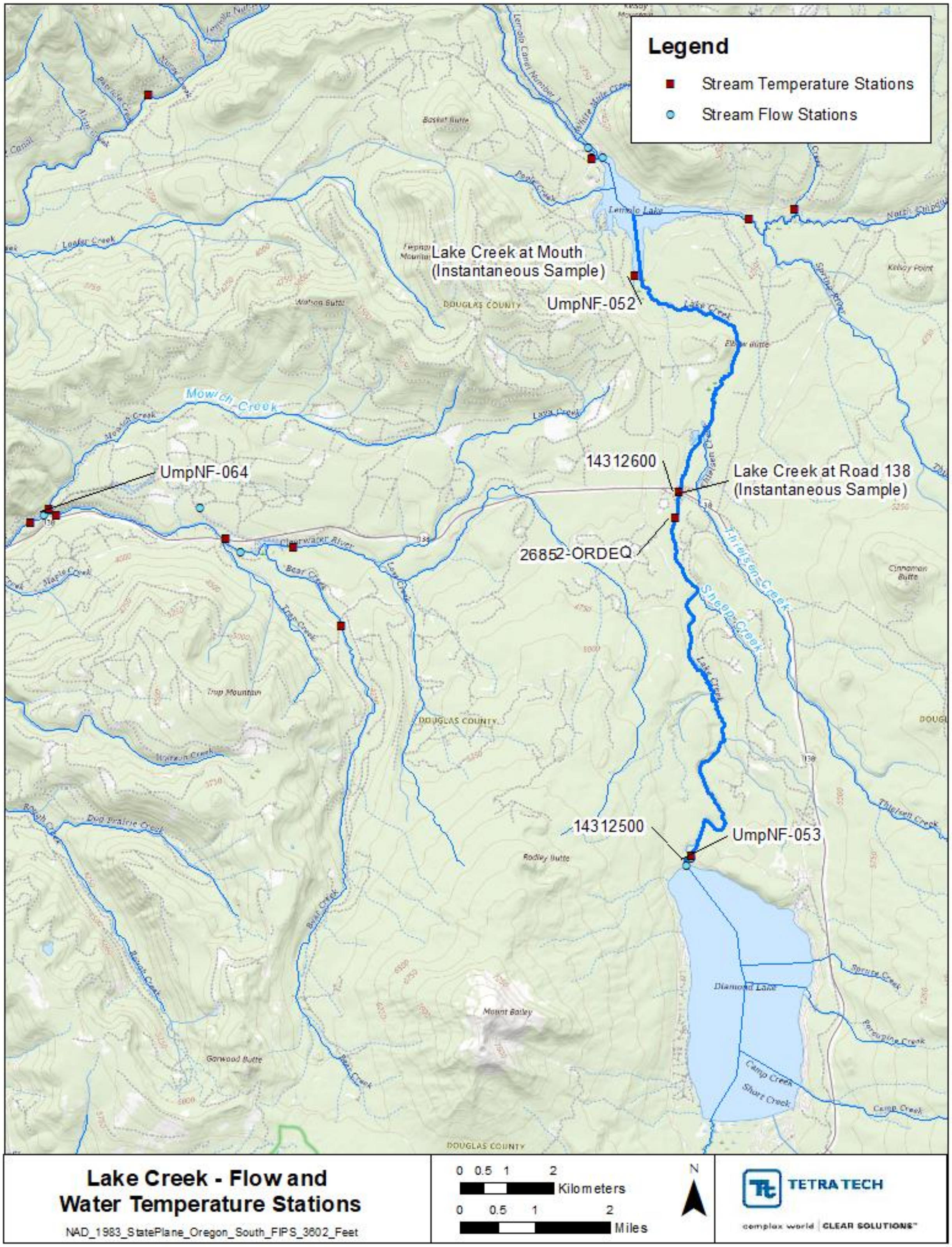

Figure 5-9 Lake Creek observed stream flow and water temperature locations.

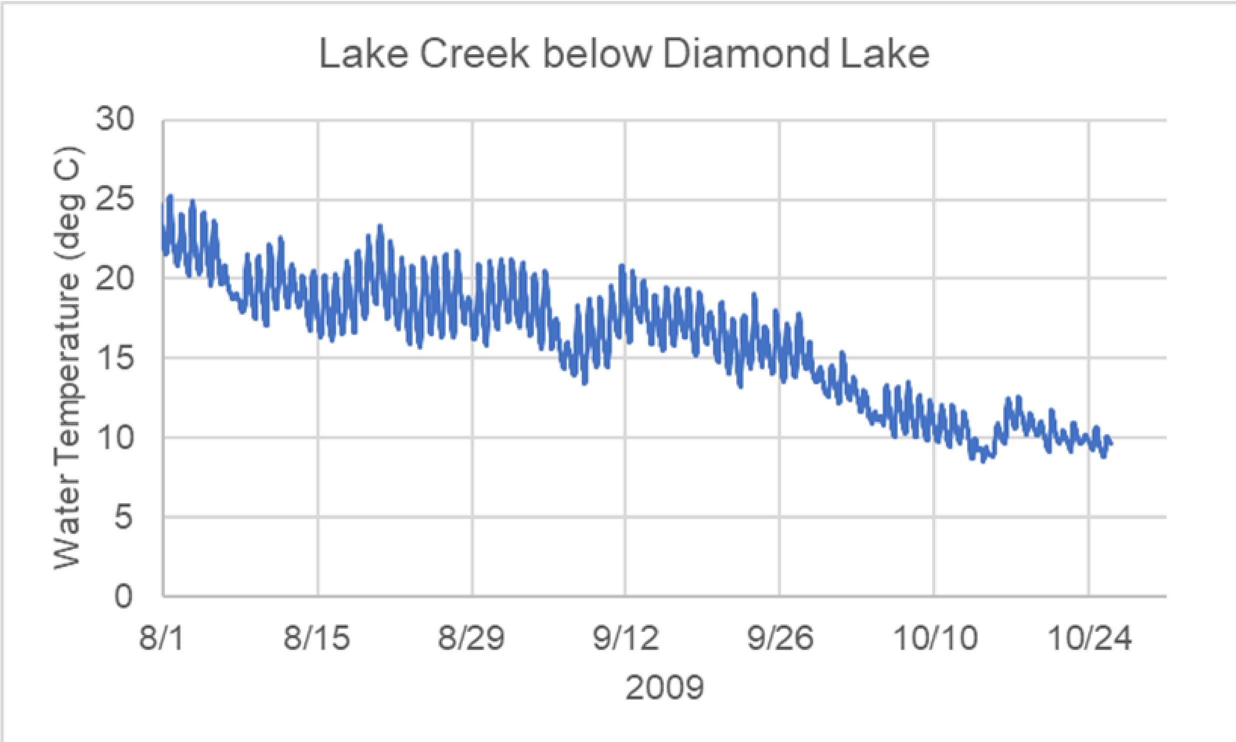

Figure 5-10 Observed hourly water temperature at Lake Creek below Diamond Lake (UmpNF-053).

As already noted, stream water temperatures for Thielson and Sheep creeks were derived using a direct surrogate from a neighboring tributary watershed – Mowich Creek at Mouth (UmpNF-064). Figure 5-11 shows the water temperature data at Mowich Creek (UmpNF-064). The accretion discussed in Section 5.3 was assigned a temperature of 12 °C.

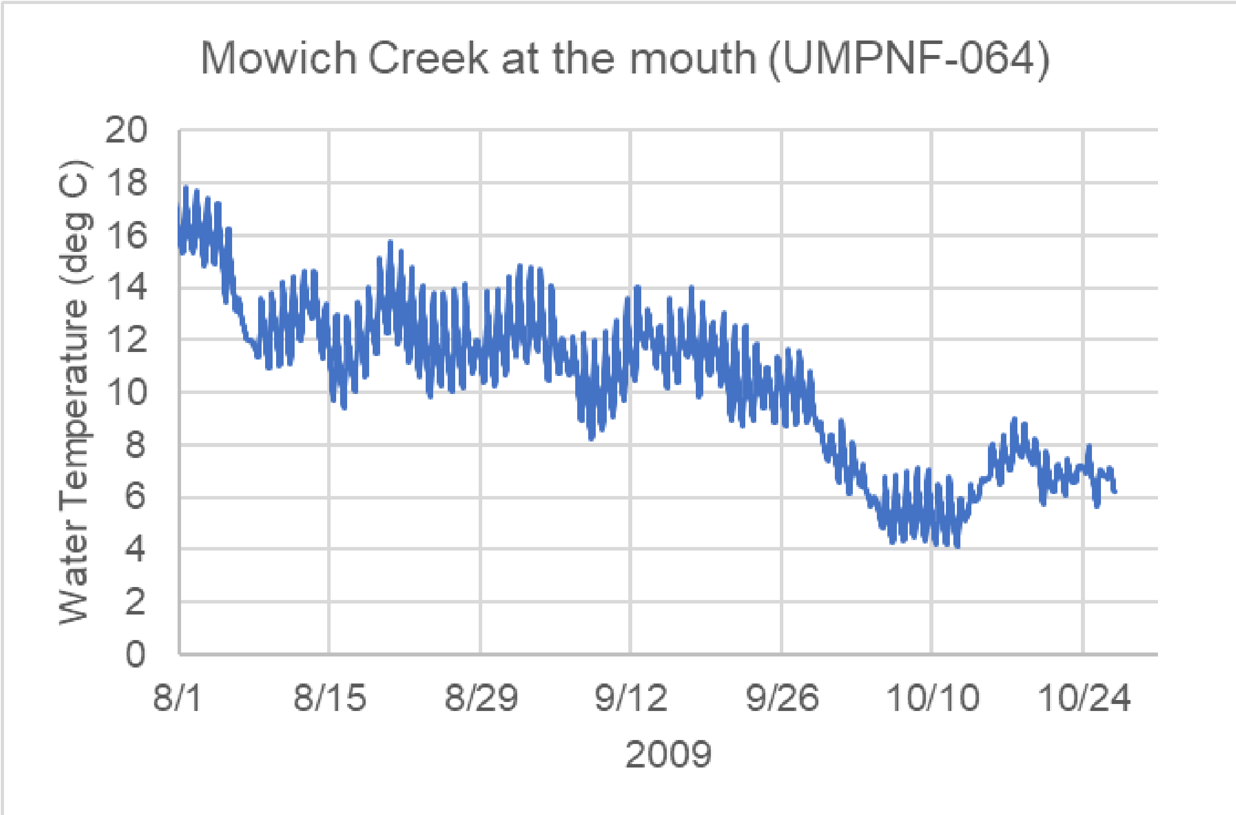

Figure 5-11. Water temperature data used for Thielsen and Sheep Creek (UmpNF-064).

5.5 METEOROLOGICAL DATA – LAKE CREEK

Meteorological data includes air temperature, sky conditions, cloudiness, relative humidity, and wind speed. Hourly meteorology inputs were available from the National Oceanic and Atmospheric Association (NOAA)'s NCDC Local Climatological Dataset (LCD). The LCD includes quality controlled meteorological data from airports and other prominent weather stations managed by the National Weather Service, Federal Aviation Administration, and the U.S. Department of Defense. The Roseburg Regional Airport. NCDC – LCD station was used for meteorological data assignment in the model. Table 5-3 includes the station inventory of available meteorological input data, and Figure 5-12 shows the location of the station.

Table 5-3. Inventory of available meteorological station data for the Lake Creek watershed

Station ID	Station Name	Elevation (m)	Latitude/ Longitude	Frequency	Available Met Data	Source
WBAN 24231	NCDC – LCD station Roseburg Regional Airport	152.9	43.23367°/ -123.35775	Hourly	Air Temperature, Relative Humidity, Wind Speed, Descriptive Cloud cover	NCDC - LCD

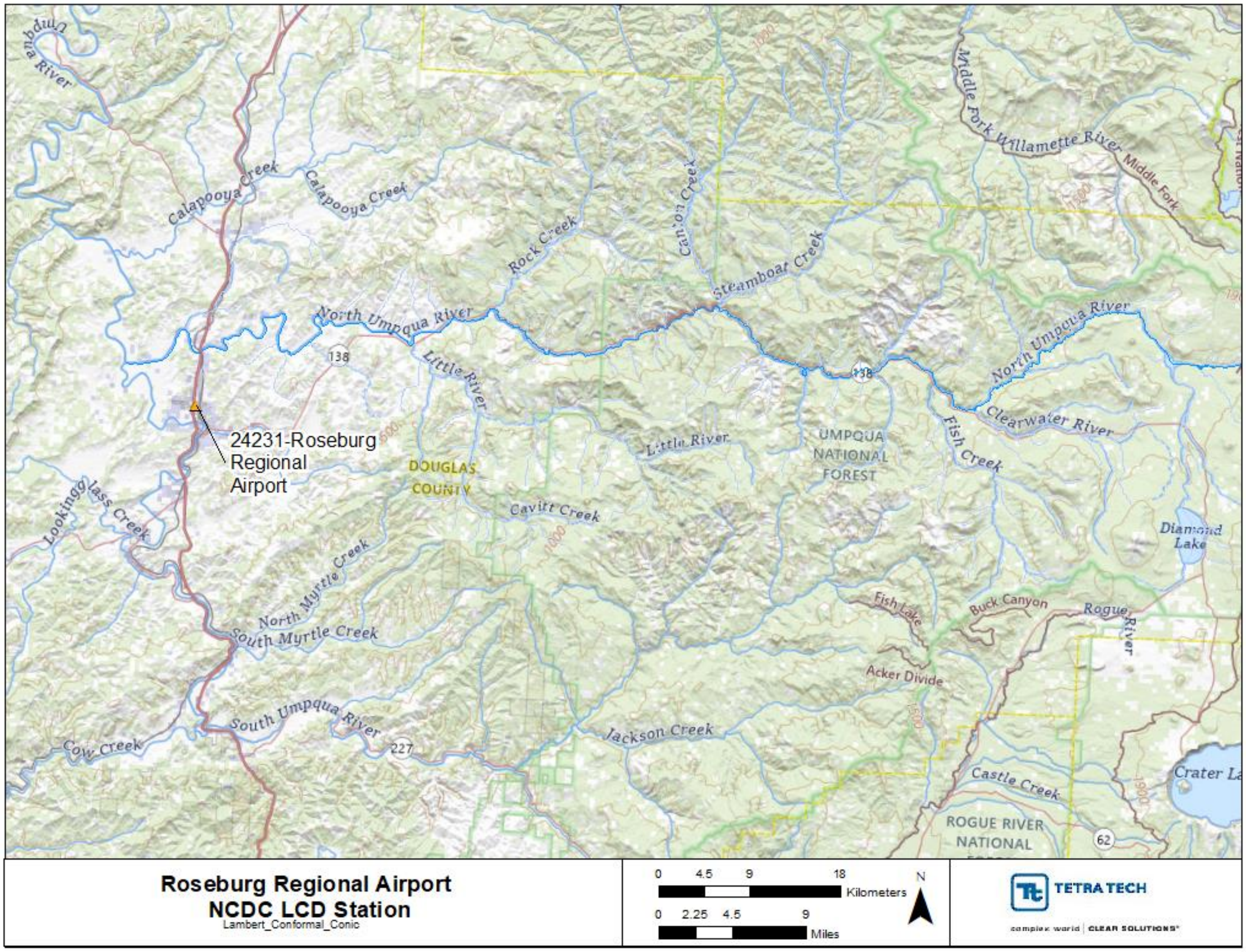

Figure 5-12. Roseburg Regional Airport Station Location

Station elevations vary widely from the reference station where the data were observed to the model location, ranging from 152.9 meters at the Roseburg Regional Airport compared to that in the vicinity of Lake Creek (1,260 meters). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. The adiabatic lapse rate was calculated as follows:

LR = 9.8·(Z_sta-Z_site)/1000

where,

LR = Dry adiabatic lapse rate adjustment (°C)

Z_sta = Elevation (meters) of the reference station (152.9 m)

Z_site = Elevation (meters) at the site of interest (1260 m)

LR calculated to be -10.8496 °C.

Wind speed, relative humidity and cloud cover were specified after applying appropriate unit conversion. Wind speeds were further adjusted during calibration which is discussed in the next section. The Roseburg Airport provided descriptive sky cover information, which was converted to tenths from 0 to 1 for input in the Heat Source Model. In general, data for all parameters were available for the modeling period no missing data. An exception to this was air temperatures which were missing for a few hours for days in August. The data were filled using data from the previous hour. Figure 5-13 show the meteorological input specified in the Heat Source Model at the Roseburg Regional Airport.

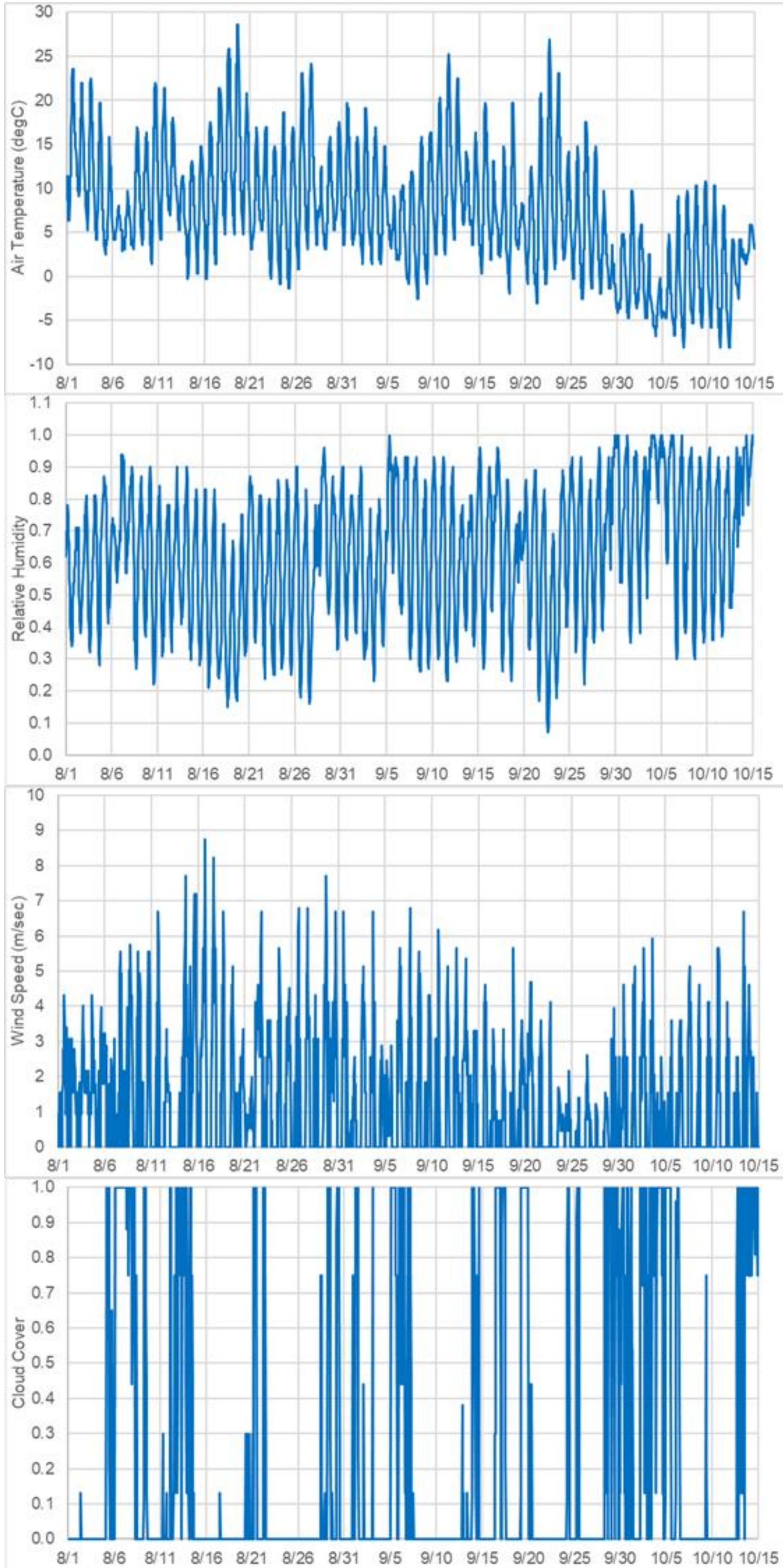

Figure 5-13. Hourly Air Temperature, Relative Humidity, Wind Speed, and Cloud Cover at Roseburg Regional Airport

5.6 MODEL CALIBRATION – LAKE CREEK

The Lake Creek Heat Source model was simulated for the time period from August 1, 2009, to October 15, 2009, over the 17.14-kilometer study area from Diamond Lake to the mouth of Lake Creek. The model incorporated hourly meteorology, three hourly flow and stream temperature inputs (including the upstream boundary and major tributaries - Thielson Creek and Sheep Creek). The model was run at a time step of 1 minute and outputs were generated hourly, every 100 meters. The modeled stream flows were calibrated first, followed by stream temperature.

The model was then calibrated against observed data. Model calibration refers to the comparison of observed data to modeled values. Table 5-4 shows the sites used in the Lake Creek Heat Source model flow and water temperature calibration. Refer to Figure 5-9 for the location of the flow and stream temperature calibration stations.

Table 5-4. Calibration sites used in the Lake Creek Heat Source Model Calibration

Station ID	Description	Model RKM	Data Type	Source
Hydraulics				
Lake Creek at Road 138	Lake Creek at Road 138 (old USGS station 14312600 location)	7.45	Instantaneous flow, velocity, maximum depth, hydraulic depth, and top width	DEQ (collected on 9/9/2009)
Lake Creek at the mouth	Lake Creek at the mouth	0.5	Instantaneous flow, velocity, maximum depth, hydraulic depth, and top width	DEQ (collected on 9/9/2009)
Hourly Water Temperature				
UmpNF-053	Lake Creek below Diamond Lake_LTWT	16.95	Water Temperature	USFS
26852-ORDEQ	Lake Creek	8.20	Water Temperature	DEQ
UmpNF-052	Lake Creek at the mouth LTWT	0.50	Water Temperature	USFS

A combination of visual and computed error statistics was used to assess the model calibration. Summary statistics (ME, MAE, RMSE, and NSE) followed the calculations described in Section 3.6.

5.7 FLOW CALIBRATION – LAKE CREEK

Modeled flows were compared with observed flows and stream hydraulic measurements including velocities, depths, and top widths at the two flow stations along Lake Creek. The flow data were collected on September 9, 2009, at Lake Creek at Road 138 (RKM 7.45) and Lake Creek at Mouth (RKM 0.1) (Figure 5-9). Figure 5-14 compares the simulated and measured hydraulic parameters measured at these two flow locations. Flow calibration statistics are not provided since there are only two instantaneous values to compare with, and it would not provide a meaning insight in the calibration, rather the calibration was performed using visual inspection.

Although the data represent a snapshot in time, the flow data were used as a guide to perform flow balance as discussed in section 5.3, and was further refined during calibration. The simulated daily flow and velocity values agreed fairly well with the observed data. The top width measurement also agreed fairly well with observed data. The model overpredicts the hydraulic depth and maximum depth. During calibration adjustments to widths were explored to further improve the depth calibration by widening the channel bottom widths. This adjustment slightly improved the depth calibration, but it further reduced the velocities, which are slightly lower than observed data already. Ultimately no changes were made to the bottom widths in the model as these data only represented a snapshot in time for a particular day.

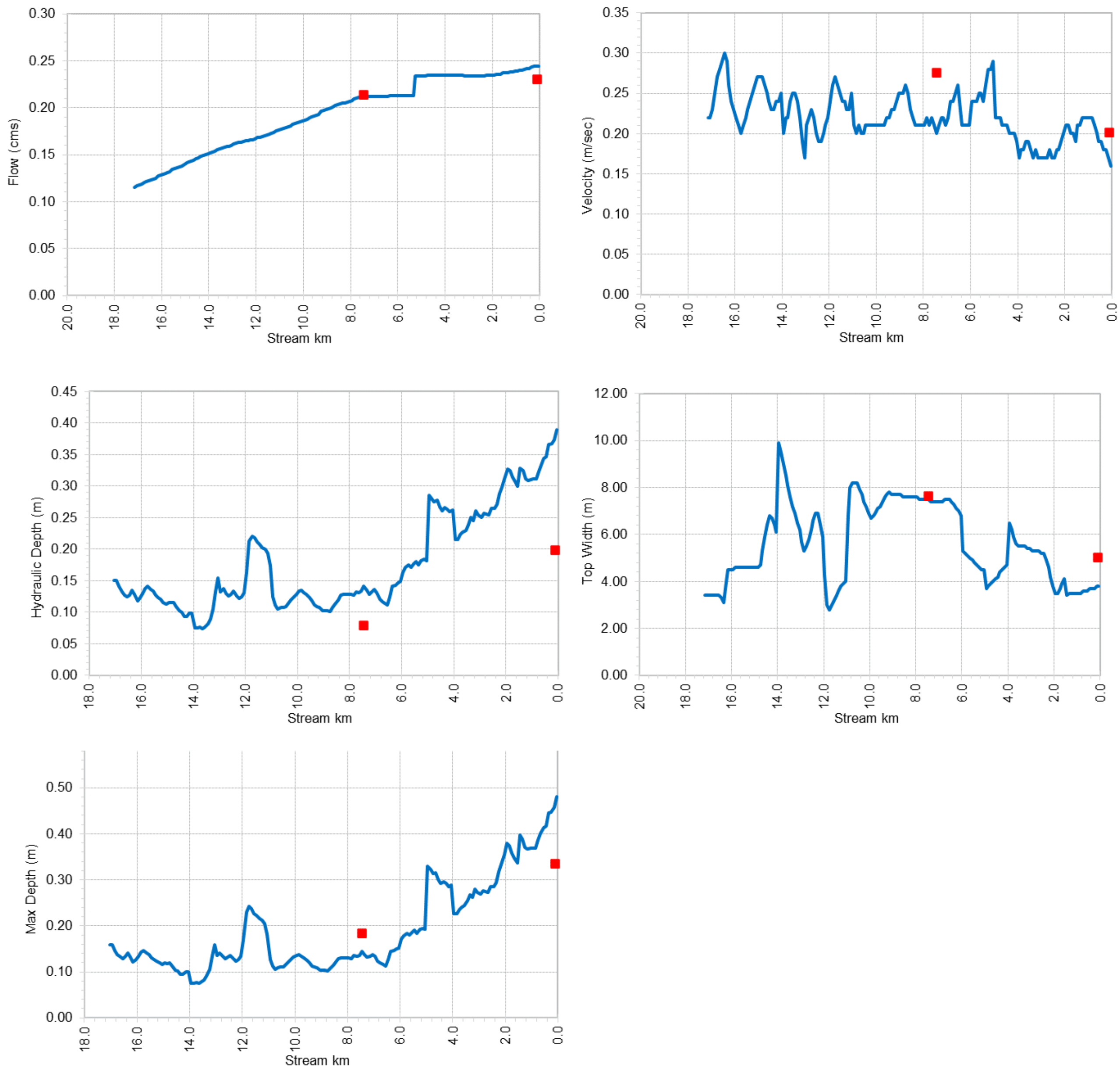

Figure 5-14 Observed Grab Sample versus Modeled Hydraulic Parameters on September 9, 2009.

5.8 TEMPERATURE CALIBRATION – LAKE CREEK

Hourly temperature observations were compared at each of the stream temperature calibration monitoring stations listed in Table 5-4. In general, the model captures the hourly diurnal pattern and daily maximums well at the upstream and downstream station locations during most of the model simulation period (Figure 5-15). The exception being during October when the flows start to increase, and the model is unable to mimic the observed patterns well as seen at the Lake Creek 26852-ORDEQ and Lake Creek at mouth stations. The modeled daily maximum temperatures were also compared with the observed daily maximum, and they agreed well as shown in Figure 5-16.

Channel morphology related inputs were retained from the HS7 model during calibration. The sediment heat exchange parameters, i.e., sediment thermal conductivity and diffusivity, and wind function coefficients, were applied at their HS8 default values. Wind speeds were adjusted during calibration to improve the calibration to represent difference in wind speed between the measurement location and above the stream within the riparian area. The wind speed adjustments were primarily used to improve the water temperature calibration.

The calculated error statistics for the hourly and daily maximum temperatures showed a ME and MAE of less than or equal to 1 ºC, except for the MAE for the hourly temperatures Lake Creek - ORDEQ 26852 station which was 1.05 ºC. The calculated RMSE error for the hourly temperatures at Lake Creek 26852-ORDEQ and Lake Creek at mouth station were over 1 ºC (1.32 ºC and 1.17 ºC respectively), the calculated RMSE error for the daily maximum temperatures was 1.29 ºC and 1.04 ºC respectively. Table 3-5 show the model calibration statistics for each of the calibration locations. Overall, all three stations were seen to capture the daily maximum fairly well, especially during the low flow periods, compared to the high flow period during October.

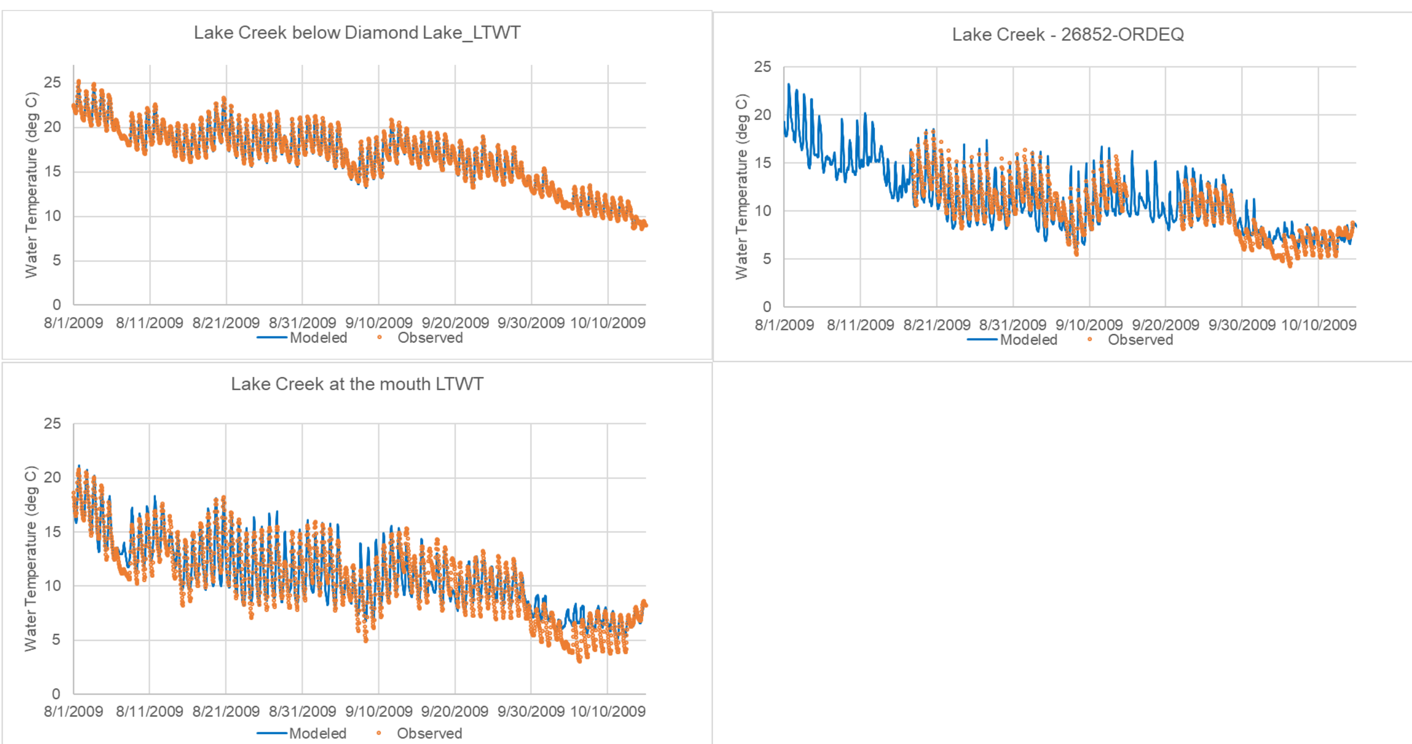

Figure 5-15 Observed versus Modeled Hourly Water Temperature – Lake Creek below Diamond Lake, Lake Creek at ORDEQ 26852, and Lake Creek at the mouth.

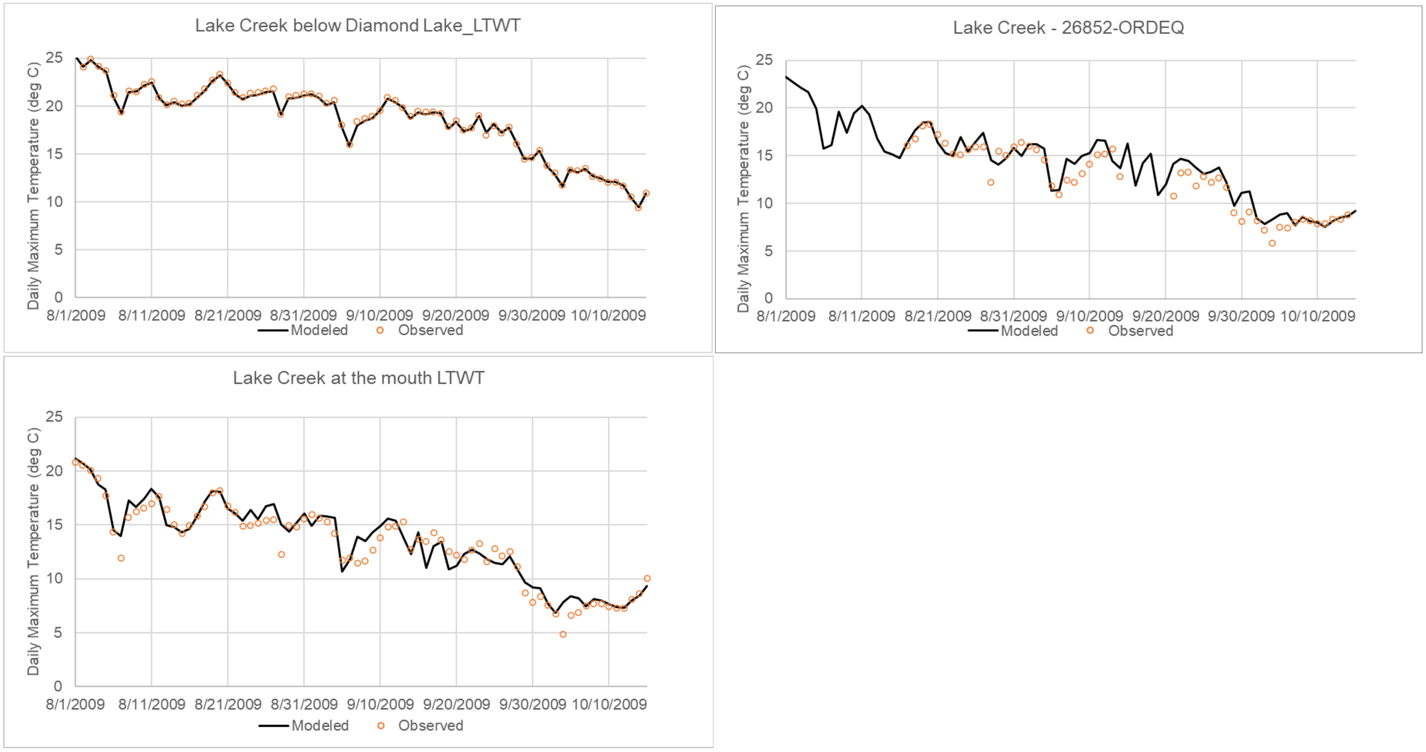

Figure 5-16. Observed versus Modeled Daily Max Water Temperature – Lake Creek below Diamond Lake, Lake Creek at ORDEQ 26852, and Lake Creek at the mouth.

Table 5-5. Hourly and Daily Maximum Stream Temperature calibration statistics with cloud cover for Lake Creek (August 1 to October 15, 2009)

Statistic	Lake Creek below Diamond Lake	Lake Creek - ORDEQ 26852	Lake Creek at the mouth
Hourly Temperature Statistics			
ME	-0.13	-0.28	0.06
MAE	0.15	1.05	0.91
RMSE	0.19	1.32	1.17
NSE	0.997	0.79	0.90
Count	1,824	1,222	1,824
Daily Maximum Temperature Statistics			
ME	-0.10	0.71	0.27
MAE	0.12	1.00	0.78
RMSE	0.15	1.29	1.04
NSE	0.998	0.85	0.92
Count	76	53	76

6.0 NORTH UMPQUA RIVER

6.1 MODEL TIME PERIOD AND EXTENT

The model was developed for the period from August 01, 2009, to October 15, 2009. This period corresponded to the period when hourly water temperature data were collected by DEQ, as listed in the QAPP (DEQ, 2022). Hourly stream temperature data were collected at several locations along North Umpqua, which were used for model boundary configuration and calibration purposes.

North Umpqua River generally flows in the westerly direction from below Lemolo Reservoir to the mouth where it ultimately flows to the Umpqua River. The North Umpqua River simulation consists of five separate Heat Source models, each separated by a reservoir or diversion dam (Figure 6-1). Since Heat Source is a one-dimensional model, the reservoirs or backwaters behind the dams were not simulated. The extent of the model domain for the modeled segments is the same as that of the summer period model (with the exception for Model 5). The overall model extent of the various Heat Source Models is shown in Figure 6-1.

Model 1: Lemolo Reservoir to Lemolo Powerhouse #1 (RKM 6.9 to RKM 0).

Model 2: Lemolo Powerhouse #1 to Toketee Reservoir (RKM 19.35 to RKM 0).

Model 3: Toketee Reservoir to Slide Powerhouse (RKM 3.15 to RKM 0).

Model 4: Slide Powerhouse to Soda Springs Reservoir (RKM 3.15 to RKM 0).

Model 5: Soda Springs Reservoir to the mouth (RKM 113.4 to RKM 0). This modeling domain comprises of two HS7 models that were developed previously. Specifically, the HS7 models North Umpqua from Soda Springs Powerhouse (PH) to Steamboat Creek that was configured for the period from 7/8/2001 to 7/11/2001 and the North Umpqua from Steamboat Creek to Mouth configured for the period from 7/12/2002 to 7/31/2002 were merged into one model i.e., Model 5 for 2009 spawning period model from August 01, 2009, to October 15, 2009.

The individual model extents of the five North Umpqua models are shown in Figure 6-2 through Figure 6-6.

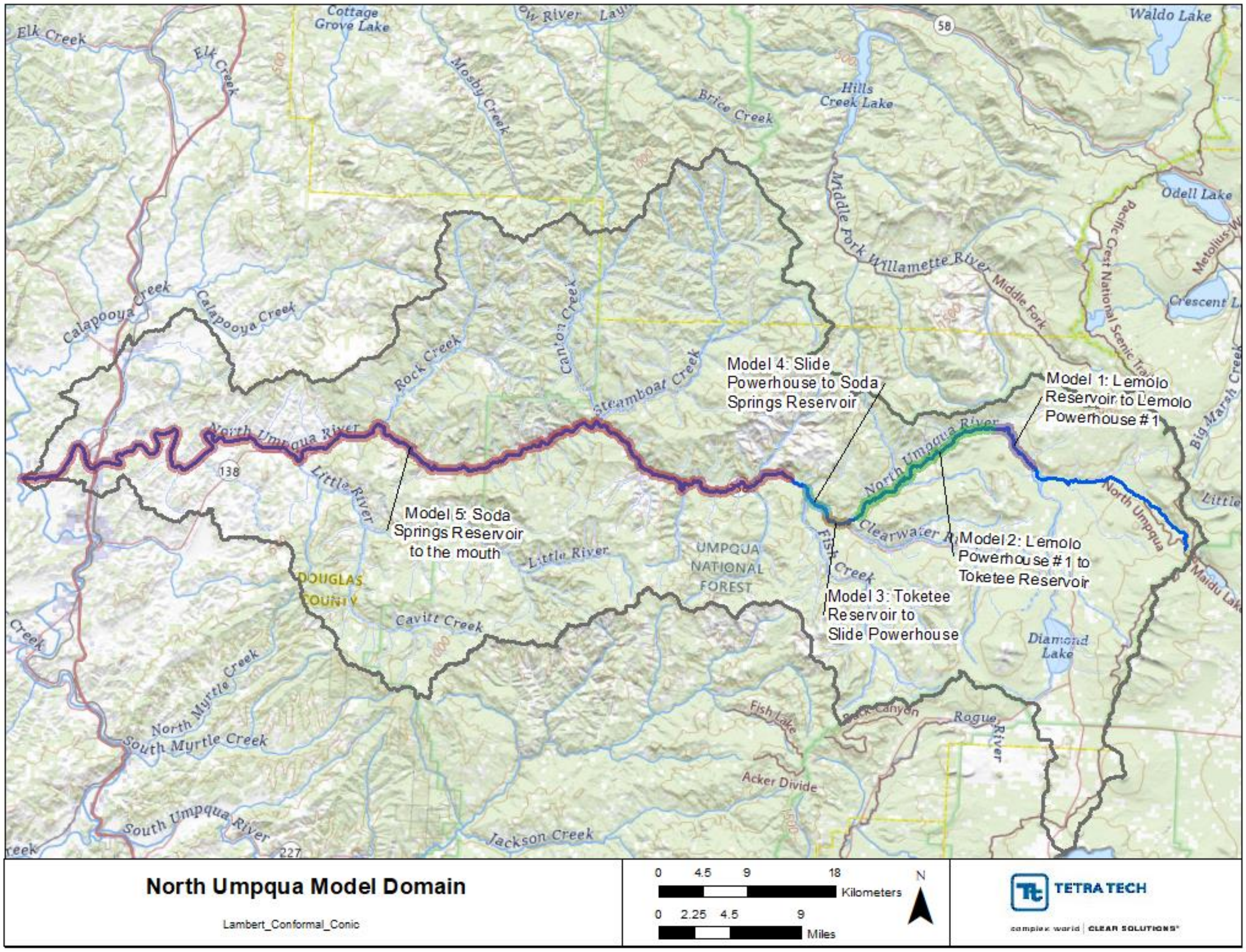

Figure 6-1. Extent of the North Umpqua River modeling domain

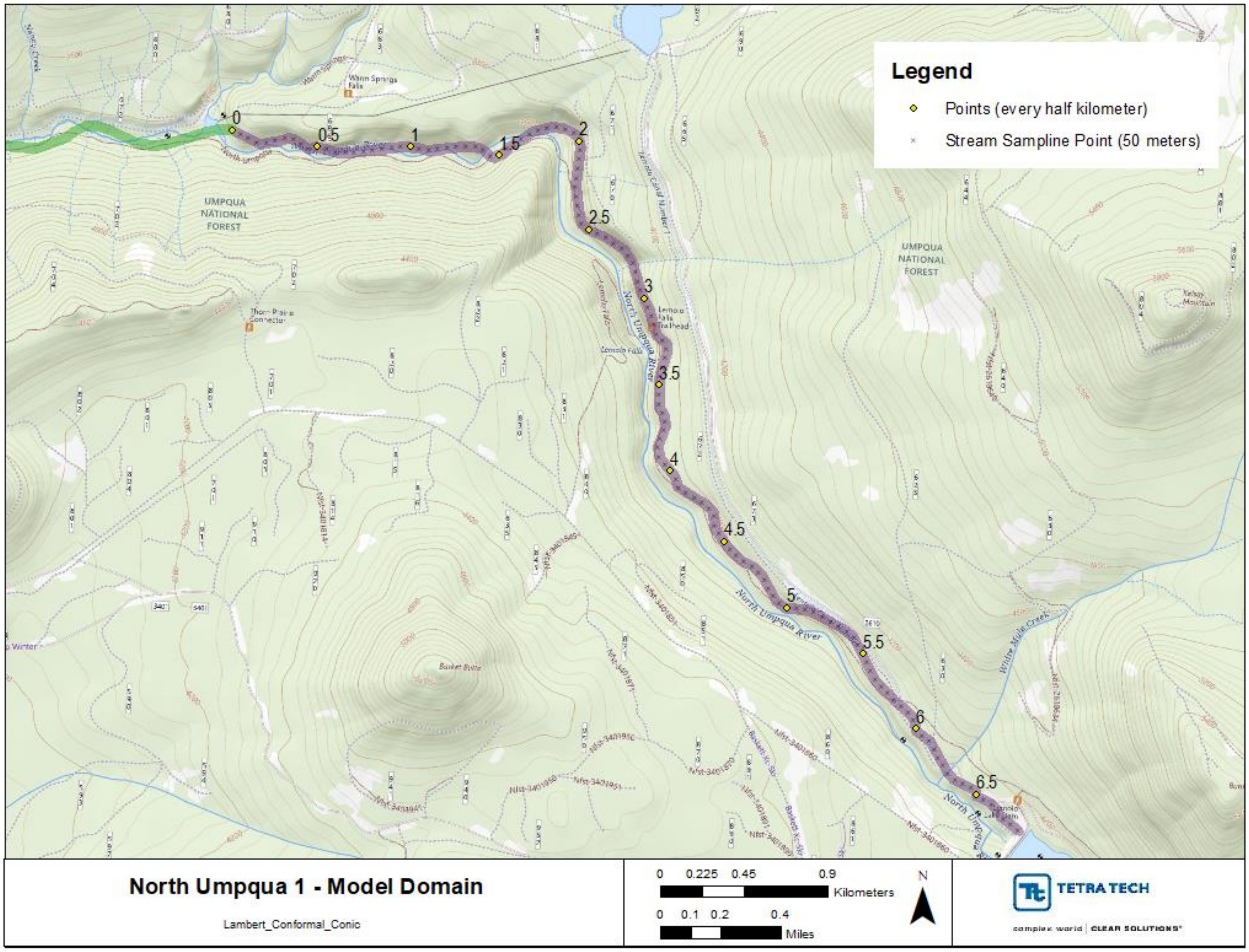

Figure 6-2. North Umpqua 1 - modeling domain

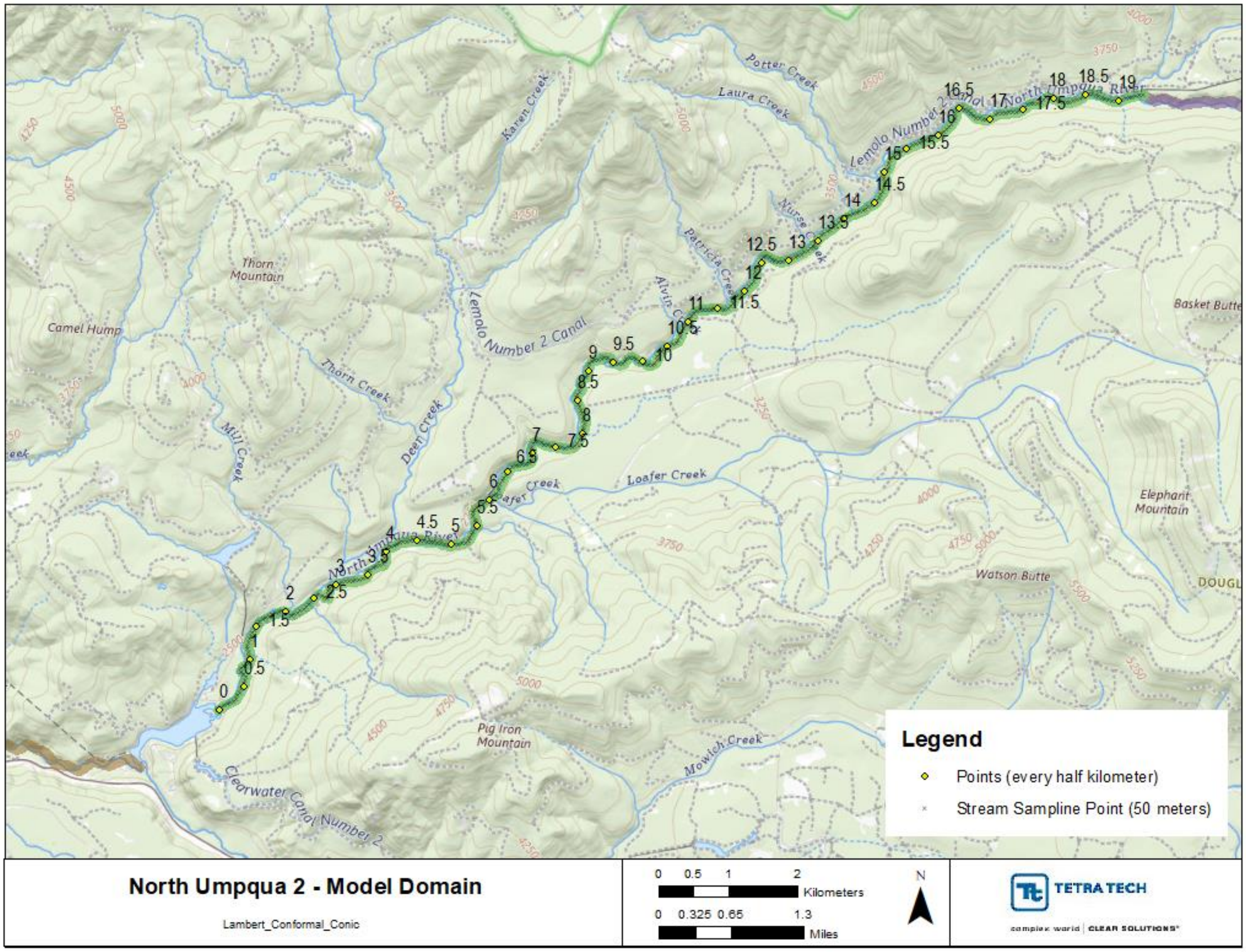

Figure 6-3. North Umpqua 2 - modeling domain

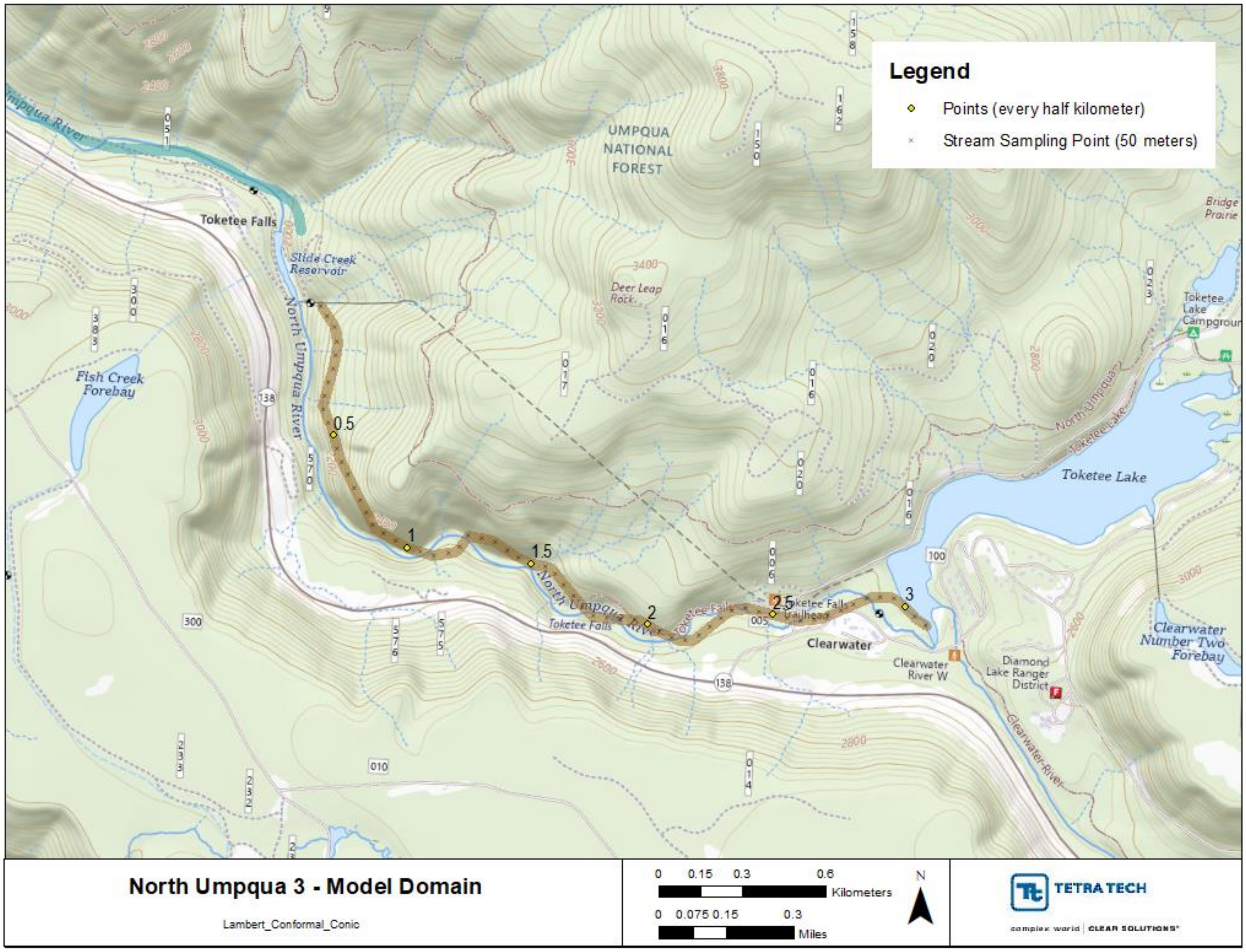

Figure 6-4. North Umpqua 3 - modeling domain

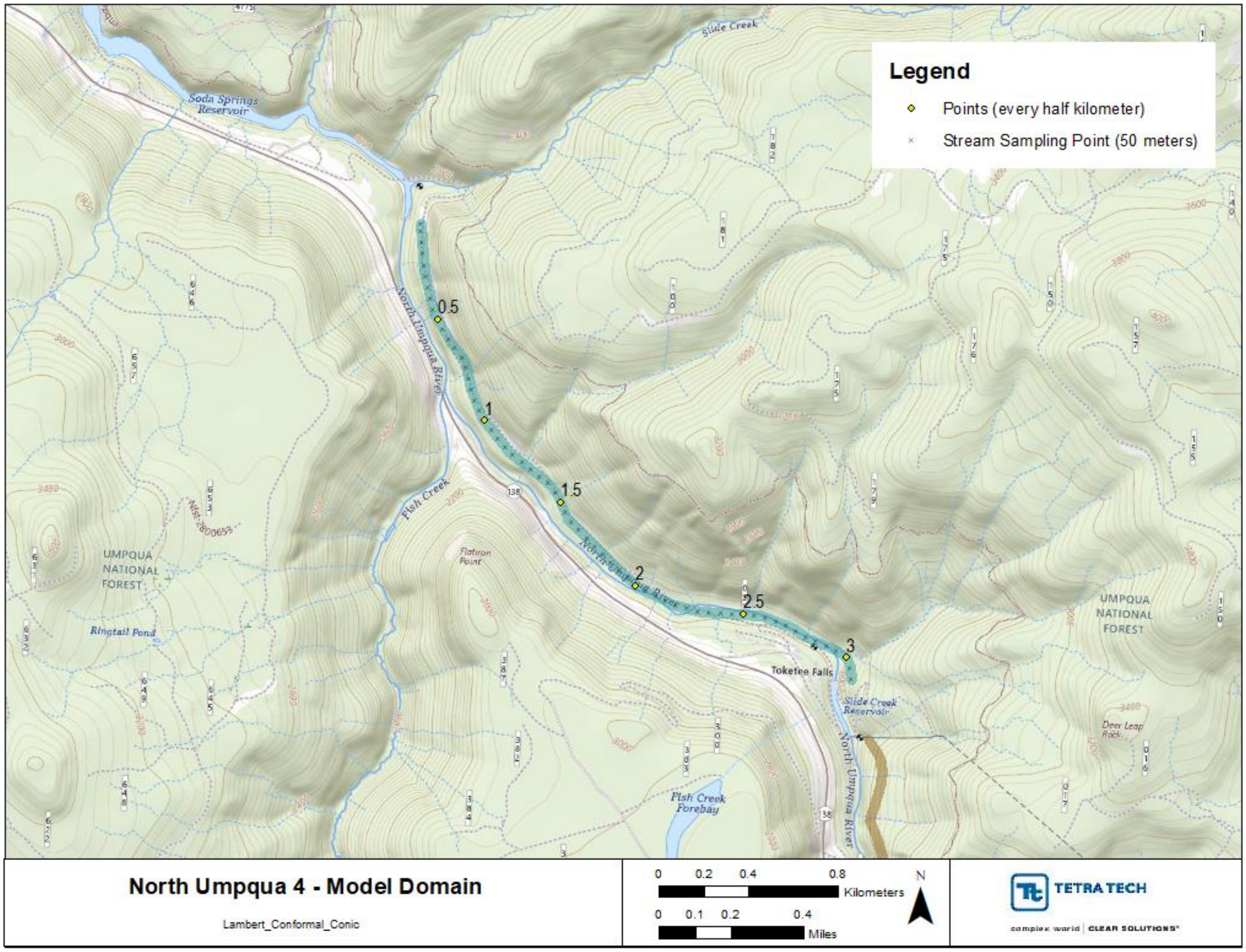

Figure 6-5. North Umpqua 4 - modeling domain

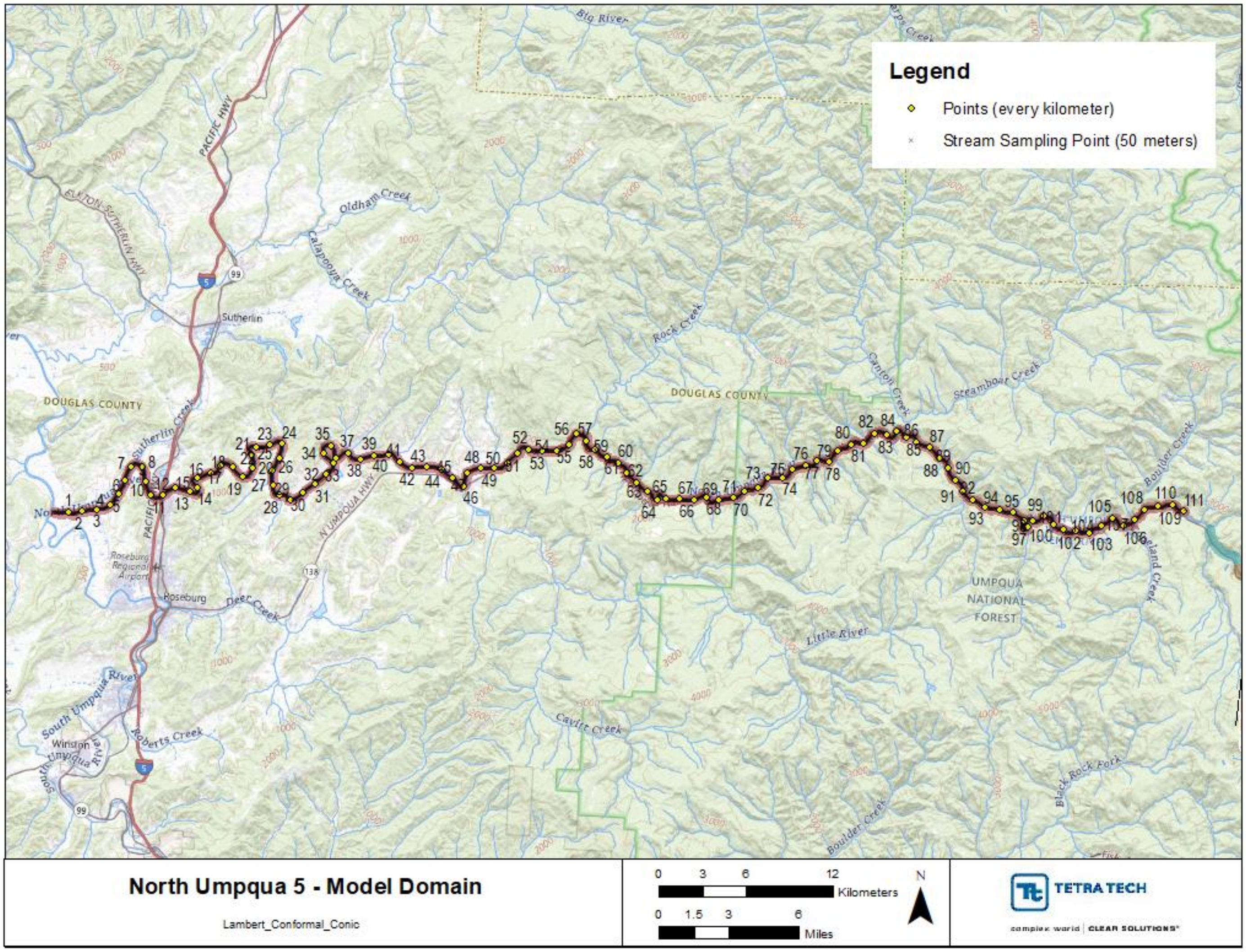

Figure 6-6. North Umpqua 5 - modeling domain

6.2 HEAT SOURCE MODEL INPUT – NORTH UMPQUA RIVER

The Heat Source spawning period model development involved using the HS7 summer models and converting them to HS8 models. The model timesteps were updated after conversion to HS8 since the model was unstable at the existing timestep. The time step for Model #1 and Model #2 needed to be reduced to 0.3 sec, whereas Model #3 and Model #5 were reduced to 0.5 sec. Model #4 was able to run at 1 sec and was left unchanged. Model morphological inputs for each model are presented in the sections 6.2.1 through 6.2.5. Remaining general set up is consistent with the description in Section 2.2.

6.2.1 North Umpqua Model #1 Morphological Inputs

Figure 6-7 and Figure 6-8 show the computed stream channel elevation and gradient, respectively, and Figure 6-9 shows the calculated channel bottom widths for North Umpqua Model #1. The calculated channel bottom widths used in the Model #1 ranged from 19.4 meters to 4.6 meters, with a mean of 8.4 meters. Figure 6-10 shows the Manning's n values used in the model. Except for the bottom width, all other parameters were left unchanged from the HS7 model. The flow and water temperature inputs are discussed in the following sections.

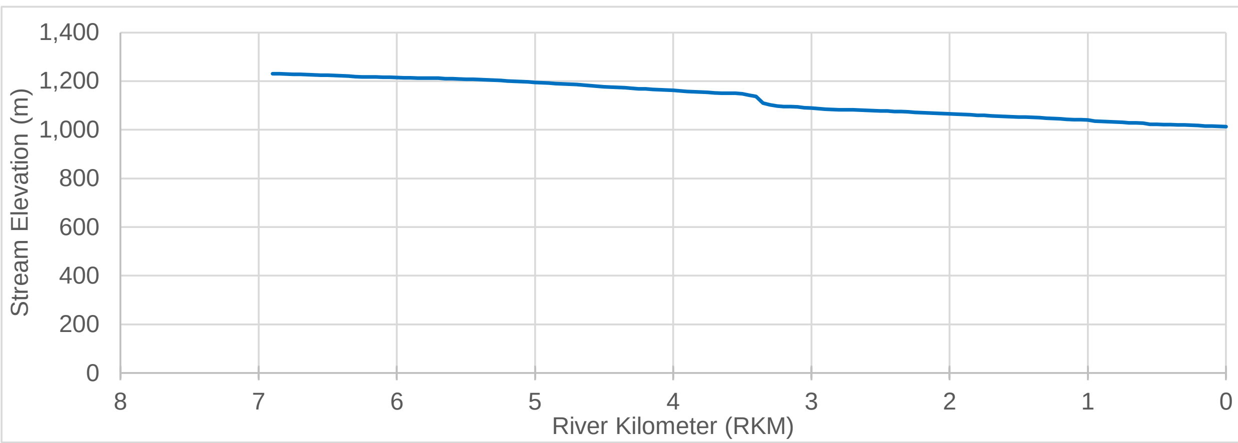

Figure 6-7. North Umpqua Model #1 - Elevation

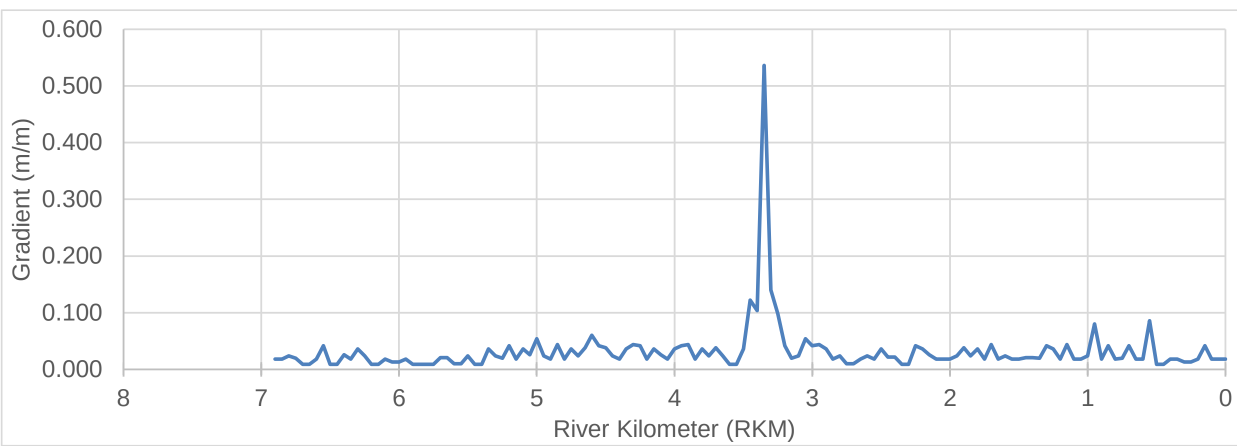

Figure 6-8. North Umpqua Model #1 – Gradient

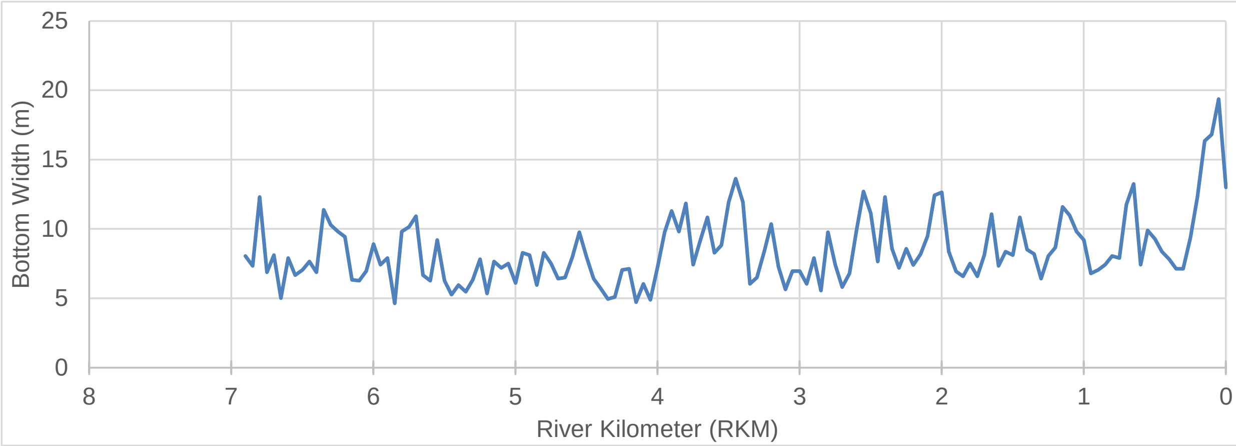

Figure 6-9. North Umpqua Model #1- calculated bottom widths.

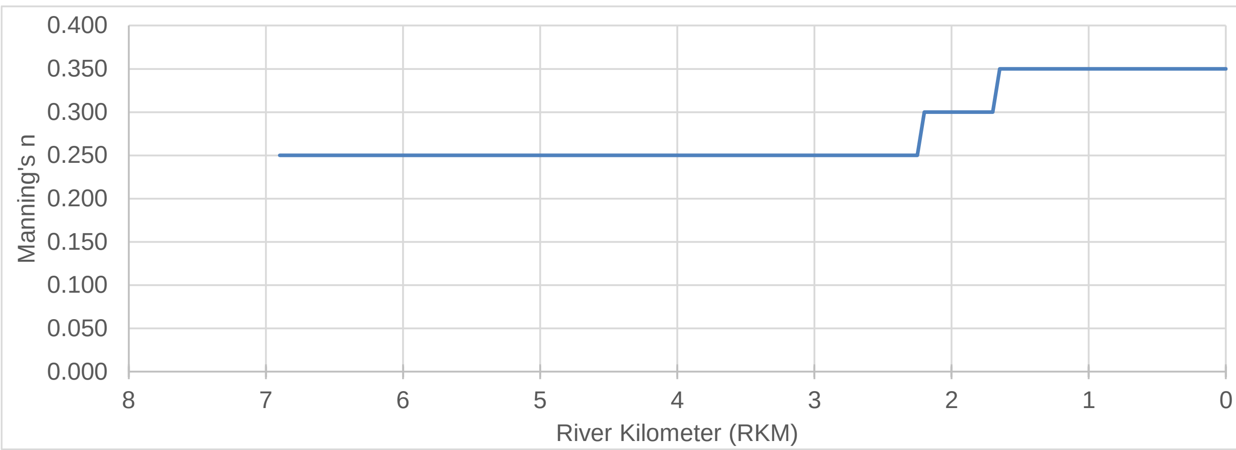

Figure 6-10. North Umpqua Model #1 assigned manning's n values.

6.2.2 North Umpqua Model #2 Morphological Inputs

Figure 6-11 and Figure 6-12 show the computed stream channel elevation and gradient, respectively, and Figure 6-13 shows the calculated channel bottom widths for North Umpqua Model #2. The calculated channel bottom widths used in the Model #2 ranged from 6.4 meters to 69.9 meters, with a mean of 14.3 meters. Figure 6-14 shows the Manning's n values used in the model. Except for the bottom width, all other parameters were left unchanged from the HS7 model. The flow and water temperature inputs are discussed in the following sections.

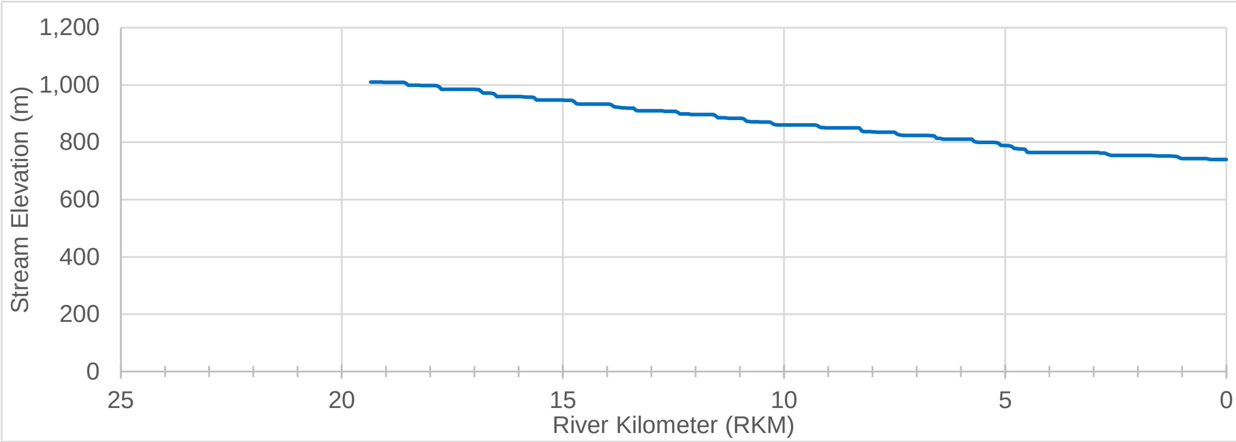

Figure 6-11. North Umpqua Model #2 - Elevation

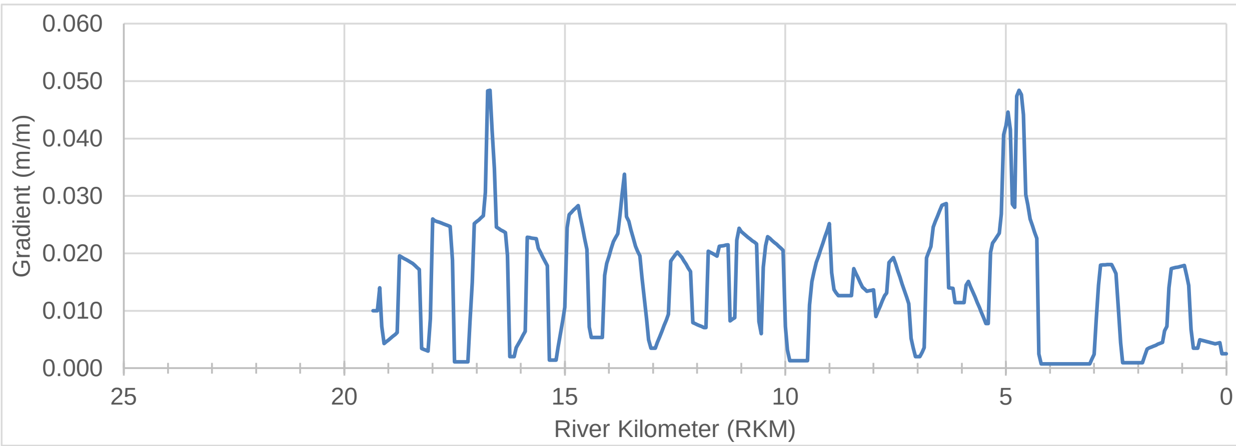

Figure 6-12. North Umpqua Model #2 - Gradient

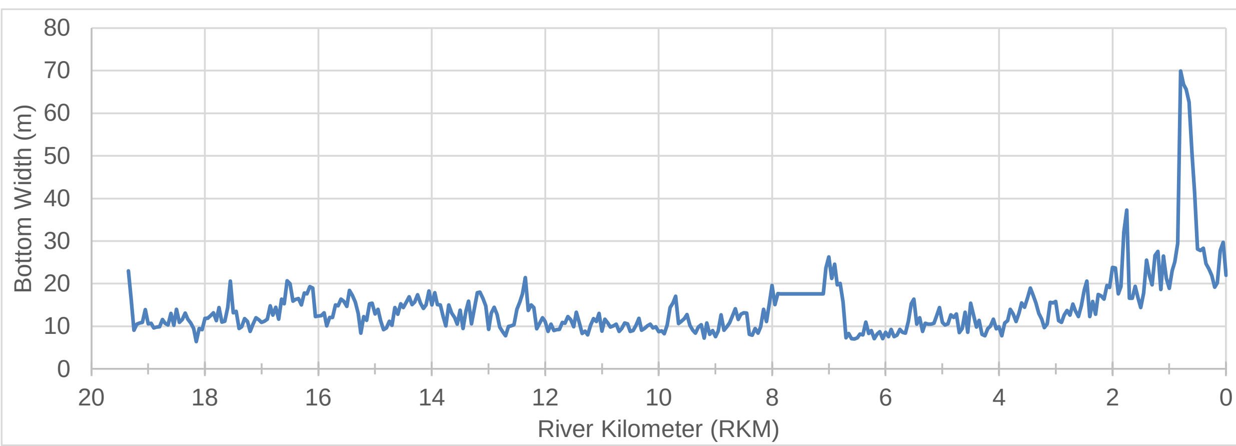

Figure 6-13. North Umpqua Model #2- calculated bottom widths.

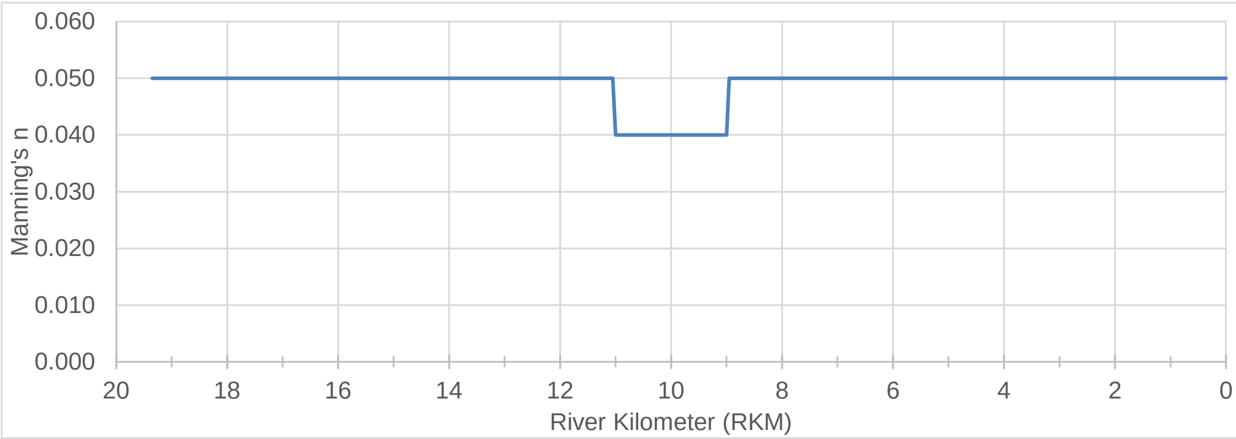

Figure 6-14. North Umpqua Model #2 assigned Manning's n values.

6.2.3 North Umpqua Model #3 Morphological Inputs

Figure 6-15 and Figure 6-19 show the computed stream channel elevation and gradient, respectively, and Figure 6-17 shows the calculated channel bottom widths for North Umpqua Model #3. The channel bottom widths used in the Model #3 ranged from 19.4 meters to 4.6 meters, with a mean of 8.4 meters. Figure 6-18 shows the Manning's n values used in the model. The flow and water temperature inputs are discussed in the following sections.

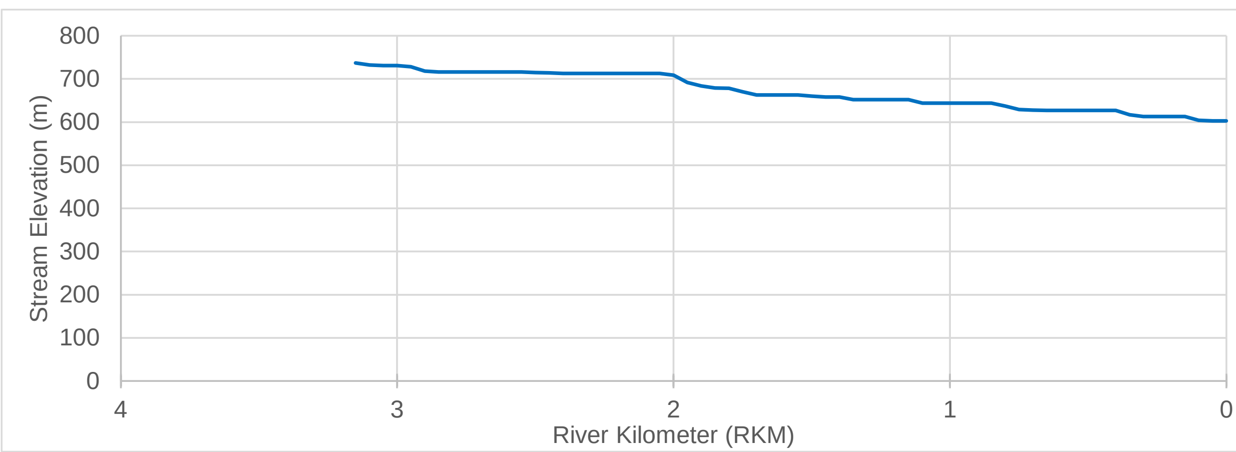

Figure 6-15. North Umpqua Model #3 - Elevation

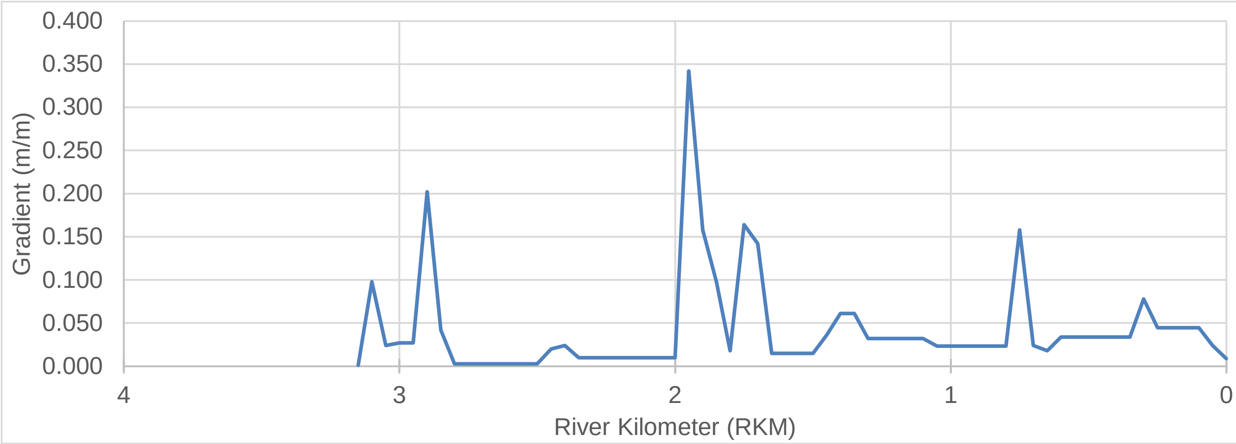

Figure 6-16. North Umpqua Model #3 - Gradient

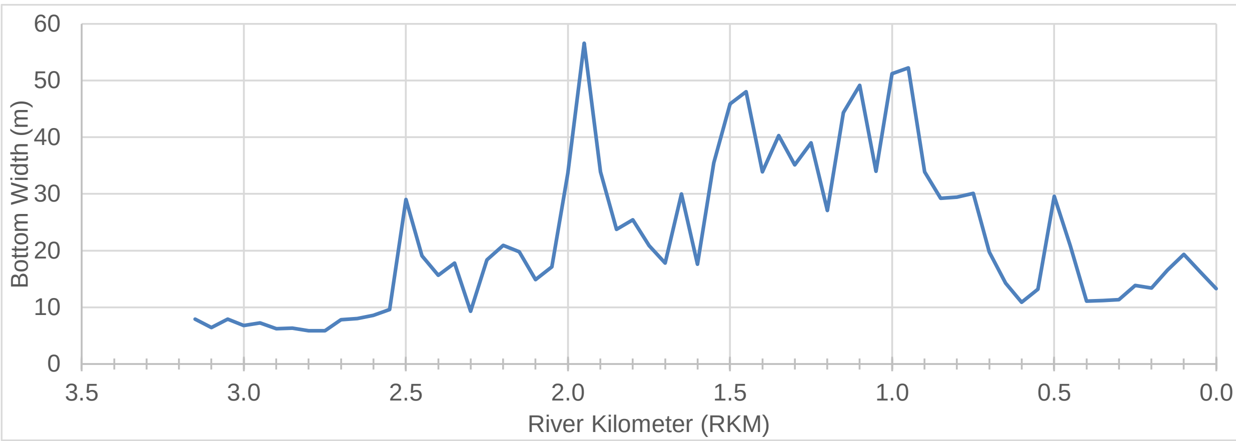

Figure 6-17. North Umpqua Model #3- calculated bottom widths.

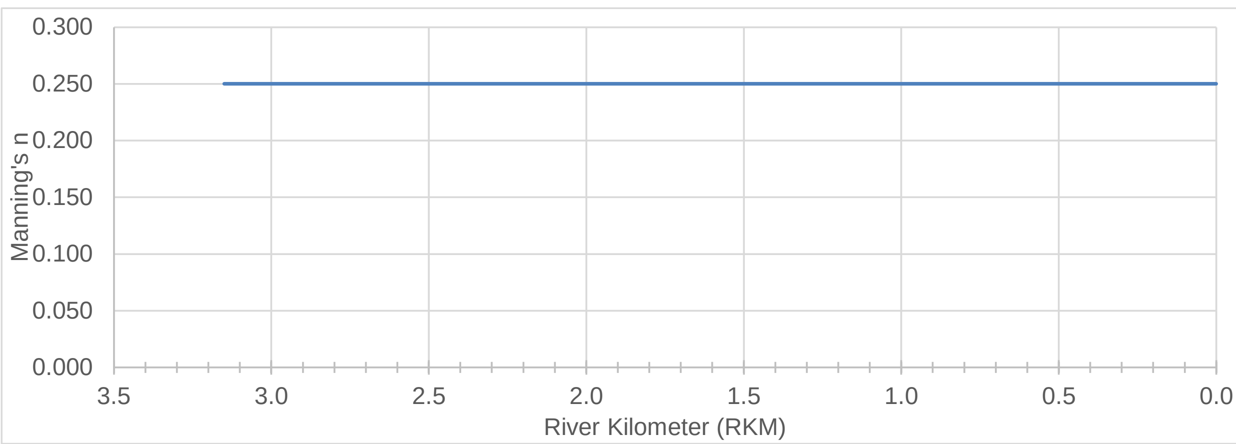

Figure 6-18. North Umpqua Model #3 assigned Manning’s n values.

6.2.4 North Umpqua Model #4 Morphological Inputs

Figure 6-19 and Figure 6-20 show the computed stream channel elevation and gradient, respectively, and Figure 6-21 shows the calculated channel bottom widths for North Umpqua Model #3. The channel bottom widths used in the Model #3 ranged from 19.4 meters to 4.6 meters, with a mean of 8.4 meters. Figure 6-22 shows the Manning's n values used in the model. The flow and water temperature inputs are discussed in the following sections.

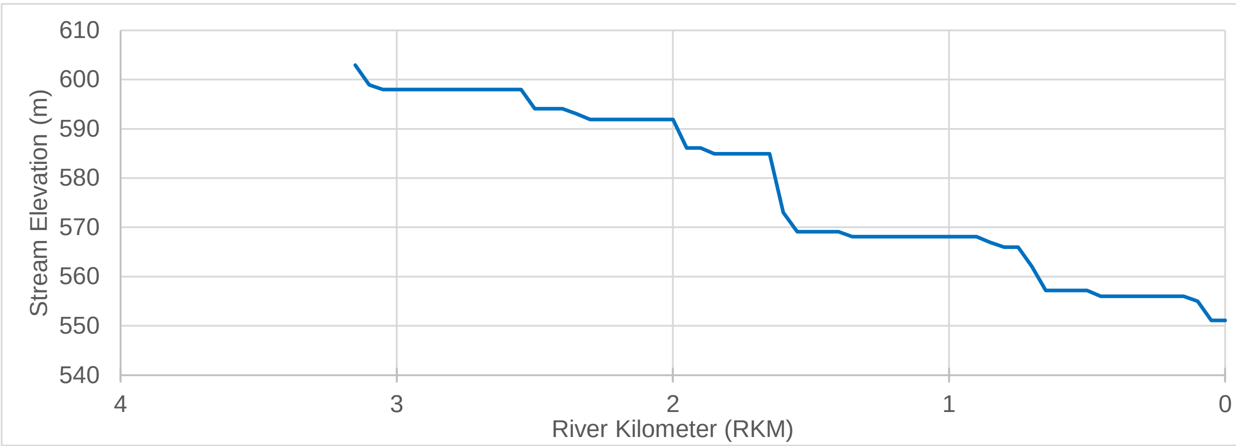

Figure 6-19. North Umpqua Model #4 - Elevation

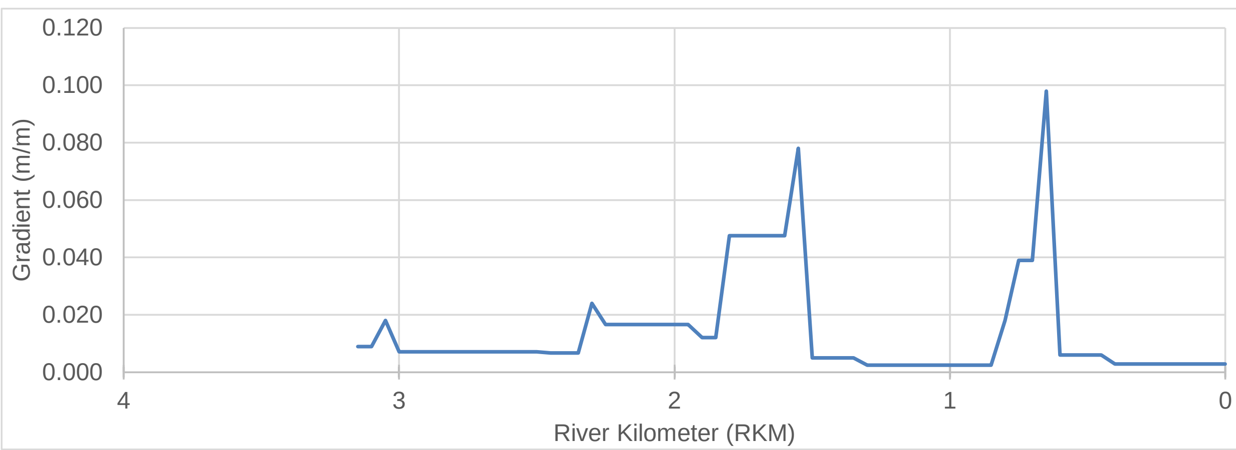

Figure 6-20. North Umpqua Model #4 - Gradient

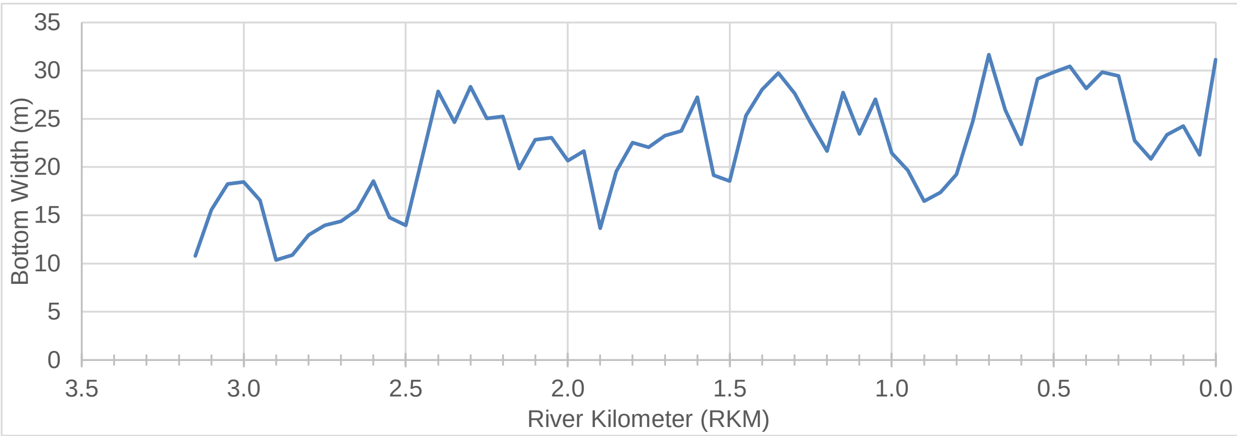

Figure 6-21. North Umpqua Model #4- calculated bottom widths.

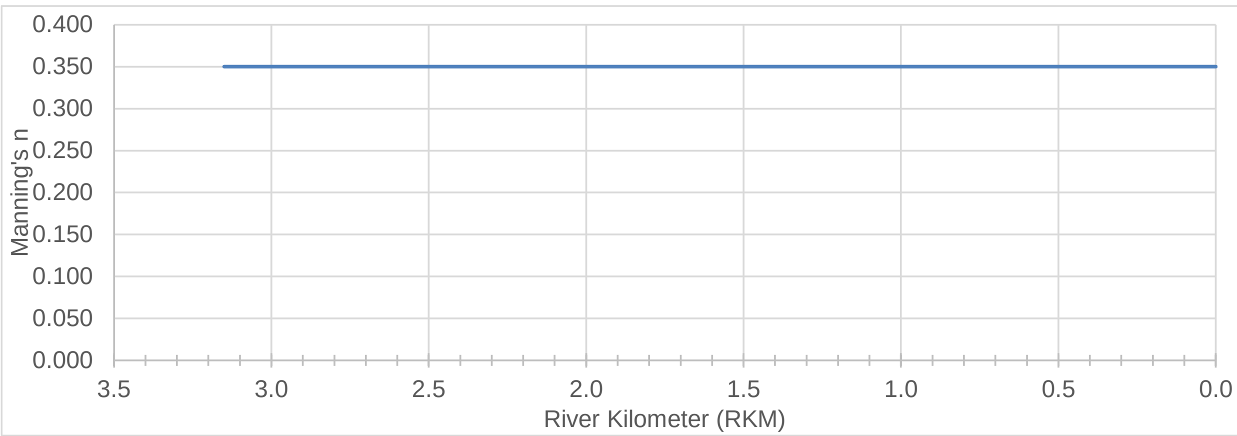

Figure 6-22. North Umpqua Model #4 assigned Manning's n values.

6.2.5 North Umpqua Model #5 Morphological Inputs

Figure 6-23 and Figure 6-24 show the computed stream channel elevation and gradient and Figure 6-25 shows the calculated channel bottom widths for North Umpqua Model #3. The channel bottom widths used in the Model #3 ranged from 19.4 meters to 4.6 meters, with a mean of 8.4 meters. Figure 6-26 shows the Manning's n values used in the model. The flow and water temperature inputs are discussed in the following sections.

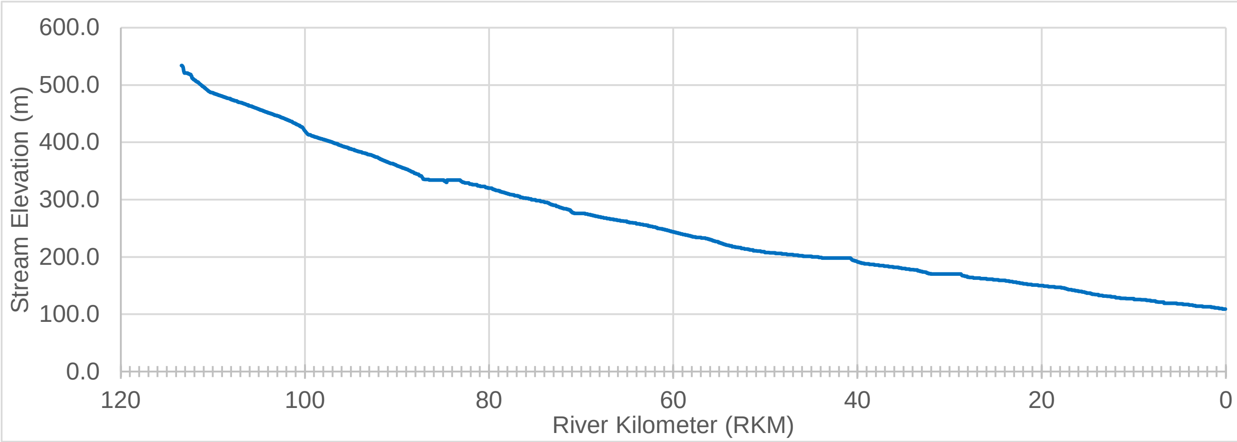

Figure 6-23. North Umpqua Model #5 - Elevation

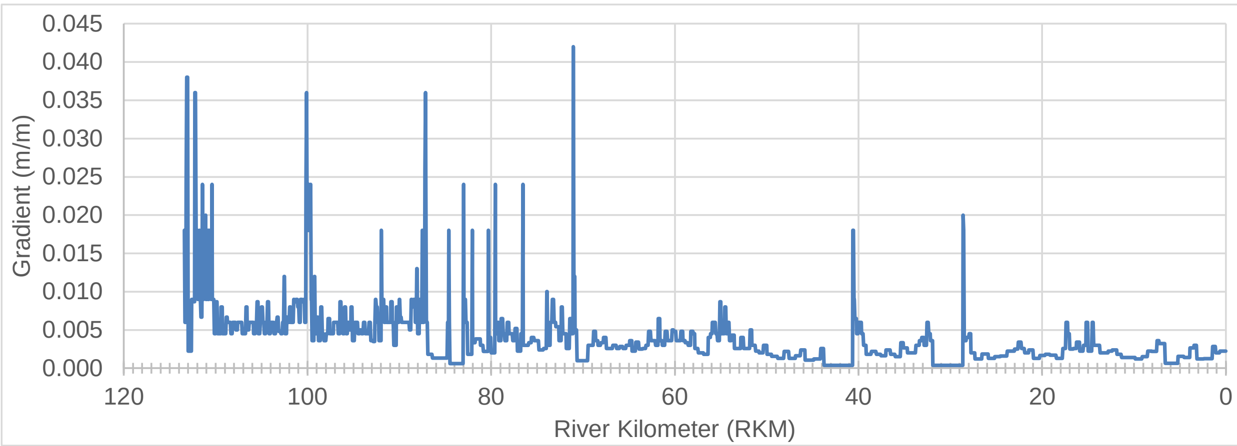

Figure 6-24. North Umpqua Model #5 - Gradient

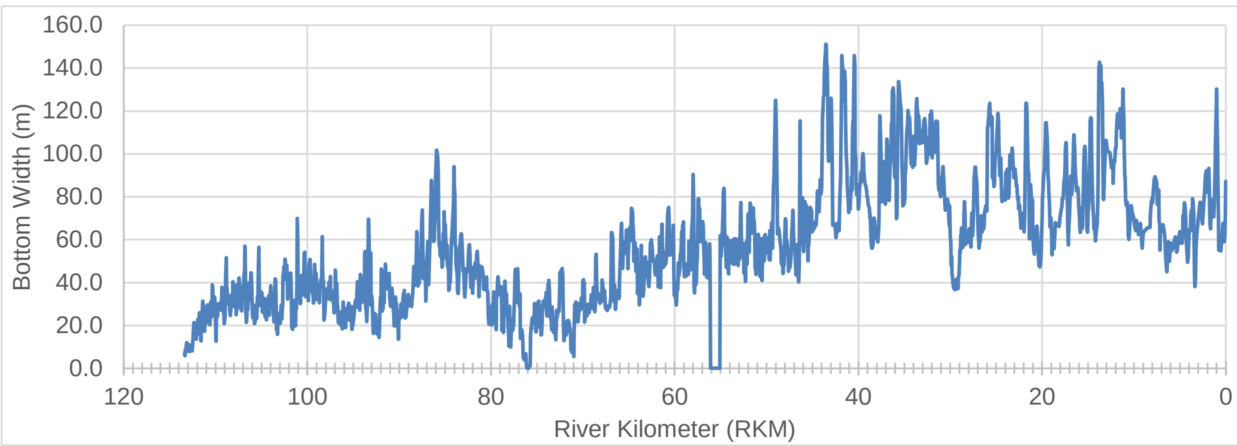

Figure 6-25. North Umpqua Model #5- calculated bottom widths.

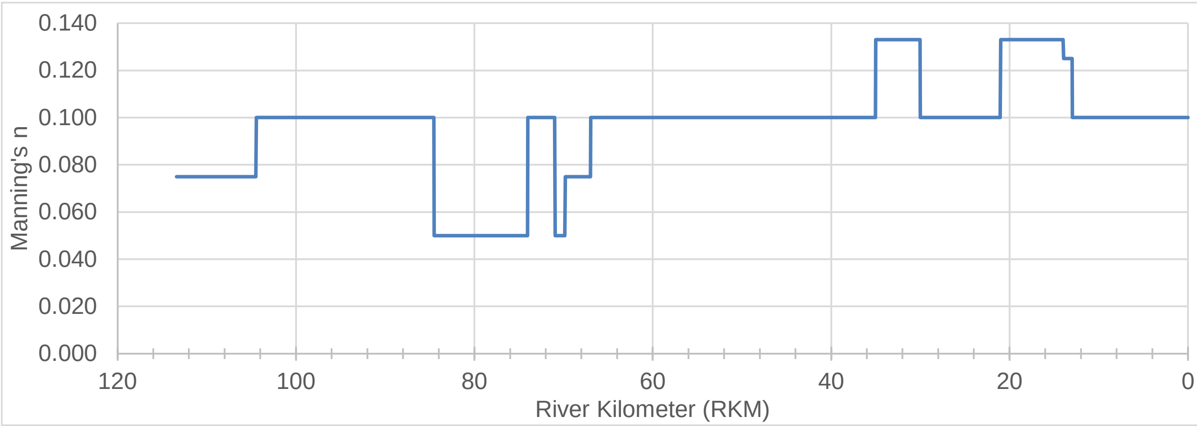

Figure 6-26. North Umpqua Model #5 assigned Manning's n values.

6.3 FLOW INPUTS – NORTH UMPQUA RIVER

Model development for the North Umpqua River involves deriving flow inputs for small tributaries that lacked flow measurements. A combination of a flow mass balance and the drainage area ratio approach was used to estimate stream flow where necessary. The goodness of fit for these approaches was assessed when measured flow data were available.

Sections 6.3.1 through 6.3.5 present an inventory of available data for each modeled segment of the North Umpqua River and discuss how the missing information was derived.

6.3.1 Flow Inputs and Estimation – North Umpqua River Model 1 (Lemolo Reservoir to Lemolo Powerhouse #1)

The North Umpqua Model 1 (Lemolo Reservoir to Lemolo Powerhouse #1) includes two inputs into the model including the flow from the Lemolo Reservoir and the flow from a spring. Table 6-1 shows an inventory of the flow data that were used in Model 1. Figure 6-27 shows the locations of the flow gage stations. The model upstream boundary flow input was specified using the observed flows from USGS gage 14313500 (N Umpqua River Below Lemolo Lk, Near Toketee Falls). The gage had missing hourly flow data from August 1 to August 11, which were filled in using the daily average flows that were available for this station. The daily flows were linearly interpolated to hourly and used in the model (Figure 6-28). The flows from the spring input were left unchanged from the summer model. A constant spring input of 0.078 cms specified in the 2002 model was used for the spring input at RKM 3.3.

Table 6-1. Inventory of available flow data in the North Umpqua River Model 1 used in the Heat Source Model

Station ID	Model location (Km)	Source	Type	Notes
Lemolo Reservoir (14313500)	6.9	USGS	Boundary condition	Hourly flows were missing on 8/1 & 8/11 and were filled in using daily flows also available at this station (interpolated to hourly)
Spring at model kilometer 3.3	3.3	Derived data	Tributary	Same as 2002 model (constant flow of 0.078 cms)

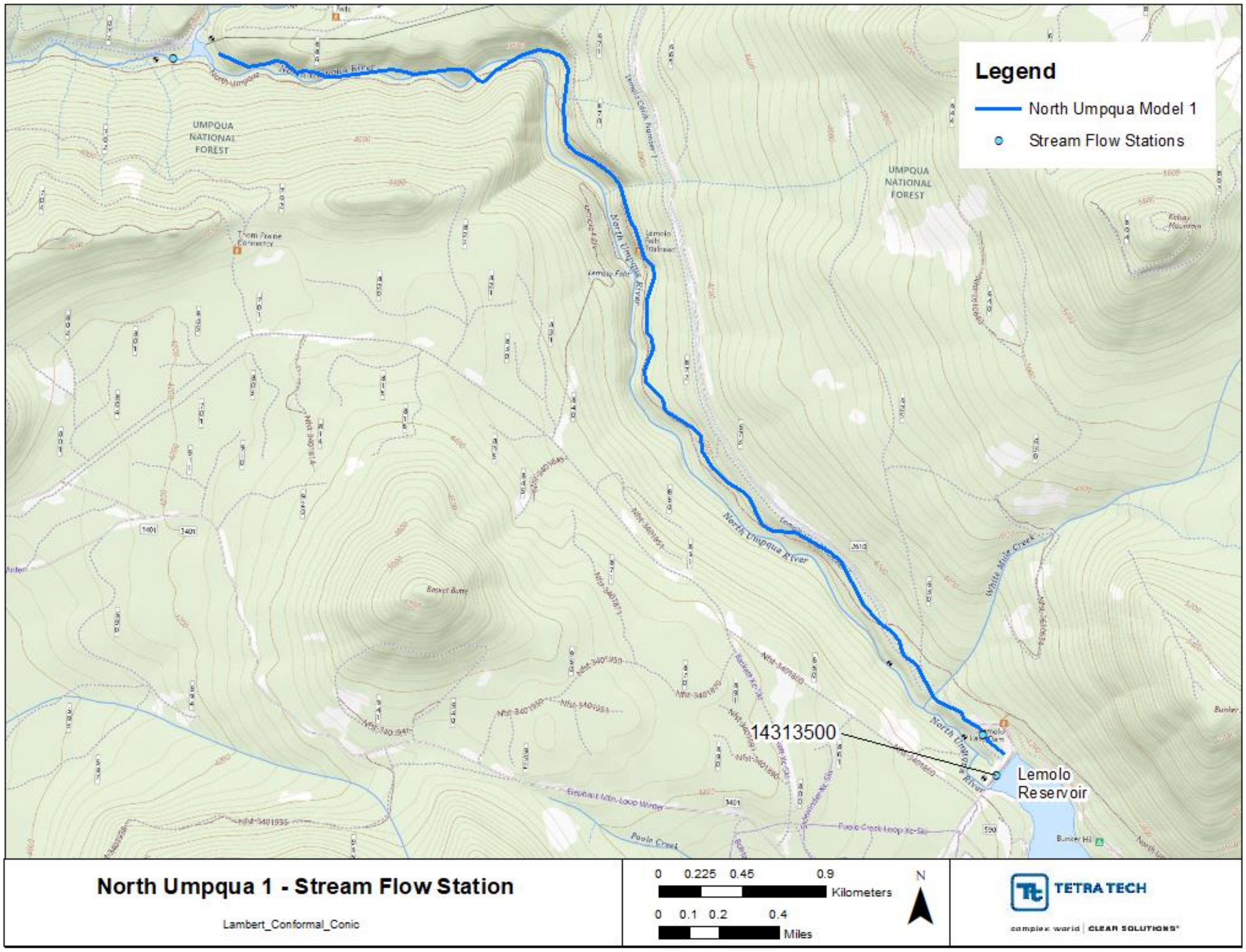

Figure 6-27. Location of flow gages for North Umpqua Model 1.

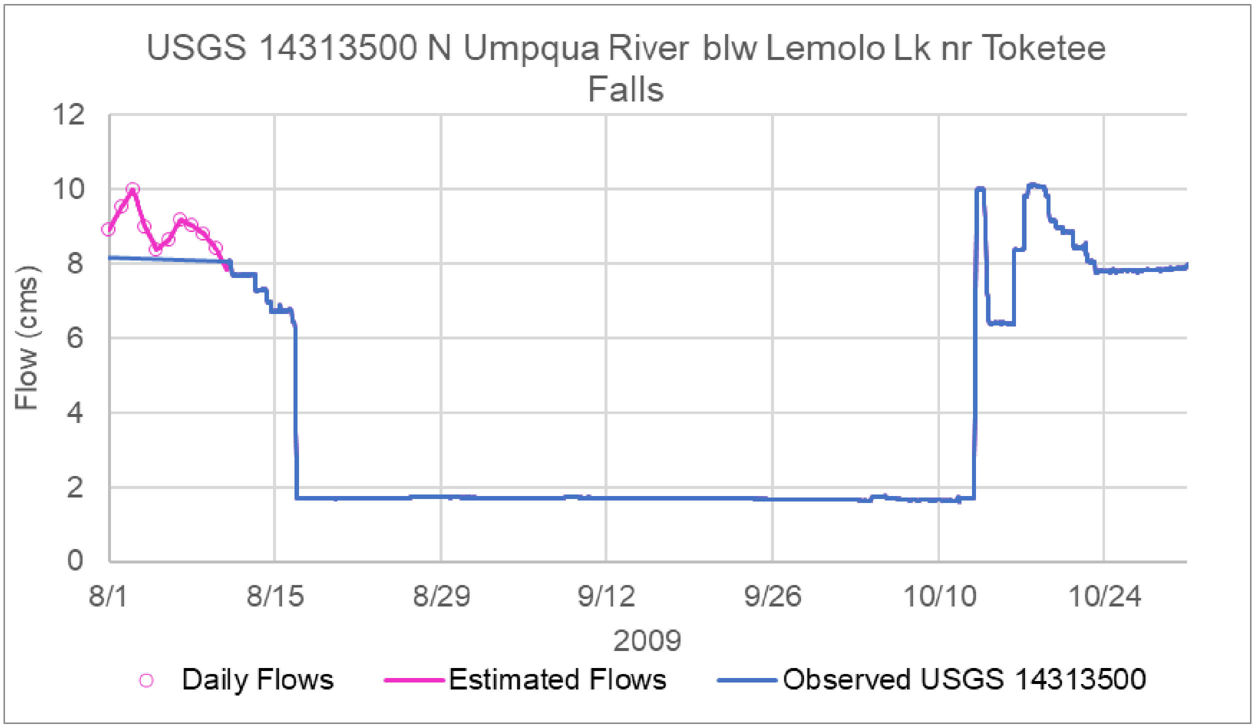

Figure 6-28. Upstream boundary flow data for North Umpqua River Model 1.

6.3.2 Flow Inputs and Estimation – North Umpqua River Model 2 (Lemolo Powerhouse #1 to Toketee Reservoir)

Table 6-2 shows an inventory of the flow data available for Model 2 (Lemolo Powerhouse #1 to Toketee Reservoir) and Figure 6-29 shows the locations of the flow gage stations. Flow data from USGS gage 14313700 (North Umpqua River below Warm Springs Creek near Toketee Falls, OR) were used to configure the upstream boundary (Figure 6-29). Flow ratios were developed using the upstream flows and the various tributary inputs from the summer model. Tributary flows for the spawning period were calculated using the derived flow ratio based on the upstream boundary and were then further refined during calibration. The tributary flows were minor compared to the upstream boundary flow. Figure 6-30 shows the calculated hourly tributary flow input timeseries and observed upstream boundary flows and Figure 6-31 shows the distribution of the total flows into the system.

Table 6-2. Inventory of available flow data in the North Umpqua River Model 2 used in the Heat Source Model

Station ID	Model location (Km)	Source	Type	Notes
North Umpqua River at Lemolo Powerhouse 1 (14313700)	19.35	USGS	Boundary condition	Hourly flows were missing on 9/14 & 9/15 and were filled in using linear interpolation to hourly flows using daily flows
Beverly Creek	17.85	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows
Helen Creek	17.6	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows

Station ID	Model location (Km)	Source	Type	Notes
Dorothy Creek	16.05	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows
Potter Creek	14.9	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows
Laura Creek	14.15	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows
Nurse Creek	13.4	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows
Barkenburger Creek	12.5	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows
Patricia Creek	11.75	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows
Spring at model kilometer 7.65	7.65	Derived data	Tributary	Zero. Same as summer model
Spring at model kilometer 7.3	7.3	Derived data	Tributary	Zero. Same as summer model
Loafer Creek	5.8	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows
Deer Creek	3	Derived data	Tributary	Ratios derived from summer model used to estimate tributary flows
Lemolo Forebay Outlet	1.15		Tributary	Set zero flows. No water was routed through the canal during 2009.

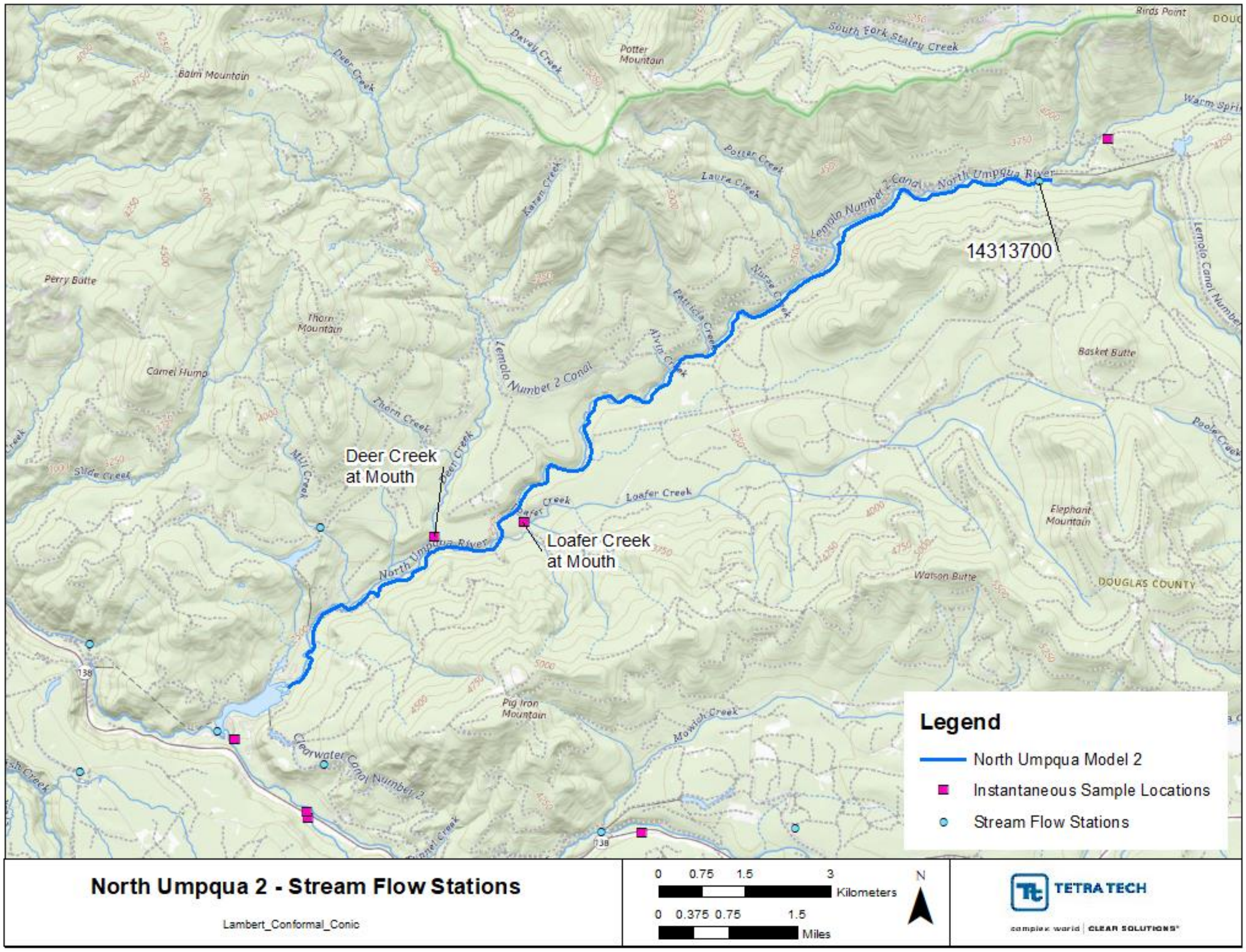

Figure 6-29. Location of Flow Gages for North Umpqua Model 2.

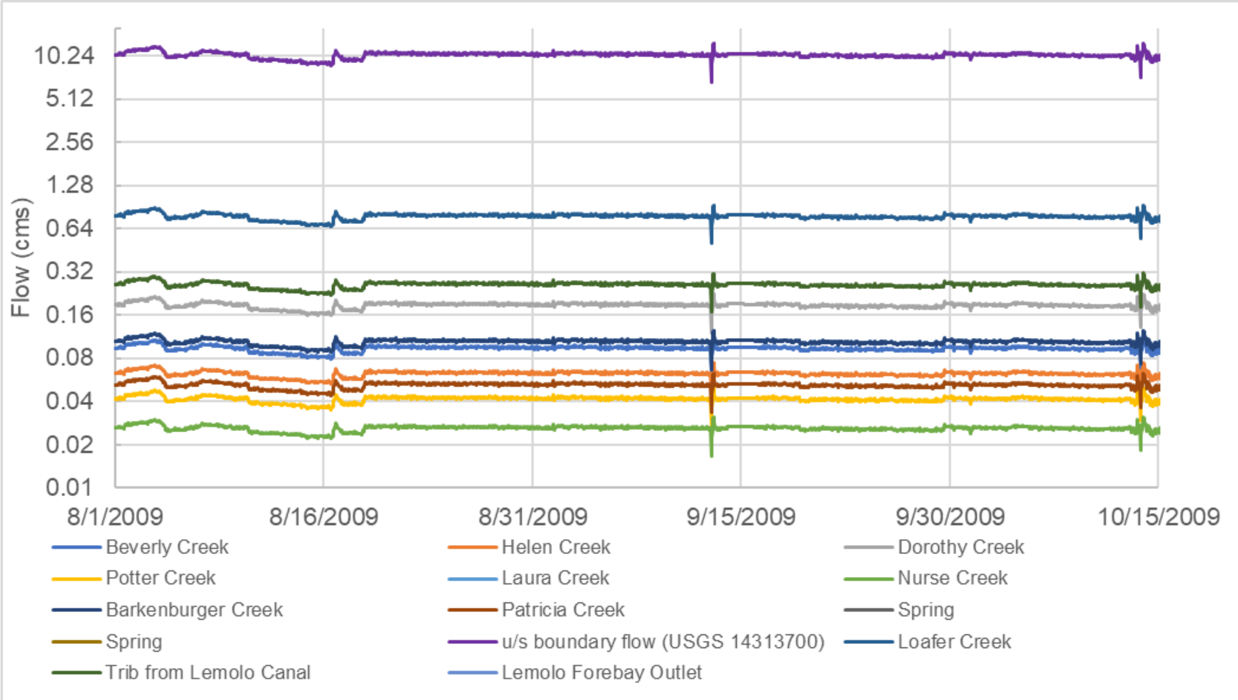

Figure 6-30. Hourly flow boundaries for North Umpqua Model 2.

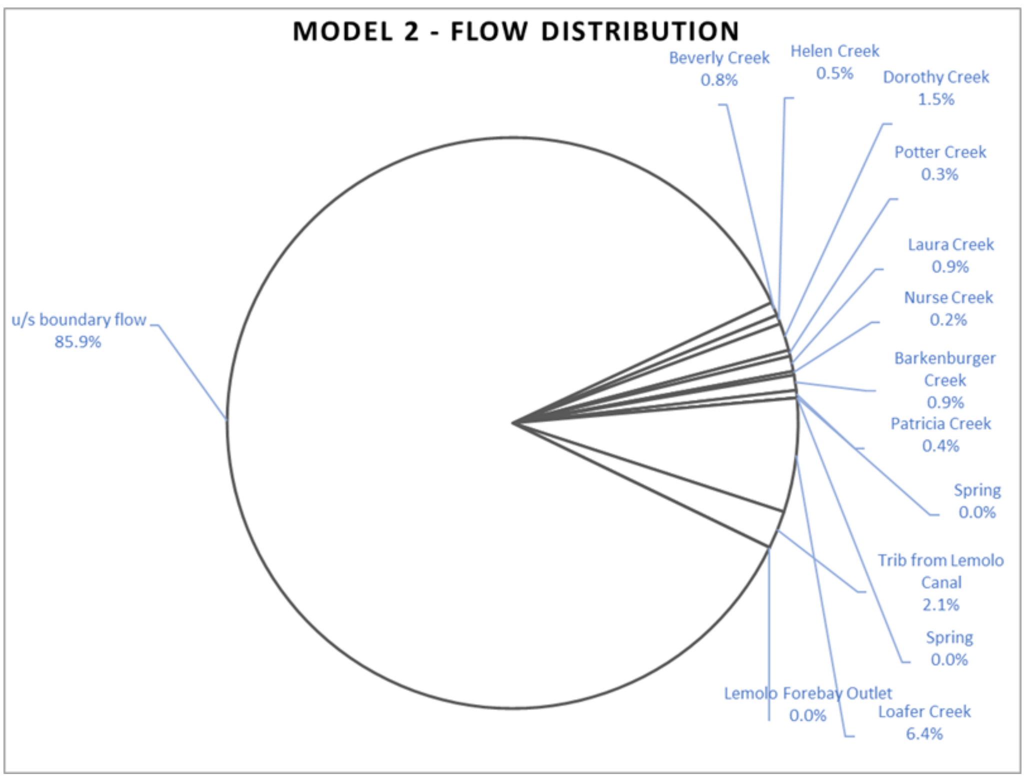

Figure 6-31. Flow distribution for North Umpqua Model 2.

Flow data were collected by DEQ at two tributaries - Deer Creek and at Loafer Creek (Figure 6-29). Flows were collected on two days in September 2009. The observed flows were used as a guide when adjusting the flows for these tributaries. Flows were also estimated at these two locations on the same dates when the flows were collected. Table 6-3 shows the observed and estimated flows at the two tributaries. The estimated flows are very close to the observed flows, which supports that the flow estimation approach is reasonable.

Table 6-3. Observed and estimated flows at Deer Creek and Loafer Creek

Location	Date	Observed Flow (cms)	Estimated Flow (cms)
Deer Creek at Mouth	9/8/2009	0.23	0.26
Deer Creek at Mouth	9/28/2009	0.23	0.25
Loafer Creek at Mouth	9/10/2009	0.82	0.80
Loafer Creek at Mouth	9/17/2009	0.78	0.81

No water was being routed through the Lemolo Forebay outlet (Lemolo #2) during the 2009 monitoring period. All the water in the reach was flowing in the natural channel of the North Umpqua River. This was further confirmed by checking the USGS gage 14313600 Lemolo No.2 canal gage which showed no flow during 2009 through mid-November during 2009.

6.3.3 Flow Inputs and Estimation – North Umpqua River Model 3 (Toketee Reservoir to Slide Powerhouse)

Table 6-4 shows an inventory of the flow data available for Model 3 (Toketee Reservoir to Slide Powerhouse). Figure 6-32 shows the locations of the flow gage station used on the model. The upstream boundary in the model was specified using hourly data from USGS 14315500 – North Umpqua River at Toketee Falls. There are no tributary inputs coming into Model 3.

Table 6-4. Inventory of available flow data in the North Umpqua River Model 3 used in the Heat Source Model

Station ID	Model location (Km)	Source	Type	Notes
North Umpqua River at Toketee Falls, OR (14315500)	3.15	USGS	Boundary condition	Upstream boundary flows from Toketee Reservoir

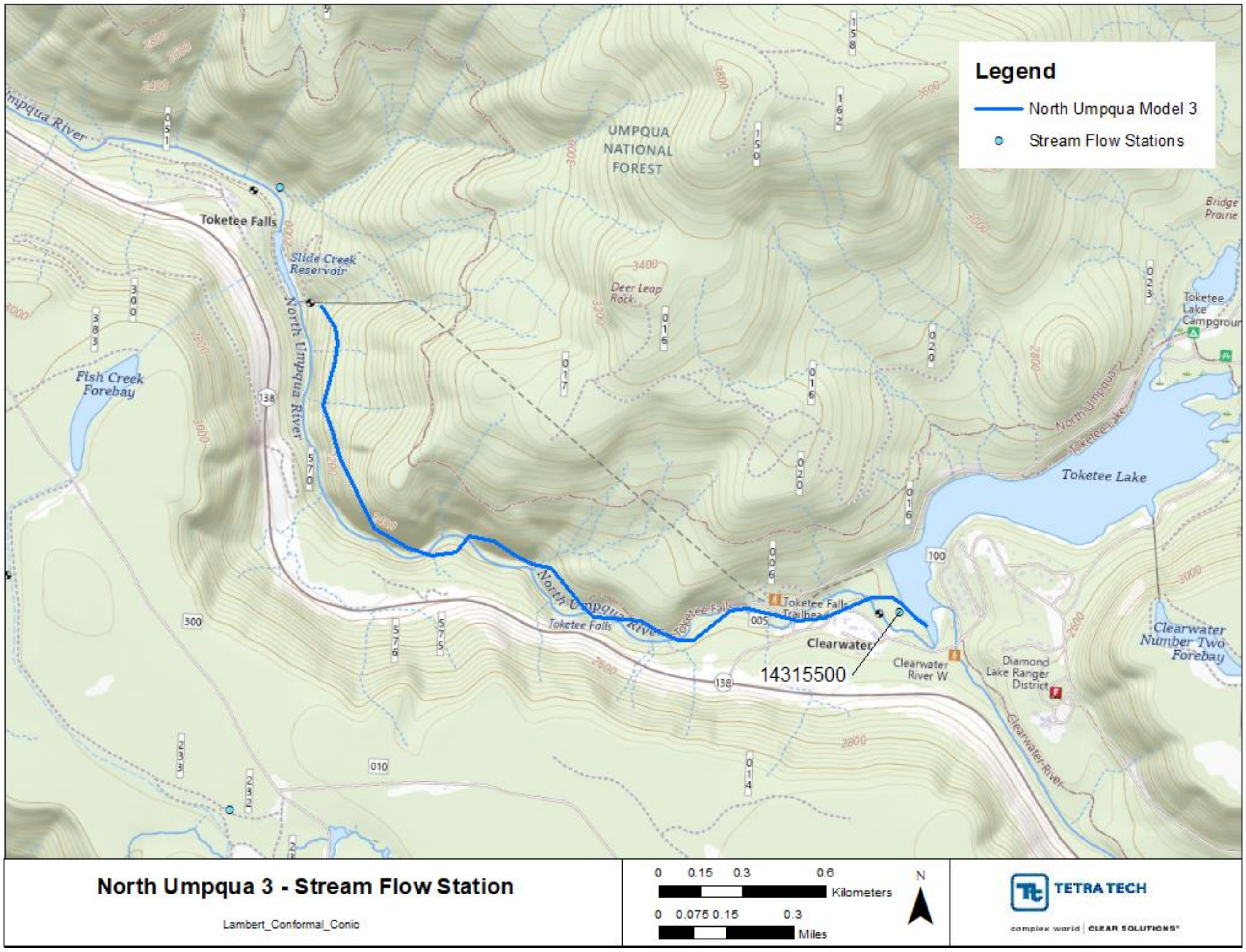

Figure 6-32. Location of Flow Gages for North Umpqua Model 3.

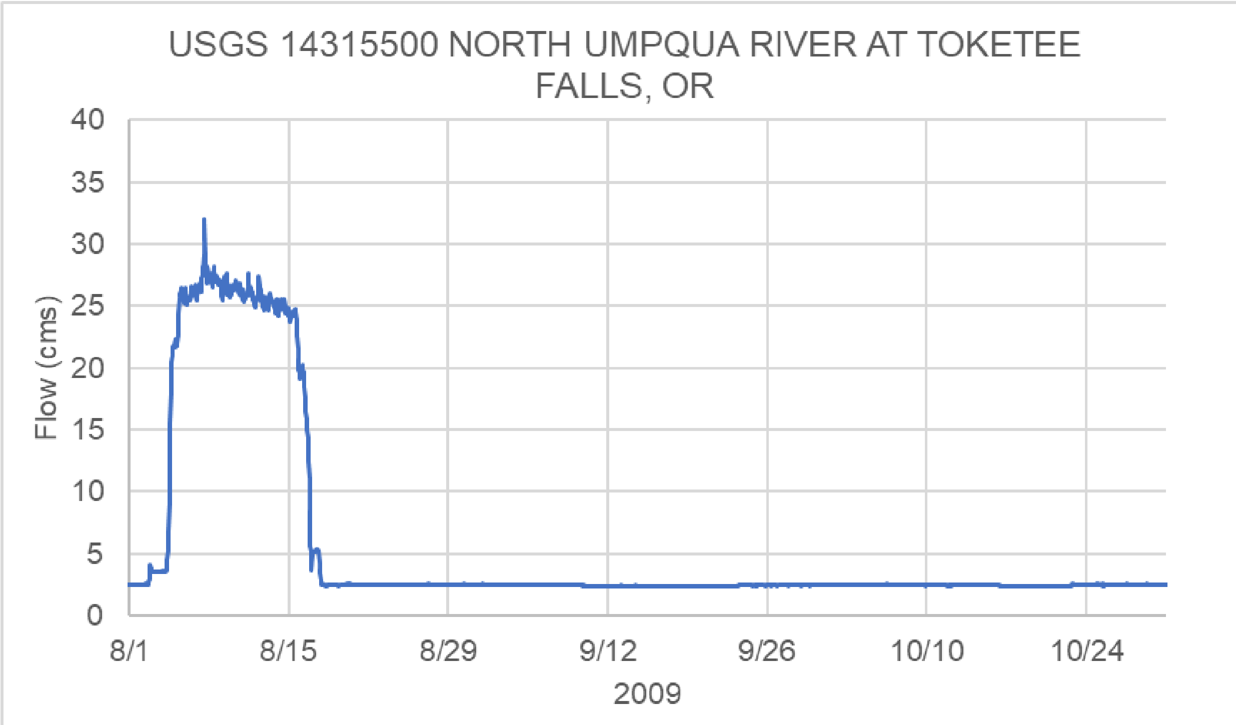

Figure 6-33. Upstream boundary flow data for North Umpqua River Model 3.

6.3.4 Flow Inputs and Estimation – North Umpqua River Model 4 (Slide Powerhouse to Soda Springs Reservoir)

Table 6-5 shows an inventory of the flow data available for Model 4 (Slide Powerhouse to Soda Springs Reservoir). Figure 6-34 shows the locations of the flow gage station used on the model.

Table 6-5. Inventory of available flow data in the North Umpqua River Model 4 used in the Heat Source Model

Station ID	Model location (Km)	Source	Type	Notes
NU below Slide Creek Dam (USGS 14315700)	3.15	USGS	Boundary Condition	
Fish Creek	0.95	Derived data	Tributary	Drainage area ratio method. Grab sample used as a guide to estimate

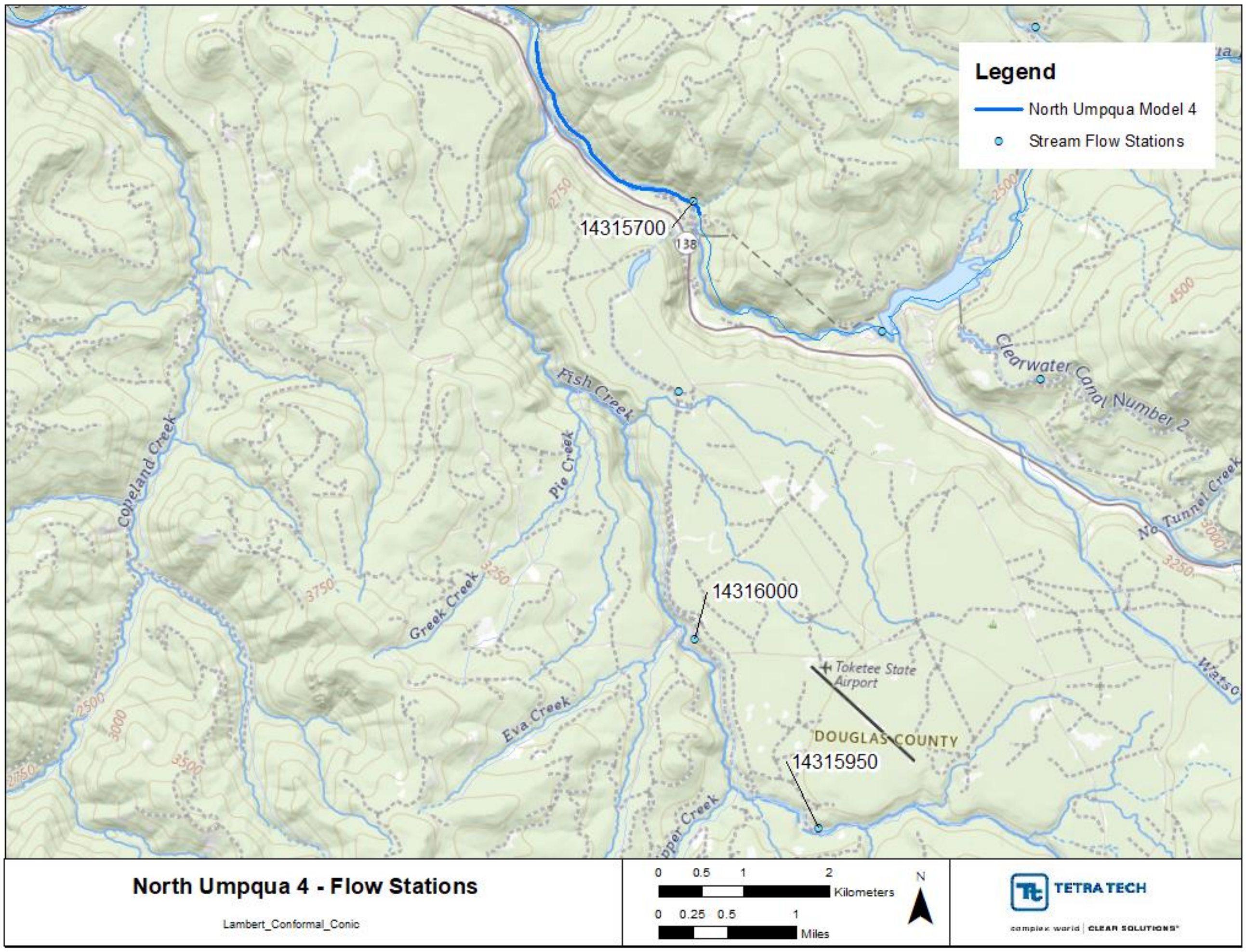

Figure 6-34. Location of Flow Gages for North Umpqua Model 4.

The upstream boundary in the model was specified using hourly data from USGS 14315700 – North Umpqua River below Slide Creek Dam near Toketee Falls (Figure 6-35).

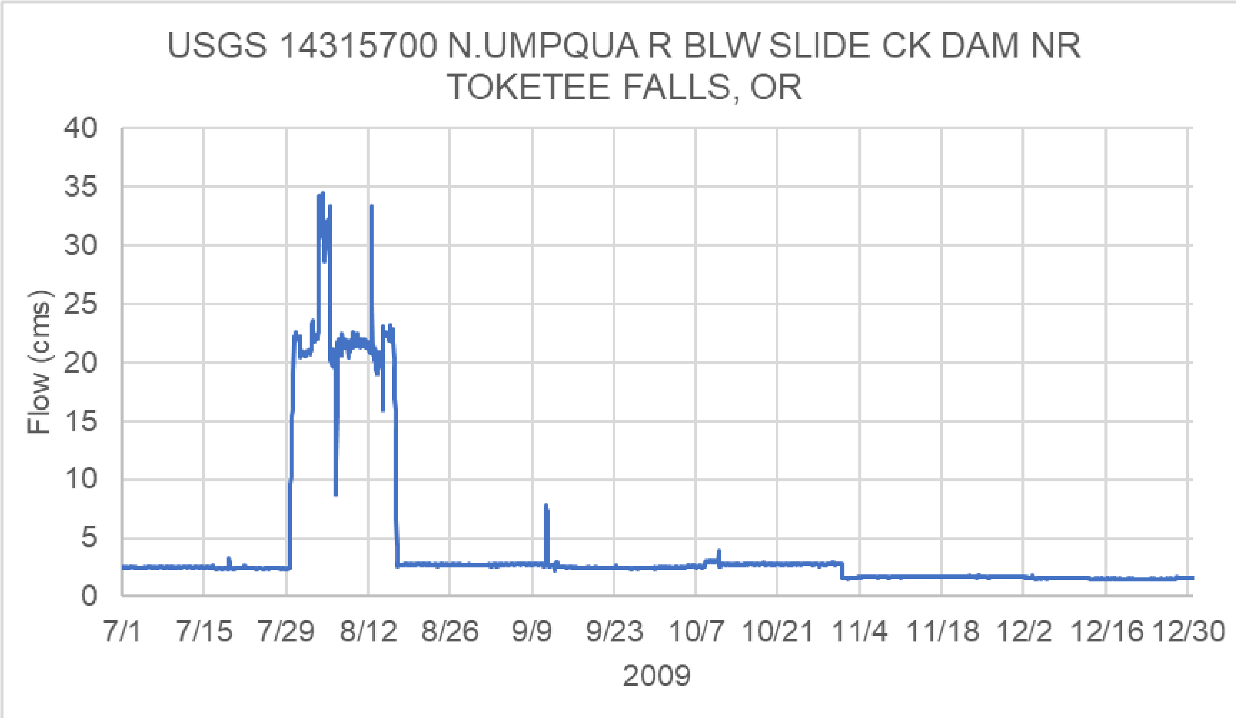

Figure 6-35. Upstream boundary flow data for North Umpqua River Model 4

The model has one tributary input for Fish Creek. Fish Creek flows were unavailable and were estimated using the drainage area ratio method. Flows from USGS 14315950 Fish Creek above Slipper Creek near Toketee Falls were used to estimate the flows. Another station USGS 14316000 (Fish Creek at Big Camas Ranger Station Near Toketee Falls), located about 2 miles downstream of this station was also available but was not used due to lack of 2009 data. A flow measurement of 1.15 cms (40.65 cfs) was observed by DEQ for Fish Creek at Mouth on September 9, 2009. The final calculated flow on September 9, 2009 in the model was calculated to be 1.25 cms. The Fish Creek drainage area calculated using the USGS Stream Stats program was calculated to be 84.3 mi^2, and the drainage area for the gage located upstream along Fish Creek at USGS 14315950 was 61.6 mi^2. An exponent of 0.55 was used to refine the flow estimates in the generalized drainage area relationship (method described in Section 4.3.1). Figure 6-36 shows the estimated Fish Creek flows used in the model.

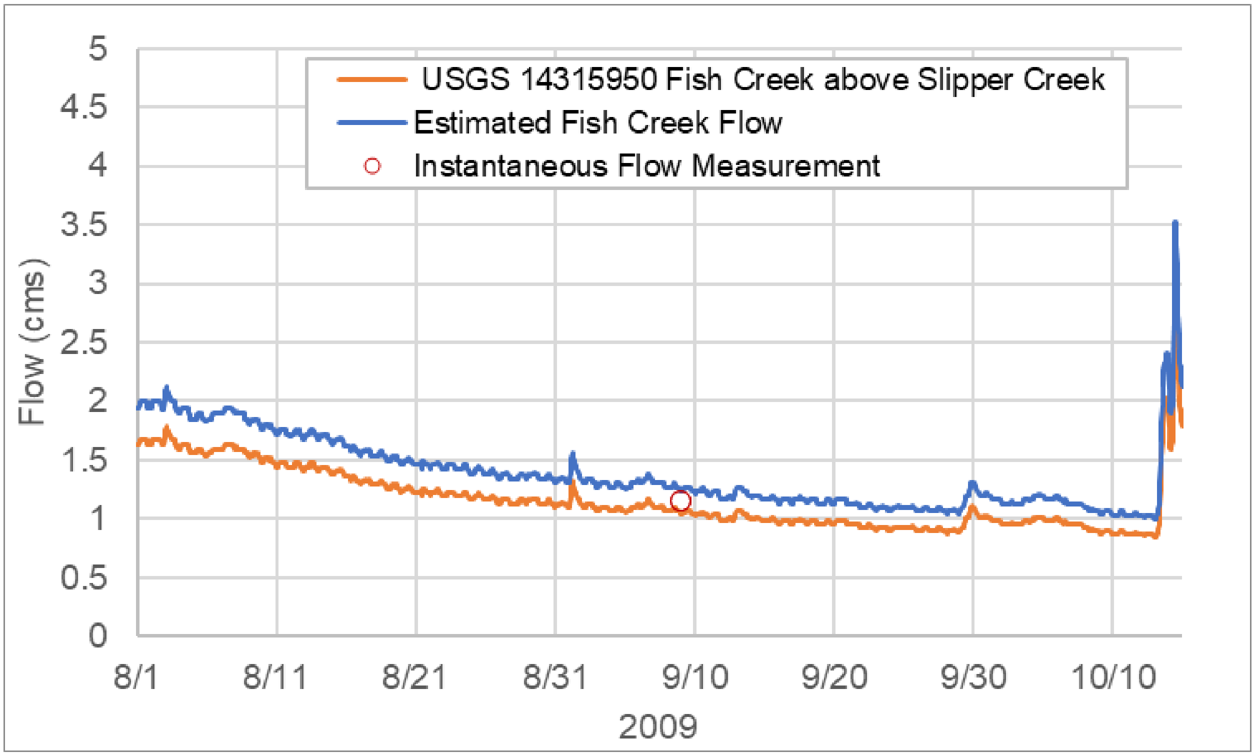

Figure 6-36. Estimated Fish Creek flows.

6.3.5 Flow Inputs and Estimation – North Umpqua River Model 5 (Soda Springs Reservoir to the mouth)

Table 6-6 shows an inventory of the available flow data for Model 5 (Soda Springs Reservoir to the mouth) and Figure 6-37 shows the locations of available flow gages. The upstream boundary of Model 5 was defined by USGS gage 14316455 (North Umpqua River below Soda Springs Reservoir, near Toketee Falls). The observed tributary inputs include Soda Springs Powerhouse – Flow through the penstock (PacifiCorp station SODP), Boulder Creek (USGS 14316495), Steamboat Creek (USGS 14316700), and Rock Creek (Estimated Rock Creek Flows at USGS 14317600 near Glide). Details on how the flows were derived for Rock at USGS 14317600 can be found in Section 7.3.1. Note that the SODP station corresponds to historical USGS station 14316350 – Soda Springs Penstock near Toketee Falls. The observed upstream boundary flow and tributary flow data are shown in Figure 6-38 and Figure 6-39.

Table 6-6. Inventory of available flow data in the North Umpqua River Model 5 used in the Heat Source Model

Station ID	Model location (Km)	Source	Type	Notes
Below Soda Springs Powerhouse (14316455)	113.4	USGS	Boundary condition	
Soda Springs Powerhouse (SODP)	112.7	PacifiCorp	Tributary	
Boulder Creek (14316495)	110.5	USGS	Tributary	
Copeland Creek	108.45	Derived data	Tributary	Derived using drainage area ratio
Deception Creek	104.2	Derived data	Tributary	Derived using drainage area ratio

Station ID	Model location (Km)	Source	Type	Notes
Dry Creek	102.5	Derived data	Tributary	Derived using drainage area ratio
Calf Creek	100.65	Derived data	Tributary	Derived using drainage area ratio
Panther Creek	93.9	Derived data	Tributary	Derived using drainage area ratio
Steamboat Creek (14316700)	86.4	USGS	Tributary	
Fox Creek	70.7	Derived data	Tributary	Derived using drainage area ratio
Rock Creek	56.9	Derived data	Tributary	Derived using monthly ratios using USGS 14317600
Little River	46.3	Derived data	Tributary	Derived using drainage area ratio

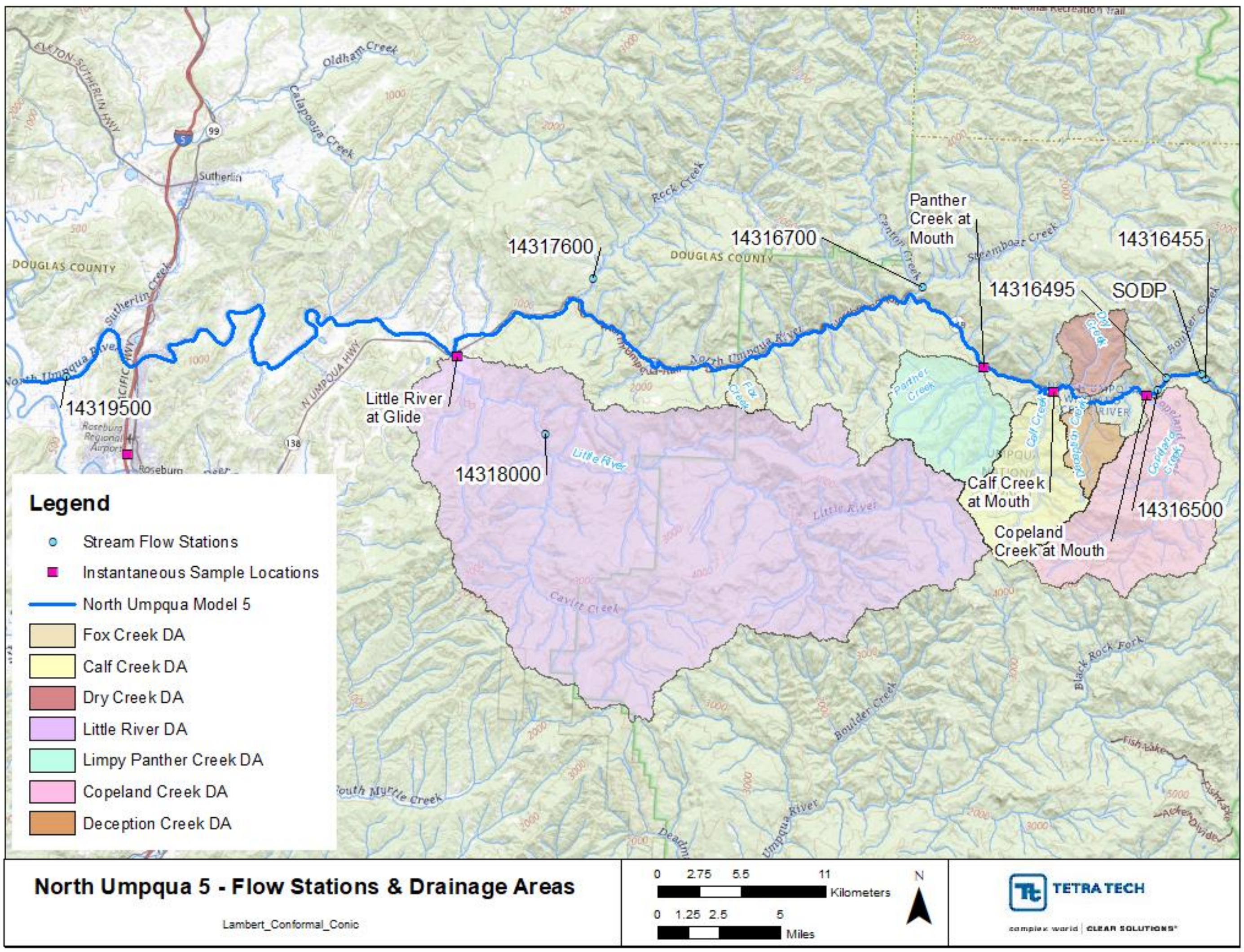

Figure 6-37. Location of Flow Gages for Model 5 and drainage areas used in the flow estimation.

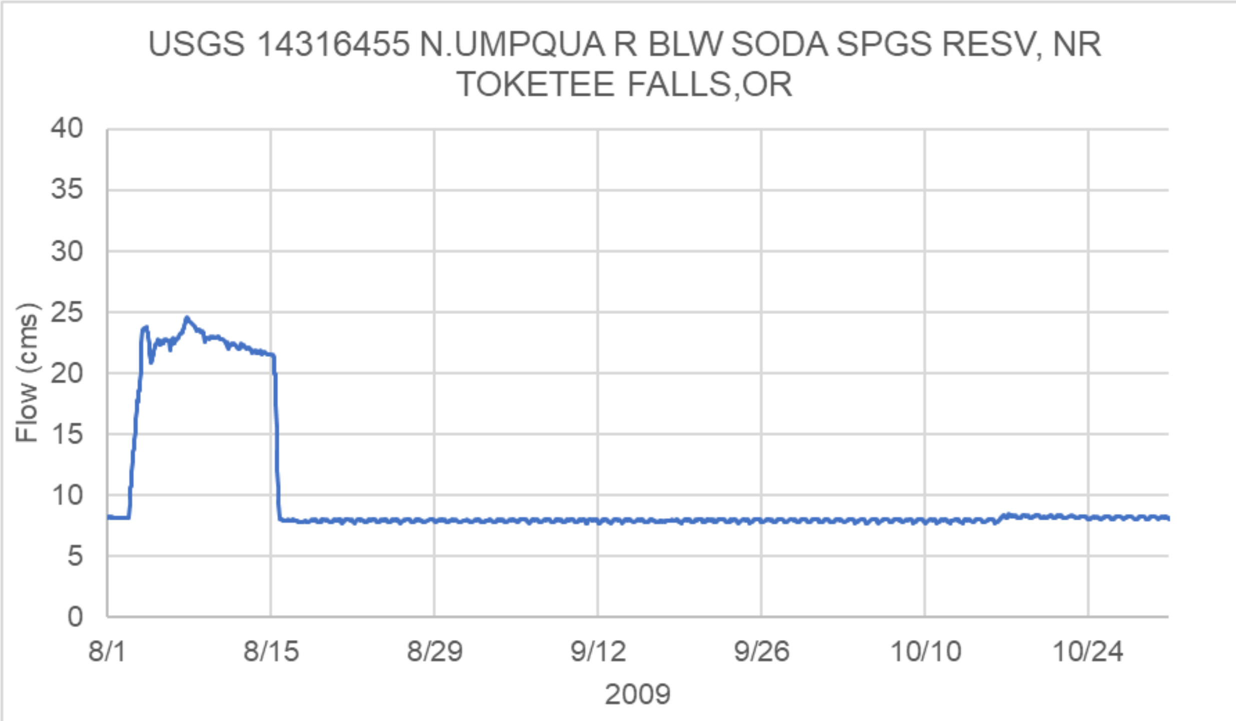

Figure 6-38. Upstream boundary flow data for North Umpqua River Model 5

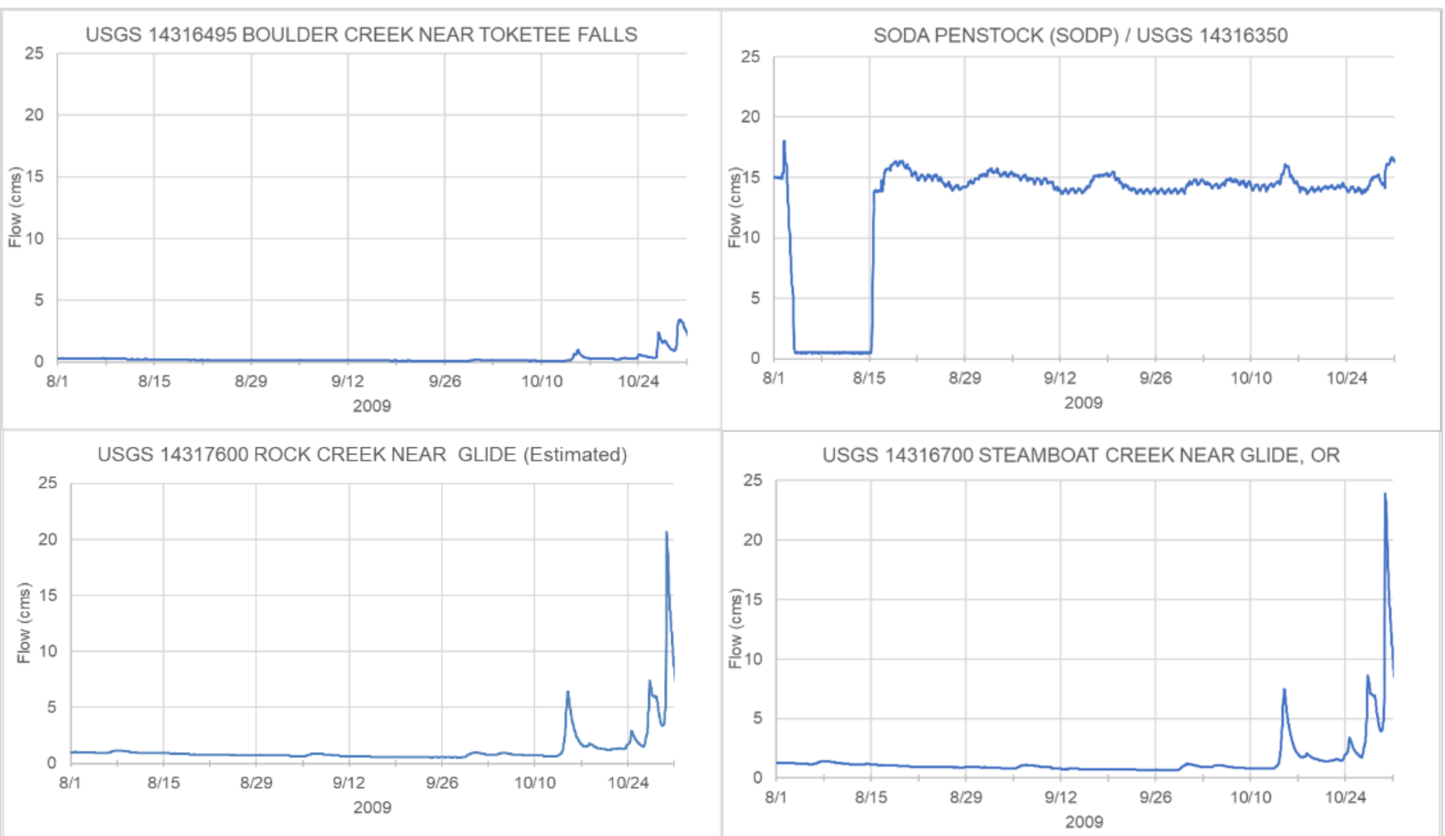

Figure 6-39. Observed tributary flow data for North Umpqua River Model 5

The remaining tributary flows were derived using a drainage area ratio. The tributaries included Copeland Creek, Calf Creek, Deception Creek, Dry Creek, Limpy/Panther Creek, Fox Creek, and Little River. Flows measured by DEQ during 2009 were also available for a few of the tributaries. The observed flows were used as a guide to further refine the flows estimated using the drainage area ratio relationship. The locations of the tributaries are shown in Figure 6-37. Flows at Little River mouth were estimated using observed flows from USGS 14318000 Little River at Peel (Drainage area = 177 mi^2) by scaling the flows based on the drainage area ratio. The remaining tributaries were scaled using the drainage area ratio and flows from USGS 14316495- Boulder Creek near Toketee Falls (Drainage area = 30.4 mi^2). The drainage areas for each of the tributaries was calculated using the StreamStats program. Table 6-7 below shows the parameters used in the estimation of the flows using the drainage area relationship, including the exponent used in the equation to further refine the flows (Equation 1, Section 4.3.1).

Table 6-7. Parameters used in the estimation of the tributary flows.

Tributary	Area of un-gaged watershed (mi2)	Area of gaged watershed (mi2)	Exponent
Copeland Creek	36	30.4	1.5
Deception Creek	5.42	30.4	1
Dry Creek	7.23	30.4	1
Calf Creek	19.7	30.4	3
Limpy/Panther Creek	19.1	30.4	2.5
Fox Creek	2.12	30.4	1
Little River	208	177	0.5

Flows were also estimated at the flow measurement locations on the days when the flows were observed. The observed and estimated flows at the various tributaries are shown below in Table 6-8. The estimated flows are very close to the observed flows, indicating that the estimation approaches are reasonable. The estimated flows time series used in the model are shown in Figure 6-40.

Table 6-8. Observed and Estimated Flows for Tributaries

Location	Date	Observed Flow (cfs)	Estimated Flow (cfs)
Copeland Creek at Mouth	9/2/2009 11:45	6.29	6.2
Copeland Creek at Mouth	9/16/2009 15:00	5.38	4.9
Calf Creek at Mouth	9/2/2009 13:25	1.04	1.3
Calf Creek at Mouth	9/16/2009 11:00	1.05	1
Panther Creek at Mouth	9/2/2009 15:00	1.45	1.6
Little River at Glide	9/1/2009 13:06	16.79	17.9
Little River at Glide	9/1/2009 8:01	19.13	17.9

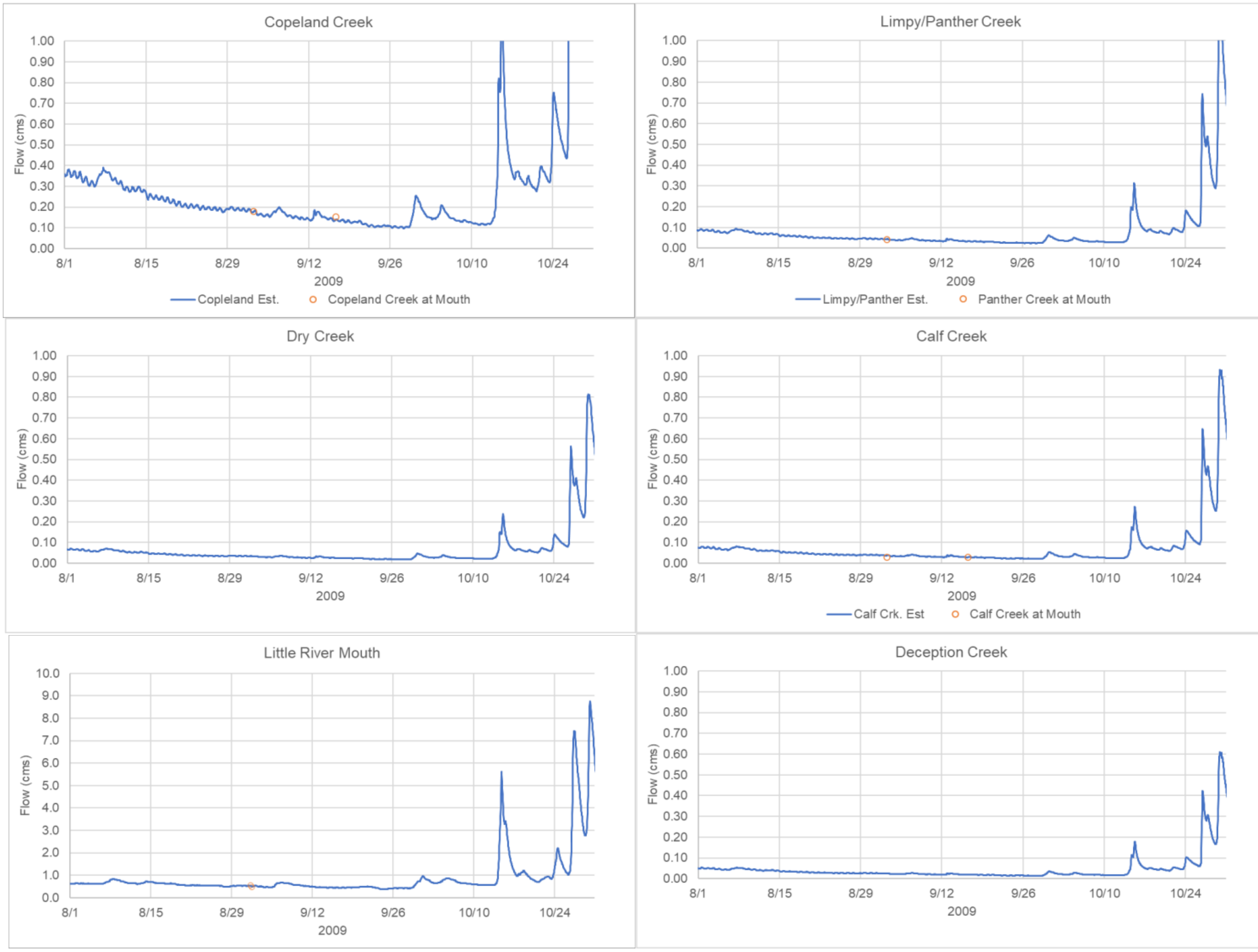

Figure 6-40. Estimated tributary flow data for North Umpqua River Model 5

6.4 WATER TEMPERATURE INPUTS – NORTH UMPQUA RIVER

Model development for the North Umpqua River involves using both observed water temperature and derived temperature inputs for a few small tributaries that lack temperature measurements. Depending on data availability either a direct surrogate or linear regression approach was used to derive stream temperature. Sections 6.4.1 through 6.4.5 provide an inventory and summary of the water temperature data used in the development of the North Umpqua River Models 1 through 5. Figure 6-41 shows the observed water temperature stations along North Umpqua.

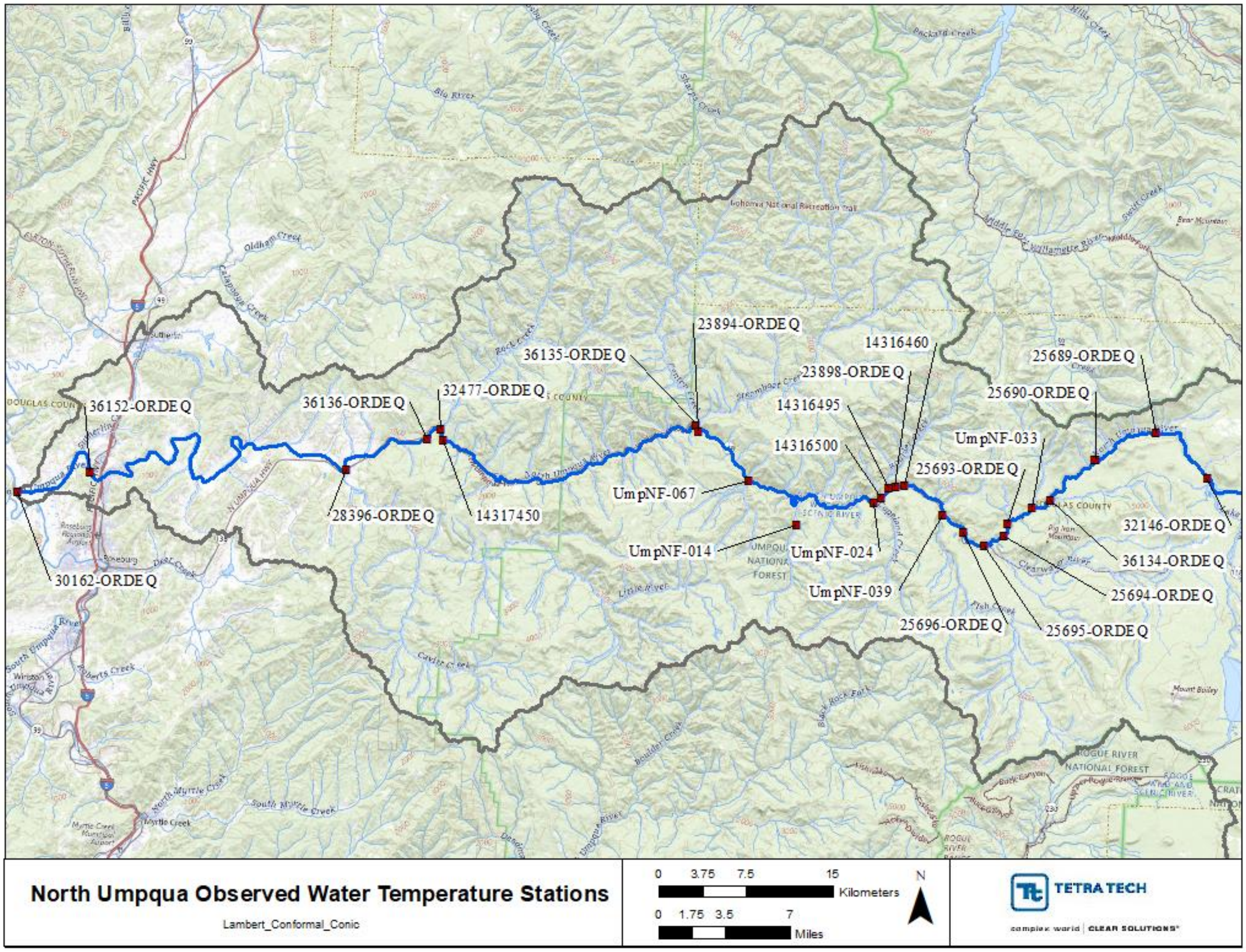

Figure 6-41. Observed water temperature locations along North Umpqua

6.4.1 Water Temperature Inputs and Estimation – North Umpqua River Model 1 (Lemolo Reservoir to Lemolo Powerhouse #1)

Water temperature data for the boundary condition of the North Umpqua River Model 1 (Lemolo Reservoir to Lemolo Powerhouse #1) were obtained from station 32146-ORDEQ (Table 6-9); however, water temperature data were missing from August 1 to August 17 and October 14 to October 15. The missing data were filled using repeated temperatures from the last observed date and an incremental adjustment factor to follow the trend. **Error! Reference source not found.** shows the upstream boundary water temperatures, with filled missing data periods shown in grey.

Table 6-9. Inventory of available water temperature data locations used to configure the North Umpqua River Model 1 (Lemolo Reservoir to Lemolo Powerhouse #1)

Station ID	Model location (Km)	Source	Type	Notes
North Umpqua River Downstream of Lemolo Lake (32146- ORDEQ)	6.9	DEQ	Boundary condition	
Spring at model kilometer 3.3	3.3	Derived data	Tributary	Same as 2002 model (constant flow of 5.8 °C)

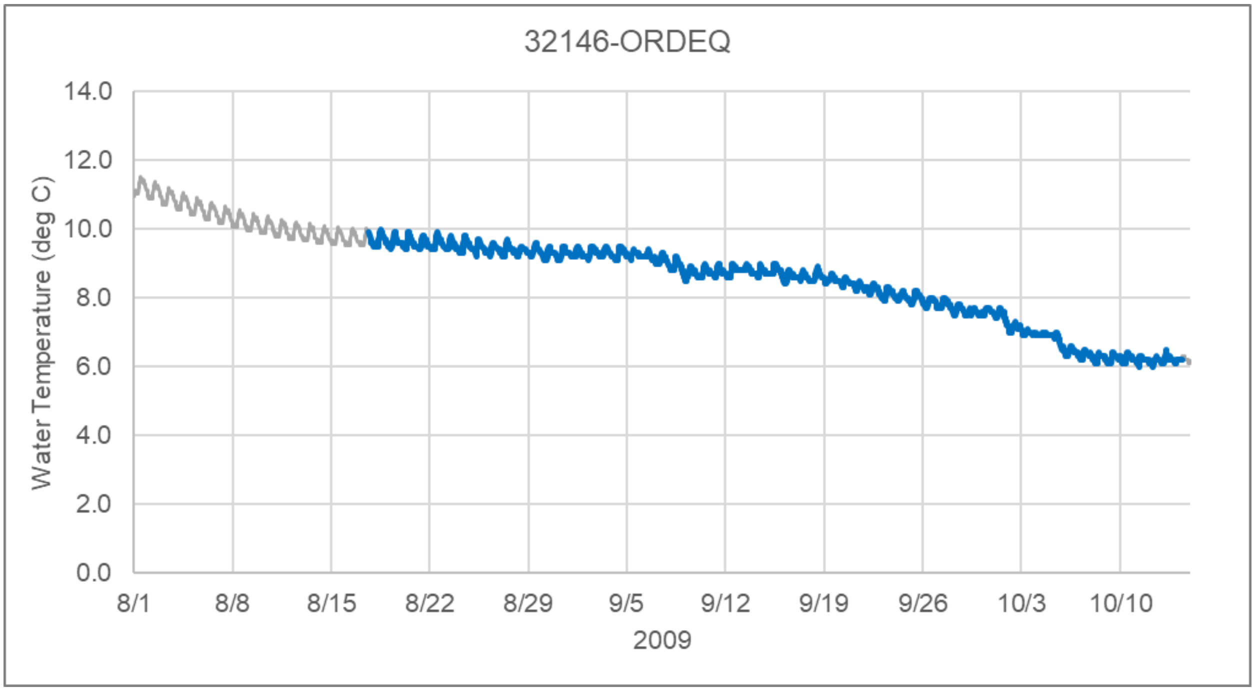

Figure 6-42. Upstream boundary water temperature data for North Umpqua Model 1.

6.4.2 Water Temperature Inputs and Estimation – North Umpqua River Model 2 (Lemolo Powerhouse #1 to Toketee Reservoir)

The upstream boundary for Model 2 (Lemolo Powerhouse #1 to Toketee Reservoir) was defined using station 25689-ORDEQ (North Umpqua River at Lemolo Powerhouse #1) (Table 6-10). Missing data (from August 1 to August 25 and October 14 to October 15) at this station were filled using repeated temperatures from the last observed date and an incremental adjustment factor to follow the trend. Figure 6-43 shows the upstream boundary hourly water temperature, with filled missing data periods shown in grey.

The constant water temperature used in the 2001 HS7 model for several of the tributaries were also used in the 2009 model. Beverly Creek was 10.6 °C; Helen Creek and Dorothy Creek were 9.6 °C; and the Potter Creek temperature values from 2001 were repeated.

Laura Creek, Nurse Creek, and the two springs in the model were filled in using the same assumptions used in 2001. Laura Creek was set as Potter Creek water temperature plus 1.4 °C and Nurse Creek was set as equal to

Potter Creek plus 3.4 °C. Water temperatures for Barkenburger Creek and Patricia Creek were assigned using data from North Umpqua River upstream of Barkenberger Creek (station 25690-ORDEQ/UmpNF-090) plus 1 °C (assumption from 2001). There are two spring inputs were set to zero °C (assumption from 2001).

Loafer Creek (station 36134-ORDEQ) water temperatures were cold and had water temperatures ranging from 6 to 6.3 °C based on data available from August 21 to October 14. Data prior to August 21 was assigned used a constant value of 6.2 °C and after October 14 were assigned a value of 6.1 °C. Deer Creek water temperatures were assigned using data from the US Forest Service station UmpNF-033 - Deer Creek. Figure 6-44 shows the hourly water temperature time series used in Model 2.

Table 6-10. Inventory of available water temperature data used to configure the North Umpqua River Model 2 (Lemolo Powerhouse #1 to Toketee Reservoir)

Station ID	Model location (Km)	Source	Type	Notes
North Umpqua River at Lemolo Powerhouse 1 (25689-ORDEQ)	19.35	DEQ	Boundary Condition	
Beverly Creek	17.85	Derived data	Tributary	Surrogate relationship
Helen Creek	17.6	Derived data	Tributary	Surrogate relationship
Dorothy Creek	16.05	Derived data	Tributary	Surrogate relationship
Potter Creek	14.9	Derived data	Tributary	Surrogate relationship
Laura Creek	14.15	Derived data	Tributary	Surrogate relationship
Nurse Creek	13.4	Derived data	Tributary	Surrogate relationship
Barkenburger Creek (25690-ORDEQ)	12.5	Derived data	Tributary	Surrogate relationship
Patricia Creek	11.75	Derived data PacifiCorp	Tributary	Surrogate relationship
Spring at model kilometer 7.65	7.65	Derived data	Tributary	Surrogate relationship
Spring at model kilometer 7.3	7.3	Derived data	Tributary	Surrogate relationship
Loafer Creek (36134-ORDEQ)	5.8	DEQ	Tributary	
Deer Creek (UmpNF-033)	3	USFS	Tributary	
Lemolo Forebay Outlet (LEM2P)	1.15	Derived data PacifiCorp	Tributary	Surrogate relationship

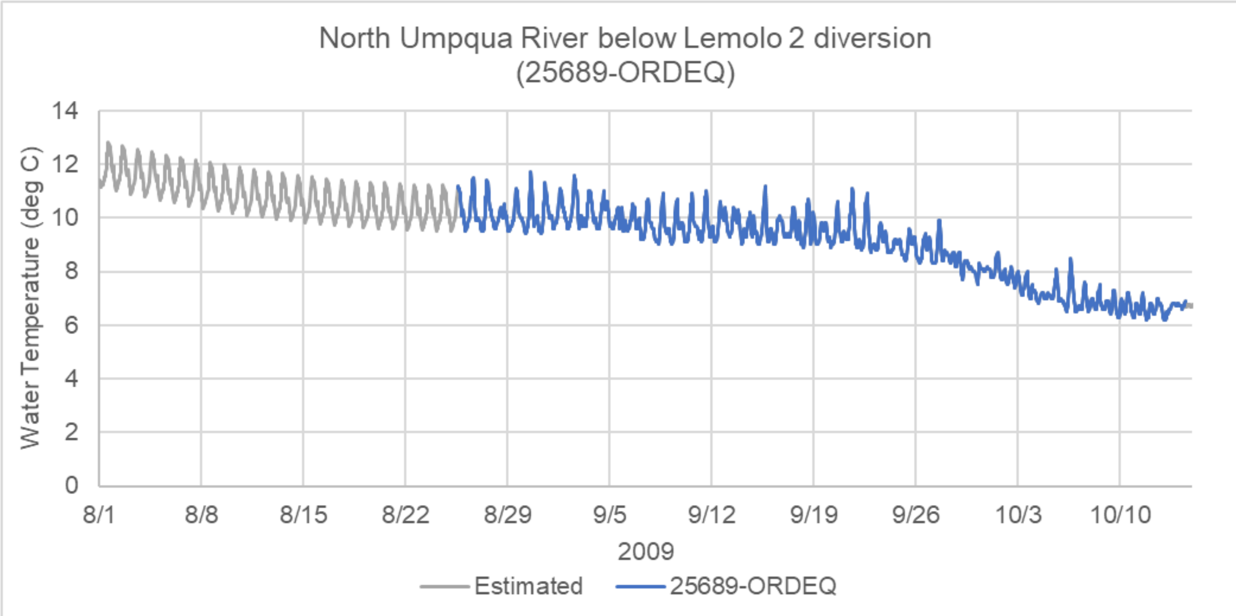

Figure 6-43. Upstream boundary hourly water temperature data (25689-ORDEQ) for North Umpqua Model 2.

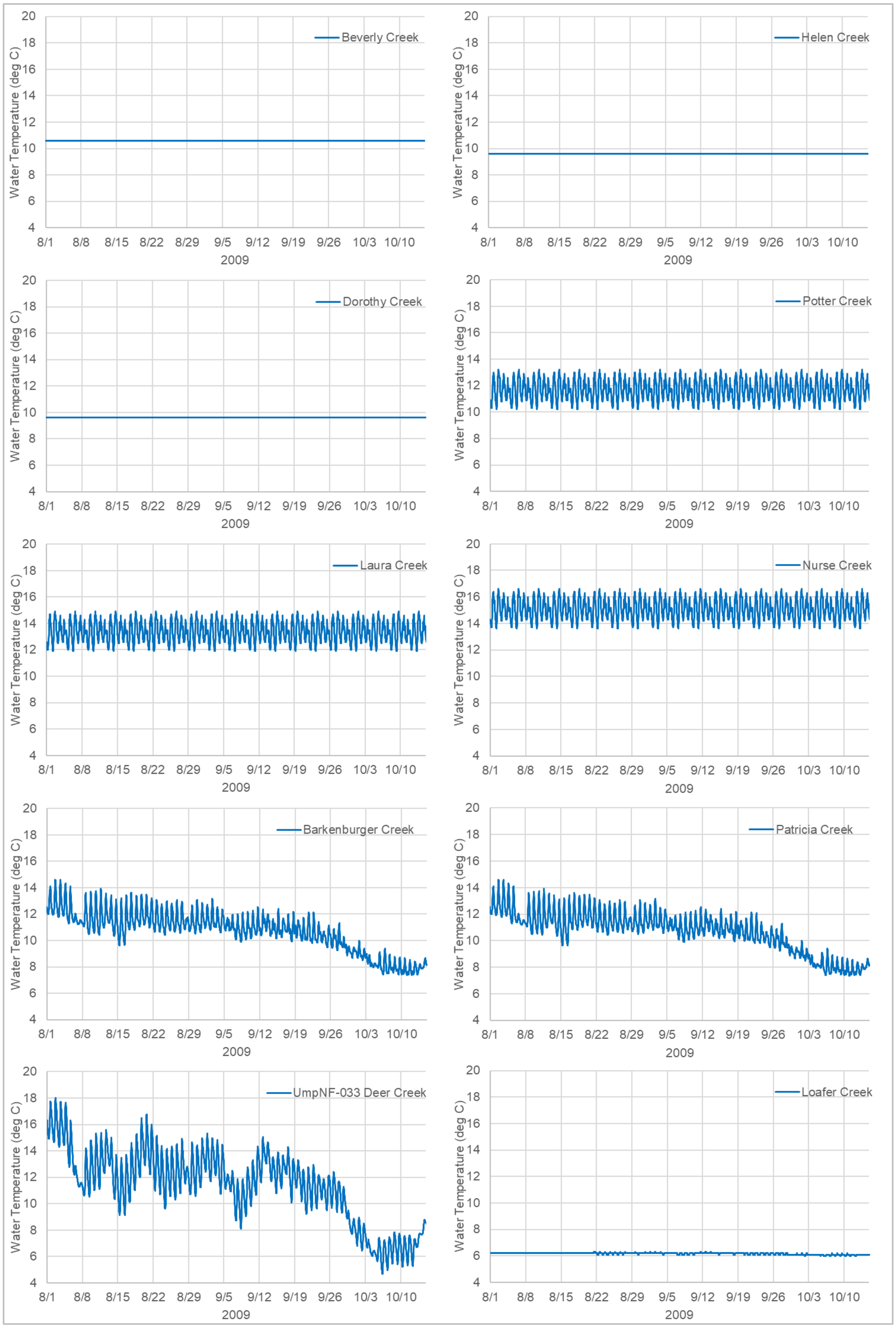

Figure 6-44. Hourly water temperature for tributaries used in the North Umpua Model 2.

6.4.3 Water Temperature Inputs and Estimation – North Umpqua River Model 3 (Toketee Reservoir to Slide Powerhouse)

The upstream boundary for Model 3 (Toketee Reservoir to Slide Powerhouse) was defined using station 25695-ORDEQ (North Umpqua River below Toketee Lake) (Table 6-11). Missing data (from August 1 to August 19 and from October 13 to October 15) were filled using repeated temperatures from the first available observed date and an incremental adjustment factor to follow the pattern of water temperature. Figure 6-45

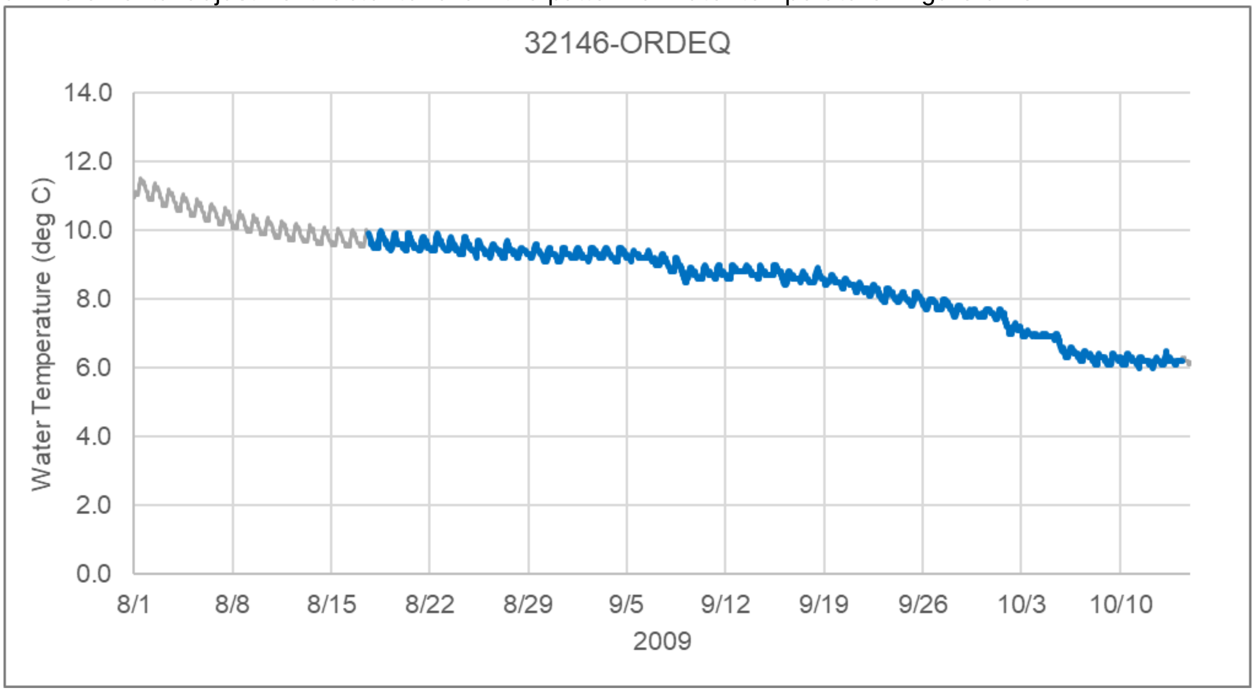

Figure 6-42. Upstream boundary water temperature data for North Umpqua Model 1.

shows the upstream boundary water temperatures, with filled missing data periods shown in grey.

Table 6-11. Inventory of available water temperature data used to configure the North Umpqua River Model 3 (Toketee Reservoir to Slide Powerhouse)

Station ID	Model location (Km)	Source	Type	Notes
Toketee Reservoir (25695-ORDEQ)	3.15	DEQ	Boundary condition	

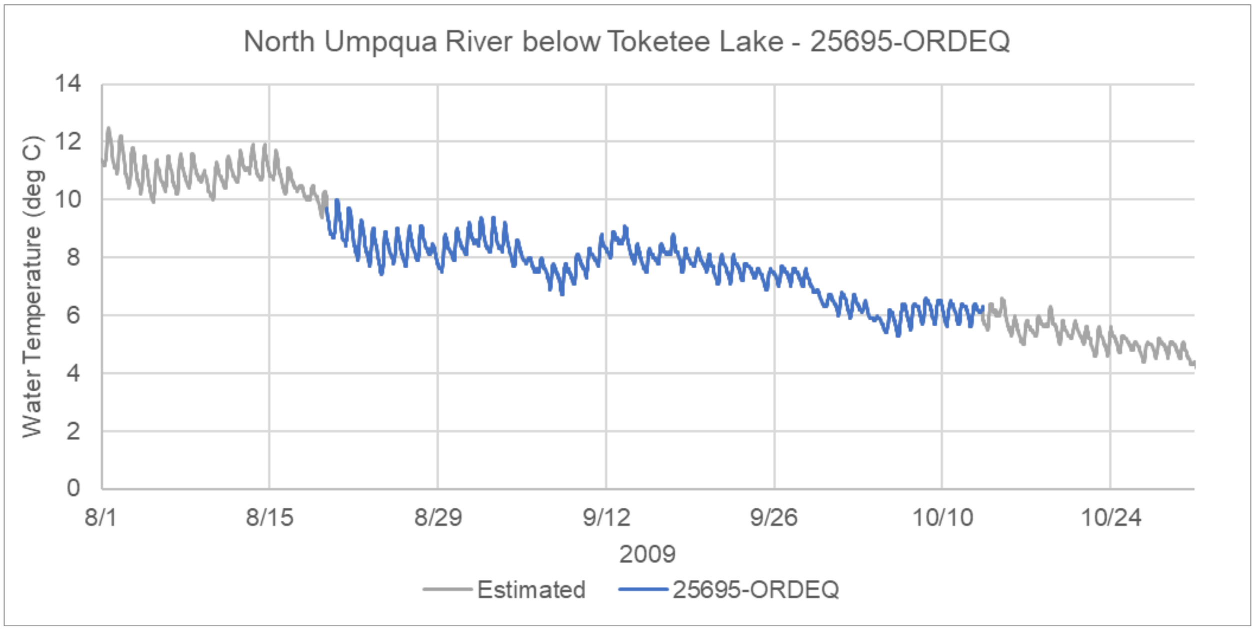

Figure 6-45. Upstream boundary hourly water temperature data (25695-ORDEQ) for North Umpqua Model 3.

6.4.4 Water Temperature Inputs and Estimation – North Umpqua River Model 4 (Slide Powerhouse to Soda Springs Reservoir)

The upstream boundary for North Umpqua Model 4 was defined using station 25696-ORDEQ (Slide Powerhouse) (Table 6-12). Missing data (from August 1 to August 26) were filled using repeated temperatures from the last observed date and an incremental adjustment factor to follow the trend.

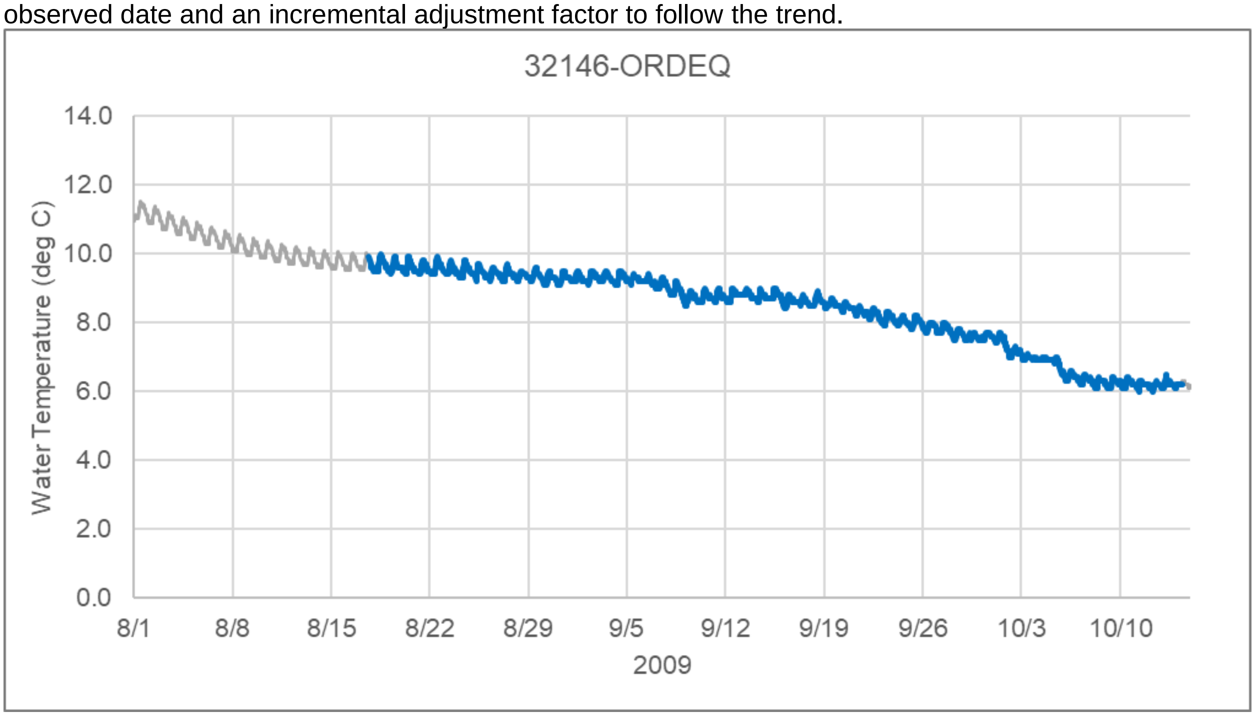

Figure 6-42. Upstream boundary water temperature data for North Umpqua Model 1.

Figure 6-46 shows the upstream boundary water temperatures, with filled missing data periods shown in grey. Fish Creek tributary water temperature inputs were specified using the USFS station UmpNF-039 (Figure 6-47).

Table 6-12. Inventory of available water temperature data used to configure the North Umpqua River Model 4 (Slide Powerhouse to Soda Springs Reservoir)

Station ID	Model location (Km)	Source	Type	Notes
Slide Powerhouse (25696-ORDEQ)	3.15	DEQ	Boundary condition	
Fish Creek (UmpNF-039)	0.95	USFS	Tributary	

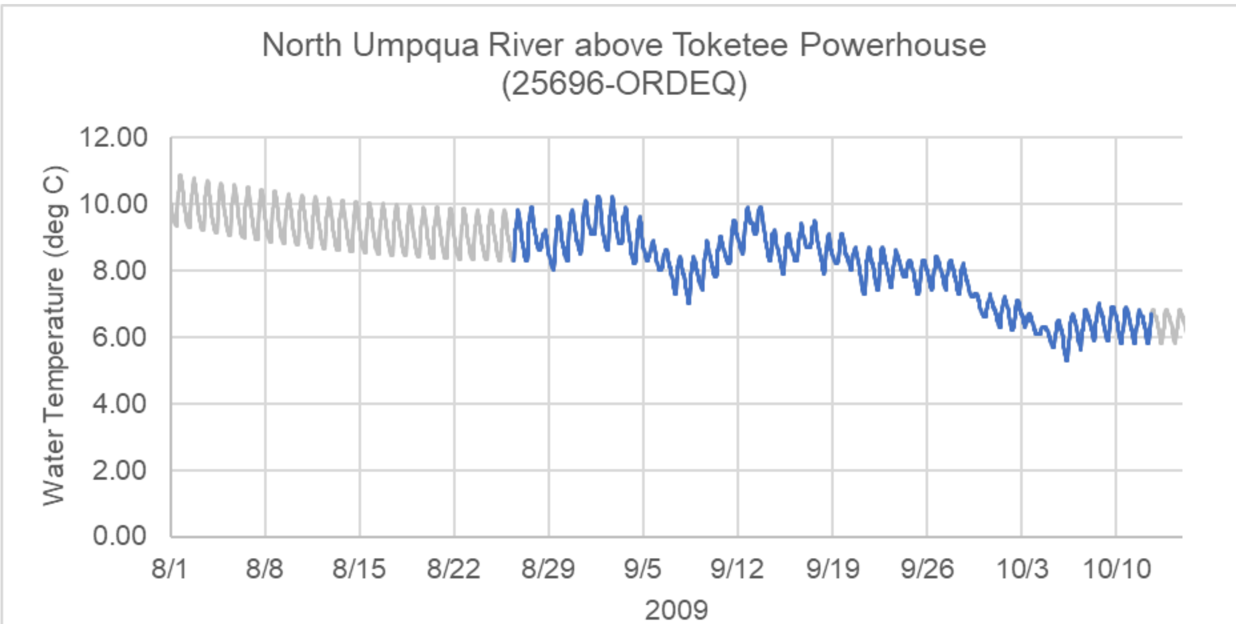

Figure 6-46. Upstream boundary hourly water temperature data (25696-ORDEQ) for North Umpqua Model 4

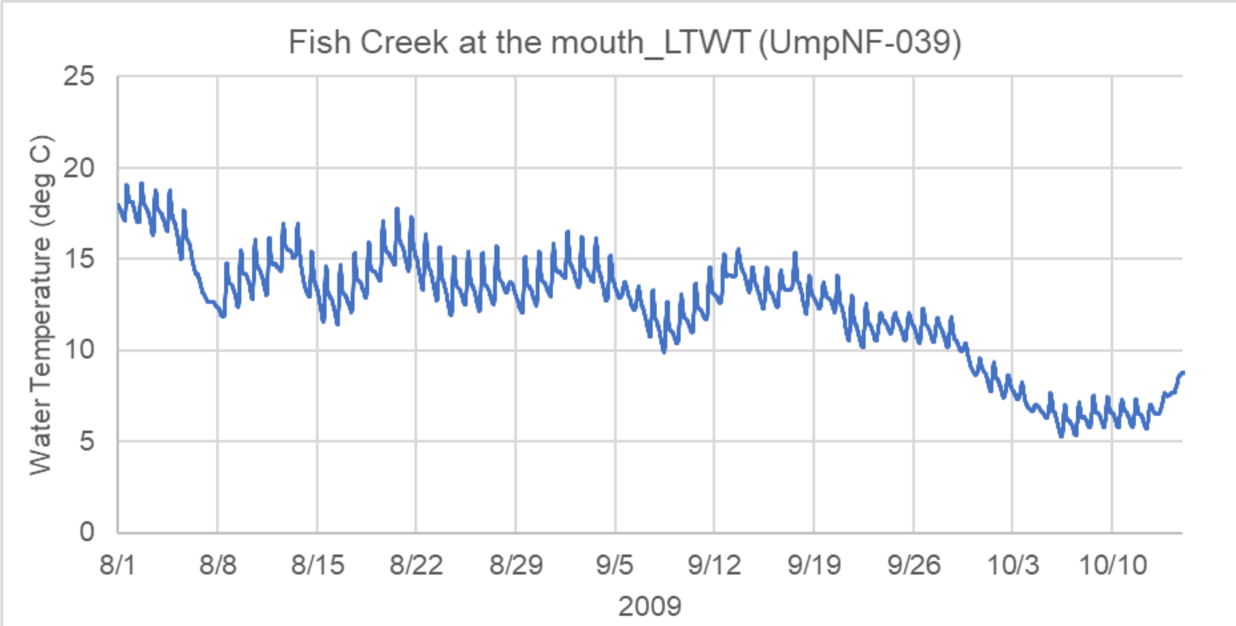

Figure 6-47. Fish Creek hourly water temperature

6.4.5 Water Temperature Inputs and Estimation – North Umpqua River Model 5 (Soda Springs Reservoir to the mouth)

Table 6-13 presents the water temperature data used to configure the North Umpqua River Model 5. The upstream boundary was specified in the model using hourly water temperature from USGS 14316460 (North Umpqua River at Soda Springs, near Toketee Falls).

Copeland Creek hourly water temperatures were configured using data from the USFS station UmpNF-024. Hourly timeseries temperature data for Boulder Creek was estimated using sine fit of daily min/max temperatures at USGS 14316495 (Boulder Creek near Toketee Falls, OR).

Steamboat Creek used observed data from the DEQ station 36135-ORDEQ. Missing data at this station from August 1 to August 17 and after October 12 was estimated using a regression relationship with Copeland Creek UmpNF-024 (y= 1.0707x + 1.0878; R^2 = 0.97). Rock Creek flows were estimated at USGS 14317600 near Glide. Missing data at this station from 8/1 to 8/20 and after 10/12 were estimated using a regression with Copeland Creek UmpNF-024 (y = 0.7824x + 3.8986 R^2 = 0.98).

Deception Creek and Dry Creek were assigned the same temperature as Copeland Creek. Calf Creek was assigned data from the USFS station UmpNF-014. Missing data after September 21, 2009 for this station was filled using a regression relationship between Calf Creek and Copeland Creek to fill in data (y = 0.9608x + 1.3755, R^2 = 0.97). Limpy/Panther Creek was configured using station UmpNF-067. Missing data at this station after 9/22/2009 was estimated using a regression with Copeland Creek station UmpNF-024 (y = 0.9501x + 2.1939, R^2 = 0.902).

Fox Creek used the same assumption that was used in the summer model (i.e., Rock Creek temperature minus 3 °C as a surrogate). Little River used water temperature data from the DEQ station 28396-ORDEQ. Missing data at this station from August 1 to August 17, 2009 and October 12, 2009 onwards were estimated using a regression with USGS 14318000 Little River at Peel temperatures (y = 1.0603x + 0.4313, R^2 = 0.9434). The hourly water temperature time series for all of these waterbodies are shown in Figure 6-48Figure 6-48 and Figure 6-49 Figure 6-49.

Table 6-13. Inventory of available water temperature data used to configure the North Umpqua River Model 5 (Soda Springs Reservoir to the mouth)

Station ID	Model location (Km)	Source	Type	Notes
Below Soda Springs Powerhouse (14316460)	113.4	USGS	Boundary Condition	
Soda Springs Powerhouse (14316460)	112.7	USGS	Tributary	
Boulder Creek (14316495)	110.5	USGS	Tributary	
Copeland Creek (UmpNF-024)	108.45	USFS	Tributary	
Deception Creek	104.2	Derived data USFS	Tributary	Surrogate relationship
Dry Creek	102.05	Derived data USFS	Tributary	Surrogate relationship
Calf Creek (UmpNF-014)	100.65	USFS	Tributary	Surrogate relationship
Panther Creek (UmpNF-067)	93.9	USFS	Tributary	
Steamboat Creek (36135-ORDEQ)	86.4	DEQ	Tributary	
Fox Creek	70.7	Derived data	Tributary	Surrogate relationship
Rock Creek (32477- ORDEQ)	56.9	DEQ	Tributary	
Little River (28396- ORDEQ)	46.3	DEQ	Tributary	

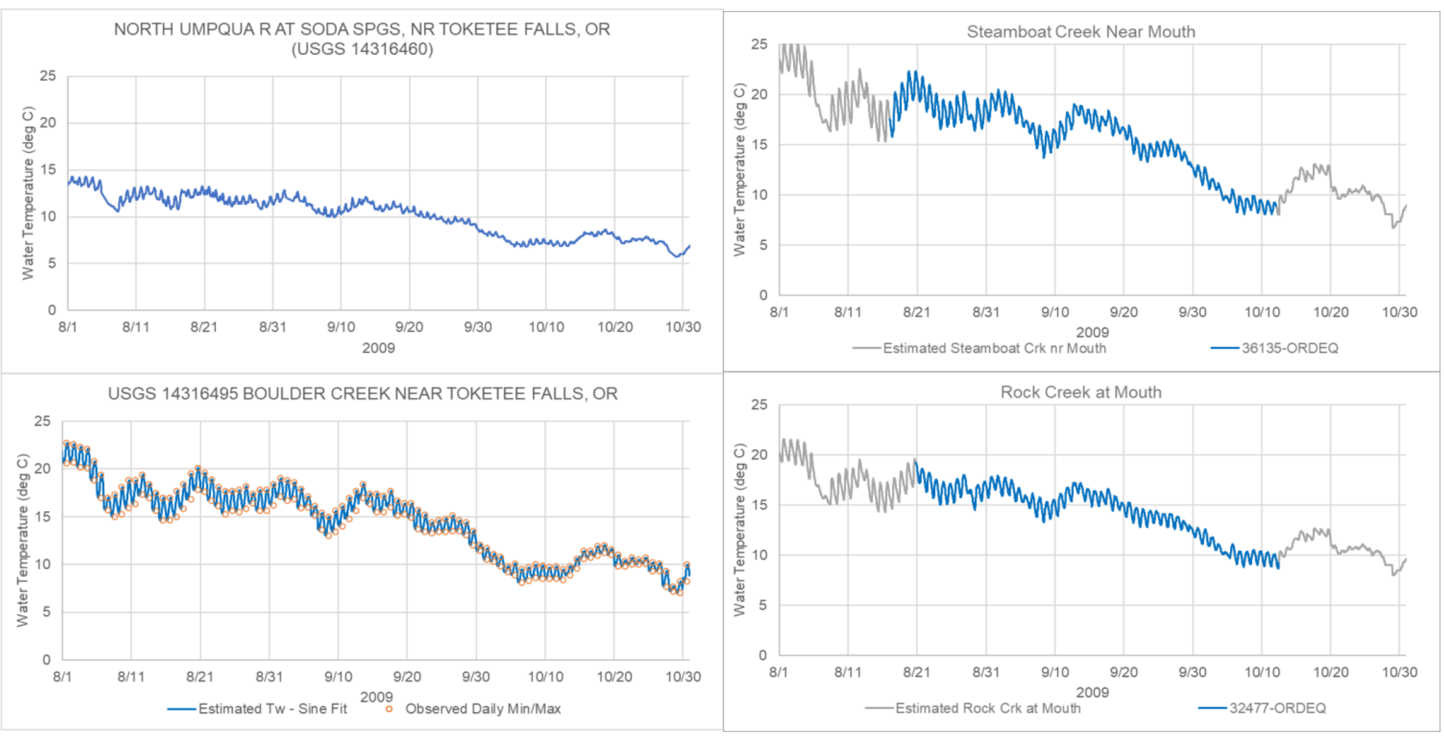

Figure 6-48. Hourly water temperature of tributaries used in the North Umpqua River Model 5 (North Umpqua River, Steamboat Creek, Boulder Creek and Rock Creek)

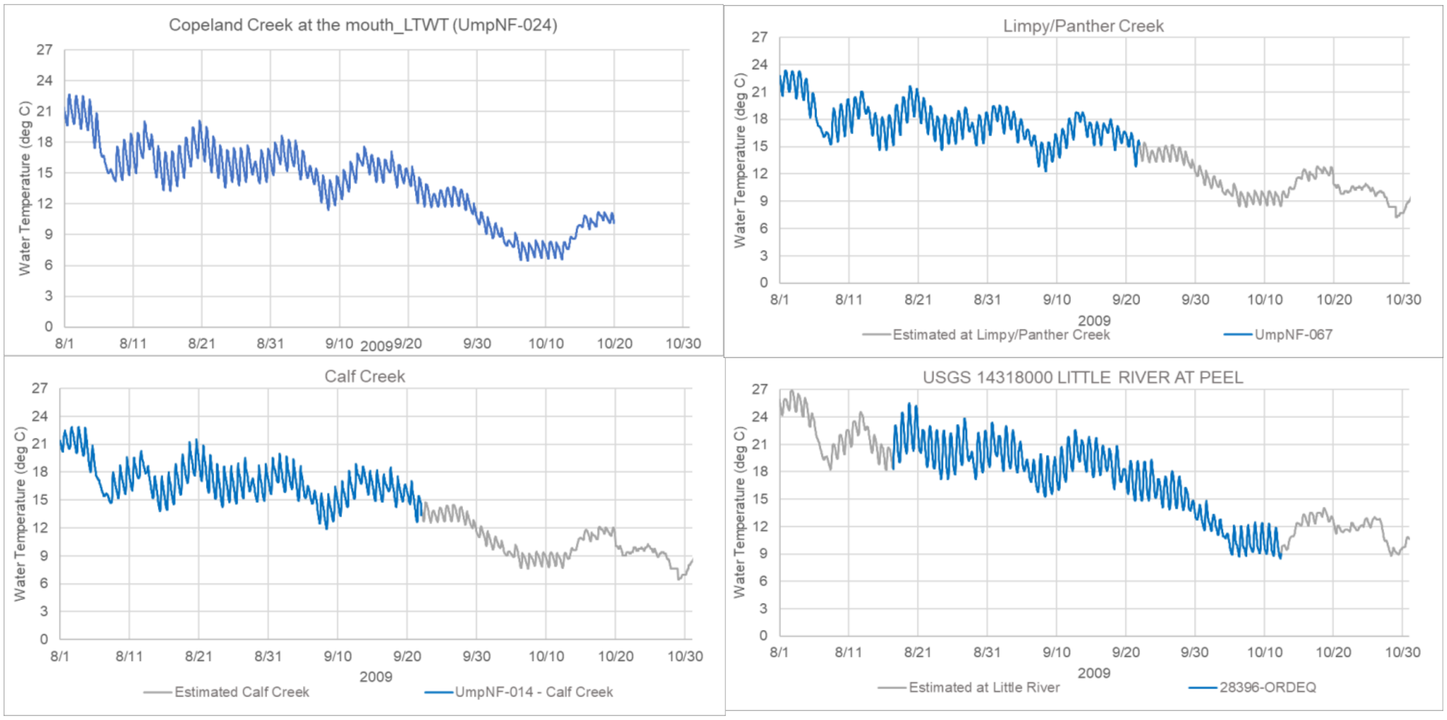

Figure 6-49. Hourly water temperature of tributaries used in the North Umpqua River Model 5 (Copeland Creek, Limpy/Panther Creek, Calf Creek and Little Creek)

6.5 POINT SOURCE DATA – NORTH UMPQUA RIVER

There is one point source that discharges to the North Umpqua River Model 5 section of the watershed. The point source is the Glide-Idleyld Sanitary District at RKM 44.1 (Figure 6-50). The raw daily flow and temperature data were transcribed from scanned Discharge Monitoring Record (DMR) documents from 2009 and 2016 to 2018. The time periods that contained raw data include: 9/1/2009-11/30/2009, 8/1/2016-10/31/2016, 8/1/2017-10/31/2017, and 8/1/2018-8/31/2018. Flow and water temperature were missing for the entire month of August 2009, with several missing water temperature data for other periods. The August 2009 flow and water temperature data were filled in using average flows from 2016 to 2018. Missing water temperature data for other periods were filled in using linear interpolation. Figure 6-51 shows the available data and Figure 6-52 shows the observed and estimated flow and temperature data used in Model 5 to configure the point source.

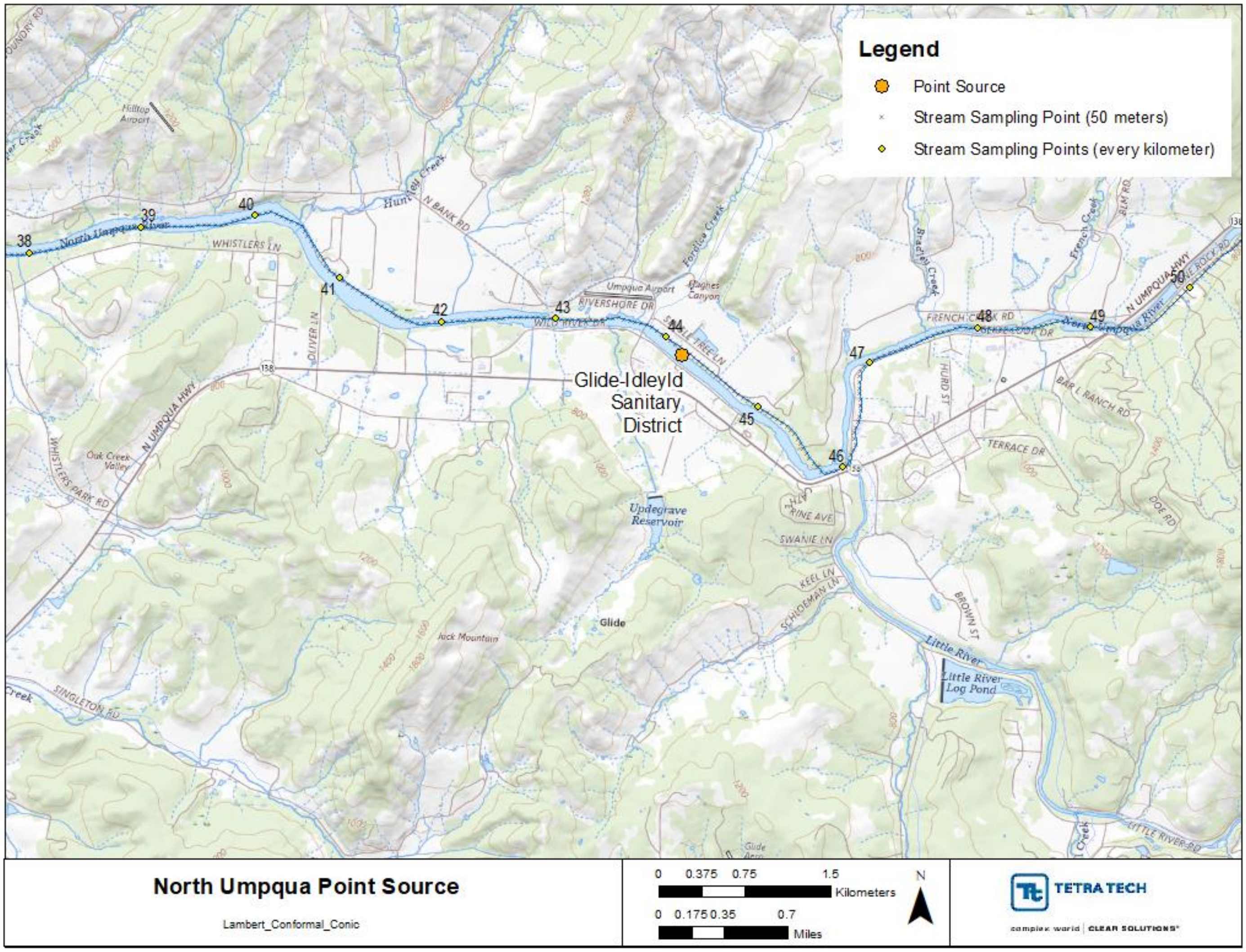

Figure 6-50. Location of the Glide-Idleyld Sanitary District

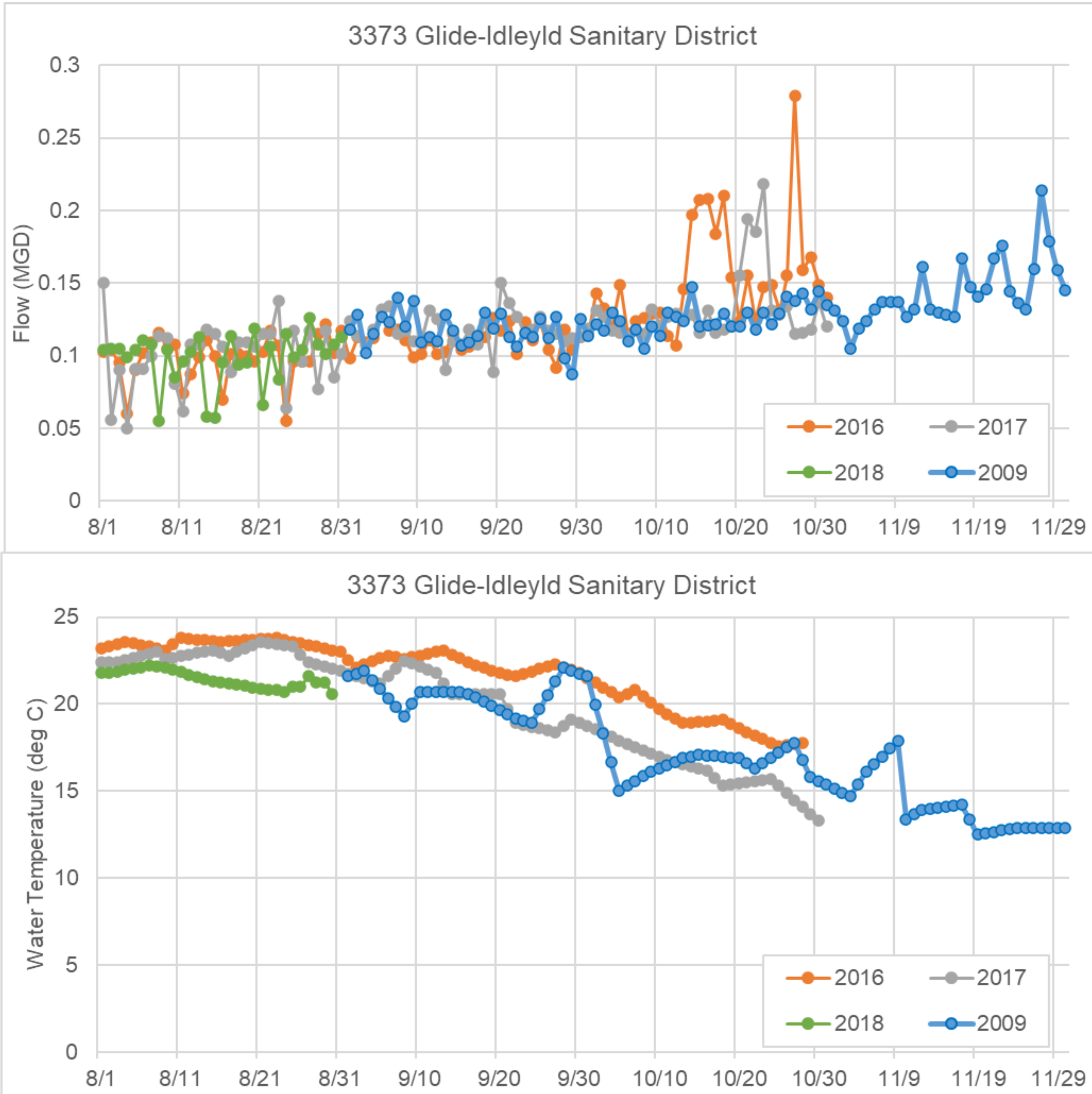

Figure 6-51. Available flow and temperature DMR data for Glide-Idleyld Sanitary District.

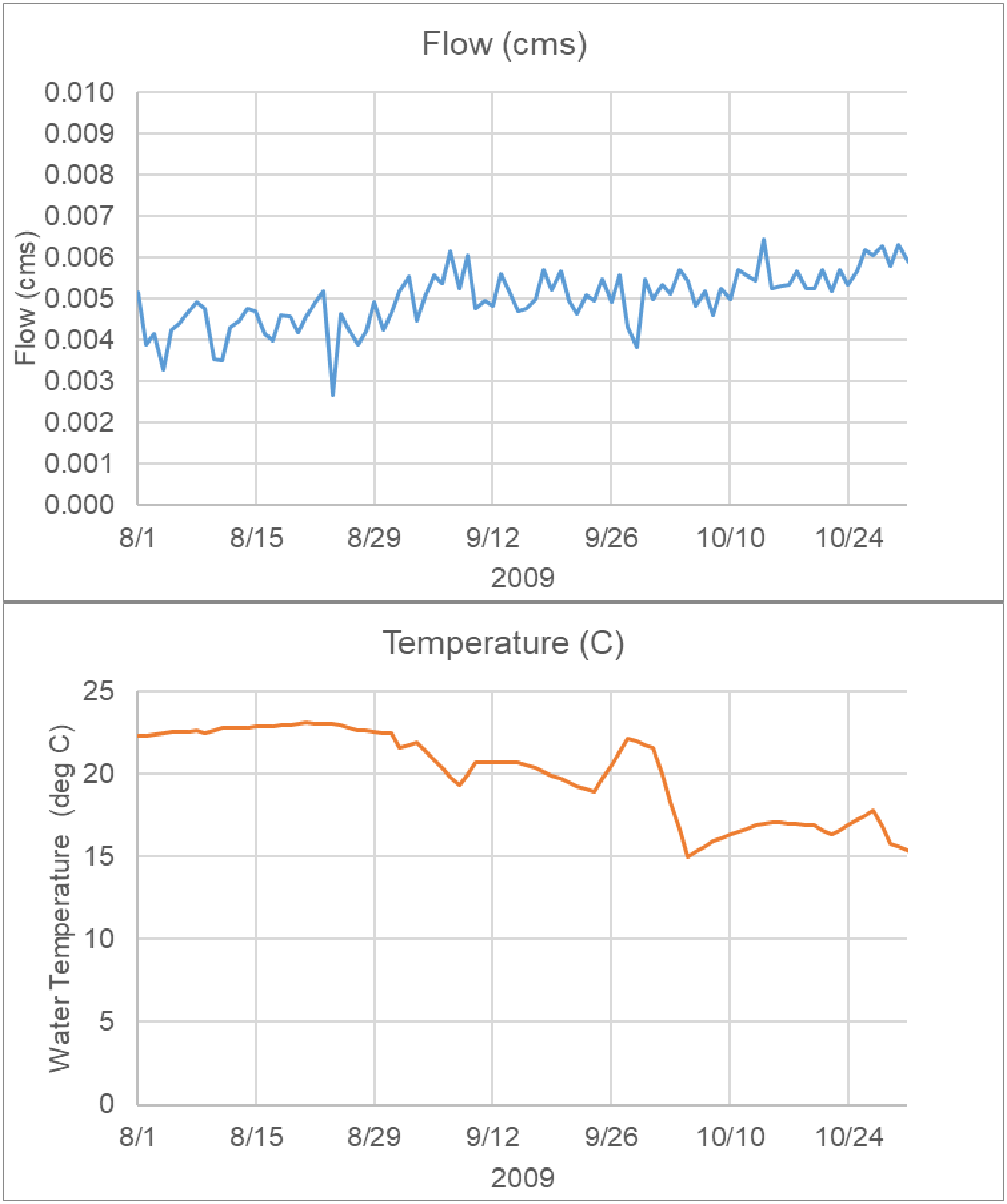

Figure 6-52. Flow and temperature data used to represent Glide-Idleyld Sanitary District in North Umpqua Model 5.

6.6 METEOROLOGICAL DATA – NORTH UMPQUA RIVER

Hourly meteorology inputs into the model include air temperature, relative humidity, wind speed, and cloud cover. Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Station elevations vary widely from east to west along the North Umpqua, ranging from approximately 120 meters at the downstream end where the North Umpqua meets Umpqua River to 540 meters near Soda Springs Dam to approximately 1240 meters near the headwaters of North Umpqua Model 1. Weather stations along the modeled North Umpqua River mainstem were identified such that this spatially varying elevation change can be accounted for using the observed meteorological data. Figure 6-53 show a map with all the meteorological stations along the North Umpqua that were in the North Umpqua Models.

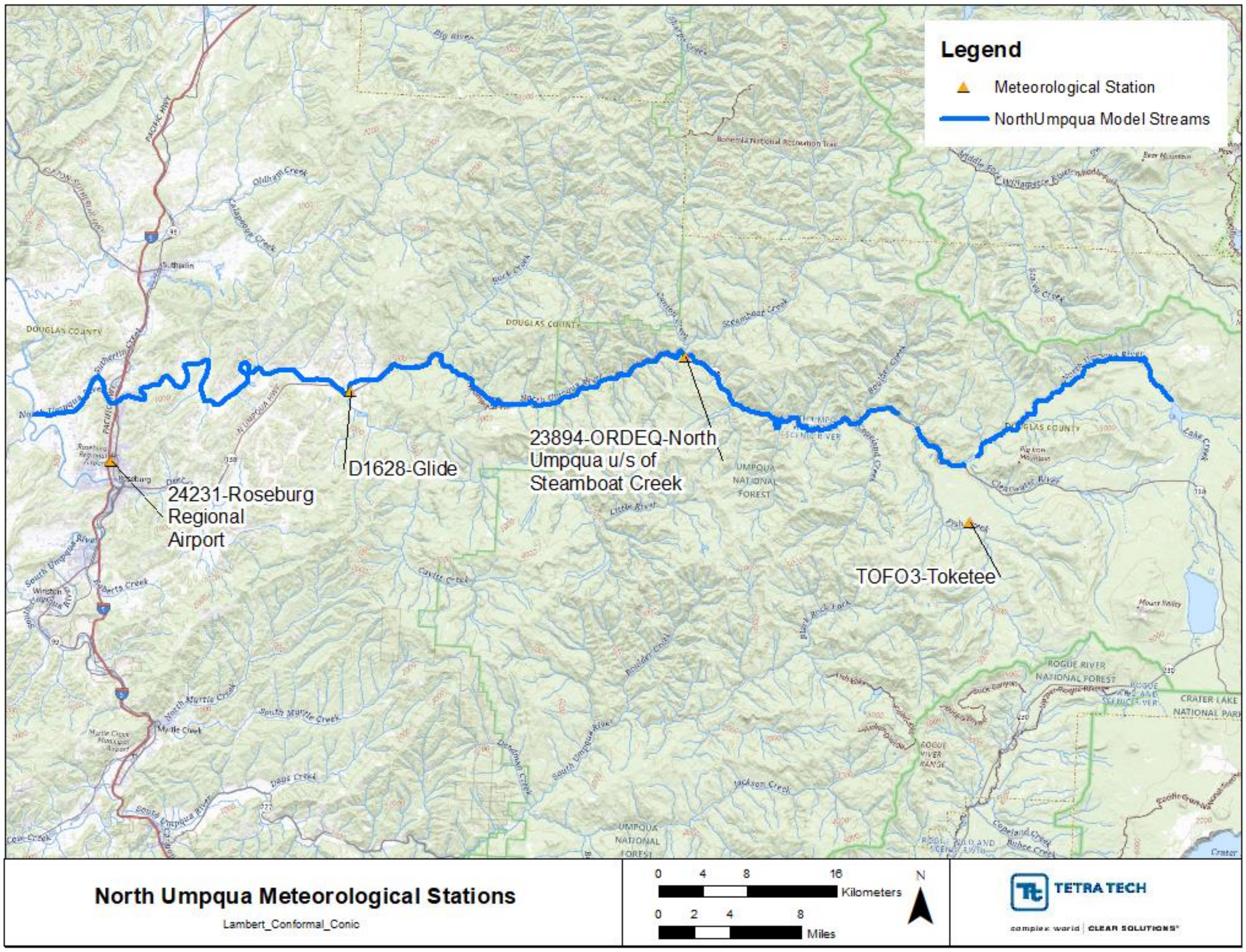

Figure 6-53. North Umpqua River Meteorological Stations

Table 6-14. Inventory of meteorological stations used to configure the North Umpqua models 1 through 4.

Station ID	Station Name	Elevation (m)	Latitude/Longitude	Frequency	Available Met Data	Source
WBAN24231	Roseburg Regional Airport	152.9	43.23367°/ 123.35775°	Hourly	Air Temperature, Relative Humidity, Wind Speed, Cloud cover	NCDC - LCD
TOFO3	Toketee Airport	1024.39	43.2186°/- 122.413°	Hourly	Air Temperature, Relative Humidity, Wind Speed	MesoWest

North Umpqua Model 1, air temperatures were specified using data from the Roseburg Regional Airport NCDC-LCD weather station after applying adiabatic adjustment to the air temperatures. All other parameters such as relative humidity, and wind speed were obtained from the MesoWest station at Toketee Airport. Cloud cover was calculated based on descriptive information about cloud cover conditions reported at the Roseburg Regional Airport. The Roseburg Airport provided descriptive sky cover information, which was converted to tenths from 0 to 1 for input in the Heat Source Model. There were a few missing hours (two hours) in the datasets which were filled in using the average of the previous hours. Table 6-14 presents the weather data available for Model 1. Figure 6-54 shows the hourly air temperature used for Model 1. The relative humidity, wind speed, and cloud cover at this station can be found in Figure 5-13.

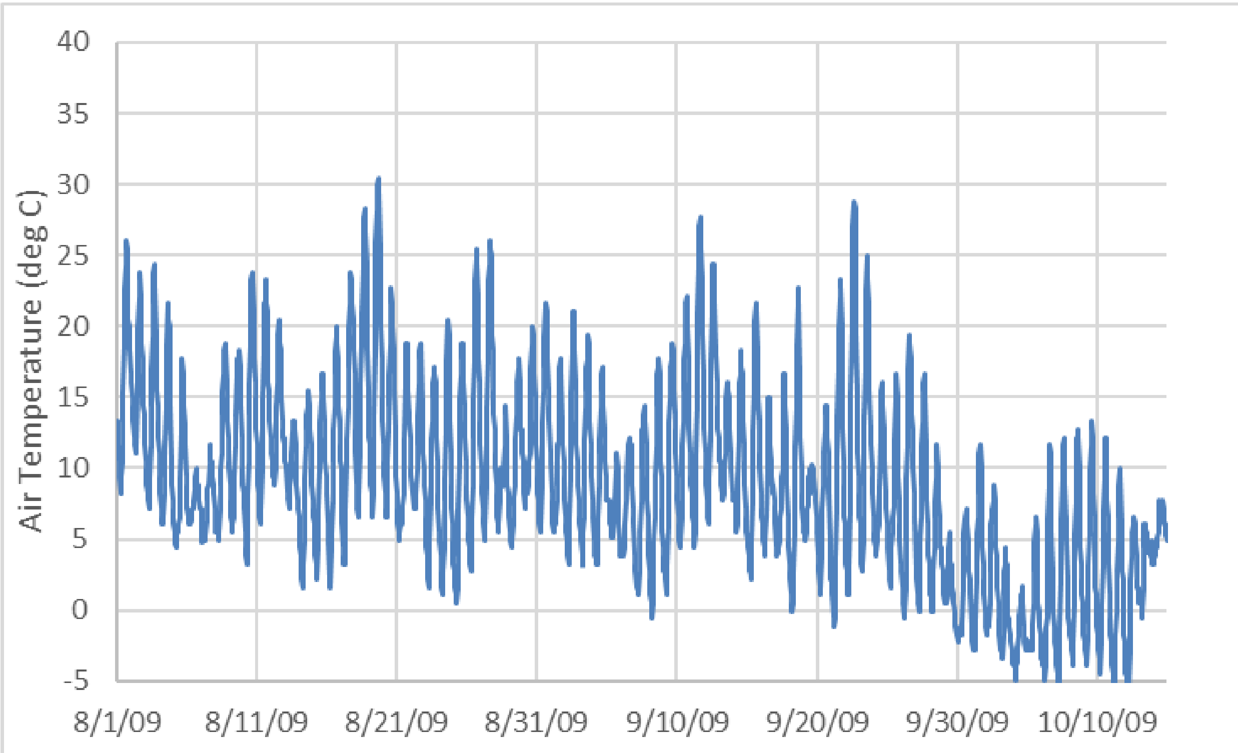

Figure 6-54. Air temperature at Roseburg station (NCDC-LCD)

Meteorological inputs for Model 2, Model 3 and Model 4 were configured using data from the Toketee Airport weather station (Table 6-14 and Figure 6-53). Cloud cover was calculated based on cloud cover descriptive information reported at the Roseburg Regional Airport for all models (Figure 5-13). The hourly meteorological input time series data at the Toketee Airport can be found in Figure 4-19.

Model 5 North Umpqua represents a long stretch of the river from RKM 113.4 to RKM 0. Several stations were used to spatially vary the meteorological inputs along the system. Table 6-15 presents the available weather stations that were used to configure North Umpqua Model 5.

Table 6-15. Inventory of available meteorological station Data in the North Umpqua River Model 5 (Soda Springs Reservoir to the mouth) watershed

Station ID	Station Name	Elevation (m)	Latitude/ Longitude	Frequency	Available Met Data	Source	Notes
WBAN 24231	Roseburg Regional Airport	152.9	43.23367°/ -123.3578°	Hourly	Air Temperature, Relative Humidity, Wind Speed, Cloud cover	NCDC - LCD	
DW1628	Glide	213.4	43.3°/ -123.1°	Hourly	Air Temperature, Relative Humidity, and Wind Speed	MesoWest	Used Wind Speed data
23894-ORDEQ	North Umpqua Upstream of Steamboat Creek	366	43.3403°/ -122.733°	Hourly	Air Temperature	DEQ	Used Air Temperature

The meteorological assignment for North Umpqua Model 5 varied spatially across six nodes represented along the Model 5 domain. Generally, data from the Roseburg Airport station were used in Model 5, with air temperatures specified after applying adiabatic adjustment, wind speed, relative humidity, cloud cover from this station. The relative humidity, wind speed, and cloud cover observed at the Roseburg Airport station can be found in Figure 5-13. The model calibration started with data from the Roseburg Airport station and then was supplemented with parameters from additional stations that were available along the system to further improve the calibration.

Wind speed data at nodes 4 (RKM 57.9, North Umpqua River near Idleyld Park upstream of Rock Creek) and 5 (RKM 55, North Umpqua River near Idleyld Park) were updated to further improve the calibration. These nodes used wind speed data from DW1628 (Glide from the MesoWest Database). The Glide data had missing data from 9/6/2009 6:03 to 9/12/2009 18:13, which was filled in by linearly interpolating the data. Figure 6-55 shows the observed wind speed at the Glide station used in the model.

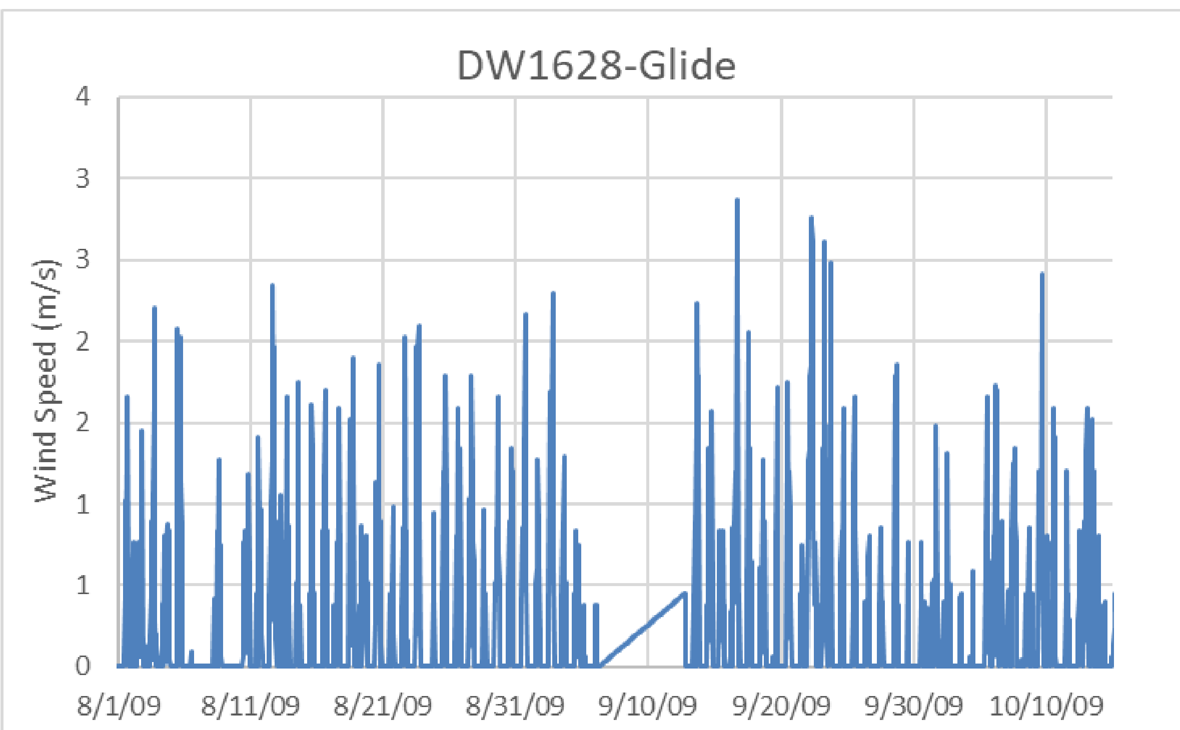

Figure 6-55. Observed wind speed at DW1628-Glide (MesoWest station).

Additionally, air temperatures at node 3 (RKM 85 North Umpqua River upstream of Steamboat Creek) were specified using data from the ORDEQ station 23894-ORDEQ (North Umpqua upstream of Steamboat Creek) that was specifically collected during 2009 to support the calibration. The 23894-ORDEQ station had missing data for the month of August and during October (from October 12 onwards). These missing air temperature data were filled using Roseburg Air Temperature after applying an adiabatic lapse rate adjustment and further refinement during calibration. Figure 6-56 shows the air temperatures timeseries used in the model.

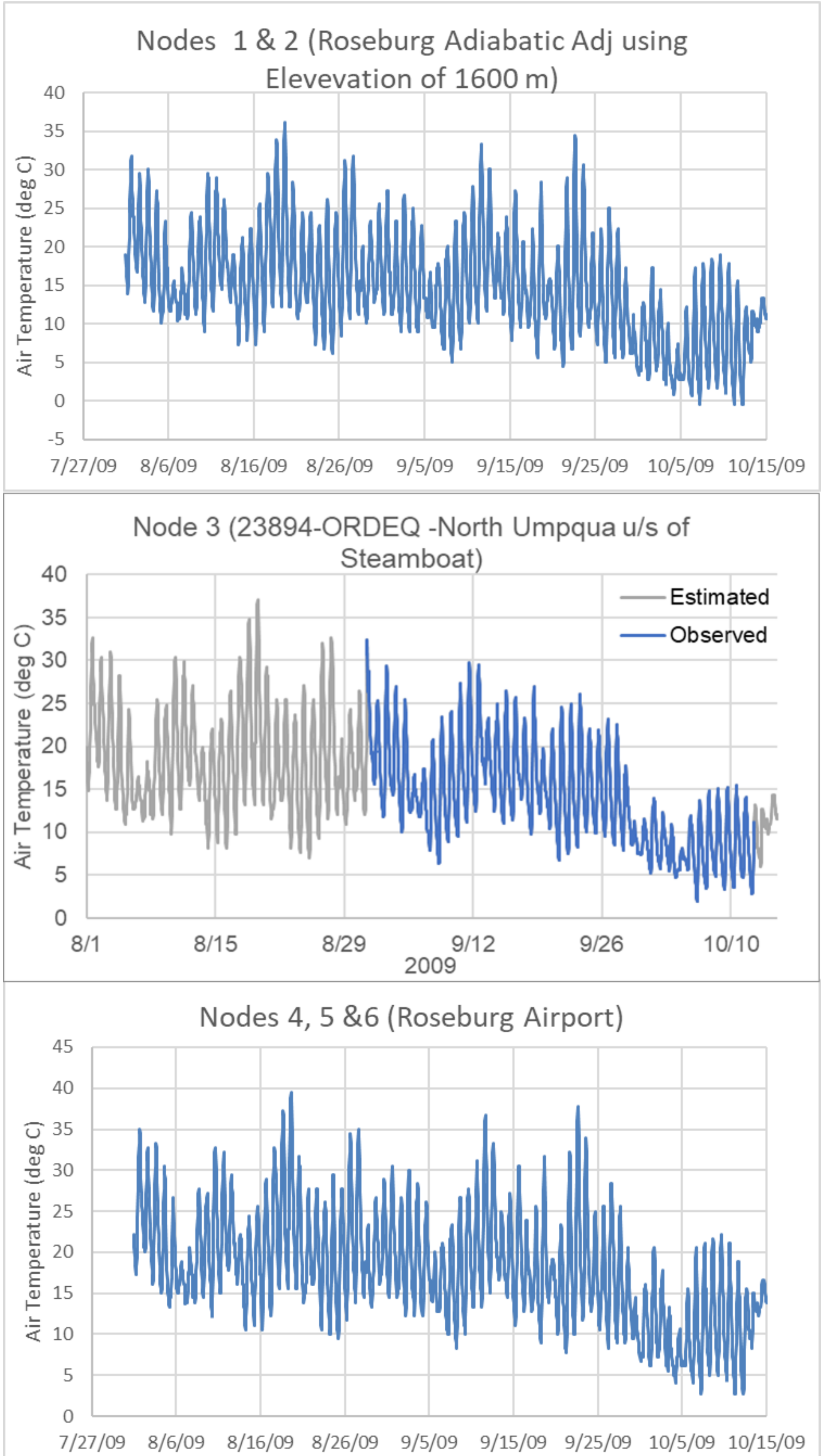

Figure 6-56. Air temperature assignment across the six nodes in North Umpqua Model 5.

6.7 MODEL CALIBRATION – NORTH UMPQUA RIVER

The North Umpqua Heat Source models from Model 1 through Model 5 were simulated for the time period from August 1, 2009, to October 15, 2009. The models incorporated hourly meteorology, hourly flow and stream temperature inputs (including the upstream boundary). The models were run at a time step ranging from 0.3 to 1 minutes and outputs were generated hourly, every 100 meters. The models were then calibrated against observed data. The modeled stream flows were calibrated first when available, followed by stream temperature. The model calibration sites and data sources for the North Umpqua River are summarized in Table 6-16 through Table 6-19. The model location (Model RKM) in the tables describes the distance of each calibration site from the most downstream model node. There are no calibration sites available for the North Umpqua River Model 4: Slide Powerhouse to Soda Springs Reservoir. Flow data were only available at Model 5 for calibration.

Table 6-16. Calibration sites used in the North Umpqua River Model 1 Heat Source Model Calibration

Station ID	Description	Model RKM	Data Type	Source
Water Temperature				
25687-ORDEQ	North Umpqua River Above Lemolo 2 Diversion	0.25	Water temperature	DEQ

Table 6-17. Calibration sites used in the North Umpqua River Model 2 Heat Source Model Calibration

Station ID	Description	Model RKM	Data Type	Source
Water Temperature				
25690-ORDEQ (UmpNF-90)	North Umpqua River upstream of Barkenburger	12.6	Water temperature	USFS
36130-ORDEQ	North Umpqua River upstream of Loafer Creek	7.81	Water temperature	DEQ
25693-ORDEQ	North Umpqua River	2.87	Water temperature	DEQ
25694-ORDEQ	North Umpqua River	1.60	Water temperature	DEQ

Table 6-18. Calibration sites used in the North Umpqua River Model 3 Heat Source Model Calibration

Station ID	Description	Model RKM	Data Type	Source
Water Temperature				
25696-ORDEQ	North Umpqua River Above Toketee Powerhouse	0	Water temperature	DEQ

Table 6-19. Calibration sites used in the North Umpqua River Model 5 Heat Source Model Calibration

Station ID	Description	Model RKM	Data Type	Source
Flow				
14316455	North Umpqua River below Soda Springs Dam	113	Flow	USGS
14316500	North Umpqua River above Copeland Creek	109	Flow	USGS

Station ID	Description	Model RKM	Data Type	Source
14319500	North Umpqua River at Winchester	2.9	Flow	USGS
Water Temperature				
23898-ORDEQ	North Umpqua Upstream of Boulder Creek	111	Water temperature	DEQ
14316500	North Umpqua River above Copeland Creek	109	Water temperature	USGS
23894-ORDEQ	North Umpqua Upstream of Steamboat Creek	85	Water temperature	DEQ
14317450	North Umpqua River near Idleyld Park, OR	57.9	Water temperature	USGS
36136- ORDEQ	North Umpqua River near Idleyld Park	55	Water temperature	DEQ
36152-ORDEQ	North Umpqua River downstream of Winchester Dam (Rod & Gun Club Access)	13.4	Water temperature	DEQ
30162- ORDEQ	North Umpqua River at Mouth	0.2	Water temperature	DEQ

A combination of visual and computed error statistics was used to assess the model calibration. Summary statistics (ME, MAE, RMSE, and NSE) followed the calculations described in Section 3.6.

6.8 FLOW CALIBRATION – NORTH UMPQUA RIVER

6.8.1 Flow Calibration – North Umpqua River Model 5 (Soda Springs Reservoir to the mouth)

Flow calibration for Model 5 was performed at three stations: North Umpqua River below Soda Springs Dam (USGS 14316455), North Umpqua River above Copeland Creek (USGS 14316500), and North Umpqua River at Winchester (USGS 14319500) (Figure 6-37). The model captured the overall trends at all these stations.

The modeled versus observed hourly flow timeseries at each of these stations are shown in Figure 6-57. The model results at the most upstream station location i.e. USGS 14316455 below Soda Springs Dam, agree well with the observed data since the upstream boundary uses flow from this nearby gage.

The differences between modeled and observed flows increase at the North Umpqua above Copeland gage. To reduce the differences, a 0.5 cms accretion was added between RKM 113.4 and 109 (spread equally across 88 nodes). These accretion flows were assigned a corresponding 14 °C water temperature in the model. The addition of accretion flow led to improvement in the flow calibration.

While the modeled flow agree well with the observed data most of the time, the model was unable to capture occasional spikes seen in the observed data at the Winchester station (14319500). It is unclear what the observed spikes in the calibration data represent, or if these data are erroneous, as these are not seen in the boundary input time series. Other than those anomalies seen in the observed data, the flows are captured well. The flow calibration statistics are presented in Table 6-20. The modeled ME and MAE were less than 1 cms, except for North Umpqua River at Winchester, which had a calculated MAE of 1.81 cms. The RMSE at North Umpqua above Copeland Creek and at North Umpqua above Winchester were 5.97 cms, and 1.97 cms, respectively. The calculated NSE at all the stations was very close to 1.

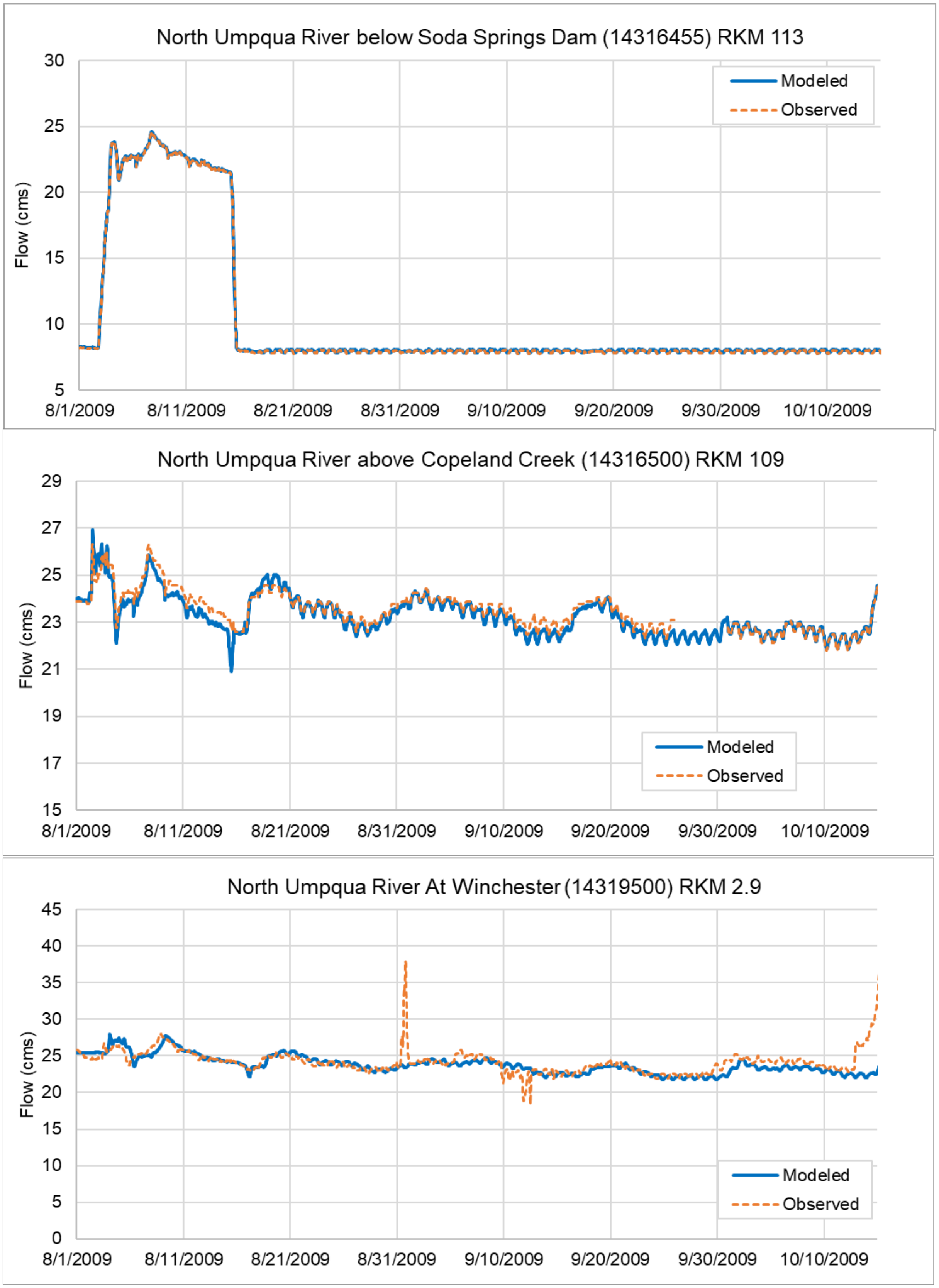

Figure 6-57. Observed versus modeled hourly flow for North Umpqua River Model 5.

Table 6-20. Flow calibration statistics for North Umpqua River Model 5 (August 1 to October 15, 2009)

Flow Statistic	North Umpqua River below Soda Springs Dam (14316455) RKM 113	North Umpqua River above Copeland Creek (14316500) RKM 109	North Umpqua River at Winchester (14319500) RKM 2.9
ME	0.04	1.42	-0.49
MAE	0.04	1.81	0.93
RMSE	0.05	5.97	1.97
NSE	1.00	0.97	1.00
Count	1824	1704	1824

6.9 TEMPERATURE CALIBRATION – NORTH UMPQUA RIVER

Hourly temperature observations were compared at each of the stream temperature calibration monitoring stations listed in Table 6-16 to Table 6-19. Calibration was performed using the observed hourly water temperature timeseries and the observed daily maximums. During calibration the daily diurnal patterns were calibrated as best as possible, with the focus primarily being on capturing the daily maximum well.

Channel morphology related inputs were retained from the HS7 model during calibration. The sediment heat exchange parameters, i.e., sediment thermal conductivity and diffusivity, and wind function coefficients were applied at their HS8 default values. Wind speeds were adjusted during calibration to improve the representation of the difference in wind speed between the measurement location and above the stream within the riparian area. The wind speed adjustments were primarily used to improve the water temperature calibration.

6.9.1 Water Temperature Calibration – North Umpqua River Model 1 (Lemolo Reservoir to Lemolo Powerhouse #1)

Model 1 was calibrated at North Umpqua River above Lemolo 2 Diversion (25687-ORDEQ). The location of the station can be found in Figure 6-41. The modeled versus observed hourly and daily maximum water temperature timeseries can be found in Figure 6-58 and Figure 6-59 respectively. The model error statistics can be found in Table 6-21. The model is able to capture the diurnal pattern and daily maximums well at this station. Cloud cover was adjusted for a few days in September to improve the calibration. Note that the lack of diurnal variation seen in the modeled data during the first two weeks of August is due to the high incoming flows seen during that period. Observed temperature at this station were available starting the last week of August. The overall calculated model calibration error statistics for the hourly and daily maximum temperatures showed a ME, MAE and RMSE of less than 1 ºC. The calculated NSE for the hourly and daily maximum temperatures was 0.85 and 0.95 respectively.

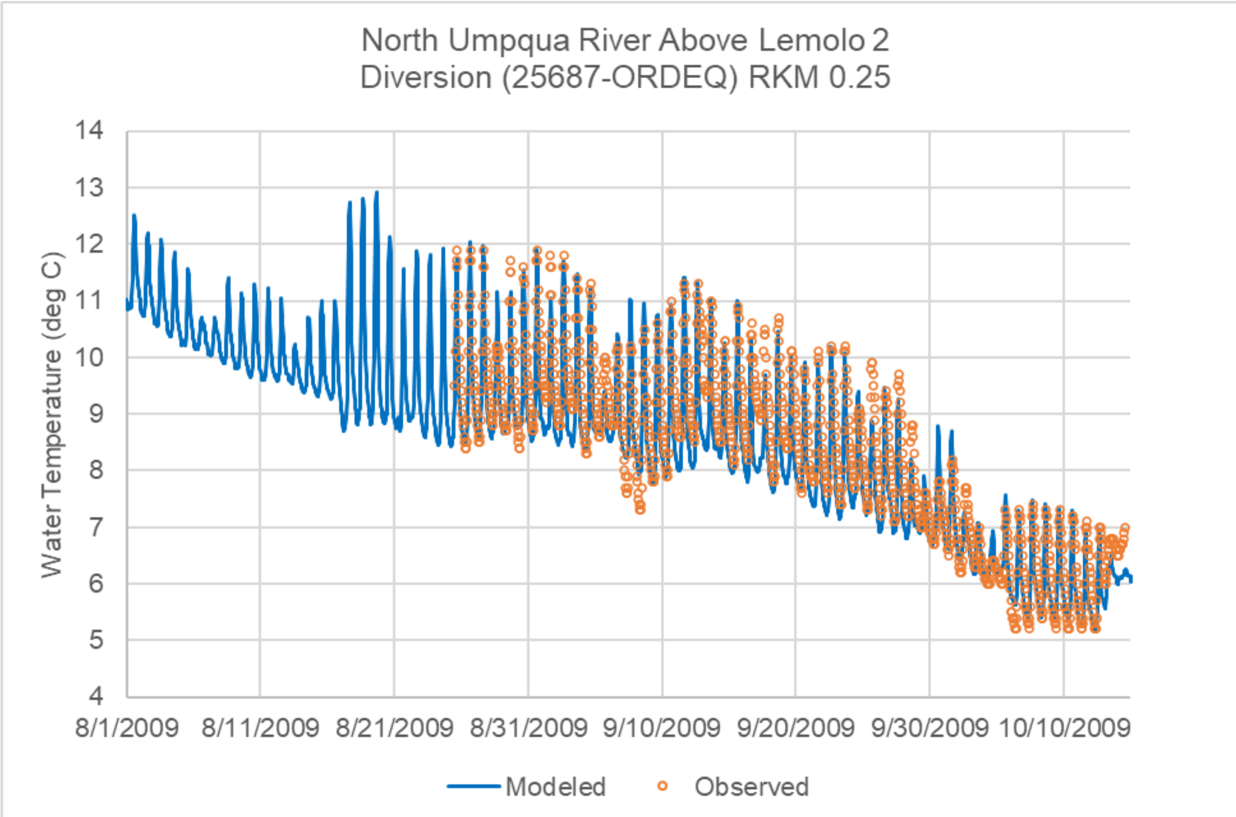

Figure 6-58. North Umpqua River Model 1–observed versus modeled hourly water temperature.

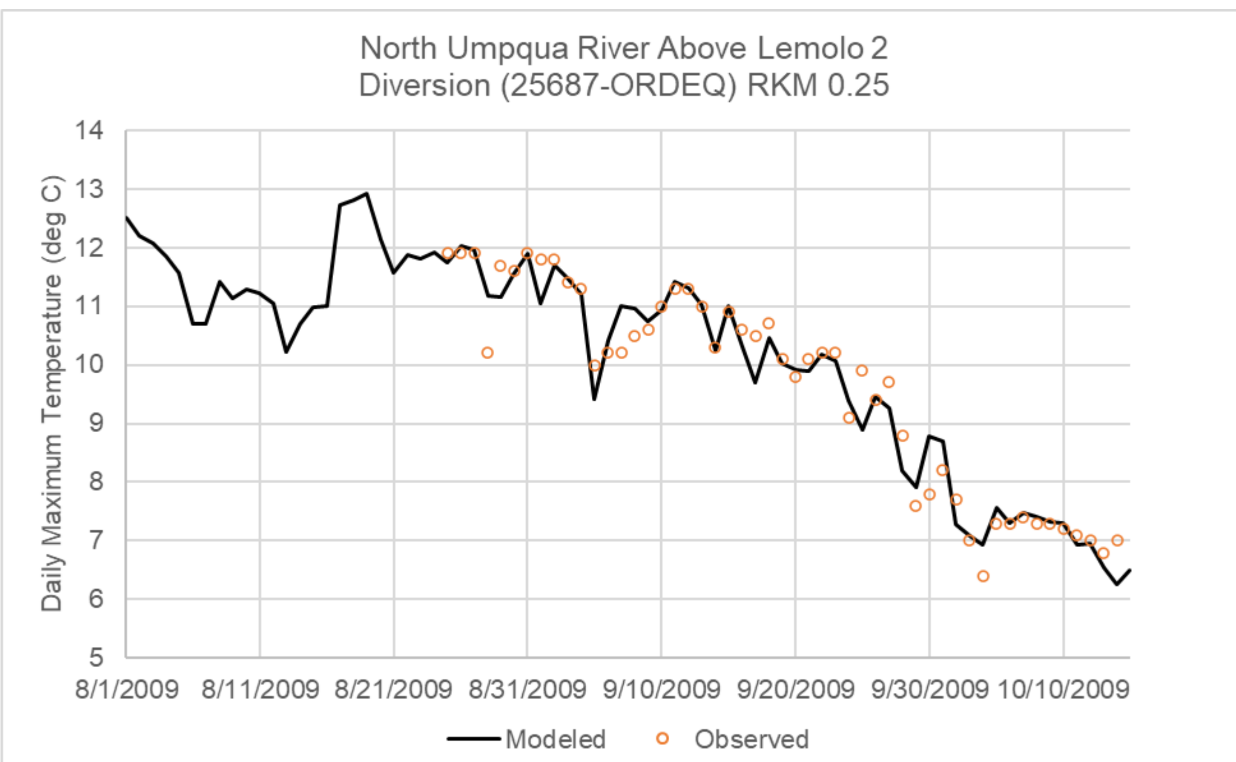

Figure 6-59. North Umpqua River Model 1–observed versus modeled daily maximum water temperature.

Table 6-21. North Umpqua River Model 1–Stream temperature calibration statistics (August 25 to October 14, 2009)

Statistic	North Umpqua River Above Lemolo 2 Diversion (25687-ORDEQ)
Hourly Temperature Statistics	
ME	-0.38
MAE	0.48
RMSE	0.60
NSE	0.85
Count	1,202
Daily Maximum Temperature Statistics	
ME	-0.03
MAE	0.28
RMSE	0.40
NSE	0.95
Count	51

6.9.2 Water Temperature Calibration – North Umpqua River Model 2 (: Lemolo Powerhouse #1 to Toketee Reservoir)

Model 2 was calibrated at four locations along North Umpqua, as shown in in Table 6-17. The locations of these stations can be found in Figure 6-41. The modeled versus observed hourly and daily maximum water temperature timeseries at each of these stations can be found in Figure 6-60 and Figure 6-61 respectively. The model is able to capture the diurnal pattern and daily maximums well at all stations. Note that no water being routed through Lemolo #2 during the 2009 temperature monitoring period. All the water in that reach during 2009 was flowing in the natural channel of the North Umpqua River. The model error statistics can be found in Table 6-22. The overall calculated model calibration error statistics for the hourly and daily maximum temperatures showed a ME, MAE and RMSE of less than 1 ºC. The calculated NSE for the hourly and daily maximum temperatures was greater than 0.92.

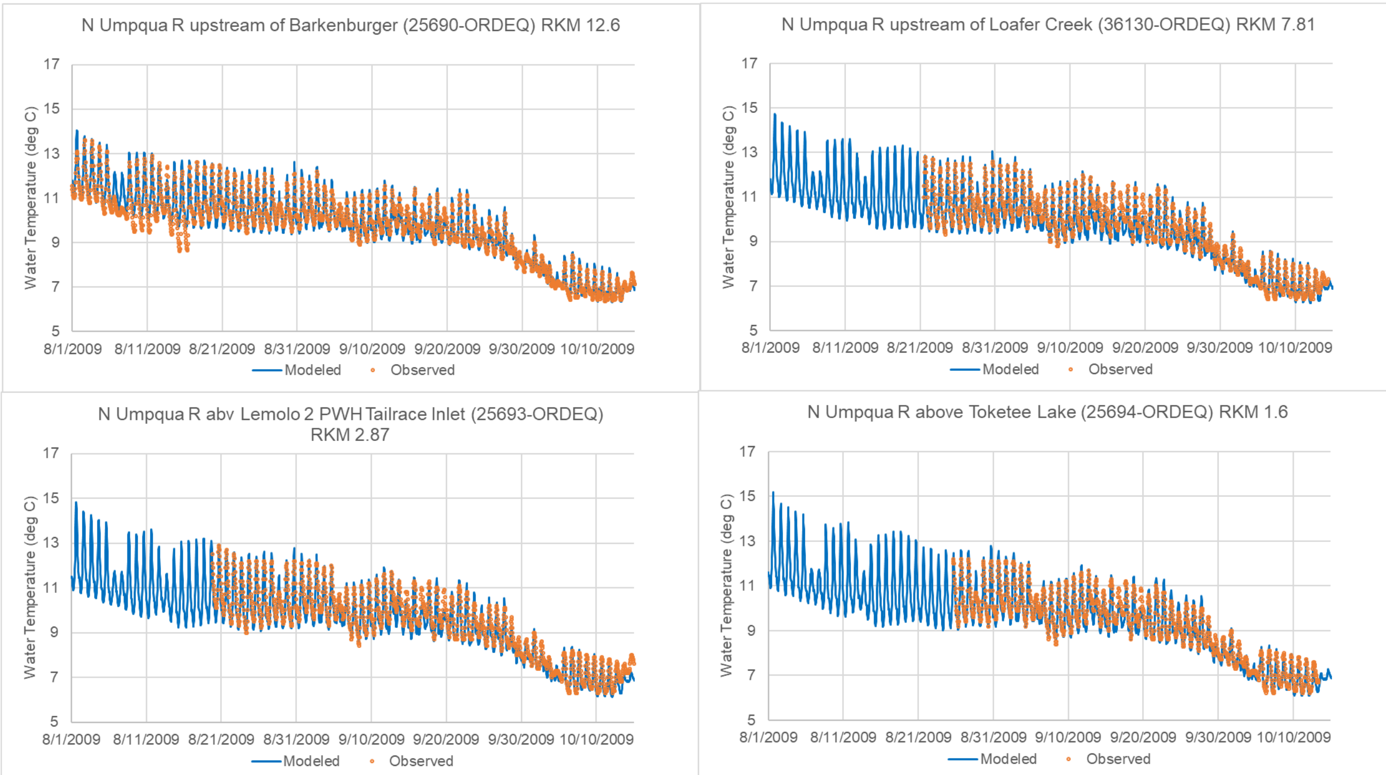

Figure 6-60. North Umpqua River Model 2 observed versus modeled hourly water temperature.

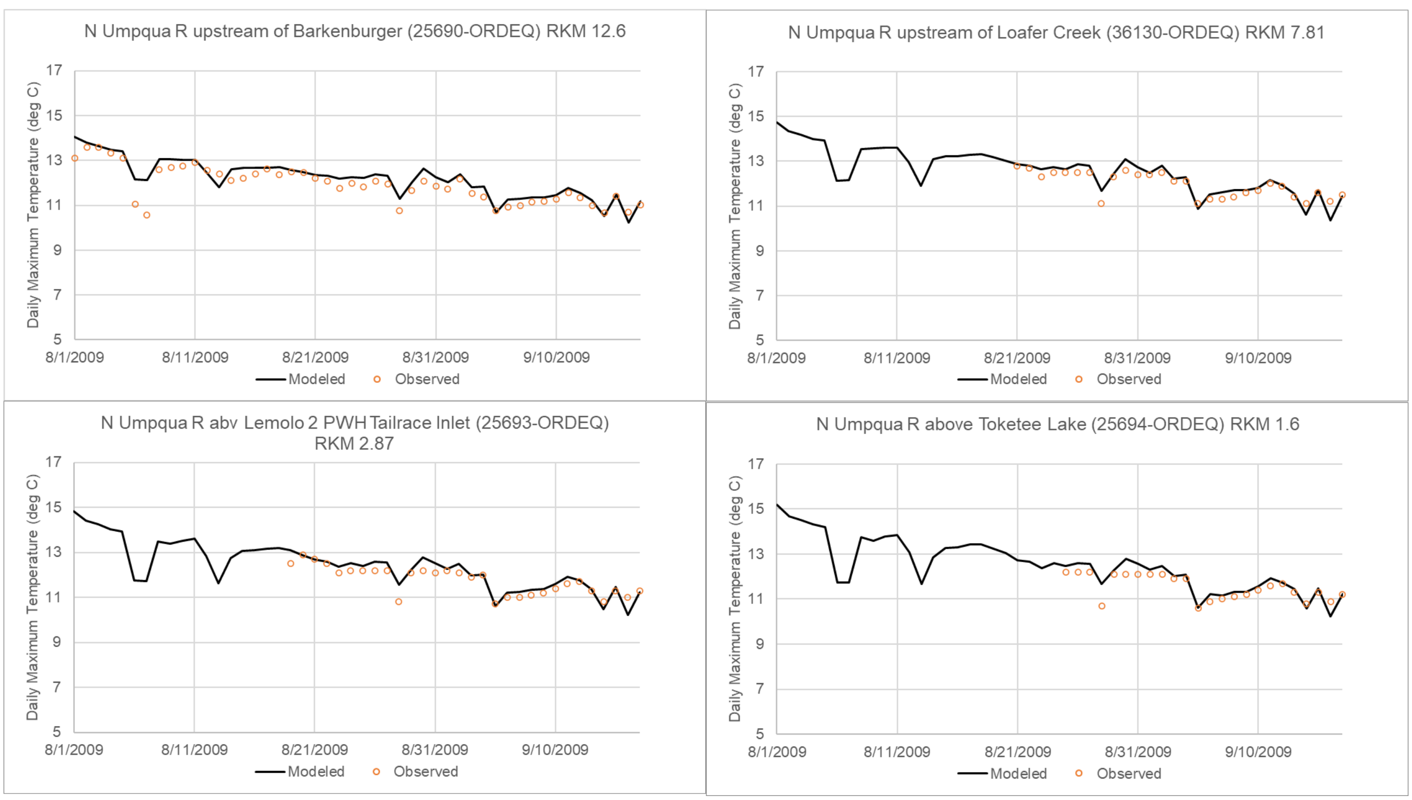

Figure 6-61. North Umpqua River Model 2–observed versus modeled daily maximum water temperature.

Table 6-22. North Umpqua River Model 2–Stream Temperature calibration statistics

Statistic	North Umpqua River upstream of Barkenburger (25690-ORDEQ) RKM 12.6[a]	North Umpqua River upstream of Loafer Creek (36130-ORDEQ) RKM 7.81 [b]	North Umpqua River above Lemolo 2 PWH Tailrace Inlet (25693-ORDEQ) RKM 2.87 [c]	North Umpqua River above Toketee Lake (25694-ORDEQ) RKM 1.6 [d]
Hourly Temperature Statistics				
ME	-0.01	-0.29	-0.29	-0.22
MAE	0.26	0.37	0.34	0.29
RMSE	0.35	0.45	0.41	0.35
NSE	0.95	0.92	0.93	0.94
Count	1,824	1,295	1,365	1,171
Daily Maximum Temperature Statistics				
ME	0.23	0.10	0.09	0.16
MAE	0.32	0.24	0.28	0.28
RMSE	0.40	0.30	0.35	0.35
NSE	0.95	0.97	0.96	0.96
Count	76	55	58	50

a: Period of Record from August 1 to October 15, 2009; b: Period of Record from August 21 to October 14, 2009; c: Period of Record from August 19 to October 15, 2009; d: Period of Record from August 25 to October 13, 2009

6.9.3 Water Temperature Calibration – North Umpqua River Model 3 (Toketee Reservoir to Slide Powerhouse)

Model 3 was calibrated using data at North Umpqua River above Toketee Powerhouse (25696-ORDEQ). The station is located at the downstream end of the modeled stream. The location of the station can be found in Figure 6-41. Observed temperature at this station were available starting the last week of August. The modeled versus observed hourly and daily maximum water temperature timeseries can be found in Figure 6-62 and Figure 6-63 respectively. The overall seasonal pattern from month to month is captured by the model. The modeled daily maximums, which were the focus of the calibration, are captured well, with some overestimation seen during a few days in September. The model is unable to capture the minimum observed in the hourly time series. Adjustments to hyporheic flow did not show significant improvements, resulting in reducing the diurnal variation but also resulted in further reducing the minimums during September. Since the TMDL is related to the maximum temperature, failure to capture the minimum observed data does not impact the model's ability to assess the maximum temperatures in support of TMDL development. The model error statistics can be found in Table 6-23. The overall calculated model calibration error statistics for the hourly and daily maximum temperatures showed a ME, MAE and RMSE of less than 1 ºC. The calculated NSE for the hourly temperatures was 0.77 and for the daily maximum temperatures was 0.95.

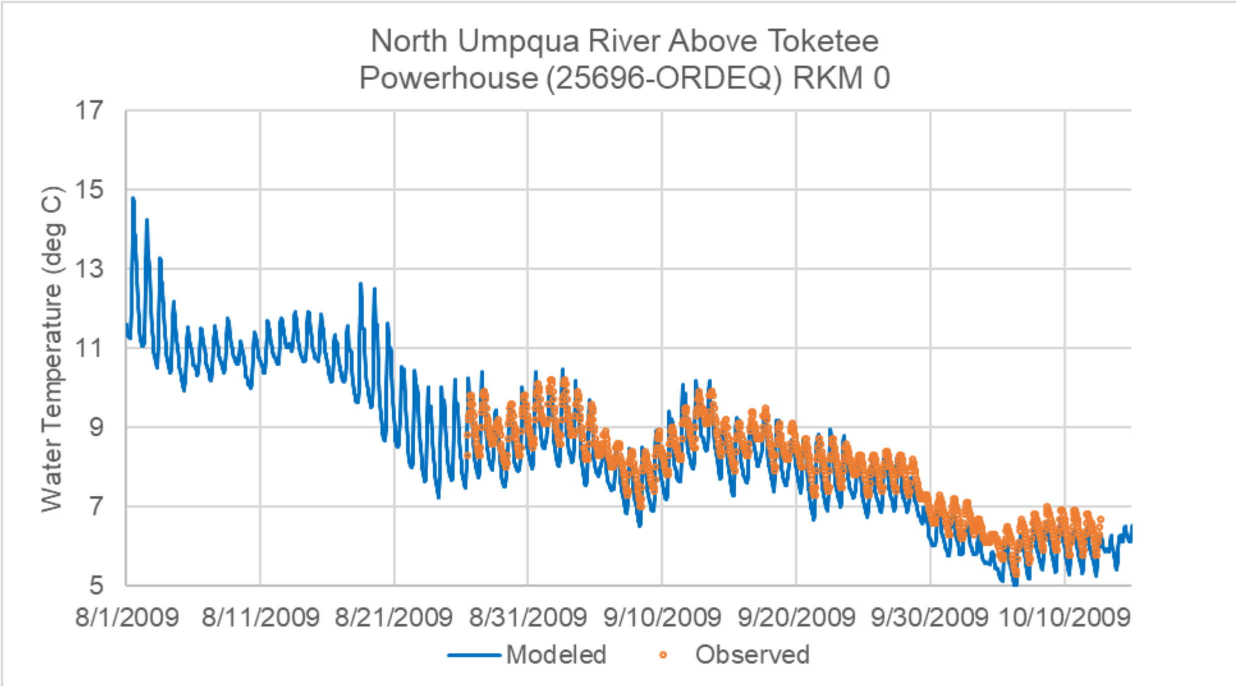

Figure 6-62. North Umpqua River Model 3–observed versus modeled hourly water temperature.

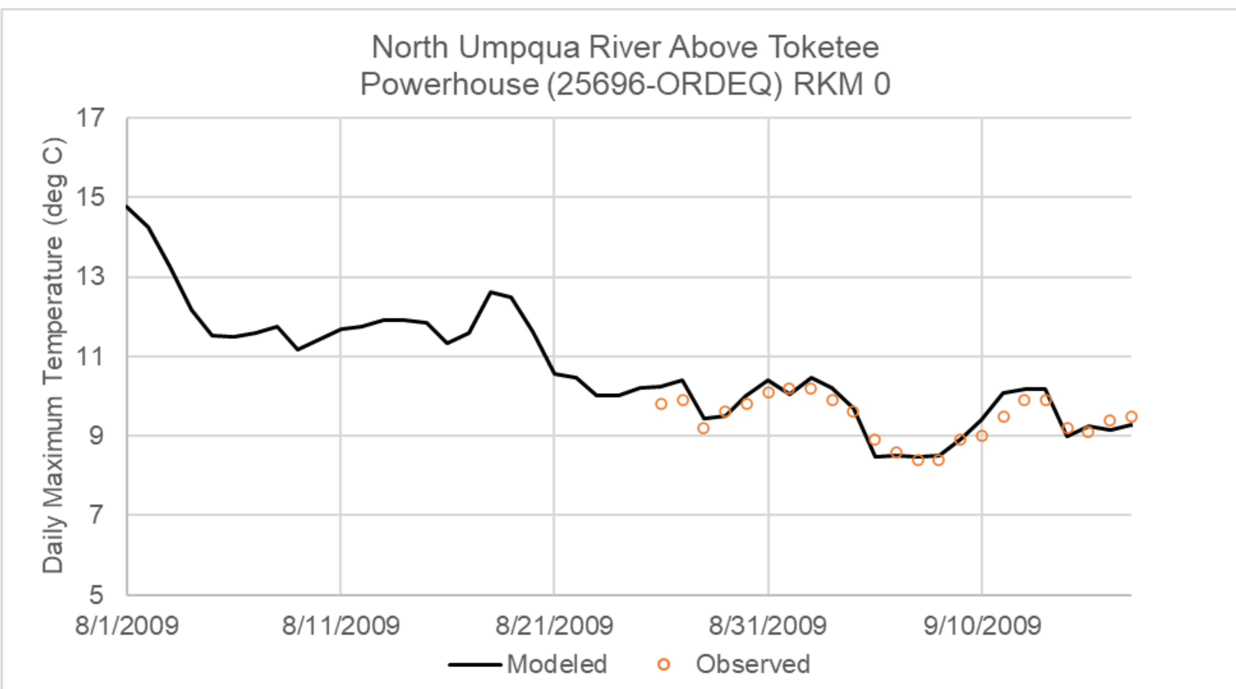

Figure 6-63. North Umpqua River Model 3–Observed versus Modeled Daily Maximum Water Temperature

Table 6-23. North Umpqua River Model 3 –Stream temperature calibration statistics (August 26 to October 12, 2009)

Statistic	North Umpqua River Above Toketee Powerhouse (25696-ORDEQ) RKM 0
Hourly Temperature Statistics	
ME	-0.41
MAE	0.50
RMSE	0.54
NSE	0.77
Count	1,134
Daily Maximum Temperature Statistics	
ME	-0.07
MAE	0.27
RMSE	0.32
NSE	0.95
Count	48

6.9.4 Water Temperature Calibration – North Umpqua River Model 4 (Slide Powerhouse to Soda Springs Reservoir)

There are no calibration data available for North Umpqua Model 4.

6.9.5 Water Temperature Calibration – North Umpqua River Model 5 (Soda Springs Reservoir to the mouth)

Model 5 was calibrated at seven locations along North Umpqua, as shown in in Table 6-19. The locations of these stations can be found in Figure 6-41. The modeled versus observed hourly and daily maximum water temperature timeseries at each of these stations can be found in Figure 6-64 and Figure 6-65 respectively. The model is able to capture the diurnal patterns and especially the daily maximum water temperatures at the upstream of Boulder Creek and upstream of Copeland Creek stations fairly well. The model shows some underprediction of the minimums in the diurnal temperatures at the upstream of Copeland Creek station from mid-September to October, however the predicted daily maximums agree well with data during that period. Adjustments to air temperature at Node 3 were made during October to better match the water temperature at the upstream of Steamboat station (data were missing during October at this station). However, the model consistently overpredicted at this station during October, which seems to be a more site-specific issue since the modeled temperatures during October agree well with data at all the other stations.

The model results mimic the observed diurnal variation of temperatures, but the model had difficulty in reaching the highest water temperature near the Idleyld Park area. Wind from a more local source - MesoWest - Station D1628 Glide (near the Idleyld Park area) was used, which improved the results. A hyporheic flow exchange rate of 25 percent was specified from RKM 83 onwards to the downstream end, to better capture observed temperatures. Further cloud cover was also adjusted at Node 6 near the downstream end for nine days during September 22 to October 15 when no cloud cover was reported.

Overall, the model is able to capture the seasonal patterns at all stations well at all stations. Model errors can be caused by a variety of reasons. For example, some unquantifiable source of error may exist, considering the data limitations (e.g., estimation is required for several incoming boundary temperatures due to lack of water temperature boundaries for the first couple of weeks in August and generally from September 20 onwards) and potential variability in meteorological conditions due to site specific conditions along the modeled waterbody.

The calculated model error statistics at all stations can be found in Table 6-24. The overall calculated model calibration error statistics for the hourly and daily maximum temperatures at all seven calibration locations showed a ME, MAE and RMSE of less than 1 ºC. The calculated NSE for the hourly and daily maximum temperatures was greater than 0.9.

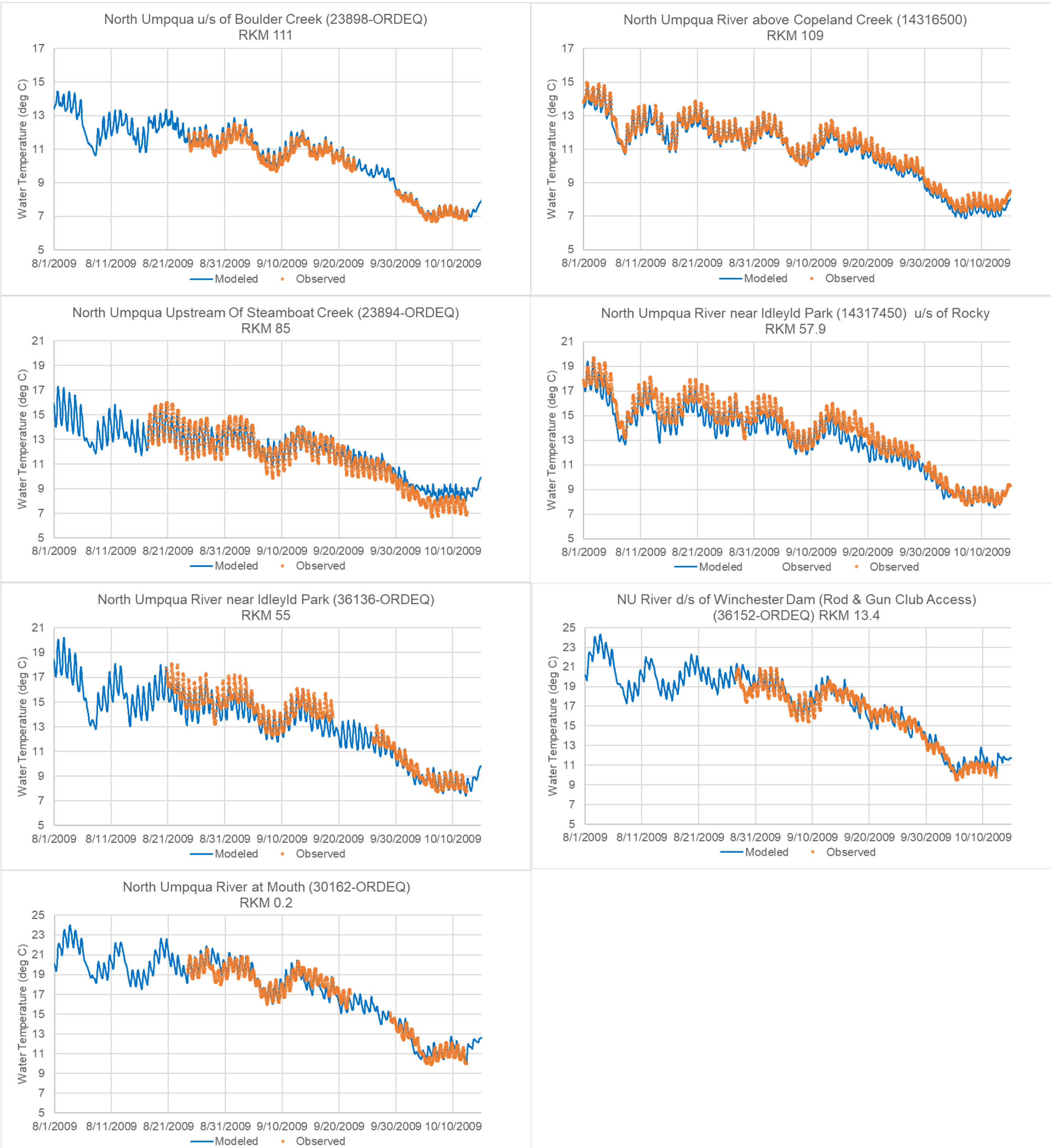

Figure 6-64. North Umpqua River Model 5–observed versus modeled hourly water temperature.

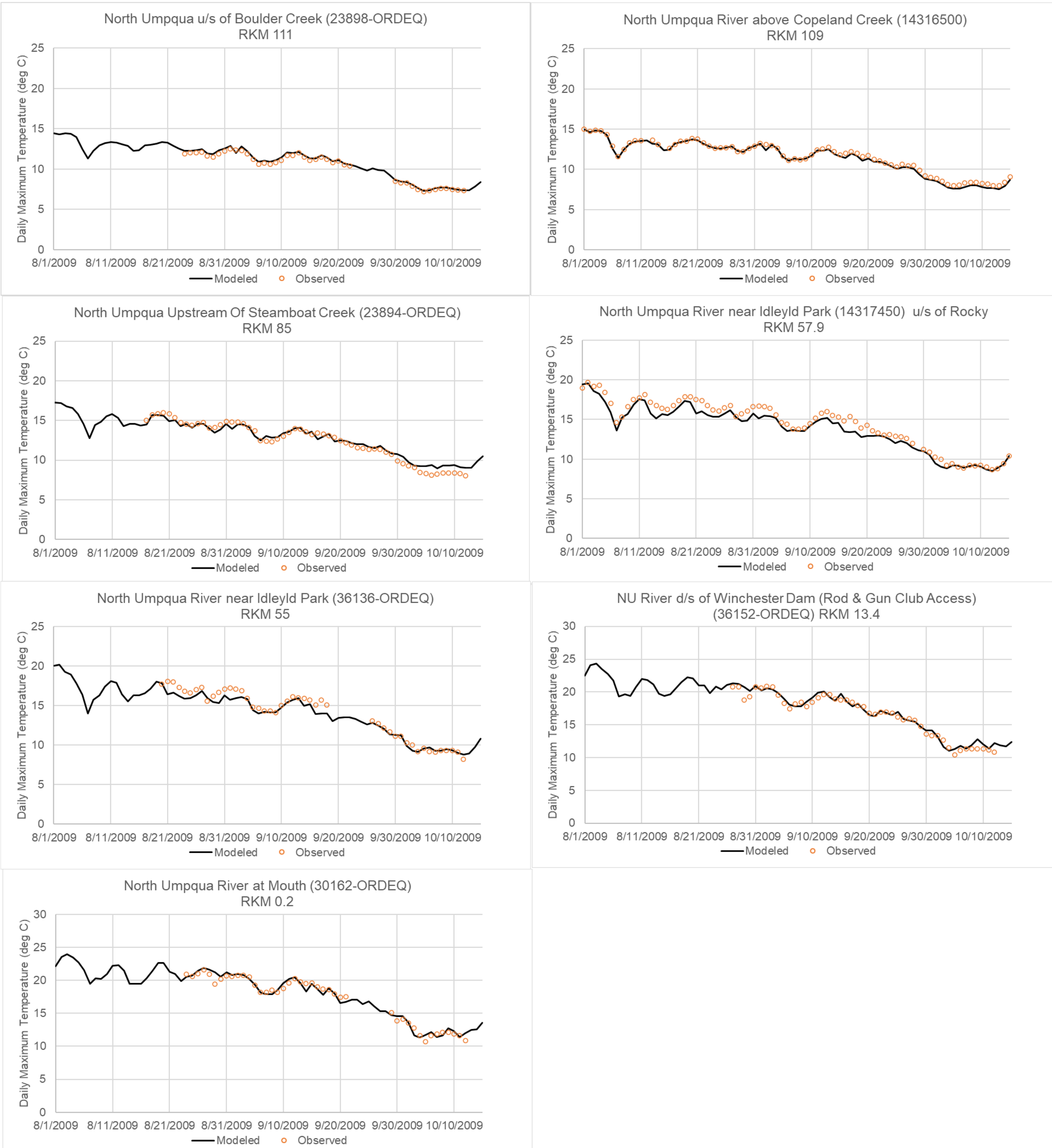

Figure 6-65. North Umpqua River Model 5–observed versus modeled daily maximum water temperature.

Table 6-24. North Umpqua River Model 5 –stream temperature calibration statistics (August 1 to October 15, 2009)

Statistic	North Umpqua River upstream of Boulder Creek (23898-ORDEQ) RKM 111[a]	North Umpqua River above Copeland Creek (14316500) RKM 109 [b]	North Umpqua River upstream of Steamboat Creek (23894-ORDEQ) RKM 85 [c]	North Umpqua River near Idleyld Park (14317450) upstream of Rocky RKM 57.9 [d]	North Umpqua River near Idleyld Park (36136-ORDEQ) RKM 55 [e]	North Umpqua River downstream of Winchester Dam (Rod & Gun Club access) (36152-ORDEQ) RKM 13.4 [f]	North Umpqua River at mouth (30162-ORDEQ) RKM 0.2 [g]
Hourly Temperature Statistics							
ME	0.20	-0.27	0.20	-0.62	-0.45	0.20	0.10
MAE	0.20	0.27	0.57	0.65	0.55	0.59	0.60
RMSE	0.22	0.31	0.70	0.79	0.68	0.76	0.75
NSE	0.98	0.97	0.91	0.93	0.94	0.94	0.95
Count	1008	1776	1346	1799	1098	1100	1008
Daily Maximum Temperature Statistics							
ME	0.22	-0.19	0.14	-0.66	-0.44	0.23	0.07
MAE	0.23	0.21	0.44	0.68	0.54	0.54	0.48
RMSE	0.26	0.27	0.55	0.82	0.72	0.72	0.60
NSE	0.98	0.98	0.93	0.92	0.93	0.93	0.97
Count	43	74	57	75	47	47	43

a: Period of Record (POR) from September 30 to October 12, 2009; b: POR from August 1 to October 15, 2009 (N/A for 8/12 & 8/15); c: POR from August 17 to October 12, 2009; d: POR from August 1 to October 15, 2009 (N/A for 9/29); e: POR from August 20 to October 12, 2009 (N/A from 9/19 to 9/25); f: POR from August 24 to October 12, 2009 (N/A from 9/22 to 9/28); g: POR from August 1 to October 15, 2009 (N/A for 9/29)

7.0 ROCK CREEK

7.1 MODEL TIME PERIOD AND EXTENT

The model was developed for the period from August 01, 2009, to October 15, 2009. This period corresponded to the period when hourly water temperature data were collected by DEQ, as listed in the QAPP (DEQ, 2022). In addition, this period also took advantage of the data collected by the BLM. Hourly stream temperature data were collected at major tributaries and locations along Rock Creek, which were used for model boundary configuration and calibration purposes respectively.

The extent of the spawning model domain was Rock Creek from the confluence of East Fork Rock Creek (RKM 14.5) to the mouth of Rock Creek at the confluence of the North Umpqua River. The spawning model domain extent i.e., from RKM 14.5, was primarily defined by the availability of data and was different from the summer model extent which was longer and extended from RKM 20.9. The spawning model extent of the Rock Creek Heat Source Model is shown in Figure 7-1.

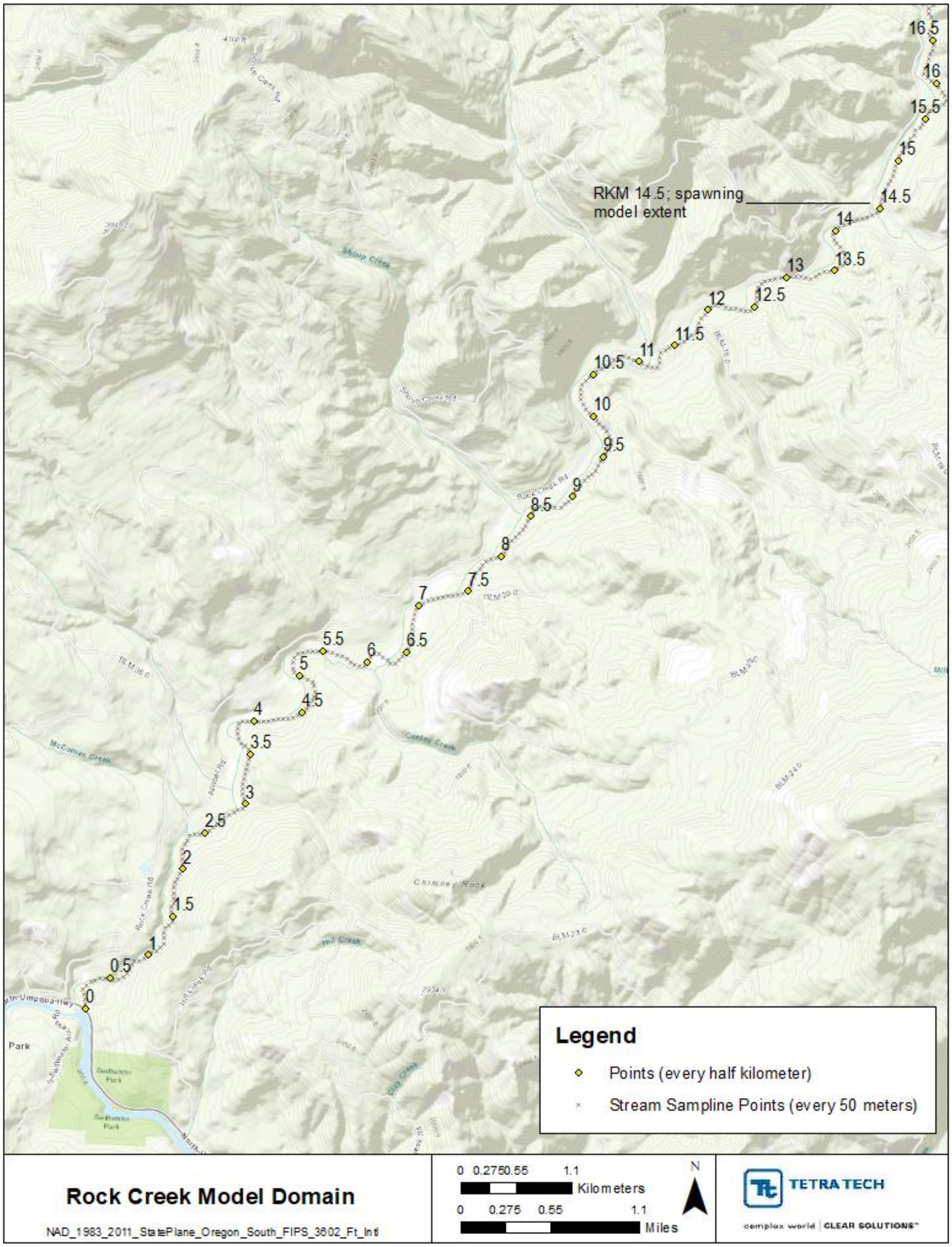

Figure 7-1. Extent of the Rock Creek modeling domain

7.2 HEAT SOURCE MODEL INPUT – ROCK CREEK

The model time step (dt) is 1 minute. Remaining general set up is consistent with the description in Section 2.2. The channel bottom widths used in the Rock Creek model ranged from 1.9 meters to 35.2 meters, with a mean of 10.8 meters. Figure 7-2 and Figure 7-3 show the computed stream channel elevation and gradient, respectively, and Figure 7-4 shows the calculated channel bottom widths for Rock Creek. Figure 7-5 shows the Manning's n values used in the model. The flow and water temperature inputs are discussed in the following sections.

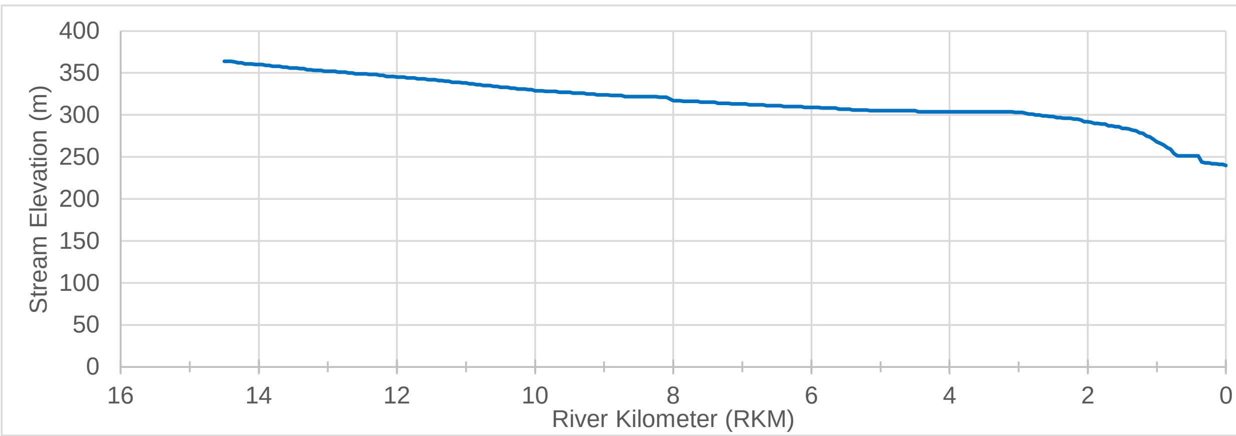

Figure 7-2. Rock Creek elevation.

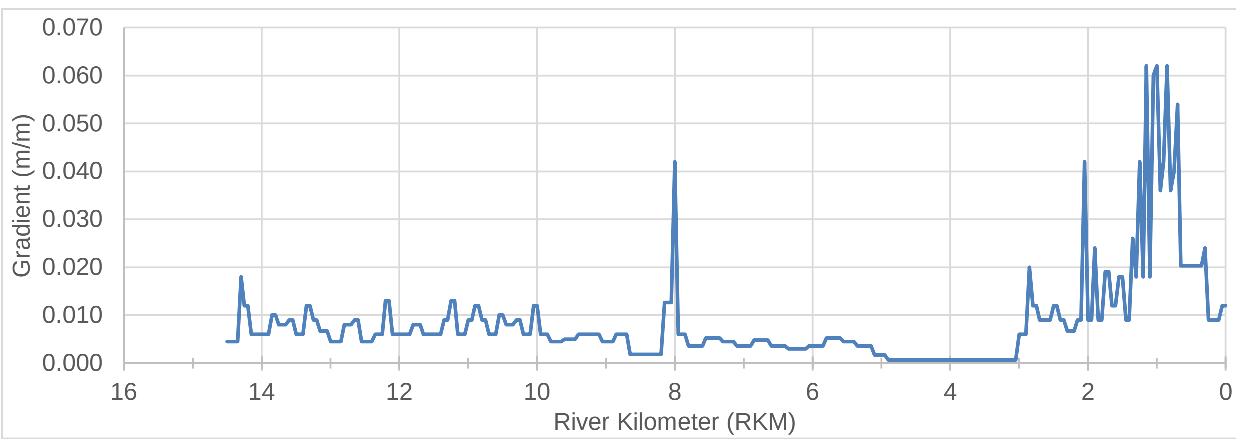

Figure 7-3. Rock Creek gradient.

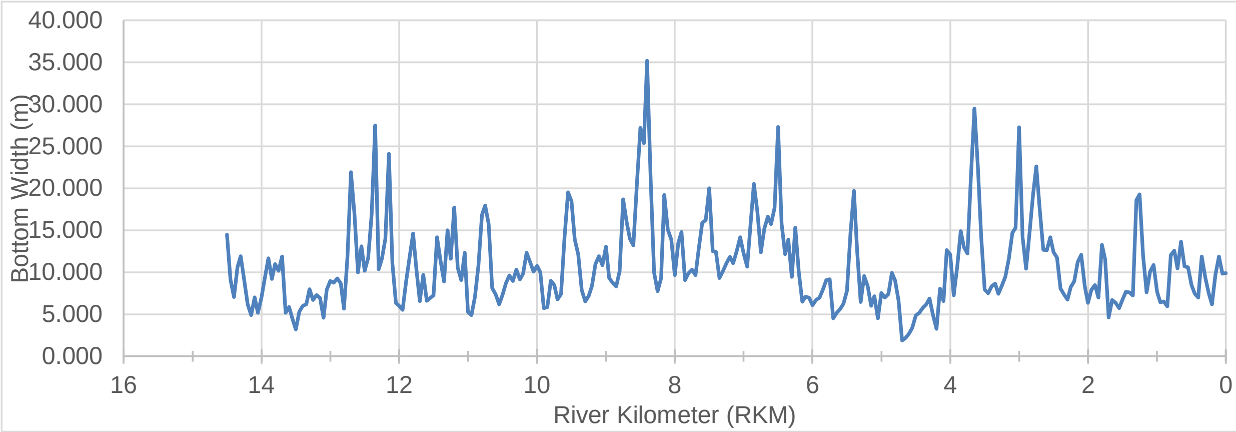

Figure 7-4. Rock Creek calculated bottom width.

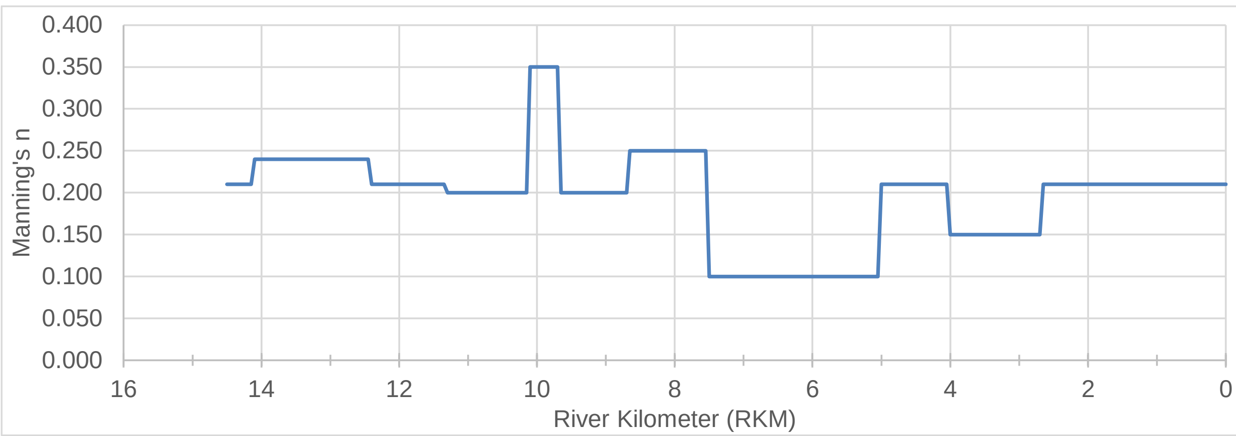

Figure 7-5. Rock Creek assigned Manning's n values.

7.3 FLOW INPUTS – ROCK CREEK

Table 7-1 shows an inventory of the available flow data available and notes how they were used. No flow data were available for the upstream boundary or any of the nine tributary inputs to the Rock Creek model. The following sections describe how the flows were derived for input into the model.

Table 7-1. Inventory of available flow data in the Rock Creek watershed used in the Heat Source Model

Station ID	Model location (Km)	Source	Type	Notes
Rock Creek upstream of East Fork Rock Creek	14.5	Derived data	Boundary condition	Derived using net flows using sum of tributaries and downstream flows
East Fork Rock Creek	14.45	Derived data	Tributary	Estimated using regression relationship with flows from Rock Creek near Glide
Unnamed spring at model kilometer 12.6	12.6	Derived data	Tributary	Unchanged from 2002 (constant 0.001 cms)

Station ID	Model location (Km)	Source	Type	Notes
Unnamed stream at model kilometer 11.8 – Unnamed Trib #5	11.8	Derived data	Tributary	Estimated using regression relationship with flows from Rock Creek near Glide
Harrington Creek	11.35	Derived data	Tributary	Estimated using regression relationship with flows from Rock Creek near Glide
Conley Creek	6.3	Derived data	Tributary	Estimated using regression relationship with flows from Rock Creek near Glide
Unnamed stream at model kilometer 5.85 – Unnamed Trib #8	5.85	Derived data	Tributary	Estimated using regression relationship with flows from Rock Creek near Glide
Kelly Creek	3.2	Derived data	Tributary	Same as Conley Creek
Unnamed stream at model kilometer 3 – Unnamed Trib #3	3	Derived data	Tributary	Same as Unnamed stream at RKM 5.85
McComas Creek	2.65	Derived data	Tributary	Estimated using regression relationship with flows from Rock Creek near Glide

7.3.1 Flow Estimation – Rock Creek

There were no flow data available for the year 2009 for Rock Creek. Limited flow data were available at a relatively new USGS gage 14317600 (Rock Creek Near Glide) located at the downstream end of Rock Creek from April 1,2021 to November 27, 2023. Flow data from this gage on Rock Creek and the gage on Steamboat Creek i.e., USGS gage 14316700-Steamboat Creek Near Glide, were used to derive flows for the Rock Creek model at the Glide location. Figure 7-6 shows the locations of the two USGS gages.

Monthly ratios were calculated based on Rock Creek Near Glide flow data and Steamboat Creek Near Glide flows for the same time period (i.e., from April 1, 2021 to November 27, 2023). The calculated monthly average ratios during August to October (2021 to 2023) were relatively similar, as can be seen in Figure 7-7.

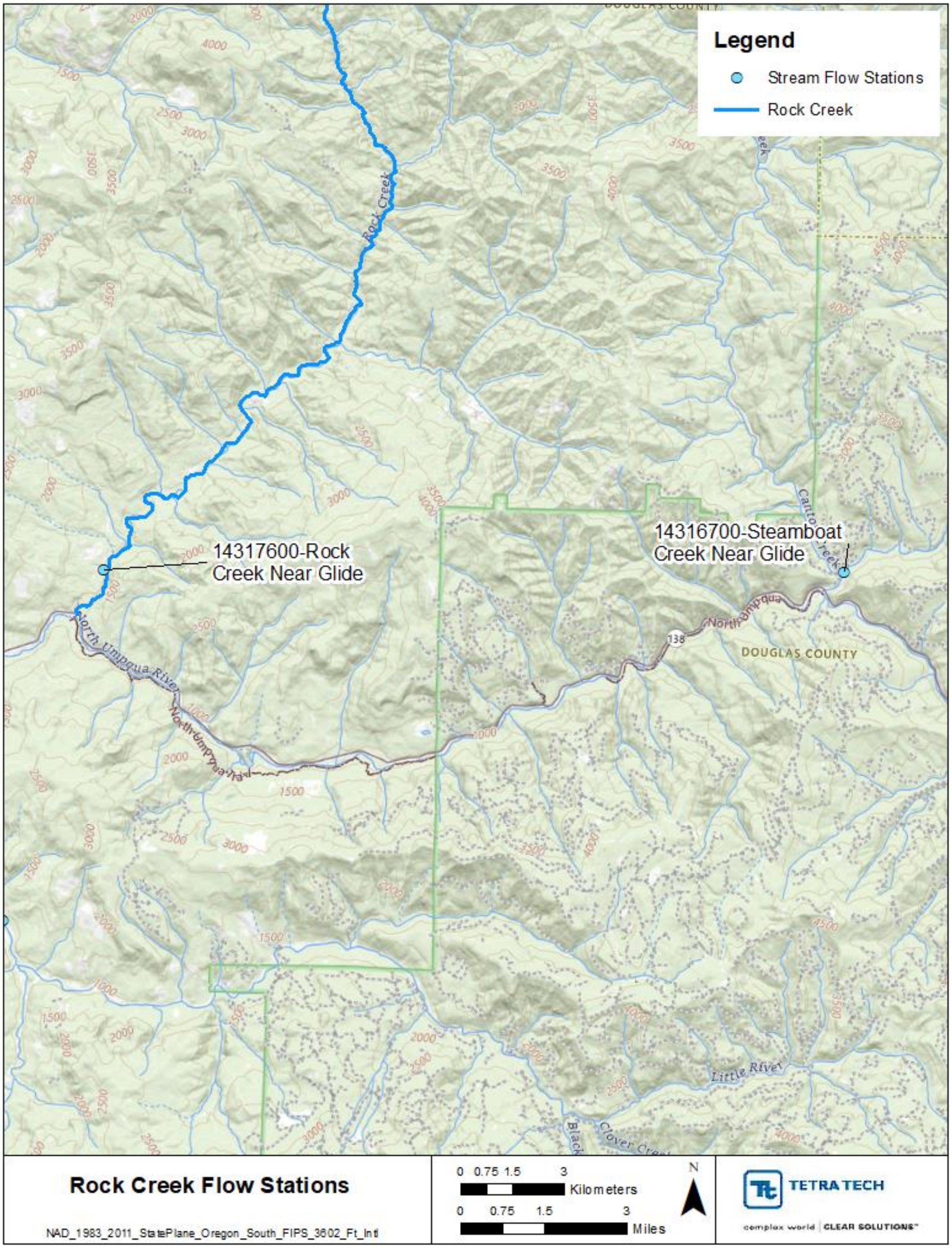

Figure 7-6. Locations of Rock Creek flow monitoring stations used to estimate flows for 2009.

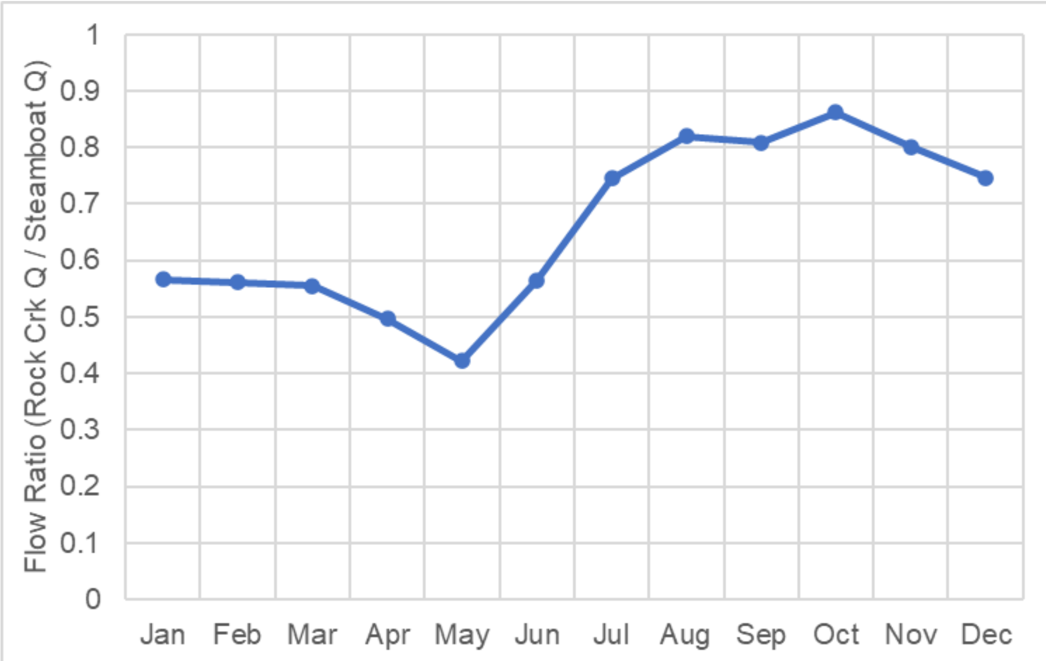

Figure 7-7. Monthly ratios for USGS 14317600 (Rock Creek Near Glide) versus USGS 14316700 (Steamboat Creek Near Glide).

The hourly Steamboat Creek flows were scaled using the calculated monthly flow ratios to derive the flows at Rock Creek near Glide for 2009 (Figure 7-8). Flows were also estimated for the year 2002 which corresponded to the year when the summer model was developed.

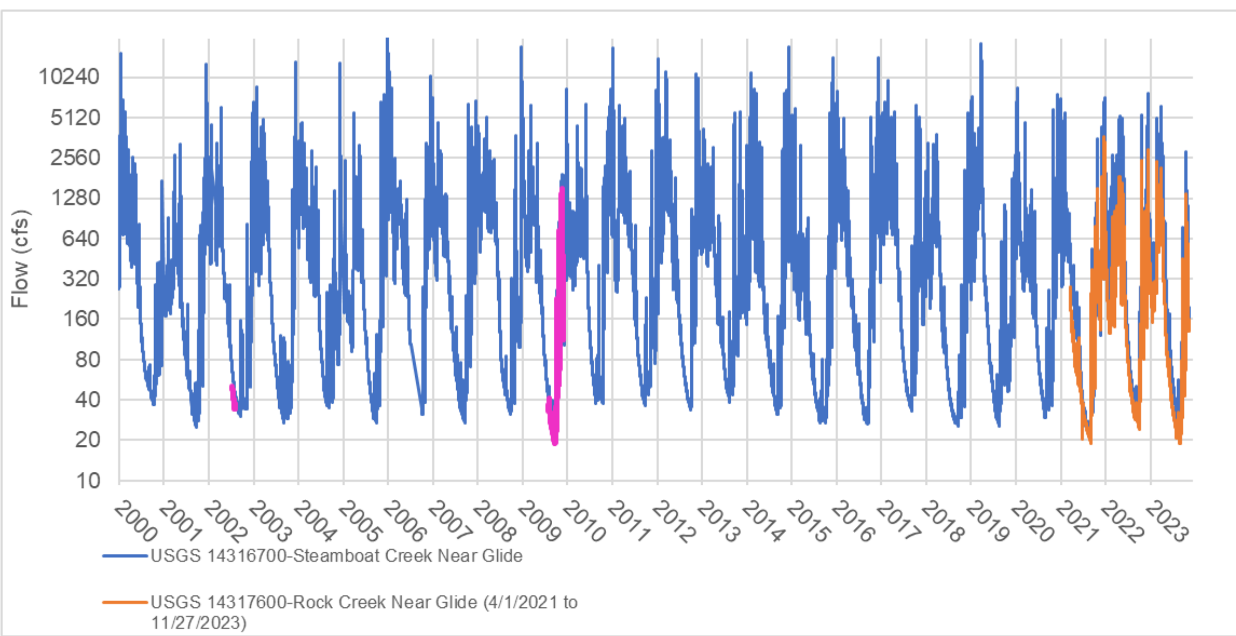

Figure 7-8. Estimated 2002 and 2009 flows at downstream Rock Creek near Glide.

Regression relationships were then established using the tributary flows in the 2002 model and the 2002 flows estimated downstream of Rock Creek near Glide (Figure 7-9). These relationships were then used to derive the tributary flows for 2009, using the estimated hourly flows for 2009 at Rock Creek near Glide.

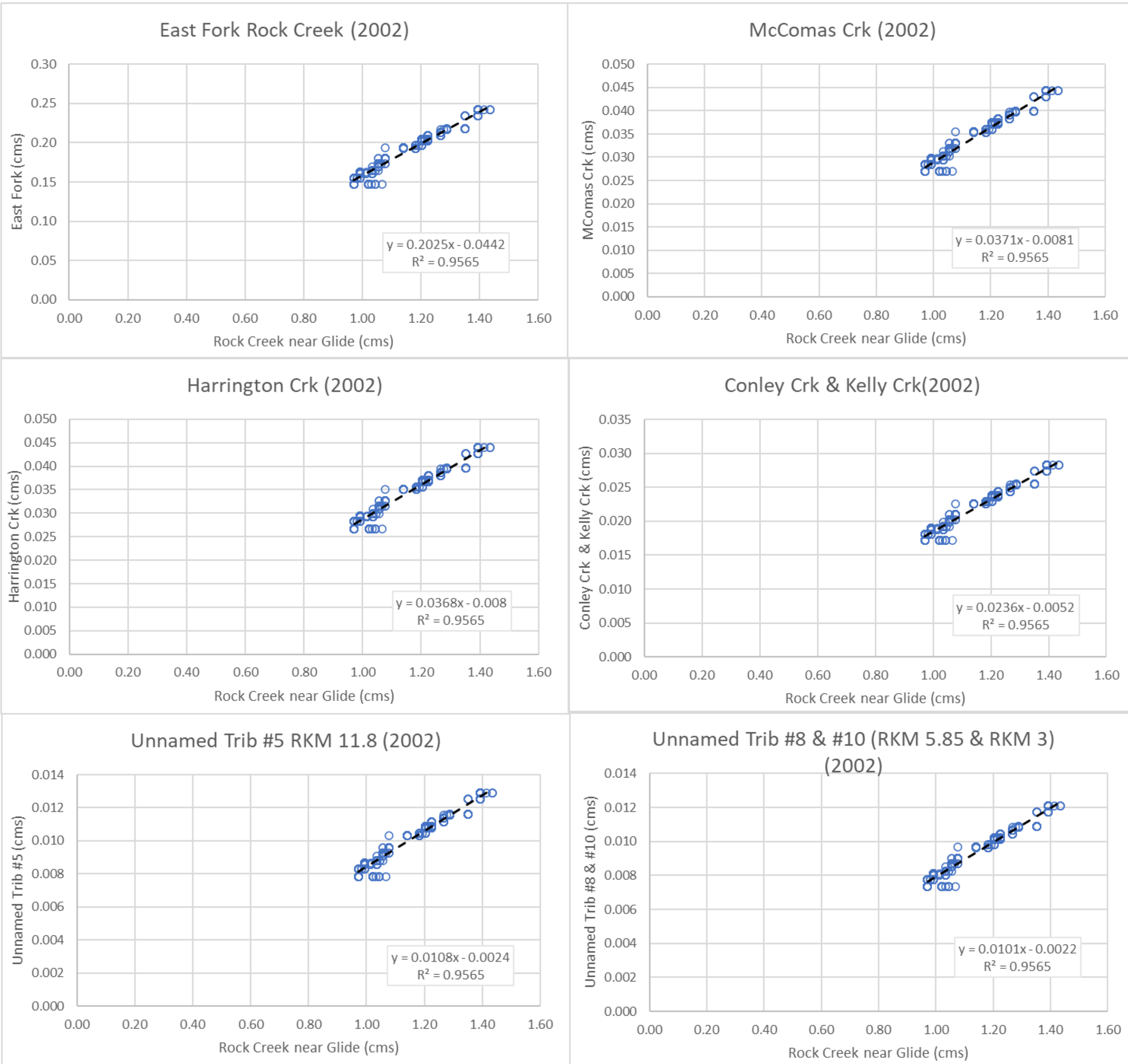

Figure 7-9. Relationships between each of the tributaries and the Rock Creek near Glide (USGS 14317600) flow data derived for 2002.

The net difference between the sum of the tributary flows and the Rock Creek near Glide flows were then added to the upstream boundary flows for 2009. Figure 7-10 shows the distribution of flows for the tributaries and upstream boundary of Rock Creek.

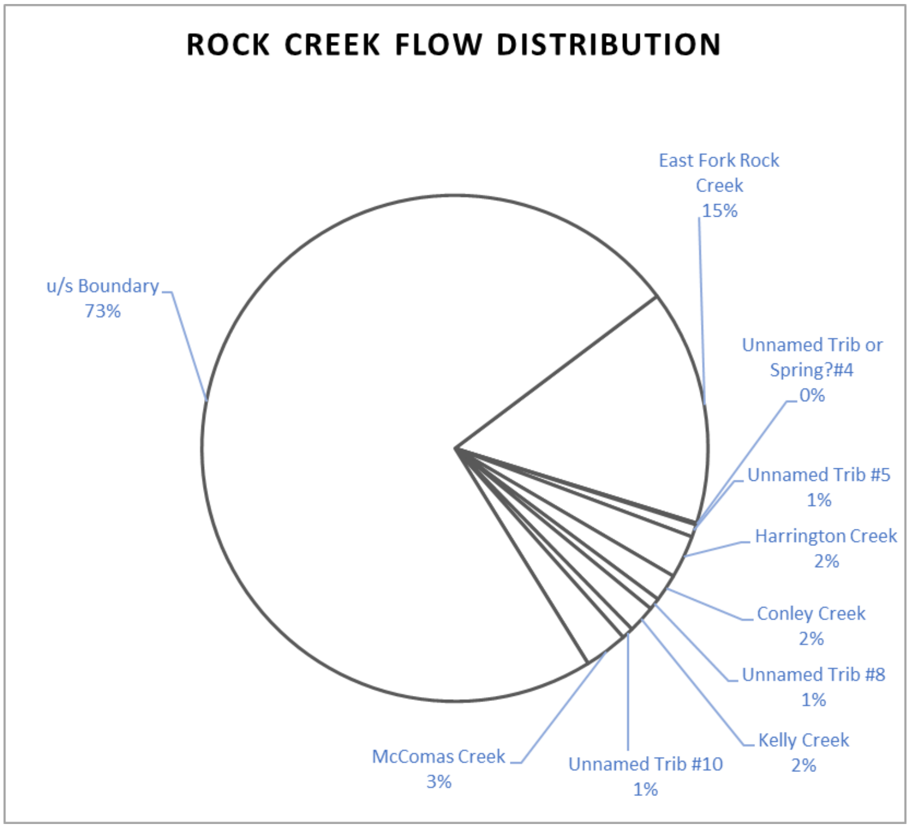

Figure 7-10. Flow distribution for the tributaries and upstream boundary of Rock Creek model.

7.4 WATER TEMPERATURE INPUTS – ROCK CREEK

There were limited water temperature data available for configuring the Rock Creek model. The data were limited to two BLM temperature stations. The two stations were Rock Creek above the confluence with East Fork Rock Creek (RCEF – upstream boundary) and East Fork Rock Creek above the confluence with Rock Creek (EFRC – tributary) (Figure 7-11). Note that the Rock Creek upstream boundary and the East Fork Rock Creek contribute the majority of flow going in the system (Figure 7-10). All others tributary inputs were derived using assumptions based on the 2002 model. The Unnamed Spring at RKM 12.6 was assigned 16 °C. Conley Creek, Kelly Creek, McComas Creek, and Unnamed Tributary #5 were taken as the EFRC temperature plus 1.5 °C. Harrington Creek and Unnamed Tributary #8 were taken as EFRC the temperature plus 3.5 °C. The Oregon Division of Fish and Wildlife (ODFW) Rock Creek Fish Hatchery, which is also an input, is discussed in the following section. Table 7-2 provides an inventory of the water temperature data used in the model development.

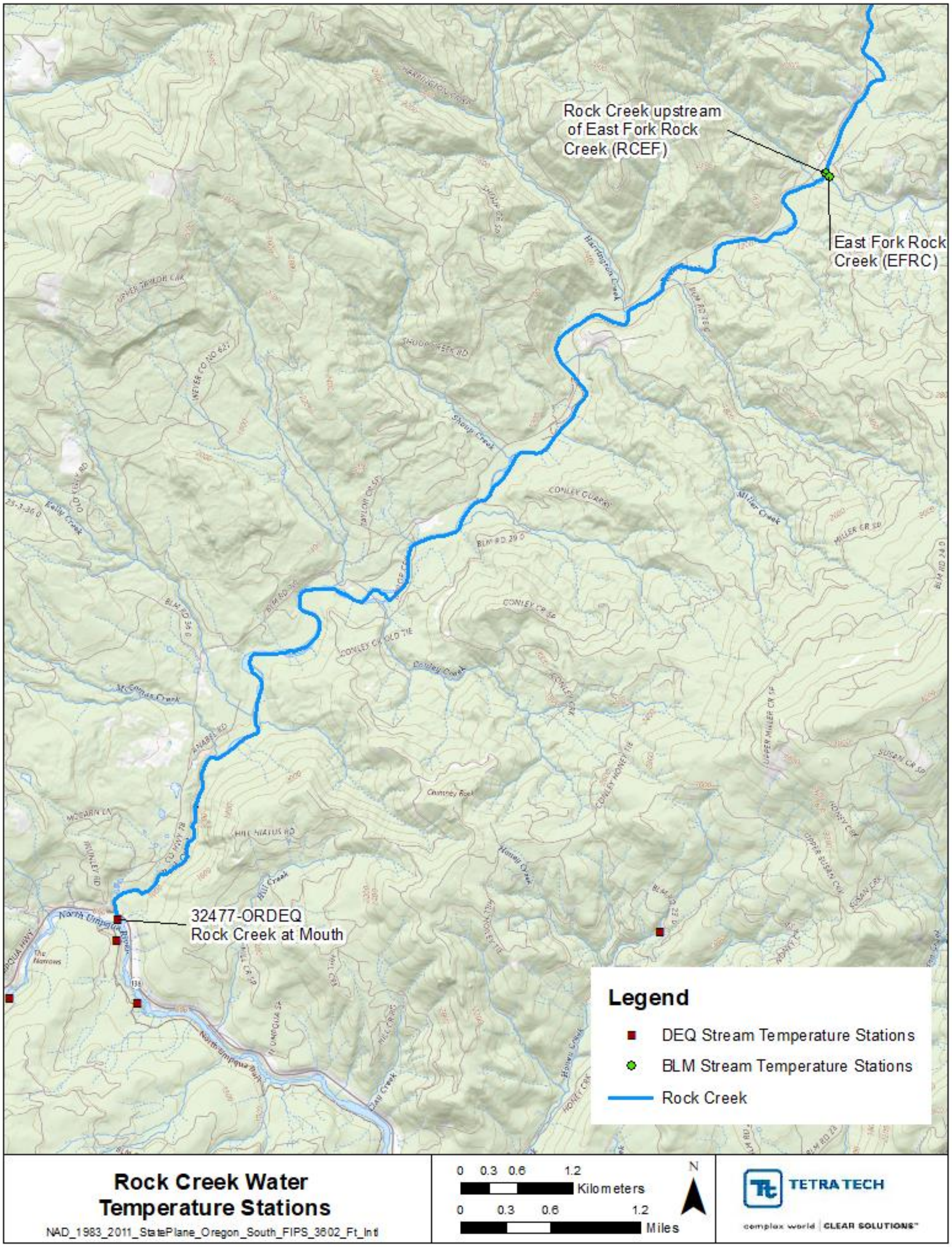

Figure 7-11 Rock Creek stream water temperature locations

Table 7-2. Inventory of available water temperature data used to configure the Rock Creek model.

Station ID	Model location (Km)	Source	Type	Notes
Rock Creek upstream of East Fork Rock Creek (RCEF) (38945-BLM)	14.5	BLM	Boundary condition	
East Fork Rock Creek (EFRC) (36671-BLM)	14.45	BLM	Tributary	
Unnamed spring at model kilometer 12.6	12.6	Derived data	Tributary	Unchanged from 2002 (constant 16 ºC)
Unnamed stream at model kilometer 11.8 – Unnamed Trib #5	11.8	Derived data	Tributary	Assumption from 2002. Same as Conley Creek
Harrington Creek	11.35	Derived data	Tributary	2002 assumption EFRC + 3.5
Conley Creek	6.3	Derived data	Tributary	2002 assumption EFRC + 1.5
Unnamed stream at model kilometer 5.85 – Unnamed Trib #8	5.85	Derived data	Tributary	Assumption from 2002. Same as Harrington Creek
Kelly Creek	3.2	Derived data	Tributary	2002 assumption EFRC + 1.5
Unnamed stream at model kilometer 3 – Unnamed Trib #10	3	Derived data	Tributary	Assumption from 2002. Same as Conley Creek
McComas Creek	2.65	Derived data	Tributary	Assumption from 2002. Same as Conley Creek

Figure 7-12 shows the observed stream temperature time series used for the upstream boundary assignment in Rock Creek and Figure 7-13 shows the observed water temperature from the East Fork Rock Creek (EFRC) tributary input. As can be seen the East Fork Rock Tributary input constitutes a relatively cold-water tributary input to Rock Creek when compared to the upstream boundary water temperatures.

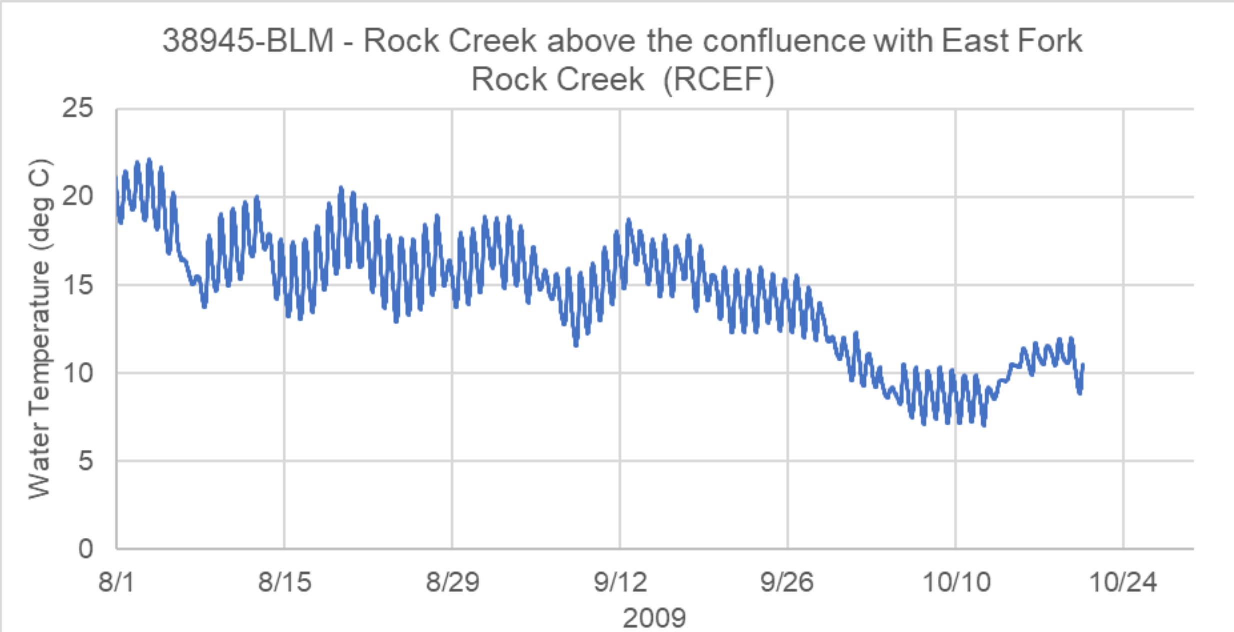

Figure 7-12. Upstream boundary hourly water temperature data (RCEF) used in the Rock Creek model.

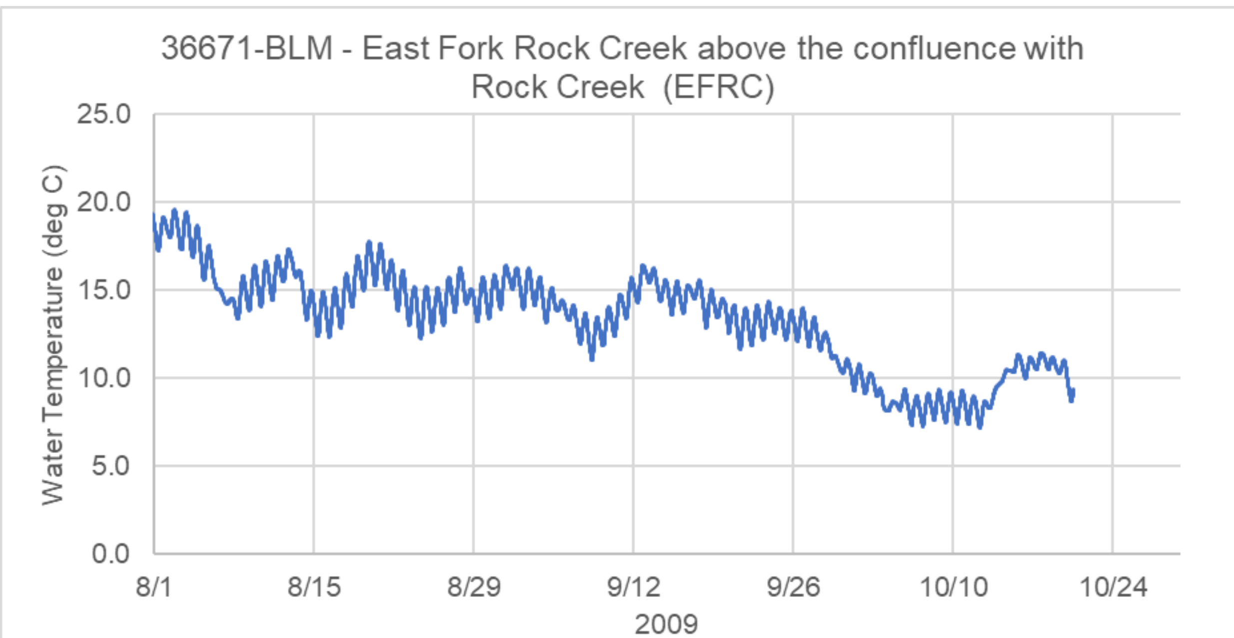

Figure 7-13. Observed hourly water temperature at East Fork Rock Creek (EFRC)

7.5 POINT SOURCE DATA – ROCK CREEK

The Oregon Department of Fish and Wildlife (ODFW) Rock Creek Fish Hatchery is a registrant under the National Pollutant Discharge Elimination System (NPDES) 300-J general permit and discharges to Rock Creek near the mouth (RKM 0.3) (Figure 7-14). There are no 2009 flow data available for the Rock Creek Fish Hatchery. Flow and water temperature from the Rock Creek Hatchery for the year 2016, received during DEQ's data solicitation effort in 2022, were used. The data included half-hourly flow and water temperature data by month. These data were averaged to hourly and used for input into the 2009 model. Figure 7-15 shows the observed hourly averaged flow and water temperature data used in the model to configure the Rock Creek Hatchery input.

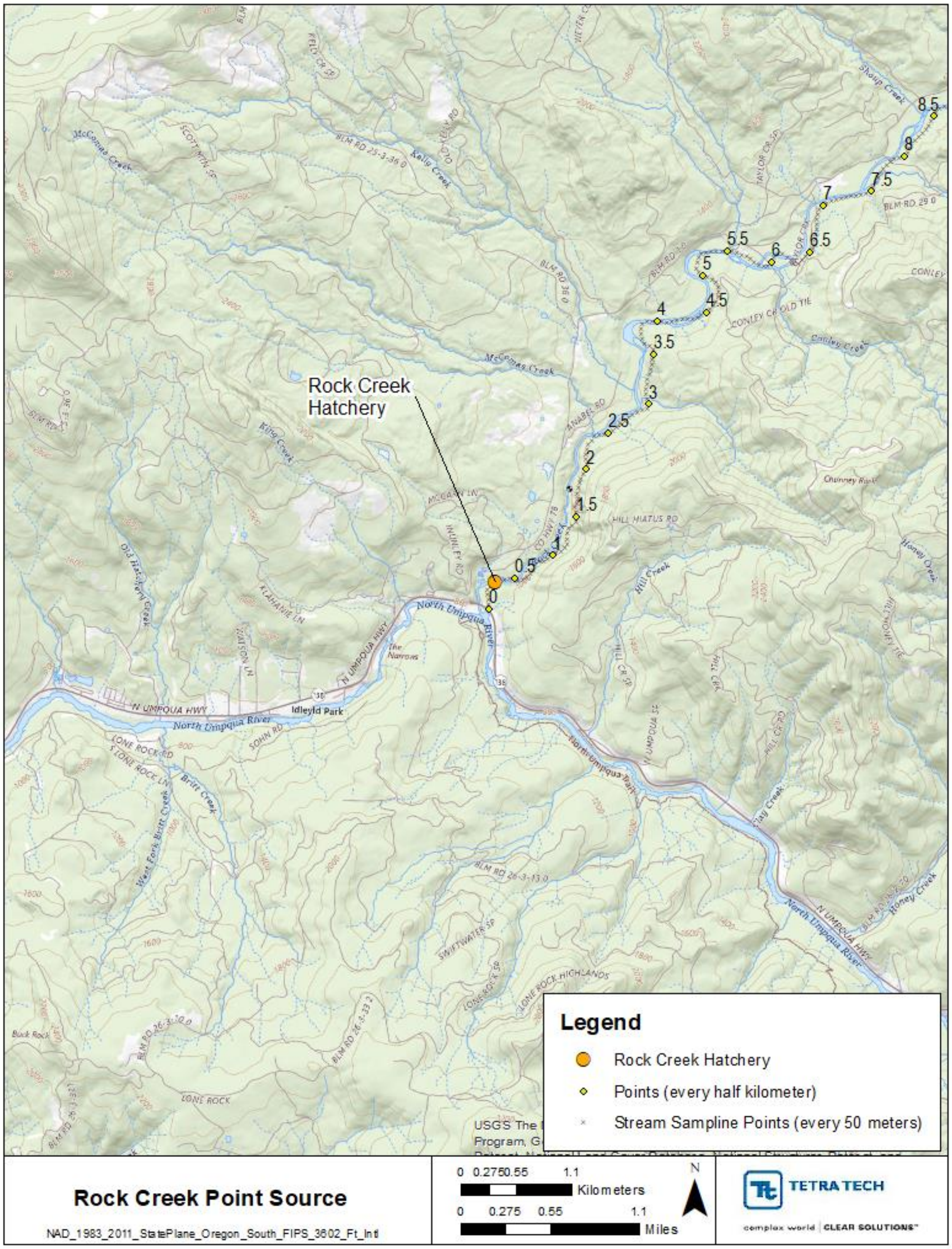

Figure 7-14. Location of the Rock Creek Hatchery

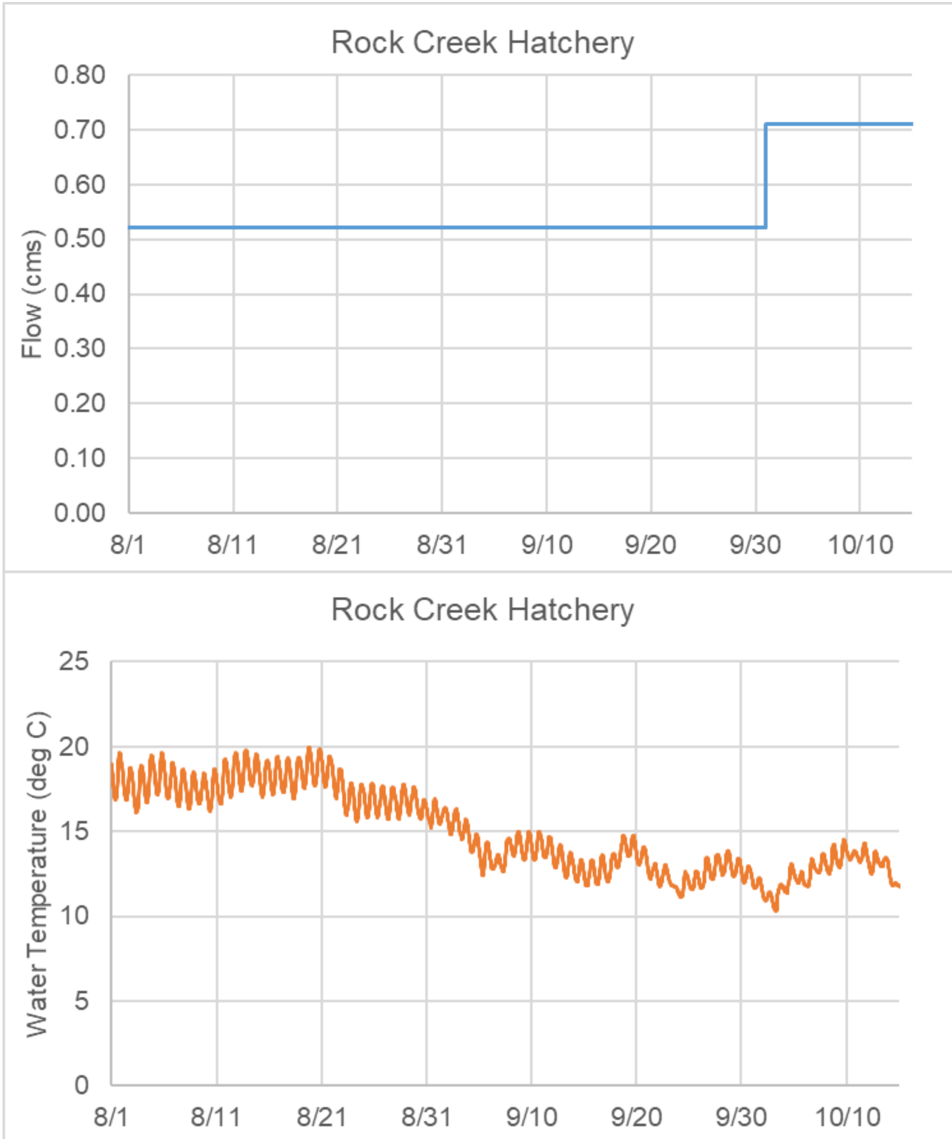

Figure 7-15. Rock Creek Hatchery flow and temperature (2016) data used in the model.

7.6 METEOROLOGICAL DATA – ROCK CREEK

Hourly meteorology inputs into the model include air temperature, relative humidity, wind speed, and cloud cover. Daily minimum and maximum air temperature observations were available from NCDC station USC00354126 (Idleyld Park 4 NE, OR) which is in close proximity to Rock Creek (Figure 7-16). Air temperature time series were constructed using hourly patterns from the Remote Automatic Weather Station (RAWS) GRANDAD station (GDFO3) (Figure 7-16). Figure 7-17 shows the hourly disaggregated air temperature time series at the Idleyld Park time series used in the model. Wind speed was taken from the GRANDAD RAWS station and adjusted during calibration. Wind speeds adjustments were necessary to improve the calibration to represent the difference in wind speed between the measurement location and above the stream within the riparian area. Other meteorological parameters as shown in Figure 7-18 were taken from the Roseburg Regional Airport station. Table 7-3 provides an inventory of all meteorological data used for the Rock Creek model.

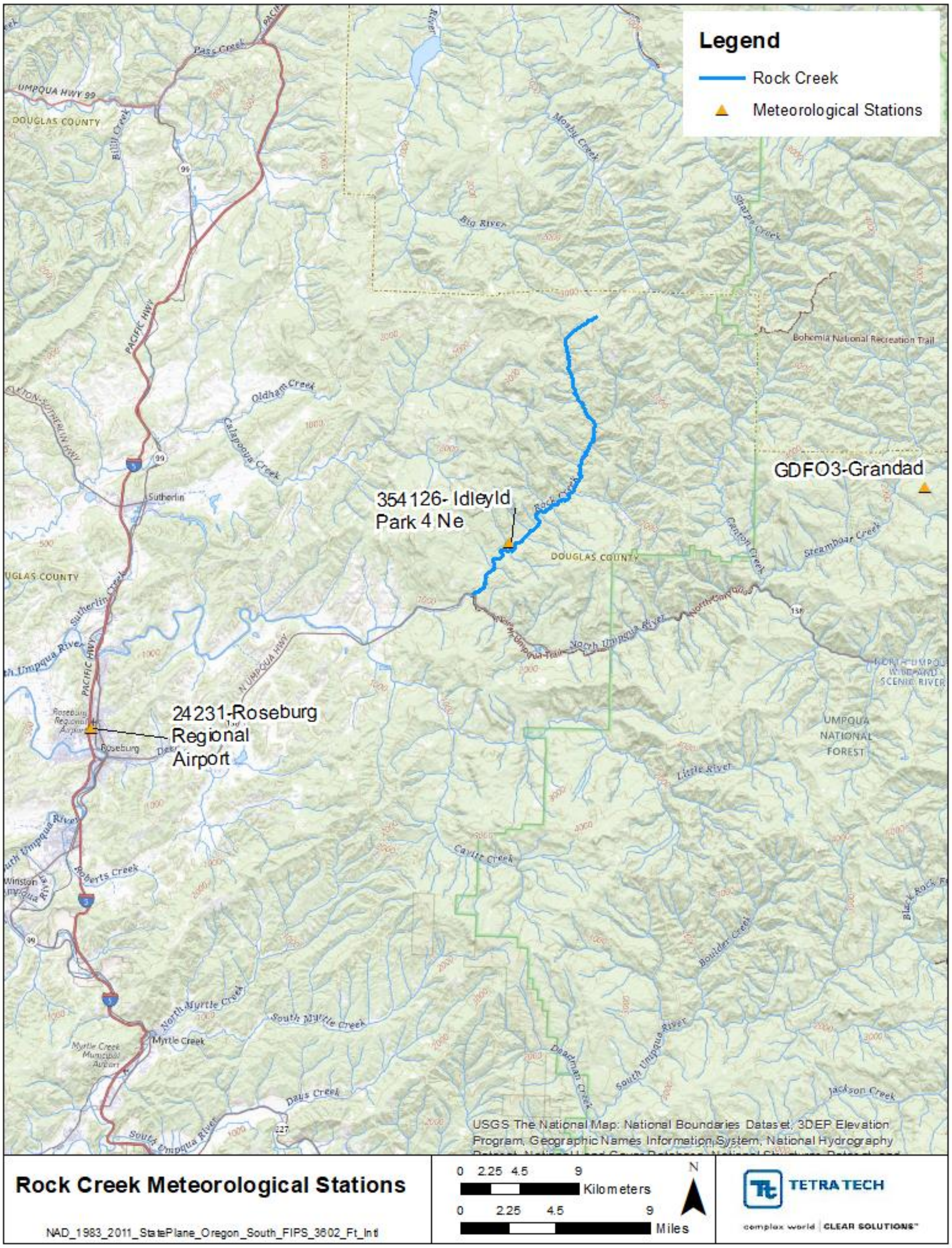

Figure 7-16. Location of the Rock Creek meteorological stations.

Table 7-3. Inventory of available Meteorological Station Data in the Rock Creek watershed

Station ID	Station Name	Elevation (m)	Latitude/ Longitude	Frequency	Available Met Data	Source	Notes
USC003 54126	Idleyld Park 4 NE, OR	329	43.3708/ -122.965		Air temperature	NCDC	Daily Min/Max Air Temperatur e
WBAN2 4231	NCDC – LCD station Roseburg Regional Airport	152.9	43.23367°/ 123.35775°	Hourly	Air Temperature, Relative Humidity, Wind Speed, Cloud cover	NCDC - LCD	Used Relative Humidity and Cloud Cover
GDFO3	GRANDAD	884.2	43.415833/ -122.57722	Hourly	Air Temperature, Wind Speed, Relative Humidity	RAWS	Used Wind Speed

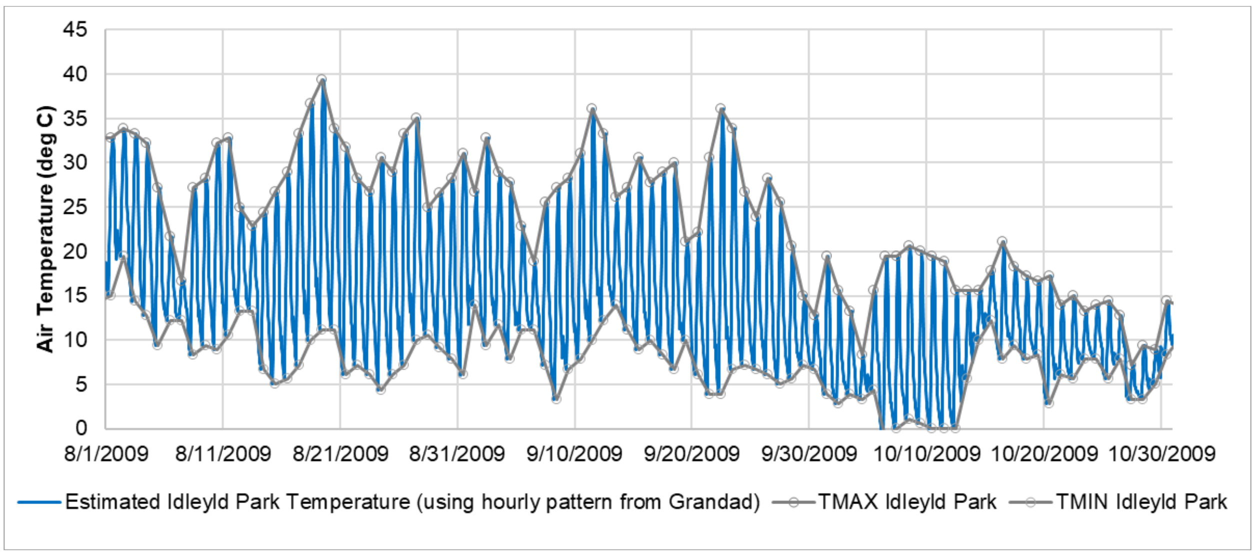

Figure 7-17. Hourly air temperature for Rock Creek (Idleyld Park 4 NE station).

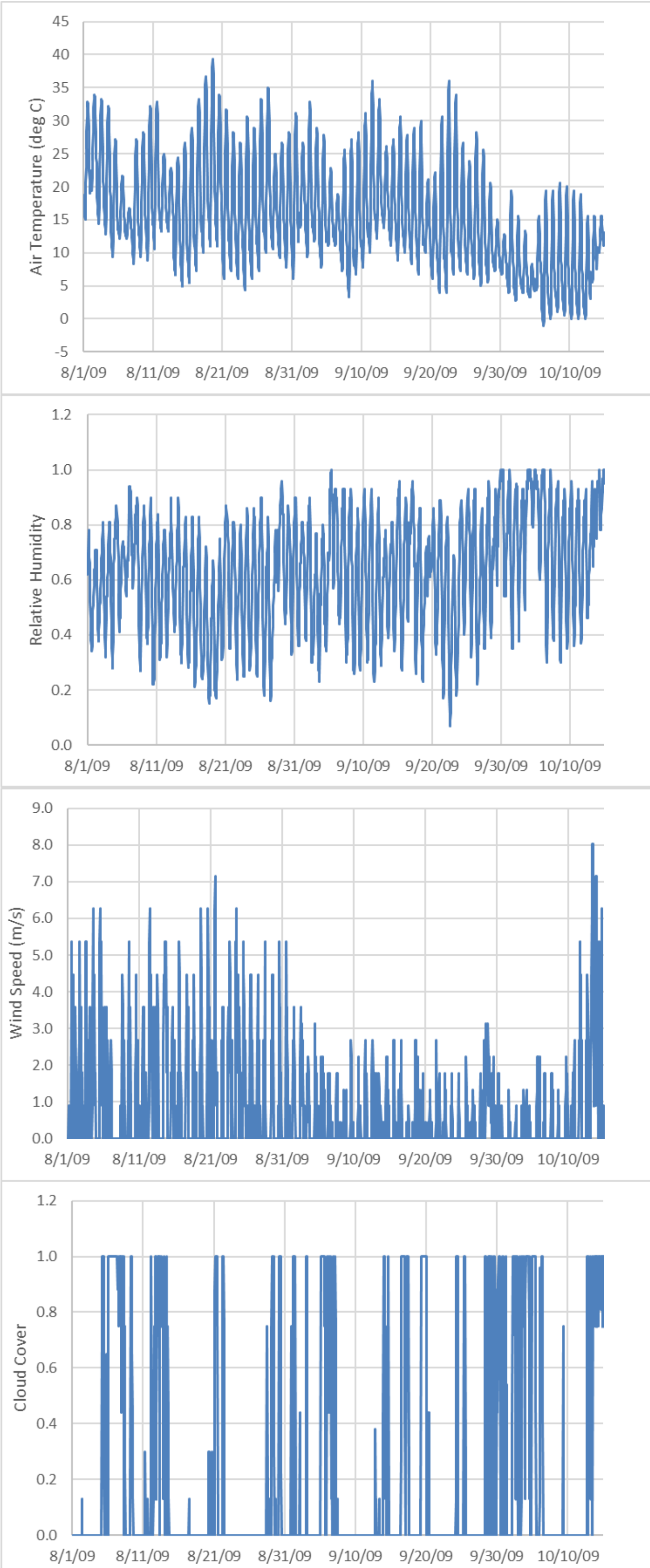

Figure 7-18. Rock Creek Model–hourly air temperature, relative humidity, wind speed, and cloud cover

7.7 MODEL CALIBRATION – ROCK CREEK

The Rock Creek Heat Source model was simulated for the time period from August 1, 2009, to October 15, 2009, over the 14.5-kilometer study area from just upstream from the confluence of East Fork Rock Creek to the mouth of Rock Creek. The model used hourly meteorology, ten hourly flow and stream temperature inputs, and the Rock Creek Hatchery near the mouth. The model was run at a time step of 1 minute and outputs were generated hourly, every 100 meters. Wind speeds and cloud cover were adjusted during calibration to represent more site-specific conditions at the modeling site and improve the water temperature calibration. These are discussed further in the following section.

The model was then calibrated against observed data. The model calibration sites and data sources for Rock Creek are summarized in Table 7-4. There are no flow calibration stations available for Rock Creek. There is only one model calibration station available for water temperature, located at the most downstream end of the model (Figure 7-11).

Table 7-4. Calibration station used in the Rock Creek Heat Source model water temperature calibration.

Station ID	Description	Model RKM	Data Type	Source
Hourly Water Temperature				
32477- ORDEQ	Rock Creek at Mouth	0	Water temperature	DEQ

A combination of visual and computed error statistics was used to assess the model calibration. Summary statistics (ME, MAE, RMSE, and NSE) followed the calculations described in Section 3.6.

7.8 TEMPERATURE CALIBRATION – ROCK CREEK

Hourly water temperature observations from Rock Creek at Mouth (32477-ORDEQ) were used for stream temperature calibration (Table 7-4). Figure 7-19 and Figure 7-20 show the hourly and daily maximum stream temperature comparison at Rock Creek at the mouth (RKM 0) station, respectively. The modeled water temperature followed the seasonal trend from summer to fall, and the modeled daily maximum values agree well with data. The model was able to generate the diurnal variations, but underpredicts the minimum values.

Channel morphology related inputs were retained from the HS7 model during calibration. The sediment heat exchange parameters, i.e., sediment thermal conductivity and diffusivity, and wind function coefficients, were applied at their HS8 default values. Several adjustments were made to improve the calibration. Minor adjustments were done to cloud cover. Cloud cover from the Roseburg Airport was adjusted from September 12 to 27. During this period the cloud cover was reduced by 50 percent for the best results. Wind speeds were also adjusted to further improve the calibration. The wind speeds during August were doubled and for the period from October 7 to 12, they were increased by one and half times. These adjustments improved the prediction of the daily maximum temperatures. Hyporheic flow was specified to better capture observed hourly temperatures. The addition of hyporheic flows helped reduce the diurnal variation but this lowered the daily minimum values at the same time. A final value of 30 percent hyporheic exchange was used after calibration.

The calculated model error statistics at all stations are listed in Table 7-5. The overall calculated model calibration error statistics for the hourly and daily maximum temperatures showed a ME and MAE of less than 1 ºC. The RMSE was calculated to be 1.01 ºC for the hourly temperatures, whereas the RMSE for the daily maximum was calculated to be 0.71 ºC. The calculated NSE for the hourly and daily maximum temperatures was greater than 0.84.

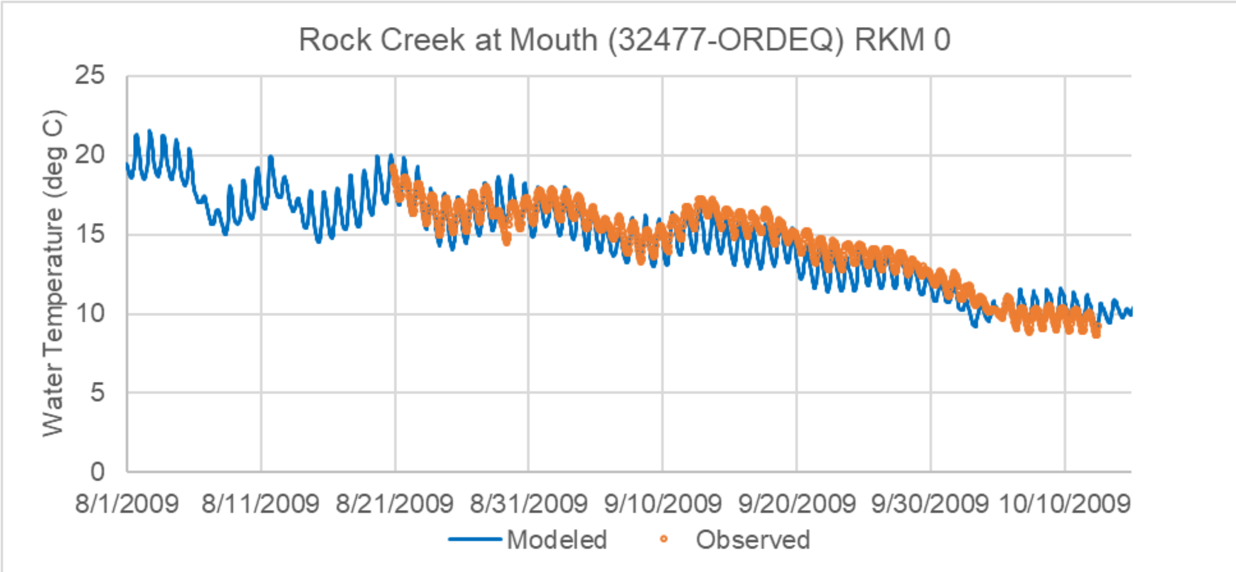

Figure 7-19 Hourly Observed versus Modeled Water Temperature – Rock Creek at Mouth (32477-ORDEQ)

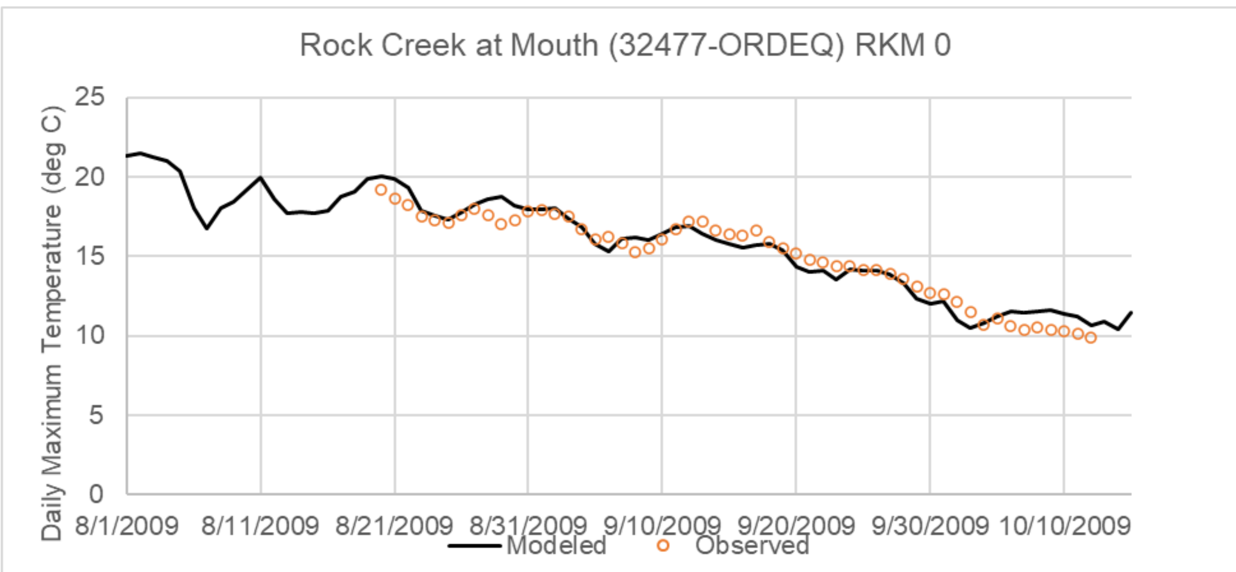

Figure 7-20 Daily Maximum Observed versus Modeled Water Temperature – Rock Creek at Mouth (32477-ORDEQ)

Table 7-5. Hourly and Daily Maximum Stream Temperature calibration statistics for Rock Creek at the Mouth (32477-ORDEQ) (August 20 to October 12, 2009)

Statistic	**Rock Creek at Mouth (32477-ORDEQ) RKM 0**
Hourly Temperature Statistics	
ME	-0.58
MAE	0.87
RMSE	1.01
NSE	0.84
Count	1265
Daily Maximum Temperature Statistics	
ME	0.10
MAE	0.58
RMSE	0.71
NSE	0.93
Count	54

8.0 STEAMBOAT CREEK

8.1 MODEL TIME PERIOD AND EXTENT

The model was developed for the period from August 01, 2009, to October 15, 2009. This period corresponded to the period when hourly water temperature data were collected by DEQ and the USFS, as listed in the QAPP (DEQ, 2022). The extent of the model domain is Steamboat Creek from the confluence of Little Rock Creek (RKM 28.5) to the mouth of Steamboat Creek at the confluence of the North Fork Umpqua River. The model extent of the Steamboat Creek model is shown in Figure 8-1, along with model stream sampling points and corresponding RKM information.

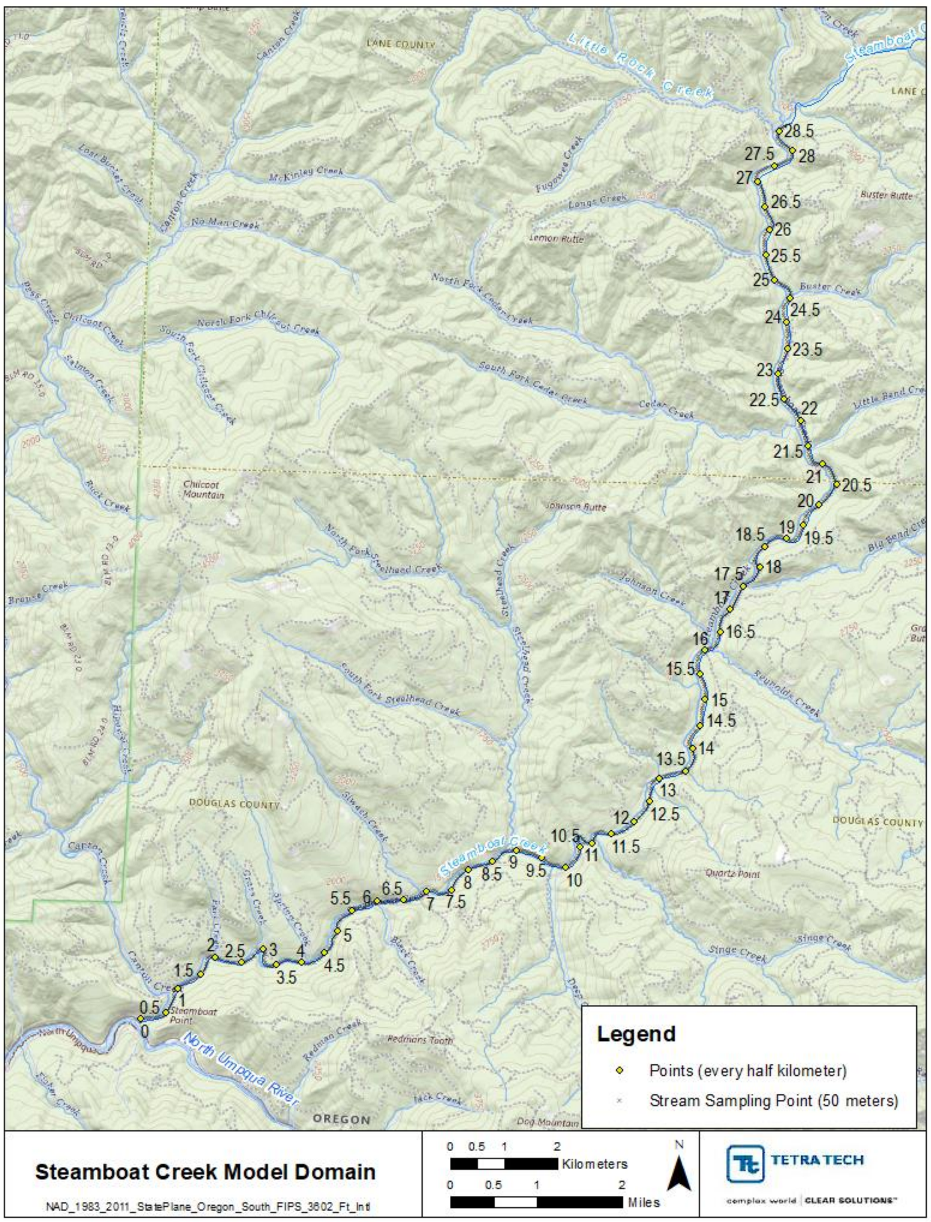

Figure 8-1. Extent of the Steamboat Creek modeling domain

8.2 HEAT SOURCE MODEL INPUT – STEAMBOAT CREEK

Outputs are generated every 100 meters. The model time step (dt) is 1 minute. Remaining general set up is consistent with the description in Section 2.2. The channel bottom widths used in the Steamboat Creek model ranged from 4.1 meters to 46.0 meters, with a mean of 20.1 meters. Figure 8-2 and Figure 8-3 show the computed stream channel elevation and gradient, respectively, and Figure 8-4 shows the calculated channel bottom widths for Steamboat Creek. Figure 8-5 shows the Manning's n values used in the model.

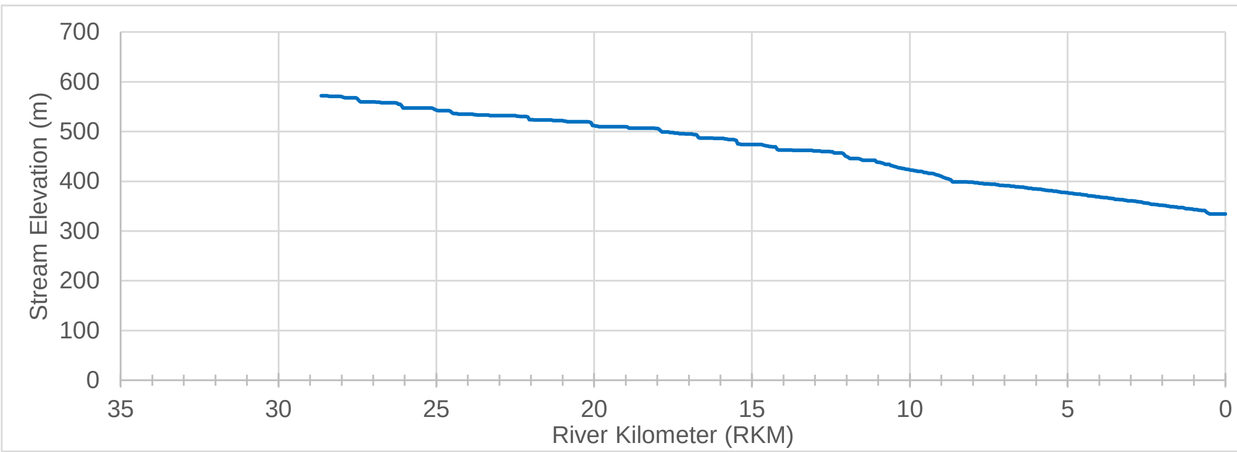

Figure 8-2. Steamboat Creek elevation.

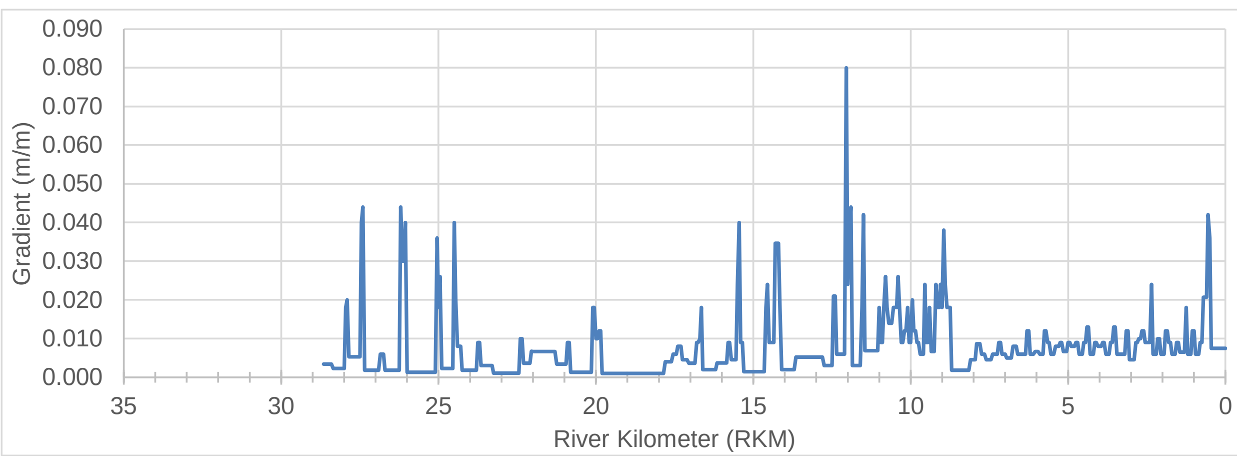

Figure 8-3. Steamboat Creek gradient.

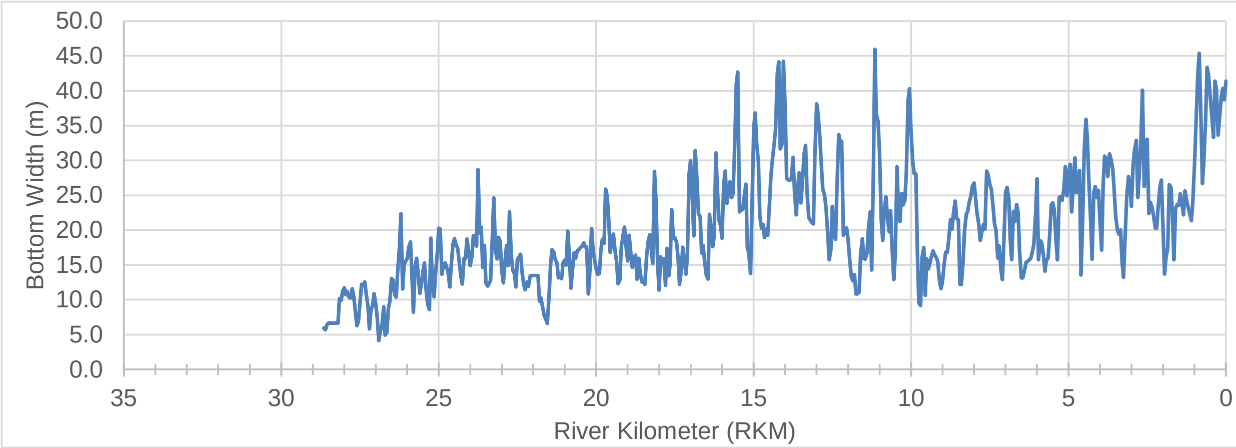

Figure 8-4. Steamboat Creek calculated bottom width.

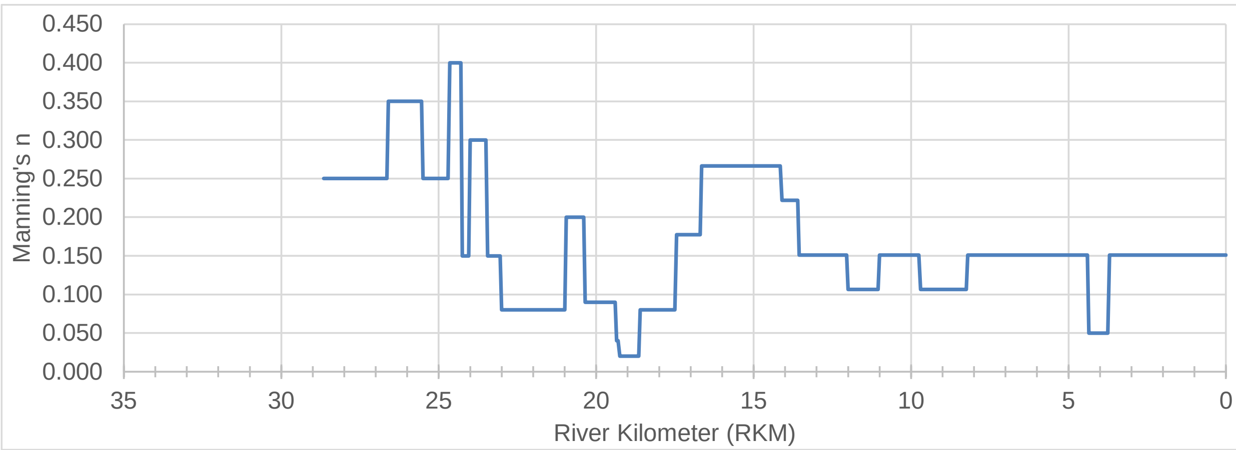

Figure 8-5. Steamboat Creek assigned Manning's n values.

Flow and water temperature stations were identified for configuring the model and for calibration. There is one USGS flow gage (14316700) at the downstream end of Steamboat Creek. Observed water temperature data from USFS were available for a few tributaries and at a calibration station along the mainstem, collected by DEQ. Figure 8-6 shows the available observed flow and water temperature stations in the vicinity of Steamboat Creek. The flow and water temperature inputs are discussed in the following sections.

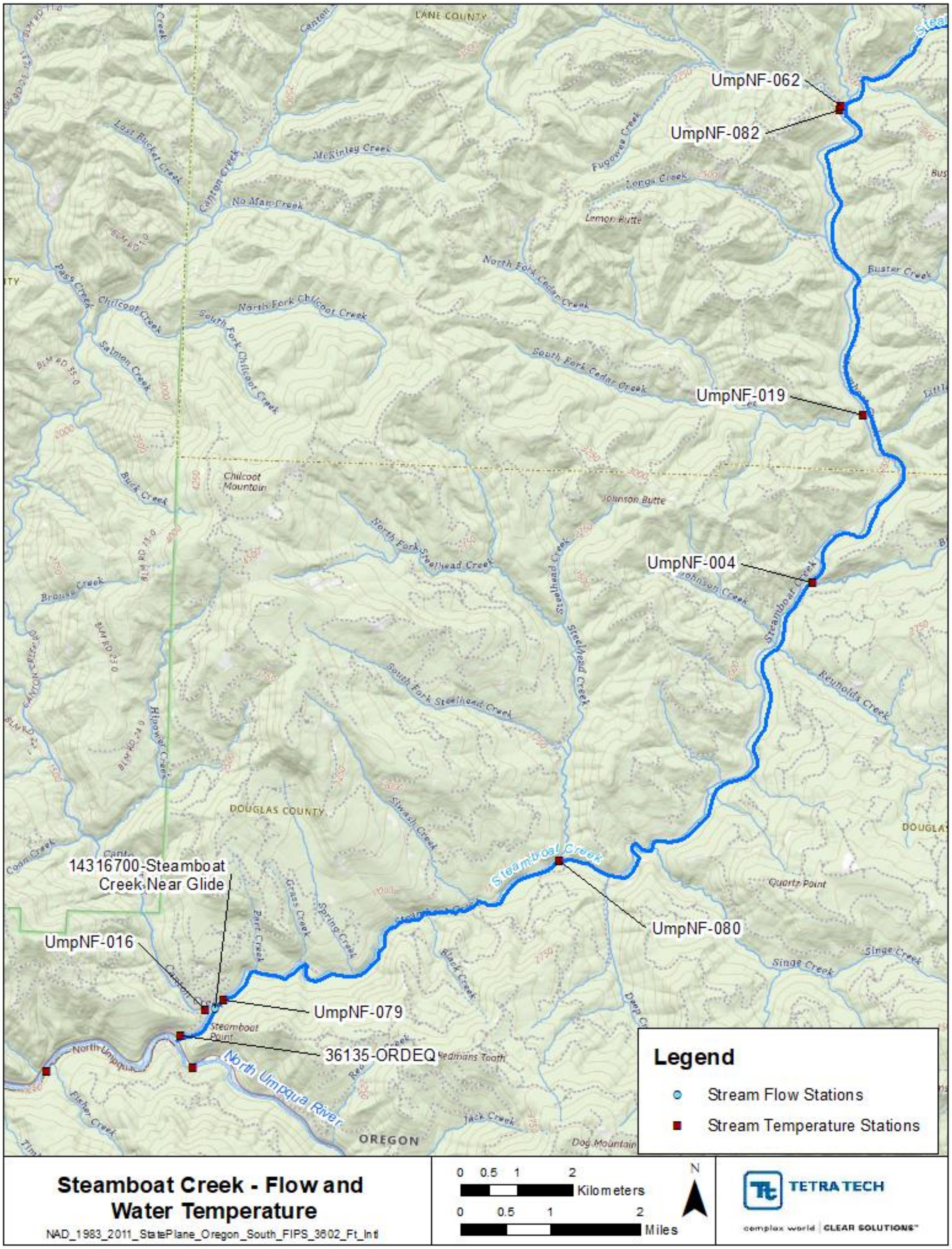

Figure 8-6 Steamboat Creek observed flow and water temperature stations.

8.3 FLOW INPUTS – STEAMBOAT CREEK

Flow data were limited for Steamboat Creek, with the only available flow station located near the mouth of the Steamboat Creek. Flow data were not available for any of the ten tributary inputs to the Steamboat Creek model or the upstream boundary. Table 8-1 shows an inventory of the tributary inputs to the model and notes how flows were derived. The following sections describe how the flows were derived for input into the model.

Table 8-1. Inventory of available flow data in the Steamboat Creek watershed used in the Heat Source Model

Station ID	Model location (Km)	Source	Type	Notes
Steamboat Creek at the confluence of Little Rock Creek	28.65	Derived data	Boundary condition	Derived using net flows using sum of tributaries and downstream flows
Little Rock Creek	28.45	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide
Longs Creek	25.45	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide
Buster Creek	24.5	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide
Cedar Creek	21.9	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide
Big Bend Creek	17.6	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide
Reynolds Creek	16.2	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide
Singe Creek	11.1	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide
Deep Creek	9.85	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide
Steelhead Creek	8.85	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide
Canton Creek	0.9	Derived data	Tributary	Estimated using regression relationship with flows from Steamboat Creek near Glide

8.3.1 Flow Estimation – Steamboat Creek

Due to the lack of flow data for most of the system, stream flows had to be estimated to configure the model inputs. Regression relationships were established using the tributary flows in the 2002 Steamboat Creek model and the observed 2002 flows at the downstream from Steamboat Creek near Glide (Figure 8-7). These relationships were then used to derive the tributary flows for 2009, using the observed hourly flows for 2009 at Steamboat Creek near Glide.

The upstream flows were further adjusted by adding a constant flow of 0.08 cms to balance the observed flows at the downstream USGS gage on Steamboat Creek. Accretion inputs in the model from RKM 1.75 to RKM 0 were increased from 0.36 cms to 0.54 cms. Flows were distributed across the nodes from RKM 1.75 to RKM 0. The corresponding accretion flow temperature of 15 ºC was left unchanged. Figure 8-8 shows the flow balance at USGS 14316700 – Steamboat near Glide. Figure 8-9 shows all the estimated tributary flows specified in the Steamboat Creek model. Note that Canton Creek flows were specified based on the Canton Creek model flow inputs. The flow estimation for Canton Creek is described in the flow estimation section for Canton Creek. Figure

8-10 shows the distribution of flows throughout the Steamboat Creek model, with the majority of the flows to the system coming from Canton Creek, Big Bend Creek, and the upstream boundary.

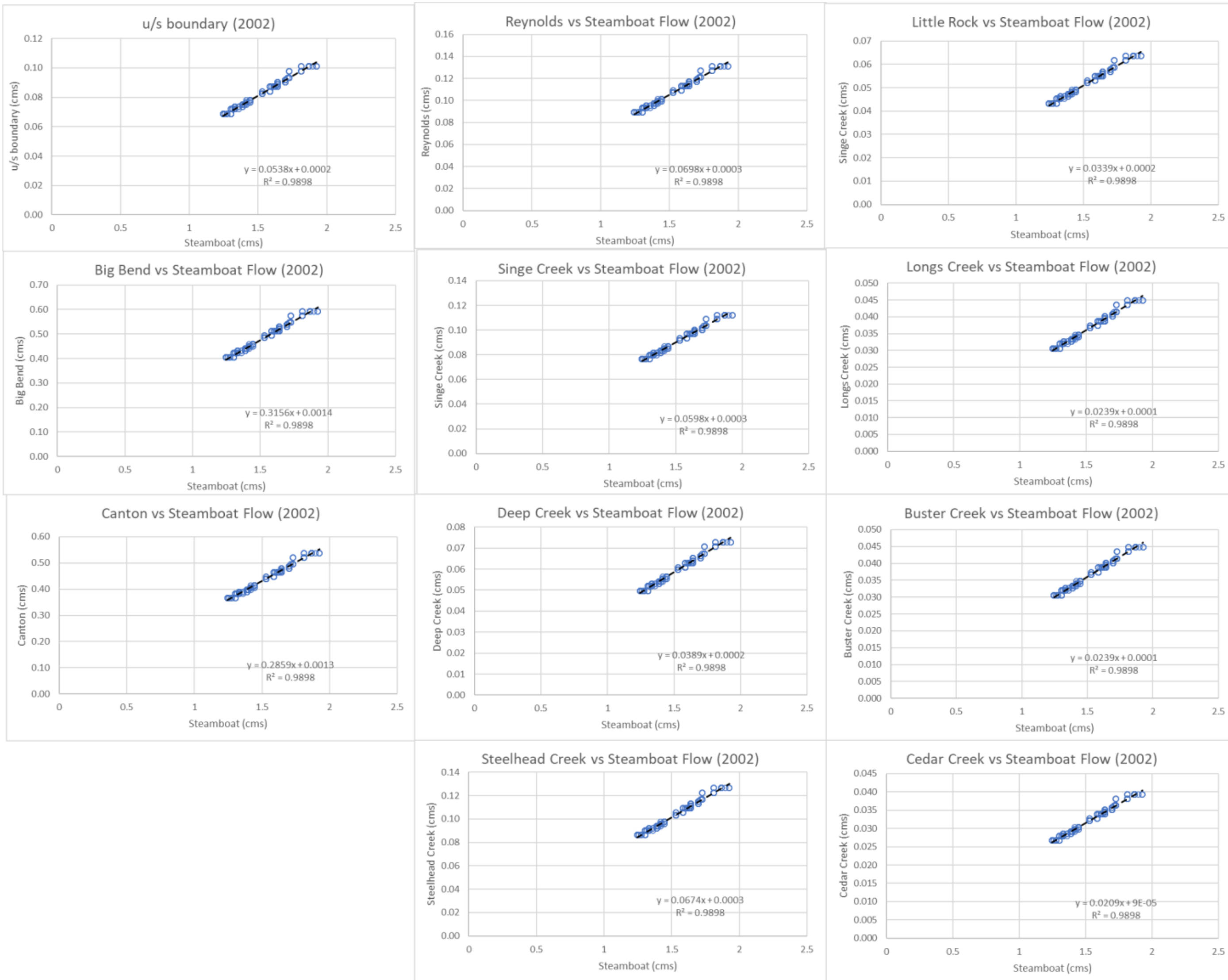

Figure 8-7. Relationships between each of the tributaries and the Steamboat Creek Near Glide station (USGS 14316700) using the 2002 model.

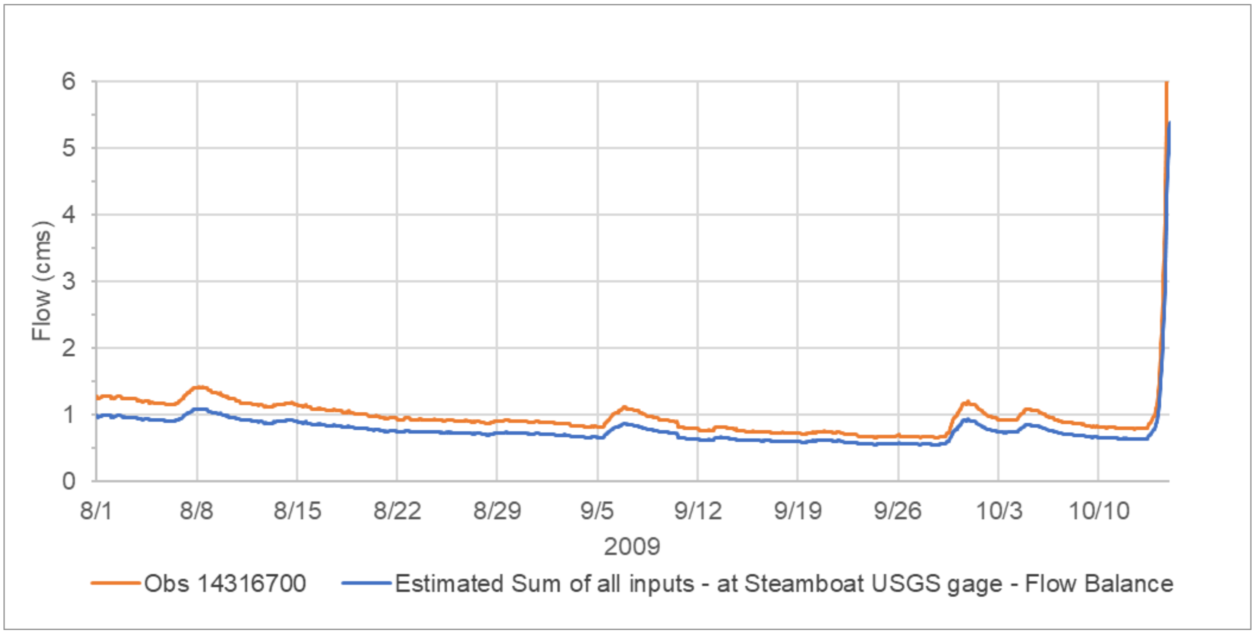

Figure 8-8. Observed flow at Steamboat Creek near Glide (USGS 14316700) and flow balance.

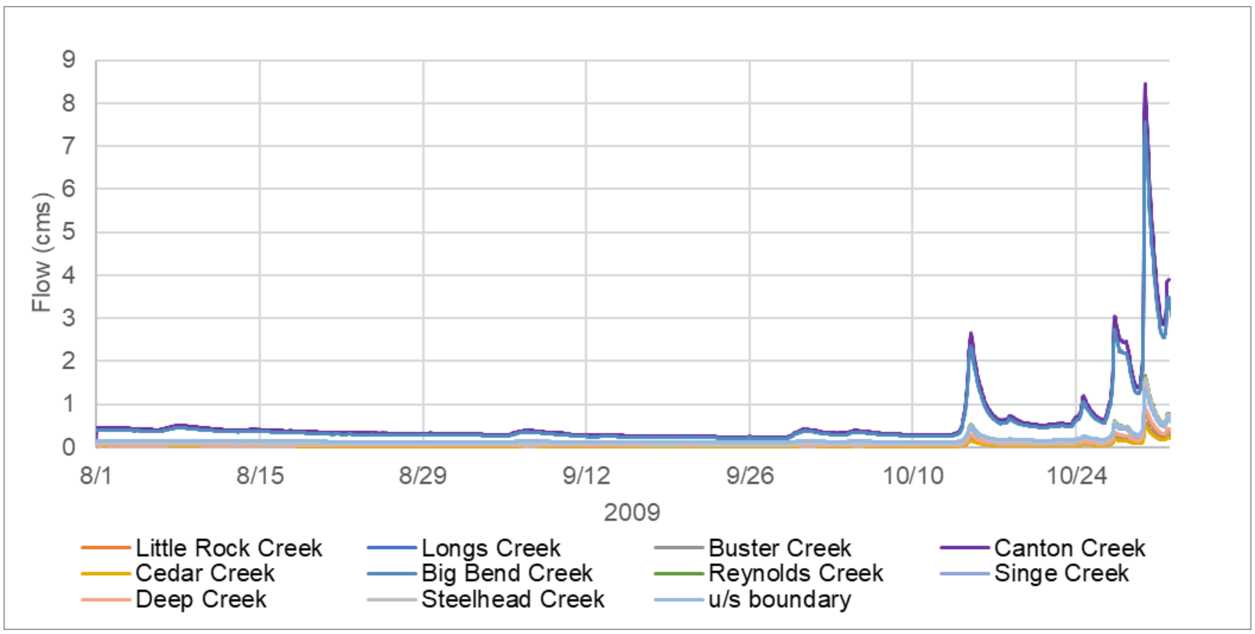

Figure 8-9. Estimated flows of tributaries to Steamboat Creek.

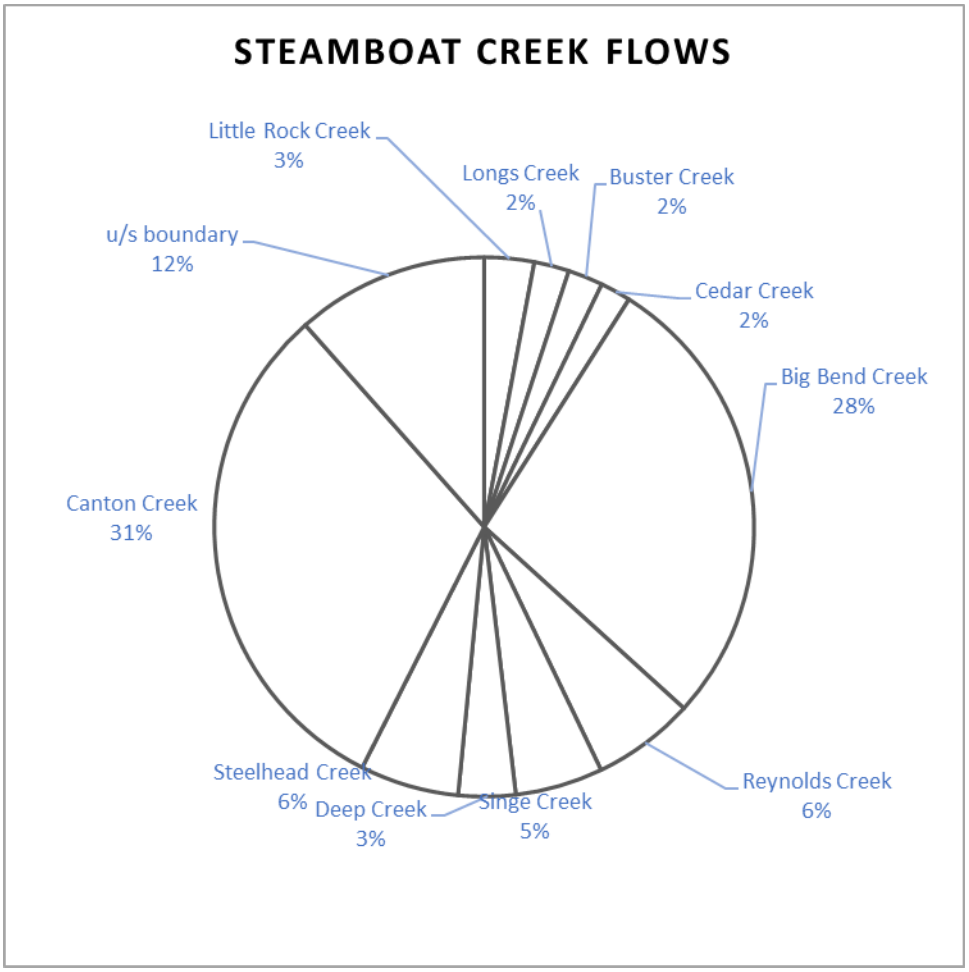

Figure 8-10. Distribution of tributary flow inputs in the Steamboat Creek model.

8.4 WATER TEMPERATURE INPUTS – STEAMBOAT CREEK

Hourly stream temperature data collected by the USFS were available for the upstream boundary and for six tributaries to Steamboat Creek. The hourly temperature data only extended up to September 21, 2009. Table 8-2 provides an inventory of the water temperature data used in the model development. Figure 8-6 shows the location of the USFS stations.

The station UmpNF-082 - Upper Steamboat below Little Rock was used for the upstream boundary. Hourly temperature data were also available for four tributaries from the USFS – Cedar Creek (UmpNF-019), Big Ben Creek (UmpNF-004), Steelhead Creek (UmpNF-080), and Canton Creek (UmpNF-016).

All other tributaries were derived using assumptions used in the 2002 model inputs. This involved using relationships derived from the 2002 model to estimate model inputs. Little Rock Creek and Longs Creek were estimated using a relationship with the upstream boundary temperature (upstream boundary plus 1.5 °C). Buster Creek was estimated using relationship with Reynolds Creek (Reynolds minus 0.5 °C). Reynolds Creek was estimated using a relationship with Steelhead Creek (Steelhead minus 0.5 °C). Singe Creek was assigned water temperatures the same as Cedar Creek, and Deep Creek was assigned water temperatures the same as Steelhead Creek.

Table 8-2. Inventory of available water temperature data locations used to configure the Steamboat Creek model.

Station ID	Model location (Km)	Source	Type	Notes
Steamboat Creek at the confluence of Little Rock Creek (UmpNF- 82)	28.65	USFS	Boundary condition	
Little Rock Creek (UmpNF-62)	28.45	USFS	Tributary	
Longs Creek	25.45	Derived data	Tributary	Assumption used in 2002 model. Upstream boundary plus 1.5 °C
Buster Creek	24.5	Derived data	Tributary	Assumption used in 2002 model. Reynolds minus 0.5 °C
Cedar Creek (UmpNF-019)	21.9	USFS	Tributary	
Big Bend Creek (UmpNF-004)	17.6	USFS	Tributary	
Reynolds Creek	16.2	Derived data	Tributary	Assumption used in 2002 model. Steelhead minus 0.5 °C
Singe Creek	11.1	Derived data	Tributary	Surrogate relationship using Cedar Creek
Deep Creek	9.85	Derived data	Tributary	Surrogate relationship using Steelhead
Steelhead Creek (UmpNF-080)	8.85	USFS	Tributary	
Canton Creek (UmpNF-016)	0.9	USFS	Tributary	

As noted previously, temperature data from USFS only extended up to September 21, 2009, and did not cover a major portion of the spawning period. Data for the period from September 22 to October 12, 2009, were filled in using regression relationships developed between data from each of the USFS stations and the DEQ station 36135-ORDEQ (Steamboat near mouth). Figure 8-11 shows the regression relationships for each of the tributaries. Finally, the station 36135-ORDEQ only had data up to October 12, 2009, the remaining three days of the modeling period from October 13 to October 15, 2009, were filled by repeating the October 12, 2009, data. Figure 8-12 shows the stream temperature inputs used in the model for the upstream headwater and the various tributaries in the Steamboat Creek.

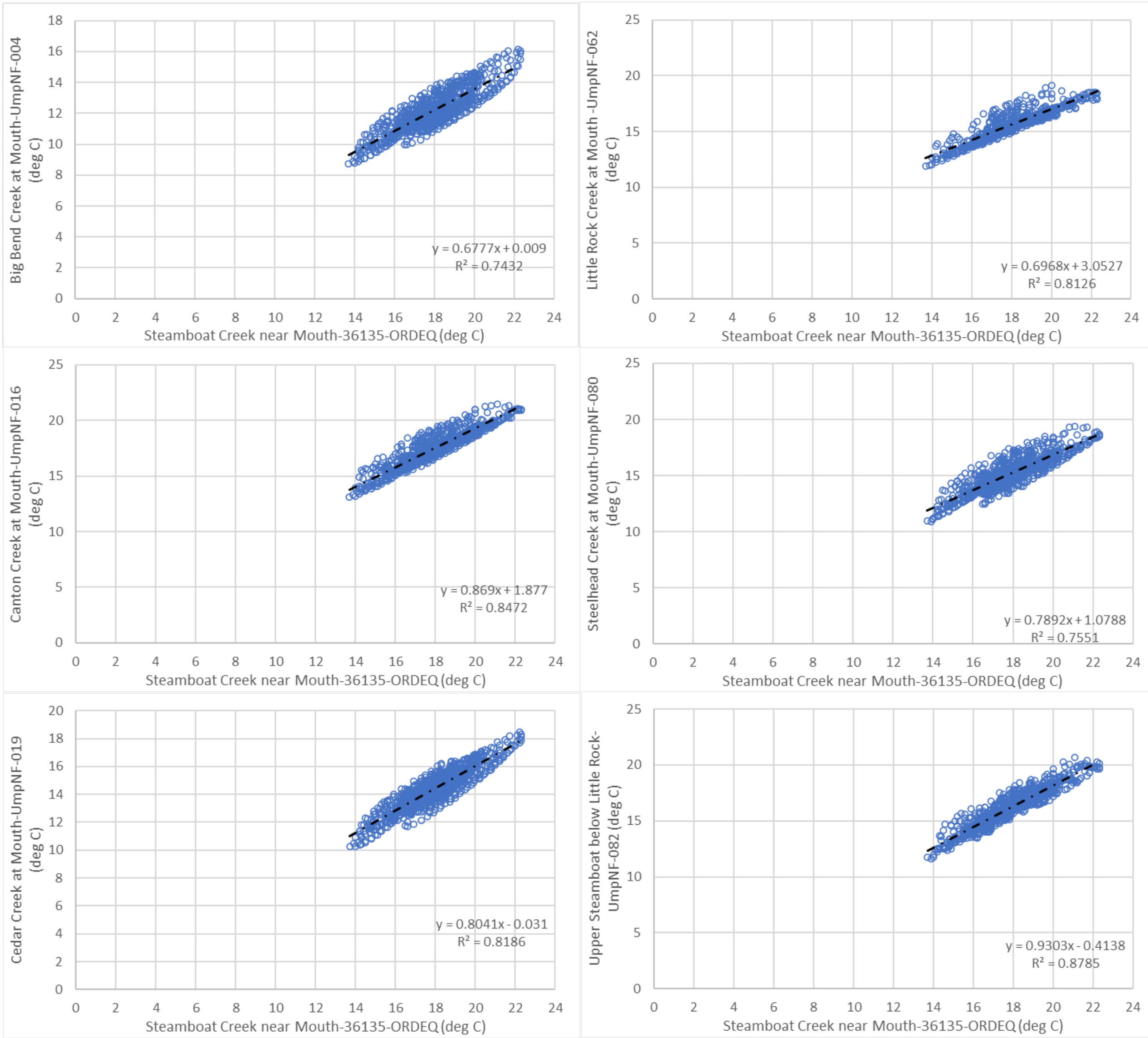

Figure 8-11. Regression relationships developed with tributaries and Steamboat Creek near Mouth to fill in missing data.

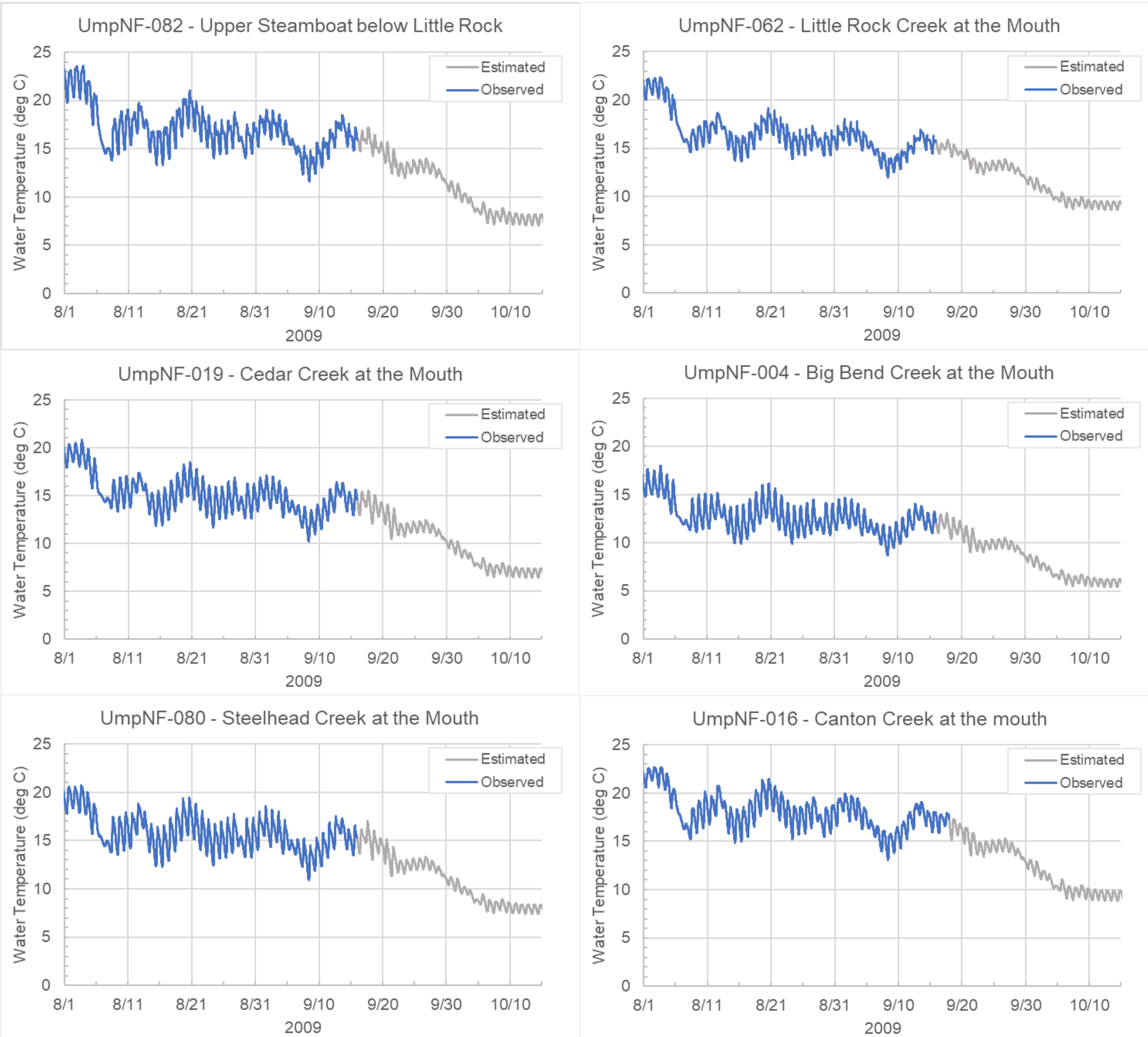

Figure 8-12. Hourly water temperature inputs to Steamboat Creek

8.5 METEOROLOGICAL DATA – STEAMBOAT CREEK

Hourly meteorology inputs into the model include air temperature, relative humidity, and wind speed. Table 8-3 presents an inventory of available meteorological data for the Steamboat Creek model. The map showing the locations of the weather stations can found in Figure 8-13.

Table 8-3. Inventory of available Meteorological Station Data in the Steamboat Creek watershed

Station ID	Station Name	Elevation (m)	Latitude/Longitude	Frequency	Available Met Data	Source
23894-ORDEQ	upstream of Steamboat Creek	366		Hourly	Air Temperature	ORDEQ
WBAN24231	NCDC – LCD station Roseburg Regional Airport	152.9	43.23367°/ 123.35775°	Hourly	Relative Humidity, Cloud cover, Wind Speed	NCDC - LCD

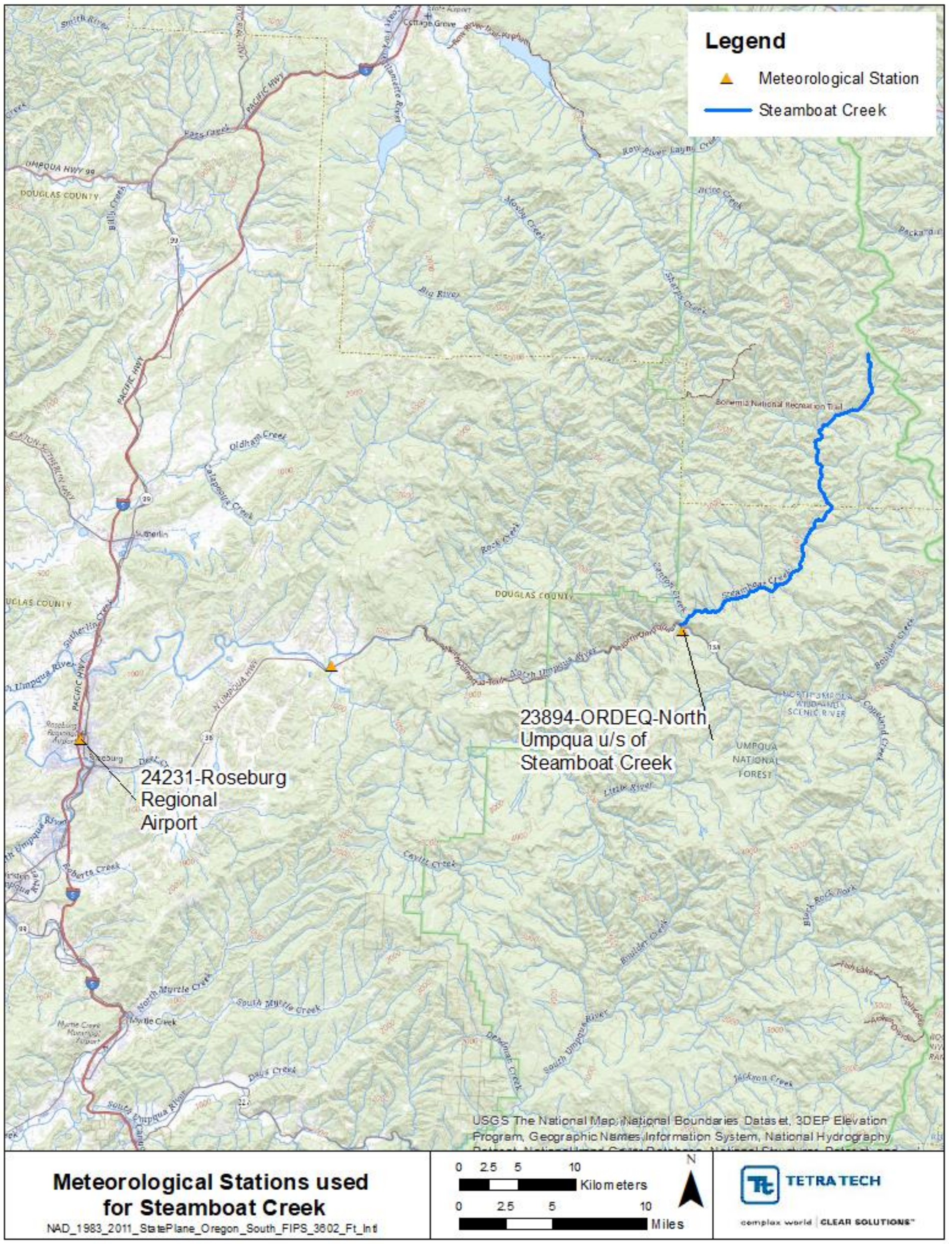

Figure 8-13 Steamboat Creek Meteorological Stations

Air temperature was specified in the model using data from the station 23894-ORDEQ (upstream of Steamboat Creek) (Figure 8-14). Data were missing at this station from August 1, 2009 to August 31, 2009 and from October 12, 2009 onwards. These missing air temperature data were filled using Roseburg Air Temperature after applying an adiabatic lapse rate adjustment. All other meteorological parameters were taken from the Roseburg Regional Airport station. Wind speed was set to zero during calibration and cloud cover was adjusted to better predict temperatures. Specifically, cloud cover adjustments were made in first two weeks of August, when the cloud cover was increased from clear conditions to 50 percent cloudy (from 0 to 0.5) and reduced from cloudy by 20 percent (from 1.0 to 0.8). Figure 8-15 show the cloud cover specified in the model.

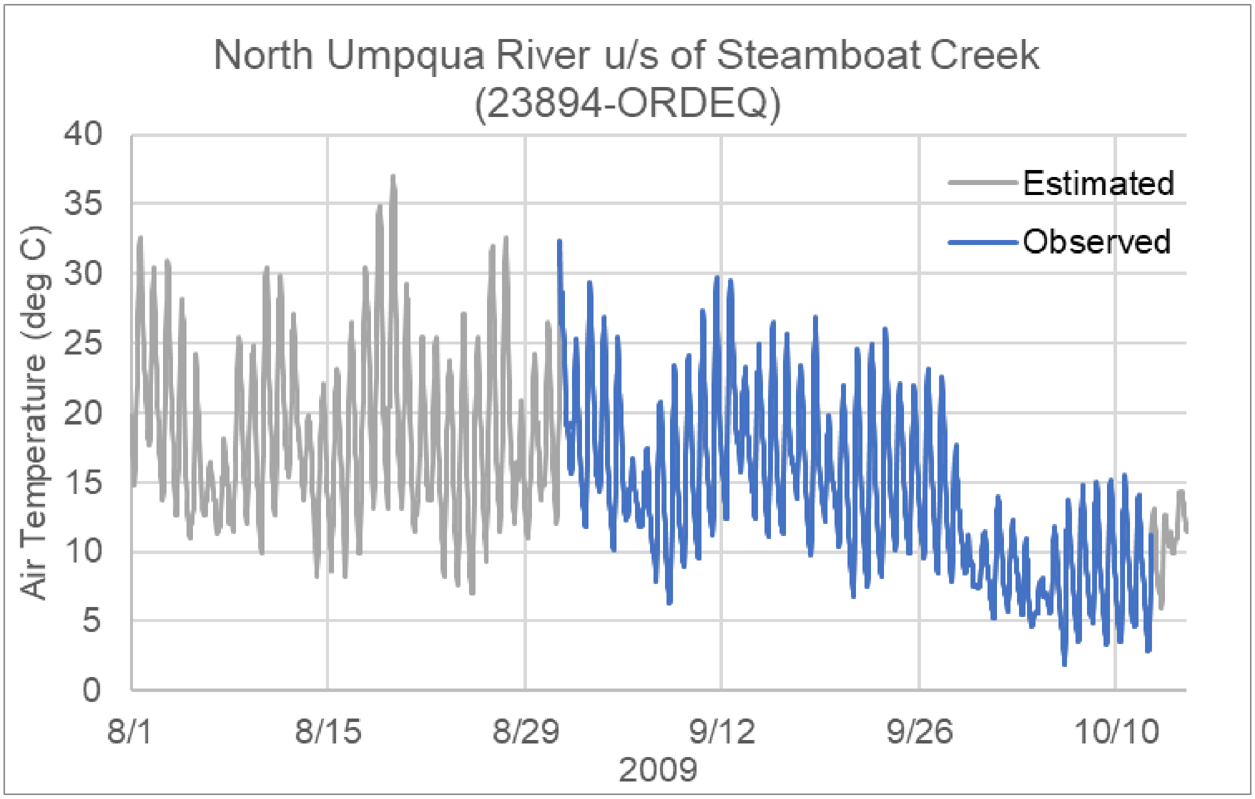

Figure 8-14 Hourly air temperature at 23894-ORDEQ

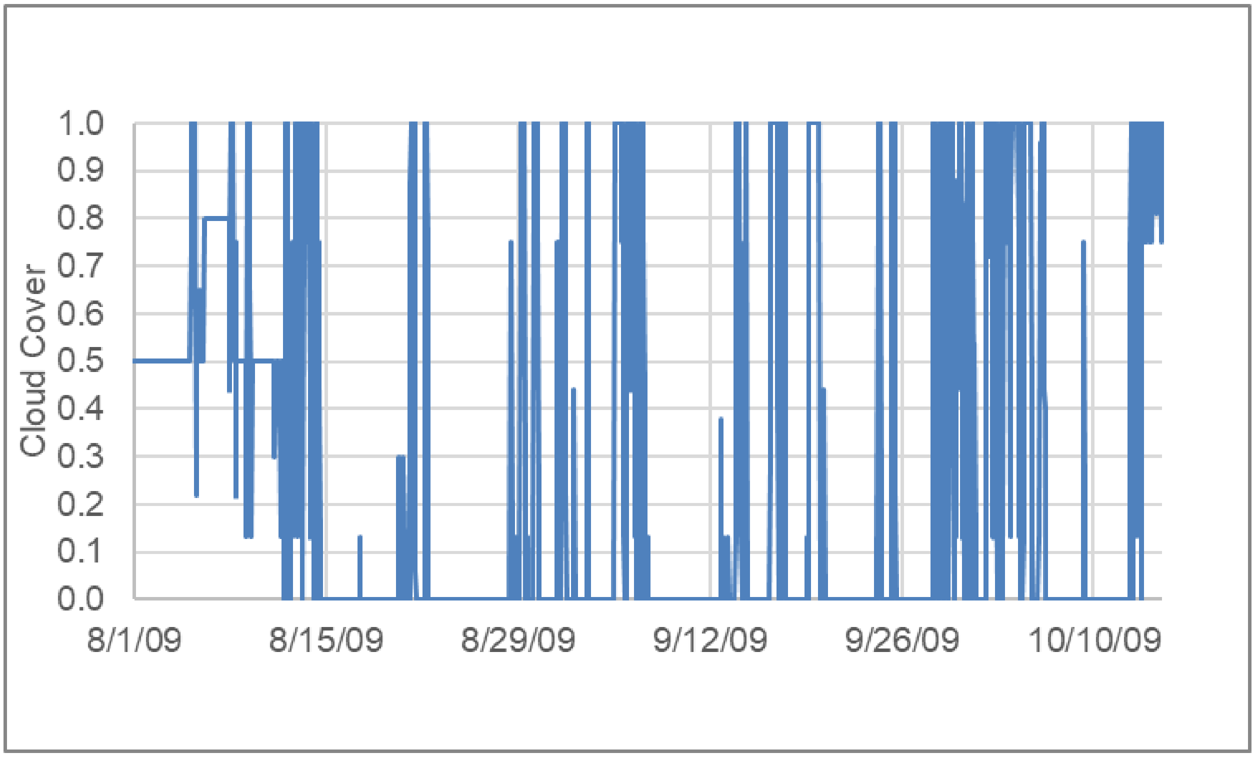

Figure 8-15 Hourly cloud cover specified in the Steamboat Creek model.

8.6 MODEL CALIBRATION – STEAMBOAT CREEK

The Steamboat Creek Heat Source model was simulated for the time period from August 1, 2009, to October 15, 2009, over the 28.5-kilometer study area from just upstream of its confluence with Little Rock Creek to the mouth. The model used hourly meteorology, and eleven hourly flow and stream temperature inputs. The model was run at a time step of 1 minute and outputs were generated hourly, every 100 meters. The model was calibrated against observed data. Wind speeds and cloud cover were adjusted during calibration to represent more site-specific conditions at the modeling site and improve the water temperature calibration. These are discussed further in the following section.

The model calibration sites and data sources for Steamboat Creek are summarized in Table 8-4. The model location in the table below describes the distance of each calibration site from the most downstream model node. The model flows were calibrated to the flows from the Steamboat Creek station near Glide. In addition, there were two water temperature stations located towards the downstream end of the model, monitored by the UFS and DEQ, that were used for calibration. Figure 8-6 shows the location of the stations.

Table 8-4. Calibration sites used in the Steamboat Creek Heat Source Model Calibration

Station ID	Description	Model RKM	Data Type	Source
Hourly Flow				
USGS 14316700	Steamboat Creek Near Glide	1.1	Flow	DEQ
Hourly Water Temperature				
UmpNF-079	Steamboat Creek above Canton Creek	2	Water temperature	USFS
36135-ORDEQ	Steamboat Creek Near Mouth	0	Water temperature	DEQ

A combination of visual and computed error statistics was used to assess the model calibration. Summary statistics (ME, MAE, RMSE, and NSE) followed the calculations described in Section 3.6.

8.7 FLOW CALIBRATION – STEAMBOAT CREEK

Hourly flows from USGS 14316700-Steamboat Creek near Glide were compared against the modeled flows (Table 8-4). Figure 8-16 compares the simulated and measured flows at the Steamboat Creek near Glide gage for the modeled time-period. Table 8-5 shows the flow calibration statistics. The observed statistics showed a MAE of around 0.1 cms and a RMSE of 0.40 cms. Since the gage was also used as a reference starting point for the stream flow balance calculations, the simulated daily flow values were generally as close as the flow balance that was performed. Refer to Section 8.3.1 for more details on the flow balance comparisons. Note that the during the last two days of the simulation period, on October 14 and 15 the observed flows increase dramatically which results in under prediction of the flows, and also results in higher calibration error statistics. If we do not include these two days, the error statistics improve considerably and both the MAE and RMSE are less than 0.1 cms (MAE:0.07 cms, RMSE: 0.08 cms, and NSE: 0.99).

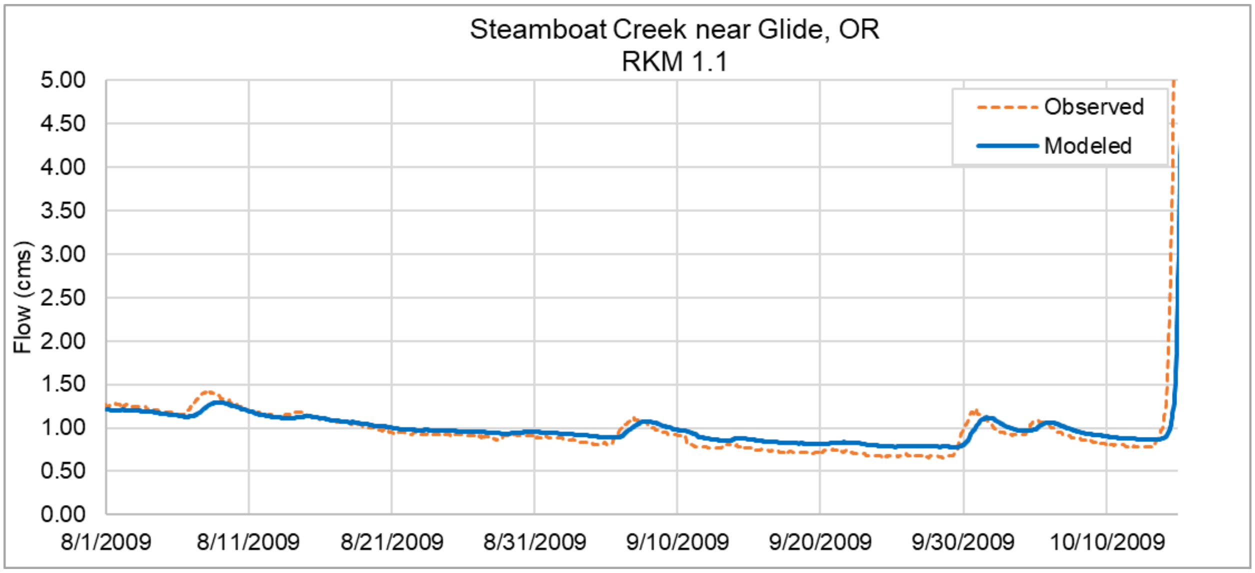

Figure 8-16 Observed versus modeled flow at Steamboat Creek near Glide

Table 8-5. Flow calibration statistics for Steamboat Creek

Flow (cms)	Steamboat Creek near Glide, OR RKM 1.1
ME	-0.01
MAE	0.11
RMSE	0.40
NSE	0.93
Count	1,824

8.8 TEMPERATURE CALIBRATION – STEAMBOAT CREEK

Hourly water temperature observations from Steamboat above Canton Creek and Steamboat at mouth were used for stream temperature calibration (Table 8-4). The modeled versus observed hourly and daily maximum water temperature timeseries at the two stations can be found in Figure 8-17 and Figure 8-18.

Channel morphology related inputs were retained from the HS7 model during calibration. The sediment heat exchange parameters, i.e., sediment thermal conductivity and diffusivity, and wind function coefficients, were applied at their HS8 default values.

The modeled water temperature captured the diurnal patterns and the daily maximum values well at the Steamboat above Canton Creek location. The calculated error statistics at this station showed a MAE and RMSE of less than 1 ºC for both the hourly and daily maximum water temperatures. The predicted water temperatures at the Steamboat Creek at mouth location follow the seasonal pattern seen in the water temperature from summer to fall, but the model underpredicts the minimums. Several adjustments were made during calibration, which included adjusting the cloud cover, wind speed, and hyporheic flow. These only improved the results marginally. As noted in the meteorology discussion, cloud cover adjustments were made in first two weeks of August, when the cloud cover was increased from clear conditions to 50 percent cloudy (from 0 to 0.5) and reduced from cloudy by 20 percent (from 1.0 to 0.8). Applying wind sheltering improved the calibration. The wind speed was set to zero for the model as it provided the best results in terms of capturing the daily maximums. Note, that this is consistent with what was done previously in DEQ's 2002 summer model. Hyporheic flow was specified to better capture observed hourly temperatures. The addition of hyporheic flows helped reduce the diurnal variation but this also lowered the daily minimum values. Final values of 30 to 50 percent hyporheic exchange were used after calibration.

The calculated model error statistics at all stations can be found in Table 8-6. The hourly temperature statistics for Steamboat Creek above Canton Creek were less than 1 ºC. The hourly water temperatures statistics for Steamboat Creek near the mouth showed that the MAE and RMSE were slightly above 1 ºC (1.05 ºC and 1.25 ºC respectively), an exception being the ME which was less than 1 ºC. The daily maximum temperature statistics for both the stations on Steamboat Creek above and below Canton Creek were less than 1 ºC. The calculated NSE for the hourly and daily maximum temperatures was greater than 0.83.

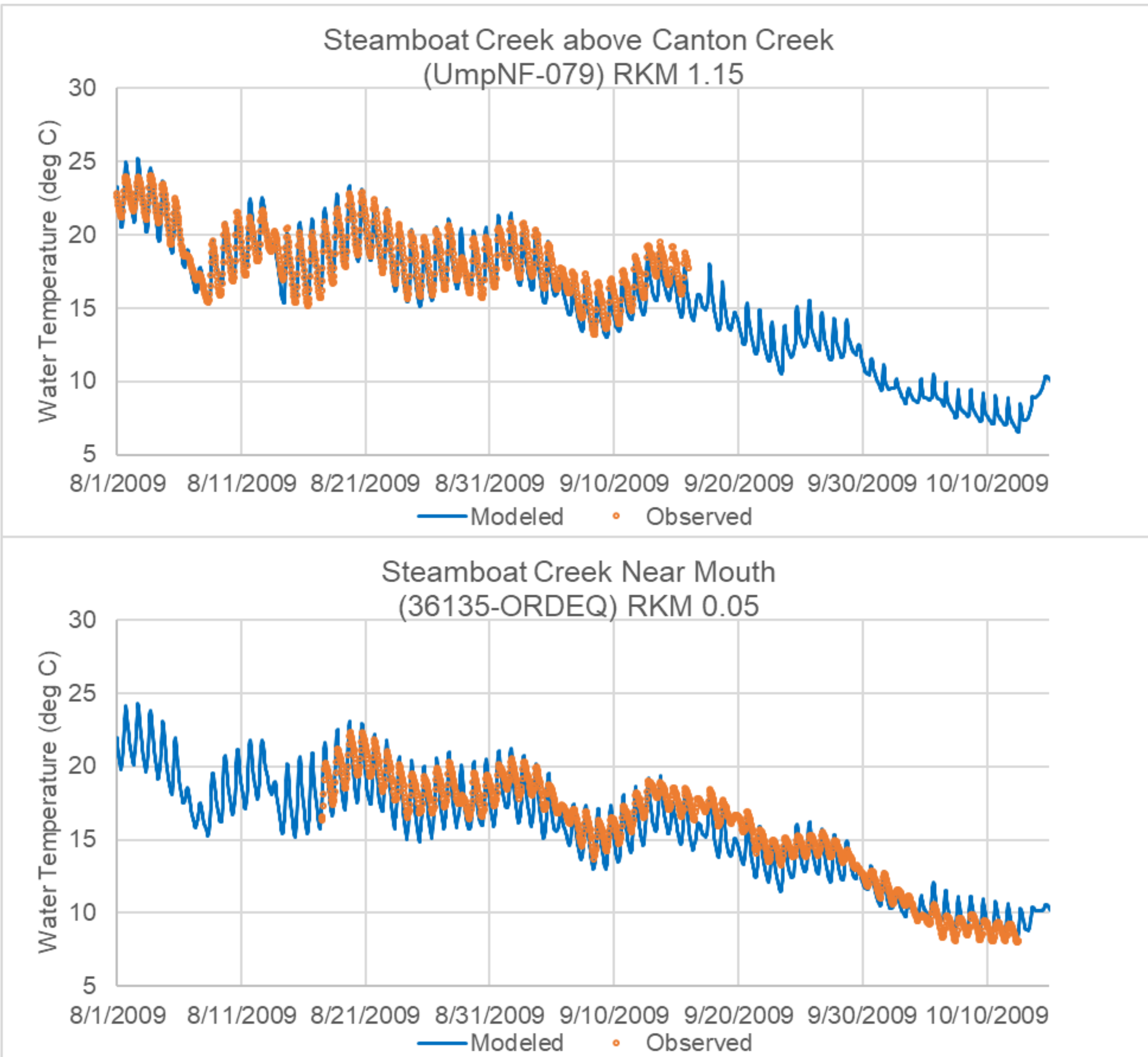

Figure 8-17. Steamboat Creek–observed versus modeled hourly water temperature.

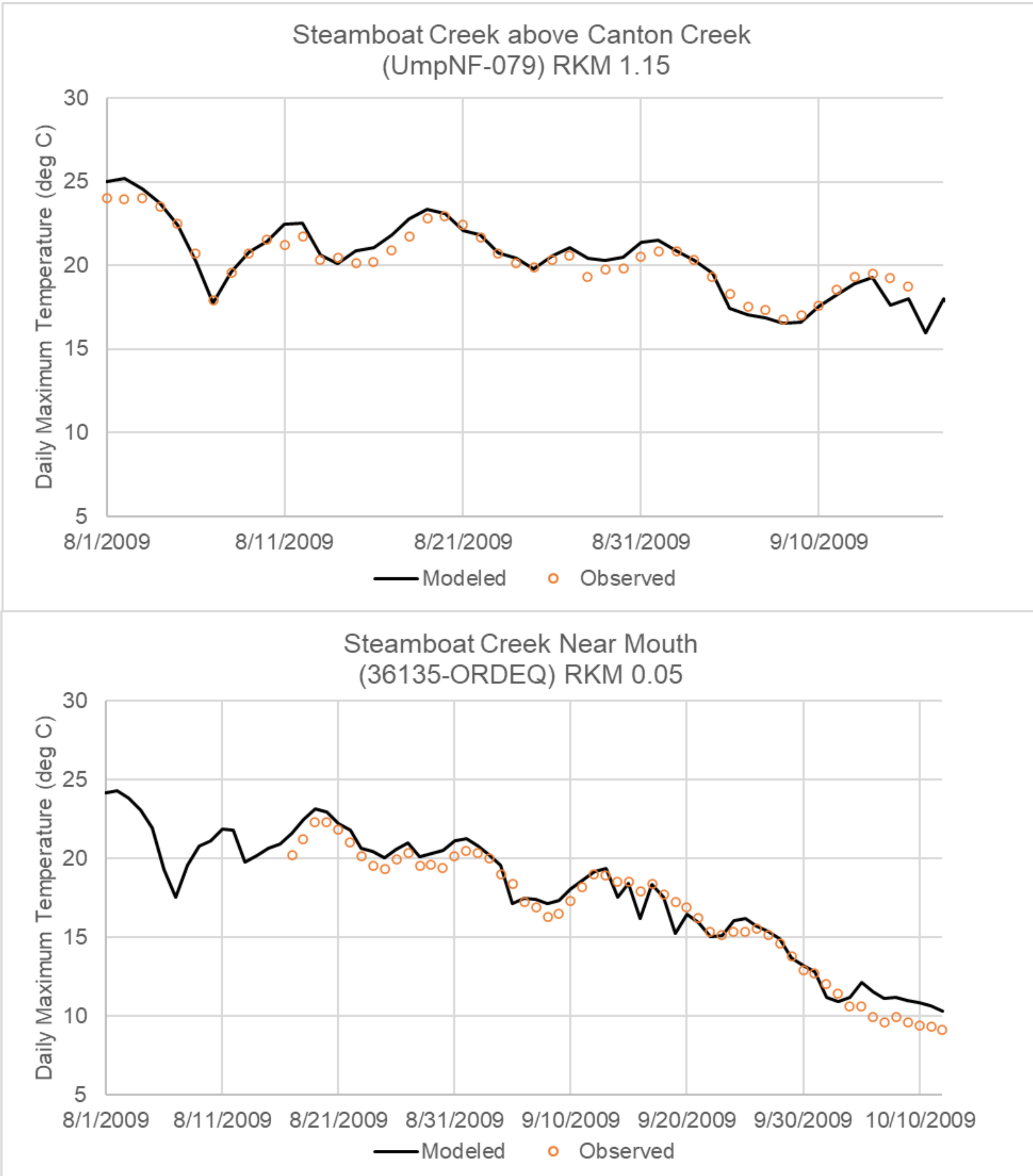

Figure 8-18. Steamboat Creek–observed versus modeled daily maximum water temperature.

Table 8-6. Hourly and Daily Maximum Stream Temperature calibration statistics for Steamboat Creek

Statistic	Steamboat Creek above Canton Creek (UmpNF-079) RKM 1.15[a]	Steamboat Creek near mouth (36135-ORDEQ) RKM 0.05[b]
Hourly Temperature Statistics		
ME	-0.45	-0.68
MAE	0.74	1.05
RMSE	0.89	1.25
NSE	0.83	0.88
Count	1104	1347
Daily Maximum Temperature Statistics		
ME	0.16	0.42
MAE	0.49	0.73
RMSE	0.61	0.87
NSE	0.92	0.95
Count	46	57

a: Period of Record (POR) from August 1 to September 15, 2009; b: POR from August 17 to October 12, 2009

9.0 SUMMARY

HS8 models were developed for six streams in the North Umpqua watershed to support TMDL development for the spawning temperature impairment. Specifically, ten separate HS 8 models were developed for the six streams - Canton Creek, Clearwater River, Lake Creek, North Umpqua River (includes five separate riverine portions models), Rock Creek, and Steamboat Creek.

The spawning period HS8 models were developed based on existing HS7 models that were developed for the summer period during July 2001/2002 from the previous TMDL (DEQ, 2006). These models were used as the basis for developing the HS8 models. No changes were made to the channel morphology and shading related information and vegetation data. An exception to this was the channel bottom widths specified in the HS8 models. The bankfull widths in HS7 were converted to bottom widths for use in version 8. Also, the North Umpqua portion from Soda Spring PH to the Mouth was modeled previously using two separate HS7 models i.e., from Soda PH to Steamboat and from Steamboat to Mouth. These two models were merged during the spawning period to form a single model HS8 model from Soda PH to Mouth. No changes were made to the morphology or shading information for the two models that were merged.

Developing all the HS8 models mainly involved determining inflows, water temperatures, and weather conditions. Observed USGS flow gages data downstream of reservoirs were used to configure the HS8 models for the North Umpqua River below the impoundments at Lemolo Lake, Toketee Lake, and Soda Springs Dam. Flow gages were only available at a few other locations, including one at the mouth of Steamboat Creek. No flow data were available for Rock Creek, Lake Creek, Canton Creek, and Clearwater River. Missing flow data were filled using available flow scaling with the gaged drainage area or by using ratios and relationships from the previous HS7 models and using flow balance.

The stream temperature (and flow data at select locations) from the 2009 DEQ monitoring effort were used to support temperature model development for the spawning period. In addition to the DEQ data, continuous temperature data were also available from the USFS and BLM. The data were available for 2009 and were used to support spawning period model development on major tributaries to the North Umpqua River and some of the data were also used for model calibration. There were still several minor tributaries for which stream temperature data were not available. Stream temperature for the remaining tributaries were derived using either a linear regression approach or using a direct surrogate from a neighboring or nearby tributary watershed or filled in using the same assumptions used to estimate temperatures in the HS7 model from surrounding tributary data.

In addition, the model updates also included adding point source inputs that were not included in the HS7 models. These included the Glide-Idleyld Sanitary District NPDES point sources input to the North Umpqua and the Rock Creek Hatchery input to Rock Creek. Rock Creek Hatchery data were not available for 2009, so 2016 data were used to configure the Hatchery input.

Flow data for calibration were limited and were evaluated at five USGS gages. There was one gage available on Clearwater River and Steamboat Creek, and there were three gages along North Umpqua in the Model 5 domain. Predicted flows at all stations agree well with data on the overall trends and magnitudes. An exception to this includes the Winchester station 14319500 along North Umpqua where the model was unable to produce occasional spikes identified in the observed data.

A total of 22 continuous hourly water temperature stations were available for water temperature calibration across the various waterbodies. Each waterbody had at least one continuous temperature station (except for North Umpqua Model 4 which had no calibration data). In general, the modeled temperature time series captured the seasonal trend of warm temperatures during August, followed by rapid cooling seen from around mid-September to mid-October at all locations into the spawning period. The models were calibrated to both the continuous hourly water temperature and the daily maximum water temperature. The model calibration focused on capturing the daily maximum values well, since the TMDL criteria is based on the seven-day average of the daily maximum values (7DADM).

- The North Umpqua Model 1 and Model 3 models had one continuous water temperature calibration station, whereas Model 2 had four and Model 5 had seven, continuous stream temperature station. The calculated ME, MAE, and RMSE for the hourly and daily maximum water temperature was less than 1 ºC at each of the calibration station locations. The calculated NSE was greater than 0.9, with the exception for Model 1 and Model 3 which had a NSE of 0.85 and 0.77 respectively.
- The calculated ME, MAE, and RMSE for the hourly and daily maximum water temperature at Canton Creek, Clearwater River, and Rock Creek was also less than 1 ºC, an exception being the RMSE for the hourly temperatures which was 1.01 ºC. The NSE for all stations was greater than 0.8, with the exception for the hourly temperatures at Canton Creek, which had a NSE of 0.73.
- The calculated MAE and RMSE for the hourly water temperature at two of the three stations on Lake Creek i.e., at ORDEQ-26852 and at mouth were greater than 1 ºC. However, the calculated MAE of the daily maximum water temperature at all locations was less than 1 ºC. The RMSE for daily maximum water temperature at that ORDEQ-26852 station and at mouth was 1.29 ºC and 1.04 ºC respectively. In general, the NSE was greater than 0.85 (an exception being station OR-DEQ-2685 which had a NSE of 0.79).
- The calculated ME, MAE, and RMSE for the two hourly and daily maximum water temperature stations at Steamboat Creek was also less than 1 ºC, an exception being the MAE and RMSE for the hourly temperatures at the mouth which was 1.05 ºC and 1.25 ºC respectively. The corresponding daily maximum MAE and RMSE at the station near the mouth was less than 1 ºC (0.61 ºC and 0.87 ºC respectively)

The calibrated models allow for evaluating various scenarios for the spawning period, to support the temperature TMDL effort for the North Umpqua watershed.

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TETRA TECH

MEMO

To:	Rebecca Veiga Nascimento, Ben Cope, Catelyn Jones
From:	Aileen Molloy, Sen Bai, Mustafa Faizullabhoy, Eugenia Hart
Date:	October 3, 2024
Subject:	North Umpqua River Scenarios

TABLE OF CONTENTS

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1.0 INTRODUCTION

This document discusses the development and results of the various model scenarios of the Heat Source (HS) models in the North Umpqua watershed. Models were developed for the following waterbodies:

- Canton Creek
- Steamboat Creek
- Clearwater Creek
- Lake Creek
- Fish Creek
- Rock Creek
- North Umpqua Model 1 (Lemolo Reservoir to Lemolo Powerhouse (PH) #1)
- North Umpqua Model 2 (Lemolo Powerhouse #1 to Toketee Reservoir)
- North Umpqua Model 3 (Toketee Reservoir to Slide Powerhouse)
- North Umpqua Model 4 (Slide Powerhouse to Soda Springs Reservoir)
- North Umpqua Model 5 (Soda Springs Reservoir to Steamboat Creek for summer period, and Soda Springs Reservoir to the mouth for spawning period)
- North Umpqua Model 6 (Steamboat to Mouth), summer period only.

Summer HS models for the North Umpqua River Models 1 through 5, Clearwater Creek, Lake Creek, and Fish Creek were developed by Oregon Department of Environmental Quality (DEQ) for four days in July 2001, while the North Umpqua Model 6 summer model, Rock Creek, Steamboat Creek, and Canton Creek summer models were configured for 20 days in July 2002. The spawning period HS model for Fish Creek was developed by PacificCorp, and the model period is from July 1 to October 15, 2009. All other spawning period HS models were developed by Tetra Tech for all the above waterbodies and spanned the period from August 1 to October 15, 2009. The North Umpqua Model 5 and North Umpqua Model 6 are merged for the spawning period model, resulting in a combined model from Soda Springs Reservoir to the mouth.

Canton Creek, Steamboat Creek, Clearwater Creek, Lake Creek, Fish Creek, and Rock Creek are all tributaries of the North Umpqua River.

Figure 1-1 shows the locations of the rivers and creeks. The extent of North Umpqua Model 5 shown in the map is for the spawning period model, i.e. from Soda Springs Reservoir to the mouth. For the summer models, Model 5 extends from Soda Spring Reservoir to Steamboat Creek, and Model 6 extends from Steamboat Creek to the mouth.

To support the TMDL development, a series of scenarios were conducted using the summer and spawning period models.

The following scenarios were evaluated:

1. Calibrated Current Condition (CCC) scenario
2. No point sources scenario
3. Point source WLA scenario
4. Fully restored vegetation scenario
5. Background scenario
6. Attainment scenario
7. Natural flow scenario

In addition to these scenarios that support the TMDL development, additional scenarios were run to gain insights on model responses to factors such as tributary and headwater temperature inputs. Two more scenarios were run:

8. Tributary/headwater plus 0.1 ^{o}C scenario
9. Fully restored vegetation with point source WLA and Tributary/headwater plus 0.1 ^{o}C scenario

Model scenario interpretation in terms of calculation metrics that applied to all scenarios is discussed first, followed by descriptions of the scenarios. The scenario results are presented following the order of the HS model list above.

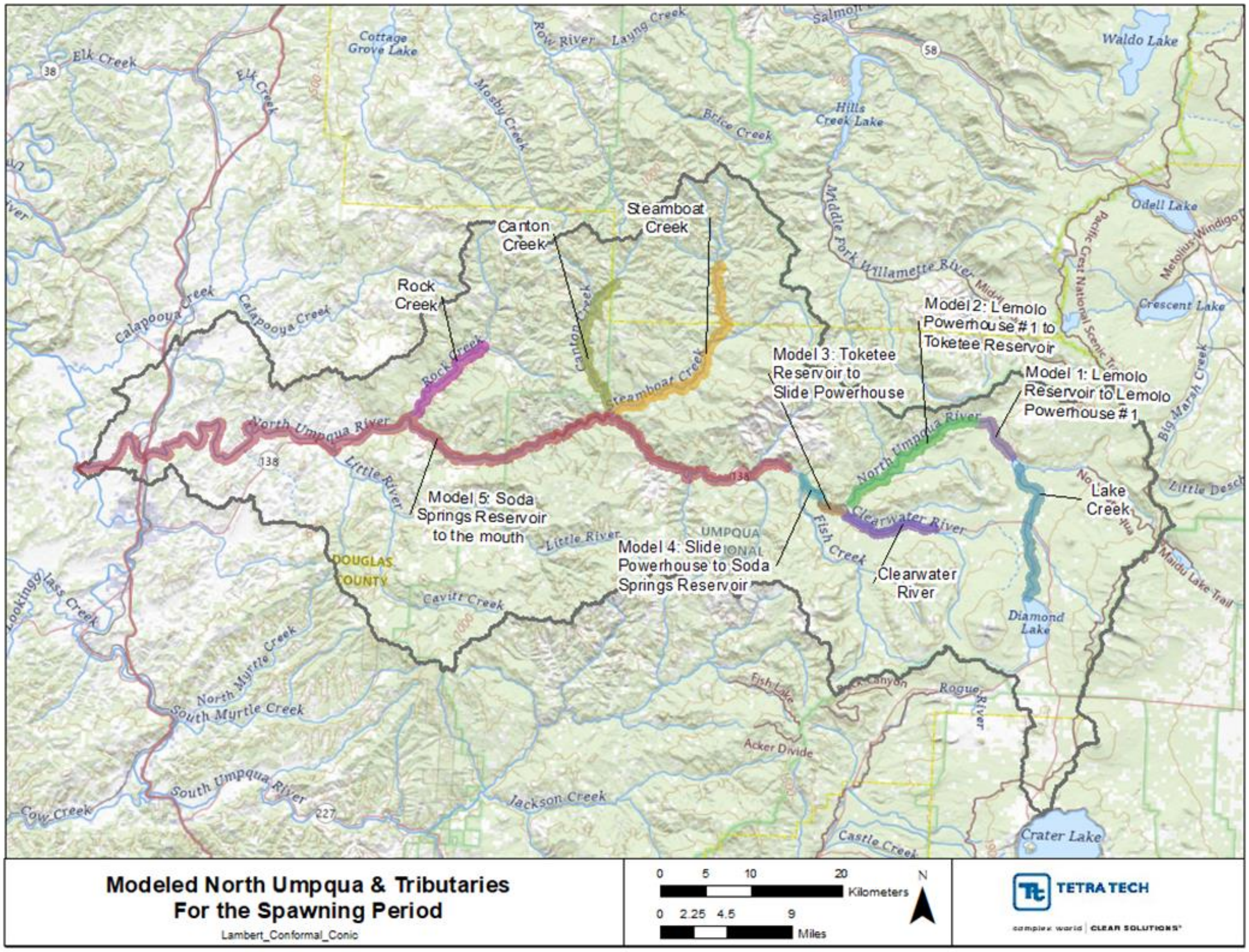

Figure 1-1. North Umpqua River and major tributaries.

2.0 MODEL SCENARIO INTERPRETATION

This section discusses the calculation metrics that were used when evaluating the scenarios.

2.1 SIGNIFICANT DIGITS AND ROUNDING

The TMDL analysis, interpretation of the model results, and all scenarios account for significant digits and rounding. For evaluation of the attainment of the human use allowance (HUA), Oregon Department of Environmental Quality (DEQ) tracks values to the hundredths. Because DEQ is providing some of the HUA allocations out to the hundredths of a degree Celsius, attainment must be tracked in a similar manner. DEQ has a permit related internal management directive (IMD) on rounding and significant digits (DEQ 2013). The TMDL analysis follows the rounding procedures outlined in this IMD. The significant figures IMD says that for “calculated values” (which includes model results), if the digit being dropped is a “5,” it is rounded up. For example, for water withdrawals DEQ is proposing a 0.05 °C HUA allocation. If the model shows warming equal to 0.054 °C it gets rounded down to 0.05 °C and the result is attainment. If the model shows warming equal to 0.055 °C, it gets rounded up to 0.06 °C, and the result is non-attainment.

2.2 CALCULATING THE 7-DAY AVERAGE MAXIMUM TEMPERATURE

For each scenario the 7-day average maximum (7DADM) temperature was calculated using the hourly model output. The 7DADM was calculated using the procedure outlined in DEQ's Temperature IMD (DEQ 2008). As outlined in the document, the 7DADM temperature is calculated by first calculating the daily maximum for each day, followed by calculating a rolling average of the daily maximums, the result for which lands on the 7th day.

2.3 COMPARING TEMPERATURE BETWEEN TWO SCENARIOS

When comparing the hourly results from two model scenarios to determine the temperature changes, the following steps were taken:

1. Calculate the 7DADM temperatures for scenario 1 at every model output for every day during the model period.
2. Calculate the 7DADM temperatures for scenario 2 at every model output for every day during the model period.
3. For allocation scenarios the HUA is based on an increase above the applicable criteria, so for determining the maximum change in temperature, the days when the 7DADM river temperatures do not exceed the applicable biologically based numeric criteria (BBNC) were excluded, which results in 0 difference on the plots when comparing results from two scenarios. The difference between two scenarios is only calculated for each time step when any of the 7DADM of the scenario exceeds the BBNC. This step was necessary to ensure that we only consider the maximum change in temperatures when the river exceeds the BBNC criteria for analysis. Note that the BBNC could vary spatially and temporally. Zero values do not indicate no temperature difference, only that the temperatures are below criteria.
4. Compute the difference between the 7DADM temperatures of scenario 1 and scenario 2 only for days that exceed the BBNC. In this manner at each node a ΔT is computed for every 7DADM temperature from each scenario for each day where the BBNC is exceeded. Finally, the max ΔT for each node location was taken and plotted longitudinally as 7DADM deficit plots.
5. The differences were rounded to the hundredths, based on the adopted rounding procedure discussed in Section 1.1.

Explanation of 7DADM ΔT Plots

Below is an illustration of when the maximum deltas are plotted. As noted above, the temperature difference between any two scenarios is only calculated and shown when one of the two exceeds the BBNC. If at a given point, the 7DADM for both scenarios do not exceed the BBNC, the delta is reflected in the plot as 0. In the example in Figure 2-1, the CCC Scenario remains below the BBNC until just downstream of Copeland Creek (top plot) and the No Dams scenario remains below the BBNC until downstream of Fox Creek (middle plot). While there is an actual difference in the 7DADM between these two scenarios, no delta is calculated for TMDL purposes until the 7DADM for one or both scenarios exceeds the BBNC. In this example, a gray line in the bottom plot shows the delta prior to the 7DADMs for either scenario exceeding the BBNC. Then, once the BBNC is exceeded in the CCC scenario (just downstream of Copeland Creek), the deltas are calculated and shown as a blue line in the bottom plot. Although there is an apparent jump in the delta from 0 to 2.5 ˚C downstream of Copeland Creek, as shown with the blue line, this does not reflect an actual sudden difference in temperatures between the two scenarios, just the beginning of accounting for the differences. While the gray line is shown in this example to illustrate the continuous nature of the deltas, it does not appear in subsequent plots throughout this document.

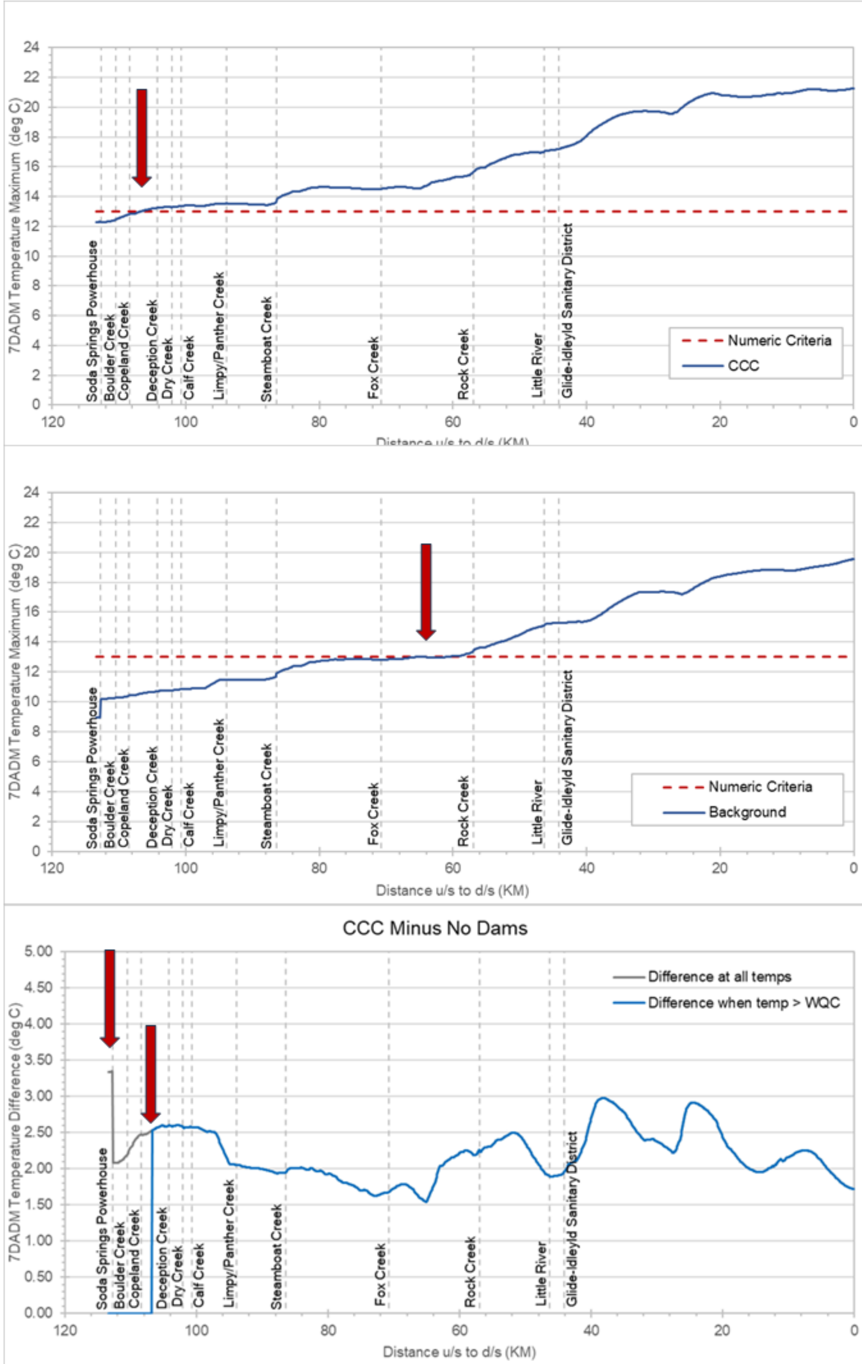

Figure 2-1.Illustration of how 7DADM deltas are displayed

2.4 BIOLOGICALLY BASED NUMERIC CRITERIA

The BBNC values could vary spatially and temporally and are evaluated based on the 7DADM. The BBNC values for streams are shown from Figure 2-2 to Figure 2-13 for the summer period. The summer models are used to evaluate the scenarios against the year-round criteria and referred to as the summer BBNC in this memo.

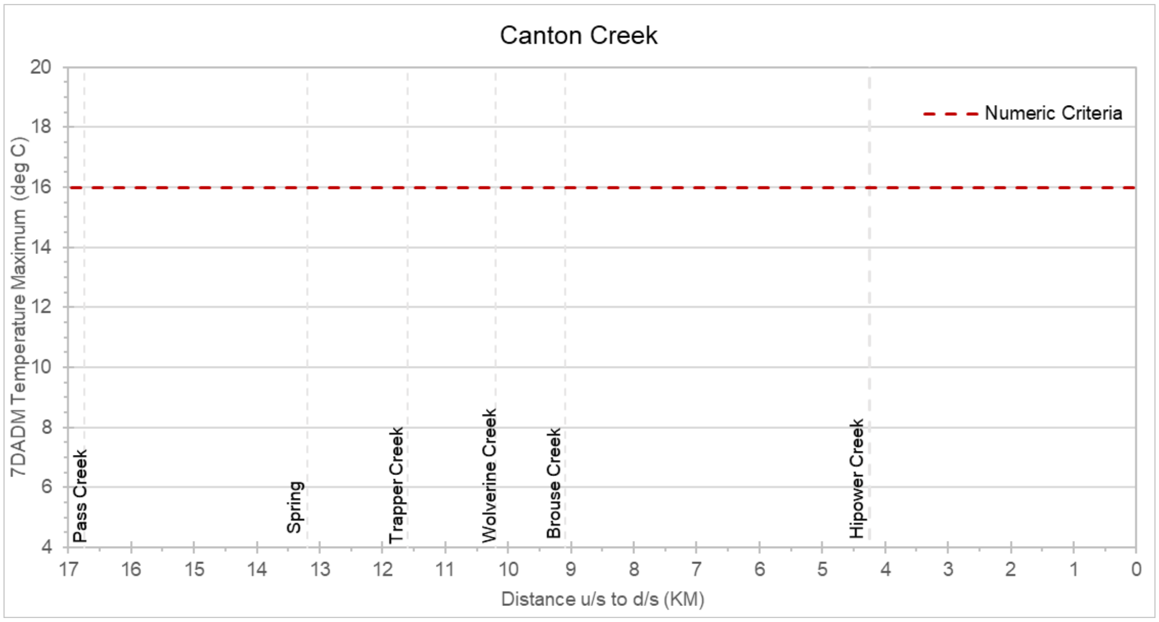

Figure 2-2. Summer Period BBNC for Canton Creek

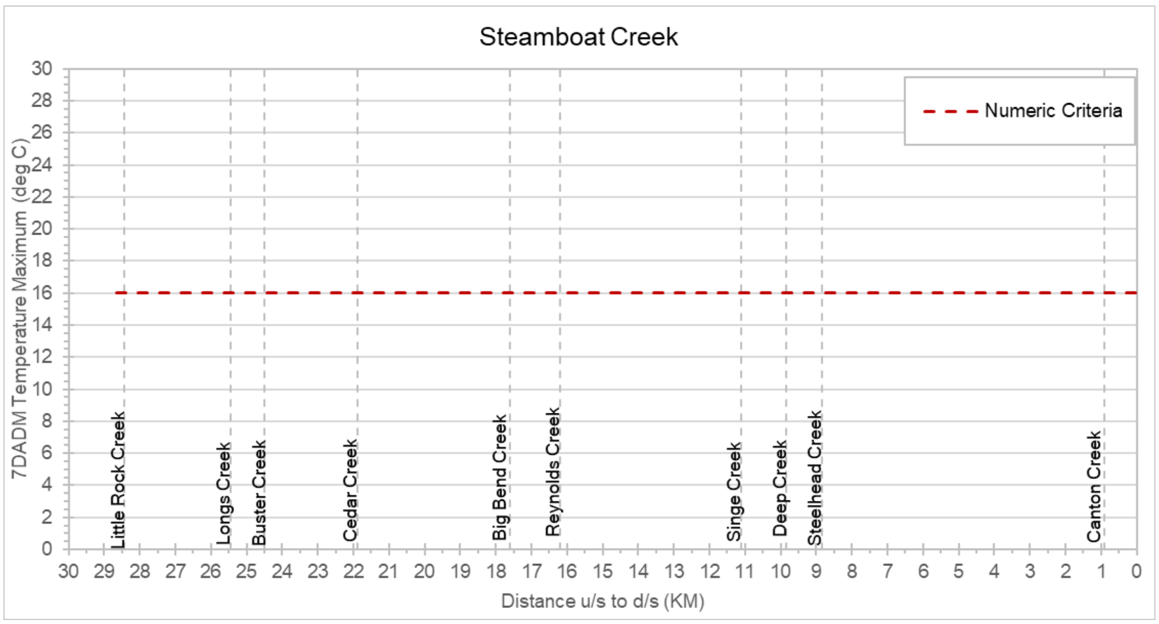

Figure 2-3. Summer Period BBNC for Steamboat Creek

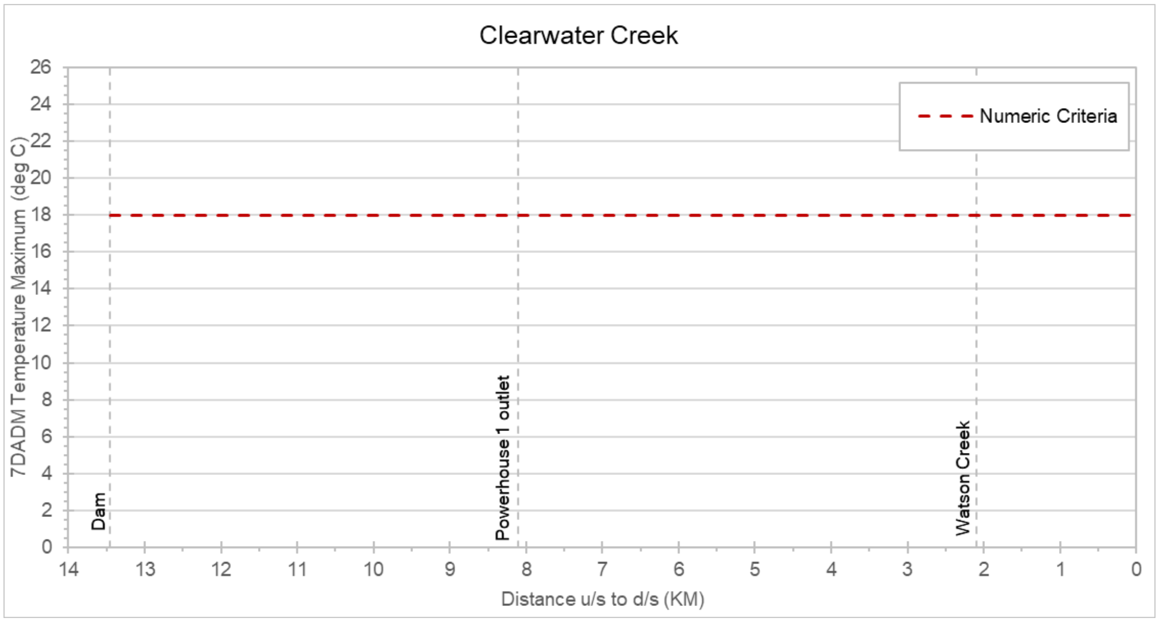

Figure 2-4. Summer Period BBNC for Clearwater Creek

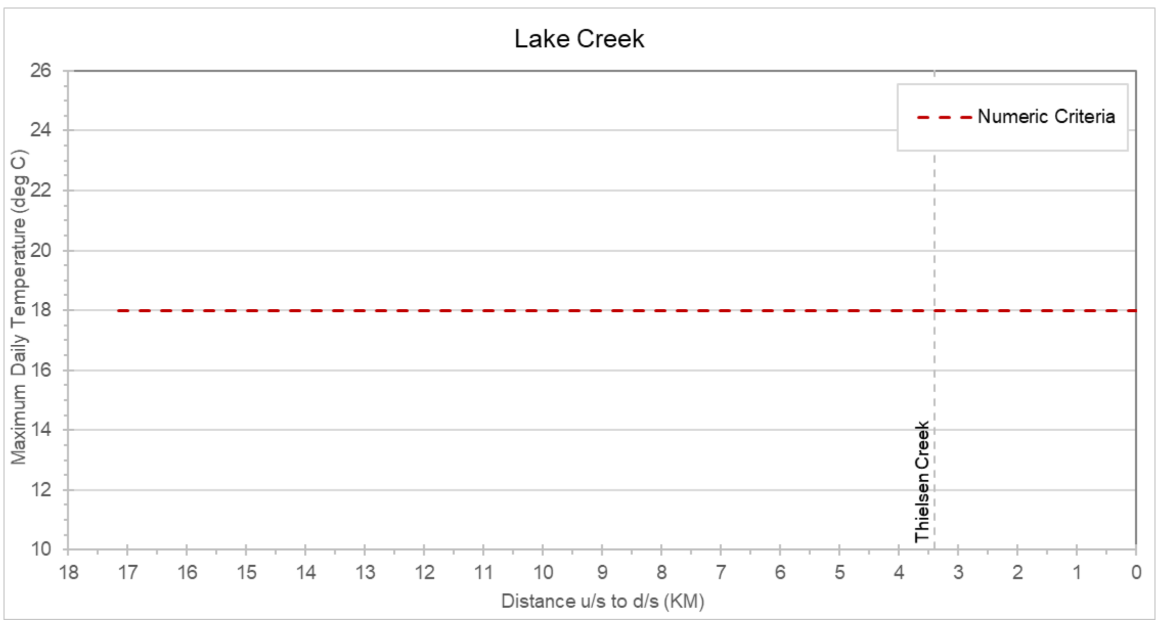

Figure 2-5. Summer Period BBNC for Lake Creek

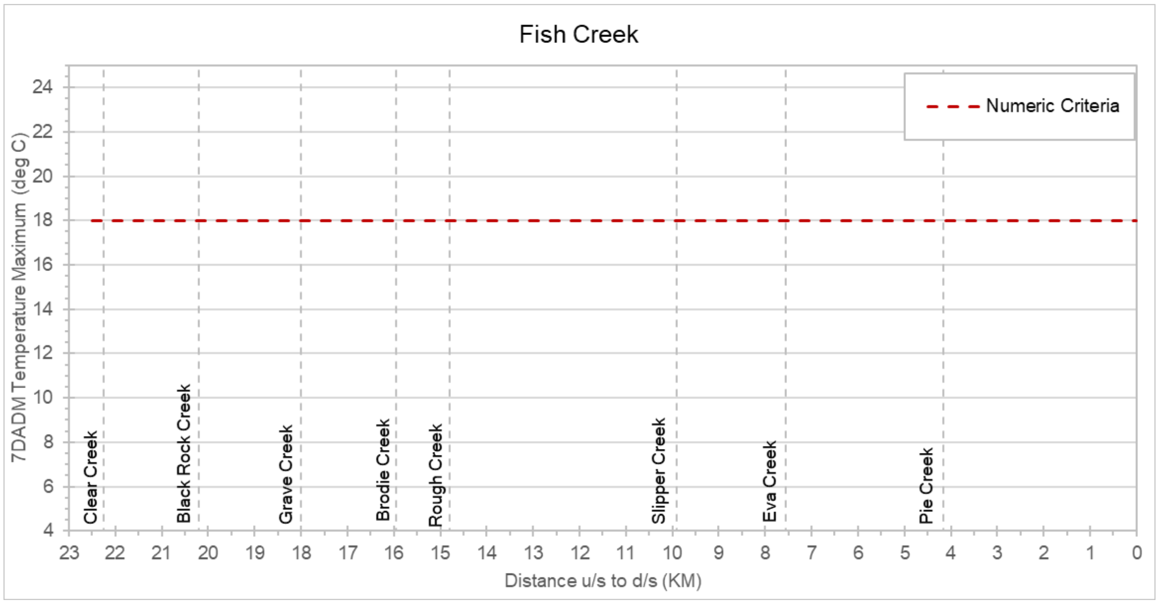

Figure 2-6. Summer Period BBNC for Fish Creek

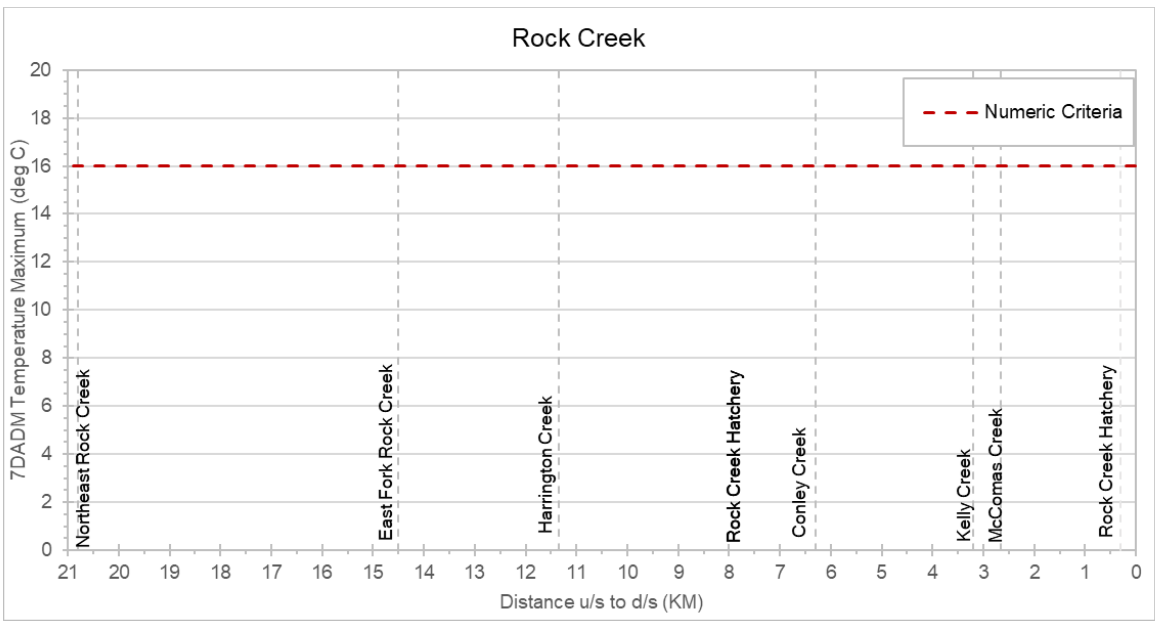

Figure 2-7. Summer Period BBNC for Rock Creek

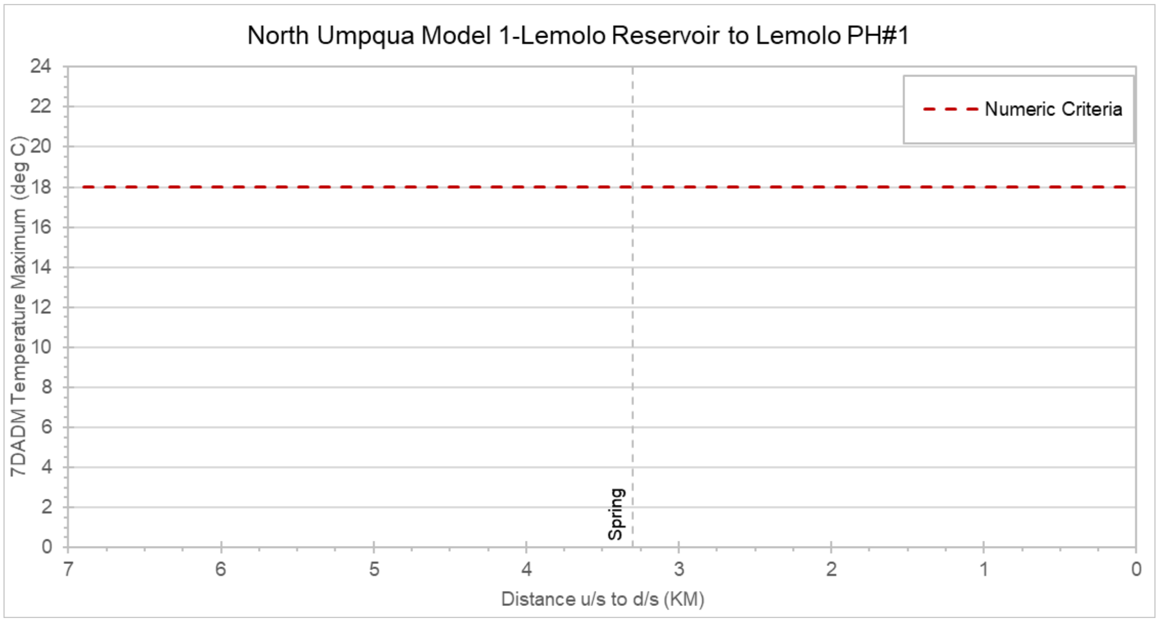

Figure 2-8. Summer Period BBNC for North Umpqua River Model 1 from Lemolo Reservoir to Lemolo PH#1

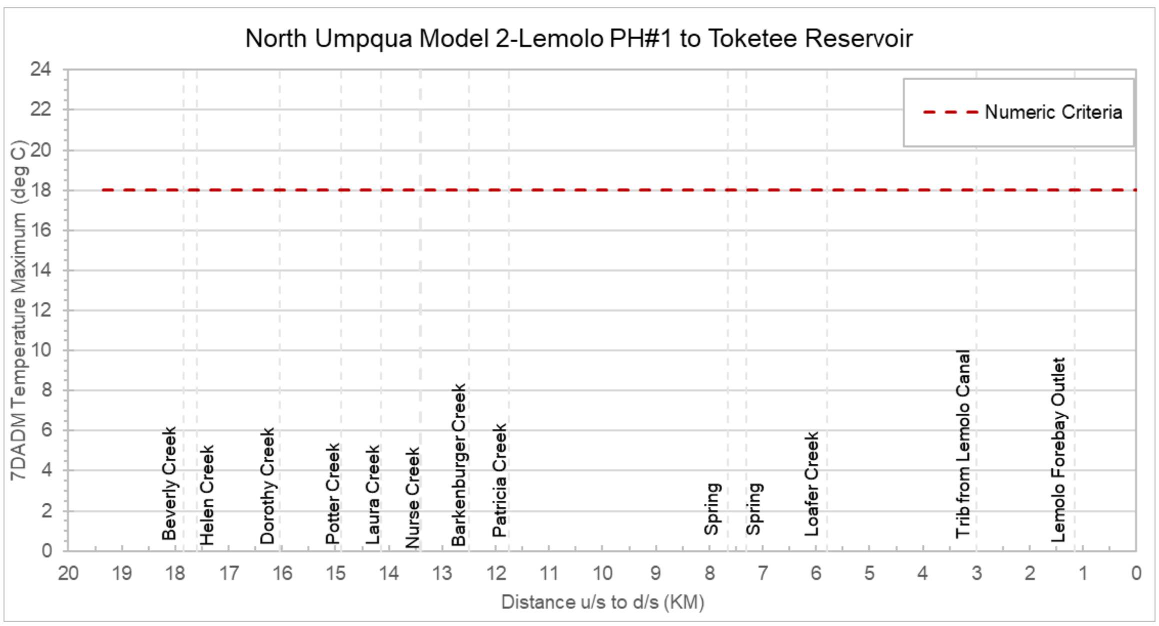

Figure 2-9. Summer Period BBNC for North Umpqua River Model 2 from Lemolo PH#1 to Toketee Reservoir

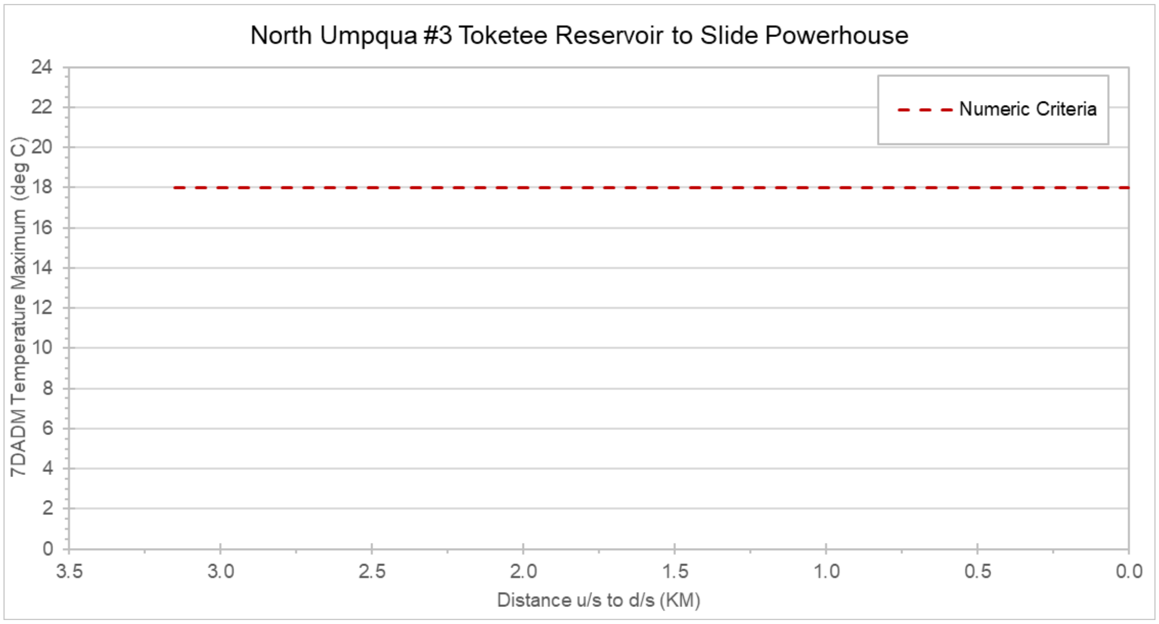

Figure 2-10. Summer Period BBNC for North Umpqua River Model 3 from Toketee Reservoir to Slide Powerhouse

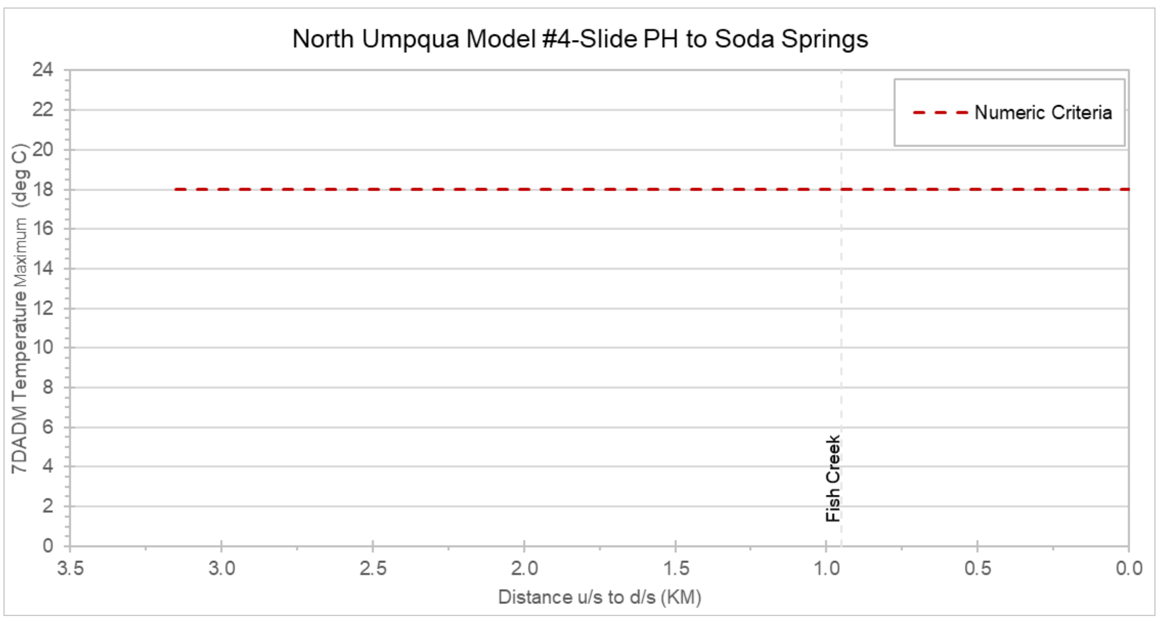

Figure 2-11. Summer Period BBNC for North Umpqua River Model 4 from Slide Powerhouse to Soda Springs Reservoir

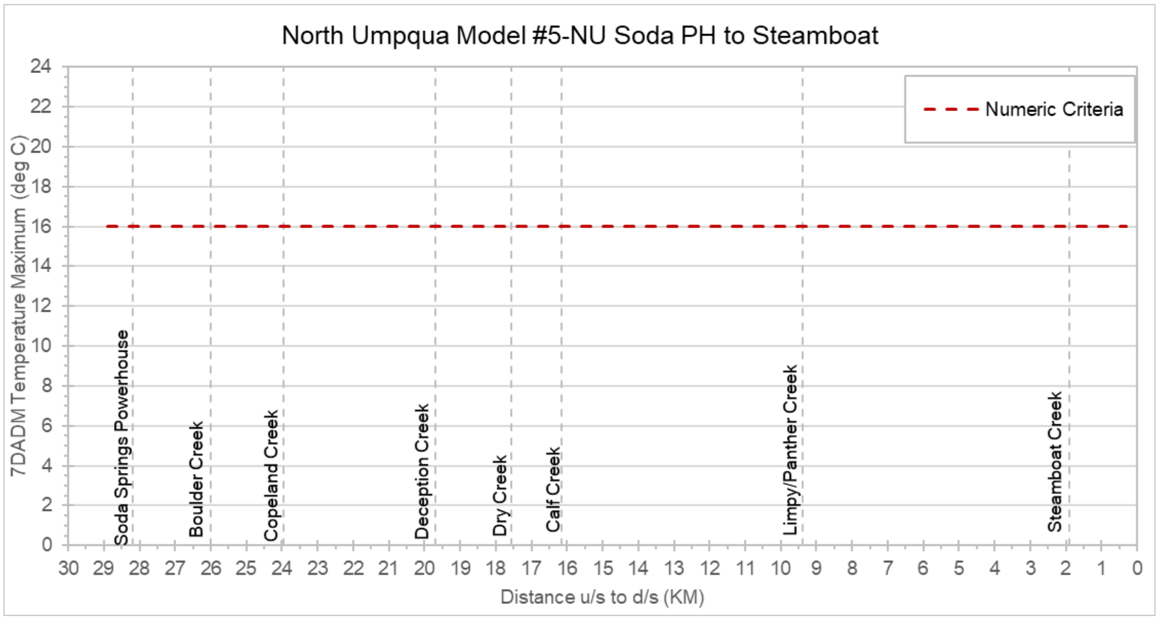

Figure 2-12. Summer Period BBNC for North Umpqua River Model 5 from Soda Springs Reservoir to Steamboat Creek

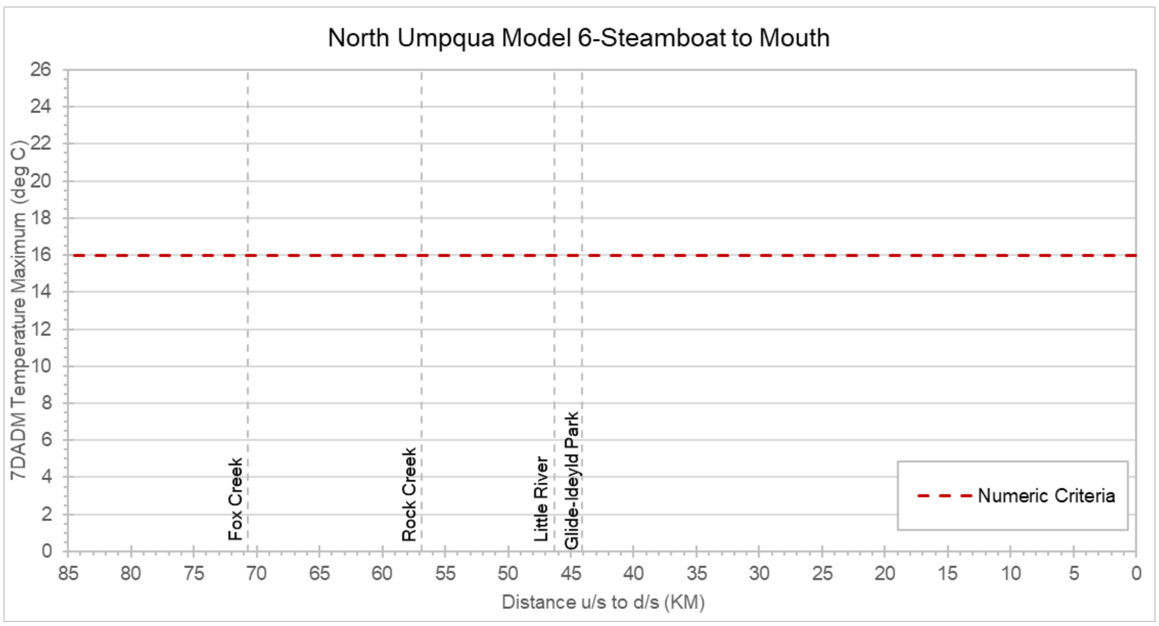

Figure 2-13. Summer Period BBNC for North Umpqua River Model 6 from Steamboat Creek to Mouth

The spawning period criteria only applies to Canton Creek, Steamboat Creek, Rock Creek, and North Umpqua River from Soda Springs Powerhouse to the mouth. The spawning period is either from September 1 to May 15 or from September 1 to June 15. The BBNC values for these streams are shown from Figure 2-14 to Figure 2-17 for the spawning period.

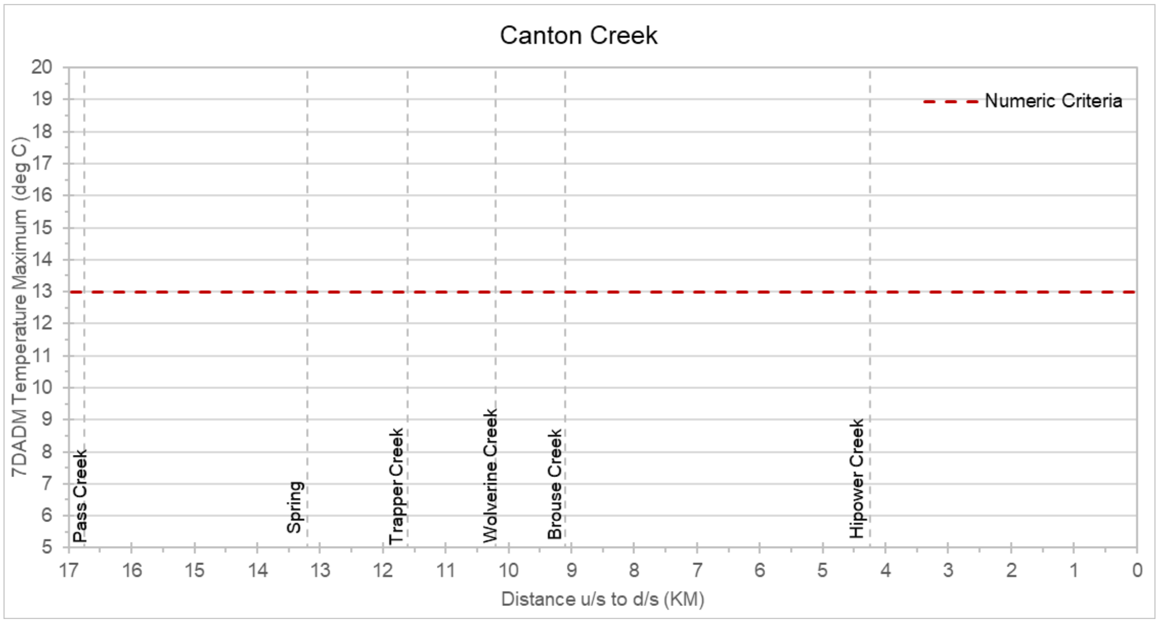

Figure 2-14. Spawning Period BBNC for Canton Creek

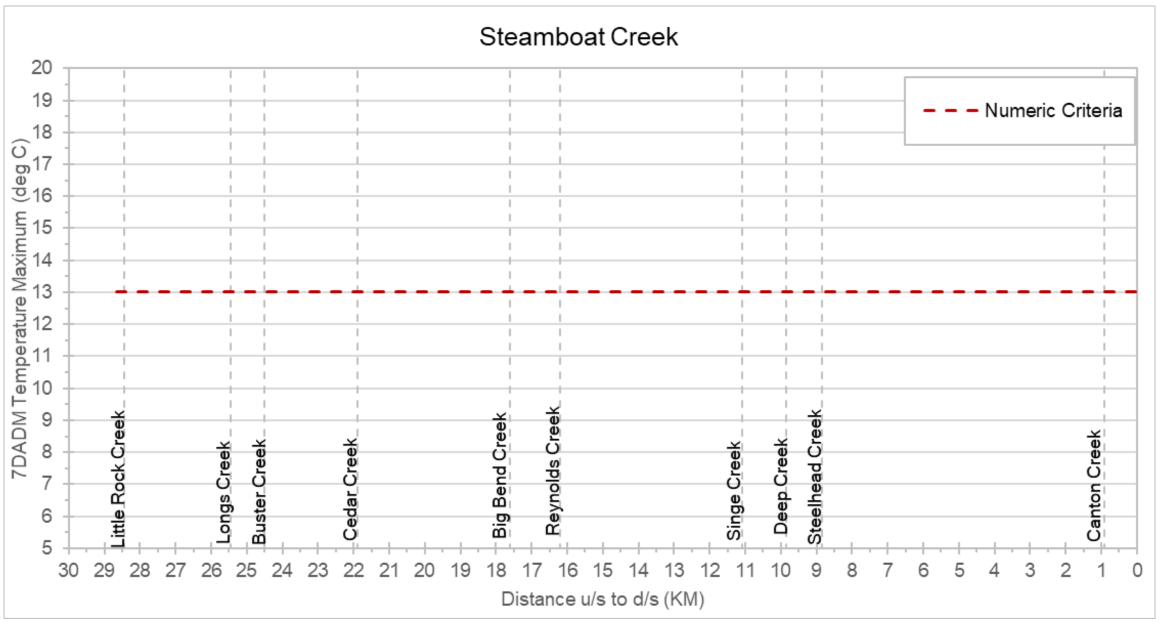

Figure 2-15. Spawning Period BBNC for Steamboat Creek

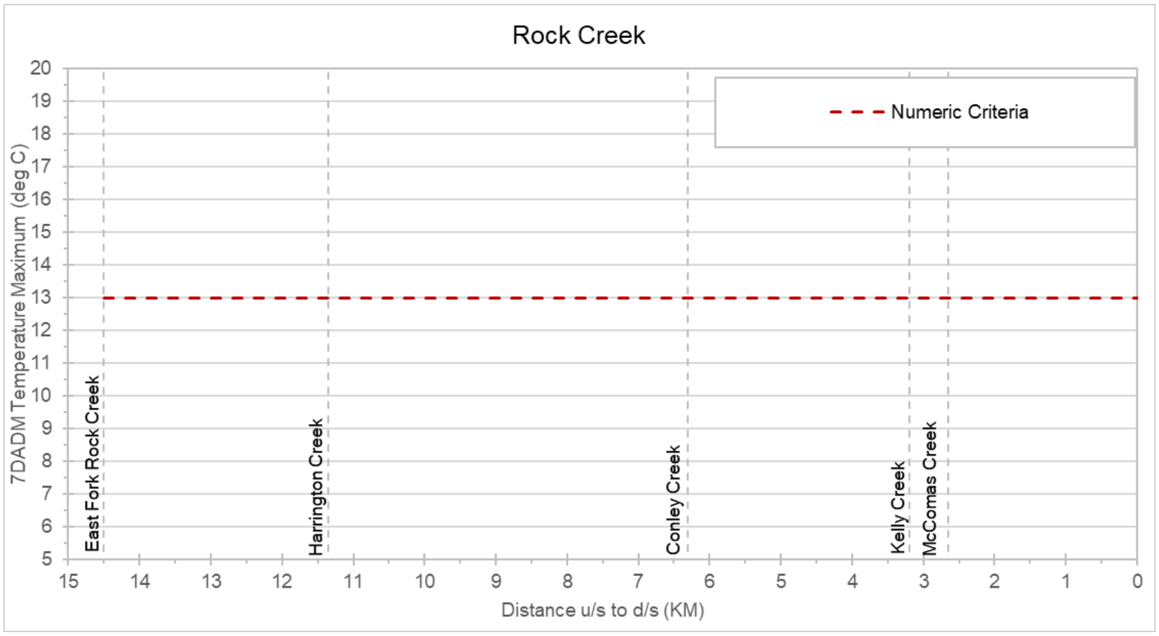

Figure 2-16. Spawning Period BBNC for Rock Creek

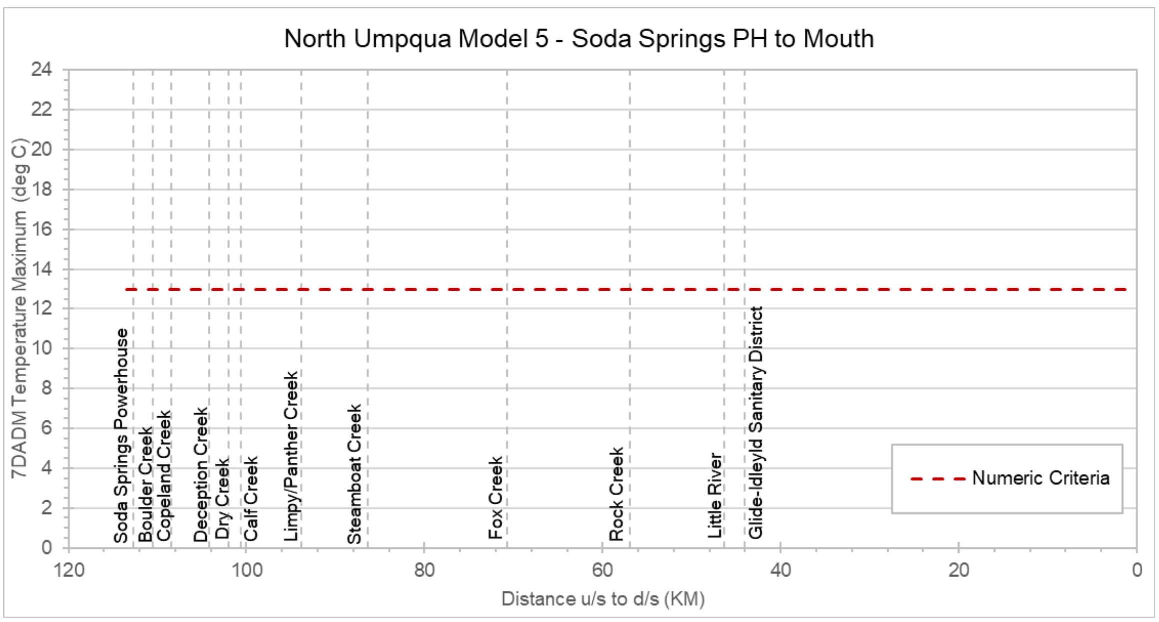

Figure 2-17. Spawning Period BBNC for North Umpqua River from Soda Springs Powerhouse to the Mouth

3.0 DEFINITIONS OF SCENARIOS

A model is usually used for scenario simulation only after it is calibrated against observed conditions. The calibration condition of the models represents the existing vegetation conditions, flow and temperature inputs as well as the existing discharges from point sources corresponding to the simulation period used to configure the model. This section describes the detailed scenarios, and a summary of the scenarios is provided in Table 3-1.

1. Calibrated Current Condition (CCC) scenario

The CCC scenario uses the existing vegetation conditions, flow and temperature inputs from upstream/headwater and tributaries as well as withdrawals. The only difference is that if a model includes point sources, the latest available flow and temperature from the point sources will be used to replace the flow and temperature from the point sources that were used for model calibration. Due to the limitation of data availability, the time period for the latest available flow and temperature from different point source may not be the same. For models without point sources, the CCC scenario is essentially identical to the calibration condition.

2. No point sources scenario

For models with point sources, the no point sources scenario removes the point sources from the CCC models. All other conditions remain the same as the CCC models.

3. Point source WLA scenario

For models with point sources, the point source WLA scenario replaces the water temperature of the effluent in the CCC scenario with the calculated WLA temperatures for the TMDL. All other conditions remain the same as the CCC scenarios. The calculated WLA temperatures consider the river flow rate, water temperature criteria, effluent rate, and an allocated HUA.

4. Fully restored vegetation scenario

The fully restored vegetation scenario uses the fully restored vegetation condition while all other conditions remain the same as in the CCC models. Therefore, if a model includes point sources, the fully restored vegetation scenario also includes the point sources as in the CCC models.

5. Background scenario

The background scenario uses the fully restored vegetation as the vegetation condition and removes all point sources in the model, if the model includes point sources. For the models without point sources, the background scenario is equivalent to the fully restored vegetation scenario.

6. Attainment scenario

The attainment scenario uses the fully restored vegetation condition and the WLA temperatures from the point sources if the model includes point sources. All other conditions such as the flow and temperature from headwater/upstream and tributaries and withdrawals remain the same. The attainment scenario is only valid for the models with point sources. For the attainment scenario, if the 7DADM increase in temperature caused by the assigned point source WLA temperatures from DEQ's calculation is higher than the HUA of 0.3 ^{o}C, the WLA temperatures need to be adjusted until the increase in temperature meets the HUA of 0.3 ^{o}C.

7. Fully restored vegetation with natural flow scenario

This scenario uses the fully restored vegetation as the vegetation condition. It also uses natural flow from the headwater/upstream and tributaries. If there are dams located above the headwater of the model, the natural flow reflects a condition where the dam is removed. All withdrawals are removed from the models, and point sources are also removed, if the model includes point sources.

In addition to these scenarios that support the TMDL development, additional scenarios were run to gain insights into model responses to factors such as tributary and headwater temperature inputs. Two more scenarios were run:

8. Tributary/headwater plus 0.1 ^{o}C scenario

This scenario adds 0.1 °C to all the tributaries and headwater/upstream inflows. All other conditions are identical to the background scenario.

9. Fully restored vegetation with point source WLA and Tributary/headwater plus 0.1 °C scenario

This scenario uses fully restored vegetation as the vegetation condition. If the model includes point sources, this scenario uses the WLA temperatures for these point sources. In addition, the temperatures in all the tributaries and headwater/upstream inflows are increased by 0.1 °C.

Table 3-1. North Umpqua River scenarios descriptive summaries

Scenario number	Scenario name	Equivalent to CCC except:
1	Calibrated Current Condition (CCC) scenario	Identical to the calibration condition except most recent flow and temperature used for any modeled point sources
2	No point sources scenario	Point sources removed from CCC models
3	Point source WLA scenario	The water temperature of the effluent in the CCC scenario is replaced with the calculated WLA temperatures
4	Fully restored vegetation scenario	Vegetation is fully restored
5	Background scenario	Vegetation is fully restored and all point sources removed
6	Attainment scenario	Vegetation is fully restored and point sources use WLA temperatures
7	Fully restored vegetation with natural flow scenario	Vegetation is fully restored and uses natural upstream flow (i.e., all dams, withdrawals, and point sources removed)
8	Tributary/headwater plus 0.1 °C scenario	0.1 °C added to all tributaries and headwater/upstream inflows and all other conditions identical to background scenario
9	Fully restored vegetation with point source WLA and Tributary/headwater plus 0.1 °C scenario	Vegetation is fully restored, point sources use WLA temperatures, and 0.1 °C added to all tributaries and headwater/upstream inflows

As noted previously, the calibrated models were run to evaluate the scenarios specific to the waterbody. The North Umpqua River is broken up into a series of riverine models below impoundments, and each individual model was run standalone for scenario evaluation. An exception to this is the No Dams scenario condition, where all the North Umpqua models were linked with each other and run sequentially with outputs from the upstream model serving as inputs to the next downstream model. The No Dams scenarios are described in an Appendix to this document.

After running the scenarios where they apply, scenario pairings were compared to evaluate the impacts of specific sources and conditions. The comparisons and evaluations follow the order in the list below. A summary of the scenario comparisons is also provided in Table 3-2.

1. Impacts of current condition vegetation (shade loss) (Rock Creek, North Umpqua #6 (summer), and North Umpqua #5 (spawning))
   - ✓ No Point Source minus background
2. Impact of current point source and current vegetation (shade loss) (All models)
   - ✓ CCC minus background
3. Impact from point source @ current condition (Rock Creek, North Umpqua #6 (summer), and North Umpqua #5 (spawning))

- ✓ CCC minus no point source

4. Impact from point sources @ WLA conditions (Rock Creek, North Umpqua #6 (summer), and North Umpqua #5 (spawning))
   - ✓ Point Source WLA minus No point source
5. Impact current point source and restored vegetation (Rock Creek, North Umpqua #6 (summer), and North Umpqua #5 (spawning))
   - ✓ Fully restored veg with point source @ current condition minus background
6. Impact point source @ WLA and restored vegetation (Rock Creek, North Umpqua #6 (summer), and North Umpqua #5 (spawning))
   - ✓ Fully restored veg with point source @ WLA minus background
7. Difference between background temperatures and criteria (All models)
   - ✓ Background minus Criteria
8. No Dams, impact of removing dams upstream (Spawning models for North Umpqua models 1 to 5)
   - ✓ CCC minus no dams
   - ✓ Following scenarios were evaluated only for North Umpqua Model 5
     - ✓ No Dams Background minus Criteria
     - ✓ PacifiCorp allocation: [Soda Spring No Dams Fully Restored Vegetation + 0.3 °C] minus [No Dams Fully Restored Vegetation]
     - ✓ Total Attainment: [Soda Spring No Dams Fully Restored Vegetation + 0.3 °C; Rock Creek + 0.3 °C; Glide-Idleyld at WLA minus [No Dams Fully Restored Vegetation]
9. Natural Flows (Summer models for North Umpqua 1 through 6, Clearwater Creek and Fish Creek)
   - ✓ Background minus fully restored vegetation with natural flows

It should be noted that not all creeks and rivers have all these comparisons. For the models without point sources, the point source related comparisons are not available.

The No Dams impacts are quite different from other scenarios and comparisons because the No Dams scenarios and comparisons involves developing Heat Source Models for the three impoundments with the assumptions that the dams are removed, and the impoundments become channels. These scenarios required the North Umpqua models to be run as a linked model, where in the output from the last segment of one model was then used as the upstream boundary of the next model downstream. The descriptions of No Dam model development, scenarios, and comparisons are in an Appendix to this document.

In addition to these 9 comparisons, additional comparisons requested by EPA are listed below:

A1. General permit evaluation in upper North Umpqua adding 0.1, 0.2, & 0.3 ^{o}C
A2. Tributary + 0.1 ^{o}C scenarios
A3. Cumulative impact of attainment and additional tributary impacts
- ✓ Restored vegetation + point source WLA + tributaries/headwater 0.1 °C minus background.

Comparisons A1 and A2 apply in the North Umpqua models. Comparison A3 only applies in the South Umpqua and Umpqua models but is itemized here for consistency.

The scenario results for the spawning period were evaluated from September 1, 2009 to October 15,2009 if there are spawning period criteria for a stream. If the spawning period criteria do not apply to a stream, then the model results from August 1, 2009 to October 15, 2009 together with the year round criteria were used to compare the scenarios.

Table 3-2. North Umpqua River comparisons descriptive summaries

Comparison number	Scenario 1	Scenario 2	Question/Topic Addressed
1[a]	No Point Source	Background	Impacts of current condition vegetation (shade loss). Temperature difference between the existing vegetation conditions and fully restored vegetation condition.
2[b]	CCC	Background	Impact of current point sources and current vegetation (shade loss). Temperature difference between the existing vegetation and point source conditions and the fully restored vegetation condition without point sources.
3[b]	CCC	No Point Source	Impact from point sources at current conditions. Temperature difference between the existing point sources and no point sources.
4[a]	Point Source WLA	No Point Source	Impact from point sources at WLA conditions. Temperature difference between the WLA discharges and no point sources.
5[a]	Fully restored vegetation with point sources at current conditions	Background	Impact from current point sources and restored vegetation. Temperature difference between fully restored vegetation at current conditions with point sources and fully restored vegetation conditions without point sources.
6[a]	Attainment Scenario: Fully restored vegetation with point source at WLA conditions	Background	Impact from point sources at WLA and restored vegetation. Temperature difference between fully restored vegetation with WLAs and fully restored vegetation without point sources.
7[b]	Background	Criteria	Difference between background conditions and criteria temperautres.
8[c]	CCC	No dams	Impact of removing upstream dams.
9[d]	Background	Fully restored vegetation with natural flows	Impact of natural flows. Temperature difference between current flows and natural flows.
A1[e]	General permit evaluation in upper North Umpqua adding 0.1, 0.2, & 0.3 °C	Background	Impacts of general permits on water temperature
A2[f]	Tributary/Headwater + 0.1°C	Background	Impacts of hypothetical tributary/headwater inputs on water temperature
A3	Restored vegetation + point source WLA + tributary + 0.1 °C	Background	Impact of the cumulative effect of the Restored Vegetation with Point Source WLA and hypothetical Tributary/Headwater increase of 0.1 ˚C

[a] Applies to Rock Creek, North Umpqua #6 (summer), North Umpqua #5 (spawning)
[b] Applies to all models
[c] Applies to North Umpqua River spawning period only.
[d] Applies to the following summer model: Clearwater Creek, Fish Creek, North Umpqua (Models 1 through 6)
[e] Applies to only North Umpqua Model 5 summer model (Soda Springs Reservoir to Steamboat Creek).
[f] Applies to Canton Creek (summer/spawning), Steamboat Creek (summer/spawning), Rock Creek(summer/spawning), and North Umpqua Model 6 (summer),North Umpqua 5 (spawning)

4.0 CANTON CREEK

The model domain for Canton Creek is shown in Figure 4-1. Canton Creek was modeled for both the summer period (July 12-31, 2002) and the spawning period models (August 1, 2009 to October 15, 2009). The summer period scenario results and scenario comparisons are presented in sections 4.1 and 4.2 while the spawning period scenario results and scenario comparisons are presented in sections 4.3 and 4.4.

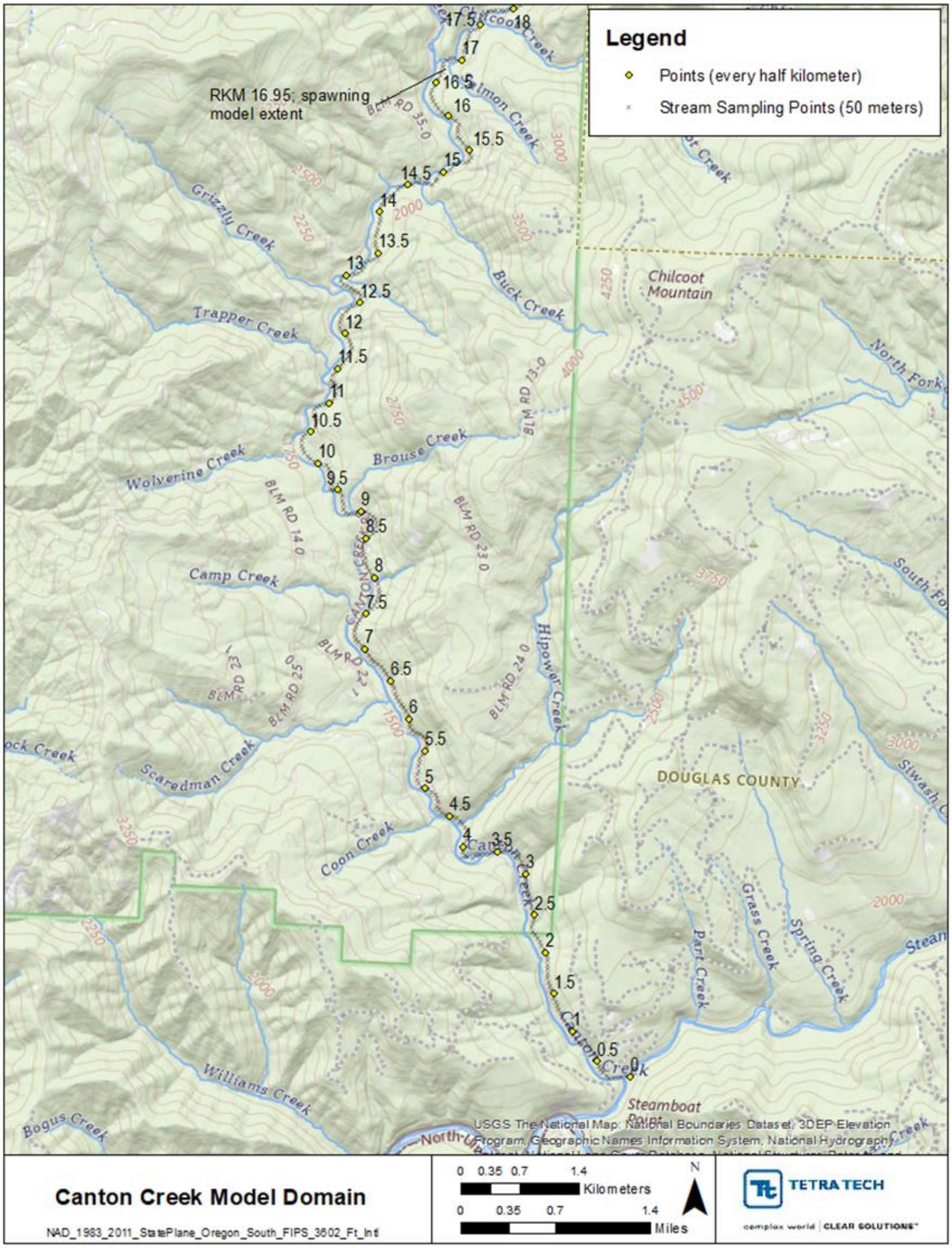

Figure 4-1. Canton Creek model domain.

4.1 CANTON CREEK SUMMER PERIOD SCENARIO RESULTS

The Canton Creek HS summer model does not include any point sources. The scenarios that are relevant to Canton Creek include the CCC scenario, which is identical to the No Point Source scenario; Background scenario; and the tributary/headwater plus 0.1 ºC scenario. The 7DADM results of these scenarios are shown in Figure 4-2 through Figure 4-4.

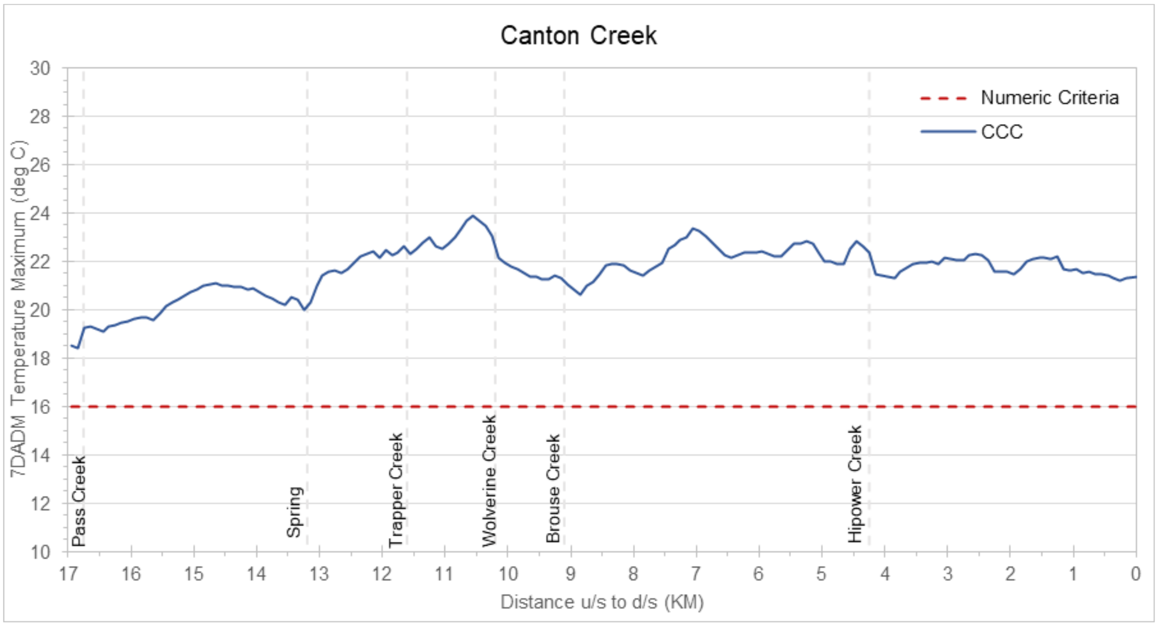

Figure 4-2. The maximum 7DADM temperature results along Canton Creek (summer period) for the No Point Source scenario.

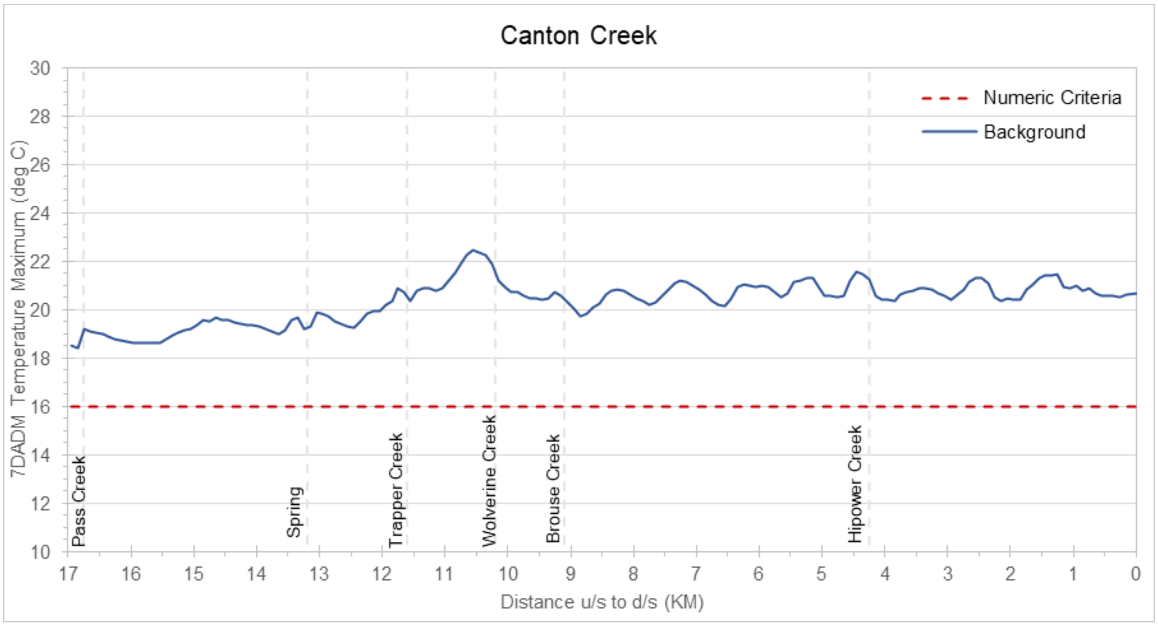

Figure 4-3. The maximum 7DADM temperature results along Canton Creek (summer period) for the Background scenario.

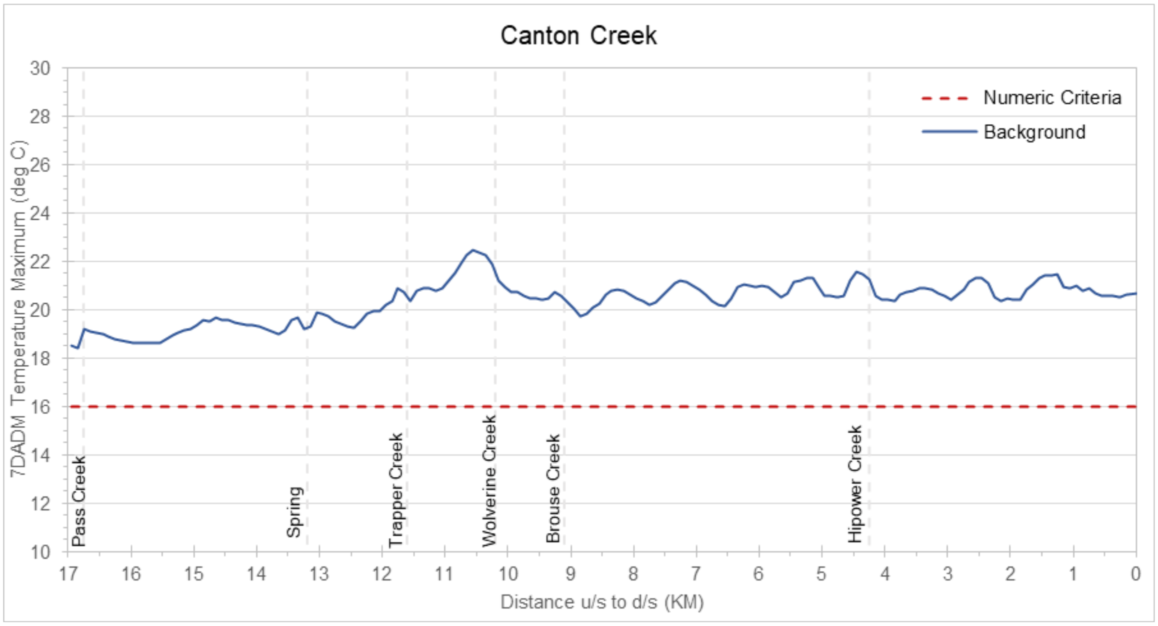

Figure 4-4. The maximum 7DADM temperature results along Canton Creek (summer period) for the Tributary/Headwater plus 0.1°C scenario.

4.2 CANTON CREEK SUMMER PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the Canton Creek summer period include:

2. Impact of current point source and current vegetation (note there are no point sources in Canton Creek, equivalent to Comparison 1. Impact of shade loss)
    - ✓ CCC minus background
7. Difference between background and criteria
    - ✓ Background minus Criteria

A2. Impact of tributary scenario (tributary/headwater plus 0.1 ^{o}C)
- ✓ Tributary plus 0.1 ^{o}C minus background

Figure 4-5 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There are no point sources in the Canton Creek model. Therefore, the CCC scenario is equivalent to the no point source scenario. In this memo, the CCC scenario was used to compare against the Background scenario to assess the impact of shade loss for all the streams without point sources The overall 7DADM temperature differences increase in the downstream direction. The maximum delta reaches 2.70 ˚C at the river kilometer (RKM) 12.45 on July 18, 2002 (Table 4-1).

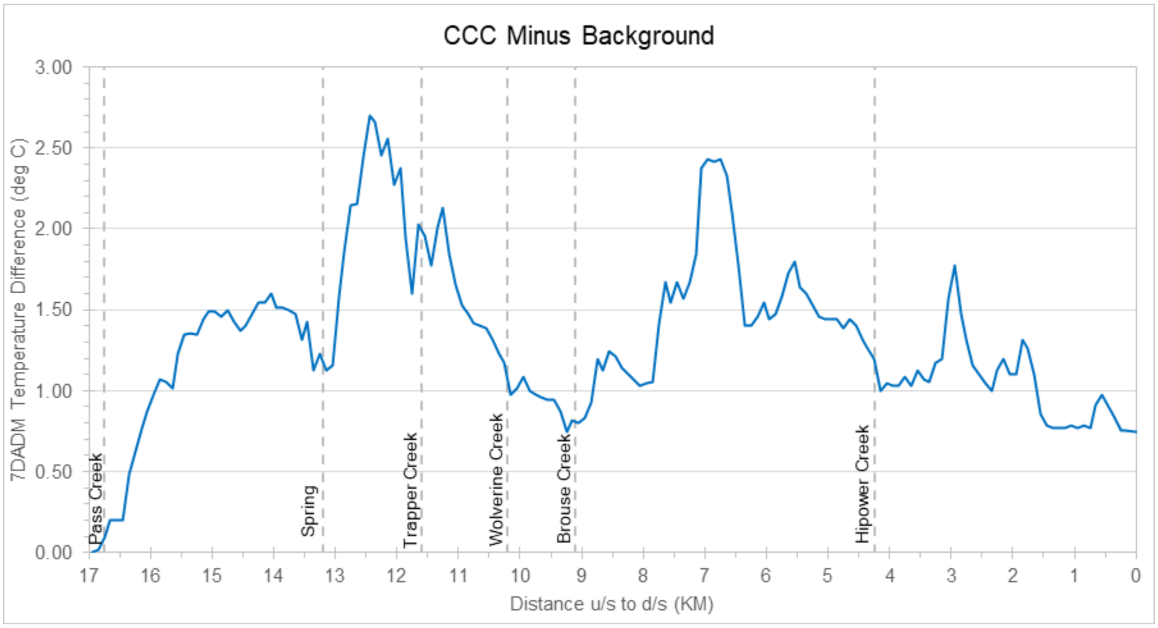

Figure 4-5. The maximum 7DADM temperature differences along Canton Creek (summer period) for the impacts of current point sources and shade loss.

Table 4-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Canton Creek summer period

Canton Creek	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	12.45	2.70	7/18/2002

Figure 4-6 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 6.49 ˚C at RKM 10.55 on July 18, 2002 (Table 4-2).

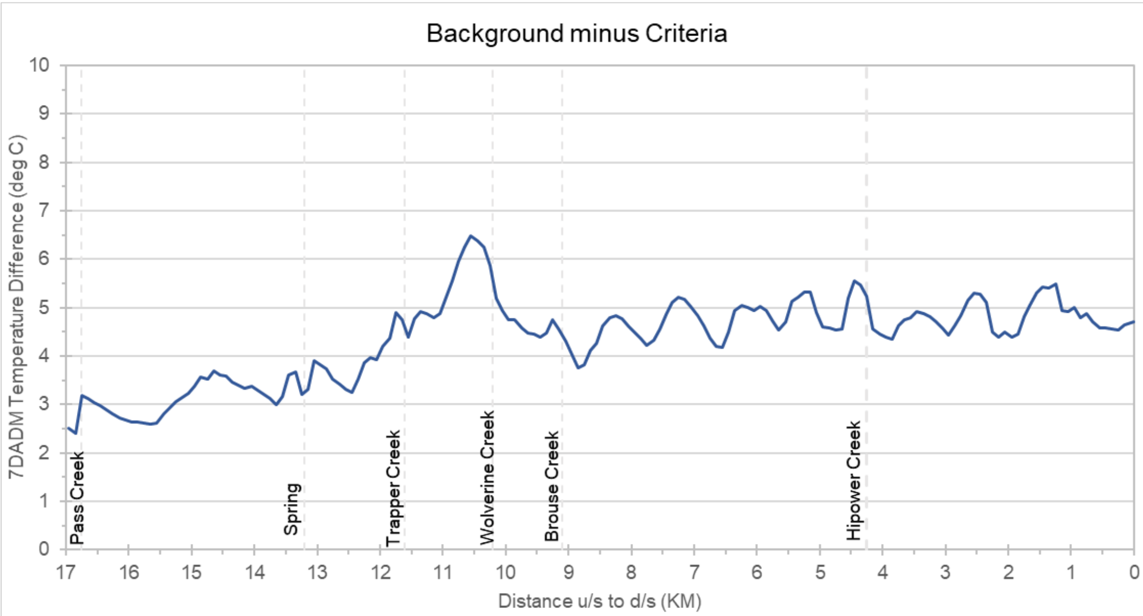

Figure 4-6. The maximum 7DADM temperature differences along Canton Creek (summer period) for the difference between background conditions and criteria temperatures.

Table 4-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Canton Creek summer period

Canton Creek	RKM	Maximum Delta	Date when maximum delta occurs
Background minus Criteria	10.55	6.49	7/18/2002

Figure 4-7 shows the results of comparison A2, the impact of adding 0.1 ºC to all the tributaries and headwater/upstream inflows in the background scenario, which is the 7DADM temperature difference between A2 and the Background scenario and criteria. The overall 7DADM temperature differences increase to 0.1 ºC and then starts decreasing in the downstream direction. The maximum delta immediately reaches 0.1 ºC at the upstream and stays at 0.1 ºC for several RKM downstream (Table 4-3). Since the 0.1 ºC delta occurs for several days, each individual date and RKM are not listed as they can be seen in the Figure 4-7.

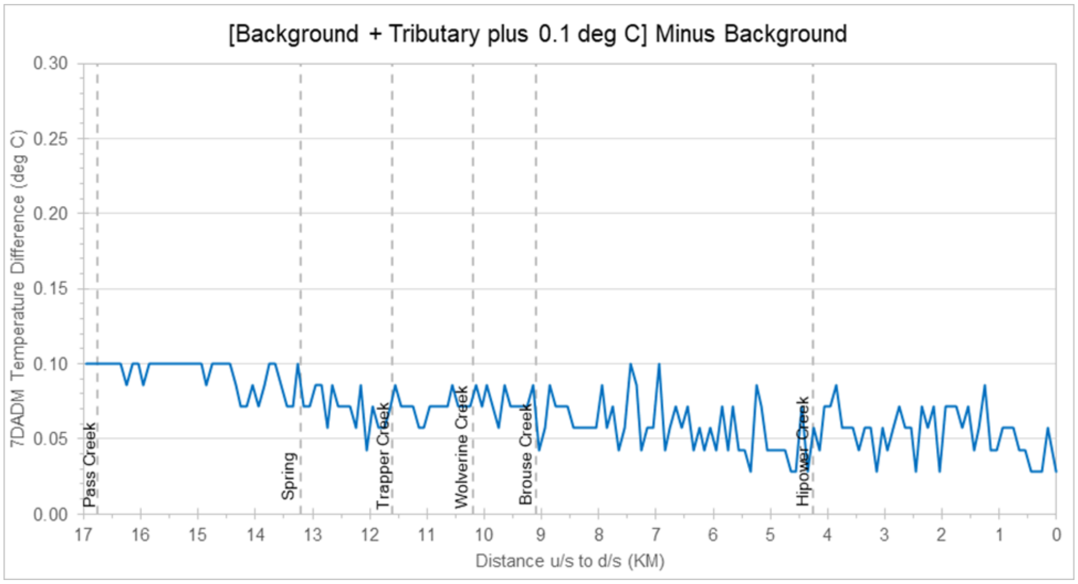

Figure 4-7. The maximum 7DADM temperature differences along Canton Creek (summer period) for the impacts of adding 0.1°C to the Tributary/Headwater.

Table 4-3. Location and date of maximum delta when temperatures are greater than criterion for comparison A2 for the Canton Creek summer period

Canton Creek	RKM	Maximum Delta	Date when maximum delta occurs
[Background + Tributary plus 0.1 deg C] Minus Background	N/A	0.10	N/A

4.3 CANTON CREEK SPAWNING PERIOD SCENARIO RESULTS

The Canton Creek HS spawning period model does not include any point sources. The scenarios that are relevant to the Canton Creek spawning period include the CCC scenario, which is identical to the No Point Source scenario, Background scenario, and the tributary/headwater plus 0.1 ºC scenario. The 7DADM results of these scenarios are shown in Figure 4-8 and Figure 4-10. The spawning criteria applies to Canton Creek and was evaluated for the period from September 1 to October 15, 2009.

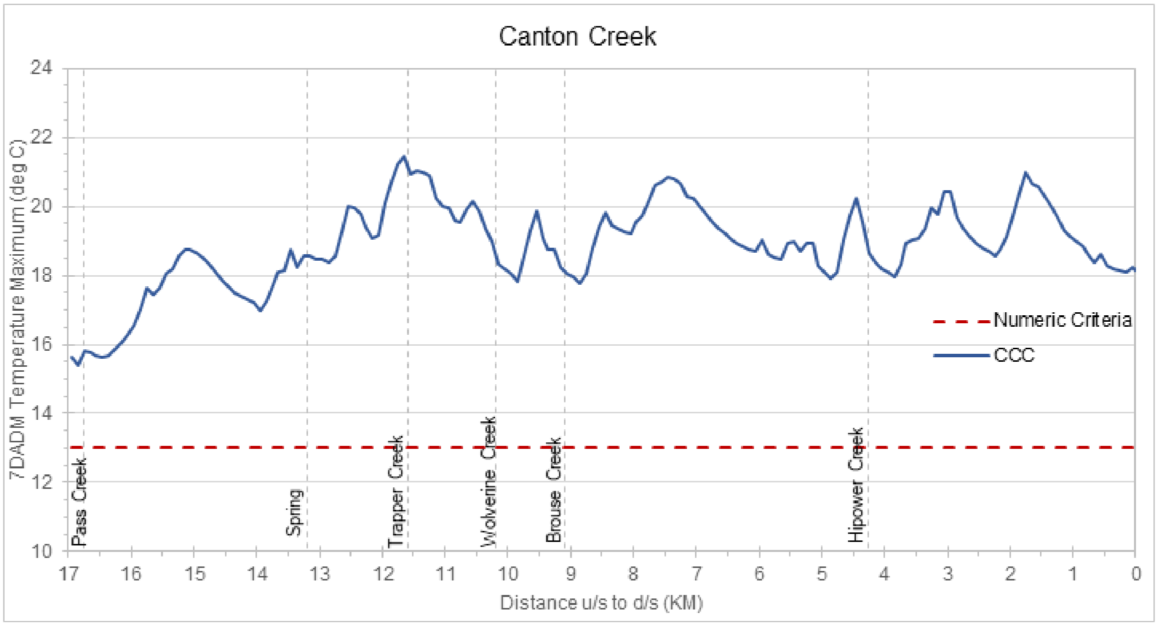

Figure 4-8. The maximum 7DADM temperature results along Canton Creek (spawning period) for the Current Condition scenario.

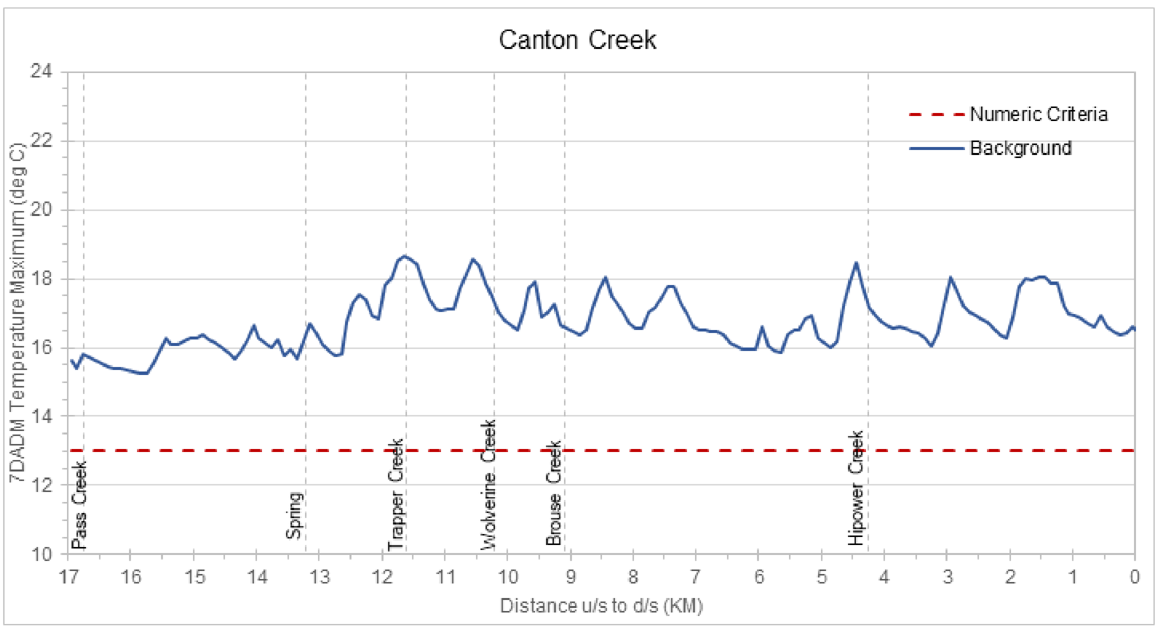

Figure 4-9. The maximum 7DADM temperature results along Canton Creek (spawning period) for the Background scenario.

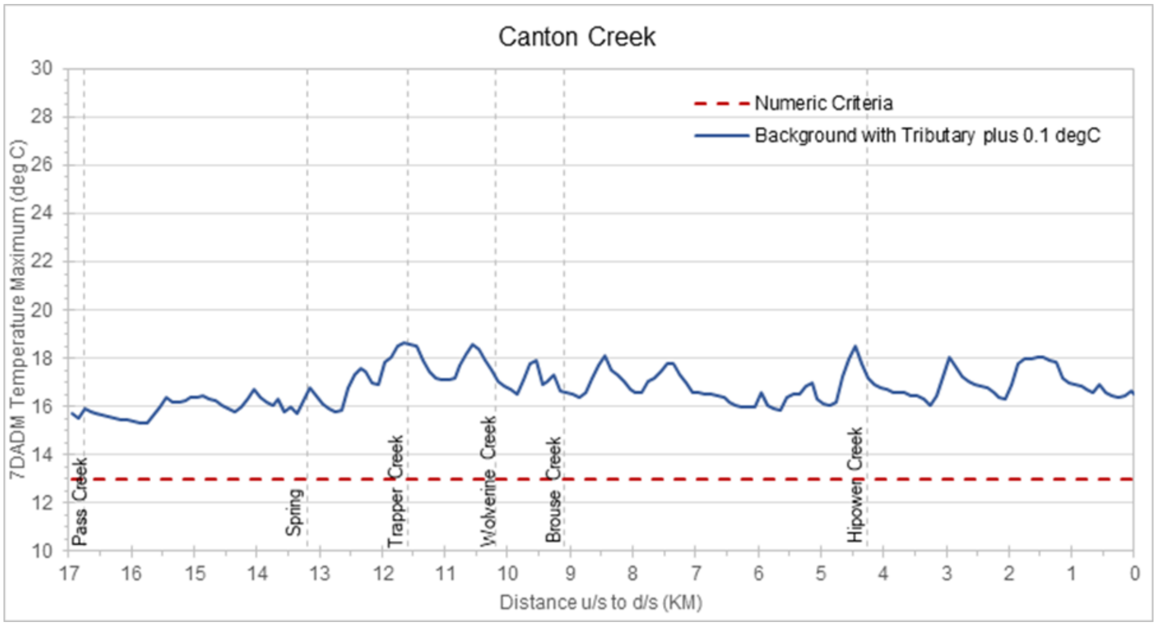

Figure 4-10. The maximum 7DADM temperature results along Canton Creek (spawning period) for the Tributary/Headwater plus 0.1°C scenario.

4.4 CANTON CREEK SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the Canton Creek spawning period include:

2. Impact of current point source and shade loss (note there are no point sources in Canton Creek)
   - ✓ CCC minus background

7. Difference between background and criteria
   - ✓ Background minus Criteria

A2. Impact of tributary scenario (tributary/headwater plus 0.1 ºC)
   - ✓ Tributary plus 0.1 ºC minus background

Figure 4-11 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There are no point sources in the Canton Creek model. The maximum delta reaches 3.99 ˚C at RKM 3.25 on September 4, 2009 (Table 4-4).

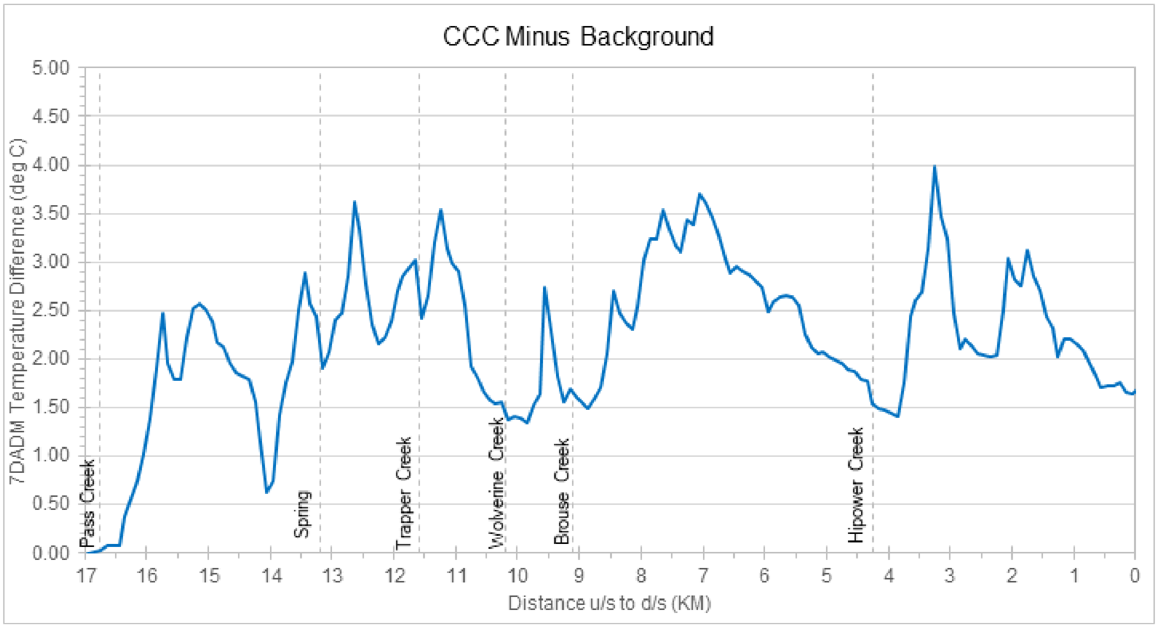

Figure 4-11. The maximum 7DADM temperature differences along Canton Creek (spawning period) for the impacts of current point sources and shade loss.

Table 4-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Canton Creek spawning period

Canton Creek	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	3.25	3.99	9/4/2009

Figure 4-12 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 5.63 ˚C at RKM 11.65 on September 2, 2009 (Table 4-5).

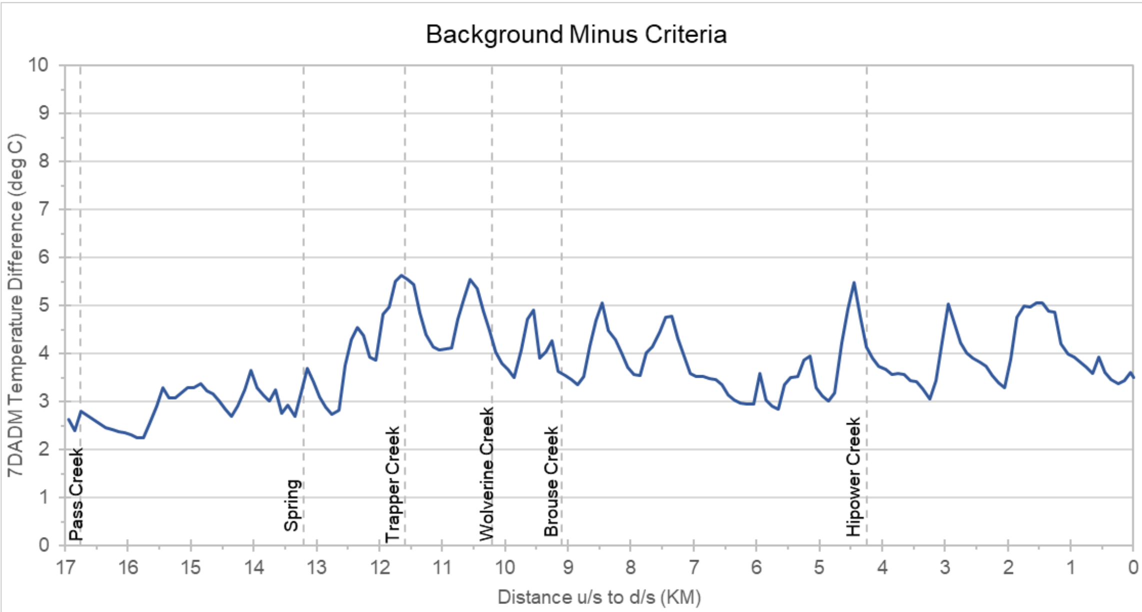

Figure 4-12. The maximum 7DADM temperature differences along Canton Creek (spawning period) for the difference between background conditions and criteria temperatures.

Table 4-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Canton Creek spawning period

Canton Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	11.65	5.63	9/2/2009

Figure 4-13 shows the results of comparison A2, the impact of adding 0.1 ºC to all the tributaries and headwater/upstream inflows in the background scenario, which is the 7DADM temperature difference between A2 and the Background scenario and criteria. The overall 7DADM temperature differences of 0.1 ºC occurs at the headwaters and then starts decreasing in the downstream direction. The maximum delta reaches 0.1 ˚C at RKM 16.5 on September 10, 2009 (Table 4-6).

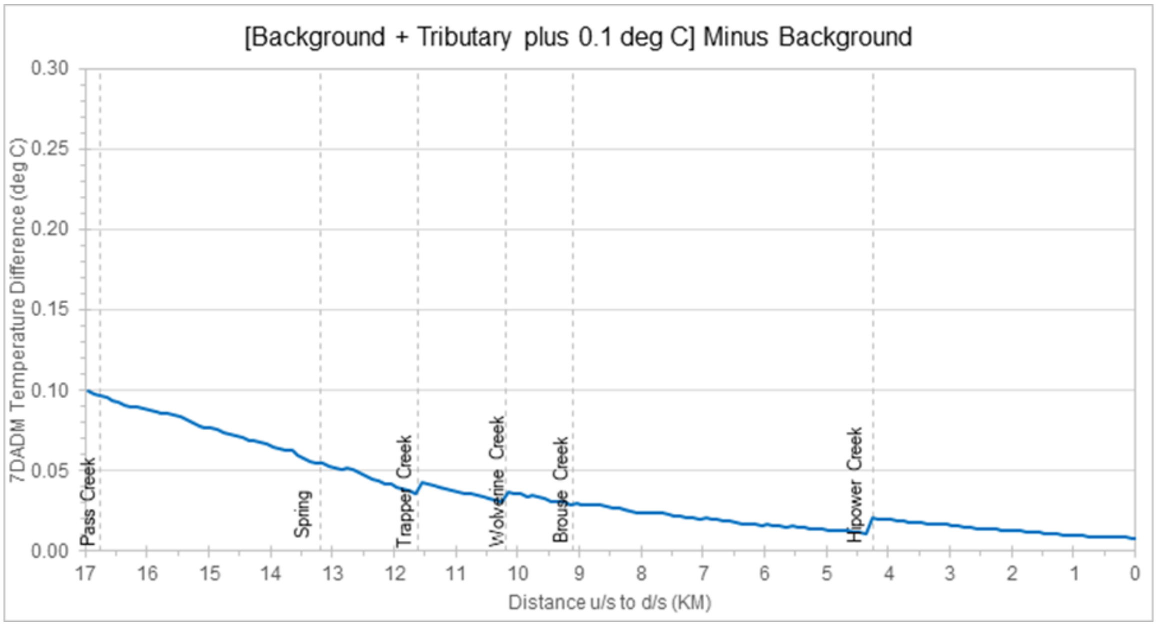

Figure 4-13. The maximum 7DADM temperature differences along Canton Creek (spawning period) for the impacts of adding 0.1°C to the Tributary/Headwater.

Table 4-6. Location and date of maximum delta when temperatures are greater than criterion for comparison A2 for the Canton Creek spawning period

Canton Creek	RKM	Maximum Delta	Date when maximum delta occurs
[Background + Tributary plus 0.1 deg C] Minus Background	16.5	0.10	9/10/2009

5.0 STEAMBOAT CREEK

The Steamboat Creek modeling domain is shown in Figure 5-1.Steamboat Creek was modeled for both the summer period (July 12-31, 2002) and the spawning period (August 1, 2009 to October 15, 2009). The summer period scenario results and scenario comparisons are presented in sections 5.1 and 5.2, while the spawning period scenario results are presented in sections 5.3 and 5.4.

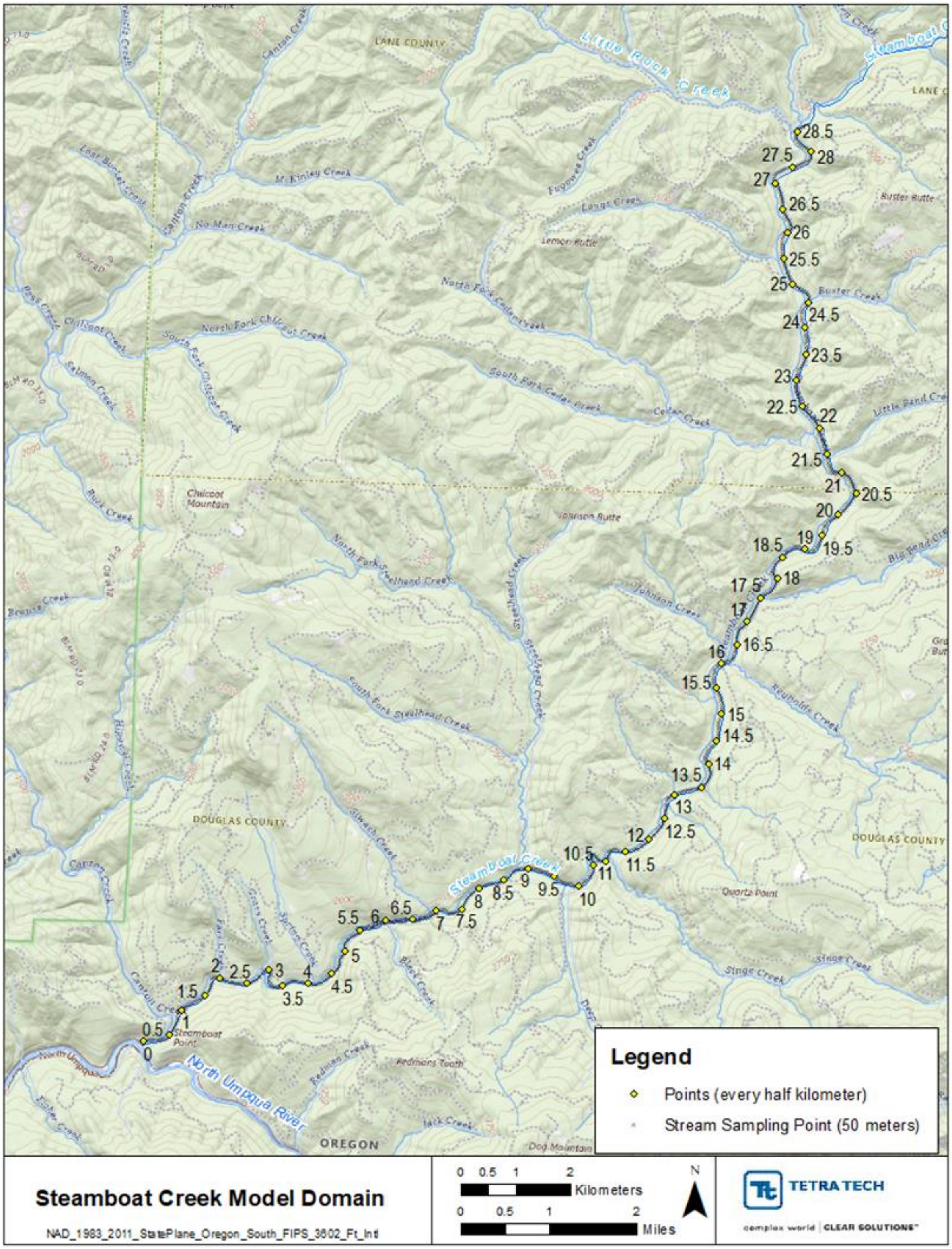

Figure 5-1. Steamboat Creek model domain.

5.1 STEAMBOAT CREEK SUMMER PERIOD SCENARIO RESULTS

The Steamboat Creek HS summer model does not include point sources. The scenarios that are relevant to the Steamboat Creek summer model include the CCC scenario, which is identical to the No Point Source scenario, Background scenario, and the tributary/headwater plus 0.1 ºC scenario. The 7DADM results of these scenarios are shown in Figure 5-2 through Figure 5-4.

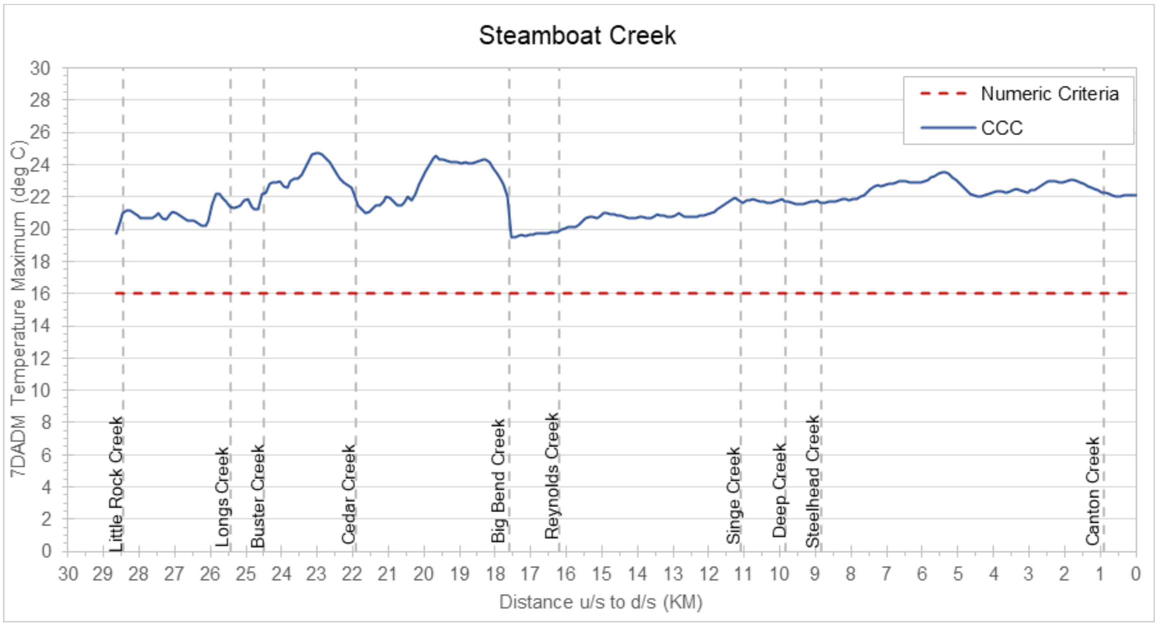

Figure 5-2. The maximum 7DADM temperature results along Steamboat Creek (summer period) for the Current Conditions scenario.

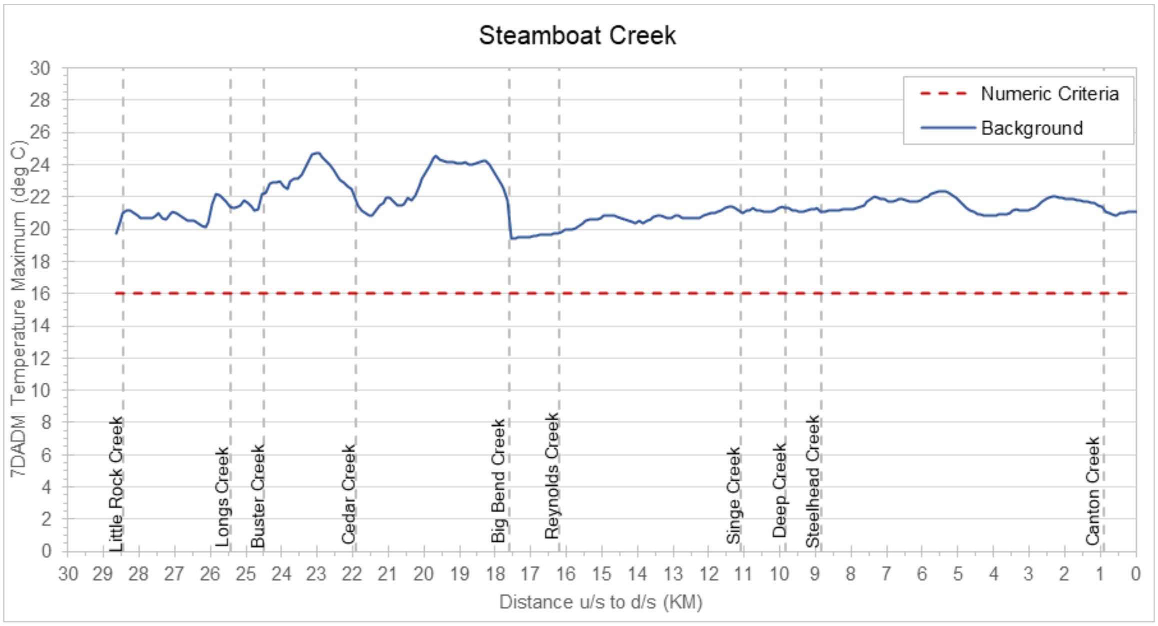

Figure 5-3. The maximum 7DADM temperature results along Steamboat Creek (summer period) for the Background scenario.

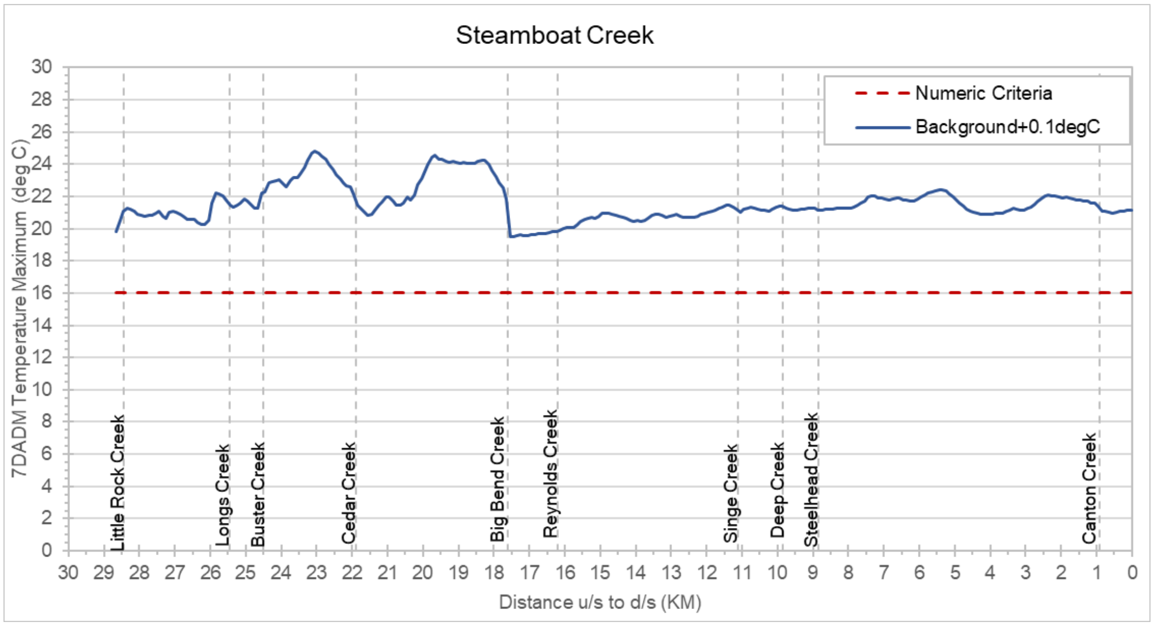

Figure 5-4. The maximum 7DADM temperature results along Steamboat Creek (summer period) for the Tributary/Headwater plus 0.1°C scenario.

5.2 STEAMBOAT CREEK SUMMER PERIOD SCENARIO COMPARISONS

Comparisons between the Steamboat Creek summer period model scenarios include:

2. Impact of current point source and shade loss (note there are no point sources in Steamboat Creek)
    - ✓ CCC minus background

7. Difference between background and criteria
    - ✓ Background minus Criteria

A2. Impact of tributary scenario (tributary/headwater plus 0.1 °C)
    - ✓ Tributary plus 0.1 °C minus background

Figure 5-5 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 1.83 ˚C at RKM 4.45 on July 31, 2002 (Table 5-1).

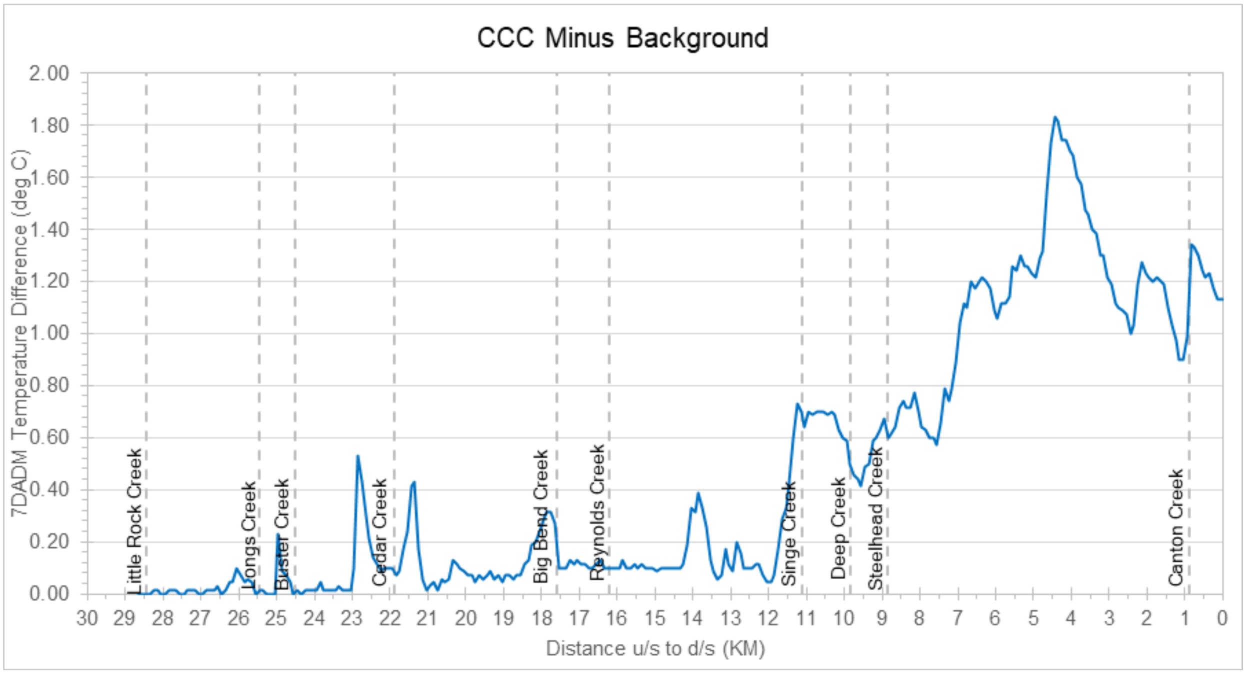

Figure 5-5. The maximum 7DADM temperature differences along Steamboat Creek (summer period) for the impacts of current point sources and shade loss.

Table 5-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Steamboat Creek summer period

Steamboat Creek	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	4.45	1.83	7/31/2002

Figure 5-6 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 8.74 ˚C at RKM 23.05 on July 18, 2002 (Table 5-2).

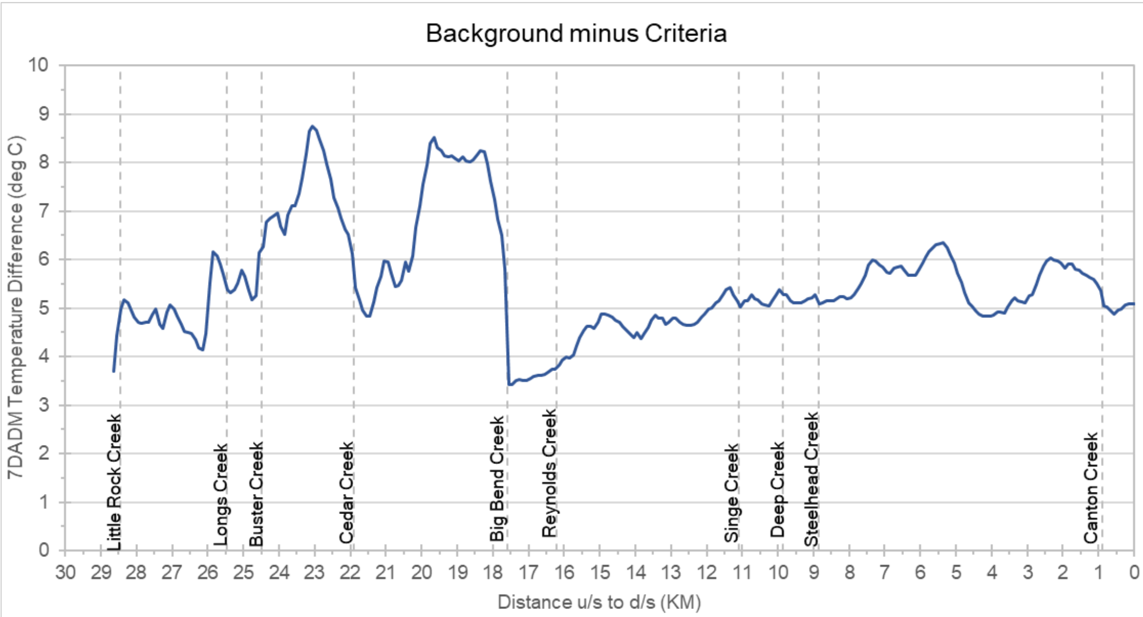

Figure 5-6. The maximum 7DADM temperature differences along Steamboat Creek (summer period) for the difference between background conditions and criteria temperatures.

Table 5-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Steamboat Creek summer period

Steamboat Creek	RKM	Maximum Delta	Date when maximum delta occurs
Background minus Criteria	23.05	8.74	7/18/2002

Figure 5-7 shows the results of comparison A2, the impact of adding 0.1 ºC to all the tributaries and headwater/upstream inflows in the background scenario, which is the 7DADM temperature difference between A2 and the Background scenario and criteria. The overall 7DADM temperature differences increase to 0.1 ºC and then starts decreasing in the downstream direction, until it encounters another tributary input that has been increased by 0.1 ºC. The maximum delta immediately reaches 0.1 ºC at the upstream and stays at 0.1 ºC for several RKM downstream (Table 5-3). Since the 0.1 ºC delta occurs for several days, each individual date and RKM are not listed as they can be seen in the Figure 5-7.

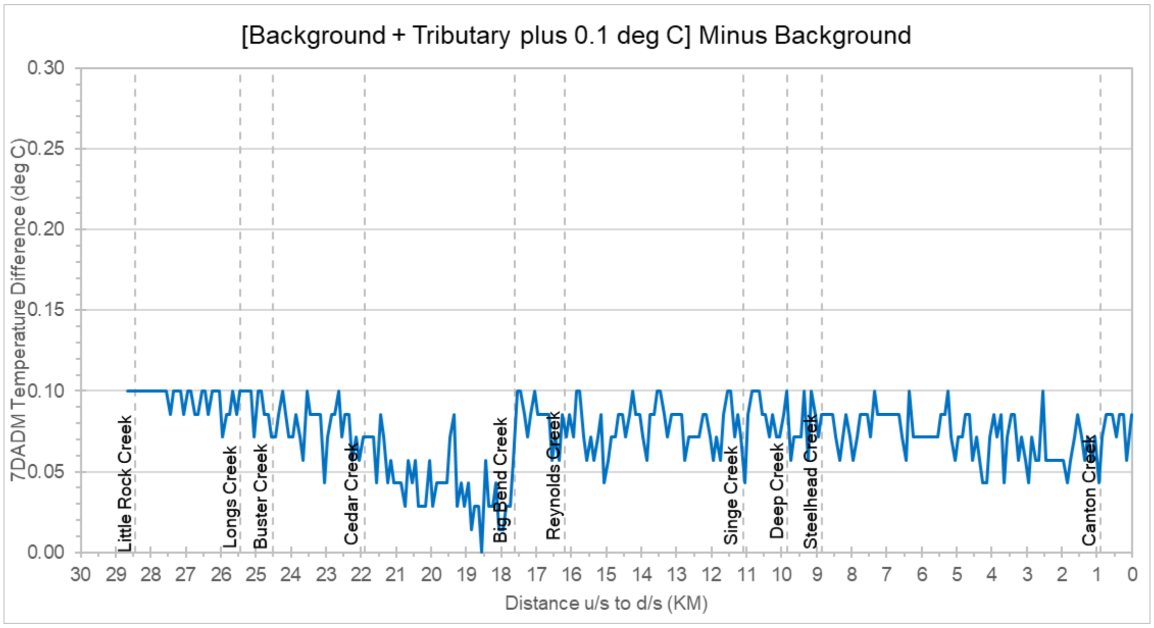

Figure 5-7. The maximum 7DADM temperature differences along Steamboat Creek (summer period) for the impacts of adding 0.1°C to the Tributary/Headwater.

Table 5-3. Location and date of maximum delta when temperatures are greater than criterion for comparison A2 for the Steamboat Creek summer period

Steamboat Creek	RKM	Maximum Delta	Date when maximum delta occurs
[Background + Tributary plus 0.1 deg C] Minus Background	N/A	0.10	N/A

5.3 STEAMBOAT CREEK SPAWNING PERIOD SCENARIO RESULTS

The Steamboat Creek HS spawning model does not include point sources. The scenarios that are relevant to the Steamboat Creek spawning model include the CCC scenario, which is identical to the No Point Source scenario, Background scenario, and the tributary/headwater plus 0.1 ºC scenario. The 7DADM results of these scenarios are shown in Figure 5-8 through Figure 5-10. The spawning criteria applies to Steamboat Creek and was evaluated for the period from September 1 to October 15, 2009.

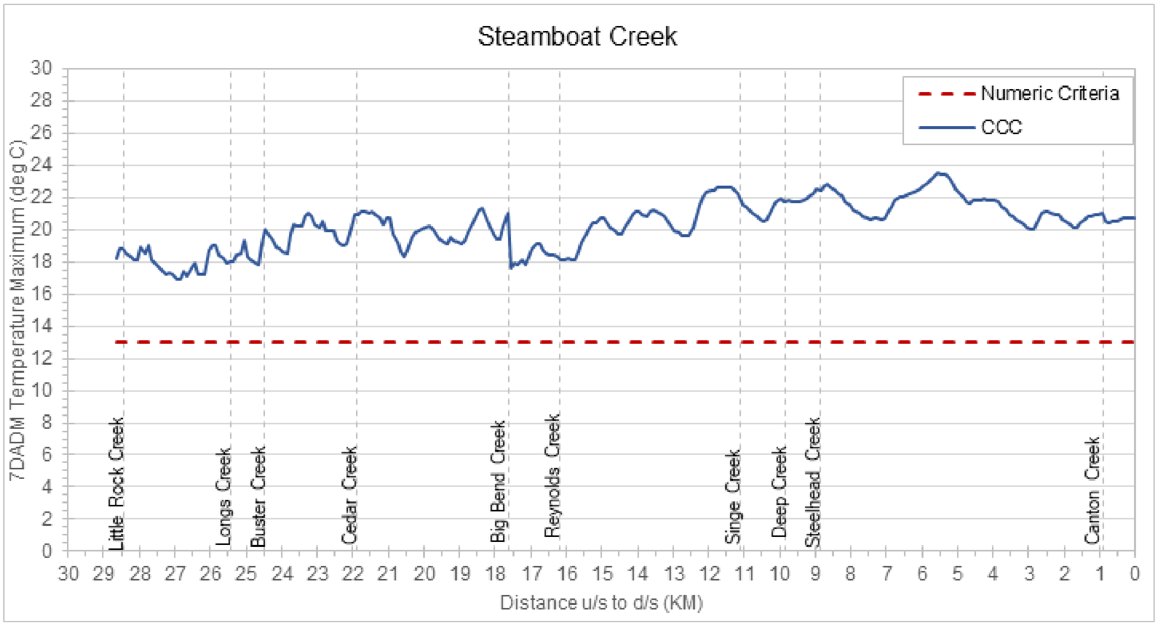

Figure 5-8. The maximum 7DADM temperature results along Steamboat Creek (spawning period) for Current Condition scenario.

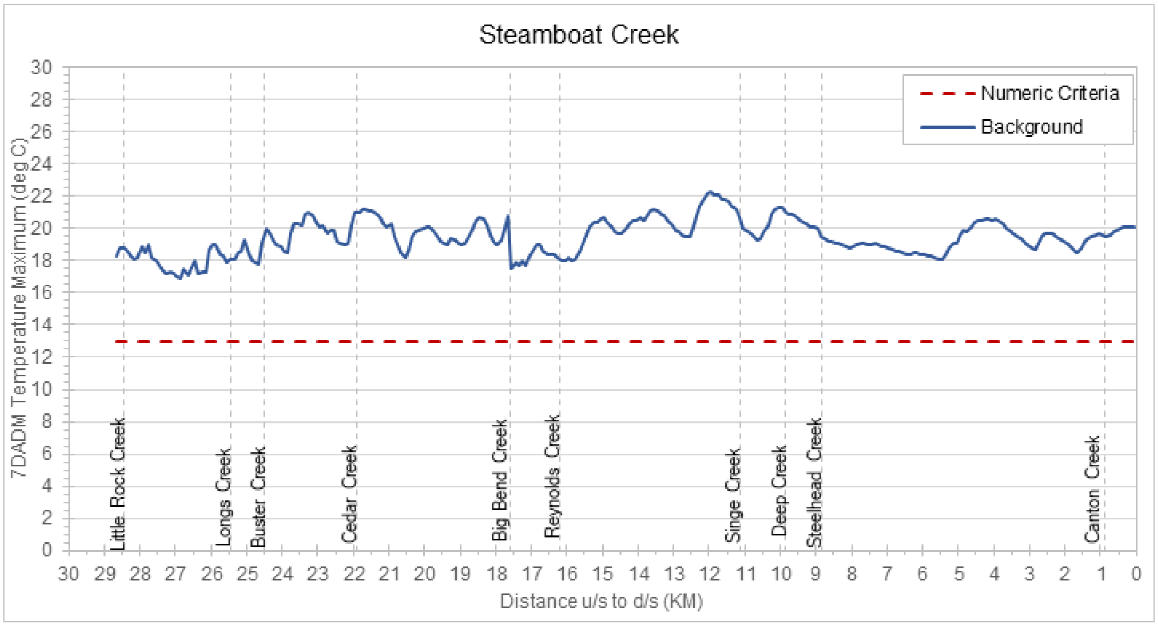

Figure 5-9. The maximum 7DADM temperature results along Steamboat Creek (spawning period) for the Background scenario.

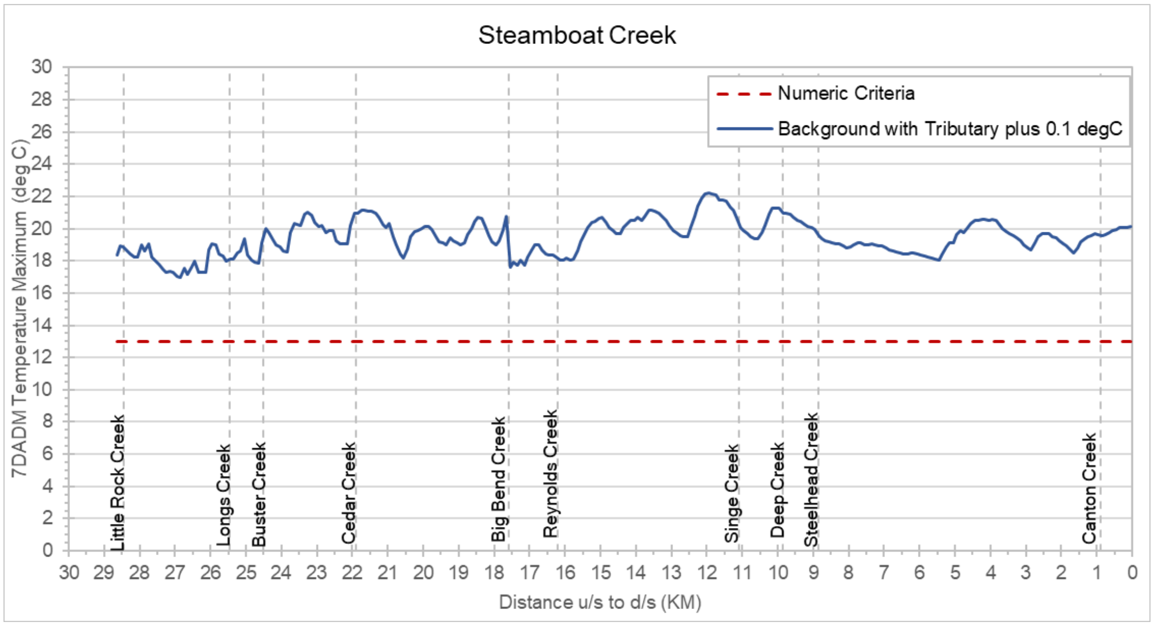

Figure 5-10. The maximum 7DADM temperature results along Steamboat Creek (spawning period) for the Tributary/Headwater plus 0.1°C scenario.

5.4 STEAMBOAT CREEK SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons between the Steamboat Creek spawning model scenarios include:

2. Impact of current point source and shade loss
    - ✓ CCC minus background (note there are no point sources in Steamboat Creek)

7. Difference between background and criteria
    - ✓ Background minus Criteria

A2. Impact of tributary scenario (tributary/headwater plus 0.1 °C)
    - ✓ Tributary plus 0.1 °C minus background

Figure 5-11 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 5.54 ˚C at RKM 5.55 on September 1, 2009. (Table 5-4).

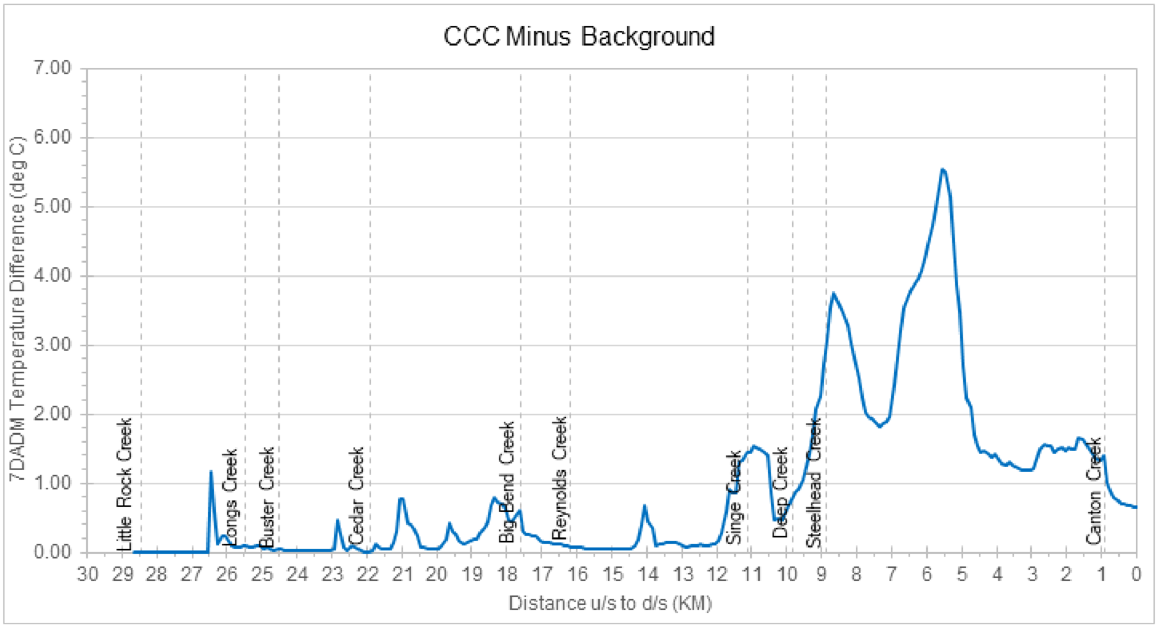

Figure 5-11. The maximum 7DADM temperature differences along Steamboat Creek spawning period for the impacts of current point sources and shade loss.

Table 5-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for Steamboat Creek spawning period

Steamboat Creek	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	5.55	5.54	9/1/2009

Figure 5-12 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 9.23 ˚C at RKM 11.95 on September 2, 2009 (Table 5-5).

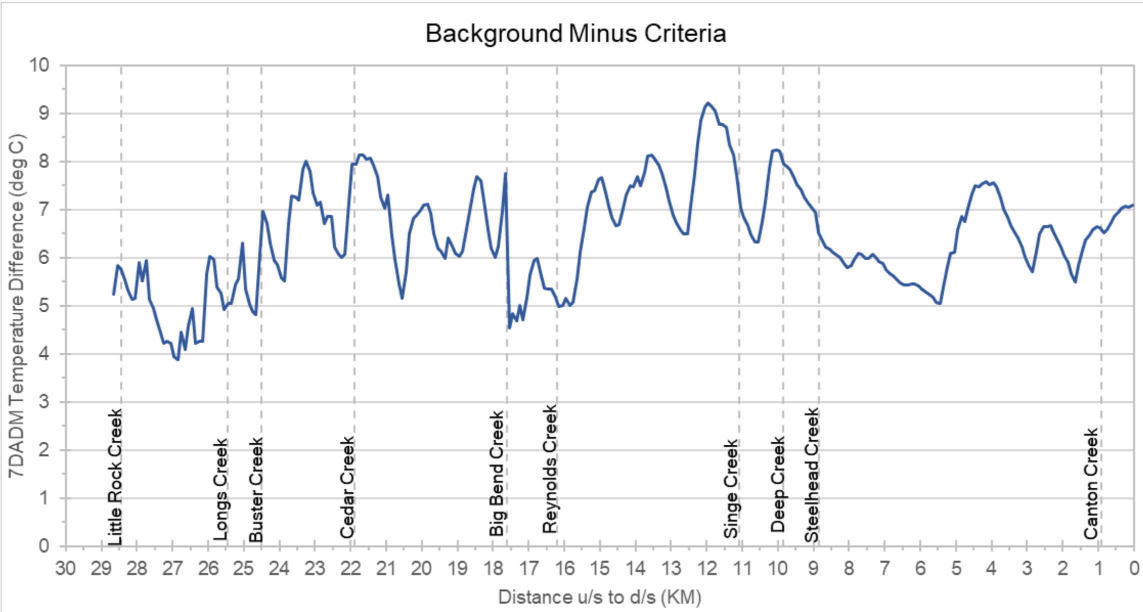

Figure 5-12. The maximum 7DADM temperature differences along Steamboat Creek (spawning period) for the difference between background conditions and criteria temperatures.

Table 5-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Steamboat Creek spawning period

Steamboat Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	11.95	9.23	9/2/2009

Figure 5-13 shows the results of comparison A2, the impact of adding 0.1 ºC to all the tributaries and headwater/upstream inflows in the background scenario, which is the 7DADM temperature difference between A2 and the Background scenario and criteria. The overall 7DADM temperature differences of 0.1 ºC occurs at the headwaters and then starts decreasing in the downstream direction. The maximum delta reaches 0.1 ˚C at RKM 28.65 on September 7, 2009 (Table 5-6).

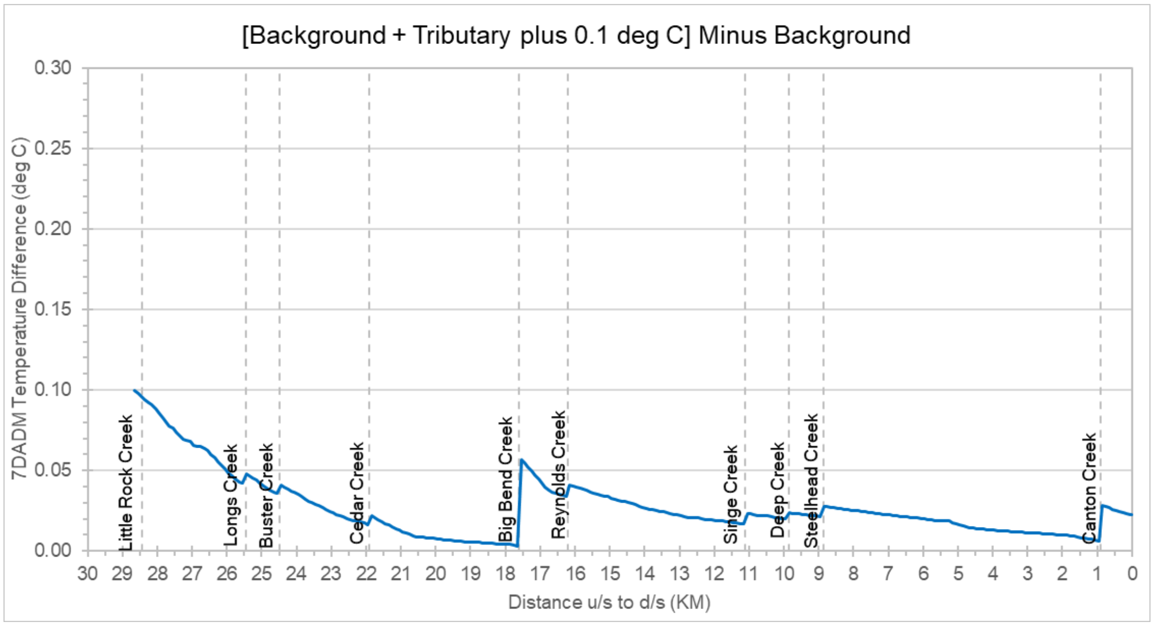

Figure 5-13. The maximum 7DADM temperature differences along Steamboat Creek (spawning period) for the impacts of adding 0.1°C to the Tributary/Headwater.

Table 5-6. Location and date of maximum delta when temperatures are greater than criterion for comparison A2 for the Steamboat Creek spawning period

Steamboat Creek	RKM	Maximum Delta	Date when maximum delta occurs
[Background + Tributary plus 0.1 deg C] Minus Background	28.65	0.10	9/7/2009

6.0 CLEARWATER CREEK

The Clearwater Creek modeling domain is shown in Figure 6-1. Clearwater Creek was modeled for both the summer period (July 8-11, 2001) and the spawning period (August 1, 2009, to October 15, 2009). The summer period scenario results and scenario comparisons are presented in sections 6.1 and 6.2, while the spawning period scenario results and scenario comparisons are presented in section 6.3 and 6.4.

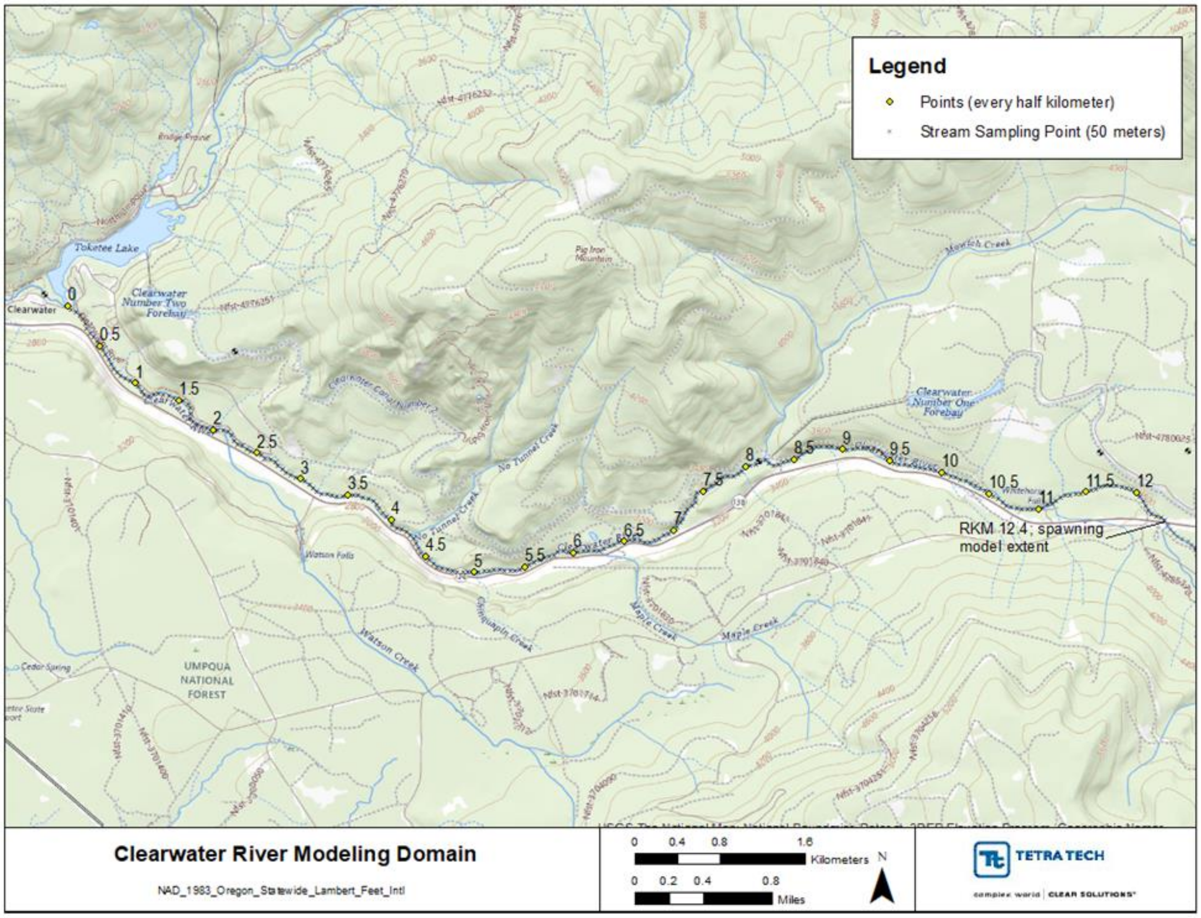

Figure 6-1. Clearwater Creek model domain.

6.1 CLEARWATER CREEK SUMMER PERIOD SCENARIO RESULTS

The Clearwater Creek HS summer model does not include any point sources. The scenarios that are relevant to the Clearwater Creek summer model include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; and the Fully Restored Vegetation with Natural Flow scenario. The 7DADM results of these scenarios are shown in Figure 6-2 through Figure 6-4.

Note that since the summer model was run for the period from July 8-11, 2001, the temperatures represent the summertime critical period for Clearwater River. The plots present the daily maximum temperature, as opposed to the 7-day average maximum temperature. Limited data availability restricted Heat Source simulations to 4 days during the critical period. The maximum daily temperature occurred on July 9.

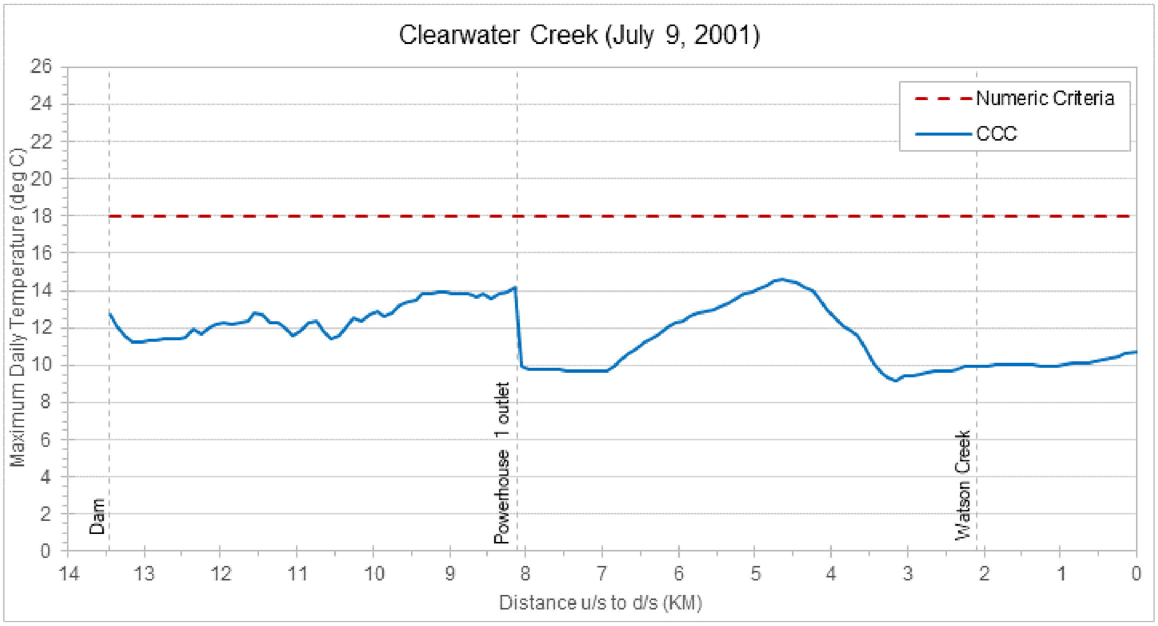

Figure 6-2. The maximum 7DADM temperature results along Clearwater Creek (summer period) for the Current Conditions scenario.

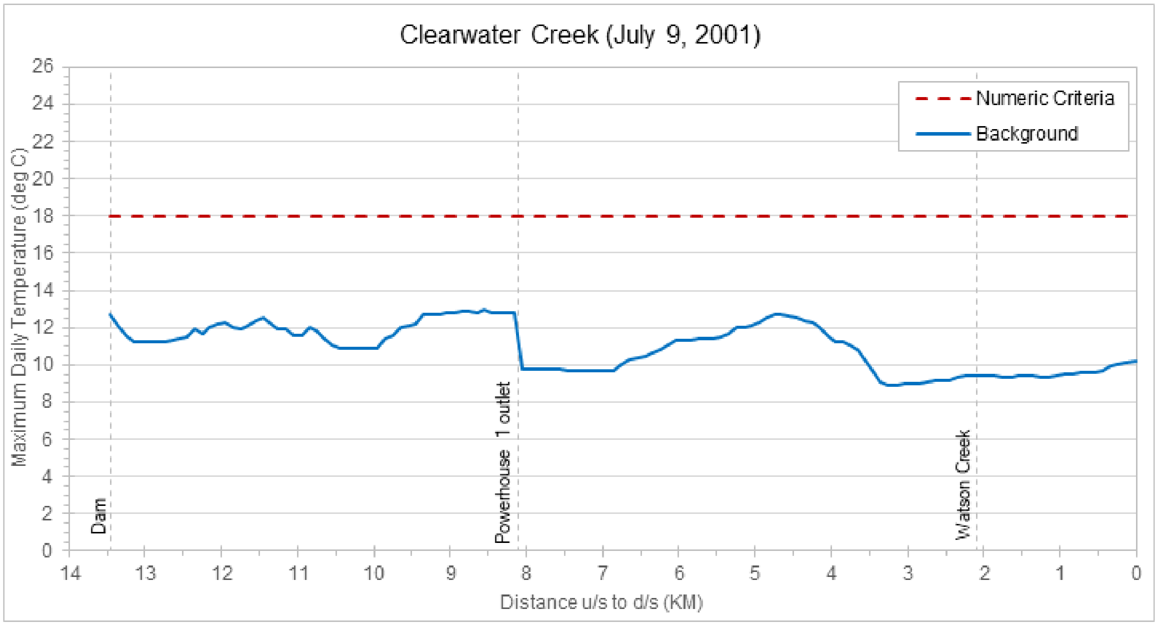

Figure 6-3. The maximum 7DADM temperature results along Clearwater Creek (summer period) for the Background scenario.

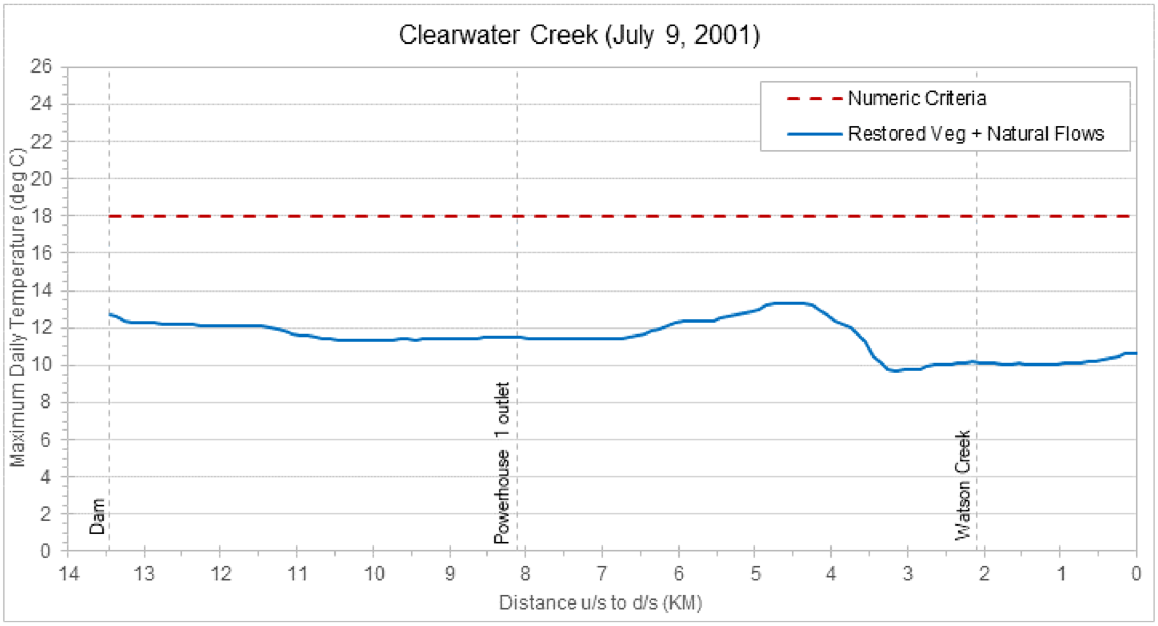

Figure 6-4. The maximum 7DADM temperature results along Clearwater Creek (summer period) for the Fully Restored Vegetation and Natural Flow scenario.

6.2 CLEARWATER CREEK SUMMER PERIOD SCENARIO COMPARISONS

Comparisons for the Clearwater Creek summer period scenarios include:

2. Impact of current point source and shade loss (note there are no point sources in Clearwater Creek)
   - ✓ CCC minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria
9. Natural Flows
   - ✓ Background minus fully restored veg with natural flows

Figure 6-5 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There is no maximum delta calculated for this scenario since the 7DADM temperatures for the scenarios are below the BBNC (Table 6-1).

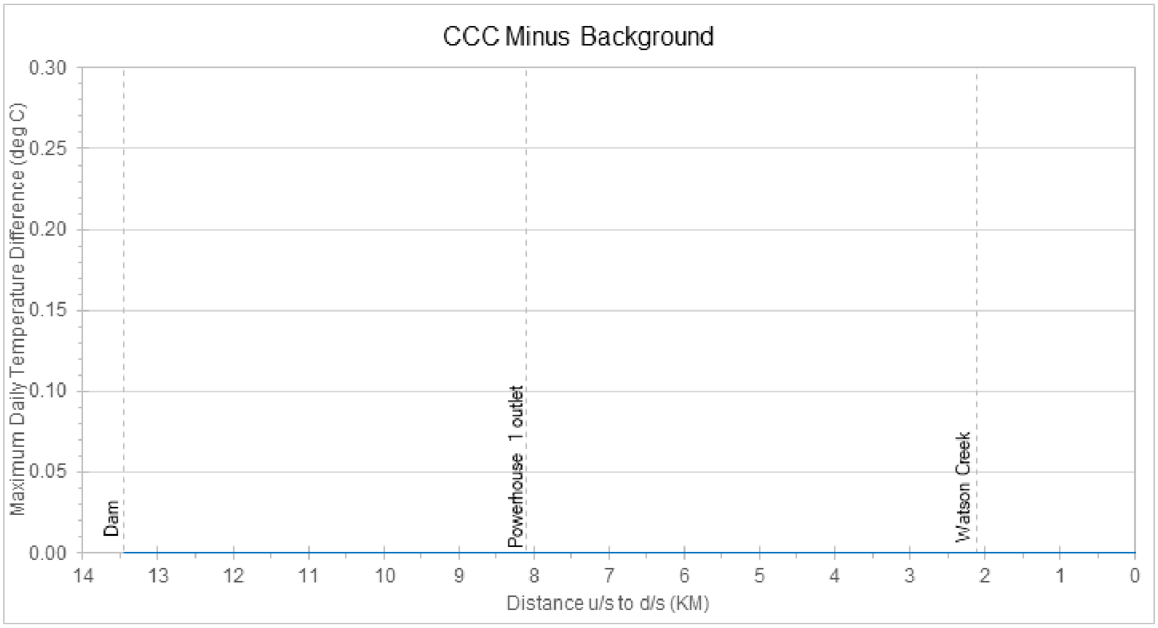

Figure 6-5. The maximum 7DADM temperature differences along Clearwater Creek (summer period) for the impacts of current point sources and shade loss.

Table 6-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Clearwater Creek summer period

Clearwater Creek	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	N/A	0.00	N/A

Figure 6-6 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -9.10 ˚C at RKM 3.25 on July 10, 2002 (Table 6-2).

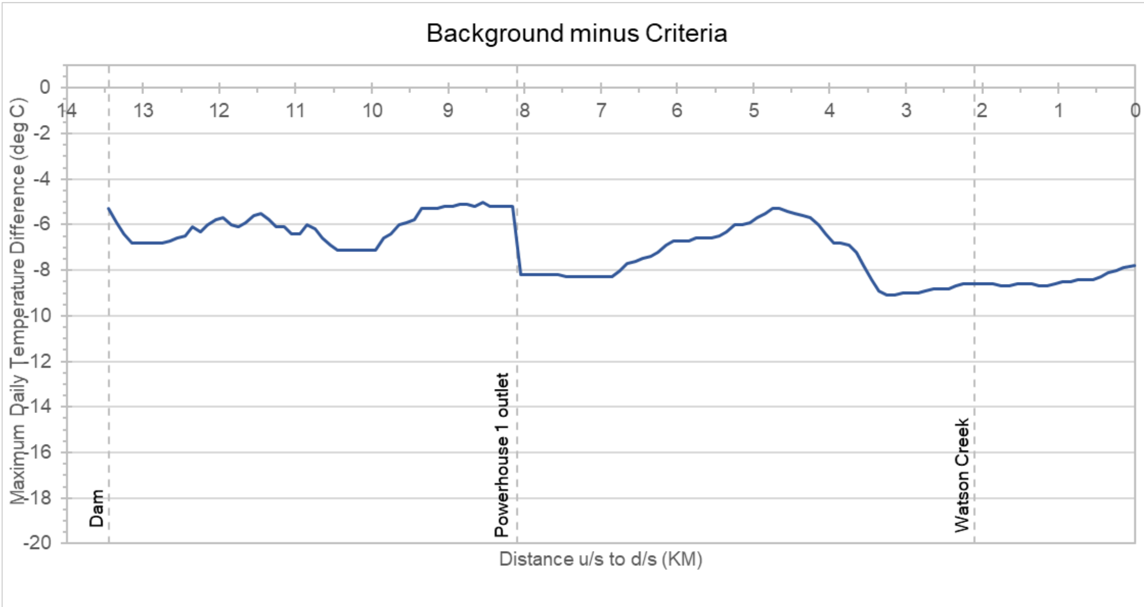

Figure 6-6. The maximum 7DADM temperature differences along Clearwater Creek (summer period) for the difference between background conditions and criteria temperatures.

Table 6-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Clearwater Creek summer period

Clearwater Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
Background minus Criteria	3.25	-9.10	7/10/2001

Figure 6-7 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. The difference between these two scenarios for Clearwater Creek is that there are no withdrawals in the Restored Vegetation with Natural Flow scenario. In addition, the flows from the headwater and the powerhouse 1 were changed in the model to reflect natural conditions in the Fully Restored Vegetation with Natural Flow model. The changed flows are directly from DEQ's summer HS7 model. There is no maximum delta calculated for the Clearwater Creek summer period for comparison 9 since the scenarios are below the BBNC value (Table 6-3).

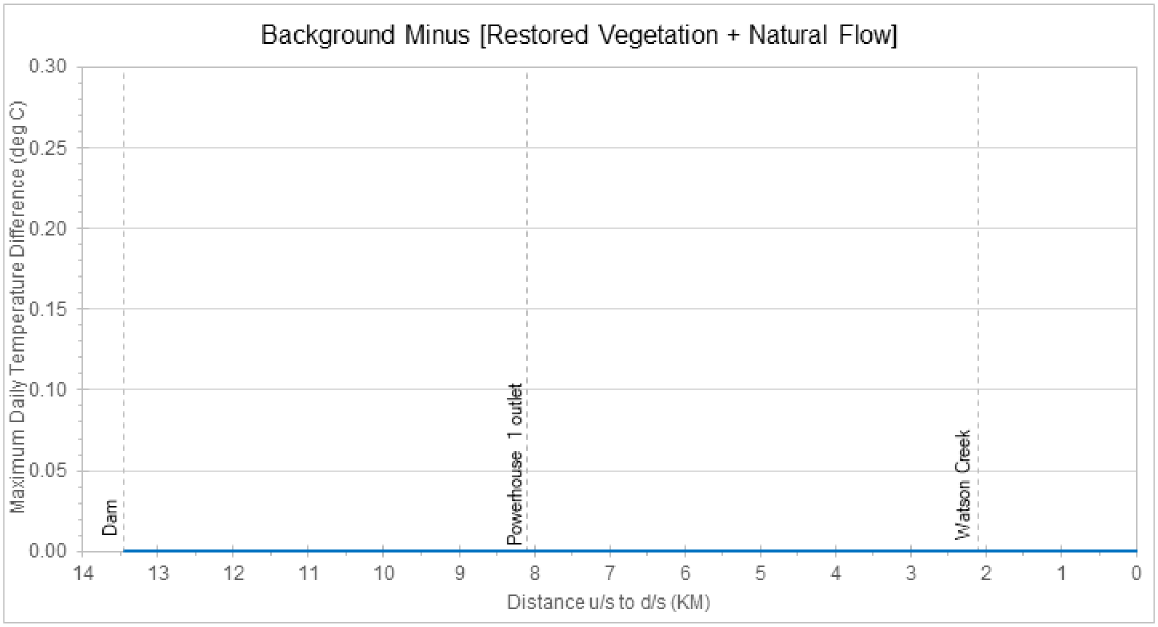

Figure 6-7. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario on Clearwater Creek (summer period).

Table 6-3. Location and date of maximum delta when temperatures are greater than criterion for comparison 9 for the Clearwater Creek summer period

Clearwater Creek	RKM	Maximum Delta	Date when maximum delta occurs
Background Minus [Restored Vegetation + Natural Flow]	N/A	0.00	N/A

6.3 CLEARWATER CREEK SPAWNING PERIOD SCENARIO RESULTS

The Clearwater Creek HS spawning period model does not include any point sources. The scenarios that are relevant to the Clearwater Creek spawning period model include the CCC scenario, which is identical to the No Point Source scenario; and the Background scenario. The 7DADM results of these scenarios are shown in Figure 6-8 and Figure 6-9. The Clearwater Creek only has the year round criteria, and the year round criteria was used in the comparisons for the entire modeling period from August 1 to October 15, 2009.

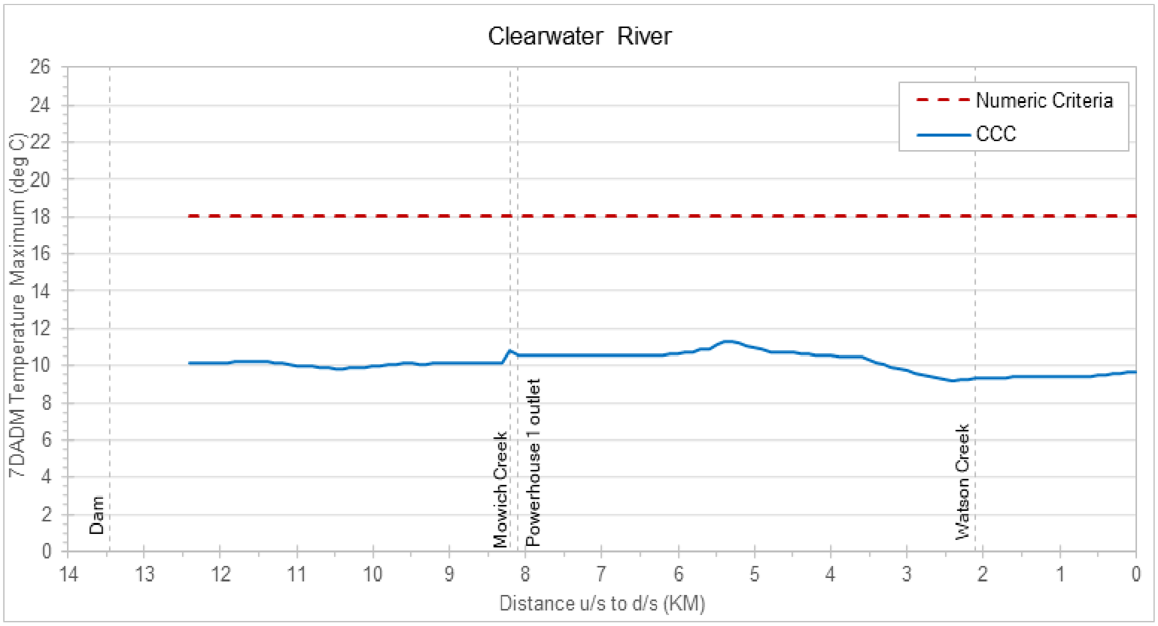

Figure 6-8. The maximum 7DADM temperature results along Clearwater Creek (spawning period) for the Current Conditions scenario.

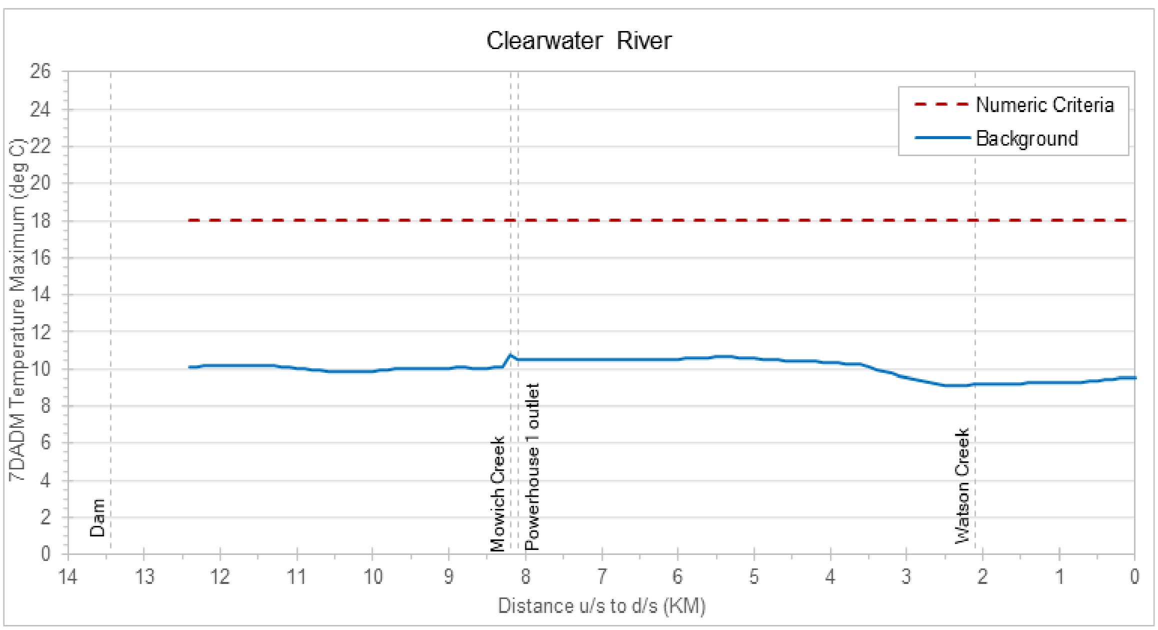

Figure 6-9. The maximum 7DADM temperature results along Clearwater Creek (spawning period) for the Background scenario.

6.4 CLEARWATER CREEK SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the Clearwater Creek spawning period include:

2. Impact of current point source and shade loss (note there are no point sources in Clearwater Creek)
    - ✓ CCC minus background
7. Difference between background and criteria
    - ✓ Background minus Criteria

Figure 6-10 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition.. There is no maximum delta for this comparison (Table 6-4).

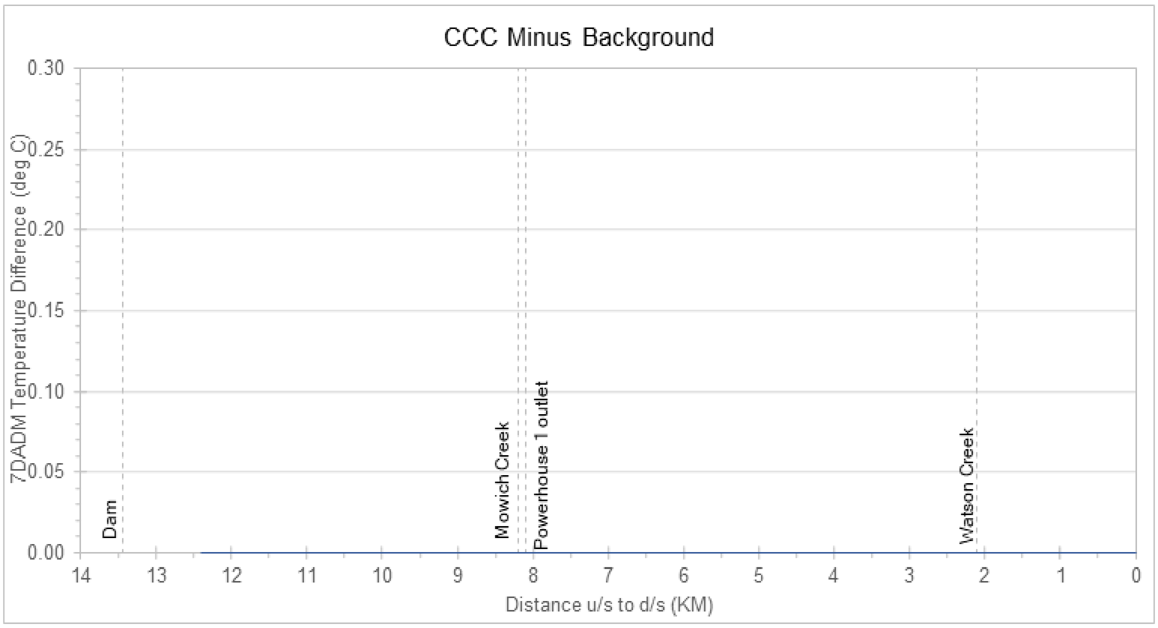

Figure 6-10. The maximum 7DADM temperature differences along Clearwater Creek (spawning period) for the impacts of current point sources and shade loss.

Table 6-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Clearwater Creek spawning period

Clearwater Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus Background	N/A	0.00	N/A

Figure 6-11 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -8.92 ˚C at RKM 2.4 on August 7, 2009 (Table 6-5).

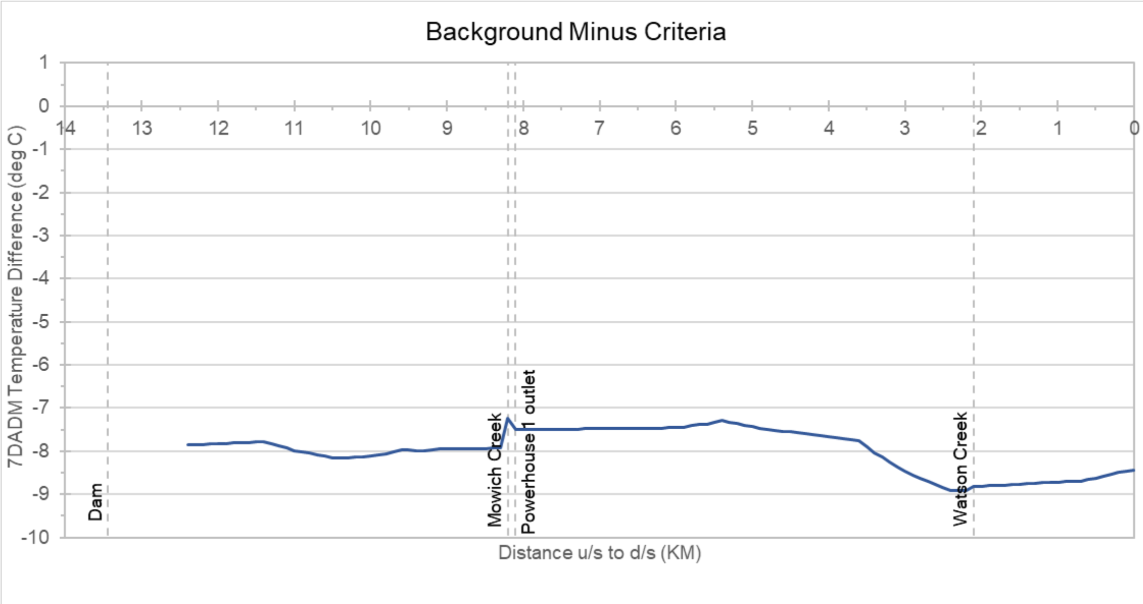

Figure 6-11. The maximum 7DADM temperature differences along Clearwater Creek (spawning period) for the difference between background conditions and criteria temperatures.

Table 6-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Clearwater Creek spawning period

Clearwater Creek	RKM	Maximum Delta	Date when maximum delta occurs
Background Minus Criteria	2.40	-8.92	8/7/2009

7.0 LAKE CREEK

The modeled portion of Lake Creek is shown in Figure 7-1. Lake Creek was modeled for both the summer period (July 8-11, 2001) and the spawning period (August 1, 2009, to October 15, 2009). The summer period scenario results and scenario comparisons are presented in sections 7.1 and 7.2, while the spawning period scenario results and scenario comparisons are presented in sections 7.3 and7.4.

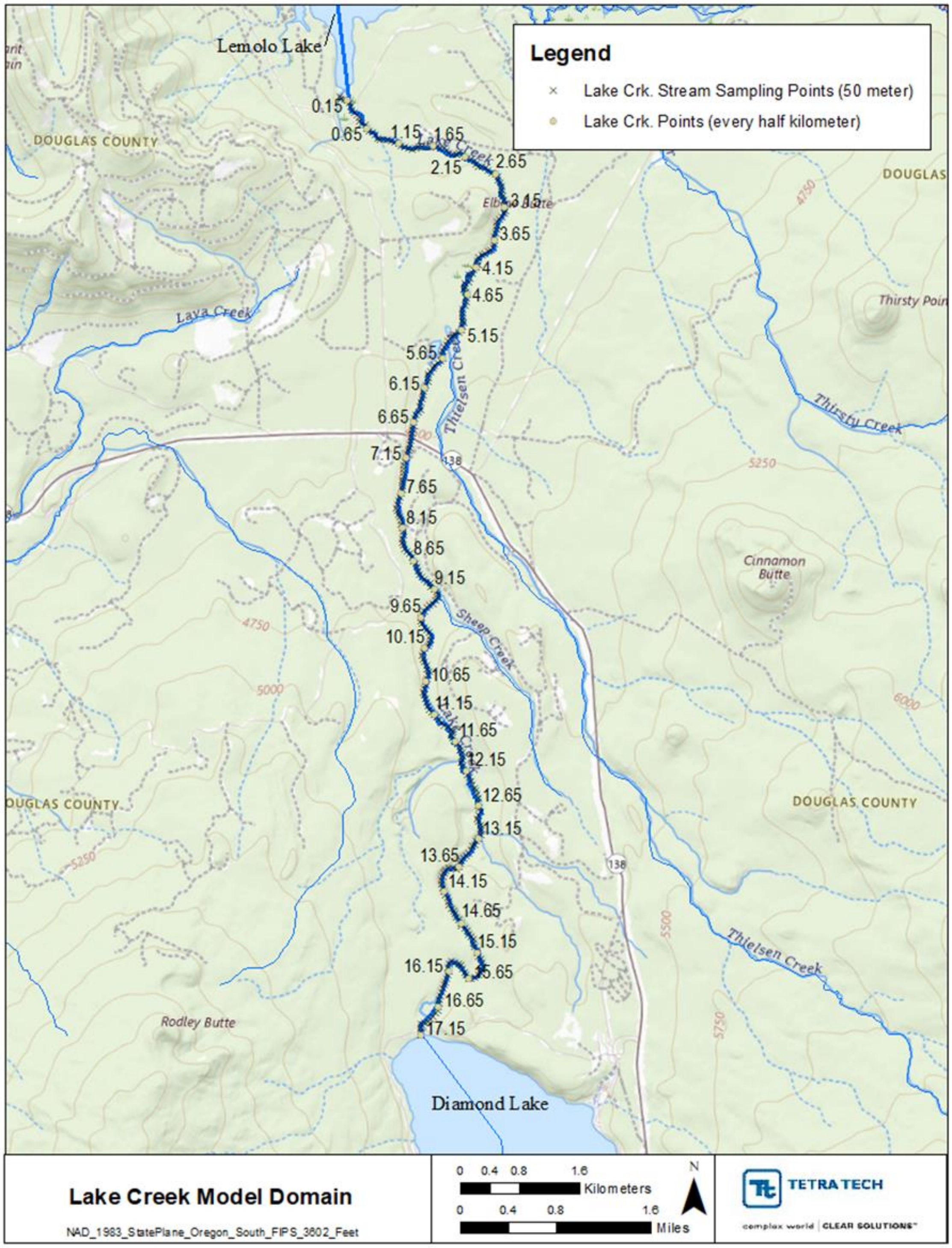

Figure 7-1. Lake Creek model domain.

7.1 LAKE CREEK SUMMER PERIOD SCENARIO RESULTS

The Lake Creek HS summer period model does not include point sources. The scenarios that are relevant to the Lake Creek summer model include the CCC scenario and the Background scenario. The 7DADM results of these scenarios are shown in Figure 7-2 and Figure 7-3.

Note that since the summer model was run for the period from July 8-11, 2001, the temperatures represent the summertime critical period for Lake Creek. The plots present the daily maximum temperature, as opposed to the 7-day average maximum temperature. Limited data availability restricted Heat Source simulations to 4 days during the critical period. The maximum daily temperature occurred on July 10.

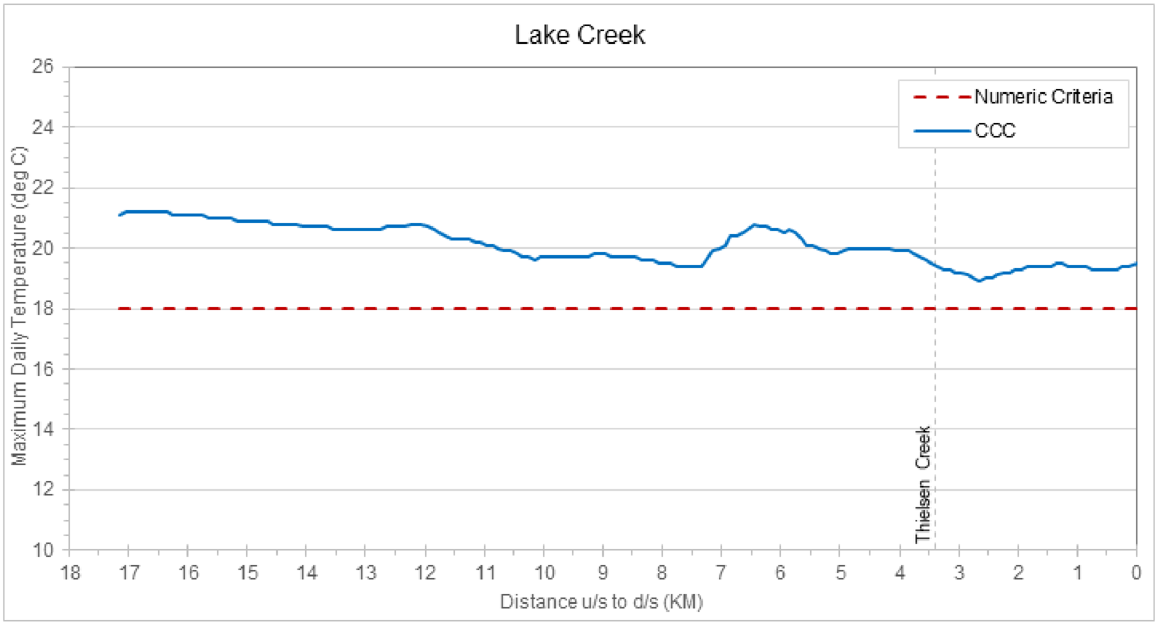

Figure 7-2. The maximum 7DADM temperature results along Lake Creek (summer period) for the Current Condition scenario.

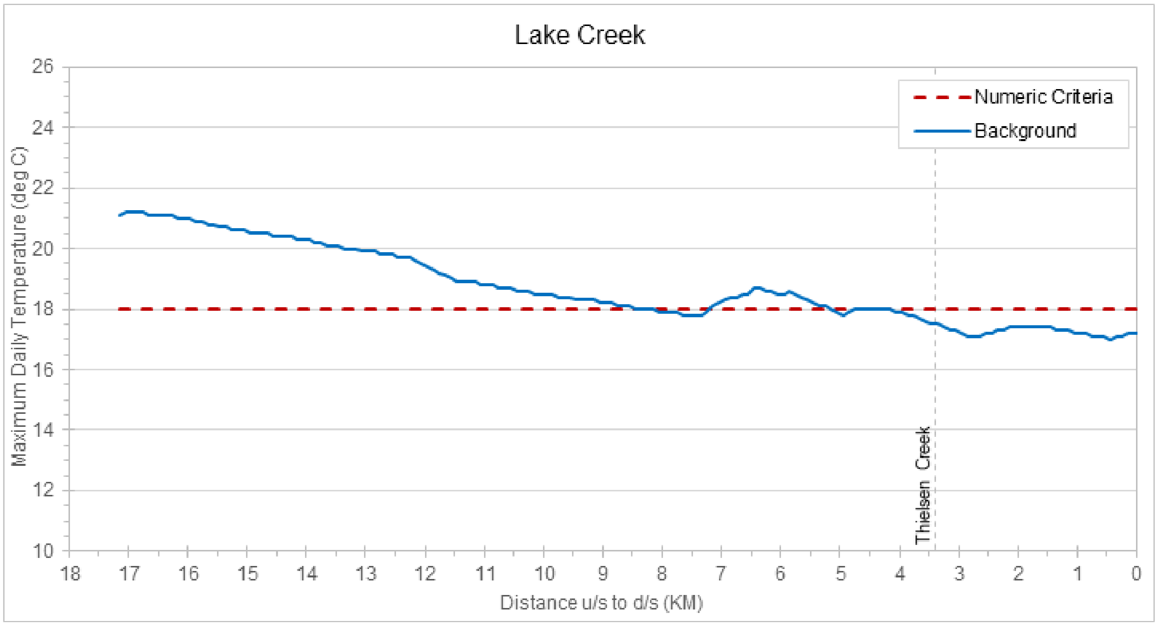

Figure 7-3. The maximum 7DADM temperature results along Lake Creek (summer period) for the Background scenario.

7.2 LAKE CREEK SUMMER PERIOD SCENARIO COMPARISONS

Comparisons between Lake Creek summer period scenarios include:

2. Impact of current point source and shade loss (note there are no point sources in Lake Creek)
   - ✓ CCC minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

Figure 7-4 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 2.5 ˚C at multiple RKMs on multiple dates (Table 7-1).

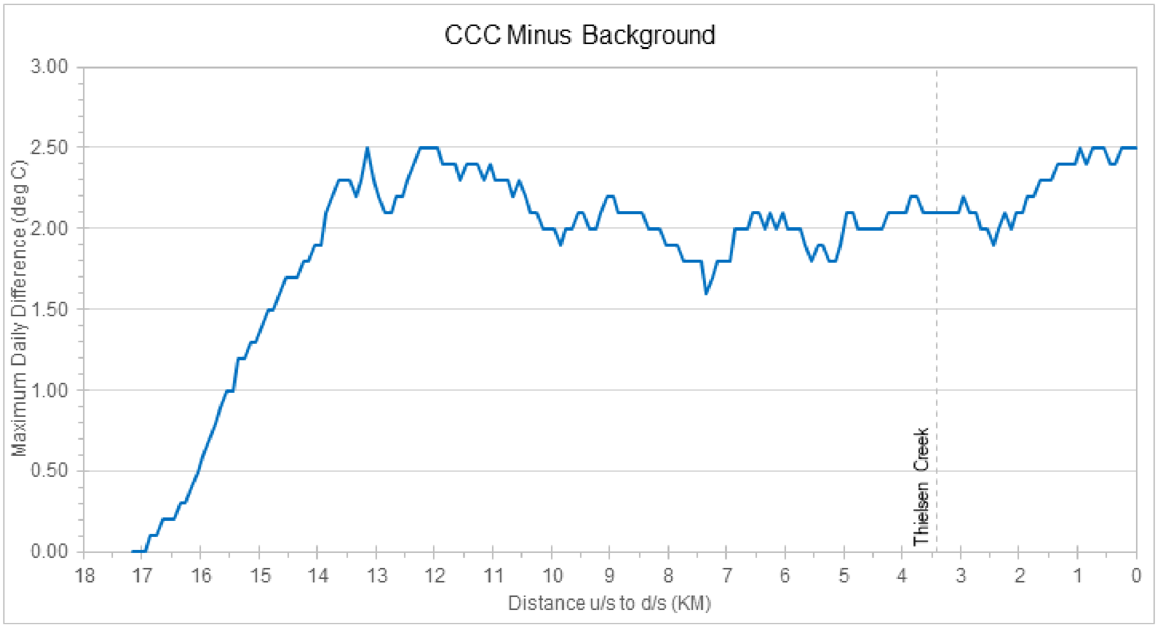

Figure 7-4. The maximum 7DADM temperature differences along the Lake Creek (summer period) for the impacts of current point sources and shade loss.

Table 7-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Lake Creek summer period

Lake Creek	RKM	Maximum Delta	Date when maximum delta occurs
	13.15	2.50	7/11/2001
	12.25	2.50	7/11/2001
	12.15	2.50	7/11/2001
	12.05	2.50	7/11/2001
	11.95	2.50	7/11/2001
	0.95	2.50	7/11/2001
	0.75	2.50	7/11/2001
	0.65	2.50	7/11/2001
	0.55	2.50	7/11/2001
	0.25	2.50	7/8/2001
	0.15	2.50	7/11/2001
CCC Minus Background	0	2.50	7/8/2001,7/10/2001, 7/11/2001

Figure 7-5 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 3.2 ˚C from river kilometers 17.05 to 16.75 on July 9, 2001, and -1.00 ˚C at RKM 0.45 on July 9, 2001 (Table 7-2).

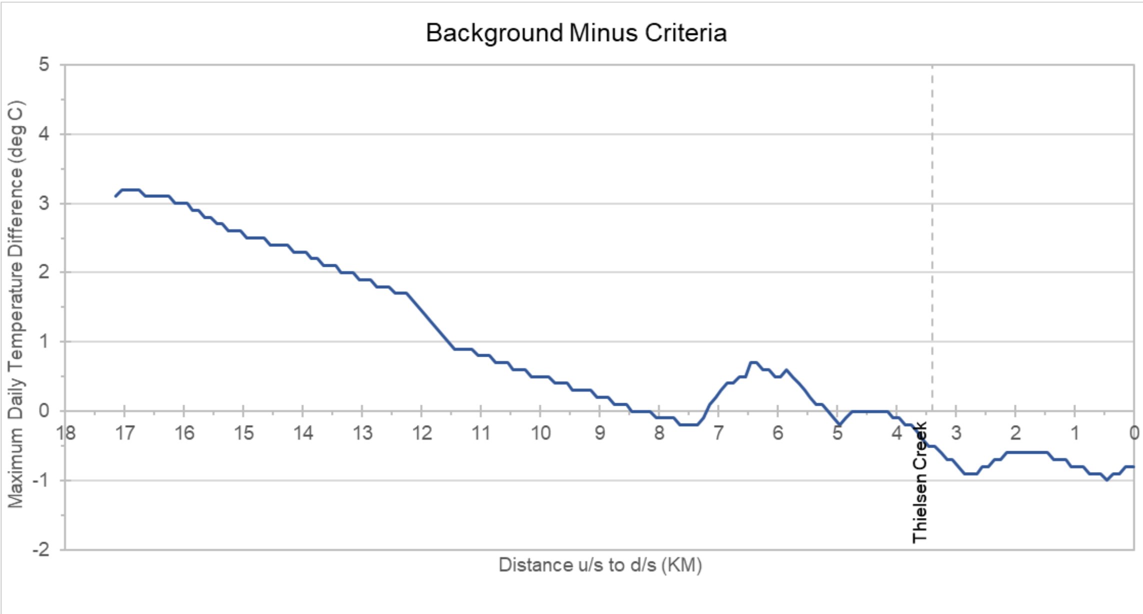

Figure 7-5. The maximum 7DADM temperature differences along the Lake Creek (summer period) for the difference between background conditions and criteria temperatures.

Table 7-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Lake Creek summer period

Lake Creek	RKM	Maximum Delta	Date when maximum delta occurs
Background Minus Criteria	17.05 to 16.75	3.20	7/9/2001
	0.45	-1.00	7/9/2001

7.3 LAKE CREEK SPAWNING PERIOD SCENARIO RESULTS

The Lake Creek HS spawning period model does not include point sources. The scenarios that are relevant to the Lake Creek spawning period include the CCC scenario, which is identical to the No Point Source scenario; and the Background scenario. The 7DADM results of these scenarios are shown in Figure 7-6 and Figure 7-7. Note that the year round (non-spawning criteria) applies to Lake Creek and was evaluated for the entire modeling period from August 1 to October 15, 2009.

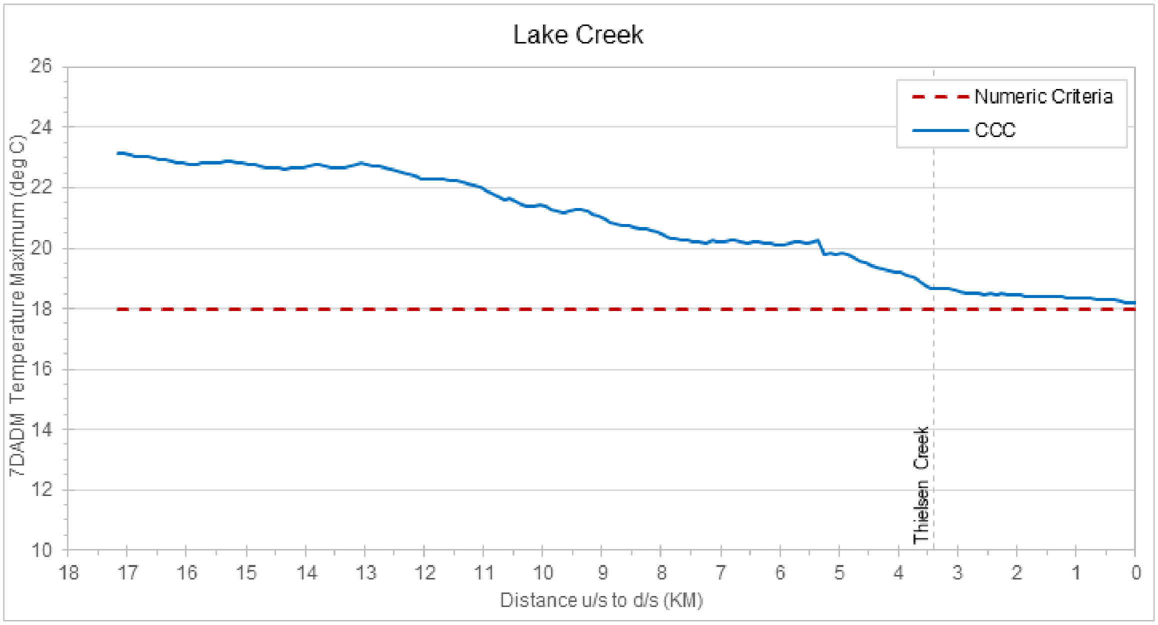

Figure 7-6. The maximum 7DADM temperature results along Lake Creek (spawning period) for the Current Condition scenario.

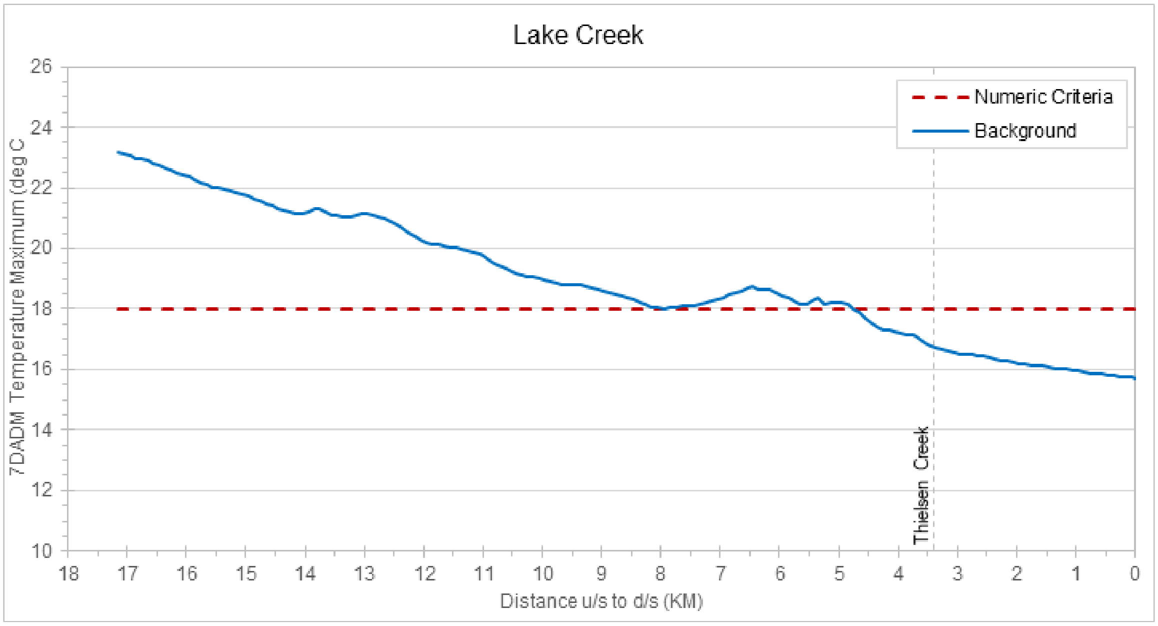

Figure 7-7. The maximum 7DADM temperature results along Lake Creek (spawning period) for the Background scenario.

7.4 LAKE CREEK SPAWNING PERIOD SCENARIO COMPARSIONS

Comparisons between Lake Creek spawning period scenarios include:

2. Impact of current point source and shade loss
    - ✓ CCC minus background
7. Difference between background and criteria
    - ✓ Background minus Criteria

Figure 7-8 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 6.97 ˚C at RKM 13.05 on September 13, 2009 (Table 7-3).

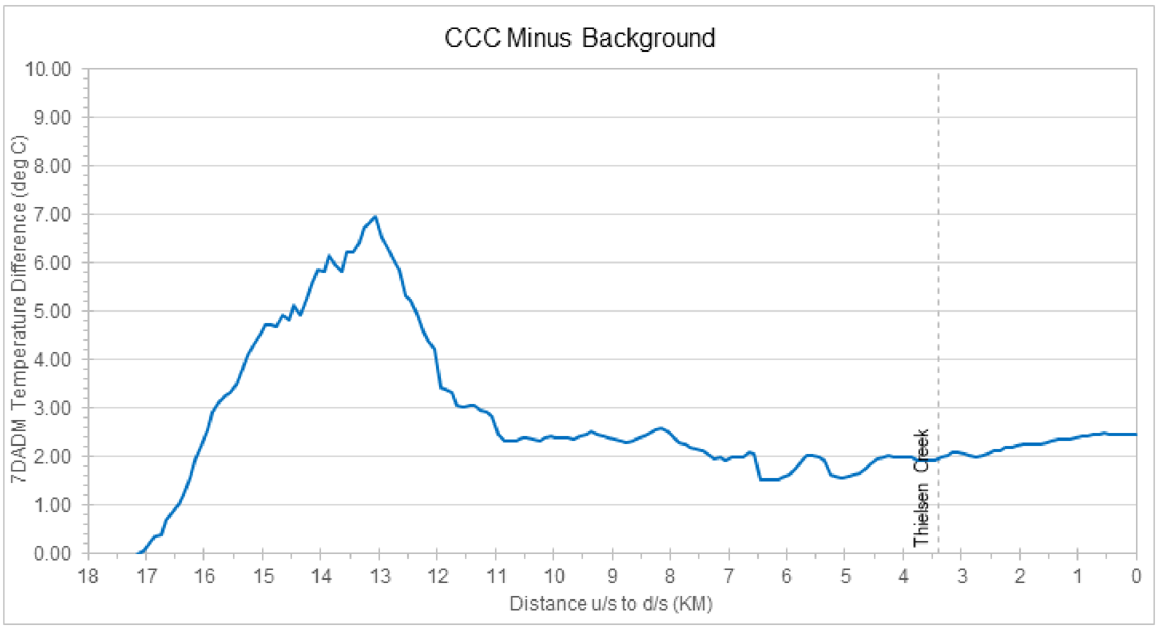

Figure 7-8. The maximum 7DADM temperature differences along Lake Creek (spawning period) for the impacts of current point sources and shade loss.

Table 7-3. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Lake Creek spawning period

Lake Creek	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	13.05	6.97	9/13/2009

Figure 7-9 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 5.17 ˚C at RKM 17.15 and -2.28 ˚C at RKM 0.0 on August 8, 2009 (Table 7-4).

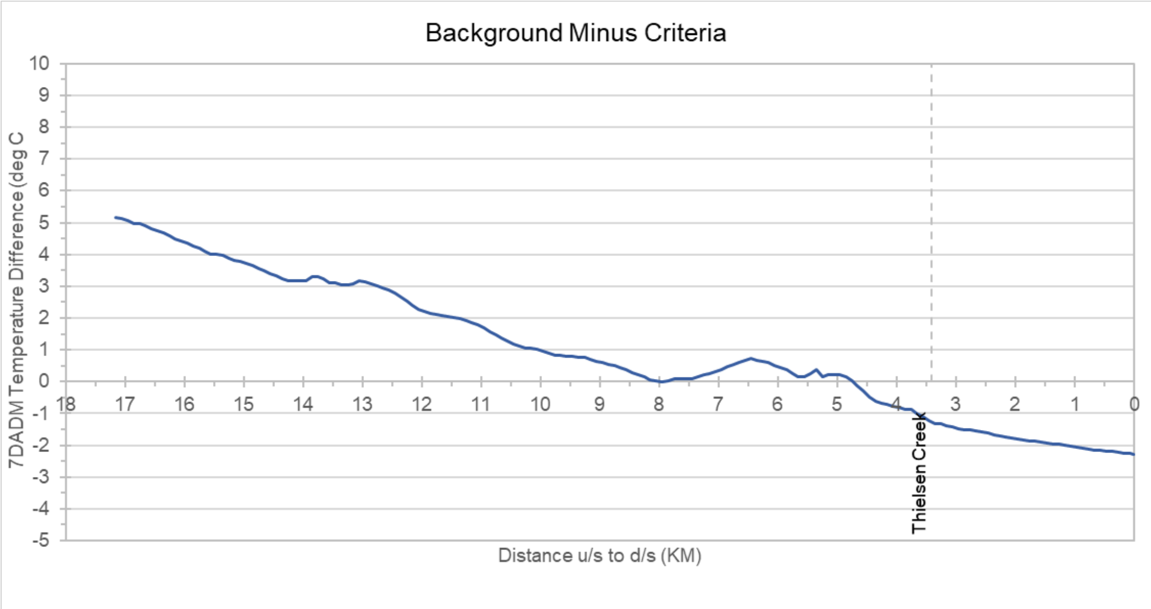

Figure 7-9. The maximum 7DADM temperature differences along Lake Creek (spawning period) for the difference between background conditions and criteria temperatures.

Table 7-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Lake Creek spawning period

Lake Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	17.15	5.17	8/7/2009
	0.00	-2.28	8/7/2009

8.0 FISH CREEK

The modeled portion of Fish Creek is shown in Figure 8-1.Fish Creek was modeled for both the summer period (July 8-11, 2001) and the spawning period (July 1, 2009 to September 30, 2009). The Fish Creek spawning period model was developed by PacificCorp, and the model domain starts at approximately RKM 11.5 to the mouth. The summer period scenario results are presented in sections 8.1 and 8.18.2, while the spawning period scenario results are presented in sections 8.3 and 8.4.

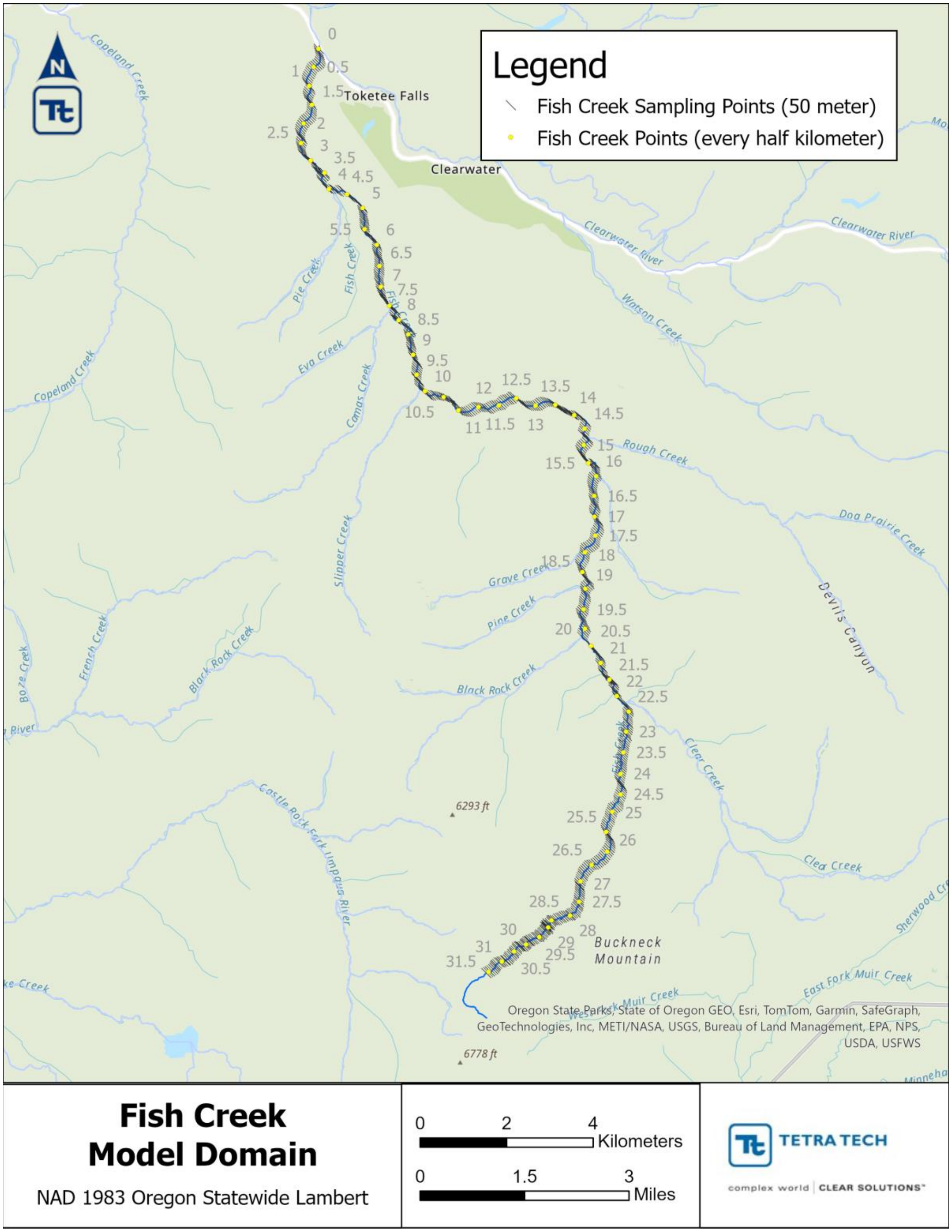

Figure 8-1. Location of Fish Creek.

8.1 FISH CREEK SUMMER PERIOD SCENARIO RESULTS

The Fish Creek HS summer model does not include any point sources. The scenarios that are relevant to the Fish Creek summer model include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; and the Fully Restored Vegetation with Natural Flow scenario. The 7DADM results of these scenarios are shown in Figure 8-2 through Figure 8-4. Note that since the summer model was run for the period from July 8-11, 2001, the temperatures represent the summertime critical period for Fish River. The plots present the daily maximum temperature, as opposed to the 7-day average maximum temperature. Limited data availability restricted Heat Source simulations to 4 days during the critical period. The maximum daily temperature occurred on July 10.

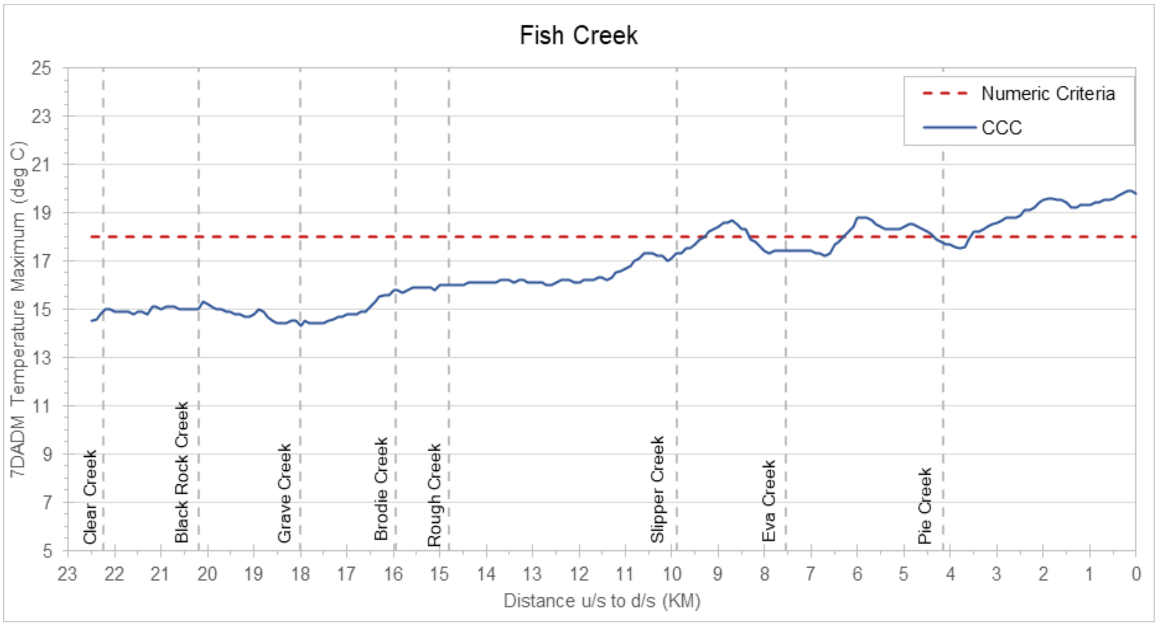

Figure 8-2. The maximum 7DADM temperature results along Fish Creek summer period for the Current Conditions scenario.

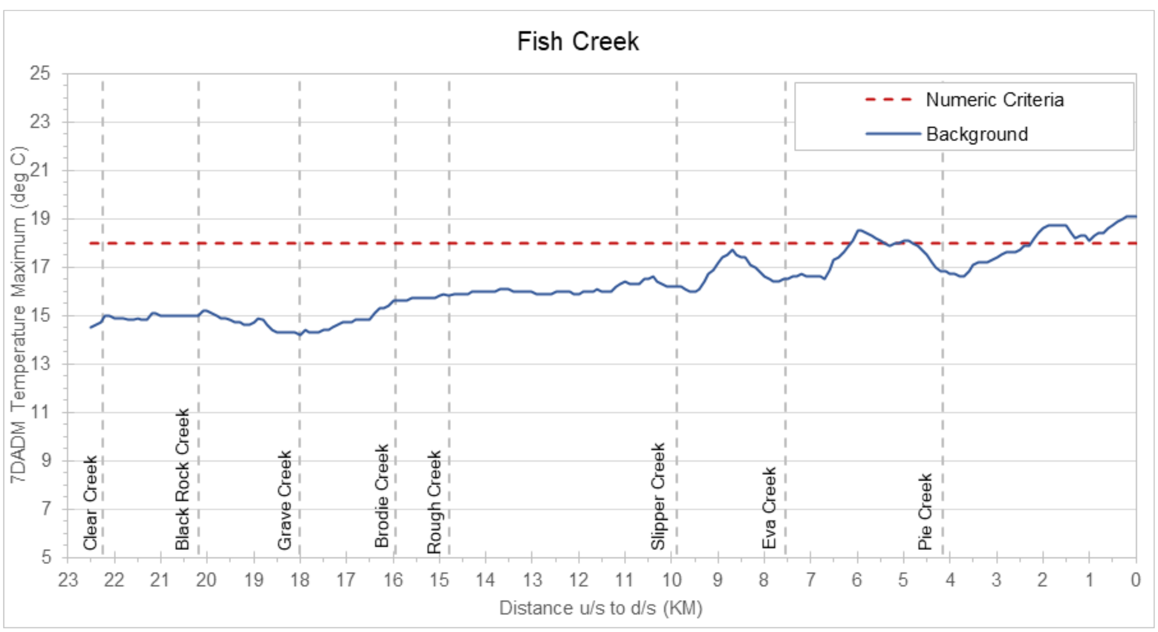

Figure 8-3. The maximum 7DADM temperature results along Fish Creek summer period for the Background scenario.

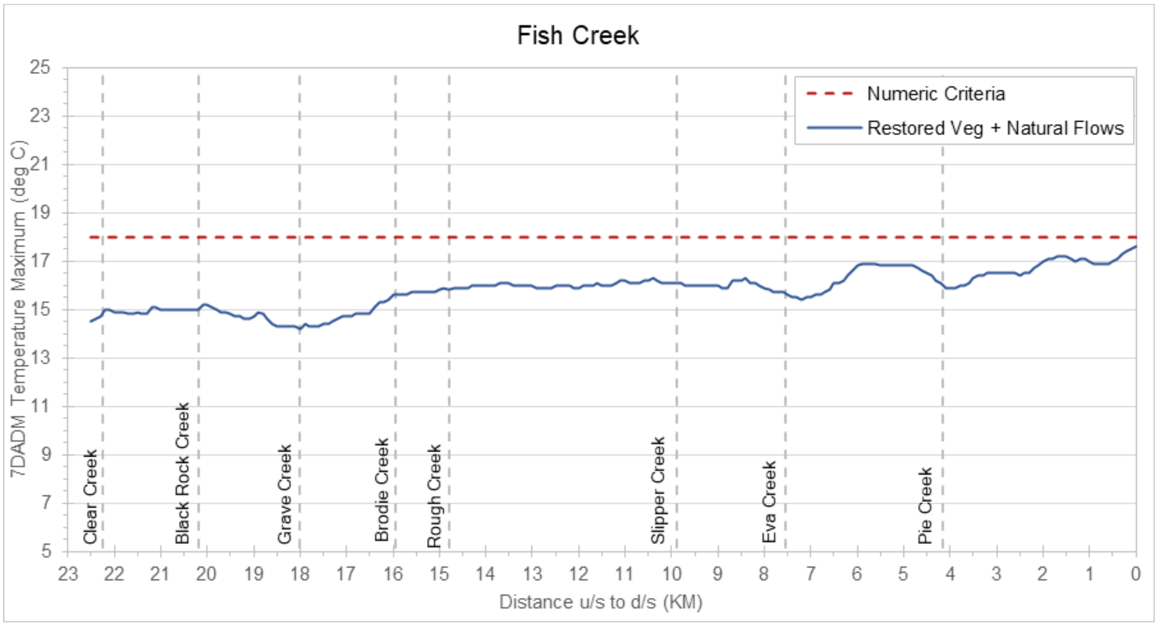

Figure 8-4. The maximum 7DADM temperature results along Fish Creek summer period for the Fully Restored Vegetation and Natural Flow scenario.

8.2 FISH CREEK SUMMER PERIOD SCENARIO COMPARISONS

Comparisons for the Fish Creek summer period scenarios include:

2. Impact of current point source and shade loss
   - ✓ CCC minus background
7. Difference between background and criteria (All models)
   - ✓ Background minus Criteria
9. Natural Flows (All models except Elk Creek)
   - ✓ Background minus fully restored veg with natural flows

Figure 8-5 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 1.5 ˚C at RKM 9.2 on July 10, 2001 (Table 8-1).

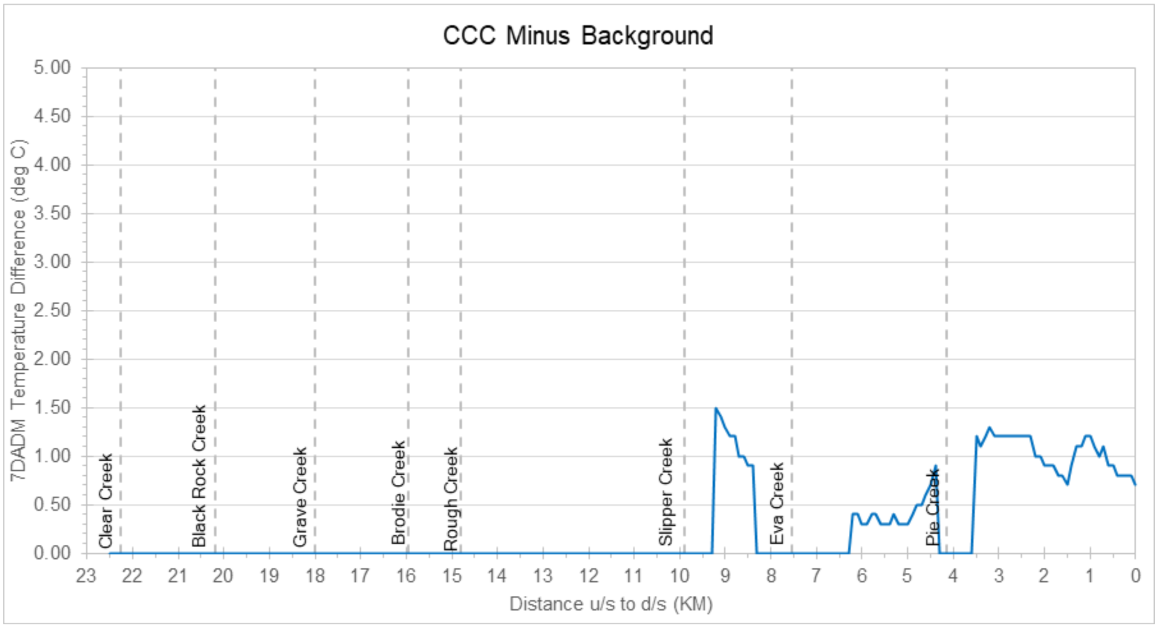

Figure 8-5. The maximum 7DADM temperature differences along Fish Creek (summer period) for the impacts of current point source and shade loss.

Table 8-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Fish Creek summer period

Fish Creek	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	9.20	1.50	7/10/2001

Figure 8-6 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 1.1 ˚C at RKMs 0.2 to 0.0 on July 11, 2001 and -3.8 ˚C at RKM 18 on July 9, 2001 (Table 8-2).

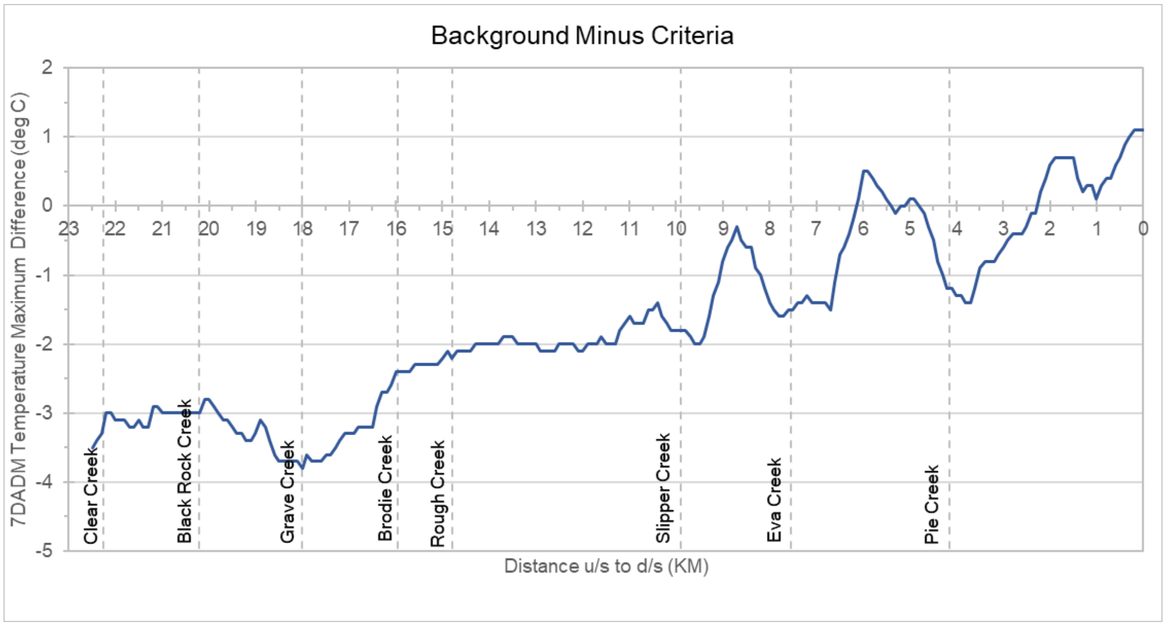

Figure 8-6. The maximum 7DADM temperature differences along Fish Creek summer period for the difference between background conditions and criteria temperatures.

Table 8-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Fish Creek summer period

Fish Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	0.20 to 0.0	1.10	7/11/2001
	18.00	-3.80	7/9/2001

Figure 8-7 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. The only difference between these two scenarios for Fish Creek is that there are no withdrawals in the Restored Vegetation with Natural Flow scenario. All other flows and temperature inputs are the same. The maximum delta reaches 1.8 ˚C at RKM 0.6 on July 11, 2001 (Table 8-3).

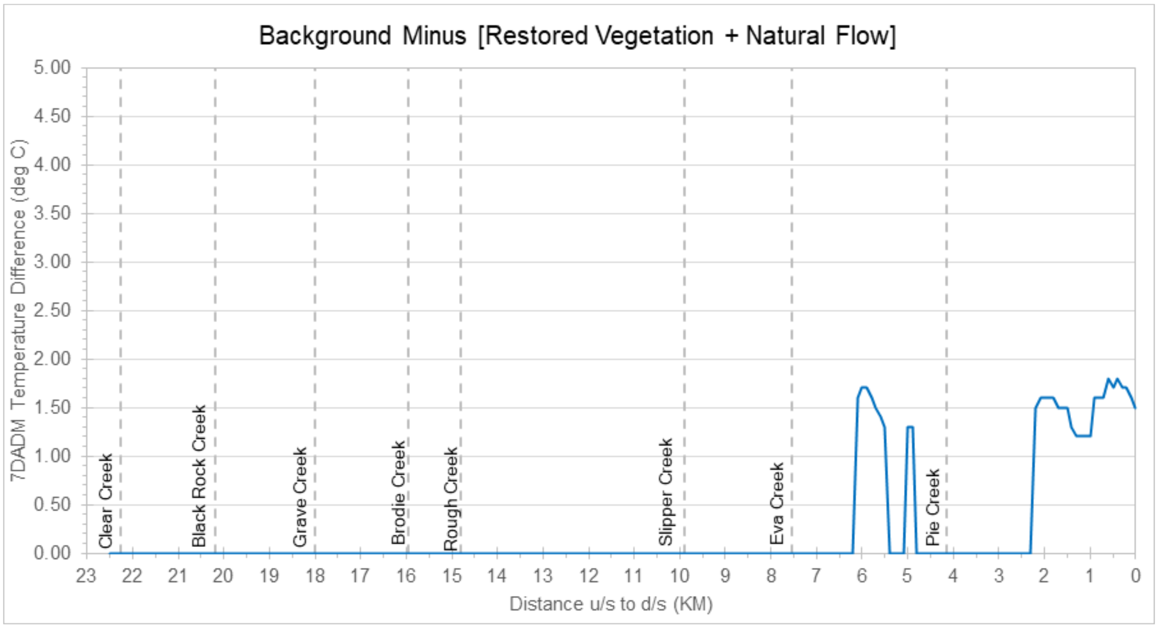

Figure 8-7. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario for Fish Creek (summer period).

Table 8-3. Location and date of maximum delta when temperatures are greater than criterion for comparison 9 for the Fish Creek summer period

Fish Creek	RKM	Maximum Delta	Date when maximum delta occurs
Background Minus [Restored Vegetation + Natural Flow]	0.60	1.80	7/11/2001

8.3 FISH CREEK SPAWNING PERIOD SCENARIO RESULTS

The Fish Creek HS spawning model does not include any point sources. The scenarios that are relevant to Fish Creek include the CCC scenario, which is identical to the No Point Source scenario; and the Background scenario. The 7DADM results are shown in Figure 8-8 and Figure 8-9 for these scenarios. Note that the year round (non-spawning criteria) applies to Fish Creek and was evaluated for the entire modeling period from July 1 to September 30, 2009.

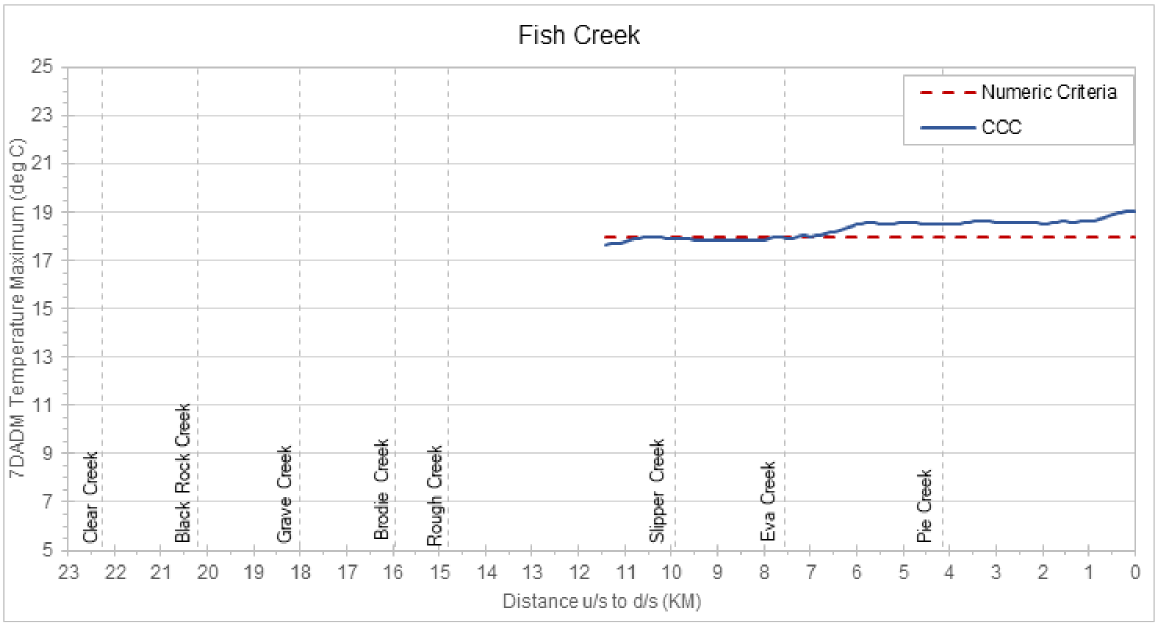

Figure 8-8. The maximum 7DADM temperature results along Fish Creek (spawning period) for the Current Conditions scenario.

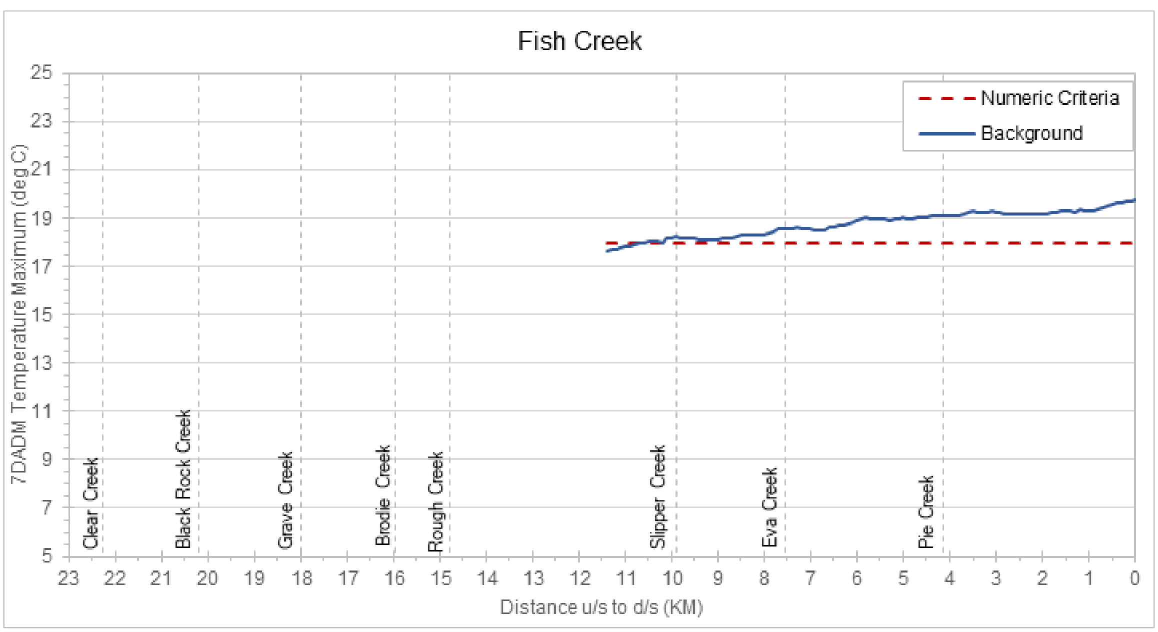

Figure 8-9. The maximum 7DADM temperature results along Fish Creek (spawning period) for the Background scenario.

8.4 FISH CREEK SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the Fish Creek spawning period include:

2. Impact of current point source and shade loss (note there are no point sources in Fish Creek)
   - ✓ CCC minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

Figure 8-10 shows the results of comparison 2, the impacts of shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches -0.68 ˚C at RKM 1.3 on 8/5/2009 (Table 8-4).

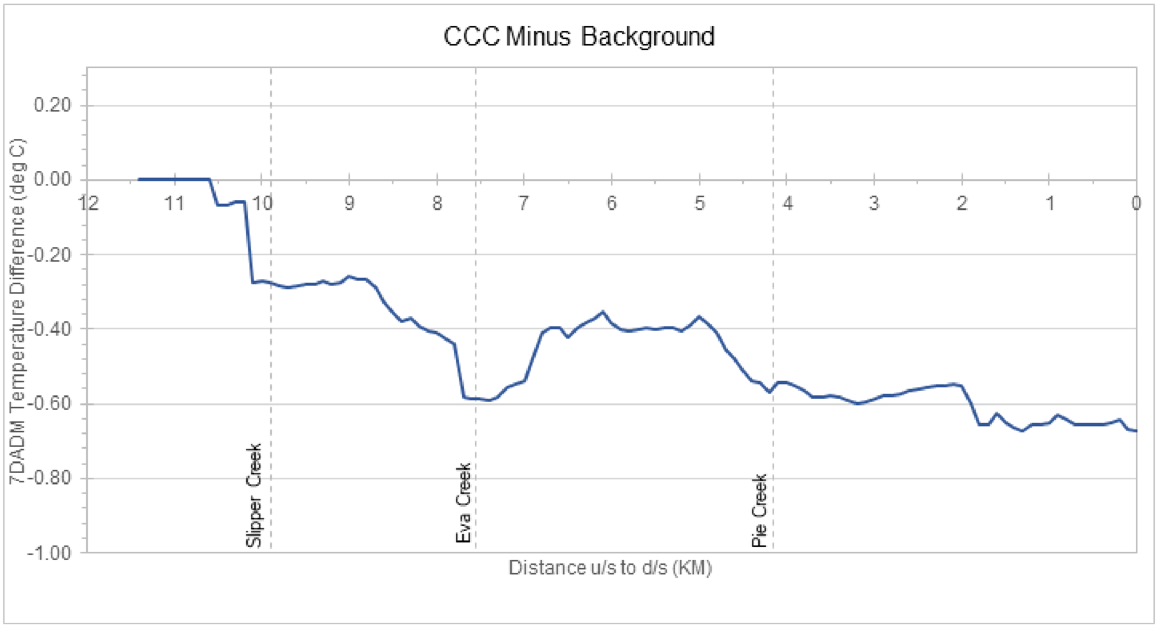

Figure 8-10. The maximum 7DADM temperature differences along Fish Creek (spawning period) for the impacts of current point sources and shade loss.

Table 8-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Fish Creek spawning period

Fish Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus Background	1.30	-0.68	8/5/2009

Figure 8-11 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 1.74 ºC at RKM 0.0 on 8/3/2009 and -0.33 ºC at RKM 11.4 on 8/2/2009 (Table 8-5).

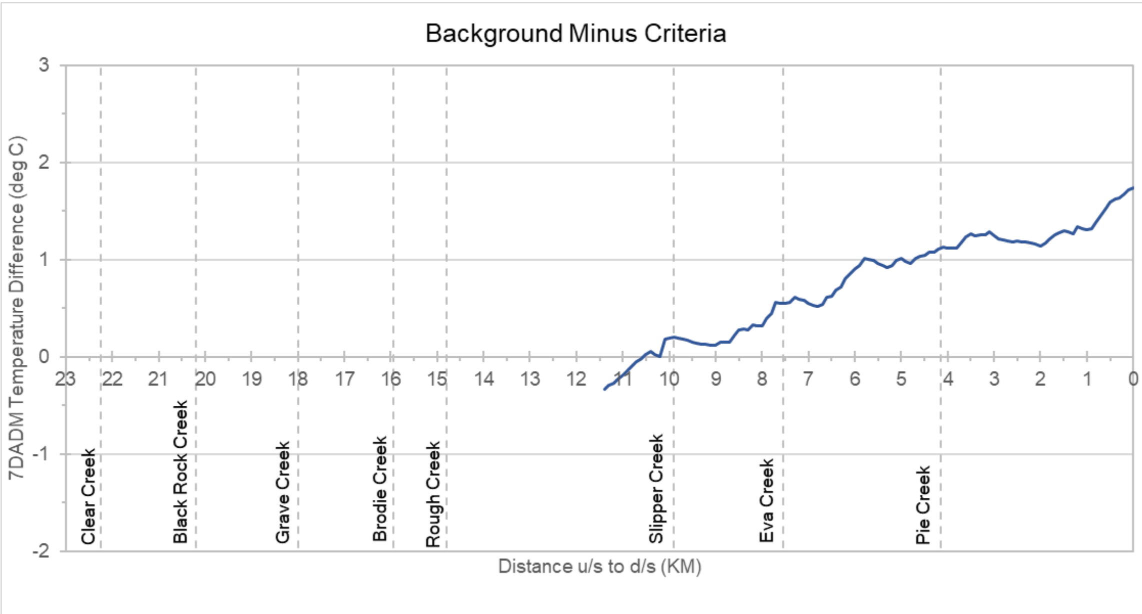

Figure 8-11. The maximum 7DADM temperature differences along Fish Creek spawning period between Background scenario and the criteria

Table 8-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Fish Creek spawning period

Fish Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	0.00	1.74	8/3/2009
	11.40	-0.33	8/2/2009

9.0 ROCK CREEK

The modeled portion of Rock Creek is shown in Figure 9-1. Rock Creek was modeled for both the summer period (July 12-31, 2002) and the spawning period (August 1, 2009 to October 15, 2009). The summer period scenario results and scenario comparisons are presented in sections 9.1 and 9.2, while the spawning period scenario results and scenario comparisons are presented in section 9.3 and 9.4.

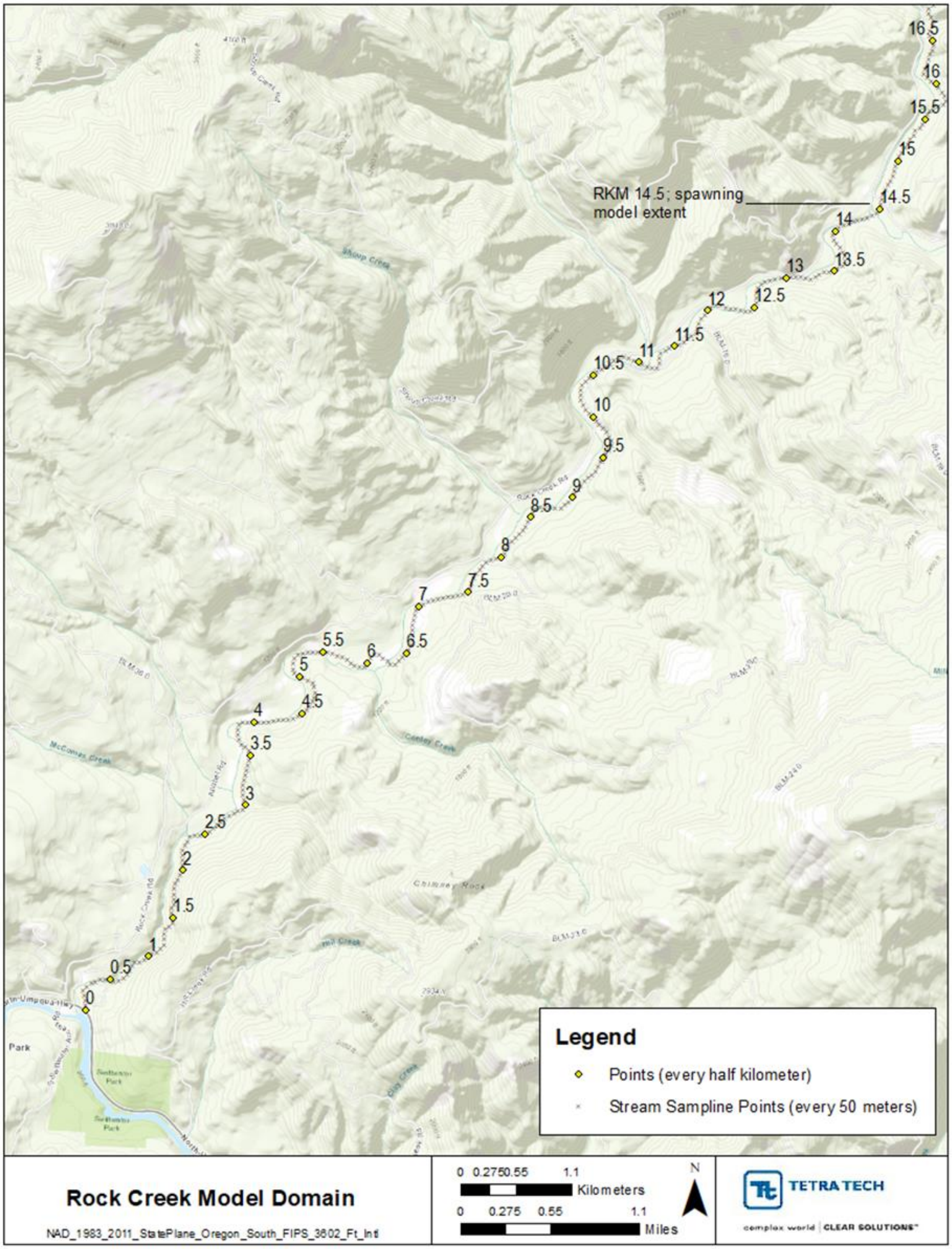

Figure 9-1. Location of Rock Creek.

9.1 ROCK CREEK SUMMER PERIOD SCENARIO RESULTS

The Rock Creek HS summer model includes the Rock Creek Hatchery input at RKM 0.3 (the hatchery is referred to as a point source in the discussion below). The scenarios that are relevant to Rock Creek include the CCC scenario; No Point Source scenario; the Background scenario; the Point Source WLA scenario; the Fully Restored Vegetation scenario; the Attainment scenario; and the tributary/headwater plus 0.1 ºC scenario. The point source WLA temperatures were calculated using a WLA analysis spreadsheet provided by DEQ which considers the river flow (at 7Q10), water temperature criteria, the effluent flow rate, and an allocated HUA of 0.3 ºC for the Hatchery. The 7DADM results for these scenarios are shown in Figure 9-2 through Figure 9-7.

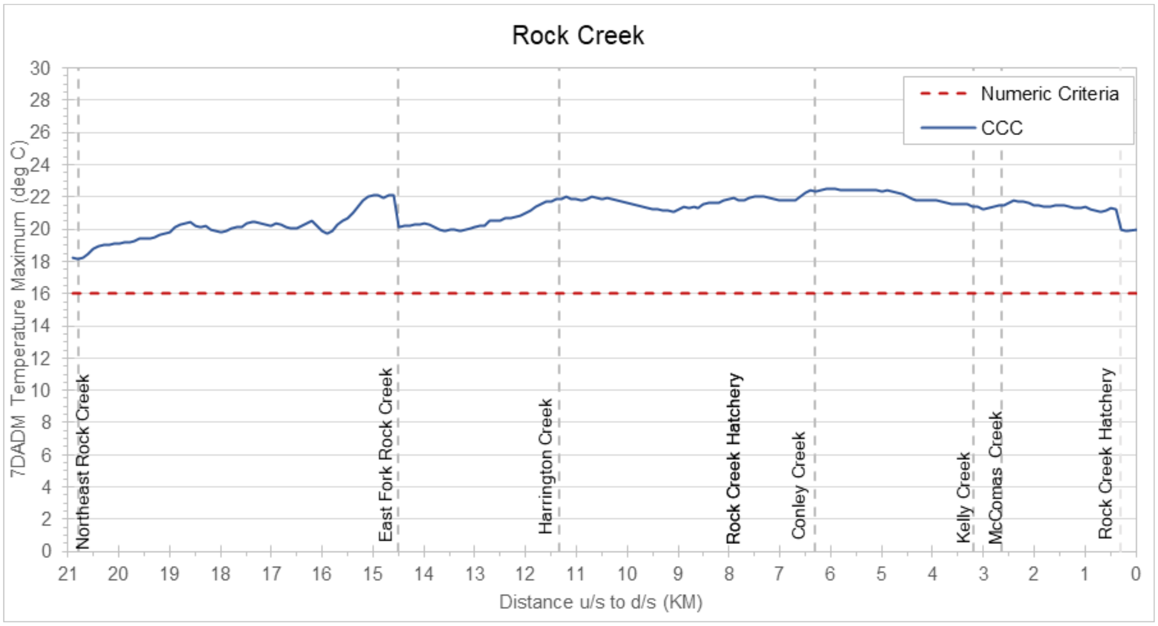

Figure 9-2. The maximum 7DADM temperature results along Rock Creek (summer period) for the Current Conditions scenario.

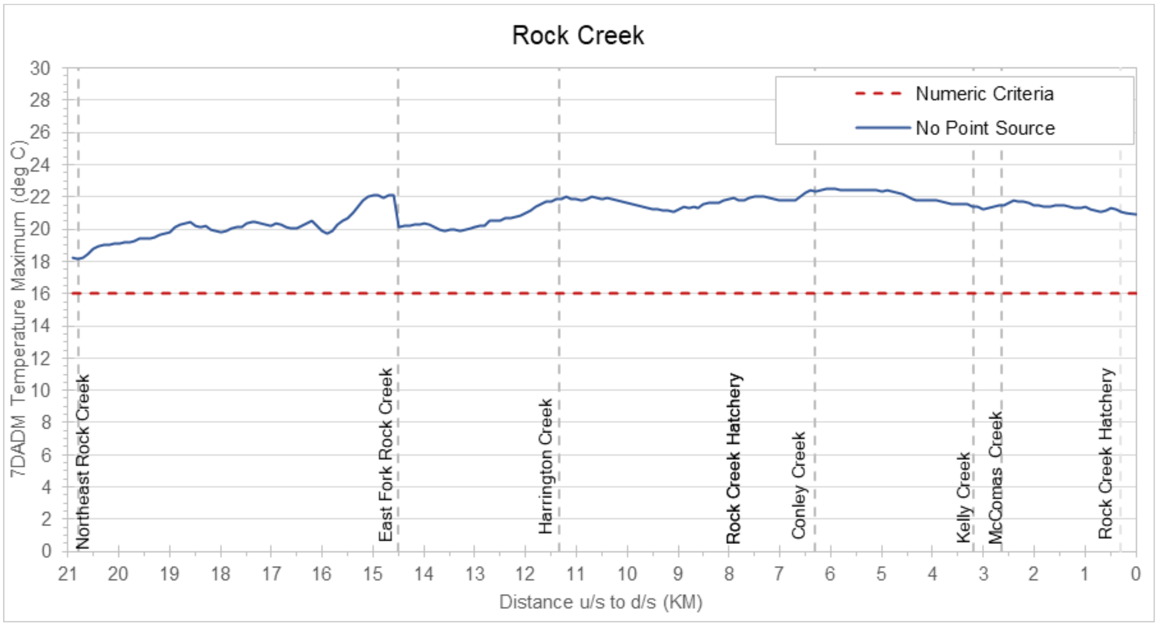

Figure 9-3. The maximum 7DADM temperature results along Rock Creek (summer period) for the No Point Source scenario.

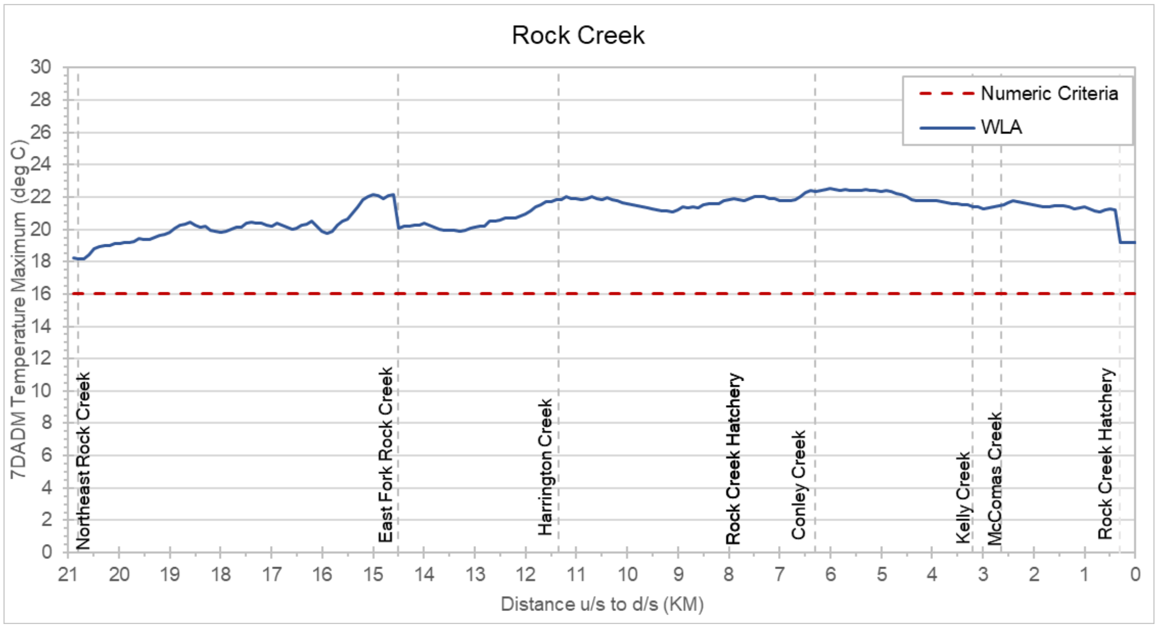

Figure 9-4. The maximum 7DADM temperature results along Rock Creek (summer period) for the Point Source WLA scenario.

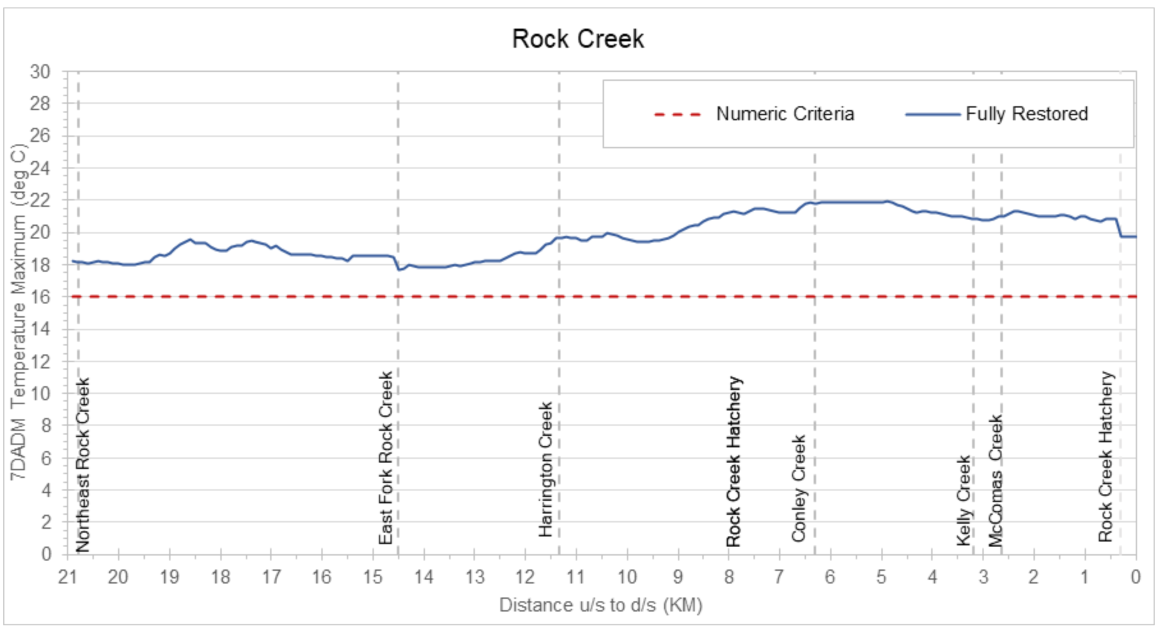

Figure 9-5. The maximum 7DADM temperature results along Rock Creek (summer period) for the Fully Restored Vegetation scenario.

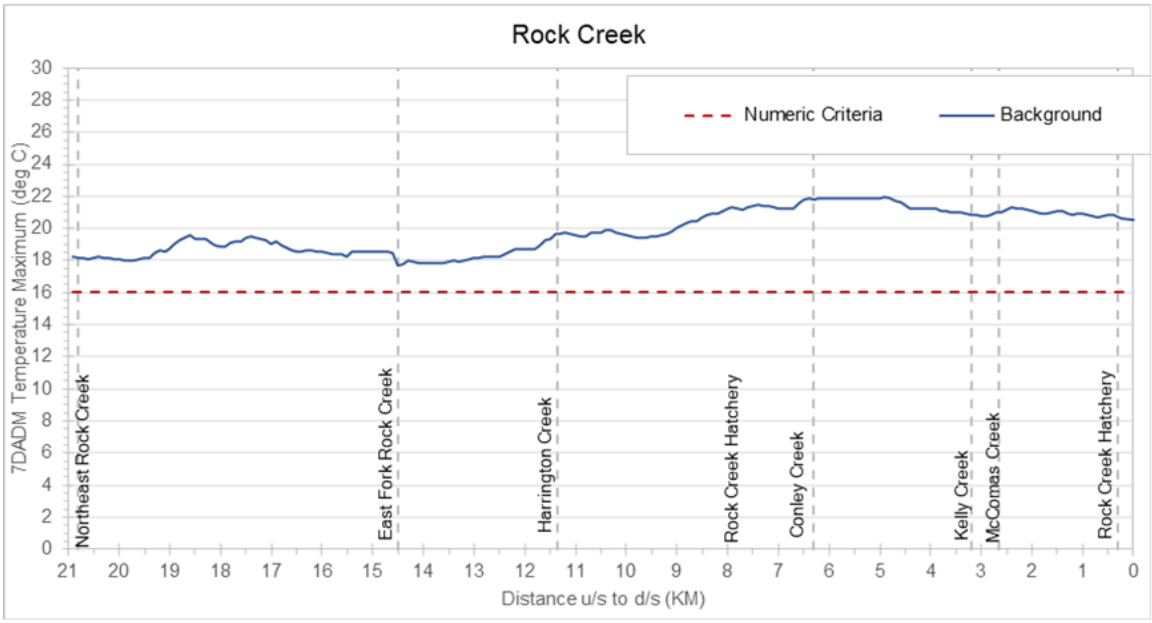

Figure 9-6. The maximum 7DADM temperature results along Rock Creek (summer period) for the Background scenario.

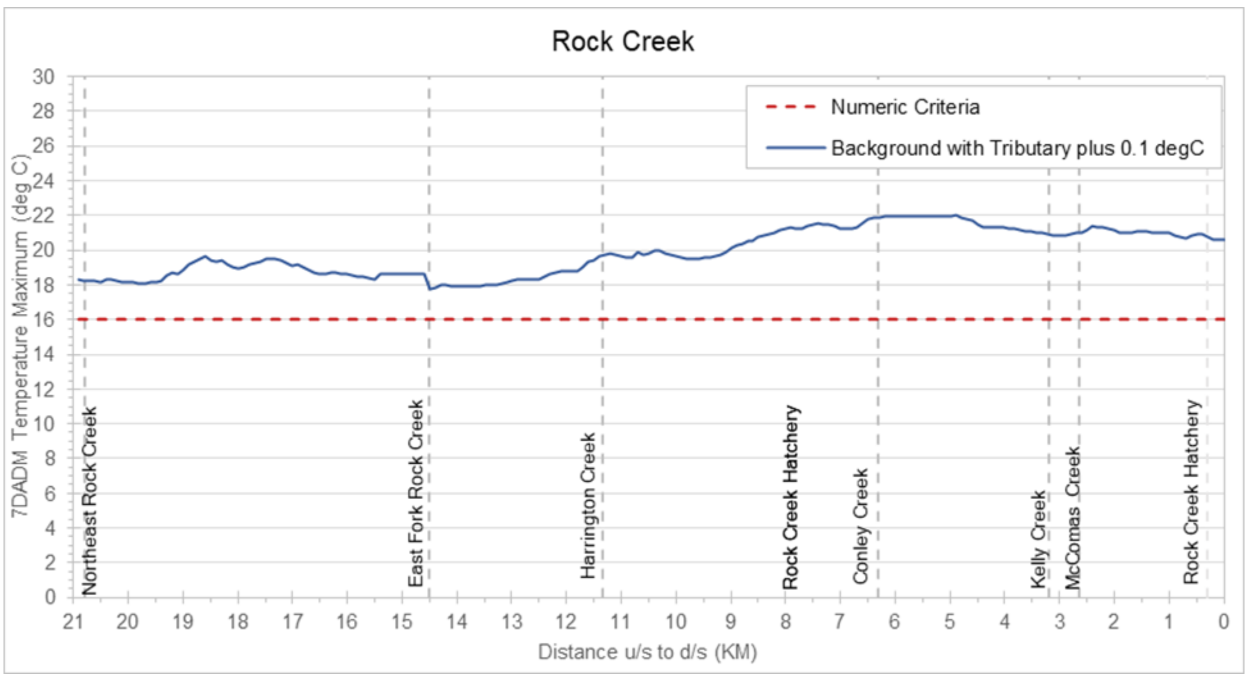

Figure 9-7. The maximum 7DADM temperature results along Rock Creek (summer period) for the Tributary/Headwater plus 0.1°C scenario.

9.2 ROCK CREEK SUMMER PERIOD SCENARIO COMPARISONS

Comparisons of summer period scenarios for Rock Creek include:

1. Impacts of shade loss
   - ✓ No Point Source minus background
2. Impact of current point source and shade loss
   - ✓ CCC minus background
3. Impact from point source @ current condition
   - ✓ CCC minus no point source
4. Impact from point sources @ WLA conditions
   - ✓ Point Source WLA minus No point source
5. Impact current point source and restored vegetation
   - ✓ Fully restored veg with point source @ current condition minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

A2. Impact of tributary scenario (tributary/headwater plus 0.1 °C)
   - ✓ Tributary plus 0.1 °C minus background

Figure 9-8 shows the results of comparison 1, which is the 7DADM temperature difference between the No Point Source scenario and Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The overall 7DADM temperature differences increase toward the downstream direction. The maximum delta reaches 3.9 °C at RKM 14.6 on July 31, 2002 (Table 9-10).

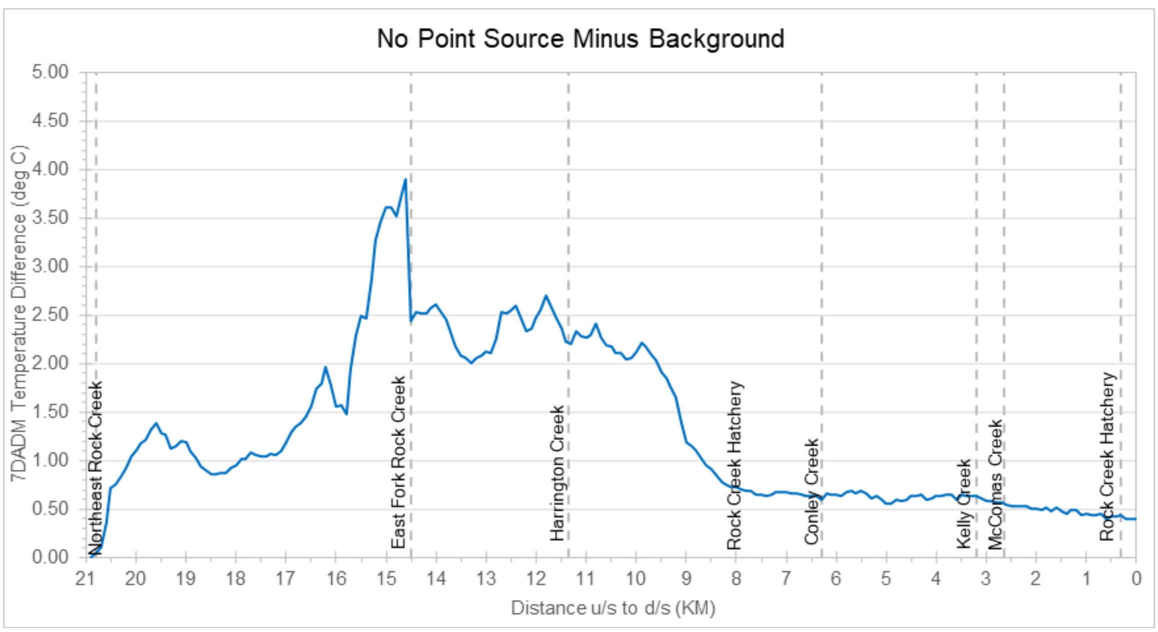

Figure 9-8. The maximum 7DADM temperature differences along Rock Creek (summer period) for the impacts of current condition vegetation.

Table 9-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 1 for Rock Creek summer period

Rock Creek	RM	Maximum Delta	Date when Maximum Delta occurs
No Point Source Minus Background	14.60	3.90	7/31/2002

Figure 9-9 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition and the point source conditions where the CCC scenario uses the latest available flow and temperature from the point sources, while the Background scenario does not include point sources. The maximum delta reaches 3.9 ˚C at RKM 14.6 on July 31, 2002 (Table 9-2).

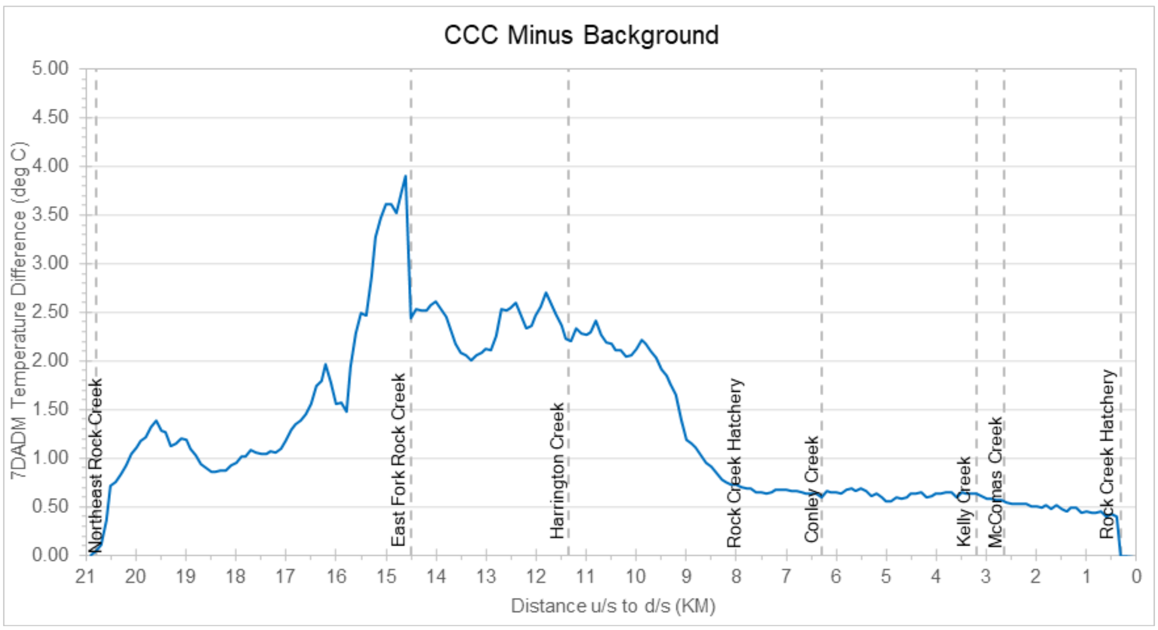

Figure 9-9. The maximum 7DADM temperature differences along Rock Creek (summer period) for the impacts of current point sources and shade loss.

Table 9-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Rock Creek summer period

Rock Creek	RM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus Background	14.60	3.90	7/31/2002

Figure 9-10 shows the results of comparison 3, the impacts of current point sources, which is the 7DADM temperature difference between the CCC scenario and No Point Source scenario. The difference between these two scenarios is the CCC scenario uses the latest available flow and temperature from the point sources, while the No Point Source scenario does not include point sources. There is no maximum delta for this comparison (Table 9-3).

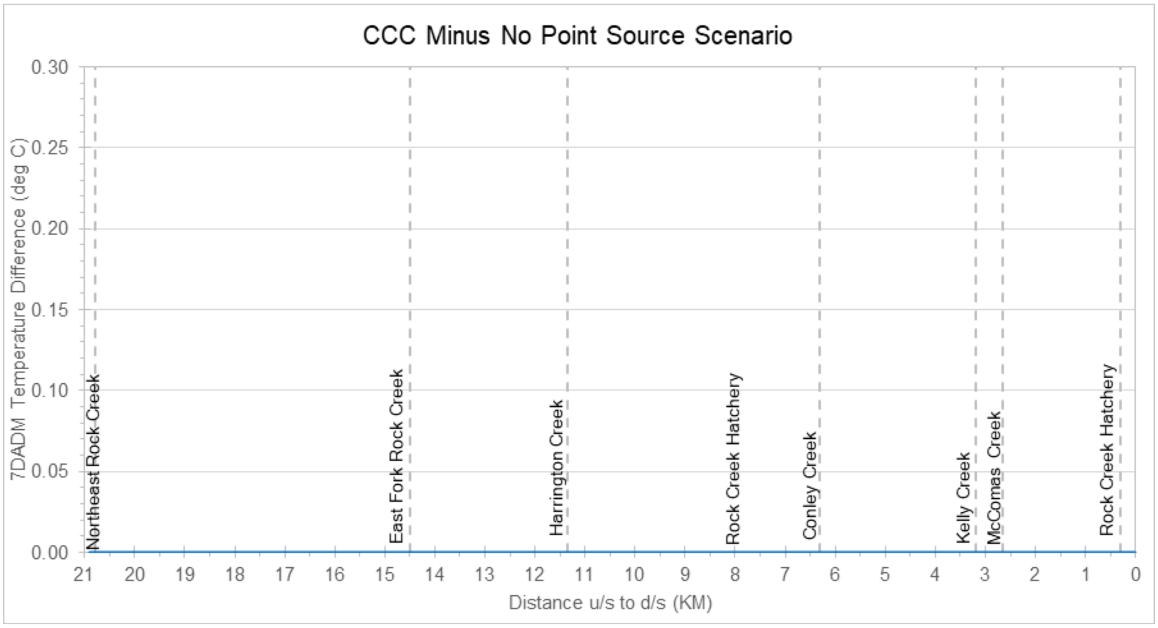

Figure 9-10. The maximum 7DADM temperature differences along the Rock Creek (summer period) for the impacts of point sources at the current condition.

Table 9-3. Location and date of maximum delta when temperatures are greater than criterion for comparison 3 for the Rock Creek summer period

Rock Creek	RM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Point Source Scenario	N/A	0.00	N/A

TETRA TECH
WTR Mid Atlantic

Figure 9-11 shows the results of comparison 4, the impact from point sources at WLA conditions, which is the 7DADM temperature difference between the Point Source WLA scenario and No Point Source scenario. The difference between these two scenarios is the Point Source WLA scenario uses the calculated WLA temperatures, while the No Point Source scenario does not include point sources. The maximum delta comparisons show a delta of -1.7 ˚C at RKM 0.3 on July 18, 2002 (Table 9-4).

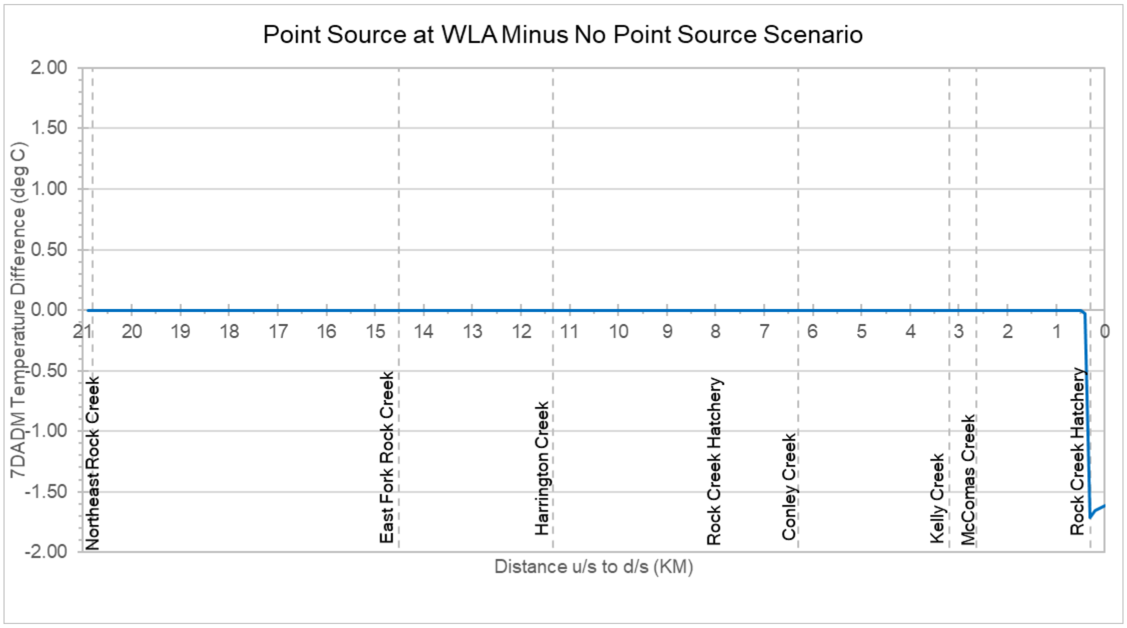

Figure 9-11. The maximum 7DADM temperature differences along the Rock Creek (summer period) for the impacts of point sources at the WLA temperatures.

Table 9-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 4 for the Rock Creek summer period

Rock Creek	RM	Maximum Delta	Date when Maximum Delta occurs
Point Source at WLA Minus No Point Source Scenario	0.30	-1.70	7/18/2002

Figure 9-12 shows the results of comparison 5, the impact from current point sources and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario at current conditions and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation scenario includes point sources and current conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. There is no maximum delta for this comparison (Table 9-5).

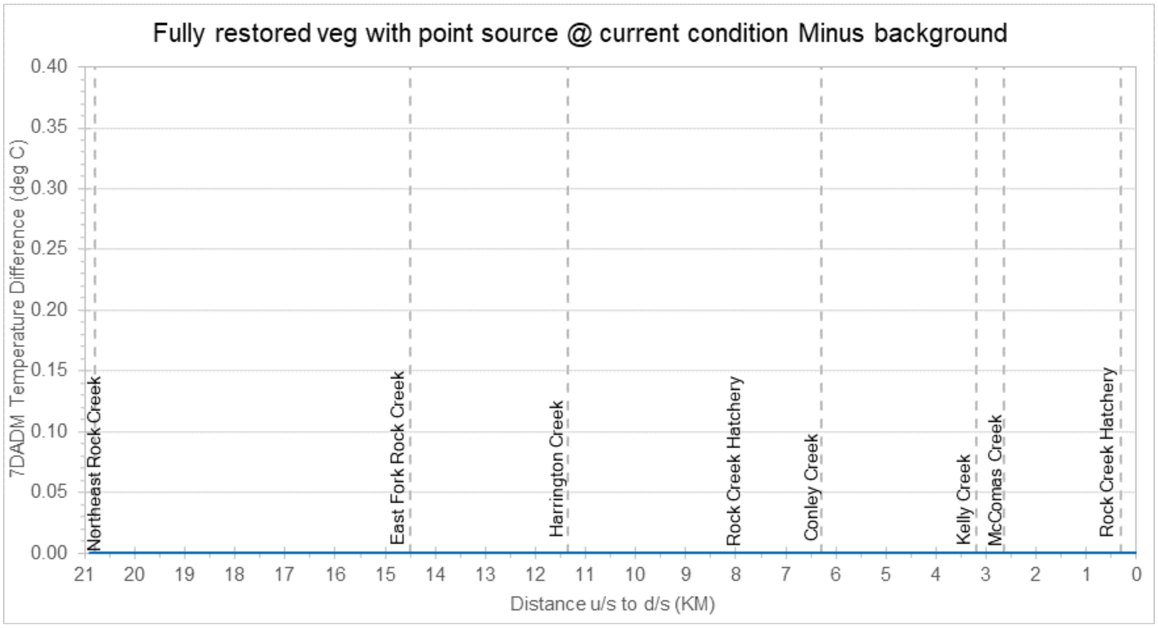

Figure 9-12. The maximum 7DADM temperature differences along Rock Creek (summer period) for the impacts of current point sources with restored vegetation.

Table 9-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 5 for the Rock Creek summer period

Rock Creek	RM	Maximum Delta	Date when Maximum Delta occurs
Fully restored veg with point source @ current condition Minus background	N/A	0.00	N/A

Figure 9-13 shows the results of comparison 7, the impacts of background conditions when they are greater than the criteria, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 5.93 ˚C at RKM 4.9 on July 18, 2002 (Table 9-6).

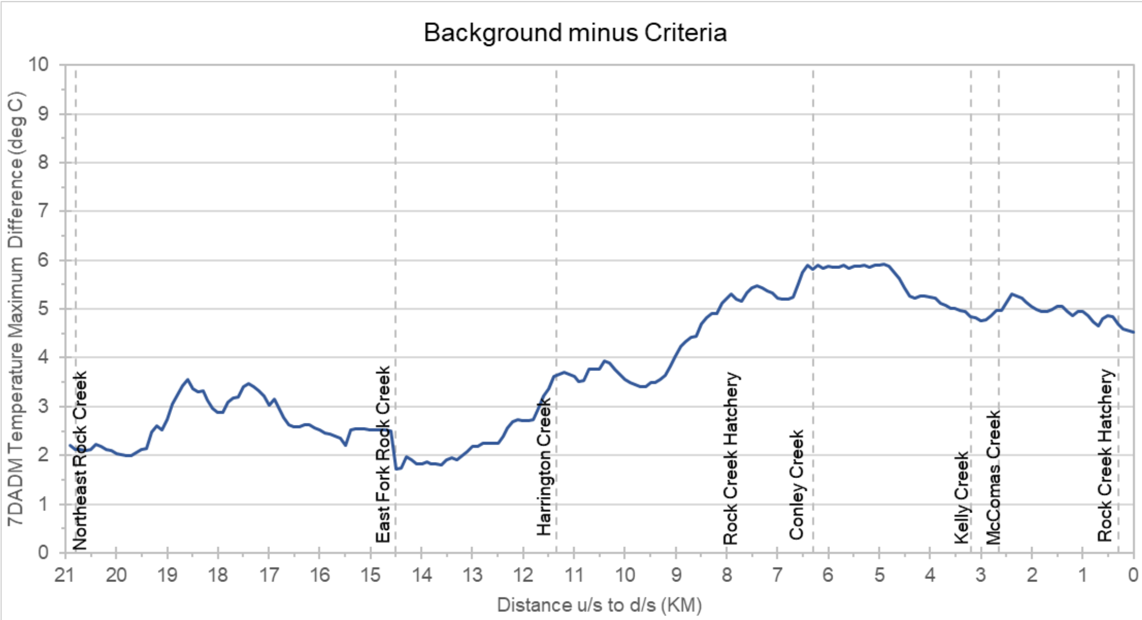

Figure 9-13. The maximum 7DADM temperature differences along the Rock Creek (summer period) for the difference between background conditions and criteria temperatures.

Table 9-6. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Rock Creek summer period

Rock Creek	RM	Maximum Delta	Date when Maximum Delta occurs
Background minus Criteria	4.90	5.93	7/18/2002

Figure 9-14 shows the results of comparison A2, the impact of adding 0.1 ºC to all the tributaries and headwater/upstream inflows in the background scenario, which is the 7DADM temperature difference between A2 and the Background scenario and criteria. The overall 7DADM temperature differences increase to 0.1 ºC and then starts decreasing in the downstream direction. The maximum delta immediately reaches 0.1 ˚C at the upstream and stays at 0.1 ºC for several RKM downstream (Table 9-7). Since the 0.1 ºC delta occurs for several days, each individual date and RKM are not listed as they can be seen in the Figure 9-14.

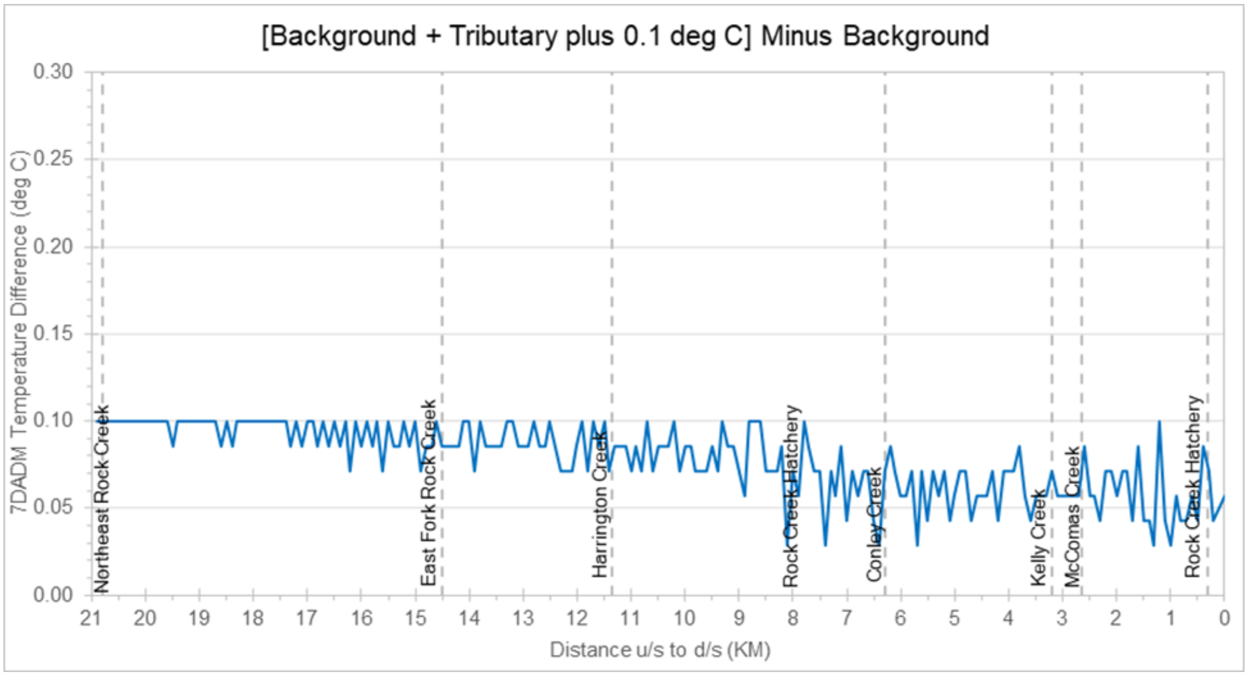

Figure 9-14. The maximum 7DADM temperature differences along Rock Creek (summer period) for the impacts of adding 0.1°C to the Tributary/Headwater.

Table 9-7. Location and date of maximum delta when temperatures are greater than criterion for comparison A2 for the Rock Creek summer period

Rock Creek	RKM	Maximum Delta	Date when maximum delta occurs
[Background + Tributary plus 0.1 deg C] Minus Background	N/A	0.10	N/A

9.3 ROCK CREEK SPAWNING PERIOD SCENARIO RESULTS

The Rock Creek HS spawning model includes the Rock Creek Hatchery input at RKM 0.3 (the hatchery is referred to as a point source in the discussion below). The scenarios that are relevant to the Rock Creek spawning period include the CCC scenario, the No Point Source scenario; the Point Source WLA scenario; the Fully Restored Vegetation scenario; the Background scenario; the Attainment scenario; and the tributary/headwater plus 0.1 ºC scenario. The 7DADM results are shown in Figure 9-15 to Figure 9-20 **Error! Reference source not found.** for these scenarios. Note that the spawning criteria applies to Rock Creek and was evaluated for the period from September 1 to October 15, 2009.

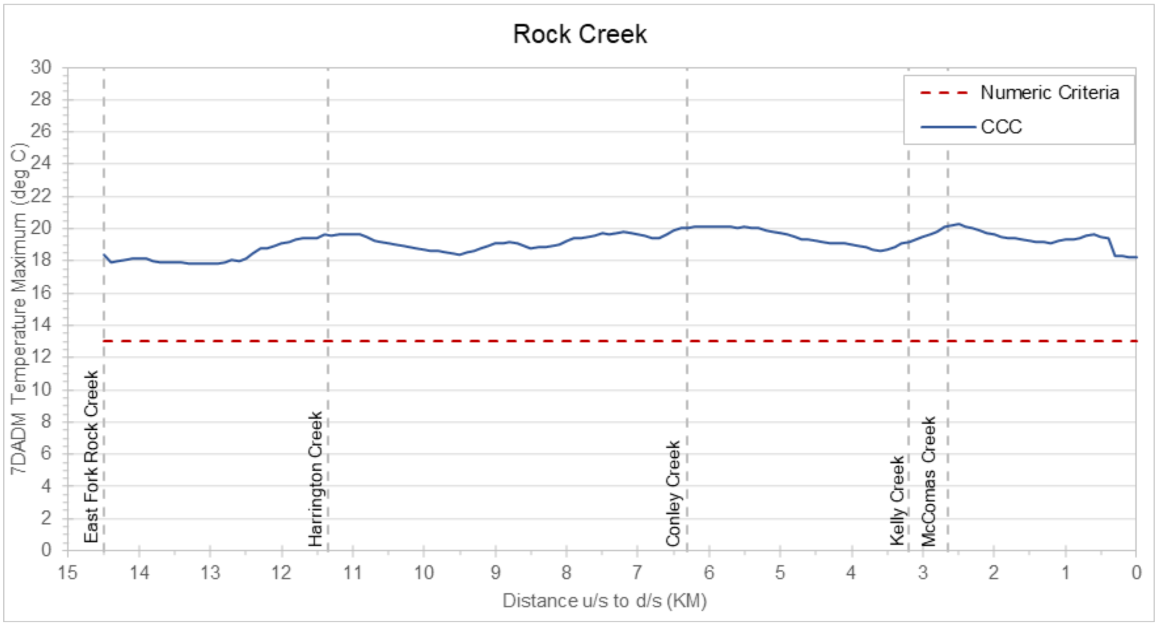

Figure 9-15. The maximum 7DADM temperature results along Rock Creek (spawning period) for Current Condition scenario.

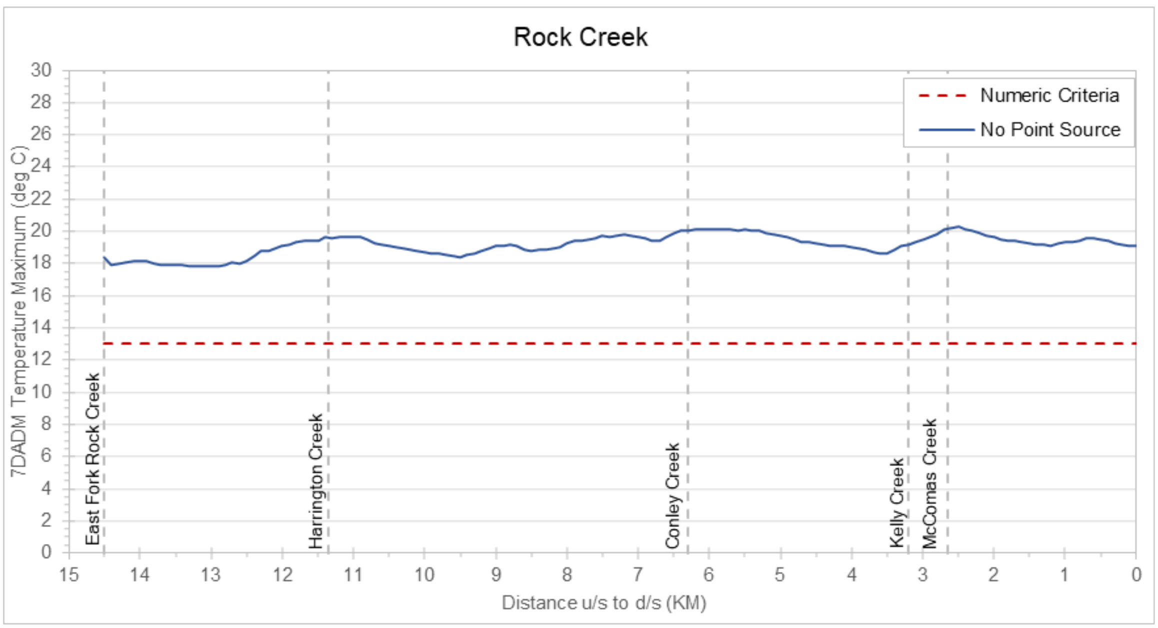

Figure 9-16. The maximum 7DADM temperature results along Rock Creek (spawning period) for the No Point Source scenario.

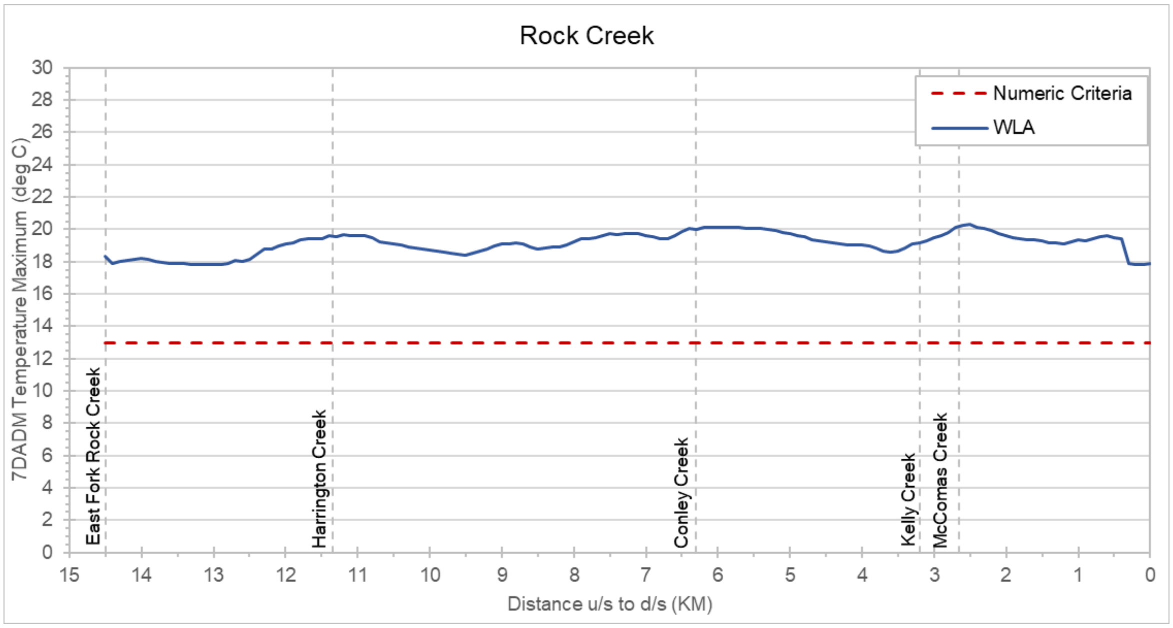

Figure 9-17. The maximum 7DADM temperature results along Rock Creek (spawning period) for the Point Source WLA Conditions scenario.

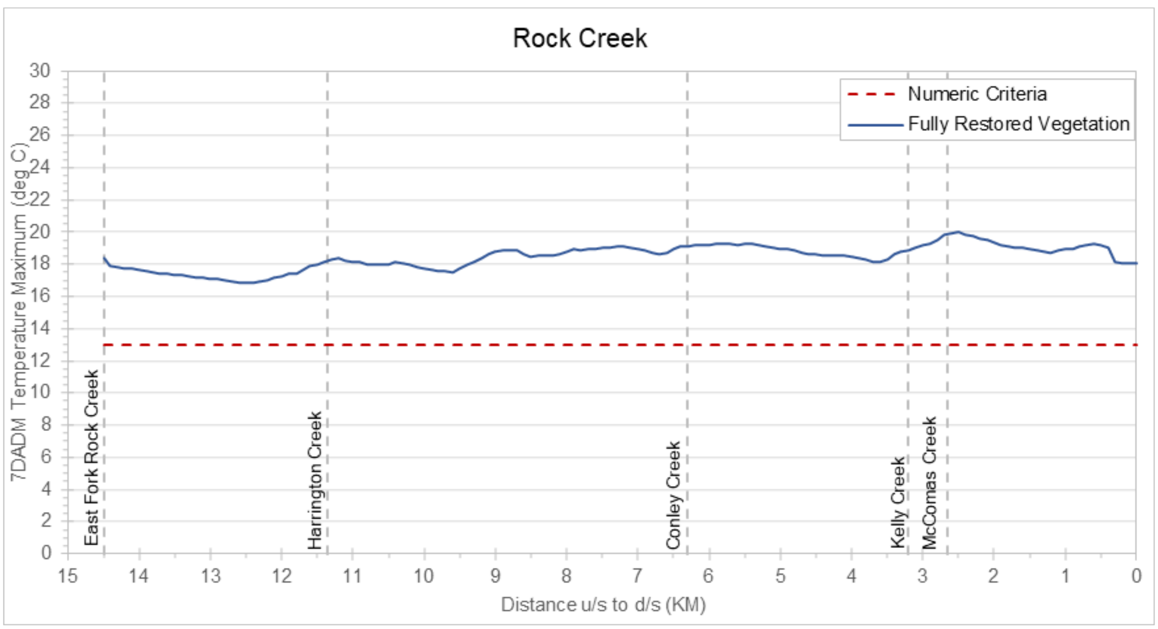

Figure 9-18. The maximum 7DADM temperature results along Rock Creek (spawning period) for the Fully Restored Vegetation scenario.

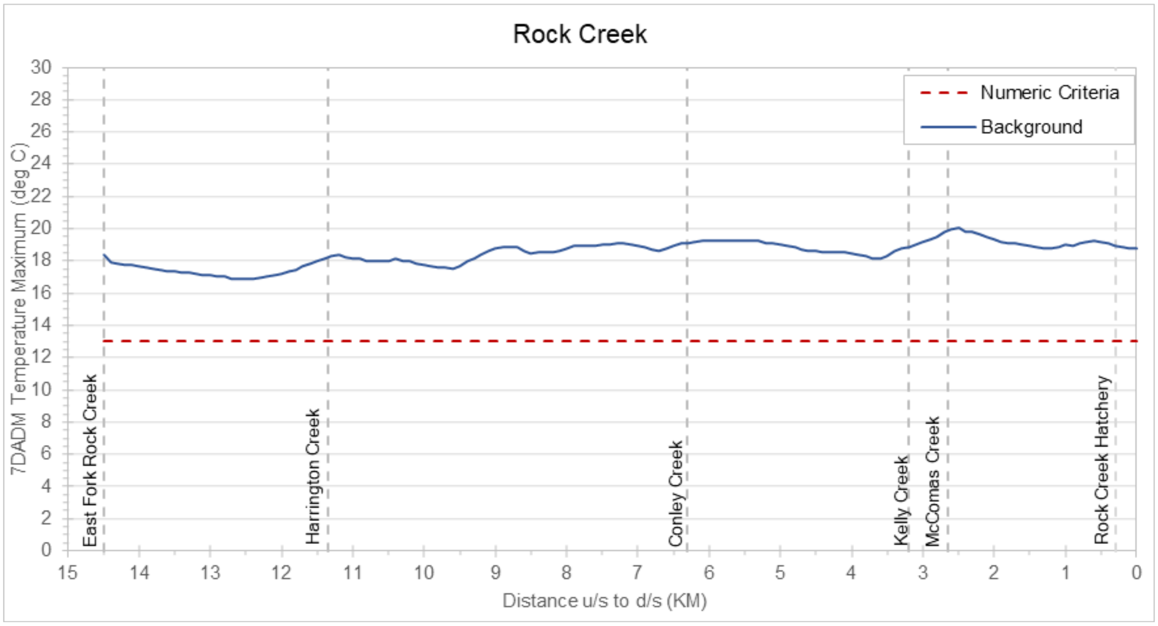

Figure 9-19. The maximum 7DADM temperature results along Rock Creek (spawning period) for the Background scenario.

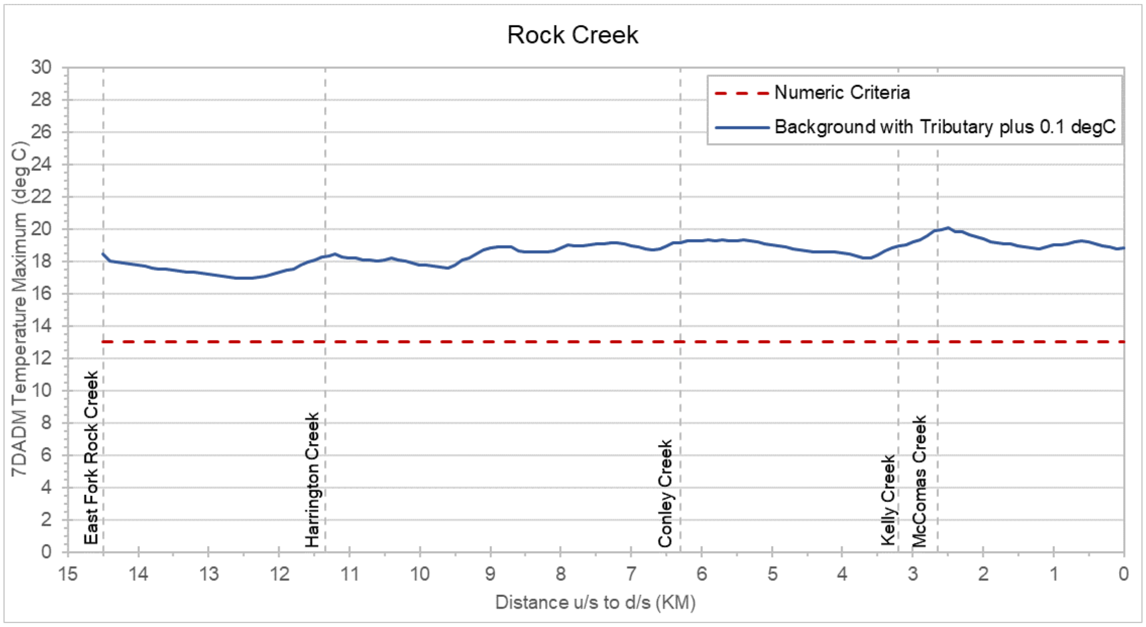

Figure 9-20. The maximum 7DADM temperature results along Rock Creek (spawning period) for the Tributary/Headwater plus 0.1°C scenario.

9.4 ROCK CREEK SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the Rock Creek spawning period include:

1. Impacts of shade loss
   - ✓ No Point Source minus background
2. Impact of current point source and shade loss
   - ✓ CCC minus background

3. Impact from point source @ current condition
   - ✓ CCC minus no point source
4. Impact from point sources @ WLA conditions
   - ✓ Point Source WLA minus No point source
5. Impact current point source and restored vegetation
   - ✓ Fully restored veg with point source @ current condition minus background
6. Impact point source @ WLA and restored vegetation
   - ✓ Fully restored veg with point source @ WLA minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

A2. Impact of tributary scenario (tributary/headwater plus 0.1 °C)
   - ✓ Tributary plus 0.1 °C minus background

Figure 9-21 shows the results of comparison 1, which is the 7DADM temperature difference between the No Point Source scenario and Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The overall 7DADM temperature differences increase until Harrington Creek and then decrease in the downstream direction. The maximum delta reaches 2.29 °C at RKM 11.8 on September 13, 2009 (Table 9-8).

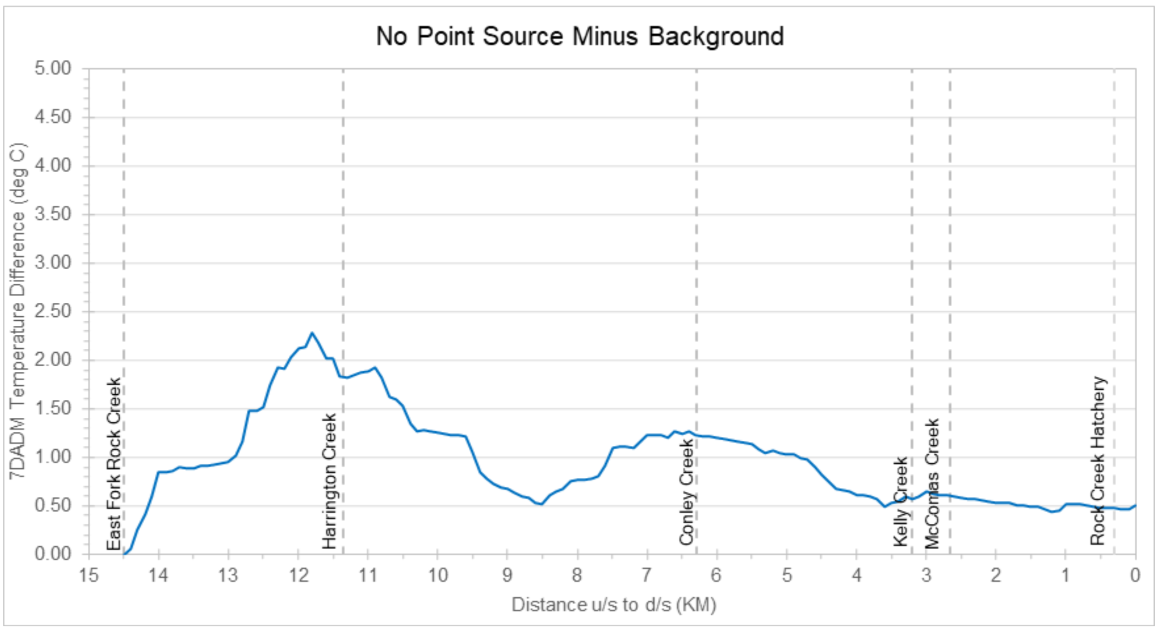

Figure 9-21. The maximum 7DADM temperature differences along Rock Creek (spawning period) for the impacts of shade loss.

Table 9-8. Location and date of maximum delta when temperatures are greater than criterion for comparison 1 for the Rock Creek spawning period

Rock Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
No Point Source Minus Background	11.80	2.29	9/13/2009

Figure 9-22 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition, and the point source conditions where the CCC scenario uses the latest available flow and temperature from the point sources, while the Background scenario does not include point sources. The maximum delta reaches 2.29 ˚C at RKM 11.8 on September 13, 2009 (Table 9-9).

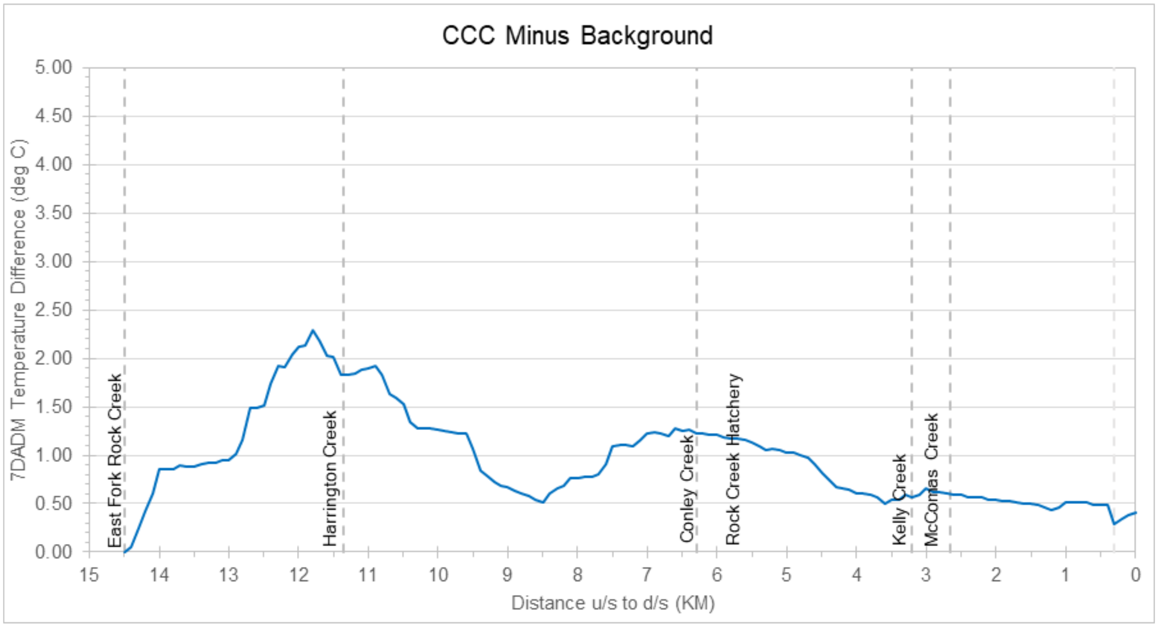

Figure 9-22. The maximum 7DADM temperature differences along Rock Creek (spawning period) for the impacts of current point sources and shade loss.

Table 9-9. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the Rock Creek spawning period

Rock Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus Background	11.80	2.29	9/13/2009

Figure 9-23 shows the results of comparison 3, the impacts of current point sources, which is the 7DADM temperature difference between the CCC scenario and No Point Source scenario. The difference between these two scenarios is the CCC scenario uses the latest available flow and temperature from the point sources, while the No Point Source scenario does not include point sources. The maximum delta reaches 0.09 ˚C at RKM 0.0 on October 1, 2009 (Table 9-10).

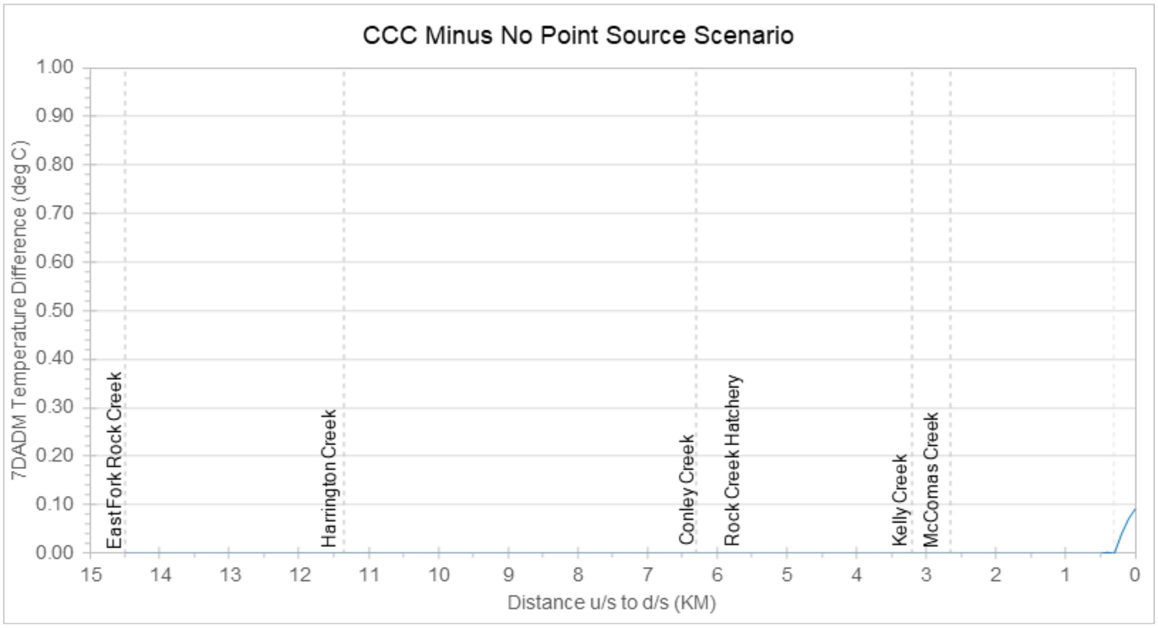

Figure 9-23. The maximum 7DADM temperature differences along Rock Creek (spawning period) for the impacts of point sources at the current condition.

Table 9-10. Location and date of maximum delta when temperatures are greater than criterion for comparison 3 for the Rock Creek spawning period

Rock Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Point Source Scenario	0.00	0.09	10/1/2009

Figure 9-24 shows the results of comparison 4, the impact from point sources at WLA conditions, which is the 7DADM temperature difference between the Point Source WLA scenario and No Point Source scenario. The difference between these two scenarios is the Point Source WLA scenario uses the calculated WLA temperatures, while the No Point Source scenario does not include point sources. The maximum delta reaches 0.26 ˚C at RKM 0.0 on October 1, 2009 (Table 9-11). Note that the maximum delta occurs on October 1, 2009, which is when the effluent flow changes from 0.52 cms (18.4 cfs) to 0.71 cms (25.1 cfs). Prior to this date the observed deltas when the BBNC was exceeded are all negative.

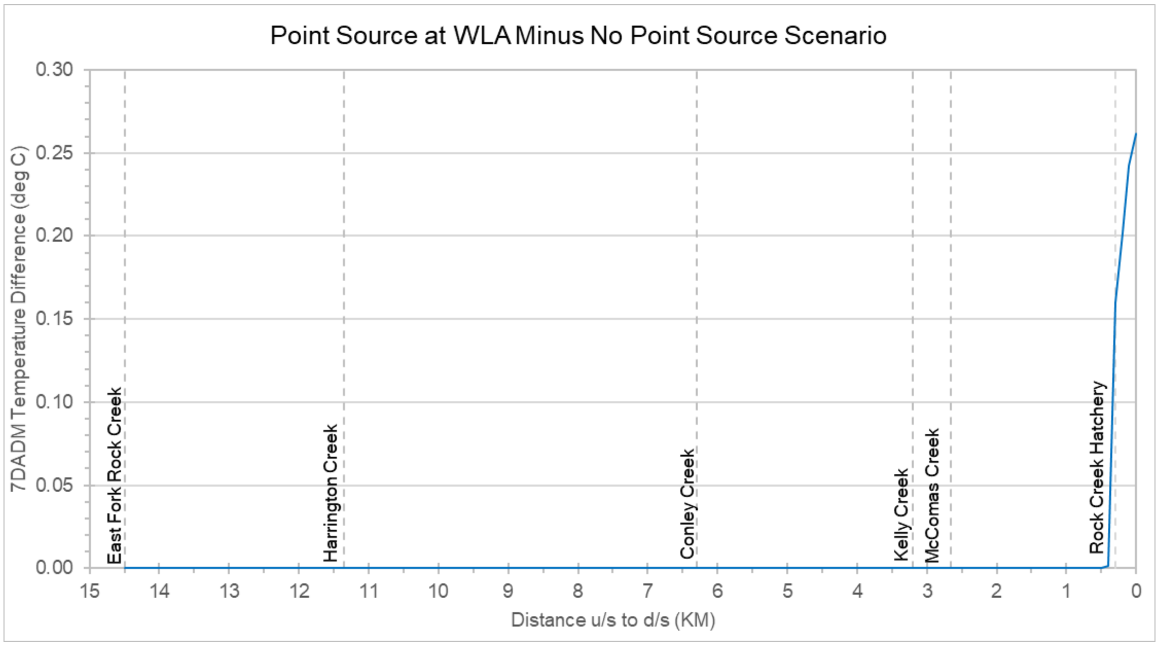

Figure 9-24. The maximum 7DADM temperature differences along Rock Creek (spawning period) for the impacts of point sources at the WLA temperatures.

Table 9-11. Location and date of maximum delta when temperatures are greater than criterion for comparison 4 for the Rock Creek spawning period

Rock Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
Point Source at WLA Minus No Point Source Scenario	0.00	0.26	10/1/2009

Figure 9-25 shows the results of comparison 5, the impact from current point sources and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario at current conditions and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation scenario includes point sources and current conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. The maximum delta reaches 0.14 ˚C at RKMs 0.3 on October 1, 2009 (Table 9-12).

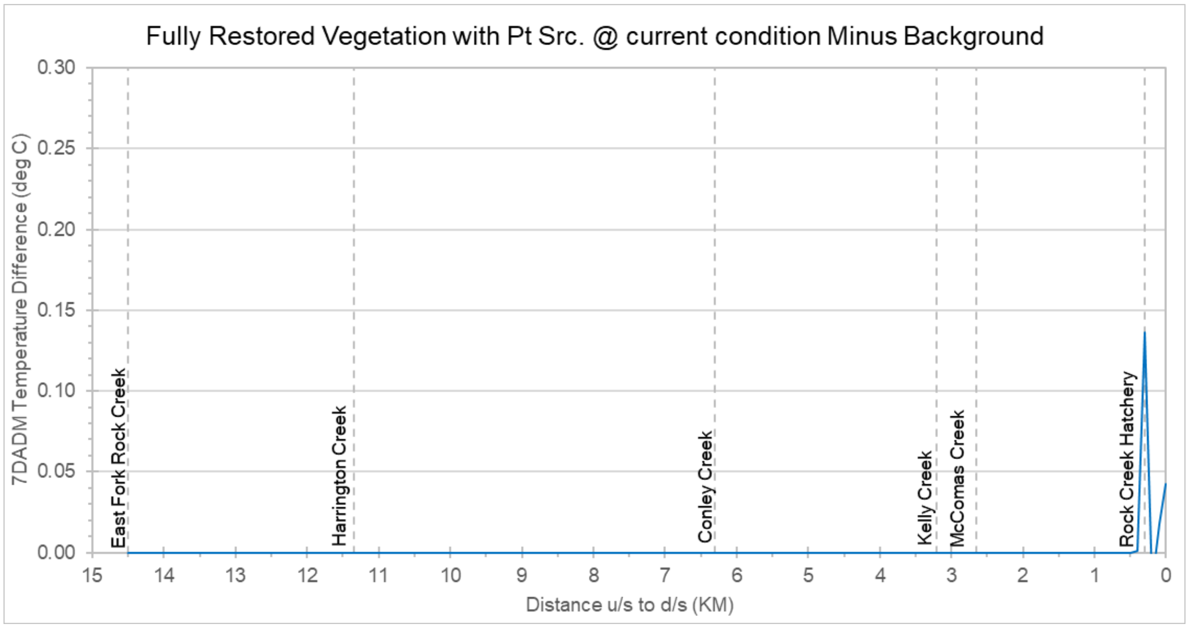

Figure 9-25. The maximum 7DADM temperature differences along Rock Creek (spawning period) for the impacts of current point sources with restored vegetation.

Table 9-12. Location and date of maximum delta when temperatures are greater than criterion for comparison 5 for the Rock Creek spawning period

Rock Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
Fully Restored Vegetation Minus Background	0.30	0.14	10/1/2009

Figure 9-26 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 7.02 ºC at RKM 2.5 on September 3, 2009 (Table 9-13).

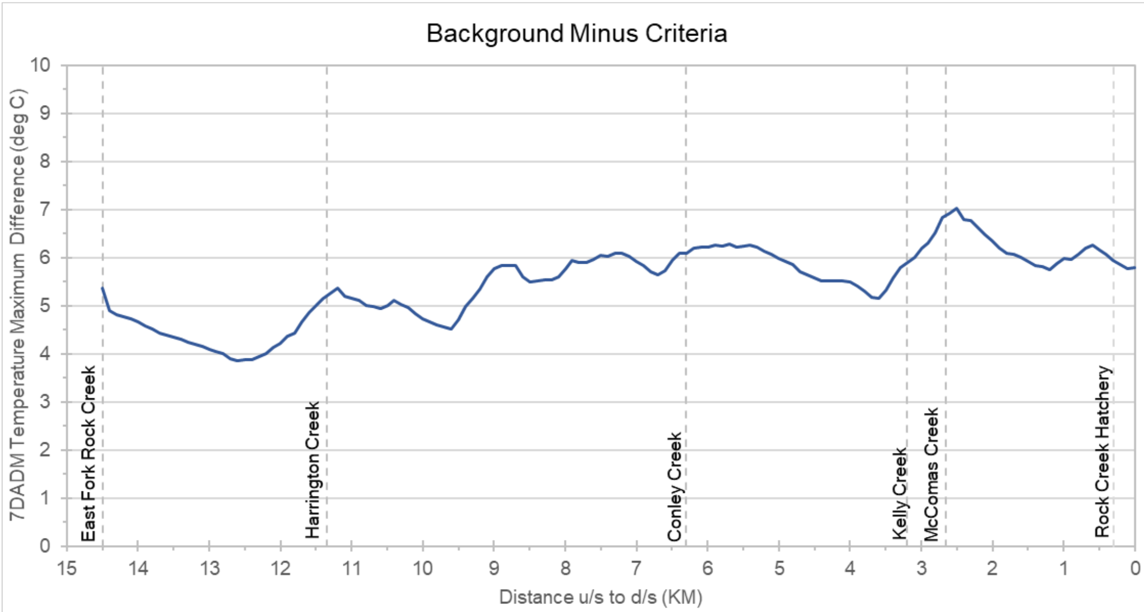

Figure 9-26. The maximum 7DADM temperature differences along Rock Creek (spawning period) between Background scenario and the criteria

Table 9-13. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the Rock Creek spawning period

Rock Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	2.50	7.02	9/3/2009

Figure 9-27 shows the results of comparison A2, the impact of adding 0.1 °C to all the tributaries and headwater/upstream inflows in the background scenario, which is the 7DADM temperature difference between A2 and the Background scenario and criteria. The overall 7DADM temperature differences of 0.1 °C occurs at the headwaters and then starts decreasing in the downstream direction. The maximum delta of 0.1 °C was observed at RKM 14.50 on September 8, 2009 (Table 9-14).

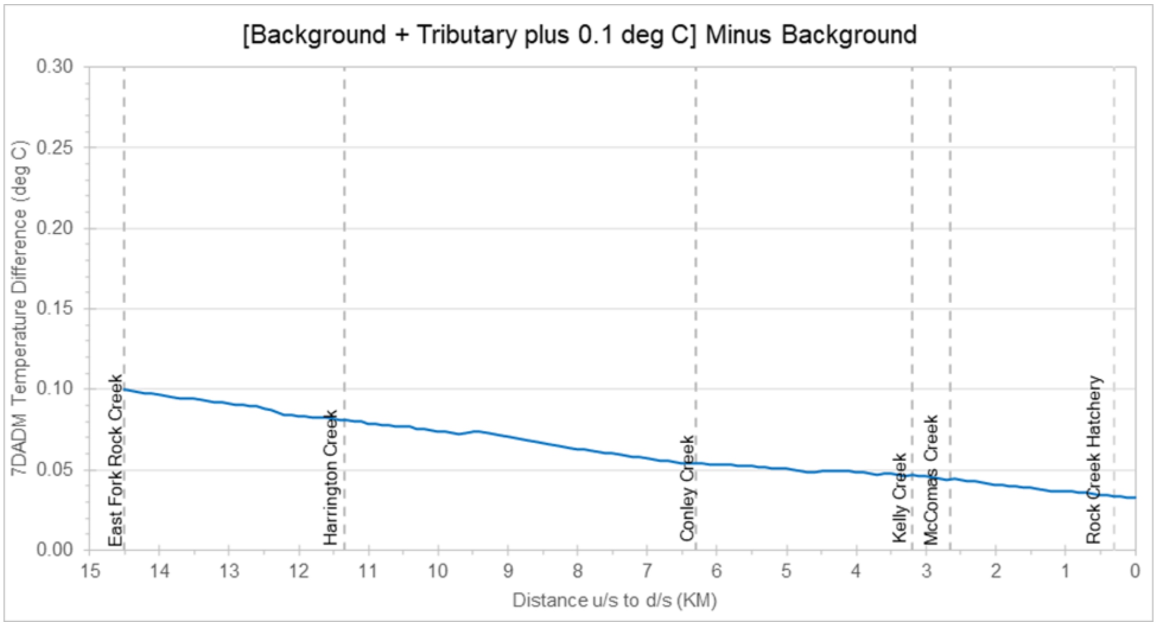

Figure 9-27. The maximum 7DADM temperature differences along Rock Creek (spawning period) for the impacts of adding 0.1°C to the Tributary/Headwater.

Table 9-14. Location and date of maximum delta when temperatures are greater than criterion for comparison A2 for the Rock Creek spawning period

Rock Creek	RKM	Maximum Delta	Date when maximum delta occurs
[Background + Tributary plus 0.1 deg C] Minus Background	14.50	0.10	9/8/2009

10.0 NORTH UMPQUA RIVER MODEL 1 (LEMOLO RESERVOIR TO LEMOLO POWERHOUSE #1)

The modeled portion of the North Umpqua River Model 1 is shown in Figure 10-1. The North Umpqua River was modeled for both the summer period (July 8-11, 2001) and the spawning period (August 1, 2009, to October 15, 2009). The summer period scenario results and scenario comparisons are presented in sections 10.1 and 10.2, while the spawning period scenario results and scenario comparisons are presented in sections10.3 10.3 and 10.4.

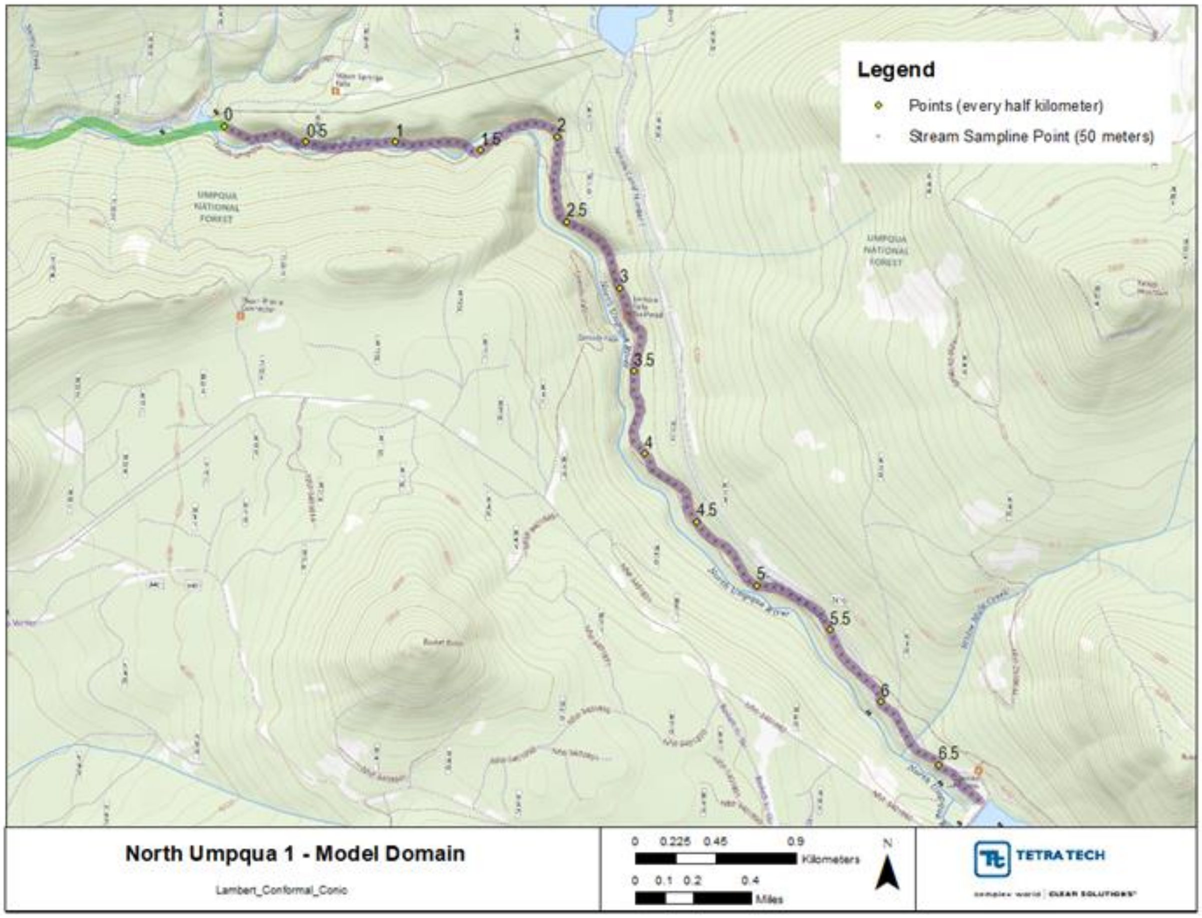

Figure 10-1. Location of the North Umpqua River 1.

10.1 NORTH UMPQUA RIVER MODEL 1 SUMMER PERIOD SCENARIO RESULTS

The North Umpqua River HS summer model 1 does not include any point sources. The scenarios that are relevant to the North Umpqua River include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; and the Fully Restored Vegetation and Natural Flow scenario. The 7DADM results are shown in Figure 10-2 to Figure 10-4 for these scenarios.

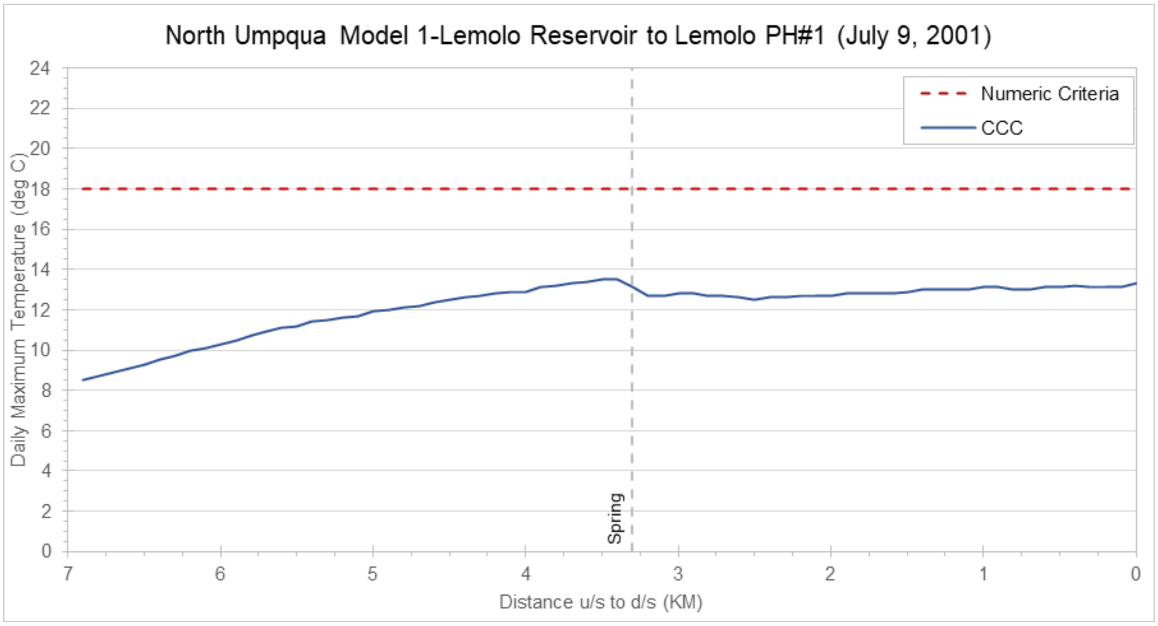

Figure 10-2. The maximum 7DADM temperature results along the North Umpqua River model 1 (summer period) for the No Point Source scenario.

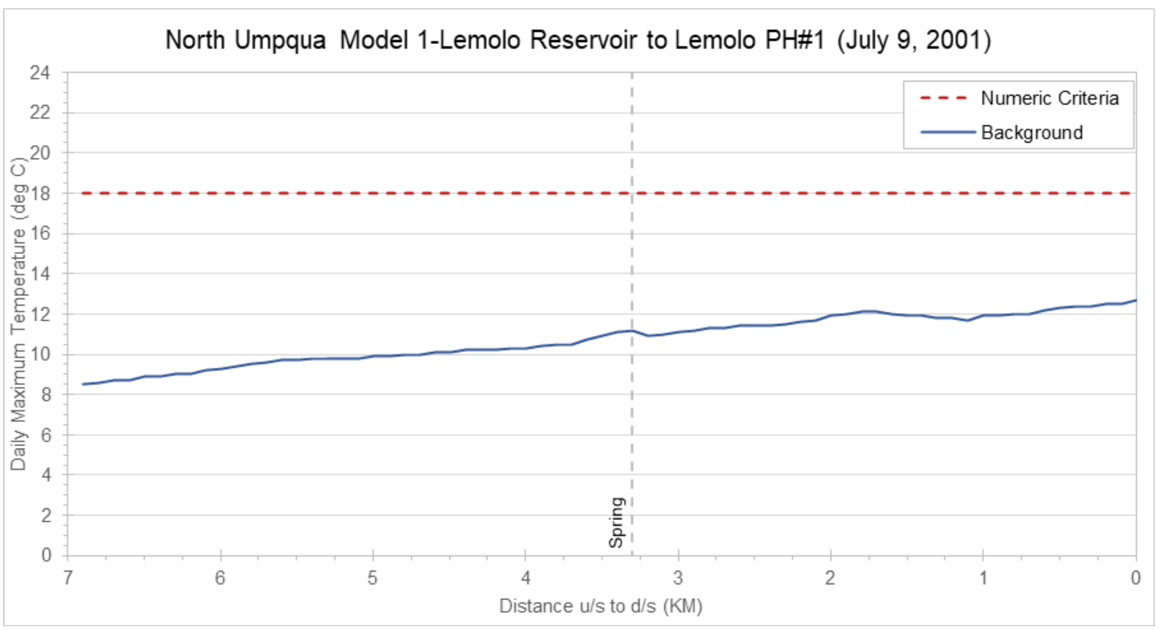

Figure 10-3. The maximum 7DADM temperature results along the North Umpqua River model 1 (summer period) for the Background scenario.

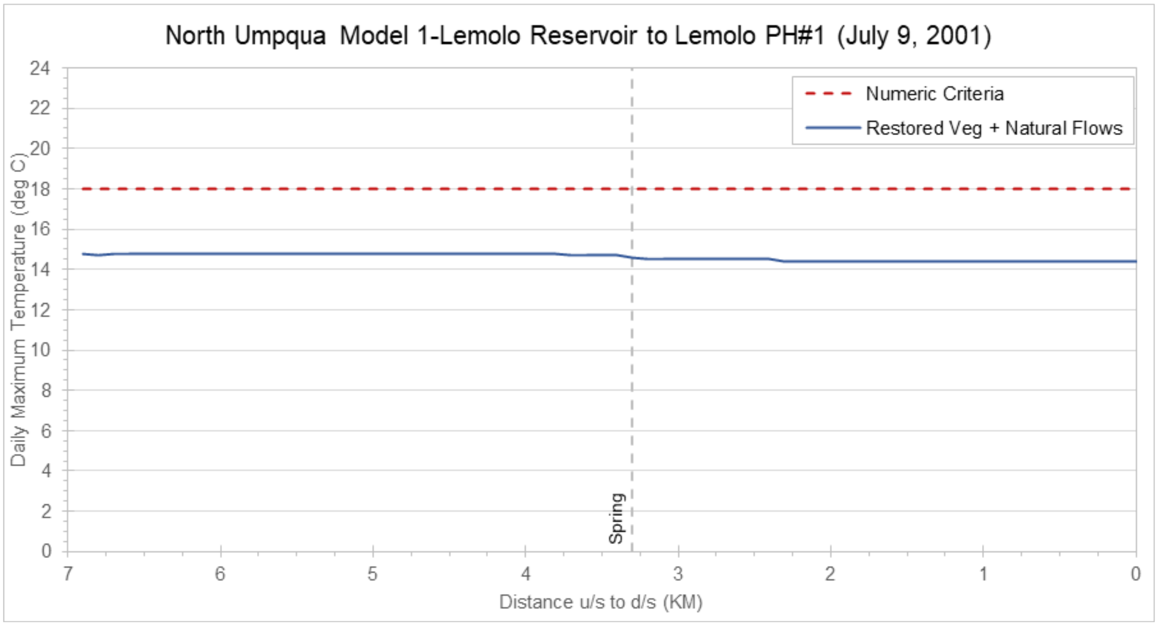

Figure 10-4. The maximum 7DADM temperature results along the North Umpqua River model 1 (summer period) for the Fully Restored Vegetation and Natural Flow scenario.

10.2 NORTH UMPQUA RIVER MODEL 1 SUMMER PERIOD SCENARIO COMPARISONS

Comparisons of the summer period North Umpqua River scenarios include:

2. Impact of current point source and shade loss (note there are no point sources in North Umpqua Model 1)
    - ✓ CCC minus background
7. Difference between background and criteria
    - ✓ Background minus Criteria
9. Natural Flows
    - ✓ Background minus fully restored veg with natural flows

Figure 10-5 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition and the point source conditions where the CCC scenario uses the latest available flow and temperature from the point sources, while the Background scenario does not include point sources. There is no maximum delta for this comparison (Table 10-1).

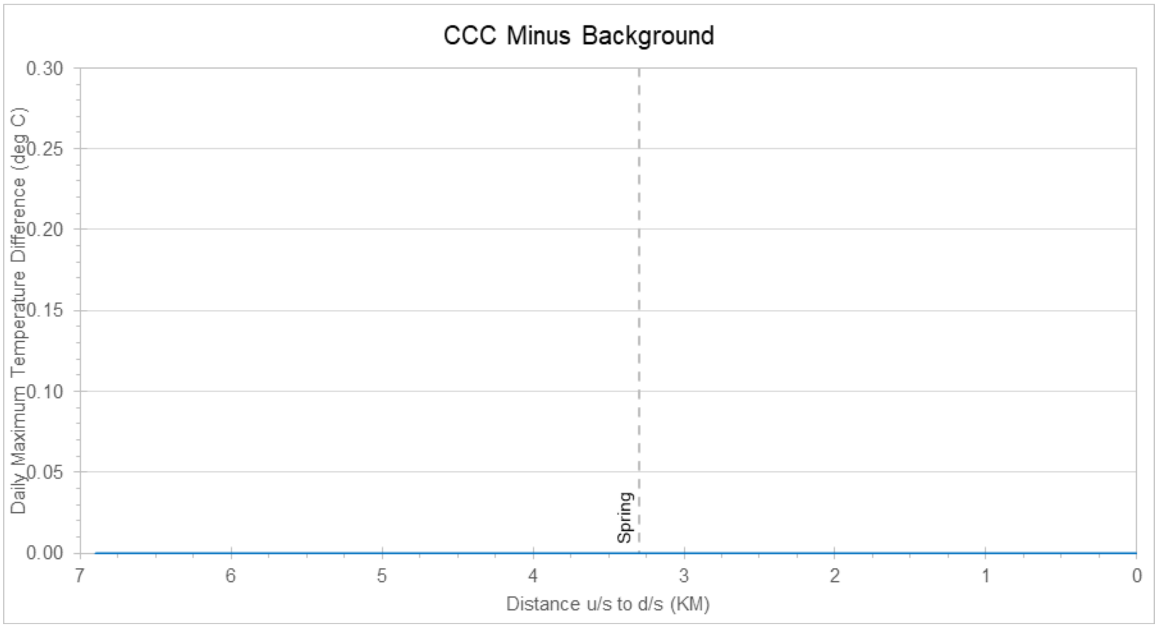

Figure 10-5. The maximum 7DADM temperature differences along the North Umpqua River model 1 (summer period) for the impacts of current point sources and shade loss.

Table 10-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the North Umpqua River summer period

North Umpqua #1	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	N/A	0.00	N/A

Figure 10-6 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -9.5 °C at RKM 0.0 on 7/8/2001 (Table 10-2).

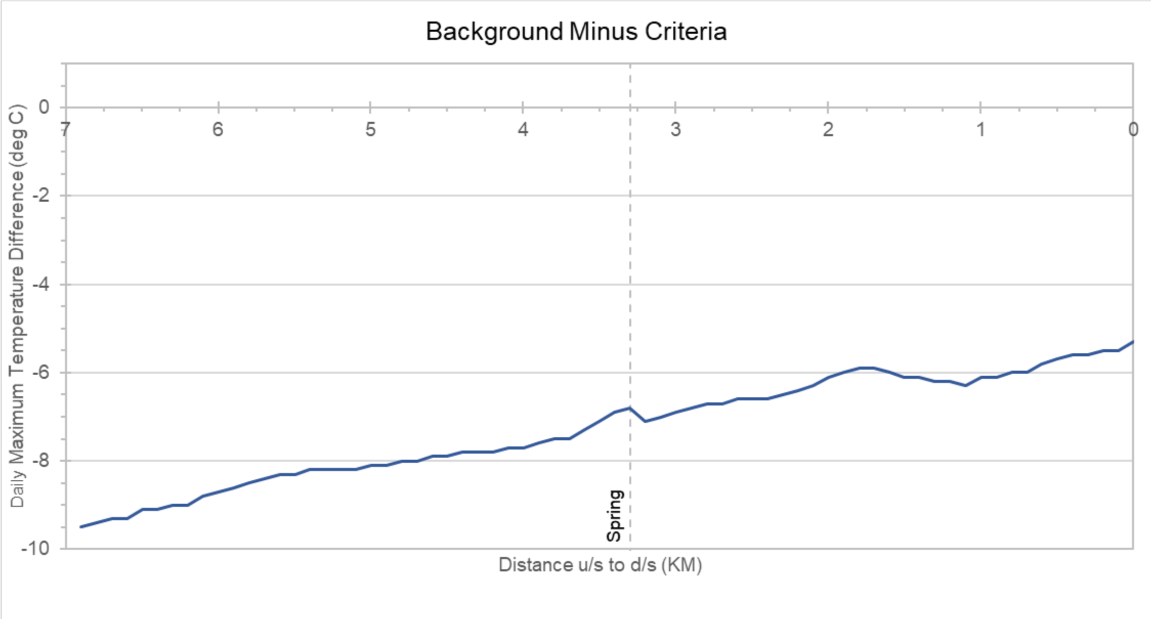

Figure 10-6. The maximum 7DADM temperature differences along the North Umpqua River model 1 (summer period) between Background scenario and the criteria

Table 10-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 1 summer period

North Umpqua #1	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	0.00	-9.50	7/8/2001

Figure 10-7 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. The difference between these two scenarios for the North Umpqua River is that the flows and temperature inputs from headwater changed in the Fully Restored Vegetation with Natural Flow scenario. There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 10-3).

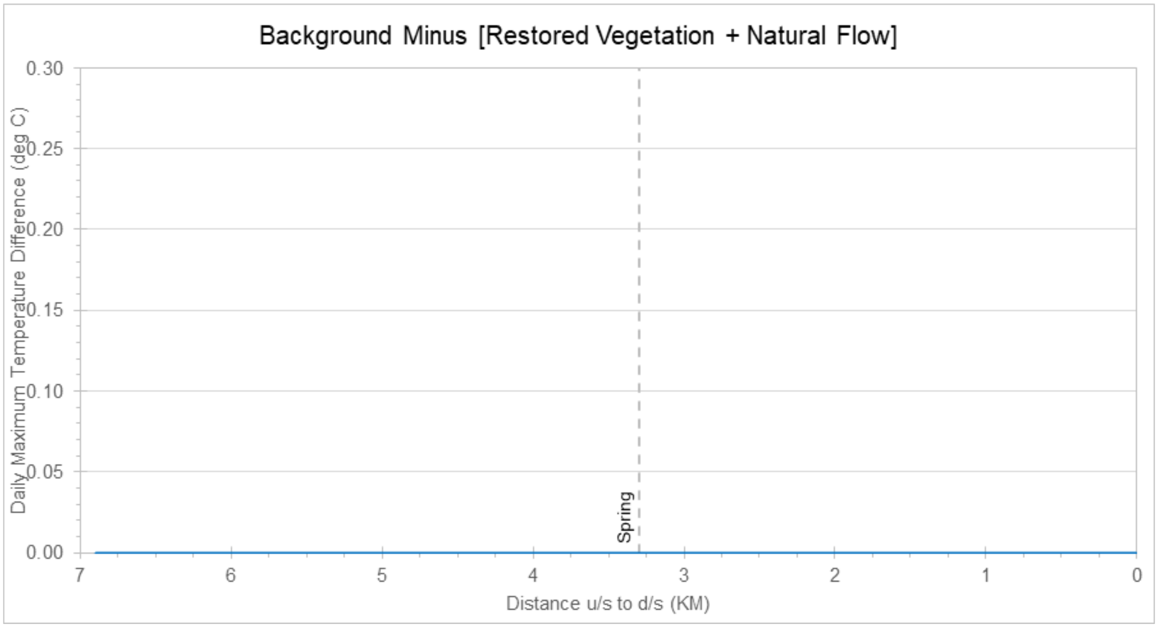

Figure 10-7. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario on the North Umpqua River model 1 (summer period).

Table 10-3. Location and date of maximum delta when temperatures are greater than criterion for comparison 9 for the North Umpqua River model 1 summer period

North Umpqua #1	RKM	Maximum Delta	Date when maximum delta occurs
Background Minus [Restored Vegetation + Natural Flow]	N/A	0.00	N/A

10.3 NORTH UMPQUA RIVER MODEL 1 SPAWNING PERIOD SCENARIO RESULTS

The North Umpqua River HS model 1 for the spawning period does not include any point sources. The scenarios that are relevant to the North Umpqua River spawning period model 1 include the CCC scenario, which is identical to the No Point Source scenario, and the Background scenario. The 7DADM results are shown in Figure 10-8 and Figure 10-9 for these scenarios. Note that the year round (non-spawning criteria) applies to North Umpqua Model 1 and was evaluated for the entire modeling period from August 1 to October 15, 2009.

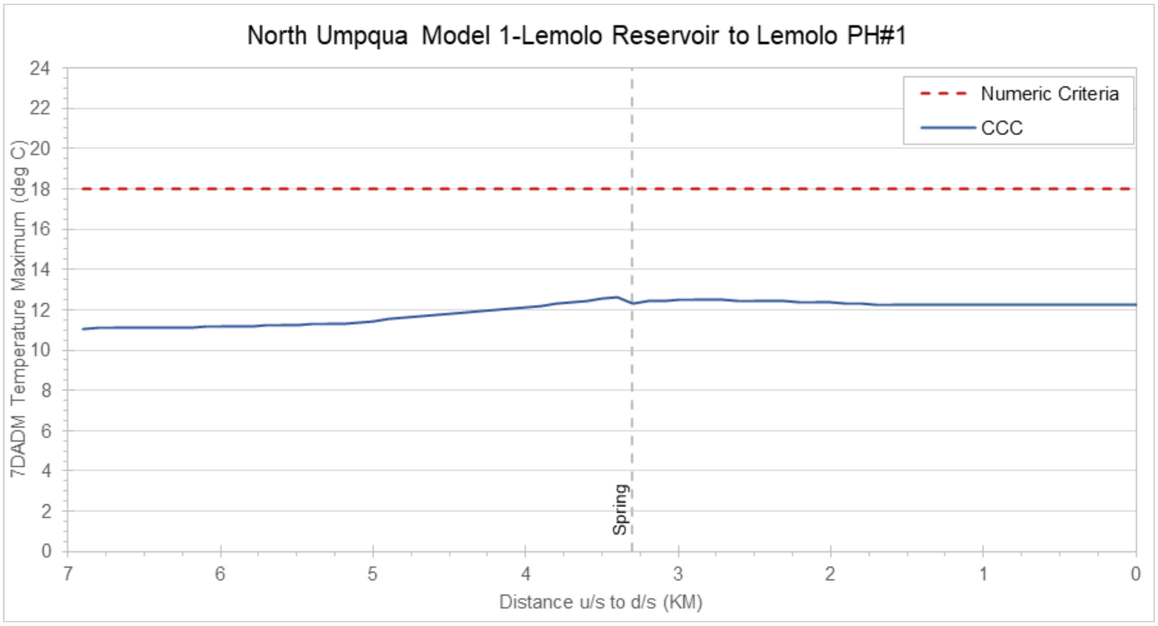

Figure 10-8. The maximum 7DADM temperature results along the North Umpqua River model 1 (spawning period) for the Current Conditions scenario.

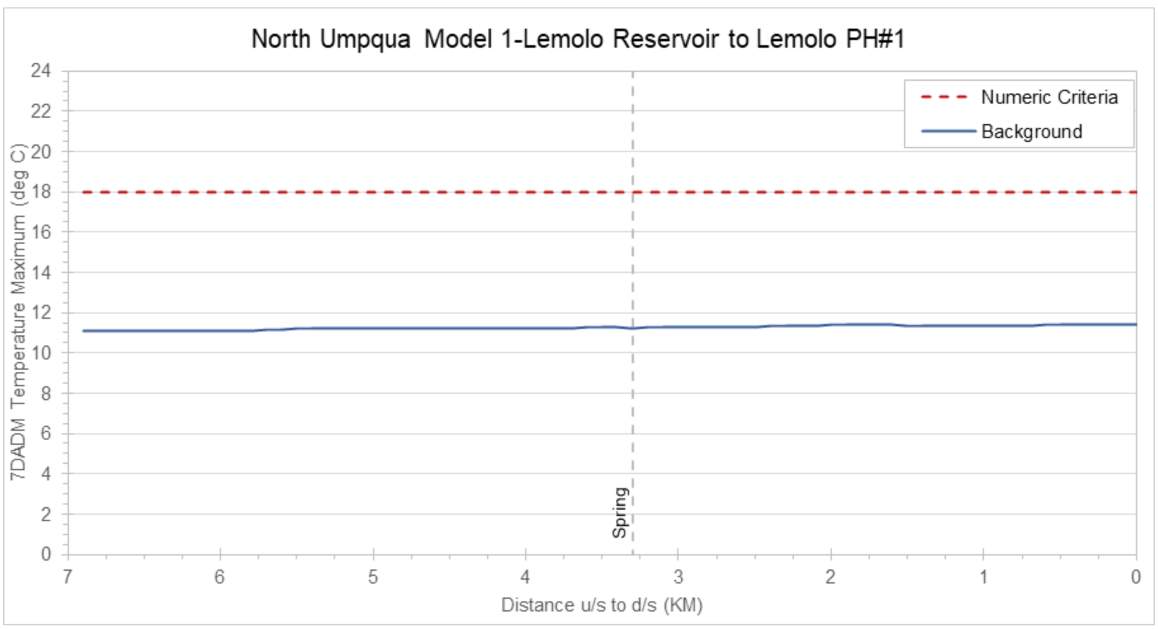

Figure 10-9. The maximum 7DADM temperature results along the North Umpqua River model 1 (spawning period) for the Background scenario.

10.4 NORTH UMPQUA RIVER MODEL 1 SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the North Umpqua River model 1 spawning period include:

2. Impact of current point source and shade loss
    - ✓ CCC minus background

7. Difference between background and criteria

✓ Background minus Criteria

Figure 10-10 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There is no maximum delta for this comparison (Table 10-4).

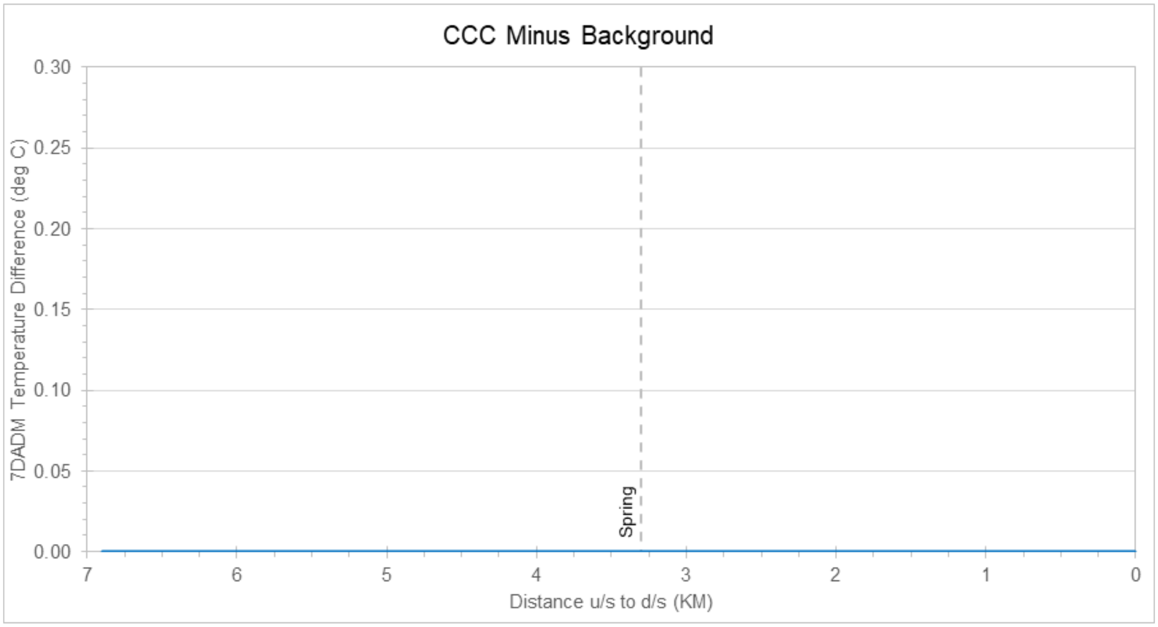

Figure 10-10. The maximum 7DADM temperature differences along the North Umpqua River model 1 (spawning period) for the impacts of current point sources and shade loss.

Table 10-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the North Umpqua River model 1 spawning period

North Umpqua #1	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus Background	N/A	0.00	N/A

Figure 10-11 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -6.93 ^{o}C at RKM 6.2 on August 8, 2009 (Table 10-5).

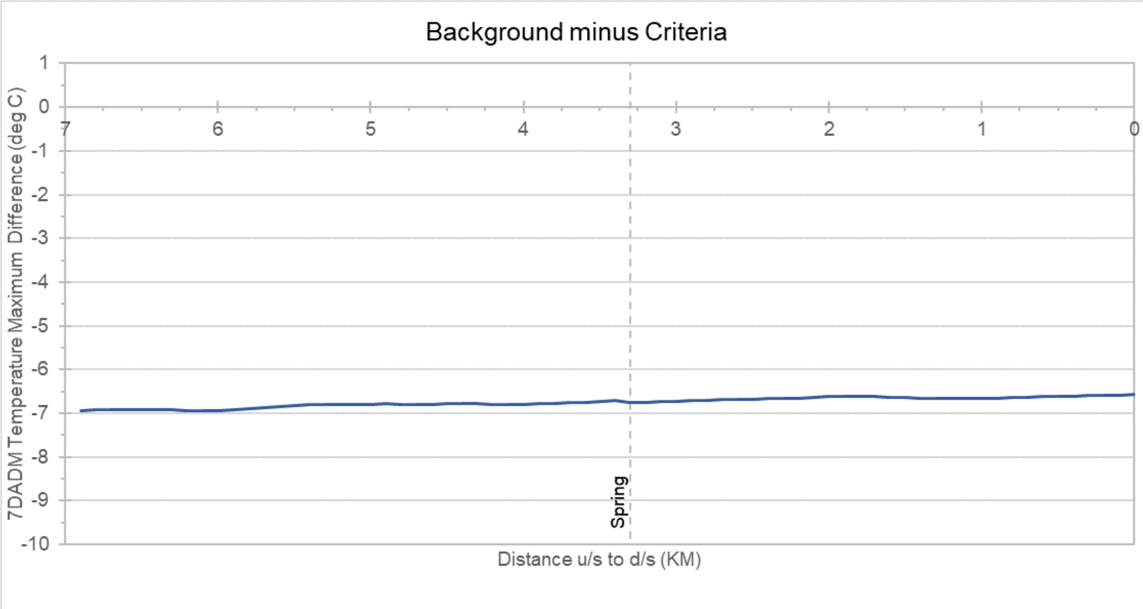

Figure 10-11. The maximum 7DADM temperature differences along the North Umpqua River model 1 (spawning period) between Background scenario and the criteria

Table 10-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 1 spawning period

North Umpqua #1	RKM	Maximum Delta	Date when Maximum Delta occurs
Background minus Criteria	6.20	-6.93	8/7/2009

11.0 NORTH UMPQUA RIVER MODEL 2 (LEMOLO POWERHOUSE #1 TO TOKETEE RESERVOIR)

The modeled portion of the North Umpqua River Model 2 is shown in Figure 11-1. North Umpqua River was modeled for both the summer period (July 8-11, 2001) and the spawning period (August 1, 2009 to October 15, 2009). The summer period scenario results and scenario comparisons are presented in sections 11.1 and 11.2, while the spawning period scenario results and scenario comparisons are presented in section 11.3 and 11.4.

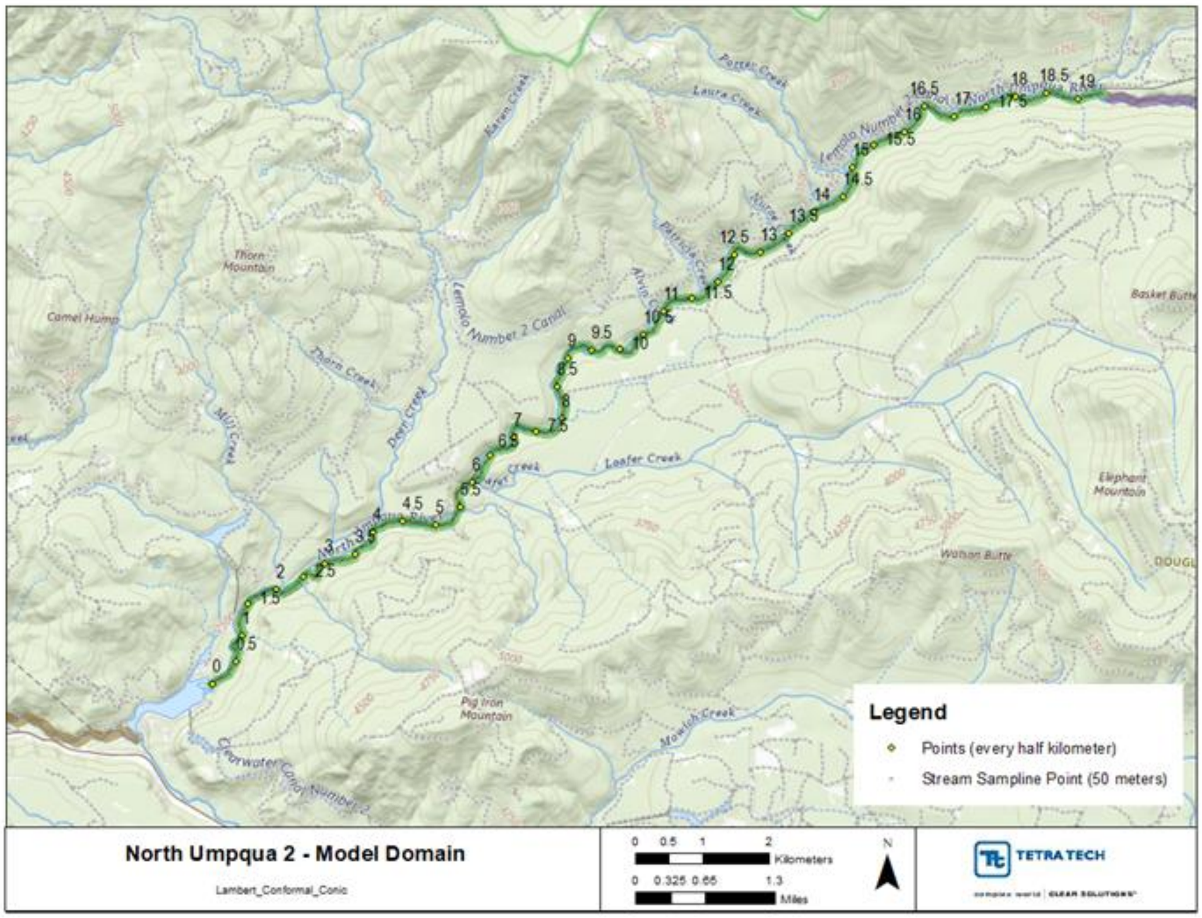

Figure 11-1. North Umpqua River Model 2 model domain.

11.1 NORTH UMPQUA RIVER MODEL 2 SUMMER PERIOD SCENARIO RESULTS

The North Umpqua River summer period HS model 2 does not include any point sources. The scenarios that are relevant to the North Umpqua River summer period model 2 include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; and the Fully Restored Vegetation with Natural Flow scenario. The 7DADM results are shown in Figure 11-2 through Figure 11-4 for these scenarios.

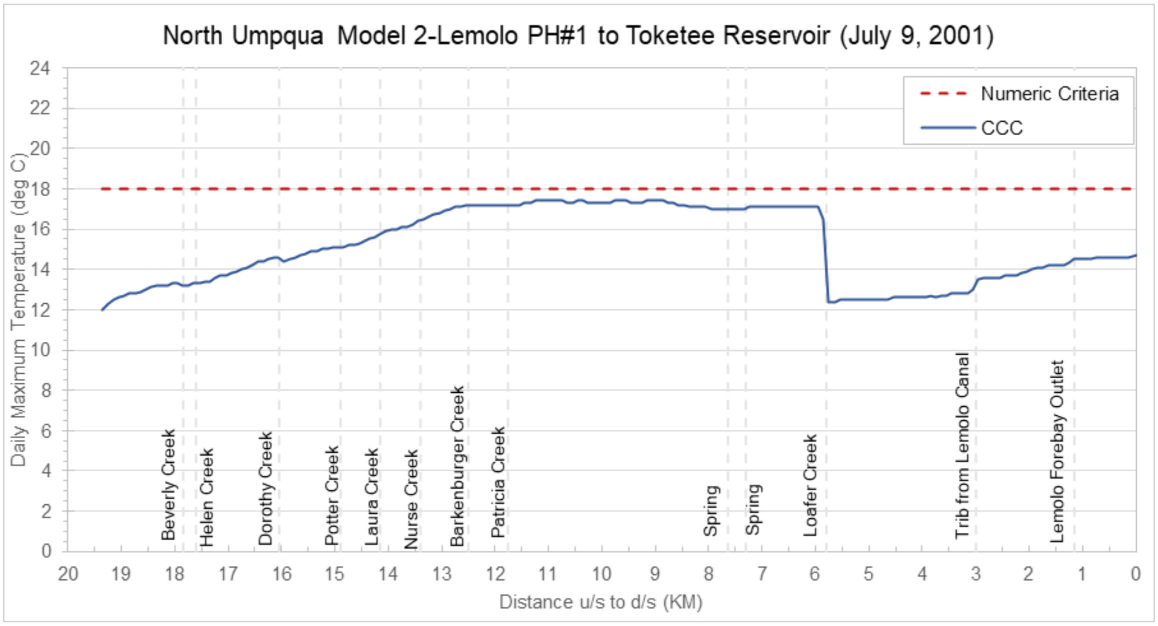

Figure 11-2. The maximum 7DADM temperature results along North Umpqua River model 2 (summer period) for the Current Conditions scenario.

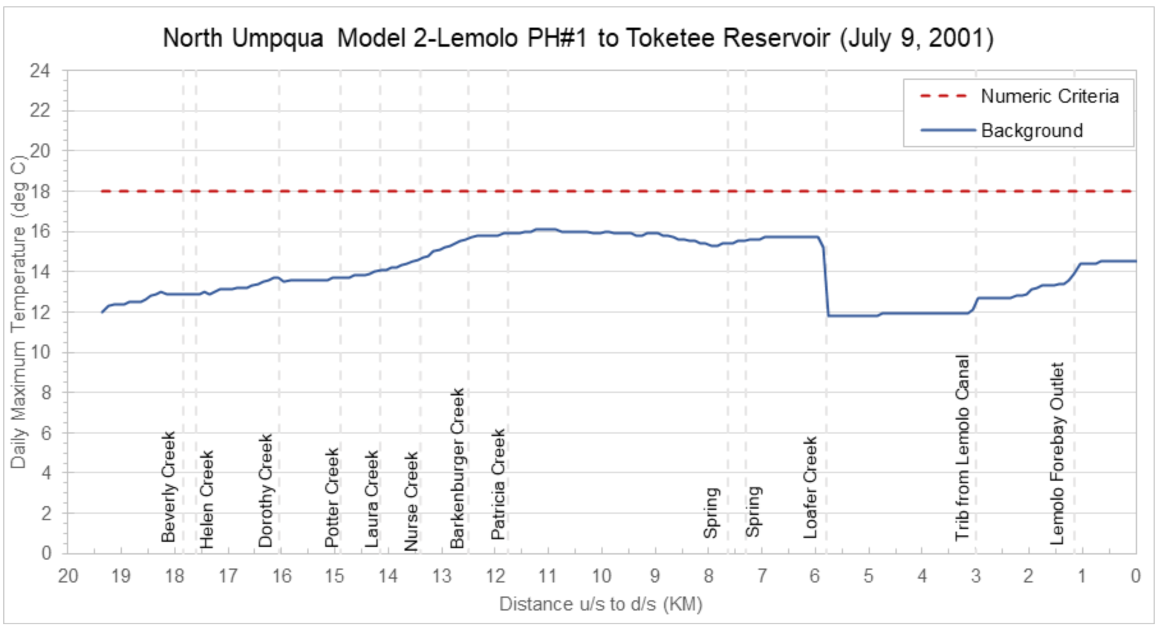

Figure 11-3. The maximum 7DADM temperature results along the North Umpqua River model 2 (summer period) for the Background scenario.

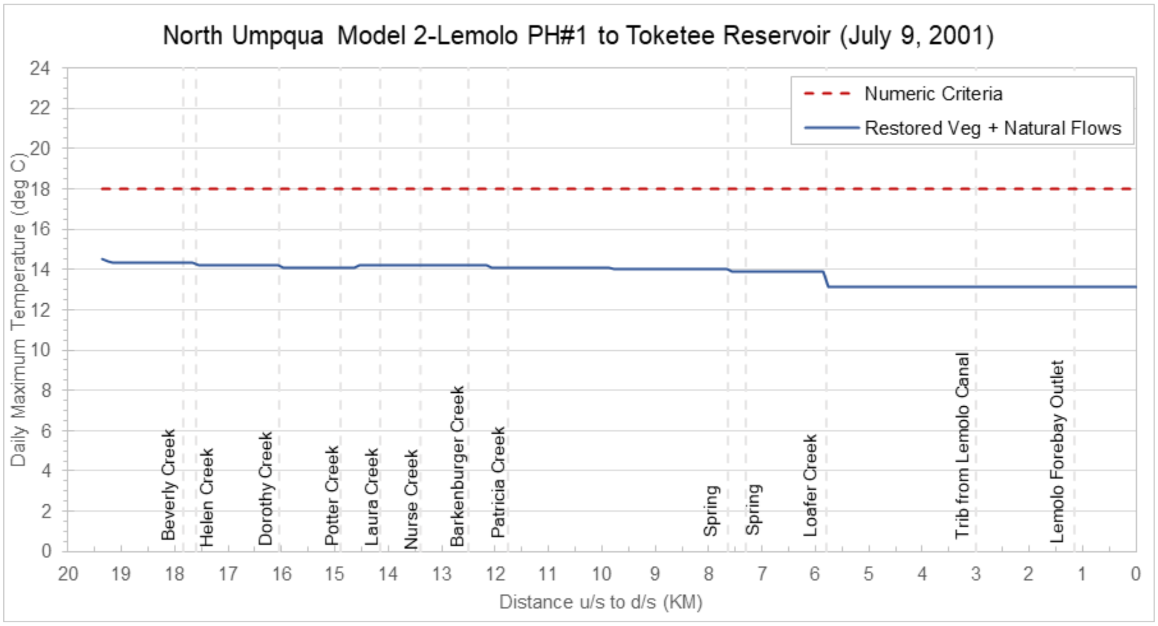

Figure 11-4. The maximum 7DADM temperature results along the North Umpqua River model 2 (summer period) for the Fully Restored Vegetation and Natural Flow scenario.

11.2 NORTH UMPQUA RIVER MODEL 2 SUMMER PERIOD SCENARIO COMPARISONS

Comparisons of the North Umpqua River model 2 summer scenarios:

2. Impact of current point source and shade loss (note there are no point sources in North Umpqua Model 2)
    - ✓ CCC minus background
7. Difference between background and criteria
    - ✓ Background minus Criteria
9. Natural Flows
    - ✓ Background minus fully restored veg with natural flows

Figure 11-5 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 11-1).

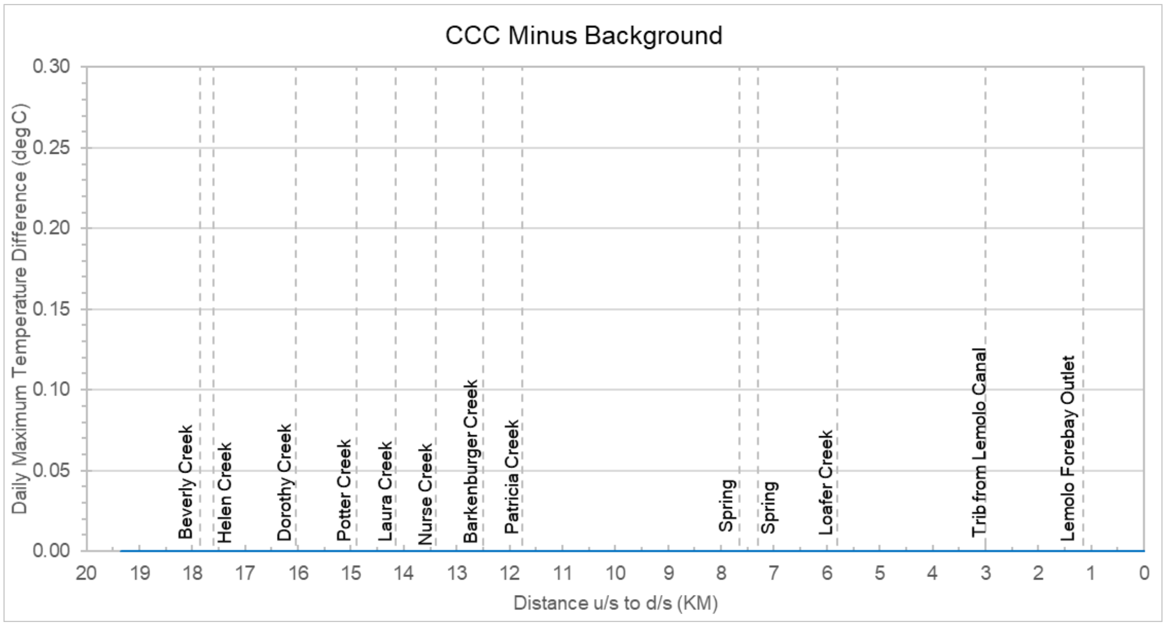

Figure 11-5. The maximum 7DADM temperature differences along the North Umpqua River model 2 (summer period) for the impacts of current point sources and current conditions vegetation.

Table 11-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the North Umpqua River model 2 summer period

North Umpqua #2	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	N/A	N/A	N/A

Figure 11-6 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -6.2 ^{o}C at RKMs 5.75 to 4.85 on July 9, 2001 (Table 11-2).

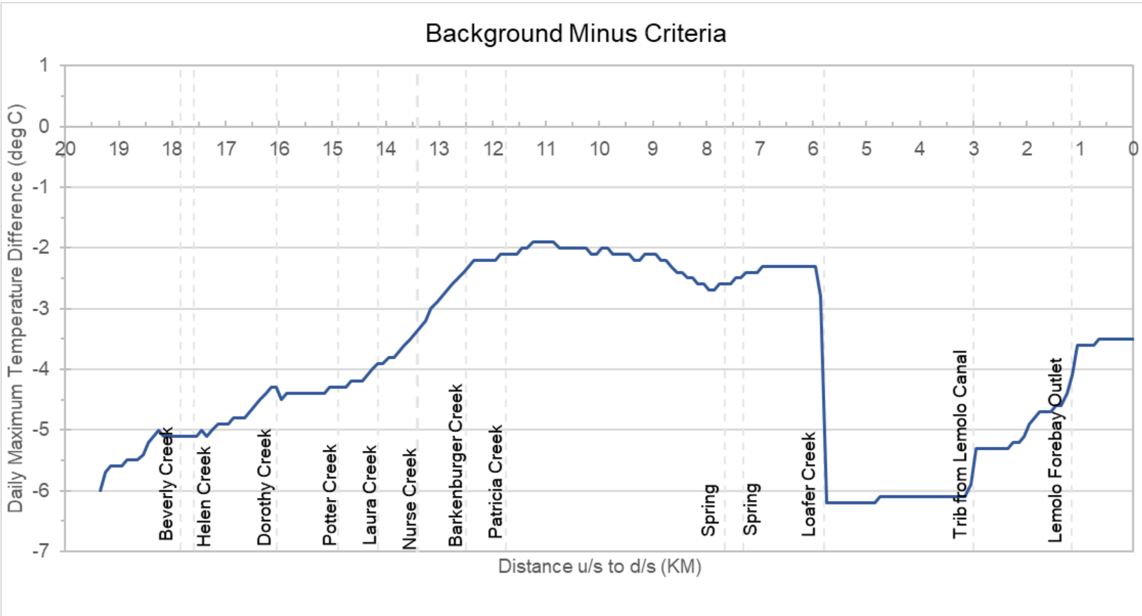

Figure 11-6. The maximum 7DADM temperature differences along the North Umpqua River model 2 (summer period) between Background scenario and the criteria

Table 11-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 2 summer period

North Umpqua #2	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	5.75 to 4.85	-6.20	7/9/2001

Figure 11-7 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. There are a few differences between these two scenarios for the North Umpqua River. The headwater flows and temperature inputs were different and reflect natural conditions with increased flow and lower temperatures. The contributions from the tributary from Lemolo Canal and Lemolo Forebay outlet were also removed in the Natural Flow scenario. There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 11-3).

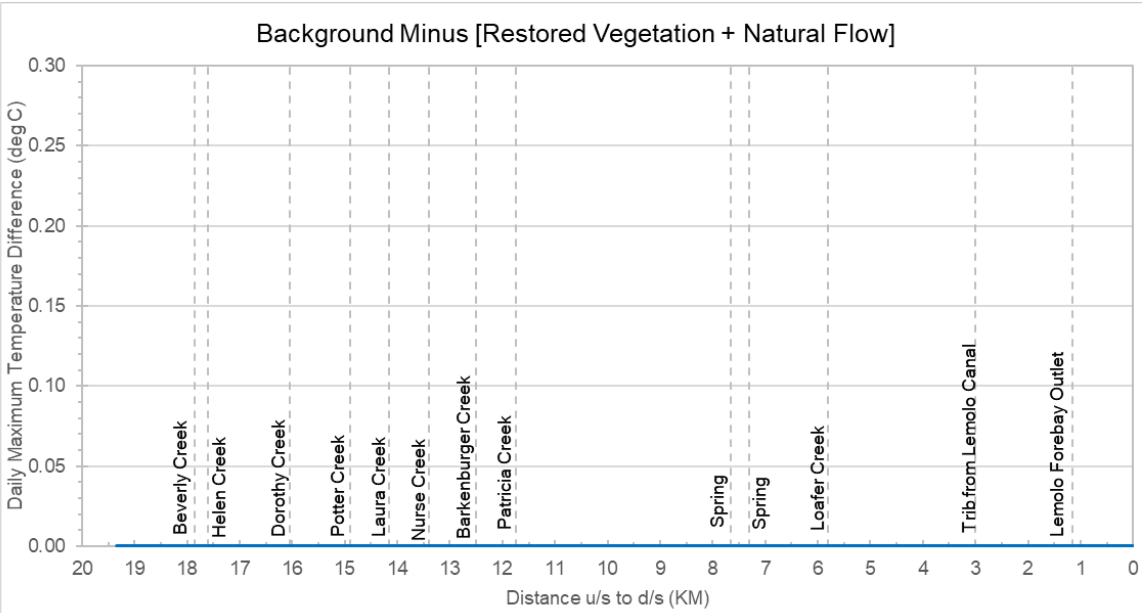

Figure 11-7. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario on the North Umpqua River model 2 (summer period).

Table 11-3. Location and date of maximum delta when temperatures are greater than criterion for comparison 9 for the North Umpqua River model 2 summer period

North Umpqua #2	RKM	Maximum Delta	Date when maximum delta occurs
Background Minus [Restored Vegetation + Natural Flow]	N/A	N/A	N/A

11.3 NORTH UMPQUA RIVER MODEL 2 SPAWNING PERIOD SCENARIO RESULTS

The North Umpqua River HS model 2 for the spawning period does not include any point sources. The scenarios that are relevant to the North Umpqua River model 2 (spawning period) include the CCC scenario, which is identical to the No Point Source scenario, and the Background scenario. The 7DADM results are shown in Figure 11-8 and Figure 11-9 for these scenarios. Note that the year round (non-spawning criteria) applies to North Umpqua Model 2 and was evaluated for the entire modeling period from August 1 to October 15, 2009.

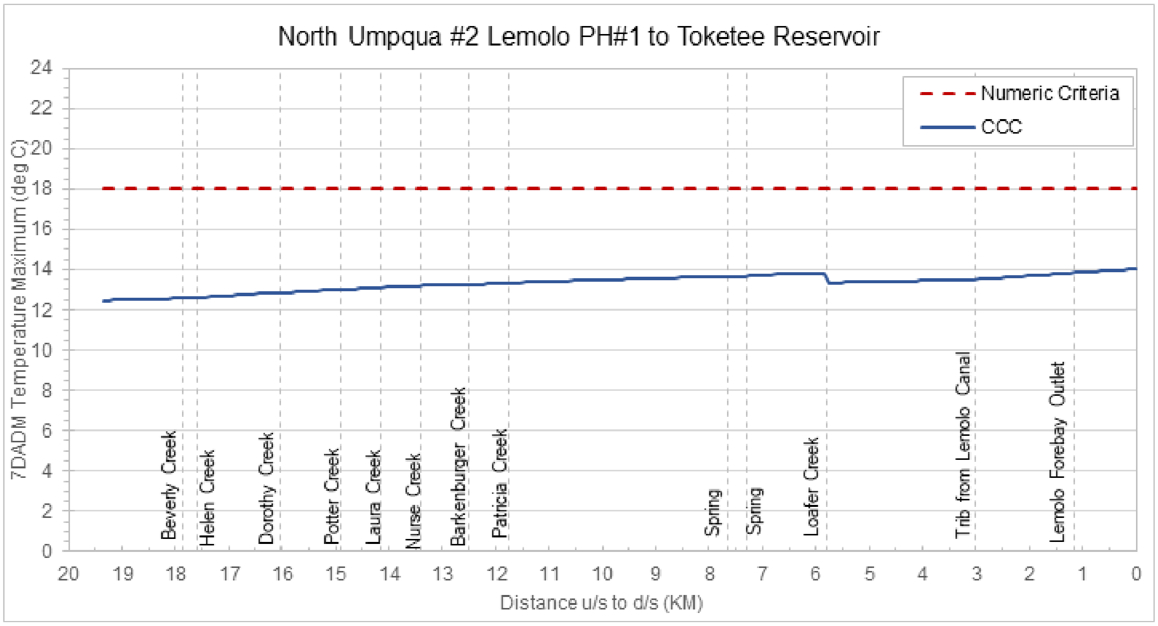

Figure 11-8. The maximum 7DADM temperature results along the North Umpqua River model 2 (spawning period) for the Current Conditions scenario.

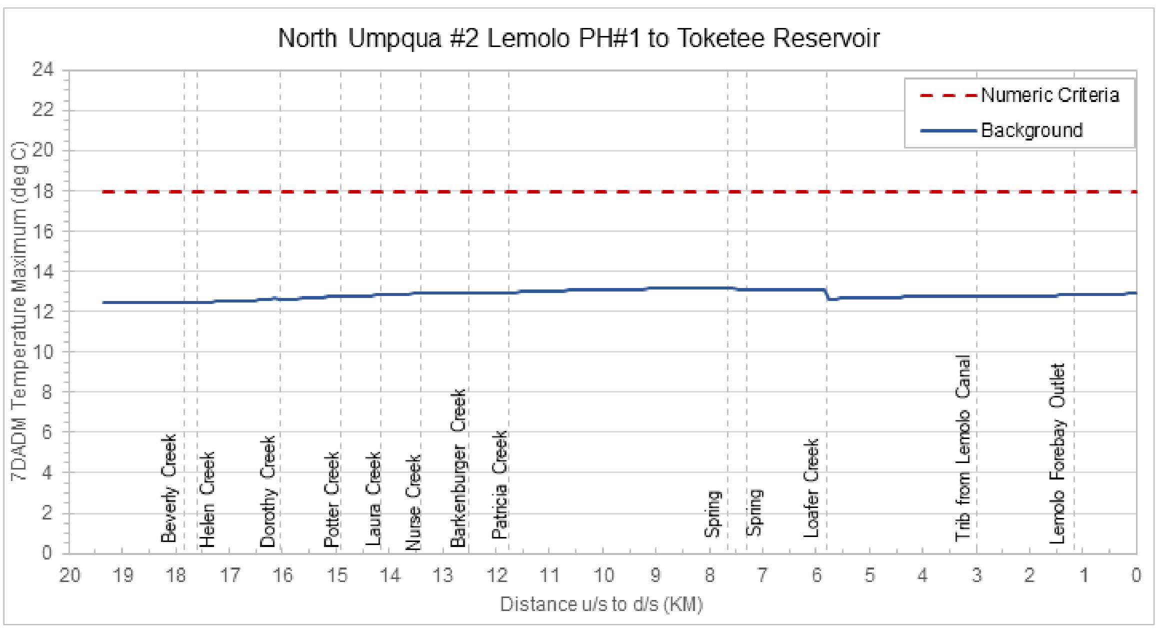

Figure 11-9. The maximum 7DADM temperature results along the North Umpqua River model 2 (spawning period) for the Background scenario.

11.4 NORTH UMPQUA RIVER MODEL 2 SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the North Umpqua River spawning period include:

2. Impact of current point source and shade loss
    - ✓ CCC minus background
7. Difference between background and criteria
    - ✓ Background minus Criteria

Figure 11-10 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 11-4)

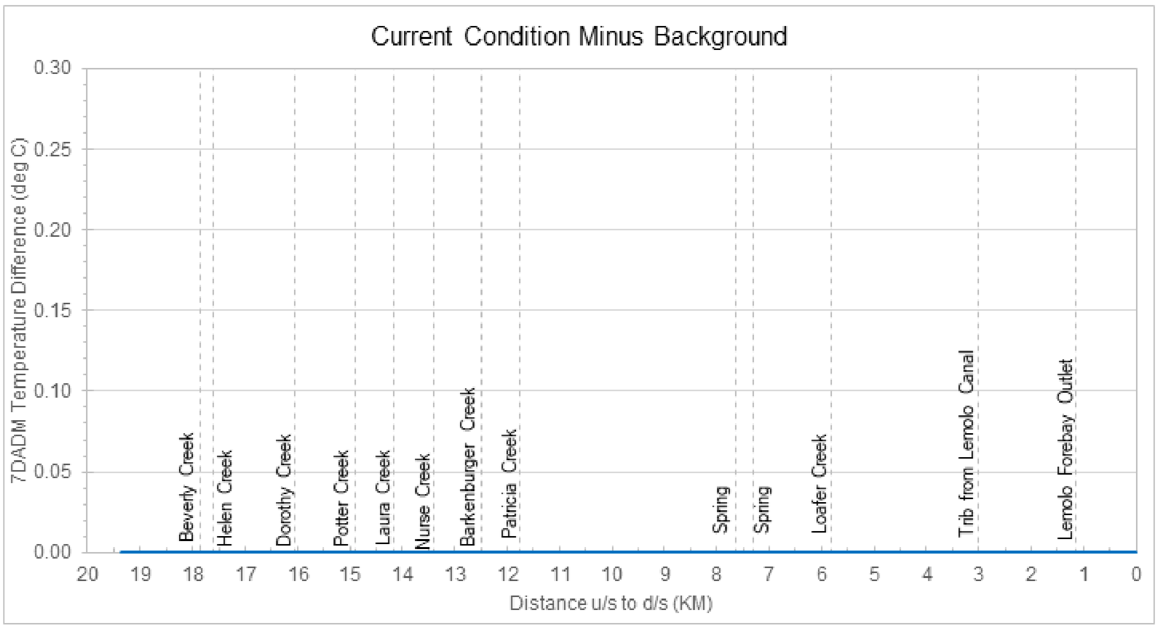

Figure 11-10. The maximum 7DADM temperature differences along the North Umpqua River model 2 (spawning period) for the impacts of current point sources and shade loss.

Table 11-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the North Umpqua River model 2 spawning period

North Umpqua #2	RKM	Maximum Delta	Date when Maximum Delta occurs
Current Condition Minus Background	N/A	N/A	N/A

Figure 11-11 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -5.57 °C at RKM 18.35 on August 7,2009 (Table 11-5).

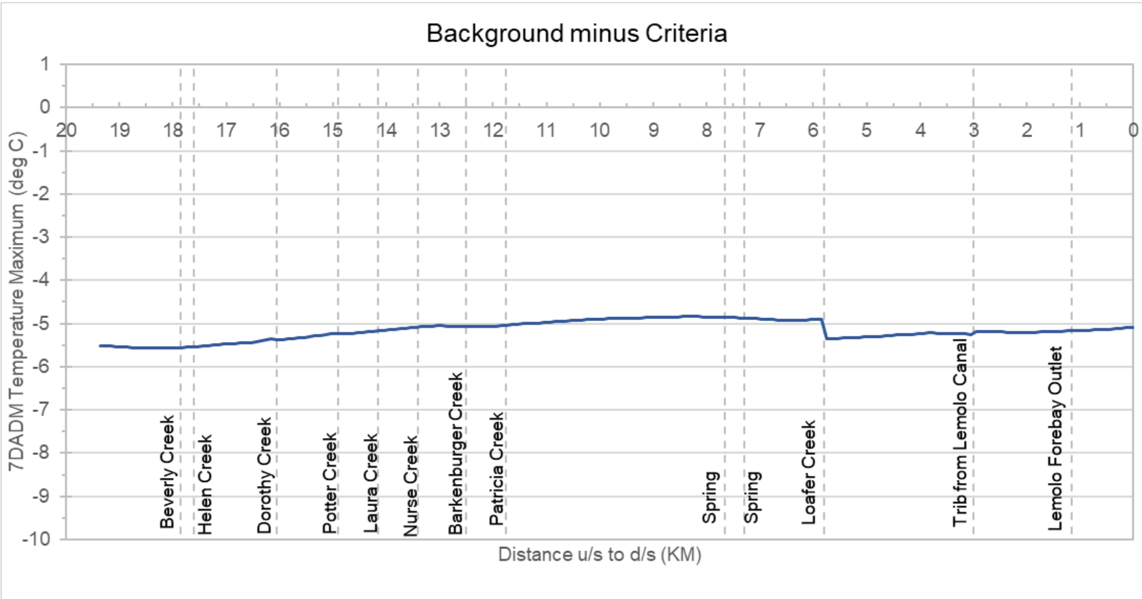

Figure 11-11. The maximum 7DADM temperature differences along the North Umpqua River model 2 (spawning period) between Background scenario and the criteria

Table 11-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 2 spawning period

North Umpqua #2	RKM	Maximum Delta	Date when Maximum Delta occurs
Background minus Criteria	18.35	-5.57	8/7/2009

12.0 NORTH UMPQUA RIVER MODEL 3 (TOKETEE RSERVOIR TO SLIDE POWERHOUSE)

The modeled portion of the North Umpqua River model 3 is shown in Figure 10-1. The North Umpqua River was modeled for both the summer period (July 8-11, 2001) and the spawning period (August 1, 2009 to October 15, 2009). The summer period scenario results and scenario comparisons are presented in section 12.1 and 12.2, while the spawning period scenario results and scenario comparisons are presented in section 10.3 and 12.4.

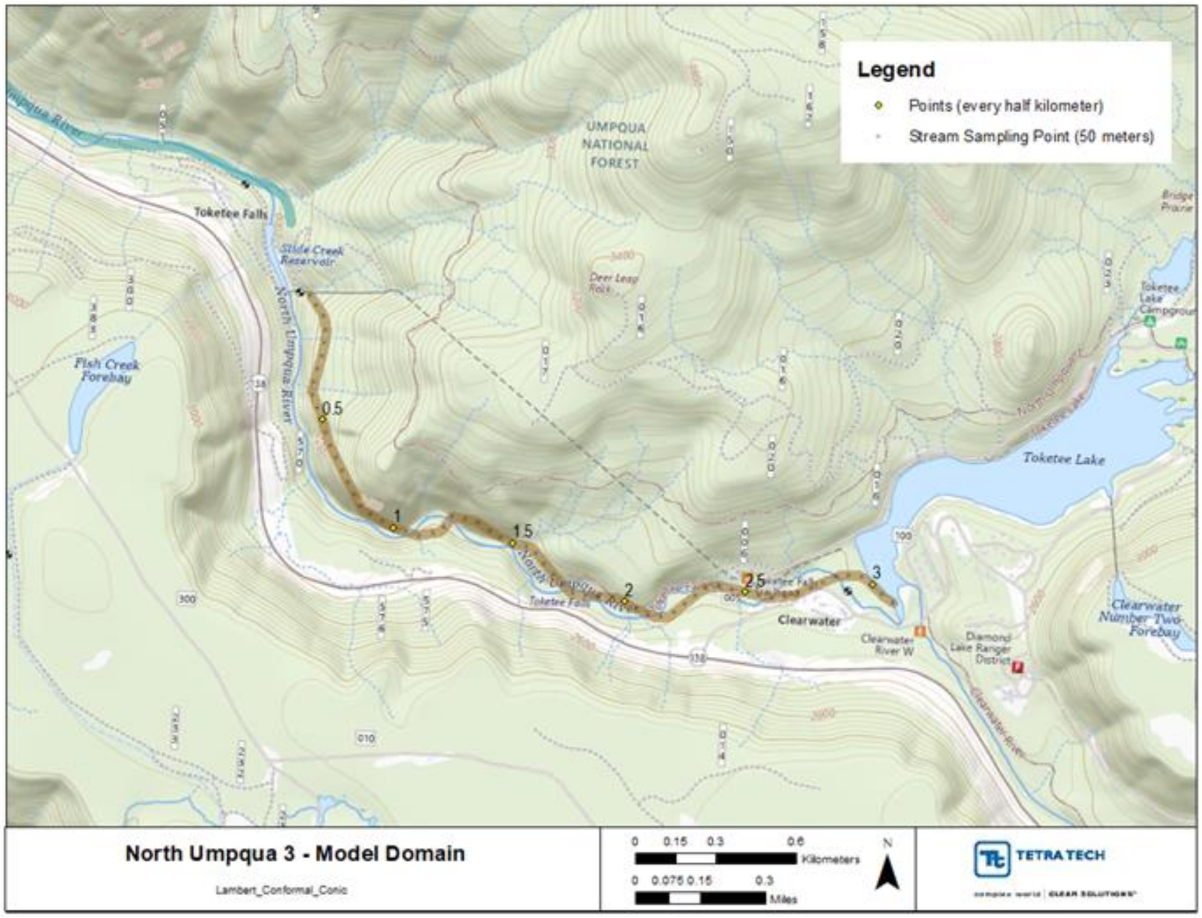

Figure 12-1. North Umpqua River Model 3 model domain.

12.1 NORTH UMPQUA RIVER MODEL 3 SUMMER PERIOD SCENARIO RESULTS

The North Umpqua River HS summer model 3 does not include any point sources. The scenarios that are relevant to the North Umpqua River summer model 3 include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; and the Fully Restored Vegetation with Natural Flow scenario. The 7DADM results are shown in Figure 12-2 to Figure 12-4 for these scenarios.

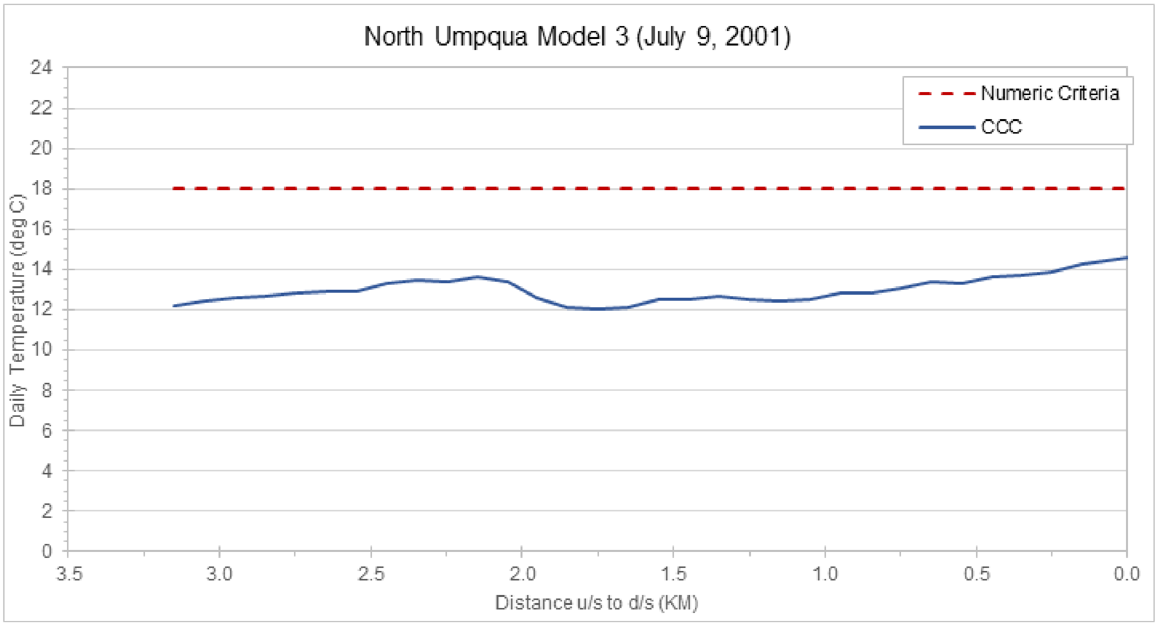

Figure 12-2. The maximum 7DADM temperature results along the North Umpqua River model 3 (summer period) for the CCC scenario.

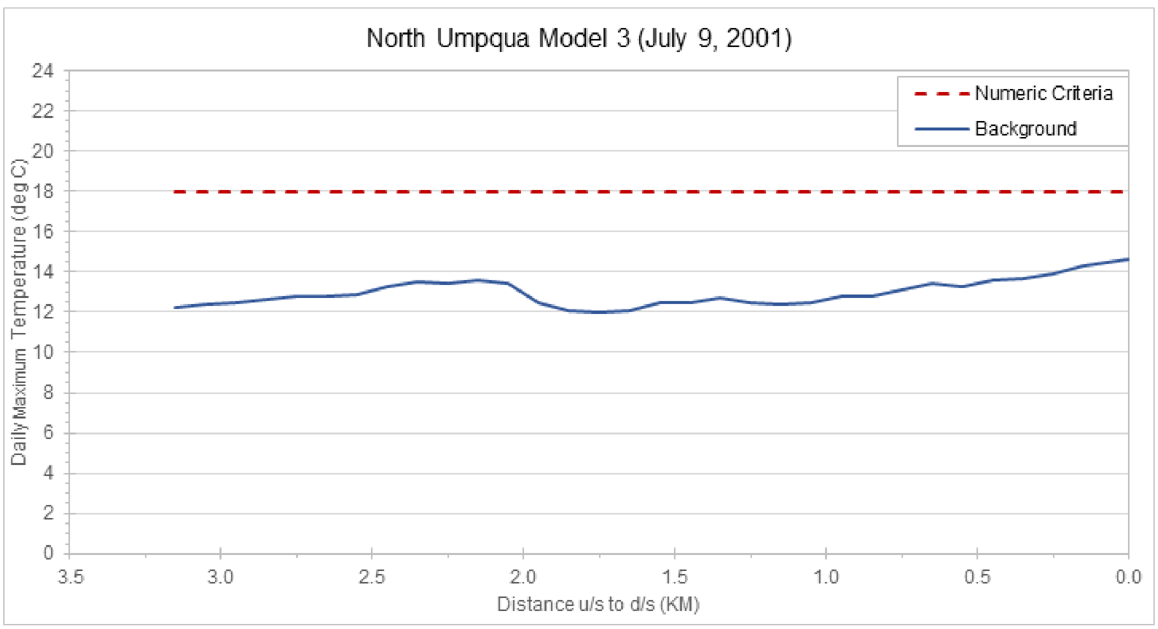

Figure 12-3. The maximum 7DADM temperature results along the North Umpqua River model 3 (summer period) for the Background scenario.

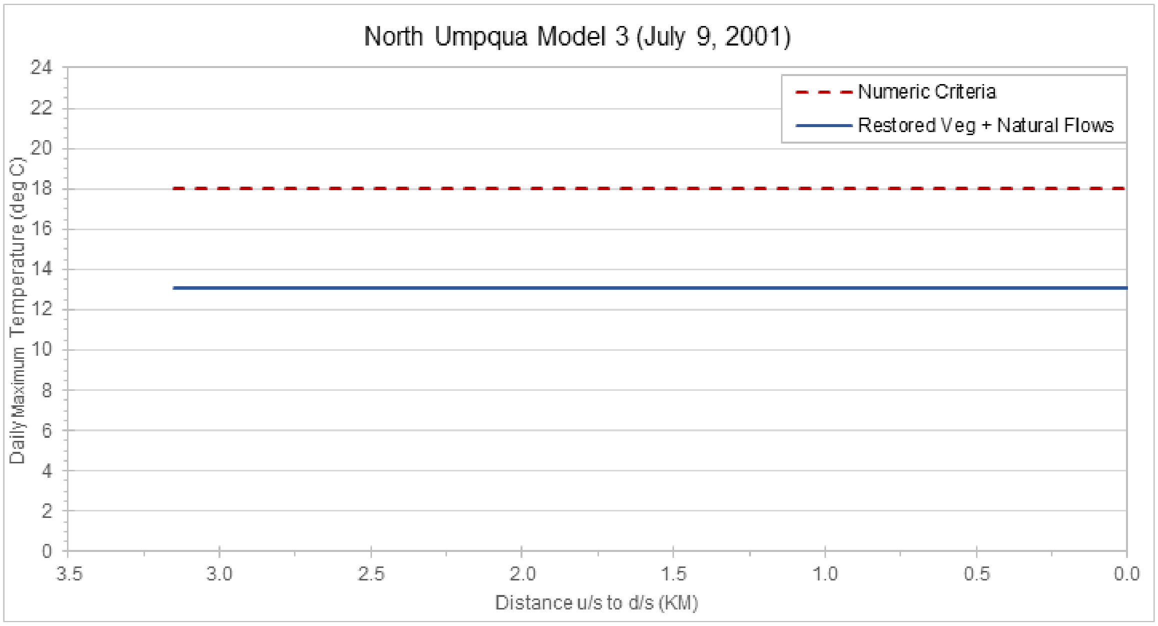

Figure 12-4. The maximum 7DADM temperature results along the North Umpqua River model 3 (summer period) for the Fully Restored Vegetation with Natural Flow scenario.

12.2 NORTH UMPQUA RIVER MODEL 3 SUMMER PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the North Umpqua River model 3 summer period include:

2. Impact of current point source and shade loss (note there are no point sources in North Umpqua Model 3)
   - ✓ CCC minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria
9. Natural Flows
   - ✓ Background minus fully restored veg with natural flows

Figure 12-5 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 12-1).

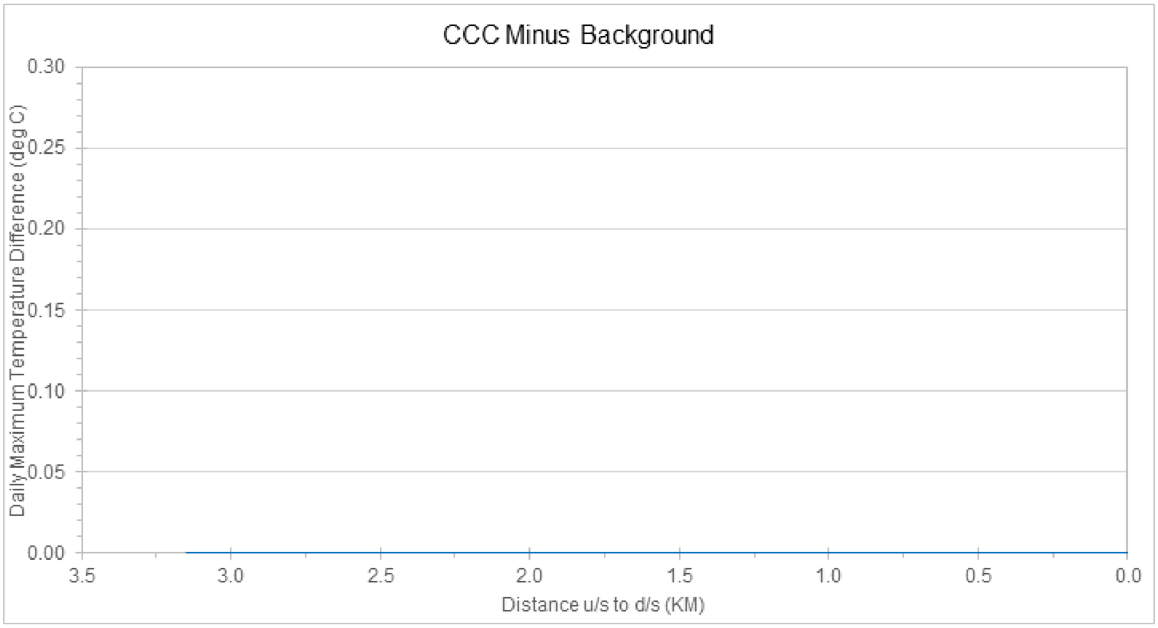

Figure 12-5. The maximum 7DADM temperature differences along the North Umpqua River model 3 (summer period) for the impacts of current point sources and current conditions vegetation.

Table 12-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the North Umpqua River model 2 summer period

North Umpqua #3	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	N/A	N/A	N/A

Figure 12-6 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -6.0 ^{o}C at RKM 0.0 on July 9, 2001 (Table 12-2).

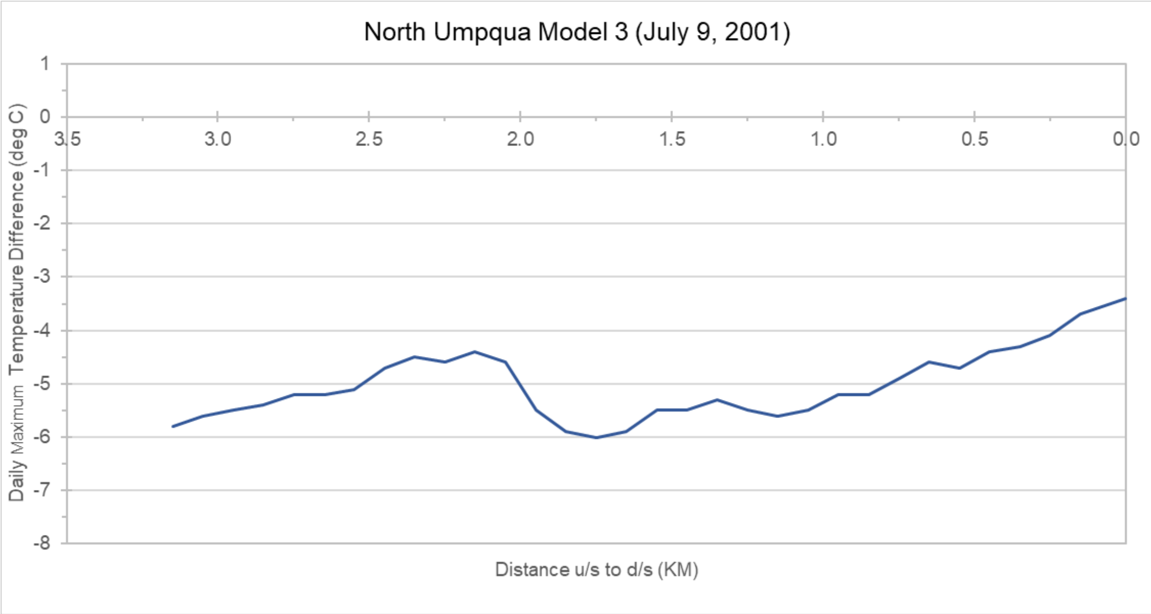

Figure 12-6. The maximum 7DADM temperature differences along the North Umpqua River model 3 (summer period) between Background scenario and the criteria.

Table 12-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 3 summer period

North Umpqua #3	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	0.00	-6.00	7/9/2001

Figure 12-7 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. There are a few differences between these two scenarios for the North Umpqua River. The headwater flows and temperature inputs were different and reflect natural conditions with increased flow and lower temperatures. In addition, a new tributary input from “Clearwater River (flow scenario)” was also included in the Natural Flow scenario There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 12-3).

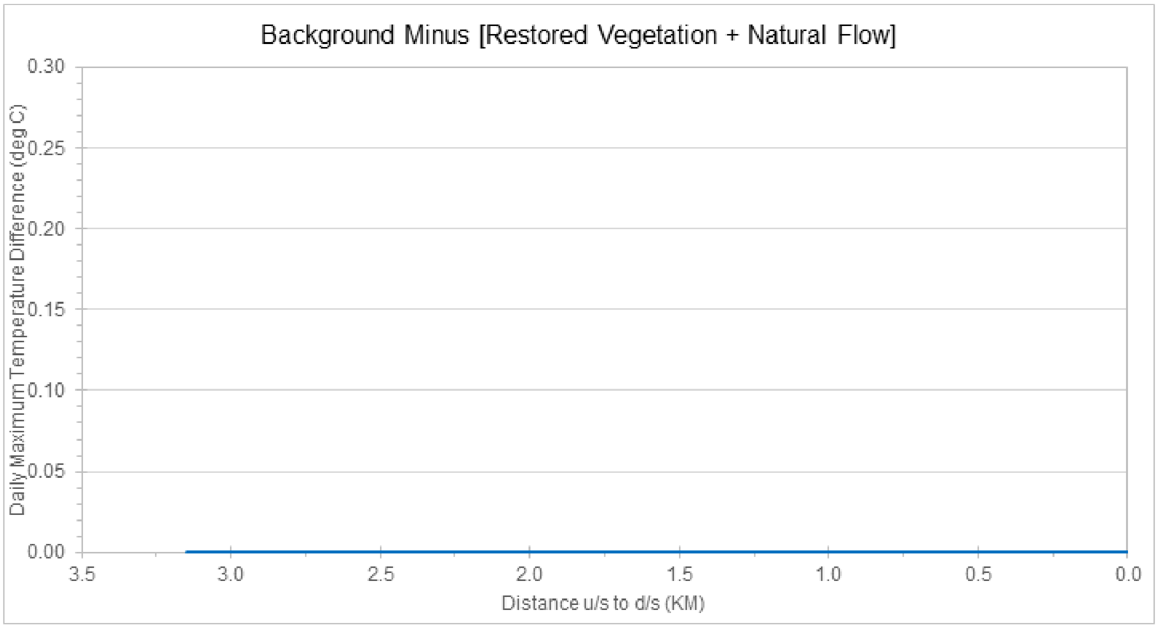

Figure 12-7. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario on the North Umpqua River model 3 (summer period).

Table 12-3. Location and date of maximum delta when temperatures are greater than criterion for comparison 9 for the North Umpqua River model 3 summer period

North Umpqua #3	RKM	Maximum Delta	Date when maximum delta occurs
Background Minus [Restored Vegetation + Natural Flow]	N/A	N/A	N/A

12.3 NORTH UMPQUA RIVER MODEL 3 SPAWNING PERIOD SCENARIO RESULTS

The North Umpqua River spawning period HS model 3 does not include any point sources. The scenarios that are relevant to the North Umpqua River spawning period model 3 include the CCC scenario, which is identical to the No Point Source scenario, and the Background scenario. The 7DADM results are shown in Figure 12-8 and Figure 12-9 for these scenarios. Note that the year round (non-spawning criteria) applies to North Umpqua Model 3 and was evaluated for the entire modeling period from August 1 to October 15, 2009.

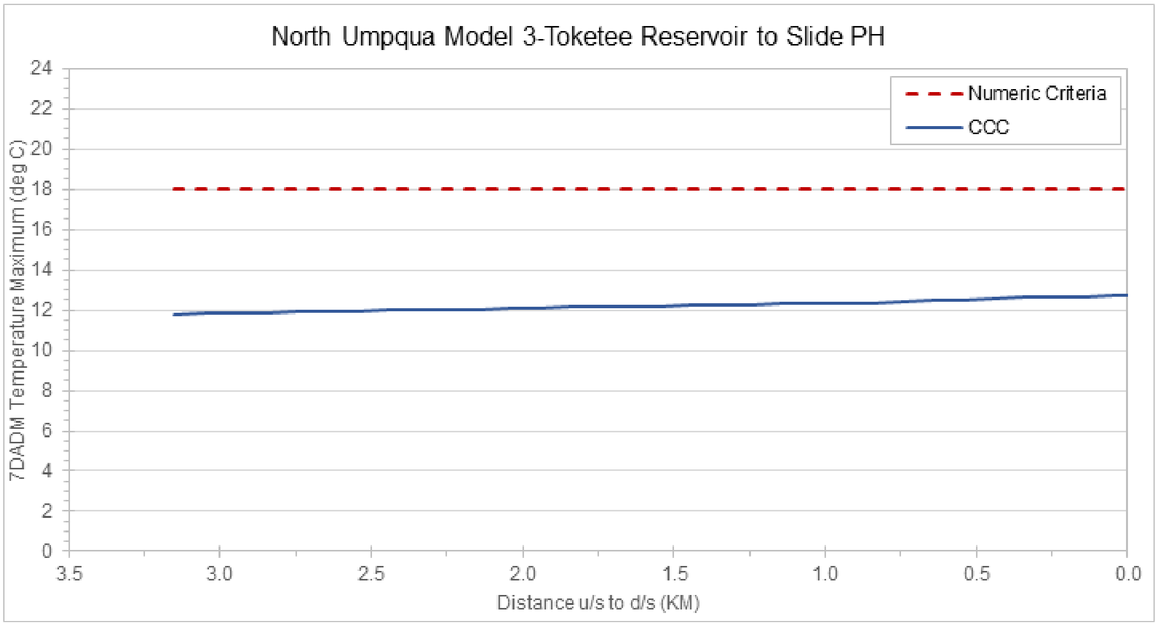

Figure 12-8. The maximum 7DADM temperature results along the North Umpqua River model 3 (spawning period) for the Current Conditions scenario.

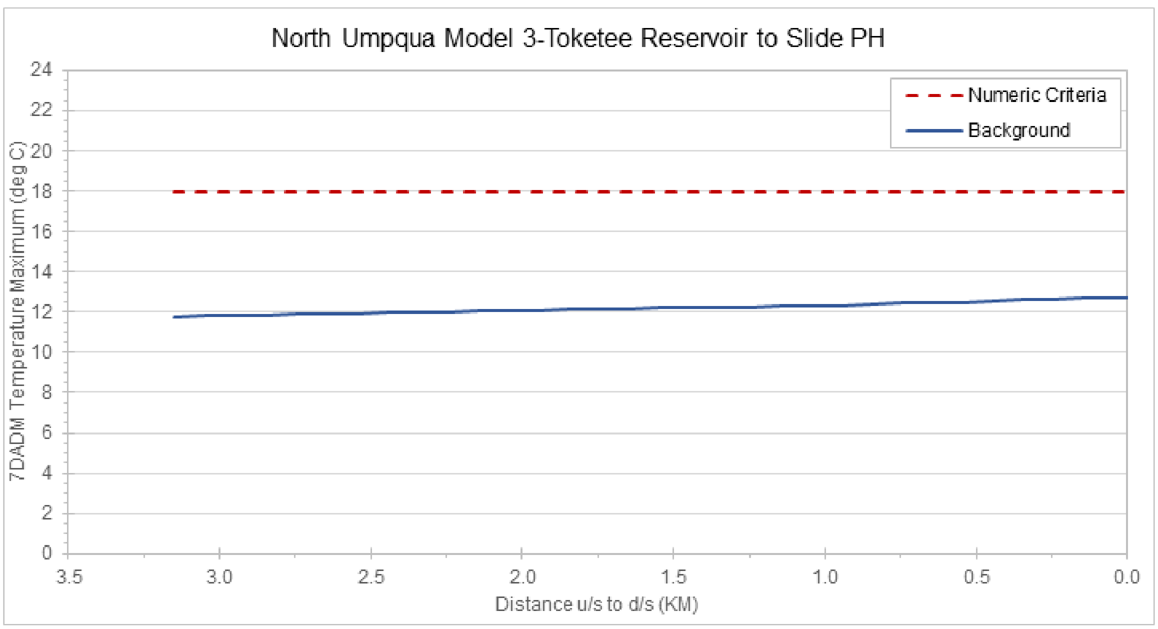

Figure 12-9. The maximum 7DADM temperature results along the North Umpqua River model 3 (spawning period) for the Background scenario.

12.4 NORTH UMPQUA RIVER MODEL 3 SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the North Umpqua River spawning period include:

2. Impact of current point source and shade loss (note there are no point sources in North Umpqua Model 3)
   - ✓ CCC minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

Figure 12-10 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 12-4).

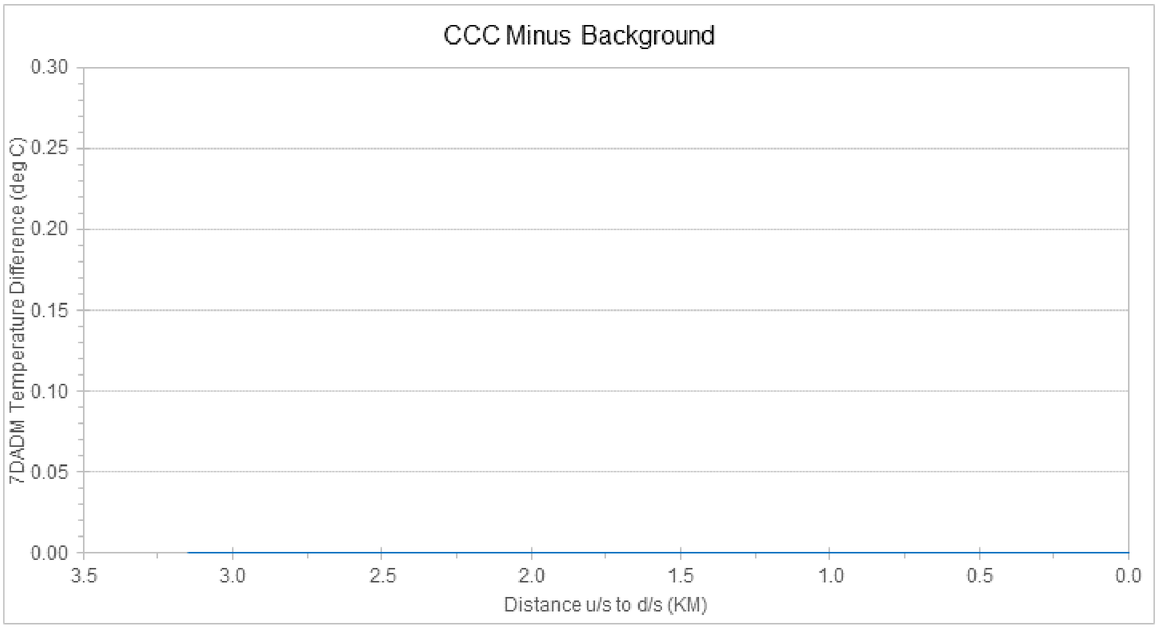

Figure 12-10. The maximum 7DADM temperature differences along the North Umpqua River model 3 (spawning period) for the impacts of current point sources and shade loss.

Table 12-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the North Umpqua River model 3 spawning period

North Umpqua #3	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus Background	N/A	N/A	N/A

Figure 12-11 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -6.21 °C at RKM 3.15 on August 7, 2009 (Table 12-5).

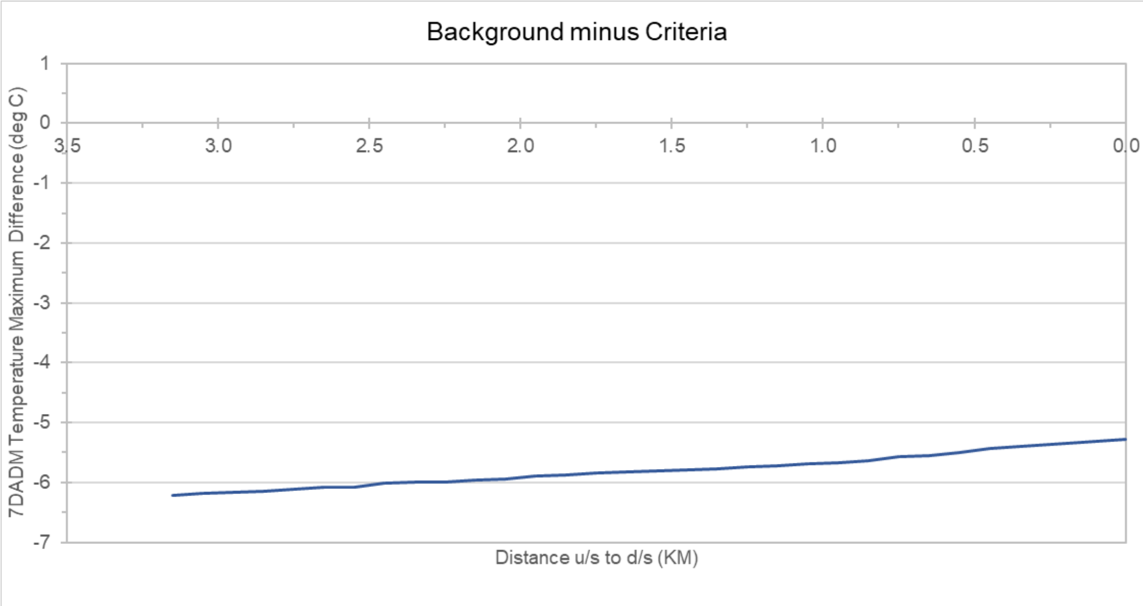

Figure 12-11. The maximum 7DADM temperature differences along the North Umpqua River model 3 (spawning period) between Background scenario and the criteria

Table 12-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 the North Umpqua River model 3 spawning period

North Umpqua #3	RKM	Maximum Delta	Date when Maximum Delta occurs
Background minus Criteria	3.15	-6.21	8/7/2009

13.0 NORTH UMPQUA RIVER MODEL 4 (SLIDE POWERHOUSE TO SOAD SPRINGS RESERVOIR)

The modeled portion of the North Umpqua River model 4 is shown in Figure 13-1. The North Umpqua River was modeled for both the summer period (July 8-11, 2001) and the spawning period (August 1, 2009 to October 15, 2009). The summer period scenario results and scenario comparisons are presented in section 13.1 and 13.2, while the spawning period scenario results and scenario comparisons are presented in section 13.3 and 13.4.

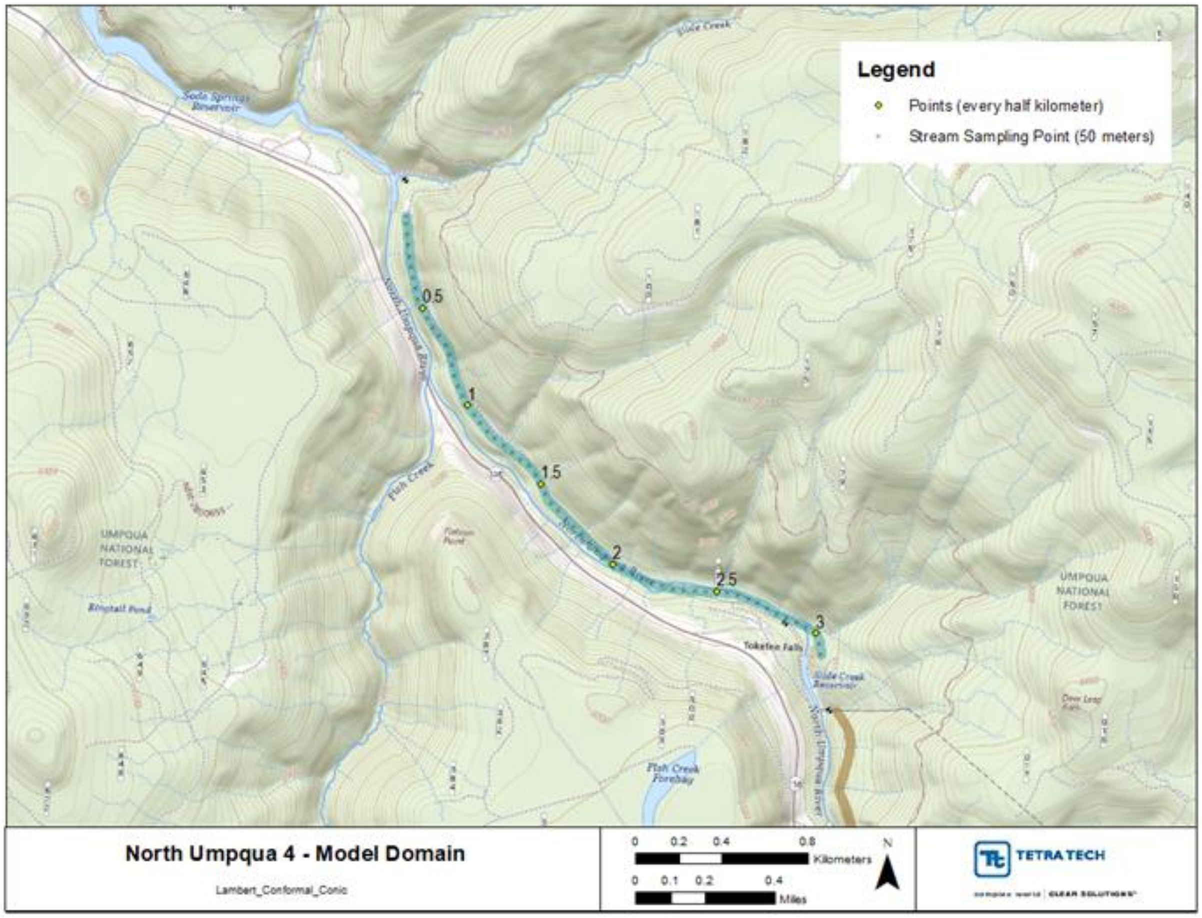

Figure 13-1. North Umpqua River Model 4 model domain.

13.1 NORTH UMPQUA RIVER MODEL 4 SUMMER PERIOD SCENARIO RESULTS

The North Umpqua River summer period HS model 4 does not include any point sources. The scenarios that are relevant to North Umpqua River summer period model 4 include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; and the Fully Restored Vegetation with Natural Flow scenario. The 7DADM results are shown in Figure 13-2 through Figure 13-4 for these scenarios.

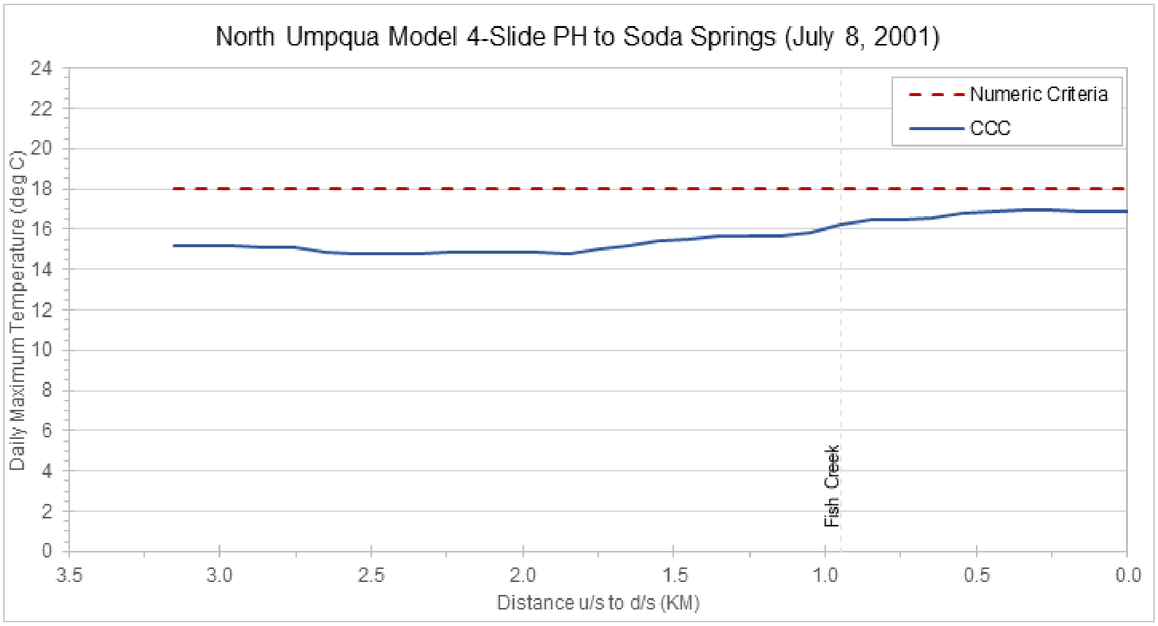

Figure 13-2. The maximum 7DADM temperature results along the North Umpqua River model 4 (summer period) for the CCC scenario.

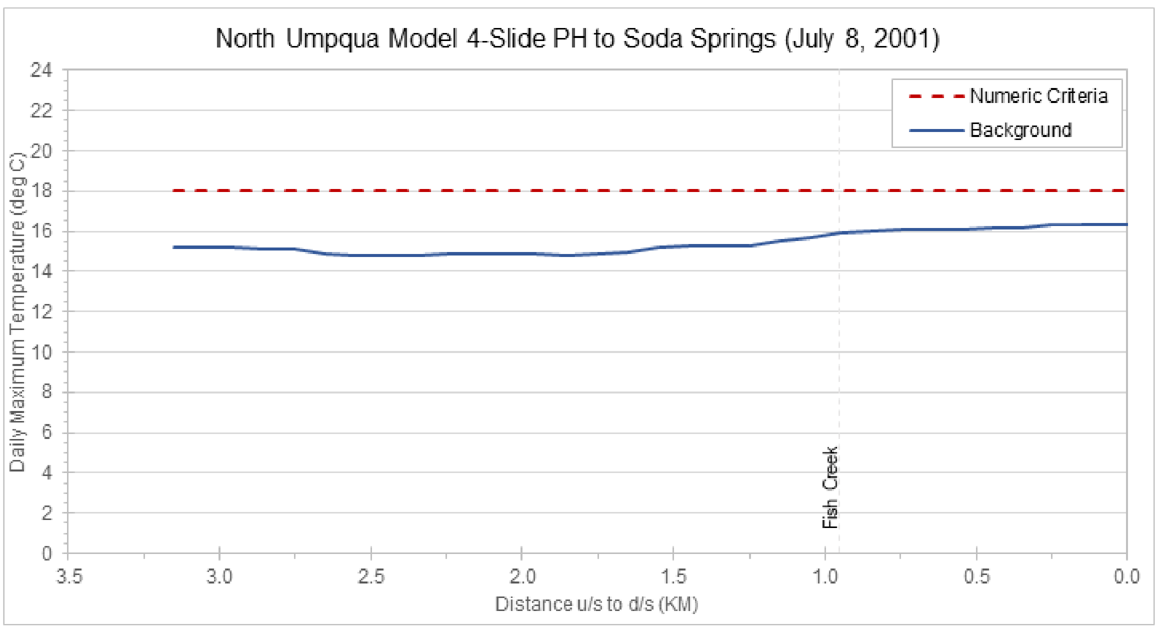

Figure 13-3. The maximum 7DADM temperature results along the North Umpqua River model 4 (summer period) for the Background scenario.

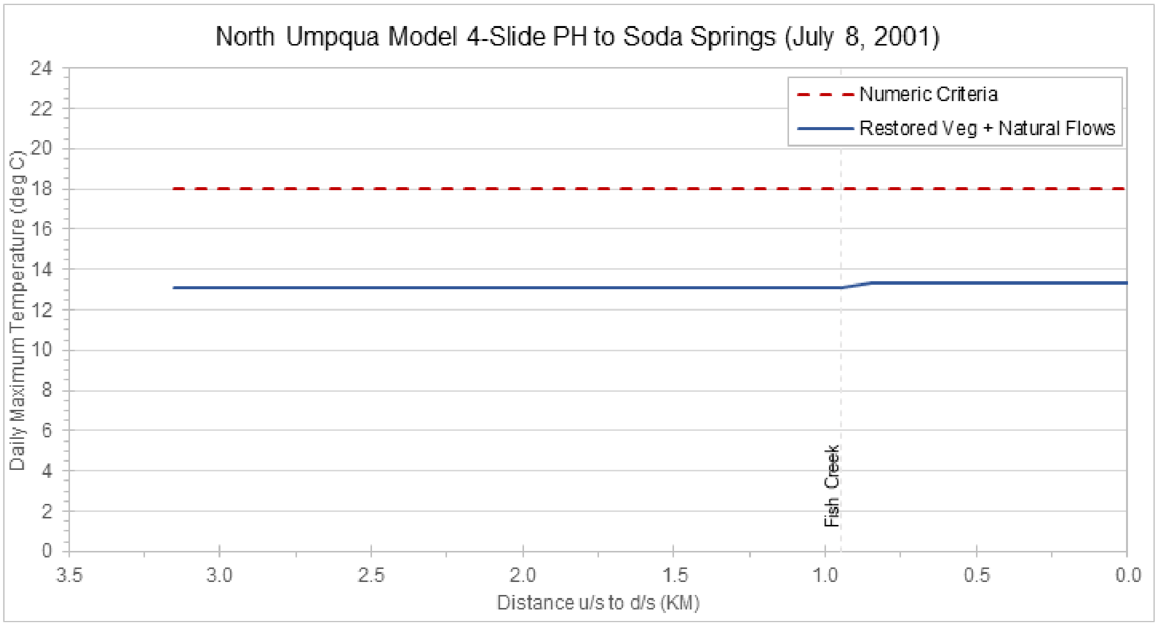

Figure 13-4. The maximum 7DADM temperature results along the North Umpqua River model 4 (summer period) for the Fully Restored Vegetation with Natural Flow scenario.

13.2 NORTH UMPQUA RIVER MODEL 4 SUMMER PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the North Umpqua River model 4 summer period include:

2. Impact of current point source and shade loss (note there are no point sources in North Umpqua Model 4)
    - ✓ CCC minus background
7. Difference between background and criteria
    - ✓ Background minus Criteria
9. Natural Flows
    - ✓ Background minus fully restored veg with natural flows

Figure 13-5 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 13-1).

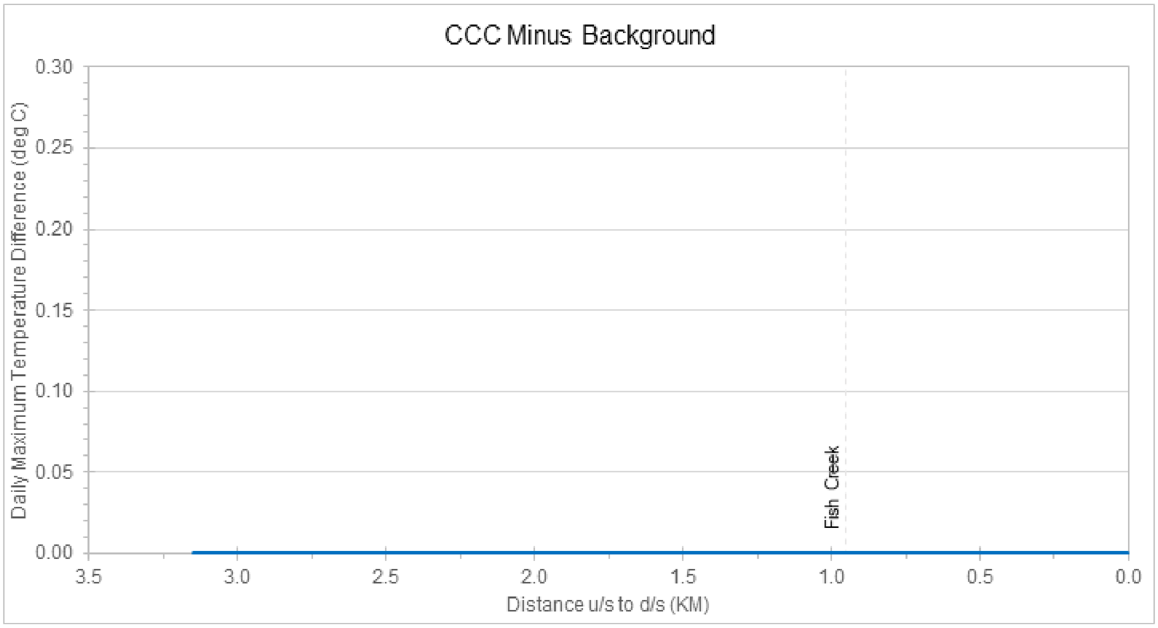

Figure 13-5. The maximum 7DADM temperature differences along the North Umpqua River model 4 (summer period) for the impacts of current point sources and current conditions vegetation.

Table 13-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the North Umpqua River model 4 summer period

North Umpqua #4	RKM	Maximum Delta	Date when maximum delta occurs
CCC Minus Background	N/A	N/A	N/A

Figure 13-6 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -3.2 °C at RKMs 2.55 to 2.35 and 1.85 on July 8, 2001 (Table 13-2).

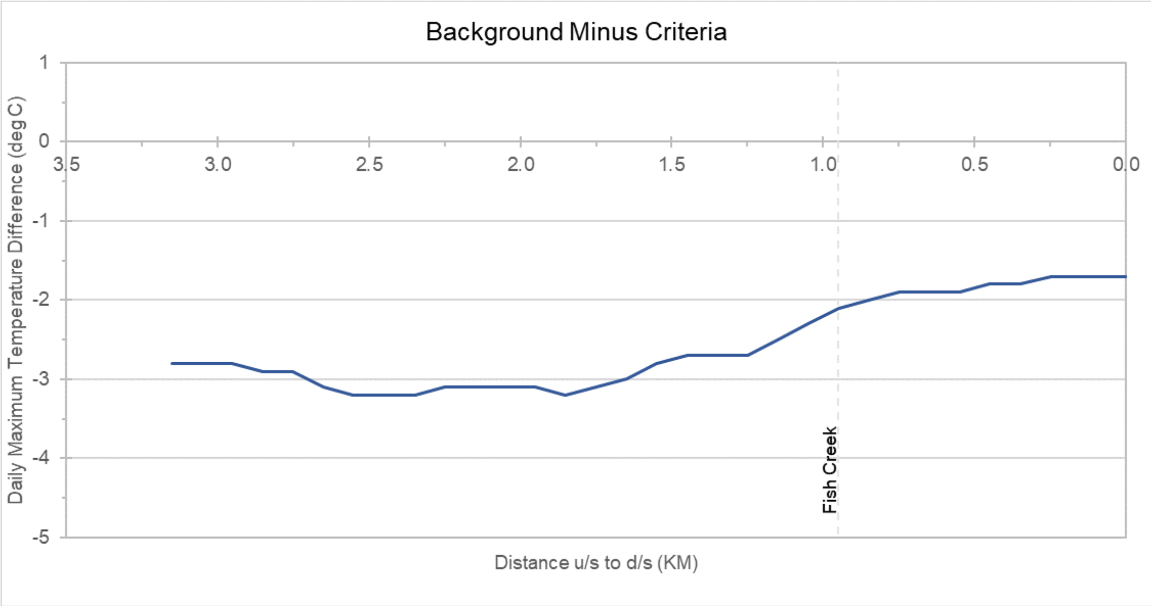

Figure 13-6. The maximum 7DADM temperature differences along the North Umpqua River model 4 (summer period) between Background scenario and the criteria.

Table 13-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 4 summer period

North Umpqua #4	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	2.55 to 2.35 & 1.85	-3.20	7/8/2001

Figure 13-7 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. There are a few differences between these two scenarios for the North Umpqua River. The headwater flows and temperature inputs are different and reflect natural conditions with increased flow and lower temperatures. In addition, the flows and temperatures inputs for Fish Creek were also updated to reflect natural flows. There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 13-3).

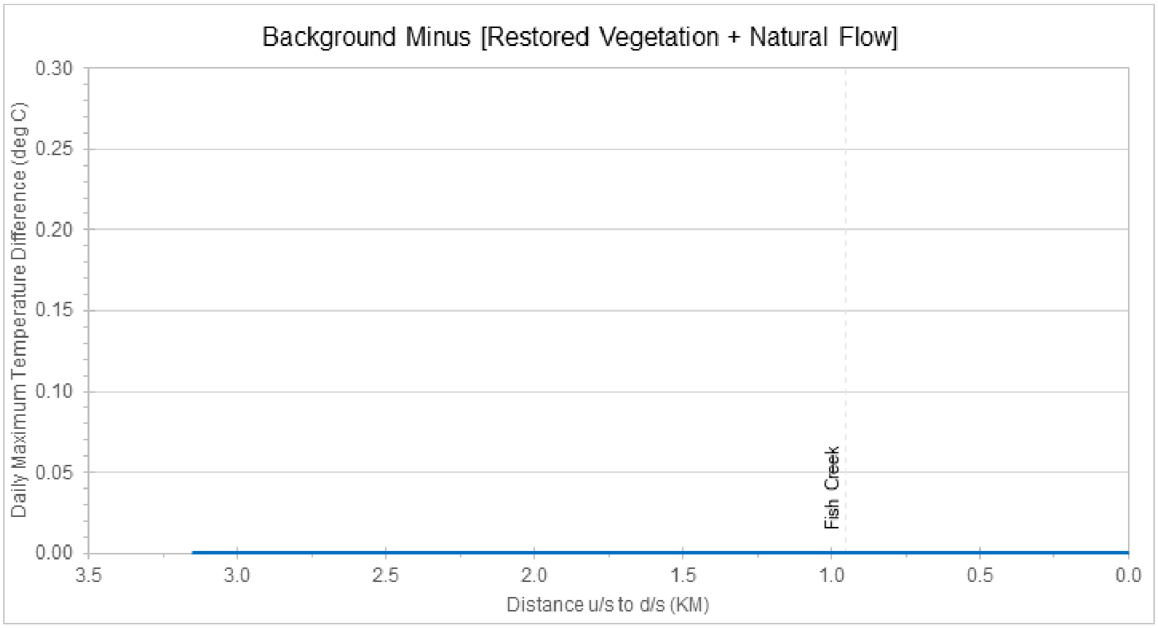

Figure 13-7. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario on the North Umpqua River model 4 (summer period).

Table 13-3. Location and date of maximum delta when temperatures are greater than criterion for comparison 9 for the North Umpqua River model 4 summer period

North Umpqua #4	RKM	Maximum Delta	Date when maximum delta occurs
Background Minus [Restored Vegetation + Natural Flow]	N/A	N/A	N/A

13.3 NORTH UMPQUA RIVER MODEL 4 SPAWNING PERIOD SCENARIO RESULTS

The North Umpqua River spawning period HS model 4 does not include any point sources. The scenarios that are relevant to the North Umpqua River spawning period model 4 include the CCC scenario, which is identical to the No Point Source scenario, and the Background scenario. The 7DADM results are shown in Figure 13-8 and Figure 13-9 for these scenarios. Note that the year round (non-spawning criteria) applies to North Umpqua Model 4 and was evaluated for the entire modeling period from August 1 to October 15, 2009.

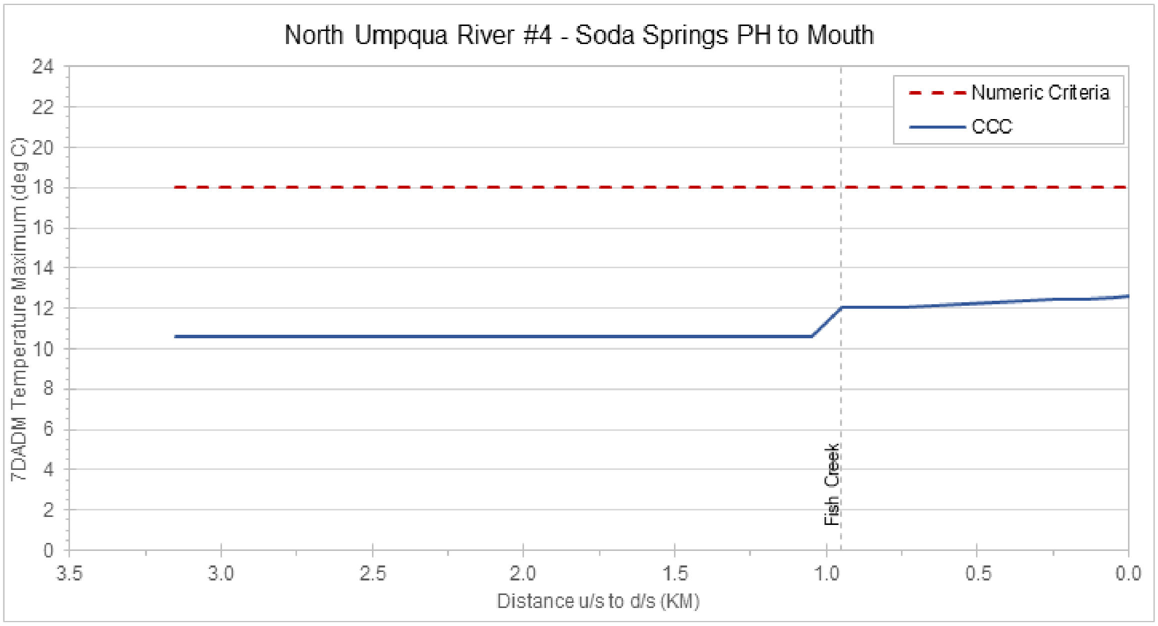

Figure 13-8. The maximum 7DADM temperature results along the North Umpqua River model 4 (spawning period) for the Current Conditions scenario.

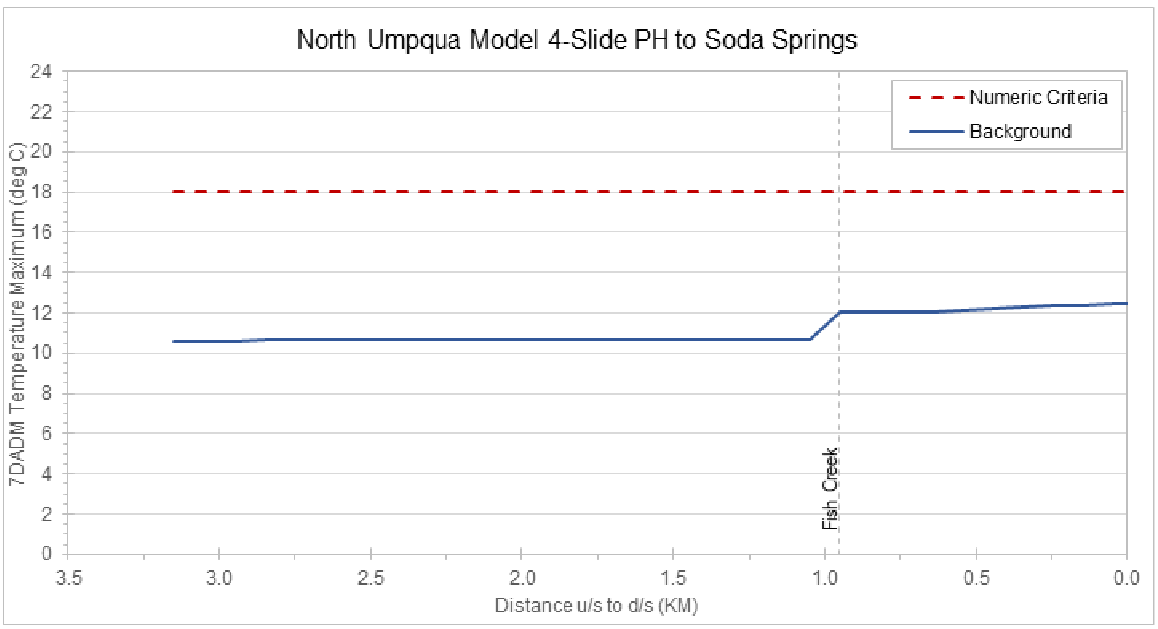

Figure 13-9. The maximum 7DADM temperature results along the North Umpqua River model 4 (spawning period) for the Background scenario.

13.4 NORTH UMPQUA RIVER MODEL 4 SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the North Umpqua River model 4 spawning period include:

2. Impact of current point source and shade loss
   - ✓ CCC minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

Figure 13-10 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. There is no delta calculated for this comparison since the 7DADM do not exceed the BBNC for either of the scenarios (Table 13-4).

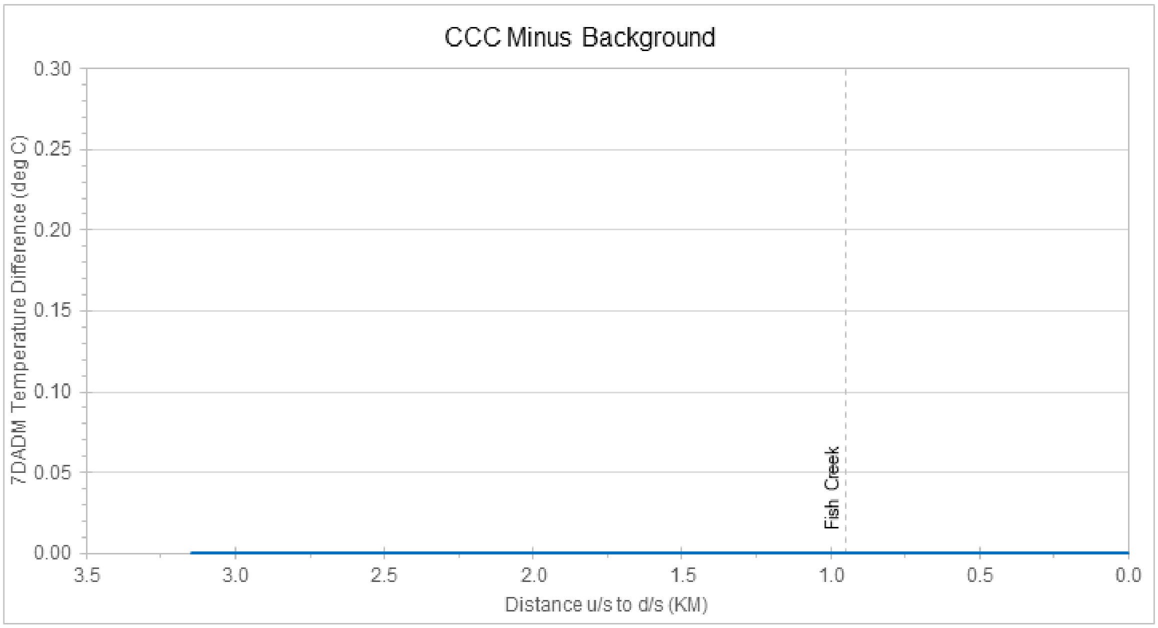

Figure 13-10. The maximum 7DADM temperature differences along the North Umpqua River model 4 (spawning period) for the impacts of current point sources and shade loss.

Table 13-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the North Umpqua River model 4 spawning period

North Umpqua #4 Creek	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus Background	N/A	N/A	N/A

Figure 13-11 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches -7.37 °C at RKM 3.15 on August 7, 2009 (Table 13-5).

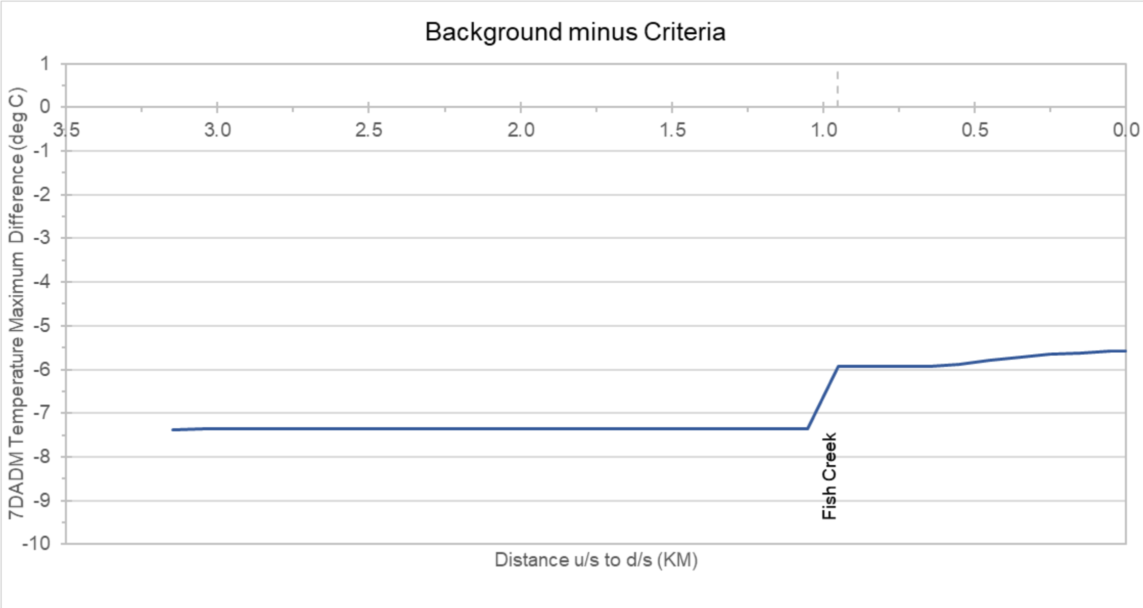

Figure 13-11. The maximum 7DADM temperature differences along the North Umpqua River model 4 (spawning period) between Background scenario and the criteria

Table 13-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 4 spawning period

North Umpqua #4	RKM	Maximum Delta	Date when Maximum Delta occurs
Background minus Criteria	3.15	-7.37	8/7/2009

14.0 NORTH UMPQUA RIVER MODEL 5 (SODA SPRINGS RESERVOIR TO THE MOUTH)

The modeled portion of the North Umpqua River model 5 is shown in Figure 14-1. The North Umpqua River was modeled for both the summer period (July 8-11, 2001) and the spawning period (August 1, 2009 to October 15, 2009). The summer period scenario results and scenario comparisons are presented in sections 14.1 and 14.2, while the spawning period scenario results and scenario comparisons are presented in sections 14.3 and 14.4.

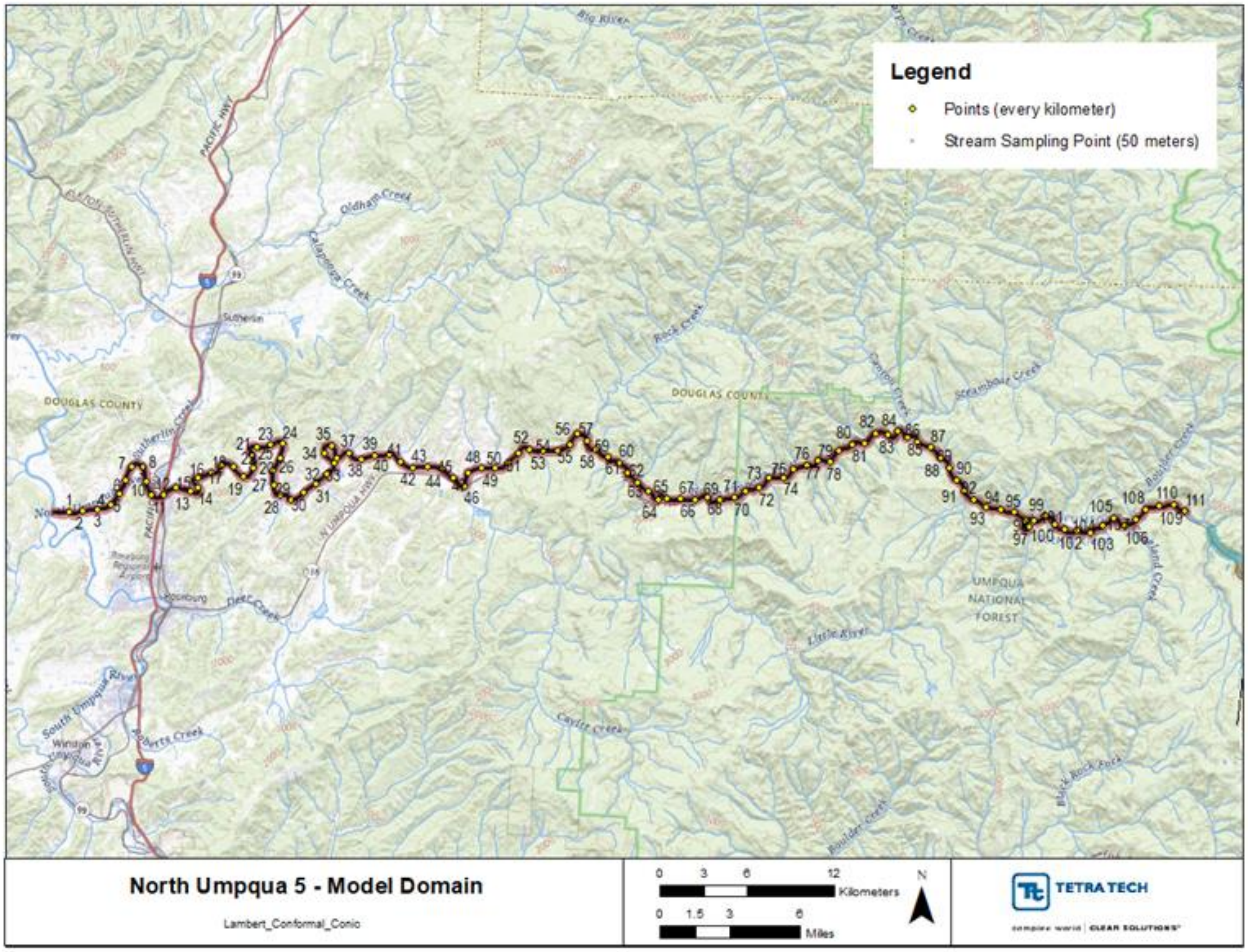

Figure 14-1. North Umpqua River Model 5 model domain.

14.1 NORTH UMPQUA RIVER MODEL 5 SUMMER PERIOD SCENARIO RESULTS

The North Umpqua River summer period HS model 5 does not include any point sources. The scenarios that are relevant to North Umpqua model 5 include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; the Fully Restored Vegetation with Natural Flow scenario; scenarios to evaluate General Permit in upper North Umpqua by adding 0.1, 0.2, & 0.3 ^oC; and the tributary/headwater plus 0.1 ^oC scenario. The 7DADM results are shown in Figure 14-2 to Figure 14-6 for these scenarios.

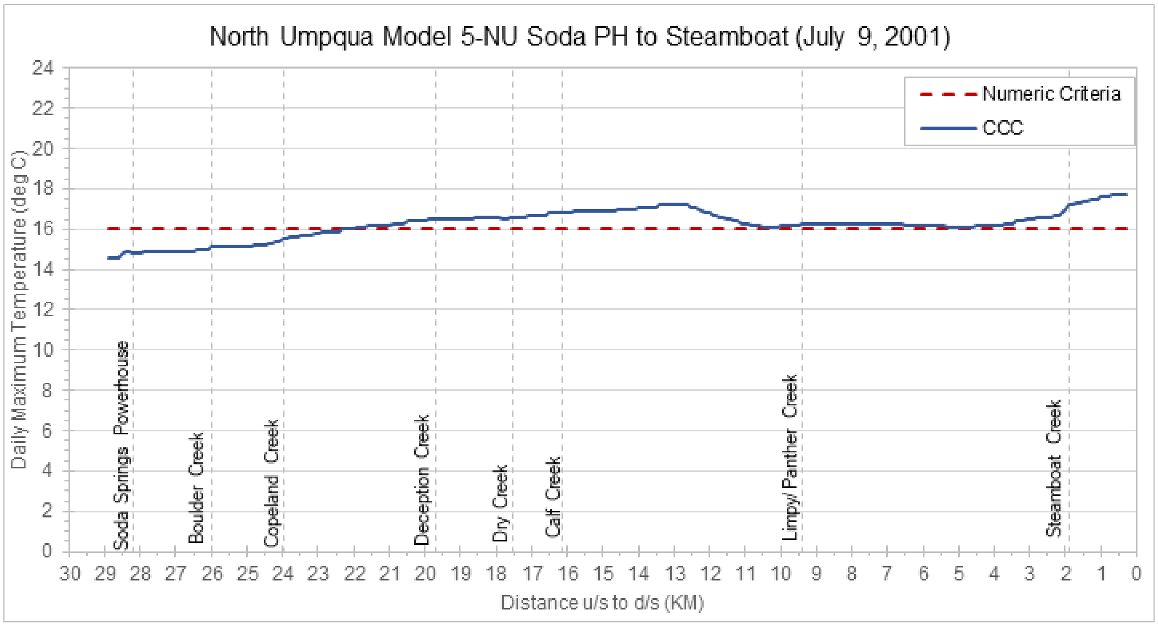

Figure 14-2. The maximum 7DADM temperature results along the North Umpqua River model 5 (summer period) for the CCC scenario.

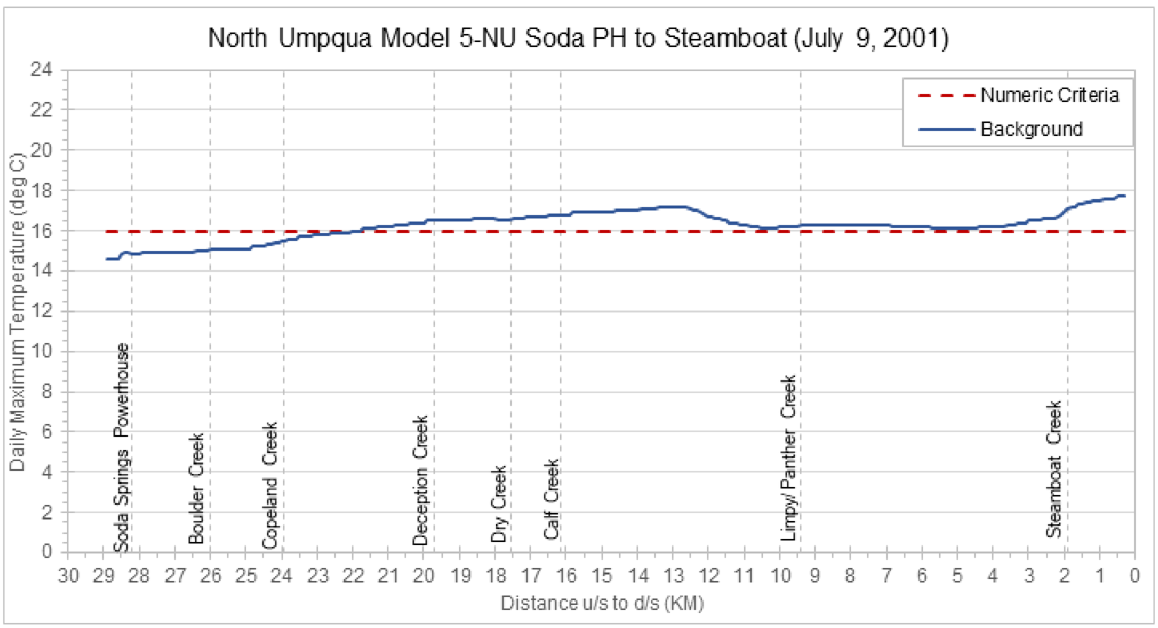

Figure 14-3. The maximum 7DADM temperature results along the North Umpqua River model 5 (summer period) for the Background scenario.

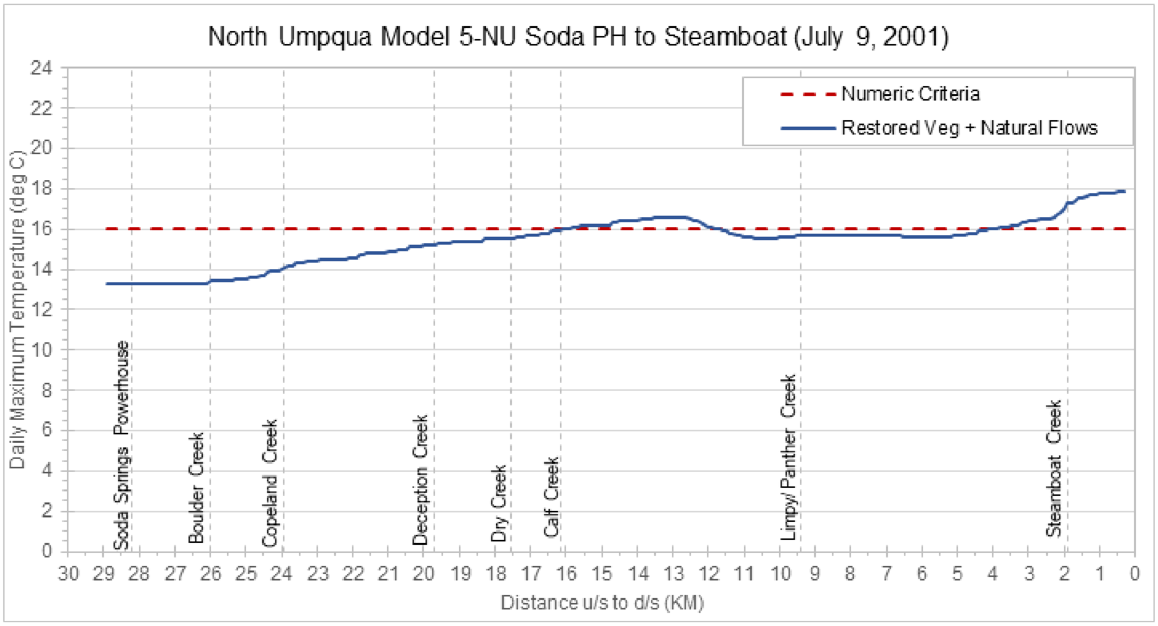

Figure 14-4. The maximum 7DADM temperature results along the North Umpqua River model 5 (summer period) for the Fully Restored Vegetation with Natural Flow scenario.

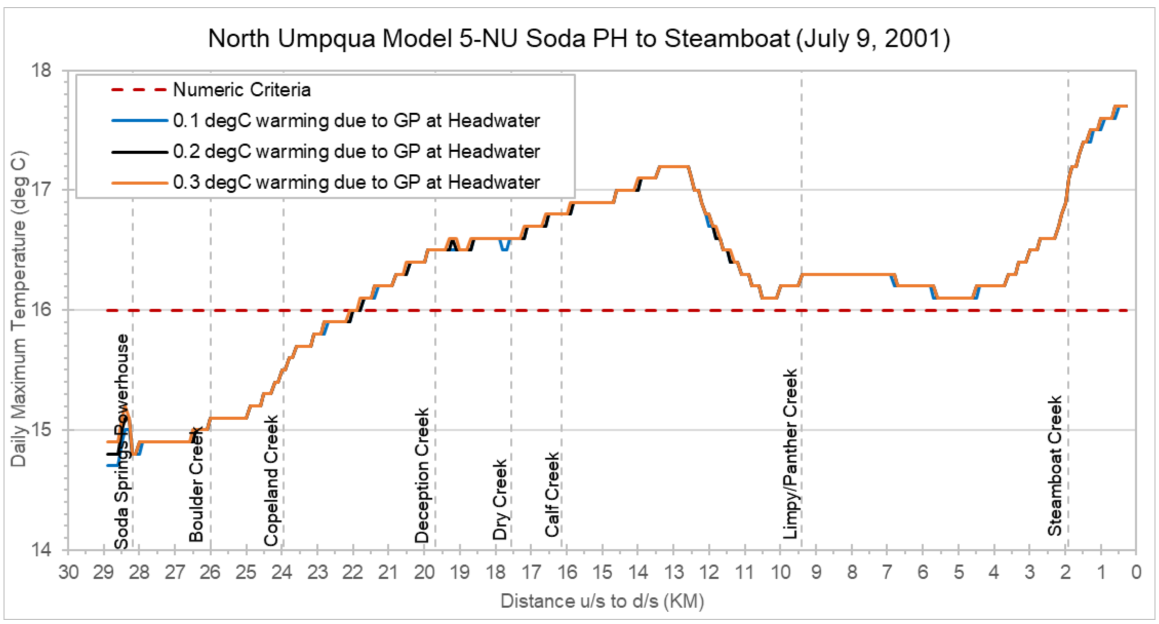

Figure 14-5. The maximum 7DADM temperature results along the North Umpqua River model 5 (summer period) General Permit (GP) evaluation scenario, Headwater plus 0.1°C, 0.2°C & 0.3°C.

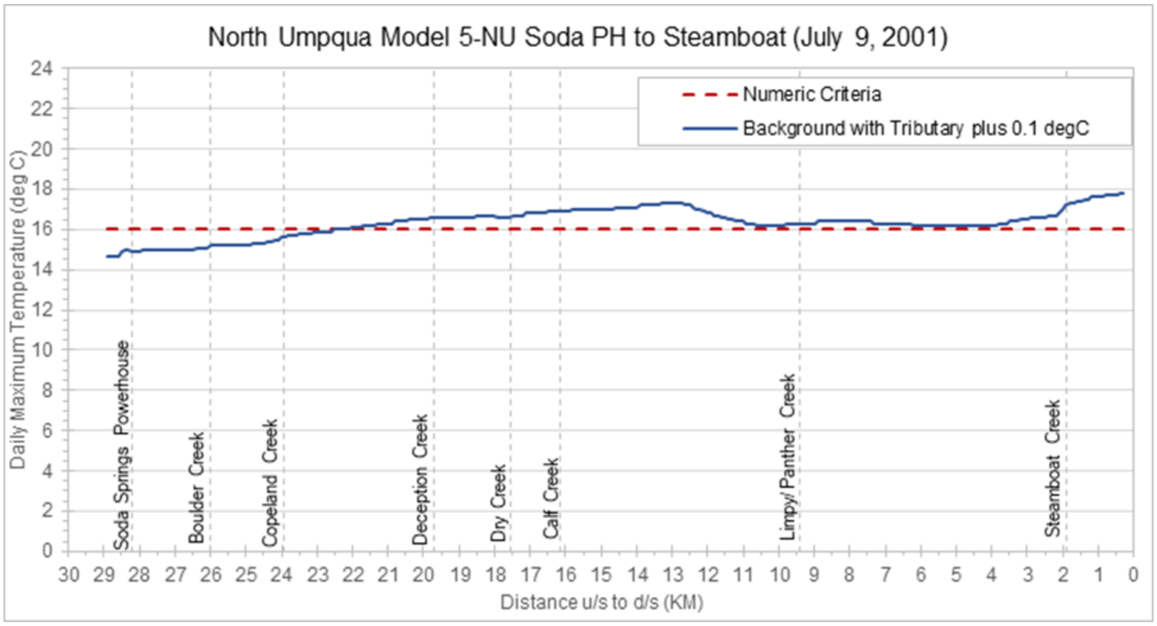

Figure 14-6. The maximum 7DADM temperature results along the North Umpqua River model 5 (summer period) for the Tributary/Headwater plus 0.1°C scenario.

14.2 NORTH UMPQUA RIVER MODEL 5 SUMMER PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the North Umpqua River model 5 summer period include:

2. Impact of current point source and shade loss (note there are no point sources in North Umpqua Model 1)
   - ✓ CCC minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria
9. Natural Flows
   - ✓ Background minus fully restored veg with natural flows

A1. General permit evaluation in upper North Umpqua adding 0.1, 0.2, & 0.3 °C
   - ✓ Headwater plus 0.1, 0.2, & 0.3 ºC minus background

A2. Impact of tributary scenario (tributary/headwater plus 0.1 ºC)
   - ✓ Tributary plus 0.1 ºC minus background

Figure 14-7 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The difference between these two scenarios is the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta seen was 0.1 °C. The delta of 0.1 °C occurs at multiple RKMs and on multiple dates as shown in Figure 14-7.

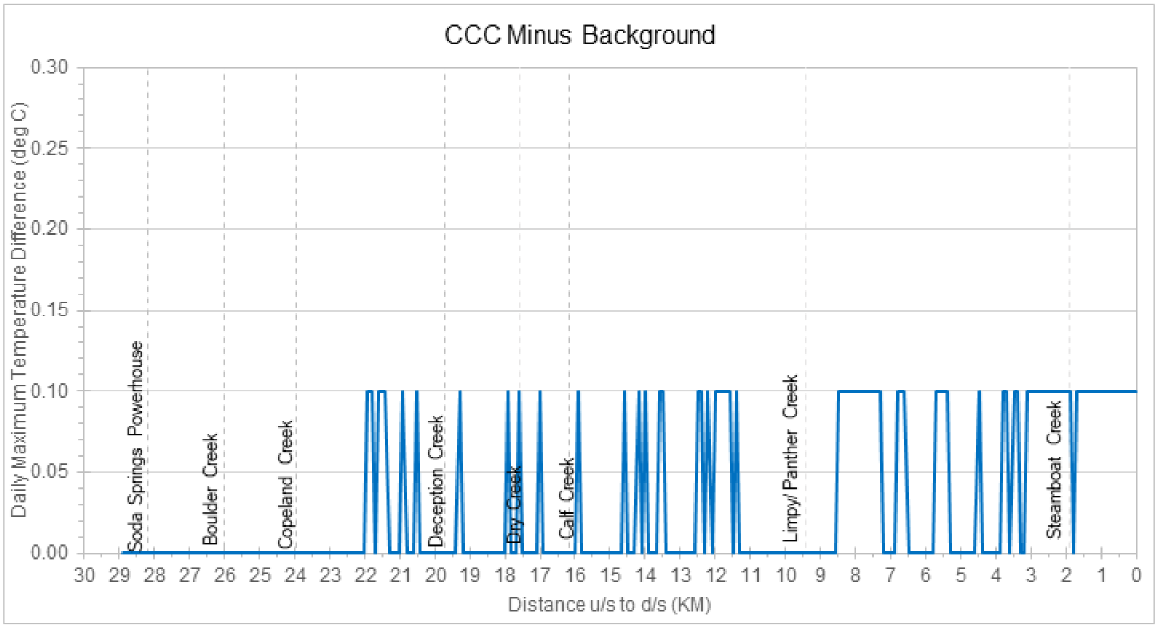

Figure 14-7. The maximum 7DADM temperature differences along the North Umpqua River model 5 (summer period) for the impacts of current point sources and current conditions vegetation.

Figure 14-8 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 1.7 °C at RKMs 0.5 to 0.0 on July 9, 2001 and -1.4 °C at RKMs 28.9 to 28.6 on July 9, 2001 (Table 14-1).

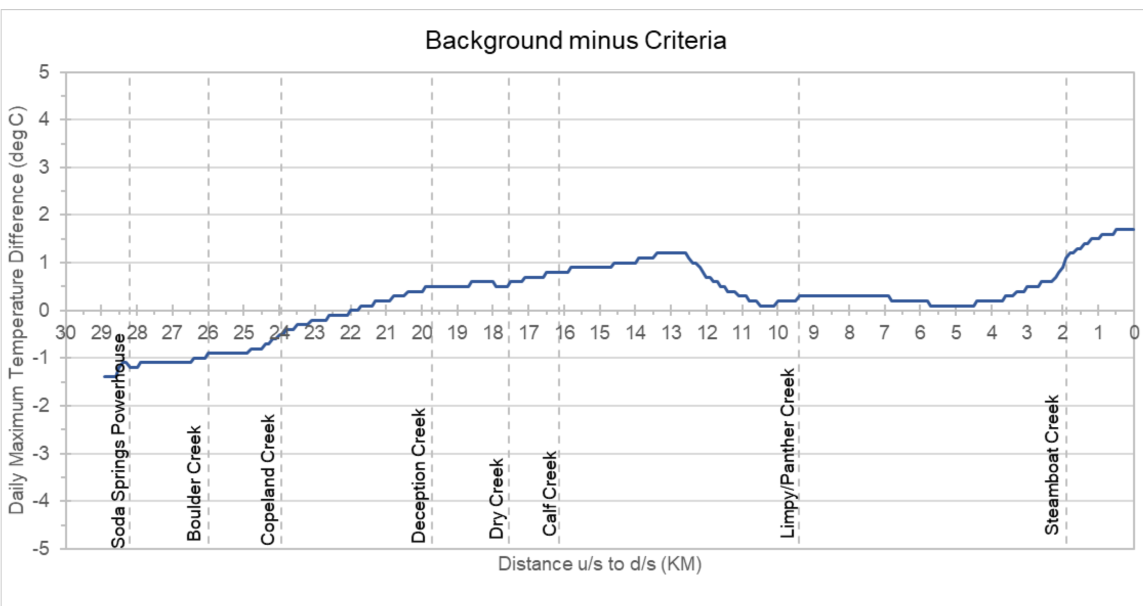

Figure 14-8. The maximum 7DADM temperature differences along the North Umpqua River model 5 summer period between Background scenario and the criteria.

Table 14-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 5 summer period

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
Background minus Criteria	0.50 to 0	1.70	7/9/2001
	28.90 to 28.6	-1.40	7/9/2001

Figure 14-9 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. There are a few differences between these two scenarios for the North Umpqua River. Specifically, the inputs from the Soda Springs Powerhouse were removed in the Natural Flows model and the headwater flows and temperature inputs were different, with increased flows and cooler temperatures. The maximum delta, calculated when the 7DADM exceeded the criteria, is 1.4 °C at RKM 21.7 on July 9, 2001 (Table 14-2). Note that there no delta shown from the headwater to RKM 21.7 since the 7DADM do not exceed the BBNC for either of the scenarios up to that point. After RKM 21.7, the 7DADM for the Background scenario exceeds the BBNC (see Figure 14-3), and the resulting maximum calculated delta are shown in Figure 14-9

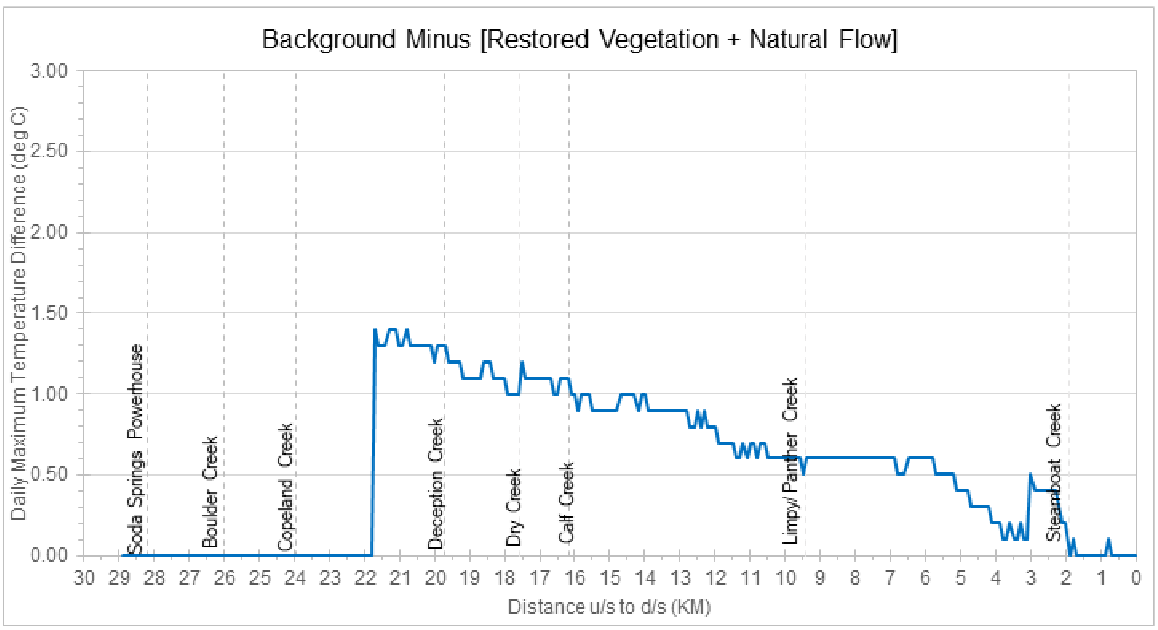

Figure 14-9. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario on the North Umpqua River model 5 (summer period).

Table 14-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 9 for the North Umpqua River model 5 summer period

North Umpqua #5	RKM	Maximum Delta	Date when maximum delta occurs
Background Minus [Restored Vegetation + Natural Flow]	21.70	1.40	7/9/2001

Three separate model runs were made to evaluate the warming due to General Permits, by adding 0.1, 0.2, & 0.3 ºC to the headwater at Soda Springs Reservoir. Figure 14-10, shows the results of three different model run comparisons for A1, the impact of adding 0.1, 0.2, 0.3 ºC to the headwater inflows in the background scenario, which is the 7DADM temperature difference between A1 and the Background scenario and criteria. The maximum delta calculated along the reach for each of the three scenarios was 0.1 ºC (Figure 14-10). This delta of 0.1 ºC is seen at several locations along the reach and increases in frequency as the warming is increased and progresses across the system. Note that although the impact of adding 0.2 and 0.3 ºC to the headwater inflows is seen within the half kilometer (i.e., a corresponding increase of 0.2 and 0.3 ºC in the North Umpqua), the delta tapers off and goes down to a maximum delta of 0.1 ºC, seen several kilometers downstream. The delta is not shown towards the upstream reach since the 7DADM does not exceed the BBNC prior to that location. Since the 0.1 ºC delta occurs for several days, each individual date and RKM are not listed.

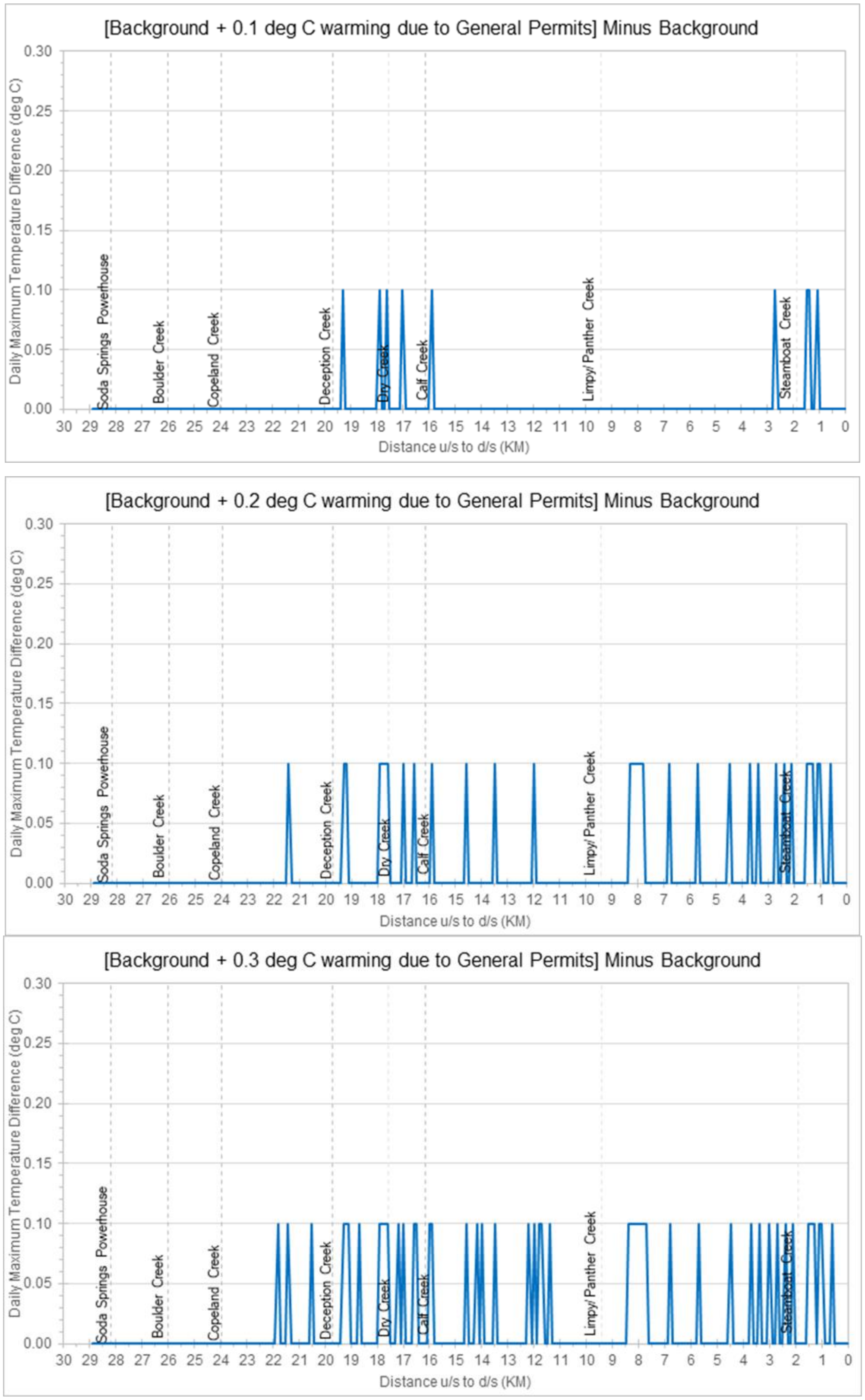

Figure 14-10. The maximum 7DADM temperature differences along North Umpqua River model 5 (summer period) for the impacts of warming (0.1, 0.2, & 0.3 °C due to General Permits.

Figure 14-11 shows the results of comparison A2, the impact of adding 0.1 ºC to all the tributaries and headwater/upstream inflows in the background scenario, which is the 7DADM temperature difference between A2 and the Background scenario and criteria. The maximum delta calculated along reach is 0.1 ºC, with the first instance occurring near RKM 22 (when the BBNC is exceeded downstream of the headwaters (Figure 14-11). This delta is seen along the reach at multiple locations. Since the 0.1 ºC delta occurs for several days, each individual date and RKM are not listed in (Table 14-3) as they can be seen in the Figure 14-11.

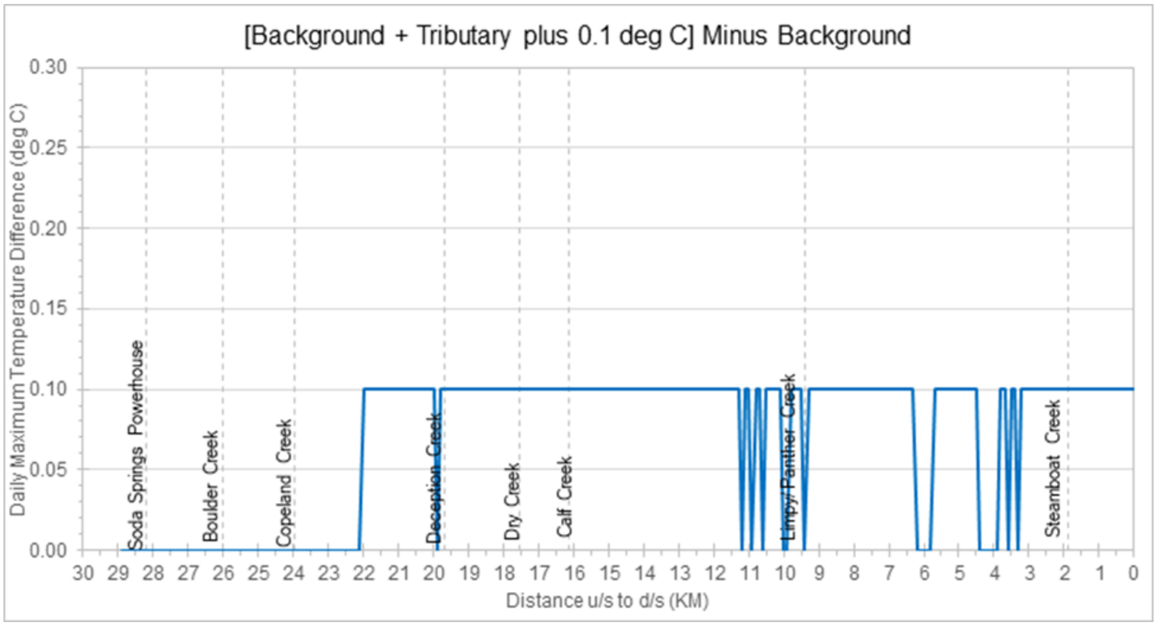

Figure 14-11. The maximum 7DADM temperature differences along North Umpqua River model 5 (summer period) for the impacts of adding 0.1°C to the Tributary/Headwater.

Table 14-3. Location and date of maximum delta when temperatures are greater than criterion for comparison A2 for the North Umpqua #5 summer period

North Umpqua #5	RKM	Maximum Delta	Date when maximum delta occurs
[Background + Tributary plus 0.1 deg C] Minus Background	N/A	0.10	N/A

14.3 NORTH UMPQUA RIVER MODEL 5 SPAWNING PERIOD SCENARIO RESULTS

The North Umpqua River spawning period HS model 5 does include point sources. The scenarios that are relevant to the North Umpqua River spawning period model 5 include the CCC scenario; the No Point Source scenario; the Point Source WLA scenario; the Fully Restored Vegetation scenario; the Background scenario; the Attainment scenario; and the tributary/headwater plus 0.1 ºC scenario. The 7DADM results are shown in Figure 14-12 through Figure 14-18 for these scenarios. Note that the spawning criteria applies to North Umpqua Model 5 and was evaluated for the period from September 1 to October 15, 2009.

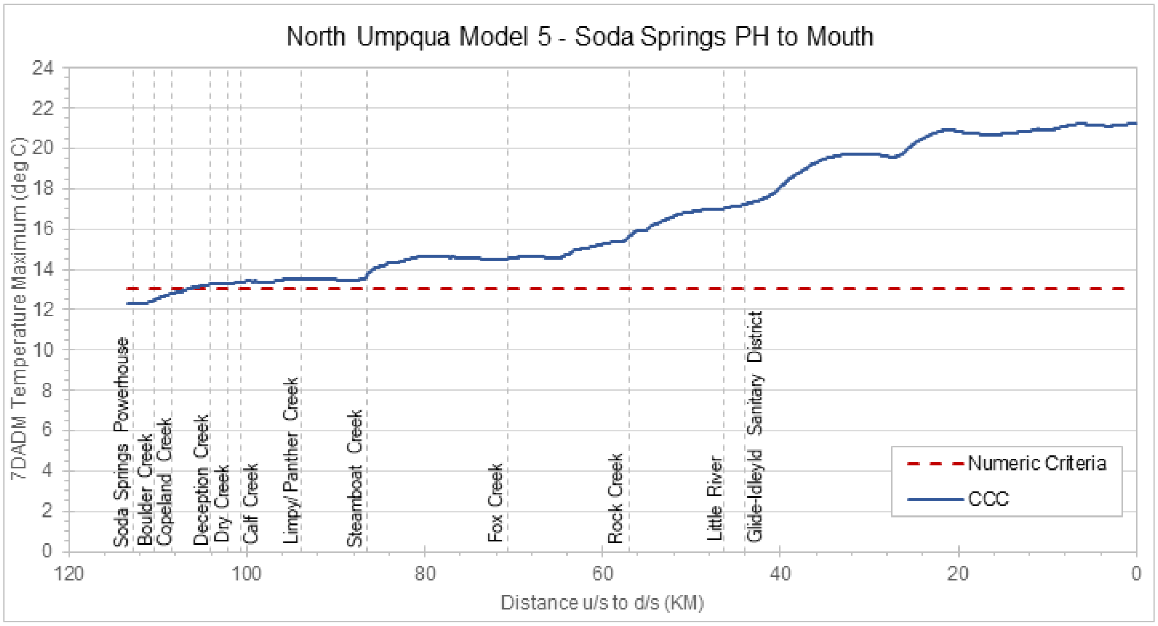

Figure 14-12. The maximum 7DADM temperature results along the North Umpqua River model 5 (spawning period) for the Current Conditions scenario.

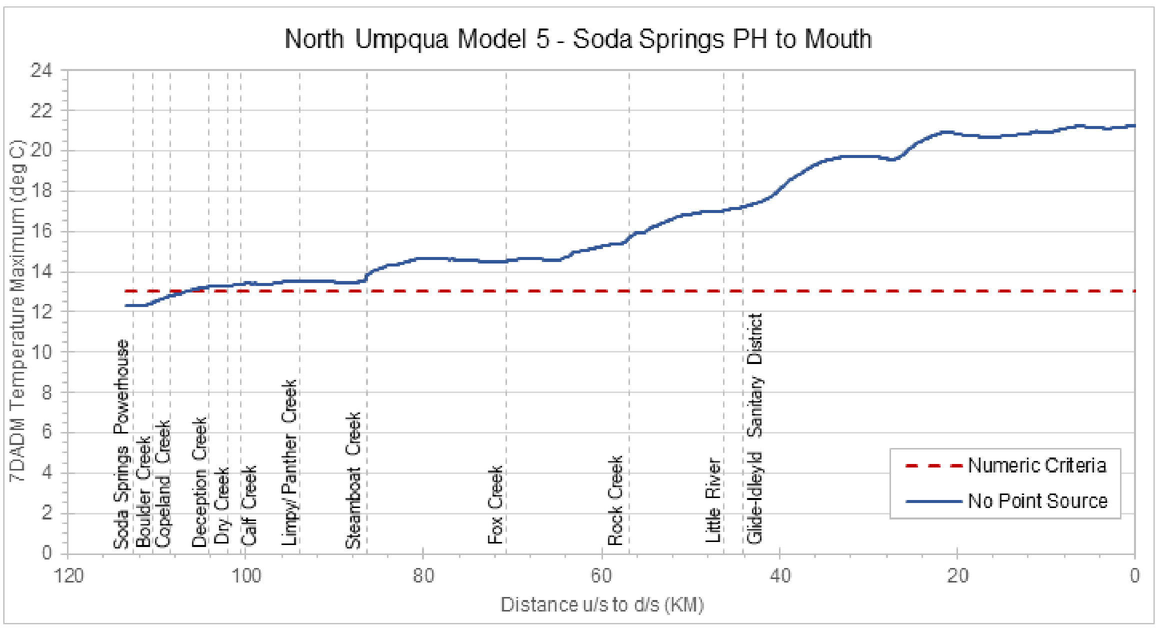

Figure 14-13. The maximum 7DADM temperature results along the North Umpqua River model 5 (spawning period) for the No Point Source scenario.

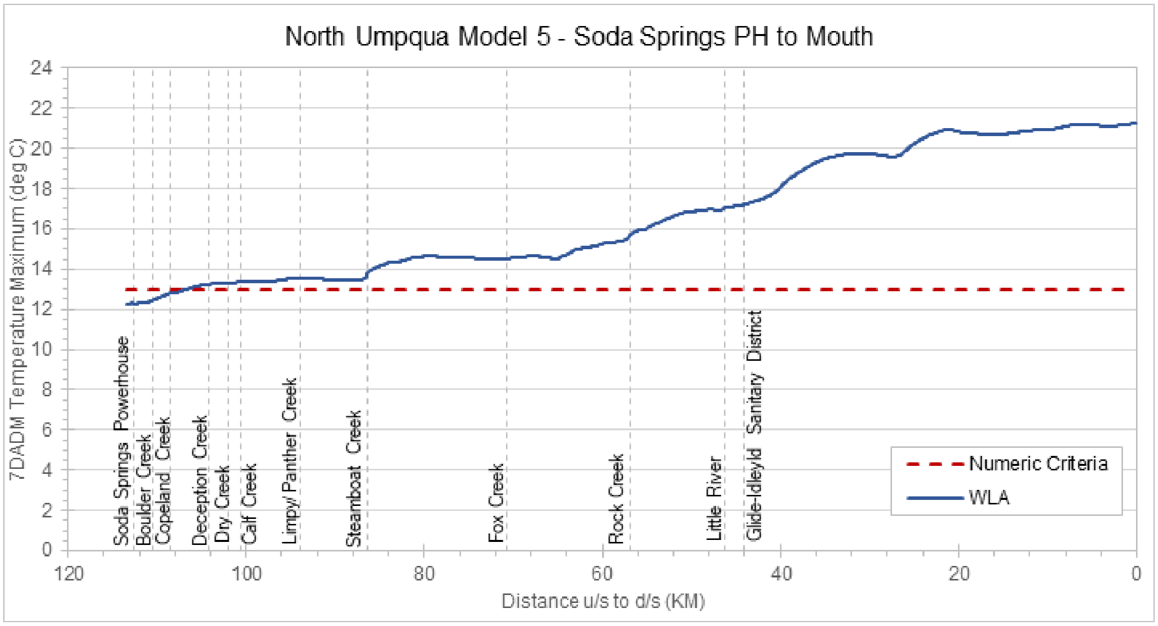

Figure 14-14. The maximum 7DADM temperature results along the North Umpqua River model 5 (spawning period) for the Point Source WLA scenario.

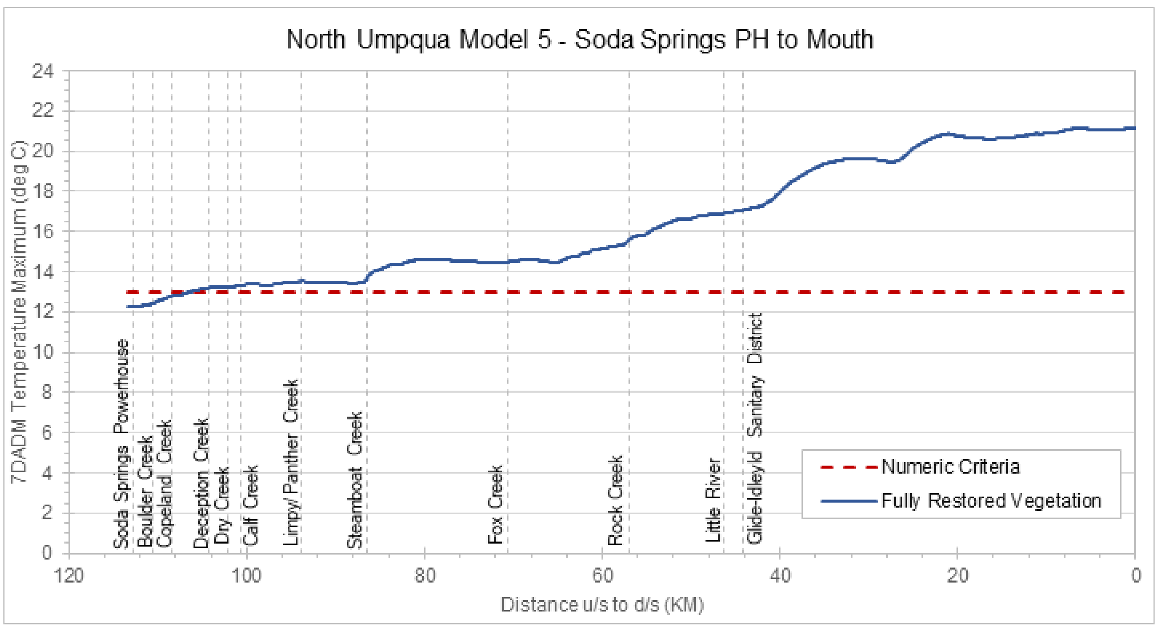

Figure 14-15. The maximum 7DADM temperature results along the North Umpqua River model 5 (spawning period) for the Fully Restored Vegetation scenario.

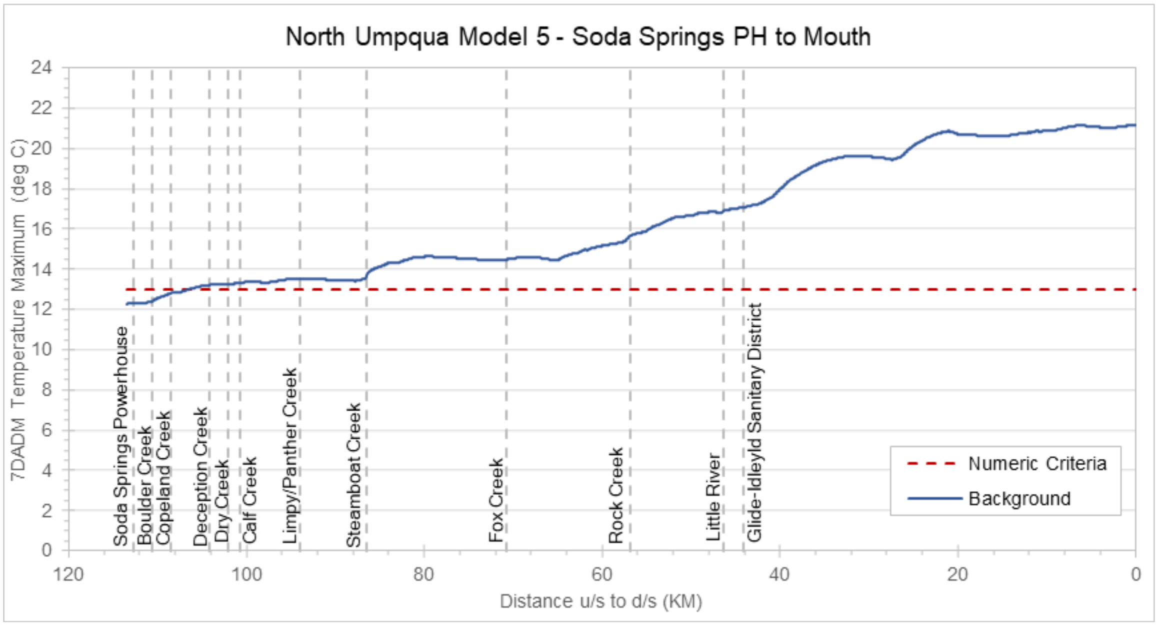

Figure 14-16. The maximum 7DADM temperature results along the North Umpqua River model 5 (spawning period) for the Background scenario.

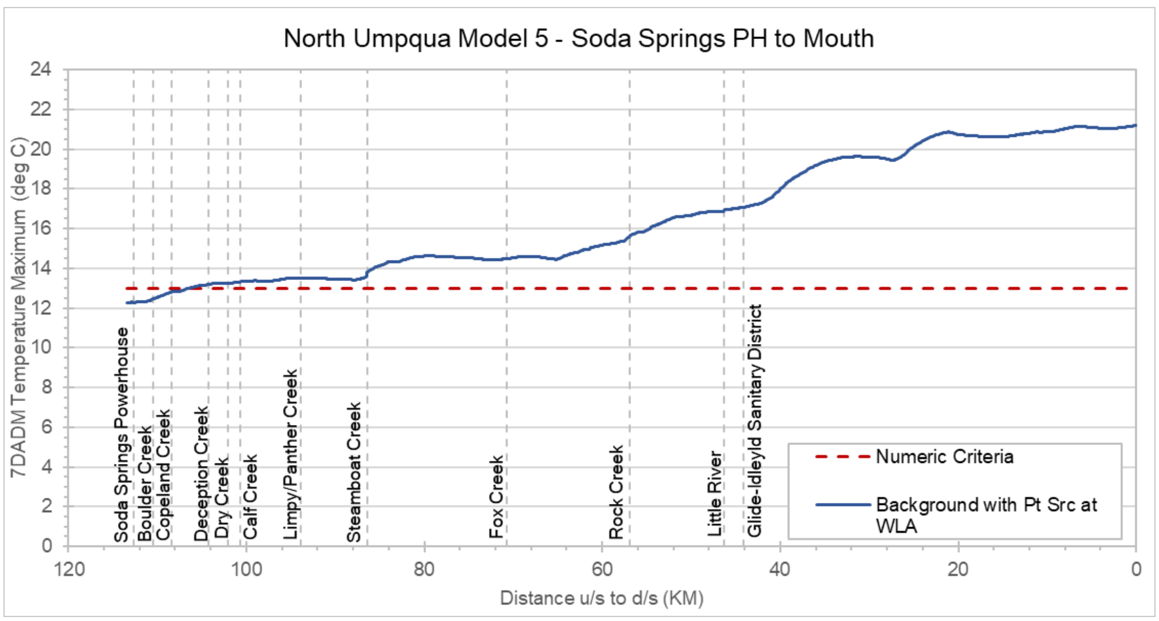

Figure 14-17. The maximum 7DADM temperature results along the North Umpqua River model 5 (spawning period) for the Attainment scenario.

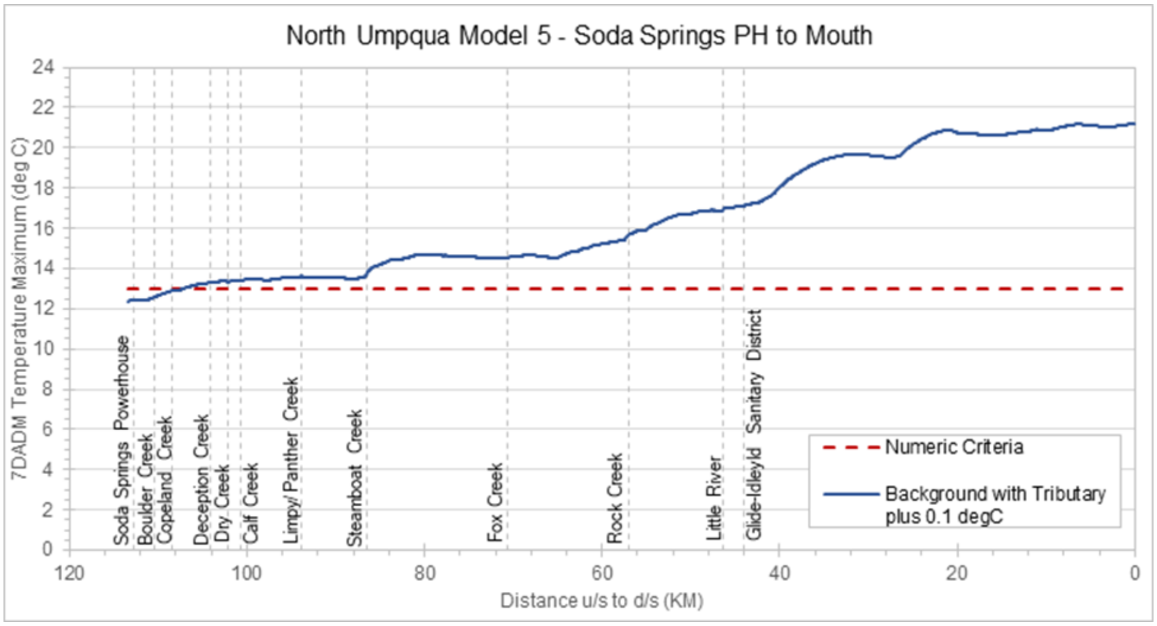

Figure 14-18. The maximum 7DADM temperature results along North Umpqua River model 5 (spawning period) for the Tributary/Headwater plus 0.1°C scenario.

14.4 NORTH UMPQUA RIVER MODEL 5 SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for North Umpqua River model 5 spawning period include:

1. Impacts of shade loss
   - ✓ No Point Source minus background
2. Impact of current point source and shade loss
   - ✓ CCC minus background
3. Impact from point source @ current condition
   - ✓ CCC minus no point source
4. Impact from point sources @ WLA conditions
   - ✓ Point Source WLA minus No point source
5. Impact current point source and restored vegetation
   - ✓ Fully restored veg with point source @ current condition minus background
6. Impact point source @ WLA and restored vegetation
   - ✓ Fully restored veg with point source @ WLA minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

A2. Impact of tributary scenario (tributary/headwater plus 0.1 °C)
   - ✓ Tributary plus 0.1 °C minus background

Figure 14-19 shows the results of comparison 1, which is the 7DADM temperature difference between the No Point Source scenario and Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The overall 7DADM temperature differences increase toward the downstream direction. The maximum delta reaches 0.56 °C at RKM 42.7 on September 27, 2009 (Table 14-4).

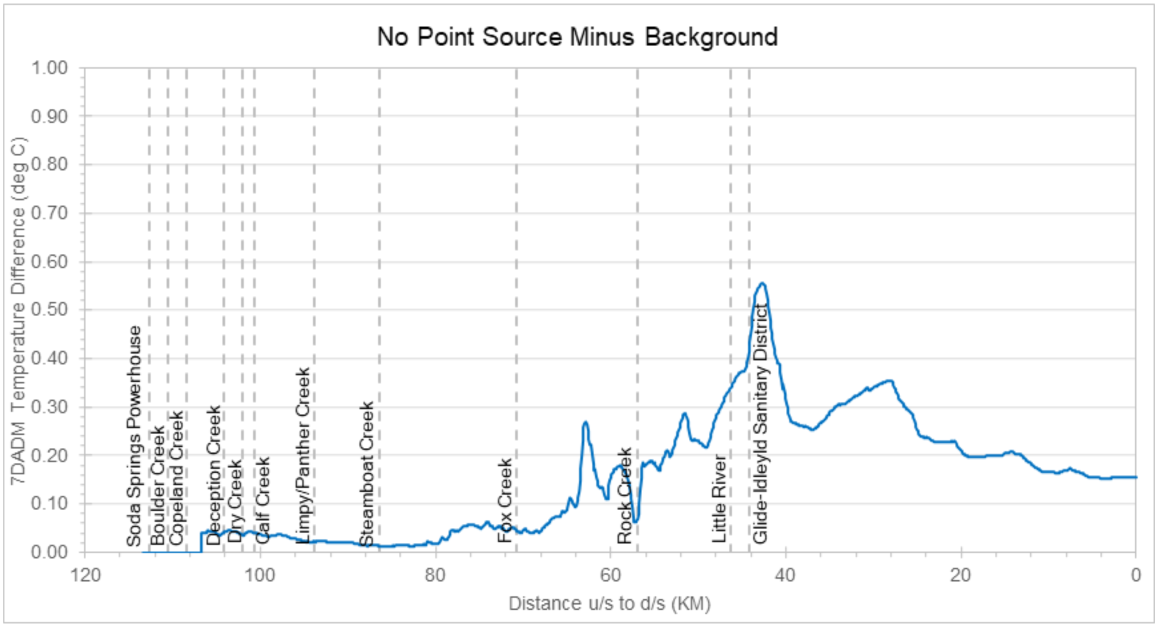

Figure 14-19. The maximum 7DADM temperature differences along the North Umpqua River model 5 (spawning period) for the impacts of shade loss.

Table 14-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 1 for the North Umpqua River model 5 spawning period

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
No Point Source Minus Background	42.70	0.56	9/27/2009

Figure 14-20 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition and the point source conditions where the CCC scenario uses the latest available flow and temperature from the point sources, while the Background scenario does not include point sources. The maximum delta reaches 0.56 ˚C at RKM 42.7 on September 27, 2009 (Table 14-5).

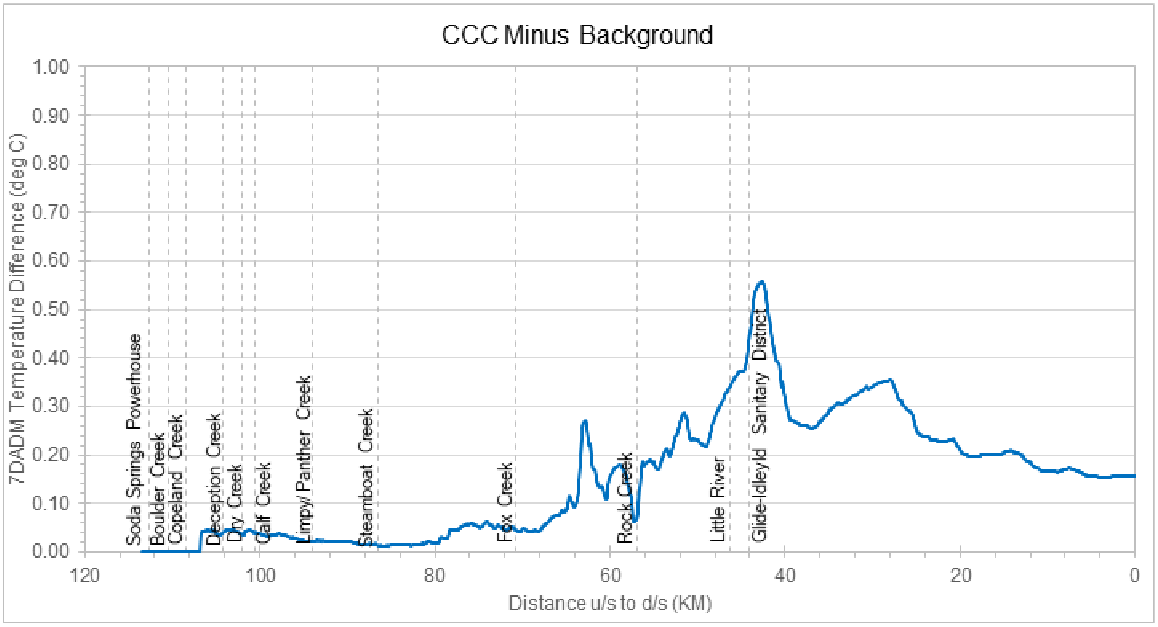

Figure 14-20. The maximum 7DADM temperature differences along the North Umpqua River model 5 (spawning period) for the impacts of current point sources and shade loss.

Table 14-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 the North Umpqua River model 5 spawning period

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus Background	42.70	0.56	9/27/2009

Figure 14-21 shows the results of comparison 3, the impacts of current point sources, which is the 7DADM temperature difference between the CCC scenario and No Point Source scenario. The difference between these two scenarios is the CCC scenario uses the latest available flow and temperature from the point sources, while the No Point Source scenario does not include point sources. The maximum delta reaches 0.002 ˚C at RKM 42.7 on October 1, 2009 (Table 14-6).

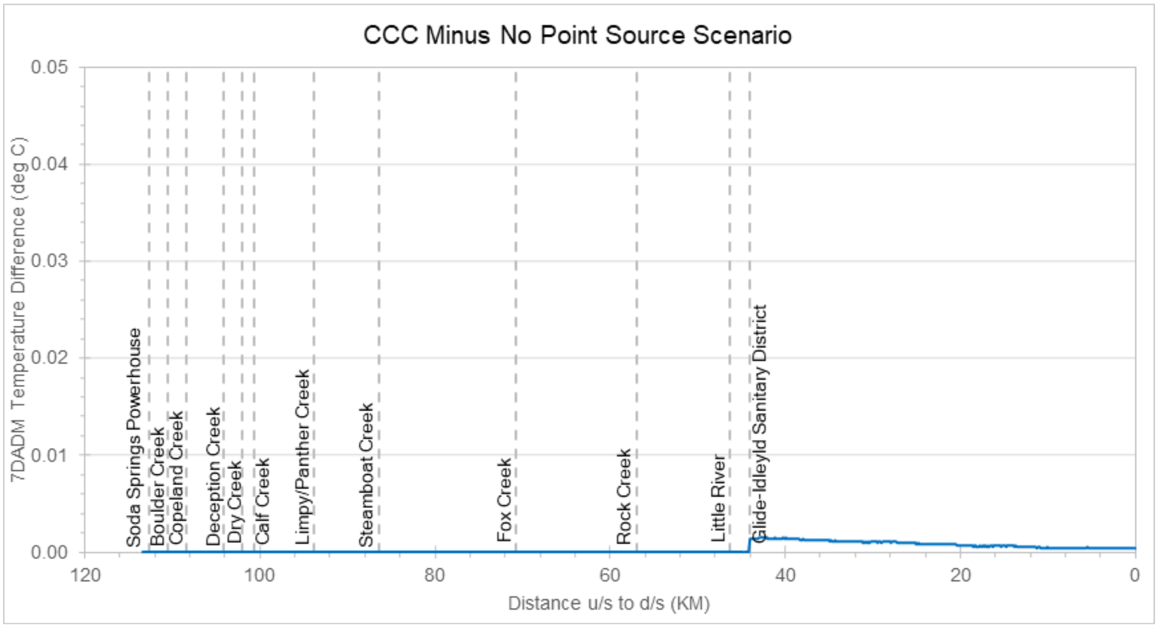

Figure 14-21. The maximum 7DADM temperature differences along the North Umpqua River model 5 (spawning period) for the impacts of point sources at the current condition.

Table 14-6. Location and date of maximum delta when temperatures are greater than criterion for comparison 3 for the North Umpqua River model 5 spawning period

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Point Source Scenario	42.70	0.002	10/1/2009

Figure 14-22 shows the results of comparison 4, the impact from point sources at WLA conditions, which is the 7DADM temperature difference between the Point Source WLA scenario and No Point Source scenario. The difference between these two scenarios is the Point Source WLA scenario uses the calculated WLA temperatures for Glide-Idleyld Sanitary District, while the No Point Source scenario does not include point source. The maximum delta reaches 0.004 ˚C at RKM 39.9 on October 2, 2009 (Table 14-7).

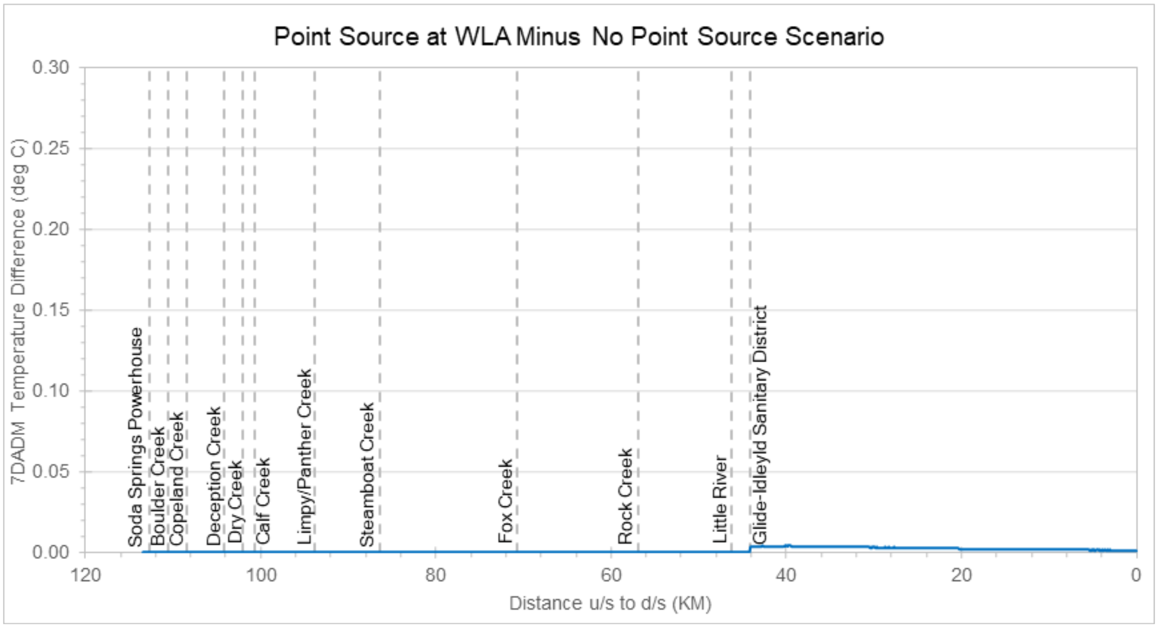

Figure 14-22. The maximum 7DADM temperature differences along the North Umpqua River model 5 (spawning period) for the impacts of point sources at the WLA temperatures.

Table 14-7. Location and date of maximum delta when temperatures are greater than criterion for comparison 4 for the North Umpqua River model 5 spawning period

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
Point Source at WLA Minus No Point Source Scenario	39.90	0.004	10/2/2009

Figure 14-23 shows the results of comparison 5, the impact from current point sources and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario at current conditions and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation scenario includes point sources and current conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. The maximum delta reaches 0.001 ˚C at RKMs 39.0 on October 2, 2009 (Table 14-8).

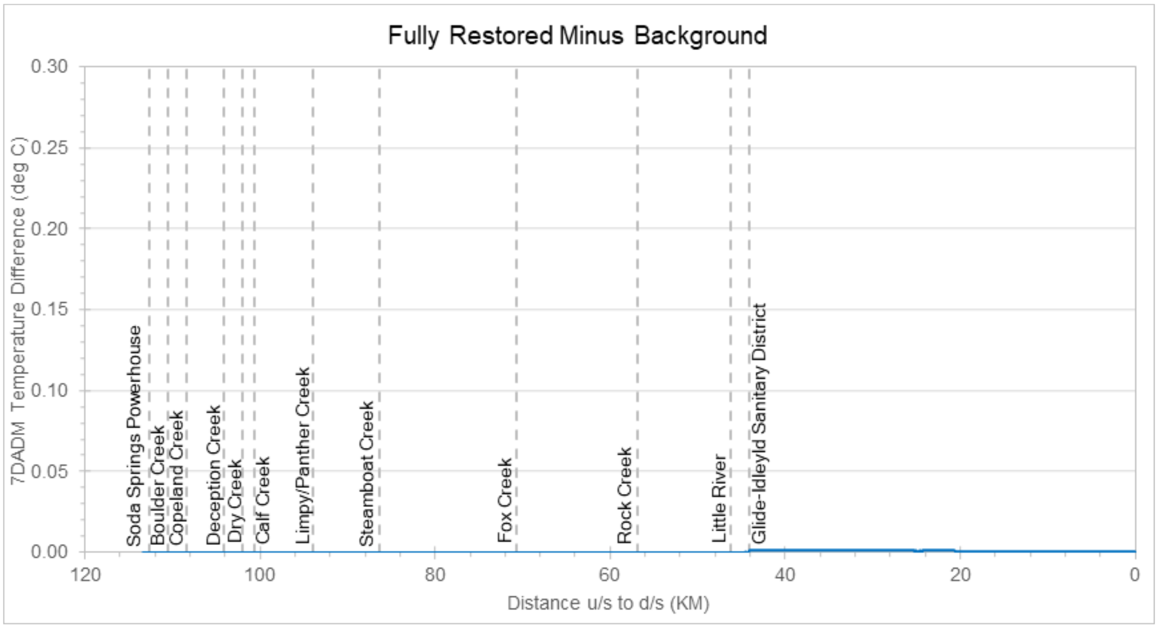

Figure 14-23. The maximum 7DADM temperature differences along the North Umpqua River model 5 (spawning period) for the impacts of current point sources with restored vegetation.

Table 14-8. Location and date of maximum delta when temperatures are greater than criterion for comparison 5 for the North Umpqua River model 5 spawning period

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
Fully Restored Minus Background	39.00	0.001	10/2/2009

Figure 14-24 shows the results of comparison 6, the impact from point sources at the WLA and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario with WLAs and the background scenario. The difference between these two scenarios is that the Fully Restored Vegetation scenario includes point sources and WLA conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. For this comparison, the Rock Creek temperature represents the Rock Creek Hatchery WLA, which is taken as Rock Creek water temperature flowing into North Umpqua plus a HUA of 0.3˚ C, and also includes the WLA discharge from Glide-Idleyld. The maximum delta reaches 0.12 ˚C at RKM 56.9 on September 3, 2009 (Table 14-9).

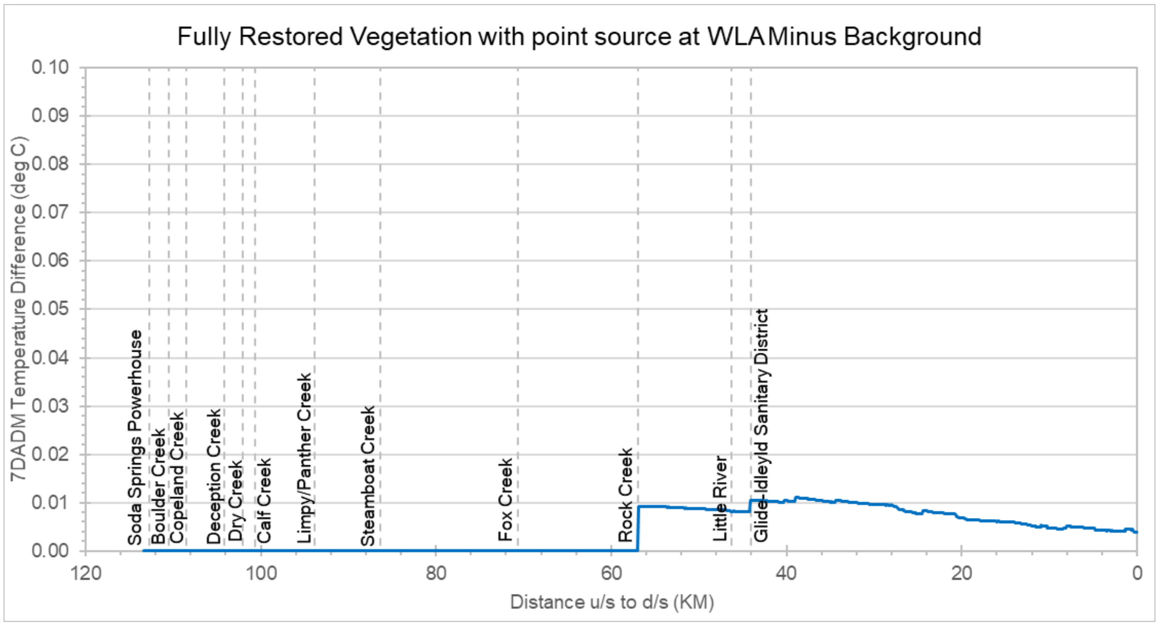

Figure 14-24. The maximum 7DADM temperature differences along the North Umpqua River model 5 (spawning period) for the impacts of point sources at the WLA temperatures and fully restored vegetation conditions.

Table 14-9. Location and date of maximum delta when temperatures are greater than criterion for comparison 6 for the North Umpqua River model 5 spawning period

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
Fully Restored Vegetation with point source at WLA Minus Background	39.00	0.01	10/2/2009

Figure 14-25 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 8.18 ºC at RKM 0.0 on September 1, 2008 and -0.72 ºC at RKM 113.4 on September 4, 2009 (Table 14-10).

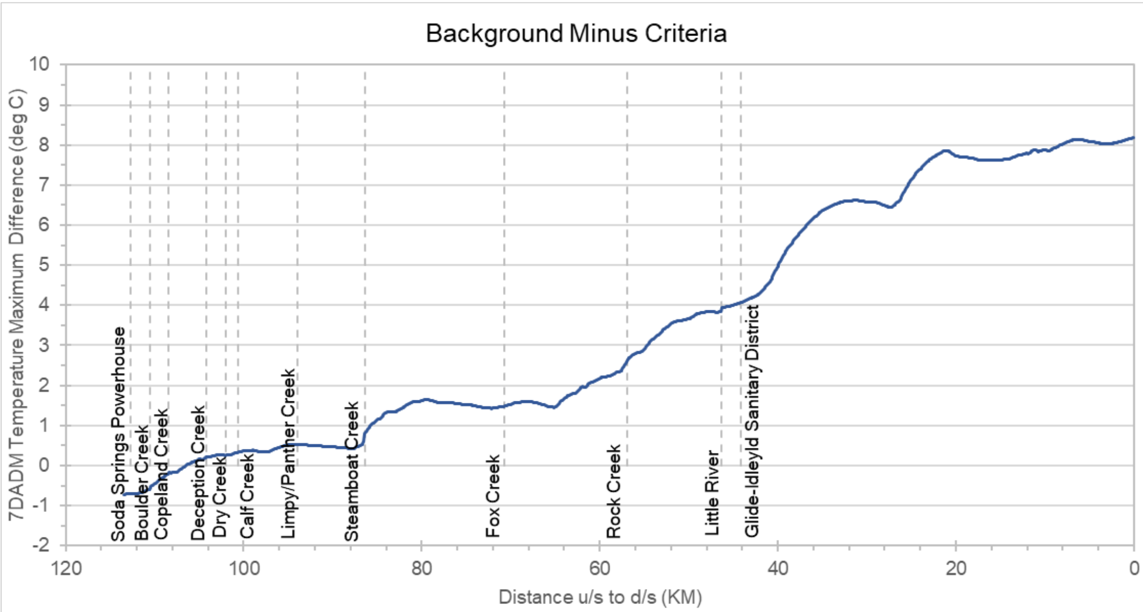

Figure 14-25. The maximum 7DADM temperature differences along the North Umpqua River model 5 (spawning period) between Background scenario and the criteria

Table 14-10. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 5 spawning period.

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	0.00	8.18	9/1/2009
	113.40	-0.72	9/4/2009

Figure 14-26 shows the results of comparison A2, the impact of adding 0.1 ºC to all the tributaries and headwater/upstream inflows in the background scenario, which is the 7DADM temperature difference between A2 and the Background scenario and criteria. The maximum delta of 0.09 ºC was observed at RKM 106.90 on September 3, 2009 (Table 14-11). Note that there is no delta shown in the several RKM above 106.90 because the 7DADM does not exceed the BBNC at those locations.

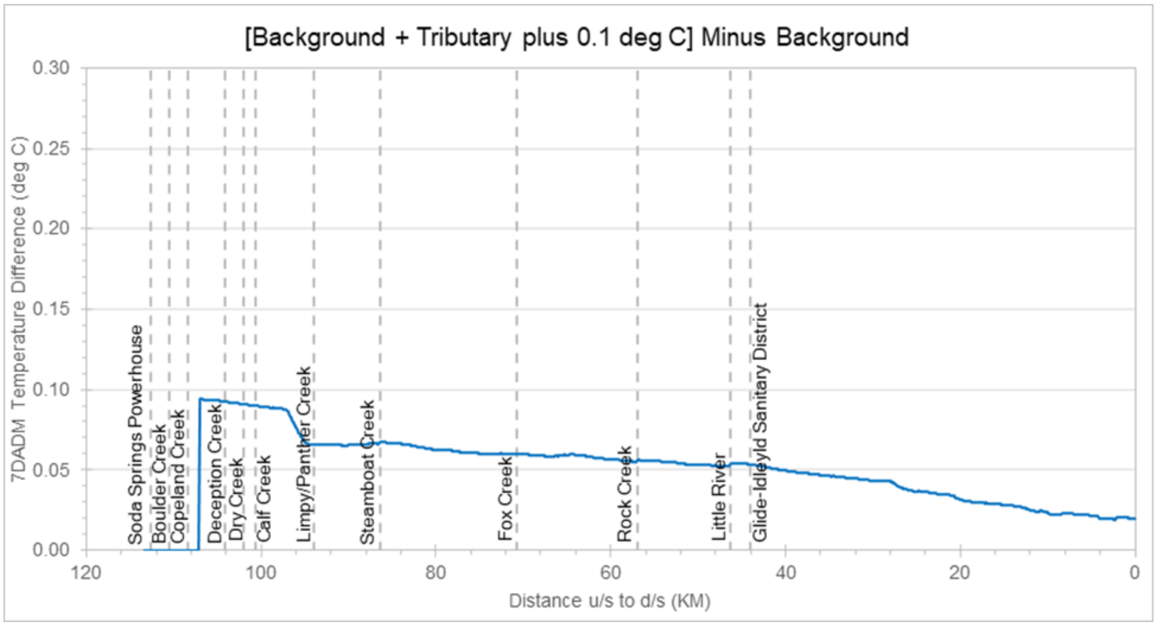

Figure 14-26. The maximum 7DADM temperature differences along North Umpqua River model 5 (spawning period) for the impacts of adding 0.1°C to the Tributary/Headwater.

Table 14-11. Location and date of maximum delta when temperatures are greater than criterion for comparison A2 for the North Umpqua River model 5 spawning period

North Umpqua #5	RKM	Maximum Delta	Date when maximum delta occurs
[Background + Tributary plus 0.1 deg C] Minus Background	106.90	0.09	9/3/2009

15.0 NORTH UMPQUA RIVER MODEL 6 (STEAMBOAT TO MOUTH)

The modeled portion of the North Umpqua River model 6 is shown in Figure 15-1. North Umpqua River was modeled for both the summer period (July 12-31, 2002) and the spawning period (August 1, 2009 to October 15, 2009). The summer period scenario results and scenario comparisons are presented in section 15.1 and 15.2. There is no HS model for North Umpqua River model 6 for the spawning period. North Umpqua Model 5 and Model 6 were combined and are included in a single Model 5 used for spawning period evaluation. The spawning period results and comparisons for North Umpqua from Soda Springs Reservoir to the mouth (Model 5) can be found under Section 14.3 and 14.4.

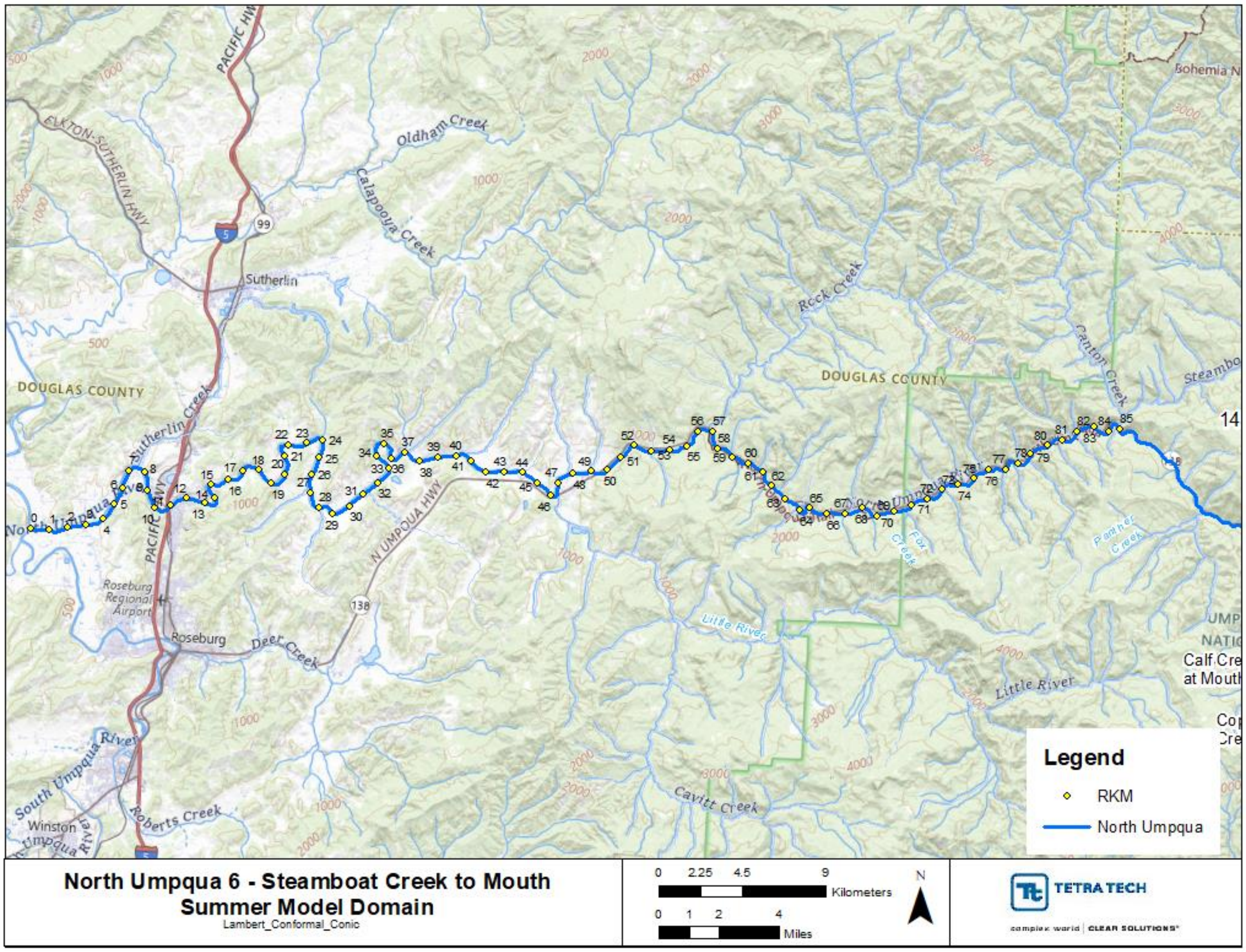

Figure 15-1. North Umpqua River Model 6 model domain.

15.1 NORTH UMPQUA RIVER MODEL 6 SUMMER PERIOD SCENARIO RESULTS

The North Umpqua River summer period HS model 6 includes the point source Glide-Idleyld Park coming in at RKM 44.1. The scenarios that are relevant to the North Umpqua River summer period model 6 include the CCC scenario; the No Point Source scenario; the Point Source WLA scenario; the Fully Restored Vegetation scenario; Background scenario; Fully Restored Vegetation with Natural Flow scenario; the Fully Restored Vegetation with Point Source at WLA scenario, and the tributary/headwater plus 0.1 °C scenario. The 7DADM results are shown in Figure 15-2 through Figure 15-9 for these scenarios.

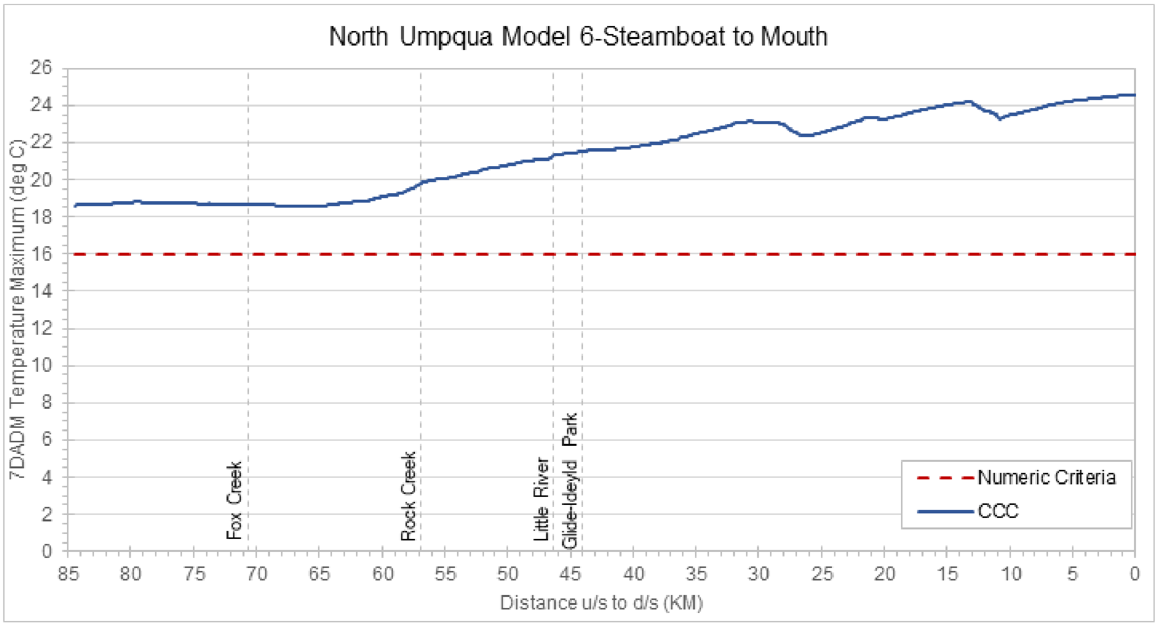

Figure 15-2. The maximum 7DADM temperature results along the North Umpqua River model 6 (summer period) for the CCC scenario.

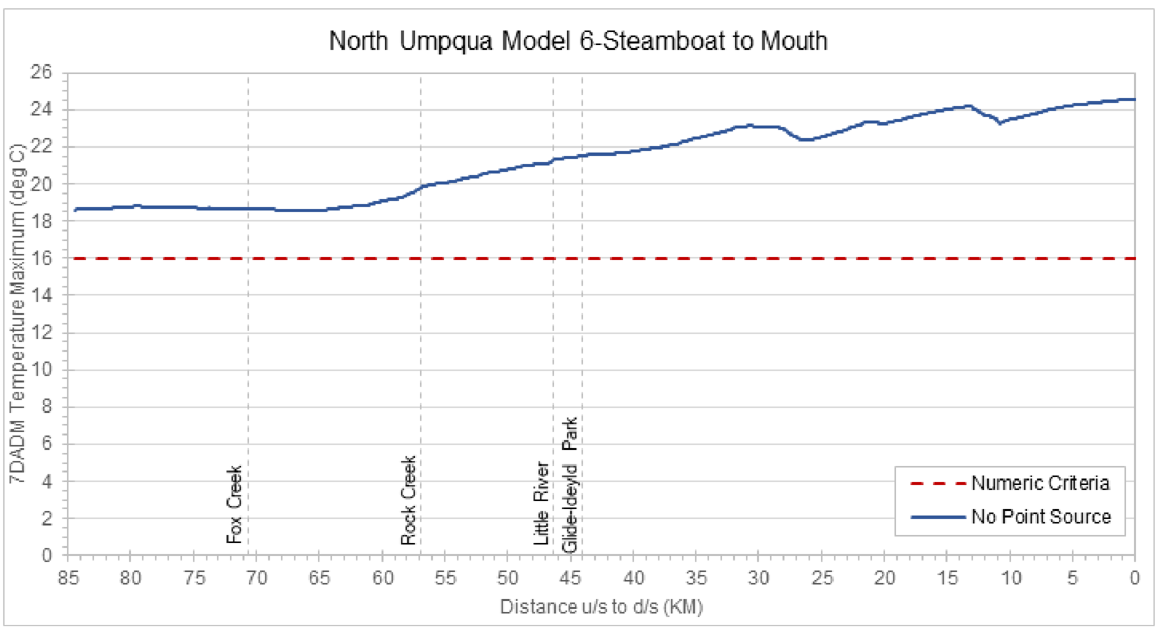

Figure 15-3. The maximum 7DADM temperature results along the North Umpqua River model 6 (summer period) for the No Point Source scenario.

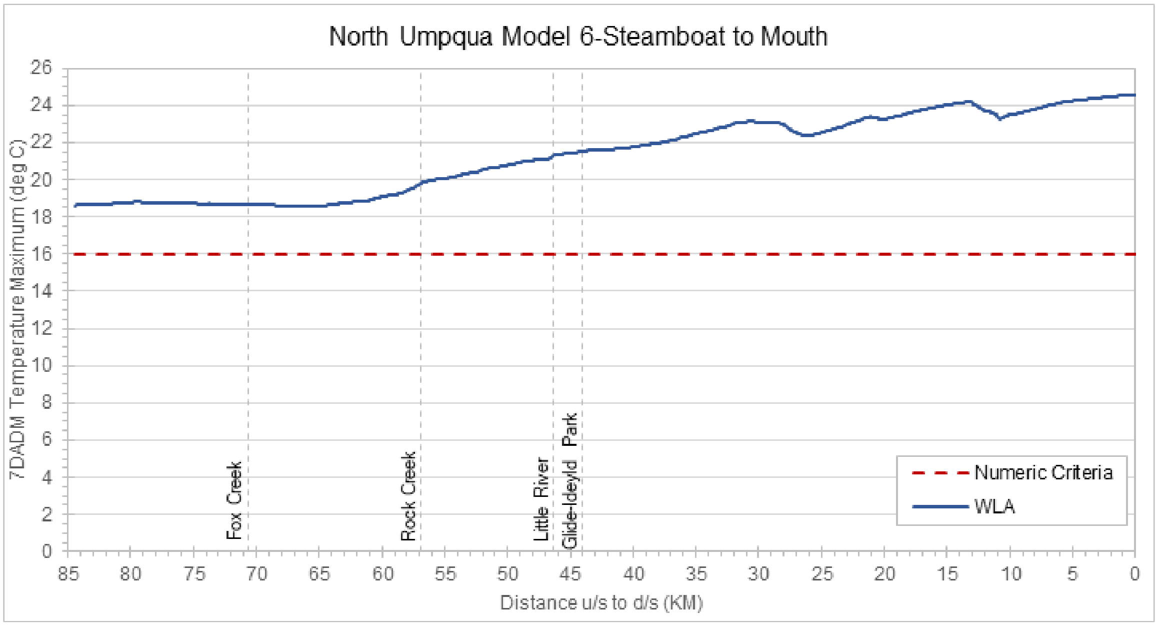

Figure 15-4. The maximum 7DADM temperature results along the North Umpqua River model 6 (summer period) for the Point Source WLA scenario.

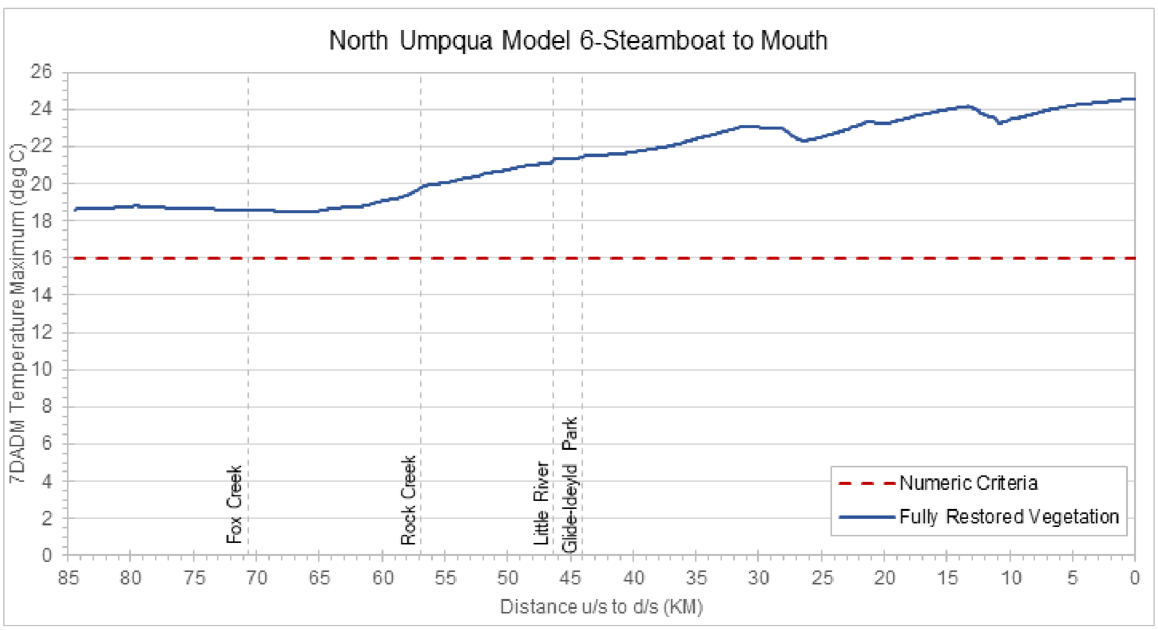

Figure 15-5. The maximum 7DADM temperature results along the North Umpqua River model 6 (summer period) for the Fully Restored Vegetation scenario.

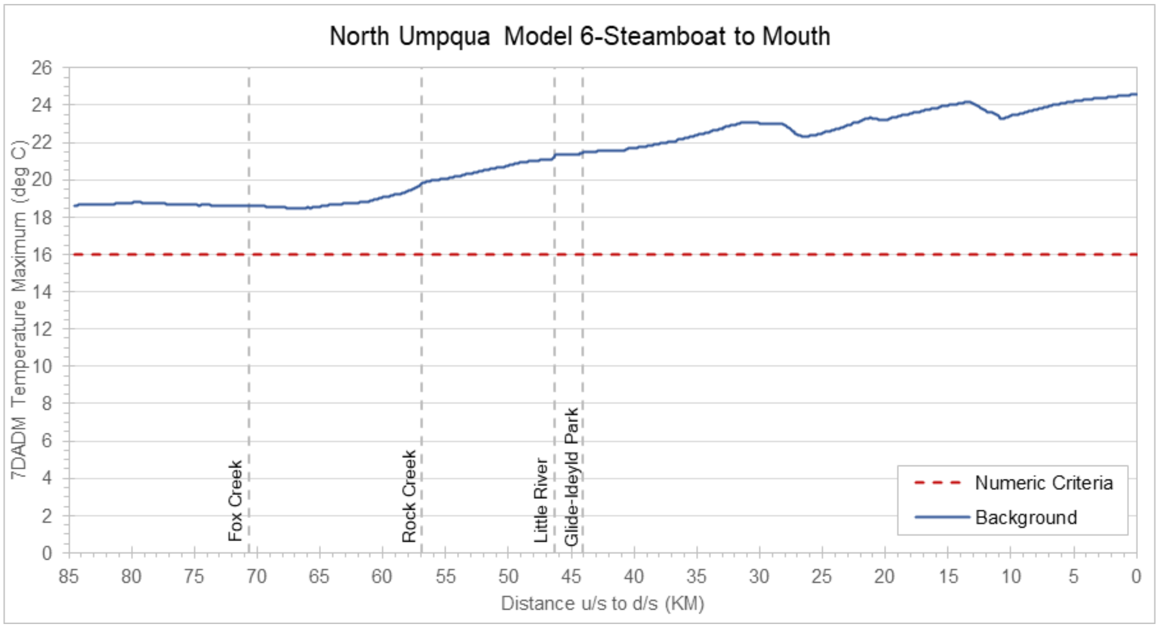

Figure 15-6. The maximum 7DADM temperature results along the North Umpqua River model 6 (summer period) for the Background scenario.

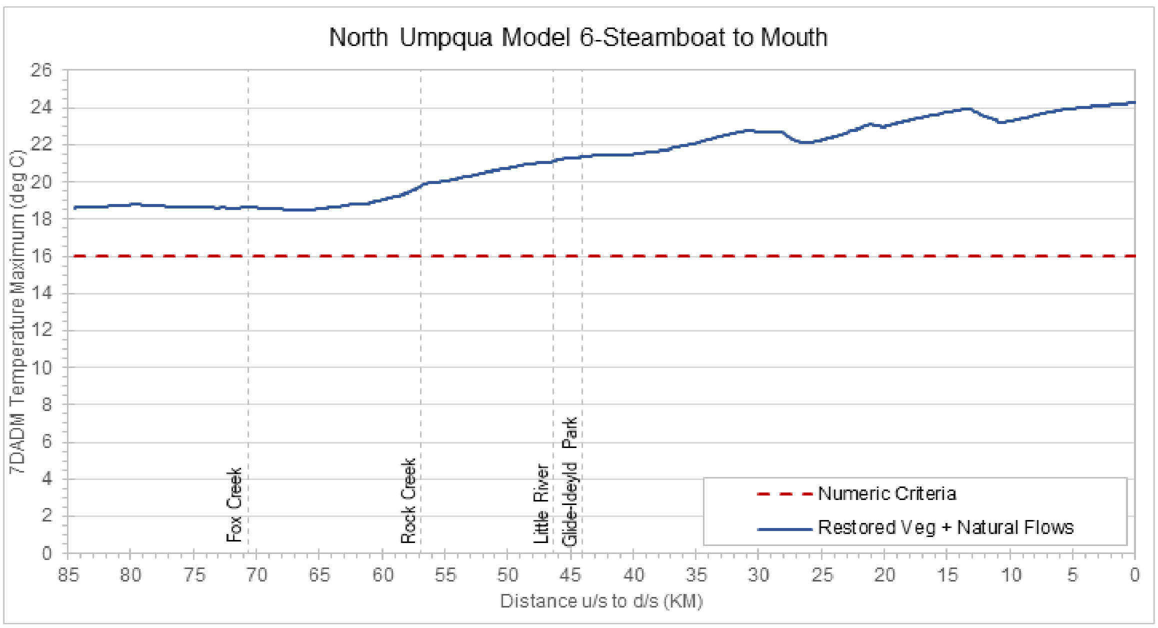

Figure 15-7. The maximum 7DADM temperature results along the North Umpqua River model 6 (summer period) for the Fully Restored Vegetation with Natural Flow scenario.

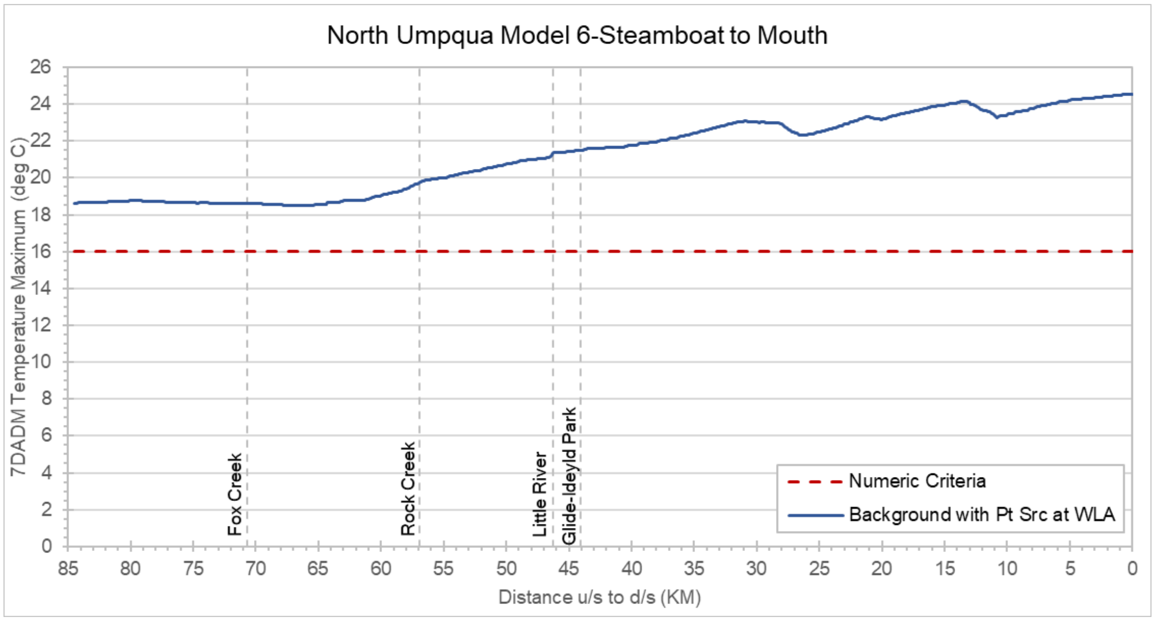

Figure 15-8. The maximum 7DADM temperature results along the North Umpqua River model 6 (summer period) for the Fully Restored Vegetation with Point Source WLA scenario.

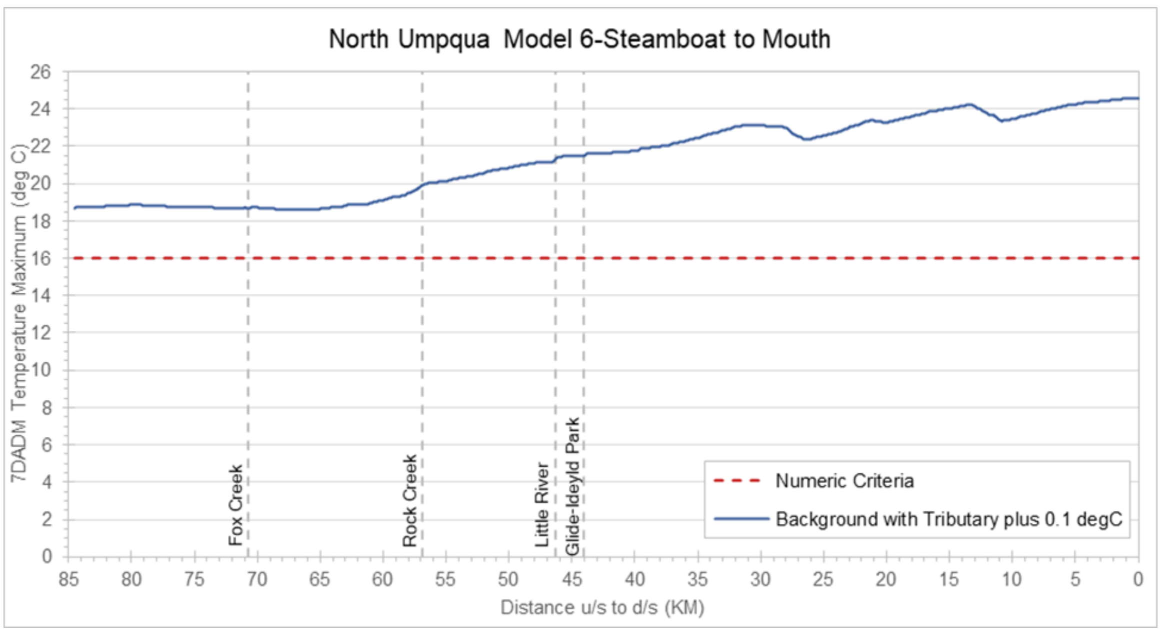

Figure 15-9. The maximum 7DADM temperature results along the North Umpqua River model 6 (summer period) for the Tributary/Headwater plus 0.1°C scenario.

15.2 NORTH UMPQUA RIVER MODEL 6 SUMMER PERIOD SCENARIO COMPARISONS

Comparisons of scenarios for the North Umpqua River model 6 summer period include:

1. Impacts of shade loss
   - ✓ No Point Source minus background
2. Impact of current point source and shade loss
   - ✓ CCC minus background
3. Impact from point source @ current condition
   - ✓ CCC minus no point source
4. Impact from point sources @ WLA conditions
   - ✓ Point Source WLA minus No point source
5. Impact current point source and restored vegetation
   - ✓ Fully restored veg with point source @ current condition minus background
6. Impact point source @ WLA and restored vegetation
   - ✓ Fully restored veg with point source @ WLA minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

9. Natural Flows
   - ✓ Background minus fully restored veg with natural flows

A2. Impact of tributary scenario (tributary/headwater plus 0.1 °C)
   - ✓ Tributary plus 0.1 °C minus background

Figure 15-10 shows the results of comparison 1, which is the 7DADM temperature difference between the No Point Source scenario and Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 0.16 °C at RKM 67.4 on July 19, 2002 (Table 15-1).

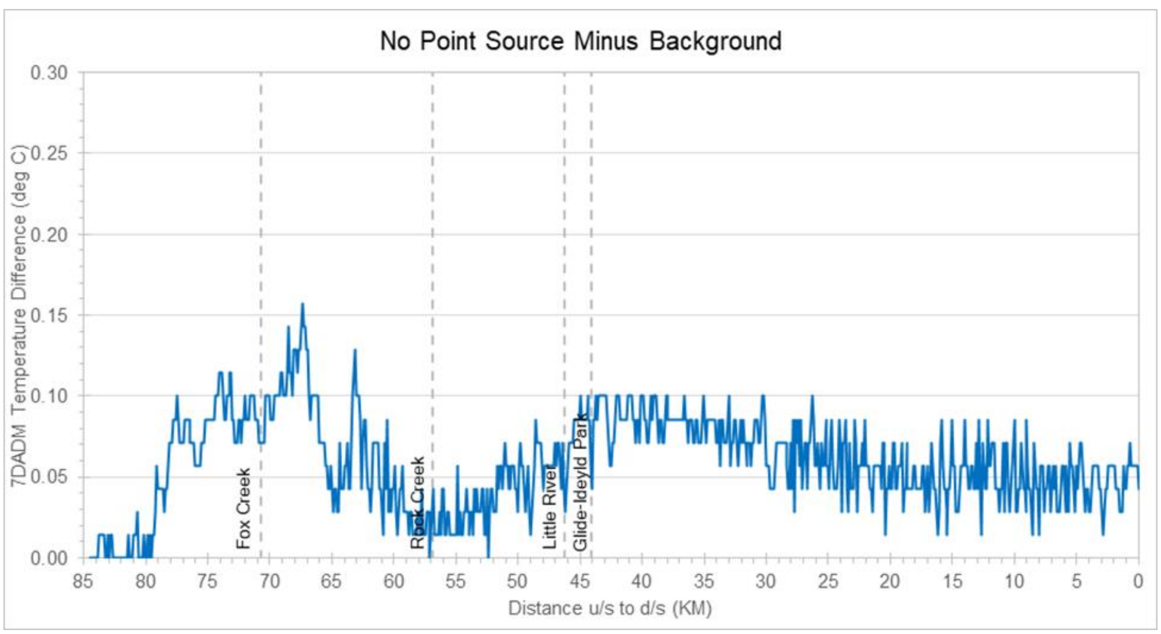

Figure 15-10. The maximum 7DADM temperature differences along the North Umpqua River model 6 summer period for the impacts of shade loss.

Table 15-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 1 for the North Umpqua River model 6 summer period

North Umpqua #6	RKM	Maximum Delta	Date when Maximum Delta occurs
No Point Source Minus Background	67.40	0.16	7/19/2002

Figure 15-11 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition and the point source conditions where the CCC scenario uses the latest available flow and temperature from the point sources, while the Background scenario does not include point sources. The maximum delta reaches 0.16 ˚C at RKM 67.4 on July 19, 2002 (Table 15-2).

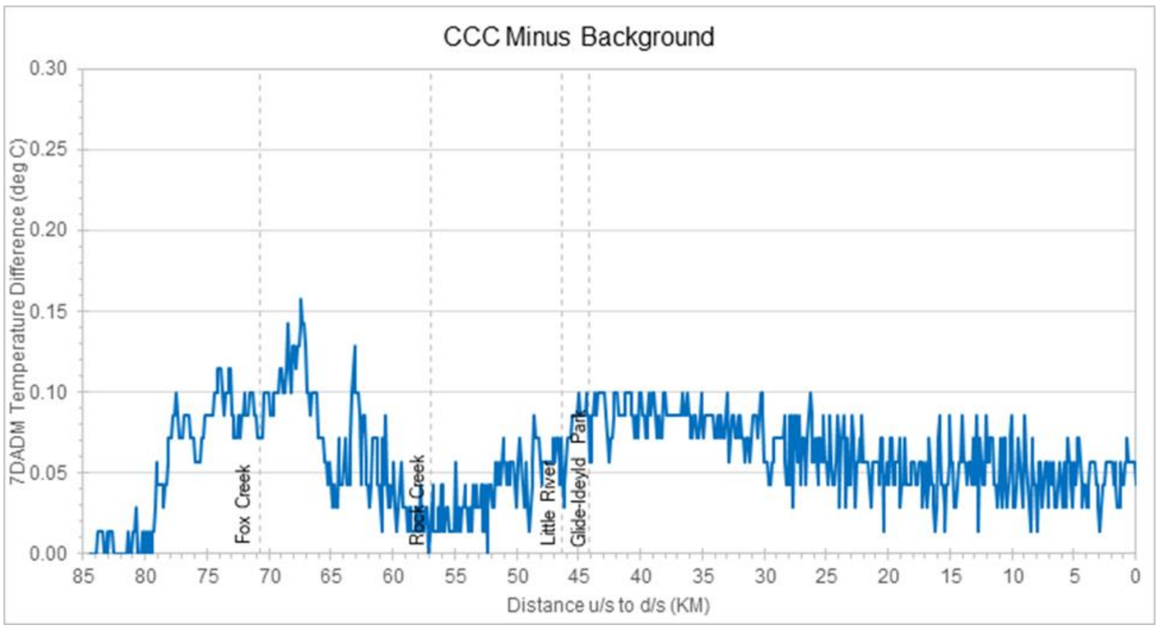

Figure 15-11. The maximum 7DADM temperature differences along the North Umpqua River model 6 (summer period) for the impacts of current point sourcess and shade loss.

Table 15-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 2 for the North Umpqua River model 6 summer period

North Umpqua #6	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus Background	67.40	0.16	7/19/2002

Figure 15-12 shows the results of comparison 3, the impacts of current point sources, which is the 7DADM temperature difference between the CCC scenario and No Point Source scenario. The difference between these two scenarios is the CCC scenario uses the latest available flow and temperature from the Glide-Idleyld Park point source, while the No Point Source scenario does not include the point source. The maximum delta reaches 0.03 ˚C at RKM 28.4 on July 28, 2002 (Table 15-3).

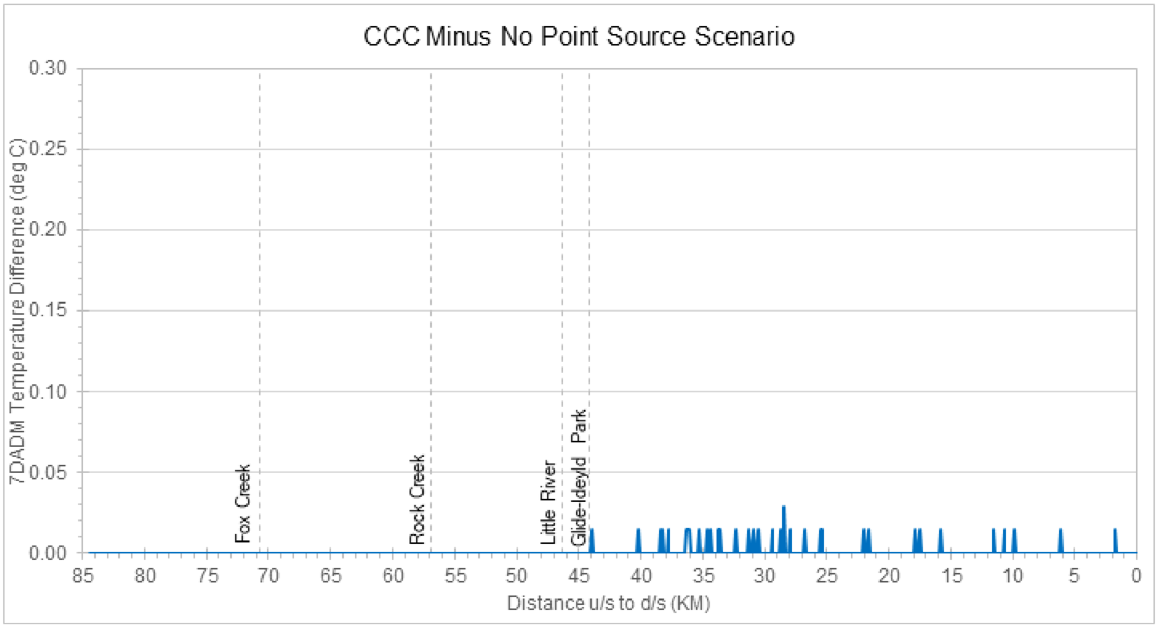

Figure 15-12. The maximum 7DADM temperature differences along the North Umpqua River model 6 (summer period) for the impacts of point sources at the current condition.

Table 15-3. Location and date of maximum delta when temperatures are greater than criterion for comparison 3 for the North Umpqua River model 6 summer period

North Umpqua #6	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Point Source Scenario	28.40	0.03	7/28/2002

Figure 15-13 shows the results of comparison 4, the impact from point sources at WLA conditions, which is the 7DADM temperature difference between the Point Source WLA scenario and No Point Source scenario. The difference between these two scenarios is the Point Source WLA scenario uses the calculated WLA temperatures, while the No Point Source scenario does not include the Glide-Idleyld Park point source. The maximum delta reaches 0.04 ˚C at RKM 42.4 on July 19, 2002 (Table 15-4).

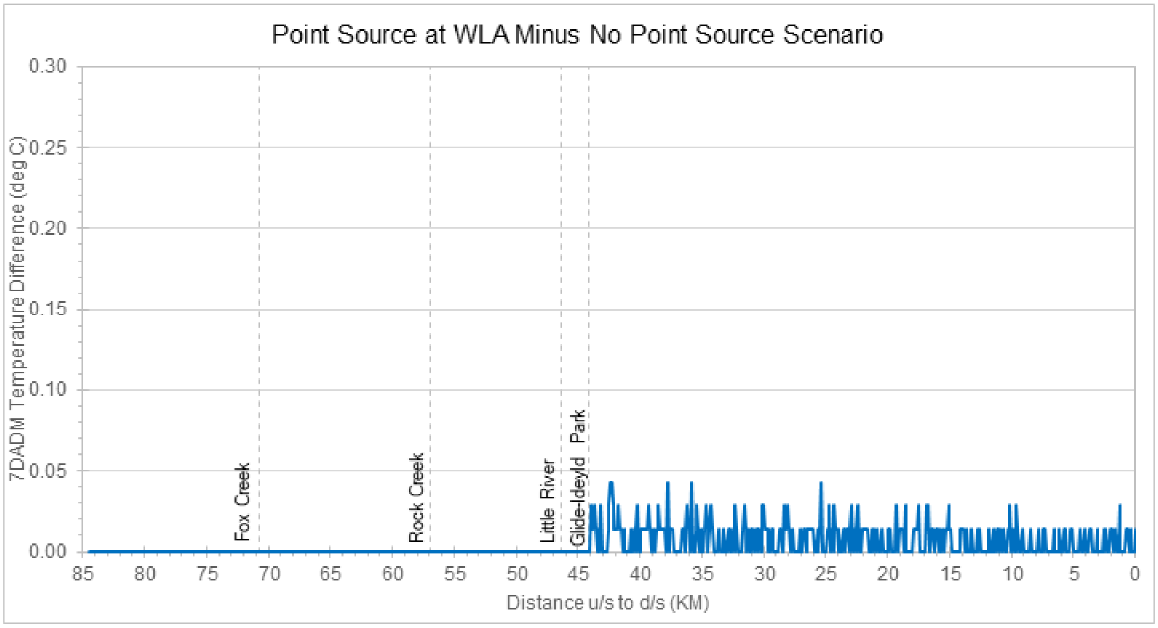

Figure 15-13. The maximum 7DADM temperature differences along the North Umpqua River model 6 (summer period) for the impacts of point sources at the WLA temperatures.

Table 15-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 4 for the North Umpqua River model 6 summer period

North Umpqua #6	RKM	Maximum Delta	Date when Maximum Delta occurs
Point Source at WLA Minus No Point Source Scenario	42.40	0.04	7/19/2002

Figure 15-14 shows the results of comparison 5, the impact from current point sources and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario with point source at current conditions and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation scenario includes the Glide-Idleyld Park point source at current conditions, while the Background scenario uses the fully restored vegetation conditions but does not include the point source. The maximum delta calculated along the reach is 0.01 ˚C with the first instance occurring at RKM 43.4 on July 31, 2002 (Figure 15-14) after which this delta is seen along the reach at multiple locations. Since the 0.01 ºC delta occurs for several days, each individual date and RKM are not listed in (Table 15-5).

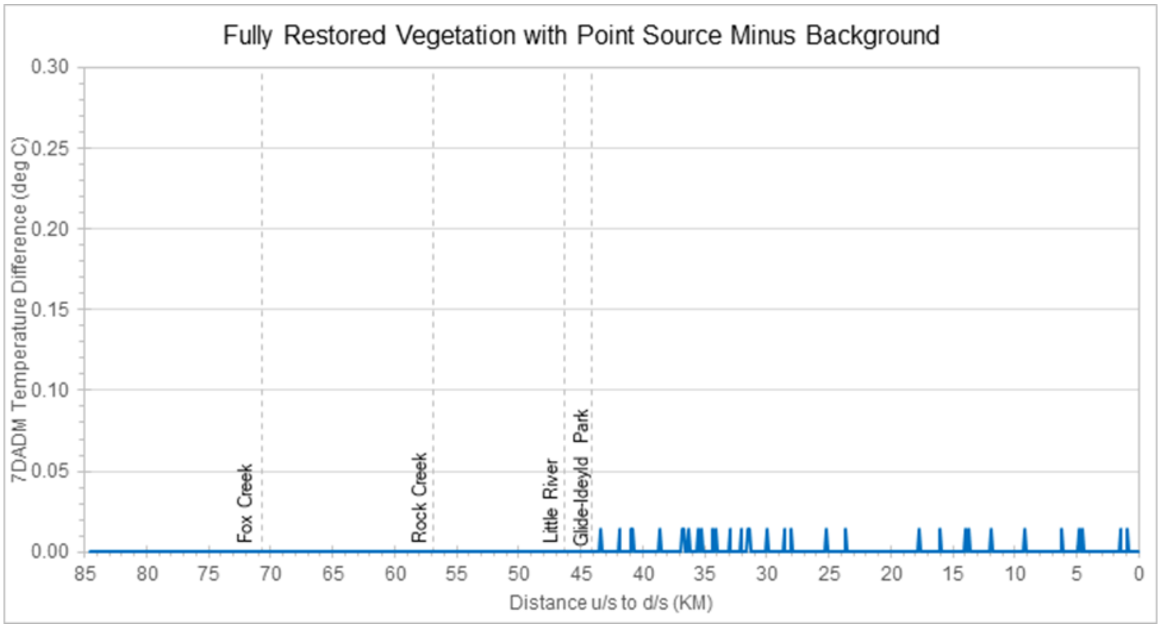

Figure 15-14. The maximum 7DADM temperature differences along the North Umpqua River model 6 summer period for the impacts of current point sources with restored vegetation.

Table 15-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 5 for the North Umpqua River model 6 summer period

North Umpqua #6	RKM	Maximum Delta	Date when Maximum Delta occurs
Fully Restored Vegetation with Point Source Minus Background	N/A	0.33	N/A

Figure 15-15 shows the results of comparison 6, the impact from point sources at the WLA and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario with WLAs and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation scenario includes point sources and WLA conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. For this comparison, the Rock Creek temperature represents the Rock Creek Hatchery WLA, which is taken as Rock Creek water temperature flowing into North Umpqua plus a HUA of 0.3˚ C, and also includes the WLA discharge from Glide-Idleyld. The maximum delta reaches 0.07 ˚C at RKM 44.2 on July 18, 2002 (Table 15-6).

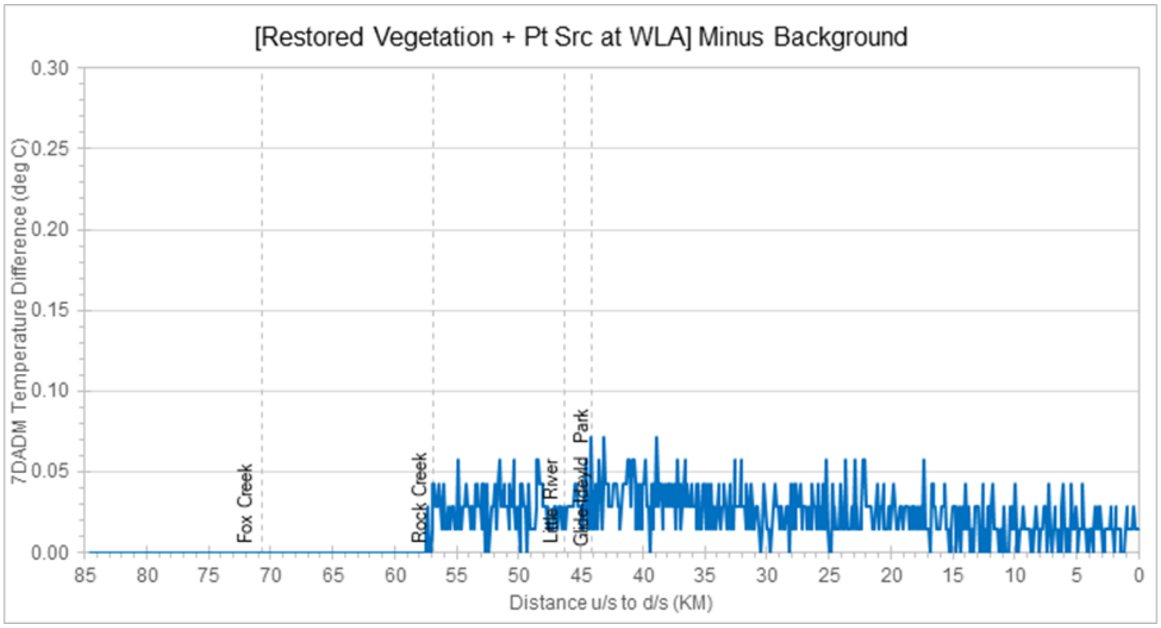

Figure 15-15. The maximum 7DADM temperature differences along the North Umpqua River model 6 (summer period) for the impacts of point sources at the WLA temperatures and fully restored vegetation conditions.

Table 15-6. Location and date of maximum delta when temperatures are greater than criterion for comparison 6 for the North Umpqua River model 6 summer period

North Umpqua #6	RKM	Maximum Delta	Date when Maximum Delta occurs
[Restored Vegetation + Pt Src at WLA] Minus Background	44.2	0.07	7/18/2002

Figure 15-16 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 8.57 °C at RKM 0.3 to 0.0 on July 18, 2002 (Table 15-7).

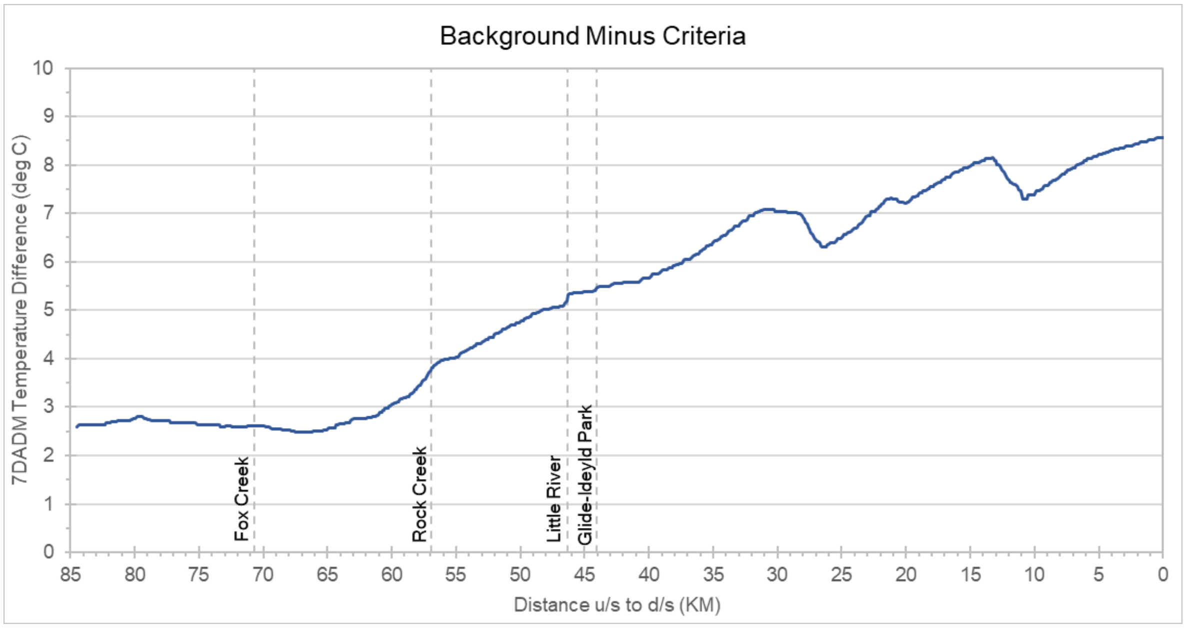

Figure 15-16. The maximum 7DADM temperature differences along the North Umpqua River model 6 (summer period) between Background scenario and the criteria

Table 15-7. Location and date of maximum delta when temperatures are greater than criterion for comparison 7 for the North Umpqua River model 6 summer period

North Umpqua Steamboat Crk to Mouth	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus Criteria	0.30 to 0	8.57	7/18/2002

Figure 15-17 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. The difference between these two scenarios for the North Umpqua River model 6 is that there are no withdrawals in the Fully Restored Vegetation with Natural Flow scenario and updates were made to the input from Little River for flow and temperatures in the Restored Vegetation + Natural Flow scenario. A maximum delta of 0.41 ˚C was noted at three separate locations, at RKM 31.50, 30.6, and 30.5. These occurred on July 30 and 31 (Table 15-8).

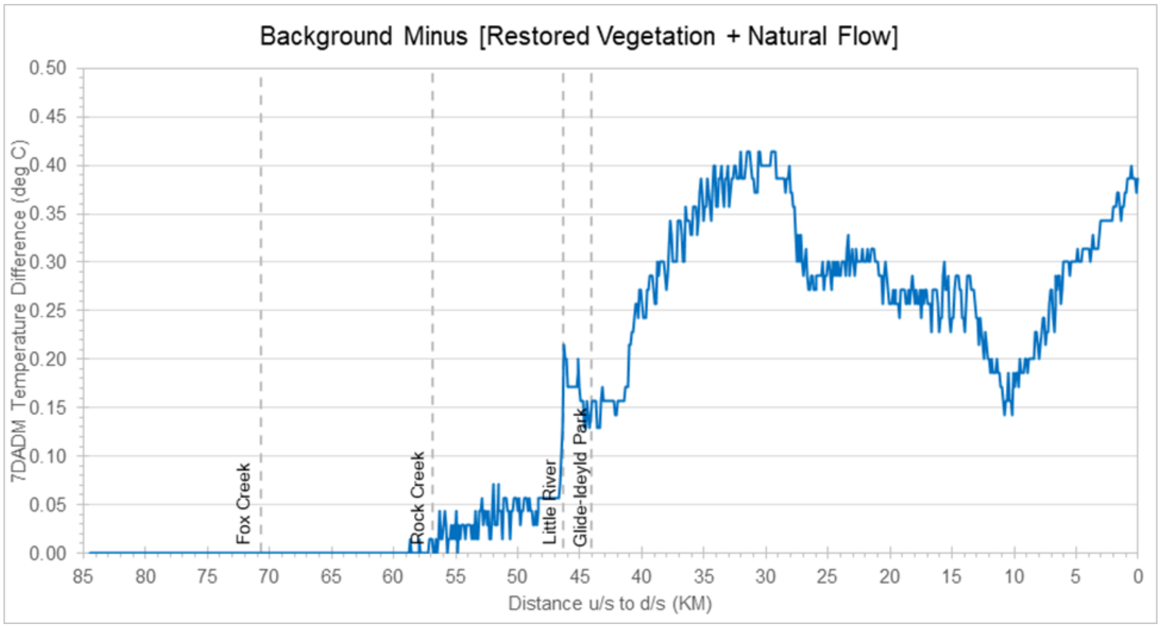

Figure 15-17. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario for the North Umpqua River model 6 summer period.

Table 15-8. Location and date of maximum delta when temperatures are greater than criterion for comparison 9 for the North Umpqua River model 6 summer period

North Umpqua #6	RKM	Maximum Delta	Date when Maximum Delta occurs
Background Minus [Restored Vegetation + Natural Flow]	31.50, 30.6, 30.5	0.41	7/31/2002, 7/30/2002, 7/30/2002

Figure 15-18 shows the results of comparison A2, the impact of adding 0.1 ºC to all the tributaries and headwater/upstream inflows in the background scenario, which is the 7DADM temperature difference between A2 and the Background scenario and criteria. The maximum delta calculated was 0.1 ºC (Table 15-9), starting near the headwater and continuing downstream, after which is starts the go below 0.1 ºC (Figure 15-18). Since the 0.1 ºC delta occurs for several days, each individual date and RKM are not provided as they can be seen in the Figure 15-18.

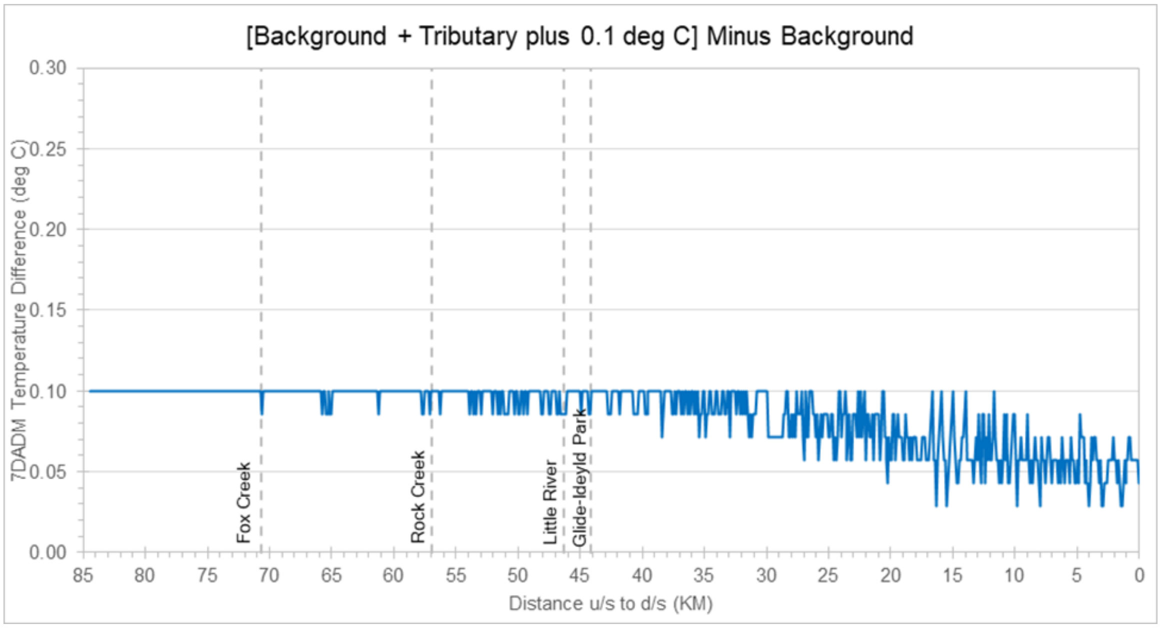

Figure 15-18. The maximum 7DADM temperature differences along North Umpqua River model 6 (summer period) for the impacts of adding 0.1°C to the Tributary/Headwater.

Table 15-9. Location and date of maximum delta when temperatures are greater than criterion for comparison A2 for the North Umpqua #6 summer period

North Umpqua #6	RKM	Maximum Delta	Date when maximum delta occurs
[Background + Tributary plus 0.1 deg C] Minus Background	N/A	0.10	N/A

16.0 SUMMARY

Scenario runs were conducted for seven streams in the North Umpqua watershed to support TMDL development for the summer and spawning temperature impairment. The streams included Canton Creek, Clearwater River, Lake Creek, Fish Creek, North Umpqua River, Rock Creek, and Steamboat Creek.

Model scenario runs for the spawning period were completed using ten separate HS8 models developed for the period from August 1 to October 2009, developed specifically to address the spawning period impairments. An exception to this was the Fish Creek HS8 model which was developed by PacifiCorp for the period from July 1 through September 30, 2009, to support the spawning period analysis.

Model scenario runs for the summer period were developed using the HS7 summer models developed DEQ. The summer models were developed for several days in July 2001/2002. The North Umpqua River itself was modeled using six separate models during the summer period. The last two North Umpqua models i.e., from Soda Springs

Reservoir to Steamboat Creek, and from Steamboat Creek to Mouth were combined into one model i.e., from Soda Springs Reservoir to mouth, for the spawning period.

The actual scenario runs differed for different waterbodies depending on whether point sources exist in the models and if flow and water temperature inputs change under the natural flow conditions, or if certain allocations were to be evaluated specifically only downstream of a particular location. Rock Creek and North Umpqua below Soda Springs Reservoir receive point source inputs in the form the Rock Creek Hatchery, and from the Glide-Idleyld Sanitary District respectively. The point source discharge data including the recorded daily effluent flows and temperature as well as calculated WLA temperature were provided by DEQ and were developed assigning HUA deltas to each of the point sources for evaluation. Riverine Heat Source models in place of each of the three impoundments (Lemolo Lake and Toketee Lake, and Soda Springs Reservoir) were also developed using HS8 for the period from August 1 to October 15, 2009. The HS models were run from upstream to downstream to evaluate the impacts of no dams along the system.

All models included restored vegetation scenarios. The scenarios show that the vegetation conditions impact the water temperature significantly. The cumulative impacts of point sources with WLA temperatures and impacts due to dams are all within 0.3 ^{o}C.

17.0 REFERENCES

DEQ (Oregon Department of Environmental Quality). 2008. *Temperature water quality standard implementation—A DEQ internal management directive, Oregon*. Oregon Department of Environmental. Quality. Portland, OR. https://www.oregon.gov/deq/Filtered%20Library/IMDTemperature.pdf

DEQ. 2013. *Internal Management Directive - The Use of Significant Figures and Rounding Conventions in Water Quality Permitting*. Water Quality Division, Surface Water Management Section, Headquarters. Portland, OR. https://www.oregon.gov/deq/Filtered%20Library/SigFigsIMD.pdf.

Appendix A. No Dams Model Development

1.0 NO DAMS MODEL DEVELOPMENT

For the no-dams scenario, a riverine Heat Source model was developed in place of each of the three impoundments—Lemolo Lake, Toketee Lake, and Soda Springs Dam—along the North Umpqua River, resulting in three separate models. The riverine reach models were configured with restored vegetation to simulate the historical natural conditions when the impoundments did not exist.

DEQs TTools GIS extension program was used to sample the required morphological and vegetation inputs for model setup and configuration. In the absence of any morphological or shading information, the channel characteristics were estimated based on existing channels upstream and downstream of the reservoir.

The development of the models required determining the length, width, slope, and Manning's roughness coefficient. A combination of existing data sources such as existing models upstream and downstream, aerial imagery, and historical U.S. Geological Survey (USGS) quadrangles were evaluated to identify the historic channel, if evident, or to determine the channel shape and digitize it using GIS.

Shading-related information was determined by sampling digitized vegetation provided by DEQ that was created for the area surrounding the existing reservoirs. Since the No Dams condition riverine reach models were configured with restored vegetation, the sampled existing condition vegetation were then converted to restored vegetation. This was done by converting the sampled landcover to system potential heights. Determination of system potential heights was based on consideration the upstream and downstream restored condition Heat Source models and adjusting the land cover accordingly to configure the model. Details of the land cover conversion for each land cover are discussed below in the individual model sections.

All models were configured for the time period from August 1, 2009, to October 15, 2009, which corresponds to the spawning period model for the existing North Umpqua streams. The riverine models are integrated with the North Umpqua mainstem models (Models 1 through 5) to create a continuous sequence of models from the most upstream end of the modeling domain to the downstream end at the mouth of North Umpqua River. The models are sequentially run from upstream to downstream, with the flow and temperature time series outputs from the upstream model serving as inputs to the next downstream model to produce results at the downstream end that represent riverine conditions (i.e. no dams) along the entire modeling domain. Note that only the upstream boundary is updated for linking the No Dams condition scenario models, all other inputs are kept at their existing condition. The details of the model setup and development for each of the riverine reaches are discussed below and serve as documentation for the no dams condition models.

1.1 LEMOLO LAKE RIVERINE MODEL

The following sections discuss the model setup, inputs, and results for the Lemolo Riverine Model.

1.1.1 Heat Source Model Input – Lemolo Lake Riverine

DEQs TTools GIS utility was used to create channel related inputs for the heat source model. TTools samples geospatial data and allows assembly of high-resolution data inputs for use in the heat source model. The utility program comprises a set of automated GIS sampling tools used to create an input database that feeds directly into Heat Source Version 8 (HS8).

The Lemolo Lake riverine channel was first delineated to be used as input into the TTools program. The channel alignment of the active channel in the vegetation shapefile layer provided by DEQ was used to digitize the stream centerline, along with the left and right banks. The DEQ vegetation layer provided the best estimate of the likely channel centerline and banks to define the Lemolo Lake riverine centerline and channel. The delineated left and right banks defined the bank full width of the channel, which on average was approximately 22 meters wide. Since the historical channel widths are unknown, the channel width was further confirmed by checking the widths in the river before it enters Lemolo Lake, using the existing USGS base map and by viewing and measuring the widths along the Lemolo Lake from the historical USGS topographic map from 1917 for the Diamond Lake area.

TTools includes five general steps for sampling/extracting data at user defined intervals along the stream, which are outlined below:

Step 1: Used TTools to establish the channel centerline sampling points every 50 meters, beginning at the upstream end of the delineated channel centerline, and the stream length between each node. Each point was then populated with the point latitude/longitude and aspect. Figure 1-1 shows the stream sampling points every 50 meters, along with the river kilometer (RKM) for reference. The Lemolo Lake channel generally flows in a northwesterly direction. Aspect is used to calculate the solar flux on the stream surface based on its orientation. Figure 1-1 shows the calculated channel aspect for each stream sampling point as a directional arrow.

Step 2: Calculated the channel width using the distance between the delineated left and right banks established with a line orthogonal to the aspect of each channel centerline point. The calculated channel widths ranged from ranged from 16.7 meters to 26 meters, with a mean of 22 meters. Channel bottom widths were calculated separately for input into the HS8 model using the bank full widths. A separate Excel macro (provided by DEQ) that utilizes the methodology from HS7, was used to calculate the channel bottom width. The macro uses the sampled bank full width, an assumed width to depth ratio and assumed channel angle to calculate the bottom width. The width to depth ratio was assumed to be 10, and the channel angle was assumed to be 0.5 (63.43°). The calculated channel bottom widths used in the model ranged from 14.9 meters to 23.2 meters, with a mean of 19.54 meters.

Step 3: Determined the channel bottom elevations at each point. Due to the lack of DEM with sufficient resolution that covers the channel, the elevation was calculated using linear interpolation. Elevations at the upstream and downstream end of the modeled reach were determined using GIS. An estimate for the upstream elevation was made by reviewing the existing USGS topographic map and the DEM data (ODF 2023) with 10-meter spatial resolution. The downstream elevation was set based on the most upstream elevation from the North Umpqua Model 1 model. The elevations ranged from 4,145 feet to 4,038 feet (1263.7 meters to 1231.1 meters) across the model domain of 4.1 kilometers. A constant gradient of 0.008 was specified in the model.

Step 4: Calculated the topographic shading from the DEM data. The DEM data was used to sample the topographic shade angles to the east, west, and south of each point in a 10-km search radius. DEQs bare earth LiDAR DEM (3 ft x 3 ft) (DOGAMI 2021) developed for the entire state was unavailable for the modeled area and the 10-meter DEM (ODF 2023) offered the best available information. The topographic shading angles ranged from 3.15 to 15.3 degrees to the east, 2.81 to 6.7 degrees to the west, and 1.75 to 7.5 degrees to the south.

Step 5: Determined the vegetation. Landcover from a vegetation raster layer was sampled at each 50-meter node using a dense radial sampling pattern. Four transverse vegetation samples were taken in each of the seven cardinal directions, with the distance between samples taken as 15 meters. This is consistent with the setting used by DEQ for all the North Umpqua models that were previously created.

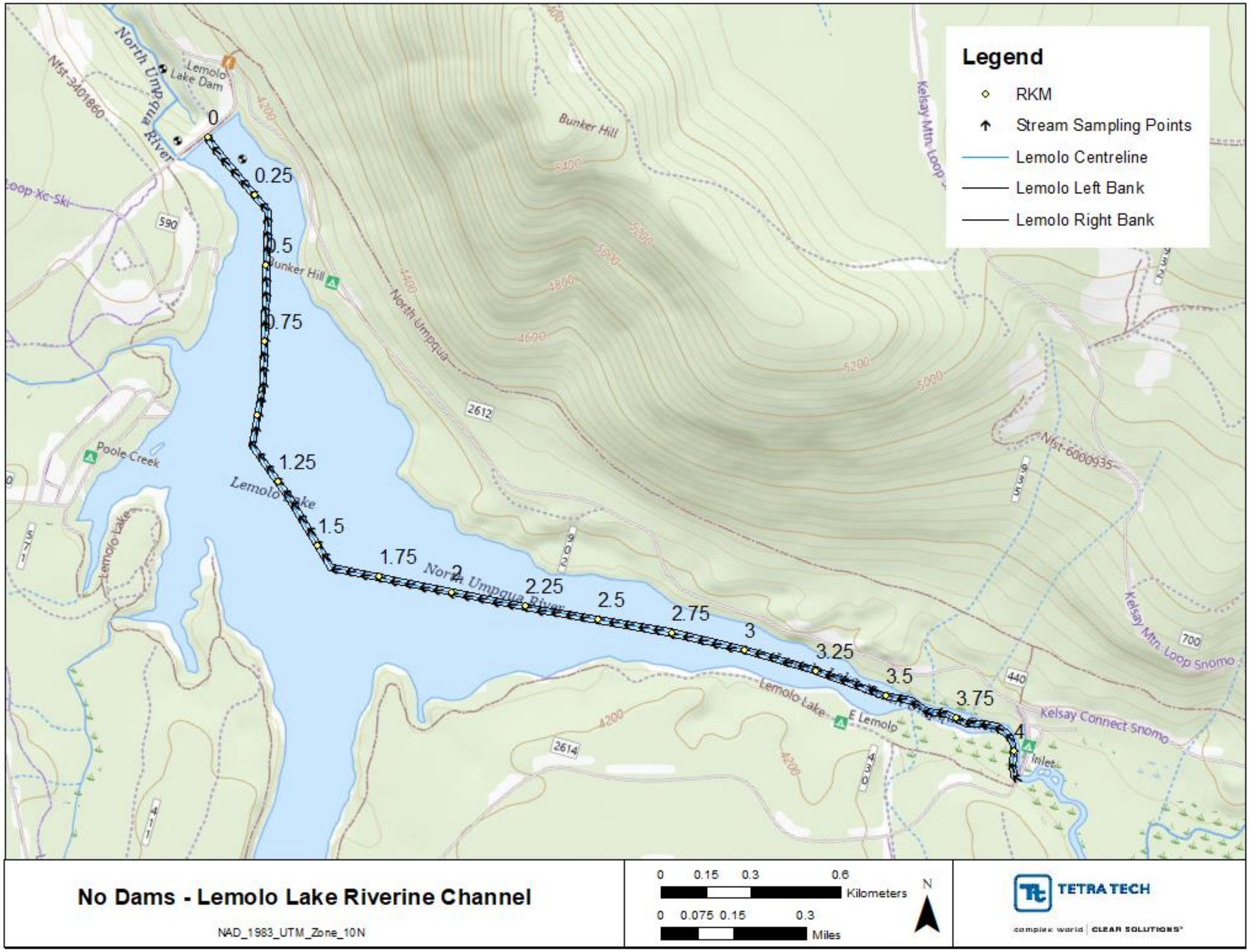

Figure 1-1. Digitized Lemolo Lake riverine Channel and stream sampling points

The raster vegetation layer used for sampling the vegetation in Step 5 above was created using a vegetation shapefile provided by DEQ. The vegetation shapefile included land cover within the stream buffered at 100-meters from each bank, and the resulting buffer was divided into polygons based on the various land cover types. Figure 1-2 shows the near stream landcover within the 100-meter buffer of the left and right channel banks around the Lemolo Lake riverine channel area. More than 90 percent of the land cover surrounding the channel is small conifers, with some grass in the upland areas. The vegetation offered the best estimate of the vegetation around the riverine channel based on interpretation from nearby vegetation.

The sampled existing vegetation were converted to fully restored condition for simulating the historical natural conditions when impoundments did not exist. The vegetation conversion to restored vegetation was determined by inspecting the surrounding North Umpqua Models with existing and restored vegetation. In the case of the Lemolo Lake riverine model, the North Umpqua Model 1 existing and restored vegetation types were evaluated and then converted accordingly. Table 1-1 shows the existing and restored vegetation categories, and Table 1-2 shows the vegetation heights for each of the land cover categories used in the Lemolo Lake riverine model. The update primarily resulted in conversion of the small conifers to large conifers.

Table 1-1. Existing and restored vegetation categories in the Lemolo Lake riverine model.

Land Cover	Lemolo Lake Reach Codes	Lemolo Lake Restored Land Cover Code	Notes
Water	301	301	No change
Road	400	700	Updated from Road to Large Conifer
Small Conifer	701	700	Updated from Small Conifer to Large Conifer
Grass - upland	900	900	No change
Active River Channel	3011	3011	No change
Dam or Weir	3252	3011	Updated from Dam/Weir to river channel

Table 1-2. Land cover information used in the Lemolo Lake riverine model.

Land Cover Name	Code	Height (m)	Density (0 - 1)	Overhang (m)
Water	301	0.0	0%	0.0
Road	400	0.0	0%	0.0
Large Conifer	700	45.7	80%	0.0
Small Conifer	701	15.0	80%	0.0
Grass - upland	900	0.9	65%	0.0
Active River Channel	3011	0.0	0%	0.0
Dam or Weir	3252	0.0	0%	0.0

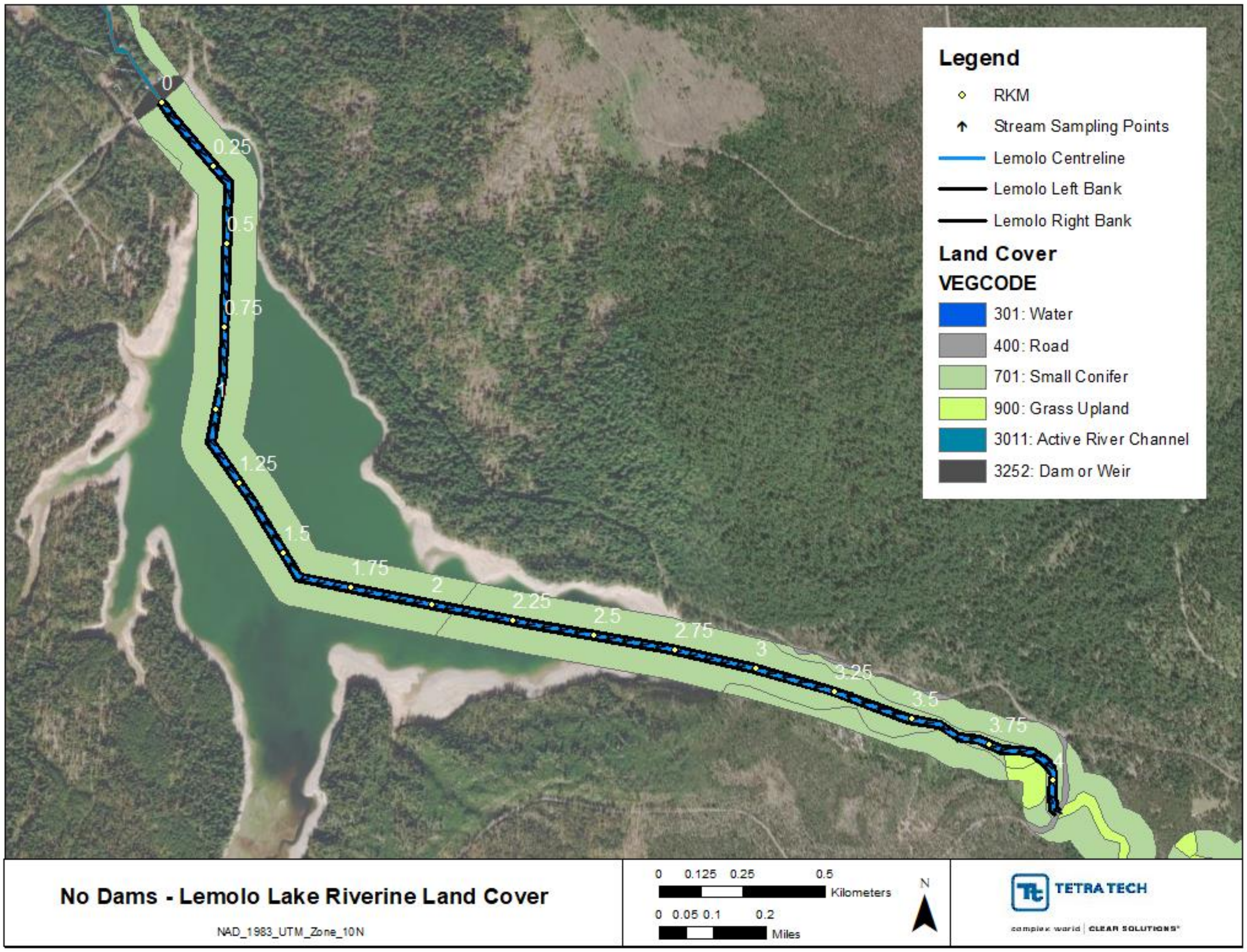

Figure 1-2. Digitized near stream land cover for Lemolo Lake riverine channel.

Manning's roughness coefficient values in the North Umpqua Model models vary significantly. The Manning's N values across all the North Umpqua models (Models 1 through 5) ranged from 0.04 to 0.35, with a mean of 0.12 and median of 0.1. The mean Manning's N value of 0.12 was used for the Lemolo Lake riverine reach. This value was used for all riverine reach models since no detailed channel information is available, and calibration of such a model is not possible.

1.1.2 Flow Data Inputs – Lemolo Lake Riverine

The modeled riverine segment for Lemolo Lake receives flows from the North Umpqua River at its upstream boundary and includes a tributary input from Lake Creek at RKM 1.5. The riverine segment ultimately feeds into North Umpqua Model 1 at its downstream end.

Flows for the upstream boundary were derived using the drainage area ratio method using flows from USGS 14316495 (Boulder Creek Near Toketee Falls). Figure 1-3 shows the drainage areas. The flows were estimated as follows using the following generalized equation.

$$Q_u = Q_g\left(A_u/A_g\right)^a$$

Qu = the estimated discharge for the ungaged watershed; Qg = discharge for the gaging station; Au = the area of the ungaged watershed; Ag = the area of the gaged watershed, and a = the exponent of area

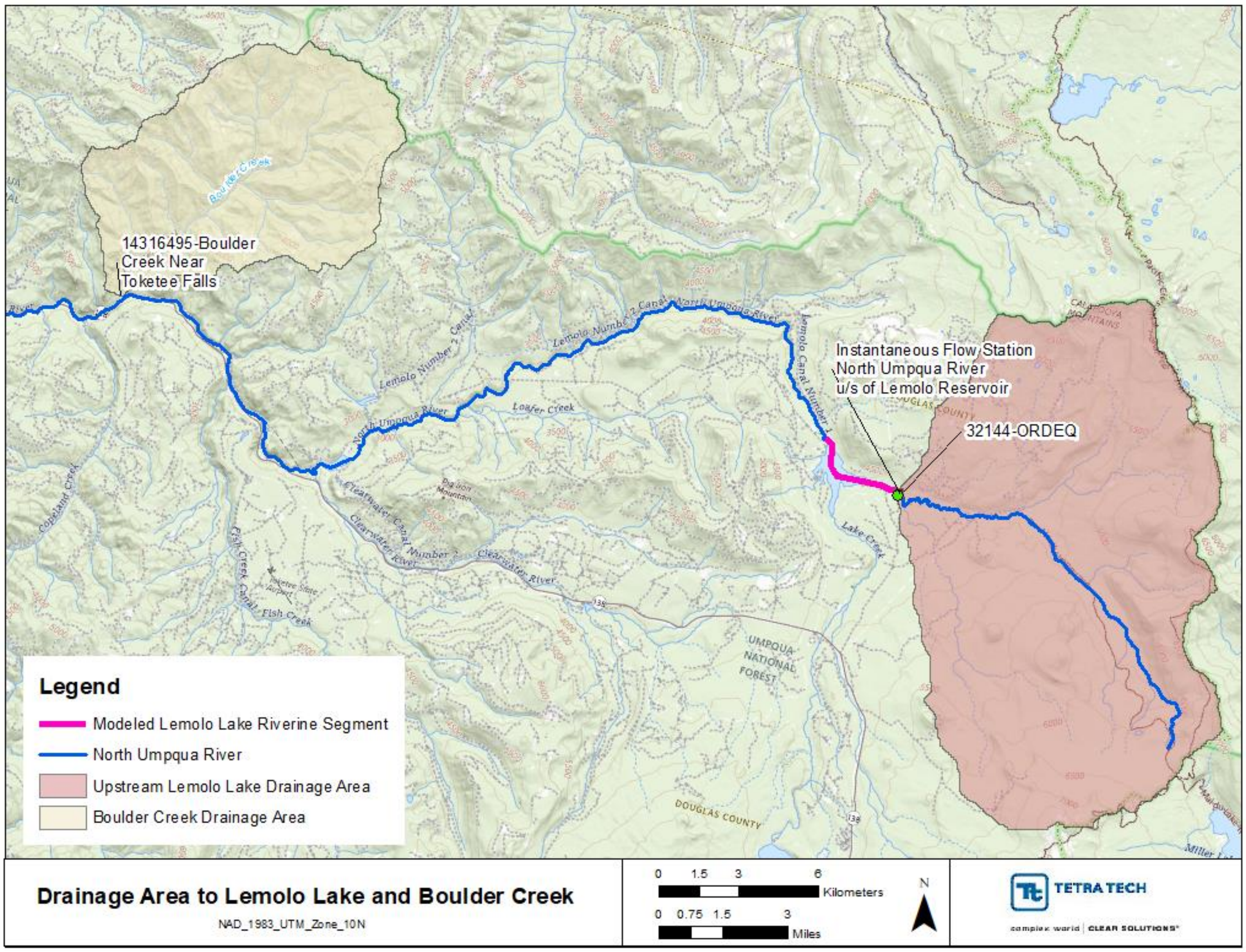

Figure 1-3. Upstream Lemolo Lake drainage area and Boulder Creek (USGS 14316495) drainage area

Instantaneous flow measurements were collected by DEQ during 2009 at the station "North Umpqua River u/s of Lemolo Reservoir". The flows were collected on two days about a week apart in September 2009 and readings were similar. The observed flow on September 9th was 288.15 cfs (8.16 cms) and on September 15th was 288.38 cfs (8.16 cms). These instantaneous flows were used as a guide in the flow estimation.

The drainage area upstream of Lemolo Lake was calculated using USGS Stream Stats and was 72.1 mi^2, and the reported drainage area for Boulder Creek USGS gage was 60.4 mi^2. Adjustments were made to the exponent in the drainage area relationship equation to better match the calculated flow magnitude to the observed flow estimates collected during September. This resulted in an exponent value of 4.9. Figure 1-4 shows the estimated flows used to define the upstream boundary inputs to the model. Note that the streamflow in this area is dominated by groundwater, the geologic characteristics of this High Cascade aquifer influence a high volume and storage capacity of groundwater that slowly releases to channels (USDA 1998 & USFS 2004).

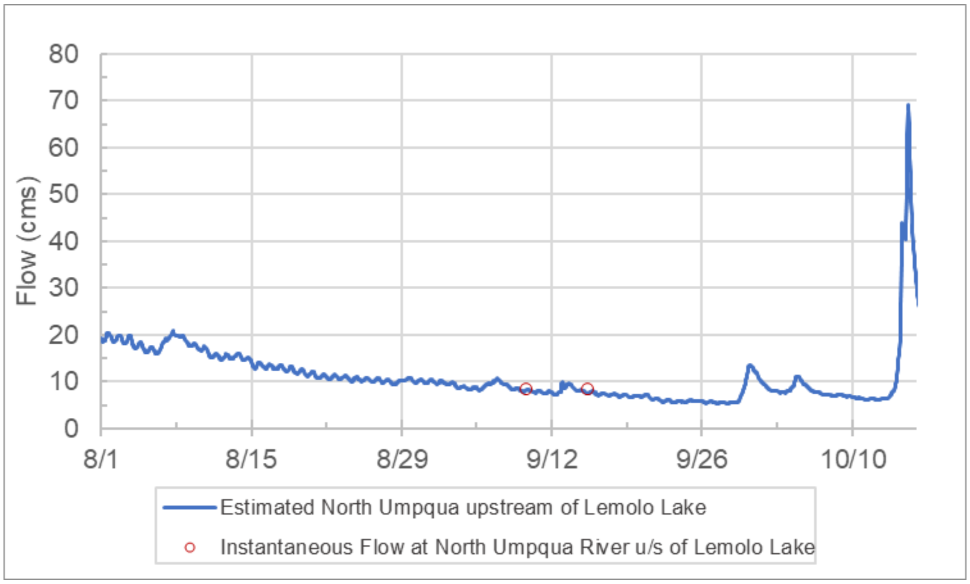

Figure 1-4. Estimated upstream boundary flows at North Umpqua upstream of Lemolo Lake

Tributary flow input from Lake Creek was specified using predicted flow from the last segment (segment 0) of the existing condition Lake Creek model. Figure 1-5 shows the flow time series for Lake Creek specified in the model.

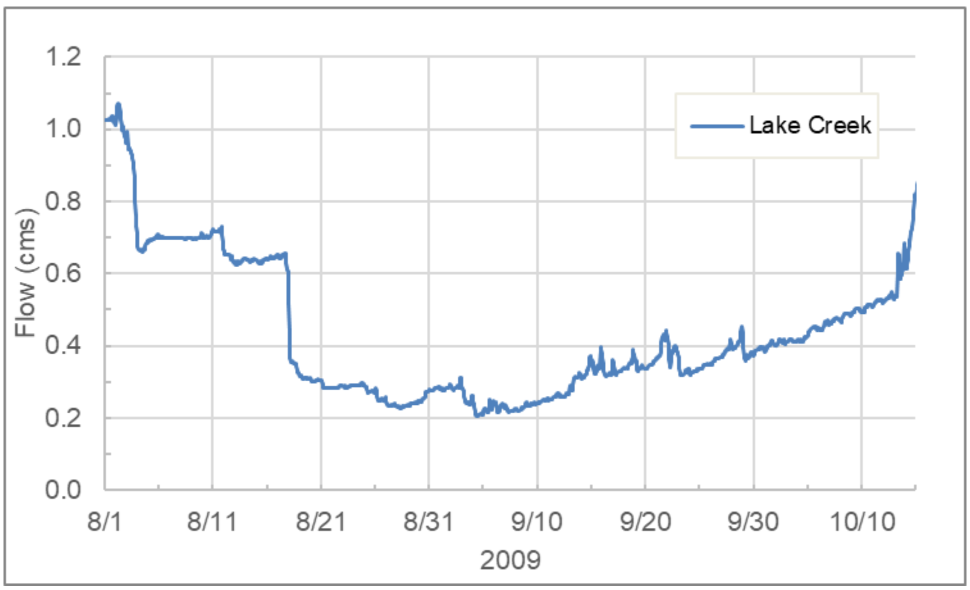

Figure 1-5. Lake Creek tributary flow input to the Lemolo Lake riverine model.

1.1.3 Water Temperature Data Inputs – Lemolo Lake Riverine

The upstream boundary of the model was configured using water temperature from the DEQ station 32144-ORDEQ. Figure 1-3 shows the location of the water temperature station 32144-ORDEQ on North Umpqua River above Lemolo Lake near Inlet Campground. Hourly water temperature observations were available at this station from August 17, 2009, to October 14, 2009.

In order to fill in the missing data at 32144-ORDEQ prior to August 17, regression relationships with the USFS station UmpNF-052 at Lake Creek at Mouth, and also with the station at Copeland Creek UmpNF-024 were explored. The correlation with Lake Creek at Mouth is fairly strong with r^2 at 0.65, however, the predicted water temperatures were not used since they showed a lower diurnal range, and higher temperatures during fall when compared to the existing observed data. The relationship with the Copeland Creek station was also not used since the correlation is weak with r^2 at 0.37. The missing data prior to August 17, 2009, were ultimately filled using repeated temperatures from the last observed date and an incremental adjustment factor to follow the trend. In addition, hourly data were missing for four days, on August 27, September 16, October 7, and October 15. The missing data for these days were filled in using data from the previous day. Figure 1-6 shows the hourly temperature time series used to configure the upstream boundary using the station 32144-ORDEQ.

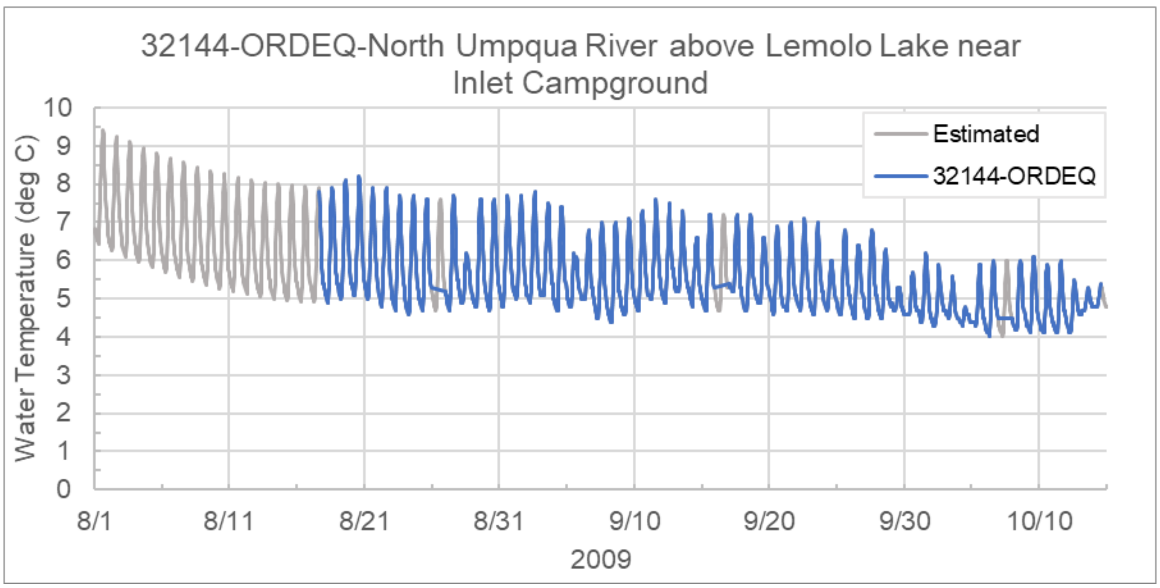

Figure 1-6. Upstream boundary water temperature - 32144-ORDEQ-North Umpqua River above Lemolo Lake near Inlet Campground.

Tributary water temperature input from Lake Creek was specified using predicted water temperature from the last segment (segment 0) of the Lake Creek existing condition model. Lake Creek provides a relatively warmer input compared to the upstream boundary water temperatures. Figure 1-7 shows the hourly water temperature time series for Lake Creek.

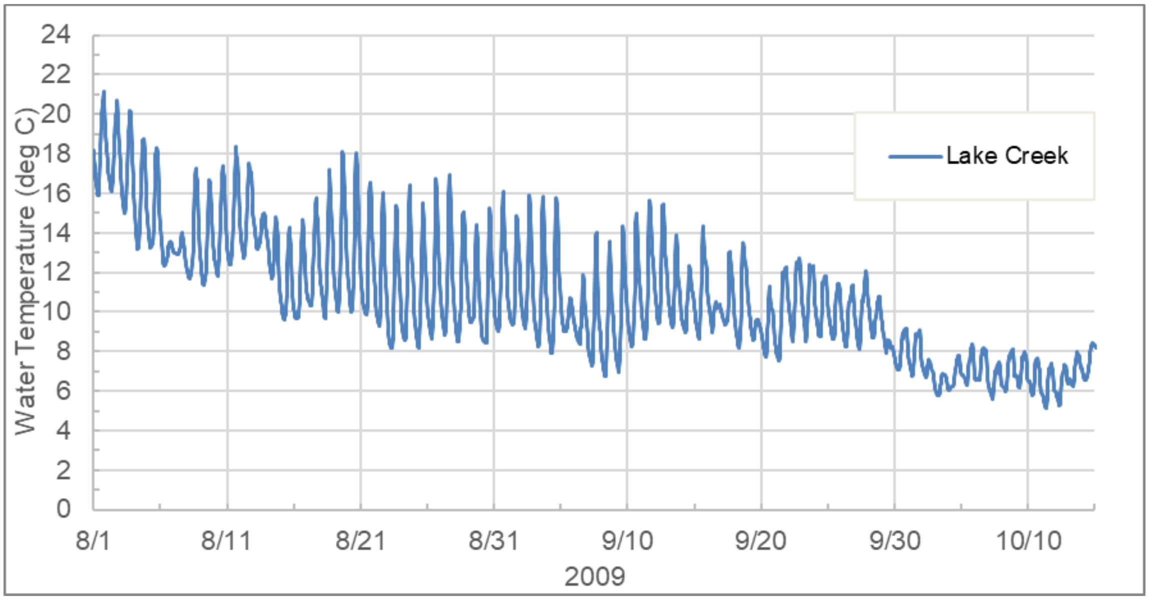

Figure 1-7. Lake Creek water temperature tributary input to the Lemolo Lake riverine model.

1.1.4 Meteorological Data – Lemolo Lake Riverine

Hourly meteorological data from the North Umpqua Model 1 were used in the Lemolo Lake riverine model. The North Umpqua Model 1 is just downstream of Lemolo Lake. The meteorology data used in the North Umpqua model comprised of air temperature (after adiabatic adjustment) and cloud cover from the Roseburg Airport, and wind speed and relative humidity from Toketee Airport.

1.1.5 Model Results – Lemolo Lake Riverine

The model was run at a 1-minute time step for the period from August 1 through October 15, 2009. The model was output every 100 meters. The simulated flow and water temperature hourly timeseries at the most downstream segment i.e., at segment 0, which was used to feed into the North Umpqua Model 1, are shown below in Figure 1-8.

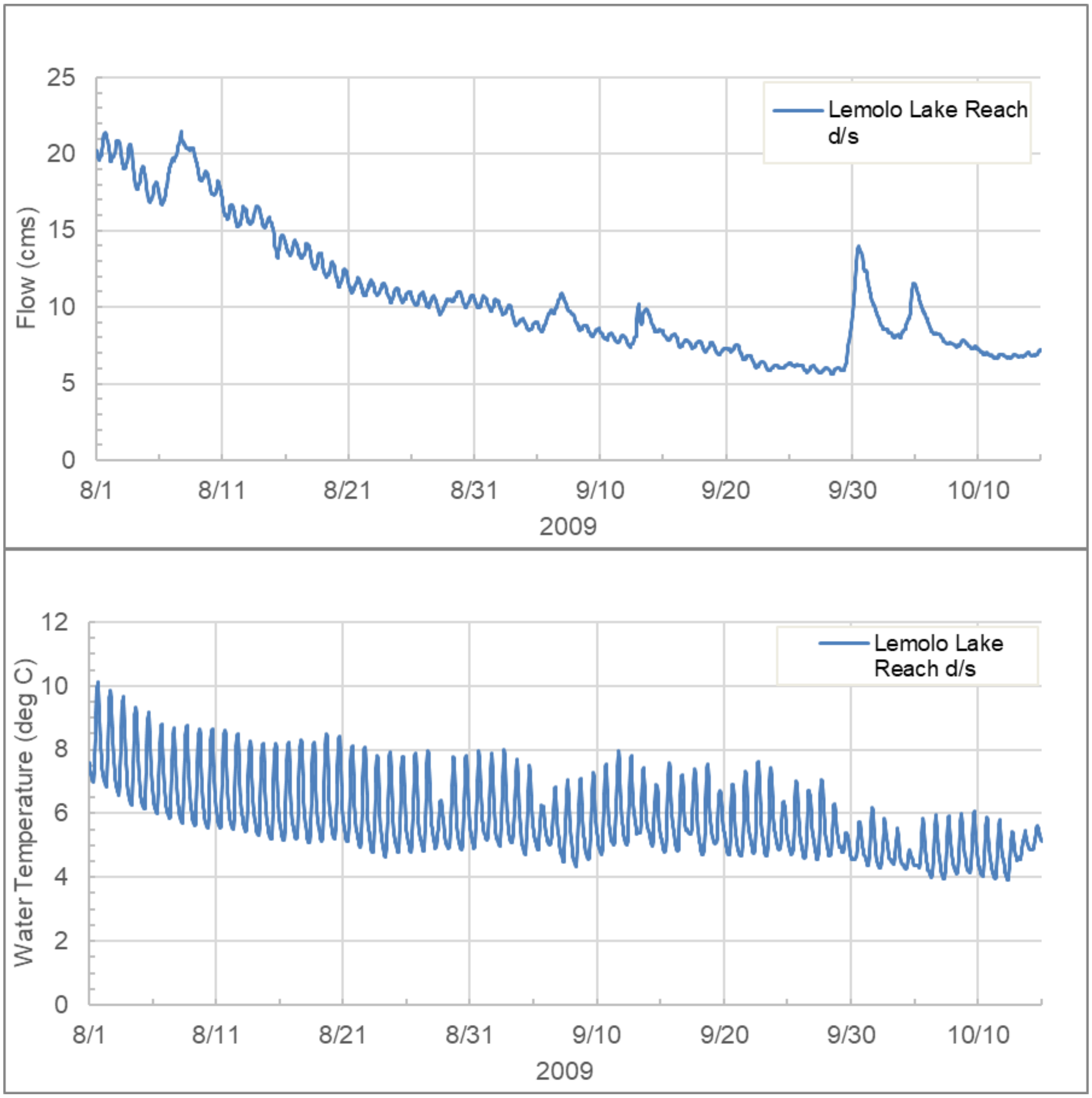

Figure 1-8. Modeled stream flow and temperature at Lemolo Lake Reach most downstream segment of Model 1

1.2 TOKETEE LAKE RIVERINE MODEL

1.2.1 Heat Source Model Input – Toketee Lake Riverine

As discussed previously in Section 1.1.1 DEQs TTools GIS utility was used to create channel related inputs for the heat source model. The Toketee Lake riverine channel was first delineated to be used as input into the TTools program. The channel alignment of the active channel in the vegetation shapefile layer was used to digitize the stream centerline, along with the left and right banks. The delineated left and right banks defined the bank full width of the channel, which on average was approximately 22 meters wide.

Since the historical channel widths are unknown, the channel width was further confirmed by checking the existing USGS base map and also by viewing and measuring the widths along the Toketee Lake from the historical USGS topographic map from 1917 for the Diamond Lake area. DEQs bare earth LiDAR DEM hill shade (3 ft x 3 ft) (DOGAMI 2021) was available for the Toketee Lake area but did not provide sufficient detail to interpret the historical channel. The layer was used as a reference guide during digitization for the channel.

TTools includes five general steps for sampling/extracting data at user defined intervals along the stream, which are outlined below:

Step 1 Used TTools to establish the channel centerline sampling points every 50 meters, beginning at the upstream end of the delineated channel centerline, and the stream length between each node. Each point was then populated with the point latitude/longitude and aspect. Figure 1-9 shows the stream sampling points every 50-meters, along with the RKM for reference. The Toketee Lake channel generally flows in a southwesterly direction. Aspect is used to calculate the solar flux on the stream surface based on its orientation. Figure 1-9 shows the calculated channel aspect for each stream sampling point as a directional arrow.

Step 2 Calculated the channel width using the distance between the delineated left and right banks established with a line orthogonal to the aspect of each channel centerline point. The calculated channel widths ranged from ranged from 21.9 meters to 22.9 meters, with a mean of 22 meters. Channel bottom widths were calculated separately for input into the HS8 model using the bank full widths. A separate Excel macro (provided by DEQ) that utilizes the methodology from HS7, was used to calculate the channel bottom width. The macro uses the sampled bank full width, an assumed width to depth ratio and assumed channel angle to calculate the bottom width. The width to depth ratio was assumed to be 10 and the channel angle was assumed to be 0.5 (63.43°). The calculated channel bottom widths used in the model ranged from 19.5 meters to 20.5 meters, with a mean of 19.7 meters.

Step 3 Determine the channel bottom elevations at each point. The elevation was calculated using linear interpolation. Elevation information from the upstream and downstream end of the modeled reach (i.e., from North Umpqua Model 2 and Model 3) were used. The elevations ranged from 740.1 meters to 737 meters across the model domain of 1.7 kilometers. A constant gradient of 0.0017 was specified in the model.

Step 4 Calculated the topographic shading using DEQs bare earth LiDAR DEM (3 ft x 3 ft) (DOGAMI 2021) to sample the topographic shade angles to the east, west, and south of each point in a 10-km search radius. The topographic shading angles ranged from 12.47 to 17.1 degree to the east, 4.02 to 19.1 degrees to the west, and 7.26 to 20.5 degrees to the south.

Step 5 Determined the vegetation. Landcover from a vegetation raster layer was sampled at each 50-meter node using a dense radial sampling pattern. Four transverse vegetation samples were taken in each of the seven cardinal directions, with the distance between samples taken as 15 meters. This is consistent with the setting used by DEQ for all the North Umpqua models that were previously created.

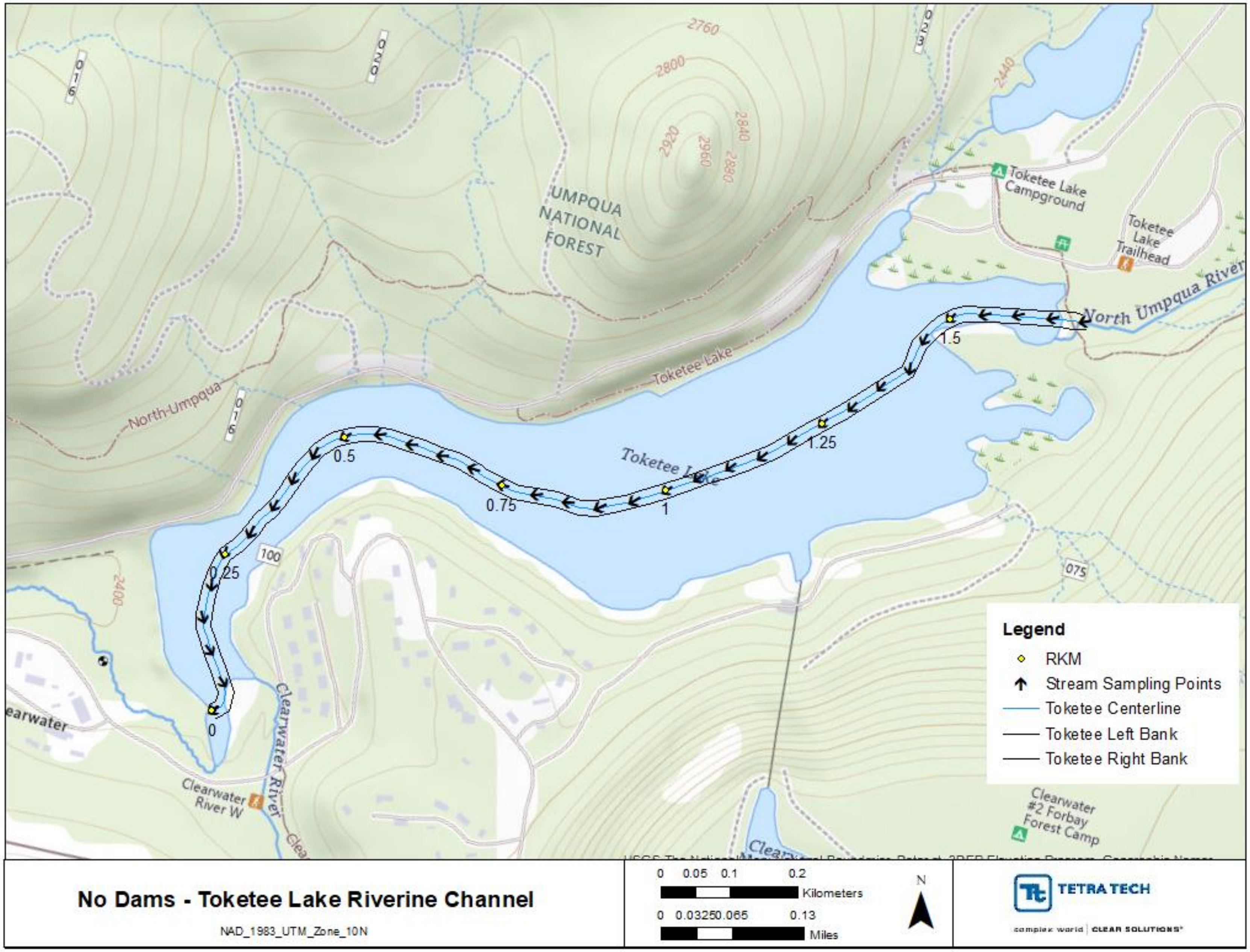

Figure 1-9 Digitized Toketee Lake riverine channel and stream sampling points.

The raster vegetation layer used for sampling the vegetation in Step 5 above was created using a vegetation shapefile provided by DEQ. The vegetation shapefile included land cover within the stream buffered at 100-meters from each bank and the resulting buffer was divided into polygons based on the various land cover types. Figure 1-10 shows the near stream landcover within the 100-meter buffer of the left and right channel bank around the Toketee Lake riverine channel area. The land cover on the left bank is dominated by large conifers and some upland shrub towards the upstream end of the channel. The right bank comprises mostly of small conifers, with some large mixed conifer hardwood in the upland areas. The vegetation offered the best estimate of the vegetation around the riverine channel based on interpretation from nearby vegetation.

The sampled existing vegetation were converted to fully restored condition for simulating the historical natural conditions when impoundments did not exist. The vegetation conversion to restored vegetation was determined by inspecting surrounding North Umpqua Models with existing and restored vegetation. In the case of the Toketee Lake riverine model, the existing and restored vegetation types in North Umpqua Model 2 and Model 3 were evaluated, and then converted accordingly. Table 1-3 shows the existing and restored vegetation categories, and Table 1-4 shows the vegetation heights for each of the land cover categories used in the Toketee Lake riverine model. The update primarily resulted in conversion of the small conifers to large conifers, which were along the right bank.

Table 1-3. Existing and restored vegetation categories in the Toketee Lake riverine model.

Land Cover	Toketee Lake Reach Codes	Toketee Lake Restored Land Cover Code	Notes
Road	400	700	Updated from Road to Large Conifer
Large Mixed Conifer-Hardwood	500	500	No change
Large Conifer	700	700	No change
Small Conifer	701	700	Updated from Small Conifer to Large Conifer
Upland Shrubs	800	800	No change
Grass - upland	900	900	No change
Active River Channel	3011	3011	No change
Dam or Weir	3252	3011	Updated from Dam/Weir to river channel

Table 1-4. Land cover information used in the Toketee Lake riverine model.

Land Cover Name	Code	Height (m)	Density (0 - 1)	Overhang (m)
Road	400	0.0	0%	0.0
Large Mixed Conifer-Hardwood	500	30.5	65%	0.0
Large Conifer	700	45.7	80%	0.0
Small Conifer	701	15.0	80%	0.0
Upland Shrubs	800	1.5	65%	0.0

Land Cover Name	Code	Height (m)	Density (0 - 1)	Overhang (m)
Grass - upland	900	0.9	65%	0.0
Active River Channel	3011	0.0	0%	0.0
Dam or Weir	3252	0.0	0%	0.0

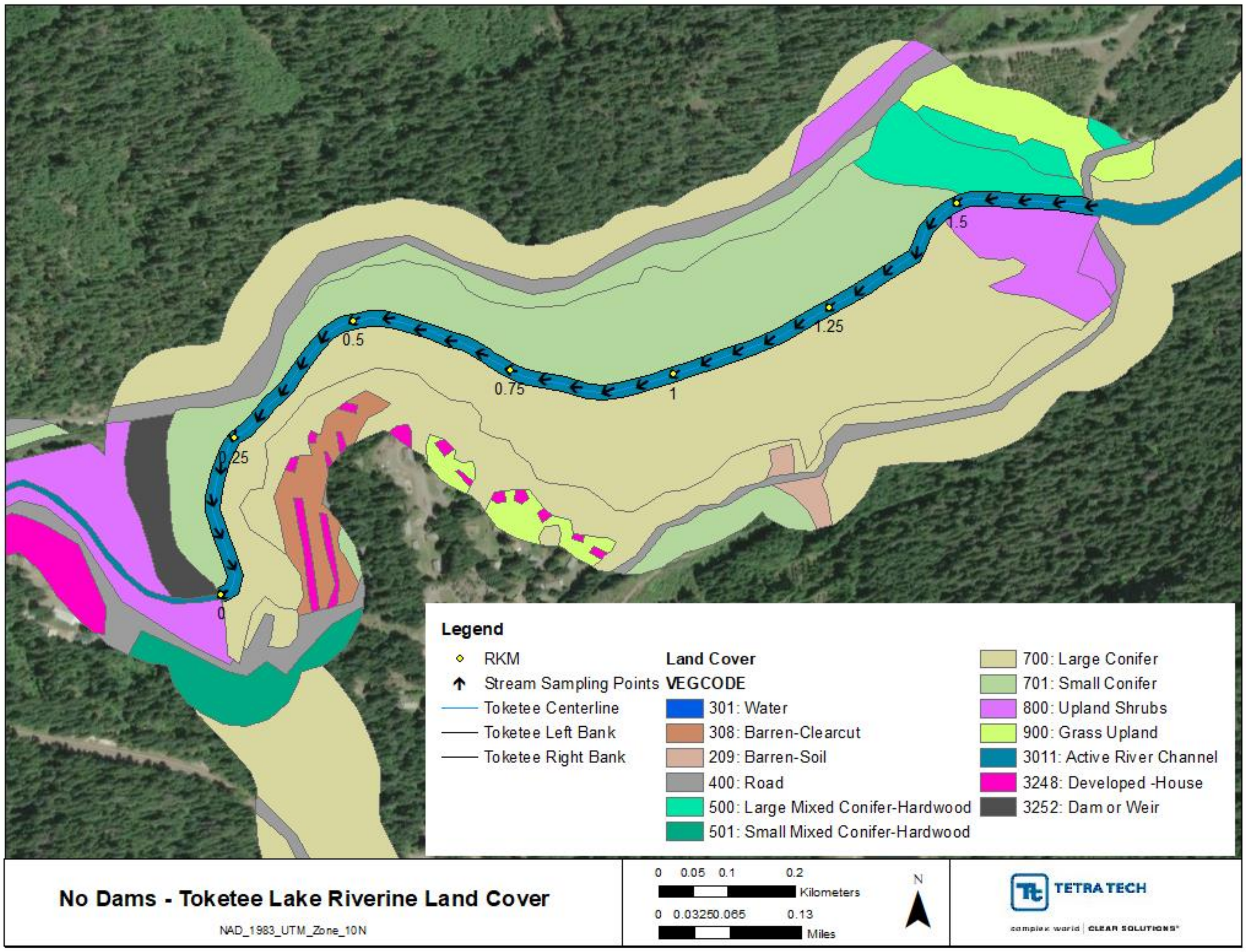

Figure 1-10 Digitized near stream land cover for Toketee Lake riverine channel.

Manning's roughness coefficient values in the North Umpqua Model models vary significantly. The Manning's N values across all the North Umpqua models (Models 1 through 5) ranged from 0.04 to 0.35, with a mean of 0.12 and median of 0.1. The mean Manning's N value of 0.12 was assumed for the Toketee Lake modeled reach. This value was used for all riverine reach models since no detailed channel information is available, and calibration of such a model is not possible

1.2.2 Flow Data Inputs – Toketee Lake Riverine

The No Dams condition models were run sequentially, with flow transferred from upstream to downstream, starting with the Lemolo Lake riverine model, followed by Model 1, and then Model 2. The modeled riverine segment for Toketee Lake receives flows from the North Umpqua River Model 2 at its upstream boundary and includes a tributary input from Clearwater River close to the downstream end at RKM 0.1. The riverine segment ultimately feeds into North Umpqua Model 3 at its downstream end.

Hourly flows from the last segment (segment 0) of North Umpqua Model 2 were used to define the upstream boundary for the Toketee Lake riverine model. Figure 1-11 shows the upstream boundary flows used in the model.

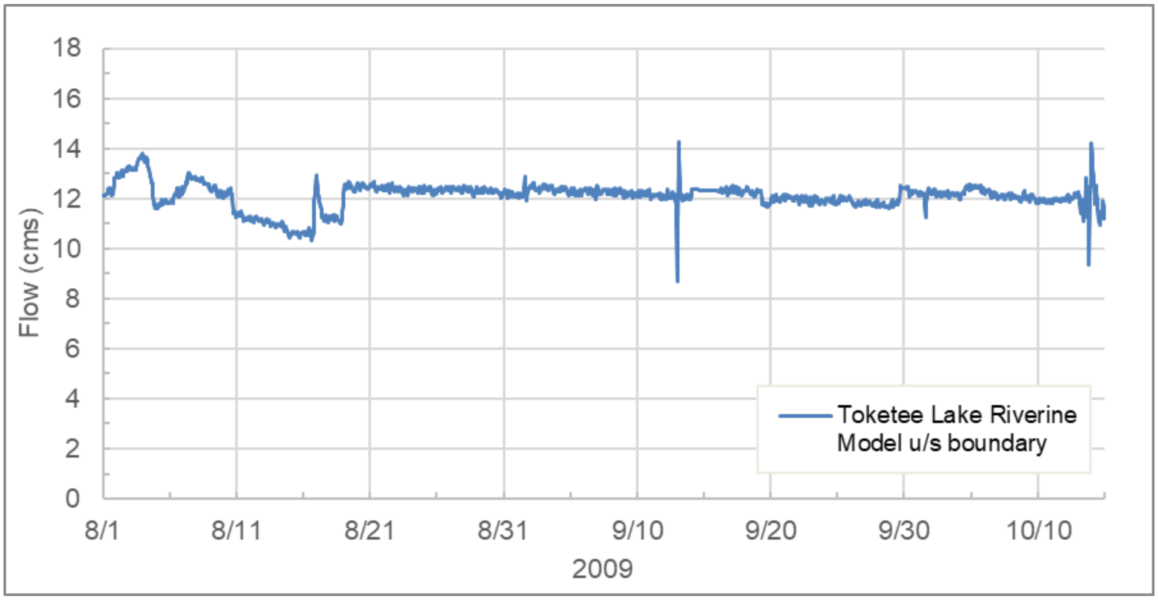

Figure 1-11. Upstream boundary flows at North Umpqua upstream of Toketee Lake

Tributary flow input from Clearwater River was specified using predicted water temperature from the last segment (segment 0) of the Clearwater River existing condition model. Figure 1-12 shows the hourly water temperature time series for Clearwater River.

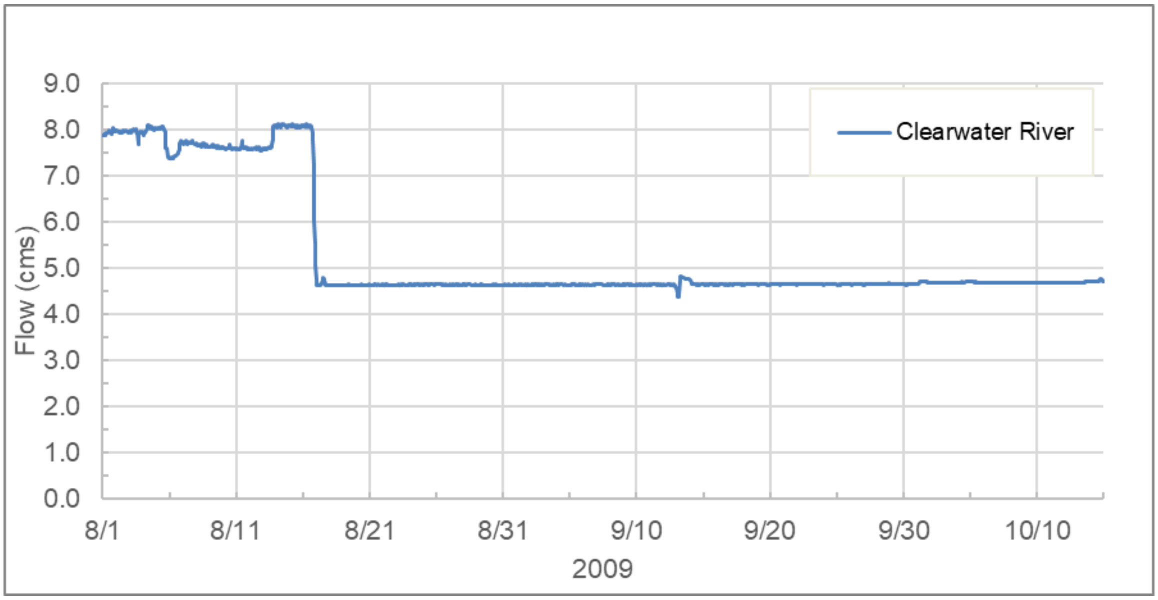

Figure 1-12. Clearwater River tributary flow input to the Toketee Lake riverine model.

1.2.3 Water Temperature Inputs – Toketee Lake Riverine

The No Dams condition models were run sequentially, with water temperature transferred from upstream to downstream, starting with the Lemolo Lake riverine model, followed by Model 1, and then Model 2. Hourly water temperature from the last segment (segment 0) of North Umpqua Model 2 were used to define the upstream boundary for the Toketee Lake riverine model. Figure 1-13 shows the upstream boundary water temperature used in the model.

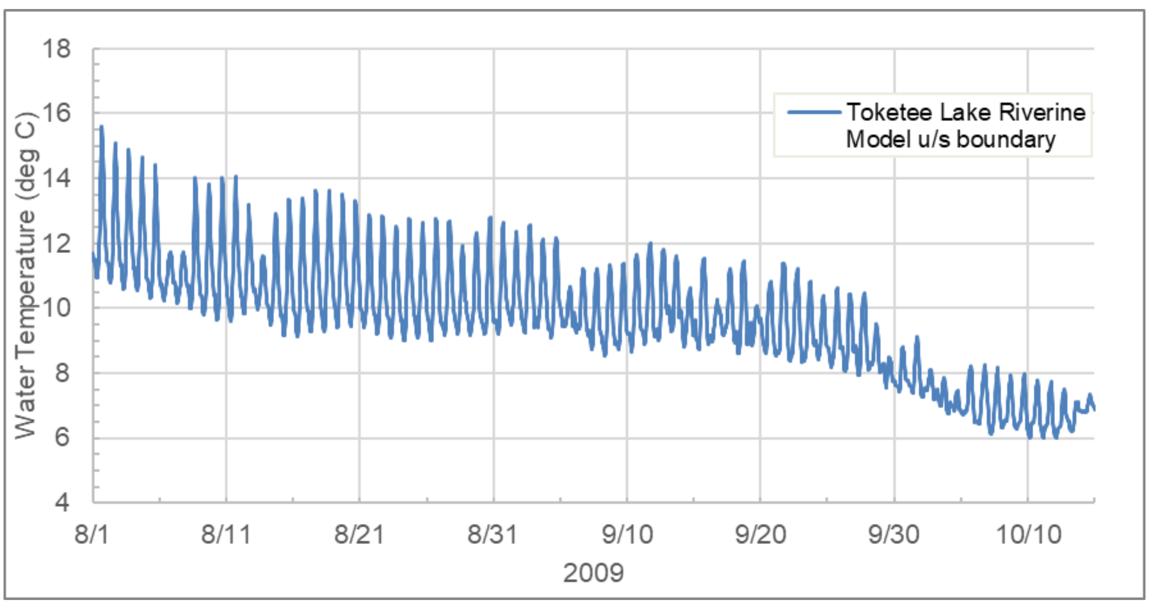

Figure 1-13. Upstream boundary water temperature at North Umpqua upstream of Toketee Lake

Tributary water temperature input from Clearwater River was specified using predicted water temperature from the last segment (segment 0) of the Clearwater River existing condition model. Figure 1-14 shows the hourly water temperature time series for Clearwater River.

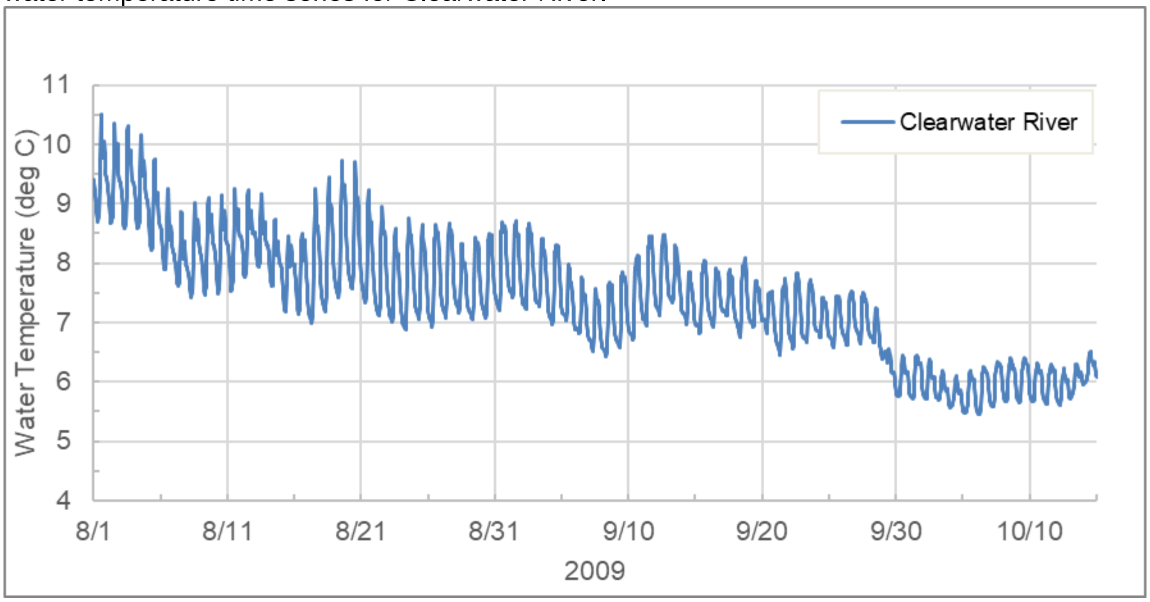

Figure 1-14. Clearwater River tributary water temperature input to the Toketee Lake riverine model

1.2.4 Meteorological Data – Toketee Lake Riverine

The model meteorology was configured using the meteorology from North Umpqua Model 2. The North Umpqua Model 2 model used data from the Toketee Airport weather station and cloud cover from the Roseburg Regional Airport. Similarly, the Toketee Lake riverine model was also configured using meteorological data from the Toketee Airport weather station and cloud cover inputs from the Roseburg Regional Airport.

1.2.5 Model Results – Toketee Lake Riverine

The model was run at a 1-minute time step for the period from August 1 through October 15, 2009. The model was output every 100 meters. The simulated flow and water temperature hourly timeseries at the most downstream segment i.e., at segment 0, which was used to feed into the North Umpqua Model 3, are shown below in Figure 1-15.

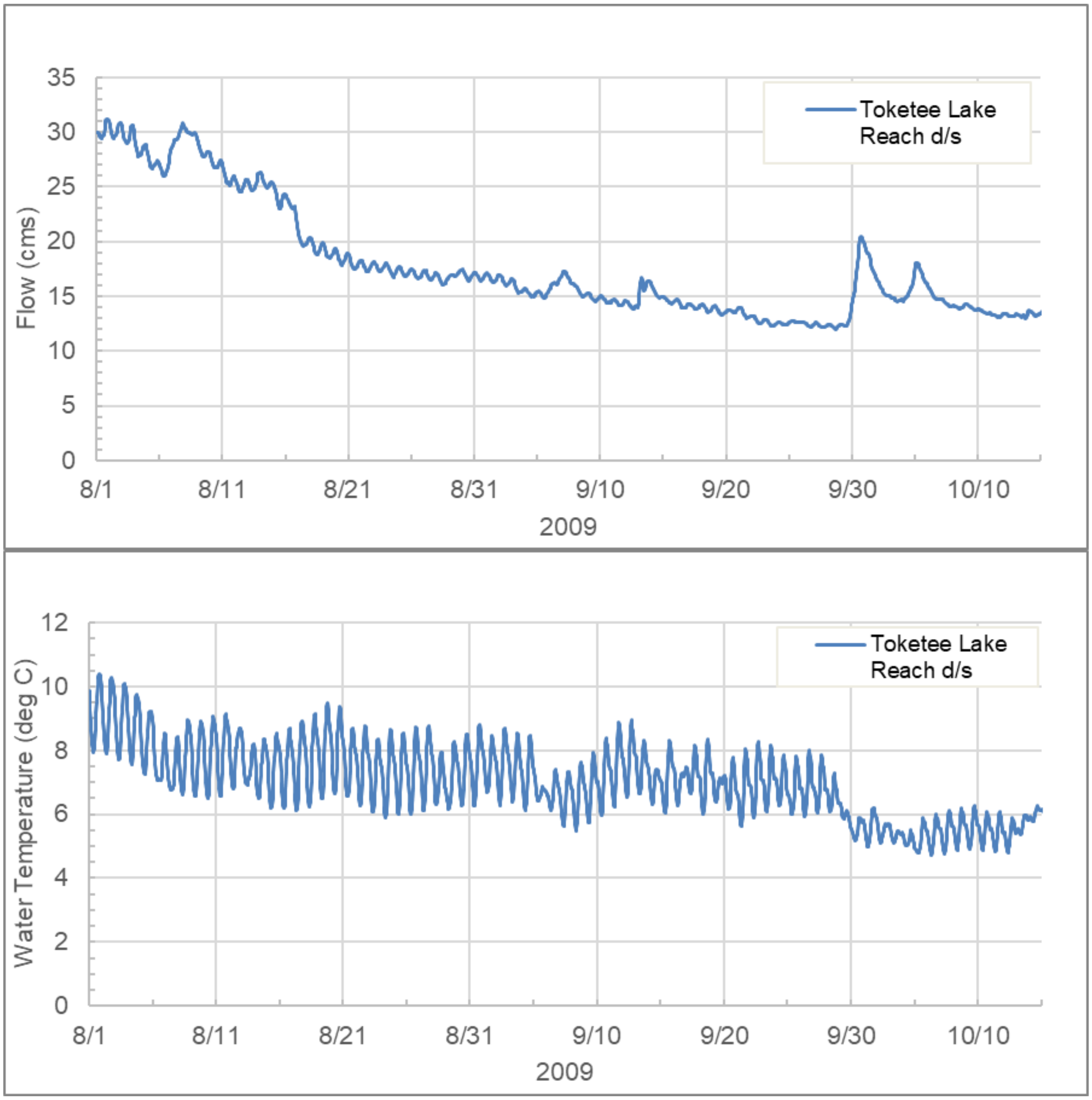

Figure 1-15. Modeled stream flow and temperature at Toketee Lake reach most downstream segment to Model 3

1.3 SODA SPRING RESERVOIR RIVERINE MODEL

1.3.1 Heat Source Model Input – Soda Spring Riverine

As discussed previously in Section 1.1.1 DEQs TTools GIS utility was used to create channel related inputs for the heat source model. The Soda Springs riverine channel was first delineated to be used as input into the TTools program. The channel alignment of the active channel in the vegetation shapefile layer was used to digitize the stream centerline, along with the left and right banks. The delineated left and right banks defined the bank full width of the channel, which was approximately 25 meters wide.

Since the historical channel widths are unknown, the channel width was further confirmed by checking the existing USGS base map and also by viewing and measuring the widths from the historical USGS topographic map from 1917 for the Diamond Lake area. DEQs bare earth LiDAR DEM hill shade (3 ft x 3 ft) (DOGAMI 2021) was available for the Soda Springs area but did not provide sufficient detail to interpret the historical channel. The layer was used as a reference guide during digitization for the channel.

TTools includes five general steps for sampling/extracting data at user defined intervals along the stream, which are outlined below:

Step 1 Used TTools to establish the channel centerline sampling points every 50 meters, beginning at the upstream end of the delineated channel centerline, and the stream length between each node. Each point was then populated with the point latitude/longitude and aspect. Figure 1-16 shows the stream sampling points every 50 meters, along with the RKM for reference. The Soda Springs channel generally flows in a northwesterly direction. Aspect is used to calculate the solar flux on the stream surface based on its orientation. Figure 1-16 shows the calculated channel aspect for each stream sampling point.

Step 2 Calculated the channel width using the distance between the delineated left and right banks established with a line orthogonal to the aspect of each channel centerline point. The calculated channel widths ranged from ranged from 18.9 meters to 27.1 meters, with a mean of 25.4 meters. Channel bottom widths were calculated separately for input into HS8 model using the bank full widths. A separate Excel macro (provided by DEQ) that utilizes the methodology from HS7, was used to calculate the channel bottom width. The macro uses the sampled bank full width, an assumed width to depth ratio and assumed channel angle to calculate the bottom width. The width to depth ratio was assumed to be 10 and the channel angle was assumed to be 0.5 (63.43°). The calculated channel bottom widths used in the model ranged from 16.9 meters to 24.3 meters, with a mean of 22.7 meters.

Step 3 Determined the channel bottom elevations at each point. The elevation was calculated using linear interpolation. Elevation information from the upstream and downstream end of the modeled reach (i.e., from North Umpqua Model 4 and Model 5) were used. The elevations ranged from 551.1 meters to 534 meters across the model domain of 2.3 kilometers. A constant gradient of 0.0075 was specified in the model.

Step 4 Calculated the topographic shading from DEQs bare earth LiDAR DEM (3 ft x 3 ft) (DOGAMI 2021) to sample the topographic shade angles to the east, west, and south of each point in a 10-km search radius. The topographic shading angles ranged from 11.27 to 38.9 degree to the east, 9.71 to 25.9 degrees to the west, and 11.29 to 31 degrees to the south.

Step 5 Determined the vegetation. Landcover from a vegetation raster layer was sampled at each 50-meter node using a dense radial sampling pattern. Four transverse vegetation samples were taken in each of the seven cardinal directions, with the distance between samples taken as 15 meters. This is consistent with the setting used by DEQ for all the North Umpqua models that were previously created.

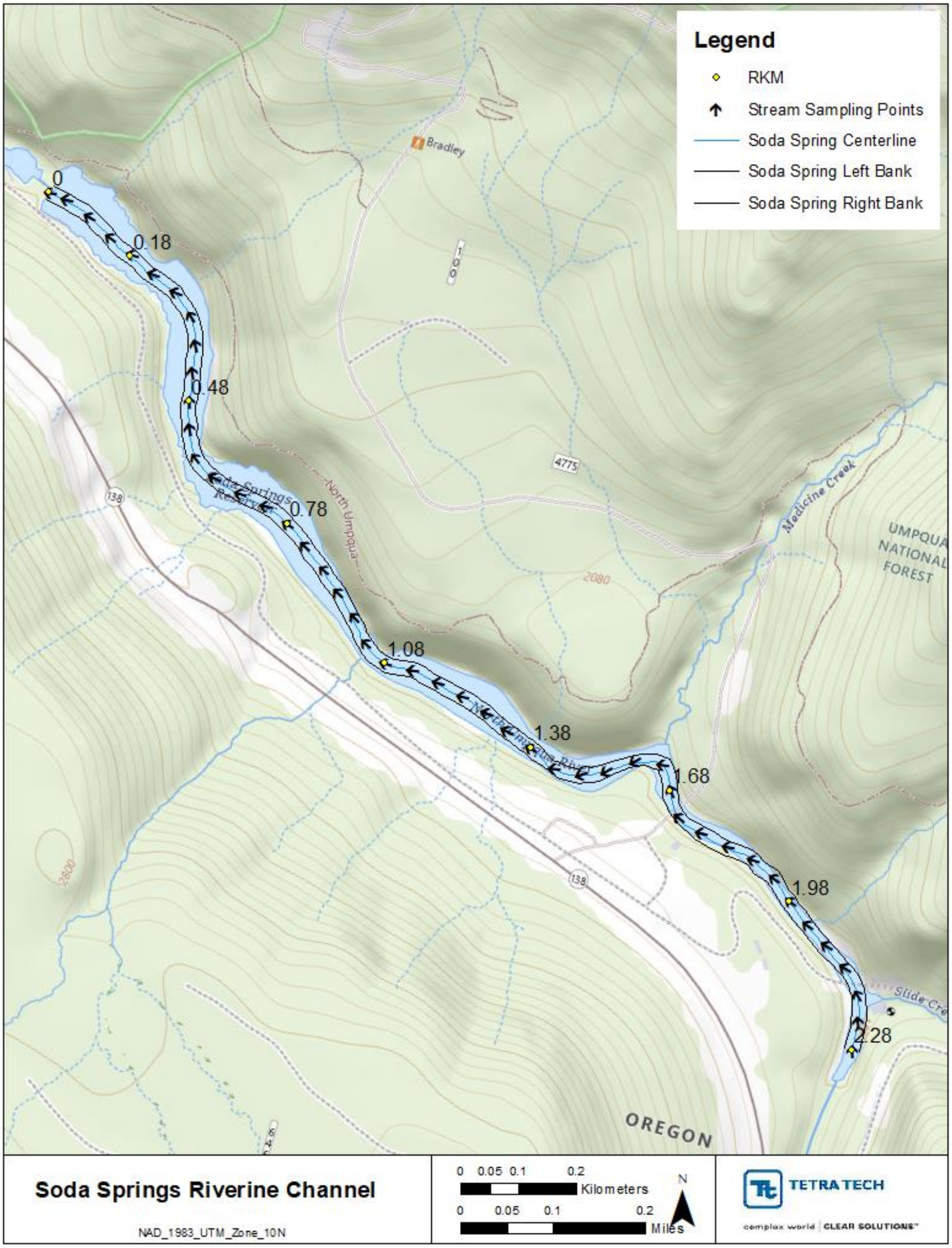

Figure 1-16 Digitized Soda Springs riverine channel and stream sampling points.

The raster vegetation layer used for sampling the vegetation in Step 5 above was created using a vegetation shapefile provided by DEQ. The vegetation shapefile included land cover within the stream buffered at 100-meters from each bank and the resulting buffer was divided into polygons based on the various land cover types. Figure 1-17 shows the near stream landcover within the 100-meter buffer of the left and right channel bank around the Soda Springs riverine channel area. More than 95 percent of the land cover surrounding the channel is large conifers, with some barren soil in the upland areas, and a few areas of small conifer towards the downstream. The vegetation offered the best estimate of the vegetation around the riverine channel based on interpretation from nearby vegetation.

The sampled existing vegetation were converted to fully restored condition for simulating the historical natural conditions when impoundments did not exist. The vegetation conversion to restored vegetation was determined by inspecting the surrounding North Umpqua Models with existing and restored vegetation. In the case of the Soda Springs riverine model, the existing and restored vegetation types in North Umpqua Model 4 and Model 5 were evaluated, and then converted accordingly. Table 1-5 shows the existing and restored vegetation categories, and Table 1-6 shows the vegetation heights for each of the land cover categories used in the Soda Springs riverine model. The vegetation update primarily resulted in conversion of the small number of small conifers to large conifers, and from road to large-mixed conifer-hardwood category. The Barren-Soil land cover was left unchanged similar to what was done in the upstream North Umpqua Model 4 model for the restored vegetation condition.

Table 1-5. Existing and restored vegetation categories in the Soda Springs riverine model.

Land Cover	Soda Spring Reach Codes	Soda Springs Restored Land Cover Code	Notes
Barren - Soil	309	309	No change
Road	400	500	Updated from Road to Large Mixed Conifer-Hardwood
Large Conifer	700	700	No change
Small Conifer	701	700	Updated from Small Conifer to Large Conifer
Active River Channel	3011	3011	No change
Canal	3255	3011	Updated from Dam/Weir to river channel

Table 1-6. Land cover information used in the Soda Springs riverine model.

Land Cover Name	Code	Height (m)	Density (0 - 1)	Overhang (m)
Barren - Soil	309	0.0	0%	0.0
Road	400	0.0	0%	0.0
Large Mixed Conifer-Hardwood	500	30.5	65%	0.0
Large Conifer	700	45.7	80%	0.0
Small Conifer	701	15.0	80%	0.0
Active River Channel	3011	0.0	0%	0.0
Canal	3255	0.0	0%	0.0

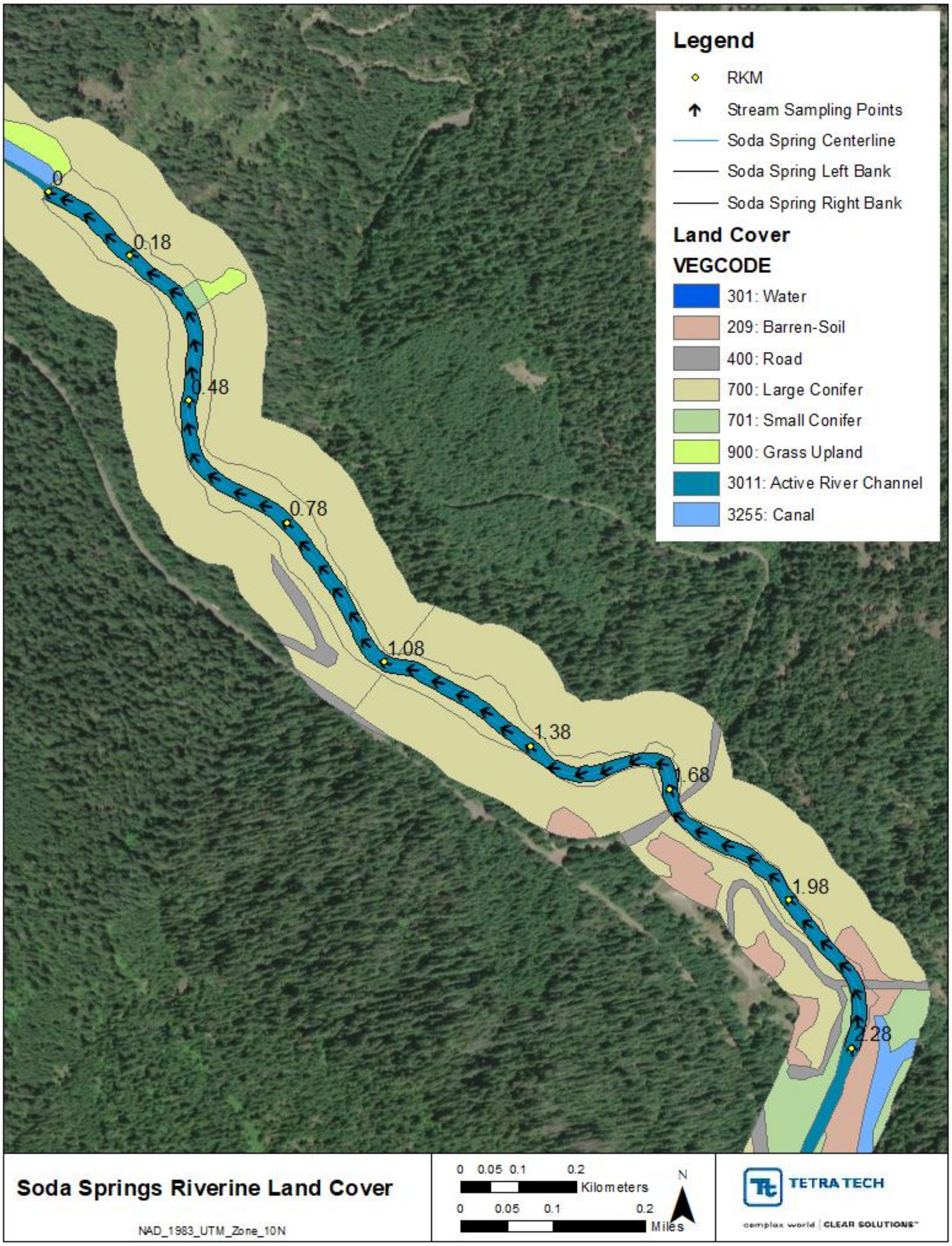

Figure 1-17 Digitized near stream land cover for Soda Spring Reservoir riverine channel.

Manning's roughness coefficient values in the North Umpqua Model models vary significantly. The Manning's N values across all the North Umpqua models (Models 1 through 5) ranged from 0.04 to 0.35, with a mean of 0.12 and median of 0.1. The mean Manning's N value of 0.12 was assumed for the Soda Springs Reservoir modeled reach. This value was assumed for all riverine reach models since no detailed channel information is available, and calibration of such a model is not possible.

1.3.2 Flow and Water Temperature Data Inputs – Soda Spring riverine

The No Dams condition models were run sequentially, with flow and water temperature transferred from upstream to downstream, starting with the Lemolo Lake riverine model, followed by Model 1, Model 2, the Toketee Lake riverine model, Model 3, and finally Model 4. Hourly flows and water temperature from the last segment (segment 0) of North Umpqua Model 4 were used to define the upstream boundary for the Soda Springs riverine model. Figure 1-18 and Figure 1-19 show the upstream boundary flows and water temperatures used in the model. There are no tributary inputs to Soda Springs.

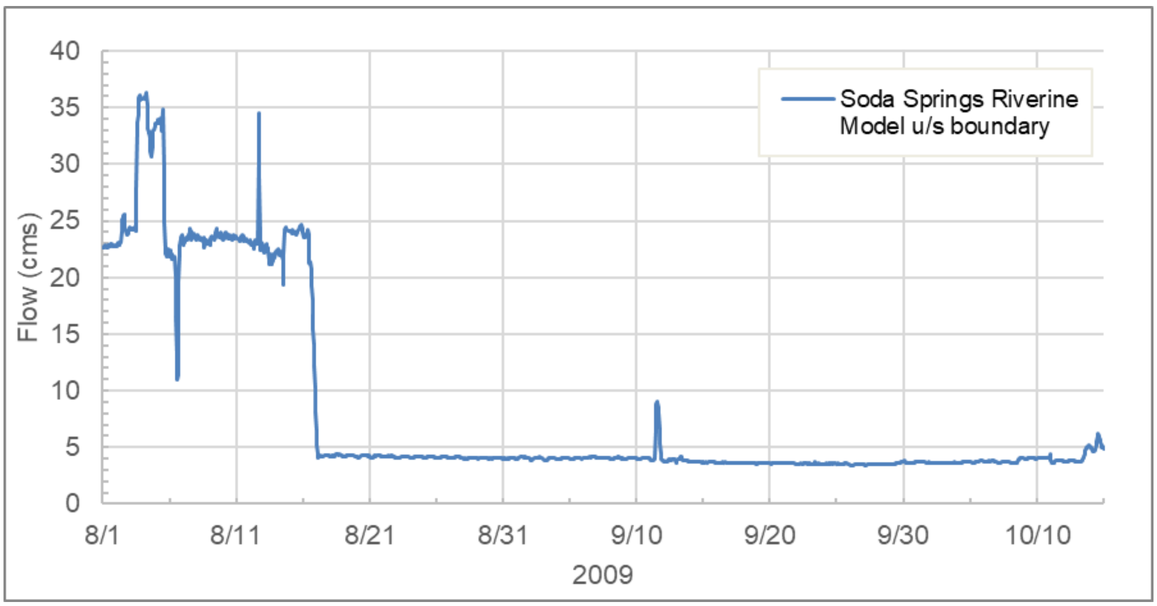

Figure 1-18. Upstream boundary flow at North Umpqua upstream of Soda Springs

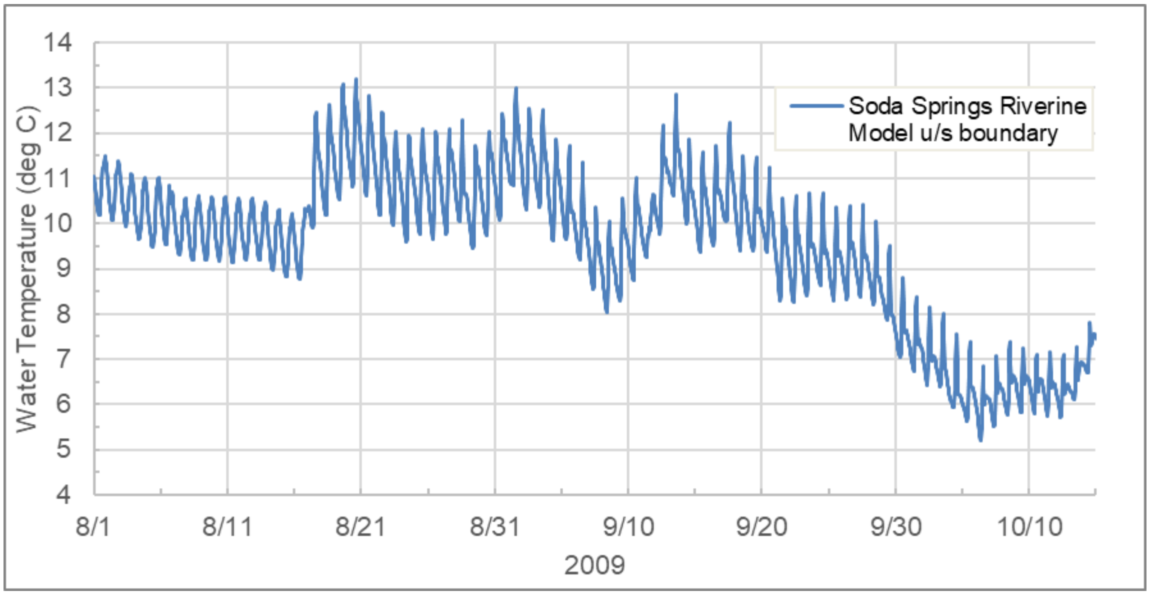

Figure 1-19. Upstream boundary water temperature at North Umpqua upstream of Soda Springs

1.3.3 Meteorological Data – Soda Spring riverine channel

The model meteorology was configured using the meteorology from North Umpqua Model 4, which feeds into the Soda Springs model. The North Umpqua Model 4 model used data from the Toketee Airport weather station and cloud cover from the Roseburg Regional Airport. Similarly, the Soda Springs riverine model was also configured using meteorological data from the Toketee Airport weather station and cloud cover inputs from the Roseburg Regional Airport.

1.3.4 Model Results – Soda Springs riverine channel

The model was run at a 1-minute time step for the period from August 1 through October 15, 2009. The model was output every 100 meters. The simulated flow and water temperature hourly timeseries at the most downstream segment i.e., at segment 0, which was used to feed into the North Umpqua Model 5, are shown below in Figure 1-20.

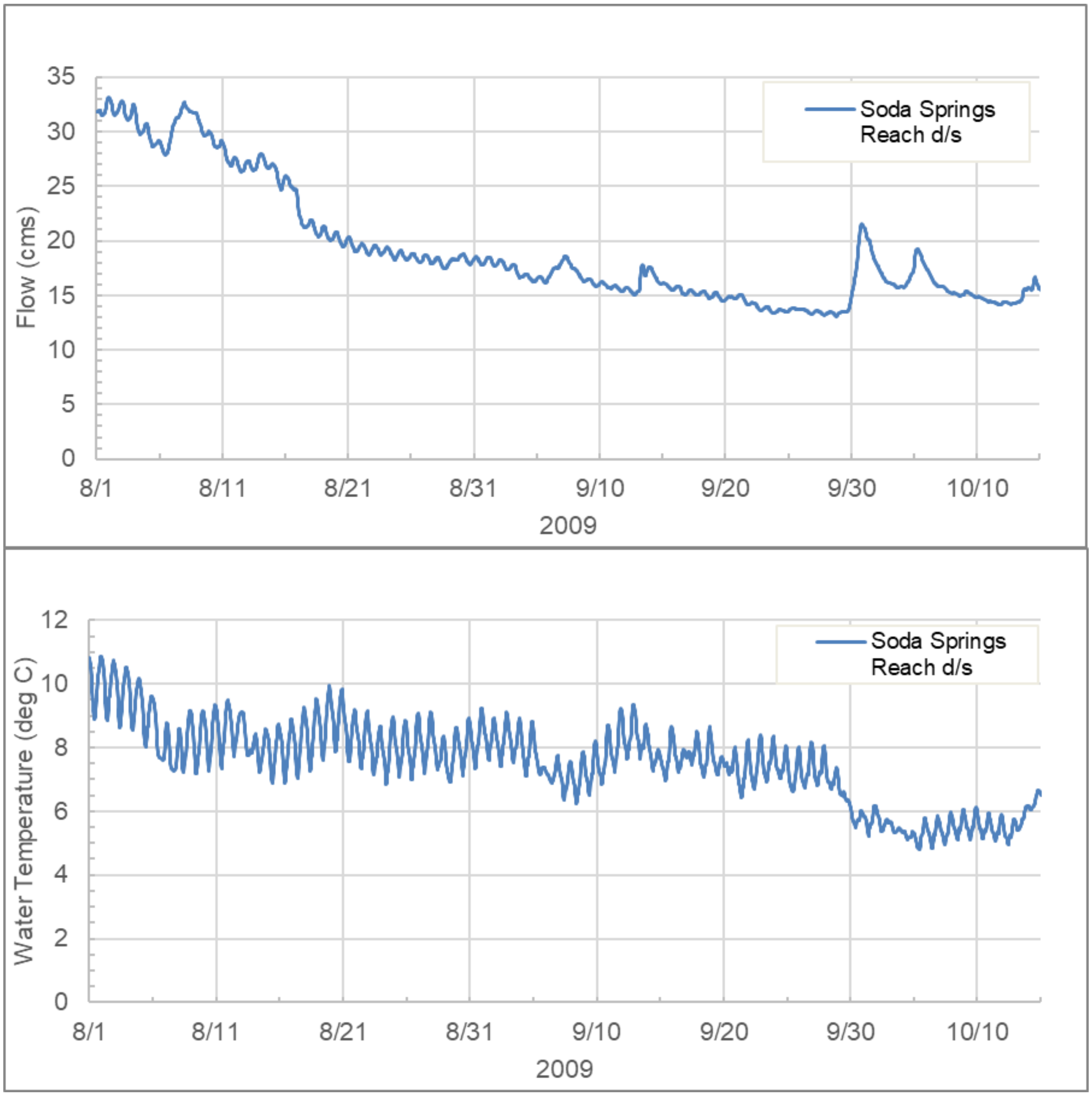

Figure 1-20. Modeled stream flow and temperature at Soda Springs reach most downstream segment to Model 5

2.0 NO DAMS SCENARIOS

The riverine Heat Source models developed in place of each of the three impoundments—Lemolo Lake, Toketee Lake, and Soda Springs Dam—along the North Umpqua River, were used to simulate conditions for the No Dams scenario. All the Heat Source models along North Umpqua (Models 1 through 5) were run sequentially from upstream to downstream, with each model feeding into the next model downstream, to evaluate the impacts of No Dams along the system. As discussed previously the models were developed for the period from August 1, 2009, to October 15, 2009. The scenarios and the individual settings of the five scenarios are discussed below.

1. Calibrated Current Condition (CCC) scenario.
   The CCC scenario uses the vegetation conditions, flow and temperature inputs from upstream/headwater and tributaries identical to the calibration condition as well as withdrawals. The only difference is that if a model includes point sources, the more recent available flow and temperature from the point sources was used to replace the flow and temperature from the point sources that were used for model calibration. Due to the

limitation of data availability, the time period for the latest available flow and temperature from different point source may not be the same. For models without point sources, the CCC scenario is essentially identical to the calibration condition.

2. No Dams scenario
   This No Dams scenario evaluated the impact of removing dams from the riverine system. The No Dams models were run using the riverine reach models to evaluate natural conditions along the riverine reaches. The No Dams model run was made by running and linking the North Umpqua models sequentially from upstream at the Lemolo Lake riverine reach downstream to the mouth of the North Umpqua. The riverine reach models for the existing impoundments were configured with restored vegetation, and all the other models were based on the CCC vegetation condition. The tributary inputs were set at CCC condition. This allowed for evaluating the impacts of dams alone.

3. No Dams background condition scenario
   This scenario evaluated the impact of the No Dams fully restored vegetation condition. For the No Dams background condition model run, the riverine reach models for the existing impoundments and all the other riverine models were configured using fully restored vegetation. These models were run sequentially from upstream to downstream by transferring the predicted flow and water temperature to the upstream boundary of each downstream model. All tributary inputs were set at CCC condition.

Additional scenarios were evaluated only for North Umpqua Model 5. The North Umpqua Model 5 model domain is from Soda Springs PH to the mouth, which is where the spawning criterion applies. North Umpqua Model 5 allows for evaluating criterion attainment at the mouth, before the confluence with the Umpqua River. The No Dams with background condition model was used as the basis for evaluation for the scenarios described below.

4. PacifiCorp allocation scenario
   This scenario evaluates the impacts due to the PacifiCorp hydroelectric project downstream of Soda Springs. Flows and water temperature were extracted from the last segment of the Soda Springs riverine model. The water temperature from the last segment of the Soda Springs riverine model was updated by adding 0.3 °C to account for the human use allowance (HUA) assigned to this operation. The resulting water temperature (and flow from last segment of Soda Spring Riverine Model) formed the upstream boundary of Model 5. No other changes were made to the inputs in Model 5.

5. Total Attainment Scenario
   This scenario builds on the PacifiCorp allocation scenario i.e., adding 0.3 °C to the water temperature from the last segment of the Soda Spring riverine model. In addition, to the PacifiCorp allocation, the point source Glide-Idleyld is set at WLA condition, and a 0.3 °C temperature is directly added to the Rock Creek tributary temperature time series. The 0.3 °C temperature is added to Rock Creek water temperature input to the North Umpqua, to account for evaluating a HUA for the Rock Creek Hatchery that is an input to Rock Creek.

The various No Dams condition related scenarios evaluated along North Umpqua are shown below and are provided in the following section below.

B1. No Dams, impact of removing dams upstream (Spawning models for North Umpqua models 1 to 5)
  - ✓ CCC minus No Dams

The following scenarios were evaluated only for North Umpqua Model 5:

B2. Impact of No Dams fully restored condition
  - ✓ No Dams Background minus Criteria

B3. PacifiCorp allocation evaluation under fully restored conditions:
  - ✓ [Soda Spring No Dams Fully Restored Vegetation + 0.3 °C] minus [No Dams Fully Restored Vegetation]

B4. Total Attainment of PacifiCorp and point source at WLA under fully restored conditions:
- ✓ [Soda Spring No Dams Fully Restored Vegetation + 0.3 °C; Rock Creek + 0.3 °C; Glide-Idleyld at WLA minus [No Dams Fully Restored Vegetation

2.1 NORTH UMPQUA RIVER 1 (LEMOLO RESERVOIR TO LEMOLO POWERHOUSE #1)

The North Umpqua River Model 1 No Dams model does not include any point sources and receives input from the riverine Lemolo Lake model, which forms the upstream boundary for this model. The CCC model boundaries were configured using observed flow and water temperature data, whereas the No Dams scenario was configured using input from the last segment of the riverine Lemolo Lake model. The flow and water temperature time series from the last segment of the riverine Lemolo Lake model are shown in Figure 1-8 of Appendix A.

The scenarios that are relevant to the No Dams comparison for the North Umpqua River Model 1 include the CCC scenario and the No Dams scenario. The 7DADM temperature results are shown in Figure 2-1 and Figure 2-2 for these scenarios. The year-round Salmon and Trout Rearing and Migration: 18.0 °C criterion applies to North Umpqua Model 1 and was evaluated for the entire modeling period from August 1 to October 15, 2009.

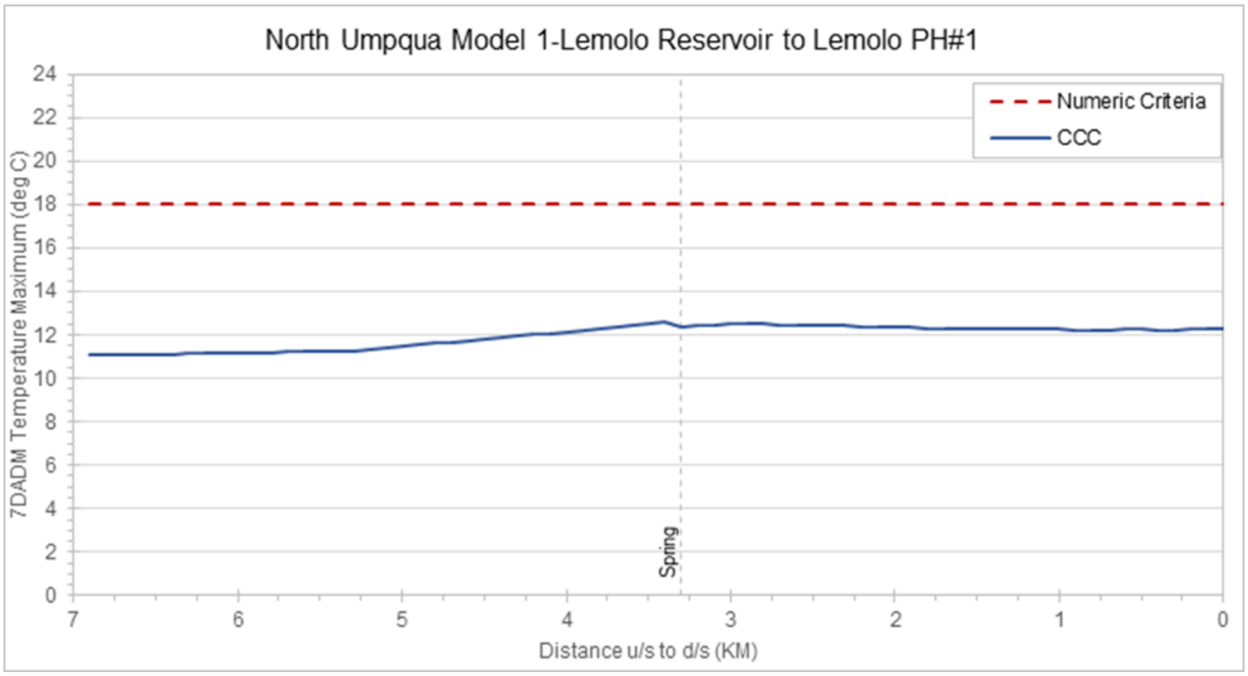

Figure 2-1. The maximum 7DADM temperature results along the North Umpqua River model 1 for the Current Conditions scenario

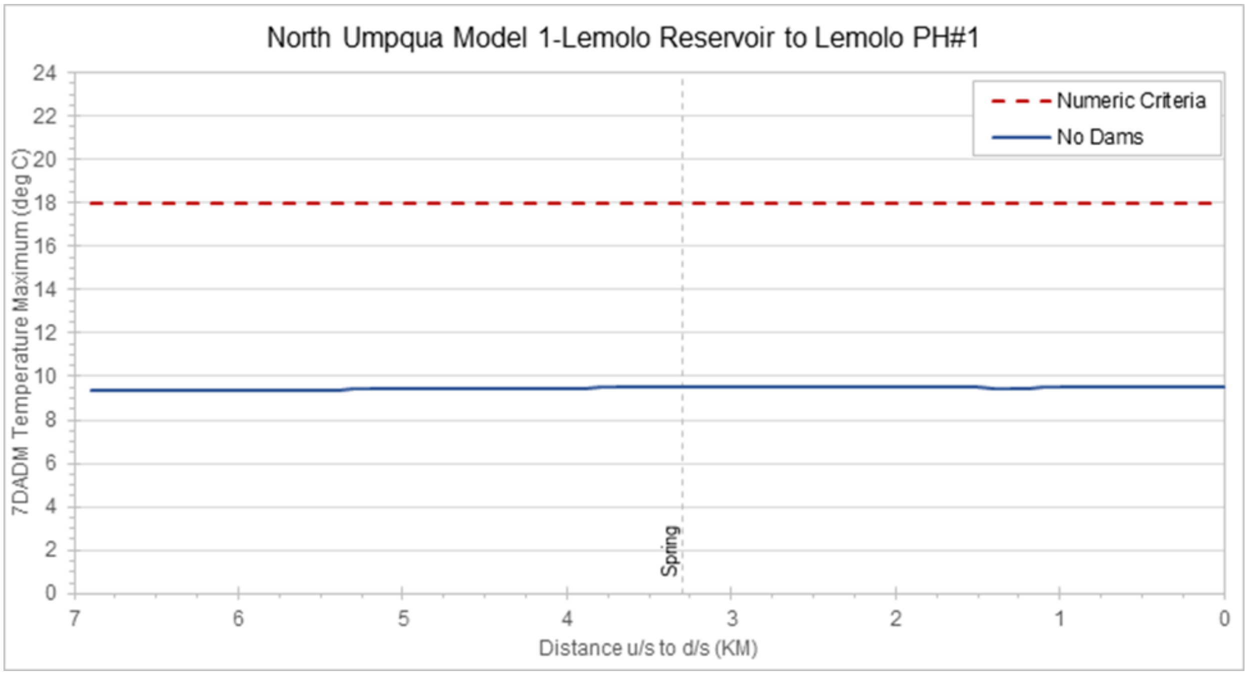

Figure 2-2. The maximum 7DADM temperature results along the North Umpqua River model 1 for the No Dams condition scenario

2.1.1 North Umpqua River Model 1 Scenario Comparison

The following No Dams condition related scenario was evaluated and is discussed in the following section below.
B1. No Dams, impact of removing dams upstream

- ✓ CCC minus No Dams

Figure 2-3 shows the results of comparison B1 for the impacts of dams, which is the change in 7DADM temperatures between the CCC scenario and No Dams scenario. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change (0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). The difference between these two scenarios is the upstream boundary condition that reflects the conditions with and without Lemolo Lake impoundment. Although the 7DADM results show that dams cause warming, with warmer temperatures seen in the CCC compared to No dams (Figure 2-1 and Figure 2-2), there is no maximum delta calculated for this scenario, since the 7DADM temperatures for the scenarios are below the criterion ~~BBNC~~ (Table 2-1).

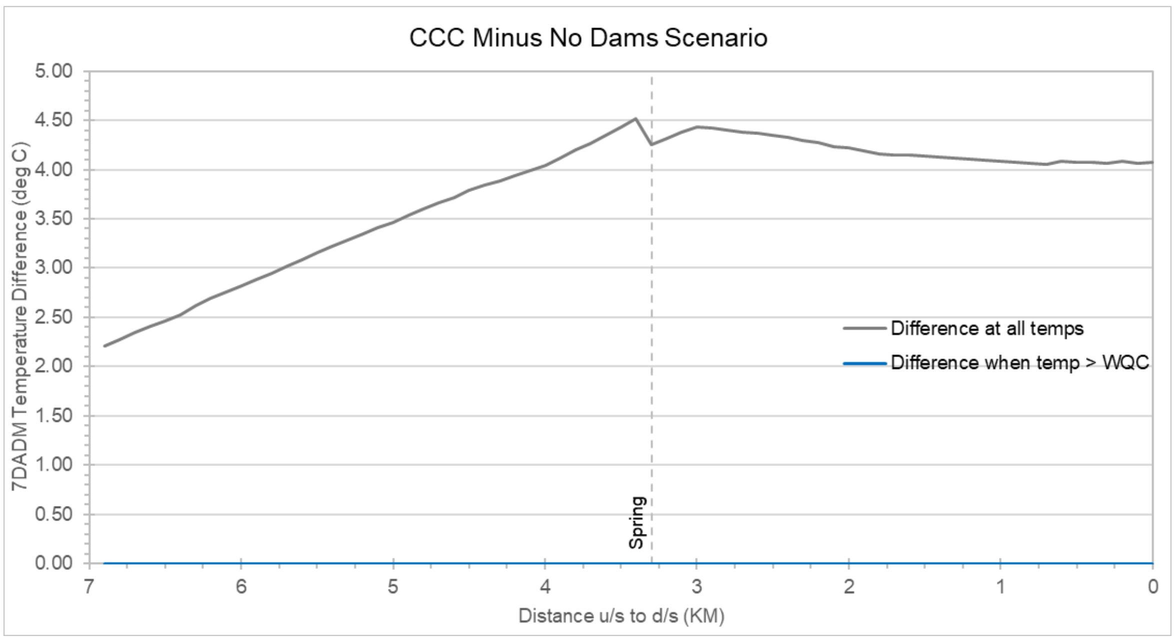

Figure 2-3. The maximum 7DADM temperature difference results along the North Umpqua River model 1 for the No Dams condition scenario

Table 2-1 Location and date of maximum delta when temperatures are greater than criterion (comparison B1) along North Umpqua River model 1

North Umpqua #1	RKM (river kilometer)	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Dams Scenario	N/A	N/A	N/A

2.2 NORTH UMPQUA RIVER 2 (LEMOLO POWERHOUSE #1 TO TOKETEE RESERVOIR)

The North Umpqua River Model 2 No Dams model does not include any point sources and receives input from the No Dam condition North Umpqua Model 1, which forms the upstream boundary for this model. Note that the CCC model boundaries are configured using observed flow and water temperature data.

The scenarios that are relevant to the No Dams comparison for the North Umpqua River Model 2 include the CCC scenario and the No Dams scenario. The 7DADM temperature results are shown in Figure 2-4 and Figure 2-5 for these scenarios. The year-round Salmon and Trout Rearing and Migration: 18.0 °C criterion applies to North Umpqua Model 2 and was evaluated for the entire modeling period from August 1 to October 15, 2009.

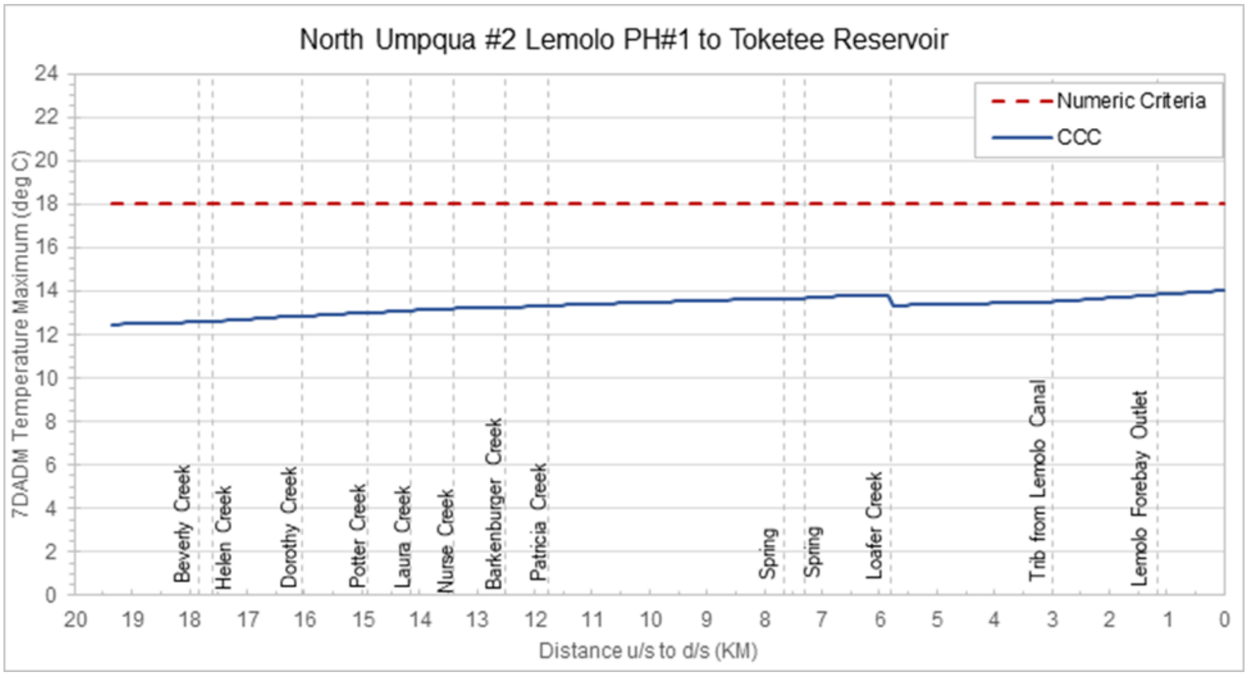

Figure 2-4. The maximum 7DADM temperature results along the North Umpqua River model 2 for the Current Conditions scenario

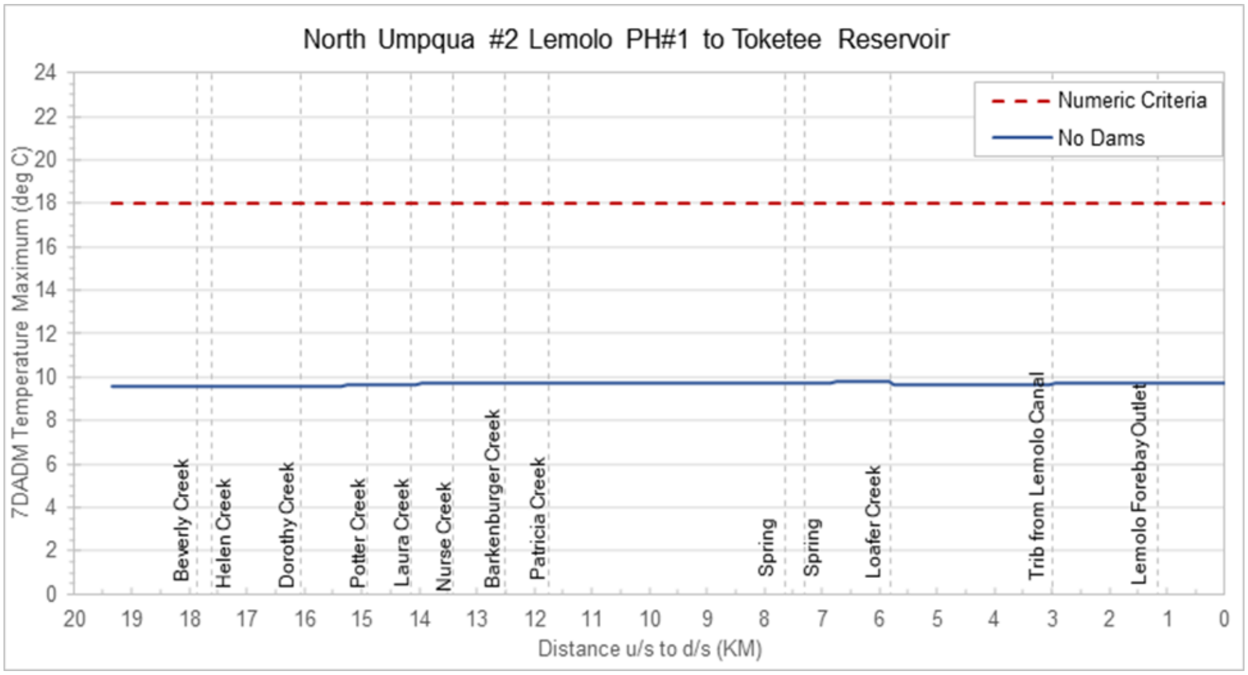

Figure 2-5. The maximum 7DADM temperature results along the North Umpqua River model 2 for the No Dams condition scenario

2.2.1 North Umpqua River Model 2 Scenario Comparison

The following No Dams condition related scenario was evaluated and is discussed in the following section below.

B1. No Dams, impact of removing dams upstream
- ✓ CCC minus No Dams

Figure 2-6 shows the results of comparison B1 for the impacts of dams, which is the 7DADM temperature difference between the CCC scenario and No Dams scenario. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change (0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). The difference between these two scenarios is the upstream boundary condition that reflects the conditions with and without Lemolo Lake impoundment. Although the 7DADM results show that dams cause warming, with warmer temperatures seen in the CCC compared to No Dams (Figure 2-4 and Figure 2-5), there is no maximum delta calculated for this scenario, since the 7DADM temperatures for the scenarios are below the BBNC (Table 2-2).

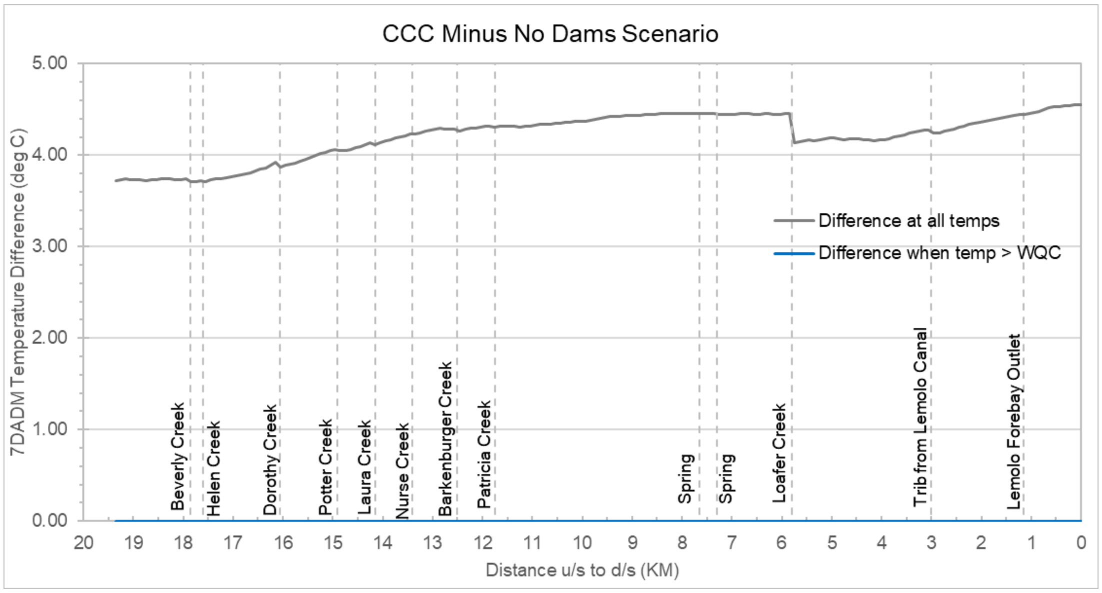

Figure 2-6. The maximum 7DADM temperature difference results along the North Umpqua River model 2 for the No Dams condition scenario

Table 2-2 Location and date of maximum delta when temperatures are greater than criterion (comparison B1) along North Umpqua River model 2

North Umpqua #2	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Dams Scenario	N/A	N/A	N/A

2.3 NORTH UMPQUA RIVER 3 (TOKETEE RESERVOIR TO SLIDE POWERHOUSE)

The North Umpqua River Model 3 No Dams model does not include any point sources and receives input from the riverine Toketee Lake model, which forms the upstream boundary for this model. The flow and water temperature time series from the last segment of the riverine Toketee Lake model are shown in Figure 1-15 in Appendix A. Note that the CCC model boundaries are configured using observed flow and water temperature data.

The scenarios that are relevant to the No Dams comparison for the North Umpqua River Model 3 include the CCC scenario and the No Dams scenario. The 7DADM results are shown in Figure 2-7 and Figure 2-8 for these scenarios. Note that the year-round Salmon and Trout Rearing and Migration: 18.0 ^{o}C criterion applies to North Umpqua Model 3 and was evaluated for the entire modeling period from August 1 to October 15, 2009.

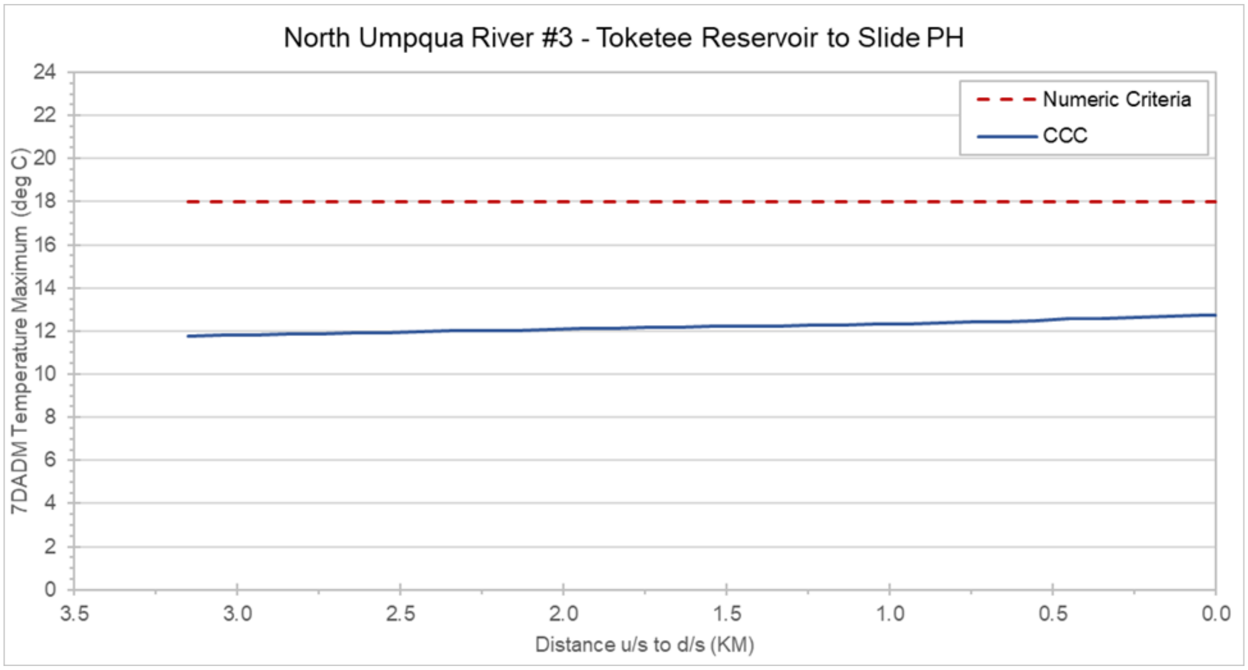

Figure 2-7. The maximum 7DADM temperature results along the North Umpqua River model 3 for the Current Conditions scenario

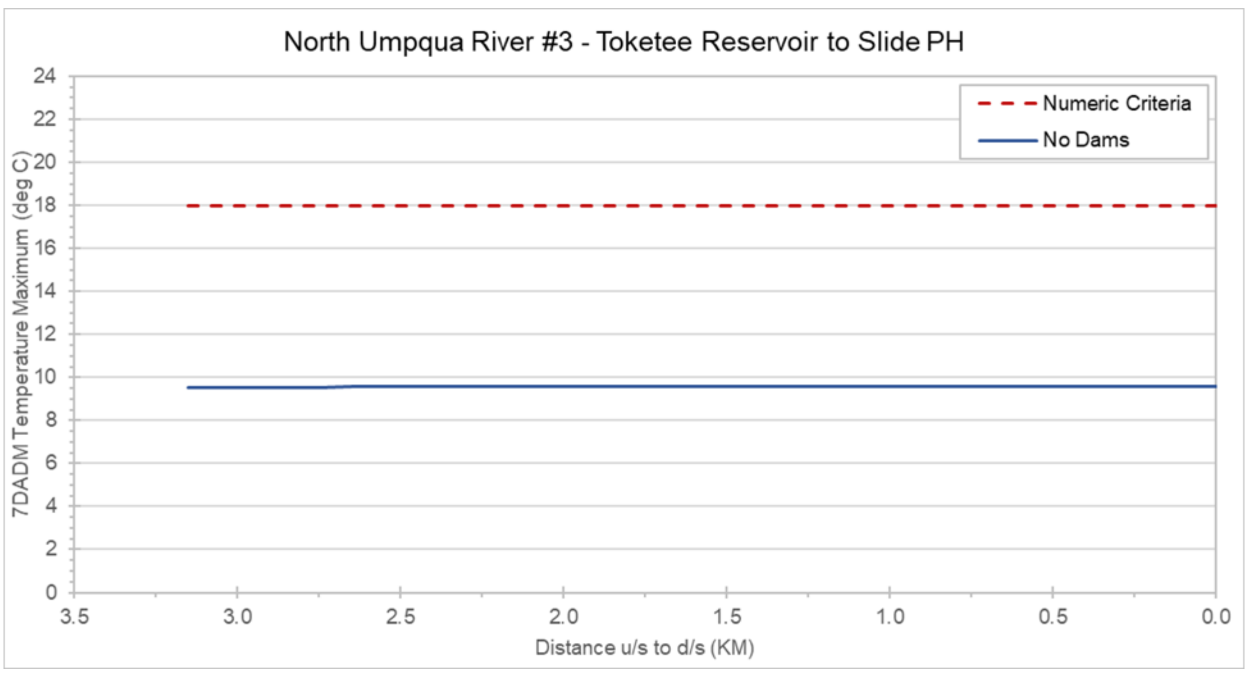

Figure 2-8. The maximum 7DADM temperature results along the North Umpqua River model 3 for the No Dams condition scenario

2.3.1 North Umpqua River Model 3 Scenario Comparison

The following No Dams condition related scenario was evaluated and is discussed in the following section below.

B1. No Dams, impact of removing dams upstream
- ✓ CCC minus No Dams

Figure 2-9 shows the results of comparison B1 for the impacts of dams, which is the 7DADM temperature difference between the CCC scenario and No Dams scenario. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change (0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). The difference between these two scenarios is the upstream boundary condition that reflects the conditions upstream with and without Lemolo Lake and Toketee Lake impoundments. Although the 7DADM results show that dams cause warming, with warmer temperatures seen in the CCC compared to No dams (Figure 2-7 and Figure 2-8), there is no maximum delta calculated for this scenario, since the 7DADM temperatures for the scenarios are below the BBNC (Table 2-3).

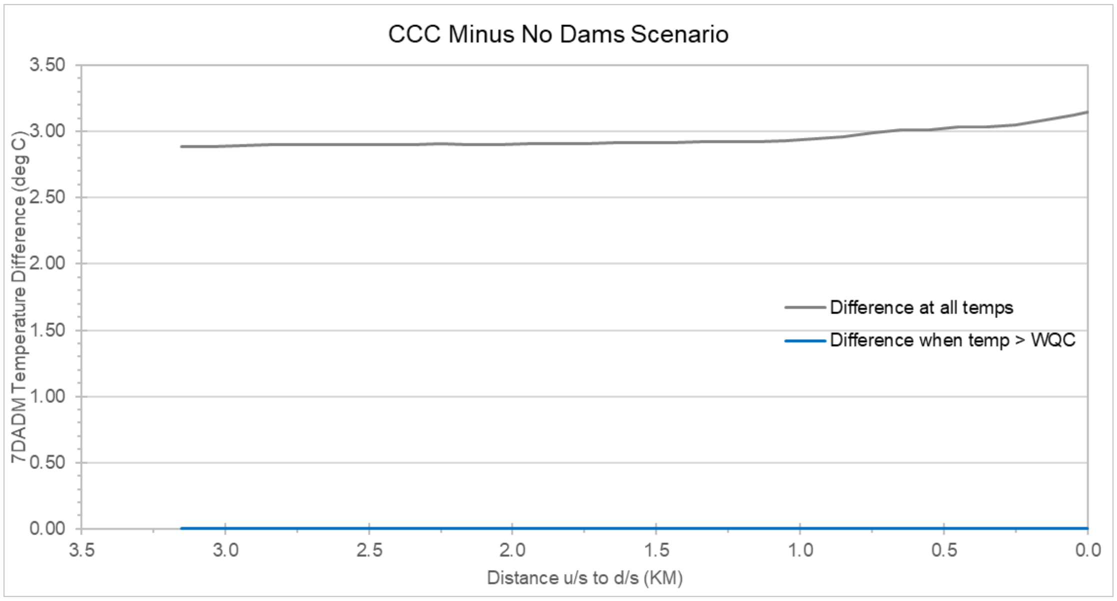

Figure 2-9. The maximum 7DADM temperature difference results along the North Umpqua River model 3 for the No Dams condition scenario

Table 2-3 Location and date of maximum delta when temperatures are greater than criterion (comparison B1) along North Umpqua River model 3

North Umpqua #3	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Dams Scenario	N/A	N/A	N/A

2.4 NORTH UMPQUA RIVER 4 (SLIDE POWERHOUSE TO SODA SPRINGS RESERVOIR)

The North Umpqua River Model 4 No Dams model does not include any point sources and receives input from the No Dam condition North Umpqua Model 3, which forms the upstream boundary for this model. Note that the CCC model boundaries are configured using observed flow and water temperature data.

The scenarios that are relevant to the No Dams comparison for the North Umpqua River Model 4 include the CCC scenario and the No Dams scenario. The 7DADM temperature results are shown in Figure 2-10 and Figure 2-11 for these scenarios. Note that the year-round Salmon and Trout Rearing and Migration: 18.0 ºC criterion applies to North Umpqua Model 4 and was evaluated for the entire modeling period from August 1 to October 15, 2009.

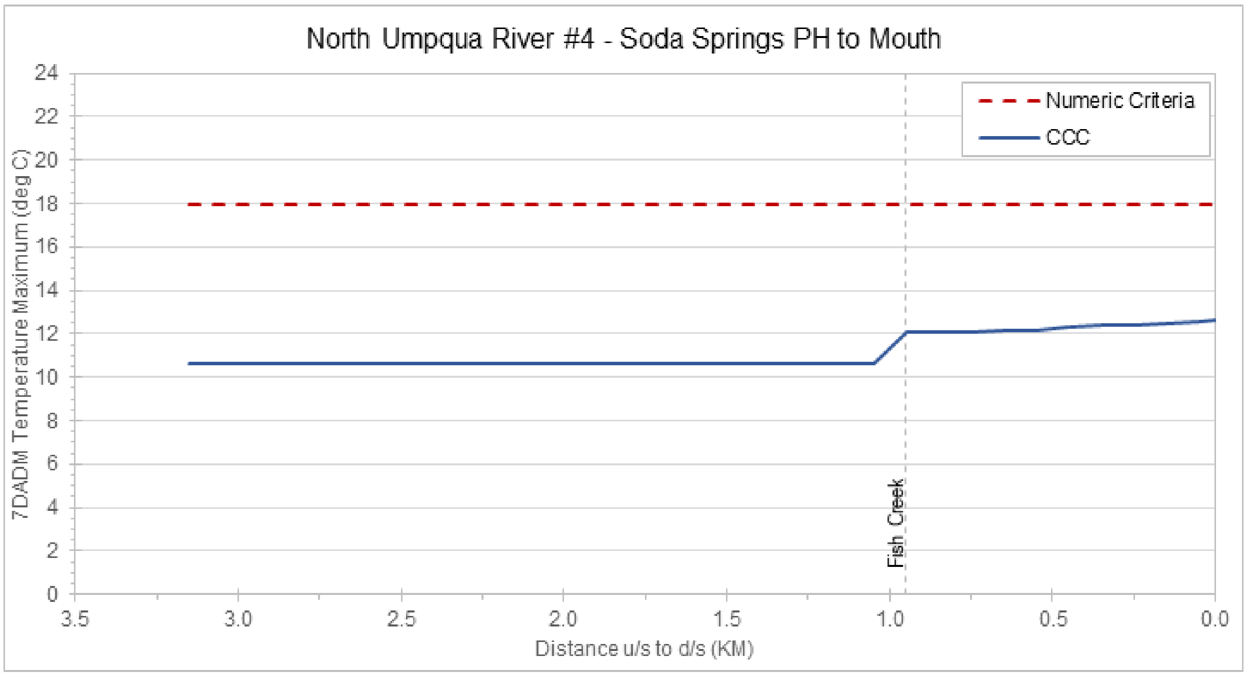

Figure 2-10. The maximum 7DADM temperature results along the North Umpqua River model 4 for the Current Conditions scenario

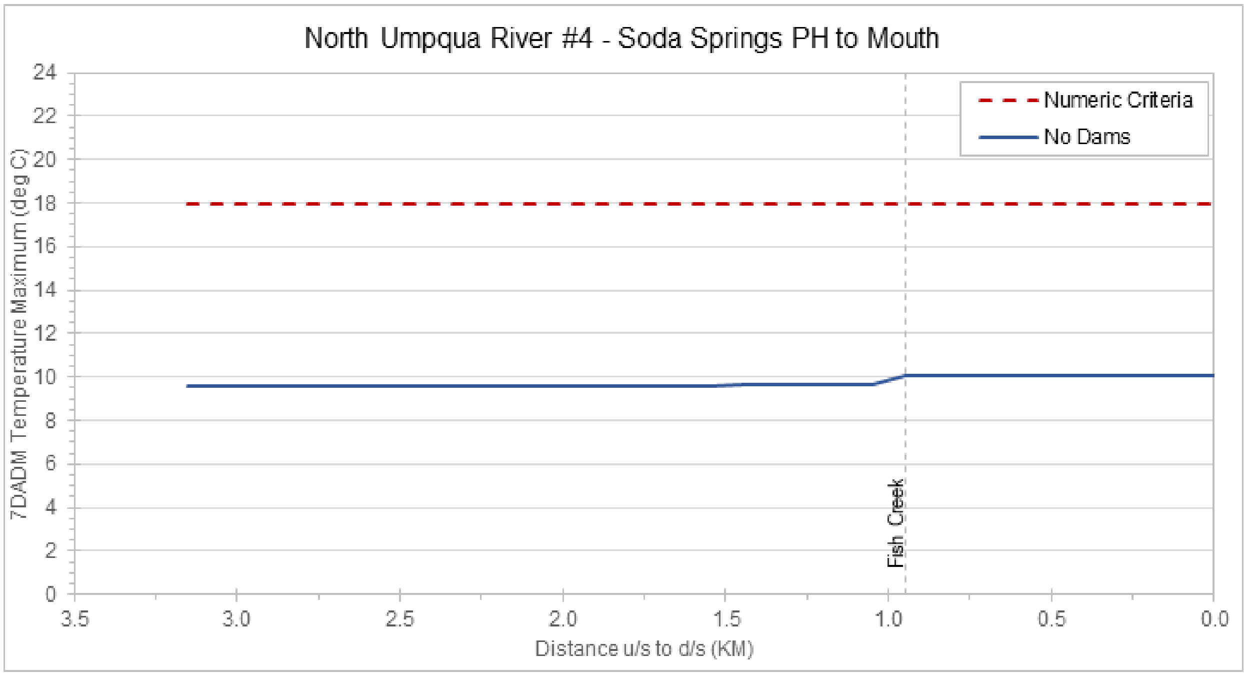

Figure 2-11. The maximum 7DADM temperature results along the North Umpqua River model 4 for the No Dams condition scenario

2.4.1 North Umpqua River Model 4 Scenario Comparison

The following No Dams condition related scenario was evaluated and is discussed in the following section below.

B1. No Dams, impact of removing dams upstream

- ✓ CCC minus No Dams

Figure 2-12 shows the results of comparison B1 for the impacts of dams, which is the 7DADM temperature difference between the CCC scenario and No Dams scenario. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change (0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). The difference between these two scenarios is the upstream boundary condition that reflects the conditions upstream with and without Lemolo Lake and Toketee Lake impoundments. Although the 7DADM results show that dams cause warming, with warmer temperatures seen in the CCC compared to No dams (Figure 2-10 and Figure 2-11), there is no maximum delta calculated for this scenario, since the 7DADM temperatures for the scenarios are below the BBNC (Table 2-4).

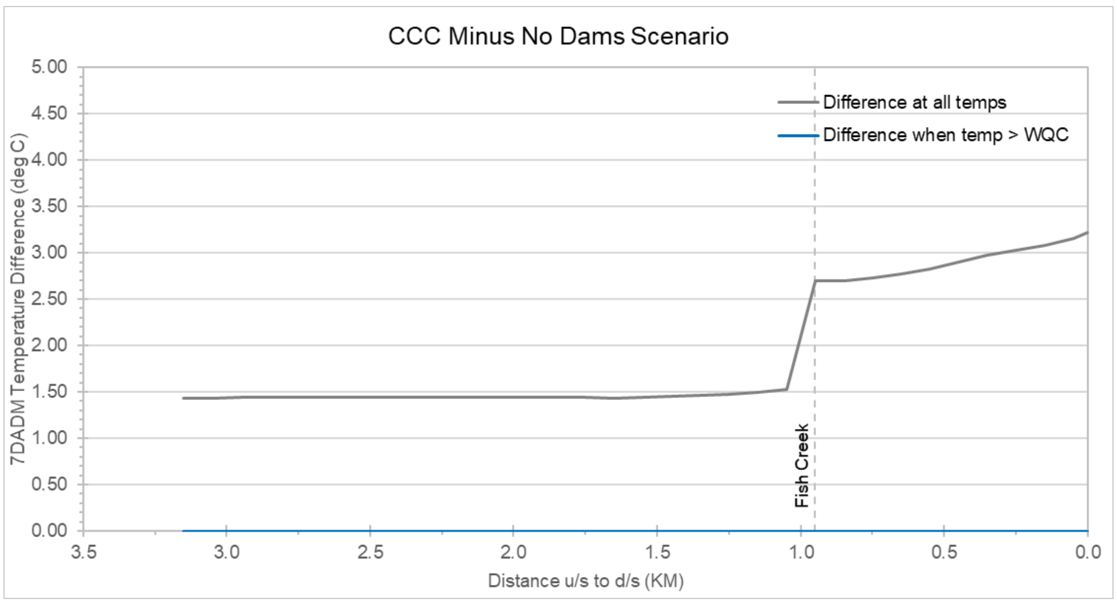

Figure 2-12. The maximum 7DADM temperature difference results along the North Umpqua River model 4 for the No Dams condition scenario

Table 2-4 Location and date of maximum delta when temperatures are greater than criterion (comparison B1) along North Umpqua River model 4

North Umpqua #4	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Dams Scenario	N/A	N/A	N/A

2.5 NORTH UMPQUA RIVER 5 (SODA SPRINGS RESERVOIR TO THE MOUTH)

The North Umpqua River Model 5 for the No Dams scenario receives input from the riverine Soda Springs Reservoir model, which forms the upstream boundary for this model, and also includes the Glide-Idleyld Sanitary District point source and Rock Creek (which receives input from the Rock Creek Hatchery). The flow and water temperature time series from the last segment of the riverine Soda Springs Reservoir model are shown in Figure 1-20 in Appendix A. Note that the CCC model boundaries are configured using observed flow and water temperature data.

Spawning period and Year-round criterion apply to North Umpqua Model 5 below Soda Springs Reservoir. The North Umpqua River Model 5 was evaluated for two periods (i) Summer period from August 1 to 31, 2009, and the (ii) Spawning period from September 1 to October 15, 2009. The Summer period was evaluated against the year-round Core Cold Water Habitat: 16.0 ºC criterion, and the spawning period was evaluated against the Salmon and Steelhead Spawning: 13.0 ºC criterion that apply to this portion of North Umpqua.

2.5.1 North Umpqua River Model 5 Summer Period

The summer period was evaluated for the period from August 1 to 31, 2009 against the year-round criterion. The scenarios that are relevant to the No Dams comparison for the North Umpqua River Model 5 included the CCC scenario, No Dams scenario, No Dams background scenario, the PacifiCorp allocation scenario, and the Total Attainment scenario. A description of the scenarios can be found in Section 2.0. The 7DADM results for these scenarios are shown in Figure 2-13 through Figure 2-17.

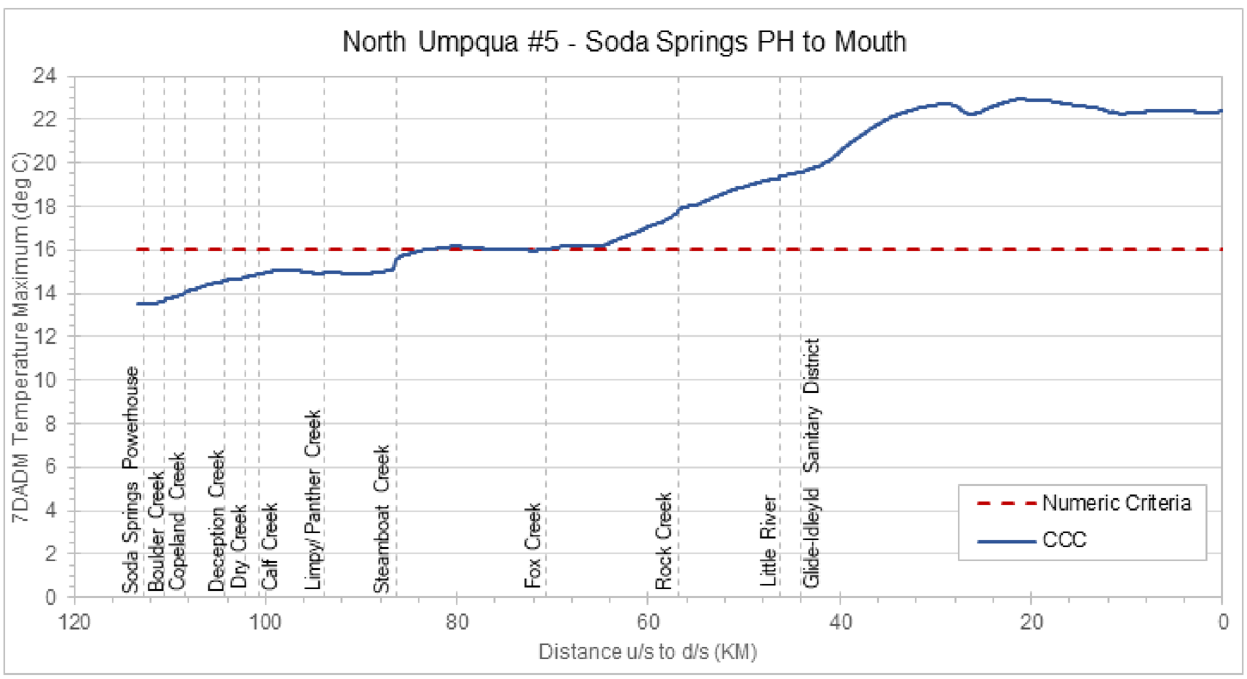

Figure 2-13. The maximum 7DADM temperature results along the North Umpqua River Model 5 (8/1/2009 to 8/31/2009) for the Current Conditions scenario

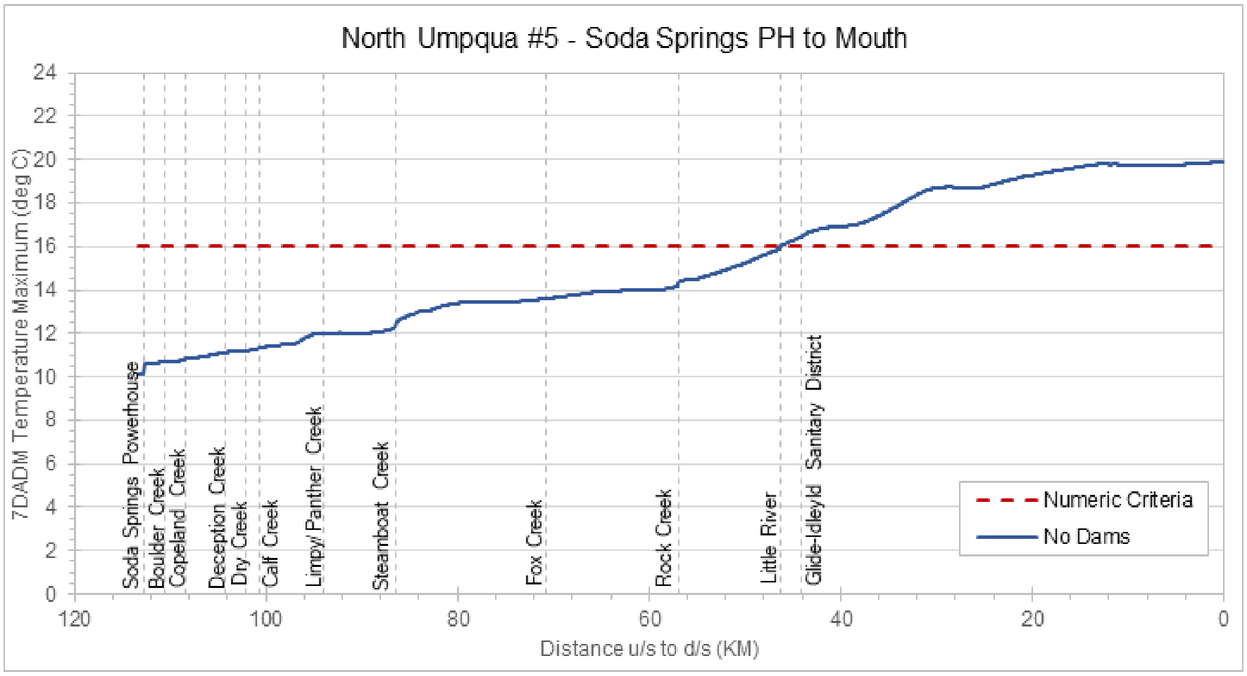

Figure 2-14. The maximum 7DADM temperature results along the North Umpqua River Model 5 (8/1/2009 to 8/31/2009) for the No Dams condition scenario

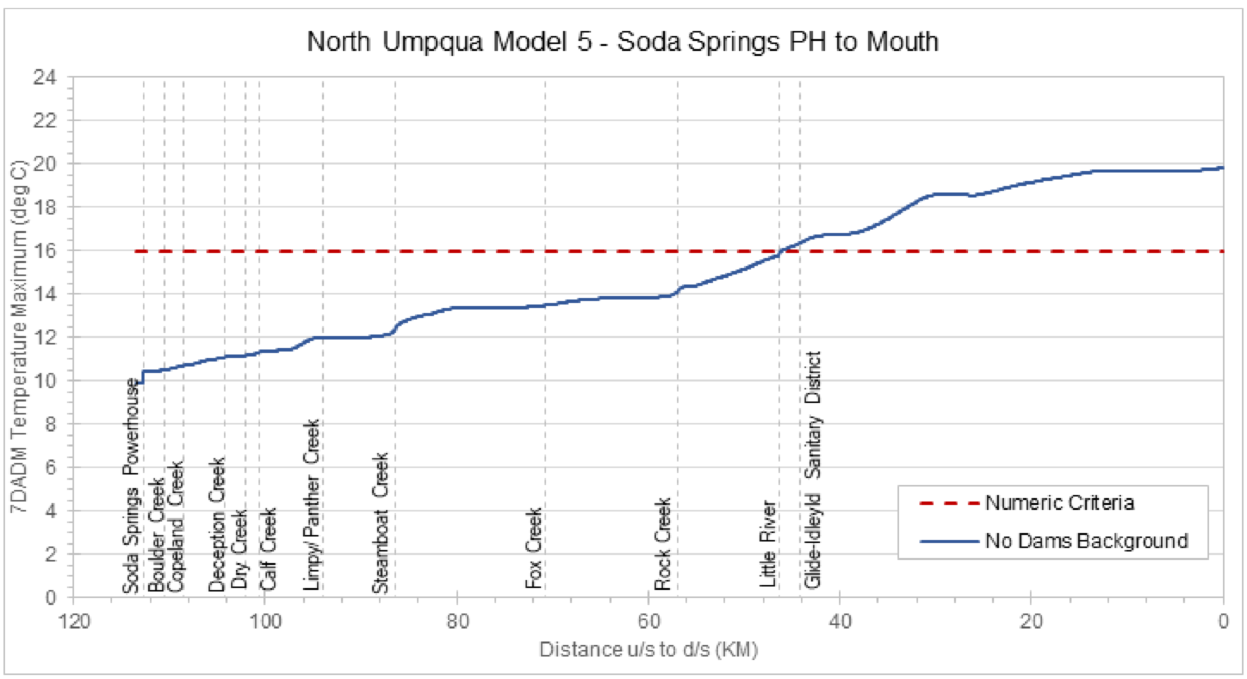

Figure 2-15. The maximum 7DADM temperature results along the North Umpqua River Model 5 (8/1/2009 to 8/31/2009) for the No Dams Background condition scenario

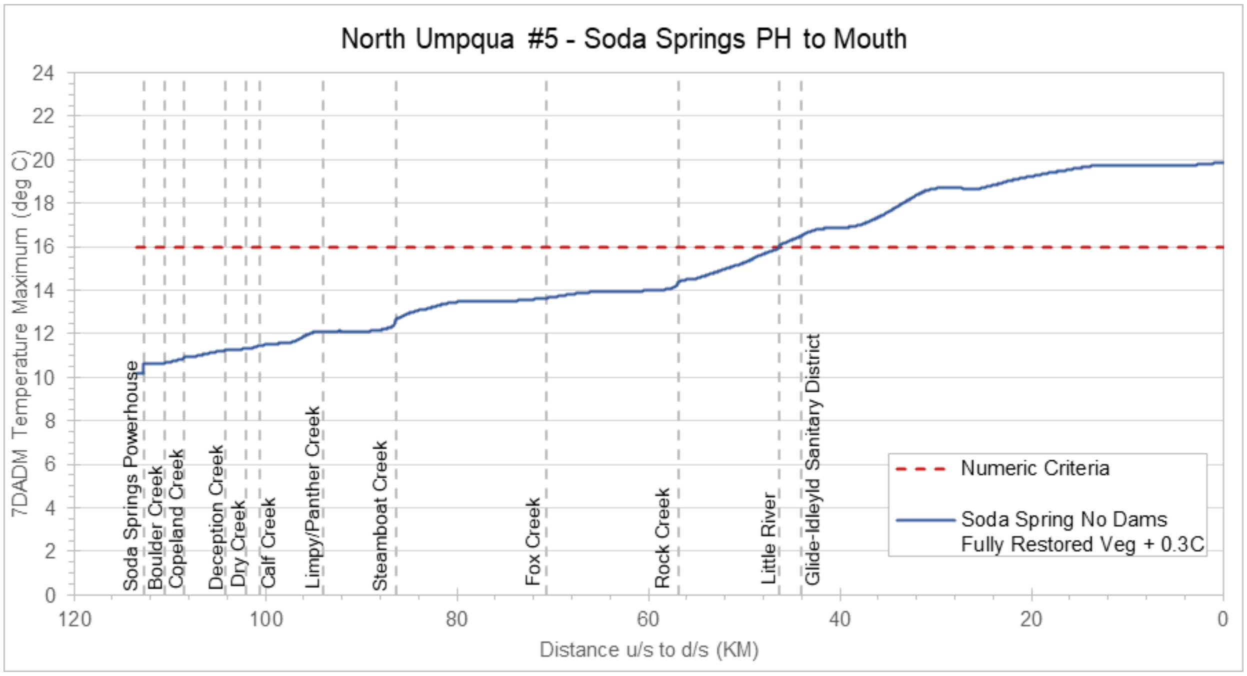

Figure 2-16. The maximum 7DADM temperature results along the North Umpqua River Model 5 (8/1/2009 to 8/31/2009) for the PacifiCorp allocation scenario.

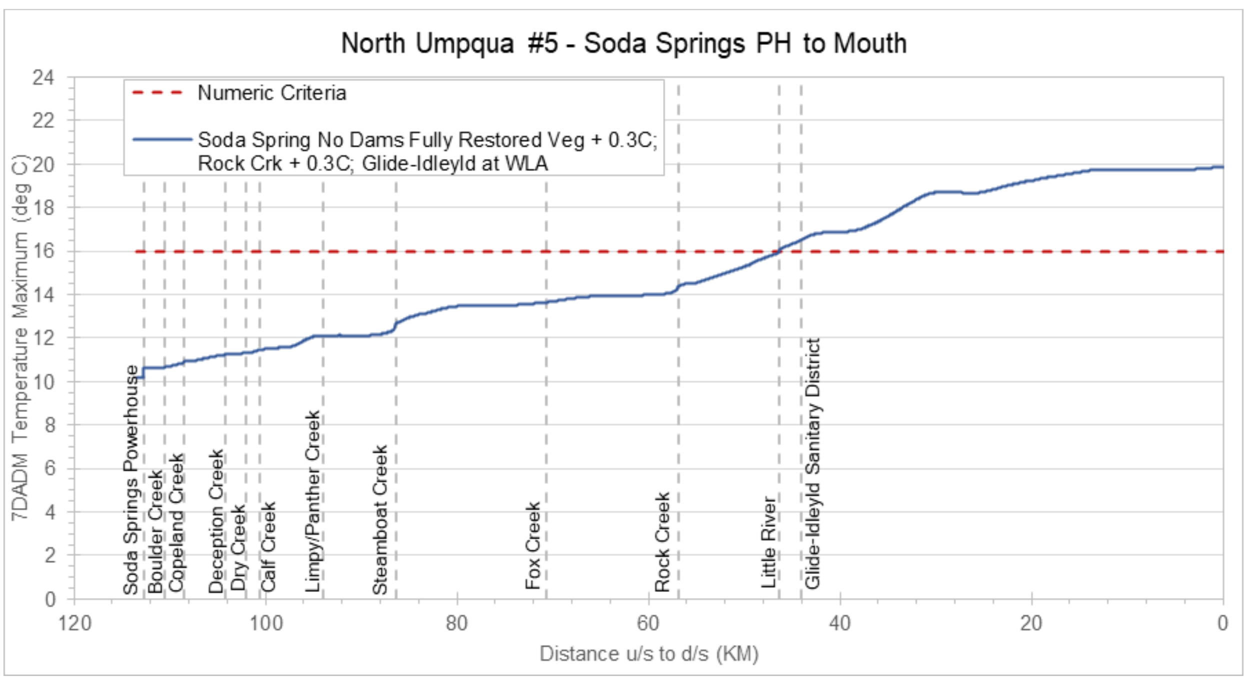

Figure 2-17. The maximum 7DADM temperature results along the North Umpqua River Model 5 (8/1/2009 to 8/31/2009) for the Total Attainment scenario

2.5.1.1 North Umpqua River Model 5 Scenario Comparison (Summer)

The various No Dams condition related scenarios evaluated along North Umpqua are shown below and are provided in the following section below.

B1. No Dams, impact of removing dams upstream
   - ✓ CCC minus No Dams

B2. Impact of No Dams fully restored condition
   - ✓ No Dams Background minus Criteria

B3. PacifiCorp impact evaluation under fully restored conditions:
   - ✓ [Soda Spring No Dams Fully Restored Vegetation + 0.3 °C] minus [No Dams Fully Restored Vegetation]

B4. Total Attainment of PacifiCorp and point source at WLA under fully restored conditions:
   - ✓ [Soda Spring No Dams Fully Restored Vegetation + 0.3 °C; Rock Creek + 0.3 °C; Glide-Idleyld at WLA minus [No Dams Fully Restored Vegetation

Figure 2-18 shows the results of comparison B1 for the impacts of dams, which is the 7DADM temperature difference between the CCC scenario and No Dams scenario. The difference between these two scenarios is the upstream boundary condition that reflects the conditions upstream with and without Lemolo Lake, Toketee Lake, Soda Springs Reservoir impoundments. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change (0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). The 7DADM temperature differences follow the increasing longitudinal variation of the modeled temperature. In addition, the 7DADM results show that dams cause warming, with warmer temperatures seen in the CCC compared to No dams. The delta is not shown towards the upstream reach and also at a few locations along the river, since the 7DADM does not exceed the BBNC at those locations. The maximum delta reaches 4.41 ˚C at RKM 35.10 on August 2, 2009 (Table 2-4).

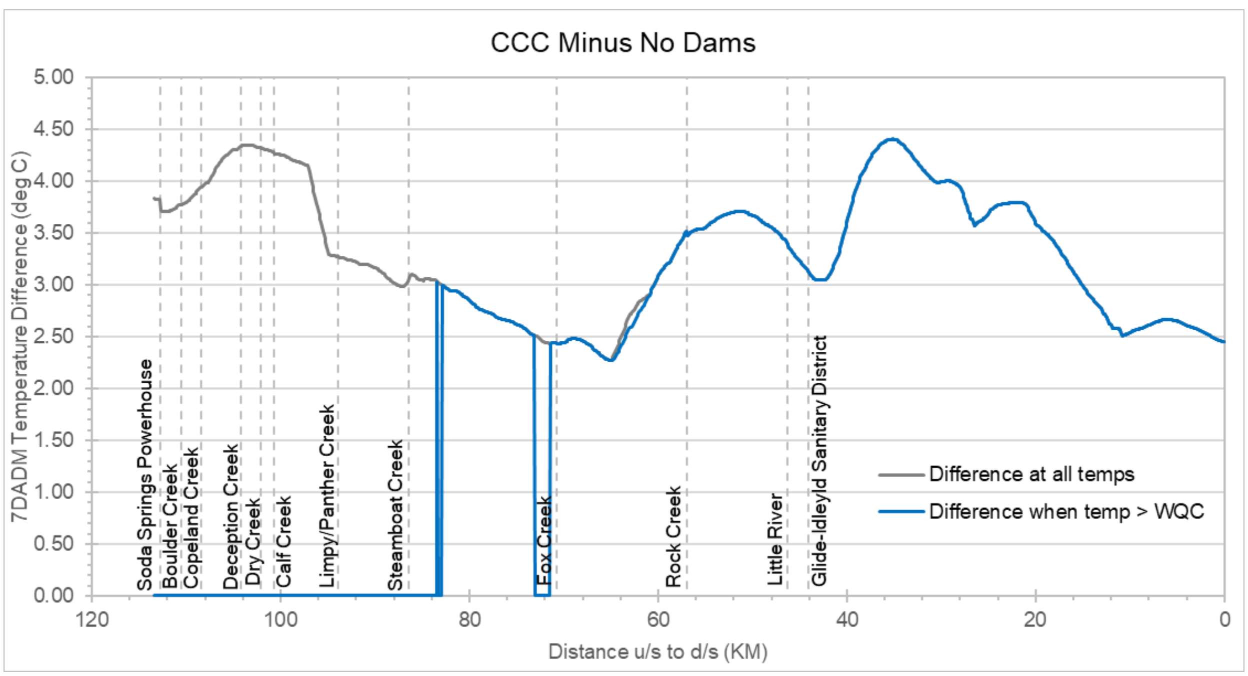

Figure 2-18. The maximum 7DADM temperature difference results along the North Umpqua River Model 5, between the CCC and the No Dams condition scenario

Table 2-5 Location and date of maximum delta when temperatures are greater than criterion (comparison B1) along North Umpqua River Model 5 (8/1/2009 to 8/31/2009)

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Dams Scenario	35.10	4.41	8/7/2009

Figure 2-19 shows the results of comparison B2, the 7DADM temperature difference between the No Dams Background scenario and criterion. The 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario and the differences increase moving downstream. The maximum delta reaches 3.8 °C at the mouth at RKM 0.0 on August 7, 2009, and -6.11 °C at RKM 113.4 on August 7, 2009 (Table 2-6).

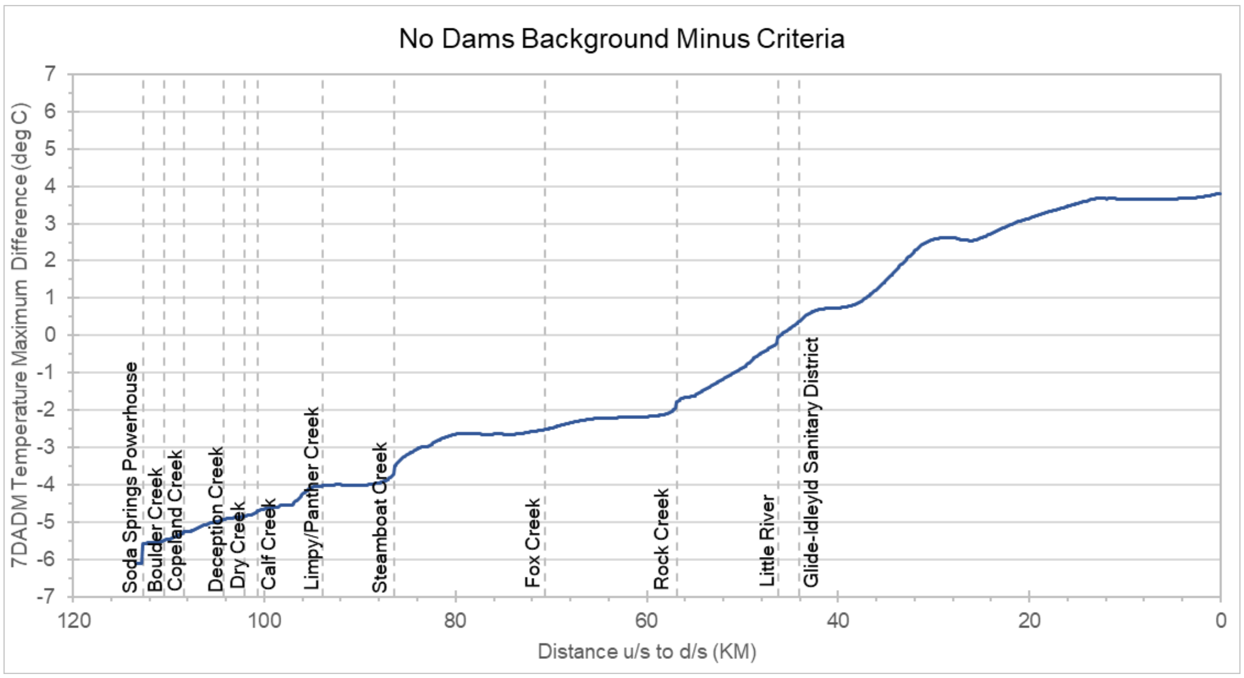

Figure 2-19. The maximum 7DADM temperature difference results along the North Umpqua River Model 5 (8/1/2009 to 8/31/2009) between No Dams Background Scenario and criterion

Table 2-6 Location and date of maximum delta (Comparison B2) along North Umpqua River Model 5 (8/1/2009 to 8/31/2009)

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
No Dams Background Minus Criteria	0.00	3.80	8/7/2009
	113.40	-6.11	8/7/2009

Figure 2-20 shows the results of comparison B3 for the impacts of dams, which is the 7DADM temperature difference between the PacifiCorp allocation evaluation and No Dams Background scenario. The difference between the two scenarios is the that 0.3 °C is added to the upstream boundary to represent the PacifiCorp HUA scenario. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change (0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). The impact due to the 0.3 °C added at the upstream end is immediately evident near the upstream end of the model but starts to decrease moving towards the mouth. While there is a temperature increase resulting in a delta starting at RKM 113.4, the impact when the 7DADM exceeds the criterion, first occurs at RKM 37.6 (Figure 2-16). The maximum delta reaches 0.14 ˚C at RKM 61 on August 13, 2009 (Table 2-7).

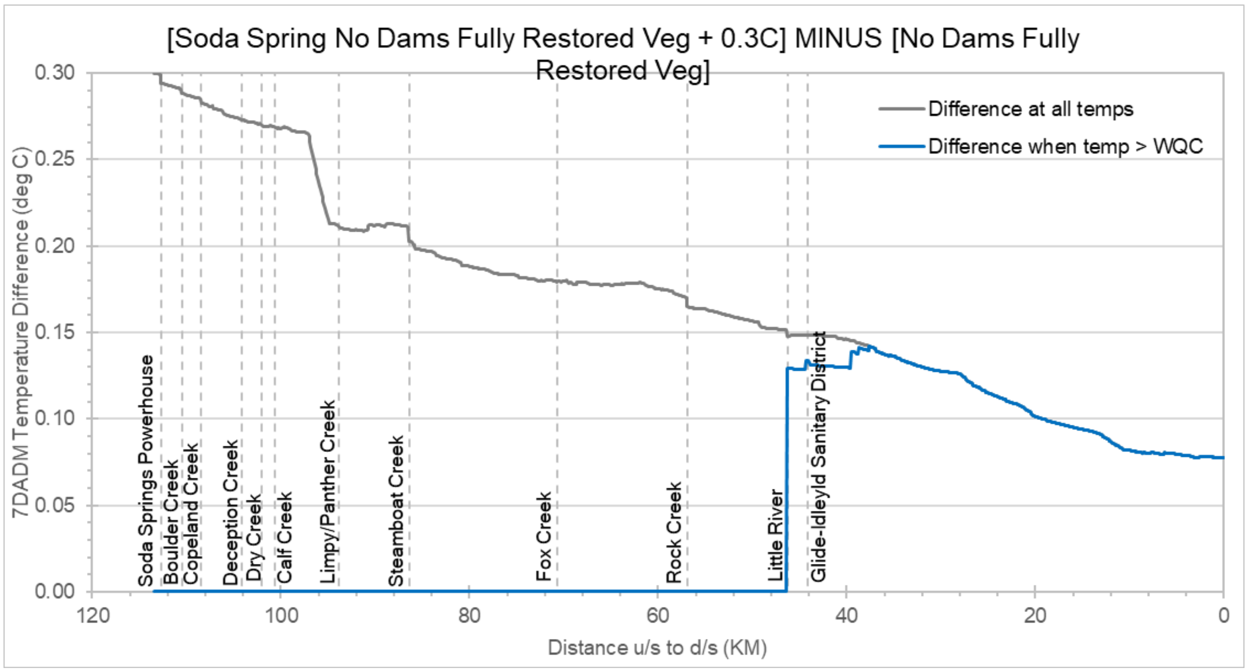

Figure 2-20. The maximum 7DADM temperature difference results along the North Umpqua River Model 5 (comparison C) (8/1/2009 to 8/31/2009)

Table 2-7 Location and date of maximum delta when temperatures are greater than criterion (Comparison B3) along North Umpqua River Model 5 (8/1/2009 to 8/31/2009)

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
[Soda Spring No Dams Fully Restored Veg + 0.3ºC] MINUS [No Dams Fully Restored Veg]	37.60	0.14	8/13/2009

Figure 2-21 shows the results of comparison B4 for the impacts of dams, which is the 7DADM temperature difference between the Total Attainment evaluation and No Dams Background scenario. The difference between the two scenarios is the that 0.3 °C is added to the upstream boundary in the PacifiCorp HUA scenario, the point source is set at WLA, and 0.3 °C HUA is added to Rock Creek for the Rock Creek Hatchery. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change

(0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). The impact due to the 0.3 °C added at the upstream end is immediately evident near the upstream end of the model but starts to decrease moving towards the mouth. While there is a temperature increase resulting in a delta starting at RKM 113.4, the impact when the 7DADM exceeds the criterion, first occurs at RKM 37.6 (Figure 2-26). The maximum delta for this scenario reaches 0.15 ˚C at RKM 61 on September 2, 2009 (Table 2-12). The maximum delta results are slightly higher than Comparison B3 where the maximum delta is 0.14 °C, and the delta for this scenario generally stays slightly higher compared to that in Comparison B3.

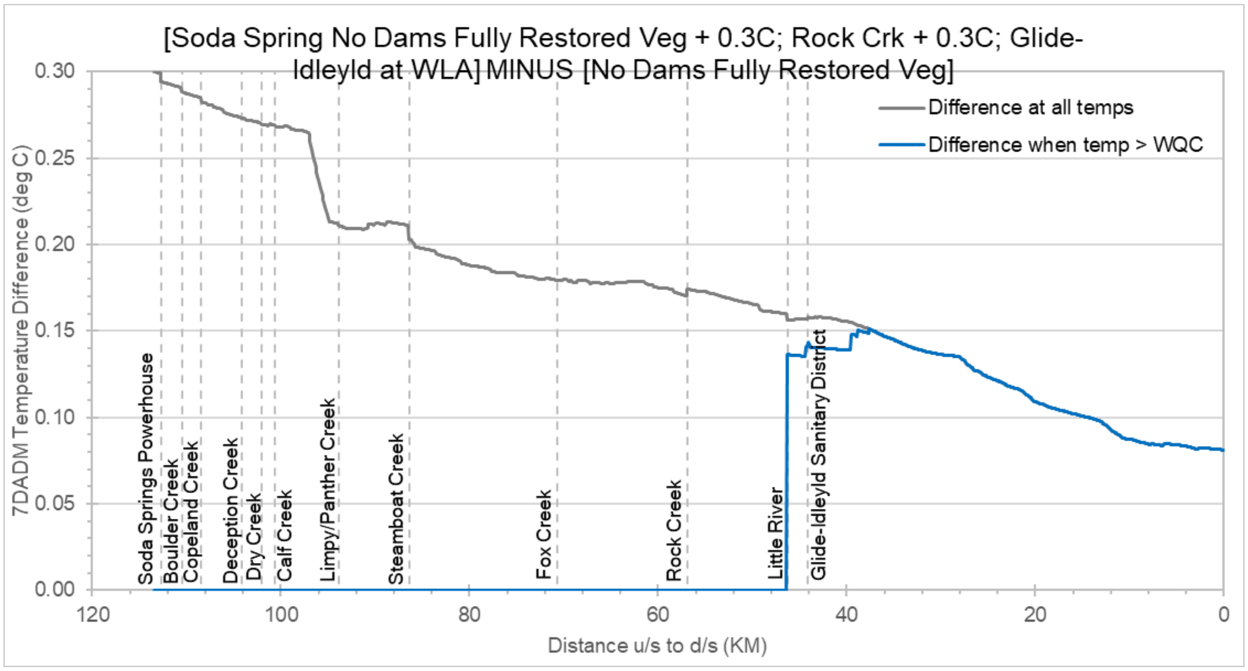

Figure 2-21. The maximum 7DADM temperature difference results along the North Umpqua River Model 5 (comparison B4) (8/1/2009 to 8/31/2009)

Table 2-8 Location and date of maximum delta when temperatures are greater than criterion (comparison B4) along North Umpqua River Model 5 (8/1/2009 to 8/31/2009)

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
[Soda Spring No Dams Fully Restored Veg + 0.3ºC; Rock Crk + 0.3ºC; Glide-Idleyld at WLA] MINUS [No Dams Fully Restored Veg]	37.60	0.15	8/13/2009

2.5.2 North Umpqua River Model 5 Spawning Period

The spawning period was evaluated for the period from September 1 to October 15, 2009. The scenarios that are relevant to the No Dams comparison for the North Umpqua River Model 5 included the CCC scenario, No Dams scenario, No Dams background scenario, the PacifiCorp allocation scenario, and the Total Attainment scenario. A description of the scenario can be found in Section 2.0. The 7DADM results for these scenarios are shown in Figure 2-13 through Figure 2-26.

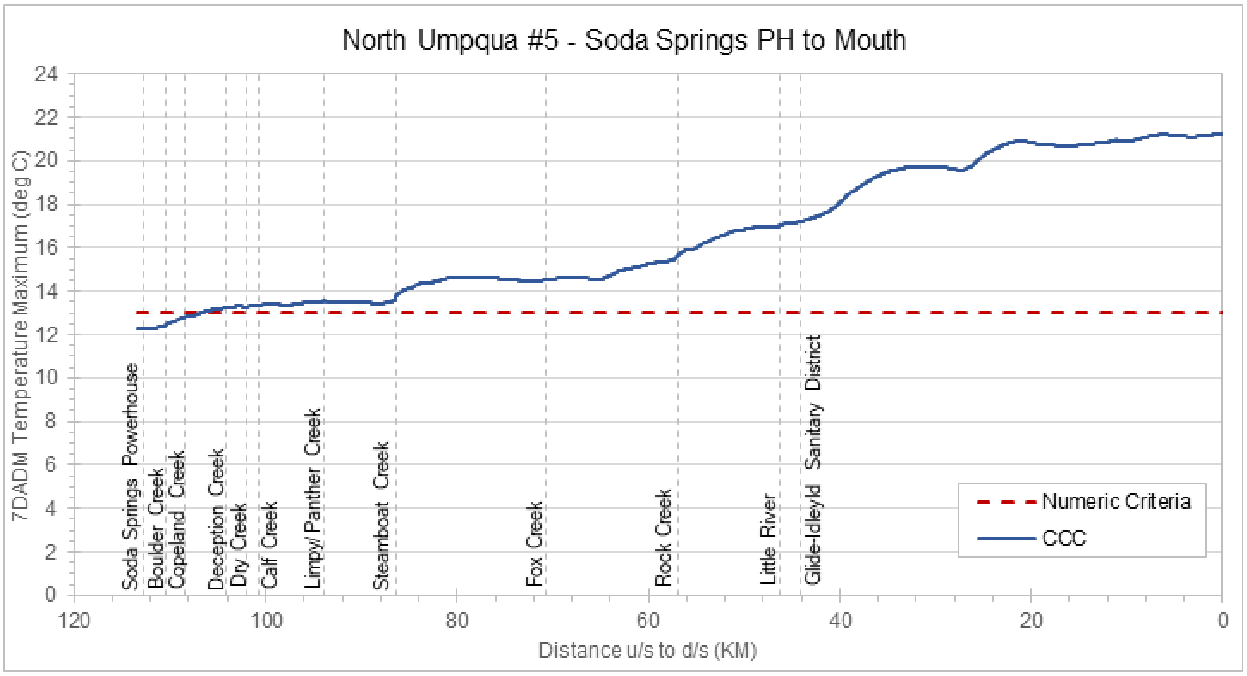

Figure 2-22. The maximum 7DADM temperature results along the North Umpqua River Model 5 (9/1/2009 to 10/15/2009) for the Current Conditions scenario

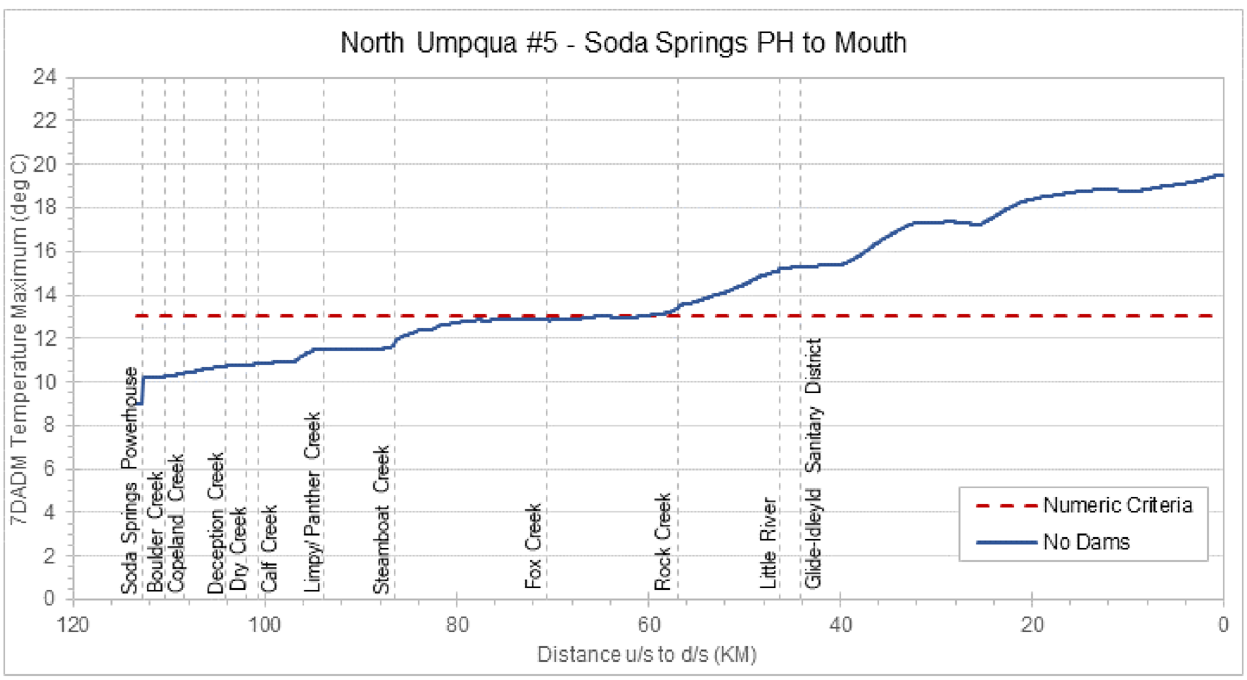

Figure 2-23. The maximum 7DADM temperature results along the North Umpqua River Model 5 (9/1/2009 to 10/15/2009) for the No Dams condition scenario

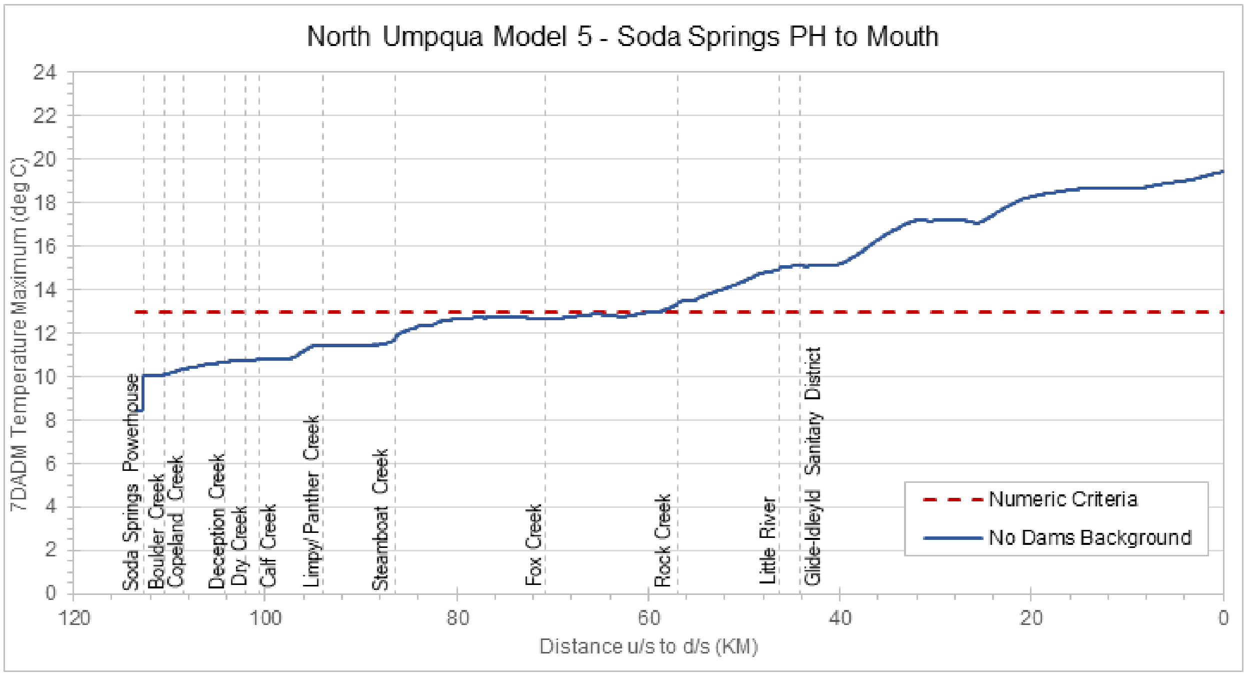

Figure 2-24. The maximum 7DADM temperature results along the North Umpqua River Model 5 (9/1/2009 to 10/15/2009) for the No Dams Background condition scenario

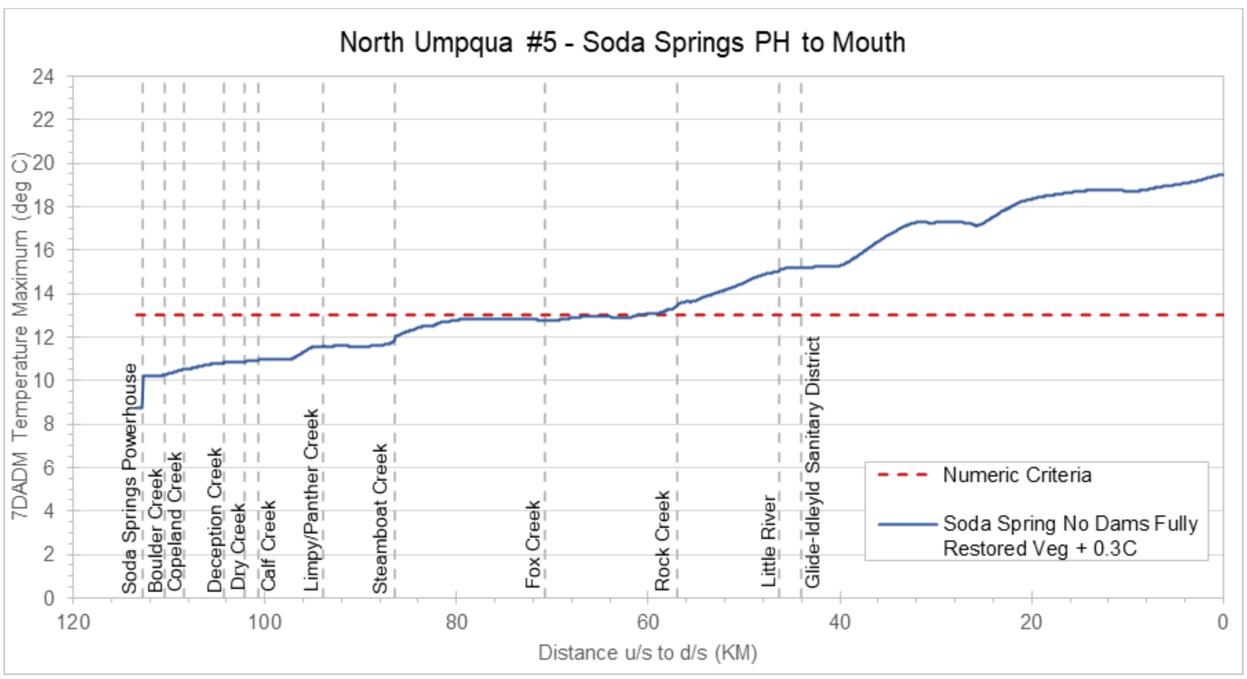

Figure 2-25. The maximum 7DADM temperature results along the North Umpqua River Model 5 (9/1/2009 to 10/15/2009) for the PacifiCorp allocation scenario

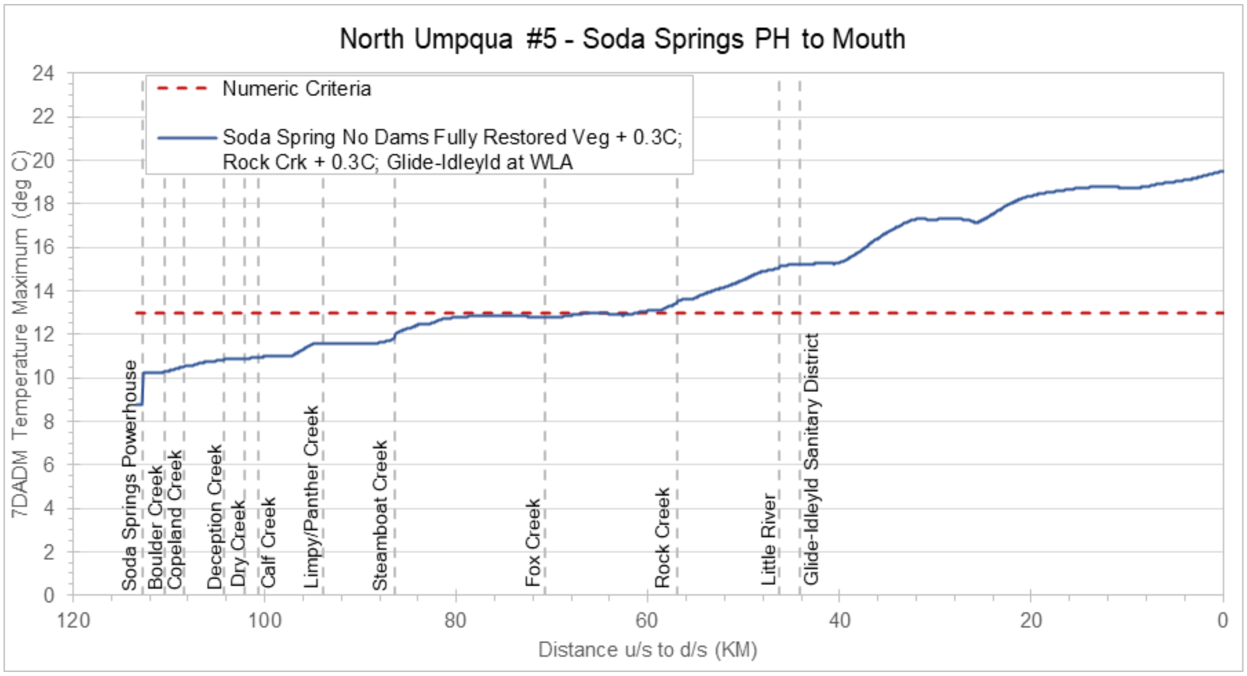

Figure 2-26. The maximum 7DADM temperature results along the North Umpqua River Model 5 (9/1/2009 to 10/15/2009) for the Total Attainment scenario.

2.5.2.1 North Umpqua River Model 5 Scenario Comparison (Spawning)

The various No Dams condition related scenarios evaluated along North Umpqua are shown below and are provided in the following section below.

B1. No Dams, impact of removing dams upstream
- ✓ CCC minus No Dams

B2. Impact of No Dams fully restored condition
- ✓ No Dams Background minus Criteria

B3. PacifiCorp impact evaluation under fully restored conditions:
- ✓ [Soda Spring No Dams Fully Restored Vegetation + 0.3 °C] minus [No Dams Fully Restored Vegetation]

B4. Total Attainment of PacifiCorp and point source at WLA under fully restored conditions:
- ✓ [Soda Spring No Dams Fully Restored Vegetation + 0.3 °C; Rock Creek + 0.3 °C; Glide-Idleyld at WLA minus [No Dams Fully Restored Vegetation

Figure 2-27 shows the results of comparison B1, for the impacts of dams, which is the 7DADM temperature difference between the CCC scenario and No Dams scenario. The difference between these two scenarios is the upstream boundary condition that reflects the conditions upstream with and without Lemolo Lake, Toketee Lake, Soda Springs Reservoir impoundments. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change (0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature. In addition, the 7DADM results show that dams cause warming, with warmer temperatures seen in the CCC compared to No dams. The delta is not shown towards the upstream reach since the 7DADM does not exceed the BBNC at those locations. The maximum delta reaches 2.98 ˚C at RKM 38.10 on September 1, 2009 (Table 2-9).

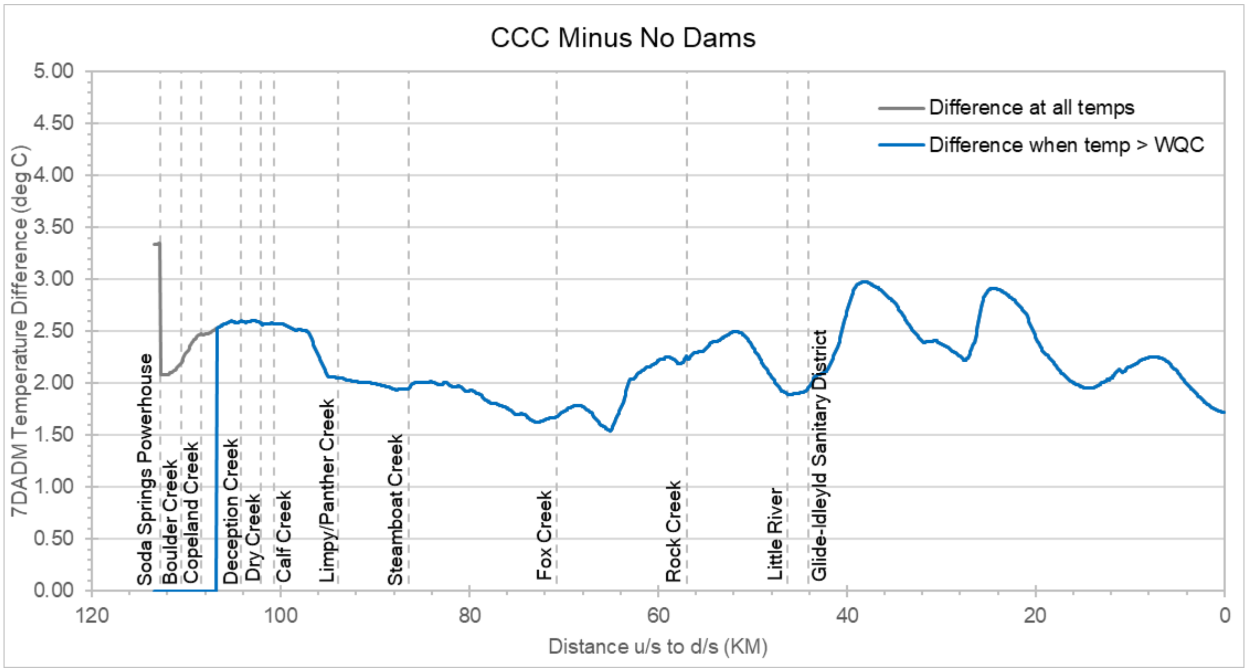

Figure 2-27. The maximum 7DADM temperature difference results along the North Umpqua River Model 5, between the CCC and the No Dams condition scenario (9/1/2009 to 10/15/2009)

Table 2-9 Location and date of maximum delta when temperatures are greater than criterion (comparison B1) along North Umpqua River Model 5 (9/1/2009 to 10/15/2009)

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
CCC Minus No Dams Scenario	38.10	2.98	9/1/2009

Figure 2-28 shows the results of comparison B2, the 7DADM temperature difference between the No Dams Background scenario and criterion. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario and the differences increase moving downstream. The maximum delta reaches 6.43 °C at the mouth at RKM 0.0 on September 1, 2009, and -4.54 °C at RKM 113.4 on September 4, 2009 (Table 2-10).

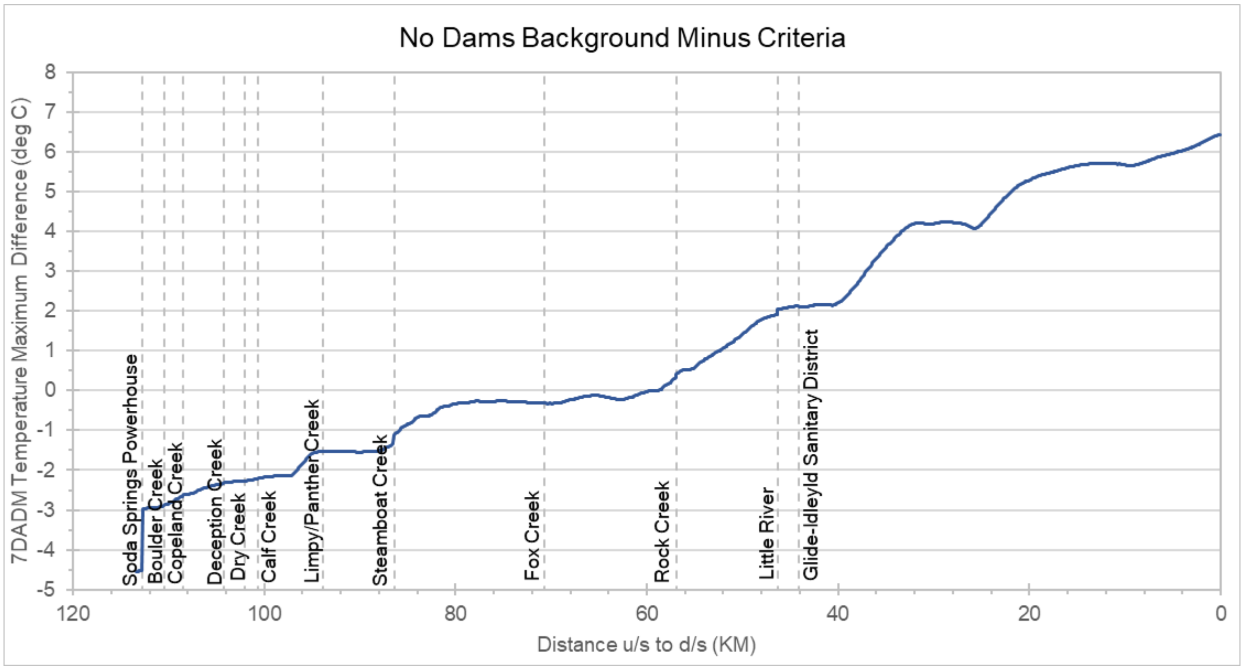

Figure 2-28. The maximum 7DADM temperature difference results along the North Umpqua River Model 5 (9/1/2009 to 10/15/2009) between No Dams Background Scenario and criterion

Table 2-10 Location and date of maximum delta when temperatures are greater than criterion (Comparison B2) along North Umpqua River Model 5 (9/1/2009 to 10/15/2009)

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
No Dams Background Minus Criteria	0.00	6.43	9/1/2009
	113.40	-4.54	9/4/2009

Figure 2-29 shows the results of comparison B3, for the impacts of dams, which is the 7DADM temperature difference between the PacifiCorp impact evaluation and No Dams Background scenario. The difference between the two scenarios is the that 0.3 °C is added to the upstream boundary in the PacifiCorp HUA scenario. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change (0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). The impact due to the 0.3 °C at the upstream is seen near the upstream end but starts to decrease moving towards the mouth. While there is a temperature increase resulting in a delta starting at RKM 113.4, the impact when the 7DADM exceeds the criterion, first occurs at RKM 61 (Figure 2-25). The maximum delta reaches 0.10 °C at RKM 61 on September 2, 2009 (Table 2-11).

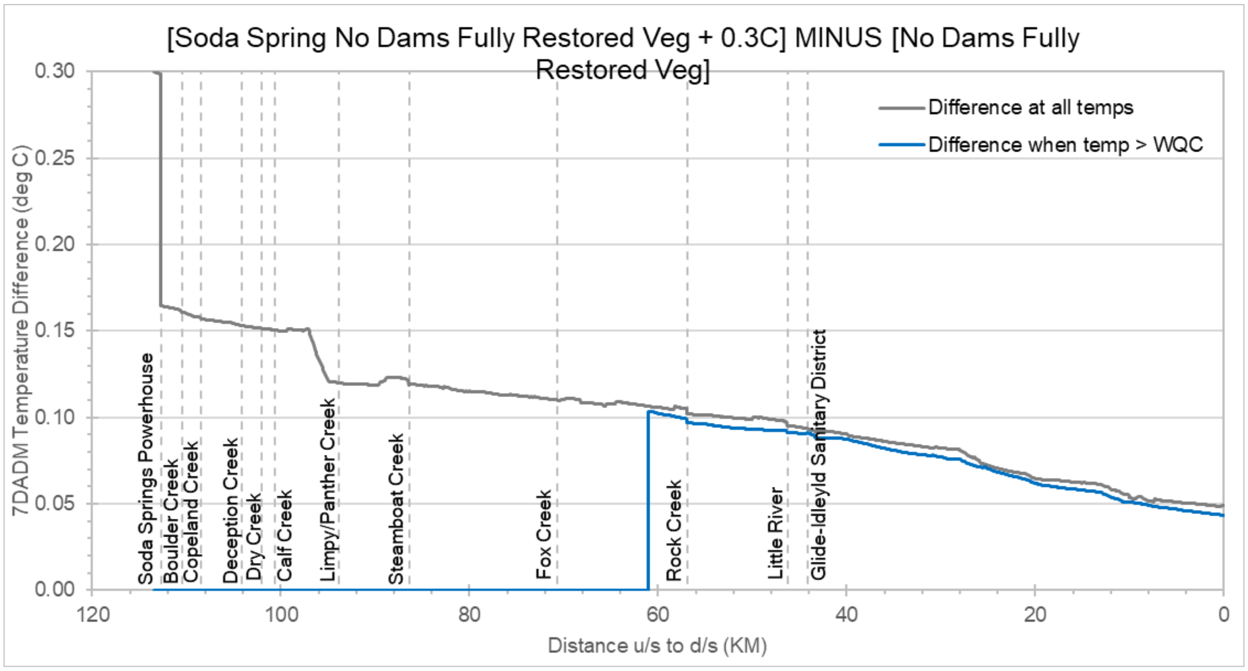

Figure 2-29. The maximum 7DADM temperature difference results along the North Umpqua River Model 5 (comparison B3) (9/1/2009 to 10/15/2009)

Table 2-11 Location and date of maximum delta when temperatures are greater than criterion (Comparison B3) along North Umpqua River Model 5 (9/1/2009 to 10/15/2009)

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
[Soda Spring No Dams Fully Restored Veg + 0.3ºC] MINUS [No Dams Fully Restored Veg]	61.00	0.10	9/2/2009

Figure 2-30 shows the results of comparison B4, for the impacts of dams, which is the 7DADM temperature difference between the Total Attainment evaluation and No Dams Background scenario. The difference between the two scenarios is the that 0.3 °C is added to the upstream boundary in the PacifiCorp HUA scenario, the point source is set at WLA, and 0.3 °C HUA is added to Rock Creek for the Rock Creek Hatchery. When a change 7DADM temperatures is considered relative to the applicable water quality criterion (blue line) there is no change (0 ºC) shown when all values in this scenario are below the criterion temperatures; although an overall change in temperature is observed (gray line). As can be seen in Figure 2-30, while there is a temperature increase resulting in a delta starting at RKM 113.4, the impact when the 7DADM exceeds the criterion first occurs at RKM 61 (Figure 2-26). The maximum delta for this scenario reaches 0.10 ˚C at RKM 61 on September 2, 2009 (Table 2-12). The maximum delta results are similar to Comparison B3 where the maximum delta is also 0.1 °C and also decreases towards the mouth. However, the delta for this scenario stays slightly higher compared to that in Comparison B3, after Rock Creek comes in due to the HUA assigned to Rock Creek.

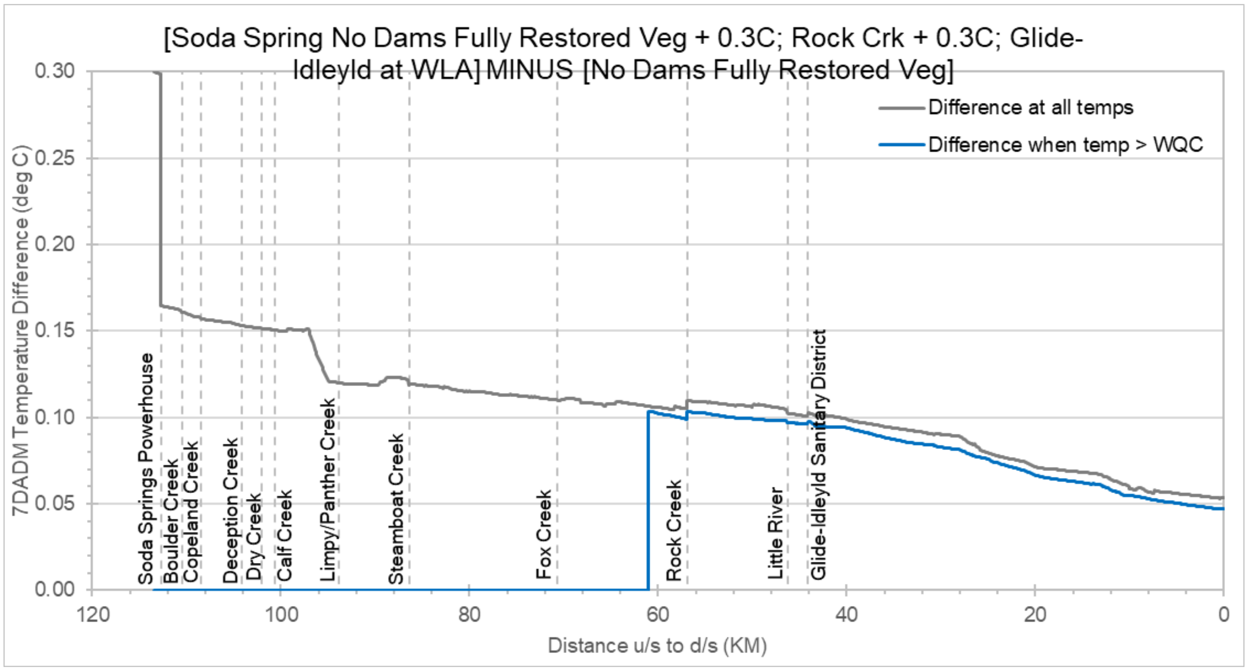

Figure 2-30. The maximum 7DADM temperature difference results along the North Umpqua River Model 5 (comparison B4) (9/1/2009 to 10/15/2009)

Table 2-12 Location and date of maximum delta when temperatures are greater than criterion (comparison B4) along North Umpqua River Model 5 (9/1/2009 to 10/15/2009)

North Umpqua #5	RKM	Maximum Delta	Date when Maximum Delta occurs
[Soda Spring No Dams Fully Restored Veg + 0.3C; Rock Crk + 0.3C; Glide-Idleyld at WLA] MINUS [No Dams Fully Restored Veg]	61.00	0.10	9/2/2009

3.0 SUMMARY

Riverine Heat Source models were developed in place of each of the three impoundments—Lemolo Lake, Toketee Lake, and Soda Springs Dam—along the North Umpqua River, to simulate conditions for the No Dams scenario. These models were used in conjunction with all the existing Heat Source models developed along North Umpqua (Models 1 through 5) to run scenarios. The models were run sequentially from upstream to downstream, with each model feeding into the next model downstream, to evaluate the impacts of No Dams along the system. Further a full restored vegetation condition model (Background condition) was also run for the entire system to evaluate the overall compliance and other scenarios. Specifically, three additional scenarios were developed and run for the portion of North Umpqua Model 5 below Soda Springs Reservoir, where the spawning criterion apply, using the No Dams Background condition model. These included evaluating the differences of 7DADM temperature between the No Dams Background scenario and the criterion, a PacifiCorp impact evaluation under fully restored conditions, and a Total Attainment scenario which included PacifiCorp and point source at WLA under fully restored conditions. The modeled scenarios showed that the dams cause warming, with warmer temperatures seen in the CCC compared to No dams, across the entire system. There was no maximum delta calculated for Models 1 through 4, for the No Dams scenario, since the 7DADM temperatures for the scenarios were below the criterion. The North Umpqua Model 1 below Soda Springs showed warming due to dams, with a 7DADM maximum delta of 4.41°C and 2.98°C towards the downstream end during the summer and spawning period respectively. The impact due to the PacifiCorp HUA applied at Soda Springs showed a maximum 7DADM temperature delta of 0.14 °C and 0.10 °C during the summer and spawning periods, respectively. Finally, the Total Attainment scenario showed a maximum 7DADM temperature delta of 0.10°C during the summer and spawning periods.

In general, the scenarios show that the dams have a warming impact in North Umpqua. The cumulative impacts simulated under fully restored vegetation conditions that take into consideration PacifiCorp HUA, point sources at WLA temperatures, and impacts due to dams are all within 0.3 °C.

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South Umpqua River Temperature Model Configuration and Calibration Report - DRAFT

October 4, 2024

PRESENTED TO

US Environmental Protection Agency, Region 10

PRESENTED BY

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APPENDICES

1.0 INTRODUCTION

Tetra Tech is assisting USEPA Region 10 with technical and modeling activities to support the development of total maximum daily loads (TMDLs) for the South Umpqua River and Main Stem Umpqua River. These TMDLs are part of a group of 15 Oregon temperature TMDLs that cumulatively address over 700 temperature impaired segments, all of which are being replaced pursuant to a court order and judgement issued October 4, 2019. The TMDLs must be replaced over an eight-year period. Oregon Department of Quality (ODEQ) developed the heat source models for the summer period. One of the tasks for supporting this TMDL is to develop a spawning period model for the South Umpqua River (Figure 1-1).

The South Umpqua River is in southern Oregon and flows southwest through Douglas County. The South Umpqua River originates from the confluence of Black Rock Fork and Castle Rock Fork in the Umpqua National Forest at an approximate elevation of 2,000 feet above sea level and travels 115 miles before it meets the North Umpqua River near the City of Roseburg. Cow Creek is a major tributary to the South Umpqua River (Figure 1-1). The development of the HS8 model for the spawning period generally followed the Modeling Quality Assurance Project Plan: South Umpqua and Umpqua Subbasins Temperature Total Maximum Daily Load (2022). The QAPP focuses on the HS7 model for the summer period model development. However, the procedures of model configuration and calibration, as well as the types of input data are all the same. This report describes the technical details of extending the original South Umpqua River summer period Heat Source 7.0 (HS7) model to a spawning period Heat Source version 8 (HS8) model. It summarizes available data and serves as documentation of the model configuration and calibration for the South Umpqua River mainstem HS8 model. The summer period HS 7 model was not adjusted from the original set up by ODEQ.

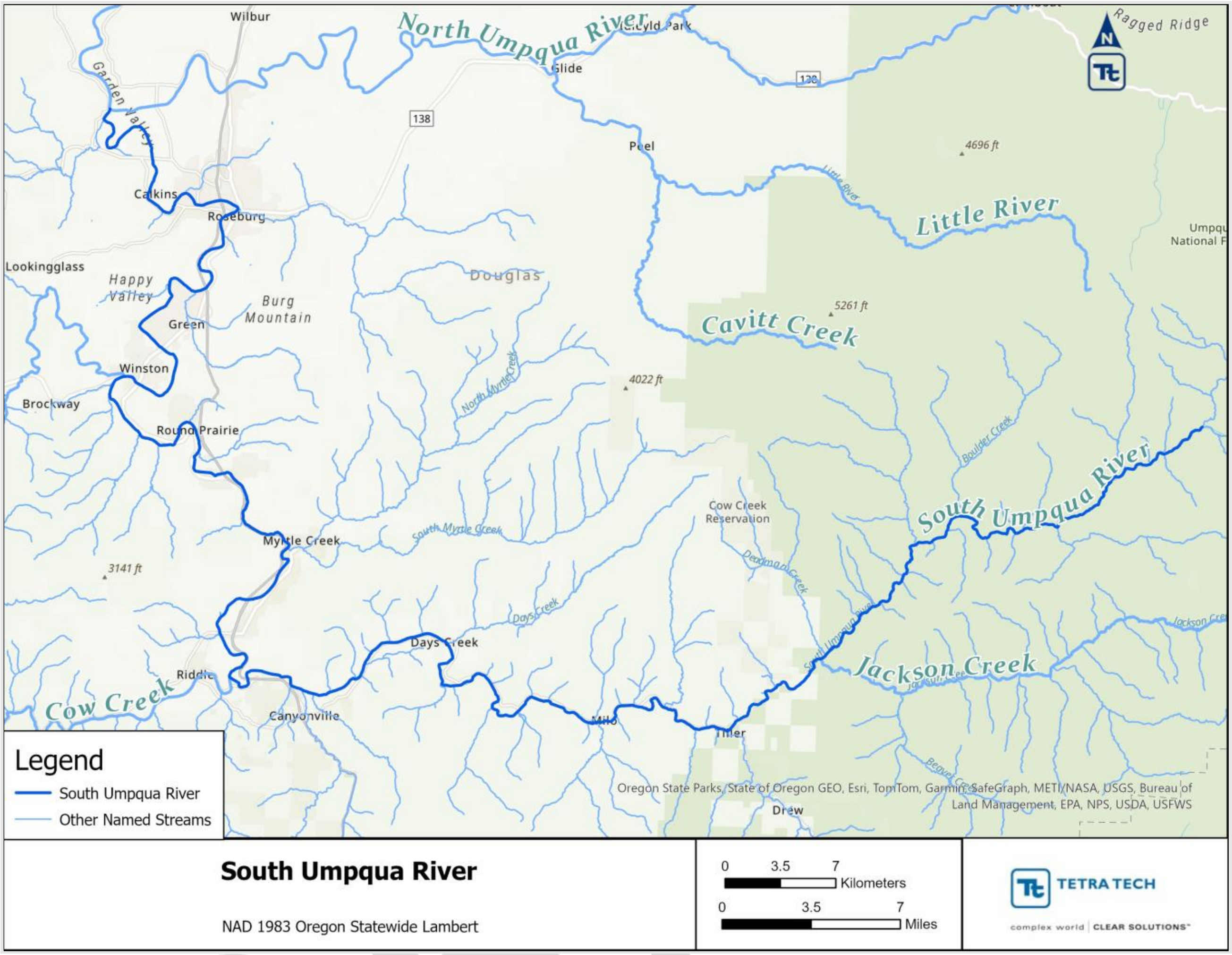


Figure 1-1 South Umpqua River and Its Watershed

2.0 TECHNICAL APPROACH

Since this project involves the replacement of an established TMDL, EPA determined that the approach to completing these TMDLs to ensure compliance with court-ordered schedules will rely on previously completed technical work as much as possible within a streamlined development process. In general, no new modeling or new data collection was conducted unless essential for source characterization or development of allocations. Updates to the model or technical analysis were only be made to characterize major new sources (e.g., new National Pollution Discharge Elimination System [NPDES] source), or when a significant change to a source or condition has occurred compared to the previous TMDL (e.g., removal of a dam, discontinued discharge by an NPDES source). Originally, a spawning period model was not developed for the mainstem South Umpqua River; therefore, the model time period was temporally expanded to include a portion of the fall spawning period. The extended modeling period is based on the availability of data needed to configure the model. Due to a lack of data, the modeling period does not include the entire spawning period. Data were reviewed and the most feasible model temporal extent and model year were selected. Based on a review of available data summarized in the QAPP, the model was extended from September 1 to October 4, 2009.

For the 2006 South Umpqua River Basin TMDL (ODEQ, 2006) HS7 was used to simulate the 2002 stream temperatures. The Heat Source model includes multiple modules that simulate open channel hydraulics and flow routing, heat exchange processes occurring in the stream, effective shade (topographic and vegetation) and predicts stream temperature (Boyd and Kasper, 2003). The modeling time-period for the HS7 model was developed for simulating conditions during July 12 through July 31, 2002. The calibrated HS7 model was used again for summer period scenario runs without recalibration. A new current conditions scenario was developed to capture changes related to point source discharges for the summer period (refer to Scenario Report for additional details). This report focuses on the configuration and calibration of the spawning models.

The Heat Source Model has been under continuous enhancement, and HS8, which has more features than the HS7 model, is now available. Therefore, for the spawning period temperature simulation in the South Umpqua River, the HS8 model was used for the development of the South Umpqua River water temperature model. The improvements in the HS8 model are discussed in the following subsection.

2.1 HEAT SOURCE MODEL VERSION 8

The model parameters for HS8 are similar to HS7; however, HS8 provides several improvements over version 7. Some of the notable examples are given below.

- The major difference is that the model code is now written in Python 2.5 and C, rather than Visual Basic, with Excel used as the interface;
- HS8 can simulate an unlimited number of days, compared to a 21-day simulation in HS7;
- HS8 channel geometry uses the channel bottom width as the starting point while HS7 uses the channel bankfull width as the starting point of channel geometry calculation;
- HS8 specifies bed conduction inputs including hyporheic exchange parameters;
- Shading calculation has been improved from HS7.

3.0 SPAWNING MODEL CONFIGURATION

3.1 MODEL TIME PERIOD AND EXTENT

The spawning model was configured for the period from July 1, 2009 to October 4, 2009 and calibrated for the spawning period between September 1 and October 4. This period corresponds to the period when hourly water temperature data were collected by the US Forest Service (USFS) at two locations along the South Umpqua River: at Three C Rock (RKM 128.1) and near the Tiller ranger station (RKM120.0). The period of record of water temperature data collected covered the entire spawning period, which is the focus of this model extension. Hourly stream temperature data were also collected at several major tributaries, which were used for the model boundary configuration.

The extent of the model domain is the same as that of the HS7 model: the South Umpqua River, which begins upstream at the confluence of Black Rock Fork and Castle Rock Fork, down to its mouth, where it meets the North Umpqua River. The extent of the South Umpqua River HS8 model is shown below (Figure 3-1).

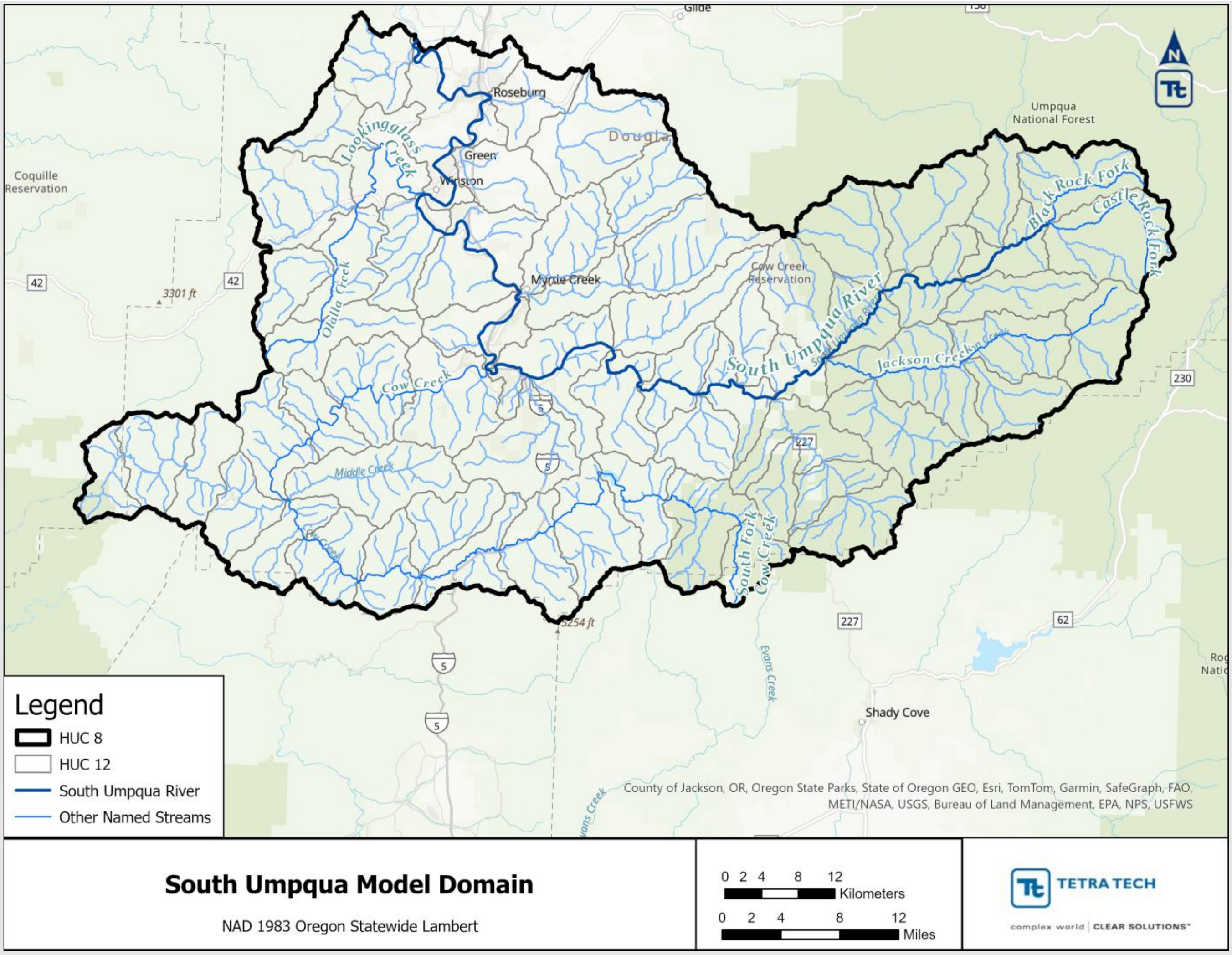


Figure 3-1. Extent of South Umpqua River modeling domain

3.2 MODEL PHYSICAL CHARACTERISTICS

The physical characteristics of the HS8 model including the digitization of stream centerline and stream banks, landcover processing, and channel-related inputs came directly from the existing HS7 model. The model includes a total of 3,295 segments, each of which is 0.5 km in length. The channel slope varies from 0.002 to 0.044; bottom width varies from 0.1 to 141.4 m; and Manning's N varies from 0.2 to 0.4.

For temperature simulation, accurate representation of shading is critical. Shading is caused by both topography and trees growing on the two sides of the river. The topographic shading angles, taken from the HS7 model, are shown in Figure 3-2.

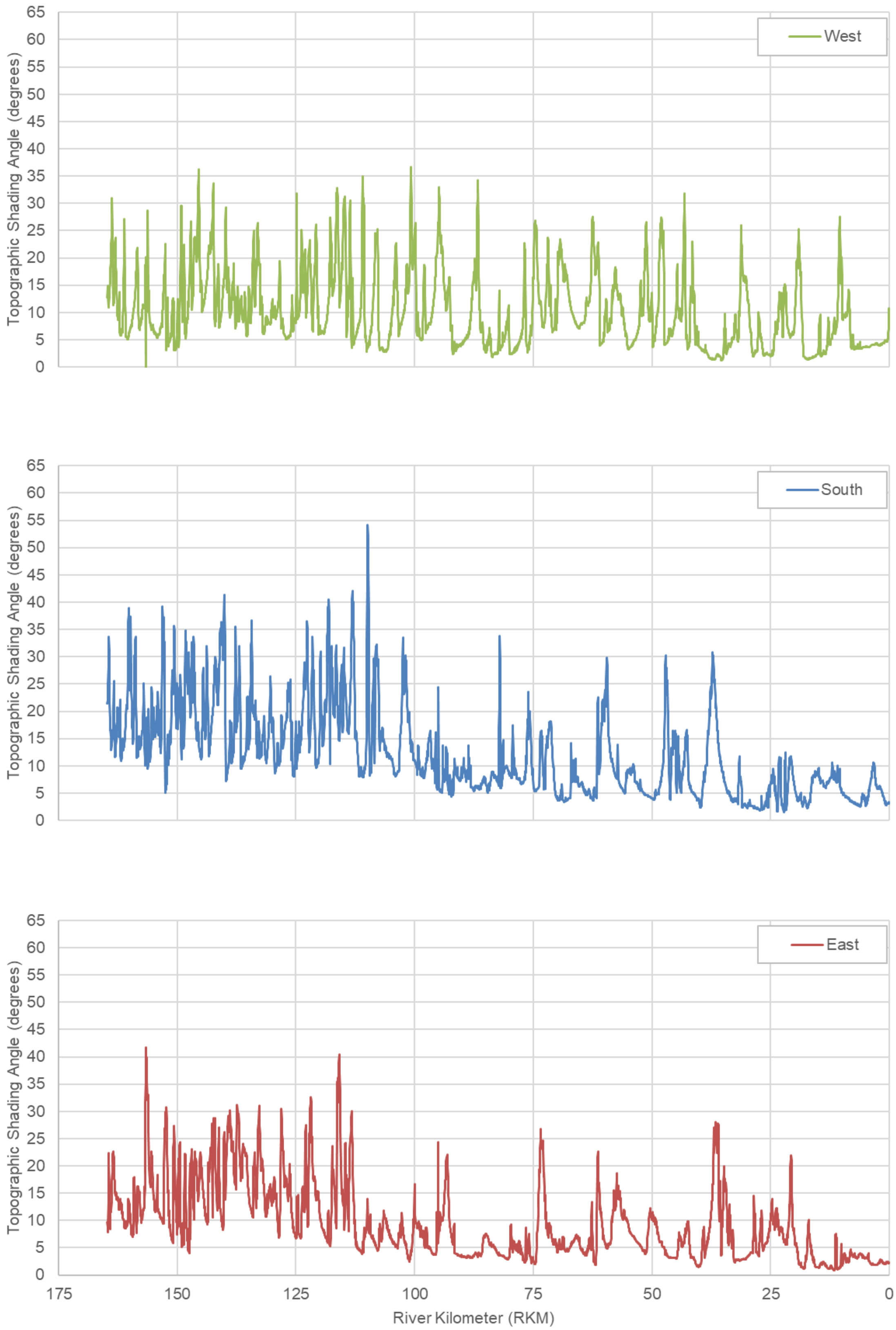


Figure 3-2. South Umpqua River Modeled Topographic Shading Angle

Riparian vegetation characteristics input into the model were those developed for the HS7 model. The vegetation characteristics determine the degree to which near-stream vegetation has the capacity to block incidental solar radiation on the surface of the modeled waterbody. Three vegetation inputs incorporated into the model are the vegetation density, overhang, and height. Field measurements offer a general understanding of vegetation characteristics within the watershed, however variability in these parameters can be significant on smaller geographic scales. Table 3-1 displays the landcover types used in the HS 8 model.

Table 3-1. Riparian Landcover Categories in the South Umpqua River Watershed Heat Source Model

Landcover
Water
Pasture/Cultivated Ag
Tree Farm
Barren - Rock
Barren - Bank
Barren - Clearcut
Barren - Soil
Clearcut - early regrowth
Road
Forest Road
Railroad
Large Mixed Conifer-Hardwood
Small Mixed Conifer-Hardwood
Small Hardwood
Large Hardwood
Large Conifer
Small Conifer
Upland Shrubs
Wetland Shrubs
Grass - upland
Active River Channel
Developed - House-sized Structures
Developed - Industrial Sized Structures
Dam or Weir
Canal
Dike
Hatchery
Sewage Pond
Tree Farm (again)
Marsh Area

The model includes the headwater/upstream inputs from Black Rock and Castle Rock Creeks, four major wastewater treatment plants (WWTPs) including Canyonville Sewage Treatment Plant (STP), Winston-Green WWTF, USFS – Umpqua National Forest, Tiller Ranger Station STP, R.U.S.A. Roseburg STP, and 7 minor WWTPs with near zero flow. A total of 66 tributaries are represented in the model. To extend the model from the summer 2002 period to the spawning period in 2009, flow and water temperature from all sources including upstream, tributaries, and WWTPs are needed. The flow and water temperature data are limited, and the following sections present how the flow and water temperature inputs were derived for the model configuration.

3.3 FLOW DATA FROM UPSTREAM AND TRIBUTARIES

Flow data were available in the South Umpqua River watershed at a limited number of locations. Specifically, flow data during the 2009 modeling period were available only for Cow Creek and Elk Creek tributaries; no flow data were available for any of the remaining tributary inputs specified in the HS8 Model. In addition, no flow data were available to configure the head water – upstream boundary condition. Two USGS flow gages were available along the South Umpqua River that were used for flow calibration purposes. Table 3-2 shows an inventory of the available continuous flow data for 2009 and notes how they were used.

Table 3-2. Inventory of Available Flow Data in the South Umpqua River Watershed Used in the Heat Source Model Development

Station ID	Latitude/ Longitude	Source	Type
Elk Creek near Drew, OR (14308500)	42.89012159/ -122.9178303	USGS	Boundary condition
Cow Creek near Riddle, OR (14310000)	42. 9234502/ - 123.428957	USGS	Boundary condition
South Umpqua River near Brockway, OR (14312000)	43.13317169/ -123.3984053	USGS	Used to derive flow boundary condition & calibration
South Umpqua River at Tiller, OR (14308000)	42.9303985/ -122.9483872	USGS	Used to derive flow boundary condition & calibration

3.3.1 Flow Estimation

For Elk Creek and Cow Creek, hourly flow data were available from USGS gages 14308500 and 14310000, respectively. There are withdrawals below these two gages, and the withdrawals are taken from the previous Elk Creek HS7 model and the Cow Creek HS7 model. Both Elk Creek and Cow Creek HS7 models represent summer conditions.

As described in detail below, the area ratio method was used to generate derived flow input time series for each of the 63 ungaged model tributary inputs in addition to the upstream headwaters boundary condition. Two USGS flow gages with continuous daily data during the model period were evaluated to be used as the source flow data for derived model flow inputs (Figure 3-3): South Umpqua River at Tiller, Oregon (14308000), and South Umpqua River Near Brockway, OR (14312000).

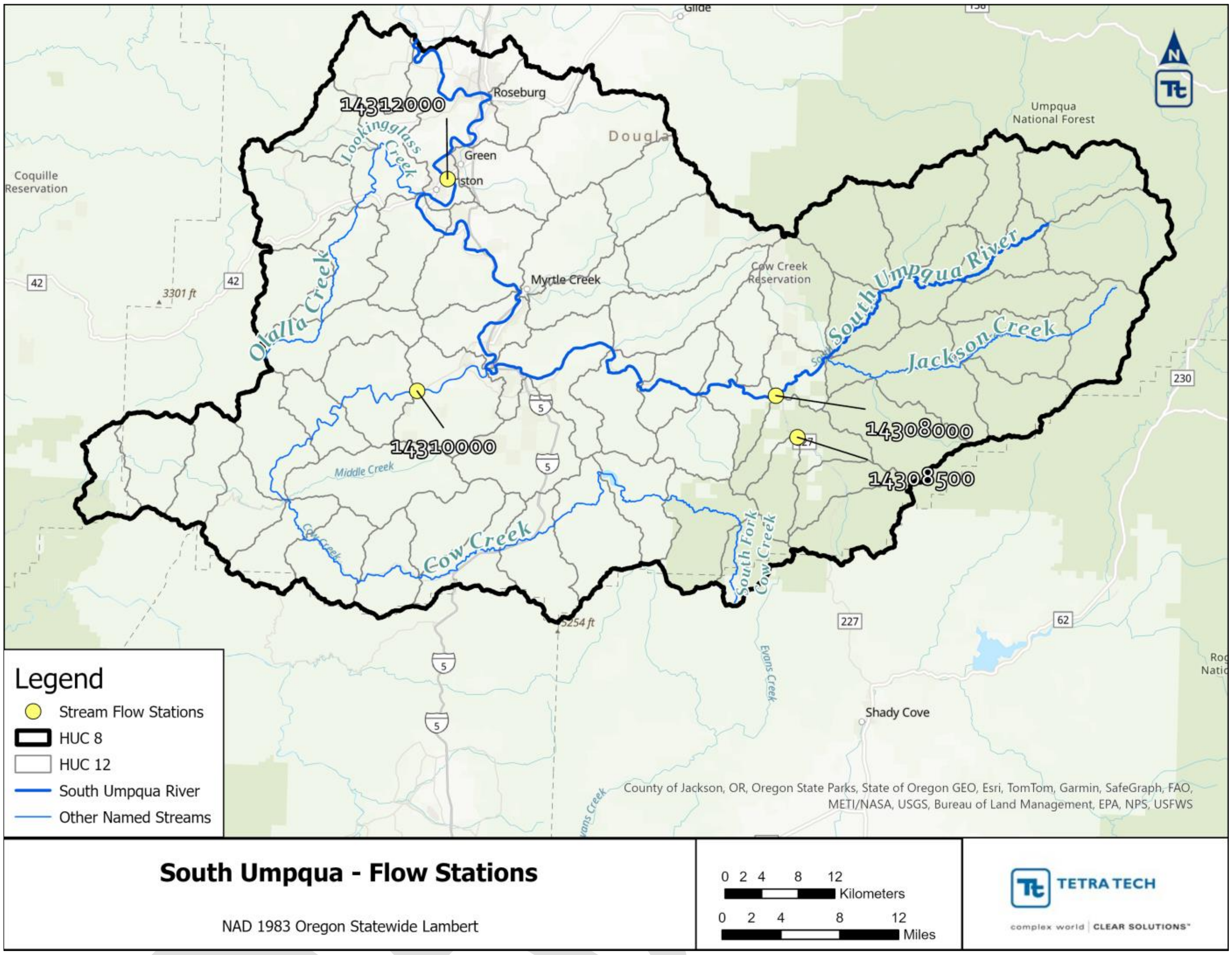


Figure 3-3 Flow gages used for flow calculations

3.3.1.1 Streams above USGS South Umpqua River at Tiller, Oregon (14308000)

NPDES permitted flows were subtracted from the observed gage flow at USGS gage 14308000, and withdrawals from the HS7 model were added back in to estimate the natural flow in the system draining to that gage. The drainage area for each stream contributing to the South Umpqua River above the gage was obtained from USGS Stream Stats, and the ratio of stream drainage area to total drainage area was applied to the adjusted hourly flow to estimate an hourly flow for each stream.

3.3.1.2 Streams between USGS South Umpqua at Tiller, Oregon (14308000) and USGS South Umpqua River Near Brockway, OR (14312000)

NPDES permitted flows and measured gage flows from USGS South Umpqua at Tiller, USGS Cow Creek near Riddle, and Elk Creek at Tiller were subtracted from the measured hourly gage flow at USGS South Umpqua River Near Brockway, and withdrawals from the HS7 model were added back in, to estimate the natural flow gain from ungaged tributaries in the system between the USGS gages on the South Umpqua River at Tiller and Brockway. The drainage area for each modeled stream contributing to this section of the South Umpqua River was obtained from USGS Stream Stats, and the ratio of stream drainage area to total drainage area was applied to the gain in hourly flow to estimate an hourly flow for each ungaged stream.

3.3.1.3 Streams between USGS Brockway and Mouth

The flow at the mouth of the South Umpqua River was estimated by scaling up the gage flow at Brockway based on drainage area. As with upstream sections of the river, NPDES permitted flows were subtracted from the Brockway gage flow and withdrawals from the HS7 model were added back in to estimate the natural flow gain in the system between Brockway and the mouth. The drainage area for each modeled stream contributing to this section of the South Umpqua River was obtained from USGS Stream Stats, and the ratio of stream drainage area to total drainage area was applied to the gain in hourly flow to estimate an hourly flow for each ungaged stream.

For permitted sources, flow data was obtained from discharge monitoring reports obtained from Oregon DEQ, where available, or was taken from the 2002 HS7 model.

3.4 WATER TEMPERATURE FROM UPSTREAM AND TRIBUTARIES

Observed hourly water temperature data were available from Oregon DEQ and the US Forest Service - Umpqua National Forest region to support this modeling effort. Data from 22 stations, one on each tributary stream, were available for configuring the model tributary boundary conditions. Although complete water temperature data for the 2009 modeling period were only available for nine out of the 22 stations, some data from other time frames were available for all 22 stations. Figure 3-4 shows the locations of these water temperature monitoring sites. Figure 3-5 shows the observed stream temperature time series data for the nine stations with data covering the entire 2009 modeling period.

Hourly temperature data for July-October 2009 were not available for all streams. For unmonitored streams, temperatures had to be estimated using data from monitored stations. Several stations had data that covered a portion of the July to September 2009 modeling period. For these streams, a correlation was established between the partial data and a reference station with a complete record of data, and the temperature data was extended using the correlation. For streams that had temperature data for a different period than 2009, a correlation was established between existing data and the data at the reference station for the same period, and then that correlation was applied to estimate the temperatures for the station of interest for July-September 2009. Three stations served as reference stations to derive data: Black Rock Fork (UmpNF-006), Jackson Creek (UmpNF-050), and North Myrtle Creek at Evergreen Park (37477-ORDEQ) because these three stations are the only ones that had data available in October 2009. For streams that did not have any temperature monitoring data, temperature data were copied from a nearby stream. Table 3-3 provides an inventory of the water temperature data used in the model development and the method used to derive missing data. The linear regression data can be found in Appendix A.

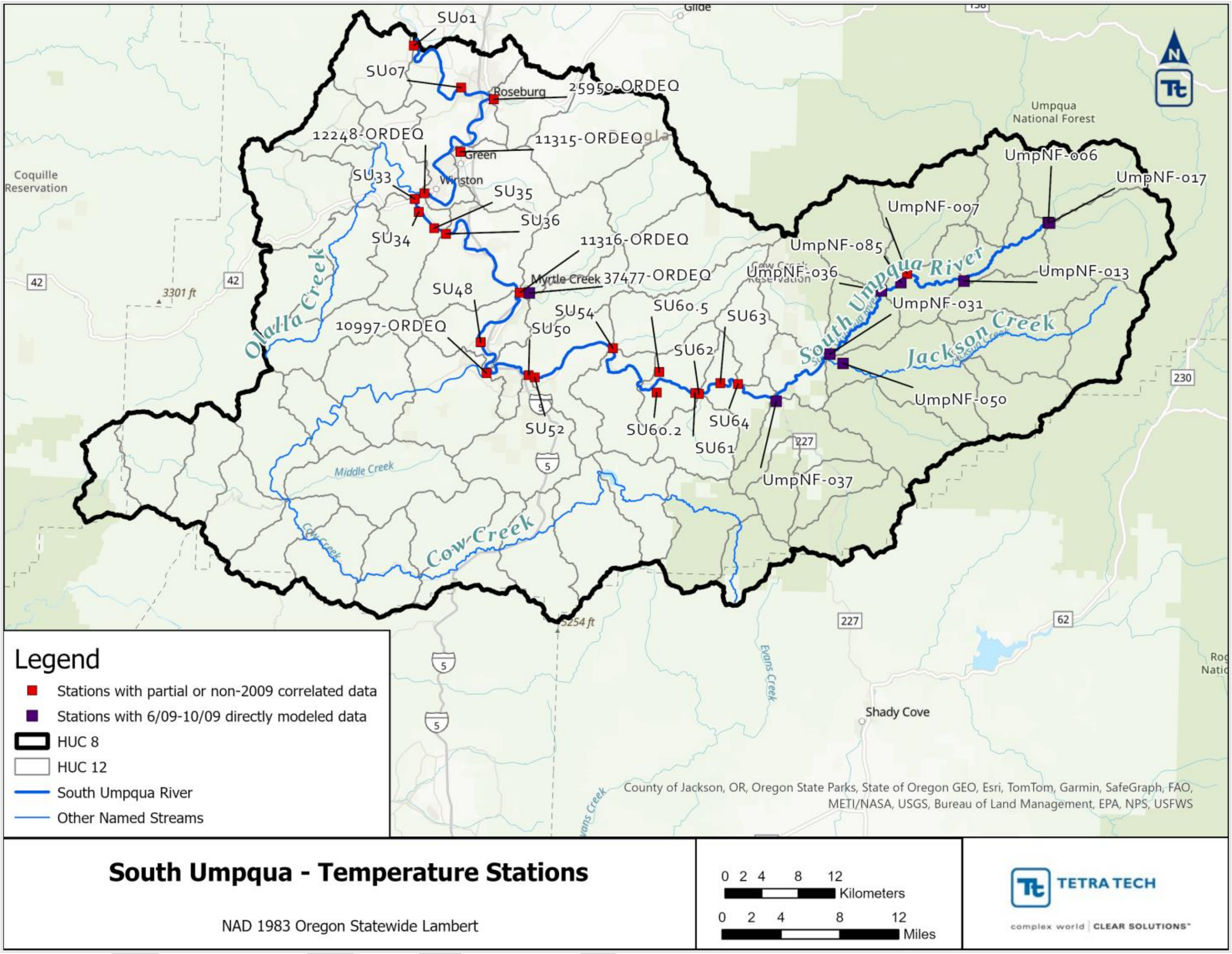
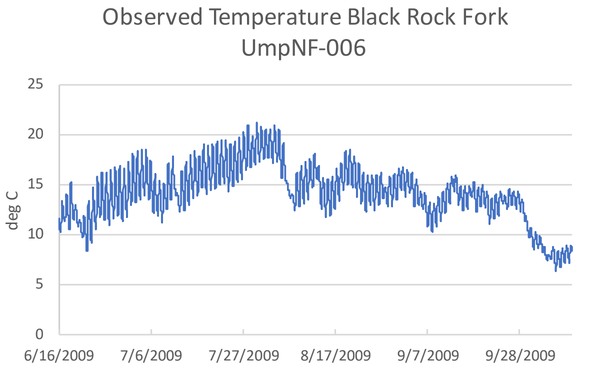
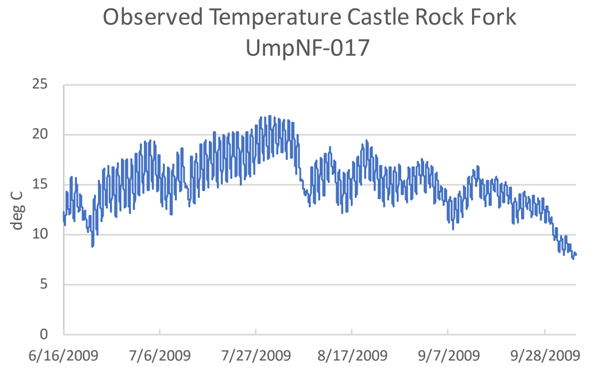
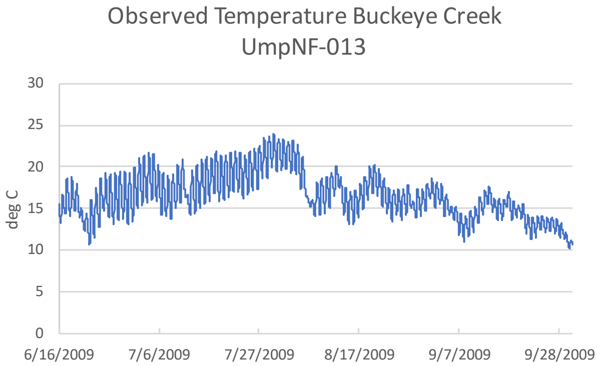
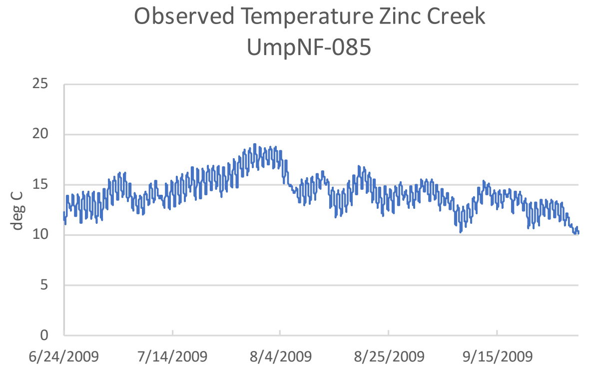


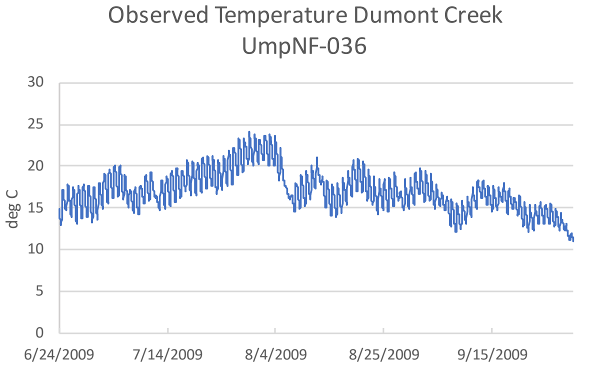
Figure 3-4 Observed Steam Water Temperature Locations for the Development of South Umpqua Model

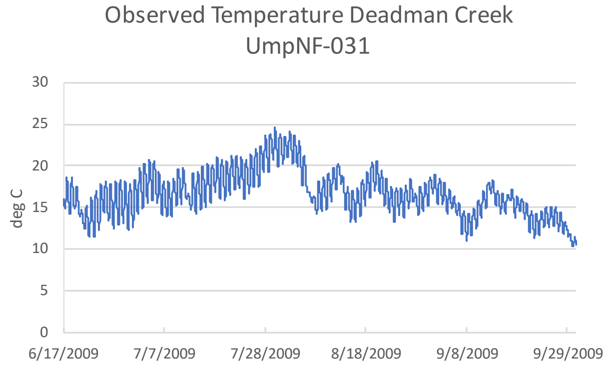

Observed Temperature Black Rock Fork
UmpNF-006
deg C
0
5
10
15
20
25
6/16/2009
7/6/2009
7/27/2009
8/17/2009
9/7/2009
9/28/2009


Observed Temperature Castle Rock Fork
UmpNF-017
deg C
0
5
10
15
20
25
6/16/2009
7/6/2009
7/27/2009
8/17/2009
9/7/2009
9/28/2009


Observed Temperature Buckeye Creek
UmpNF-013
deg C
0
5
10
15
20
25
30
6/16/2009
7/6/2009
7/27/2009
8/17/2009
9/7/2009
9/28/2009


Observed Temperature Zinc Creek
UmpNF-085
deg C
0
5
10
15
20
25
6/24/2009
7/14/2009
8/4/2009
8/25/2009
9/15/2009


Observed Temperature Dumont Creek
UmpNF-036
deg C
0
5
10
15
20
25
30
6/24/2009
7/14/2009
8/4/2009
8/25/2009
9/15/2009


Observed Temperature Deadman Creek
UmpNF-031
deg C
0
5
10
15
20
25
30
6/17/2009
7/7/2009
7/28/2009
8/18/2009
9/8/2009
9/29/2009

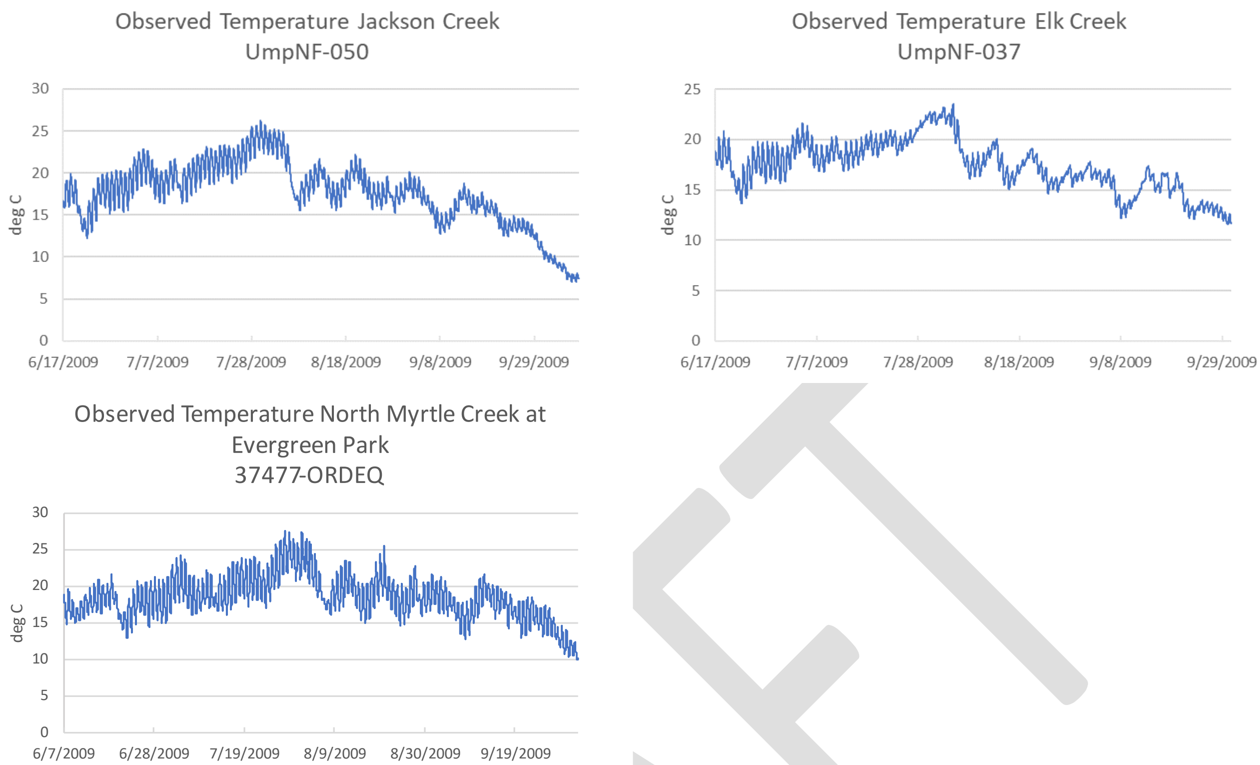


Figure 3-5 Observed Stream Water Temperature Data for the Development of the South Umpqua Model

Table 3-3. Inventory of available water temperature data locations used to configure the South Umpqua River model

Name	Model Inflow ID	Station ID	Reference Station	Derivation Method
Black Rock Creek	Boundary Condition	UmpNF-006	N/A	N/A
Castle Rock Fork	Boundary Condition	UmpNF-017	N/A	N/A
Buckeye Creek	1	UmpNF-013	Ump-NF-006	Extended
Ash Creek	2	N/A	Inflow 1	Copied
Unnamed (LB)	3	N/A	Inflow 1	Copied
Coffeepot Creek (RB)	4	N/A	Inflow 1	Copied
Unnamed (LB)	5	N/A	Inflow 7	Copied
Unnamed Trib (LB)	6	N/A	Inflow 7	Copied
Boulder Creek (RB)	7	UmpNF-007	Ump-NF-006	Correlation
Zinc Creek (LB)	8	UmpNF-085	Ump-NF-006	Extended

Name	Model Inflow ID	Station ID	Reference Station	Derivation Method
Dumont Creek (RB)	9	UmpNF-036	UmpNF-050	Extended
Unknown (LB)	10	N/A	Inflow 9	Copied
Francis Creek (RB)	11	N/A	Inflow 9	Copied
Unnamed Trib (LB)	12	N/A	Inflow 9	Copied
unknown (LB)	13	N/A	Inflow 9	Copied
Collins Creek	14	N/A	Inflow 15	Copied
Deadman Creek (RB)	15	UmpNF-031	UmpNF-050	Extended
Jackson Creek (LB)	16	UmpNF-050	N/A	N/A
Dompier Creek (RB)	17	N/A	Inflow 16	Copied
Salt Creek (RB)	18	N/A	Inflow 20	Copied
Tiller Ranger Station (Permit)	19	N/A	N/A	DMR Data
Elk Creek (LB)	20	UmpNF-037	UmpNF-050	Extended
Slate Creek (RB)	21	N/A	Inflow 20	Copied
Hatchet Creek	22	N/A	Inflow 20	Copied
Coffee Creek (RB)	23	SU64 Coffee Creek at Mouth	37477-ORDEQ	Correlation
Corn creek (RB)	24	SU63 Corn Creek near Mouth	37477-ORDEQ	Correlation
Lick Creek (LB)	25	N/A	Inflow 24	Copied
Stouts Creek (LB)	26	SU62 Stouts Creek near Mouth	37477-ORDEQ	Correlation
Saint John Creek	27	SU61 St. John Creek near Mouth	37477-ORDEQ	Correlation
Coon Creek	28	N/A	Inflow 27	Copied
Ash Creek (RB)	29	N/A	Inflow 30	Copied
Lavadoure Creek (RB)	30	SU60.5 Lavadoure Creek near Mouth	37477-ORDEQ	Correlation
Poole Creek (LB)	31	SU60.2 Poole Creek near Mouth	37477-ORDEQ	Correlation
Shively Creek (LB)	32	N/A	Inflow 31	Copied
Bland Branch (RB)	33	N/A	Inflow 31	Copied
Hammon Creek (RB)	34	N/A	Inflow 31	Copied
unknown (LB)	35	N/A	Inflow 31	Copied
Slimwater Creek	36	N/A	Inflow 31	Copied
Beals Creek (LB)	37	N/A	Inflow 38	Copied
Days Creek (RB)	38	SU54 Days Creek at Mouth	37477-ORDEQ	Correlation
Stinger Gulch (RB)	39	N/A	Inflow 38	Copied

Name	Model Inflow ID	Station ID	Reference Station	Derivation Method
Packard Gulch (RB)	40	N/A	Inflow 38	Copied
Unknown (LB)	41	N/A	Inflow 38	Copied
Morgan Creek (RB)	42	N/A	Inflow 44	Copied
Small Creek (RB)	43	N/A	Inflow 44	Copied
Oshea Creek (LB)	44	SU52 O'Shea Creek at Mouth	37477-ORDEQ	Correlation
Canyonville STP (Permit)	45	N/A	N/A	DMR Data
Canyon Creek (LB)	46	SU50 Canyon Creek at Mouth	37477-ORDEQ	Correlation
Jordan Creek (LB)	47	N/A	Inflow 46	Copied
Cow Creek (LB)	48	10997-ORDEQ	37477-ORDEQ	Correlation
Lane Creek (LB)	49	SU48 Lane Creek at Mouth	37477-ORDEQ	Correlation
Myrtle Creek (RB)	50	11316-ORDEQ	37477-ORDEQ	Correlation
unknown	51	N/A	Inflow 50	Copied
Trib (LB)? Farm drainage	52	N/A	Inflow 50	Copied
Clark Branch	53	N/A	Inflow 50	Copied
Umpqua Lumber (Permit)	54	N/A	N/A	Copied from HS7
Trib (RB)	55	N/A	Inflow 56	Copied
Willis Creek	56	SU36 Willis Creek at Mouth	37477-ORDEQ	Correlation
Rice Creek	57	SU35 Rice Creek at Mouth	37477-ORDEQ	Correlation
Roseburg Forest Products -Dillard (Permit)	58	N/A	N/A	Copied from HS7
Kent Creek (LB)	59	SU34 Kent Creek below Squaw Creek	37477-ORDEQ	Correlation
Brockway Creek (LB)	60	SU33 Brockway Creek near Mouth	37477-ORDEQ	Correlation
Lookingglass Creek (LB)	61	12248-ORDEQ	37477-ORDEQ	Correlation
Beaver State Sand and Gravel (Permit)	62	N/A	N/A	Copied from HS7
Winston-Green WWTP (Permit)	63	N/A	N/A	DMR Data
Durham School Services (Permit)	64	N/A	N/A	Copied from HS7
Marsters Creek (LB)	65	N/A	Inflow 66	Copied
Roberts Creek (RB)	66	11315-ORDEQ	37477-ORDEQ	Correlation

Name	Model Inflow ID	Station ID	Reference Station	Derivation Method
Lone Rock Timber Company (Permit)	67	N/A	N/A	Copied from HS7
Roseburg Landfill - Douglas County (Permit)	68	N/A	N/A	Copied from HS7
Parrott Creek (RB)	69	N/A	Inflow 70	Copied
Deer Creek (RB)	70	25950-ORDEQ	37477-ORDEQ	Correlation
Newton Creek (RB)	71	SU07 Newton Creek at Mouth	37477-ORDEQ	Correlation
RUSA (Permit)	72	N/A	N/A	DMR Data
Sylman Creek	73	N/A	Inflow 71	Copied
Umpqua Sand and Gravel (Permit)	74	N/A	N/A	Copied from HS7
Stockel Creek	75	N/A	Inflow 76	Copied
Champagne Creek (LB)	76	SU01 Champagne Creek at Mouth	37477-ORDEQ	Correlation

3.5 POINT SOURCE DISCHARGES

There are eleven active point sources that discharge to the South Umpqua River, including four major STPs and seven facilities with general NPDES permits. Table 3-4 and Table 3-5 provide information related to each of the point sources. Figure 3-6 shows the spatial location of the four major point sources along the South Umpqua River.

Table 3-4. Summary of individual NPDES permitted discharges to the South Umpqua River

Facility Name (Facility Number)	Latitude/Longitude	Permit Type and Description	South Umpqua River Model River Mile
Canyonville STP (13745)	42.9422/-123.28	NPDES-DOM-Da: Sewage - less than 1 MGD	South Umpqua River RKM 81.2
R.U.S.A. Roseburg STP (76771)	43.2092/-123.396	NPDES-DOM-Ba: Sewage - 5 MGD or more but less than 10 MGD	South Umpqua River RKM 12.15
USFS - Umpqua National Forest; Tiller Ranger Station STP (90944)	42.9278/-122.949	NPDES-DOM-Da: Sewage - less than 1 MGD	South Umpqua River RKM 120.95
Winston-Green WWTF (98400)	43.1367/-123.4	NPDES-DOM-C2a: Sewage - 1 MGD or more but less than 2 MGD	South Umpqua River RKM 33.05

Table 3-5. Summary of general NPDES permitted discharges to the South Umpqua River

Facility Name (Facility Number)	South Umpqua River Model RKM
Umpqua Lumber	50.2
Roseburg Forest Products	44.5
Beaver State Sand & Gravel	34.05
Durham School Services	29.3
Lone Rock Timber Company	24.85
Roseburg Landfill – Douglas County	22.45
Umpqua Sand & Gravel	3.9

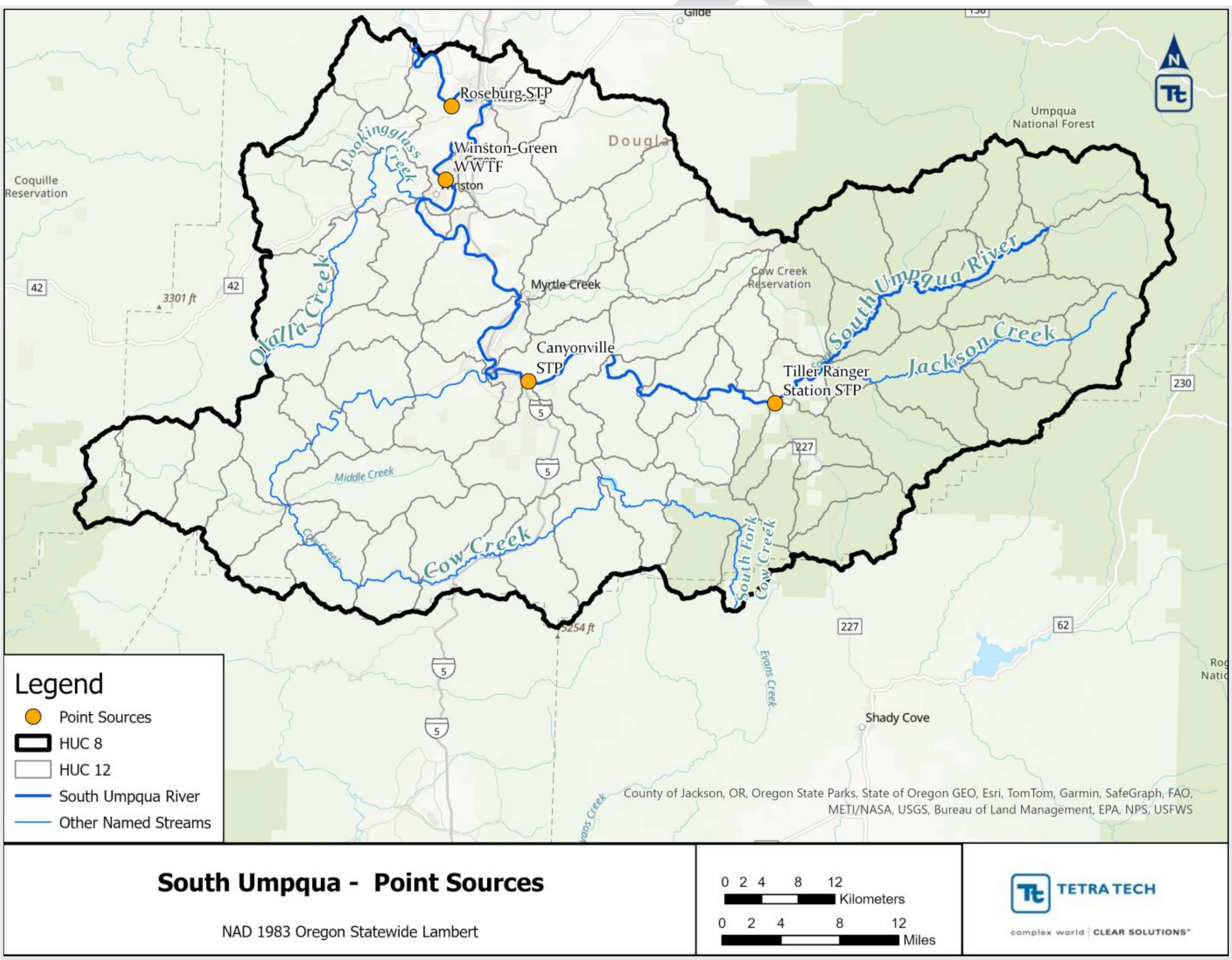
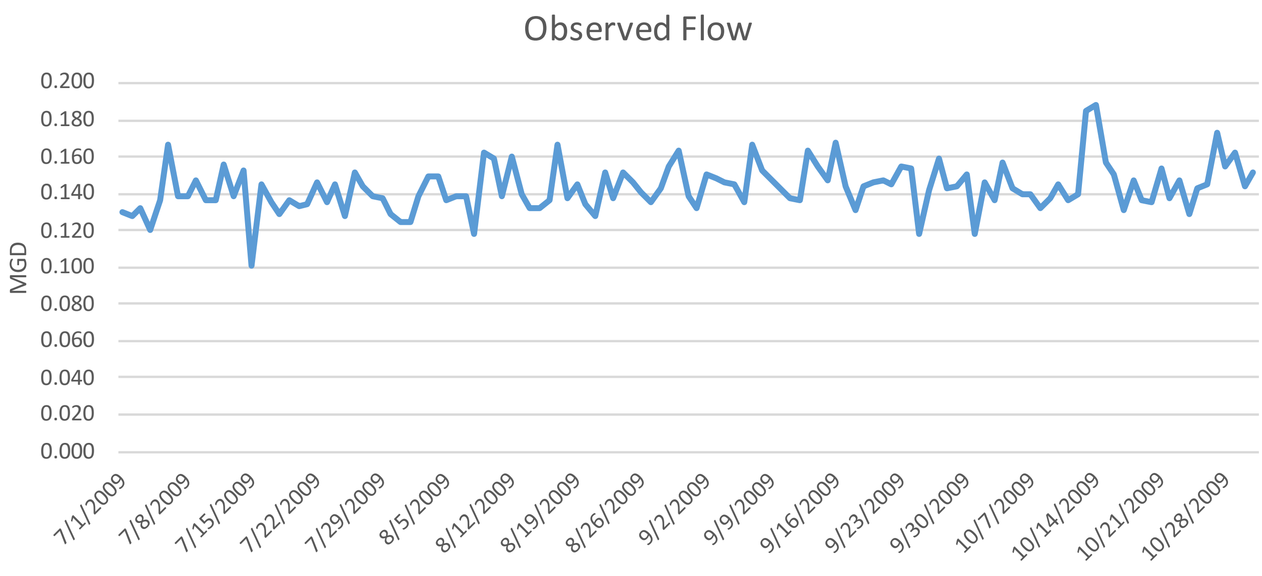


Figure 3-6 South Umpqua River Point Source Locations

Daily flow and water temperature from monthly DMR data were provided by the four major NPDES permitted sources listed in Table 3-4, above. Note that the water temperature provided was most often daily maximum water temperature. Typically, hourly water temperature timeseries are desired but since hourly data were not available, the daily maximum was used as it was the best information available. The daily data were compiled along with appropriate unit conversion, and then linearly interpolated to create hourly time series of flow and water temperature for specification into the model. Figure 3-7 through Figure 3-10 show the flow and water temperature data specified in the model for each of the four major permitted sources. The flow and temperature data for the smaller sources with general NPDES permits listed in Table 3-5 were represented in the original HS7 model with a constant flow at 0.01 cfs and temperature time series, and these same values were used in the HS8 model.



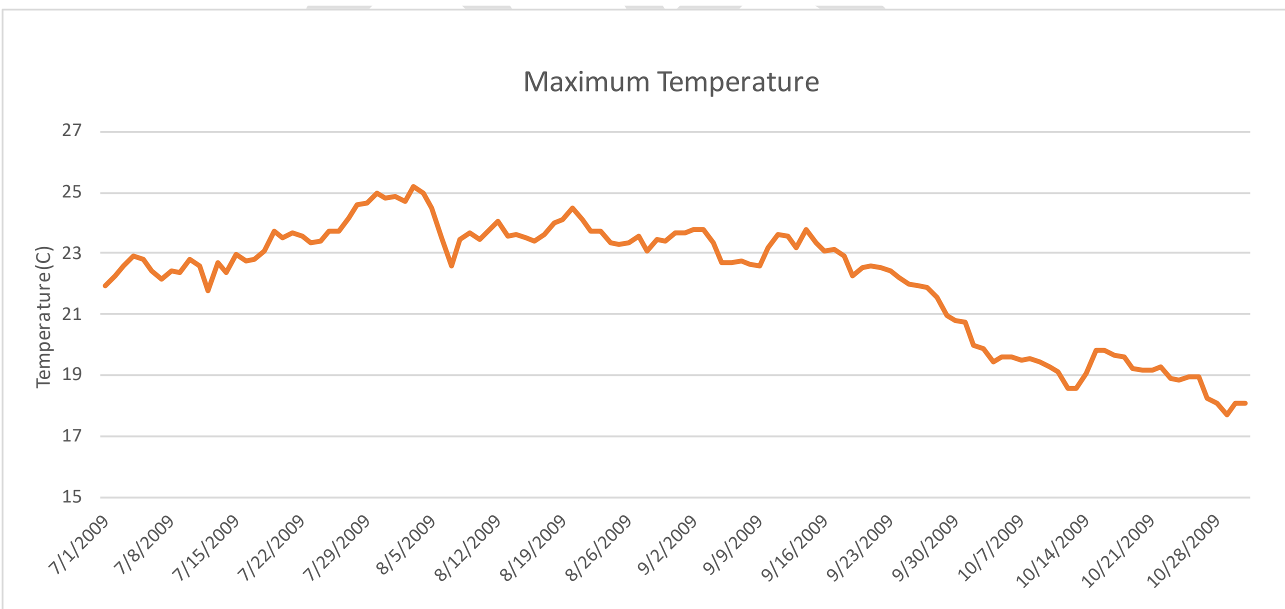


Figure 3-7 Canyonville STP - daily flow and water temperature DMR data

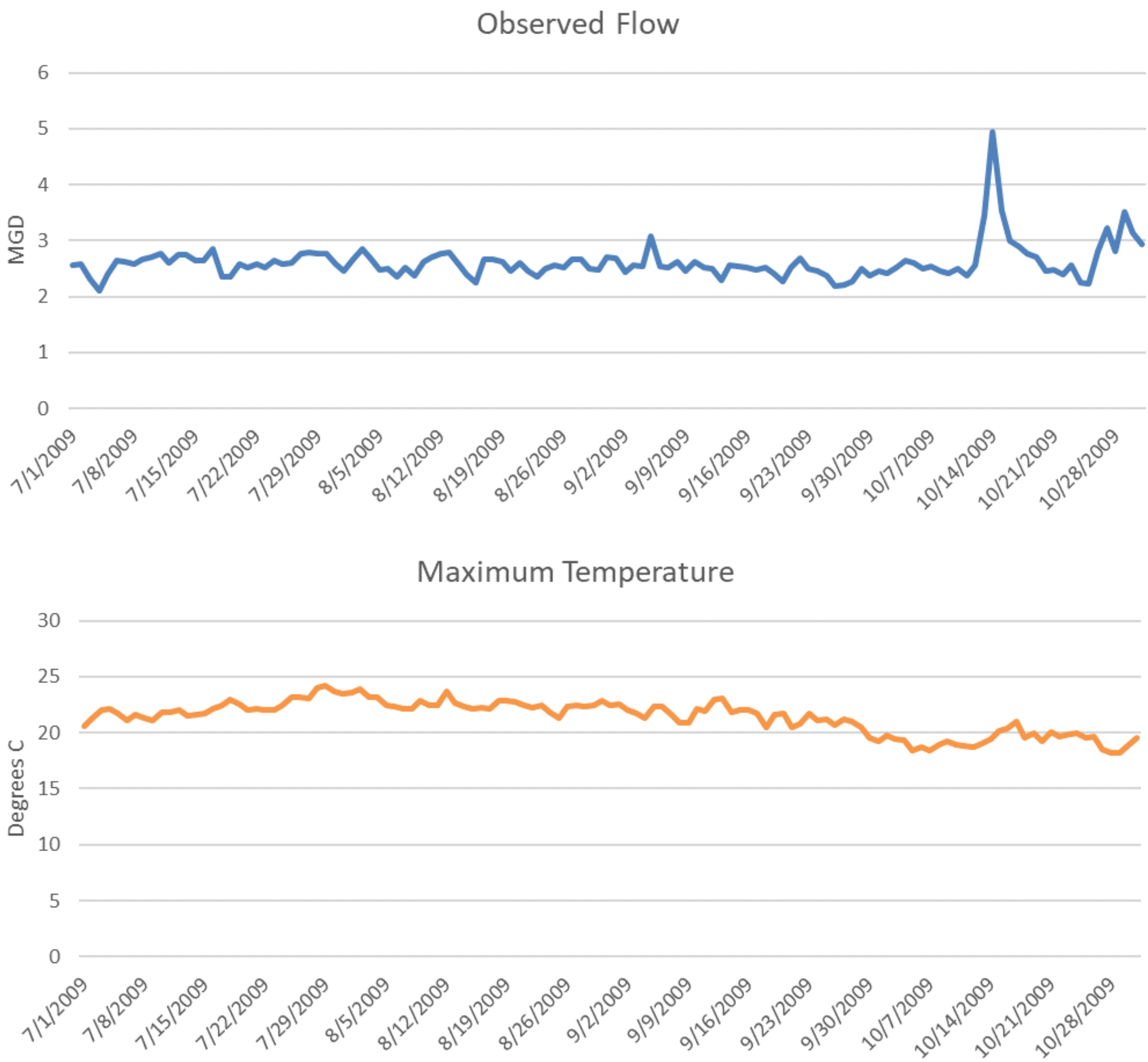
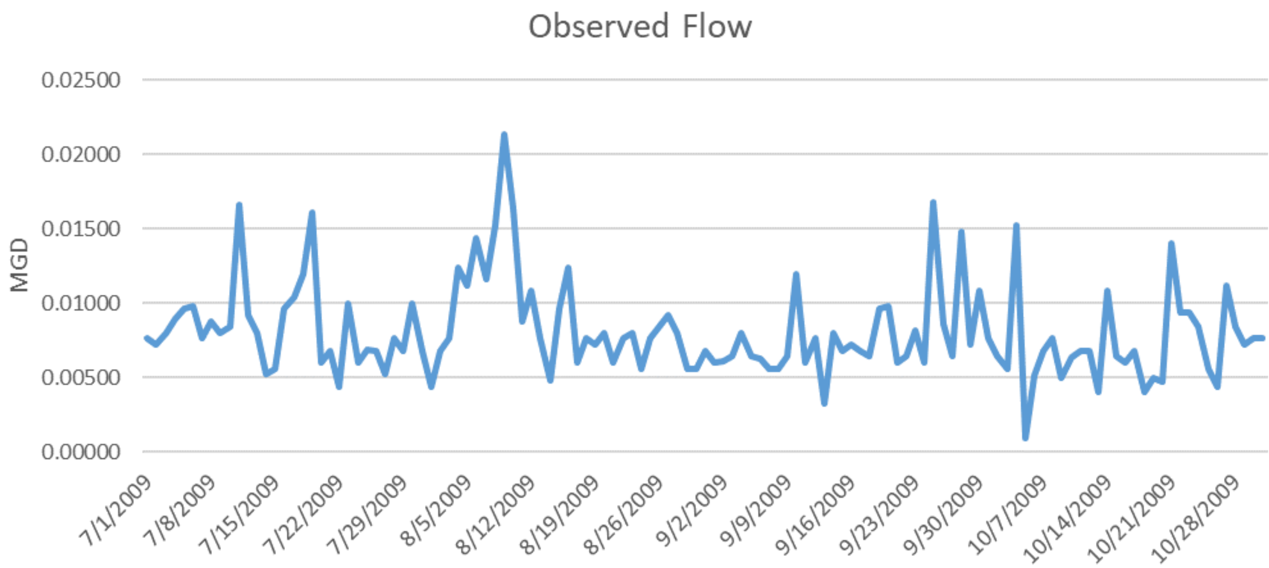


Figure 3-8 R.U.S.A. Roseburg STP - daily flow and water temperature DMR data



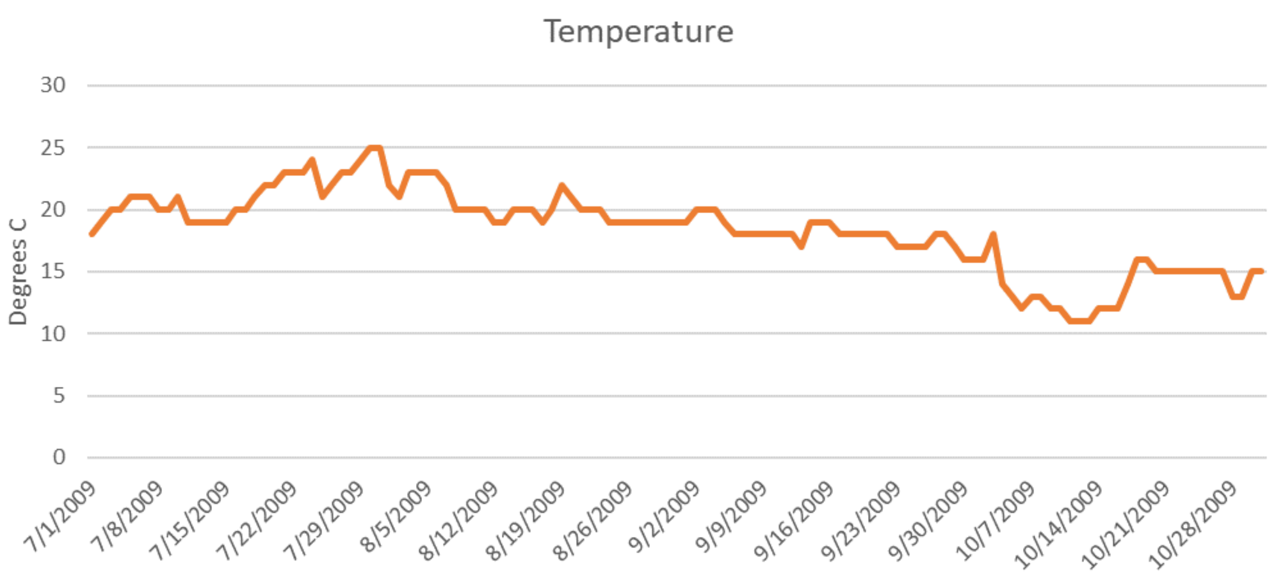
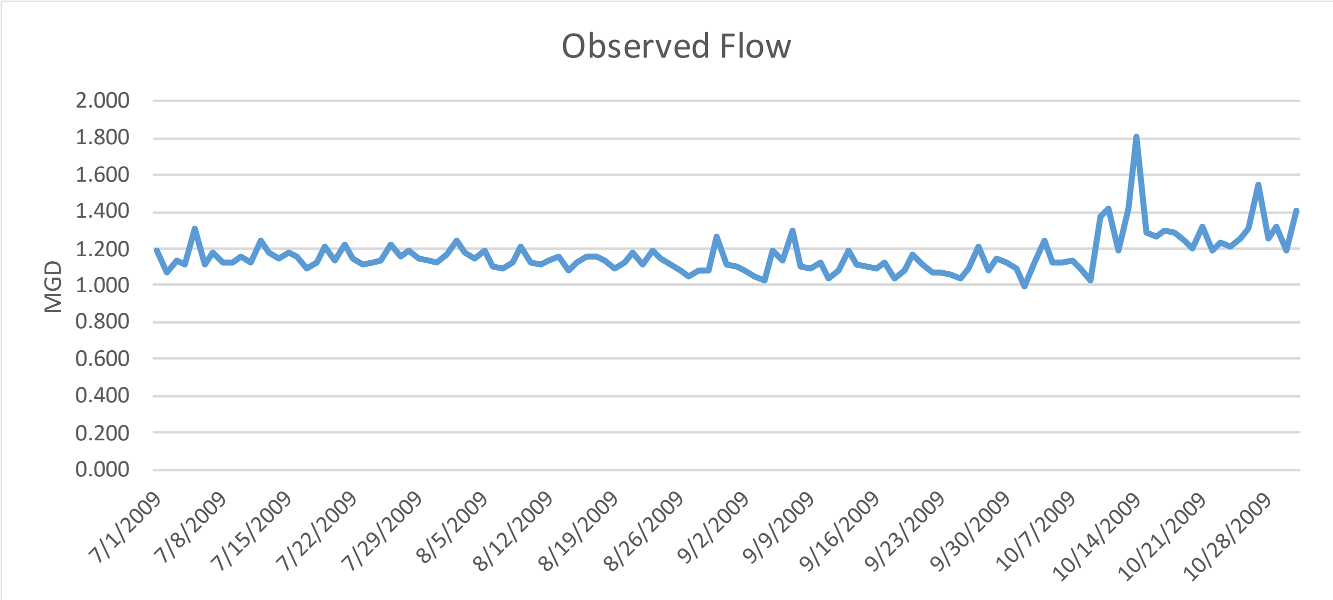


Figure 3-9 USFS – Umpqua National Forest, Tiller Ranger Station STP - daily flow and water temperature DMR data



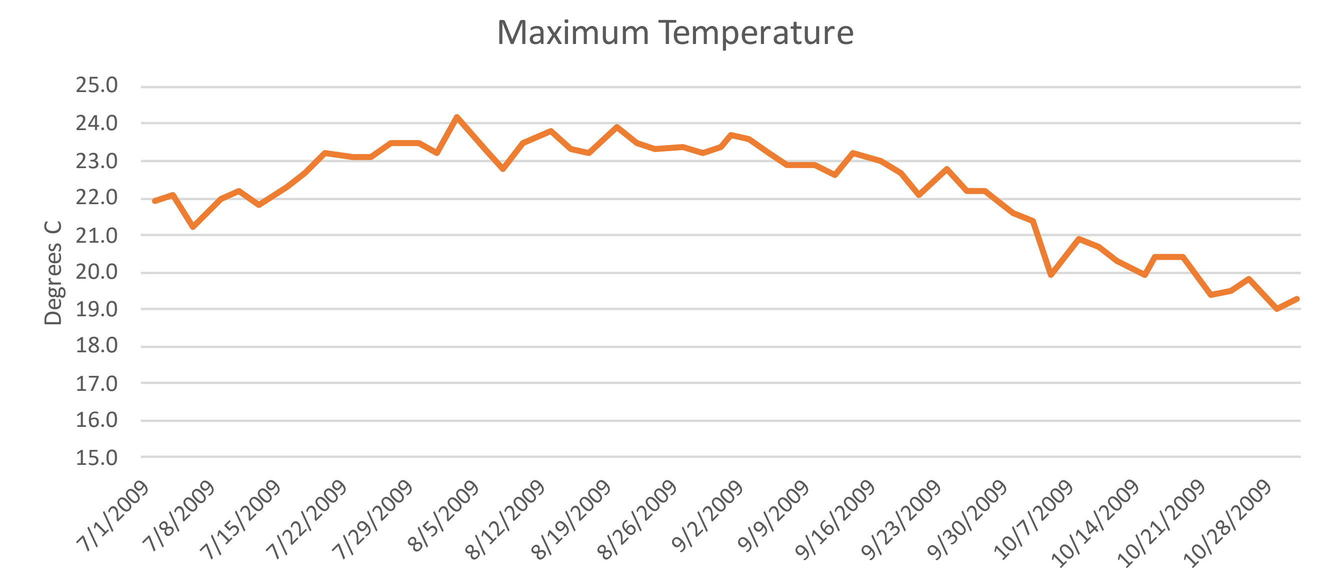


Figure 3-10 Winston Green WWTF - daily flow and water temperature DMR data

3.6 METEOROLOGICAL DATA

Meteorological data includes air temperature, sky conditions, cloudiness, relative humidity, and wind speed. Hourly meteorology inputs were available from the National Oceanic and Atmospheric Association (NOAA)'s National Climatic Data Center (NCDC) Local Climatological Dataset (LCD). The LCD includes quality controlled meteorological data from airports and other prominent weather stations managed by the National Weather Service, Federal Aviation Administration, and the U.S. Department of Defense. The Roseburg Regional Airport. NCDC – LCD station was used for meteorological data assignment in the model. Table 3-6 includes the station inventory of available meteorological input data, and Figure 3-12 shows the location of the station.

Table 3-6. Available meteorological station data in the South Umpqua River watershed

Station ID	Station Name	Latitude/ Longitude	Elevation (m)	Frequency	Available Met Data	Source
WBAN24 231	NCDC – LCD station Roseburg Regional Airport	152.9	43.23367°/ - 123.35775	Hourly	Air Temperature, Relative Humidity, Wind Speed, Descriptive Cloud Cover	NCDC - LCD

Elevations vary widely along the South Umpqua River, ranging from 112 m above sea level at the mouth to 152.9 m above sea level at the Roseburg Regional Airport and 520 m above sea level South Umpqua Falls, near the headwaters. Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. The adiabatic lapse rate was calculated as follows:

LR = 9.8·(Z_sta-Z_site)/1000

where,

LR = Dry adiabatic lapse rate adjustment (°C)

Z_sta = Elevation (meters) of the reference station (152.9 m)

Z_site = Elevation (meters) at the site of interest (1260 m)

LR calculated to be -10.8496 °C.

Wind speed, relative humidity and cloud cover were specified after applying appropriate unit conversion. Wind speeds were further adjusted during calibration, which is discussed in the next section. The Roseburg Airport provided descriptive sky cover information, which was converted to tenths from 0 to 1 for input in the HS8 Model. In general, data for all parameters were available for the modeling period with no missing data. An exception to this was air temperatures, which were missing for a few hours on 16 days throughout the modeling period. The data were filled using data from the previous hour. The largest gap was 5 hours. Figure 3-12 shows the meteorological input specified in the HS8 Model at the Roseburg Regional Airport.

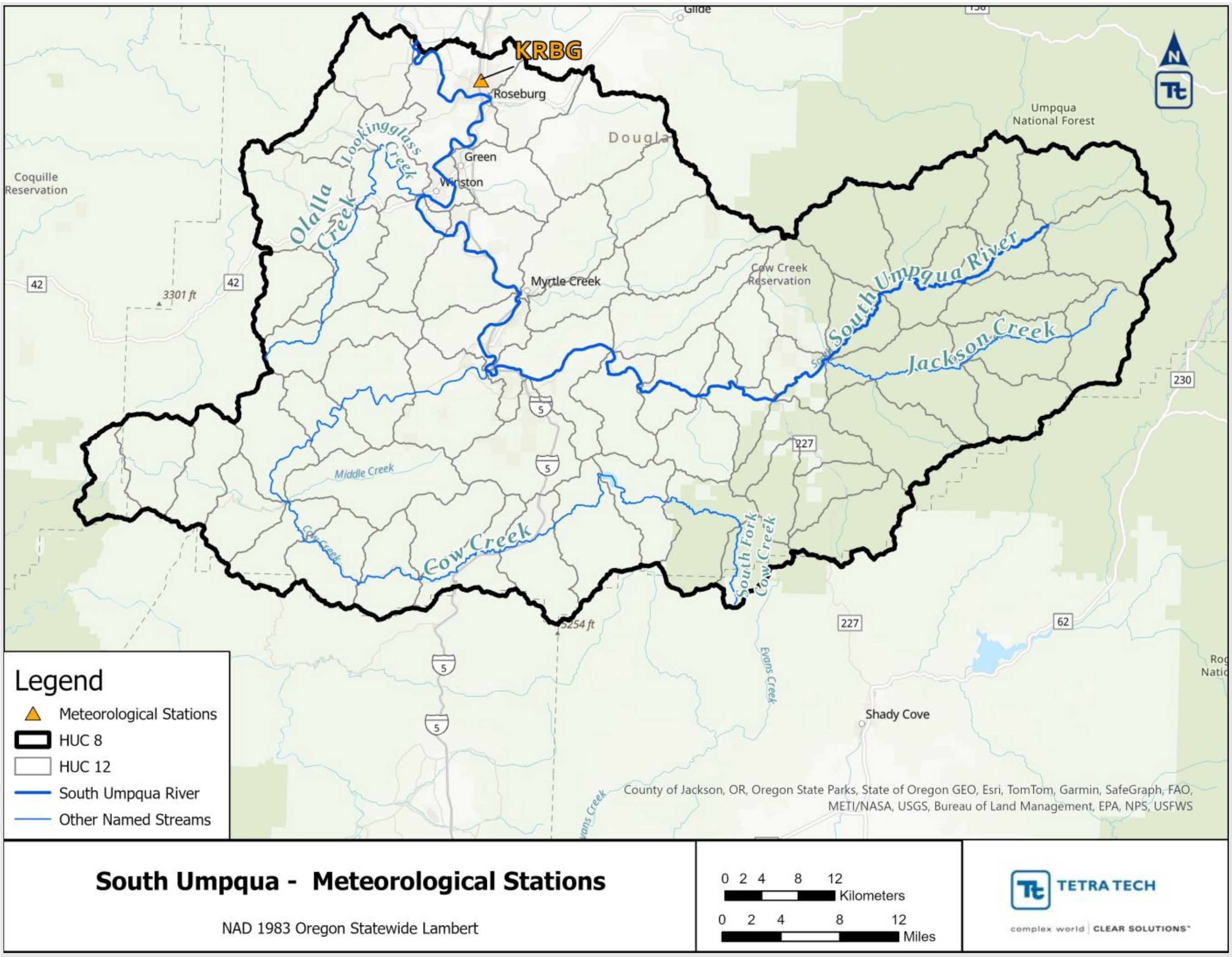


Figure 3-11 South Umpqua River Meteorological Station

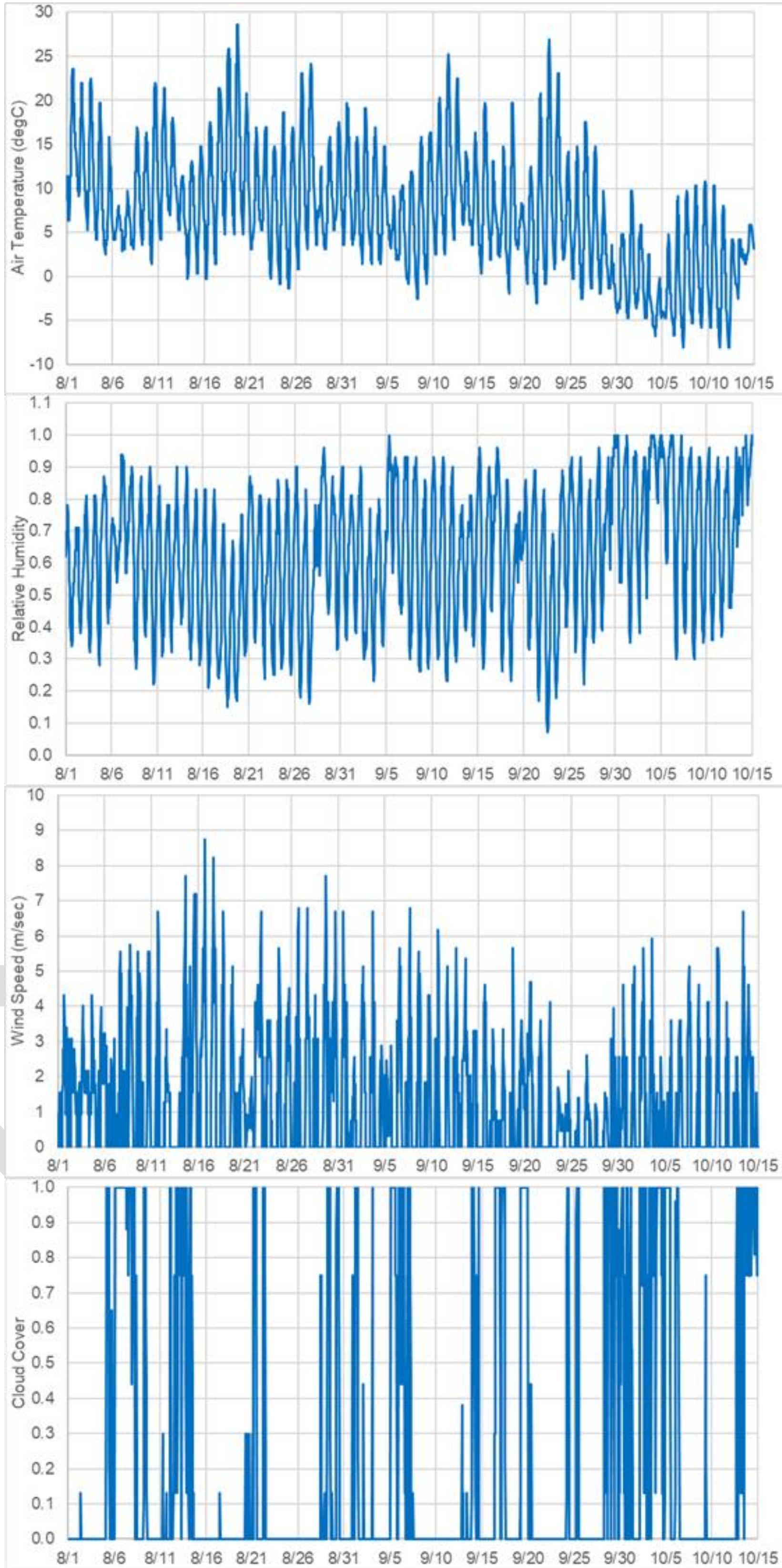
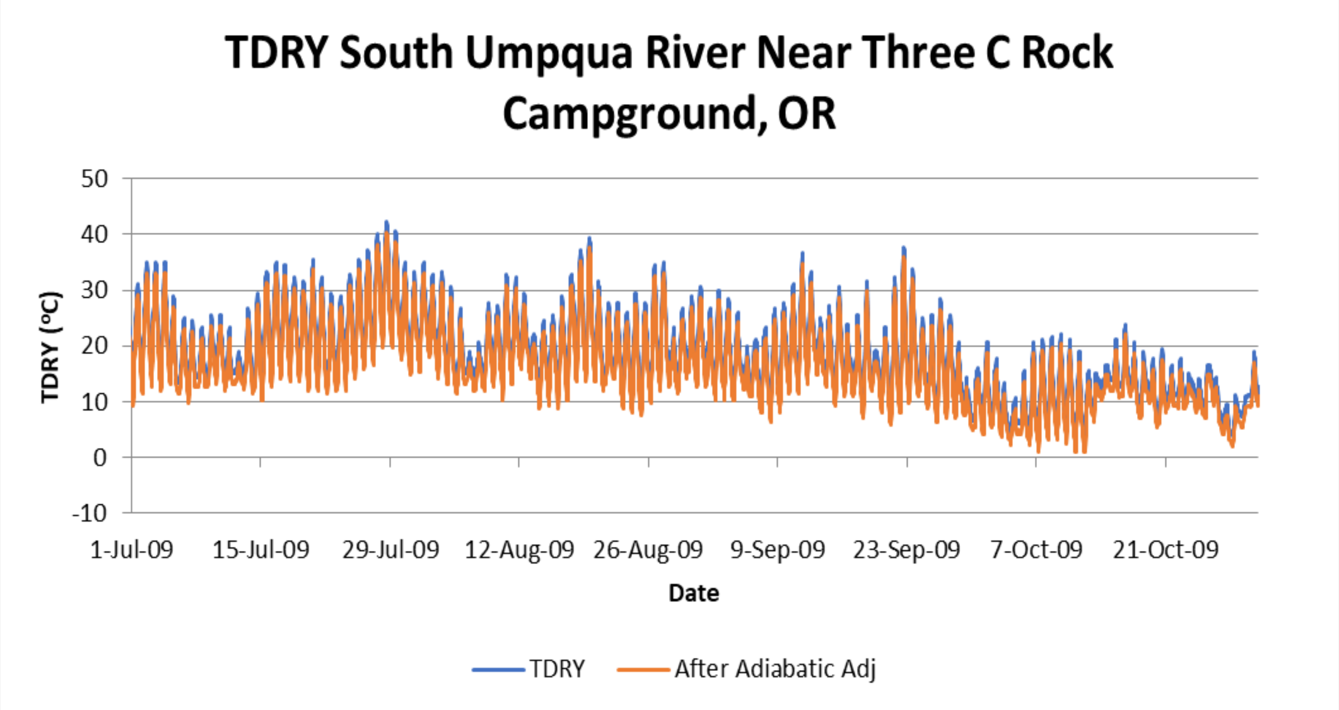


Figure 3-12. Hourly Air Temperature, Relative Humidity, Wind Speed, and Cloud Cover at Roseburg Regional Airport

The dry bulb air temperature or ambient air temperature (TDRY) from the weather data should be adjusted based on altitude before being applied in the model. The Rosedale weather station sits at an elevation of 152.9 m, while the Three C Rock and Tiller calibration segments are located at elevations of 344m and 304 m, respectively. The temperature was adjusted for both locations, as shown in Figure 3-9, which represents weather conditions from the headwaters to Tiller, using the Three C Rock adjusted values, and from Tiller to the mouth South Umpqua River, using the Tiller adjusted values.



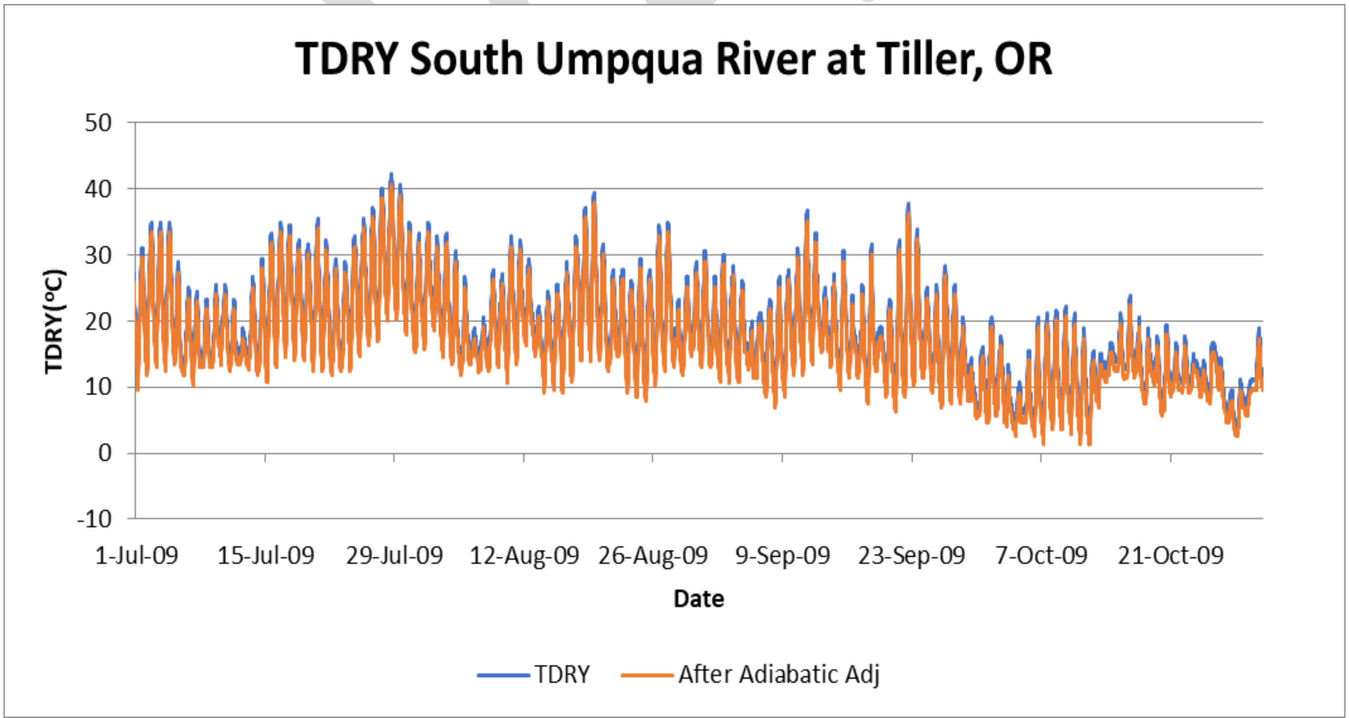


Figure 3-13 Calibration Node Air Temperatures after Adiabatic Adjustment. (Units are in Celsius)

4.0 MODEL CALIBRATION

The South Umpqua River HS8 model was configured for the time period from July 1, 2009, to October 3, 2009, over the 165-kilometer study area from the confluence of Black Rock Fork and Castle Rock Fork to the mouth of the Umpqua River. The purpose of this model is to simulate the water temperature during the spawning season. Therefore, model calibration focuses on the model results after September 1, 2009. The model incorporated spatially varying hourly meteorology, 66 hourly flow and stream temperature inputs (including the upstream boundary, and major tributaries such as Cow Creek and Elk Creek), and 11 NPDES point sources that discharge into the system.

The model was then calibrated against observed data. Model calibration refers to the comparison of observed data to modeled values. Table 4-1 shows the sites used in the South Umpqua River HS8 model flow and water temperature calibration. Figure 4-1 shows the location of the flow and stream temperature calibration stations.

Table 4-1. Calibration sites used in the Sandy River Heat Source Model Calibration

Station ID	Description	Latitude/ Longitude	Model RKM	Data Type	Source
Hourly Flow					
14312000	South Umpqua River near Brockway, OR	43.13317169/ -123.3984053	48.05	Hourly Flow	USGS
14308000	South Umpqua River at Tiller, OR	42.9303985/ -122.9483872	120	Hourly Flow	USGS
Hourly Water Temperature					
UmpNF-076	South Umpqua at Tiller Ranger Station, OR	42.92768346/ --122.9500002	120	Hourly Water Temperature	USFS
UmpNF-075	South Umpqua at Three C Rock, OR	42.9656/ -122.886	128.1	Hourly Water Temperature	USFS

The model was run at a time step of 0.3 minutes and outputs were generated hourly, every 50 meters. The modeled stream flows were calibrated first, followed by stream temperature.

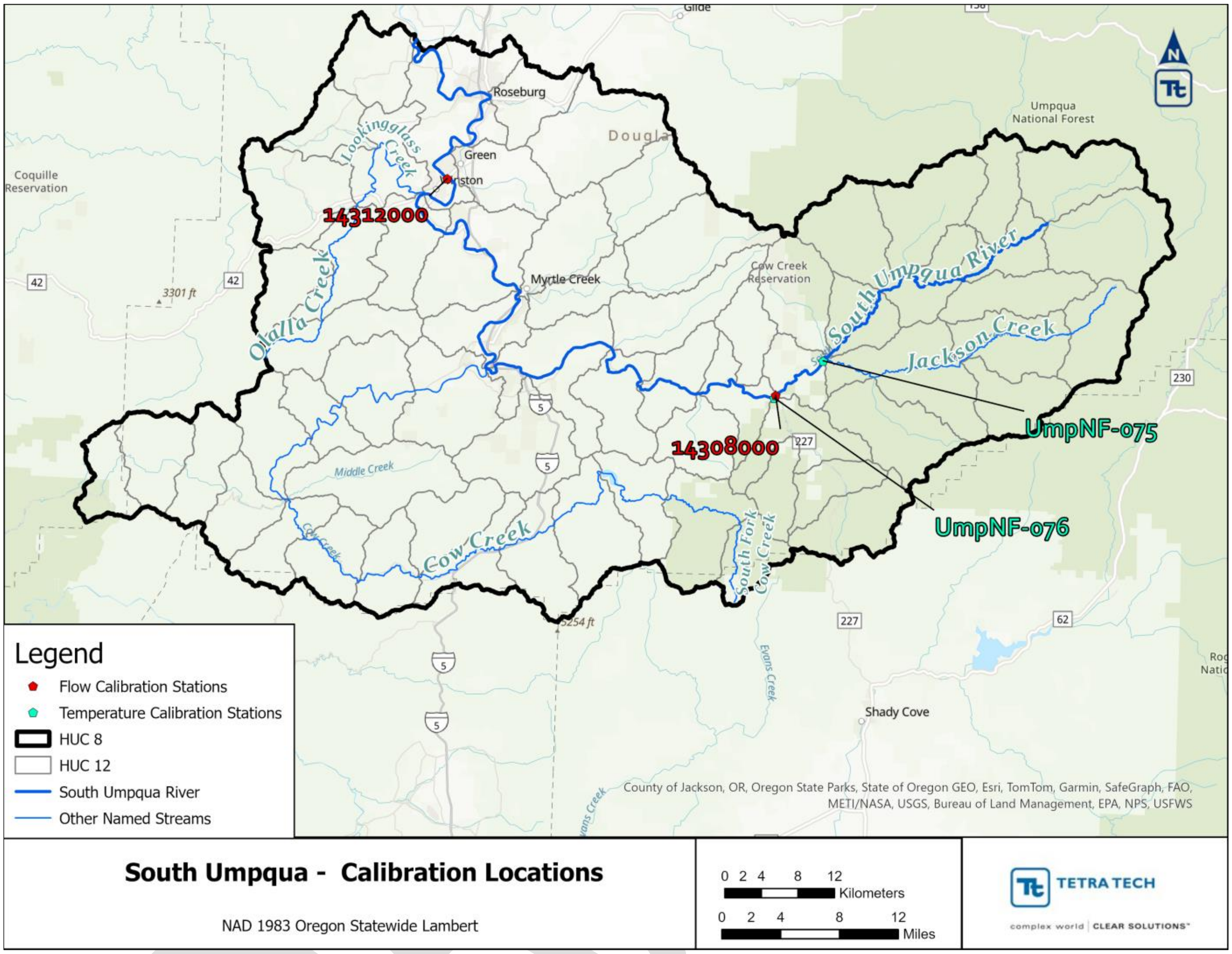


Figure 4-1 South Umpqua River Meteorological Stations

4.1 FLOW BALANCE

Observed and modeled hourly flow values at the two flow stations along the South Umpqua River (Table 4-1) were compared against each other. Figure 4-2 and Figure 4-3 compare the simulated and measured flow volumes at the gages for the simulation time-period. The simulated daily flow values were very similar to the gage flow data because those gages were used as a reference starting point for the stream flow balance calculations. Refer to section 3.3.1 for more details on the flow balance comparisons. The same channel geometry and Manning's roughness coefficient values as the South Umpqua summer HS7 model were used in the 2009 spawning period model. The main change is the new flow estimates for tributaries for the 2009 spawning period model for flow calibration. In addition, the estimated flow time series was temporally shifted to better match observed flow data. Table 4-2 shows the flow calibration error statistics. The error statistics include mean error (ME), absolute mean error (AME), root mean square error (RMSE), and Nash-Sutcliffe Efficiency (NSE).

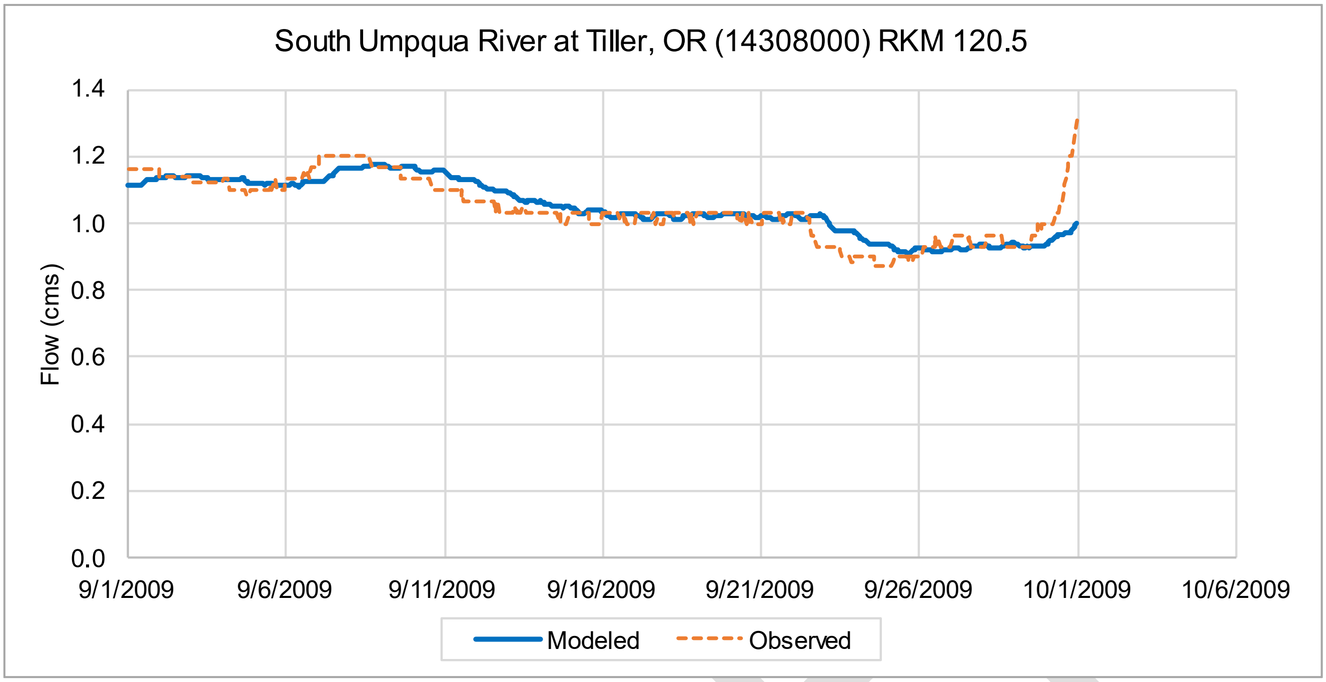


Figure 4-2 South Umpqua River at Tiller (USGS 14308000)

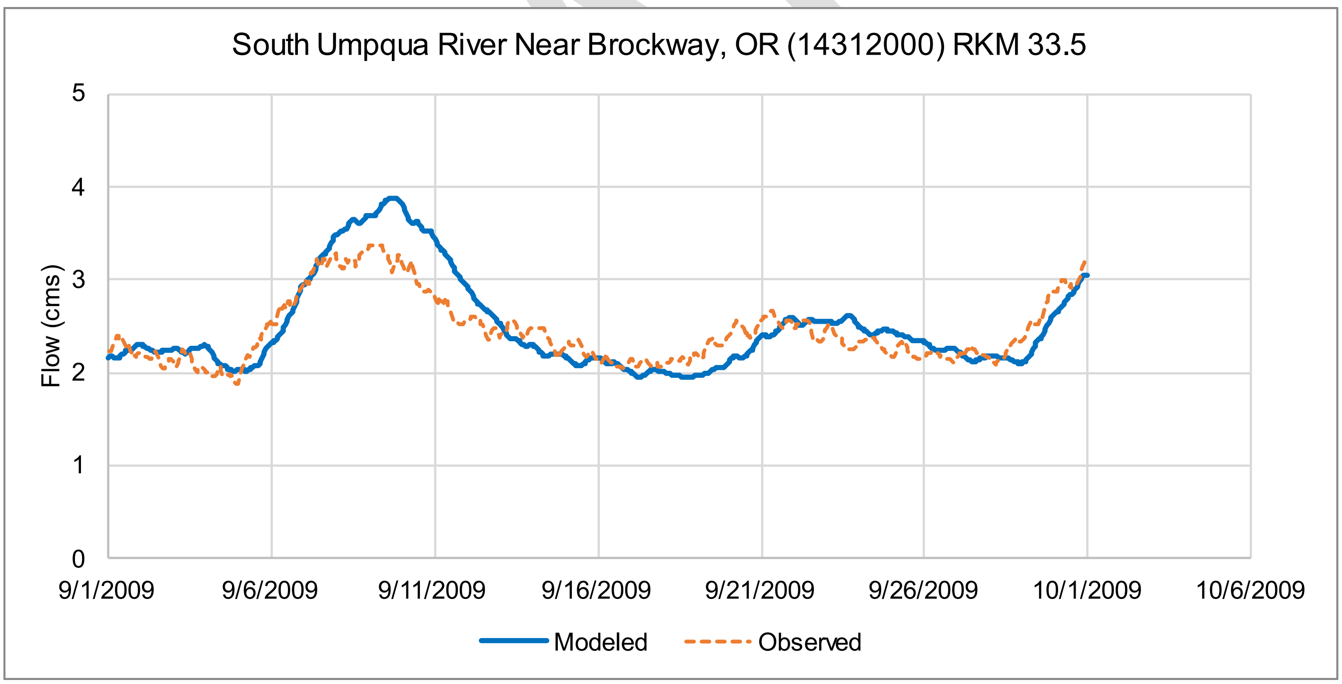


Figure 4-3 South Umpqua River Near Brockway (USGS 14312000)

Table 4-2. Flow Calibration Statistics

Flow (m^3/s)	South Umpqua River at Tiller, OR (14308000) RKM 120.5	South Umpqua River Near Brockway, OR (14312000) RKM 33.5
ME	0.005	0.04
MAE	0.03	0.19
RMSE	0.05	0.25
NSE	1.00	1.00
Count	720	720

4.2 TEMPERATURE CALIBRATION

Hourly temperature observations were compared at each of the stream temperature calibration monitoring stations shown in Figure 4-1 and listed in Table 4-1. In order to refine modeled temperature, cloud cover was adjusted near the calibration sites, and sediment heat exchange and hyporheic exchange were also adjusted. Eventually, the sediment thermal conductivity was set to 1.57 W/m/ºC; the sediment thermal diffusivity was set to 0.0064 cm^2/sec, the porosity of sediment layer was set to 30%, the sediment hyporheic zone thickness was set to 0.5 m, and the percent hyporheic exchange was set to 10%. The calibrated model is able to capture the hourly diurnal pattern and daily maximums at the two upstream stations - South Umpqua River at Three C Rock (Figure 4-4) and South Umpqua above Tiller Reservoir (Figure 4-5). The calculated error statistics show a MAE and RMSE of less than 1 ˚C. The NSE value at all four stations was greater than 0.65 for the hourly and greater than 0.85 for the daily maximum. Table 4-3 shows the model calibration statistics for each of the calibration locations.

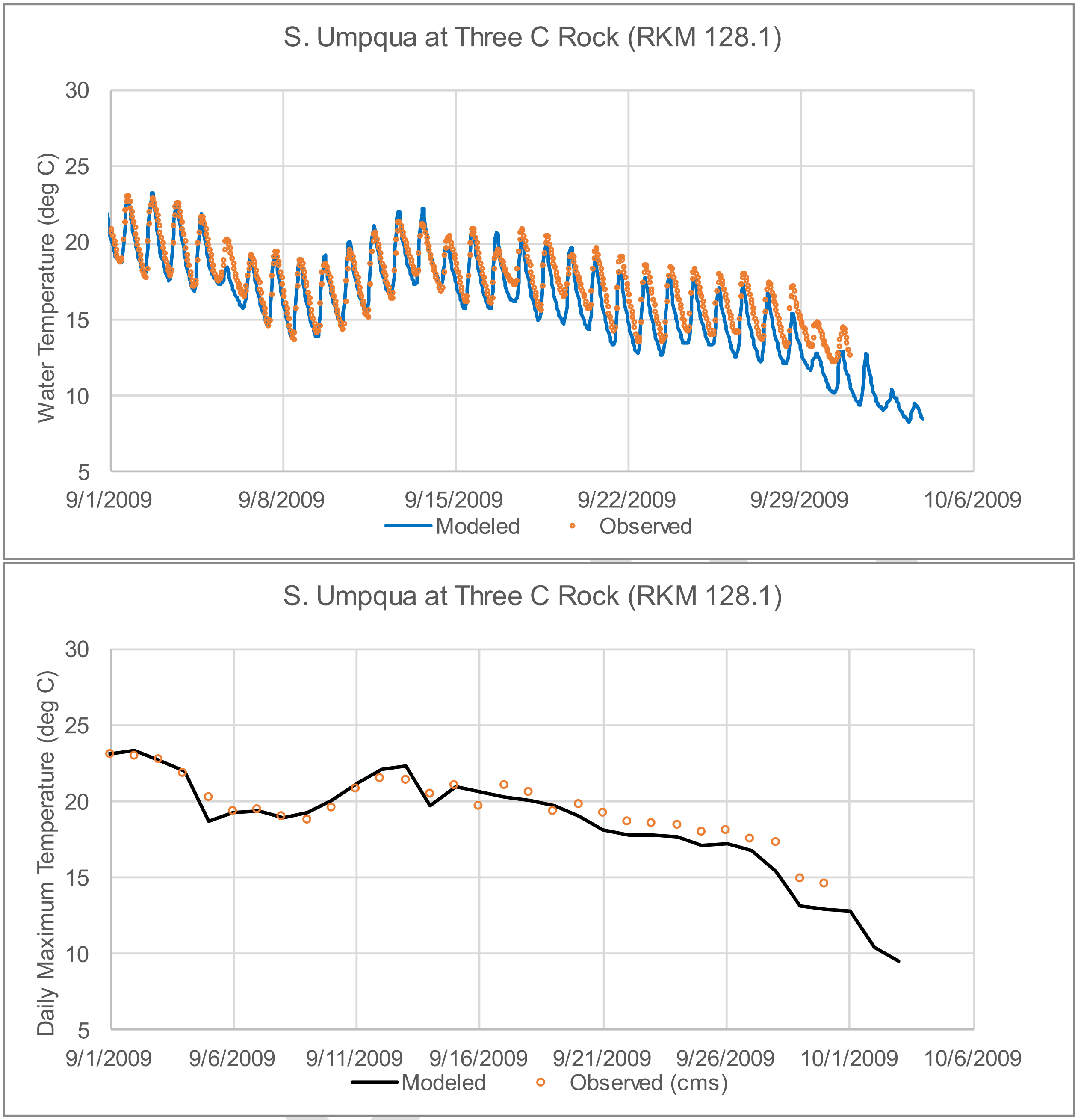
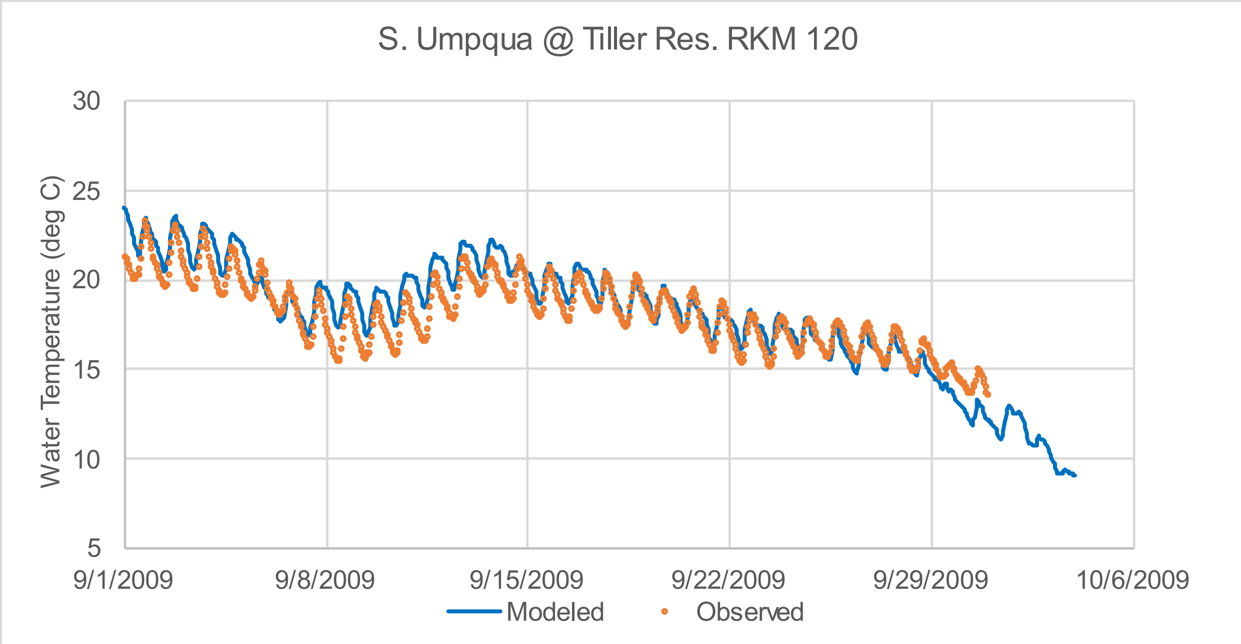


Figure 4-4 Observed versus Modeled Water Temperature - South Umpqua River at Three C Rock



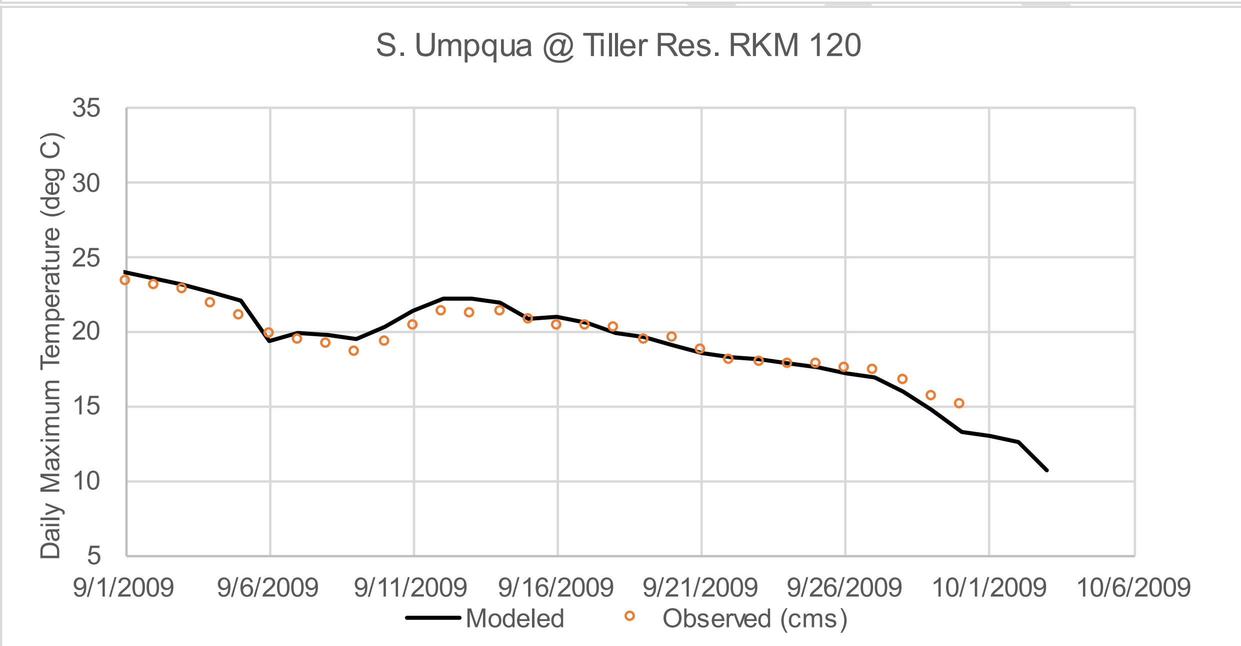


Figure 4-5 Observed versus Modeled Water Temperature - South Umpqua River at Tiller Reservoir

Table 4-3. Hourly and Daily Maximum Stream Temperature calibration statistics for South Umpqua River (September 1 to September 30, 2009)

Statistic	South Umpqua River at Three C Rock	South Umpqua River above Tiller Reservoir
Hourly temperature (˚C)		
ME	-0.90	0.54
MAE	0.97	0.91
RMSE	1.14	1.11
NSE	0.75	0.690
Count	720	720
Daily Maximum Temperature (˚C)		
ME	-0.36	0.19
MAE	0.68	0.59
RMSE	0.85	0.70
NSE	0.89	0.925
Count	30	30

5.0 SUMMARY

A HS8 shade and water temperature model was developed for the South Umpqua River to support TMDL development for spawning temperature impairment in the river. The extent of the modeling domain was from the mouth at the Umpqua River to the confluence of Black Rock Fork and Castle Rock Fork. The model was developed for the critical spawning period during 2009 when data are available for model development. The model used the existing HS7 base model, reconfigured for HS8 and the new time period. Observed meteorological data from the Roseburg airport station was used. The model used DMR data four large, active point sources that discharge to the South Umpqua River: Canyonville STP, R.U.S.A. Roseburg STP, USFS – Umpqua National Forest, Tiller Ranger Station STP, and Winston-Green WWTF. Flow data required for configuring the flow boundaries for all model tributaries were not available and were estimated using observed reference flow gages on the South Umpqua River at Tiller and Brockway. Model water temperature data boundaries were configured using observed hourly stream temperature data that was available for nine of the 22 tributaries. Stream water temperature for the remaining tributaries were derived using either a linear regression approach or using a direct surrogate from a neighboring or nearby tributary watershed.

The model was calibrated using hourly water temperature at two separate locations along the South Umpqua River mainstem. Overall, the diurnal temperature patterns and daily maximum, especially during the low flow periods were captured at each of the station locations. In general, the calculated ME, MAE and RMSE were less than 1 ˚C at each of the calibration station locations, with the exception of RMSE for hourly temperature, which was 1.1 ˚C for both stations.

6.0 REFERENCES

Boyd, M., and B. Kasper. 2003. Analytical Methods for Dynamic Open Channel Heat and Mass Transfer: Methodology for Heat Source Model Version 7.0.

Oregon Department of Environmental Quality (DEQ).2006. Umpqua Basin TMDL. Daniel Turner, Brian Kasper, Paul Heberling, Bobbi Lindberg, Mike Wiltsey, Gary Arnold, and Ryan Michie Watershed Management Section, WQ Division. October, 2006.

Oregon Department of Environmental Quality (DEQ). 2022. Modeling Quality Assurance Project Plan: South Umpqua and Umpqua Subbasins Temperature Total Maximum Daily Load.

APPENDIX A

Temperature Correlation Plots

TETRA TECH

MEMO

To:	Rebecca Veiga Nascimento, Ben Cope, Catelyn Jones
From:	Aileen Molloy, Sen Bai, Mustafa Faizullabhoy, Eugenia Hart
Date:	October 4, 2024
Subject:	South Umpqua and Umpqua River Scenarios

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1.0 INTRODUCTION

This document discusses the development and results of the various model scenarios of the heat source (HS) models in the Umpqua and South Umpqua watersheds. For the 2006 TMDL, summer HS models were developed by Oregon Department of Environmental Quality (DEQ) to simulate the July 12- July 31 2002 period for:

- Jackson Creek
- Cow Creek
- Olalla-Lookingglass Creek
- South Umpqua River
- Calapooya Creek
- Elk Creek
- Umpqua River

Among these creeks, Jackson Creek, Cow Creek, Olalla-Lookingglass Creek are tributaries of the South Umpqua River. The South Umpqua River is a headwater river for the Umpqua River. Calapooya Creek and Elk Creek are tributaries of the Umpqua River.

For this 2025 temperature replacement TMDL, a separate spawning period model was developed for the South Umpqua River using available data from 2009, and this report provides scenario results for the fall period.

The locations of the North Umpqua River, South Umpqua River, Umpqua River and their tributaries are shown in Figure 1-1.

Figure 1-1. Umpqua River, North and South Umpqua rivers and major tributaries.

To support the 2025 TMDL development, a series of scenarios were conducted using the summer models and the spawning period model for South Umpqua.

The following scenarios were evaluated using these models:

1. Calibrated Current Condition (CCC) scenario
2. No point sources scenario
3. Point source WLA scenario
4. Fully restored vegetation scenario
5. Background scenario
6. Attainment scenario
7. Natural flow scenario

In addition to these scenarios that support the TMDL development, additional scenarios were run to gain insights on model responses to factors such as tributary and headwater temperature inputs. Two more scenarios were run:

8. Tributary/headwater plus 0.1 ^{o}C scenario
9. Fully restored vegetation with point source WLA and Tributary/headwater plus 0.1 ^{o}C scenario

Model scenario interpretation in terms of calculation metrics that applied to all scenarios is discussed first, followed by descriptions of the scenarios. The scenario results are presented following the order of the summer HS model list above.

2.0 MODEL SCENARIO INTERPRETATION

This section discusses the calculation metrics that were used when evaluating the scenarios.

2.1 SIGNIFICANT DIGITS AND ROUNDING

The TMDL analysis, interpretation of the model results, and all scenarios account for significant digits and rounding. For evaluation of the attainment of the human use allowance (HUA), DEQ tracks values to the hundredths of a degree Celsius. Because DEQ is providing some of the HUA allocations out to the hundredths, attainment must be tracked in a similar manner. DEQ has a permit-related internal management directive (IMD) on rounding and significant digits (DEQ 2013). The TMDL analysis follows the rounding procedures outlined in this IMD. The significant figures IMD says that for “calculated values” (which includes model results), if the digit being dropped is a “5,” it is rounded up. For example, for water withdrawals DEQ is proposing a 0.05 °C HUA allocation. If the model shows warming equal to 0.054 °C it gets rounded down to 0.05 °C and the result is attainment. If the model shows warming equal to 0.055 °C, it gets rounded up to 0.06 °C, and the result is non-attainment.

2.2 CALCULATING THE 7-DAY AVERAGE MAXIMUM TEMPERATURE

For each scenario the 7-day average maximum (7DADM) temperature was calculated using the hourly model output. The 7DADM was calculated using the procedure outlined in DEQ’s Temperature IMD (DEQ 2008). As outlined in the document, the 7DADM temperature is calculated by first calculating the daily maximum for each day, followed by calculating a rolling average of the daily maximums, the result for which lands on the 7th day.

2.3 COMPARING TEMPERATURE BETWEEN TWO SCENARIOS

When comparing the hourly results from two model scenarios to determine the temperature changes, the following steps were taken:

1. Calculate the 7DADM temperatures for scenario 1 at every model output for every day during the model period.
2. Calculate the 7DADM temperatures for scenario 2 at every model output for every day during the model period.

3. For allocation scenarios the HUA is based on an increase above the applicable criteria, so for determining the maximum change in temperature, the days when the 7DADM river temperatures do not exceed the applicable biologically based numeric criteria (BBNC) were excluded, which results in 0 differences on the plots when comparing results from two scenarios. The difference between two scenarios is only calculated for each time step when any of the 7DADM of the scenario exceeds the BBNC. This step was necessary to ensure that we only consider the maximum change in temperatures when the river exceeds the BBNC criteria for analysis. Note that the BBNC could vary spatially and temporally. Zero values do not indicate no temperature difference, only that the temperatures are below criteria.
4. Compute the difference between the 7DADM temperatures of scenario 1 and scenario 2 only for days that exceed the BBNC. In this manner at each node a ∆T is computed for every 7DADM temperature from each scenario for each day where the BBNC is exceeded. Finally, the max ∆T for each node location was taken and plotted longitudinally as 7DADM deficit plots.
5. The differences were rounded to the hundredths, based on the adopted rounding procedure discussed in Section 2.1.

Explanation of 7DADM ∆T Plots

Below is an illustration of when the maximum deltas are plotted. As noted above, the temperature difference between any two scenarios is only calculated and shown when one of the two exceeds the BBNC. If at a given point, the 7DADM for both scenarios do not exceed the BBNC, the delta is reflected in the plot as 0. In the example in Figure 2-1, the CCC Scenario remains below the BBNC until just downstream of Copeland Creek (top plot) and the No Dams scenario remains below the BBNC until downstream of Fox Creek (middle plot). While there is an actual difference in the 7DADM between these two scenarios, no delta is calculated for TMDL purposes until the 7DADM for one or both scenarios exceeds the BBNC. In this example, a gray line in the bottom plot shows the delta prior to the 7DADMs for either scenario exceeding the BBNC. Then, once the BBNC is exceeded in the CCC scenario (just downstream of Copeland Creek), the deltas are calculated and shown as a blue line in the bottom plot. Although there is an apparent jump in the delta from 0 to 2.5 ˚C downstream of Copeland Creek, as shown with the blue line, this does not reflect an actual sudden difference in temperatures between the two scenarios, just the beginning of accounting for the differences. While the gray line is shown in this example to illustrate the continuous nature of the deltas, it does not appear in subsequent plots throughout this document.

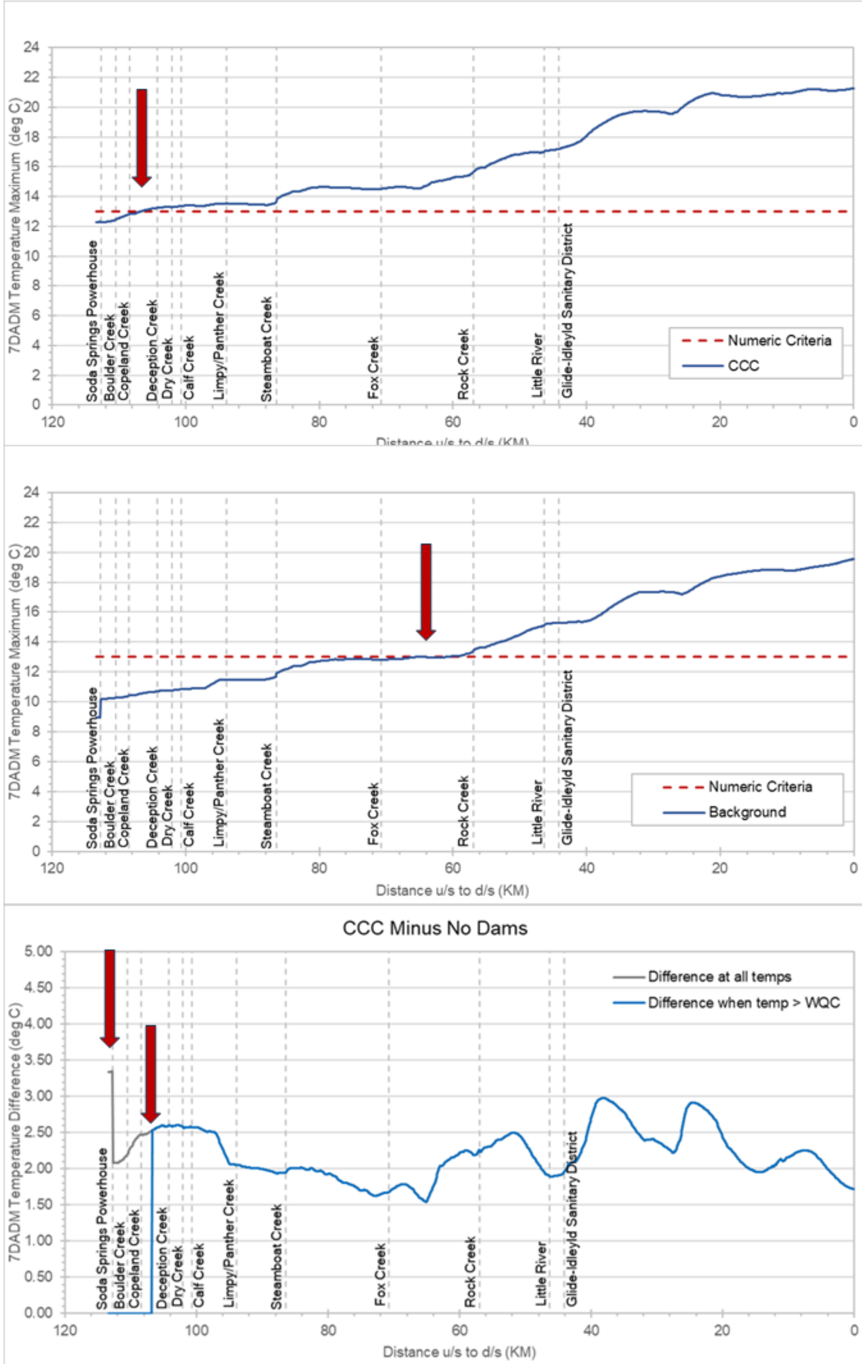


Figure 2-1.Illustration of how 7DADM deltas are displayed

2.4 BIOLOGICALLY BASED NUMERIC CRITERIA

The BBNC values could vary spatially and temporally and are evaluated based on the 7DADM. The BBNC values for streams are shown from Figure 2-2 to Figure 2-8 for the summer period. It should be noted that the BBNC values for the year-round criteria are used to evaluate the summer period models.

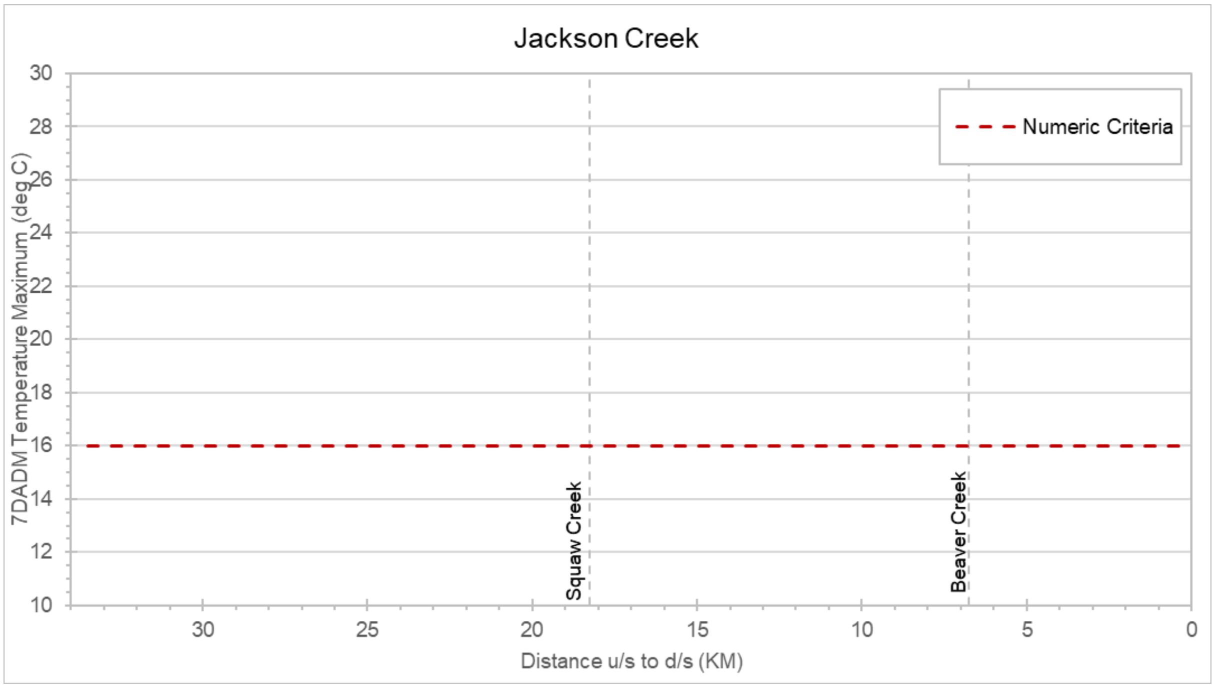


Figure 2-2. BBNC for Jackson Creek, summer period

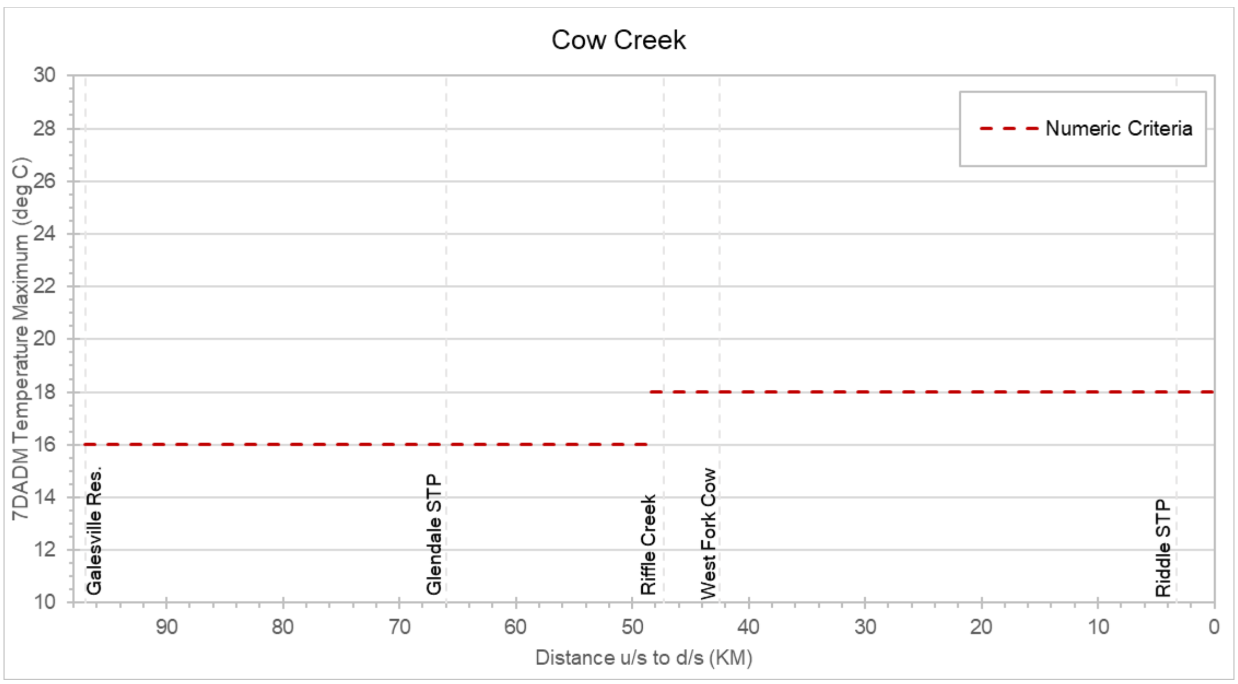


Figure 2-3. BBNC for Cow Creek, summer period

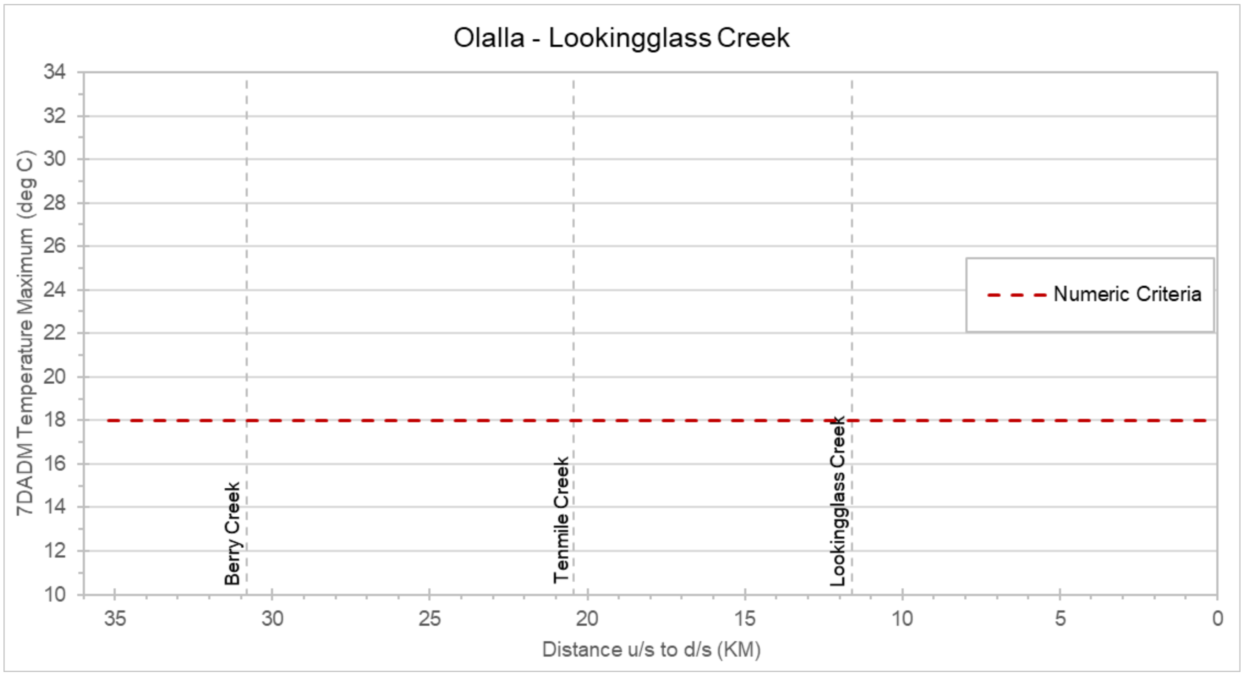


Figure 2-4. BBNC for Olalla – Lookingglass Creek, summer period

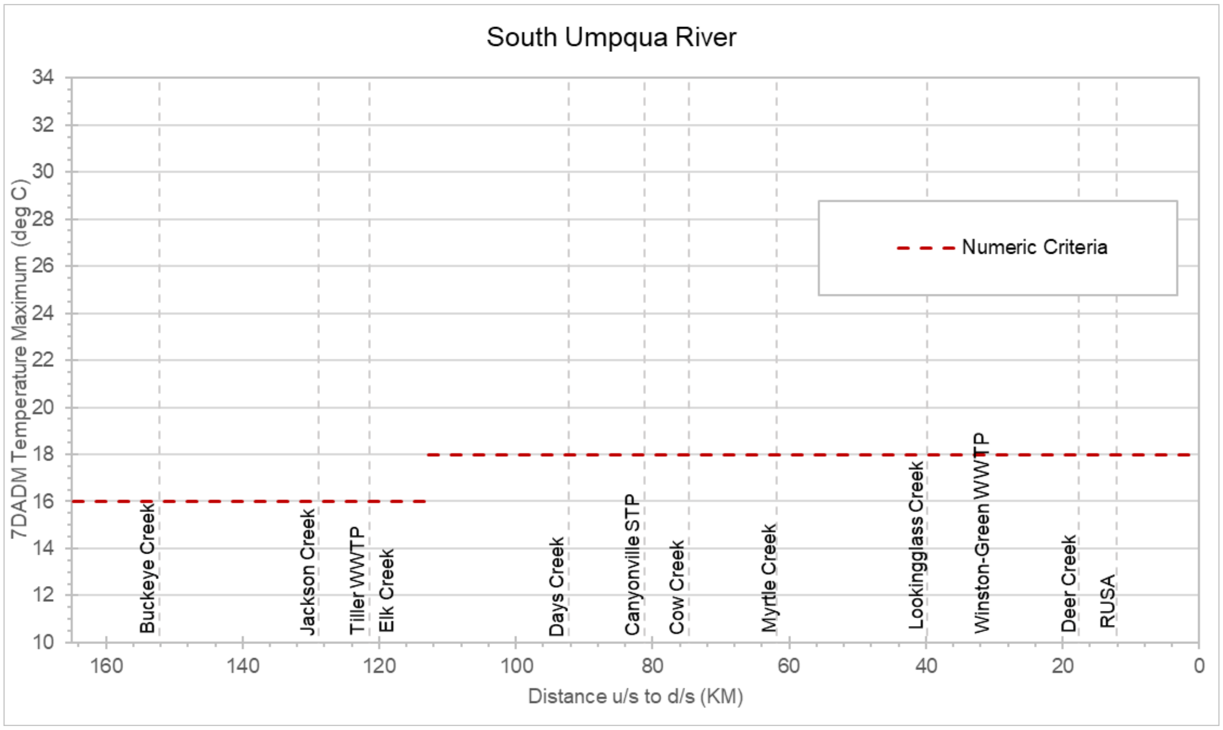


Figure 2-5. BBNC for South Umpqua River, summer period

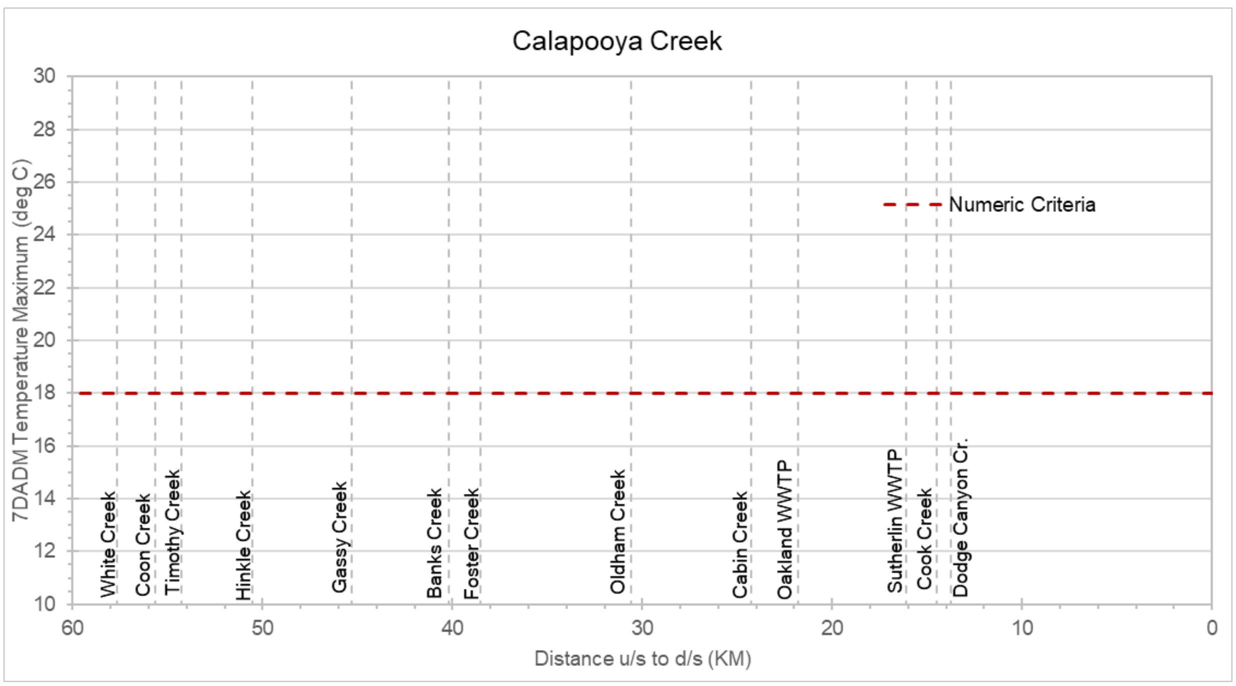


Figure 2-6. BBNC for Calapooya Creek, summer period

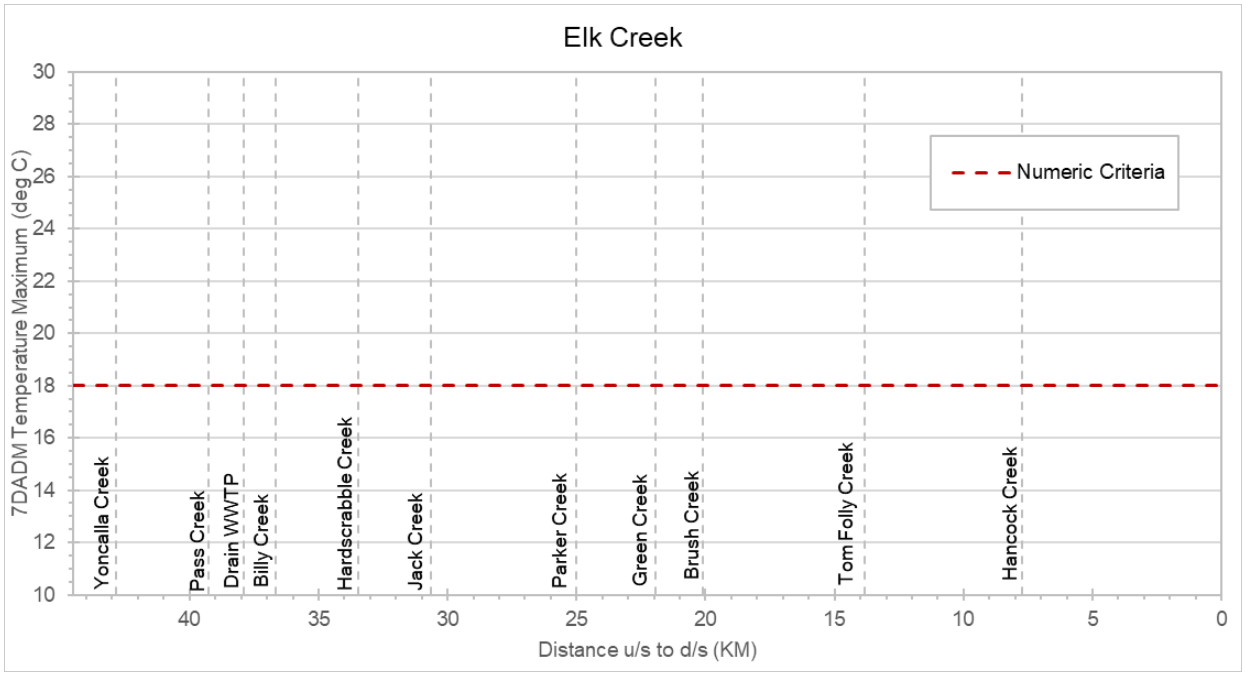


Figure 2-7. BBNC for Elk Creek, summer period

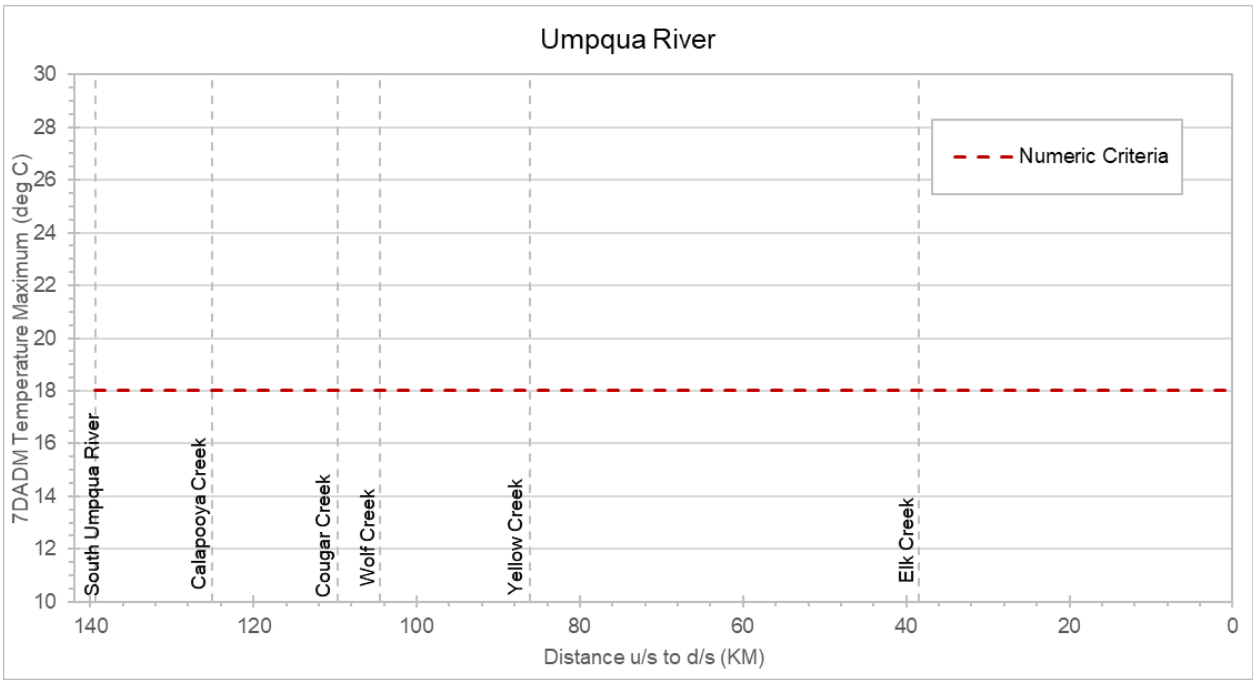


Figure 2-8. BBNC for Umpqua River, summer period

Figure 2-9 shows the BBNC value for the spawning period on the South Umpqua River. The spawning periods for different portions of the South Umpqua River are different and are listed below:

- Oct 15 - May 15: South Umpqua River mouth upstream to Lick Creek
- Sept 1 - May 15: South Umpqua River at confluence with Lick Creek upstream to Elk Creek
- No Spawning: South Umpqua River at confluence with Elk Creek upstream to Jackson Creek

- Jan 1 - Jun 15: South Umpqua River at confluence with Jackson Creek upstream to Dumont Creek
- Sept 1 - Jun 15: South Umpqua River at confluence with Dumont Creek upstream to confluence of Black Rock Fork and Castle Rock Fork

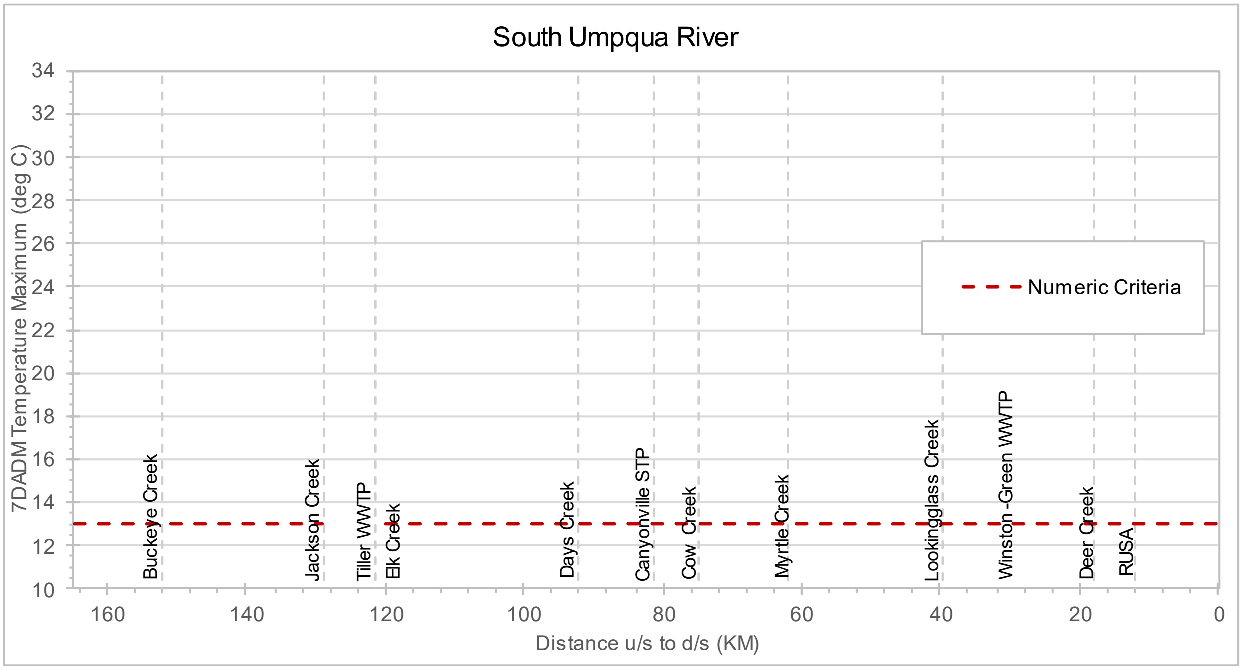


Figure 2-9. BBNC for the Spawning Period on the South Umpqua River

3.0 DEFINITIONS OF SCENARIOS

A model is usually used for scenario simulation only after it is calibrated against observed conditions. The calibration condition of the models represents the existing vegetation conditions, flow and temperature inputs as well as the existing discharges from point sources corresponding to the simulation period used to configure the model. This section describes the detailed scenarios, and a summary of the scenarios is provided in Table 3-1.

1. Calibrated Current Condition (CCC) scenario

The CCC scenario uses the existing vegetation conditions, flow and temperature inputs from upstream/headwater and tributaries as well as withdrawals. The only difference is that if a model includes point sources, the latest available flow and temperature from the point sources will be used to replace the flow and temperature from the point sources that were used for model calibration. Due to the limitation of data availability, the time period for the latest available flow and temperature from different point source may not be the same. For models without point sources, the CCC scenario is identical to the calibration condition.

2. No point sources scenario

For models with point sources, the no point sources scenario removes the point sources from the CCC models. All other conditions remain the same as the CCC models.

3. Point source WLA scenario

For models with point sources, the point source WLA scenario replaces the water temperature of the effluent in the CCC scenario with the calculated WLA temperatures for the TMDL. All other conditions remain the same as the CCC scenarios. The calculated WLA temperatures consider the river flow rate, water temperature criteria, effluent rate, and an allocated HUA.

4. Fully restored vegetation scenario

The fully restored vegetation scenario uses the fully restored vegetation condition, while all other conditions remain the same as in the CCC models. Therefore, if a model includes point sources, the fully restored vegetation scenario also includes the point sources as in the CCC models.

5. Background scenario

The background scenario uses the fully restored vegetation as the vegetation condition and removes all point sources in the model, if the model includes point sources. For the models without point sources, the background scenario is equivalent to the fully restored vegetation scenario.

6. Attainment scenario

The attainment scenario uses the fully restored vegetation condition and the WLA temperatures from the point sources, if the model includes point sources. All other conditions such as the flow and temperature from headwater/upstream and tributaries and withdrawals remain the same. For the attainment scenario, if the 7DADM increase in temperature caused by the assigned point source WLA temperatures from DEQ's calculation is higher than the HUA of 0.3 °C, the WLA temperatures were adjusted until the increase in temperature meets the HUA of 0.3 °C.

7. Fully restored vegetation with natural flow scenario

This scenario uses the fully restored vegetation as the vegetation condition. It also uses natural flow from the headwater/upstream and tributaries. If there are dams located above the headwater of the model, the natural flow reflects a condition where the dam is removed. All withdrawals are removed from the models, and point sources are also removed, if the model includes point sources. This scenario only applies to models with dams or other structures impacting natural flow on tributaries or headwaters. There are separate no dam scenarios that evaluate the impact of dam removal, which only applies to North Umpqua.

In addition to these scenarios that support the TMDL development, additional scenarios were run to gain insights into model responses to factors such as tributary and headwater temperature inputs. Two more scenarios were run:

8. Tributary/headwater plus 0.1 °C scenario

This scenario adds 0.1 °C to all the tributaries and headwater/upstream inflows. All other conditions are identical to the background scenario.

9. Fully restored vegetation with point source WLA and Tributary/headwater plus 0.1 °C scenario

This scenario uses fully restored vegetation as the vegetation condition. If the model includes point sources, this scenario uses the WLA temperatures for these point sources. In addition, the temperatures in all the tributaries and headwater/upstream inflows are increased by 0.1 °C.

Table 3-1. Umpqua River and South Umpqua River scenarios descriptive summaries

Scenario number	Scenario name	Equivalent to CCC except:
1	Calibrated Current Condition (CCC) scenario	Identical to the calibration condition except most recent flow and temperature used for any modeled point sources
2	No point sources scenario	Point sources removed from CCC models
3	Point source WLA scenario	The water temperature of the effluent in the CCC scenario is replaced with the calculated WLA temperatures
4	Fully restored vegetation scenario	Vegetation is fully restored
5	Background scenario	Vegetation is fully restored, and all point sources removed
6	Attainment scenario	Vegetation is fully restored, and point sources use WLA temperatures
7	Fully restored vegetation with natural flow scenario	Vegetation is fully restored and uses natural upstream flow (i.e., all dams, withdrawals, and point sources removed)
8	Tributary/headwater plus 0.1 °C scenario	0.1 °C added to all tributaries and headwater/upstream inflows and all other conditions identical to background scenario
9	Fully restored vegetation with point source WLA and Tributary/headwater plus 0.1 °C scenario	Vegetation is fully restored, point sources use WLA temperatures, and 0.1 °C added to all tributaries and headwater/upstream inflows

After running the scenarios where they apply, scenario pairings were compared to evaluate the impacts of specific sources and conditions. The comparisons and evaluations follow the order in the list below. Note that there are no major dams on the modeled tributaries, and the main South Umpqua and Umpqua rivers. The Cow Creek model starts below the Galesville Dam. The "No Dams" scenario is included in these scenario descriptions for consistency between the South Umpqua and Umpqua scenario report and the North Umpqua report.

A summary of the scenario comparisons is also provided in Table 3-2.

1. Impacts of current condition vegetation (shade loss) (All models)
   - ✓ No Point Source minus background
2. Impact of current point source and current vegetation (shade loss) (Cow and South Umpqua)
   - ✓ CCC minus background
3. Impact from point source @ current condition (Cow and South Umpqua)
   - ✓ CCC minus no point source
4. Impact from point sources @ WLA conditions (Cow and South Umpqua)
   - ✓ Point Source WLA minus No point source
5. Impact current point source and restored vegetation (Cow and South Umpqua)
   - ✓ Fully restored veg with point source @ current condition minus background
6. Impact point source @ WLA and restored vegetation (Cow and South Umpqua)
   - ✓ Fully restored veg with point source @ WLA minus background
7. Difference between background temperatures and criteria (All models)
   - ✓ Background minus Criteria
8. No Dams, impact of removing dams upstream (No dams are in the South Umpqua and Umpqua models)
   - ✓ CCC minus no dams
9. Natural Flows (All models except Elk Creek)
   - ✓ Background minus fully restored veg with natural flows

It should be noted that not all creeks and rivers have all these comparisons. For the models without point sources, the point source related comparisons are not available.

In addition to these 9 comparisons, additional comparisons requested by EPA are listed below:

A1. General permit evaluation in upper North Umpqua adding 0.1, 0.2, & 0.3 °C
A2. Tributary + 0.1°C scenarios
A3. Cumulative impact of attainment and additional tributary impact

- ✓ Restored veg + point source WLA + tributaries 0.1 °C minus background.

For A1 to A3, the model results are compared against the results from the Background scenario.

A1 only applies in the North Umpqua models. For South Umpqua and Umpqua models, A2 and A3 were conducted.

Table 3-2. Umpqua River and South Umpqua River comparisons descriptive summaries

Comparison number	Scenario 1	Scenario 2	Question/Topic Addressed
1[a]	No Point Source	Background	Impacts of shade loss. Temperature difference between the existing vegetation conditions and fully restored vegetation condition.
2[b]	CCC	Background	Impact of current point sources and current vegetation. Temperature difference between the existing vegetation and point source conditions and the fully restored vegetation condition without point sources.
3[b]	CCC	No Point Source	Impact from point sources at current conditions. Temperature difference between the existing point sources and no point sources.
4[b]	Point Source WLA	No Point Source	Impact from point sources at WLA conditions. Temperature difference between the WLA discharges and no point sources.
5[b]	Fully restored vegetation with point sources at current conditions	Background	Impact from current point sources and restored vegetation. Temperature difference between fully restored vegetation at current conditions with point sources and fully restored vegetation conditions without point sources.
6[b]	Attainment scenario: Fully restored vegetation with point source at WLA conditions	Background	Impact from point sources at WLA and restored vegetation. Temperature difference between fully restored vegetation with WLAs and fully restored vegetation without point sources.
7[a]	Background	Criteria	Difference between background conditions and criteria temperatures.
8[c]	CCC	No dams	Impact of removing upstream dams.
9[d]	Background	Fully restored vegetation with natural flows	Impact of natural flows. Temperature difference between current flows and natural flows.
A1[c]	General permit evaluation in upper North Umpqua adding 0.1, 0.2, & 0.3 °C	Background	Impacts of general permits on water temperature
A2[a]	Tributary + 0.1°C	Background	Impacts of hypothetical tributaries inputs on water temperature
A3[b]	Restored vegetation with point source WLA and tributary plus 0.1 °C	Background	Impact of the cumulative effect of the Restored Vegetation with Point Source WLA and hypothetical Tributary/Headwater increase of 0.1 ˚C

[a]Applies to all models
[b]Applies to Cow Creek and the South Umpqua River
[c]Applies to North Umpqua River only. Does not apply to any waterbodies in this memo.
[d]Applies to all models except Elk Creek

4.0 JACKSON CREEK

Jackson Creek is a tributary to the South Umpqua River (Figure 4-1).

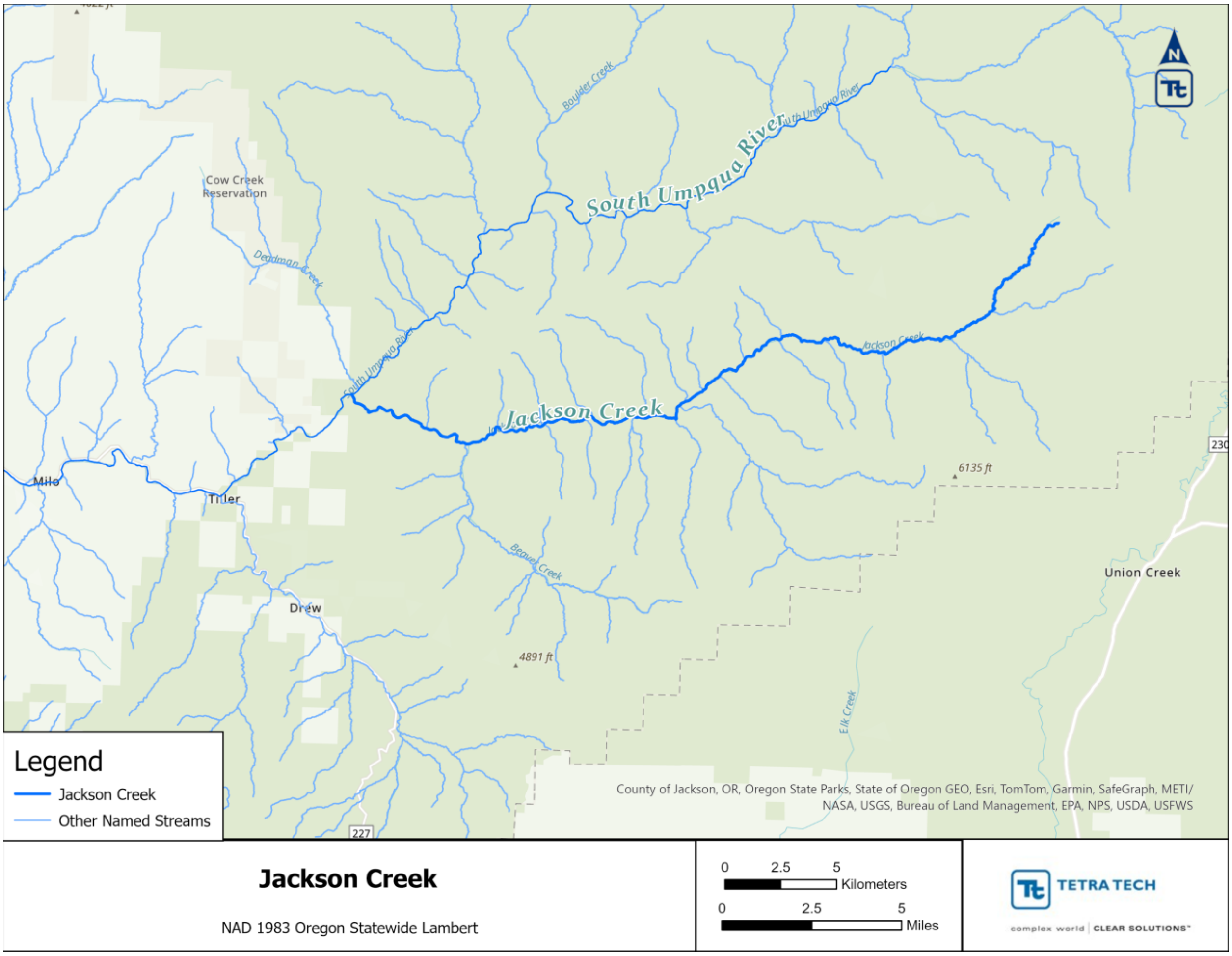


Figure 4-1. Location of Jackson Creek.

4.1 JACKSON CREEK SCENARIO RESULTS

The Jackson Creek HS model does not include any point sources. The model simulation period is July 12 to July 31. 2002. The scenarios that are relevant to Jackson Creek include the CCC scenario, which is identical to the no point source scenario; the background scenario; the fully restored vegetation with natural flow scenario; and the tributary/headwater plus 0.1 ºC scenario. The 7DADM results of these scenarios are shown in Figure 4-2, Figure 4-3, Figure 4-4,and Figure 4-5.

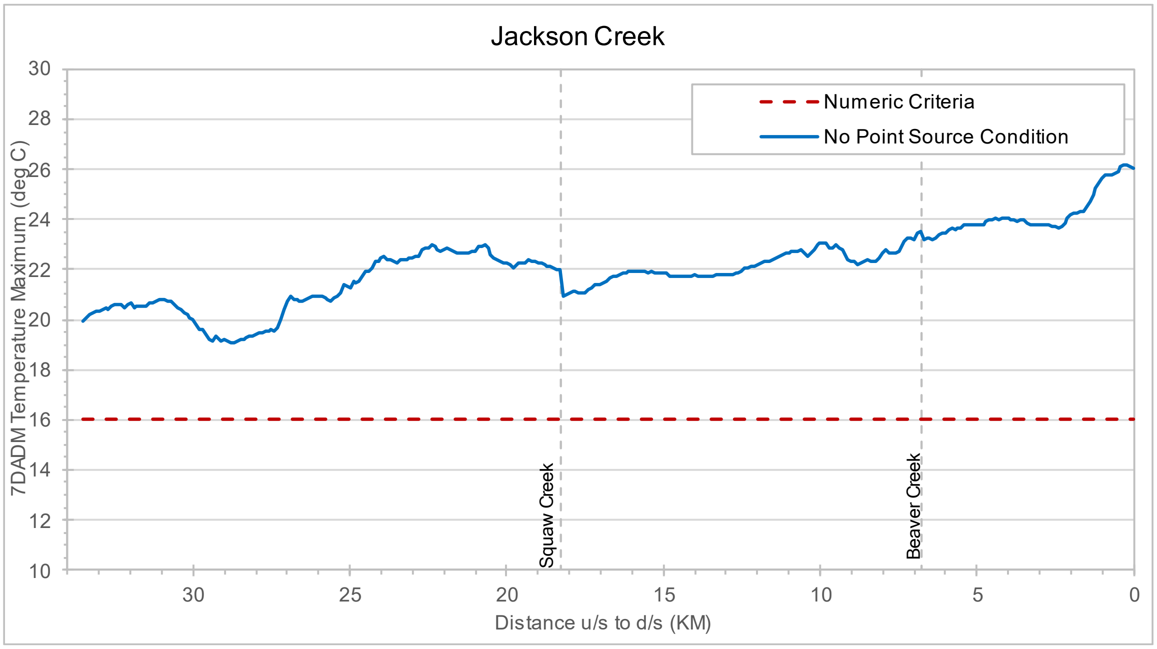


Figure 4-2. The maximum 7DADM temperature results along Jackson Creek for the No Point Source scenario.

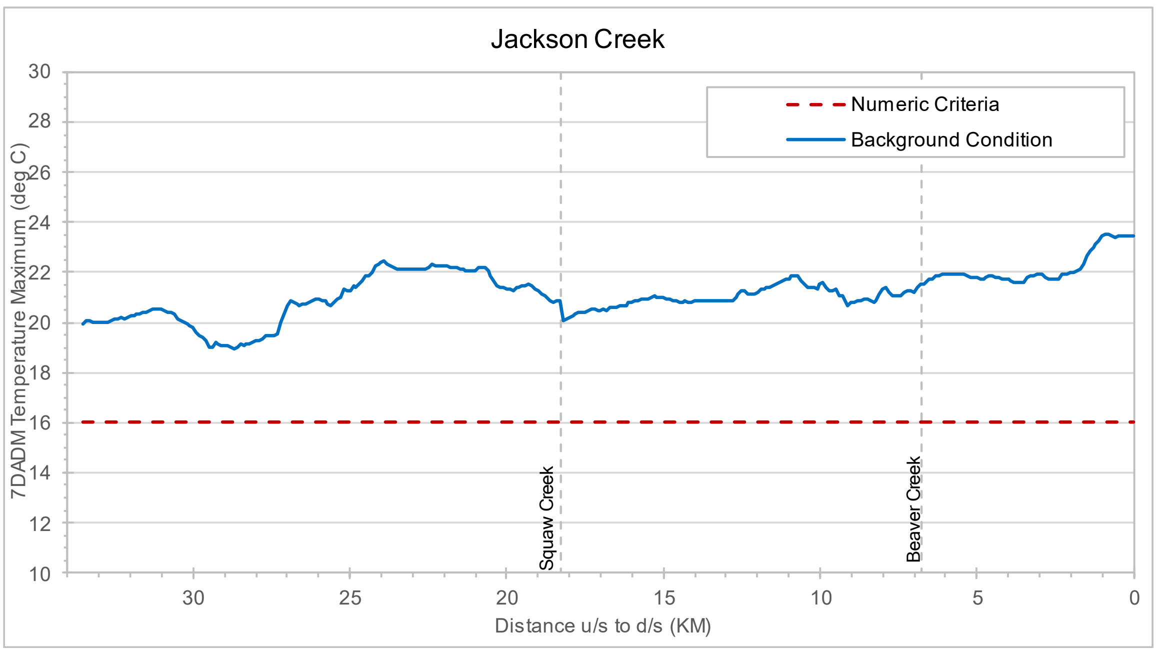


Figure 4-3. The maximum 7DADM temperature results along Jackson Creek for the Background scenario.

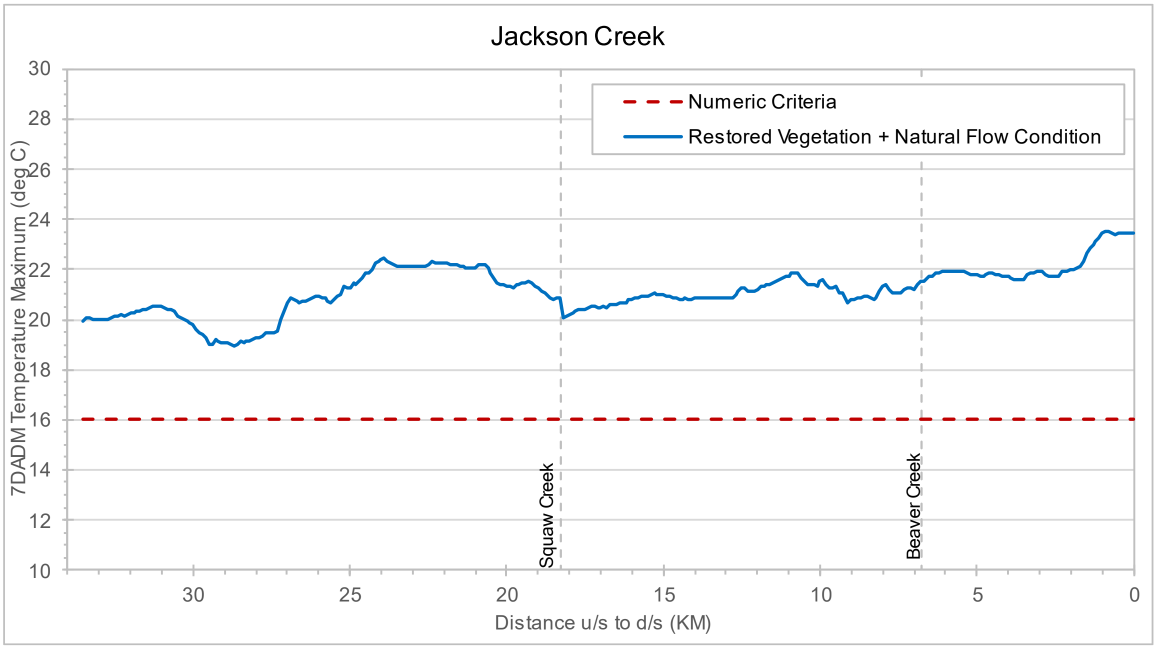


Figure 4-4. The maximum 7DADM temperature results along Jackson Creek for the Fully Restored Vegetation with Natural Flow scenario.

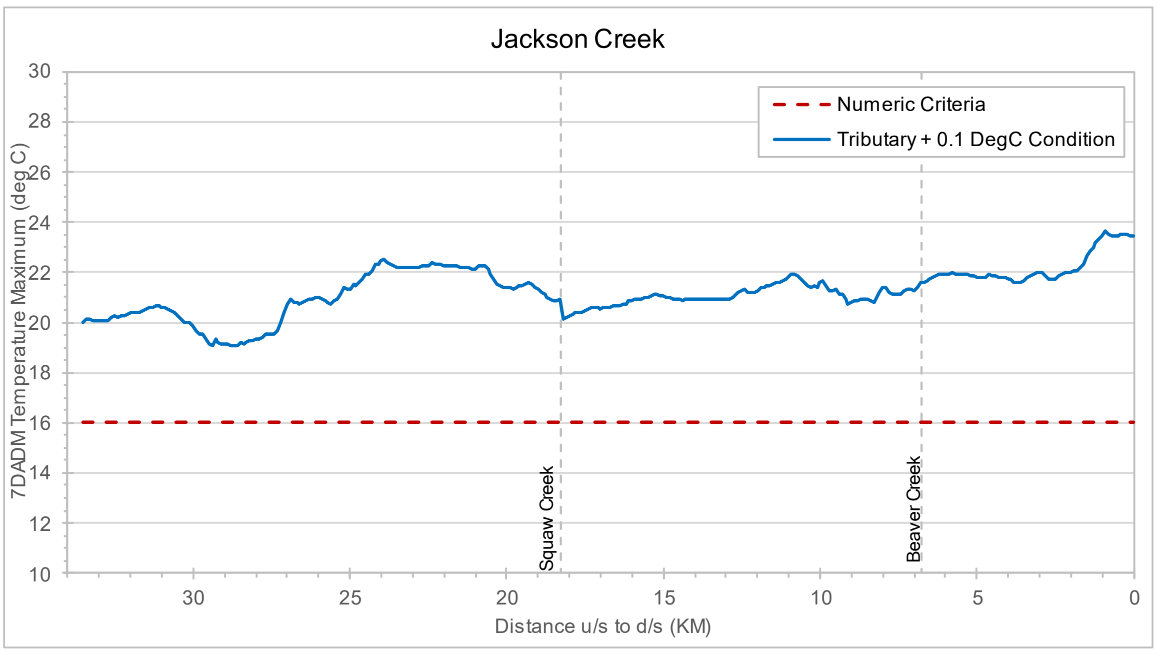


Figure 4-5. The maximum 7DADM temperature results along Jackson Creek for the Tributary/Headwater Plus 0.1 ˚C scenario.

4.2 JACKSON CREEK SCENARIO COMPARISONS

Comparisons of scenarios for the Jackson Creek include:

1. Impacts of shade loss
   - ✓ No Point Source minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria
9. Natural Flows
   - ✓ Background minus (fully restored veg with natural flows)

A2. Tributary + 0.1ºC scenarios

Figure 4-6 shows the results of comparison 1, the impacts of shade loss, which is the 7DADM temperature difference between the No Point Source scenario and Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The overall 7DADM temperature differences increase in the downstream direction. The maximum delta reaches 2.83 ˚C at the mouth of Jackson Creek on 7/31/2002 (Table 4-1).

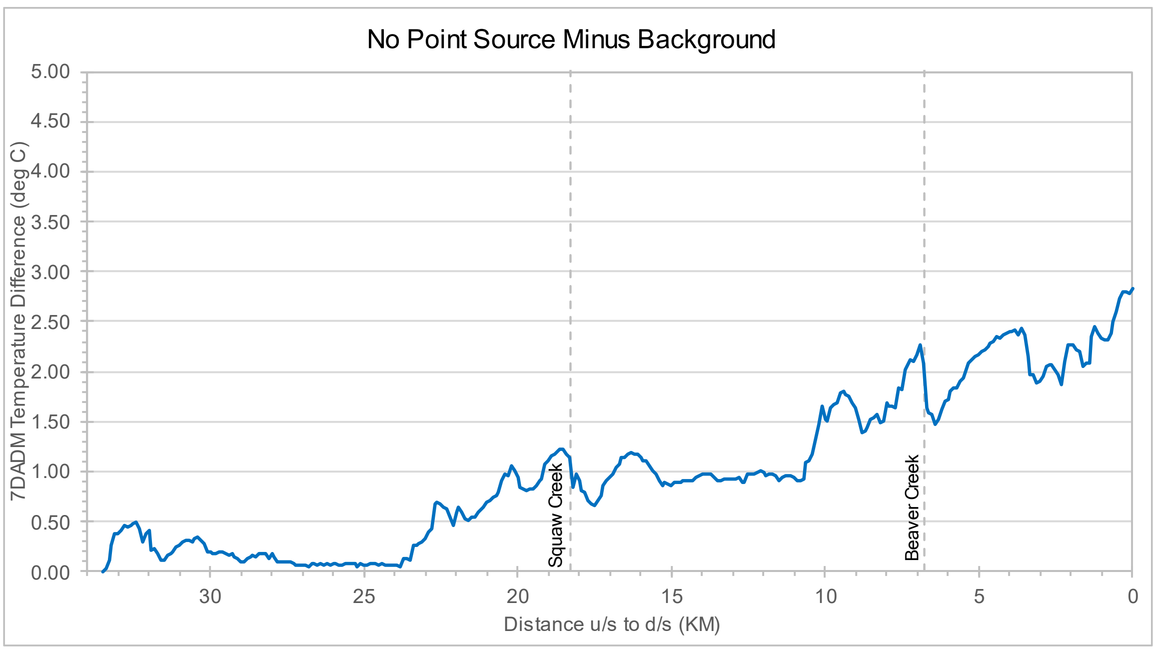


Figure 4-6. The maximum 7DADM temperature differences along Jackson Creek for the Impacts of current condition vegetation (shade loss) shade loss.

Table 4-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 1

Maximum Delta	2.83 ˚C
RKM	0
Date	7/31/2002

Figure 4-7 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 7.54 ˚C at river kilometer 0.9 on 7/18/2002 (Table 4-2).

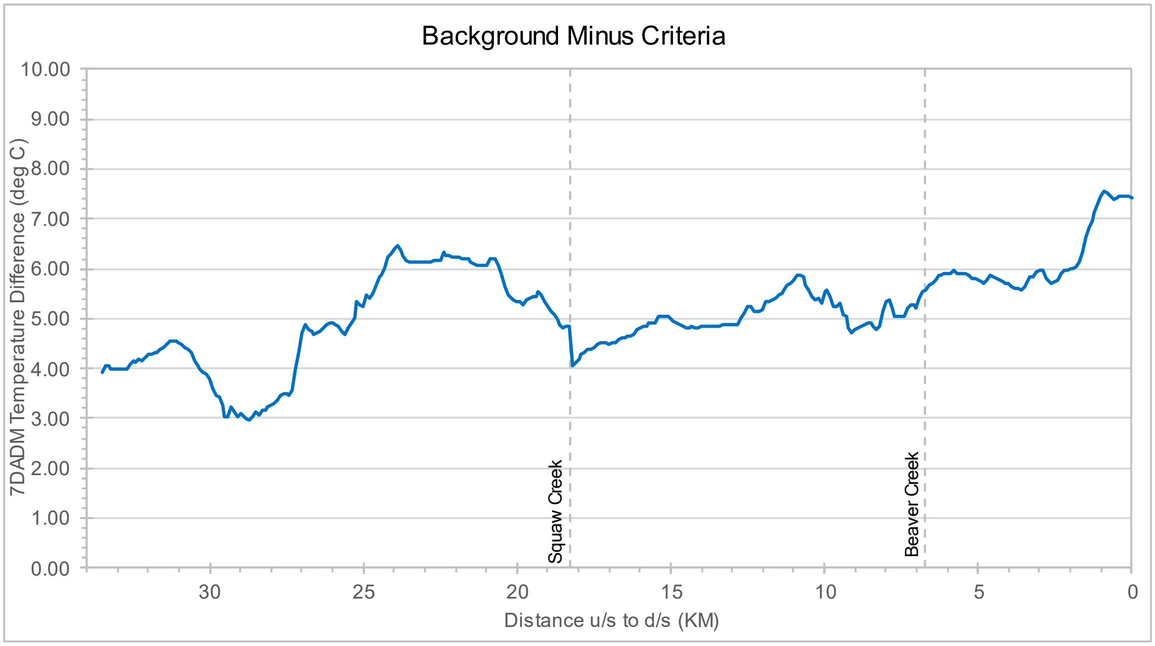


Figure 4-7. The maximum 7DADM temperature differences along Jackson Creek for the impacts of the background conditions.

Table 4-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7

Maximum Delta	7.54 ˚C
RKM	0.9
Date	7/18/2002

Figure 4-8 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. The only difference between these two scenarios for the Jackson Creek is that two minor withdrawals were removed in the Fully Restored Vegetation with Natural Flow scenario. There are no upstream dams or point sources. Therefore, no noticeable delta was identified.

Figure 4-9 shows the results of comparison A2, which is the 7DADM temperature difference between the Tributary/Headwater plus 0.1 ˚C scenario and the Background scenario. The only difference between these two scenarios is that water temperature from all tributaries and headwater are increased by 0.1 ˚C in the Tributary/Headwater plus 0.1 ˚C scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperatures in tributaries and headwater increase by 0.1 ˚C, the temperature in Jackson Creek may also increase by the full 0.1 ˚C or increase by amounts lower than 0.1 ˚C. Since there are numerous increases of the maximum delta of 0.1 ˚C for this comparison, locations and dates of the maximum delta are not listed in a table.

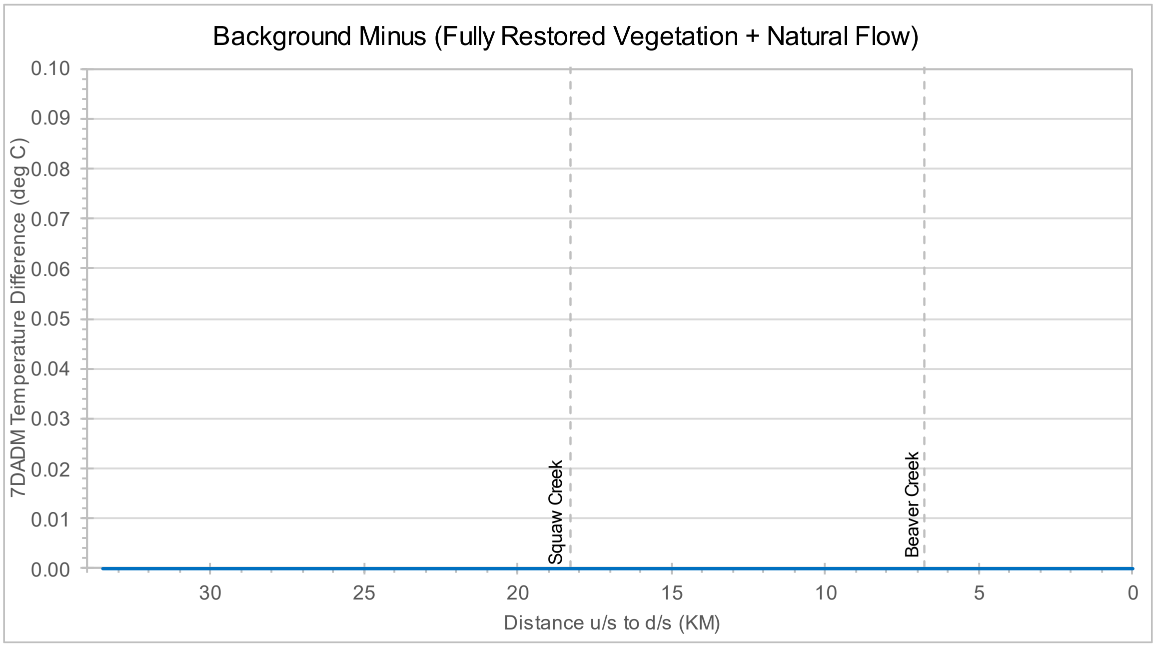


Figure 4-8. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario.

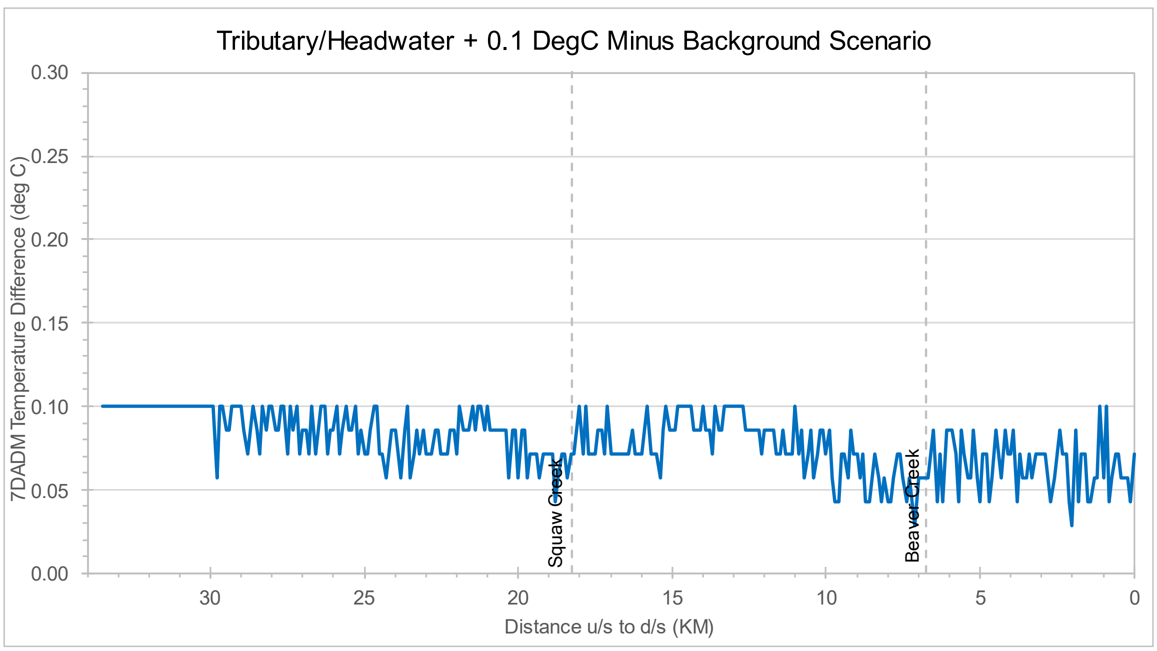


Figure 4-9. The maximum 7DADM temperature differences between Tributary/Headwater Plus 0.1 ˚C scenario and the Background scenario.

5.0 COW CREEK

Cow Creek is a tributary to the South Umpqua River (Figure 5-1).

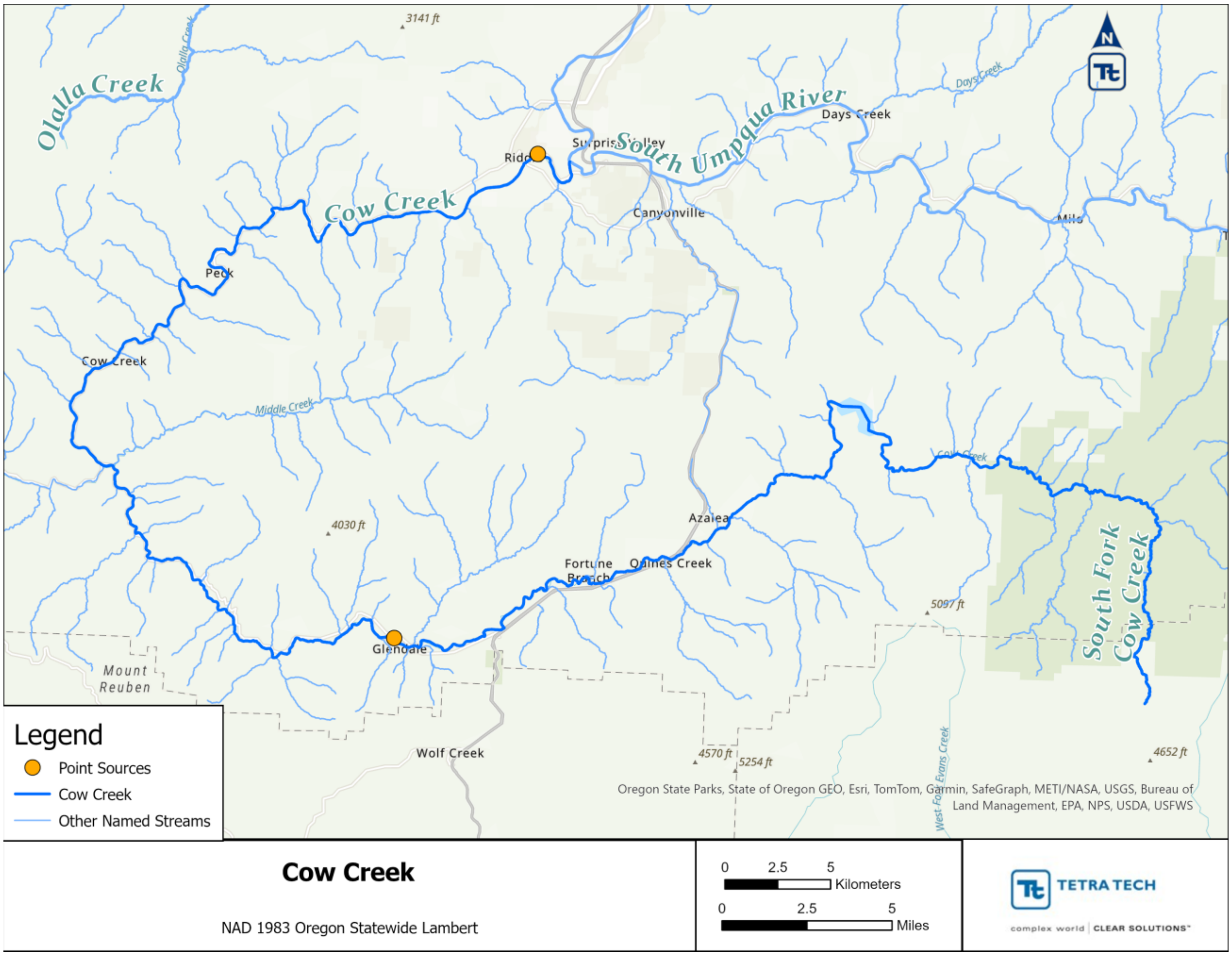


Figure 5-1. Location of Cow Creek.

5.1 COW CREEK SCENARIO RESULTS

The Cow Creek HS model includes point sources. The model simulation period is July 12 to July 31. 2002. The scenarios that are relevant to Cow Creek include the CCC scenario, the No Point Source scenario; the Point Source WLA scenario; the Fully Restored Vegetation scenario; the background scenario; the Attainment scenario; the Fully Restored Vegetation with Natural Flow scenario; the Tributary/Headwater Plus 0.1 °C scenario; and the Fully restored Vegetation with Point Source WLA and Tributary/Headwater Plus 0.1 °C scenario. The 7DADM results of these scenarios are shown in Figure 5-2 through Figure 5-10.

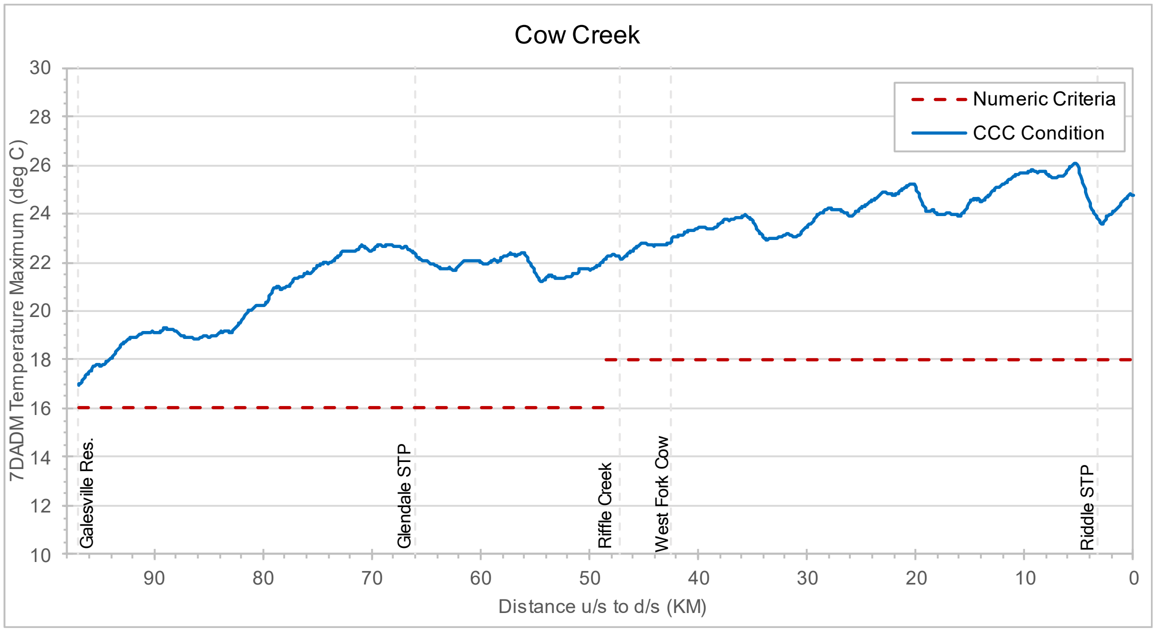


Figure 5-2. The maximum 7DADM temperature results along Cow Creek for Current Condition scenario.

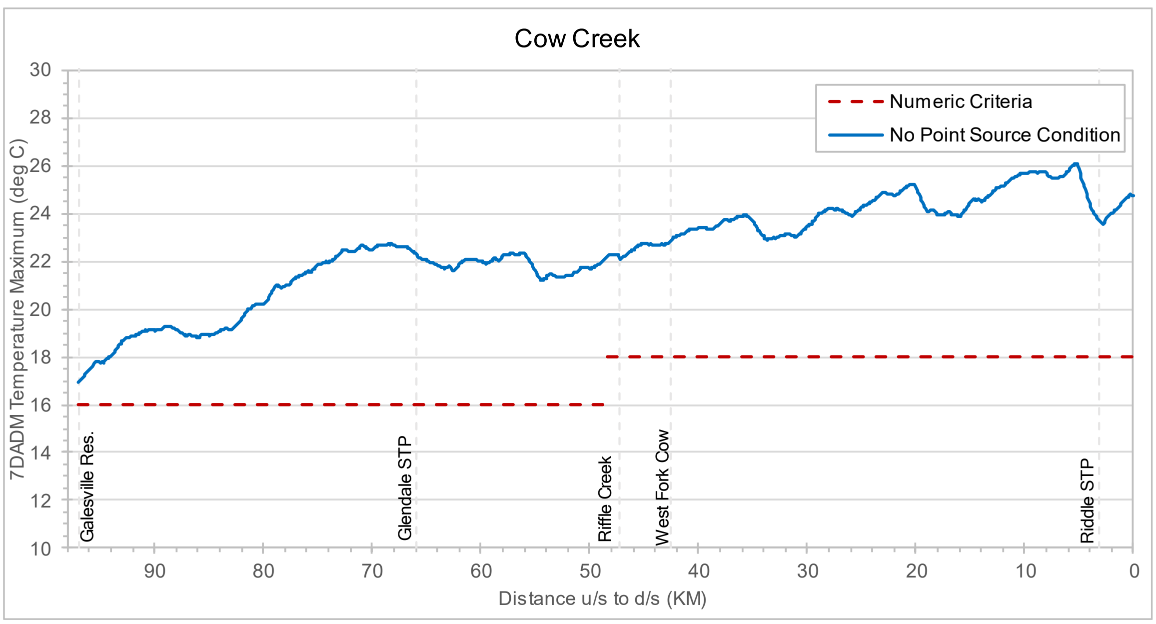


Figure 5-3. The maximum 7DADM temperature results along Cow Creek for No Point Source scenario.

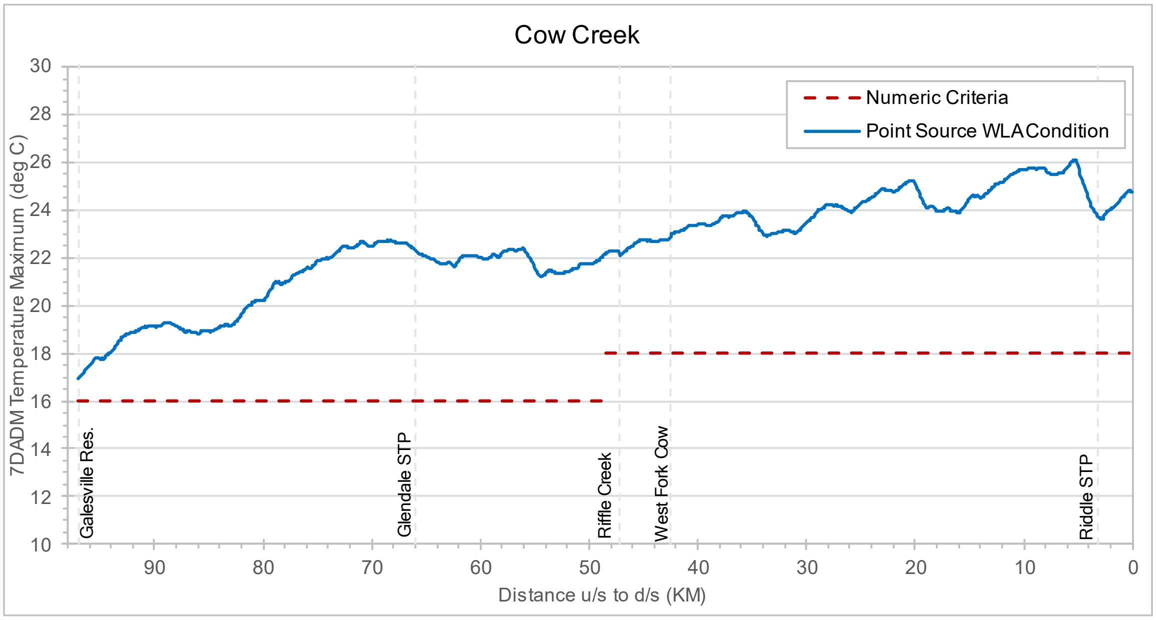


Figure 5-4. The maximum 7DADM temperature results along Cow Creek for the Point Source WLA Conditions scenario.

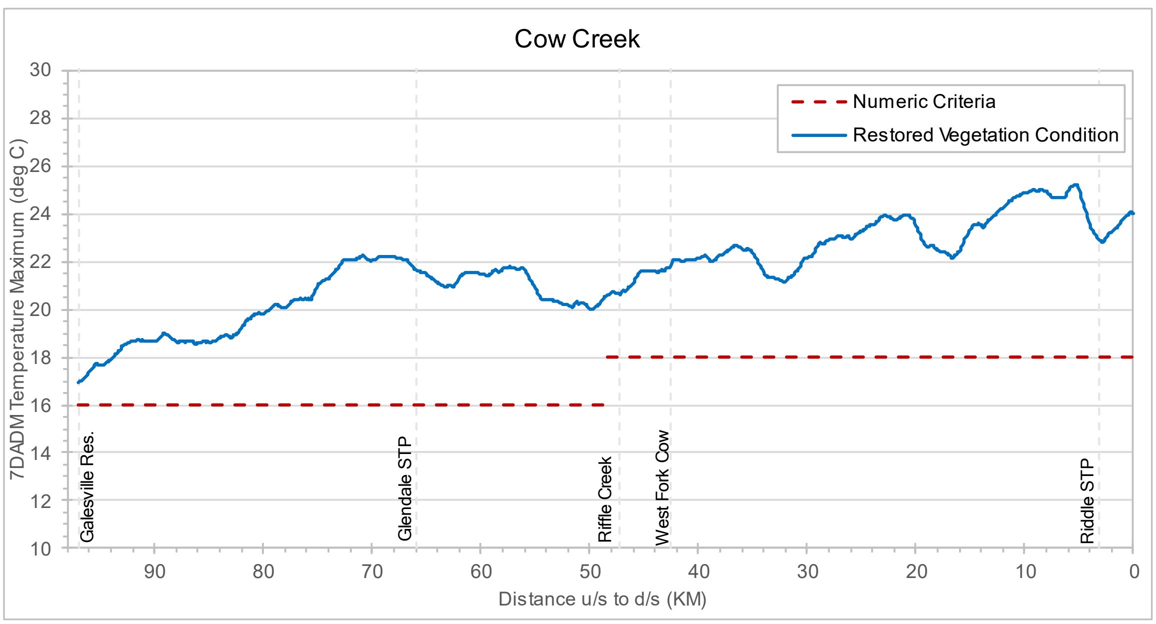


Figure 5-5. The maximum 7DADM temperature results along Cow Creek for the Fully Restored Vegetation scenario.

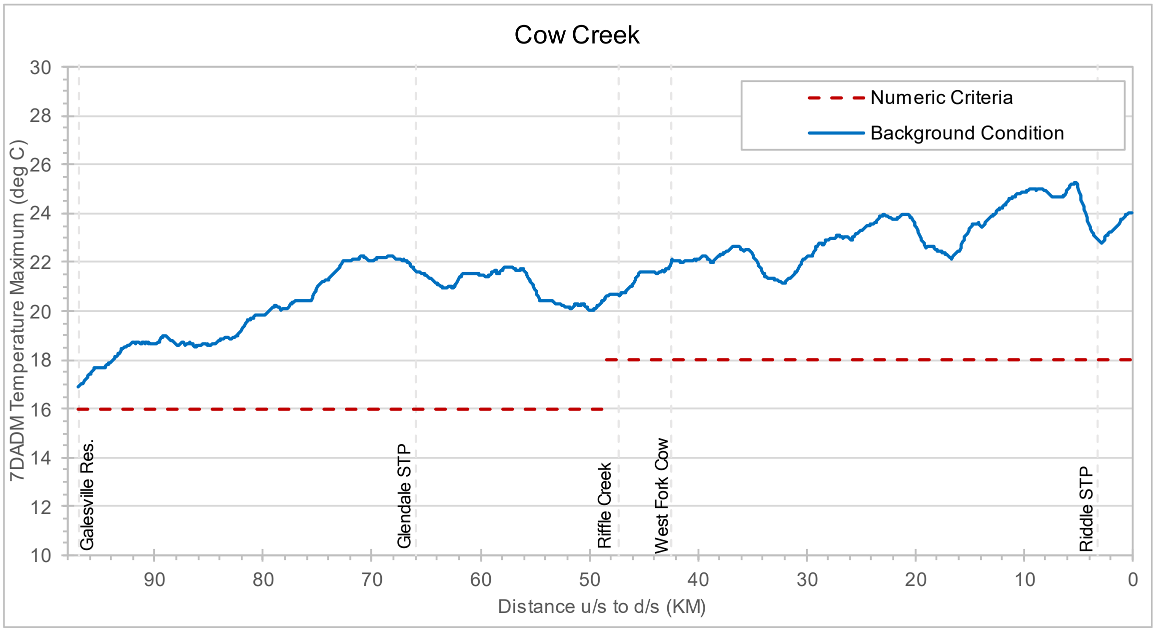


Figure 5-6. The maximum 7DADM temperature results along Cow Creek for the Background scenario.

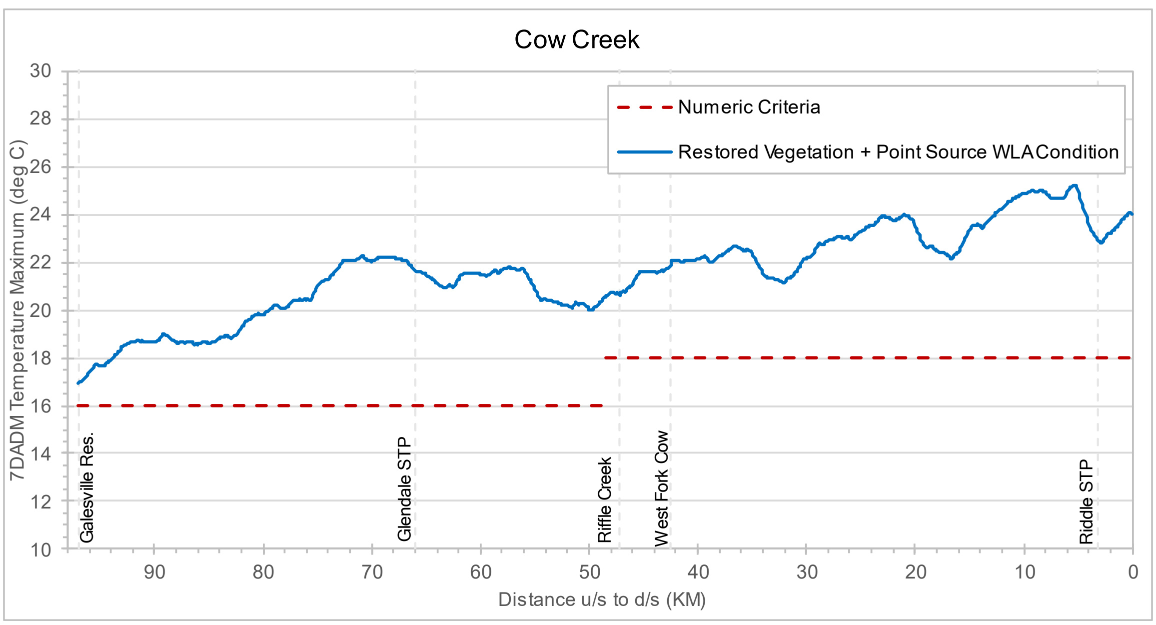


Figure 5-7. The maximum 7DADM temperature results along Cow Creek for the Attainment scenario.

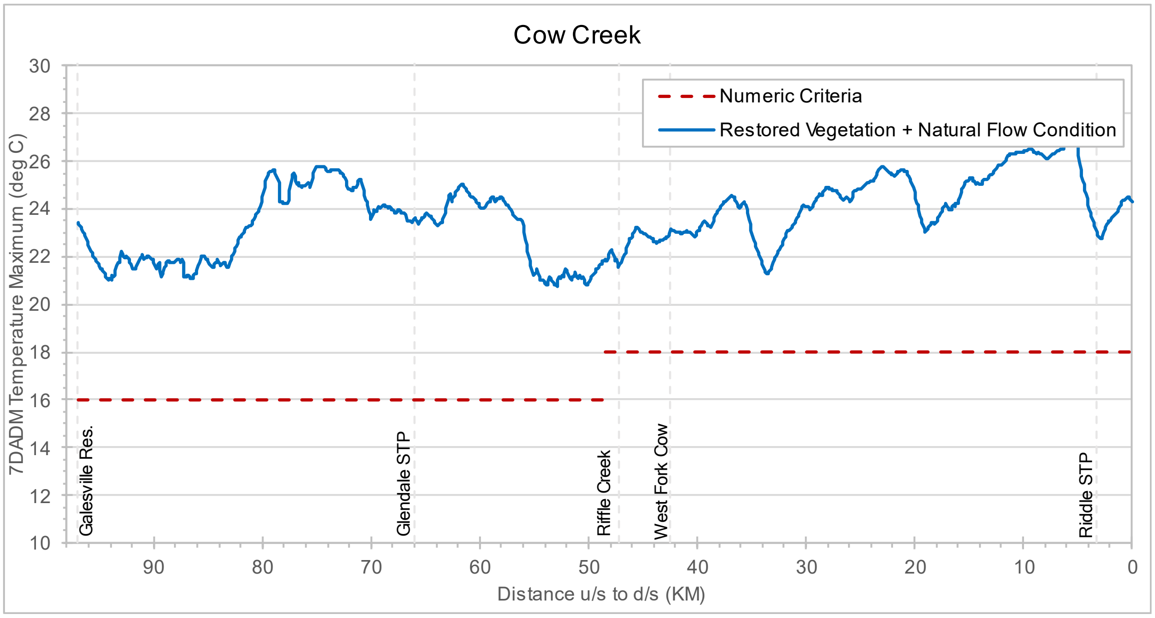


Figure 5-8. The maximum 7DADM temperature results along Cow Creek for the Fully Restored Vegetation and Natural Flow scenario.

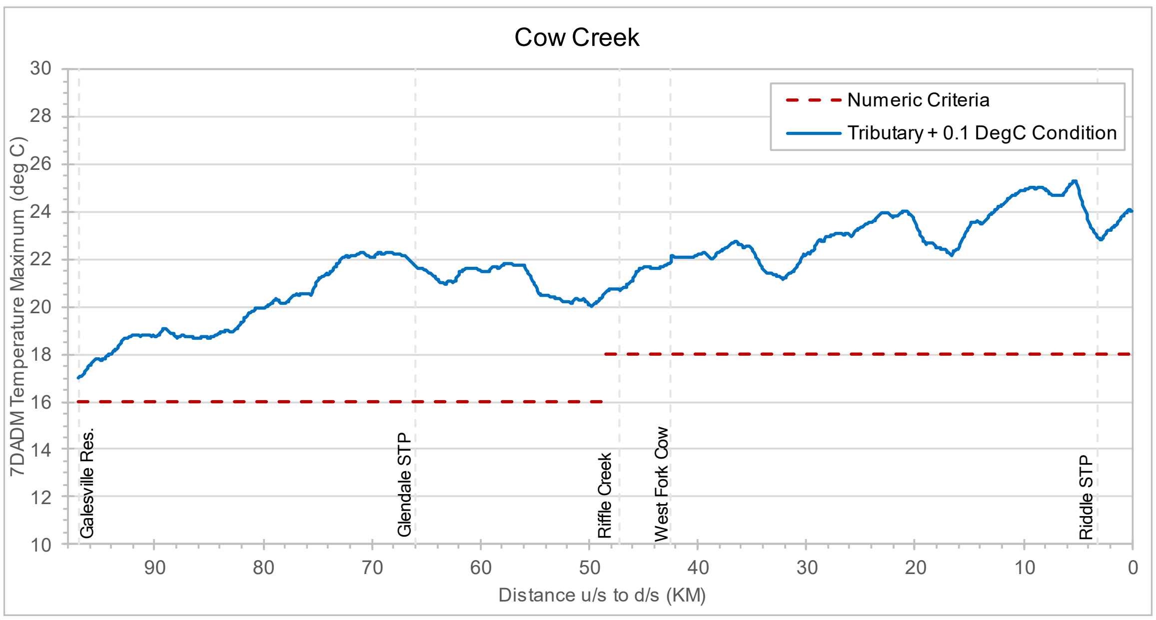


Figure 5-9. The maximum 7DADM temperature results along Cow Creek for the Tributary/Headwater Plus 0.1 °C scenario.

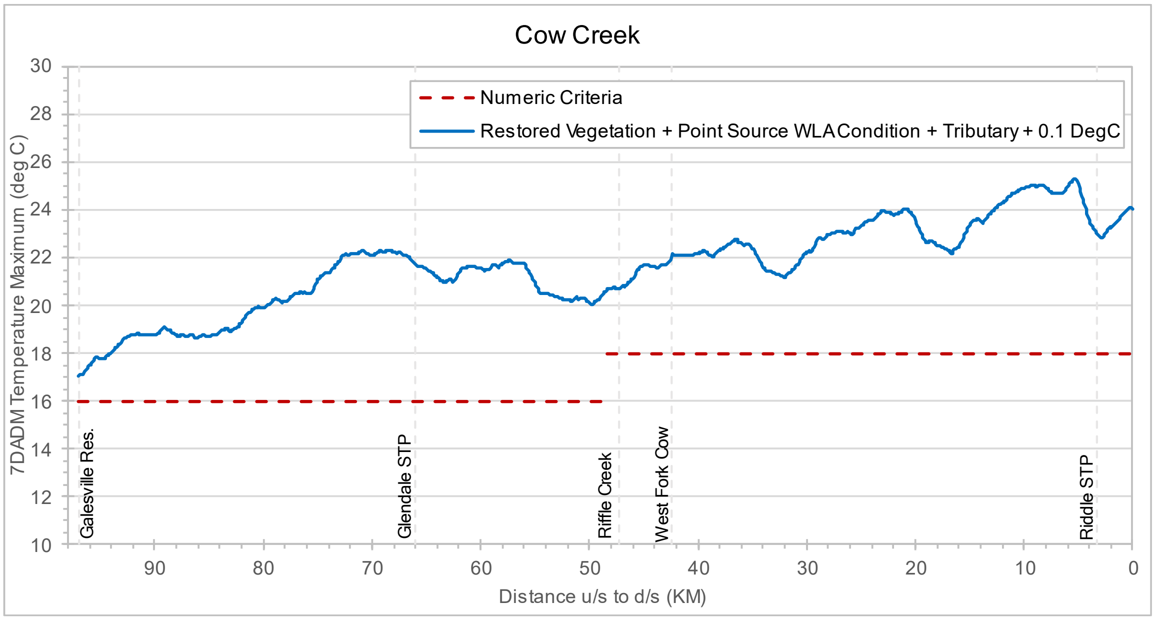


Figure 5-10. The maximum 7DADM temperature results along Cow Creek for the Fully Restored Vegetation with Point Source WLA and Tributary/Headwater Plus 0.1 °C scenario.

5.2 COW CREEK SCENARIO COMPARISONS

Comparisons between scenarios include:

1. Impacts of current condition vegetation (shade loss)
   - ✓ No Point Source minus background
2. Impact of current point source and current vegetation (shade loss)
   - ✓ CCC minus background
3. Impact from point source @ current condition
   - ✓ CCC minus no point source
4. Impact from point sources @ WLA conditions
   - ✓ Point Source WLA minus No point source
5. Impact current point source and restored vegetation
   - ✓ Fully restored veg with point source @ current condition minus background
6. Impact point source @ WLA and restored vegetation
   - ✓ Fully restored veg with point source @ WLA minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria
9. Natural Flows
   - ✓ Background minus fully restored veg with natural flows

A2. Tributary + 0.1ºC scenarios
A4. Cumulative
- ✓ Restored veg + point source WLA + tributaries 0.1 °C minus background.

Figure 5-11 shows the results of comparison 1, the impacts of shade loss, which is the 7DADM temperature difference between the No Point Source scenario and Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. In general, the temperature differences increase toward the downstream with fluctuations along the river. The maximum delta reaches 2.00 ˚C at river kilometer 31.9 on 7/30/2002 (Table 5-1).

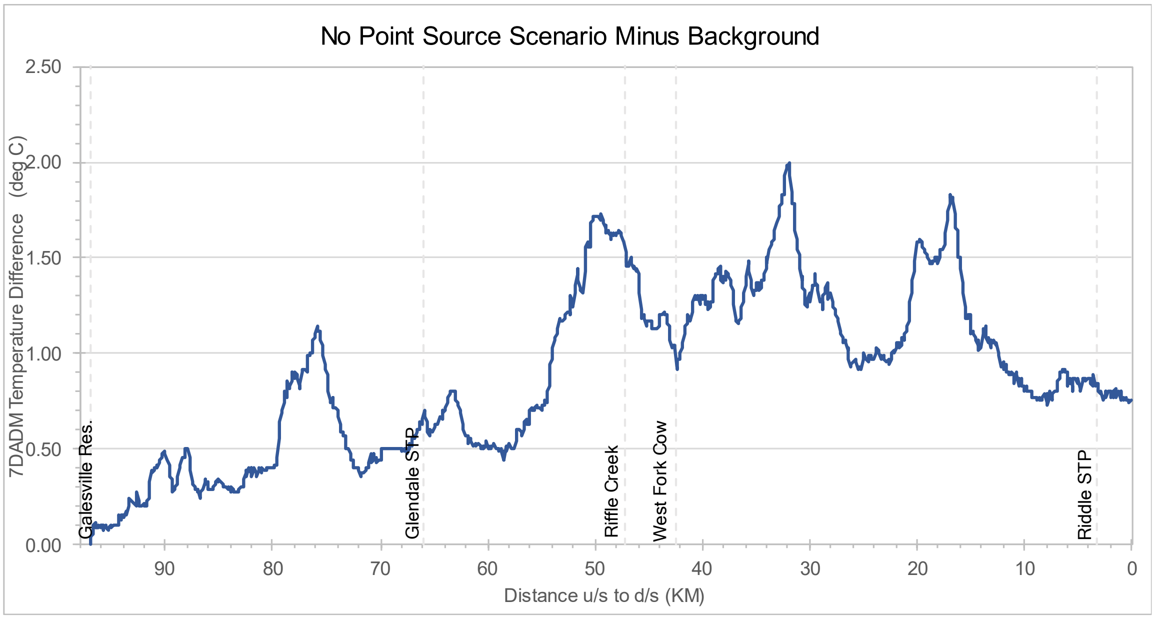


Figure 5-11. The maximum 7DADM temperature differences along Cow Creek for the impacts of shade loss.

Table 5-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 1

Maximum Delta	2.00 ˚C
RKM	31.9
Date	7/30/2002

Figure 5-12 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition and the point source conditions where the CCC scenario uses the latest available flow and temperature from the point sources, while the Background scenario does not include point sources. The maximum delta reaches 2.00˚C at river kilometer 31.9 on 7/30/2002 (Table 5-2).

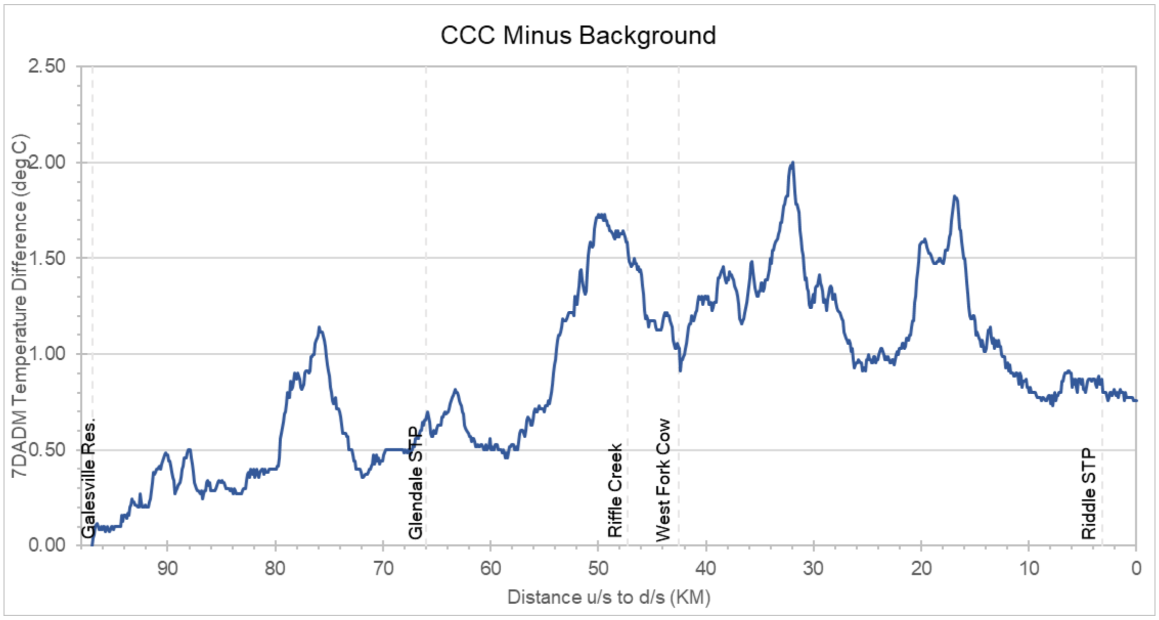


Figure 5-12. The maximum 7DADM temperature differences along Cow Creek for the impacts of current point sources and shade loss.

Table 5-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 2

Maximum Delta	2.00 ˚C
RKM	31.9
Date	7/30/2002

Figure 5-13 shows the results of comparison 3, the impacts of current point sources, which is the 7DADM temperature difference between the CCC scenario and No Point Source scenario. The difference between these two scenarios is the CCC scenario uses the latest available flow and temperature from the point sources, while the No Point Source scenario does not include point sources. The maximum delta reaches 0.04 ˚C at river kilometer 64.3, 1.9 and 1.4 on multiple days throughout the modeling period (Table 5-3).

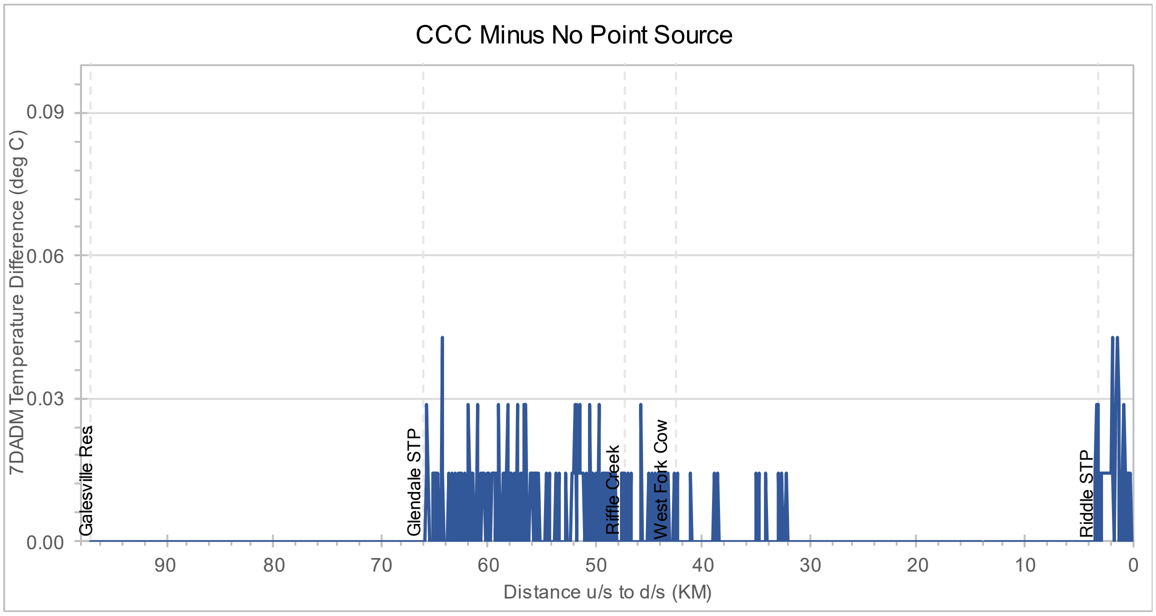


Figure 5-13. The maximum 7DADM temperature differences along Cow Creek for the impacts of point sources at the current condition.

Table 5-3. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 3

Maximum Delta	0.04 ˚C	0.04 ˚C	0.04 ˚C
RKM	64.3	1.9	1.4
Date	7/29/2002	7/21/2002	7/26/2002
		7/22/2002	7/27/2002
		7/23/2022	

Figure 5-14 shows the results of comparison 4, the impact from point sources at WLA conditions, which is the 7DADM temperature difference between the Point Source WLA scenario and No Point Source scenario. The difference between these two scenarios is the Point Source WLA scenario uses the calculated WLA temperatures provided by DEQ, while the No Point Source scenario does not include point sources. The maximum delta reaches 0.09 ˚C at river kilometer 0.9 on 7/20/2002 (Table 5-4).

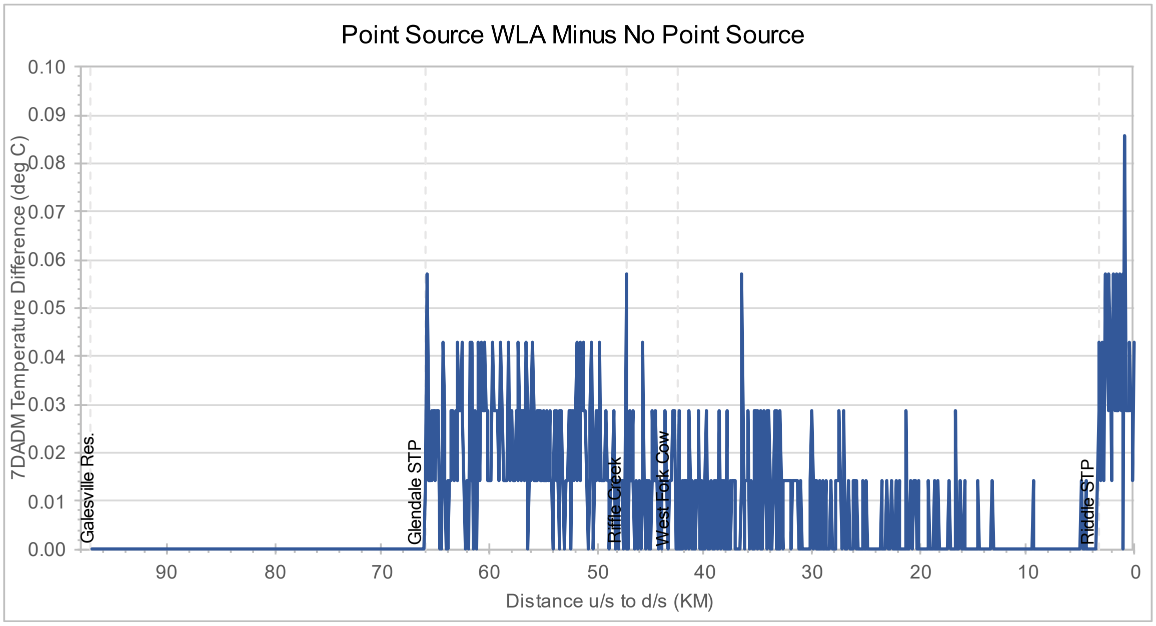


Figure 5-14. The maximum 7DADM temperature differences along Cow Creek for the impacts of point sources at the WLA temperatures.

Table 5-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 4

Maximum Delta	0.09 ˚C
RKM	0.9
Date	7/20/2002

Figure 5-15 shows the results of comparison 5, the impact from current point sources and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario at current conditions and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation scenario includes point sources at the current conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. The maximum delta reaches 0.04 ˚C at river kilometers 59.4, 55.3, and 53.4 on multiple dates (Table 5-5).

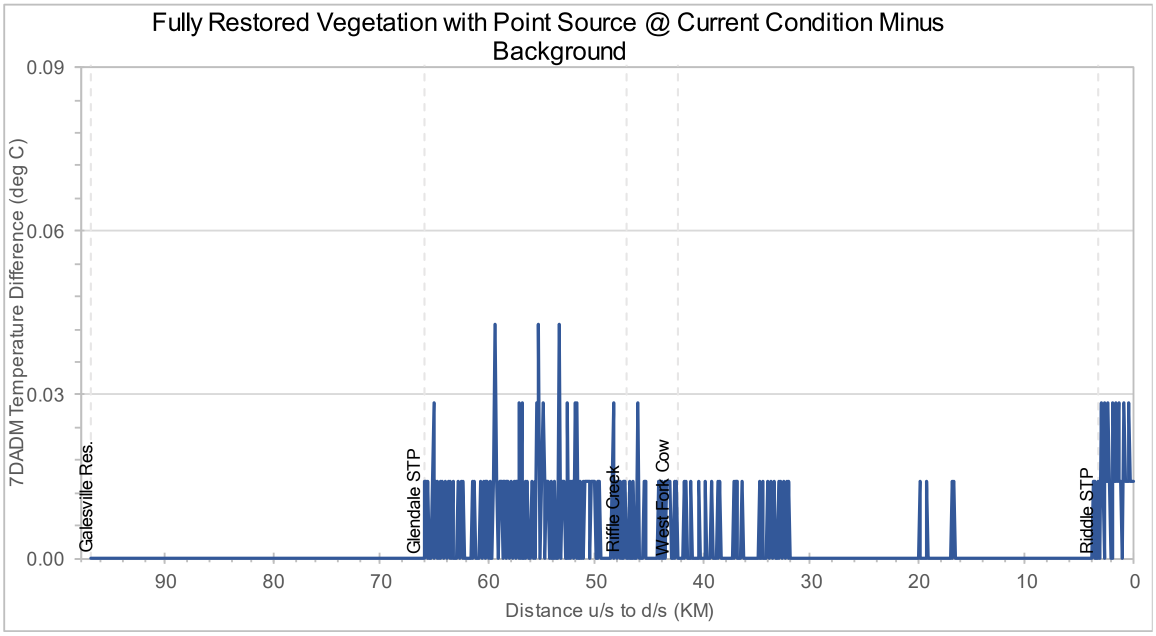


Figure 5-15. The maximum 7DADM temperature differences along Cow Creek for the impacts of current point sources with restored vegetation.

Table 5-5. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 5

Maximum Delta	0.04 ˚C	0.04 ˚C	0.04 ˚C
RKM	59.4	55.3	53.4
Date	7/24/2002	7/31/2002	7/18/2002
	7/25/2002		7/19/2002
	7/26/2002		7/20/2002

Figure 5-16 shows the results of comparison 6, the impact from point sources at the WLA and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario with WLAs (attainment scenario) and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation with point source WLA scenario includes point sources at the WLA conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. The maximum delta reaches 0.07 ˚C at river kilometers 3.2 and 1.5 on 7/26/2002 and 7/27/2002, respectively (Table 5-6).

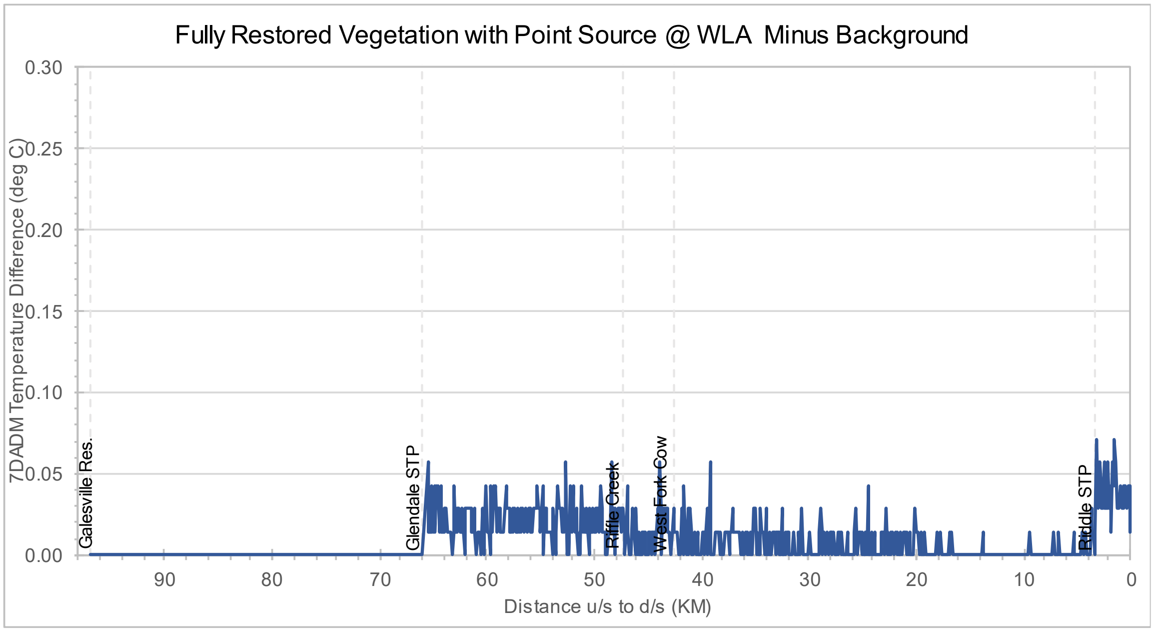


Figure 5-16. The maximum 7DADM temperature differences along Cow Creek for the impacts of point sources at the WLA temperatures and fully restored vegetation conditions.

Table 5-6. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 6

Maximum Delta	0.07 ˚C	0.07 ˚C
RKM	3.2	1.5
Date	7/26/2002	7/27/2002

Figure 5-17 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 7.24 ˚C at river kilometers 5.3 and 5.2 on 7/31/2002 (Table 5-7).

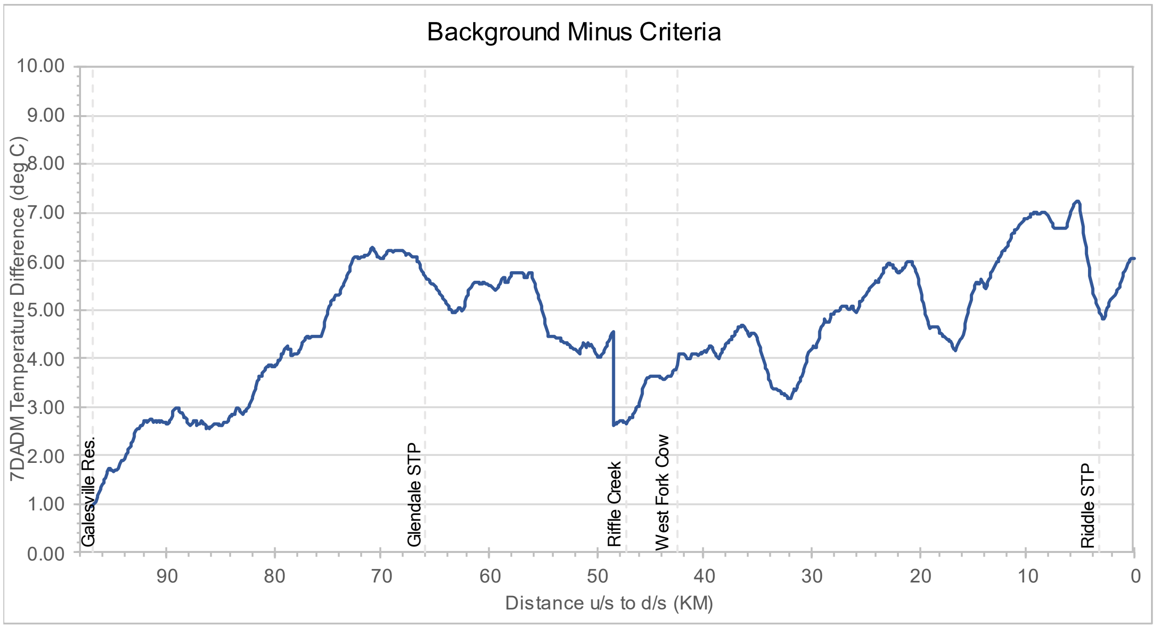


Figure 5-17. The maximum 7DADM temperature differences along Cow Creek for the difference between background conditions and criteria temperatures.

Table 5-7. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 7

Maximum Delta	7.24	7.24
RKM	5.3	5.2
Date	7/31/2002	7/31/2002

Figure 5-18 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. The main difference between these two scenarios for Cow Creek is that there are no withdrawals in the Fully Restored Vegetation with Natural Flow scenario, and headwater inputs also changed with decreased flow and increased temperatures in the Restored Vegetation with Natural Flow scenario. The maximum delta reaches 0.13 ˚C at river kilometer 33.6 on 7/27/2002 and 7/28/2002 and -9.31 ˚C at river kilometer 97 on 7/31/2002 (Table 5-8).

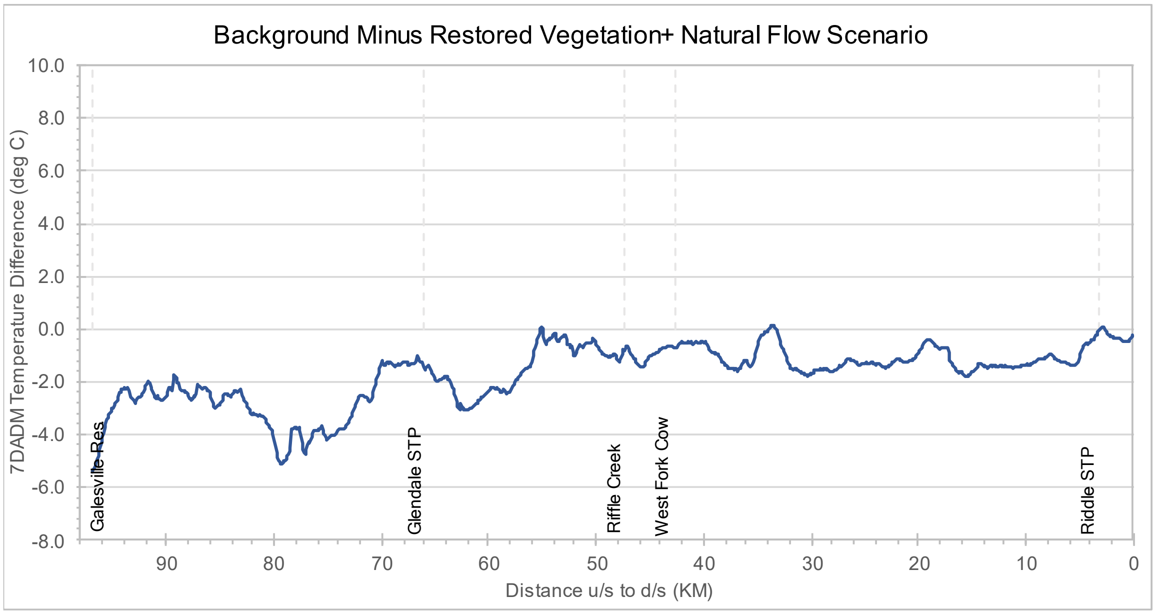


Figure 5-18. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario for Cow Creek.

Table 5-8. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 9

Maximum Delta	0.13	-9.31
RKM	33.6	97
Date	7/27/2002	7/31/2002
	7/28/2002	

Figure 5-19 shows the results of comparison A2, which is the 7DADM temperature difference between the Tributary/Headwater plus 0.1 ˚C scenario and the Background scenario. The difference between these two scenarios is that water temperature from all tributaries and headwater are increased by 0.1 ˚C in the Tributary/Headwater plus 0.1 ˚C scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperatures in tributaries and headwater increase by 0.1 ˚C, the temperature in Cow Creek may also increase by the full 0.1 ˚C or increase by amounts lower than 0.1 ˚C. Since there are numerous increases of the maximum delta of 0.1 ˚C for this comparison, locations and dates of the maximum delta are not listed in a table.

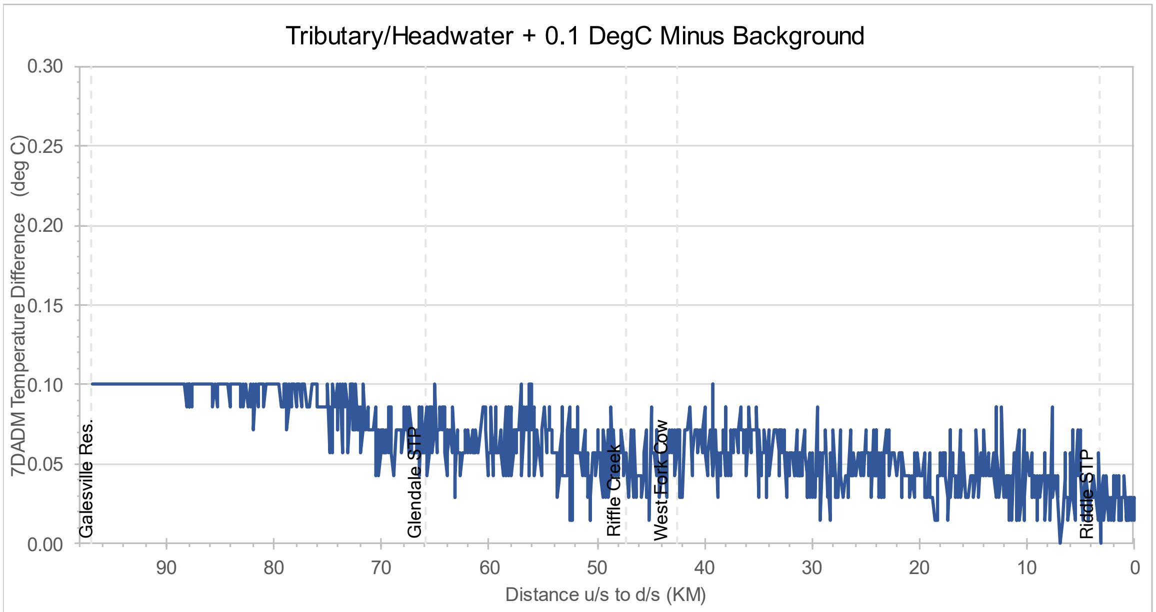


Figure 5-19. The maximum 7DADM temperature differences between Tributary/Headwater Plus 0.1 ˚C scenario and the Background scenario for Cow Creek.

Figure 5-20 shows the results of comparison A4, which is the 7DADM temperature difference between the cumulative effect of the Restored Vegetation with Point Source WLA and Tributary/Headwater plus 0.1 ˚C scenario minus the Background scenario. The difference between these two scenarios is that water temperature from all tributaries and headwater are increased by 0.1 ˚C and the point source water temperature is using the WLA temperature that is provided by DEQ in the Restored Vegetation with Point Source WLA and Tributary/Headwater plus 0.1 ºC scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperatures in tributaries and headwater increase by 0.1 ºC, the temperature in Cow Creek may also increase by the full 0.1 ºC or increase by amounts lower than 0.1 ºC. Since there are numerous increases of the maximum delta of 0.1 ºC for this comparison, locations and dates of the maximum delta are not listed in a table.

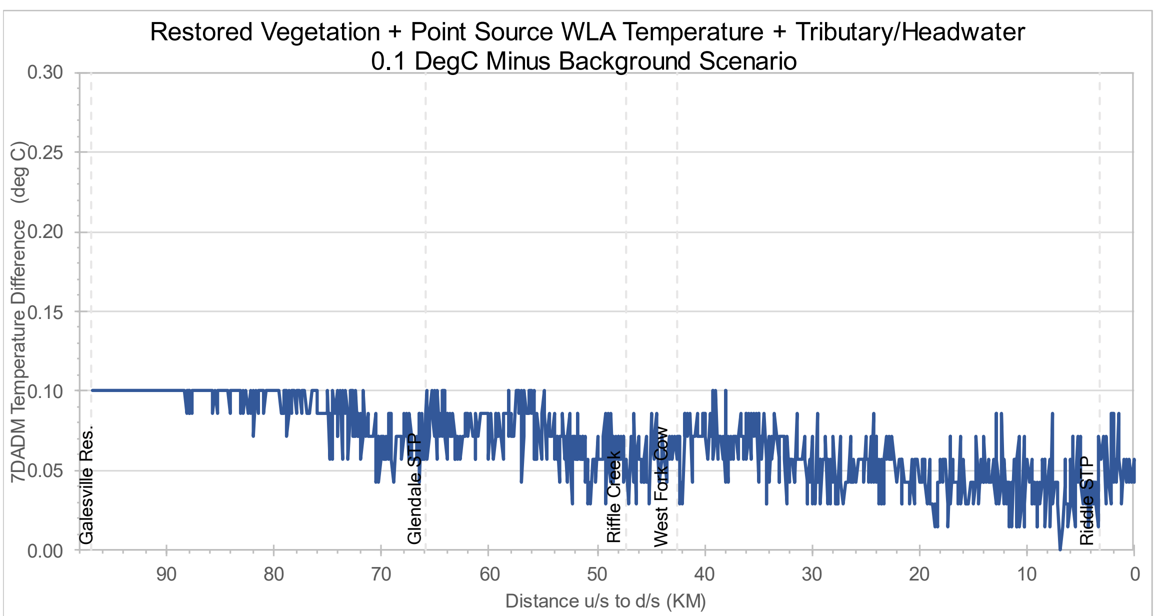


Figure 5-20. The maximum 7DADM temperature differences between the Restored Vegetation with Point Source WLA and Tributary/Headwater Plus 0.1 ˚C scenario and the Background scenario for Cow Creek.

6.0 OLALLA-LOOKINGGLASS CREEK

Olalla-Lookingglass Creek is a tributary to the South Umpqua River (Figure 6-1).

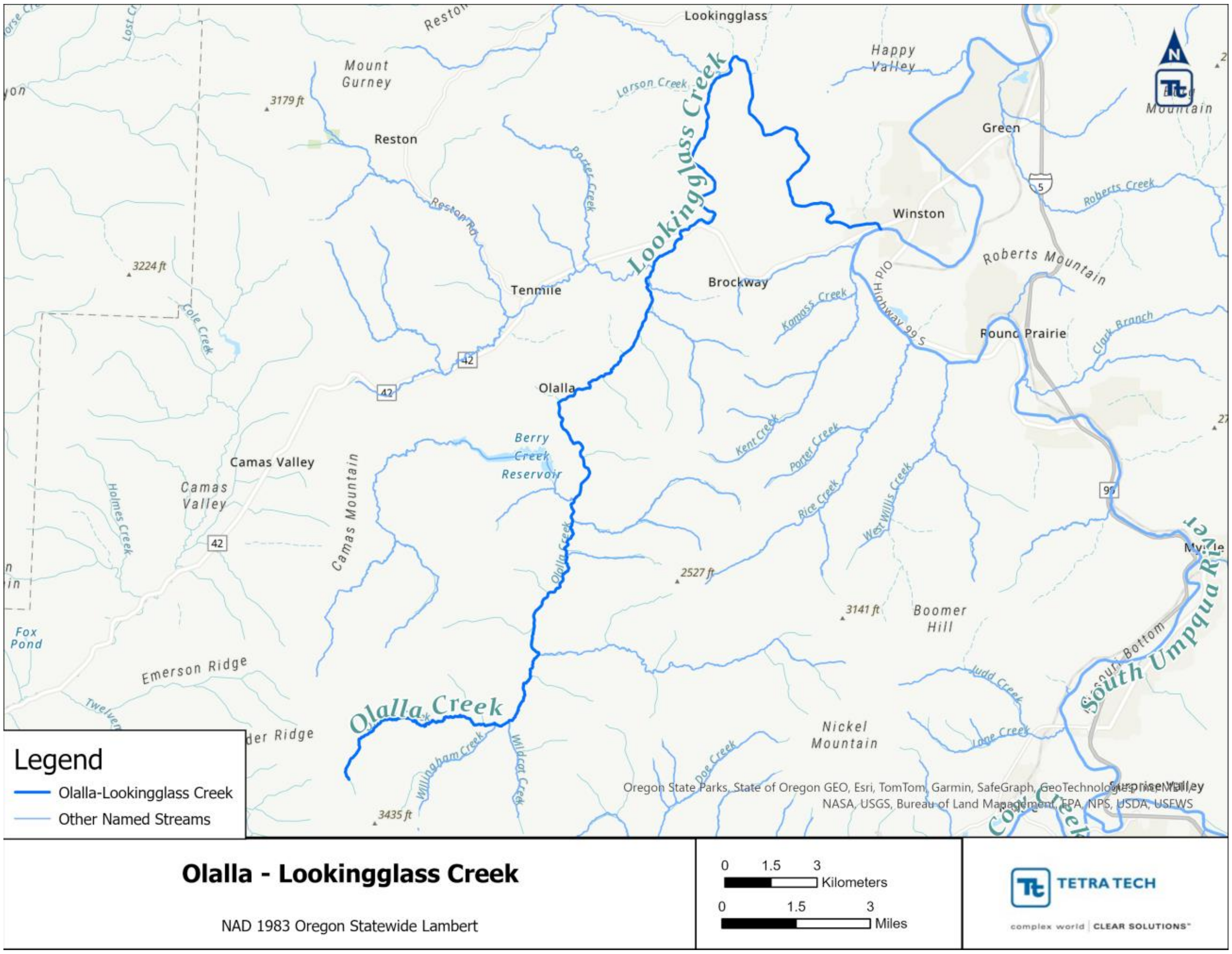


Figure 6-1. Location of Olalla-Lookingglass Creek.

6.1 OLALLA-LOOKINGGLASS CREEK SCENARIO RESULTS

The Olalla-Lookingglass Creek HS model does not include any point sources. The model simulation period is July 12 to July 31. 2002. The scenarios that are relevant to Olalla-Looking Glass Creek include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; the Fully Restored Vegetation with Natural Flow scenario; and the tributary/headwater plus 0.1 ºC scenario. The 7DADM results of these scenarios are shown in Figure 6-2 through Figure 6-5.

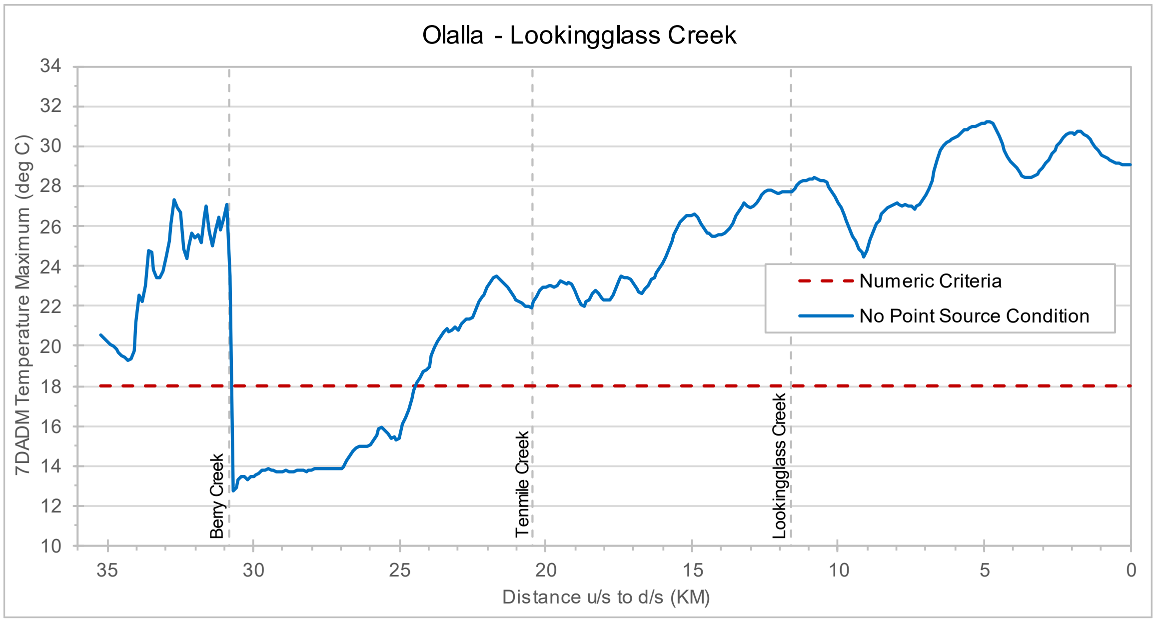


Figure 6-2. The maximum 7DADM temperature results along Olalla-Lookingglass Creek for the No Point Source scenario.

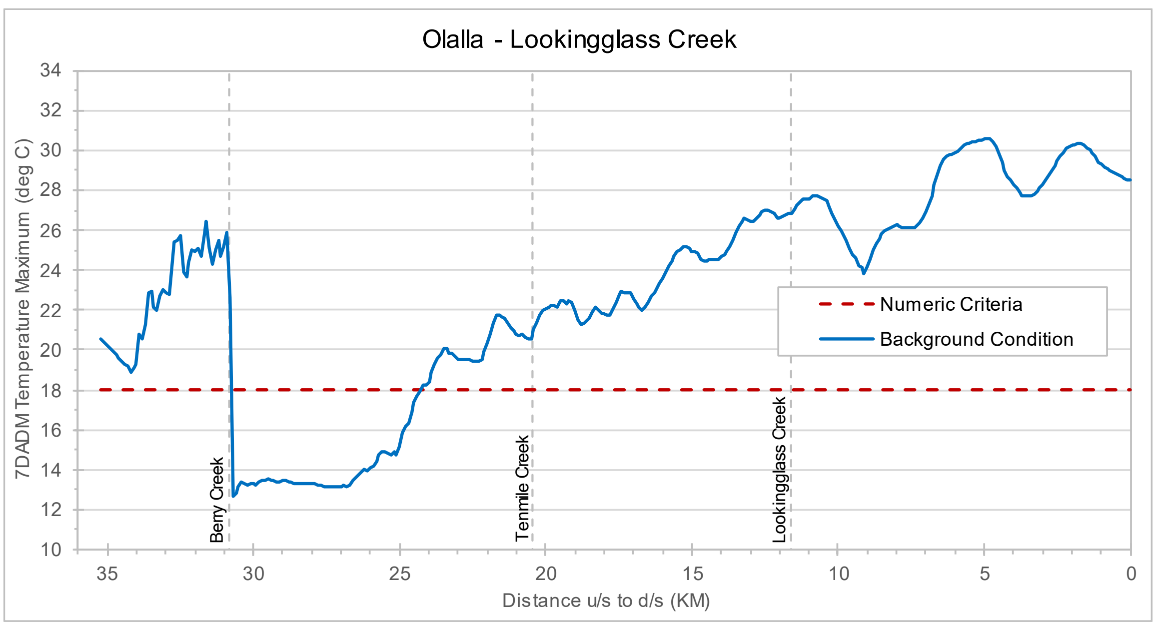


Figure 6-3. The maximum 7DADM temperature results along Olalla-Lookingglass Creek for the Background scenario.

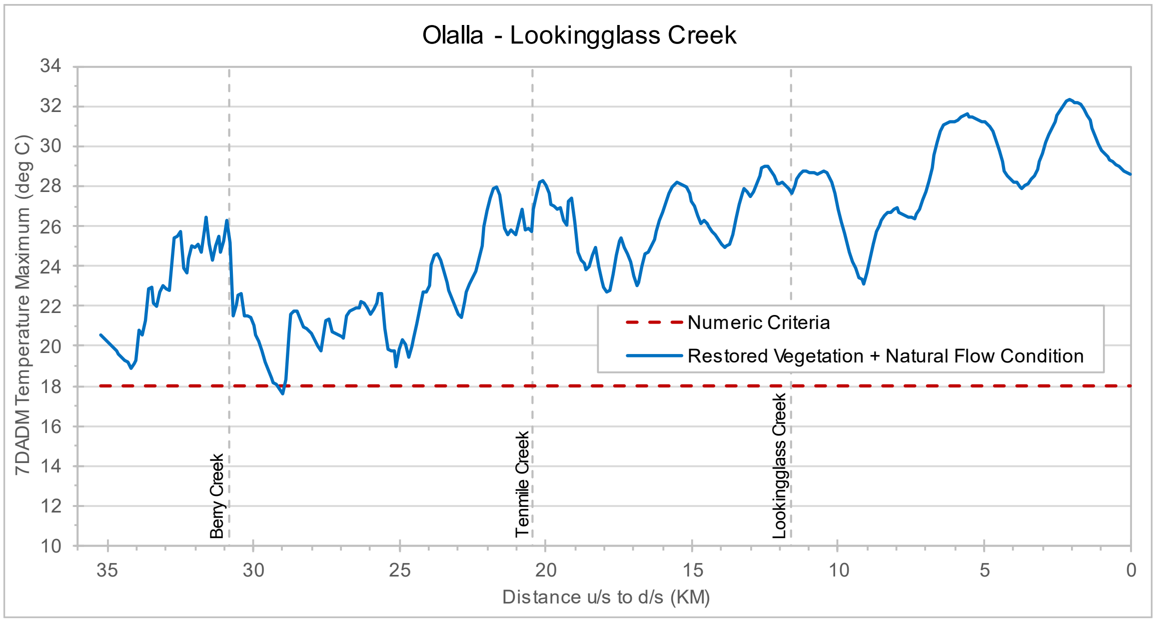


Figure 6-4. The maximum 7DADM temperature results along Olalla-Lookingglass Creek for the Fully Restored Vegetation and Natural Flow scenario.

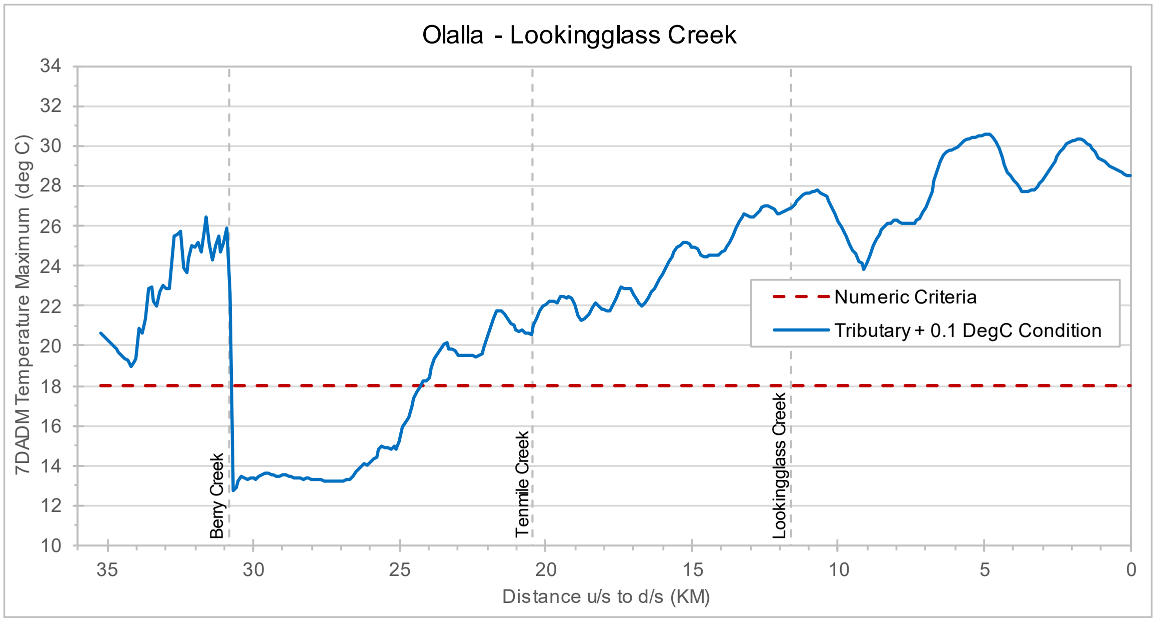


Figure 6-5. The Maximum 7DADM Temperature Results along Olalla-Lookingglass Creek for the Tributary/Headwater Plus 0.1 ˚C Scenario.

The spatial variations of the model results from the Fully Restored Vegetation with Natural Flow scenario are significantly different from other scenarios below the location where Berry Creek enters the Olalla-Lookingglass Creek. Flow from Berry Creek under the current condition is 0.43 m^3/s. The headwater inflow is 0.057 m^3/s; the flows from the three tributaries between headwater and Berry Creek mouth are both 0.00028 m^3/s. Temperatures from the three tributaries are approximately 14 to 20 ^oC. Headwater inflow temperatures are approximately 15 to 21 ^oC. The temperature from Berry Creek is cooler (7 to 11 ^oC).

6.2 OLALLA-LOOKINGGLASS CREEK SCENARIO COMPARISONS

Comparisons of scenarios for Olalla-Lookingglass Creek include:

1. Impacts of current condition vegetation (shade loss)
   - ✓ No Point Source minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria
9. Natural Flows
   - ✓ Background minus fully restored veg with natural flows

A2. Tributary + 0.1ºC scenarios

Figure 6-6 shows the results of comparison 1, the impacts of shade loss, which is the 7DADM temperature difference between the No Point Source scenario (same as calibration condition for models without point sources) and the Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 2.97 ˚C at river kilometer 22.2 on 7/18/2002 (Table 6-1).

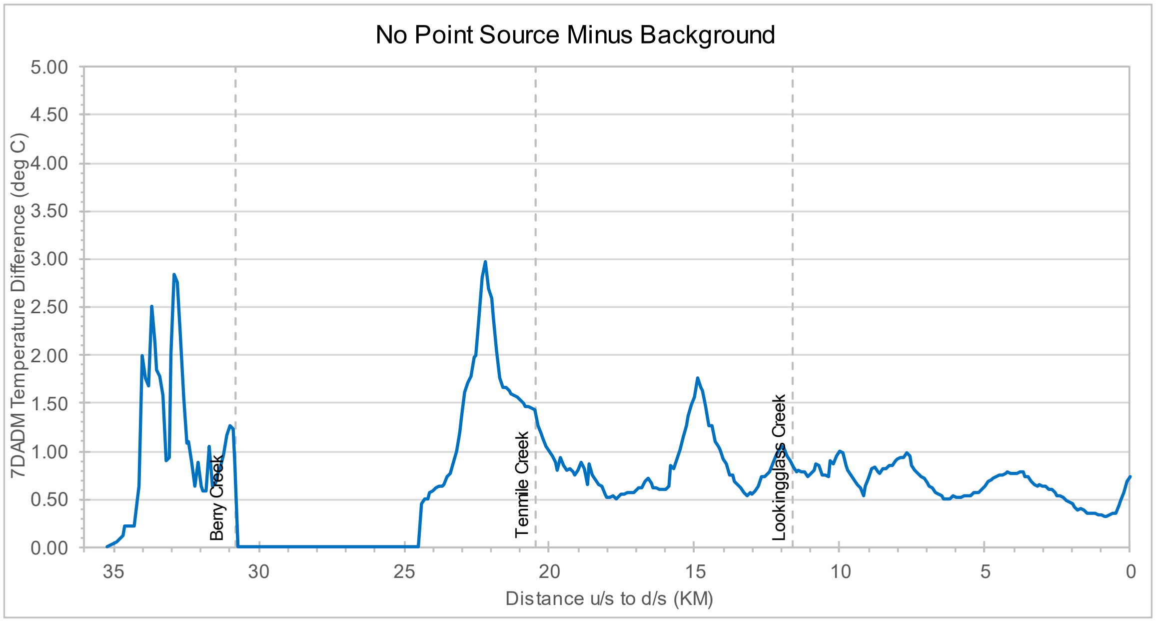


Figure 6-6. The maximum 7DADM temperature differences along Olalla-Lookingglass Creek for the impacts of shade loss.

Table 6-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 1

Maximum Delta	2.97
RKM	22.2
Date	7/18/2002

Figure 6-2 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 12.57 ˚C at river kilometers 4.9 and 4.8 on 7/26/2002 (Table 6-2).

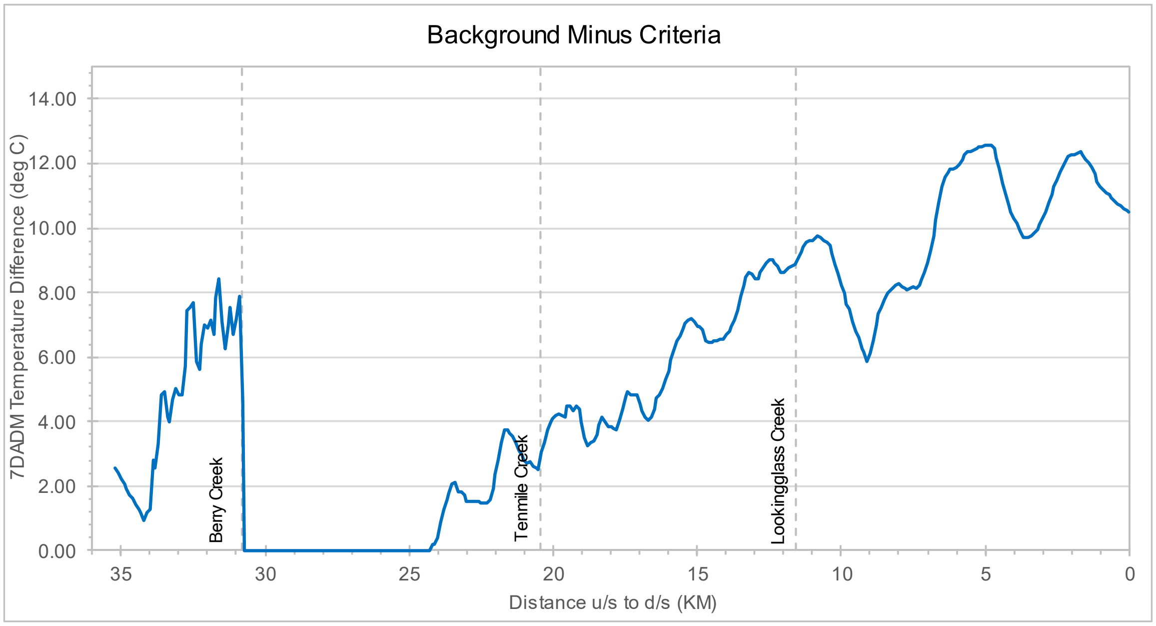


Figure 6-7. The maximum 7DADM temperature differences along Olalla-Lookingglass Creek for the difference between background conditions and criteria temperatures.

Table 6-2. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 7

Maximum Delta	12.57	12.57
RKM	4.9	4.8
Date	7/26/2002	7/26/2002

Figure 6-8 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. The only difference between these two scenarios for Olalla-Lookingglass Creek is that the flow from Berry Creek changed in addition to the removal of withdrawals in the Restored Vegetation with Natural Flow scenario. All other flows and temperature inputs are the same. The maximum delta reaches 0.13 ˚C at river kilometer 33.6 on 7/27/2002 and 7/28/2002 and -9.31 ˚C at river kilometer 97 on 7/31/2002 (Table 6-3).

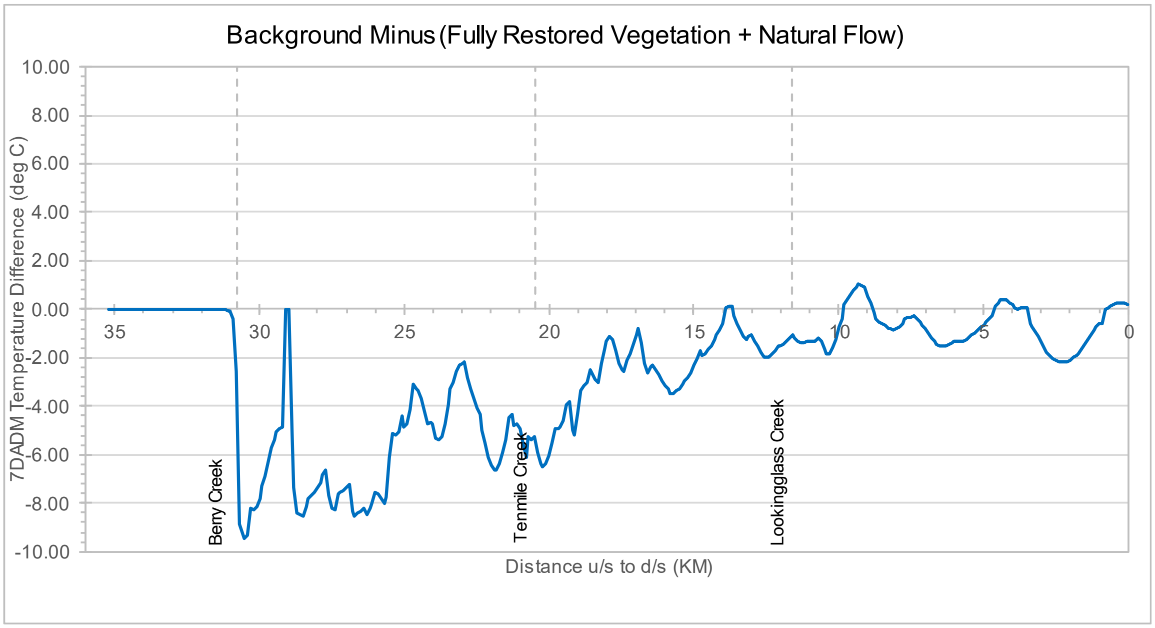


Figure 6-8. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario on Olalla-Lookingglass Creek.

Table 6-3. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 9

Maximum Delta	1.06	-9.44
RKM	9.3	33.6
Date	7/19/2002	7/30/2002
		7/28/2002

Figure 6-9 shows the results of comparison A2, which is the 7DADM temperature difference between the Tributary/Headwater plus 0.1 ˚C scenario and the Background scenario. The only difference between these two scenarios is that water temperature from all tributaries and headwaters are increased by 0.1 ˚C in the Tributary/Headwater plus 0.1 ˚C scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperatures in tributaries and headwater increase by 0.1 ˚C, the temperature in Olalla-Lookingglass Creek may also increase by the full 0.1 ˚C or increase by amounts lower than 0.1 ˚C. Since there are numerous increases of the maximum delta of 0.1 ˚C for this comparison, locations and dates of the maximum delta are not listed in a table.

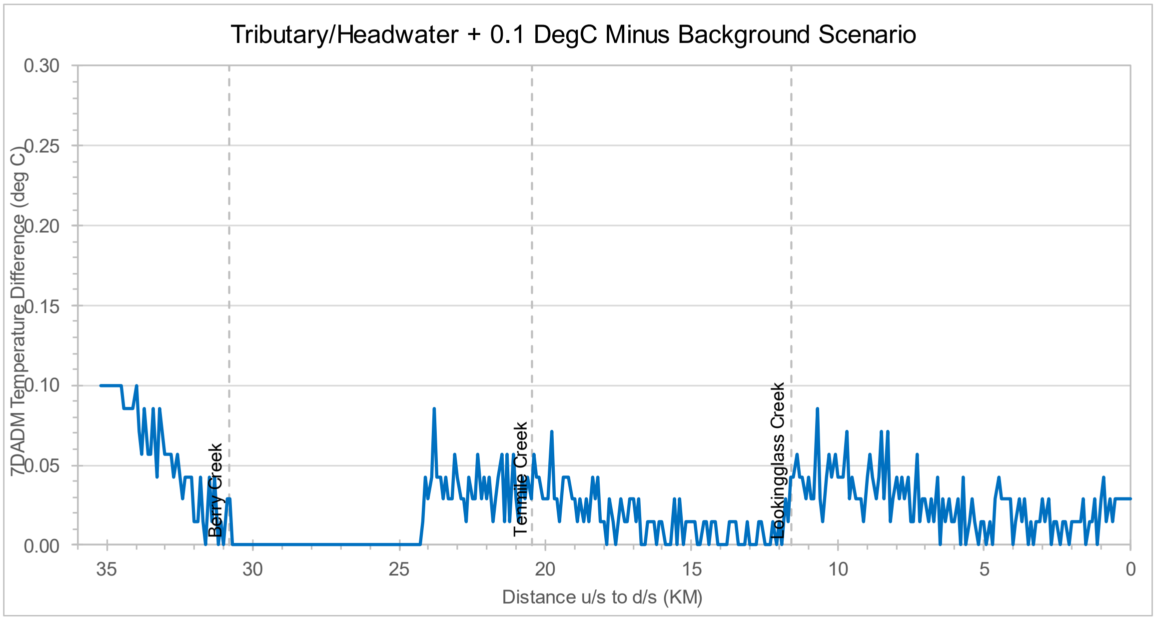


Figure 6-9. The maximum 7DADM temperature differences between Tributary/Headwater Plus 0.1 ˚C scenario and the Background scenario.

7.0 SOUTH UMPQUA RIVER

The modeled portion of the South Umpqua River is shown in Figure 7-1. The South Umpqua River was modeled for both the summer period (July 2002) and the spawning period (September 1, 2009 to October 5, 2009). The summer period scenario results and scenario comparisons are presented in sections 7.1 and 7.2 while the spawning period scenario results and scenario comparisons are presented in sections 7.3 and 7.4.

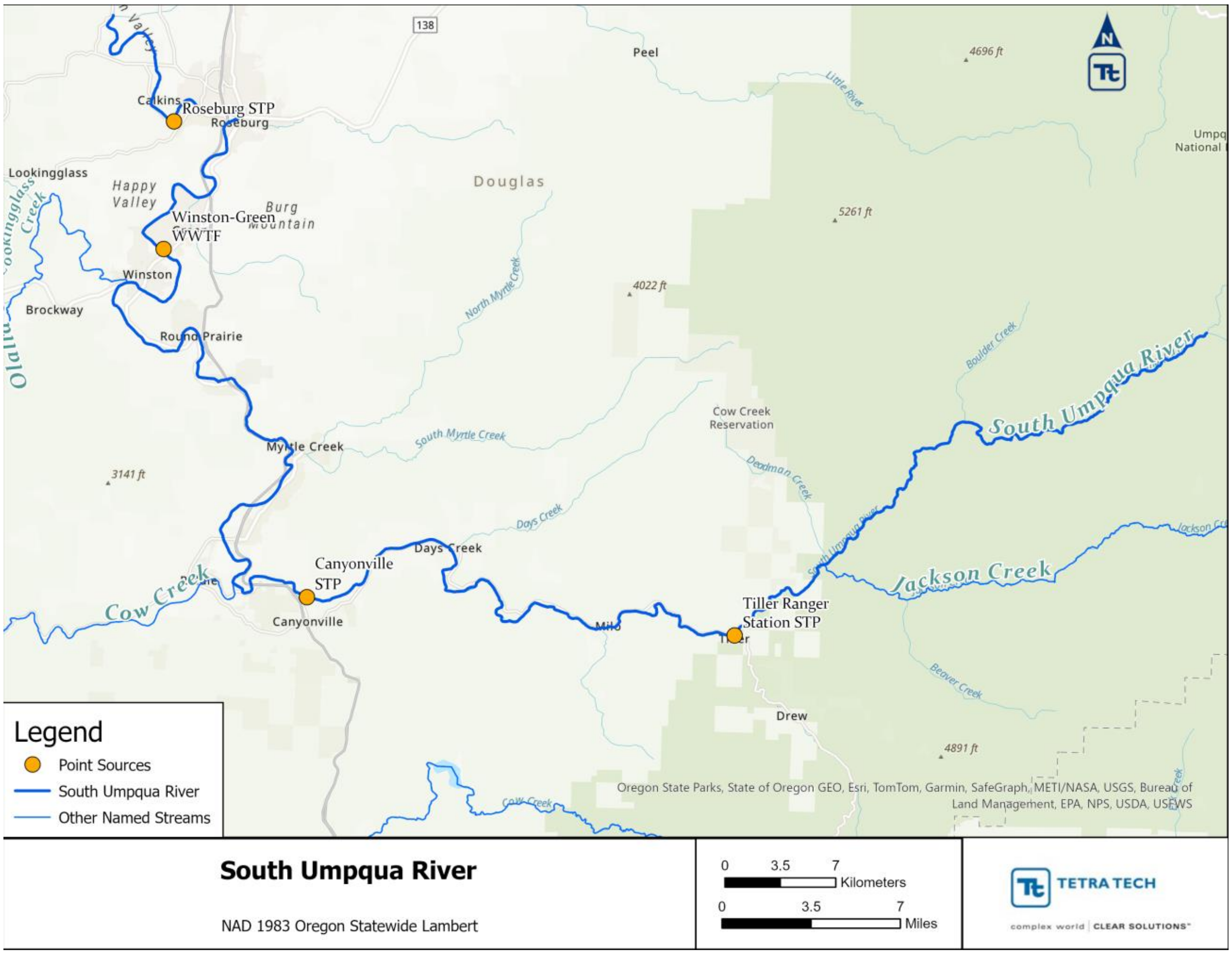


Figure 7-1. Location of the South Umpqua River.

7.1 SOUTH UMPQUA RIVER SUMMER PERIOD SCENARIO RESULTS

The South Umpqua River HS summer period model includes point sources. The model simulation period is from July 12 to July 31, 2002. The scenarios that are relevant to the South Umpqua River summer period include the CCC scenario, the No Point Source scenario; the Point Source WLA scenario; the Fully Restored Vegetation scenario; the Background scenario; the Attainment scenario; the Fully Restored Vegetation with Natural Flow scenario; the Tributary/Headwater Plus 0.1 °C scenario; and the Fully restored Vegetation with Point Source WLA and Tributary/Headwater Plus 0.1 °C scenario. The 7DADM results of these scenarios are shown in Figure 7-2 through Figure 7-10.

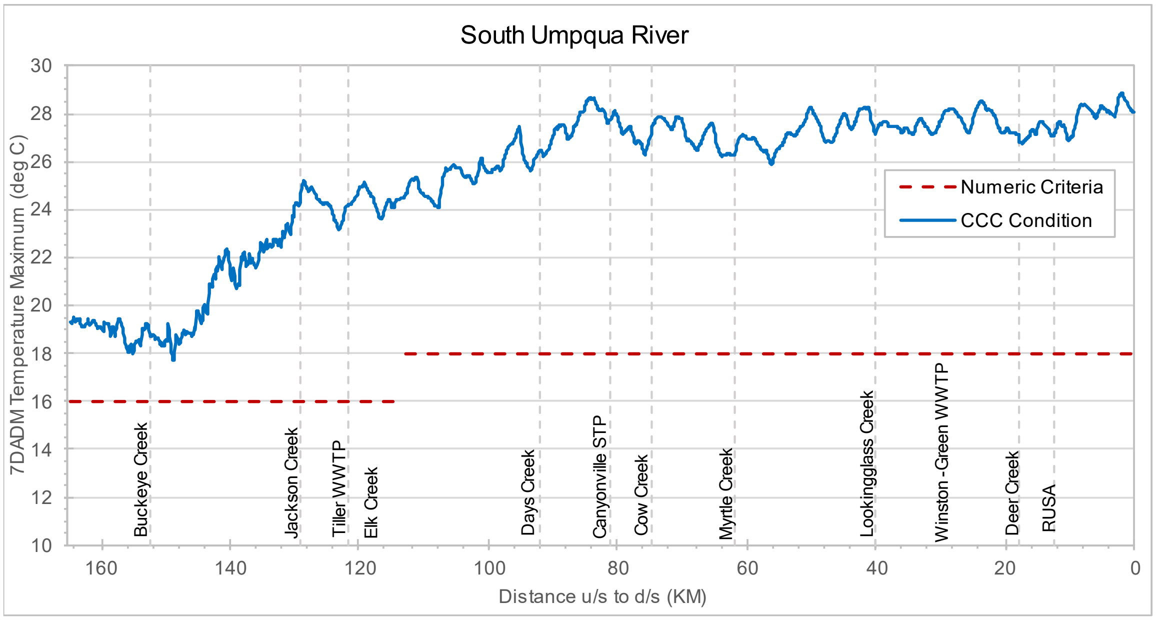


Figure 7-2. The maximum 7DADM temperature results along the South Umpqua River for the summer period Current Condition scenario.

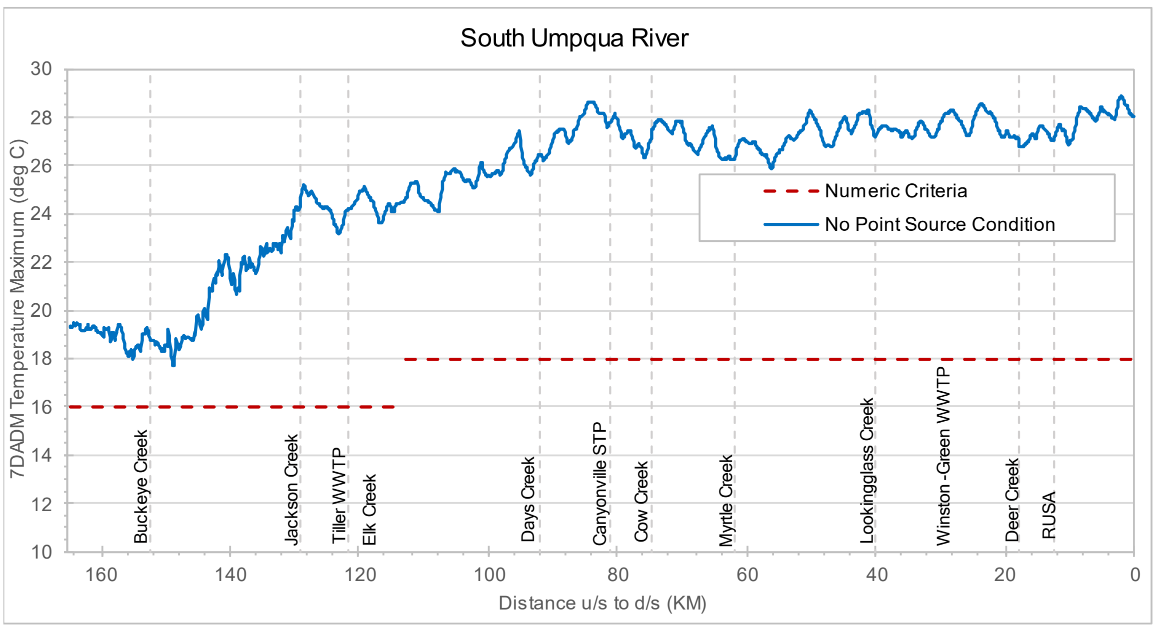


Figure 7-3. The maximum 7DADM temperature results along the South Umpqua River for the summer period No Point Source scenario.

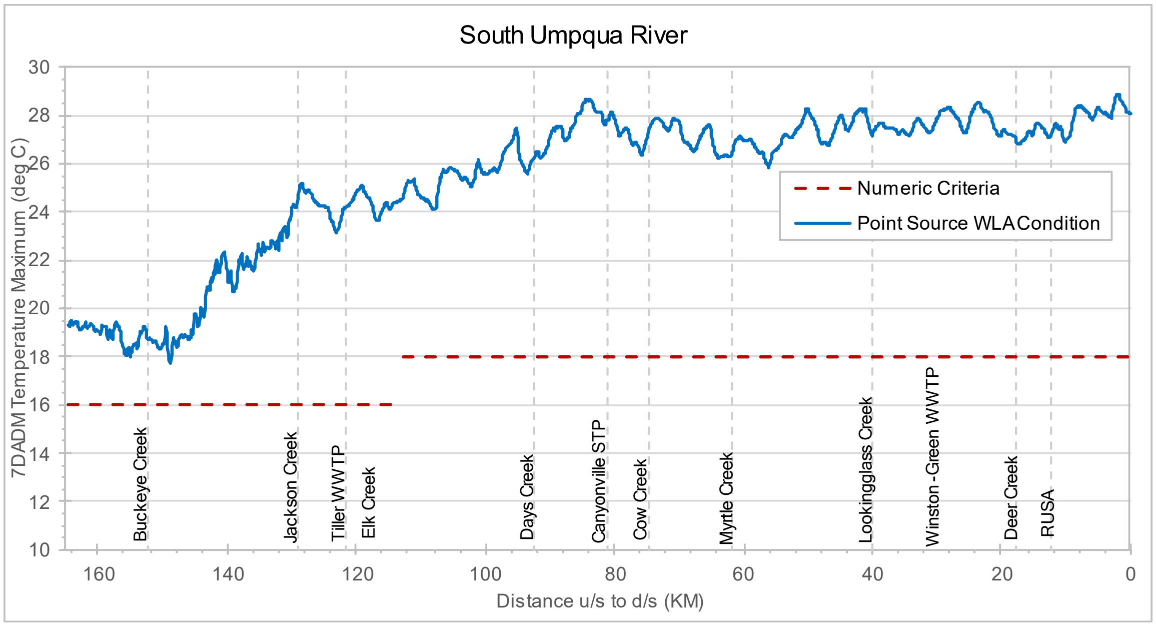


Figure 7-4. The maximum 7DADM temperature results along the South Umpqua River for the summer period Point Source WLA Conditions scenario.

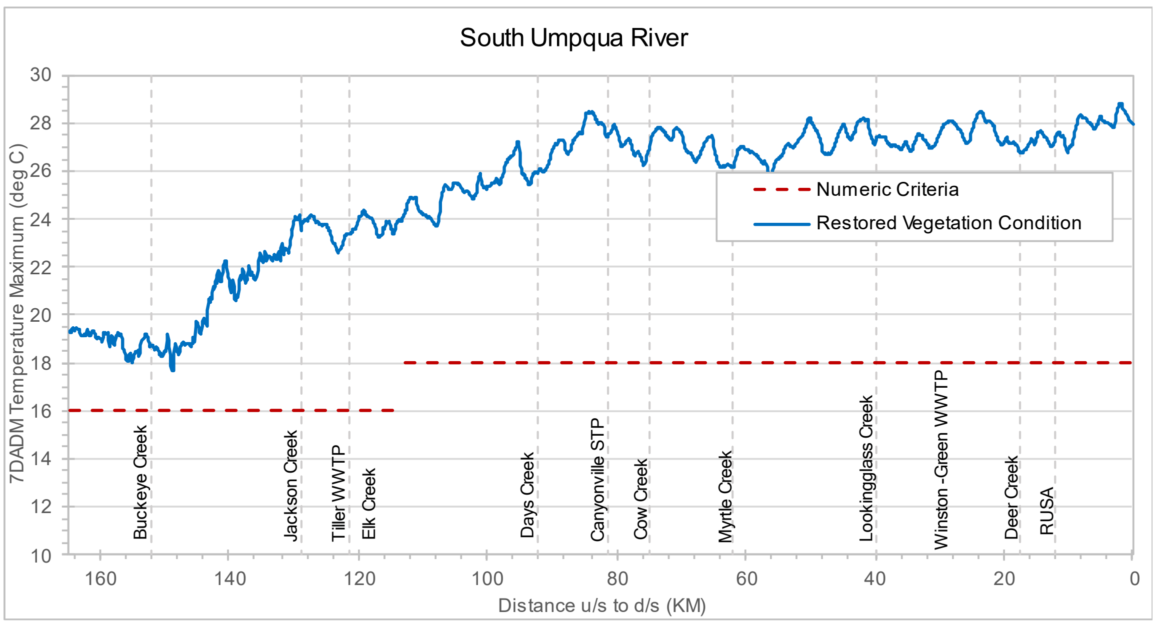


Figure 7-5. The maximum 7DADM temperature results along the South Umpqua River for the summer period Fully Restored Vegetation scenario.

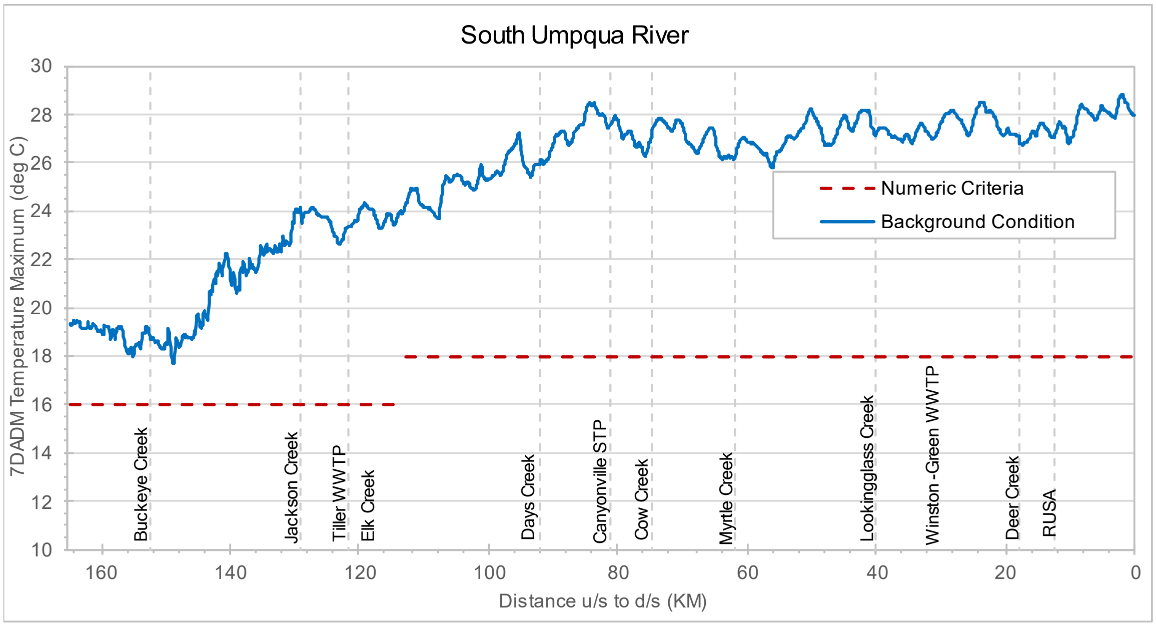


Figure 7-6. The maximum 7DADM temperature results along the South Umpqua River for the summer period Background scenario.

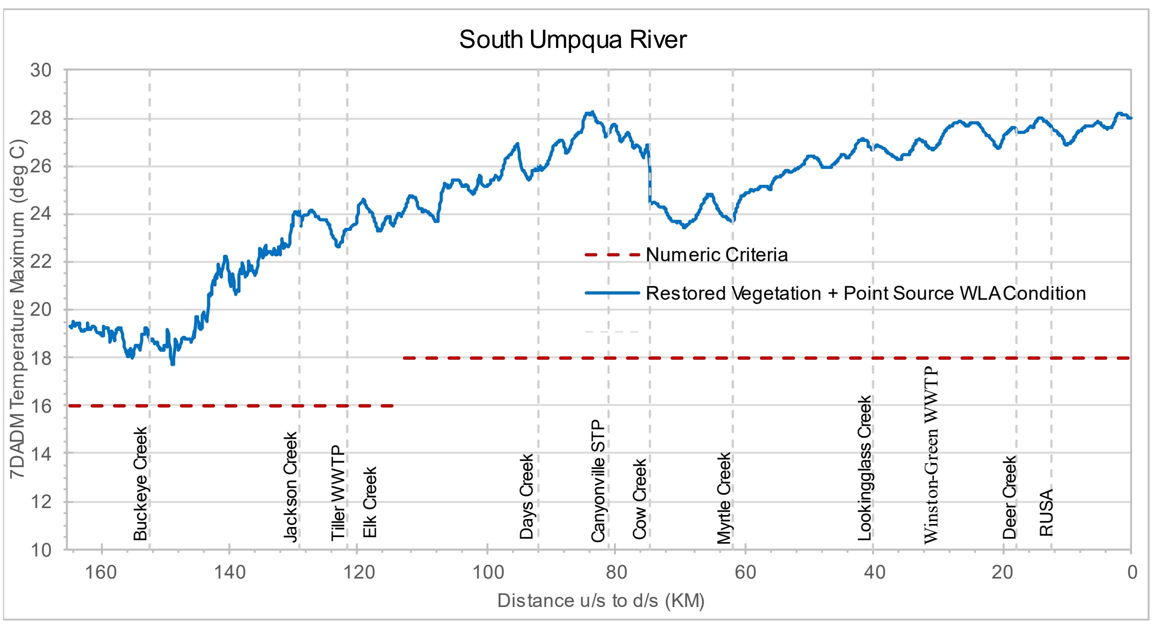


Figure 7-7. The maximum 7DADM temperature results along the South Umpqua River for the summer period Attainment scenario.

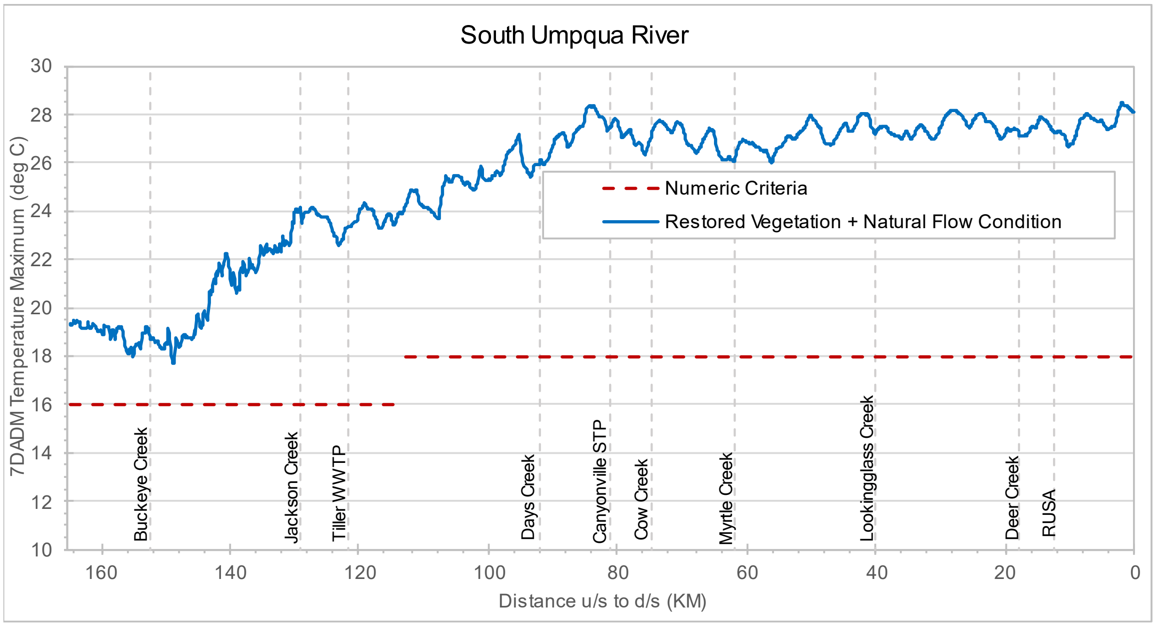


Figure 7-8. The maximum 7DADM temperature results along the South Umpqua River for the summer period Fully Restored Vegetation and Natural Flow scenario.

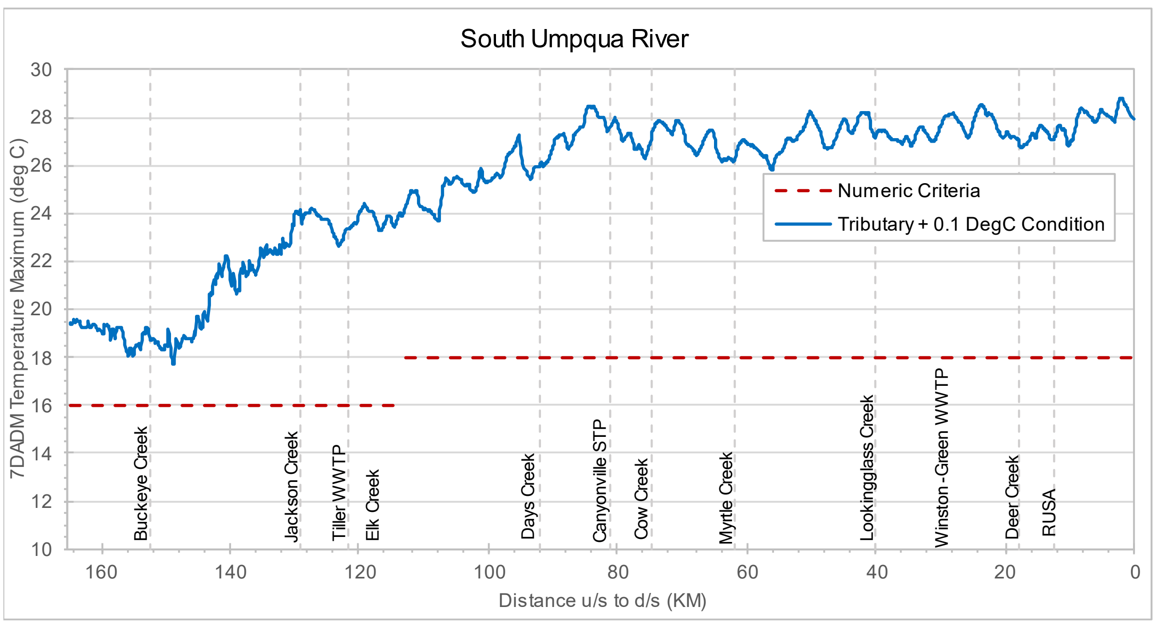


Figure 7-9. The maximum 7DADM temperature results along South Umpqua River for the summer period Tributary/Headwater Plus 0.1 °C scenario.

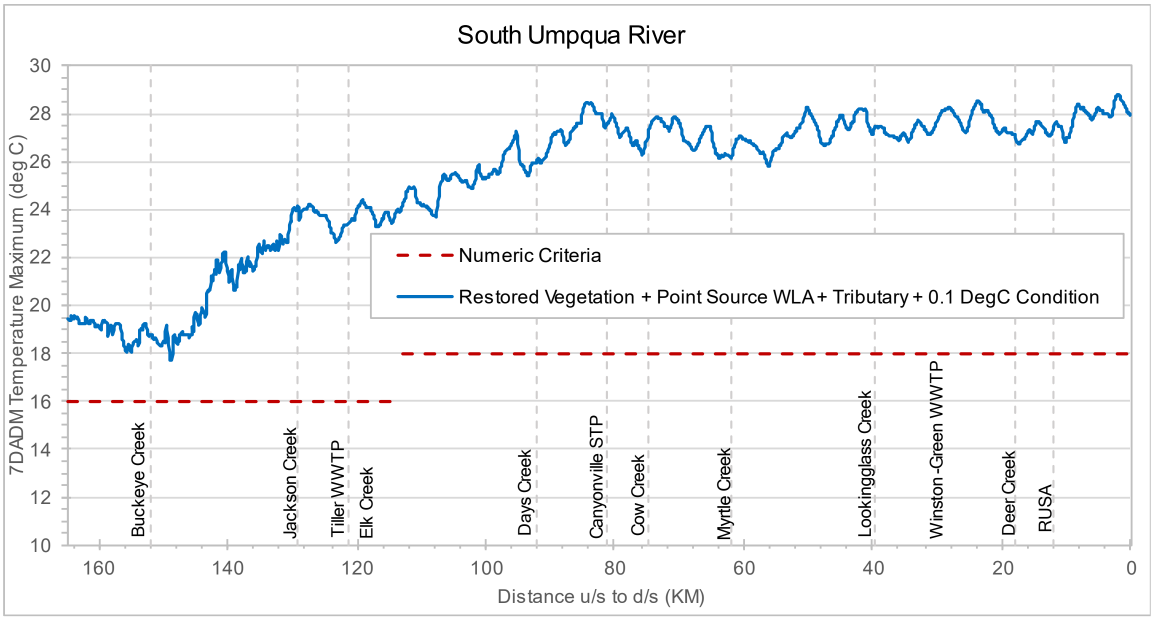


Figure 7-10. The maximum 7DADM temperature results along the South Umpqua River for the summer period Fully Restored Vegetation with Point Source WLA and Tributary/Headwater Plus 0.1 °C scenario.

7.2 SOUTH UMPQUA RIVER SUMMER PERIOD SCENARIO COMPARISONS

Comparisons between summer period scenarios include:

1. Impacts of current condition vegetation (shade loss)
   - ✓ No Point Source minus background
2. Impact of current point source and current vegetation (shade loss)
   - ✓ CCC minus background
3. Impact from point source @ current condition
   - ✓ CCC minus no point source
4. Impact from point sources @ WLA conditions
   - ✓ Point Source WLA minus No point source
5. Impact current point source and restored vegetation
   - ✓ Fully restored veg with point source @ current condition minus background
6. Impact point source @ WLA and restored vegetation
   - ✓ Fully restored veg with point source @ WLA minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria
9. Natural Flows
   - ✓ Background minus fully restored veg with natural flows

A2. Tributary + 0.1ºC scenarios

A4. Cumulative
   - ✓ Restored veg + point source WLA + tributaries 0.1 °C minus background.

Figure 7-11 shows the results of comparison 1, the impacts of shade loss, which is the 7DADM temperature difference between the No Point Source scenario and Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 1.61 ˚C at river kilometer 128.9 on 7/31/2002 (Table 7-1).

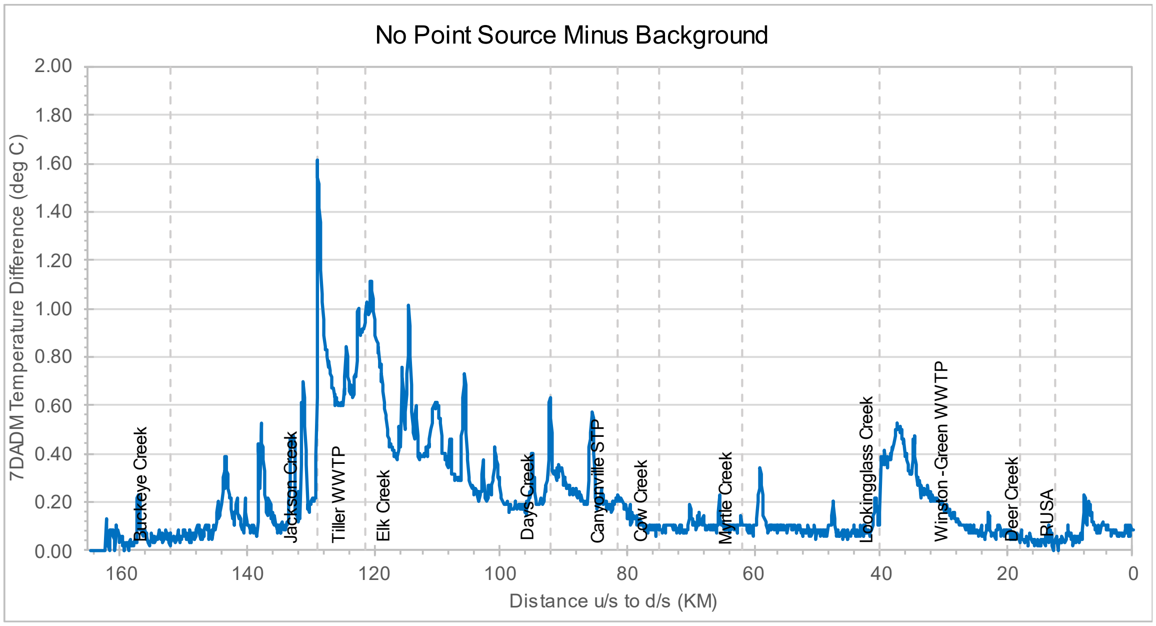


Figure 7-11. The maximum 7DADM temperature differences along the South Umpqua River summer period for the impacts of shade loss.

Table 7-1. Location and date of maximum delta when temperatures are greater than criterion for comparison 1

Maximum Delta	1.61
RKM	128.9
Date	7/31/2002

TETRA TECH
WTR Mid Atlantic

Figure 7-12 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition and the point source conditions where the CCC scenario uses the latest available flow and temperature from the point sources, while the Background scenario does not include point sources. The maximum delta reaches 1.61˚C at river kilometer 128.9 on 7/31/2002 (Table 7-2).

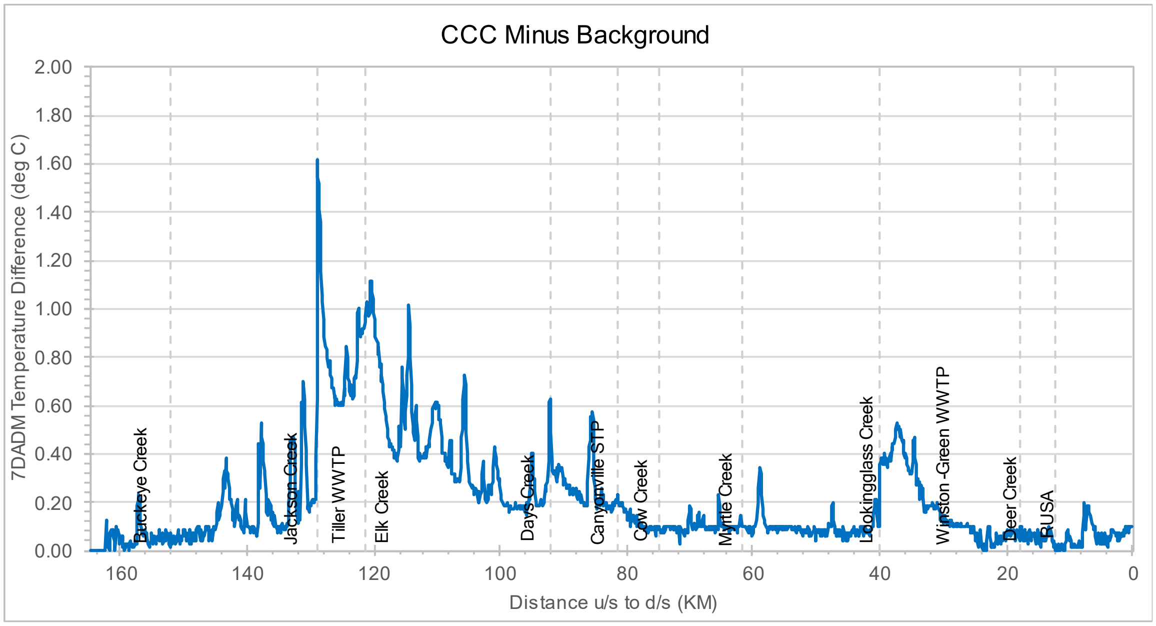


Figure 7-12. The maximum 7DADM temperature differences along the South Umpqua River summer period for the impacts of current point source and shade loss.

Table 7-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 2

Maximum Delta	1.61
RKM	128.9
Date	7/31/2002

Figure 7-13 shows the results of comparison 3, the impacts of current point sources, which is the 7DADM temperature difference between the CCC scenario and No Point Source scenario. The difference between these two scenarios is the CCC scenario uses the latest available flow and temperature from the point sources, while the No Point Source scenario does not include point sources. The maximum delta reaches 0.06 ˚C at multiple river kilometers and days throughout the modeling period (Table 7-3).

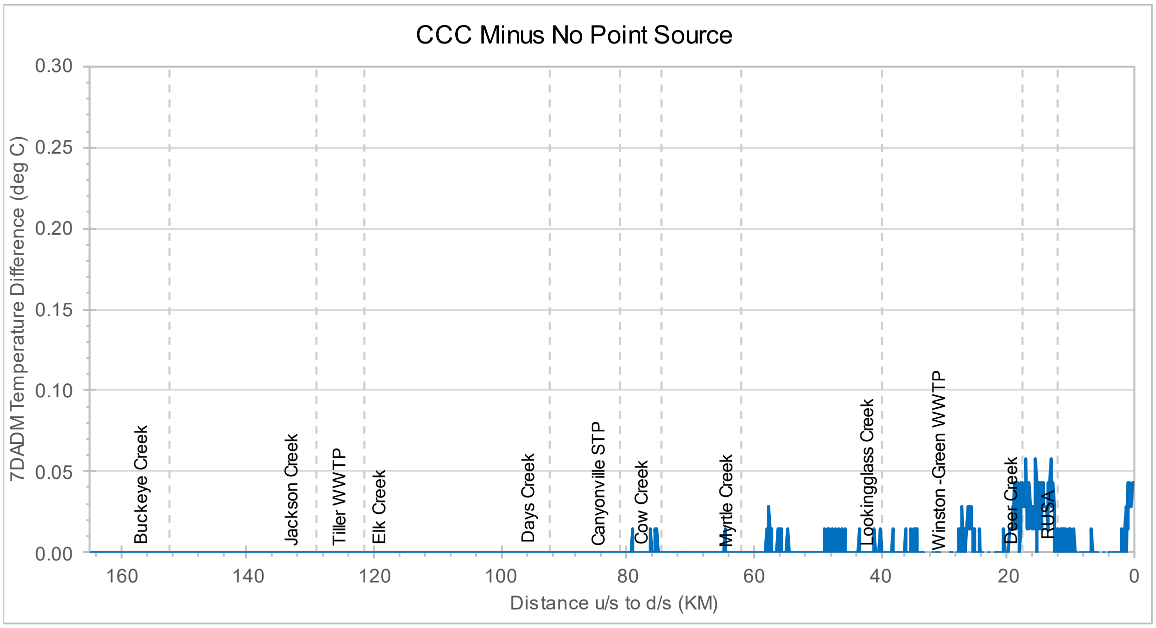


Figure 7-13. The maximum 7DADM temperature differences along the South Umpqua River summer period for the impacts of point sources at the current condition.

Table 7-3. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 3

Maximum Delta	0.06	0.06	0.06
RKM	17	15.5	13.1
Date	7/25/2002	7/28/2002	7/18/2002
	7/27/2002	7/29/2002	
	7/28/2002		
	7/29/2002		

Figure 7-14 shows the results of comparison 4, the impact from point sources at WLA conditions, which is the 7DADM temperature difference between the Point Source WLA scenario and No Point Source scenario. The difference between these two scenarios is the Point Source WLA scenario uses the calculated WLA temperatures, while the No Point Source scenario does not include point sources. The maximum delta reaches 0.16 ˚C at river kilometer 31.6 on 7/21/2002 (Table 7-4).

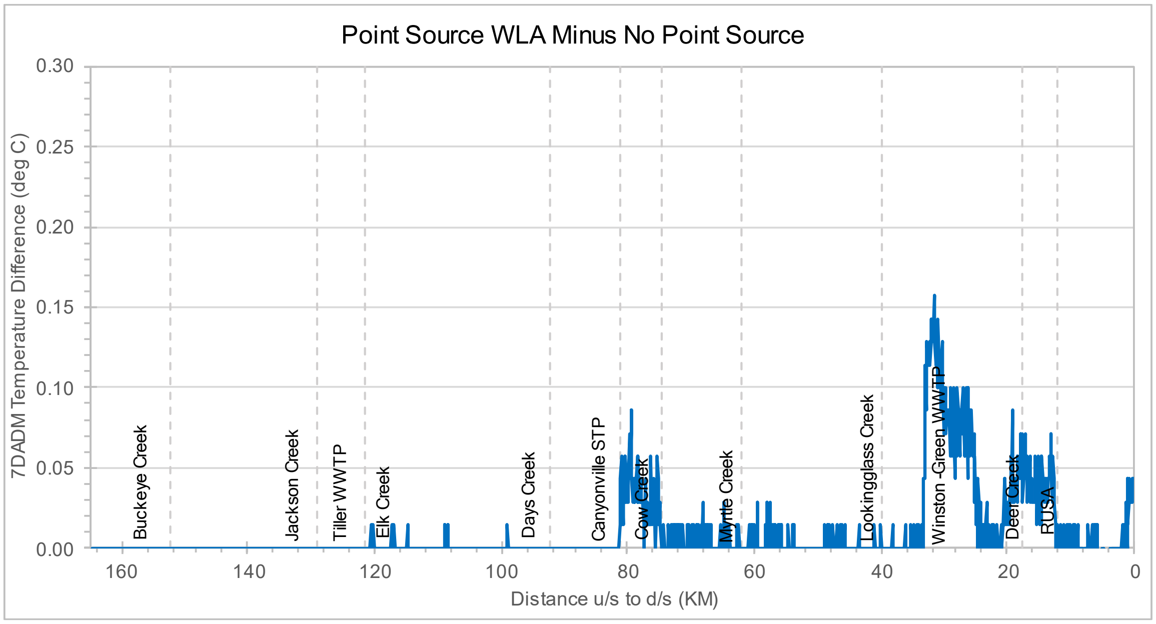


Figure 7-14. The maximum 7DADM temperature differences along the South Umpqua River summer period for the impacts of point sources at the WLA temperatures.

Table 7-4. Location and date of maximum delta when temperatures are greater than criterion for comparison 4

Maximum Delta	0.16
RKM	31.6
Date	7/21/2002

Figure 7-15 shows the results of comparison 5, the impact from current point sources and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario at current conditions and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation scenario includes point sources at the current conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. The maximum delta reaches 0.09 ˚C at river kilometer 0.6 on 7/18/2002 (Table 7-5).

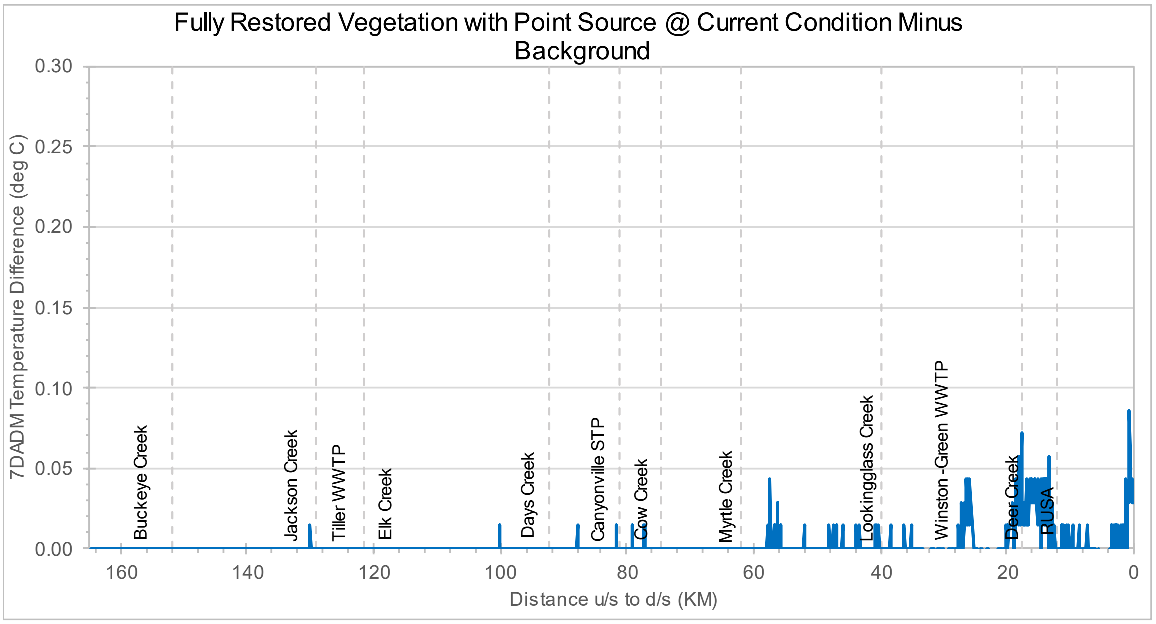


Figure 7-15. The maximum 7DADM temperature differences along the South Umpqua River summer period for the impacts of current point sources with restored vegetation.

Table 7-5. Location and date of maximum delta when temperatures are greater than criterion for comparison 5

Maximum Delta	0.09
RKM	0.6
Date	7/18/2002

Figure 7-16 shows the results of comparison 6, the impact from point sources at the WLA and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario with WLAs (attainment scenario) and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation with point source WLA scenario includes point sources and WLA conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. The maximum delta reaches 0.09 ˚C at multiple river kilometers and multiple dates (Table 7-6).

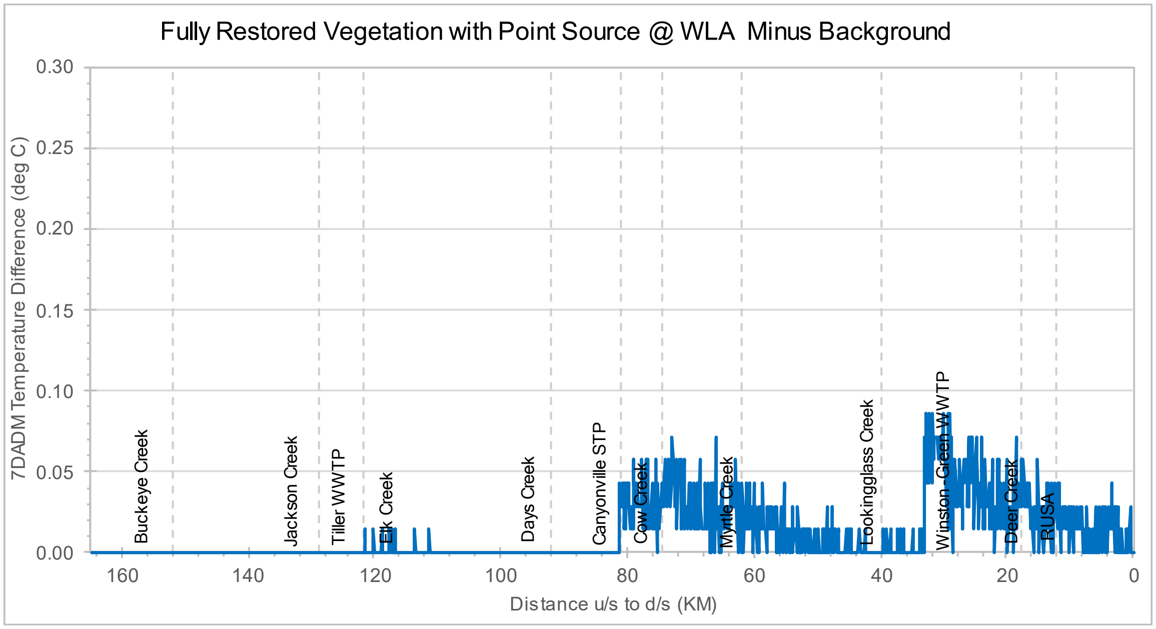


Figure 7-16. The maximum 7DADM temperature differences along the South Umpqua River summer period for the impacts of point sources at the WLA temperatures and fully restored vegetation conditions.

Table 7-6. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 6

Maximum Delta	0.09	0.09	0.09	0.09	0.09	0.09
RKM	32.8	32.4	31.7	30.1	29.2	29
Date	7/19/2002	7/20/2002	7/20/2002	7/19/2002	7/18/2002	7/21/2002
	7/21/2002	7/21/2002	7/21/2002		7/19/2002	7/22/2002
		7/22/2002			7/20/2002	
					7/21/2002	
					7/22/2002	

Figure 7-17 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 10.26 ˚C at river kilometer 83.7 on 7/18/2002 (Table 7-7).

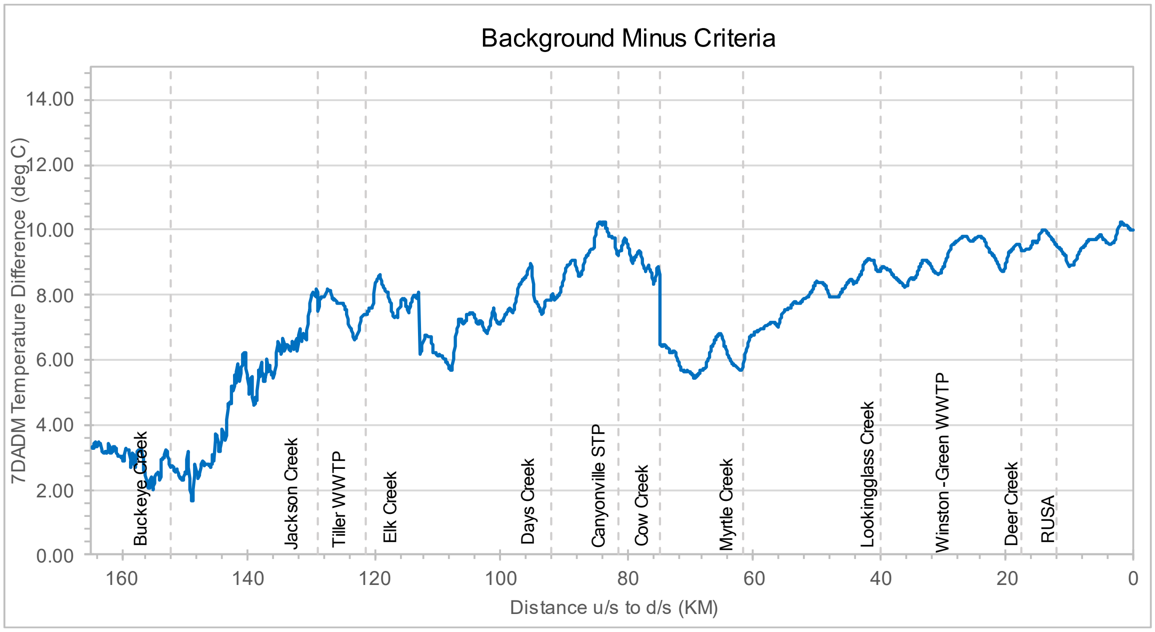


Figure 7-17. The maximum 7DADM temperature differences along the South Umpqua River summer period for the difference between background conditions and criteria temperatures.

Table 7-7. Location and date of maximum delta when temperatures are greater than criterion for comparison 7

Maximum Delta	10.26
RKM	83.7
Date	7/18/2002

Figure 7-18 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. The main difference between these two scenarios for the South Umpqua River is that there are no withdrawals in the Fully Restored Vegetation with Natural Flow scenario. In addition, the flows from Jackson Creek and Olalla-Lookingglass Creek are the natural flows in the Fully Restored Vegetation with Natural Flow scenario, which are different from the flows used in the Background scenario. The maximum delta reaches 0.87 ˚C and -0.43 at multiple river kilometers and dates (Table 7-8).

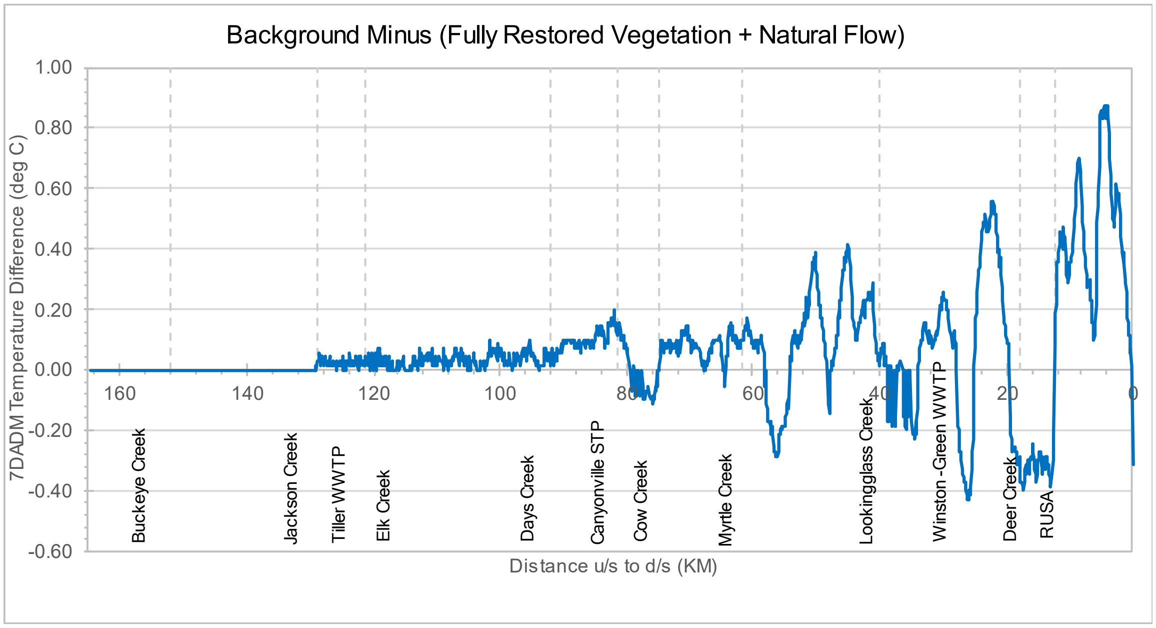


Figure 7-18. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario for the South Umpqua River summer period.

Table 7-8. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 9

Maximum Delta	0.87	0.87	0.87	-0.43	-0.43
RKM	4.5	4.4	4.3	26.1	25.9
Date	7/31/2002	7/31/2002	7/28/2002	7/19/2002	7/19/2002
			7/31/2002		

Figure 7-19 shows the results of comparison A2, which is the 7DADM temperature difference between the Tributary/Headwater plus 0.1 ˚C scenario and the Background scenario. The only difference between these two scenarios is that water temperature from all tributaries and headwater are increased by 0.1 ˚C in the Tributary/Headwater plus 0.1 ˚C scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperatures in tributaries and headwater increase by 0.1 ˚C, the temperature in the South Umpqua River may also increase by the full 0.1 ˚C or increase by amounts lower than 0.1 ˚C. Since there are numerous increases of the maximum delta of 0.1 ˚C for this comparison, locations and dates of the maximum delta are not listed in a table.

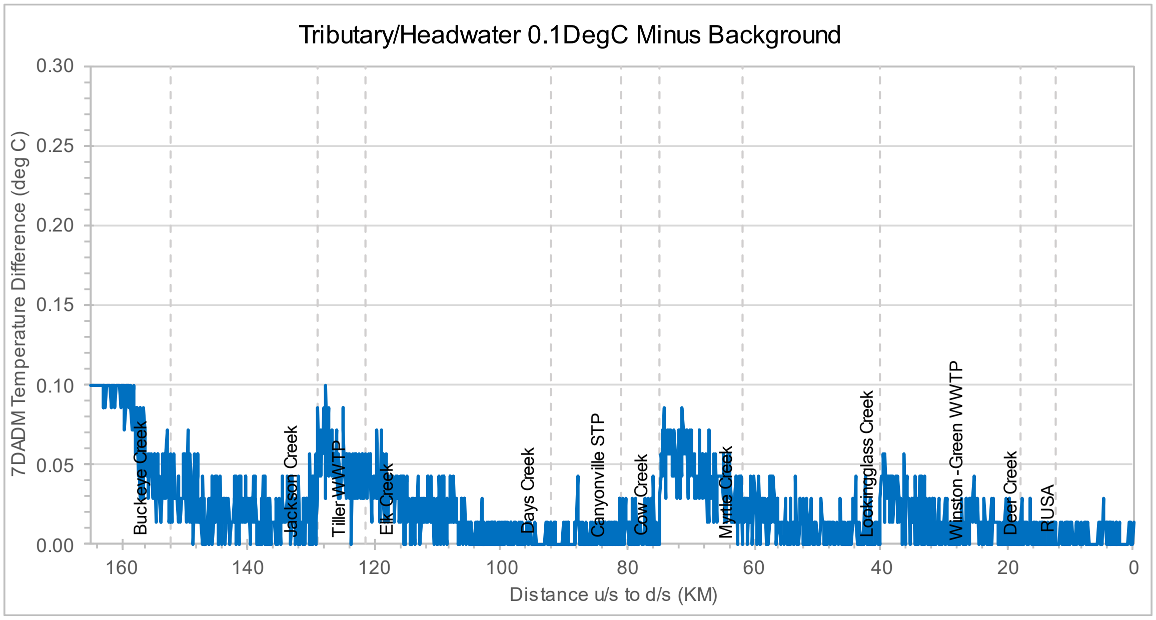


Figure 7-19. The maximum 7DADM temperature differences between Tributary/Headwater Plus 0.1 ˚C scenario and the Background scenario for the South Umpqua River summer period.

Figure 7-20 shows the results of comparison A4, which is the 7DADM temperature difference between the cumulative effect of the Restored Vegetation with Point Source WLA and Tributary/Headwater plus 0.1 ˚C scenario minus the Background scenario. The difference between these two scenarios is that water temperature from all tributaries and headwater are increased by 0.1 ˚C and point sources use the WLA temperature in the Restored Vegetation with Point Source WLA and Tributary/Headwater plus 0.1 ˚C scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperatures in tributaries and headwater increase by 0.1 ˚C, the temperature in the South Umpqua River may also increase by the full 0.1 ˚C or increase by amounts lower than 0.1 ˚C. The maximum cumulative impact (point sources + tributaries/headwater) is 0.17 °C.

Since there are numerous increases of the maximum delta of 0.1 ˚C for this comparison, locations and dates of the maximum delta are not listed in a table.

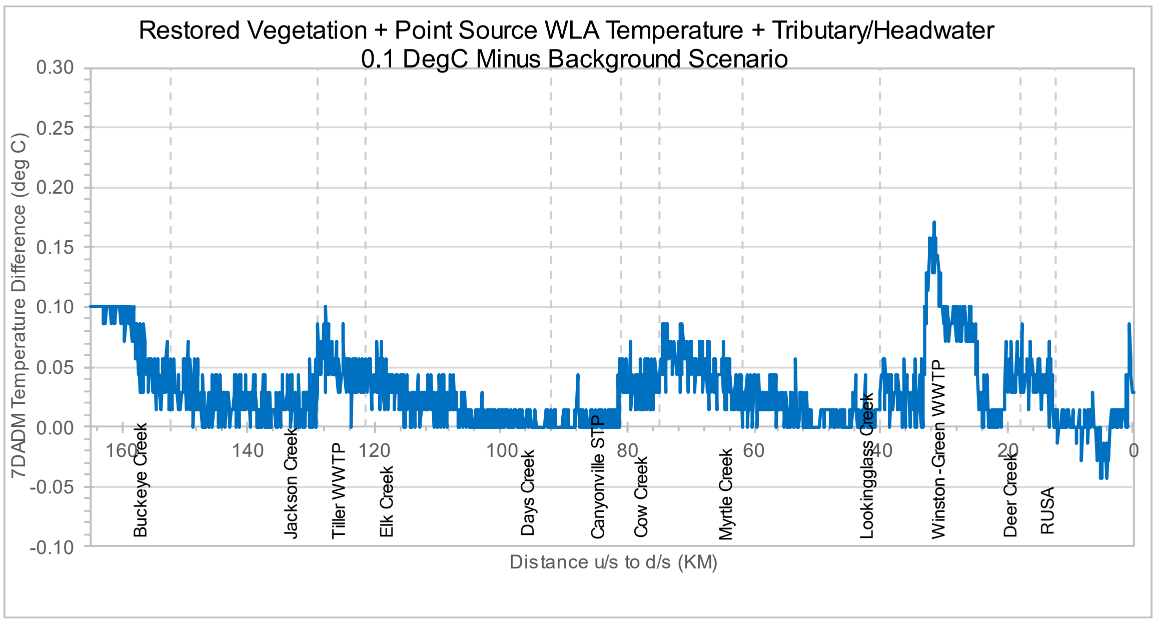


Figure 7-20. The maximum 7DADM temperature differences between the Restored Vegetation with Point Source WLA and Tributary/Headwater Plus 0.1 ˚C scenario and the Background scenario for the South Umpqua River summer period.

7.3 SOUTH UMPQUA RIVER SPAWNING PERIOD SCENARIO RESULTS

The South Umpqua River HS spawning period model includes point sources. The spawning period model simulation period is from September 1 to October 4, 2009. The scenarios that are relevant to the South Umpqua River spawning period include the CCC scenario; the No Point Source scenario; the Point Source WLA scenario; the Fully Restored Vegetation scenario; the Background scenario; the Attainment scenario; the Tributary/Headwater Plus 0.1 °C scenario; and the Fully restored Vegetation with Point Source WLA and Tributary/Headwater Plus 0.1 °C scenario. The 7DADM results of these scenarios are shown in Figure 7-21 through Figure 7-28.

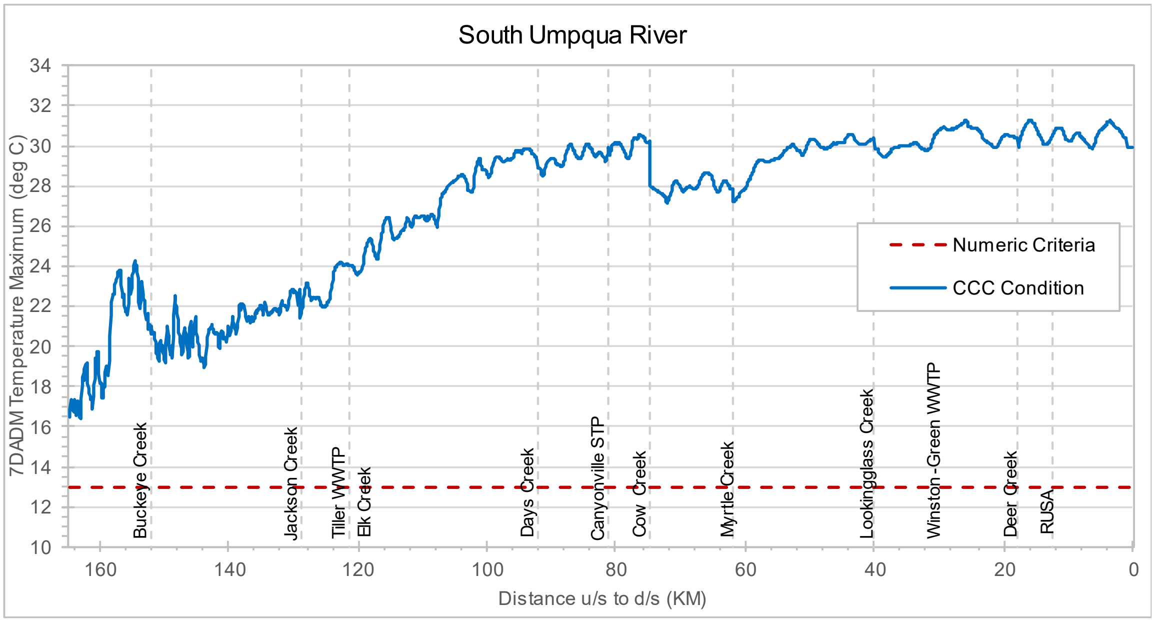


Figure 7-21. The maximum 7DADM temperature results along the South Umpqua River for the spawning period Current Condition scenario.

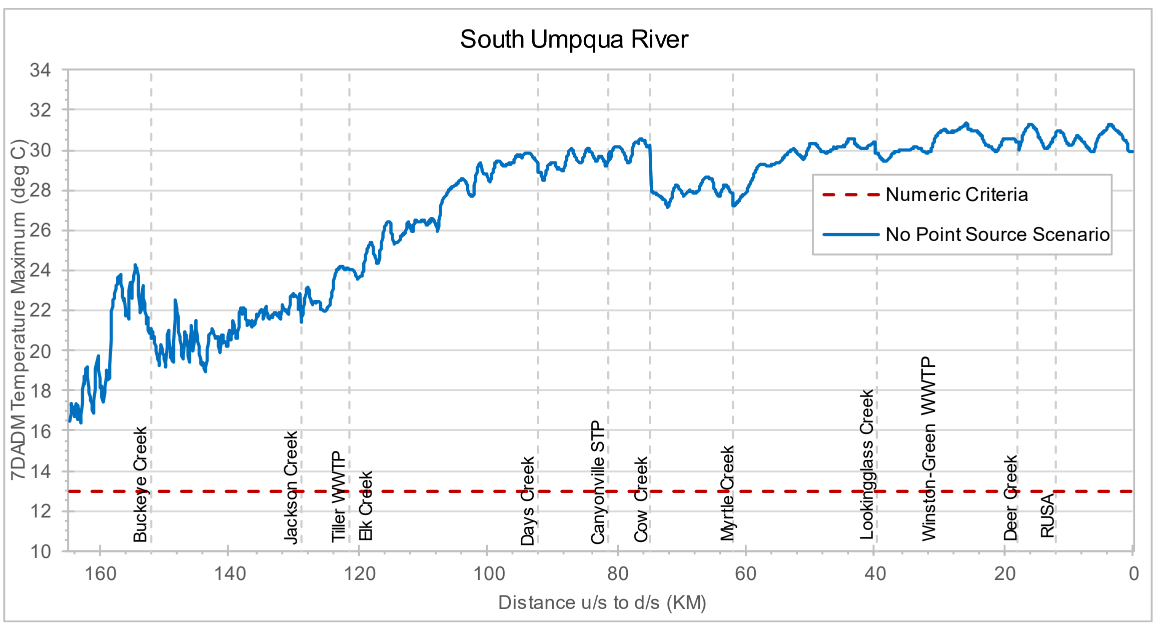


Figure 7-22. The maximum 7DADM temperature results along the South Umpqua River for the spawning period No Point Source scenario.

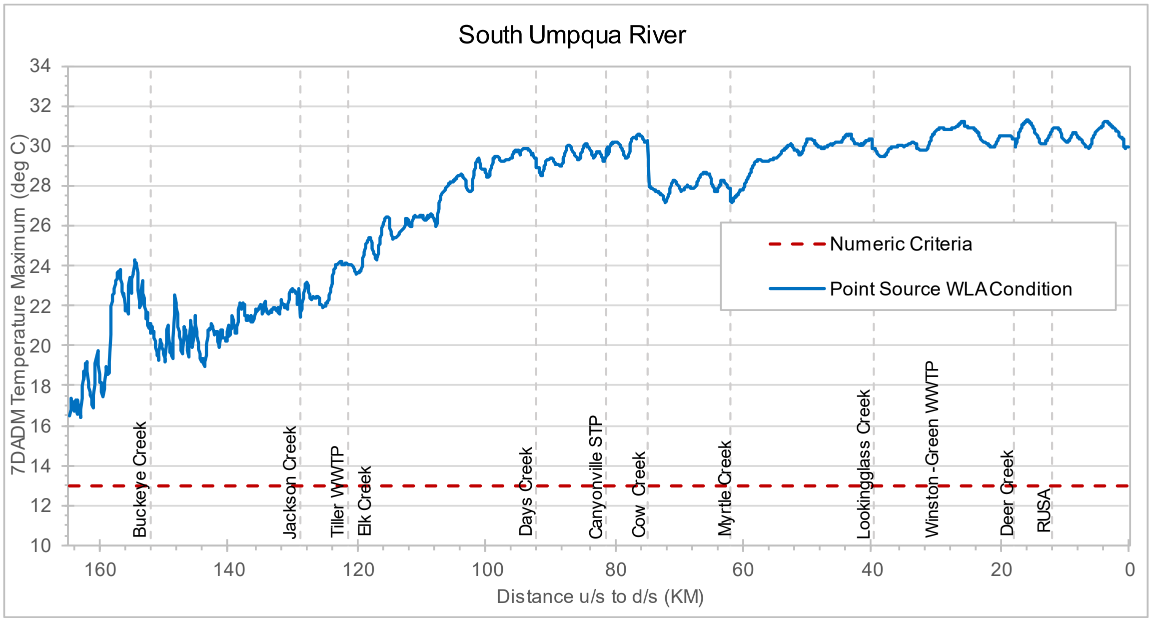


Figure 7-23. The maximum 7DADM temperature results along the South Umpqua River for the spawning period Point Source WLA Conditions scenario.

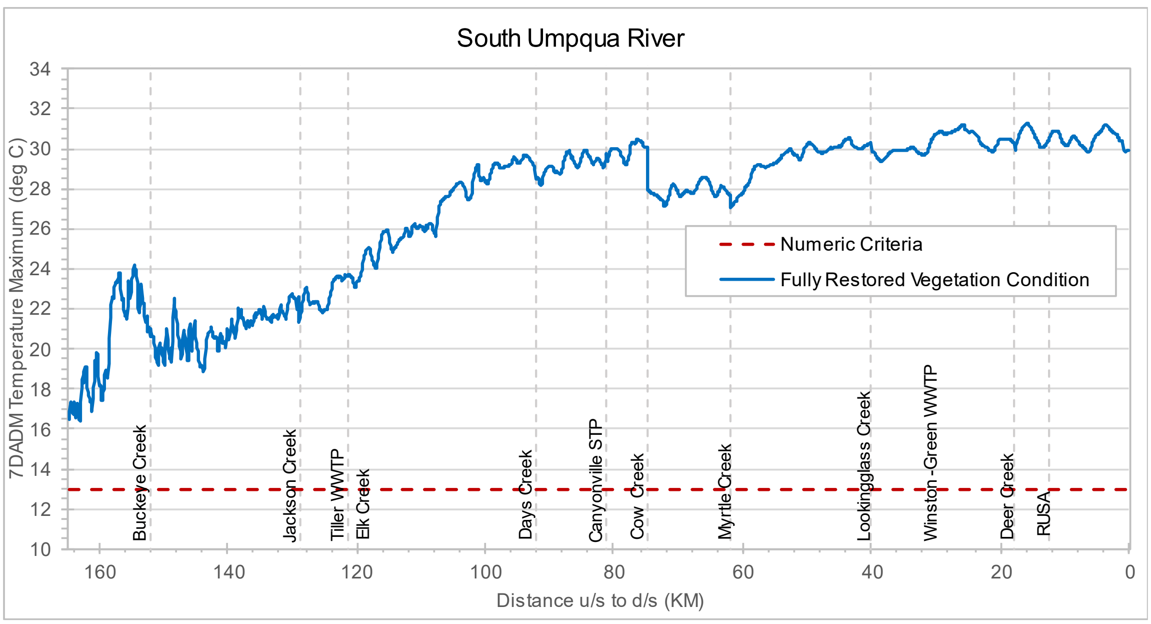


Figure 7-24. The maximum 7DADM temperature results along the South Umpqua River for the spawning period Fully Restored Vegetation scenario.

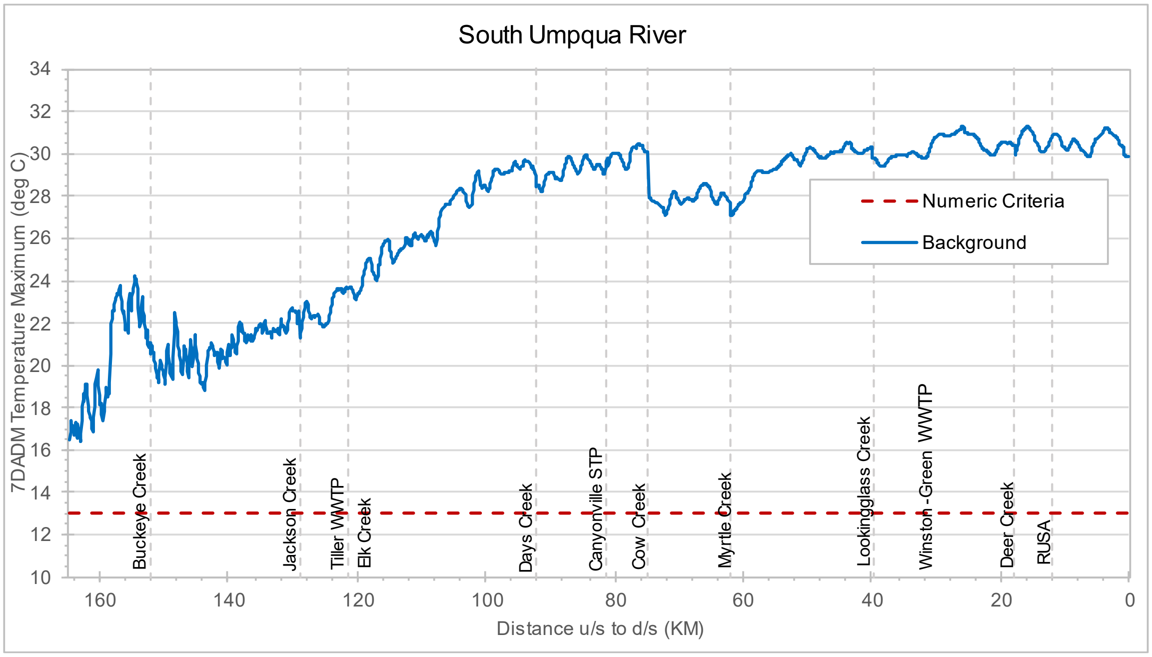


Figure 7-25. The maximum 7DADM temperature results along the South Umpqua River for the spawning period Background scenario.

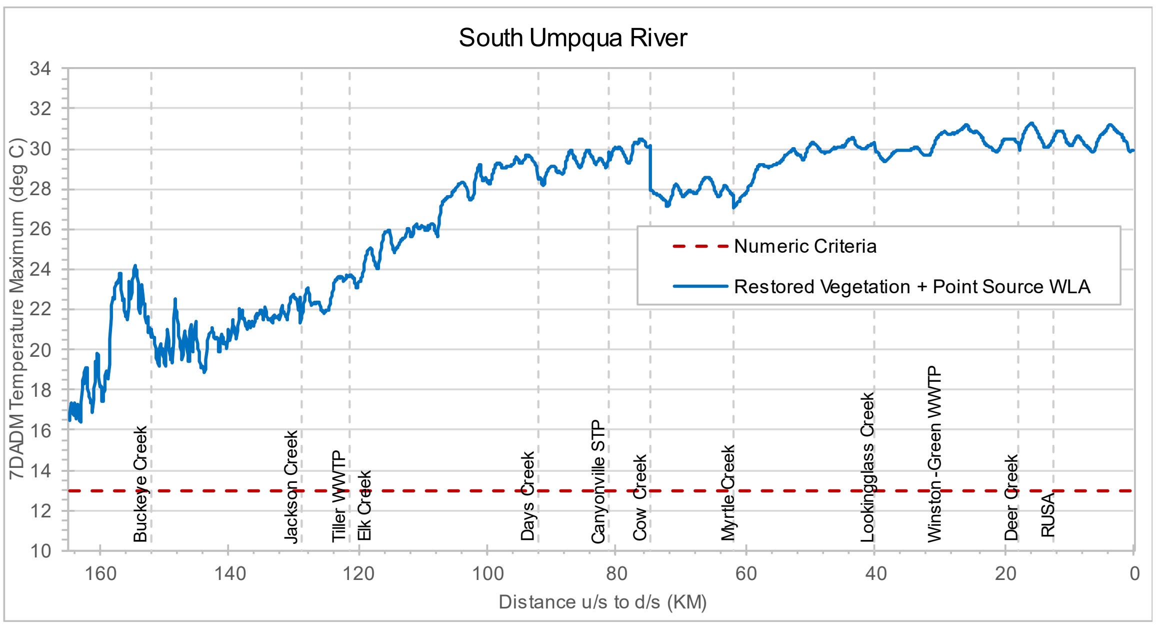


Figure 7-26. The maximum 7DADM temperature results along the South Umpqua River for the spawning period Attainment scenario.

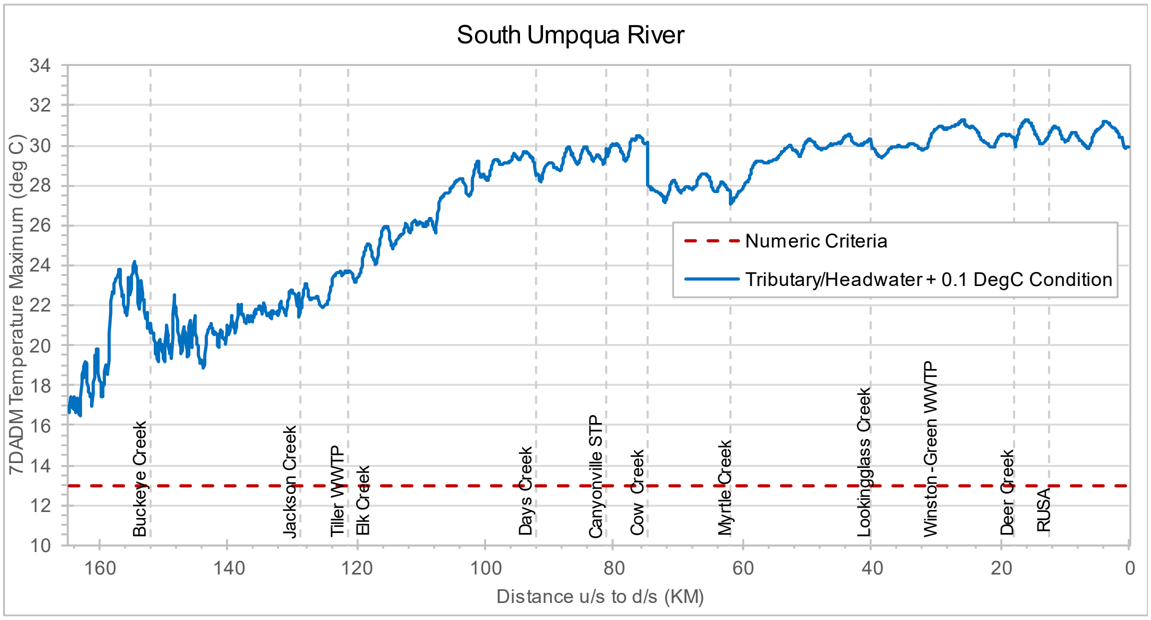


Figure 7-27. The maximum 7DADM temperature results along South Umpqua River for the spawning period Tributary/Headwater Plus 0.1 °C scenario.

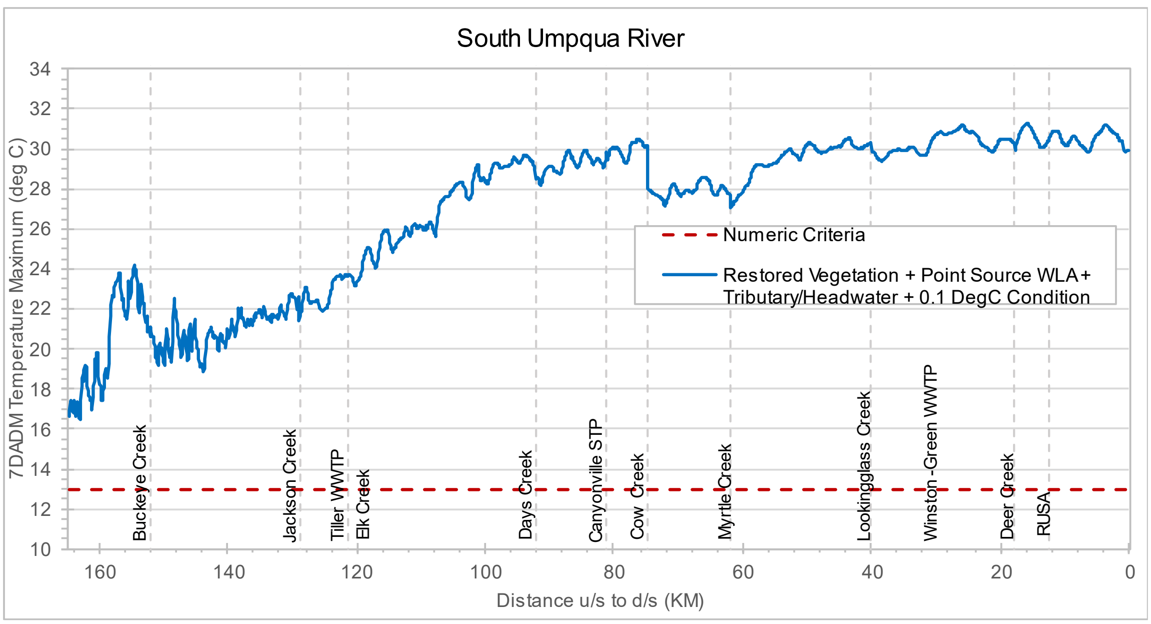


Figure 7-28. The maximum 7DADM temperature results along the South Umpqua River for the spawning period Fully Restored Vegetation with Point Source WLA and Tributary/Headwater Plus 0.1 °C scenario.

7.4 SOUTH UMPQUA RIVER SPAWNING PERIOD SCENARIO COMPARISONS

Comparisons between spawning period scenarios include:

1. Impacts of current condition vegetation (shade loss)
   - ✓ No Point Source minus background
2. Impact of current point source and current vegetation (shade loss)
   - ✓ CCC minus background
3. Impact from point source @ current condition

- ✓ CCC minus no point source

4. Impact from point sources @ WLA conditions
   - ✓ Point Source WLA minus No point source
5. Impact current point source and restored vegetation
   - ✓ Fully restored veg with point source @ current condition minus background
6. Impact point source @ WLA and restored vegetation
   - ✓ Fully restored veg with point source @ WLA minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

A2. Tributary + 0.1ºC scenarios

A4. Cumulative

- ✓ Restored veg + point source WLA + tributaries 0.1 °C minus background.

Figure 7-29 shows the results of comparison 1, the impacts of shade loss, which is the 7DADM temperature difference between the No Point Source scenario and Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 1.85 ˚C at river kilometer 123.8 on 9/27/2009 (Table 7-9).

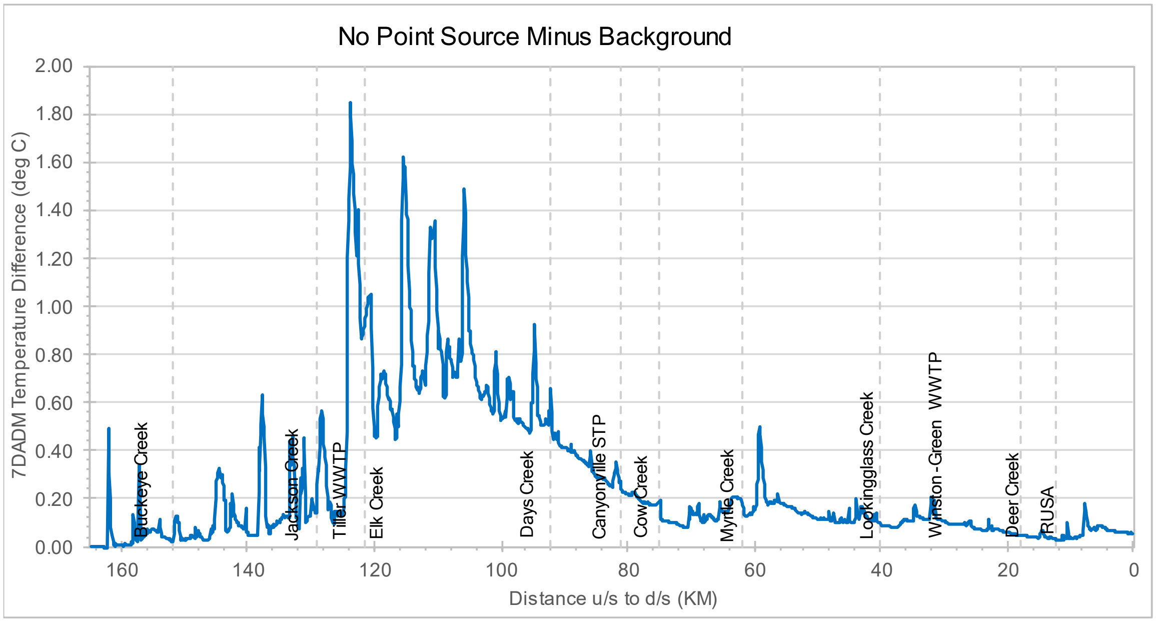


Figure 7-29. The maximum 7DADM temperature differences along the South Umpqua River spawning period for the impacts of shade loss.

Table 7-9. Location and date of maximum delta when temperatures are greater than criterion for comparison 1

Maximum Delta	1.85
RKM	123.8
Date	9/27/2009

Figure 7-30 shows the results of comparison 2, the impacts of current point sources and shade loss, which is the 7DADM temperature difference between the CCC scenario and Background scenario. The differences between these two scenarios are the vegetation conditions, where the CCC scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition and the point source conditions where the CCC scenario uses the latest available flow and temperature from the point sources, while the Background scenario does not include point sources. The maximum delta reaches 1.846 ˚C at river kilometer 123.8 on 9/27/2009 (Table 7-10).

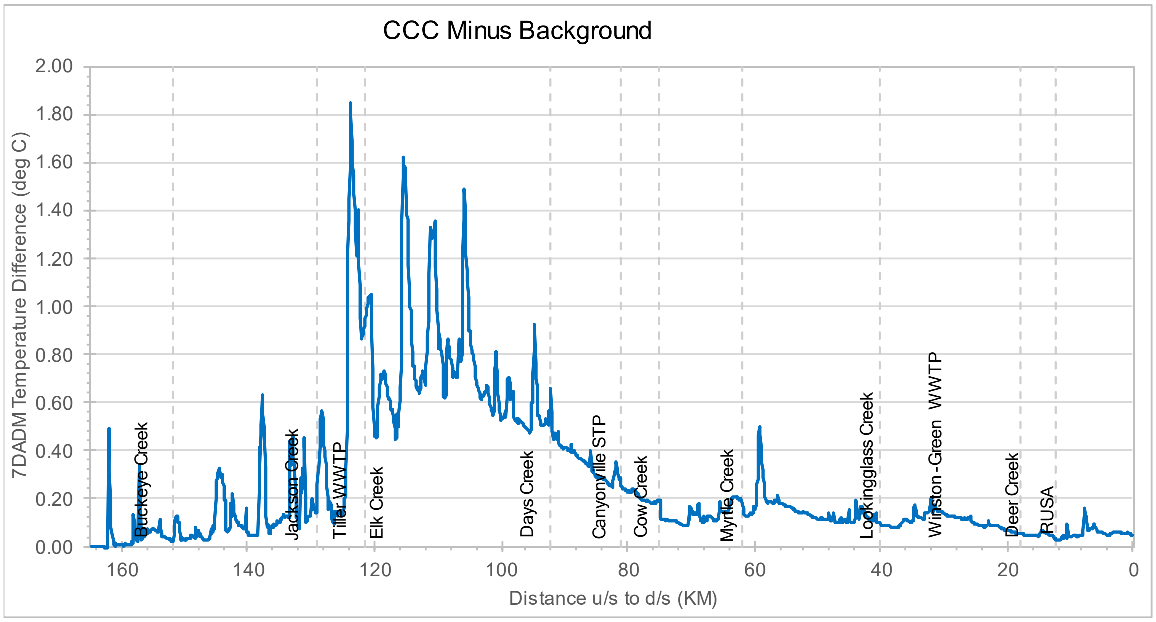


Figure 7-30. The maximum 7DADM temperature differences along the South Umpqua River spawning period for the impacts of current point source and shade loss.

Table 7-10. Location and date of maximum delta when temperatures are greater than criterion for comparison 2

Maximum Delta	1.846
RKM	123.8
Date	9/27/2009

Figure 7-31 shows the results of comparison 3, the impacts of current point sources, which is the 7DADM temperature difference between the CCC scenario and No Point Source scenario. The difference between these two scenarios is the CCC scenario uses the latest available flow and temperature from the point sources, while the No Point Source scenario does not include point sources. The maximum delta reaches 0.05 ˚C at river kilometer 31.8 on 10/3/2009 (Table 7-3).

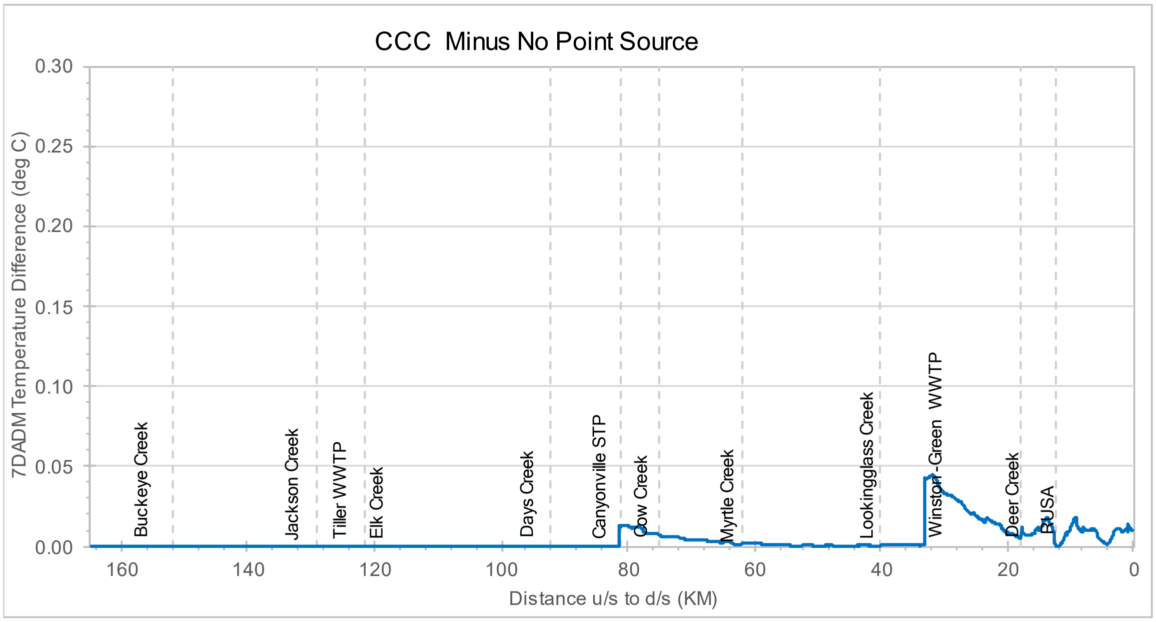


Figure 7-31. The maximum 7DADM temperature differences along the South Umpqua River spawning period for the impacts of point sources at the current condition.

Table 7-11. Location and date of maximum delta when temperatures are greater than criterion for comparison 3

Maximum Delta	0.05
RKM	31.8
Date	10/3/2009

Figure 7-32 shows the results of comparison 4, the impact from point sources at WLA conditions, which is the 7DADM temperature difference between the Point Source WLA scenario and No Point Source scenario. The difference between these two scenarios is the Point Source WLA scenario uses the calculated WLA temperatures, while the No Point Source scenario does not include point sources. The maximum delta reaches 0.16 ˚C at river kilometer 32.5 on 10/212009 (Table 7-12).

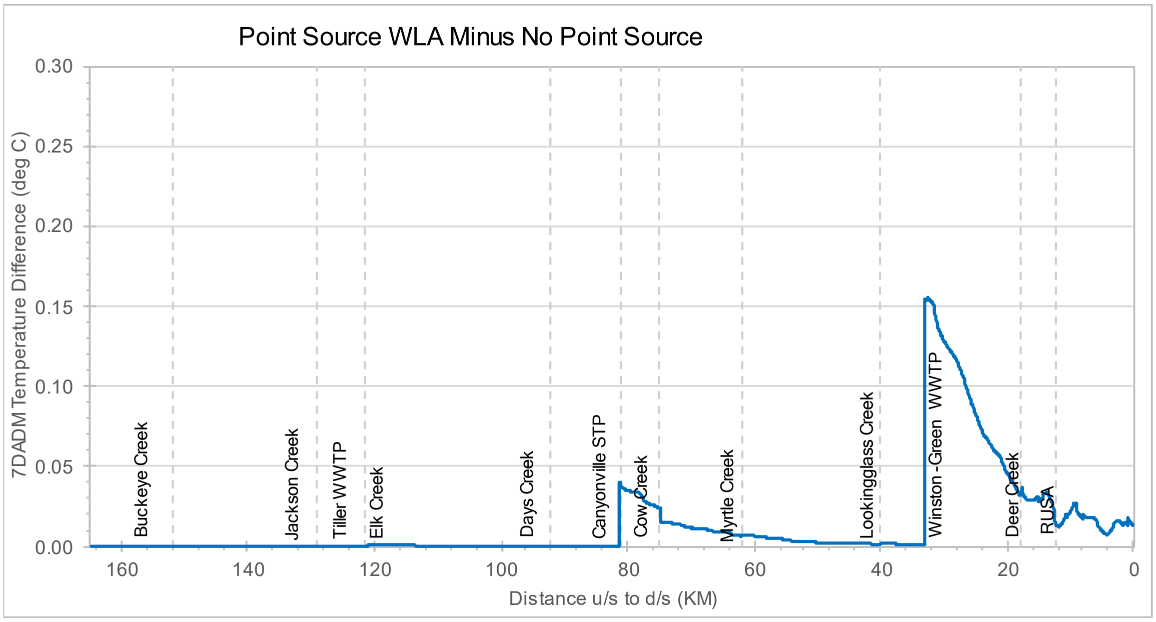


Figure 7-32. The maximum 7DADM temperature differences along the South Umpqua River spawning period for the impacts of point sources at the WLA temperatures.

Table 7-12. Location and date of maximum delta when temperatures are greater than criterion for comparison 4

Maximum Delta	0.16
RKM	32.5
Date	10/2/2009

Figure 7-33 shows the results of comparison 5, the impact from current point sources and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario at current conditions and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation scenario includes point sources at the current conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. The maximum delta reaches 0.05 ˚C at river kilometers 32.9, 32.5, and 32.4 on 10/3/2009, 10/4/2009, and 10/5/2009, respectively (Table 7-13).

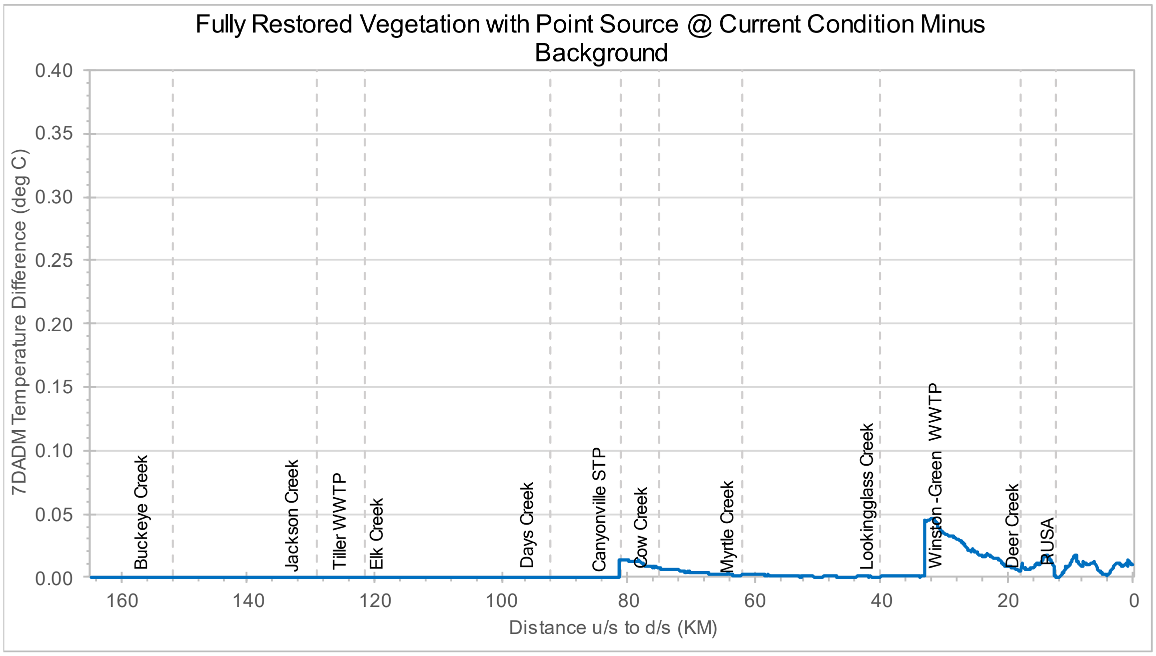


Figure 7-33. The maximum 7DADM temperature differences along the South Umpqua River spawning period for the impacts of current point sources with restored vegetation.

Table 7-13. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 5

Maximum Delta	0.05	0.05	0.05
RKM	32.9	32.5	32.4
Date	10/3/2009	10/4/2009	10/5/2009

Figure 7-34 shows the results of comparison 6, the impact from point sources at the WLA and restored vegetation, which is the 7DADM temperature difference between fully restored vegetation scenario with WLAs (attainment scenario) and the background scenario. The difference between these two scenarios is the Fully Restored Vegetation with point source WLA scenario includes point sources at the WLA conditions, while the Background scenario uses the fully restored vegetation conditions but does not include point sources. The maximum delta reaches 0.16 ˚C at multiple river kilometers on 10/2/2009 (Table 7-14).

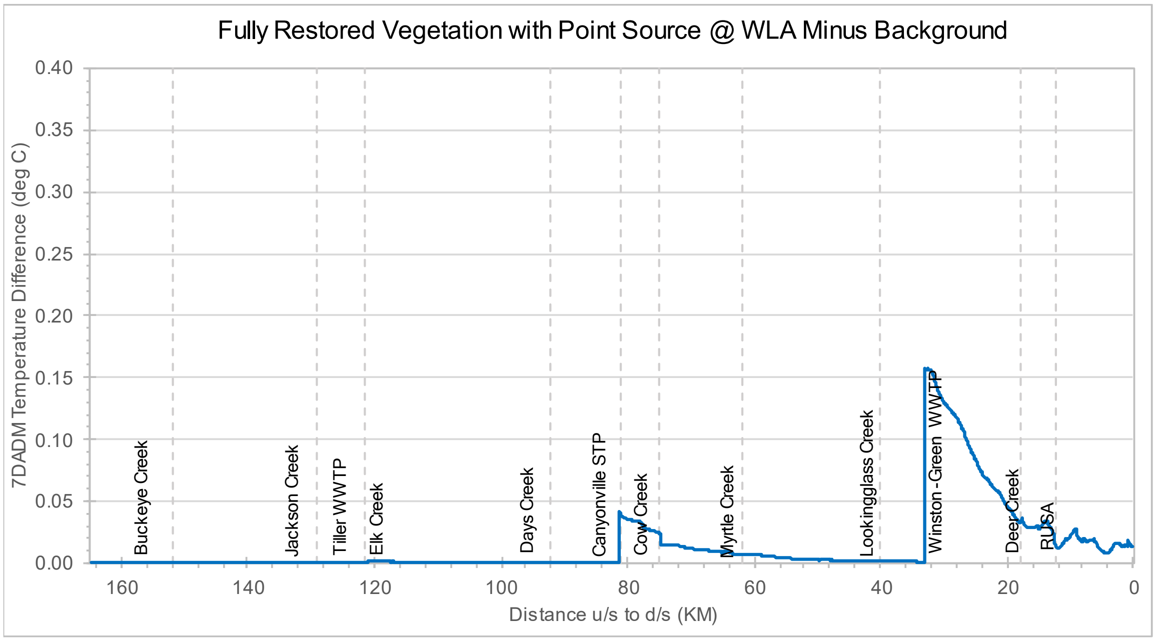


Figure 7-34. The maximum 7DADM temperature differences along the South Umpqua River spawning period for the impacts of point sources at the WLA temperatures and fully restored vegetation conditions.

Table 7-14. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 6

Maximum Delta	0.16	0.16	0.16	0.16
RKM	32.9	32.6	32.5	32.4
Date	10/2/2009	10/2/2009	10/2/2009	10/2/2009

Figure 7-35 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 18.28 ˚C at river kilometer 15.7 on 9/1/2009 (Table 7-15).

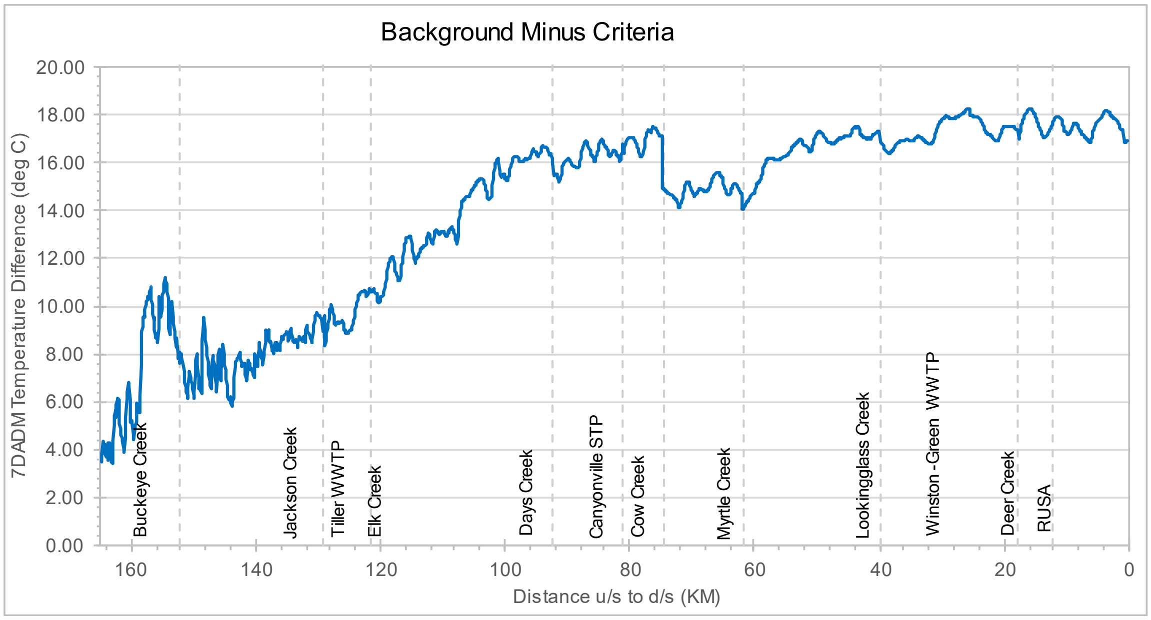


Figure 7-35. The maximum 7DADM temperature differences along the South Umpqua River spawning period for the difference between background conditions and criteria temperatures.

Table 7-15. Location and date of maximum delta when temperatures are greater than criterion for comparison 7

Maximum Delta	18.28
RKM	15.7
Date	9/1/2009

Figure 7-36 shows the results of comparison A2, which is the 7DADM temperature difference between the Tributary/Headwater plus 0.1 ˚C scenario and the Background scenario. The only difference between these two scenarios is that water temperature from all tributaries and headwater are increased by 0.1 ˚C in the Tributary/Headwater plus 0.1 ˚C scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperatures in tributaries and headwater increase by 0.1 ˚C, the temperature in the South Umpqua River may also increase by the full 0.1 ˚C or increase by amounts lower than 0.1 ˚C. The maximum delta is 0.1 ˚C and the location of the maximum delta occurs at the headwater location, which is river RKM 164.7. The maximum delta occurs for the entire September (Table 7-16).

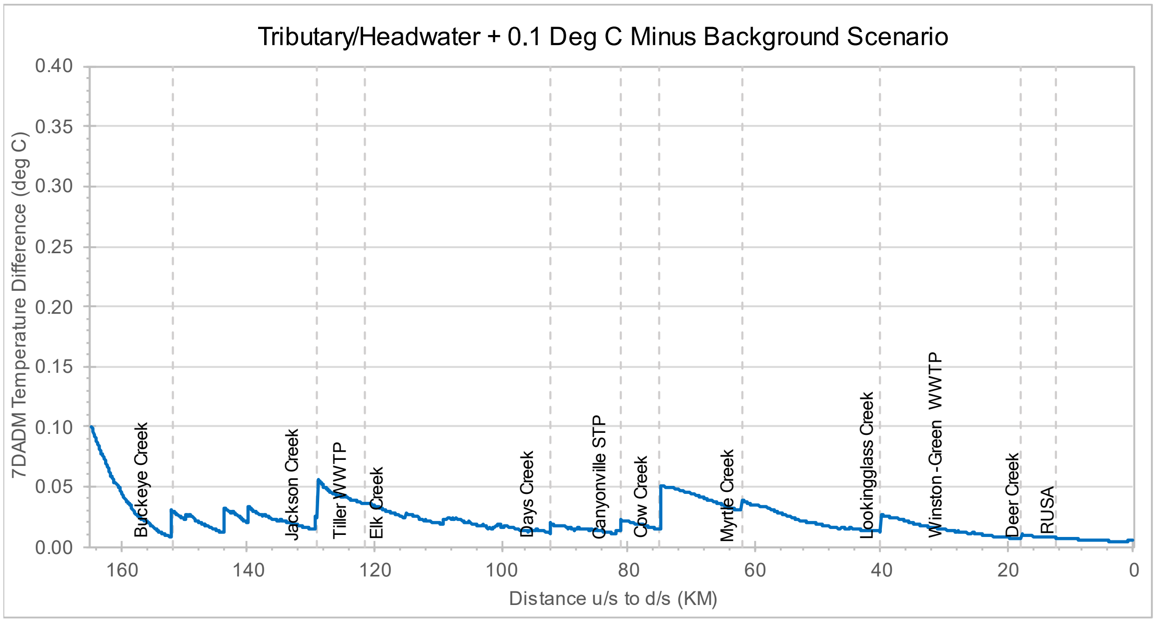


Figure 7-36. The maximum 7DADM temperature differences between Tributary/Headwater Plus 0.1 ˚C scenario and the Background scenario for the South Umpqua River spawning period.

Table 7-16. Location and dates of maximum delta when temperatures are greater than criterion for comparison A2

Maximum Delta	0.10
RKM	164.7
Date	9/1/2009 to 9/30/2009

Figure 7-37 shows the results of comparison A4, which is the 7DADM temperature difference between the cumulative effect of the Restored Vegetation with Point Source WLA and Tributary/Headwater plus 0.1 ˚C scenario minus the Background scenario. The difference between these two scenarios is that water temperature from all tributaries and headwater are increased by 0.1 ˚C and the point sources use the WLA temperatures in the Restored Vegetation with Point Source WLA and Tributary/Headwater plus 0.1 ˚C scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperatures in tributaries and headwater increase by 0.1 ˚C, the temperature in the South Umpqua River may also increase by the full 0.1 ˚C or increase by amounts lower than 0.1 ˚C. The maximum cumulative impact (point sources + tributaries/headwater) is 0.17 °C (Table 7-17).

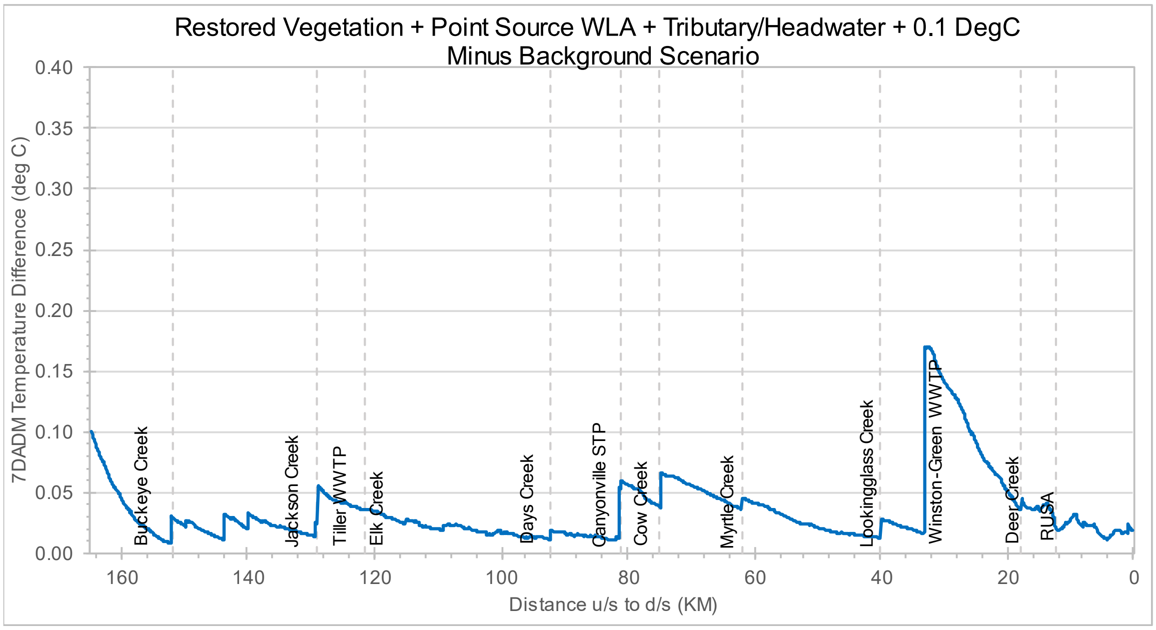


Figure 7-37. The maximum 7DADM temperature differences between the Restored Vegetation with Point Source WLA and Tributary/Headwater Plus 0.1 ˚C scenario and the Background scenario for the South Umpqua River spawning period.

Table 7-17. Location and date of maximum delta when temperatures are greater than criterion for comparison A4

Maximum Delta	0.17
RKM	32.5
Date	10/2/2009

8.0 CALAPOOYA CREEK

Calapooya Creek is a tributary to the Umpqua River below the North Umpqua River (Figure 8-1).

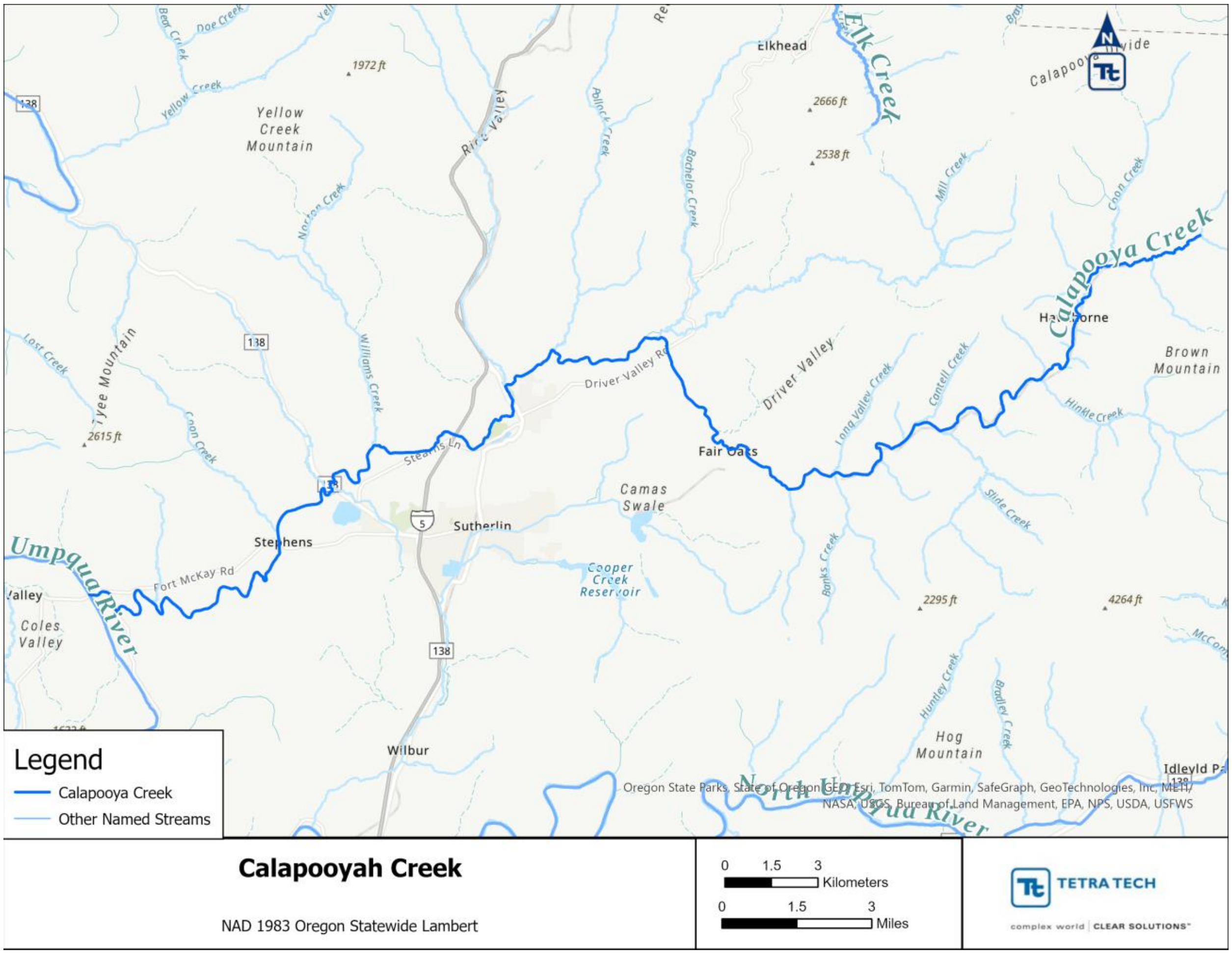


Figure 8-1. Location of Calapooya Creek.

8.1 CALAPOOYAH CREEK SCENARIO RESULTS

The Calapooya Creek HS model does not include any point sources. The model simulation period is July 12 to July 31. 2002. The scenarios that are relevant to Calapooya Creek include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; the Fully Restored Vegetation with Natural Flow scenario; and the tributary/headwater plus 0.1 ºC scenario. The 7DADM results of these scenarios are shown in Figure 8-2 through Figure 8-3.

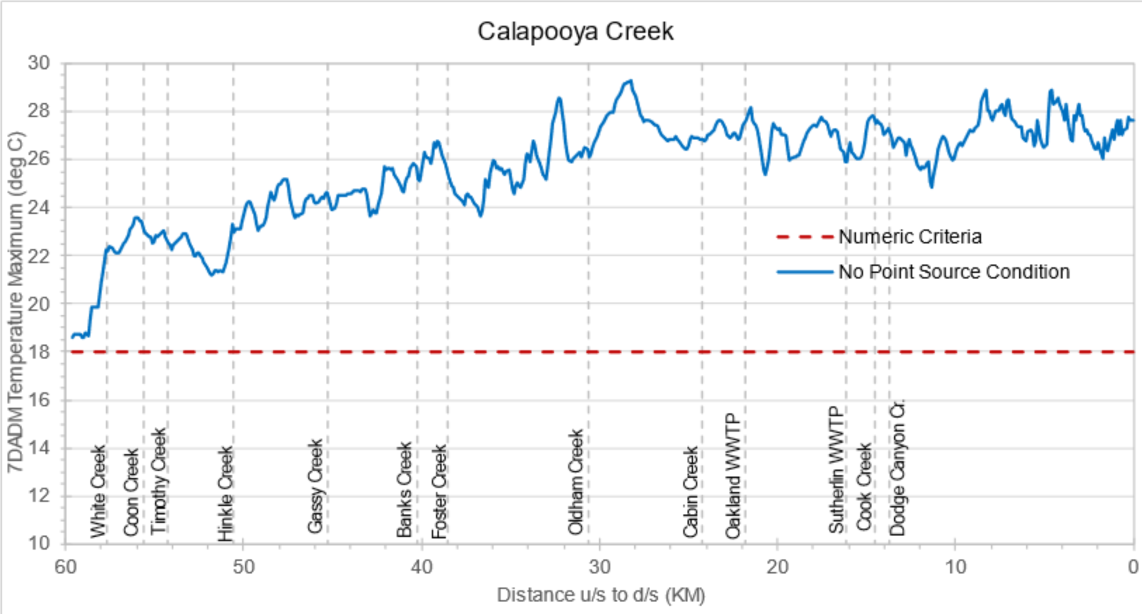


Figure 8-2. The maximum 7DADM temperature results along Calapooya Creek for the No Point Source scenario.

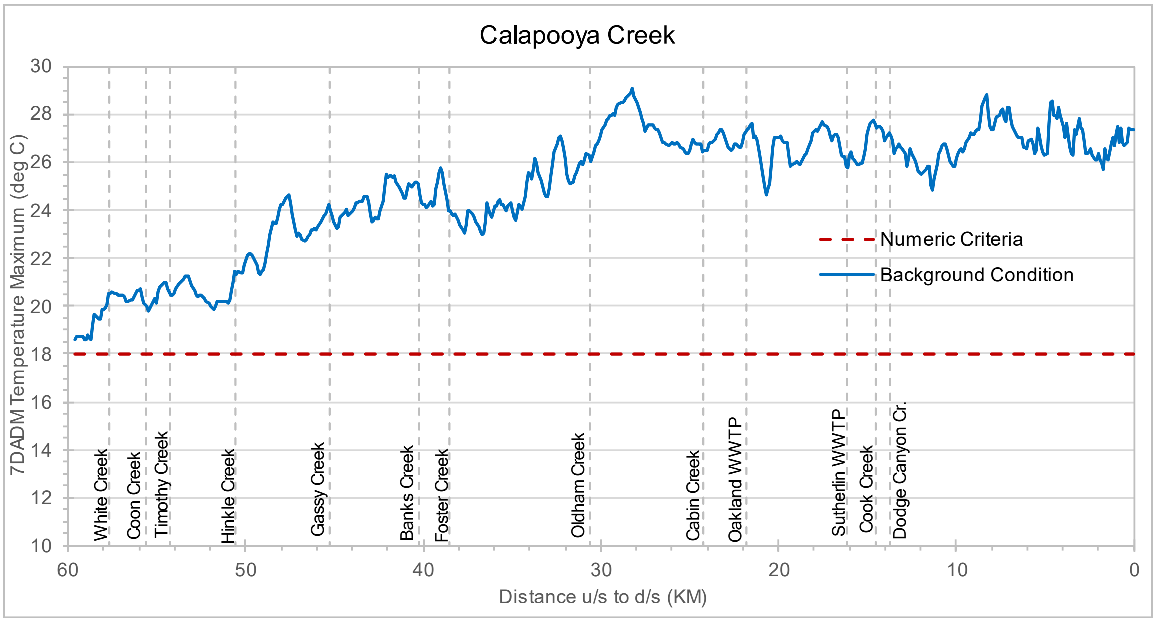


Figure 8-3. The maximum 7DADM temperature results along Calapooya Creek for the Background scenario.

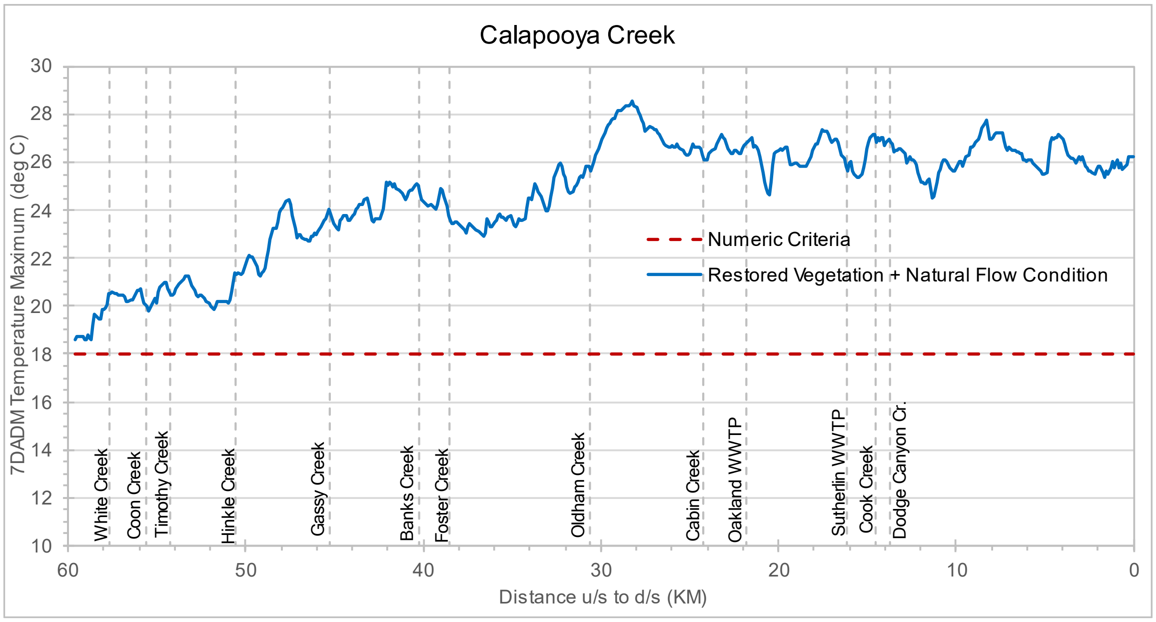


Figure 8-4. The maximum 7DADM temperature results along Calapooya Creek for the Fully Restored Vegetation and Natural Flow scenario.

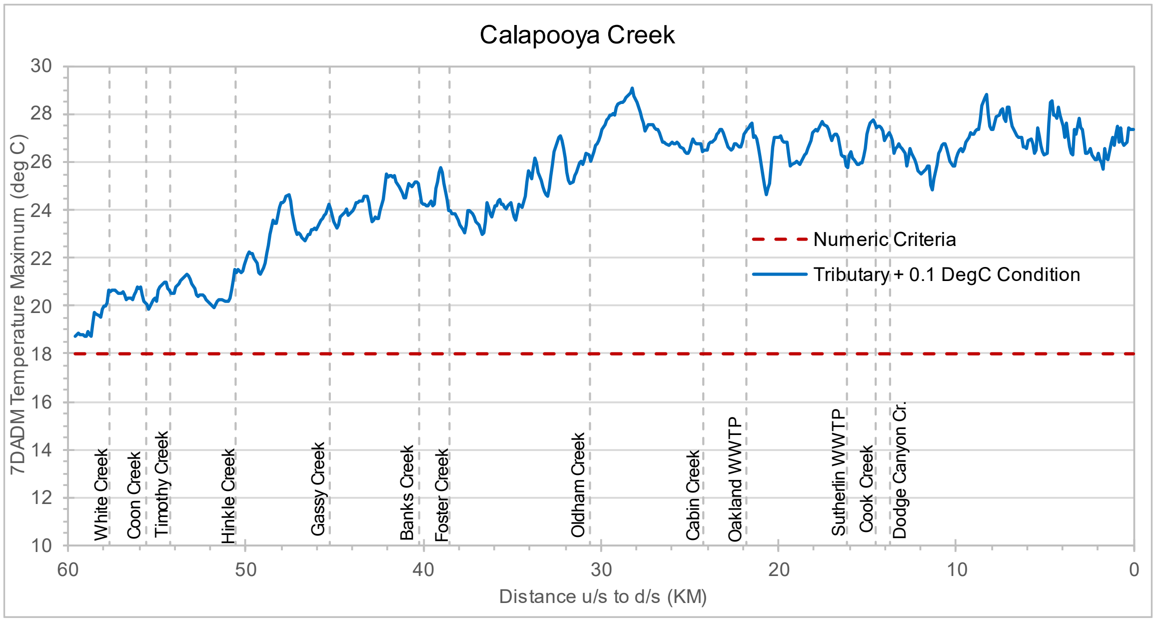


Figure 8-5. The maximum 7DADM temperature results along Calapooya Creek for the Tributary/Headwater Plus 0.1 ˚C scenario.

8.2 CALAPOOYA CREEK SCENARIO COMPARISONS

Comparisons of scenarios for Calapooya Creek include:

1. Impacts of current condition vegetation (shade loss)
   - ✓ No Point Source minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria
9. Natural Flows
   - ✓ Background minus fully restored veg with natural flows

A2. Tributary + 0.1ºC scenarios

Figure 8-6 shows the results of comparison 1, the impacts of shade loss, which is the 7DADM temperature difference between the No Point Source scenario (same as calibration condition for models without point sources) and the Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 3.30 ˚C at river kilometer 55.7 on 7/18/2002 and 7/19/2002 (Table 8-1).

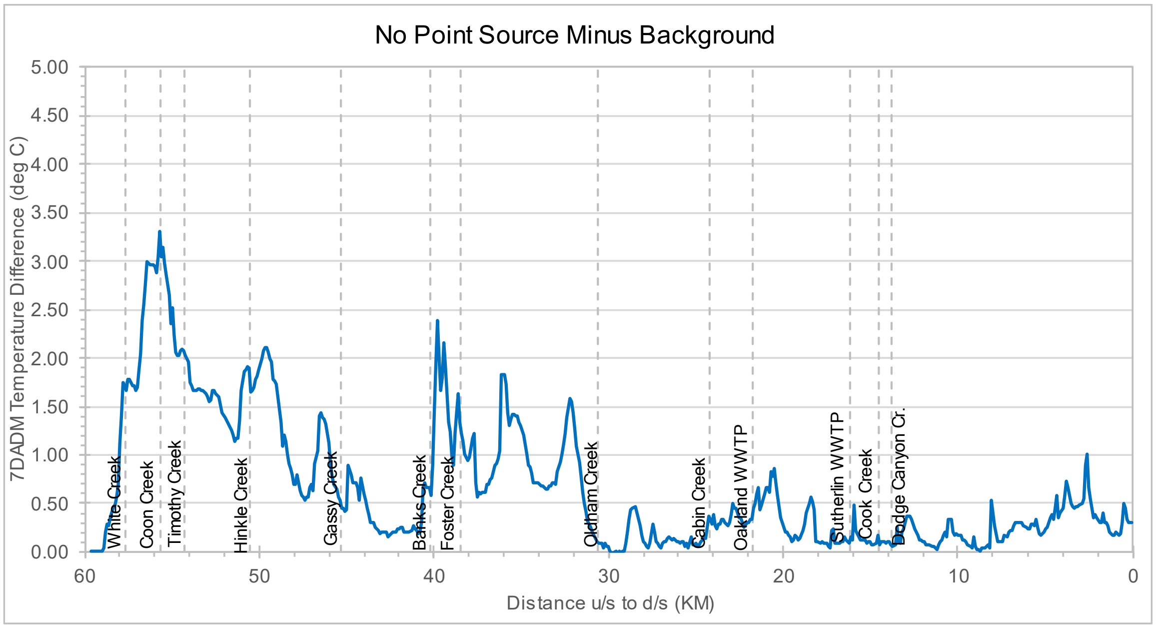


Figure 8-6. The maximum 7DADM temperature differences along Calapooya Creek for the impacts of shade loss.

Table 8-1. Location and dates of maximum delta when temperatures are greater than criterion for comparison 1

Maximum Delta	3.30
RKM	55.7
Date	7/18/2002
	7/19/2002

Figure 8-7 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 11.06 ˚C at river kilometer 28.2 on 7/26/2002 (Table 8-2).

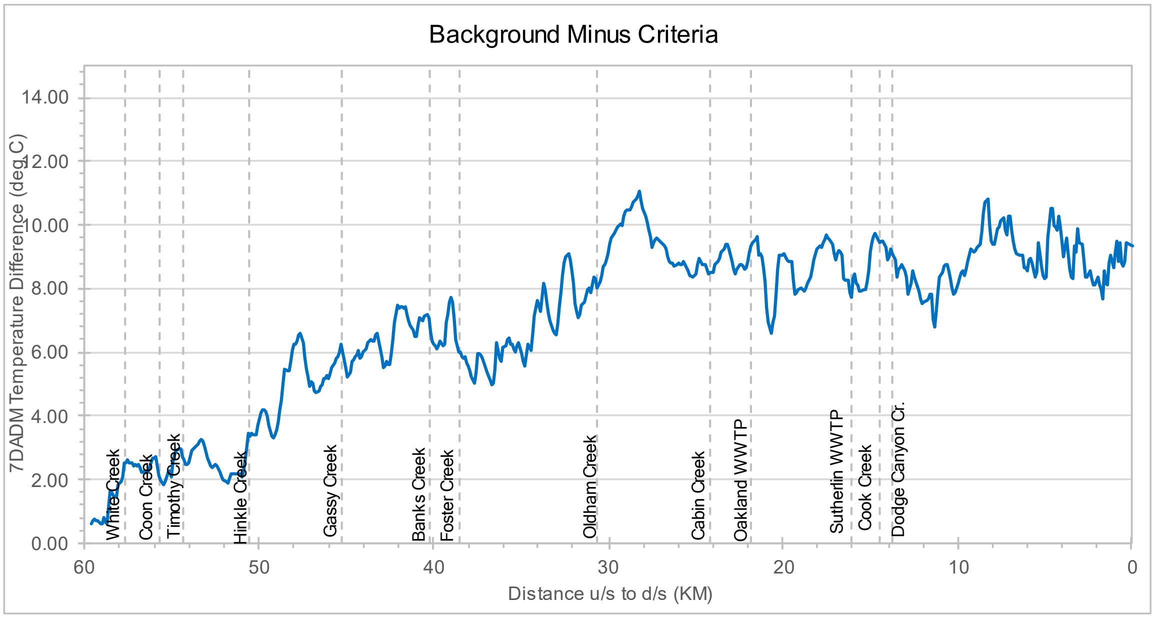


Figure 8-7. The maximum 7DADM temperature differences along Calapooya Creek for the difference between background conditions and criteria temperatures.

Table 8-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7

Maximum Delta	11.06
RKM	28.2
Date	7/26/2002

Figure 8-8 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. The only difference between these two scenarios for Calapooya Creek is that there are no withdrawals in the Restored Vegetation with Natural Flow scenario. All other flows and temperature inputs are the same. The maximum delta reaches 1.76 ˚C at river kilometer 7.1 on multiple dates and -0.36 ˚C at river kilometer 20.7 on 7/30/2002 (Table 8-3).

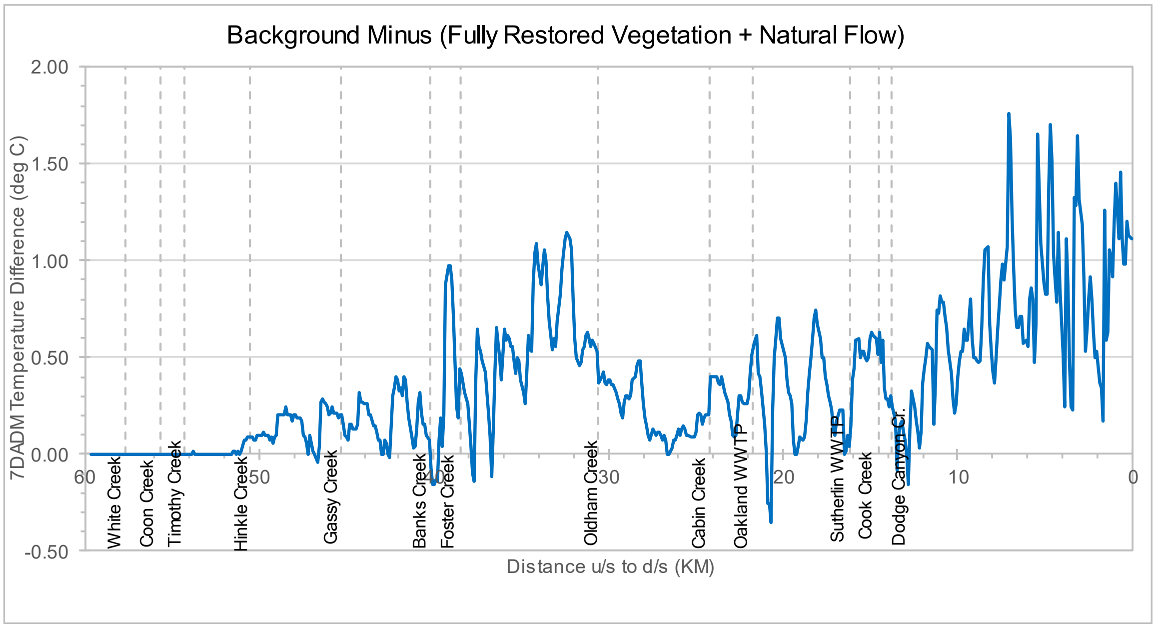


Figure 8-8. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario on Calapooya Creek.

Table 8-3. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 9

Maximum Delta	1.76	-0.36
RKM	7.1	20.7
Date	7/24/2002	7/30/2002
	7/25/2002	
	7/26/2002	

Figure 8-9 shows the results of comparison A2, which is the 7DADM temperature difference between the Tributary/Headwater plus 0.1 ˚C scenario and the Background scenario. The only difference between these two scenarios is that water temperature from all tributaries and headwaters are increased by 0.1 ˚C in the Tributary/Headwater plus 0.1 ˚C scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperatures in tributaries and headwater increase by 0.1 ˚C, the temperature in Calapooya Creek may also increase by the full 0.1 ˚C or increase by amounts lower than 0.1 ˚C. Since there are numerous increases of the maximum delta of 0.1 ˚C for this comparison, locations and dates of the maximum delta are not identified in a table.

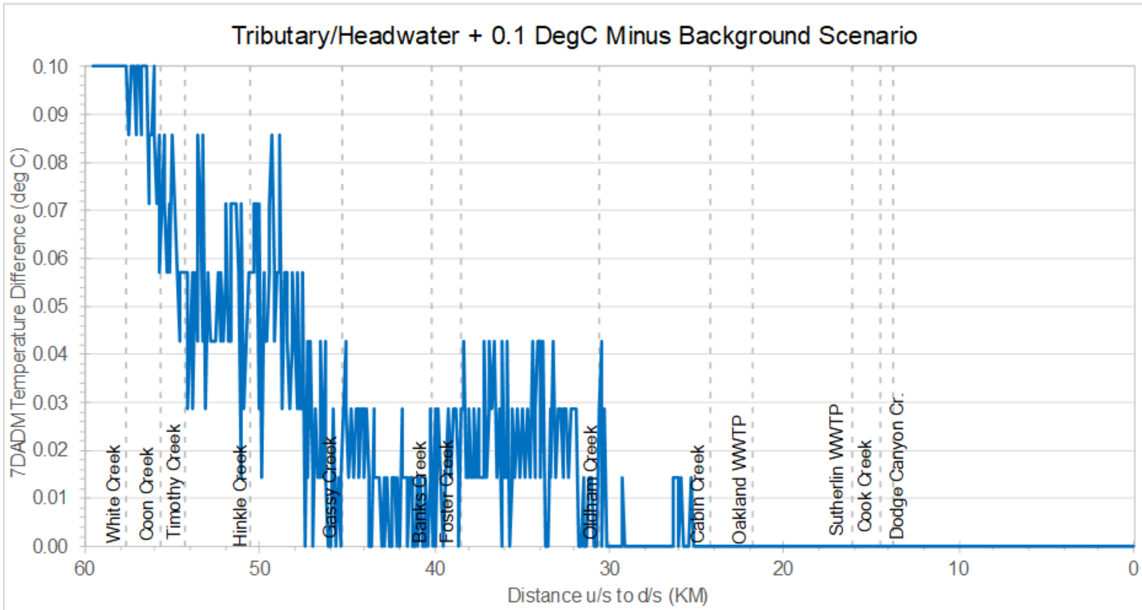


Figure 8-9. The maximum 7DADM temperature differences between Tributary/Headwater Plus 0.1 ˚C scenario and the Background scenario for Calapooya Creek.

9.0 ELK CREEK

Elk Creek is a tributary to the Umpqua River (Figure 9-1).

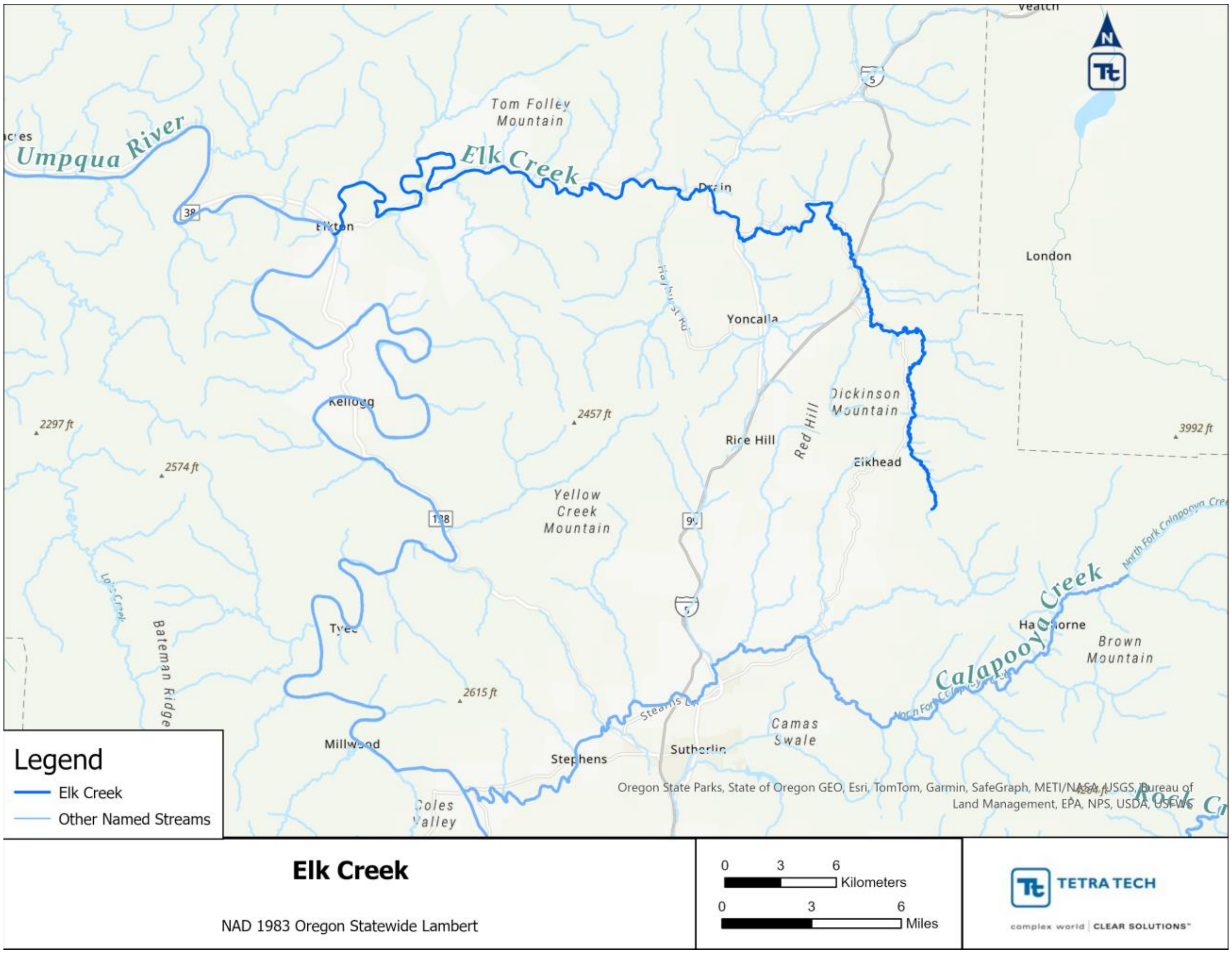


Figure 9-1. Location of Elk Creek.

9.1 ELK CREEK SCENARIO RESULTS

The Elk Creek HS model does not include any point sources. The model simulation period is July 12 to July 31. 2002. There are no withdrawal or other flow modifications in Elk Creek. Therefore, there is no Fully Restored Vegetation with Natural Flow scenario for Elk Creek. The scenarios that are relevant to Elk Creek include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; and the tributary/headwater plus 0.1 ^{o}C scenario. The 7DADM results are shown in Figure 9-2 to Figure 9-4 for these scenarios.

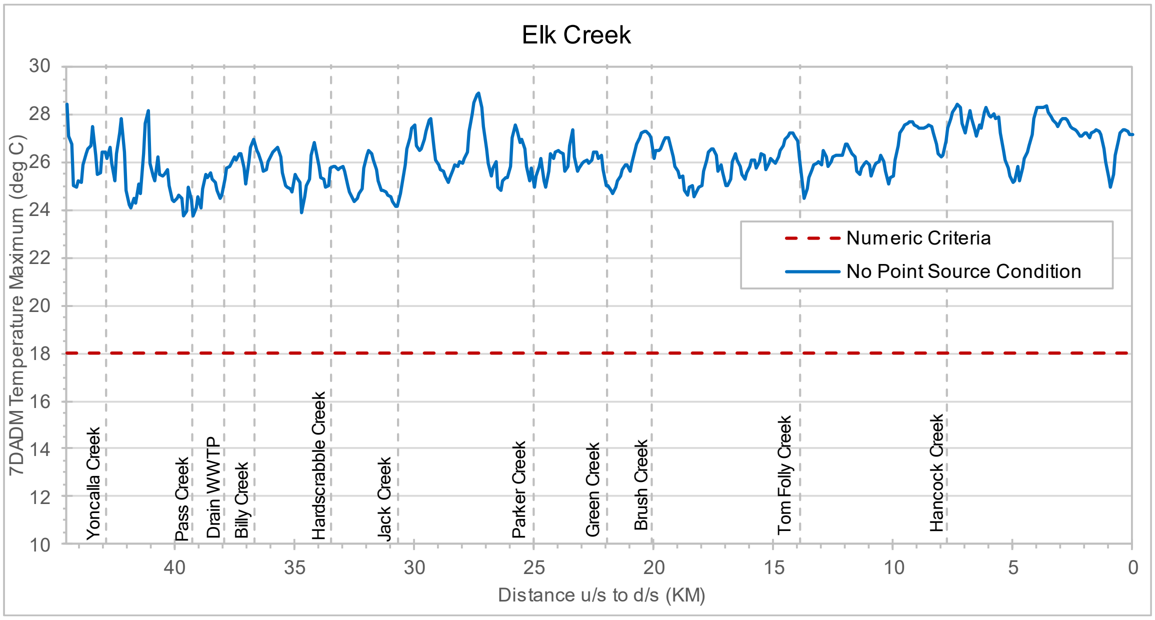


Figure 9-2. The maximum 7DADM temperature results along Elk Creek for the No Point Source scenario.

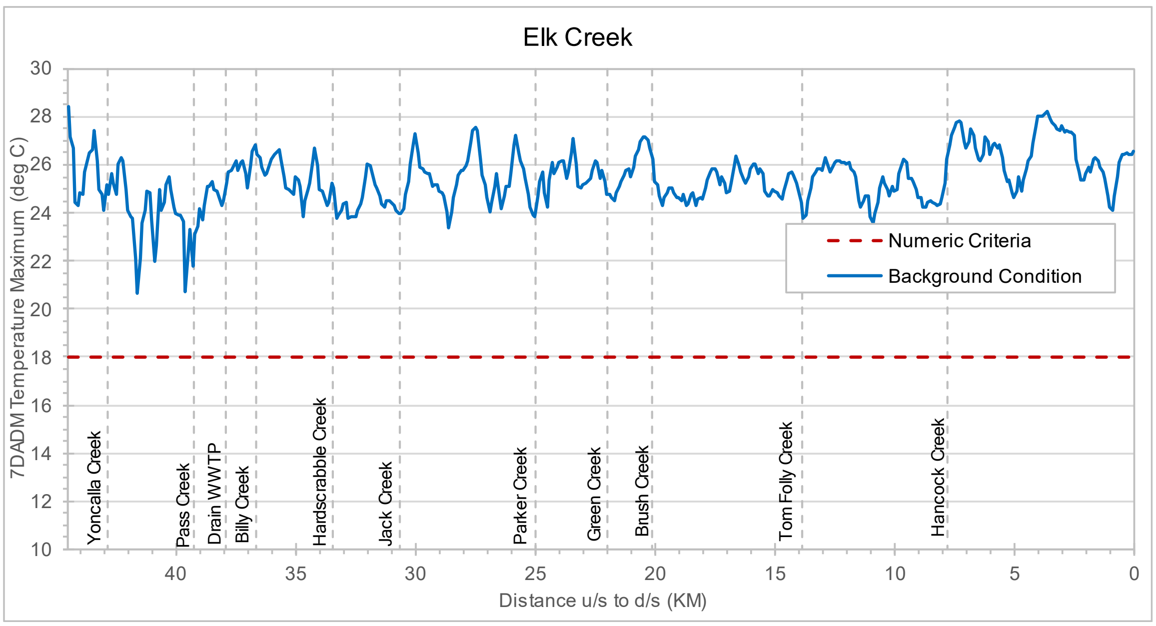


Figure 9-3. The maximum 7DADM temperature results along Elk Creek for the Background scenario.

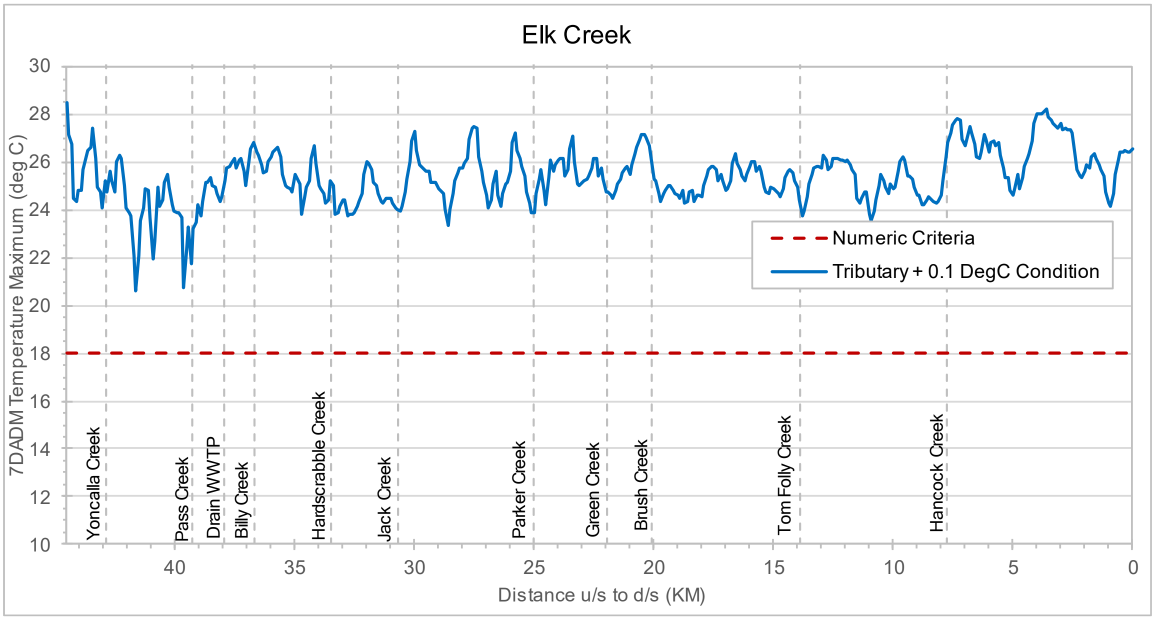


Figure 9-4. The maximum 7DADM temperature results along Elk Creek for the Tributary/Headwater Plus 0.1 ˚C scenario.

9.2 ELK CREEK SCENARIO COMPARISONS

Comparisons of scenarios for Elk Creek include:

1. Impacts of current condition vegetation (shade loss)
   - ✓ No Point Source minus background
7. Difference between background and criteria
   - ✓ Background minus Criteria

A2. Tributary + 0.1ºC scenarios

Figure 9-5 shows the results of comparison 1, which is the 7DADM temperature difference between the No Point Source scenario and Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The overall 7DADM temperature differences increase toward the downstream direction. The maximum delta reaches 3.79 °C at river kilometer 41.6 on 7/24/2002 and 7/25/2002 (Table 9-1).

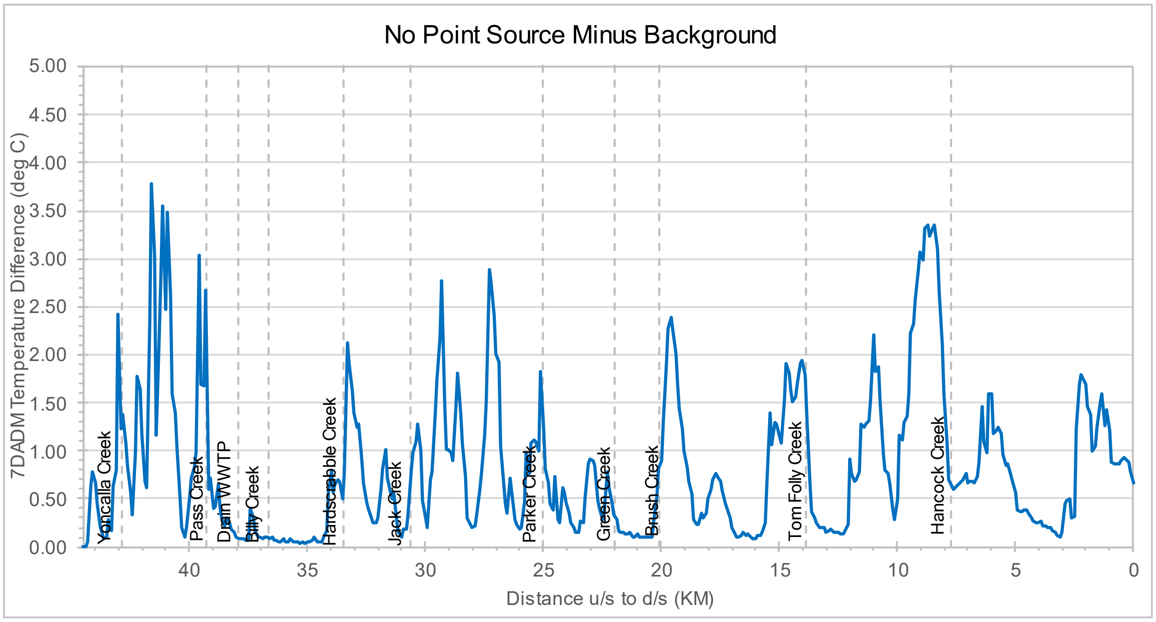


Figure 9-5. The maximum 7DADM temperature differences along Elk Creek for the impacts of shade loss.

Table 9-1. Location and dates of maximum delta when temperatures are greater than criterion for comparison 1

Maximum Delta	3.79
RKM	41.6
Date	7/24/2002
	7/25/2002

Figure 9-6 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 10.43 ^{o}C at river kilometer 44.5 on 7/28/2002 (Table 9-2).

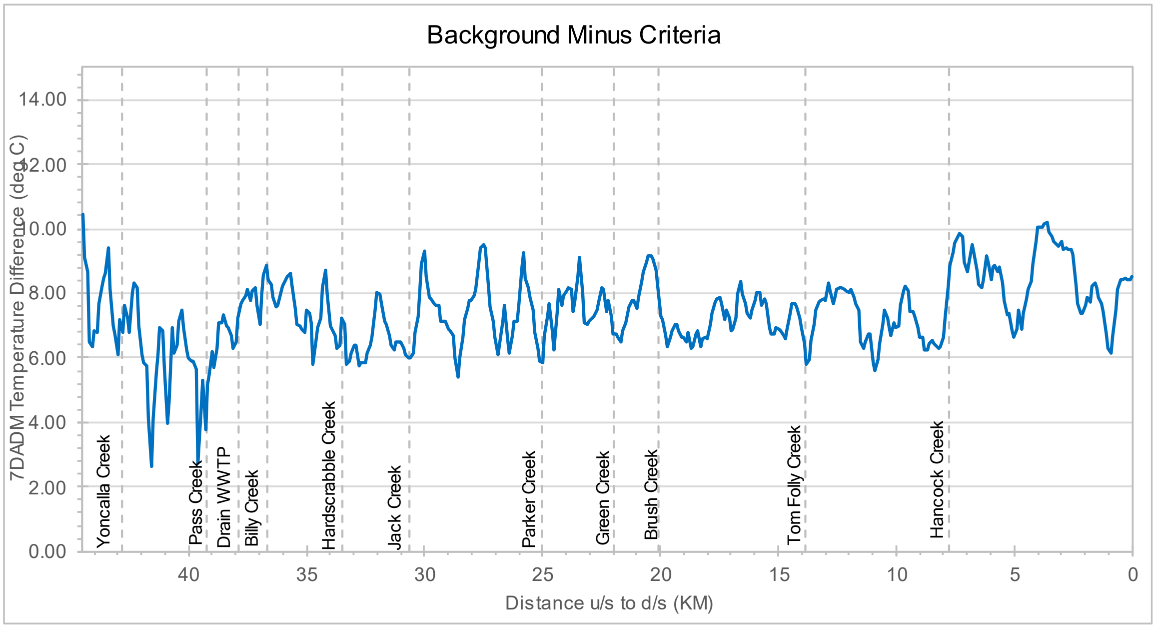


Figure 9-6. The maximum 7DADM temperature differences along Elk Creek for the difference between background conditions and criteria temperatures

Table 9-2. Location and date of maximum delta when temperatures are greater than criterion for comparison 7

Maximum Delta	10.43
RKM	44.5
Date	7/28/2002

Figure 9-7 shows the results of comparison A2, which is the 7DADM temperature difference between the Tributary/Headwater plus 0.1 ºC scenario and the Background scenario. The only difference between these two scenarios is that water temperature from all tributaries and headwater are increased by 0.1 ºC in the Tributary/Headwater plus 0.1 ºC scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperature in tributaries and headwater increase by 0.1 ºC, temperature in Elk Creek may also increase by 0.1 ºC or lower than 0.1 ºC. Since there are a lot of increase at 0.1 ºC for this comparison, locations and dates of the maximum delta which is 0.1 ºC are not identified.

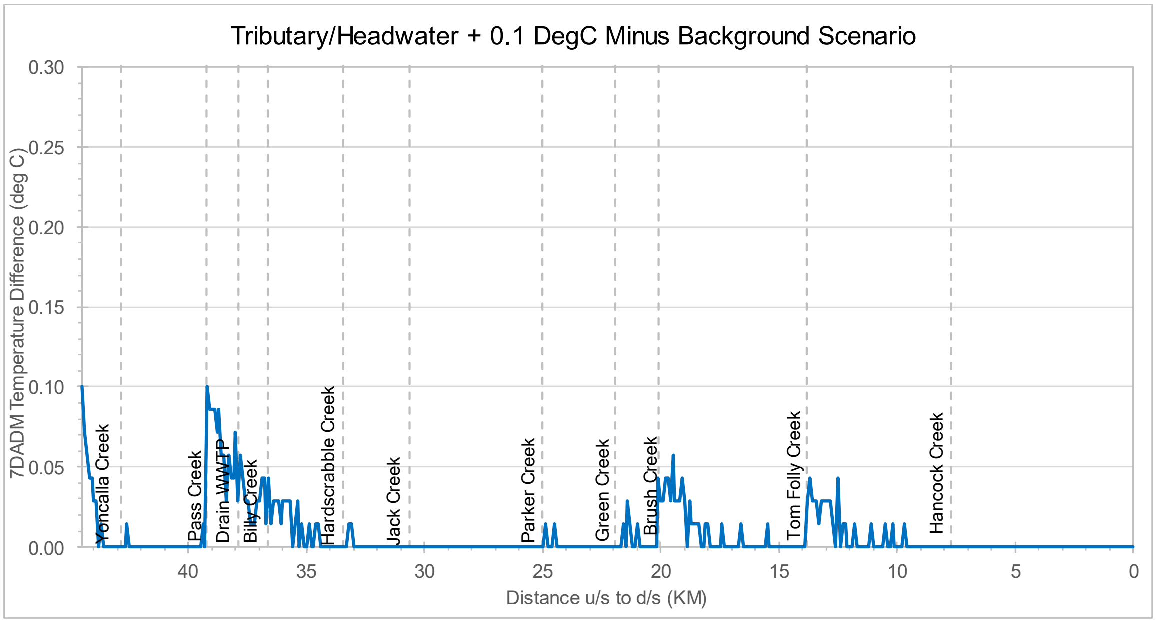


Figure 9-7. The Maximum 7DADM Temperature Differences between Tributary/Headwater Plus 0.1 ºC Scenario and the Background Scenario for Elk Creek.

Table 9-3. Locations and dates of maximum delta when temperatures are greater than criterion for comparison A2

Maximum Delta	0.10	0.10
RKM	44.5	39.2
Date	7/18/2002 – 7/31/2009	7/26/2002
		7/27/2002

10.0 UMPQUA RIVER

The modeled portion of the Umpqua River is shown in Figure 10-1.

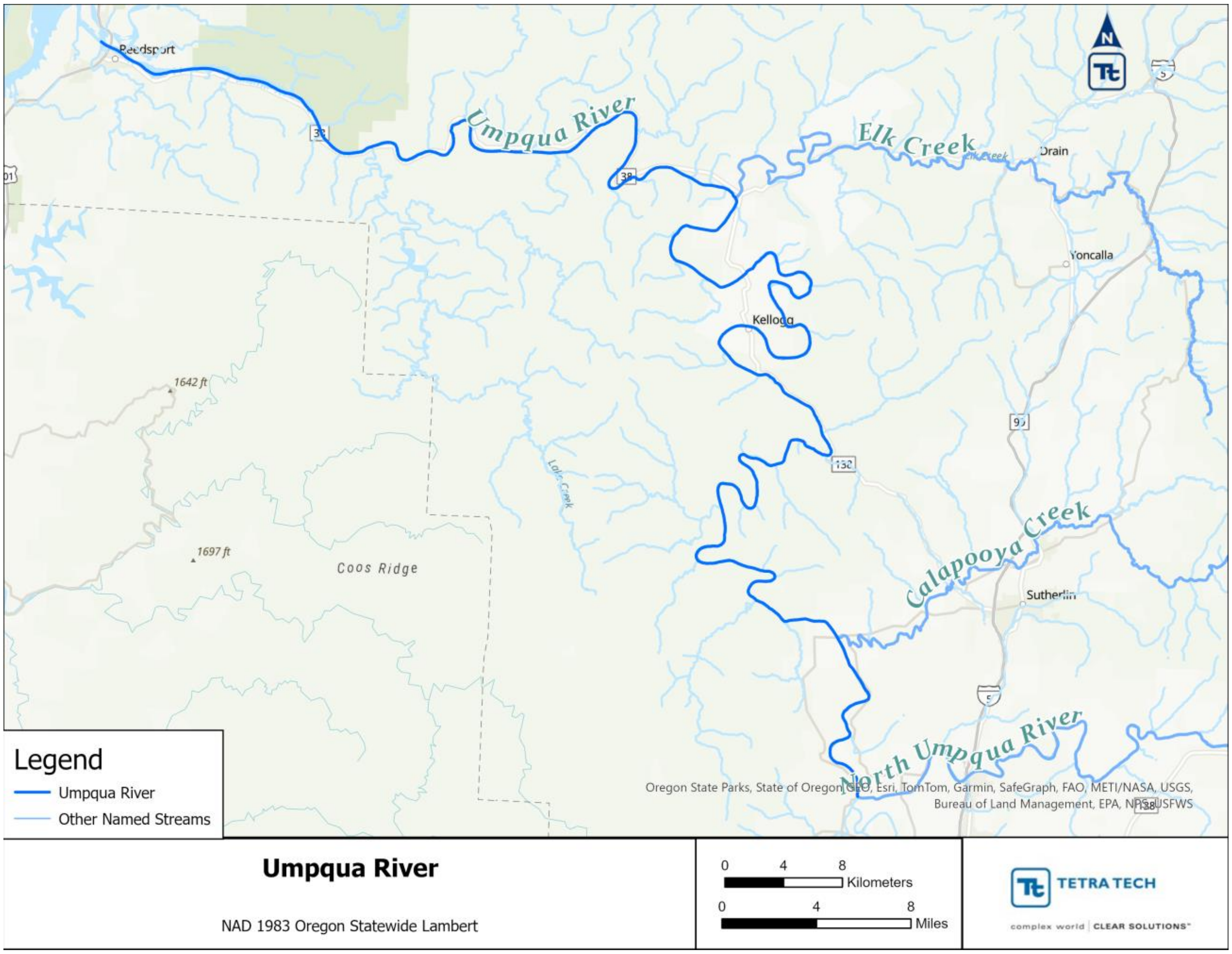


Figure 10-1. Location of the Umpqua River.

10.1 UMPQUA RIVER SCENARIO RESULTS

The Umpqua River HS model does not include any point sources. The model simulation period is July 12 to July 31. 2002. The scenarios that are relevant to the Umpqua River include the CCC scenario, which is identical to the No Point Source scenario; the Background scenario; the Fully Restored Vegetation and Natural Flow scenario and the Tributary/Headwater Plus 0.1 °C scenario. The 7DADM results are shown in Figure 10-2 to Figure 10-5 for these scenarios. The Umpqua River scenarios in Figure 10-2 through Figure 10-5 were run without linked results from North Umpqua and South Umpqua as well as Calapooya Creek and Elk Creek models. Therefore, these scenarios do not include the changes of water temperature from the upstream North Umpqua and South Umpqua rivers and the changes from these two tributaries. For example, for the Background scenario where all vegetation is set to the fully restored condition, the vegetation was only changed along the Umpqua River without considering the temperature changes after vegetation restoration along the North Umpqua and South Umpqua rivers.

Because the Umpqua River receives inflows from the North Umpqua River and South Umpqua River as well as two tributaries in the Umpqua mode, this section also includes two scenarios for the linked Umpqua River. In the Umpqua River model, the North Umpqua River is treated as headwater and the South Umpqua River is treated as a tributary, which enters the Umpqua River 50 meters below the headwater location. With the linked scenario, the results are pulled from North Umpqua and South Umpqua models as well as the two tributary models and the results from these models are used as inputs to the Umpqua River model. The Linked Point Source WLA with Rock Creek + 0.3 °C scenario uses the model results from the North Umpqua model with the point source at the WLA condition and with setting Rock Creek temperature 0.3 °C higher, and uses the model results from the South Umpqua model with point sources at the WLA conditions. The Linked Background scenario uses the model results from the Background scenario for both the North Umpqua model and South Umpqua model. The Linked Point Source WLA with Rock Creek + 0.3 °C scenario and the Linked Background scenario are presented in Figure 10-6 and Figure 10-7, respectively.

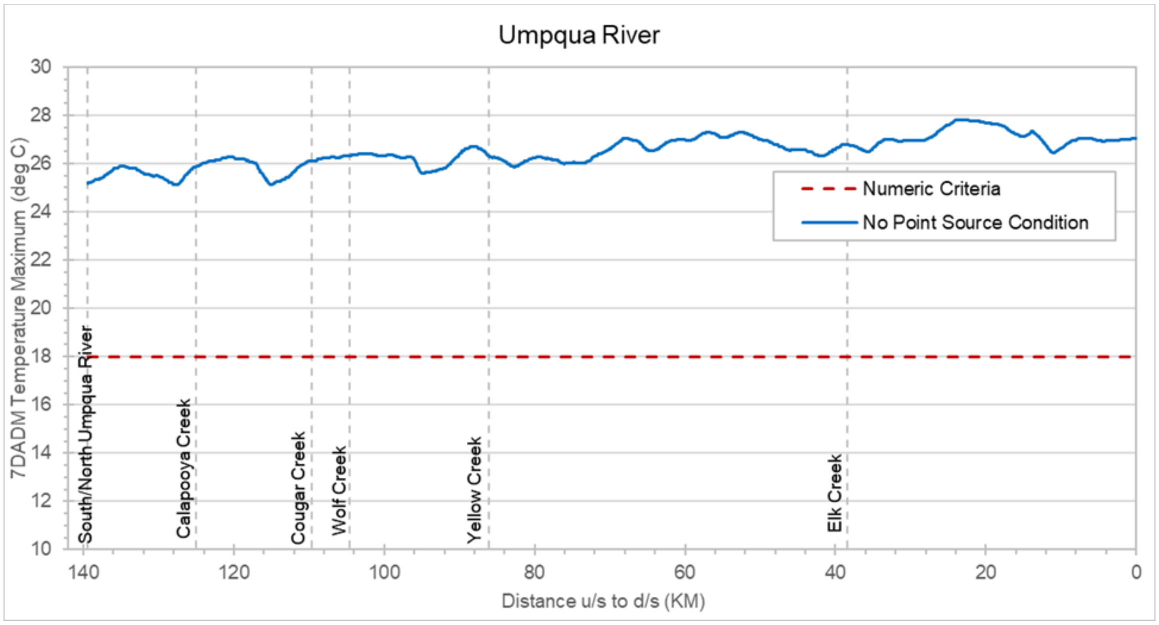


Figure 10-2. The maximum 7DADM temperature results along the Umpqua River for the No Point Source scenario.

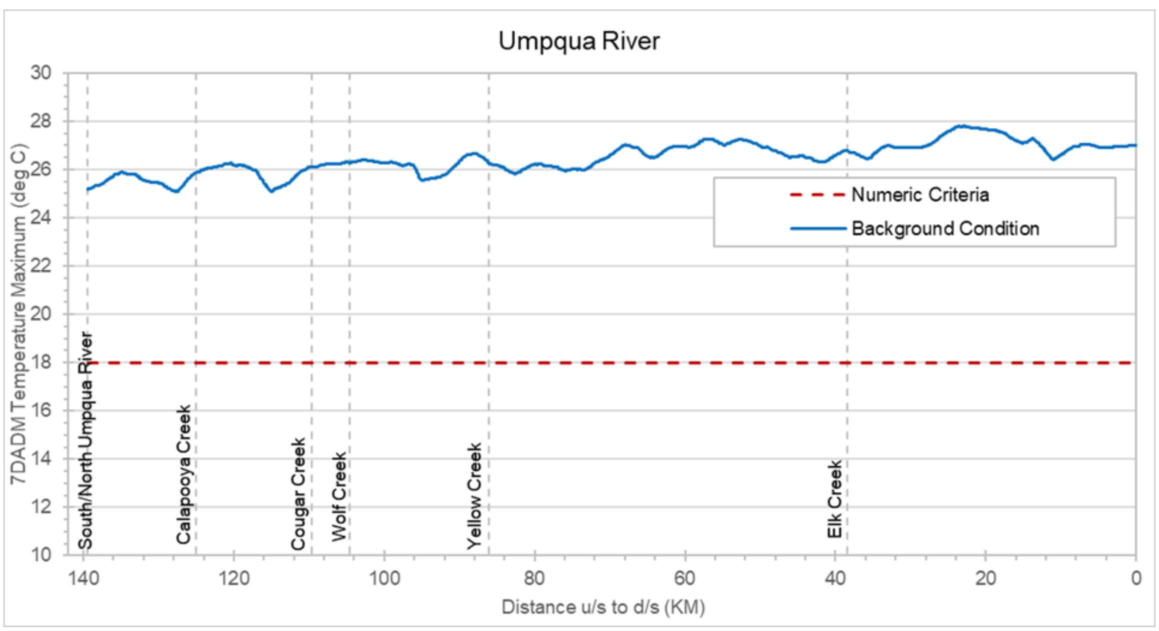


Figure 10-3. The maximum 7DADM temperature results along the Umpqua River for the Background scenario.

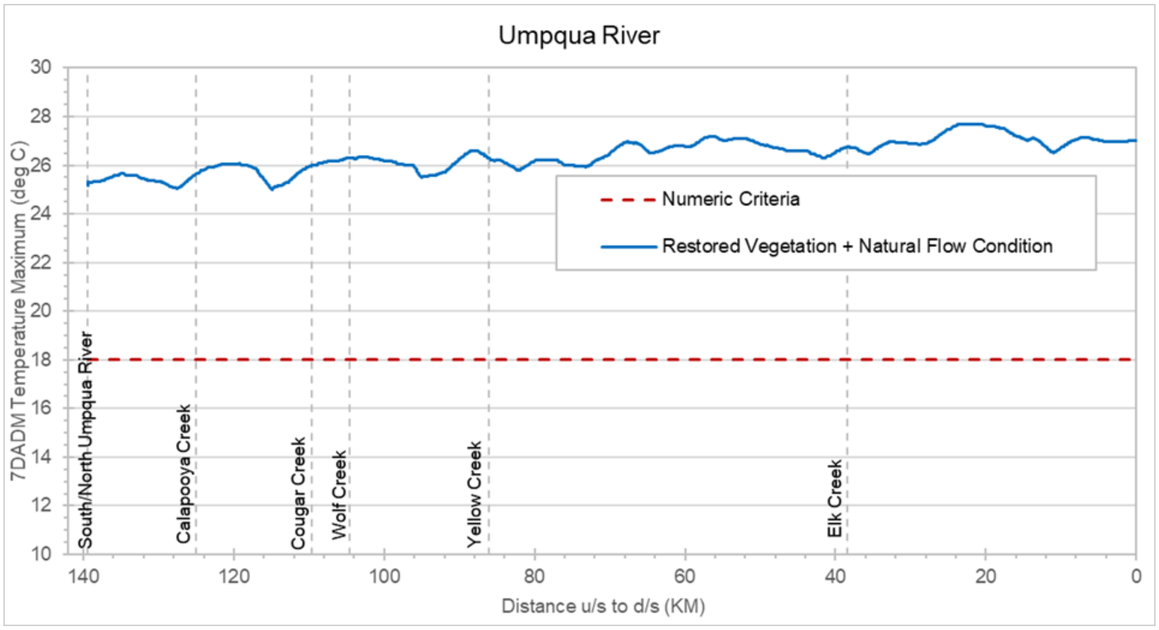


Figure 10-4. The maximum 7DADM temperature results along the Umpqua River for the Fully Restored Vegetation and Natural Flow scenario.

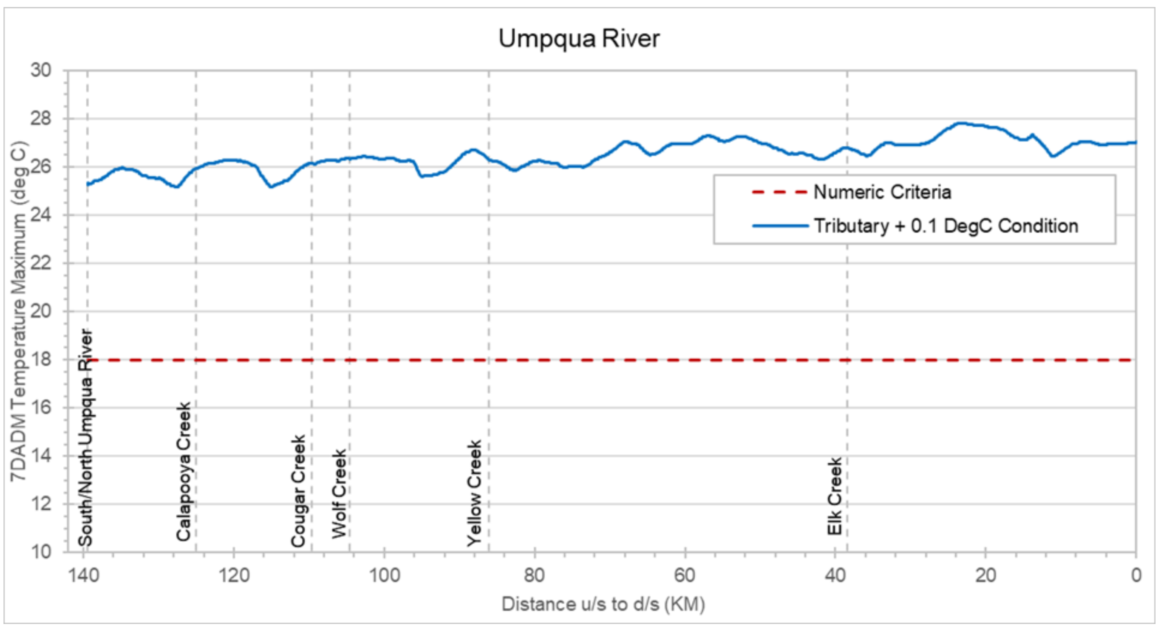


Figure 10-5. The maximum 7DADM temperature results along the Umpqua River for the Tributary/Headwater Plus 0.1 ˚C scenario.

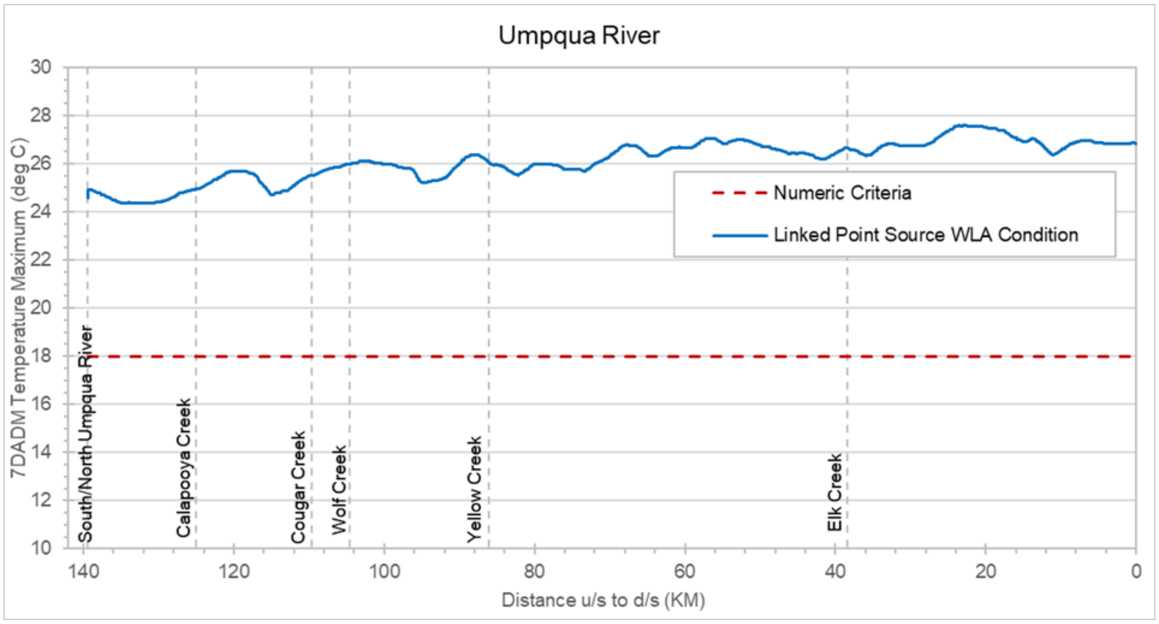


Figure 10-6. The maximum 7DADM temperature results along the Umpqua River for the linked point source WLA condition (Point Source WLA on North Umpqua and South Umpqua, and Rock Creek + 0.3°C on the North Umpqua).

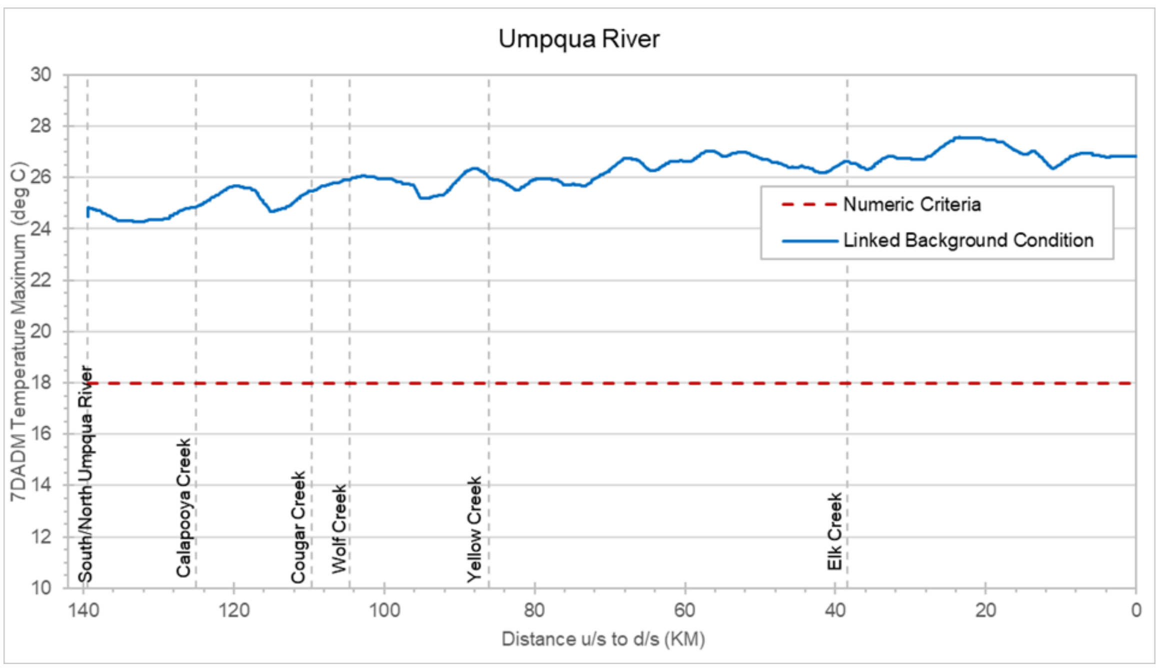


Figure 10-7. The maximum 7DADM temperature results along the Umpqua River for the linked Umpqua River Background scenario.

10.2 UMPQUA RIVER SCENARIO COMPARISONS

Comparisons of scenarios for the Umpqua River include:

1. Impacts of current condition vegetation (shade loss)
   - ✓ No Point Source minus background
6. Impact point source @ WLA and restored vegetation
   - ✓ Fully restored veg with point source @ WLA minus background

7. Difference between background and criteria
    ✓ Background minus Criteria
9. Natural Flows
    ✓ Background minus fully restored veg with natural flows
A2. Tributary + 0.1ºC scenarios

Figure 10-8 shows the results of comparison 1, the impacts of shade loss, which is the 7DADM temperature difference between the No Point Source scenario (same as calibration condition for models without point sources) and the Background scenario. The only difference between these two scenarios are the vegetation conditions, where the No Point Source scenario uses the current/existing vegetation condition while the Background scenario uses the fully restored vegetation condition. The maximum delta reaches 0.10 ˚C at river kilometers 98.05, 97.95, and 91.55 on multiple dates (Table 10-1).

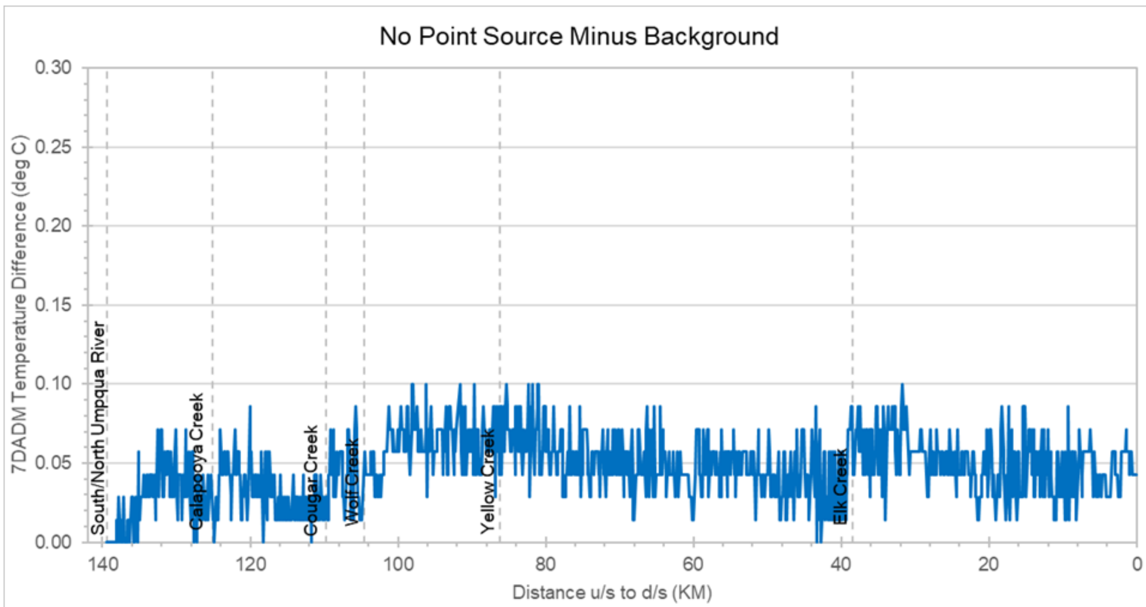


Figure 10-8. The maximum 7DADM temperature differences along the Umpqua River for the impacts of shade loss.

Table 10-1. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 1

Maximum Delta	0.10	0.10	0.10
RKM	98.05	97.95	91.55
Date	7/27/2002	7/27/2002	7/28/2002
	7/28/2002	7/28/2002	
	7/29/2002	7/29/2002	
		7/30/2002	
		7/31/2002	

Figure 10-9 shows the results of the comparison of the 7DADM temperature difference between the Linked Point Source WLA scenario for both North and South Umpqua rivers (attainment scenario) and the Background scenario, which is considered as comparison 6 even though there are no point sources directly discharging to the Umpqua River. There are 65 locations with a maximum delta of 0.1 ^{o}C for this comparison, therefore, locations and dates of the maximum delta are not listed in a table.

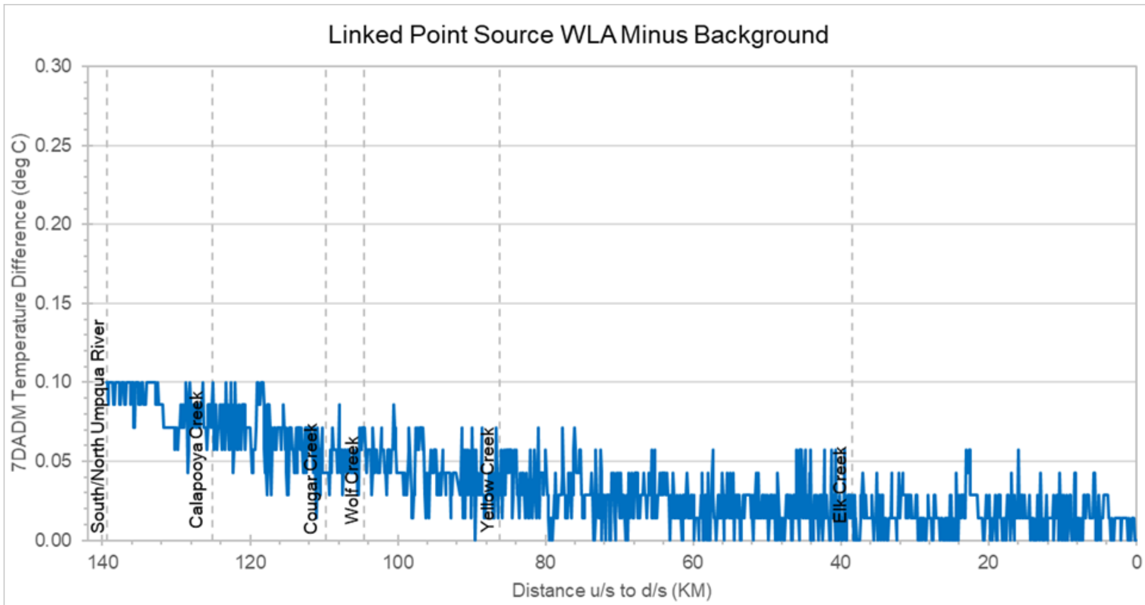


Figure 10-9. The Maximum 7DADM Temperature Differences between the Linked Point Source WLA for South and North Umpqua rivers and the Background scenario for the Umpqua River.

Figure 10-10 shows the results of comparison 7, which is the 7DADM temperature difference between the Background scenario and criteria. The overall 7DADM temperature differences follow the longitudinal variation of the modeled temperature of the Background scenario. The maximum delta reaches 9.79 ^{o}C between river kilometers 22.75 and 23.65 on 7/18/2002 (Table 10-2).

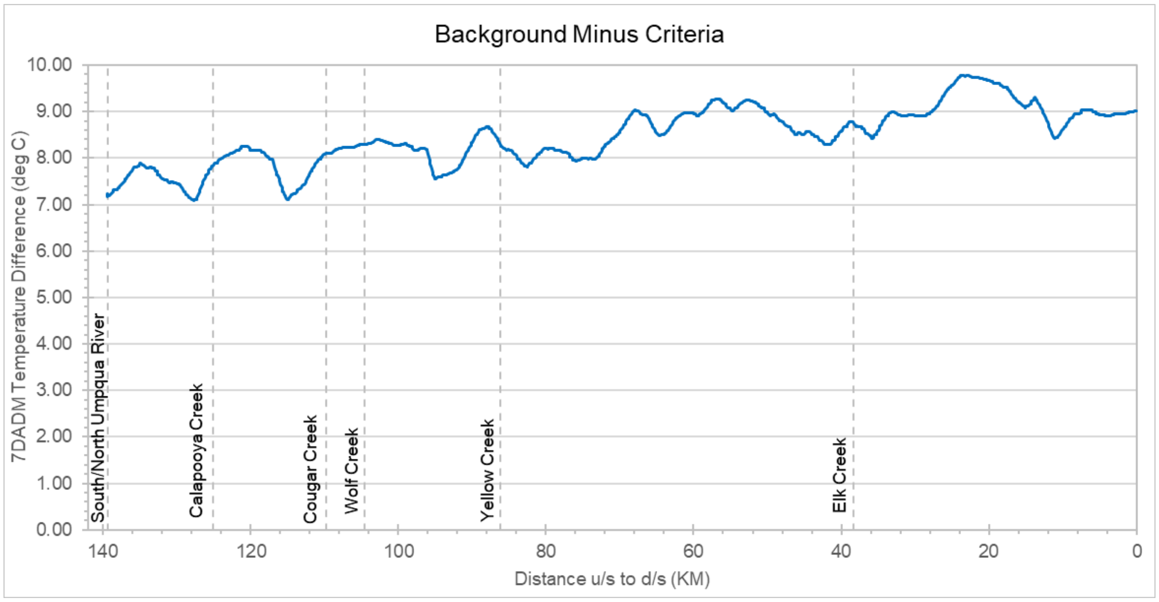


Figure 10-10. The maximum 7DADM temperature differences along the Umpqua River for the difference between background conditions and criteria temperatures

Table 10-2. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 7

Maximum Delta	9.79	9.79	9.79	9.79	9.79	9.79	9.79
RKM	23.65	23.55	23.45	23.05	22.95	22.85	22.75
Date	7/18/2002	7/18/2002	7/18/2002	7/18/2002	7/18/2002	7/18/2002	7/18/2002

Figure 10-11 shows the results of comparison 9 which is the 7DADM temperature difference between the Background scenario and the Fully Restored Vegetation with Natural Flow scenario. There are a few differences between these two scenarios for the Umpqua River. One difference is that there are no withdrawals in the Restored Vegetation with Natural Flow scenario. The headwater flows are also different while the headwater temperature inputs are the same. In addition, the flows and temperatures for some of the tributaries are different from what are used in the Background scenarios. The maximum delta reaches 0.30 ˚C at river kilometer 125.35 on 7/26/2002 dates and -0.16 ˚C at river kilometer 7.55 on 7/20/2002 (Table 10-3).

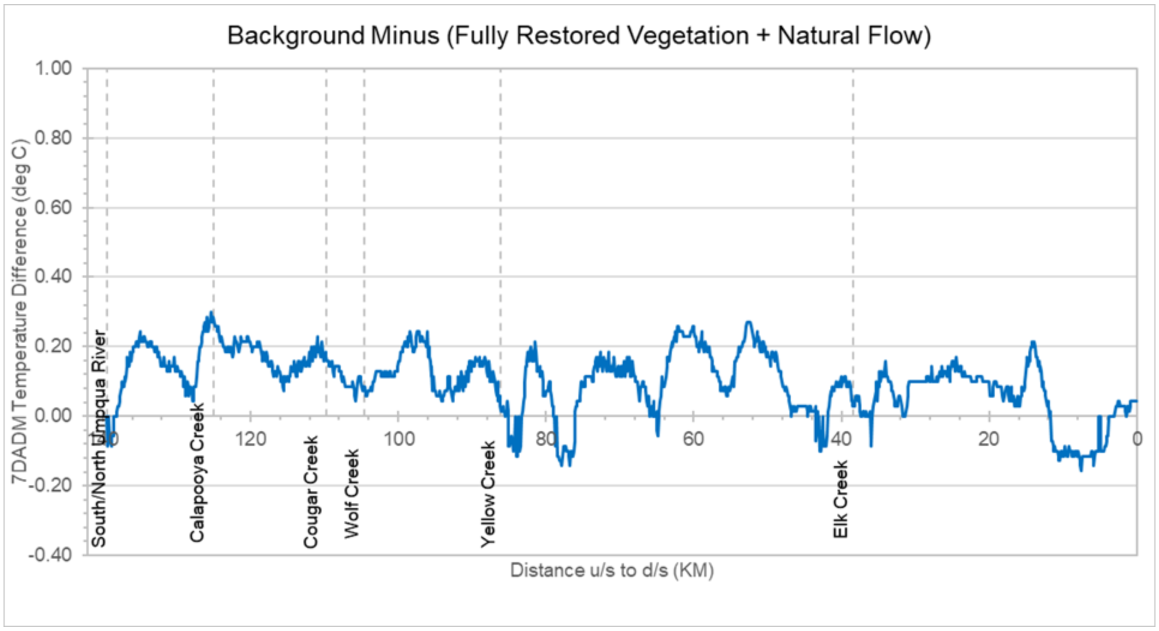


Figure 10-11. The maximum 7DADM temperature differences between Background scenario and the Fully Restored Vegetation with Natural Flow scenario on the Umpqua River.

Table 10-3. Locations and dates of maximum delta when temperatures are greater than criterion for comparison 9

Maximum Delta	0.30	-0.16
RKM	125.35	7.55
Date	7/26/2002	7/20/2002

Figure 10-12 shows the results of comparison A2, which is the 7DADM temperature difference between the Tributary/Headwater plus 0.1 ºC scenario and the Background scenario. The only difference between these two scenarios is that water temperature from all tributaries and headwater are increased by 0.1 ºC in the Tributary/Headwater plus 0.1 ºC scenario. The impact of the increase of temperature from tributaries and headwater is related to the relative flow conditions as well as the weather conditions. When temperature in tributaries and headwater increase by 0.1 ºC, temperature in the Umpqua River may also increase by up to 0.1 ºC. Since there numerous increases to 0.1 ºC for this comparison, locations and dates of the maximum delta which is 0.1 ºC are not listed in a table.

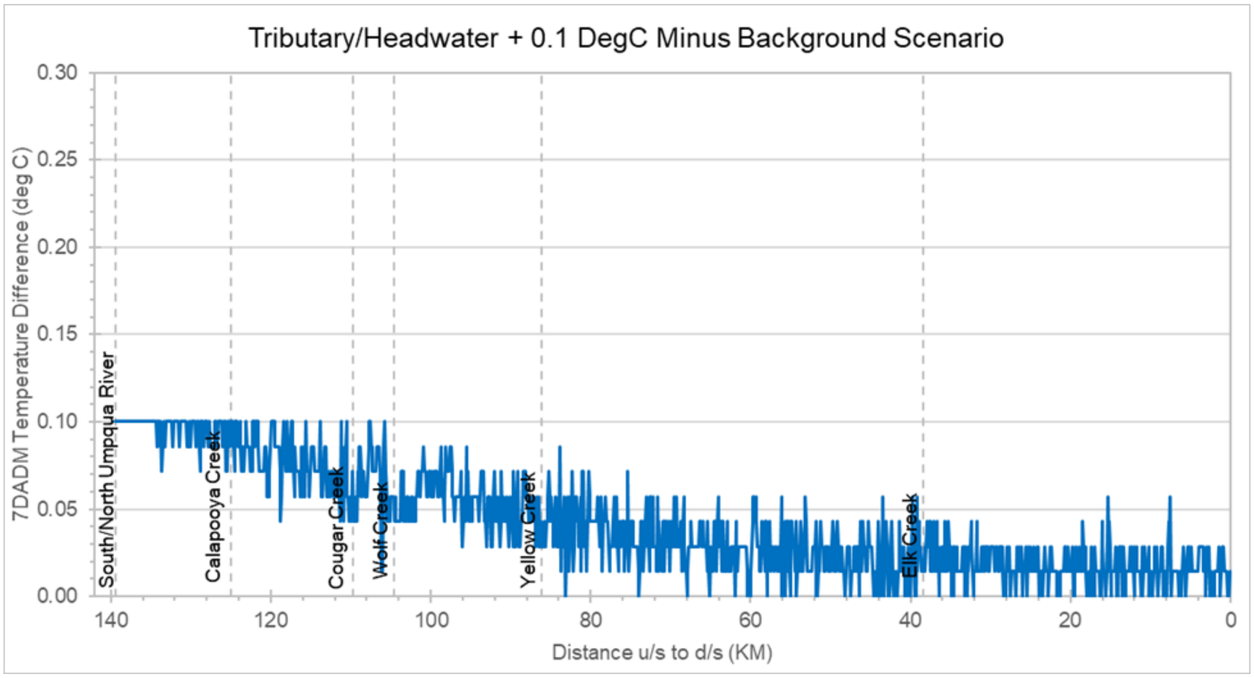


Figure 10-12. The Maximum 7DADM Temperature Differences between Tributary/Headwater Plus 0.1 °C Scenario and the Background Scenario for the Umpqua River.

11.0 SUMMARY

Scenarios runs were conducted for the seven streams and rivers in the South Umpqua and Umpqua watershed. The summer scenarios are based on the HS7 models developed by DEQ. For the South Umpqua River, scenarios were also simulated for the spawning period using the newly developed South Umpqua River HS8 model. The actual scenario runs may differ for different streams and rivers depending on if point sources exist in the models and if flow and water temperature inputs change under the natural flow conditions. Only Cow Creek and South Umpqua River receives point source discharges. The point source discharge data including the recorded daily effluent flows and temperature as well as calculated WLA temperature were provided by DEQ. For the Umpqua River, even though no point sources directly discharge to the river, the upstream inflows from the North Umpqua and South Umpqua Rivers are impacted by point sources. Therefore, an attainment scenario was also simulated and the impacts from point sources was evaluated.

12.0 REFERENCES

DEQ (Oregon Department of Environmental Quality). 2008. *Temperature water quality standard implementation—A DEQ internal management directive, Oregon*. Oregon Department of Environmental. Quality. Portland, OR. https://www.oregon.gov/deq/Filtered%20Library/IMDTemperature.pdf

DEQ. 2013. *Internal Management Directive - The Use of Significant Figures and Rounding Conventions in Water Quality Permitting*. Water Quality Division, Surface Water Management Section, Headquarters. Portland, OR. https://www.oregon.gov/deq/Filtered%20Library/SigFigsIMD.pdf.

Appendix A

Temperature Correlation Plots

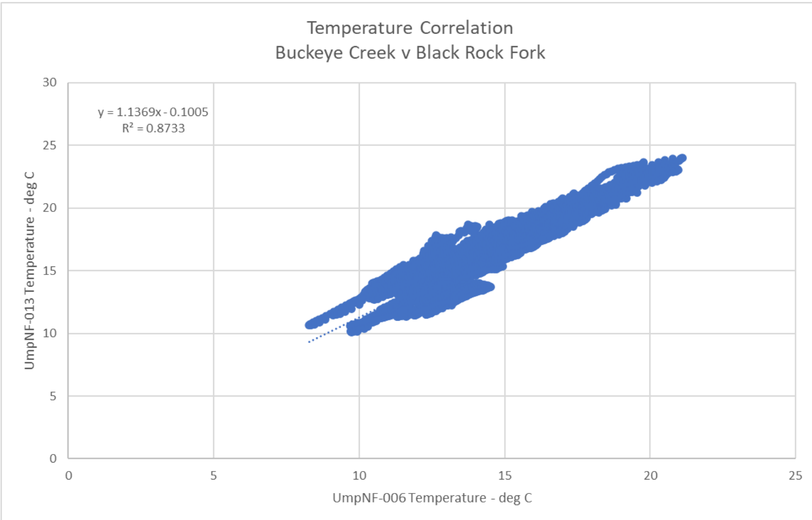


Figure A-1. Buckeye Creek Temperature Correlation

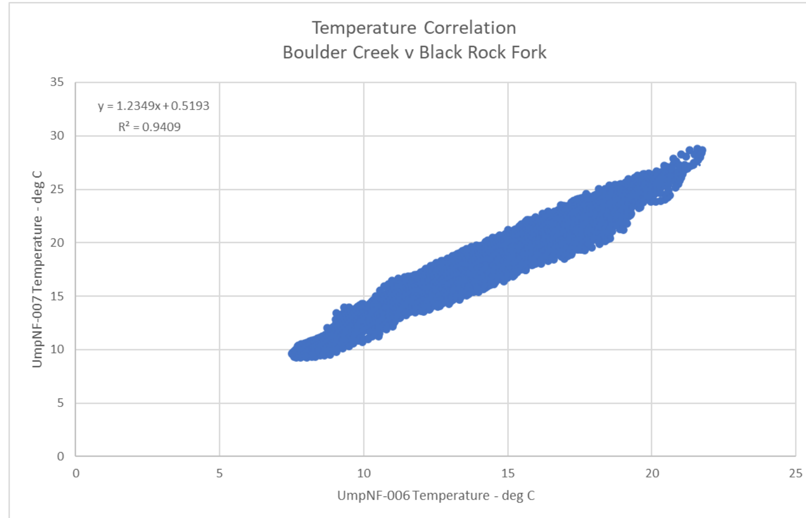


Figure A-2. Boulder Creek Temperature Correlation

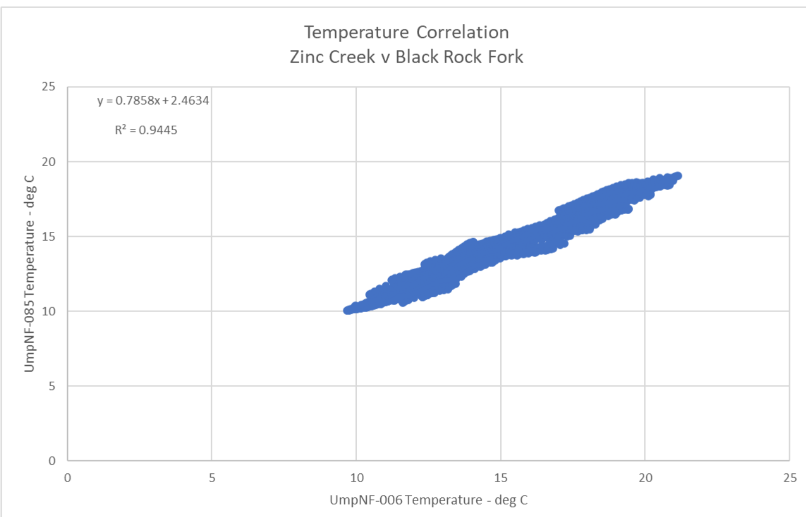


Figure A-3. Zinc Creek Temperature Correlation

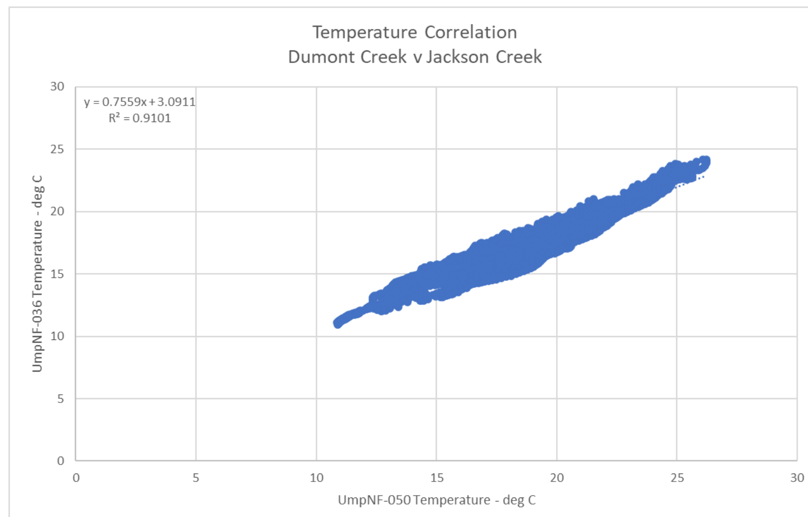


Figure A-4. Dumont Creek Temperature Correlation

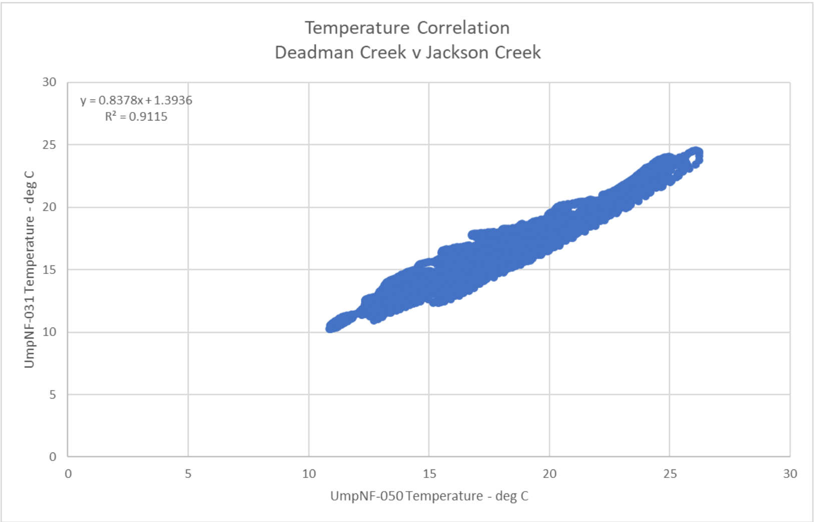


Figure A-5. Deadman Creek Temperature Correlation

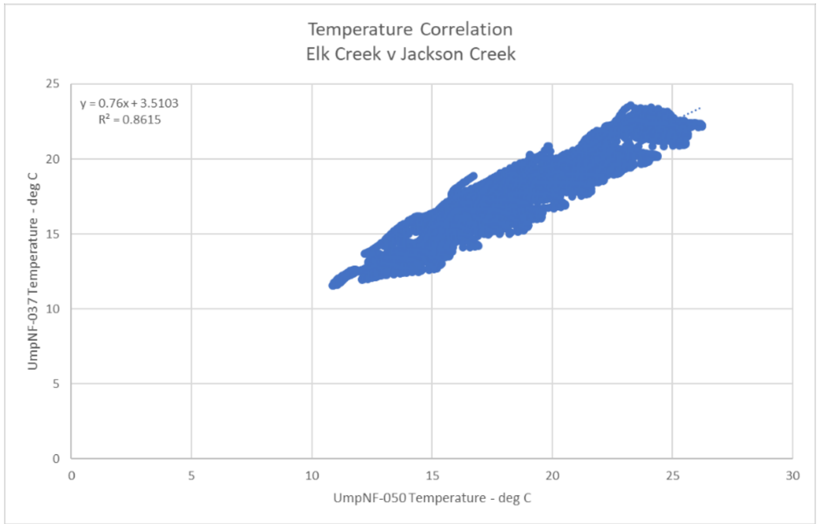


Figure A-6. Elk Creek Temperature Correlation

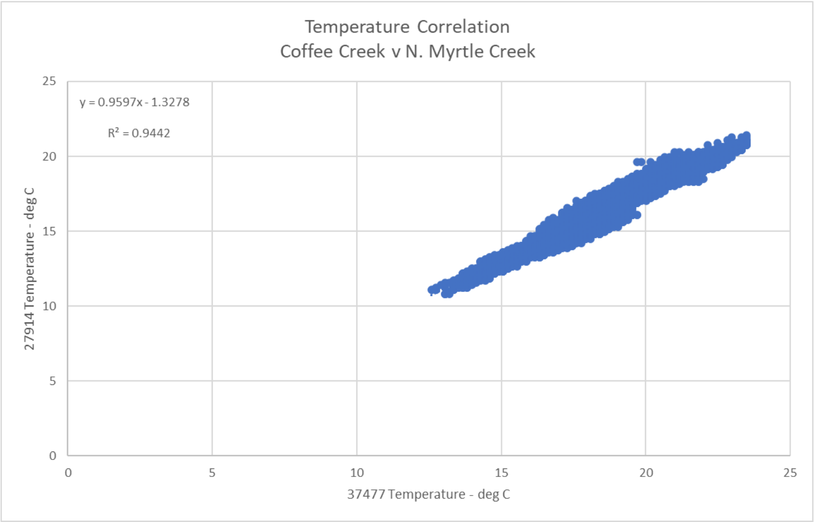


Figure A-7. Coffee Creek Temperature Correlation

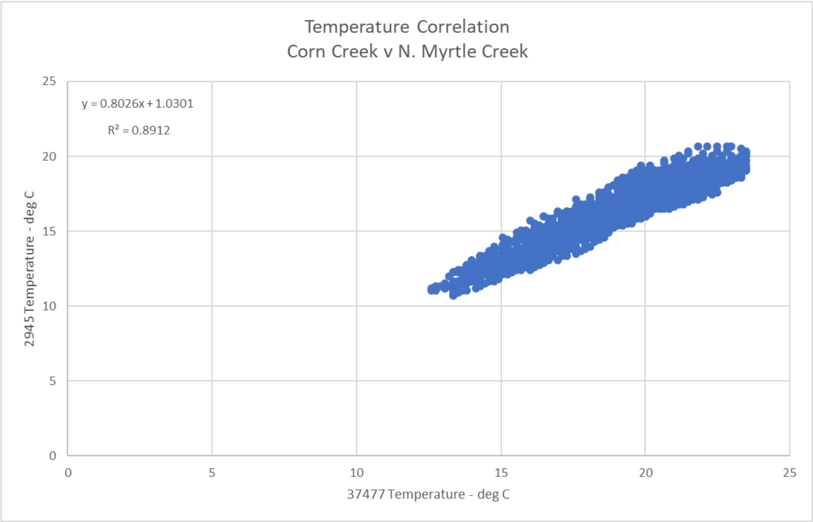


Figure A-8. Corn Creek Temperature Correlation

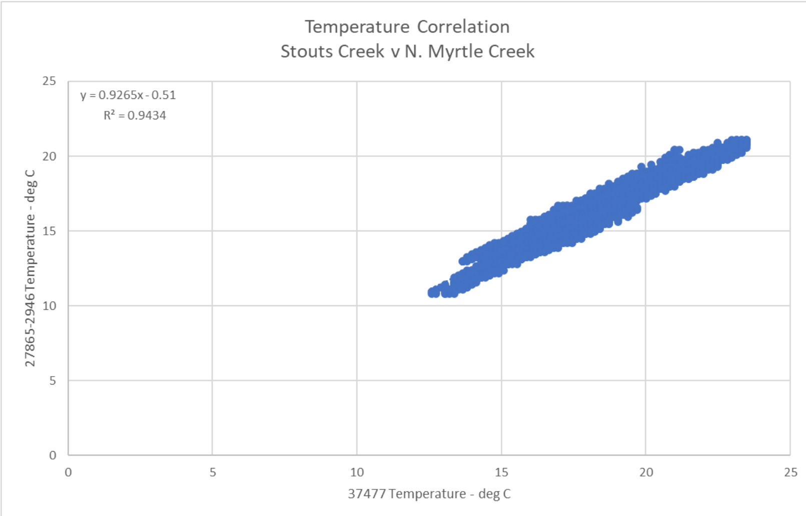


Figure A-9. Stouts Creek Temperature Correlation

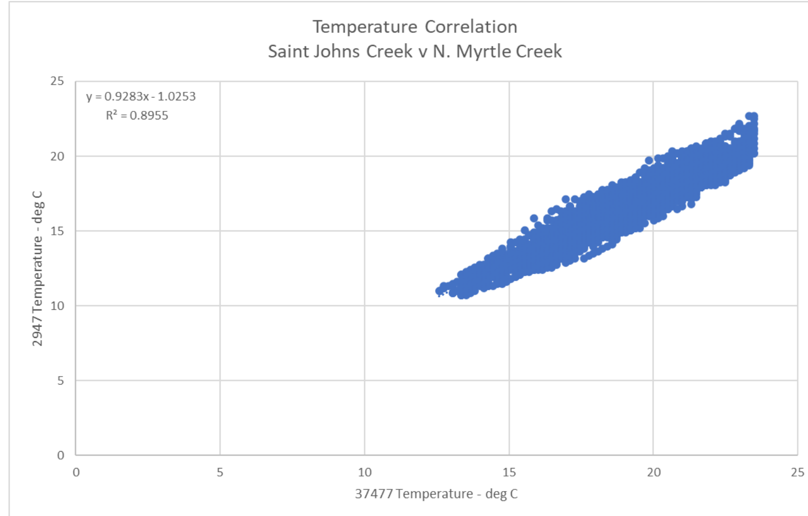


Figure A-10. Saint Johns Creek Temperature Correlation

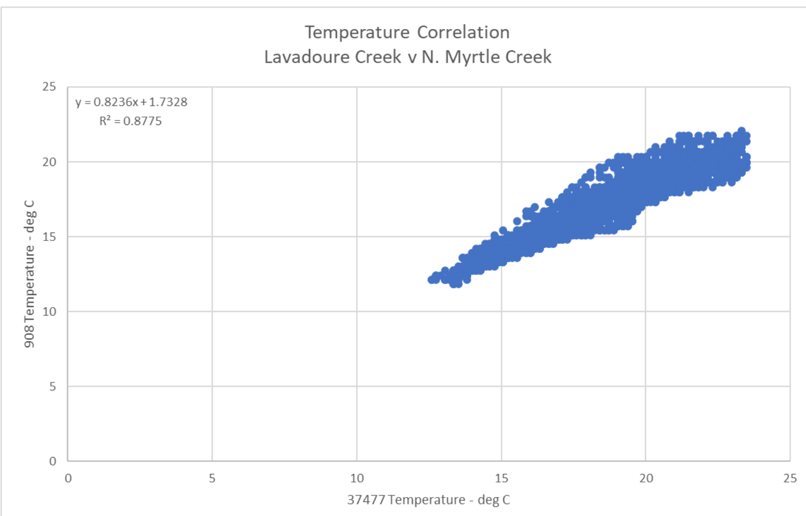


Figure A-11. Lavadoure Creek Temperature Correlation

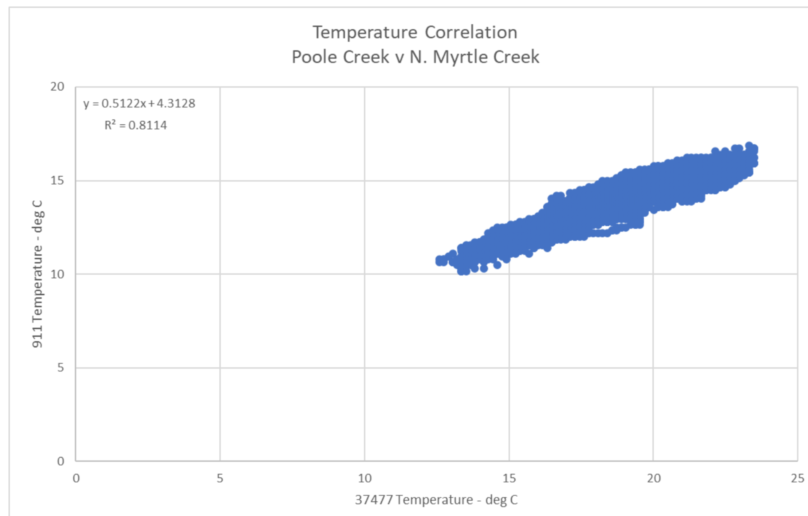


Figure A-12. Poole Creek Temperature Correlation

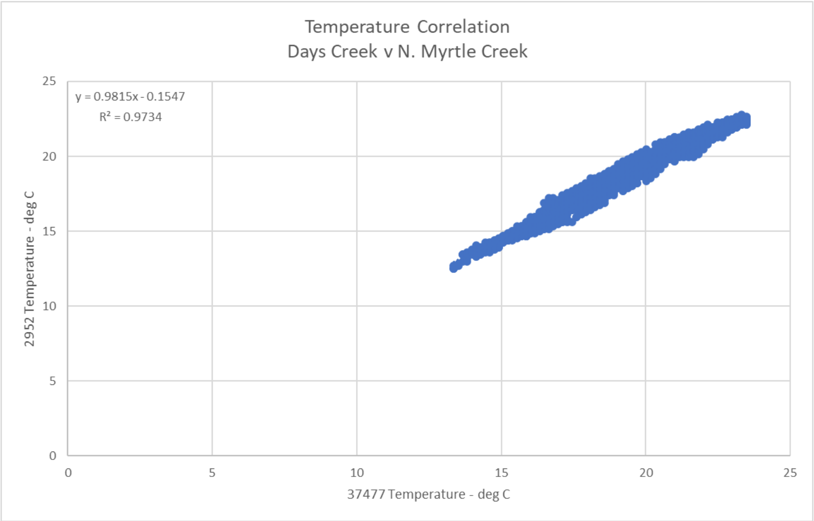


Figure A-13. Days Creek Temperature Correlation

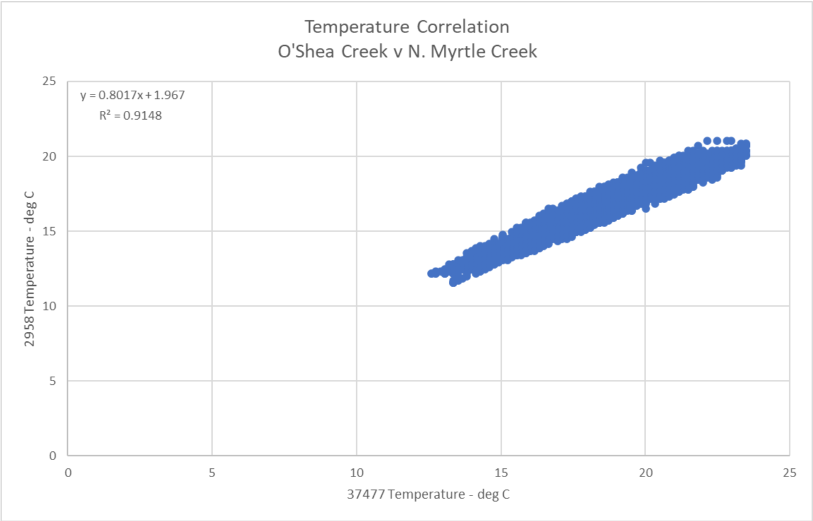
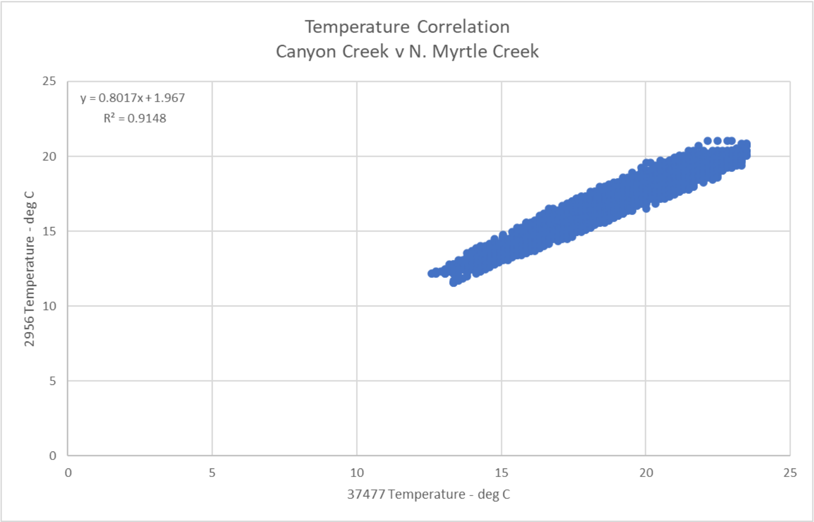


Figure A-14. O'Shea Creek Temperature Correlation



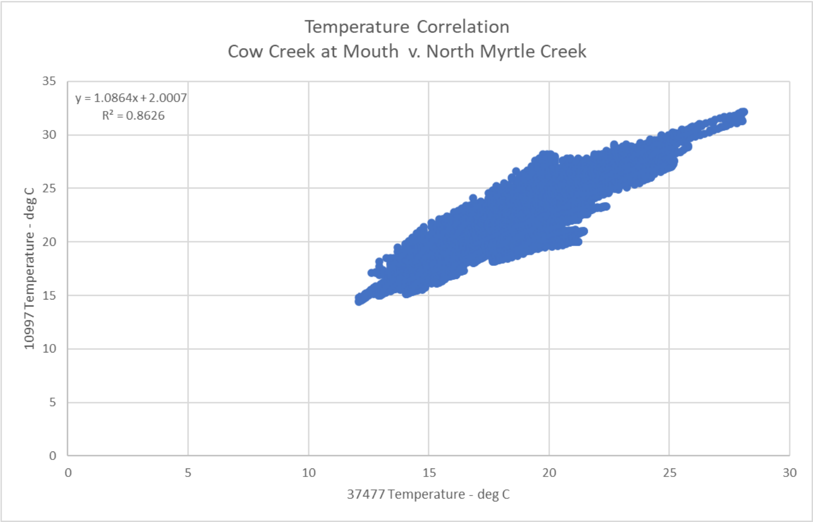


Figure A-15. Canyon Creek Temperature Correlation

Figure A-16. Cow Creek Temperature Correlation

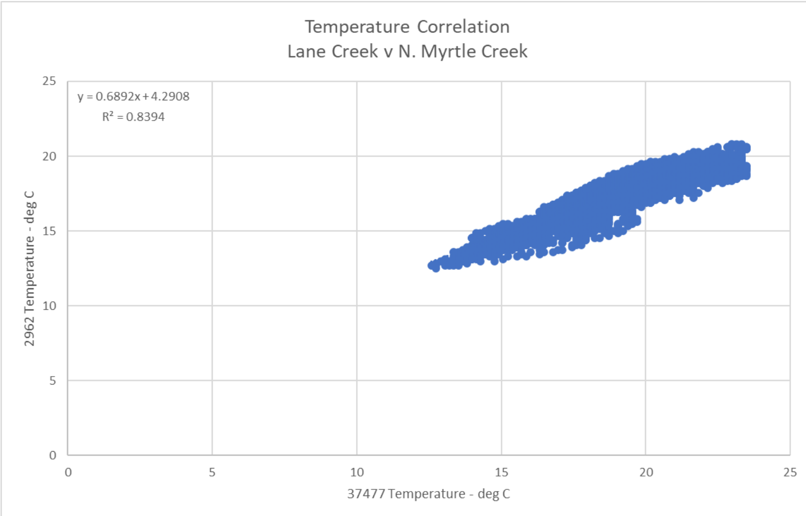


Figure A-17. Lane Creek Temperature Correlation

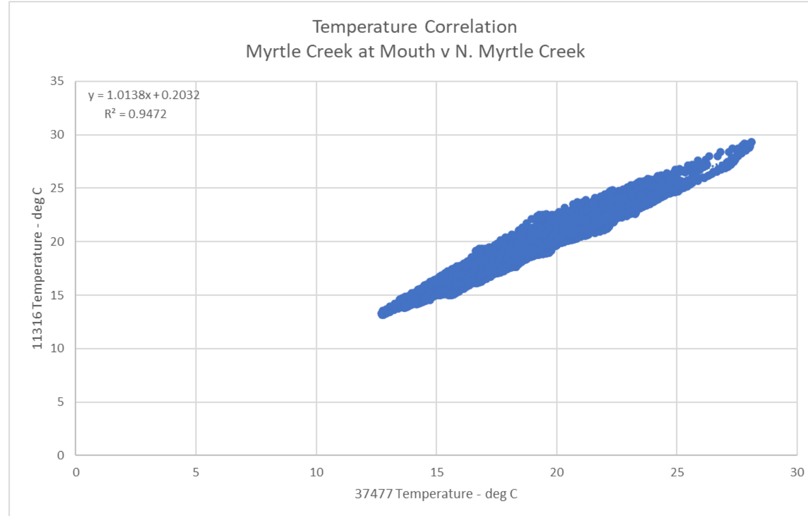


Figure A-18. Myrtle Creek Temperature Correlation

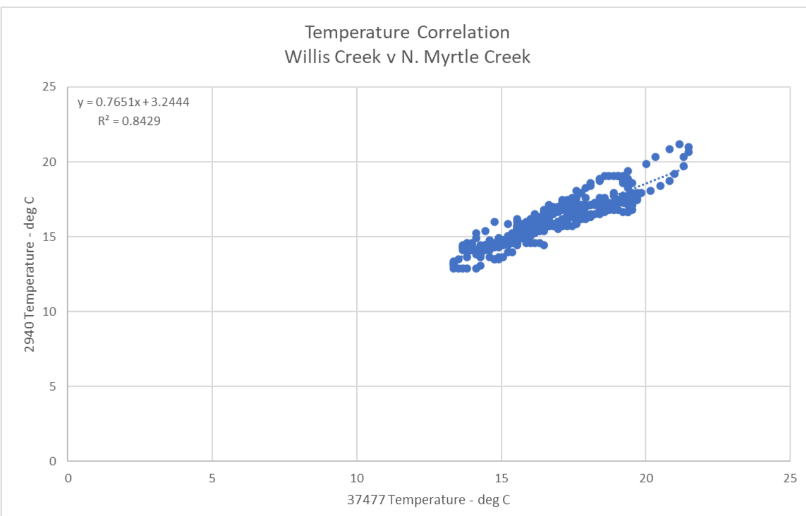


Figure A-19. Willis Creek Temperature Correlation

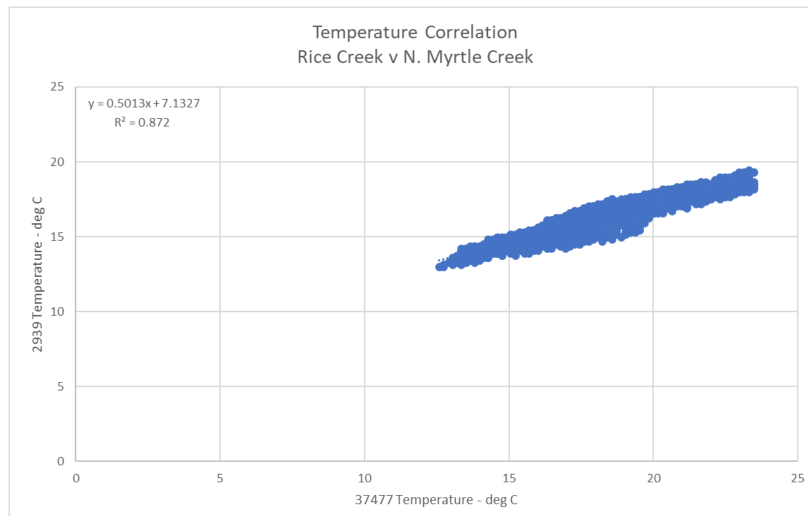


Figure A-20. Rice Creek Temperature Correlation

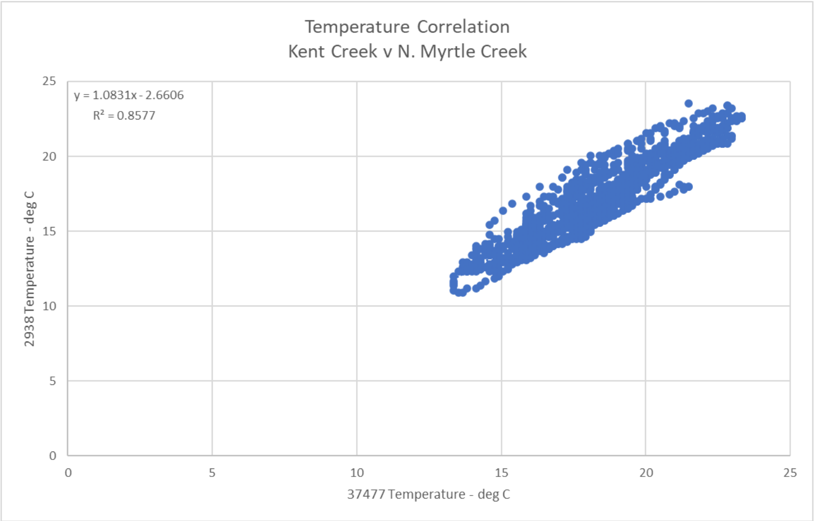


Figure A-21. Kent Creek Temperature Correlation

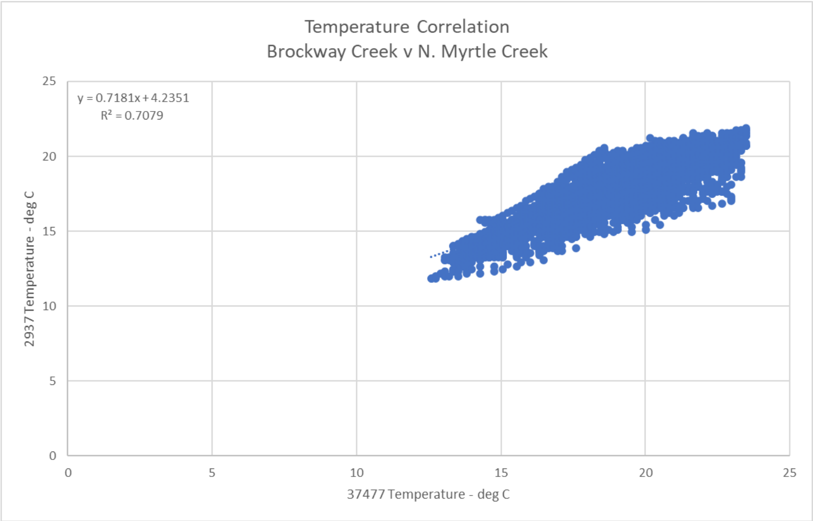


Figure A-22. Brockway Creek Temperature Correlation

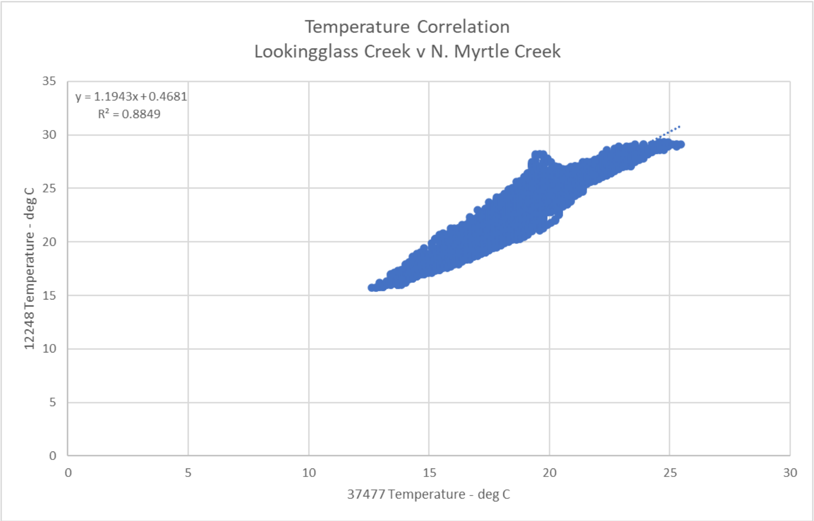


Figure A-23. Lookingglass Creek Temperature Correlation

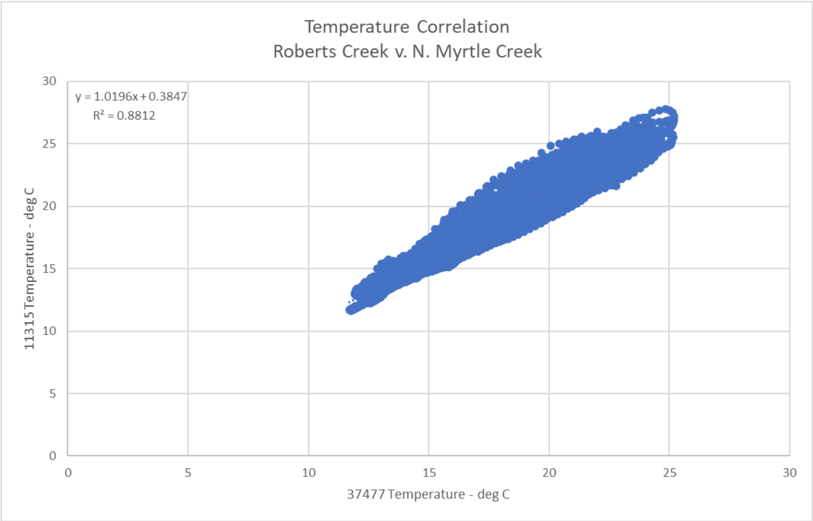


Figure A-24. Roberts Creek Temperature Correlation

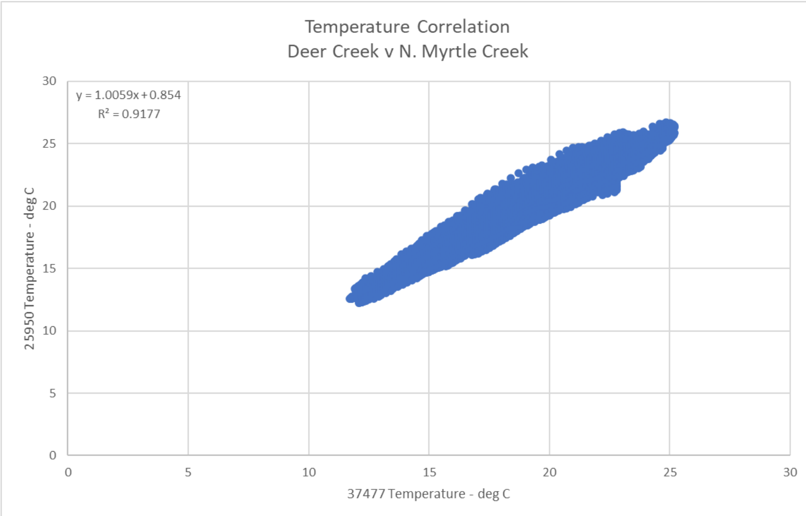


Figure A-25. Deer Creek Temperature Correlation

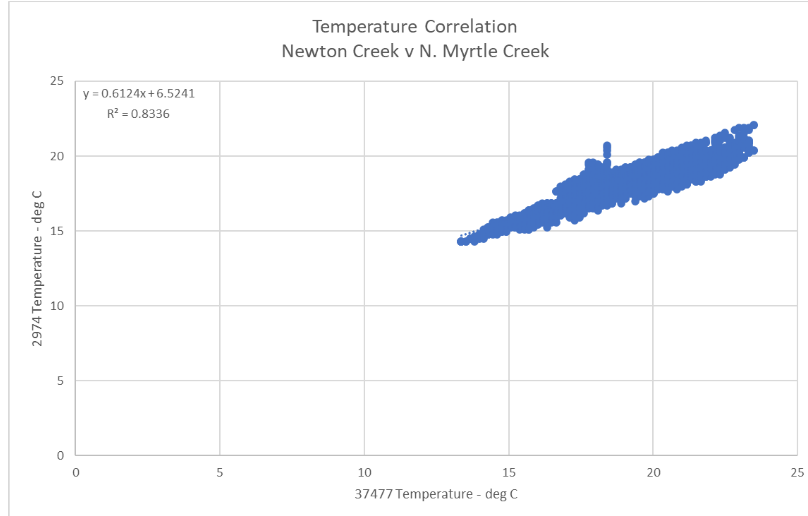


Figure A-26. Newton Creek Temperature Correlation

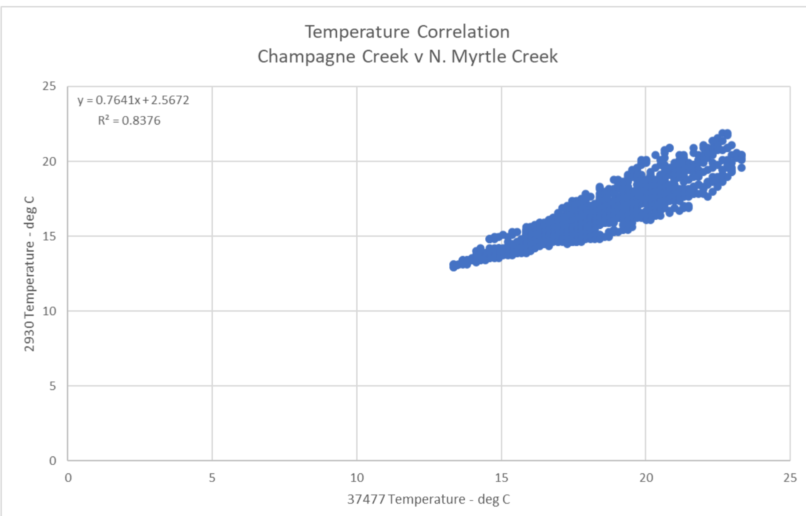


Figure A-27. Champagne Creek Temperature Correlation