

Total Maximum Daily Loads for the Rogue River Basin

Technical Support Document

Appendix A: Model Report



State of Oregon
DEQ Department of Environmental Quality

Document information

This document was prepared by Oregon Department of Environmental Quality

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1 Overview

This document, Technical Support Document Appendix A of the replacement Rogue River Basin Total Maximum Daily Load for temperature impairments, summarizes the data, numerical modeling, analytic methods, and results applicable to the TMDL. This includes basin- and river-specific descriptions of data and data sources, current conditions model set up and calibration, and alternative scenario models and results comparisons.

Stream temperatures and shade conditions for the Applegate Subbasin TMDL (DEQ, 2004), Bear Creek Watershed TMDL (DEQ, 2007), Lobster Creek Watershed TMDL (DEQ, 2002a), and Rogue River Basin TMDL (DEQ, 2008) were simulated using the computer models Heat Source (temperature and shade) and SHADOW (shade only). The model extents include most of the main rivers and their larger tributaries that contain or influence primary fish habitat (Figure 1-1). The stream-specific model discussions in Section 3 provide details on the specific models used and parameters simulated for each modeled stream.

Site-specific load allocations were developed for the modeled streams. Other streams are assigned generalized load allocations based on effective shade surrogate measures that target restored vegetation types. Numeric or narrative wasteload allocations will be developed for all NPDES permittees that were deemed to be potentially significant thermal sources.

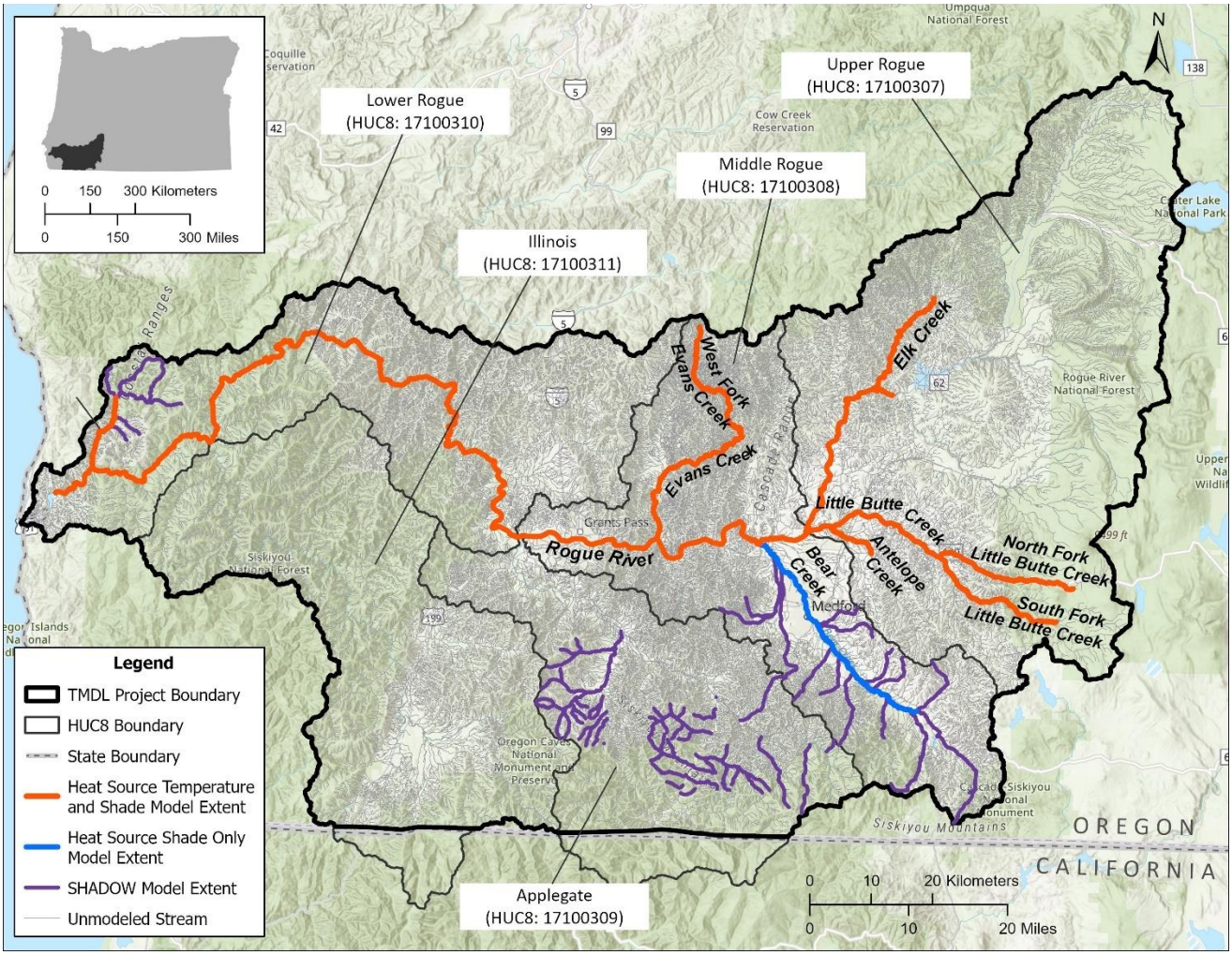


Figure 1-1: Overview of TMDL project area with model extents.

2 Available data

This section describes the field collected (2.1), GIS- or remotely-acquired (2.2), and other derived (2.3) data that were available and applied to support this TMDL modeling effort.

2.1 Field data

2.1.1 Meteorology

Meteorological data include air temperature, sky conditions, cloudiness, relative humidity, and wind speed. QAPP Appendix A Tables 60 - 65 list the stations with available meteorological data in the Rogue River Basin, including 131 stations from National Oceanic and Atmospheric Association (NOAA)'s National Climatic Data Center (NCDC), 5 stations from National Interagency Fire Center's Remote Automatic Weather Stations (RAWS), 2 stations from Bureau of Reclamation Cooperative Agricultural Weather Network (AgriMet), 2 stations from Automated Hydrologic and Meteorological Monitoring Stations Network (Hydromet), 144 stations from University of Utah MesoWest database,

and 5 stations from DEQ's files. The meteorological monitoring stations are also shown in the HTML interactive map that accompanies this TMDL. The station IDs in QAPP Appendix A Table 60 are the NCDC ID, which may differ from the station identifiers used by other sources.

The meteorological data obtained from the NCDC include the Local Climatological Dataset (NOAA, 2005) and the Global Integrated Surface Dataset (NOAA, 2001). The Local Climatological Dataset 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 Global Integrated Surface Dataset provides a long-term record of hourly, sub-hourly and synoptic weather observations from a variety of meteorological networks worldwide. The dataset includes observations from the World Meteorological Organization, Automated Surface Observing System, Automated Weather Observing Stations, U.S. Climate Reference Network, and others.

Details on the specific meteorological data sources used for various stream models are provided in each streams model setup and calibration discussion in Sections 3.2 - 3.12.

2.1.2 Continuous stream temperature

All available continuous stream temperature data were retrieved from DEQ's Ambient Water Quality Monitoring System (AWQMS), USGS's National Water Information System (NWIS), or were obtained during the data solicitation for DEQ's temperature TMDL replacement project. Some temperature data presented in this QAPP were retrieved from DEQ's files and were not available in AWQMS or USGS's database.

The data retrieval period for continuous stream temperature data was January 1, 1990 to December 31, 2020. Data retrieved from the AWQMS database have a Data Quality Level (DQL) of A, B or E and a result status of "Final" or "Provisional". The data quality level criteria are outlined in DEQ's Data Quality Matrix for Field Parameters (DEQ, 2013). The TMDL program uses waterbody results with a data quality level of A, B, or E (DEQ, 2021). Data of unknown quality were used after careful review. Stream temperature datasets are available from DEQ by request.

QAPP Appendix B Table 66 summarizes 365 Rogue River Basin continuous stream temperature data collection locations and associated monitoring organizations, while Table 67 summarizes the data collection dates. The station locations are shown in the HTML interactive map that accompanies this TMDL.

Available continuous stream temperature monitoring site data are listed in the respective model setup sections. These data were used:

- To evaluate if the waterbody achieves temperature water quality standards,
- As model inputs for tributary inflows and/or the upstream boundary condition,
- To assess model performance and goodness-of-fit by comparing observed to predicted stream temperature data.

Details on the specific stream temperature sources used for various stream models are provided in each streams model setup and calibration discussion in Sections 3.2 - 3.12.

2.1.3 Streamflow – continuous and instantaneous measurements

QAPP Appendix C Tables 68 - 71 list the Rogue River Basin stations where continuous and instantaneous flow data were available, including 28 USGS stations, 42 Oregon Water Resources Department (OWRD) stations, 2 Hydromet stations, and 42 DEQ stations, while Table 72 lists the continuous stream flow data years for each location. The station locations are shown in the HTML interactive map that accompanies this TMDL. DEQ relied upon quality control checks implemented by USGS and OWRD. DEQ-collected stream flow measurements utilize field and quality control methods outlined in DEQ's Mode of Operations Manual (DEQ, 2020). These measurements supported DEQ estimations of flow mass balances, tributary inputs, and other parameters required for the temperature models.

Details on the specific streamflow data sources used for various stream models are provided in each streams model setup and calibration discussion in Sections 3.2 - 3.12.

2.1.4 Point source discharges

Table 2-1 identifies all the active individual NPDES permittees in the Rogue River Basin as of the date of this QAPP. Table 2-2 lists the registrants covered under the general NPDES GEN01, GEN03, GEN04, and GEN40 (MS4) permits in the Rogue River Basin. This group of general permits are highlighted because the permits require temperature monitoring at a frequency of at least one grab sample per month. The location of these NPDES permittees is shown in the HTML interactive map that accompanies this TMDL. Many of these permittees submit Discharge Monitoring Reports (DMRs) as a condition of their permit. Depending on the monitoring requirements in the permit, some permittees are required to report effluent temperature and effluent flow rates in the DMR. The frequency and type of reporting vary by permit and permit type. Some permits only require monthly, weekly, or daily grab samples while others require summary statistics such as daily maximum, daily mean, or seven-day average daily maximum. The NPDES permits require data collection and reporting via DMRs using appropriate methods based on a quality assurance and quality control plan.

Where possible, DEQ used any continuous effluent data that was provided to DEQ. When continuous data were not available, point source discharges were characterized using DMR data, if available. If neither DMR nor continuous effluent data were available, DEQ referred to permit information and other information to estimate facility discharges. Table 2-3 lists the current number of registrants for all the other general NPDES permits in the Rogue River Basin that are not listed in Table 2-2. Details on the specific point source discharges pertinent to various stream models are provided in the stream-specific model setup and calibration discussion in Sections 3.2 - 3.12.

Table 2-1: Summary: individual NPDES permitted discharges, Rogue River Basin.

Facility name (DEQ #)	Lat/Long	Permit type and description	Stream (river mile)
Allweather Wood, White City (105365)	42.4312/-122.885	NPDES-IW-B21: Timber and Wood Products - Wood preserving	Rogue River (130.5)
Ashland STP (3780)	42.2136/-122.714	NPDES-DOM-C1a: Sewage, ≥2 MGD but <5 MGD	Ashland Creek (0.2)
Boise - Medford Plywood (9539)	42.355/-122.903	NPDES-IW-B19: Timber and Wood Products - Sawmills, log storage, instream log storage.	Bear Creek (6)

Facility name (DEQ #)	Lat/Long	Permit type and description	Stream (river mile)
Butte Falls STP (12800)	42.5457/-122.57	NPDES-DOM-Da: Sewage, <1 MGD	South Fork Big Butte Creek (1)
Cascade Wood Products - White City (101757)	42.4387/-122.851	NPDES-IW-B20: Timber and Wood Products - Hardboard, veneer, plywood, particle board, pressboard manufacturing, wood products.	Military Slough (1.6)
Cave Junction Wastewater Treatment Facility (15243)	42.1757/-123.651	NPDES-DOM-Da: Sewage, <1 MGD	Illinois River (54.6)
Country View Mobile Home Estates (96385)	42.6374/-122.809	NPDES-DOM-Db: Sewage, <1 MGD with discharging lagoons	Cusick Creek (143.8)
Fleming Middle School STP (29920)	42.5173/-123.373	NPDES-DOM-Da: Sewage, <1 MGD	Harris Creek (2.8)
Gold Hill STP (33901)	42.4374/-123.077	NPDES-DOM-Da: Sewage, <1 MGD	Rogue River (118.5)
Grants Pass STP (34630)	42.4284/-123.344	NPDES-DOM-C1a: Sewage, ≥2 MGD but <5 MGD	Rogue River (100.9)
Hidden Valley High School STP (38625)	42.3286/-123.336	NPDES-DOM-Da: Sewage, <1 MGD	Applegate River (12.5)
Medford RWRF (55125)	42.4348/-122.889	NPDES-DOM-A3: Sewage, ≥10 MGD but <25 MGD	Rogue River (130.5)
Riviera Mobile Park (75500)	42.4292/-123.426	NPDES-DOM-Da: Sewage, <1 MGD	Rogue River (96)
Rogue River STP (76030)	42.4313/-123.186	NPDES-DOM-Da: Sewage, <1 MGD	Rogue River (110)
Shady Cove STP (80535)	42.6005/-122.835	NPDES-DOM-Da: Sewage, <1 MGD	Rogue River (142.5)
Valley View Landfill (104019)	42.2624/-122.736	NPDES-IW-B15: All facilities not classified elsewhere that dispose of process wastewater (includes remediated groundwater) - Tier 2 sources	Jeffery Creek (1.3)

Table 2-2: Summary: current general permit registrants (NPDES GEN01, GEN03, GEN04, and GEN40 (MS4)), Rogue River Basin.

Facility name (DEQ #)	Lat/Long	Permit type and description	Stream (river mile)
Ashland Municipal Stormwater, MS4 (113604)	42.1956/-122.696	GEN40: 4000 MS4-Phase 2 General Permit – Water Quality NPDES General Permit	Multiple discharge locations
Biomass One, Limited Partnership (100110)	42.4363/-122.851	GEN01: Industrial Wastewater; NPDES cooling water	Rogue River (131.5)
Boise Cascade – White City Veneer (9590)	42.4293/-122.856	GEN04: Industrial Wastewater; NPDES log ponds	Rogue River (131)
City of Central Point Municipal Stormwater, MS4 (126214)	42.376/-122.916	GEN40: 4000 MS4-Phase 2 General Permit – Water Quality NPDES General Permit	Multiple discharge locations
City of Eagle Point Municipal Stormwater, MS4 (126232)	42.4735/-122.806	GEN40: 4000 MS4-Phase 2 General Permit – Water Quality NPDES General Permit	Multiple discharge locations
City of Grants Pass Point Municipal Stormwater, MS4 (126215)	42.439/-123.328	GEN40: 4000 MS4-Phase 2 General Permit – Water Quality NPDES General Permit	Multiple discharge locations
City of Rogue River Municipal Stormwater, MS4 (126217)	42.436/-123.172	GEN40: 4000 MS4-Phase 2 General Permit – Water Quality NPDES General Permit	Multiple discharge locations
Harry and David (37200)	42.3009/-122.849	GEN01: Industrial Wastewater; NPDES cooling water	Bear Creek (12.5)
Josephine County Municipal Stormwater, MS4 (126216)	42.426/-123.336	GEN40: 4000 MS4-Phase 2 General Permit – Water Quality NPDES General Permit	Multiple discharge locations

Facility name (DEQ #)	Lat/Long	Permit type and description	Stream (river mile)
Medford Municipal Stormwater, MS4 (113603)	42.3278/-122.867	GEN40: 4000 MS4-Phase 2 General Permit – Water Quality NPDES General Permit	Multiple discharge locations
Murphy Rogue River Plywood Division (55170)	42.427/-123.161	GEN04: Industrial Wastewater; NPDES log ponds	Rogue River (111)
Murphy Veneer (83367)	42.4327/-122.859	GEN04: Industrial Wastewater; NPDES log ponds	Whetstone Creek (4)
ODFW – Cole M. Rivers Hatchery (64445)	42.6638/-122.684	GEN03: Industrial Wastewater; NPDES fish hatcheries	Rogue River (157)
Pacific Power & Light Company – Eagle Point (66600)	42.46/-122.845	GEN01: Industrial Wastewater; NPDES cooling water	Little Butte Creek (2)
Pacific Power & Light Company – Prospect Plant #1 (66620)	42.7331/-122.514	GEN01: Industrial Wastewater; NPDES cooling water	Rogue River (169.3)
Pacific Power & Light Company – Prospect Plant #2 (66622)	42.7331/-122.514	GEN01: Industrial Wastewater; NPDES cooling water	Rogue River (169.4)
Pacific Power & Light Company – Prospect Plant #3 (66624)	42.7306/-122.42	GEN01: Industrial Wastewater; NPDES cooling water	South Fork Rogue River (1.5)
Pacific Power & Light Company – Prospect Plant #4 (66626)	42.731/-122.515	GEN01: Industrial Wastewater; NPDES cooling water	Rogue River (169.3)
Rogue Valley Sewer Services Stormwater, MS4 (116270)	42.2667/-122.817	GEN40: 4000 MS4-Phase 2 General Permit – Water Quality NPDES General Permit	Multiple discharge locations

Table 2-3: Summary: current number of registrants to all general NPDES permits not listed in Table 2-2, Rogue River Basin.

Permit type and description	Current number of registrants
GEN02: Industrial Wastewater; NPDES filter backwash	6
GEN12A: Stormwater; NPDES sand & gravel mining	18
GEN12C(AGENT): Stormwater; NPDES construction >1 acre disturbed ground, issued by agent	6
GEN12C: Stormwater; NPDES construction >1 acre disturbed ground	114
GEN12CA: Stormwater; NPDES government agency construction, >1 acre disturbed ground	2
GEN12Z: Stormwater; NPDES specific SIC codes	49
GEN15A: Industrial Wastewater; NPDES petroleum hydrocarbon cleanup	1
GEN17A: Industrial Wastewater; NPDES wash water	8

2.1.5 Effective shade measurements

Effective shade is the percent of potential daily solar radiation flux that is blocked by vegetation and topography. DEQ and/or partner agency staff used an instrument called a solar pathfinder to collect effective shade measurements in the field. The effective shade measurement methods and quality control procedures used are outlined in the Water Quality Monitoring Technical Guide Book (OWEB, 1999) and the solar pathfinder manual (Solar Pathfinder, 2016). Table 2-4 and Figure 2-1 show the locations where effective shade measurements were collected. Data were collected in Elk Creek in August 2007, in Evans Creek and West Fork Evans Creek in July 2003, and in Little Butte Creek and tributaries in July 2001.

Table 2-4: Effective shade data collected in the Rogue River Basin.

Station ID	Station	Latitude/longitude	Effective shade (%)	Data source
11372-ORDEQ	Evans Creek at Mouth	42.4336/-123.174	38	DEQ
11372-ORDEQ	Evans Creek at Mouth	42.4336/-123.174	51	DEQ

Station ID	Station	Latitude/longitude	Effective shade (%)	Data source
11372-ORDEQ	Evans Creek at Mouth	42.4336/-123.174	35	DEQ
11372-ORDEQ	Evans Creek at Mouth	42.4336/-123.174	37	DEQ
11372-ORDEQ	Evans Creek at Mouth	42.4336/-123.174	49	DEQ
11372-ORDEQ	Evans Creek at Mouth	42.4336/-123.174	35	DEQ
11373-ORDEQ	Evans Creek downstream of Wimer Bridge	42.5331/-123.159	5	DEQ
11373-ORDEQ	Evans Creek downstream of Wimer Bridge	42.5331/-123.159	6	DEQ
11373-ORDEQ	Evans Creek downstream of Wimer Bridge	42.5331/-123.159	4	DEQ
11373-ORDEQ	Evans Creek downstream of Wimer Bridge	42.5331/-123.159	4	DEQ
11373-ORDEQ	Evans Creek downstream of Wimer Bridge	42.5331/-123.159	8	DEQ
11373-ORDEQ	Evans Creek downstream of Wimer Bridge	42.5331/-123.159	8	DEQ
11461-ORDEQ	Evans Creek at Palmerton Park	42.4397/-123.172	68	DEQ
11461-ORDEQ	Evans Creek at Palmerton Park	42.4397/-123.172	38	DEQ
11461-ORDEQ	Evans Creek at Palmerton Park	42.4397/-123.172	17	DEQ
11461-ORDEQ	Evans Creek at Palmerton Park	42.4397/-123.172	66	DEQ
11461-ORDEQ	Evans Creek at Palmerton Park	42.4397/-123.172	37	DEQ
11461-ORDEQ	Evans Creek at Palmerton Park	42.4397/-123.172	17	DEQ
11466-ORDEQ	Evans Creek downstream of Bridge 341	42.5845/-123.023	38	DEQ
11466-ORDEQ	Evans Creek downstream of Bridge 341	42.5845/-123.023	39	DEQ
11466-ORDEQ	Evans Creek downstream of Bridge 341	42.5845/-123.023	46	DEQ
11466-ORDEQ	Evans Creek downstream of Bridge 341	42.5845/-123.023	43	DEQ
11466-ORDEQ	Evans Creek downstream of Bridge 341	42.5845/-123.023	44	DEQ
11466-ORDEQ	Evans Creek downstream of Bridge 341	42.5845/-123.023	40	DEQ
25596-ORDEQ	NF Little Butte at Little Butte	42.4207/-122.612	82	DEQ
25598-ORDEQ	NF Little Butte from Fish Lake (headwater)	42.3775/-122.349	25	DEQ
25799-ORDEQ	SF Little Butte Creek upstream Beaver Dam	42.3286/-122.38	73	DEQ
30188-ORDEQ	WF Evans Creek near headwaters	42.6986/-123.107	96	DEQ
30188-ORDEQ	WF Evans Creek near headwaters	42.6986/-123.107	98	DEQ
30188-ORDEQ	WF Evans Creek near headwaters	42.6986/-123.107	83	DEQ
30188-ORDEQ	WF Evans Creek near headwaters	42.6986/-123.107	89	DEQ
30188-ORDEQ	WF Evans Creek near headwaters	42.6986/-123.107	86	DEQ
30188-ORDEQ	WF Evans Creek near headwaters	42.6986/-123.107	86	DEQ
30189-ORDEQ	WF Evans Creek downstream of Sand Creek	42.6588/-123.095	34	DEQ
30189-ORDEQ	WF Evans Creek downstream of Sand Creek	42.6588/-123.095	34	DEQ
30189-ORDEQ	WF Evans Creek downstream of Sand Creek	42.6588/-123.095	86	DEQ
30189-ORDEQ	WF Evans Creek downstream of Sand Creek	42.6588/-123.095	80	DEQ
30189-ORDEQ	WF Evans Creek downstream of Sand Creek	42.6588/-123.095	75	DEQ
30189-ORDEQ	WF Evans Creek downstream of Sand Creek	42.6588/-123.095	77	DEQ
30190-ORDEQ	WF Evans Creek downstream of Battle Creek	42.6191/-123.042	52	DEQ
30190-ORDEQ	WF Evans Creek downstream of Battle Creek	42.6191/-123.042	52	DEQ
30190-ORDEQ	WF Evans Creek downstream of Battle Creek	42.6191/-123.042	72	DEQ
30190-ORDEQ	WF Evans Creek downstream of Battle Creek	42.6191/-123.042	71	DEQ
30190-ORDEQ	WF Evans Creek downstream of Battle Creek	42.6191/-123.042	61	DEQ
30190-ORDEQ	WF Evans Creek downstream of Battle Creek	42.6191/-123.042	55	DEQ
No Station ID	Elk Creek at mouth	42.6632/-122.755	34	DEQ
No Station ID	Elk Creek at end of bottom rod upstream Alto Creek 1	42.7458/-122.705	58	DEQ
No Station ID	Elk Creek at end of bottom rod upstream Alto Creek 2	42.7458/-122.705	60	DEQ
No Station ID	Elk Creek at end of bottom rod upstream Alto Creek 3	42.7458/-122.705	10	DEQ
No Station ID	Elk Creek 1/4 mile upstream dam 1	42.6805/-122.734	10	DEQ

Station ID	Station	Latitude/longitude	Effective shade (%)	Data source
No Station ID	Elk Creek 1/4 mile upstream dam 2	42.6805/-122.734	60	DEQ
No Station ID	Elk Creek 1/4 mile upstream dam 2	42.6805/-122.734	15	DEQ
No Station ID	Elk Creek upstream dam	42.6798/-122.735	0	DEQ
No Station ID	Little Applegate River downstream of Muddy Gulch	42.1574/-122.9	85	DEQ File
No Station ID	Little Applegate River near headwaters	42.0708/-122.815	90	DEQ File
No Station ID	Little Applegate River near river mile 14.1	42.1344/-122.837	99	DEQ File
25592-ORDEQ	Little Butte upstream confluence w/ Nichols Branch	42.4823/-122.778	51.5	LBWSC/BLM
No Station ID	Little Butte upstream Hwy 62 Bridge	42.4622/-122.816	32	LBWSC/BLM
No Station ID	Little Butte above mouth in Denman	42.4485/-122.878	12	LBWSC/DEQ
14346700	Little Butte at Lake Creek Town	42.4218/-122.623	10	OWRD
25595-ORDEQ	SF Little Butte Creek at gage	42.4192/-122.613	33	OWRD
25597-ORDEQ	SF Little Butte Creek upstream Dead Indian Creek	42.3383/-122.45	24.5	OWRD
25792-ORDEQ	SF Little Butte Creek below Lost Creek	42.3796/-122.575	35.5	OWRD
25795-ORDEQ	SF Little Butte Creek upstream Soda Creek	42.3552/-122.512	87.5	OWRD

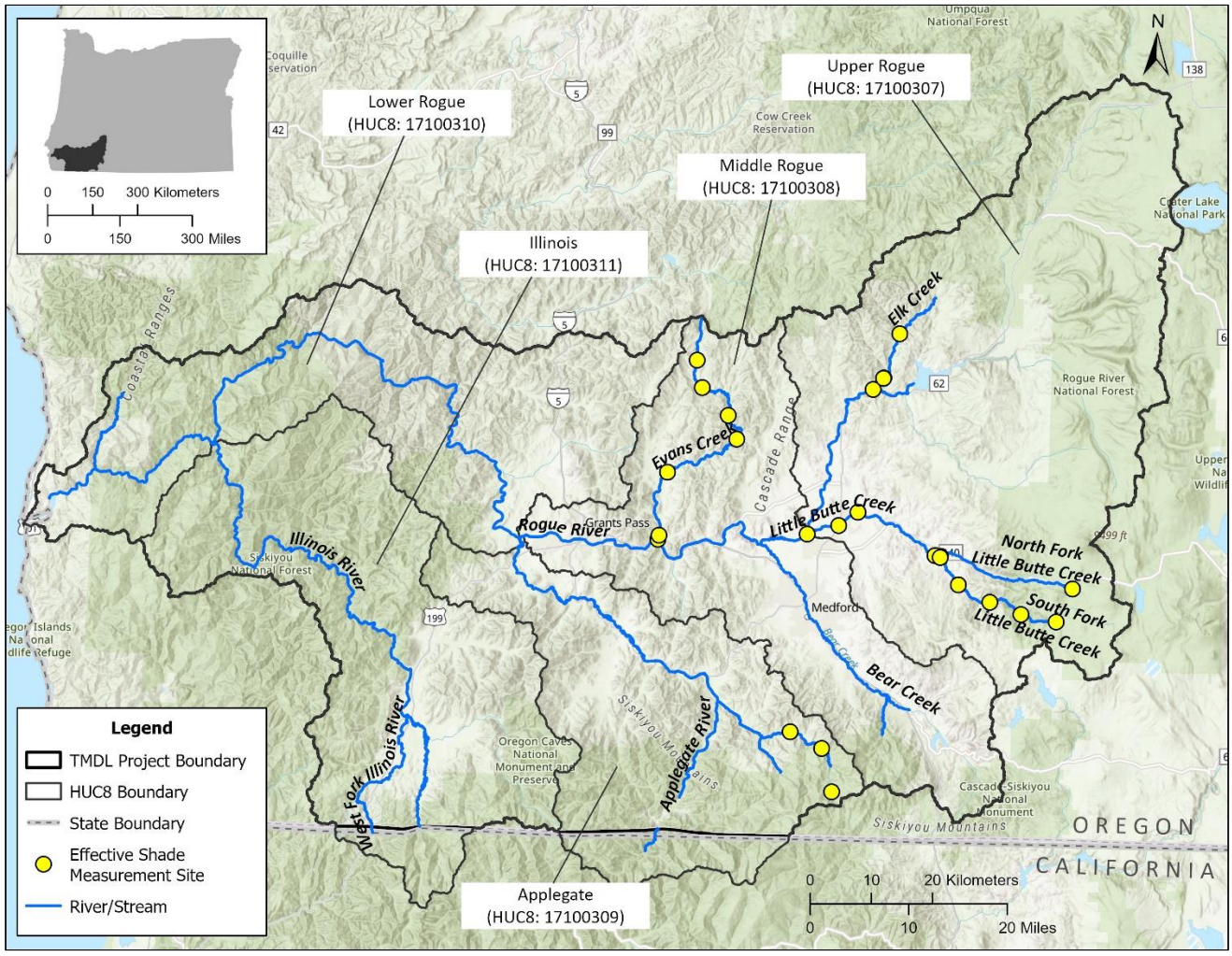


Figure 2-1: Effective shade measurement locations, Rogue River Basin TMDL project area.

2.1.6 Thermal Infrared Radiometry (TIR) temperature data

DEQ contracted with Watershed Sciences, Inc. to provide airborne Thermal Infrared Radiometry (TIR) imagery of spatial temperature patterns in the Rogue River Basin in 2001 and 2003 (Figure 2-2). TIR data are used to characterize stream thermal regimes and habitat quality. Table 2-5 summarizes TIR collection dates for all streams. TIR data details for various stream model efforts are provided in the stream-specific model setup and calibration discussions (Sections 3.2 - 3.12).

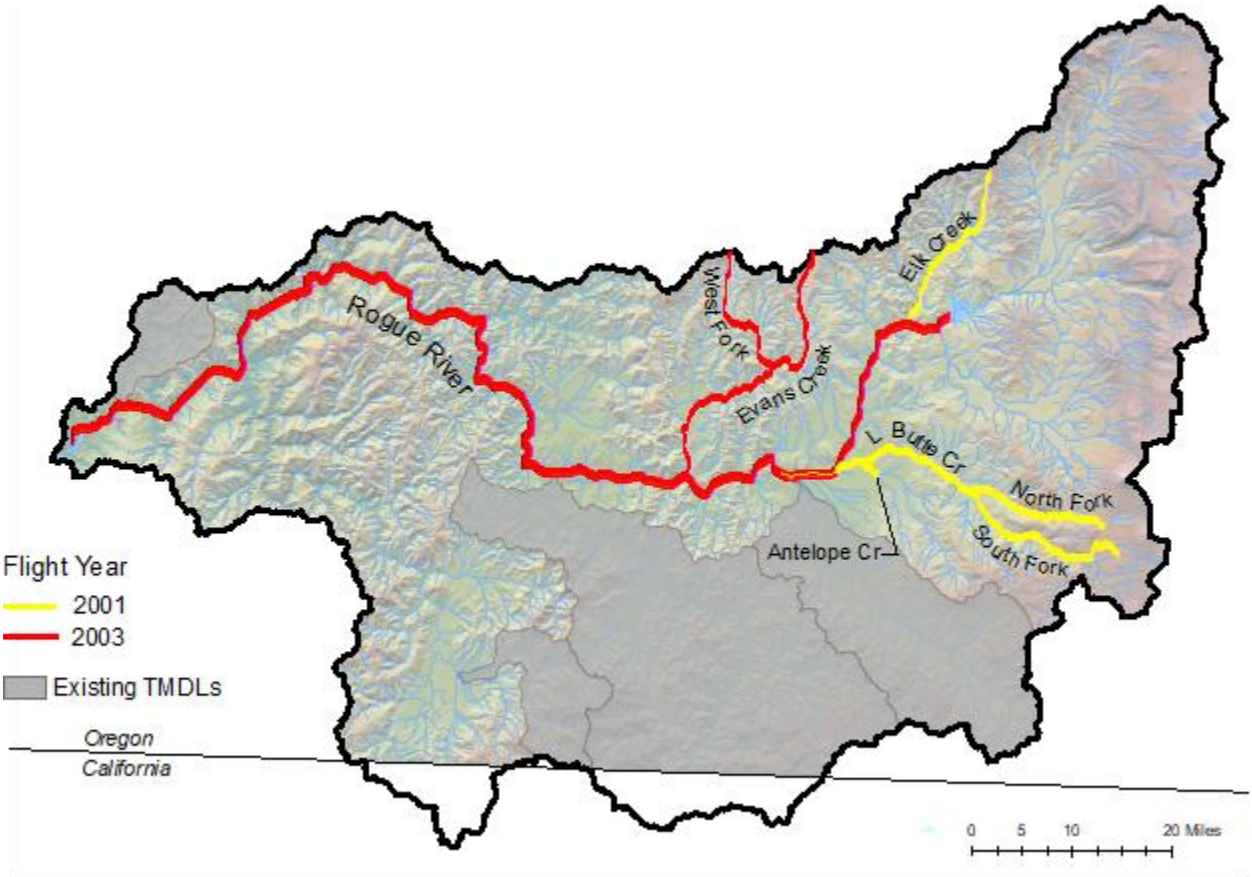


Figure 2-2: TIR flight paths, Rogue River Basin.

Thermal infrared radiometry (TIR) stream temperature data were used to:

- Develop continuous spatial temperature data sets,
- Calculate longitudinal heating profiles/gradients,
- Visually observe complex stream temperatures distributions at a large landscape scale,
- Map/identify significant thermal features,
- Develop flow mass balances, and
- Validate simulated stream temperatures.

Table 2-5: Rogue Basin model development: TIR survey extents and collection dates.

Stream	Survey extent	Date	Time	Survey distance
Antelope Creek	Mouth to Quarter Branch	2001-07-13	14:08-14:12	2.39 mi
Applegate River	Mouth to Applegate Dam	1999-07-19	15:37-16:16	75 km

Stream	Survey extent	Date	Time	Survey distance
Applegate River	Mouth to Applegate Dam	1998-08-18	15:04 - 15:43	75.4 km
Dog Face Creek	Mouth upstream 2.0 km	1998-08-18	14:24 - 14:26	2 km
East Fork Evans Creek	Mouth to headwaters	2003-08-01	14:24-15:00	17.7 mi
East Fork Williams Creek	Mouth to just upstream of Rock Creek	1999-07-21	15:23-15:25	4.1 km
Elk Creek	Mouth to headwaters	2001-07-14	13:43-14:19	19.49 mi
Evans Creek	Mouth to Forks	2003-08-01	13:50-14:22	19.1 mi
Fish Lake	Lake shoreline	2001-07-13	15:41-15:48	5.3 mi
Glade Creek	Mouth to approximately 1620 meters downstream of Jack Creek	1998-08-18	14:05 - 14:09	6.4 km
Little Applegate River	Mouth to headwaters	1999-07-21	14:26-14:45	32.3 km
Little Applegate River	Mouth to approximately 790 m upstream of Bear Gulch	1998-08-18	13:30 - 13:52	30.5 km
Little Butte Creek	Mouth to Forks	2001-07-13	14:04-14:34	16.67 mi
McDonald Creek	Mouth to headwaters	1998-08-18	13:54 - 13:59	6.8 km
North Fork Little Butte Creek	Mouth to Fish Lake	2001-07-13	15:19-15:40	15.41 mi
Rogue River	Gold Ray Dam to Little Butte Creek	2001-07-13	13:55-14:02	6.76 mi
Rogue River	Ferry Hole Bar to Applegate River	2003-07-30	14:30-15:59	91.9 mi
Rogue River	Pickett Creek to Lost Creek Lake	2003-07-31	14:20-15:29	71.4 mi
Slate Creek	Mouth to approximately 1,180 m upstream of Butcherknife Creek	1998-08-18	13:16 - 13:31	12.2 km
South Fork Little Butte Creek	Mouth to headwaters	2001-07-13	14:34-15:07	21.68 mi
Sterling Creek	Mouth to Miller Gulch	1998-08-18	14:33 - 14:41	7.8 km
Thompson Creek	Mouth to Ninemile Creek	1998-08-18	14:03 - 14:10	13 km
West Fork Evans Creek	Mouth to headwaters	2003-08-01	15:10-15:41	16.3 mi
West Fork Williams Creek	Mouth to just upstream of Lone Creek	1999-07-21	15:28-15:31	5.4 km
Williams Creek	Mouth to East Fork Williams Creek	1999-07-21	15:13-15:21	11.3 km
Williams Creek	Mouth to East Fork Williams Creek	1998-08-18	13:45 - 13:57	11.1 km
Yale Creek	Mouth to Headwaters	1998-08-18	14:15 - 14:21	6.9 km

TIR imagery measures the temperature of the outermost portions of the bodies/objects in the image (i.e., ground, riparian vegetation, and stream). The bodies of interest are opaque to longer wavelengths and there is little, if any, infrared penetration of the bodies.

TIR data were collected through a helicopter-mounted sensor that collected data to an on-board computer at a rate to ensure a continuous image overlap of ≥40%. The TIR detected emitted radiation at 8-12 µm wavelengths (long-wave) and recorded emitted radiation levels as a digital image across the sensor's full 12-bit dynamic range. Each image pixel contained a measured value that was converted to temperature. Each thermal image had a spatial resolution of <0.5 m/pixel. A visible video sensor captured the same field-of-view as the TIR sensor, with GPS time encoded on the imagery.

Data collection was timed to capture maximum daily stream temperatures, which typically occur between 1400h – 1800h. The helicopter was flown longitudinally over the stream channel center with the sensors in a vertical (or near-vertical) position. Generally, the flight altitude was selected so that the stream channel occupied approximately 20-40% of the image frame. A minimum altitude of approximately 300m was used for maneuverability and safety reasons. If the stream split into two channels that could not be covered in the sensor's field of view, the survey was conducted over the larger of the two channels.

In-stream temperature data loggers (Onset Stowaways or VEMCOs) were deployed in each subbasin prior to the survey to ground-truth the TIR-measured radiant temperatures. TIR data can be viewed as GIS point coverages or TIR imagery.

Direct observation of spatial temperature patterns and thermal gradients is a powerful application of TIR-derived stream temperature data. Thermally significant areas can be identified in a longitudinal stream temperature profile and related to specific sources (i.e., water withdrawal, tributary confluence, vegetation patterns, etc.). Areas where stream water mixes with subsurface flows (i.e., hyporheic and inflows) are apparent and often dramatic in TIR data. Thermal changes captured with TIR data can be quantified as a stream temperature change or gradient that indicates a temperature change over a specified distance.

2.2 GIS-derived data

For model setup, several spatial datasets were derived from landscape-scale GIS data. Sampling density was user-defined and typically matched GIS data resolution and accuracy. The derived parameters used in stream temperature analyses were:

- Stream position and aspect,
- Stream elevation and gradient,
- Maximum topographic shade angles (East, South, West),
- Channel width,
- Landcover classification and mapping, and
- Tributary stream temperatures and flow.

Details on derived data used in various stream models are provided in the stream-specific model setup and calibration discussion (Sections 3.2 - 3.12).

2.2.1 10-meter digital elevation model (DEM)

A digital elevation model (DEM) consists of digital information that provides a uniform matrix of terrain elevation values (Figure 2-3). It provides basic quantitative data to derive terrain elevation, stream elevation, stream slope, and topographic information. The 10m DEM contains a land surface elevation value for each 10m square. The USGS produced these digital geographic files as part of the National Mapping Program in 1999.

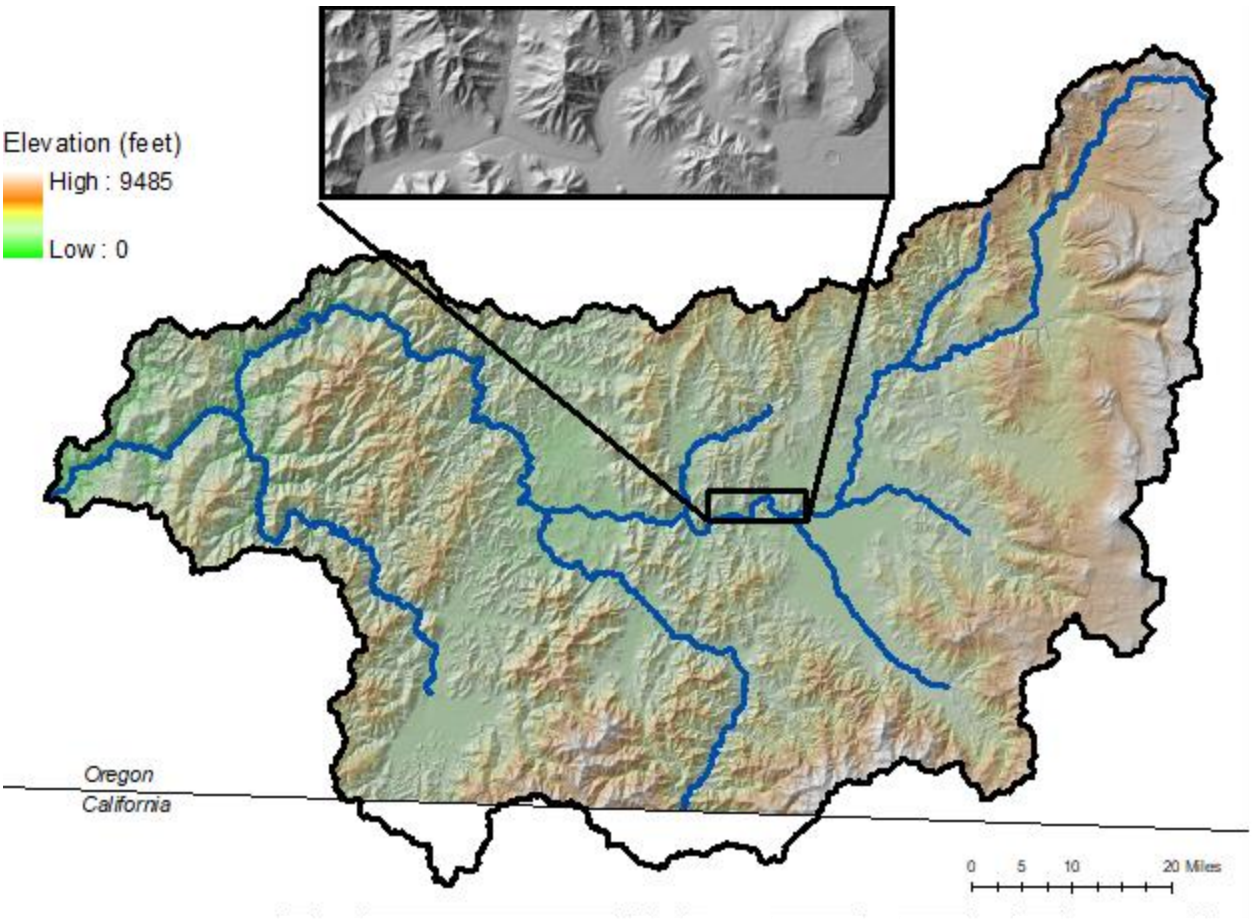


Figure 2-3: Rogue River Basin 10-meter DEM, hill-shaded for contrast (zoom of Rogue River).

2.2.2 Aerial imagery: Digital orthophoto quads (DOQs)

A digital orthophoto quad (DOQ) is a digital image of an aerial photograph from which displacements caused by the camera angle and terrain have been removed. DOQs are projected in map coordinates and thus combine photographic image characteristics with map geometric qualities. For this analysis, color DOQs were provided by Jackson County (images from 2001 – 2003) and Josephine County (images from 2002).

These were used to:

- Map/digitize stream features such as position, channel edges, and wetted channel edges,
- Map/digitize near-stream vegetation, and
- Map/digitize instream structures such as dams, gages, and unmapped diversions/withdrawals.

2.2.3 WRIS and POD data: Water withdrawal mapping

The OWRD maintains the Water Rights Information System (WRIS), which is a database of Oregon water rights information. Another database tracks points of diversions (POD). DEQ linked these two databases to map Rogue River Basin water use diversion locations, rates, and types (Figure 2-4**).**

Consumptive use was estimated using these data and incorporated in developing mass balance flow profiles for the simulated streams.

WRIS and POD Data were used to:

- Map stream diversions/withdrawals,
- Associate an estimated flow rate to each diversion/withdrawal

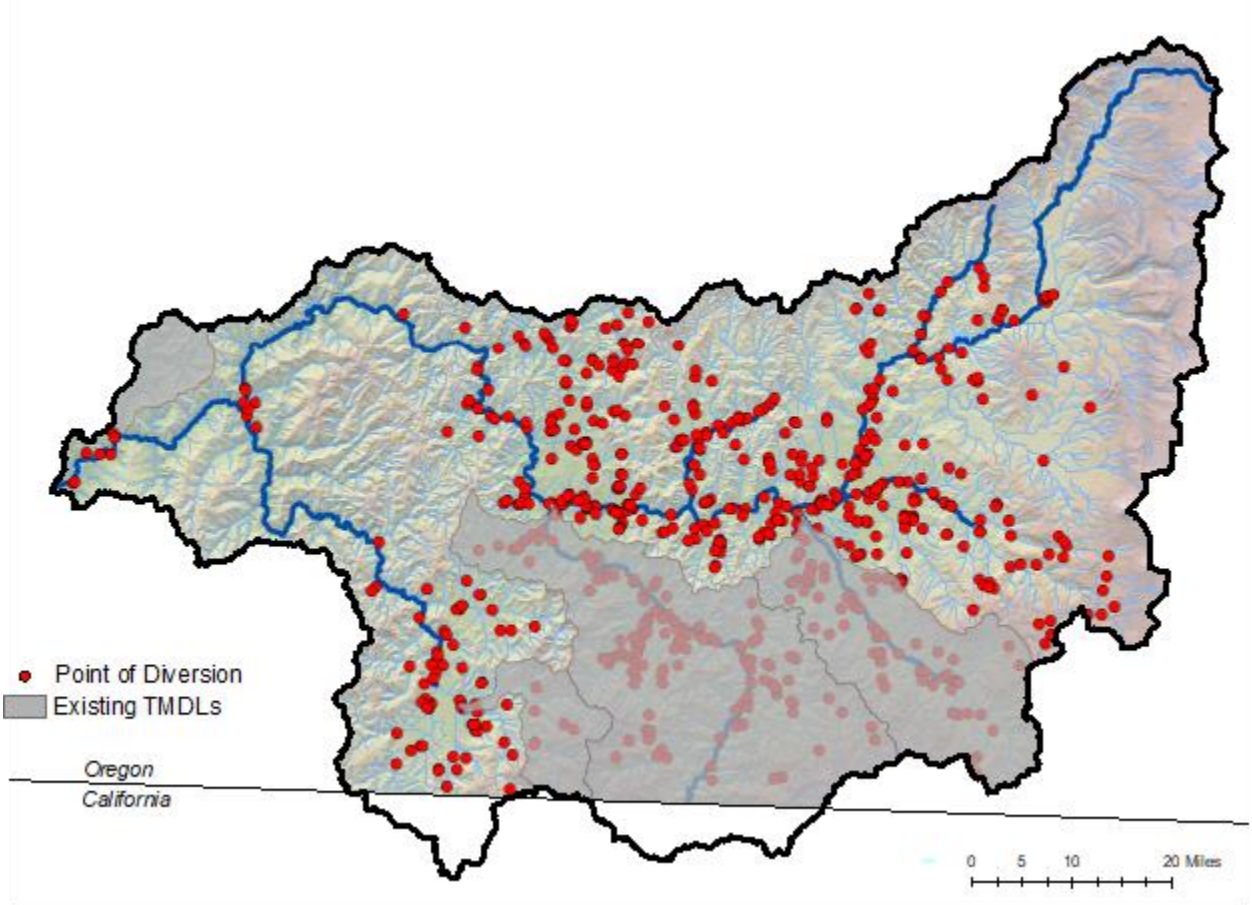


Figure 2-4: Rogue River Basin points of diversion derived from WRIS and POD databases (OWRD).

2.2.4 Stream position, elevation, gradient, and channel width

The Heat Source 8 model (DEQ, 2012) assumes a trapezoidal channel shape and required channel bottom width inputs (b_2) (Figure 2-6) that were estimated with Equation 2-1. For Equation 2-1, the active channel width (b_1) was the digitized channel width (Section 2.2.3). Mean depth (D) was calculated as b_1/(width:depth) (measured or estimated) at each node. Channel angle (z) and the width:depth ratios were estimated model calibration parameters. Stream gradients were calculated as the inter-node elevation change divided by the inter-node distance. The stream position and channel width assessment steps were:

1. **Stream channel edges were digitized from DOQs at a 1:5,000 or less map scale (Figure 2-5).** These channel boundaries established the active channel width, which was defined for TMDL purposes as the width between shade-producing near-stream vegetation on each bank. Where near-stream vegetation was absent, the near-stream boundary was used, which

was defined as downcut stream banks or areas where the near-stream zone was unsuitable for vegetation growth due to external factors (e.g., roads, railways, buildings, etc.).

2. **Channel widths were sampled every 50m using TTools.** The sampling algorithm measured the channel width in the transverse direction relative to the stream aspect.

3. **Comparison of sampled channel widths and measured ground levels.** TTools-sampled channel widths were compared to ground level measurements for quality assurance.

4. **Channel bottom widths** were derived by assuming a trapezoidal channel with parameterized side slopes and width-to-depth ratios.

Equation 2-1

$$b_2 = b_1 - 2 \cdot z \cdot \mathrm{D}$$

where,

$b_2 =$	Bottom width (m)
$b_1 =$	Active channel width (m)
$\mathrm{D} =$	Mean active channel depth (m). Estimated as b_1/(width:depth).
$z =$	Channel angle (unitless), defined as the horizontal distance change per unit vertical distance change of the channel side slope.



Figure 2-5: Example: Digitized channel (blue line) and stream nodes (green dots) for Heat Source 8.

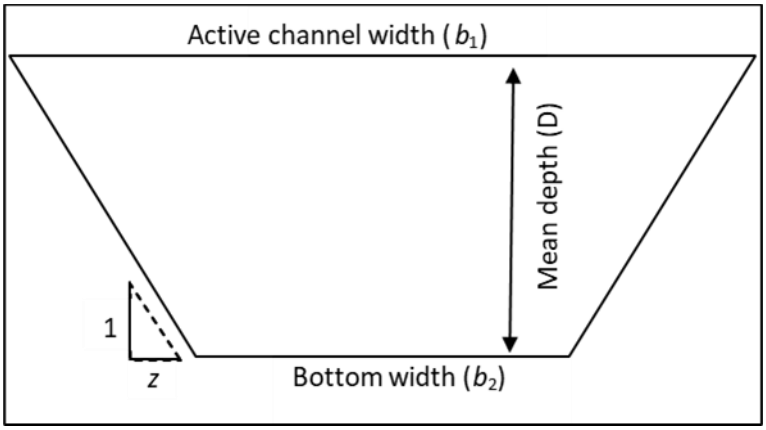


Figure 2-6: Conceptual diagram of Equation 2-1: trapezoidal channel and terms.

2.2.5 Topographic shade angles

A topographic shade angle represents the vertical angle from a node along a flat horizon to the highest (visible) topographic feature in each direction. When the sun's angle is less than or equal to the topographic shade angle, the referenced topographic feature casts a shadow over the referenced stream node. Topographic shade angles were used to derive effective shade information for the current conditions model and various modeled scenarios. Topographic shade angles were determined through stream-specific GIS analysis for three directions (W, S, E) using Equation 2-2.

Equation 2-2: Topographic shade angle calculation.

$$\boldsymbol{\theta_T = \tan^{-1}\left(\frac{Z_T - Z_S}{d}\right)}$$

where,

$\theta_T =$ The topographic shade angle (°).
$Z_T =$ The elevation (m) at the topographic feature.
$Z_S =$ The elevation (m) at the stream node.
$d =$ Horizontal distance (m) from stream node to topographic feature.

Because there is a direct and quantifiable relationship between effective shade and thermal flux, OAR 340-042-0030(14) and OAR 340-042-0040(5)(b) allow the use of effective shade as a surrogate measure target for thermal loading targets. One benefit of this surrogate measure is that it is simpler and thus more feasible for many practitioners to assess effective shade than thermal loading in their management areas.

2.2.6 Land cover mapping

Variable Rogue River Basin vegetation conditions required a higher resolution than GIS data sources available for the original TMDL. To meet this need, DEQ mapped vegetation using DOQs at a 1:5,000 map scale. Existing vegetation was digitized and sampled for streams with TIR data (Figure 2-7). Vegetation features were mapped for 300' in the transverse direction from channel edge. Vegetation data was developed by DEQ using the following successive steps:

1. **Vegetation polygons and stream polylines were digitized from DOQs**. All digitized polygons were drawn to capture visually similar vegetation features. All digitized line work was completed at a 1:5,000 map scale or less.

2. **Basic vegetation types were categorized and assigned to individual polygons.** The vegetation categories used in this effort were aggregate vegetation groups, e.g., conifers, hardwoods, shrubs, etc. Existing heights and densities were assigned according to aerial photograph analysis and ground level data collection.

3. **Two-dimensional automated sampling was conducted** on classified vegetation spatial data sets with TTools. Every 50m along the stream (i.e., in the longitudinal direction), vegetation was sampled radially, in seven directions, every 15m from the channel center out to 60m. This sampling rate resulted in 29 vegetation measurements per stream node (928 per stream mile).

4. **Ground level vegetation data were statistically summarized and sorted** by vegetation type. Median values for vegetation height and density were then used to describe DEQ vegetation classifications.

Figure 2-8 summarizes the vegetation classification steps. Boyd and Kasper (2003) provide detailed methodological information.

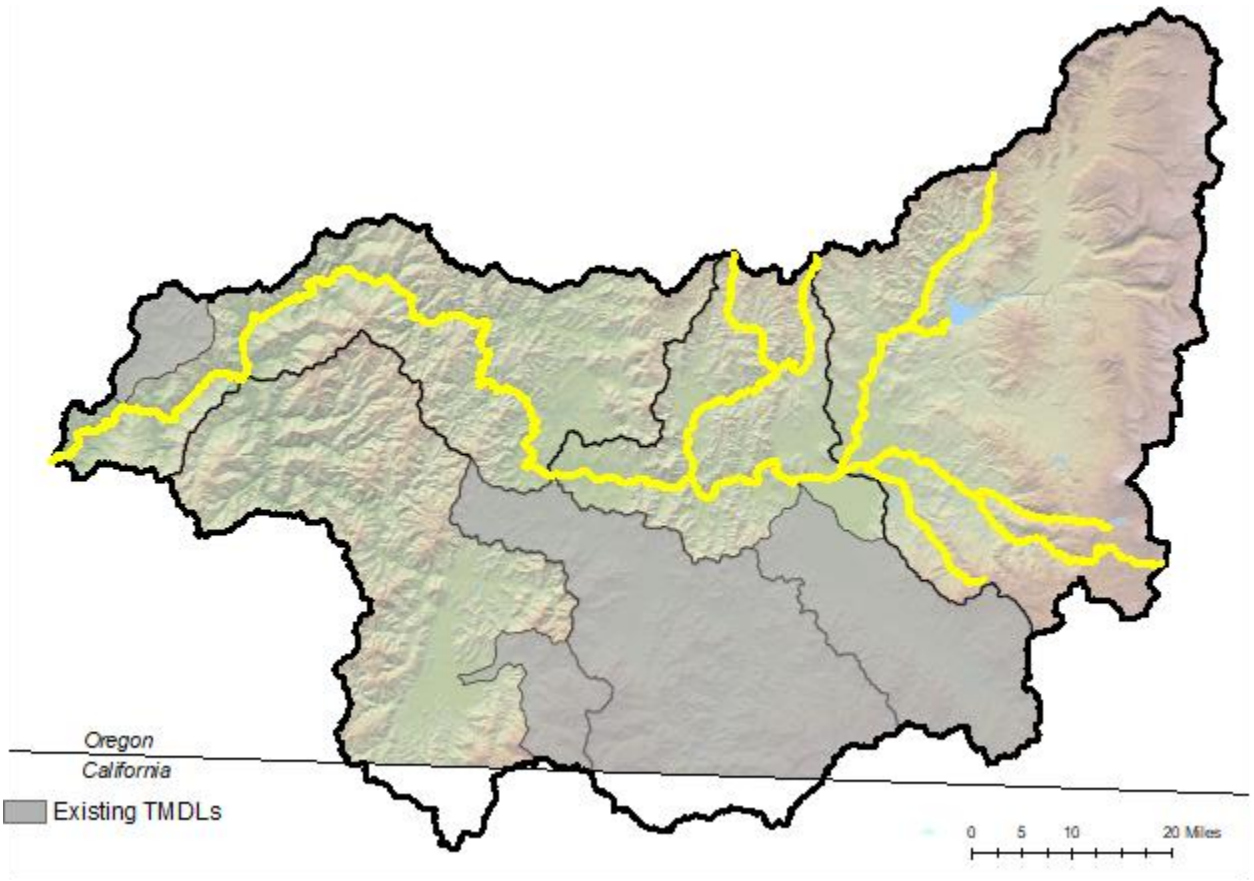


Figure 2-7: Streams with digitized near-stream vegetation and channel morphology.

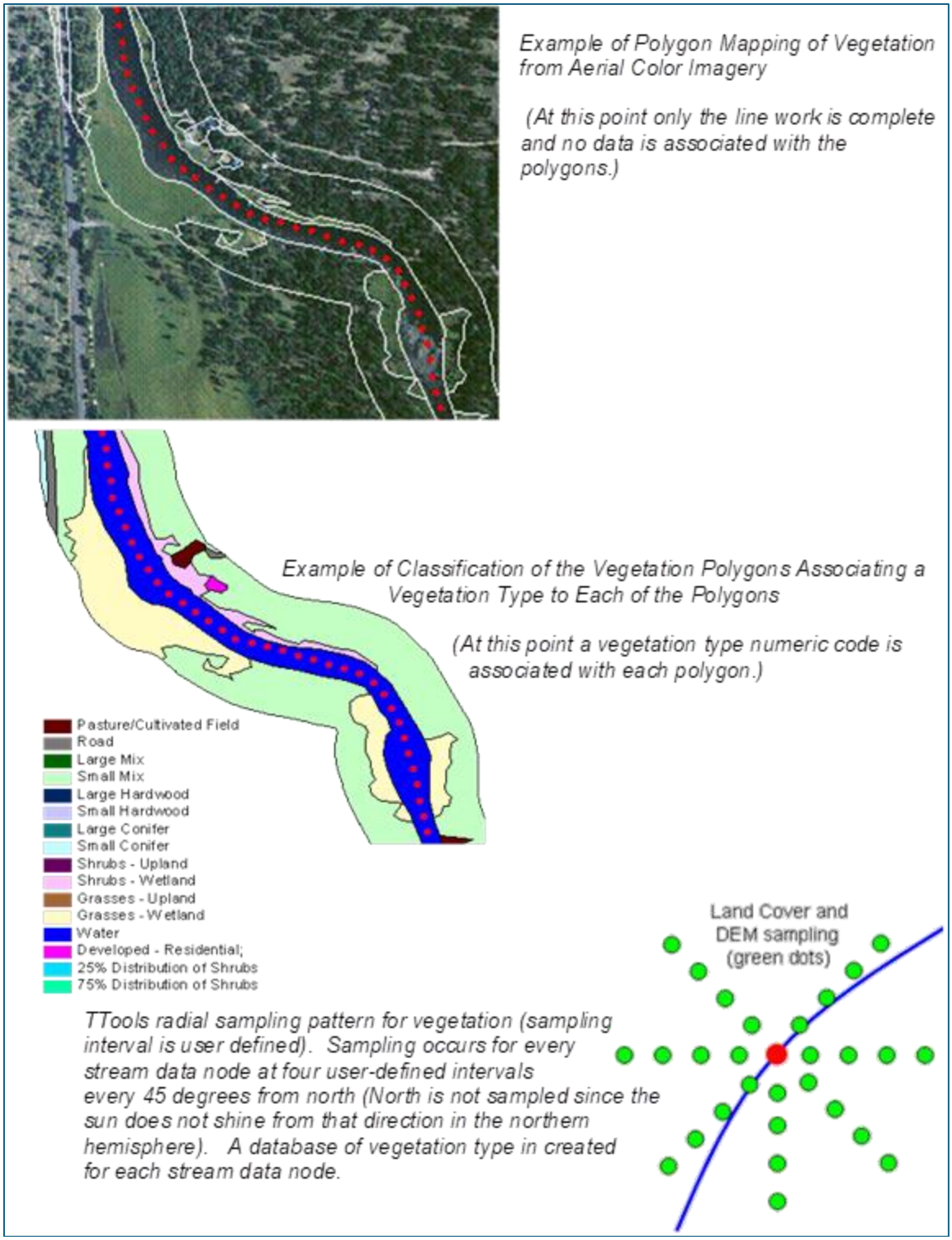


Figure 2-8: Visual summary: vegetation digitization and classification steps.

Table 2-6: Land cover codes used in land cover mapping (Heat Source 8).

Code	Description	Height (m)	Density (%)	Overhang (m)
301x	Water	0	0%	0.0

Code	Description	Height (m)	Density (%)	Overhang (m)
301y	River Bottom or Floodplain	0	0%	0.0
302x	Pasture/Cultivated Field/Lawn	0	0%	0.0
302y	Young Orchard	3	75%	0.5
303	Mature Orchard	12.2	75%	1.8
304	Barren-Rock	0	0%	0.0
305	Barren-Embankment	0	0%	0.0
306	Barren-Campground	0	0%	0.0
307	Barren-Gravel Pit	0	0%	0.0
308	Barren-Clear Cut	0	0%	0.0
309	Clearcut, below 50% dense regeneration	4.6	25%	0.7
321	Lumber Yard	0	0%	0.0
400	Barren-Road	0	0%	0.0
401	Barren-Forest Road	0	0%	0.0
402	Barren-Railroad	0	0%	0.0
403	Barren-Ag.Road	0	0%	0.0
500	Large Mixed Conifer/Hardwood (>75% Canopy)	24.4	75%	3.7
501	Small Mixed Conifer/Hardwood (>75% Canopy)	12.2	25%	1.8
550	Large Mixed Conifer/Hardwood (>25% Canopy)	24.4	75%	3.7
551	Small Mixed Conifer/Hardwood (>25% Canopy)	12.2	25%	1.8
600	Large Hardwood (>75% Canopy)	24.4	75%	3.7
601	Small Hardwood (>75% Canopy)	12.2	75%	1.8
650	Large Hardwood (>25% Canopy)	24.4	25%	3.7
651	Small Hardwood (>25% Canopy)	12.2	25%	1.8
700	Large Conifer (>75% Canopy)	24.4	75%	3.7
701	Small Conifer (>75% Canopy)	12.2	75%	1.8
750	Large Conifer (>25% Canopy)	24.4	25%	3.7
751	Small Conifer (>25% Canopy)	12.2	25%	1.8
800	Shrubs (>75% Canopy)	4.6	75%	0.7
850	Shrubs (>25% Canopy)	4.6	25%	0.7
900	Grasses	1	75%	0.2
324x	Developed-Residential Buildings	6.1	100%	0.9
324y	Developed-Industrial Buildings	9.1	100%	1.4
325x	Dam	0	0%	0.0
325y	Pipeline	0	0%	0.0
325z	WWTP	0	0%	0.0

2.2.7 Land ownership or management responsibility

Anthropogenic stream warming caused by nonpoint sources is closely associated with the uses, the activities, and the condition of vegetation adjacent to the stream. How activities and uses are managed in these areas is partially determined by a variety of different rules and management plans established by the landowner and any agency with land use authority. To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (DMAs).

A DMA is defined in OAR 340-042-0030(2) as a federal, state, or local governmental agency that has legal authority over a sector or source contributing pollutants. Typically, persons or designated management agencies that are identified in the TMDL Water Quality Management Plan (WQMP) are responsible for developing TMDL implementation plans and implementing management strategies to reduce pollutant loading. The DMAs relevant to specific streams are discussed in the model setup, Section 3.

2.2.8 Effective shade curves

Effective shade curves are plots that present the maximum possible effective shade as a function of natural near-stream vegetation type, active channel width, and stream aspect. Channel width is plotted on the x-axis, effective shade is on the y-axis, and each line represents a different stream aspect. Each natural vegetation type expected in the TMDL project area has its own plot. The plots are called *effective shade curves* because they resemble gentle downward-sloping curves. As channel width increases, effective shade decreases. The plots were produced from results of Heat Source version 6 shade models that were parameterized with all combinations of the aforementioned factors.

The effective shade curve approach can be used almost anywhere to quantify background solar radiation loading and the effective shade necessary to eliminate temperature increases from anthropogenic near-stream vegetation removal or disturbance. This approach may also be used to develop lookup tables to determine effective shade based on other combinations of vegetation height, density, overhang, and buffer widths. For TMDL users, such lookup tables are convenient to estimate effective shade for current conditions without need of a model. Additionally, lookup tables may be used to "reverse-lookup" the vegetation height, density, and buffer width required to achieve a certain effective shade. The main TMDL document includes these lookup tables and plots.

Sections 2.2.8.1 to 2.2.8.6 describe the general shade curve methods. For area-specific shade curve details, see the relevant Section 3 subsections.

2.2.8.1 Model domain

The model domain is not specific to any waterbody but was parameterized using a latitude and longitude in the TMDL area to ensure that the modeled solar altitude and sun angles were appropriate for the area.

2.2.8.2 Spatial and temporal extent

The effective shade model period is a single day (August 1) in a given year. This day was selected to characterize solar loading when maximum stream temperatures are typically observed, the sun's angle is greatest, and the solar exposure period is longest.

2.2.8.3 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30m. Outputs are generated every 100m. The spatial resolution is not meaningful for the shade curves, however, since each output distance step simply represents a unique combination of the modeled vegetation and channel condition variables. The model time step (*dt*) is 1 minute and outputs are generated every hour.

2.2.8.4 Source characteristics

Effective shade curve models quantify background solar radiation loading and the effective shade necessary to eliminate temperature increases from anthropogenic near-stream vegetation disturbance or removal. The lookup tables can be used to estimate existing shade or current solar loading. This model did not evaluate other potential sources of thermal loading.

2.2.8.5 Important assumptions

The effective shade curve models assumed no clouds or topographic shade. The modeled terrain is assumed flat, i.e., the stream and adjacent vegetation buffer area have identical ground elevation. The vegetation density, height, overhang, and buffer width are assumed equal on both stream banks. The active channel width is assumed to equal the distance between the near-stream vegetation on opposing stream banks.

Effective shade curves were developed for the original Applegate Subbasin TMDL (DEQ, 2004), Bear Creek Watershed TMDL (DEQ, 2007), Lobster Creek Watershed TMDL (DEQ, 2002a), and Rogue River Basin TMDL (DEQ, 2008). The existing shade curve models were retained without adjustment for this replacement TMDL project.

2.2.8.6 Model inputs

There are two categories of models, each with different sets of inputs:

- Effective shade curves: Model input values for vegetation height, density, overhang, and buffer width corresponded to the restored streamside vegetation types expected in areas currently lacking streamside vegetation due to anthropogenic disturbance. For the streams pertinent to this TMDL, the specific values applied were those applied in the Applegate Subbasin TMDL (DEQ, 2004), Bear Creek Watershed TMDL (DEQ, 2007), Lobster Creek Watershed TMDL (DEQ, 2002a), and Rogue River Basin TMDL (DEQ, 2008). TMDL Section 9.4 and TMDL Table 9-24 provide information on the model inputs used to develop shade curves.

- Effective shade lookup tables: TMDL Section 13 provides effective shade curve tables for this TMDL.

2.2.9 Derived tributary streamflows

When flow data were unavailable for a given tributary to a modeled stream for the model period, streamflow was estimated based on either historical data for the stream or on model period data from proxy monitoring site(s). For small tributary inputs, a constant flow was often assigned if detailed proxy or historical data were unavailable. In some cases, constant flow rates were derived using TIR data and a mass balance approach. Otherwise, flows were estimated using StreamStats v4 (USGS, 2019) and the flow-percentile-percentile-flow (QPPQ) method to derive time-series data for target unmonitored locations from proxy (monitored) locations based on their relative characteristics and the proxy streamflow data (Lorenz and Ziegeweid, 2016; Ziegeweid et al, 2015). DEQ staff identified suitable proxy stations for StreamStats parameterization based on between-location similarities in location, stream aspect, land cover, and watershed size. Proxy information for

locations represented by derived flow data is provided in Section 3 in the stream-specific model "Flow Inputs" subsections.

2.3 Additional data derivation methods

Non-steady state stream models typically require large datasets because of the large spatial and temporal model extents. As model extent increases, the model parameterization data requirements also increase. Often it is infeasible to parameterize a model solely with field data due to resource limitations or other impracticalities in required data acquisition. Generally, data gaps may be addressed in several ways. Table 2-7 summarizes the data derivation methods used to address data gaps to parameterize models for this TMDL.

To the extent possible, the methods used to derive parameters for existing TMDL models have been summarized in the boundary conditions and tributary inputs tables in Section 3.

Table 2-7: Methods to derive model parameters for data gaps.

Method	Possible parameters	Description
Direct surrogate	Tributary temperatures, meteorological inputs, sediment	Neighboring or nearby tributary watersheds often share climatological and landscape features. Model parameters with incomplete records or no data may be parameterized with data from neighboring or nearby locations with available data.
Calibration adjustment	All inputs	Sometimes, appropriate representation of an important input is required for a model, but information on that input is lacking. For example, groundwater influx and temperatures are important parameters that may be derived during calibration by adjusting them within acceptable ranges identified in literature or other studies.
Literature-based values	All inputs	Literature values are often used for unquantified model parameters or inputs where site-specific information is lacking. Example parameters include streambed heat transfer properties, hyporheic characteristics, or substrate porosity (Bencala and Walters, 1983; Hart, 1995; Pelletier et al., 2006; Sinokrot and Stefan, 1993).
Mass balance Flow balance	Tributary temperature and flow	For modeled reaches, a mass balance can be used to estimate tributary flow if tributary temperature is known, and vice versa. Often, TIR data are used to estimate tributary flow because upstream, downstream and tributary temperatures are known, and upstream and tributary flows are known (or estimated). A flow balance may also be used (without temperature data) to estimate tributary flows; this requires some available upstream/downstream flow data to estimate the tributary flow inputs between the upstream/downstream points.
Simple linear regression	Tributary temperature and flow	Parameters such as flow and temperature in neighboring or nearby tributaries often have similar diurnal patterns or hydrographs, which may be appropriate for simple linear regression to address data gaps for those inputs. To develop this relationship, the incomplete dataset must have some existing data.

Method	Possible parameters	Description
Drainage area ratio	Tributary flow	For ungaged tributaries, flows can be estimated from the ratio between the drainage areas of the ungaged location and a nearby gaged tributary (Ries et al., 2017; Risley, 2009; Gianfagna, 2015). For example, if the drainage area of an ungaged tributary is 5km^2 and that of a gaged tributary is 10km^2, then the ungaged tributary flows are estimated to be 50% of the gaged tributary flows. This method is typically used to calculate low-flow or flood frequency statistics. In that context, a weighting factor is recommended if the drainage area ratio of the two sites is between 0.5 - 1.5. Weighting factors can be evaluated if instantaneous observed flows are available at the ungaged location.
Adiabatic adjustment	Air temperature	Air temperature can vary significantly throughout a watershed, particularly with large elevation differences between headwaters and the drainage mouth. Air temperatures may be adjusted to account for such differences with an equation that relates air temperature at two different elevations based on the elevation difference and the dry adiabatic lapse rate of 9.8°C/km.
GIS Data	Channel position and width, landcover, gradient, elevation, topographic shade angle	Several landscape-scale GIS datasets can be used to derive various model parameters. E.g., digital orthophotos quads (DOQs) are used to classify landcover and estimate vegetation type, height, density, and overhang. DOQs can also be used to determine stream position, stream aspect, and channel width. Likewise, a DEM consists of digital information that provides a uniform matrix of terrain elevation values. It provides basic quantitative data to derive surface elevation, stream gradient, and maximum topographic shade angles.

3 Model setup and calibration

3.1 Background and general set-up methods

3.1.1 Model selection

Table 3-1 lists waterbodies in the TMDL area where models were previously developed and were available for this TMDL effort; the associated TMDLs include the Applegate Subbasin TMDL (DEQ, 2004), Bear Creek Watershed TMDL (DEQ, 2007), Lobster Creek Watershed TMDL (DEQ, 2002a), and Rogue River Basin TMDL (DEQ, 2008). The extent and location of these models is shown in the HTML interactive map that accompanies this TMDL.

Table 3-1: Waterbodies where previously developed models were available.

Model version	Model waterbody
Heat Source version 6 temperature model	Lobster Creek
Heat Source version 6 shade model	Bear Creek
Heat Source version 8 temperature model	Antelope Creek, Elk Creek, Evans Creek and West Fork Evans Creek, Little Butte Creek and North Fork Little Butte Creek, Rogue River, South Fork Little Butte Creek
SHADOW shade model	Multiple streams in the Applegate Subbasin, Bear Creek Watershed, and Lobster Creek Watershed (see sections 3.3, 3.5, and 3.10)

The Heat Source stream thermodynamics model (Boyd and Kasper, 2003) was used to model several streams for the development of TMDLs in the Rogue River Basin (DEQ, 2002a; DEQ, 2002b; DEQ, 2004; DEQ, 2007; and DEQ, 2008). Because these models already exist and meet all the

model framework needs, Heat Source was selected for stream temperature simulation in the project area. The Heat Source model was originally developed at Oregon State University as a master's thesis where it was evaluated and approved by an academic committee (Boyd, 1996). Development of the model continued and in 1999 DEQ submitted the model equations and methodology for peer review (DEQ, 1999a) and again in 2004 to the Independent Multidisciplinary Science Team (IMST, 2004) where the model was found to be scientifically sound.

The Heat Source model was used to simulate hourly stream temperatures, solar radiation fluxes, daily effective shade, and stream temperature responses in modeled stream. Figure 3-1 provides an overview of where the Heat Source model was used to simulate temperature conditions. Section 6.1 of the QAPP (DEQ 2024) describes the various Heat Source model versions and their inputs, quality assurance, and output.

The setup and calibration for the Heat Source models listed in Table 3-1 was completed by DEQ and documented in the Applegate Subbasin TMDL (DEQ, 2004), Bear Creek Watershed TMDL (DEQ, 2007), Lobster Creek Watershed TMDL (DEQ, 2002a), and Rogue River Basin TMDL (DEQ, 2008). The SHADOW models are shade-only models that were developed and calibrated by the BLM, USFS, and Lower Rogue Watershed Council. DEQ did not adjust the existing calibrated models for this project.

Not listed in Table 3-1 are existing: SHADOW models for various streams in the Sucker Creek Watershed (DEQ, 1999b; DEQ, 2002b); Heat Source temperature models for Sucker Creek (DEQ, 2002b), Applegate River, and the Little Applegate River (DEQ, 2004); and Heat Source shade models for Cheney Creek, Thompson Creek, Slate Creek, and Waters Creek in the Applegate Subbasin (DEQ, 2004). These models were documented in their respective TMDLs but are missing from DEQ's files. DEQ did not replace these models with new ones. Instead DEQ applied a "Shade Curve" approach for these areas as described in Section 2.2.8.

DEQ developed effective shade curves for all waterbodies not specified in Table 3-1. Effective shade curves represent the maximum possible effective shade for different vegetation types, stream widths, and stream aspect. All combinations of these conditions are modeled in Heat Source to develop effective shade estimates. The results are summarized in a shade curve plot. The results can also be summarized in a lookup table with additional combinations of vegetation height, density, and buffer width included. Effective shade curves were developed for the original Applegate Subbasin TMDL (DEQ, 2004), Bear Creek Watershed TMDL (DEQ, 2007), Lobster Creek Watershed TMDL (DEQ, 2002a), and Rogue River Basin TMDL (DEQ, 2008). Adjustments to the existing shade curve models were not completed for this project.

3.1.2 General background, purpose, and objectives

Stream temperature TMDLs are generally scaled to the subbasin- or basin-scale since water temperatures are influenced by cumulative effects of upstream and local sources. Accordingly, this TMDL considered all surface waters that affect the temperatures of 303(d)-listed waterbodies (e.g., the Rogue River) in the basin. To address listings in this TMDL, the analysis considered all upstream waters of the state and applies TMDL allocations through the entire stream network. While no new calibrated current conditions models were developed for this TMDL, some new model scenarios were developed; this appendix describes and reports the results of the pre-existing calibrated models (Sections 3.2 to 3.12) and the pre-existing and new model scenarios (Section 5).

A primary purpose of this modeling was to provide quantitative stream heat source assessments that differentiate various background and anthropogenic source contributions. Another was to determine seasonal variation and delineate periods when any applicable temperature criterion/criteria, called "biologically-based temperature criteria" (BBNC), are or will be exceeded at various locations. Ultimately, this modeling was used to evaluate loading capacity allocations that specify the amount of heat that relevant waterbodies can receive and still meet water quality standards. This also allowed quantification of effects that various watershed parameter modifications would have on the flow and water temperature regimes overall and for critical periods and instream locations. Modeling these *potential* conditions is referred to as "scenario modeling" and is discussed in Sections 4 and 5. Anthropogenic nonpoint and NPDES-permitted point sources may not heat a waterbody more than 0.30°C above the applicable BBNC, cumulatively at the point of maximum impact (POMI). Modeling helps determine the portion of the human use allowance (HUA) allocated to each source in the TMDL. Certain HUA portions were translated into numeric or narrative wasteload allocations (WLAs) for each NPDES permittee.

The modeling framework requirements for this project included:

1) Prediction of hourly stream temperatures over a period of months at ≤500m longitudinal resolution.

2) Prediction of hourly solar radiation flux and daily effective shade at ≤100m longitudinal resolution.

3) Ability to evaluate hourly stream temperature response from streamside vegetation changes.

4) Ability to evaluate hourly stream temperature response from changes in water withdrawals and tributary stream flow in the upstream catchment.

5) Ability to evaluate hourly stream temperature response from channel morphology changes in the upstream catchment.

6) Ability to evaluate hourly stream temperature response from changes in effluent temperature and flow discharge from NPDES permitted facilities.

3.1.3 General model inputs and parameters

3.1.3.1 Heat Source

The primary input parameter types for Heat Source include tributary temperature and flow, meteorology, stream morphology, vegetation, and more general geographic, geologic, and spatiotemporal parameters and boundaries. The acquisition and development of the corresponding datasets are described in Section 2. Stream-specific procedures and characteristics are discussed in Sections 3.2 to 3.12.

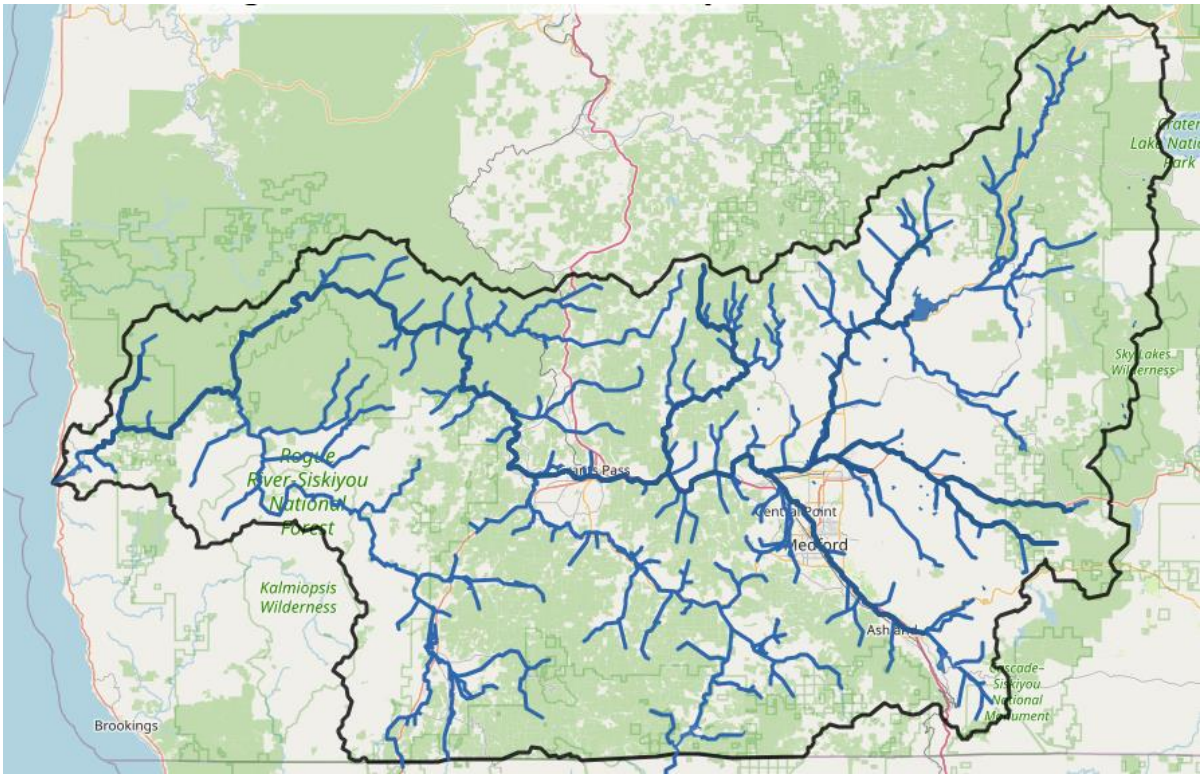


Figure 3-1: Overview of TMDL project area with Heat Source model extents (thick blue lines).

Model calibration was conducted when basic model setup was complete. The basic approach to calibration was to compare actual available field data for water and temperature in the modeled stream (i.e., calibration data) to the model results for the same parameters and locations as existing calibration data. Calibration data and model results are compared using goodness-of-fit procedures in the R statistical software environment (R Core Team, 2023) and visually to assess model precision, accuracy, and identify specific results (e.g., certain times or stream locations) where model accuracy should be improved. To improve model fitness, different model iterations reflecting variations of specific DEQ-identified model parameters were completed. Model output was reassessed, and the optimal model, based on the aforementioned goodness-of-fit and other model output assessments, was selected as the final calibrated model. Stream-specific calibrations are discussed in 3.2 to 3.12. Calibration parameters included meteorological (e.g., wind speed, air temperature, cloudiness), hydrological (e.g., tributary temperatures, withdrawal rates), and stream morphological (e.g., channel gradient and width, Manning's roughness coefficient, hyporheic zone thickness and porosity, and sediment thermal conductivity) parameters.

Heat Source models the effective shade parameter. Because Heat Source modeling can determine thermal loading under current conditions and various scenarios, which includes quantification of the TMDL for the modeled area, and because effective shade is accepted as a surrogate measure for thermal loading, this modeling also allows determination of effective shade targets (that will effectively meet the Temperature TMDL). The effective shade achieved under current conditions and various potential conditions (model scenarios) can thus be compared to effective shade targets to determine (i) if a given area meets its shade target (i.e., meets the TMDL requirement), and (ii) the amount of any "shade gap" between the modeled condition and the target.

A combination of visual assessment and computed error (goodness-of-fit) statistics was used to assess model calibration. Heat Source model fitness was summarized using mean error (ME), mean

absolute error (MAE), root-mean-square error (RMSE), and the Nash-Sutcliffe efficiency coefficient (NSE) to quantify deviation of modeled from observed values. These statistics are explained in detail in Section 7.2 of the QAPP (DEQ 2024) and calculated as follows:

$$ME = \frac{1}{n}\sum(P - O) \qquad MAE = \frac{1}{n}\sum|P - O| \qquad RMSE = \sqrt{\frac{1}{n}\sum(P - O)^2} \qquad NSE = 1 - \frac{\sum(P-O)^2}{\sum(O-\bar{O})^2}$$

where

P *= model predicted values*
O *= observed values*
$\bar{O}$ *= the mean of observed values*
n = number of samples

3.1.3.1.1 Heat Source version 6

Table 3-2 summarizes all user-entered model inputs and parameters required to run Heat Source version 6 and identifies the subset of inputs and parameters that are potentially modifiable to improve model calibration. Note that it is unlikely that all would be used as calibration parameters; and DEQ does not plan to update the model calibrations that were previously peer-reviewed and published. However, calibrations completed for previous TMDLs are discussed herein where those models are included for this TMDL. The following list of categorical and specific inputs describes the general form and function of the inputs, and why they are candidates for adjustment during calibration:

- Morphology – Morphologic inputs that may be used as calibration parameters include upstream and downstream channel elevations, Manning's *n*, and rating curve coefficients *a* and *b* for a power function. Channel hydraulics are important in stream temperature predictions because they govern the water surface area that may be exposed to solar radiation, the exposure residence time, and the extent of light penetration into the water column. Field data for these inputs are often difficult to collect over large spatial scales, and values can vary significantly over small scales. Heat Source is a one-dimensional model and represents complex channel configurations as trapezoids. Adjustments to inputs that affect channel hydraulics are often necessary to calibrate models.

- Meteorology – The meteorological input modified in calibration is wind speed. Wind speed can vary significantly on a small geographic scale, and the distance to the meteorological data source is often much greater than the small scale of localized weather variations. Hence, wind adjustment is an appropriate calibration method to account for more site-specific weather patterns.

- Mass and thermal flux – Mass and thermal inflow and outflow inputs are often adjusted during calibration. These heat and water inflows consist of tributary and groundwater inflows, diversions, and groundwater losses. The temporal and geographic extents of flow gaging and temperature monitoring on tributaries in or groundwater are generally sparse. An effective method to improve calibration is to complete a flow mass balance with available data, and then add, subtract, or adjust flows, either globally or in specific locations, within the bounds of the flow mass balance, available measurements, and model-predicted temperatures.

- Vegetation – Vegetation parameters used as model inputs are often derived from aerial imagery or LiDAR. Vegetation characteristics determine the capacity of near-stream vegetation to block incidental solar radiation on the surface of the modeled waterbody. Three vegetation

parameters often included in the calibration process are vegetation density, overhang, and height. Field measurements offer a general understanding of vegetation characteristics in a watershed; however, variability in these parameters can be significant over small geographic scales. To improve model fit, these model inputs may be modified on a global scale for various vegetation classes within the bounds of available data.

Table 3-2: Heat Source version 6: Required model inputs summary.

Input type	Input/parameter	Units	Calibration parameter
General	Model date	date (mm/dd/yyyy)	No
General	Longitudinal stream sample distance	meters	No
General	Number of tributary inflow sites	-	No
General	Number of meteorological data sites	-	No
General	Total longitudinal distance	meters	No
General	Stop distance	meters	No
General	Latitude	decimal degrees	No
General	Longitude	decimal degrees	No
General	Riparian zone width	meters	No
Meteorological data	Meteorological data model kilometers	kilometers	No
Meteorological data	Wind speed	meters/second	Yes
Meteorological data	Relative humidity	proportion (0-1)	No
Meteorological data	Air temperature	degrees Celsius	No
Boundary condition	Boundary condition inflow rate	cubic meters/second	No
Boundary condition	Water temperature	degrees Celsius	No
Tributary	Tributary inflow model kilometers	kilometers	No
Tributary	Tributary inflow rate	cubic meters/second	Yes
Tributary	Water Temperature	degrees Celsius	Yes
Land cover data	Topographic shade angle - West	degrees	No
Land cover data	Topographic shade angle - South	degrees	No
Land cover data	Topographic shade angle - East	degrees	No
Land cover data	Landcover code	-	No
Land cover codes	Landcover height	meters	Yes
Land cover codes	Canopy density	proportion (0-1)	Yes
Land cover codes	Landcover overhang	meters	Yes
Morphology data	Channel bed elevation	meters	No
Morphology data	Manning's Roughness Coefficient, n	seconds/meter	Yes
Morphology data	Near-stream disturbance zone (NSDZ) width	meters	No
Morphology data	Rating curve coefficient, a	unitless	Yes
Morphology data	Rating curve coefficient, b	unitless	Yes
Morphology data	Percent bedrock	proportion (0-1)	No
Morphology data	Channel aspect	degrees	No
Morphology data	Channel incision	meters	No
Morphology data	Valley length (optional)	meters	No

3.1.3.1.2 Heat Source version 8

The model inputs and parameters for Heat Source version 8 are similar to version 6 with a few notable exceptions:

- Model can simulate an unlimited number of days;

- Star pattern landcover input with variable landcover height, density, and ground elevation inputs;
- Allows for variable flow rate time-series on the boundary conditions and tributary inputs;
- Requires inputs of latitude, longitude and aspect for each model node;
- Uses Manning's equation exclusively to calculate channel hydraulics, and omits the option to specify rating curve coefficients for certain aspects of channel hydraulics;
- Includes cloudiness (as a percentage of clear sky) as a meteorological input—Heat Source version 6 assumes clear sky conditions;
- Allows specifically for groundwater accretion and diversion inputs to the model;
- Specifies additional morphology data such as bottom width, bed sediment parameters, and channel gradient;
- Specifies bed conduction inputs such as hyporheic exchange parameters; and
- Allows the use of LiDAR data for vegetation density and overhang.

Table 3-3 summarizes the list of model parameters that differ between Heat Source version 6 and Heat Source version 8. Columns V6 and V8 indicate if the parameter or input is included in Heat Source version 6 and/or version 8. The calibration parameter column indicates if the input or parameter may be modified to improve calibration.

Table 3-3: Heat Source version 8: Model inputs and parameters that differ from Heat Source version 6.

Input type	Input/parameter	Units	V6	V8	Calibration parameter
General	Riparian zone width	meters	Yes	No	No
General	Initial conditions (assumed/user defined)	-	Yes	No	No
Land Cover data	Landcover source	-	Yes	No	No
Morphology data	Flow volume	cubic meters/second	Yes	No	No
Morphology data	Percent bedrock	proportion (0-1)	Yes	No	No
Morphology data	Channel incision	meters	Yes	No	No
Morphology data	Valley length	meters	Yes	No	No
Meteorological data	Cloudiness	proportion (0-1)	No	Yes	Yes
Accretion	Accretion inflow rate	cubic meters/second	No	Yes	Yes
Accretion	Water temperature	degrees Celsius	No	Yes	Yes
Accretion	Withdrawal Flow rate	cubic meters/second	No	Yes	Yes
Morphology data	Channel gradient	meters/meters	No	Yes	Yes
Morphology data	Channel angle z	meters/meters	No	Yes	Yes
General	LiDAR density	proportion (0-1)	No	Yes	Yes
General	LiDAR overhang	meters	No	Yes	Yes
Morphology data	Channel bottom width	meters	No	Yes	Yes
Morphology data	Hyporheic zone thickness	meters	No	Yes	Yes
Morphology data	Percent hyporheic exchange	proportion (0-1)	No	Yes	Yes
Morphology data	Porosity	proportion (0-1)	No	Yes	Yes
General	Stream length	kilometers	No	Yes	No
General	Modeling start date	date (mm/dd/yyyy)	No	Yes	No

Input type	Input/parameter	Units	V6	V8	Calibration parameter
General	Flush initial condition	days	No	Yes	No
General	Model time step	minutes	No	Yes	No
General	Model distance step	meters	No	Yes	No
General	Include evaporation losses from flow (True/False)	-	No	Yes	No
General	Evaporation method (Mass Transfer/Penman)	-	No	Yes	No
General	Wind function coefficient a	unitless	No	Yes	No
General	Wind function coefficient b	unitless	No	Yes	No
General	Include deep alluvium temperature (True/False)	-	No	Yes	No
General	Deep alluvium temperature	degrees Celsius	No	Yes	No
General	Distance between transect samples	meters	No	Yes	No
Accretion	Stream kilometers	kilometers	No	Yes	No
Land cover codes	Landcover code	-	No	Yes	No
Morphology data	Stream kilometers	kilometers	No	Yes	No
Morphology data	Sediment thermal conductivity	watts/meters/degrees Celsius	No	Yes	No
General	Time offset from UTC	hours	No	Yes	No
General	Number Of samples per transect	-	No	Yes	No
General	Account for emergent veg shading (True/False)	-	No	Yes	No
General	Land cover sample method (Point/Zone)	-	No	Yes	No
General	LiDAR data used for veg codes (True/False)	-	No	Yes	No
Morphology data	Sediment thermal diffusivity	square centimeters/second	No	Yes	No

3.1.3.2 SHADOW

In addition to Heat Source, several SHADOW models exist and were used to model shade on multiple streams for TMDLs in the Rogue Basin (DEQ, 2002a; DEQ, 2004; DEQ, 2007). The SHADOW model version 2.3 is a shade, solar, and stream temperature model developed by the U.S. Forest Service (USFS, 1993). DEQ does not plan to update these models or use SHADOW for development of new shade or temperature models.

SHADOW uses the angle of the sun on August 1st of the given model year to determine the distance a tree projects its shadow across a stream for each hour of the day. For each stream segment, data from the map and aerial photo inventory, field measurements and photos, and stream surveys on file at the Gold Beach Ranger District office were entered into the SHADOW model. The model estimates shade for each stream reach based on its aspect, which was categorized as diagonal, north-south, or east-west. The USFS WQMP provides details on assumptions made for the data. Details of the model methodology, inputs, and outputs are discussed in the SHADOW user's manual (USFS, 1993). For each stream reach, we used our map/photo information along with the field measurements to estimate a bankfull channel width and existing tree height.

Potential shade is obtained from SHADOW by assuming a tree will grow to a certain height in the next 100 years. Potential shade results differ from existing shade results only in riparian areas that have been harvested or where it is reasonable to assume that future vegetation will differ from current conditions under natural growth. Potential tree heights and shade densities were based on measured and estimated tree heights in adjacent areas that are undisturbed by human activities. No changes in channel morphology were assumed.

Figure 3-2 provides an overview of where the SHADOW model was used to simulate shade conditions.

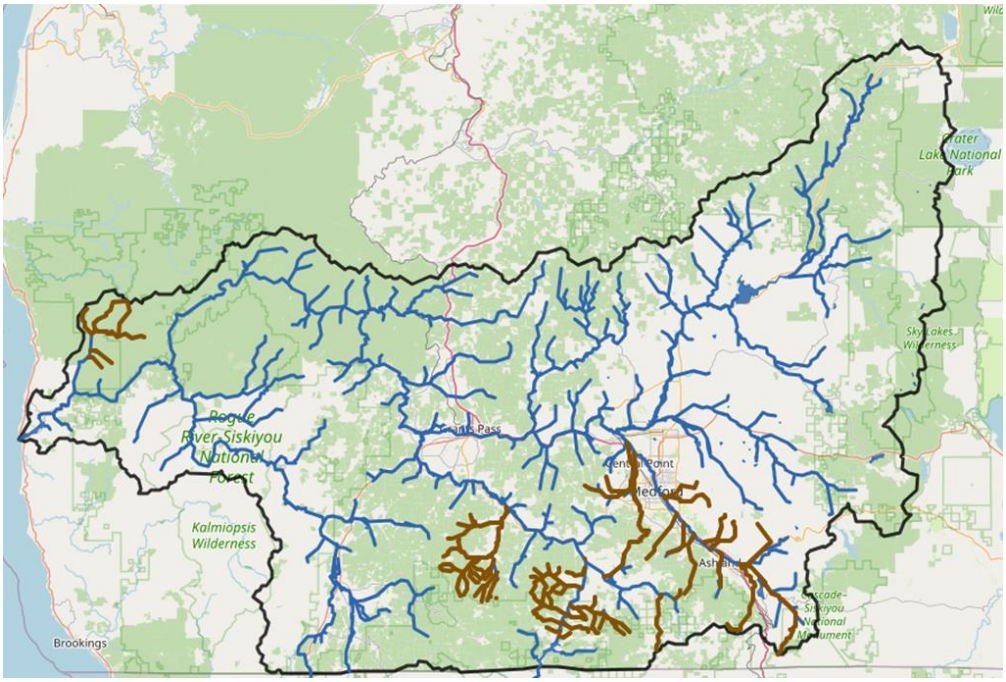


Figure 3-2: PLACEHOLDER Overview of TMDL project area with SHADOW model extents.

3.2 Antelope Creek

The Antelope Creek model is a temperature model developed by DEQ using Heat Source 8.0.

3.2.1 Model extent

The extent of the Antelope Creek model domain is 10.1 km, from its confluence with Little Butte Creek to just upstream of Yankee Creek (river km 10.1). The model extent is shown in the HTML interactive map that accompanies this TMDL and in Figure 3-3.

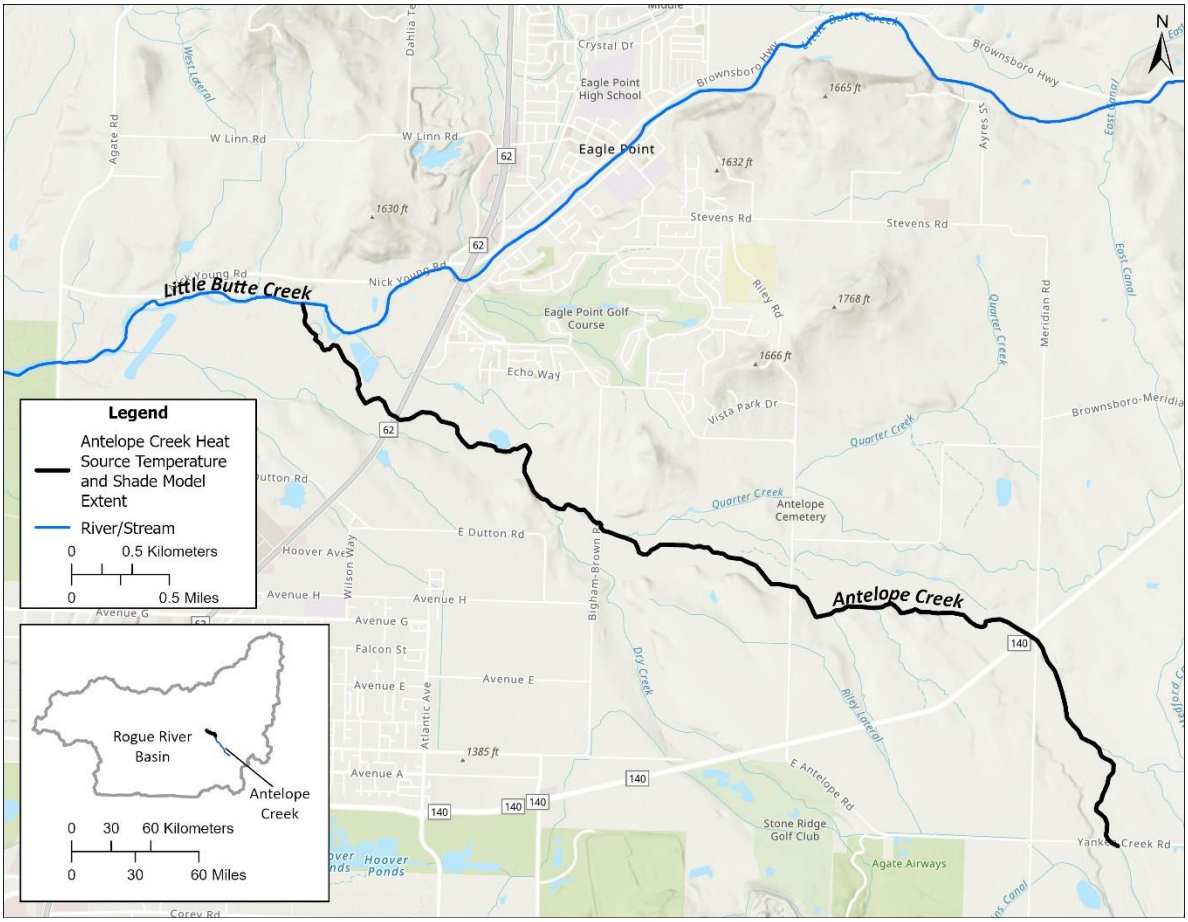


Figure 3-3: Extent of the Antelope Creek temperature and shade model.

3.2.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 50 m. Outputs are generated every 100 m. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.2.3 Source characteristics

The primary thermal loading sources that contribute to Antelope Creek temperatures exceedances include increased solar radiation from near-stream vegetation disturbance or removal; streamflow rate or volume reductions; and background sources (DEQ, 2008). Other potential sources include channel modification and widening, and warming due to climate change.

Along Antelope Creek, the majority land use is agriculture, which accounts for about 71% of the near-stream area. Table 3-4 summarizes all land uses within 100m of the digitized Antelope Creek centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that Shrub/scrub and Herbaceous land uses can be in areas where forest clearcuts have occurred and would be classified as forest after regrowth. Table 3-5 summarizes the potential designated management agencies and responsible persons along Antelope Creek model extent.

Table 3-4: Summary of land uses along the model extent within 100m of the digitized Antelope Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD land cover	Acres	Percent (%) of total acres
Hay/pasture	353.8	70.7
Emergent herbaceous wetlands	65.6	13.1
Woody wetlands	43.8	8.7
Developed, open space	15.6	3.1
Shrub/scrub	10.9	2.2
Developed, low intensity	7.1	1.4
Developed, medium intensity	2.7	0.5
Developed, high intensity	0.7	0.1
Herbaceous	0.4	0.1

Table 3-5: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Antelope Creek centerline.

DMA or Responsible Person	Acres	Percent (%) of total acres
Oregon Department of Agriculture	424.9	81.5
Jackson County	84.8	16.3
Oregon Department of Transportation	6.0	1.2
Oregon Department of Fish and Wildlife	5.6	1.1

3.2.4 Time frame of simulation

The model period is from July 1, 2001, to August 31, 2001.

3.2.5 Important assumptions

The effort described here references existing models. Key calibration assumptions made during the model setup and calibration process were documented in the original Rogue River Basin TMDL (DEQ, 2008) and the model user guide (Boyd and Kasper, 2003); please refer to those reference documents for questions about the representations provided herein.

3.2.6 Meteorological inputs

Hourly meteorological model inputs included air temperature, cloudiness, relative humidity, and wind speed. The model used air temperature, relative humidity, wind speed and cloudiness data collected at the Medford airport (KMFR - Medford Airport, model km 0.3 and 5.45). These data are presented in Section 3.8.4. Air temperature data were modified using the dry adiabatic lapse rate to adjust for elevation differences between the measurement location and the model input location. Wind speeds were adjusted to improve calibration using a wind-sheltering coefficient of 0.5 to represent difference in wind speed between the measurement location and above the stream within the riparian area.

3.2.7 Temperature inputs

Figure 3-4 maps the various stream temperature monitoring locations used in model setup or calibration. The headwater temperature condition was based on continuous monitoring (Table 3-6, Figure 3-5). The same temperature values were applied to Quarter Branch and Dry Creek as no additional data were available.

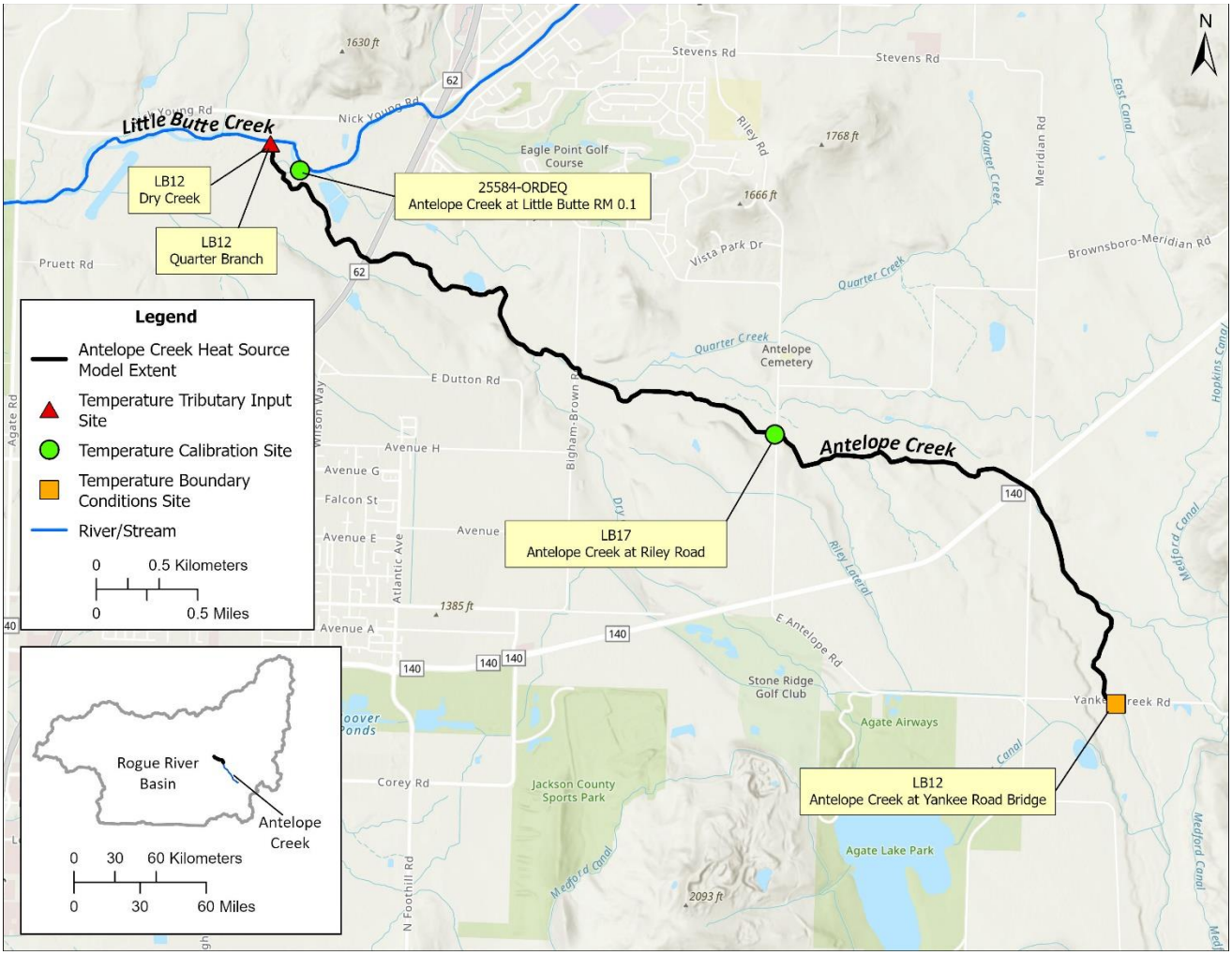


Figure 3-4: Temperature monitoring locations used for Antelope Creek model setup and calibration.

Table 3-6: Antelope Creek boundary condition model input: water temperature.

Model location name (Station ID)	Stream km	Temperature data source
Antelope Creek at Yankee Road Bridge (LB12)	10.1	Medford Water Commission
Quarter Branch (LB12)	4.05	Used Antelope Creek temperatures at Yankee Road Bridge
Dry Creek (LB12)	3.35	Used Antelope Creek temperatures at Yankee Road Bridge

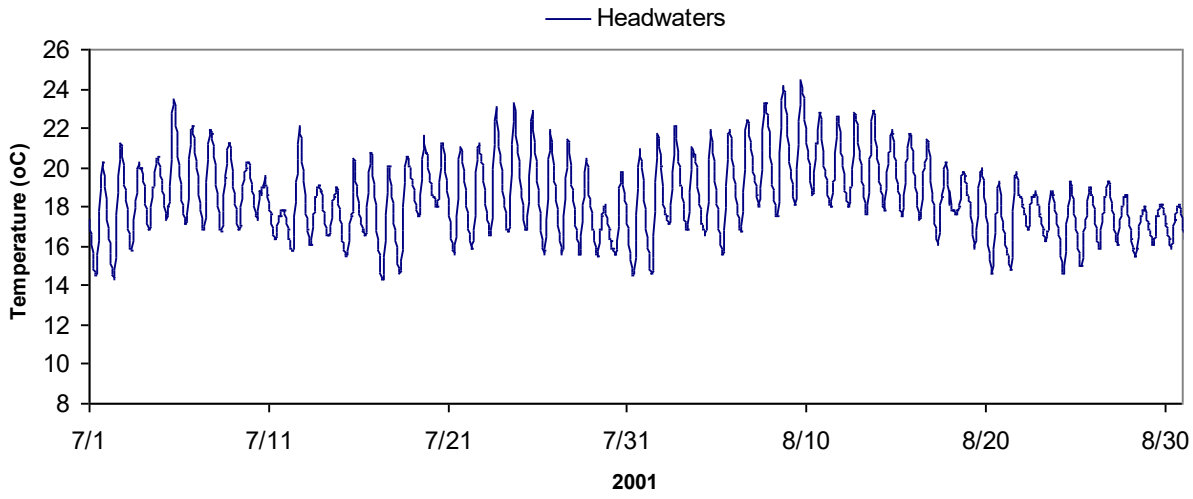


Figure 3-5: Antelope Creek model boundary condition: water temperature values.

3.2.8 Flow inputs

For 2001, no continuous gage data were available and one instantaneous flow measurement was collected at the mouth. Figure 3-6 shows the stream flow monitoring locations used for model setup or calibration. WRD reported 1.3 cfs withdrawal in the model reach, with 2.5 cfs total withdrawal on Antelope Creek. However, given the paucity of flow data, those withdrawals were not included in the calibrated model. Temporally variable flows were computed to match inflows into the Little Butte Creek model. The flow at the mouth was proportioned to the headwater, Quarter Branch (river km 4.05), and Dry Creek (river km 3.35) based on professional judgment (Figure 3-7).

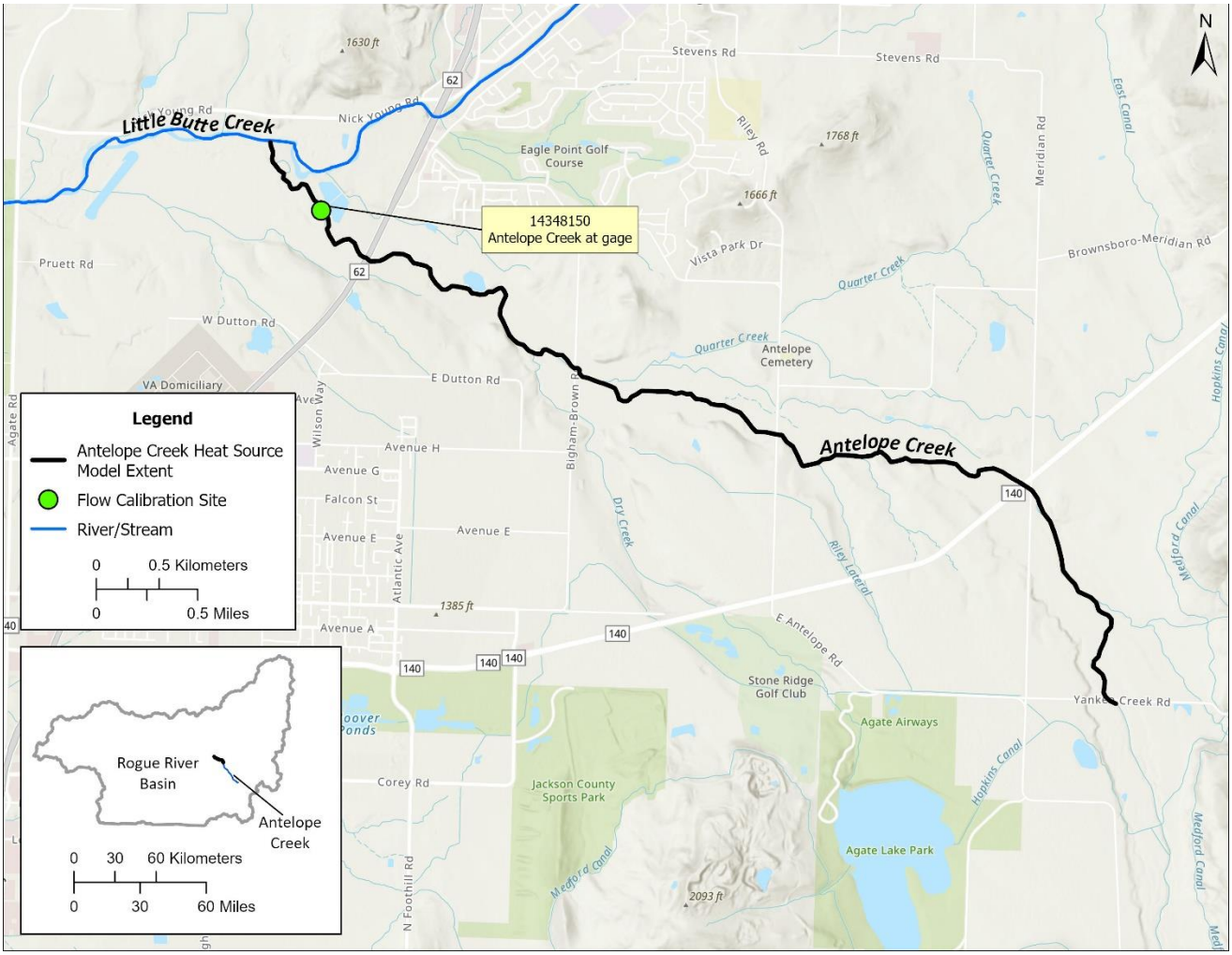


Figure 3-6: Flow monitoring locations used for Antelope Creek model setup and calibration.

Table 3-7: Source of tributary and boundary condition flow inputs for Antelope Creek model.

Model location name (Station ID)	Stream km	Flow data source
Antelope Creek at Yankee Road Bridge (14348150)	10.1	Derived from instantaneous measurement at mouth by proportioning flows at the mouth between the headwaters and tributaries based on location in the watershed.
Quarter Branch (14348150)	4.05	Same method as Antelope Creek at Yankee Road Bridge.
Dry Creek (14348150)	3.35	Same method as Antelope Creek at Yankee Road Bridge.

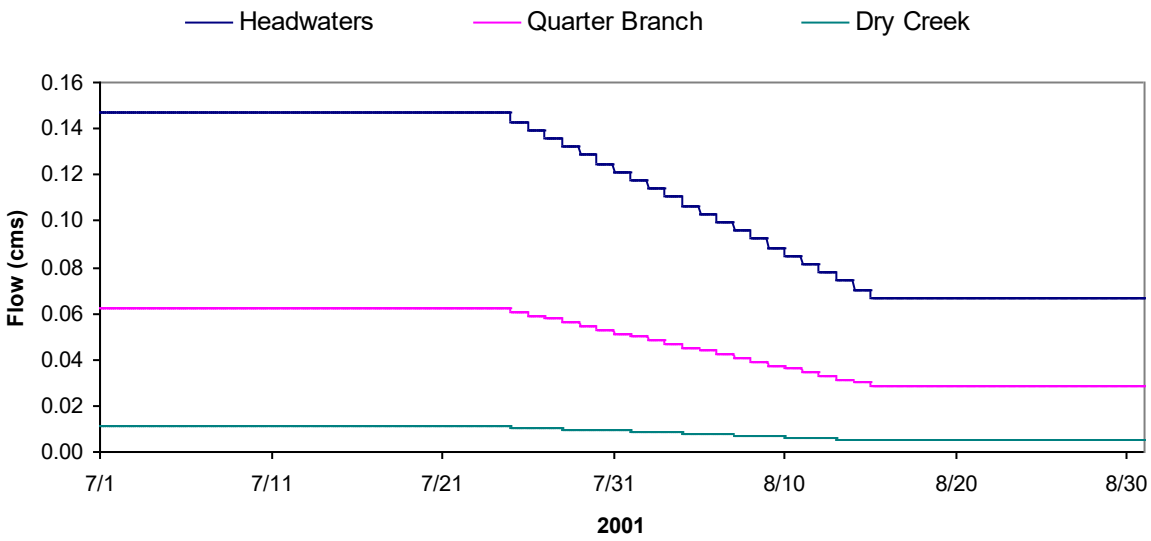


Figure 3-7: Antelope Creek model boundary condition and tributary flows.

3.2.9 Point source inputs

There are no point source discharges within the model extent.

3.2.10 Landcover and topographic shade inputs

Topographic and riparian vegetation heights and densities were determined through GIS analysis (Figure 3-8, Figure 3-9, and Figure 3-10) and used to predict effective shade. No shade data were available to corroborate the predicted effective shade.

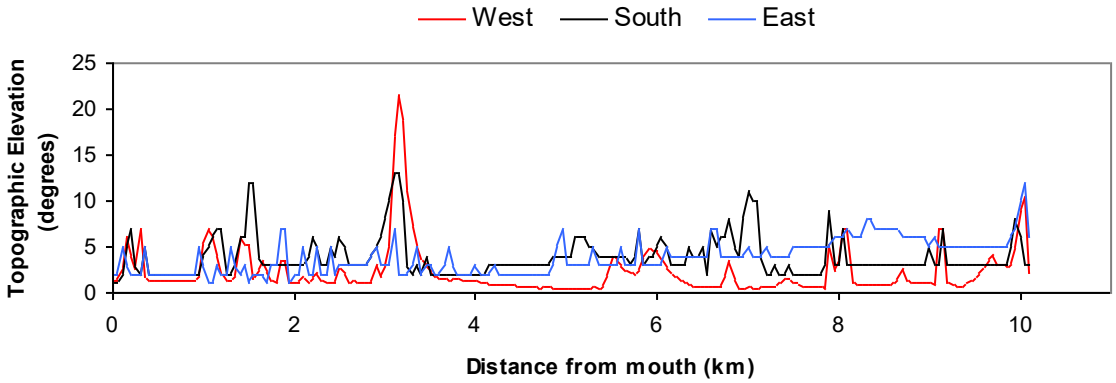


Figure 3-8: Antelope Creek model: topographic angle setup.

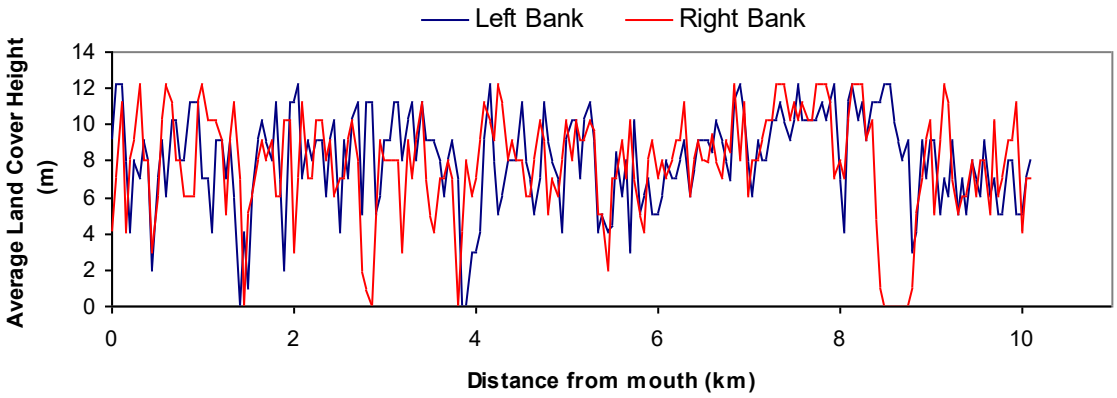


Figure 3-9: Antelope Creek model setup: streamside vegetation height.

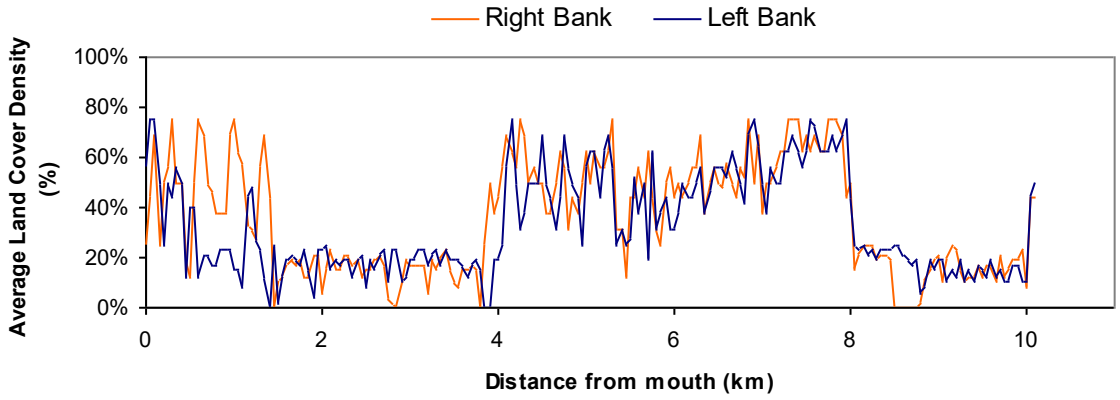


Figure 3-10: Antelope Creek model setup: streamside vegetation density.

3.2.11 Channel setup

The channel properties were determined using the methodology documented previously in this document (see Section 2.2.3). Figure 3-11 shows the elevation and reach gradient profiles. The bottom width was derived using the active channel width measured from aerial photographs. Bottom width was estimated by assuming a trapezoidal channel with variable side slopes and a constant width-to-depth ratio of 8:1 determined through model calibration. Non-spatially varying coefficients are presented in Table 3-8. Manning's n was iteratively altered so that the model temperatures approximately reproduced measured temperatures (Figure 3-13).

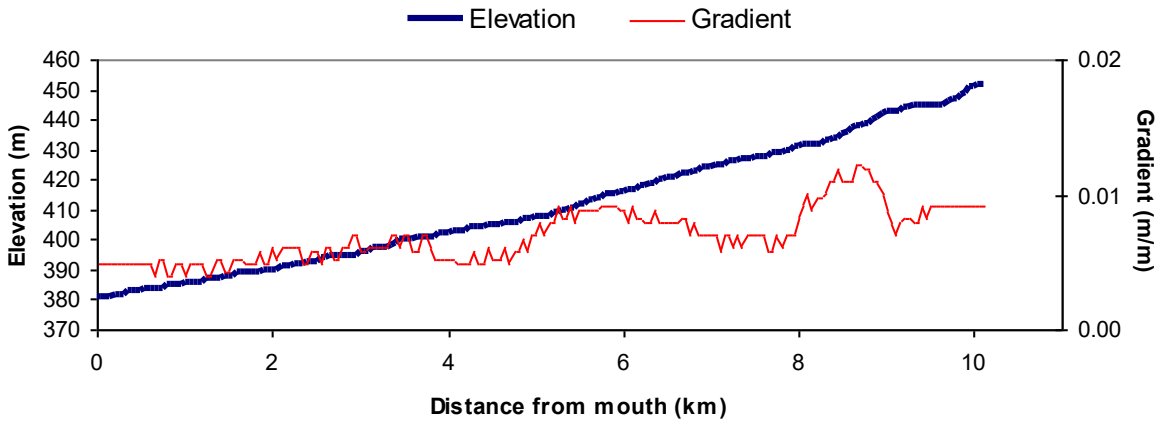


Figure 3-11: Antelope Creek model setup: Channel elevation and gradient.

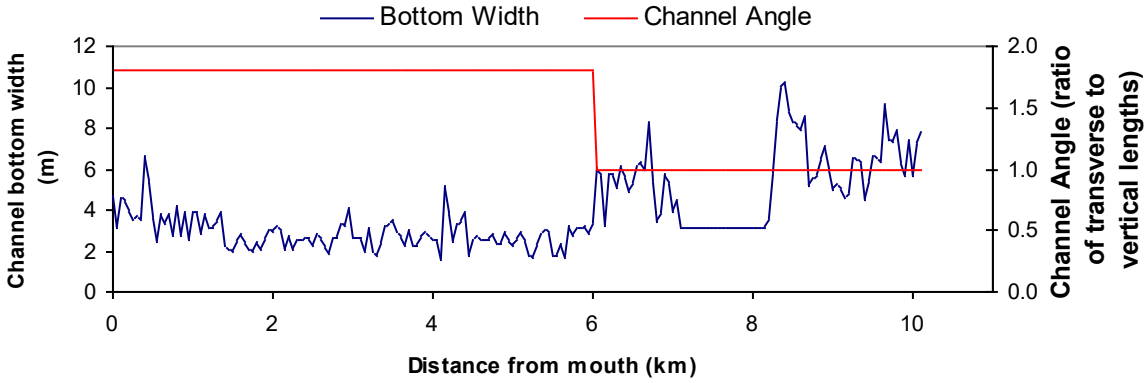


Figure 3-12: Antelope Creek model setup: Channel bottom width and angle.

Table 3-8: Model coefficients for non-spatially varying parameters.

Parameter name (units)	Value
Wind function, coefficient a	1.51×10^{-9}
Wind function, coefficient b	1.60×10^{-9}
Sediment thermal conductivity (W/m/°C)	1.57
Sediment thermal diffusivity (cm^2/sec)	0.0064
Sediment / hyporheic zone thickness (m)	0.5
Percent hyporheic exchange	0%
Porosity	30%

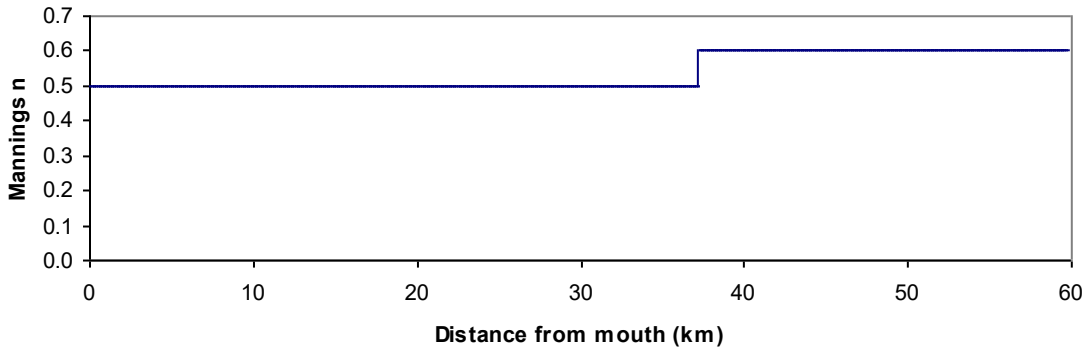


Figure 3-13: Antelope Creek model setup: Manning's roughness coefficient.

3.2.12 Calibration results

The flow-prediction performance of the Antelope Creek model is shown in Figure 3-14.

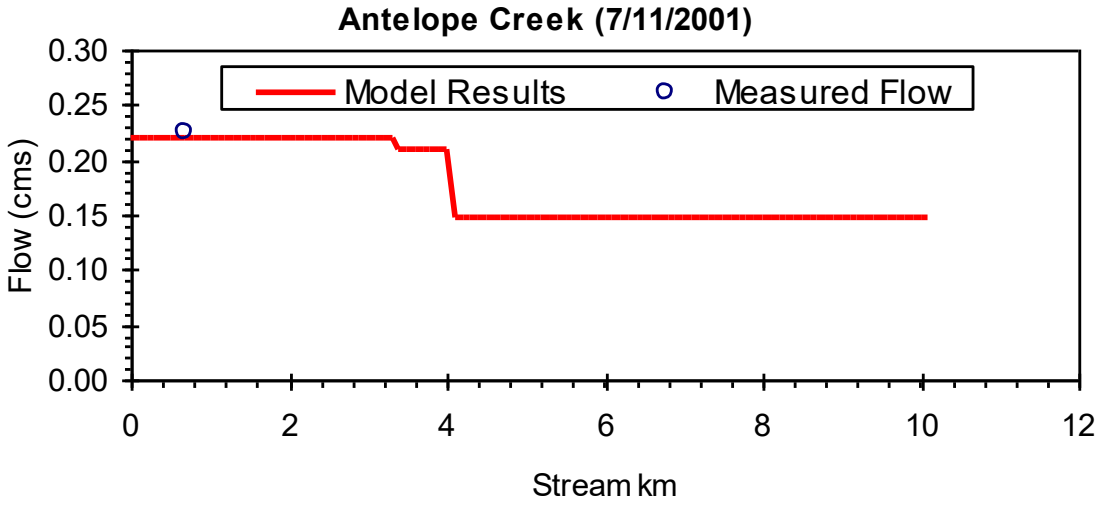


Figure 3-14: Antelope Creek model: Longitudinal profile of measured vs. modeled flows.

The temperature model was calibrated to TIR data collected on July 13, 2001 and to continuous temperature data collected at two Antelope Creek sites during the model period (Figure 3-15, Figure 3-16). Goodness-of-fit statistics for comparisons of field-observed and model-predicted temperatures are summarized in Table 3-9. See Section 3.1.3.1 for definitions and discussions of statistical metrics. The model outputs generally reproduced spatially and temporally varying temperature measurements (Table 3-9, Figure 3-15, and Figure 3-16). Comparison of the TIR data with the Antelope Creek model results met the targets of MAE <0.50°C and RMSE <1.50°C.

Table 3-9: Antelope Creek temperature model goodness-of-fit statistics, field data vs. model results.

Monitoring location	Site ID	Model km	Temperature statistic	ME	MAE	RMSE	NSE	n
All Stations			Daily maximum	0.17	1.10	1.37		
All Stations			Hourly	-0.41	0.99	1.21	0.73	
Antelope Cr. at Riley Road	LB17	5.45	Daily maximum	-0.27	1.09	1.29		62
Antelope Cr. at Little Butte RM 0.1	25584-ORDEQ	0.30	Daily maximum	0.62	1.12	1.45		59

Monitoring location	Site ID	Model km	Temperature statistic	ME	MAE	RMSE	NSE	n
Antelope Cr. at Riley Road	LB17	5.45	Hourly	-0.25	0.87	1.09	0.79	1488
Antelope Cr. at Little Butte RM 0.1	25584-ORDEQ	0.30	Hourly	-0.58	1.11	1.33	0.66	1425
TIR		Model extent		-0.49	0.50	0.63	-0.18	

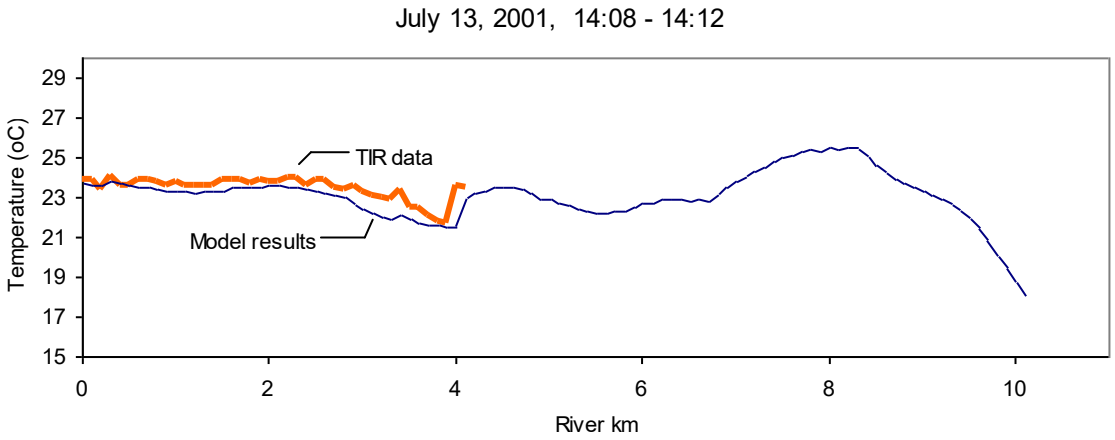


Figure 3-15: Longitudinal profile of Antelope Creek TIR and modeled stream temperatures.

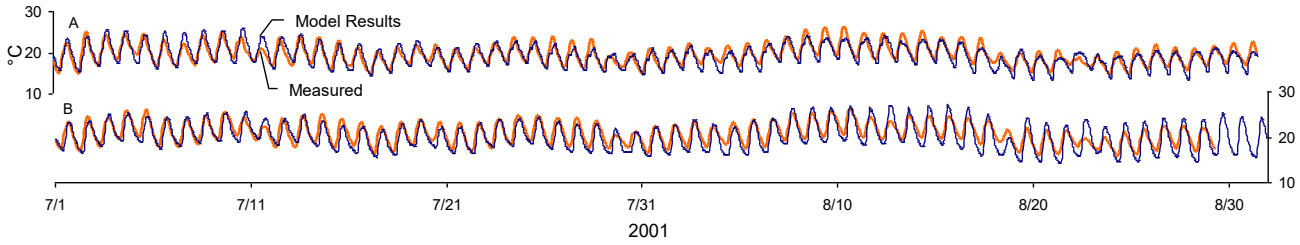


Figure 3-16: Measured and modeled hourly stream temperatures at (A) Antelope Creek at Riley Road and (B) Antelope Creek at Little Butte RM 0.1 monitoring sites.

3.3 Applegate Subbasin

Portions of the Applegate Subbasin (HUC8: 17100309) were modeled for effective shade by DEQ for previous TMDLs (Table 3-10). The SHADOW model was used for Beaver, Palmer, Powell, Star Gulch, Sterling, Williams and Yale Creeks (Section 3.3.2). The Applegate Subbasin SHADOW models are shade models developed by the USFS and BLM. DEQ did not update these models. The model setup is described in the original Applegate Subbasin TMDL (DEQ, 2004). Effective shade curves developed with Heat Source 6.0 are applicable to all areas not specified in this paragraph (Section 3.3.3).

3.3.1 Model extent

The extent of the model domain is select tributaries to the Applegate River and Little Applegate River in the Williams Creek Watershed (1710030905), Upper Applegate River Watershed (1710030902), and Little Applegate River Watershed (1710030903). Select tributaries include 1917 Gulch, 1918

Gulch, Alexander Gulch, Armstrong Gulch, Bailey Gulch, Bear Wallow Creek, Beaver Creek, Benson Gulch, Bill Creek, Brushy Gulch, Charley Buck Gulch, Clapboard Gulch, Deadman Gulch, East Fork Williams Creek, Glade Creek, Glade Fork, Goodwin Creek, Hanley Gulch, Haskins Gulch, Honeysuckle Creek, Kinney Creek, Ladybug Gulch, Lightning Gulch, Lime Gulch, Lone Creek, Mule Creek, Munger Creek, Nine Dollar Gulch, North Fork Munger Creek, Palmer Creek, Petes Camp Creek, Powell Creek, Right Hand Fork of the West Fork Williams, Right Hand Fork Rock Creek, Rock Creek, Rock Gulch, Star Gulch, Sterling Creek, Sugar Loaf Gulch, Tree Branch Creek, Wallow Creek, Water Gulch, West Fork Williams Creek, Williams Creek, and Yale Creek. The model extent is shown in the HTML interactive map that accompanies this TMDL.

Table 3-10: Applegate Subbasin: Summary of models and extents.

Name	HUC or AU_ID	Area (ac)	R Miles	Rkm	Model
Palmer Creek-Applegate River	OR_WS_171003090201_02_105784		5.6		SHADOW
Beaver Creek-Applegate River	OR_WS_171003090202_02_105785	14,108			SHADOW
Star Gulch-Applegate River	OR_WS_171003090203_02_105786				SHADOW
Star/Boaz	OR_WS_17100310902	17,651	35.8		SHADOW
Yale Creek	OR_SR_1710030903_02_105605 OR_SR_1710030903_02_105796	15229	14.8		SHADOW
Glade Creek		8727	17.0		SHADOW
Powell Creek-Williams Creek	OR_WS_171003090503_02_106358	7625	2.3		SHADOW
Williams Creek	OR_WS_1710030905	51,971	78.5		SHADOW
Sterling Creek	OR_WS_171003090304_02_105789	11,930	6.8		SHADOW

3.3.2 Stream-specific SHADOW Models: Williams Creek, Star/Boaz, Beaver/Palmer, Glade, Sterling, and Yale Creeks

3.3.2.1 General methods

Aerial photo interpretation and mapping were performed using BLM-supplied 1996 color air photos at 1:12,000 scale, 7.5' USGS quadrangle maps, and ODF stream classification maps. Streams and tributaries were included in the assessment if they were: 1) on the state's 303(d) list (for temperature); 2) the tributary drainage area is 5% or greater of the watershed drainage area above its confluence with the receiving stream; 3) fish-bearing status as per ODF stream classification maps and protocols; and 4) perennial stream flow. Note: tributary streams that are listed as intermittent on the USGS quadrangles or have an area less than 5% may have also been included in this assessment if they cross non-federal lands to get a comprehensive overview of the existing conditions.

Reach breaks were established using the following criteria: 1) confluence of perennial streams; 2) change in ODF stream classification; 3) ownership boundaries; 4) significant changes in terrain slope; 5) changes in aspect; and 6) changes in riparian vegetation. Each reach was given a unique alphanumeric identification, typically consisting of the first three letters of the stream name followed by a number. Reaches were numbered sequentially from confluence to headwaters.

The riparian assessment consisted of interpretation or measurement of shade parameters, riparian vegetation, and channel conditions. These values were derived either from color aerial photos or USGS quadrangle maps.

Field verification (ground truthing) was conducted at 16 of 17 identified sites in Williams Creek and 5 identified sites in Star/Boaz. Ground truthing sites were spread across the Williams Creek basin, with 4 sites on lower Williams Creek (below the East/West Fork confluence), 6 in the East Fork sub-watershed, and 7 in the West Fork sub-watershed.

Field measurements followed standard DEQ procedures and protocols for SHADOW model ground truthing. Ground truthing reaches were 200' in length with the shade values assessed for only this length. Sampling was conducted at three transects (lower, middle, and upper) along the 200' reach. If the active channel was less than 25' wide, then only one Solar Pathfinder measurement was taken at center channel. For channels greater than 25', two or three measurements were taken across the channel. An average reach value for each parameter was computed from the measurement set. Field measurements were compared to interpreted values and adjustments made if indicated.

Margin of safety: Riparian assessment. A conservative assessment was used in the measurement of shade density and vegetation overhang. Shade density accounted for the riparian vegetation composition, with a maximum value of 80% (heavily stocked hardwood stand). Vegetation overhang was measured by estimating the percentage of stream channel covered with vegetation. The greatest overhang value recorded was 80%, even for closed canopy reaches.

Margin of safety: Shade curve assumptions. The shade model SHADOW was used to calculate percent shade. Shade is based on the earth-sun-terrain/vegetation relationship on August 1 for specified latitudes.

3.3.2.2 Williams Creek specifics

During the development of shade curves, three parameters were averaged for the basin: terrain slope, vegetation overhang, and tree-to-channel distance (Table 3-11). Valley and upland reaches were segregated and averaged to assess the magnitude of difference between them. The average slope value used for the model (30%) are conservative for the upland reaches where there are more areas of steeper terrain slopes. For valley reaches, the slope value may be greater than observed in some locations. However, the overall impact of terrain slope is nominal given an average tree-to-channel distance of five feet. Table 3-12 lists the percent ownership by land area (acre) and stream miles assessed in the basin.

Table 3-11: Williams Cr. shade curve assumptions by stream type

	Valley reaches (n=42)	Upland reaches (n=163)	All reaches	SHADOW inputs used
Terrain slope (%)	10	30	30	30
Vegetation overhang (%)	40	50	50	50
Tree-to-channel distance (ft)	5	5	5	5

Table 3-12: Williams Creek Watershed – Overview.

Hydrologic Unit Code	1710030905
Watershed Area / ownership	Total: 51,971 acres BLM Ownership: 26,990 ac. (52%) USFS Ownership: 819 ac. (2%) Non-Fed. Ownership: 24,162 ac. (46%)

Stream miles assessed	Total: 78.5 miles BLM Ownership: 35.6 mi. (45%) USFS Ownership: 0.8 mi. (1%) Non-Fed. Ownership: 42.1 mi. (54%)
303(d) listed parameters	Temperature
Key resources and uses	Salmonid, domestic, agricultural, aesthetic
Known impacts	Water withdrawals, timber harvests, roads, agriculture

Table 3-13: Williams Creek, photo and map assessed attributes.

Assessment parameter	Resolution	Comments
Shade		
Percent Overhang	10%	Photo estimated
Percent Shade Density	10%	Photo estimated
Terrain Slope	10%	Photo or map
Aspect Class	60 deg.	Map
Tree-to-Channel Distance	5 ft.	Photo estimated
Tree Height	20 ft.	Average of primary shade vegetation
Width – Active Channel	10 ft.	Photo measure if possible
Width – Wetted Channel	10 ft.	Photo estimated
Reach Length	100 ft.	Map wheeled
Vegetation		
Tree Heights	20 ft.	Average of primary shade vegetation
Species / Composition mix	Spp / 10%	If possible or Deciduous / Conifer
Buffer Width	10 ft.	Non-federal land only
Percent of Reach	10%	Non-federal land only
Channel		
Stream Order (Strahler)		USGS 7½' quadrangles
Valley Slope	1%	Slope gradient / Valley length (map)
Channel Sinuosity	0.1	Stream Length / Valley length (photo)
Stream Slope	0.001-0.1%	Valley slope / Sinuosity
Rosgen Channel – Level 1		A, B, C, E, F, G, D
Bank Stability		Yes / No
Comments		Disturbance type and notes
Others		
ODF Stream Class		Lg./Med./Sm/; Fish/None/Domestic
Land Use		BLF,BLN, BLM, FS, AG, PR, PF, PN
Impervious Surface		Yes / No (affecting riparian veg.)
Stream Diversions		In / Out (observable on photo)

3.3.2.3 Star/Boaz specifics

Three different shade curves/tables (Table 3-14) were used based on the channel size and the landscape that the stream traverses. Curves were stratified by large streams and small streams with channel widths ranging from 30-120' and 5-25', respectively; and by large, open valleys with channel widths ranging from 10-120'. Tree heights ranged from 20-180'. Percent shade was calculated for each combination of channel width and tree height, with shade densities ranging from 10%-80%, at 10% steps. The base assumptions used for each set of curves are listed in Table 3-14. Valley curves were used for the Applegate River. Table 3-15 lists the percent ownership by land area (acre) and stream miles assessed in the basin.

Table 3-14: Star/Boaz shade curve assumptions by stream type.

Shade variable	Large streams	Small streams	Valley streams
Vegetation Overhang (%)	0	0	0
Tree to Channel Slope (%)	30	50	20
Tree to Channel Distance (ft)	25	10	10

Table 3-15: Applegate-Star-Boaz Watershed – Overview

Hydrologic Unit Code	17100310902*
Watershed Area / Ownership	Total: 17,651 acres BLM Ownership: 14,811 ac. (84%) USFS Ownership: 544 ac. (3%) Non-Fed. Ownership: 2,296 ac. (13%)
Stream Miles Assessed	Total: 35.8 miles BLM Ownership: 23.3 mi. (65%) USFS ownership: 0.3 mi. (1%) Non-Fed. Ownership: 12.2 mi. (34%)
303(d) Listed Parameters	Temperature, Flow Modification
Key Resources and Uses	Salmonid, domestic, agricultural, aesthetic
Known Impacts	Timber harvests, roads, water withdrawals, residential structures, transportation infrastructures

Table 3-16: Star/Boaz, photo and map assessed attributes.

Assessment Parameter	Resolution	Comments
Shade		
Percent Overhang	10%	Photo Estimated
Percent Shade Density	10%	Photo Estimated
Terrain Slope	10%	Photo or map
Aspect Class	60 deg.	Map
Tree-to-Channel Distance	5 ft.	Photo Estimated
Tree Height	20 ft.	Average of primary shade vegetation
Width – Active Channel	10 ft.	Photo measure if possible
Reach Length	100 ft.	Map wheeled
Vegetation		
Buffer Width	10 ft.	Fed. = 300’ max; Non-fed. = 100’ max
Percent of Reach	10%	Non-federal land only
Veg. / Composition mix	10%	Percent deciduous / conifer
Channel		
Stream Order (Strahler)		USGS 7½’ quadrangles
Valley Slope	1%	Slope gradient / Valley length (map)
Channel Sinuosity	0.1	Stream Length / Valley length (photo)
Stream Slope	0.001-0.1%	Valley slope / Sinuosity
Rosgen Channel – Level 1		A, B, C, E, F, G, D
Bank Stability		Yes / No
Comments		Disturbance type and notes
Others		
ODF Stream Class		Size and classification
Land Use		BLF,BLM, BLN, PRS, PRN
Impervious Surface		Yes / No (affecting riparian veg.)
Stream Diversions		In / Out (observable on photo)

3.3.2.4 Sterling Creek, Glade, L. Applegate specifics

Data parameters were determined using several sources and methods:

1. Vegetation was categorized using mosaics of infrared imagery from July 2000, stereoscopic interpretation of 1998 and 1996 aerial photographs and 1994 digital ortho-photos;

2. Stream orientation and percent slope were obtained from USGS topographic maps;

3. Active channel width and flow width were obtained from stream surveys conducted by ODFW and ARWC.

All data were recorded in meters except tree height (in feet). Line segments documenting stream reaches were drawn in ArcView. An accompanying layer was generated in ArcView to identify key features and stream habitat survey reaches from which data was obtained. Data parameters are defined in Table 3-19. Table 3-17 lists the percent ownership by land area (acre) and stream miles assessed in the basin.

Ground truthing data was collected at reaches S3, S13, S16, and S20. Solar Pathfinder readings indicate that percent shade varies widely within each reach, but SHADOW estimates fall within the range of measured values.

Table 3-17: Sterling Creek Watershed – Overview.

Hydrologic Unit Code	171003090305*
Watershed Area / Ownership	Total: 11,930 acres BLM Ownership: 7279 ac. (61%) Non-Fed. Ownership: 4651 ac. (39%)
Stream Miles Assessed	Total: 6.8 miles (13.6 miles of stream bank) Non-Fed. Ownership: 12.76 miles of stream bank BLM ownership: .87 miles of stream bank (6.3%)
303(d) Listed Parameters	Temperature
Key Resources and Uses	Salmonid, domestic, agricultural, aesthetic
Known Impacts	Mining, roads, water withdrawals, residential structures, and timber harvests.

Table 3-18: Applegate/Glade/Yale Creeks Watershed – Overview.

Hydrologic Unit Code	171003090305*
Watershed Area / Ownership	Little Applegate: 72242 acres Yale Creek 15229 acres Glade Creek 8727 acres
Stream Miles Assessed	Little Applegate: 20.1 miles Yale Creek: 14.8 miles Glade Creek: 17.0 miles
303(d) Listed Parameters	Temperature
Key Resources and Uses	Salmonid, domestic, agricultural, aesthetic
Known Impacts	Mining, roads, water withdrawals, residential structures, and timber harvests.

Table 3-19: Applegate Subbasin SHADOW model definitions

Selected	"Yes", to incorporate data into model. "No", to exclude data from reach for the model run.
Length	Reach lengths were automatically calculated in Arcview.
Bank	E for east bank. W for west bank.
Slope (%)	The distance between lines on the U.S.G.S. topographic maps was measured and correlated to the closest slope value using a U.S.G.S. Timesaver Land and Slope Indicator.
Orientation	Determined by overlaying SHADOW Orientation Scale tool onto U.S.G.S. topographic maps.
Channel width	From most recent stream surveys conducted by ODFW or ARWC.
Flow Width	From most recent stream surveys conducted by ODFW or ARWC.
ODF fish bearing classification	From ODF classifications. L, M, S for large, medium, and small streams, respectively.
Tree channel distance	Rough estimate based on tree line distance to bankfull width of stream habitat surveys conducted by ODFW or ARWC.
Tree height	Stereoscopic interpretation of aerial photos was used and correlated to field measurements using an Impulse laser instrument. Older (taller) deciduous stands had larger tree top circumferences, often with more continuous and thicker canopy. These parameters were smaller with mid and early successional stages. Additionally, color and depth changed from one canopy to the next, which indicated deciduous species mixtures. Late successional coniferous canopies showed high relief, variable regularity and density, and uniform dark green color. Stand age (height) correlated with less-pointed cone-shaped shadows.
Overhang (%)	The fraction of underlying stream channel visible through directly overhead vegetation.
Shade density	Successional stage, slope, vegetation classification, and vegetation spacing were indicators of shade density. Dense canopies with little "openings" correlated with greater shade densities. Lower shade densities were characterized by larger or more numerous canopy openings, where more light reached the stream surface.
Vegetation width	Measured in Arcview. Measured distances incorporated moderate vegetation changes where vegetation was continuous. For example, if the immediate riparian area vegetation was classified as mid-successional deciduous and then transitioned to mid-successional coniferous, the measured distance included both communities. If vegetation transitioned from a mid-successional deciduous to a grass/forbs community, however, only the immediate riparian vegetation was included in the measurement.
Species composition	D, C, M for deciduous, coniferous, and mixed species composition, respectively. A stand with <66% of either coniferous or deciduous species was categorized as "mixed".
Vegetation age	E, M, L for early, mid, and late successional stages, respectively. Deciduous age ranges (yr) were (early) 0-10, (mid) 10-40, (late) 40-100s. Coniferous age ranges (yr) were (early) 0-30, (mid) 30-100, and (late) >100. Early deciduous stands were dominated by alder, willow, blackberries, and/or grasses and forbs with an average height range of 0-39' and diameter at breast height (dbh) of <8". Mid-successional deciduous stands were dominated by ash, cottonwood, big leaf maple, alder, and understory shrubs with a height range of 40-79' and dbh 8-17". Late deciduous communities were dominated by cottonwood, Oregon ash, big leaf maple, and understory shrubs with an absence of willows, alders and blackberries; heights were >80' and dbh range was ≥18". Early coniferous stands were dominated by Douglas fir, white fir, incense cedar, and/or ponderosa pine with average dbh <12" and heights <60'. Mid- successional coniferous stands had a dbh range of 13-24" and heights of 60-109'. Late successional coniferous stands had dbh ≥25" and heights ≥110'.
Ground-truthed	"G" if most of the data were obtained from field surveys.
Notes	Applicable notes.

3.3.3 Generalized shade curve models: all other streams

This method used soil data to describe associated vegetative communities and applies to Applegate Subbasin stream reaches not covered in Section 3.3.2. Characteristics of these communities defined their vegetation height and canopy density at restored vegetation conditions. Those parameters were

input to a modified Heat Source model that calculated daily percent shade at a range of NSDZs. There were 17 unique combinations of soil type, restored vegetation height, and restored vegetation canopy closure. For each combination, three simulations were run: one at stream aspect of North-South, one at stream aspect of East-West, and one at stream aspect of Northwest-Southeast/Northeast-Southwest. The data from those three simulations were averaged into one NSDZ-percent shade relationship. No topographic shading corrections were made for these simulations. Output from 51 simulations was used to plot the NSDZ vs. percent shade relationship for a series of defined conditions.

Restored vegetative heights for Douglas fir, ponderosa pine, Jeffery pine (using Lodgepole data) and incense cedar were scaled from site quality curves contained in (Bell and Dillworth, 1988). The restored vegetation height for white fir stands in southwestern Oregon was taken from the USFS web site: www.na.fs.fed.us/spfo/pubs/silvics_manual/Volume_1/abies/concolor.htm

Canopy Density. The soil-defined plant communities were matched with Applegate Subbasin-specific communities defined in USDA/USFS (1996) as shown in Table 3-20. Each plant community had defined canopy closures for high, middle and low vegetative layers. For each community, these closures were converted to a single, overall canopy density, which was input as that community's shade density in the Heat Source shade curve development model (see Section 5.3.2).

Table 3-20: Applegate subbasin plant communities and references.

Soil type	Plant community	Reference - page
Type 16	Western White Pine-Common Beargrass	PIMO – 3,4
Type 17	Douglas Fir-Incense Cedar	PSME – 21-22
Type 18	Shasta Red Fir-White Fir	ABMAS - 10,11
Type 50	Ponderosa Pine-Douglas Fir	PIPO – 4,5
Type 56	Ponderosa Pine-California Black Oak	PIPO – 6,7

3.4 Bear Creek

Bear Creek was modeled for effective shade with Heat Source 6.0 by DEQ.

3.4.1 Model extent

The model domain extends 44.0 km, from the mouth of Bear Creek to its confluence with Walker and Emigrant Creeks. The model extent is shown in the HTML interactive map that accompanies this TMDL and Figure 3-17.

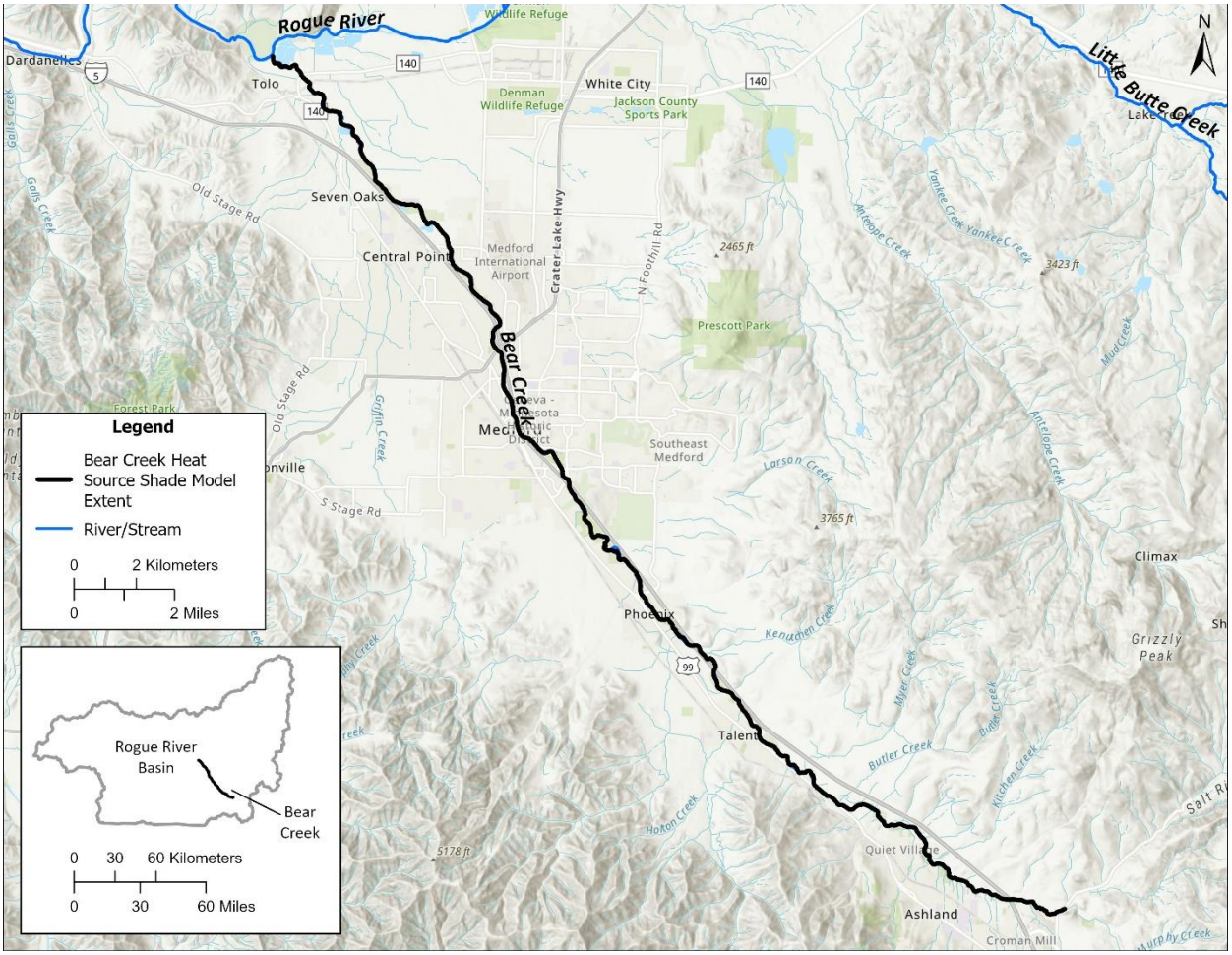


Figure 3-17: Extent of the Bear Creek shade model.

3.4.2 Spatial and temporal resolution

The model input spatial resolution (dx) is 100 meters. Outputs are generated every 100 meters. The model time step (dt) is 1 minute and outputs are generated every hour.

3.4.3 Time frame of simulation

The model period is one day: August 3rd, 1999.

3.4.4 Meteorological inputs

All weather data were sourced the OSU Extension facility station on Hanley Road in Central Point.

3.4.5 Landcover and topographic shade inputs

The near-stream vegetation inputs parameters included shade height, width, density, and overhang. These riparian parameters relate to shade quality and quantity and were measured from aerial photography, digital imagery, and on-site field measurements.. Values assumed for restored

vegetation conditions were based on forest characteristics applicable to the Bear Creek ecoregion given the soil class, species composition, and expected tree density. Channel wetted widths and near-stream disturbance zones were measured from field observations and digital aerial photos. Elevations were obtained from Digital Elevation Models. The elevation of each reach break was derived from the DEM.

Shade height is defined as the height of trees standing in the riparian corridor. This variable was modified during Heat Source model simulations. Figure 3-18 shows the current measured shade heights. Shade density describes how much sunlight penetrates the riparian shade vegetation. It was also modified during model simulations. The average shade densities for left- and right-bank segments are shown in Figure 3-19. Figure 3-20 shows estimated shade width. Figure 3-21 shows estimated shade overhang. Figure 3-22 shows estimated shade due to topographic features only.

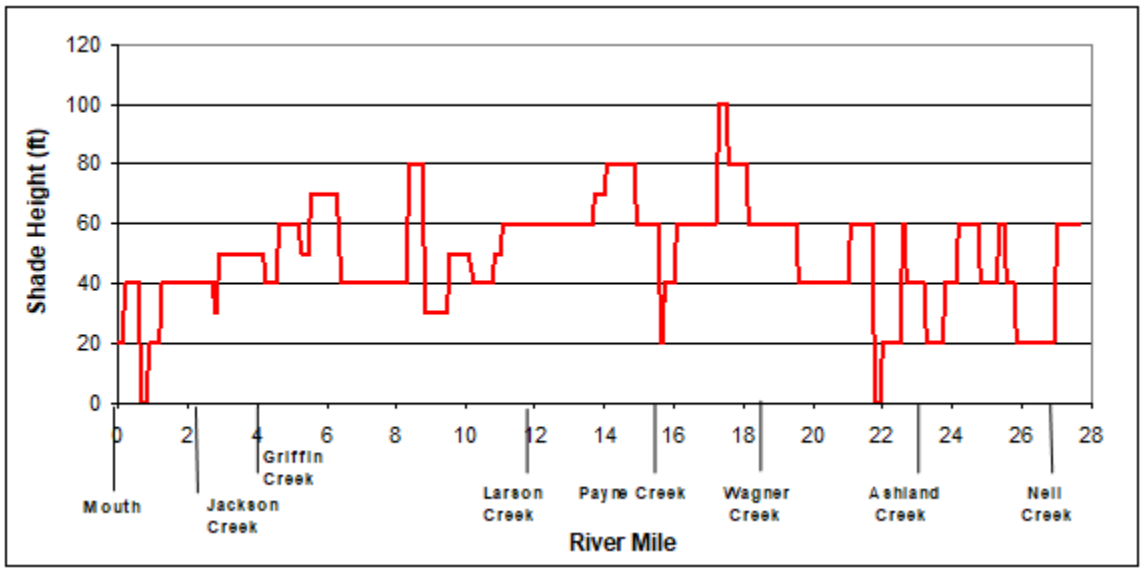


Figure 3-18: Bear Creek estimated shade height.

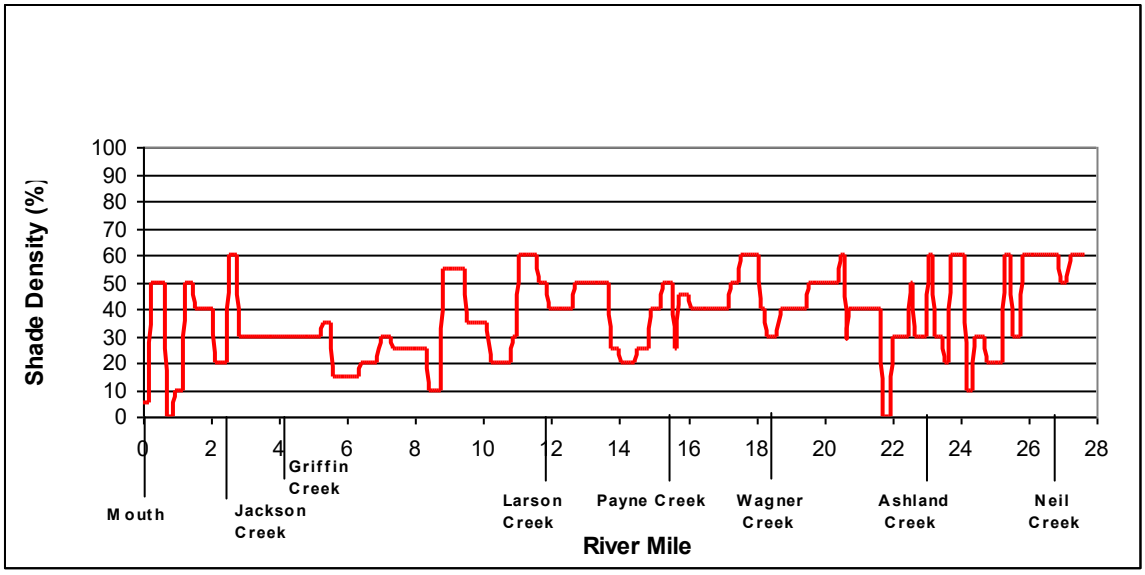


Figure 3-19: Bear Creek estimated shade density.

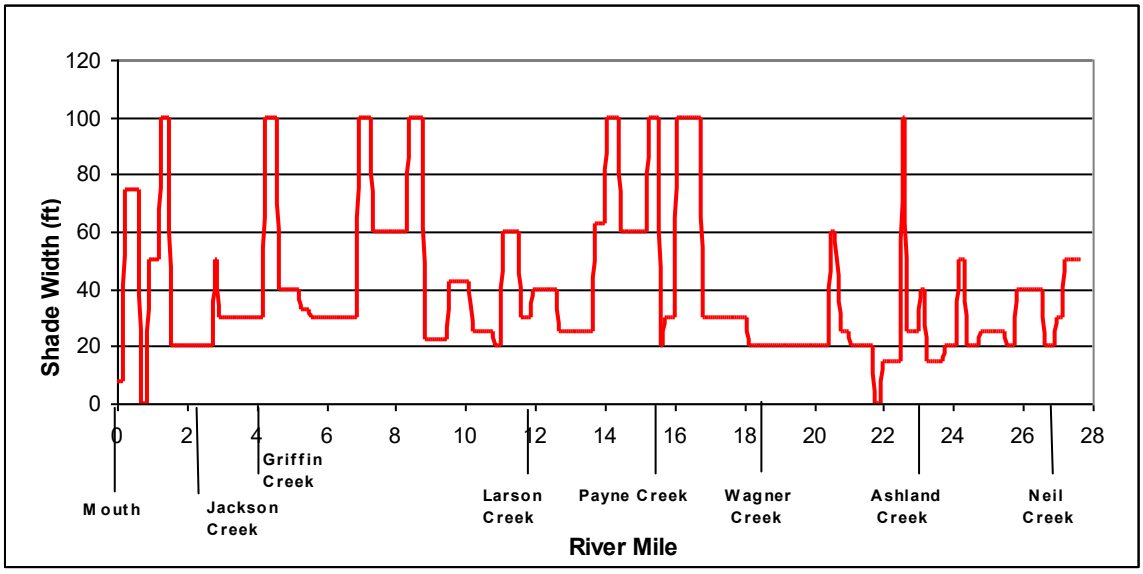


Figure 3-20: Bear Creek estimated shade width.

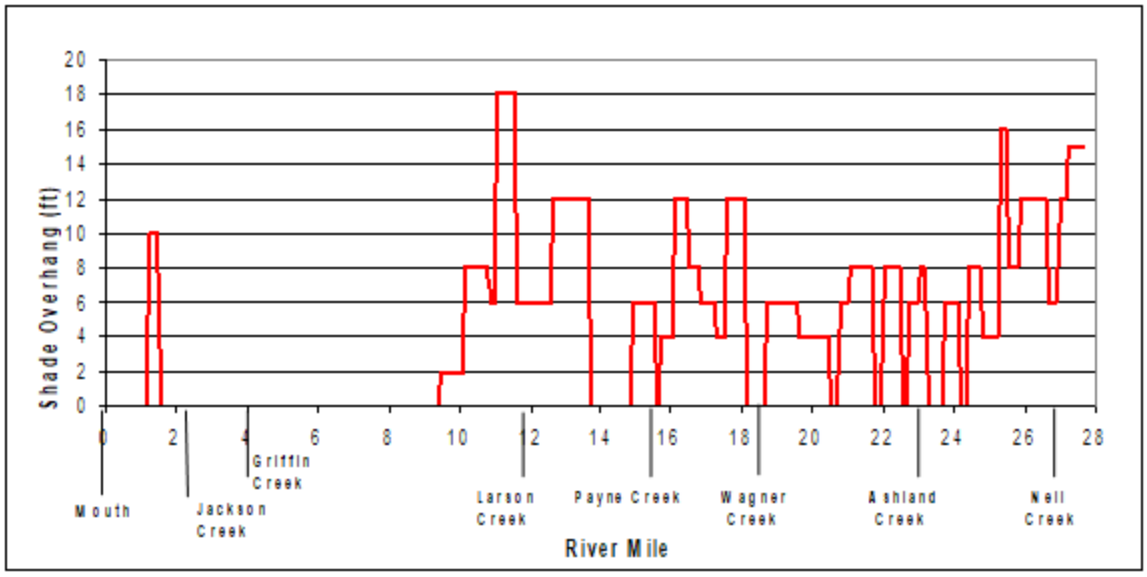


Figure 3-21: Bear Creek estimated shade overhang.

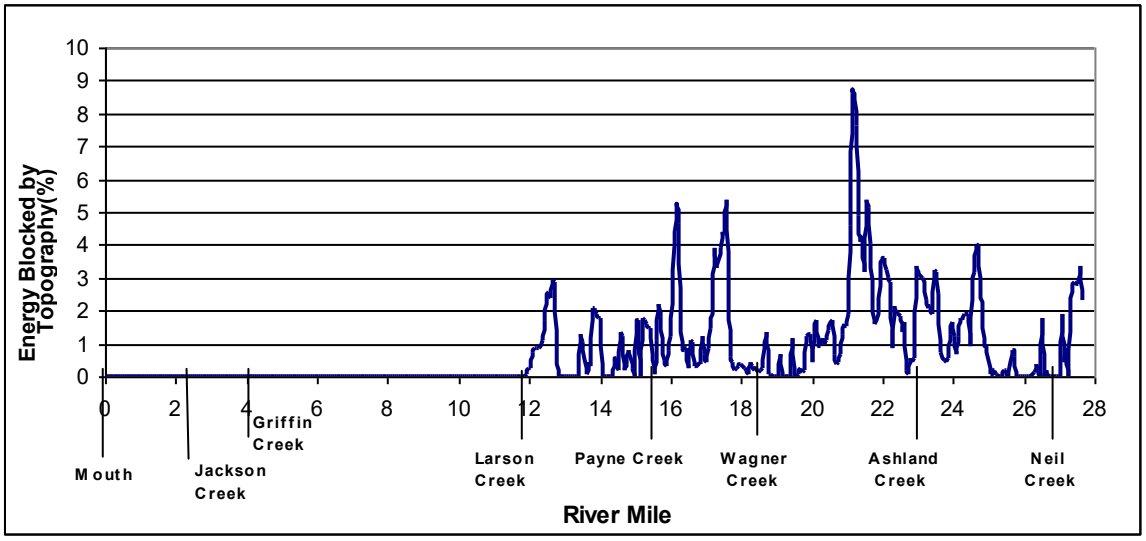


Figure 3-22: Bear Creek estimated topographic shade.

3.4.6 Source characteristics

The primary thermal loading sources contributing to temperatures exceedances in Bear Creek include increases in solar radiation loading from the disturbance or removal of near-stream vegetation, point source discharges, reductions to stream flow rate or volume, water impoundments behind irrigation structures, and background sources (DEQ, 2007). Other potential sources include channel modification and widening, and warming caused by climate change.

The majority land uses along Bear Creek are developed areas, forestry, and agriculture accounting for about 91 percent of the near-stream area. Table 3-21 summarizes all the land uses within 100 meters of the digitized Bear Creek centerline. Land uses were summarized using the 2016 National

Land Cover Database (Yang et al., 2018). Note that Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.
To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 3-22).

Table 3-21: Summary of land uses along the model extent within 100 meters of the digitized Bear Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Hay/Pasture	497.5	22.9
Woody Wetlands	467.7	21.5
Developed, Low Intensity	293.3	13.5
Developed, Open Space	282.2	13
Developed, Medium Intensity	219.7	10.1
Emergent Herbaceous Wetlands	186.8	8.6
Shrub/Scrub	122.1	5.6
Developed, High Intensity	62.0	2.9
Herbaceous	22.0	1
Evergreen Forest	16.2	0.7
Barren Land	1.6	0.1
Cultivated Crops	0.7	<0.05
Mixed Forest	0.2	<0.05

Table 3-22: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Bear Creek centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
Jackson County	938.6	35.7
City of Medford	542.7	20.6
Oregon Department of Agriculture	369.8	14.1
Oregon Department of Transportation	270.6	10.3
City of Ashland	121.0	4.6
State of Oregon	116.9	4.4
City of Phoenix	88.9	3.4
City of Talent	75.6	2.9
City of Central Point	61.0	2.3
Oregon Department of Fish and Wildlife	36.8	1.4
U.S. Government	4.9	0.2
Central Oregon & Pacific Railroad	2.2	0.1

3.4.7 Point sources

There is one permitted individual NPDES point source along the model extent. Detail about the point source is summarized in Table 2-1. The City of Ashland (#3780) owns and operates a wastewater treatment facility that discharges treated effluent into Ashland Creek upstream of its confluence with Bear Creek at river mile 0.2. Currently there are plans to move the outfall to Bear Creek approximately 100’ downstream from the confluence of Ashland Creek near river mile 22.8. The locations of the outfalls are shown in Figure 3-23. DEQ considered this new outfall in the Bear Creek assessment for this TMDL.

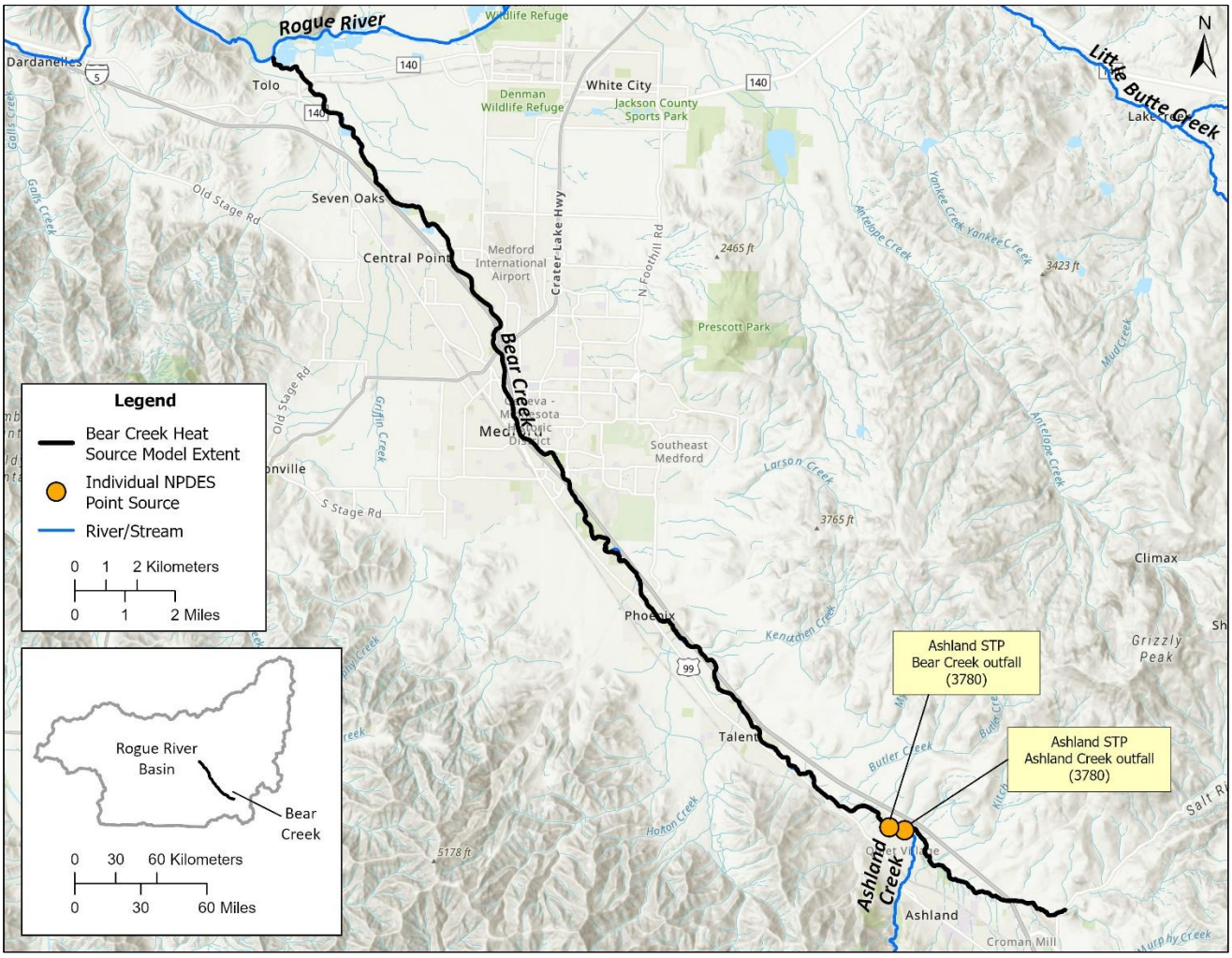


Figure 3-23: Locations of permitted individual NPDES point sources along the Bear Creek model extent.

3.4.8 Channel setup

COMPLETE OR DELETE

3.5 Bear Creek Watershed

The Bear Creek Watershed SHADOW models are shade models developed by the USFS. The model setup for the USFS SHADOW models were described in the original Bear Creek Watershed TMDL (DEQ, 2007). DEQ did not update these models or the results presented in this TMDL.

3.5.1 Model extent

The extent of the model domain is select tributaries to Bear Creek from the mouth to headwaters in the Bear Creek Watershed (1710030801). Select tributaries include Anderson Creek, Ashland Creek, Butler Creek, Coleman Creek, Emigrant Creek, Griffin Creek, Jackson Creek, Larson Creek, Lazy Creek, Myer Creek, Neil Creek, Wagner Creek, and Walker Creek. The model extent is shown

in the HTML interactive map that accompanies this TMDL. Approximately 453.1 stream km were assessed.

Impacts to the stream channel and riparian vegetation include: urbanization and urban infrastructures; agricultural activity; suburban and rural residential developments; water withdrawals; timber harvests; active and legacy aggregate mines; local and forest access roads; and federal, state, and county highways. Impacts more specific to federally managed lands included: timber harvests and roads; mining activity; and a few remnant homesteads or residential inholdings.



Figure 3-24: Location of the Bear Creek watershed and assessed stream network.

3.5.2 Landcover and topographic shade inputs

Aerial photo interpretation and mapping were performed using BLM-supplied 1996 color air photos at 1:12,000 scale, 7½' USGS quadrangle maps, and ODF stream classification maps. Streams and tributaries were included in the assessment if they were: 1) on the state's 303(d) list (for temperature); 2) the tributary area is 5% or greater of the watershed area above its confluence with the receiving stream; 3) fish-bearing status as per ODF stream classification maps and interim protocols; and/or 4) perennial stream flow. Note: tributary streams that are listed as intermittent on the USGS quadrangles or have an area less than 5% may have been included in this assessment if they cross non-federal lands to get a comprehensive overview of the existing conditions.

Reach breaks were established using the following criteria: 1) confluence of perennial streams; 2) change in ODF stream classification; 3) ownership boundaries as identified by the Medford District BLM "Recreation Map"; 4) significant changes in terrain slope or valley type; 5) change in aspect class; 6) change in riparian vegetation. Each reach was given a unique alphanumeric identification using (generally) the first three letters of the stream name followed by a number. Reaches were

numbered sequentially from mouth to headwaters. Reach breaks were recorded on hard copy 7½' USGS quadrangles and transferred onto a GIS streams layer. The GIS streams layer was developed from an existing 1:24k BLM hydrography layer compiled from DLG and CFF files of the basin's hydrography.

The riparian assessment consisted of interpretation or measurement of shade parameters, riparian vegetation, and channel conditions. These values were taken from color aerial photos, USGS quadrangle maps, or GIS 1:24k streams layer (Table 3-23).

Table 3-23: Assessment Parameters included in Bear Creek watershed riparian assessment.

Assessment parameter	Resolution	Comments
Overhang (%)	10	Photo-estimated
Shade density (SD, %)	10	Photo-estimated; if current riparian trees have SD<10%, then SD=0%
Terrain slope (%)	10	Photo or map estimated
Aspect class (°)	60	Map; 229-29; 30-60/120-150; 61-119
Tree-to-channel distance (ft)	5	Photo estimated / measured
Tree height (ft)	20	Average of primary shade vegetation
Width, active channel (ft)	5	Photo estimated / measured
Reach length (ft)	100	GIS calculated
Buffer width (ft)	10	Fed. = 300' max; Non-fed. = 100' max
Percent of reach (%)	10	
Vegetation composition		Deciduous, conifer, herbaceous
Stream order (Strahler)		USGS 7½' quadrangles
Valley slope	0.1	Slope gradient / valley length (map)
Channel sinuosity	0.1	Stream length / valley length (photo)
Stream slope	0.001	Valley slope / sinuosity
Rosgen channel, level 1		Stream slope and photo interpreted
OWEB channel confinement		Photo or map estimated
Bank stability		Photo estimated (Yes / No)
Stream class		Size and classification
Land use class*		URB, PF, AG, RS, NR, MIX, CITY, ST, BLM, FS
Impervious surface		Affecting riparian vegetation (yes / no)
Stream diversions		Known or observable on photo (in / out)

* Land use class key: Urban infrastructure and facilitates (URB), Private forestry (PF), irrigated or cultivated agricultural lands (AG), Private resource lands (non-cultivated agriculture, mining, county) (RS), Private non-resource lands (i.e. rural residential) (NR), mixed private land uses (MIX), City lands (specifically, City of Ashland) (CITY), State of Oregon (ST), Bureau of Land Management forest, mixed, and non-forest lands (BLM), United States Forest Service (FS)

3.5.3 Channel setup

3.5.3.1 Shade Curves

The SHADOW model was used to calculate percent shade based on three sets of average channel, terrain, and vegetation characteristics and three aspect classes. Shade was based on the earth-sun-terrain/vegetation relationship on August 1 for specified latitudes. Shade tables were broken into large streams and small streams with confined channels and valley streams with unconfined channels. Channel widths ranged from 30' – 120' and 5' – 25' for large and small streams, respectively, and 10' – 120' for valley streams. Tree heights ranged from 20' – 180' in 20' intervals. Percent shade was calculated for each channel width - tree height combination using shade densities from 10% - 80% at 10% intervals. Table 3-24 shows the base assumptions for each shade table. Valley tables were used for Bear Creek (all reaches), Jackson Creek reaches 1-2, Griffin

Creek reach 1, Coleman Creek reaches 1-8, Anderson Creek reach 1, Wagner Creek reach 1, and Lazy Creek reaches 1-7.

Table 3-24: Bear Creek, base assumptions for shade tables.

Shade variable	Large streams	Small streams	Valley streams
Vegetation overhang	0%	0%	0%
Tree-to-channel slope	30%	50%	20%
Tree-to-channel distance	25 feet	10 feet	10 feet

Table 3-25: Base assumptions for shade tables, Ashland Creek.

Shade variable	Upland streams
Vegetation overhang	50%
Tree-to-channel slope	30%
Tree-to-channel distance	5 feet

3.5.3.2 Future Conditions Modeling

Forest growth models were used to project growth rates and heights for the dominant riparian tree species. Growth models were constructed by species and delineated by site index or site class values that related to growing conditions. Table 3-26 lists Bear Creek tree species and associated site values.

Riparian corridors were assumed as managed to reach their full restored vegetation condition. Shade densities for restored vegetation conditions were set at 70% for conifer-dominant, mixed old growth, and cottonwood-dominant hardwood stands; and 80% for mature hardwood-dominant stands (non-cottonwood). Stand densities and recovery times (i.e., years to grow to restored vegetation heights) assumed that existing vegetation would grow through successional progressions to a late successional stage. Natural events such as floods or fires may alter the progression rate and achievement of late successional stand conditions.

Generally, vegetation overhang increases as riparian stands grow and mature. The extent of this increase is difficult to predict but may exceed 90% on small headwater streams. Overhang was set to 0% in the shade tables, which is as an extreme conservative assumption for restored conditions.

Along Bear Creek's lower reaches where channel widths are >100', future conditions were modeled with a 100' channel width. The recovery time required to regain channel width was not included in this assessment. The time needed to stabilize and rebuild stream banks and establish riparian trees for an existing bankfull channel is difficult to confidently estimate.

Table 3-26: Tree species and forest growth model site values

Tree species	Site index	Site class	Height	Years
Red alder[1]	70		88	80
Cottonwood[2]	85	II	97	101
Douglas fir[3]	85		148	120
Ponderosa pine[3]	85		153	120

1 - Worthington, N.P., Johnson, F.A., Stoebler, G.R., and Lloyd, W.S., 1960. PNW Experiment Station Paper 36.
2 - Burns, R. M. and B. H. Honkala (1990). Silvics of North American Trees. Vol2, Hardwoods. Washington, D.C., U.S. Department of Agriculture. pp. 570-582.

3 - Hann, D.W., and Scrivani, J.A., 1987. Research Bulletin 59, Oregon St. Univ. Forest Research Lab. "Dominant-Height-Growth and Site Index Equations for Douglas-Fir and Ponderosa Pine in SW Oregon." pg. 7 equation, "Estimating Future Heights of Dominant Trees in Hypothetical Stands."

3.5.4 Margin of safety

The shade density and vegetation overhang measurement included conservative assumptions. Shade density accounted for the riparian vegetation composition and stocking level with a maximum value of 80% (heavily stocked hardwood stand). Vegetation overhang was measured by estimating the stream channel (%) covered with vegetation. The greatest overhang value recorded was 80%, even for closed canopy reaches

3.5.5 Calibration

Field verification (ground truthing) was conducted at 14 sites during the summer of 1999. Field measurements were conducted using standard DEQ procedures and protocols for SHADOW model ground truthing. Ground truthing reaches were 200’ long with the shade values assessed for only this length. Sampling was conducted at three transects (bottom, middle, and top) along the 200’ reach. For active channel widths <25’, one solar pathfinder measurement was taken at center channel. For channels >25’, three pathfinder measurements were taken across the channel at 25% intervals of the active channel width. The reach value for each parameter was the average of all measurements in that reach. Field measurements were compared to photo-interpreted values and adjustments made to existing conditions as indicated.

3.6 Elk Creek

Elk Creek was modeled for temperature with Heat Source 8.0.8 by DEQ.

3.6.1 Model extent

The extent of the model domain is Elk Creek from the confluence with the Rogue River to just upstream of Bitter Lick Creek. The model extent is shown in the HTML interactive map that accompanies this TMDL and Figure 3-25.

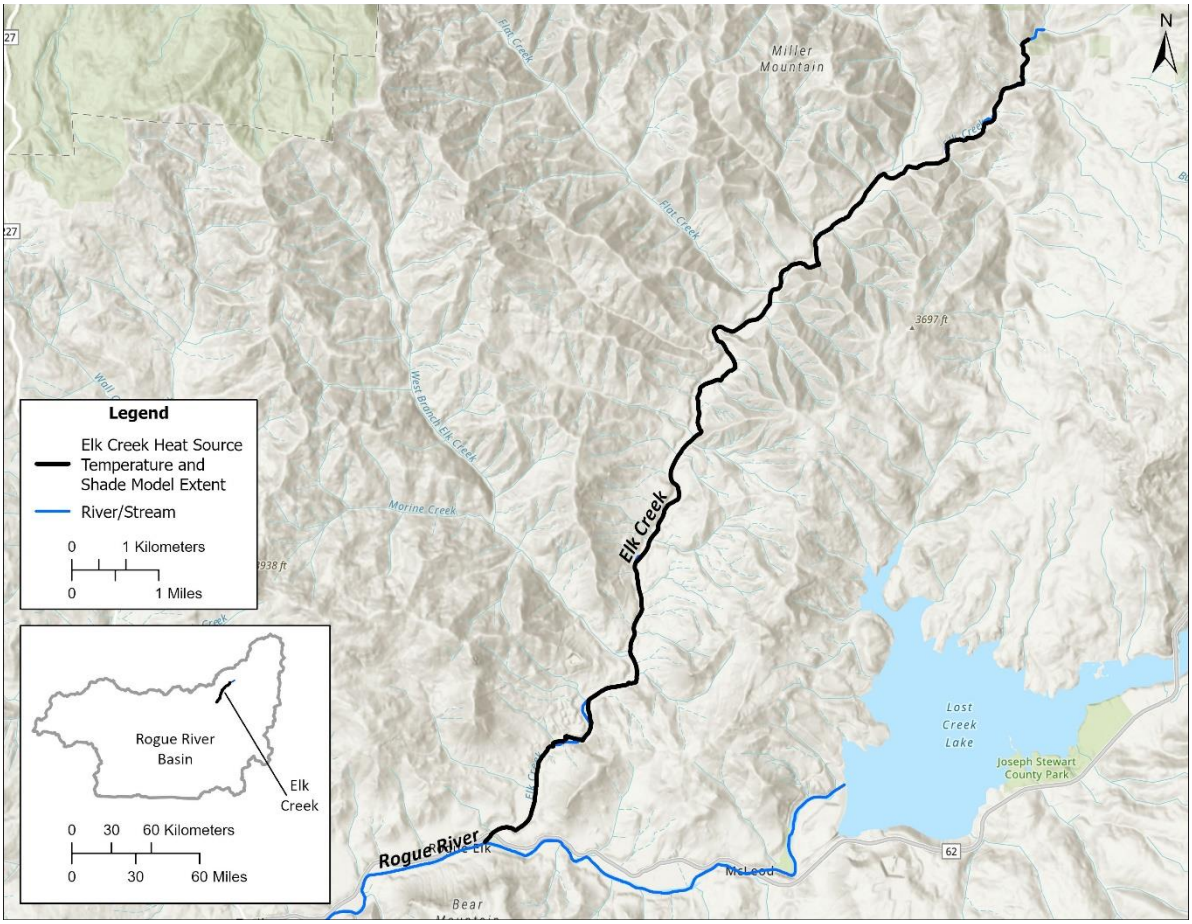


Figure 3-25: Extent of the Elk Creek temperature and shade model.

3.6.2 Spatial and temporal resolution

The model input spatial resolution (dx) is 50 meters. Outputs are generated every 100 meters. The model time step (dt) is 1 minute and outputs are generated every hour.

3.6.3 Source characteristics

The primary sources of thermal loading contributing to temperatures exceedances in Elk Creek include increases in solar radiation loading from the disturbance or removal of near-stream vegetation and background sources (DEQ, 2008). Other potential sources include channel modification and widening, reductions to stream flow rate, and warming caused by climate change. The contribution of these latter potential sources may be investigated as part of the model scenarios. The majority land use along Elk Creek is forestry, accounting for about 93% of the near-stream area. Table 3-27 summarizes the land uses within 100 meters of the digitized Elk Creek centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

To better understand the spatial distribution of different agency rules or management plans along the model extent DEQ mapped known designated management agencies (Table 3-28).

Table 3-27: Summary of land uses along the model extent within 100 meters of the digitized Elk Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Shrub/Scrub	515.7	46.4
Evergreen Forest	431.9	38.9
Hay/Pasture	48.7	4.4
Herbaceous	35.4	3.2
Mixed Forest	23.1	2.1
Developed, Open Space	22.2	2
Deciduous Forest	21.3	1.9
Developed, Low Intensity	6.2	0.6
Woody Wetlands	3.6	0.3
Developed, Medium Intensity	1.3	0.1
Developed, High Intensity	0.9	0.1
Barren Land	0.7	0.1

Table 3-28: Summary of potential designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Elk Creek centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
U.S. Government	602.6	51.7
Oregon Department of Forestry - Private Forestland	253.0	21.7
Jackson County	120.7	10.4
U.S. Bureau of Land Management	100.0	8.6
Oregon Department of Agriculture	68.0	5.8
State of Oregon	12.0	1
Oregon Department of Transportation	4.3	0.4
U.S. Forest Service	3.5	0.3
Bonneville Power Administration	1.2	0.1

3.6.4 Time frame of simulation

The model period is from July 1, 2001 to August 31, 2001.

3.6.5 Important assumptions

The effort described here references existing models. Key calibration assumptions made during the model setup and calibration process were documented in the original Rogue River Basin TMDL (DEQ, 2008) and the model user guide (Boyd and Kasper, 2003); those documents should be used as reference for questions about the representation provided in this document.

3.6.6 Meteorological inputs

Hourly meteorology inputs into the model included air temperature, relative humidity, wind speed and cloudiness from the Medford airport (KMFR - Medford Airport). These data are presented in Section 3.8.4 of this document. Multiplicative wind sheltering coefficients, which represent differences in wind speed between measurement locations and riparian locations, were applied to the wind speed data for calibration (Table 3-29). 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. Additionally, the model originally over-predicted the daily maximum temperatures for all continuous monitoring stations between 8/7 and 8/17. Satellite images showed smoke from forest fires during

this period (NOAA 2001). Therefore, cloudiness was iteratively increased to 0.5 to match daily stream temperatures during this period.

Table 3-29: Elk Creek model wind sheltering coefficients by reach.

Range (river km)	Wind sheltering coefficient
23 - 10	0
10 - 4	0.5
4 - 0	0.75

3.6.7 Temperature inputs

Figure 3-26 shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration. Table 3-30 and Figure 3-27 document the temperatures of the headwaters and tributaries incorporated in the model.

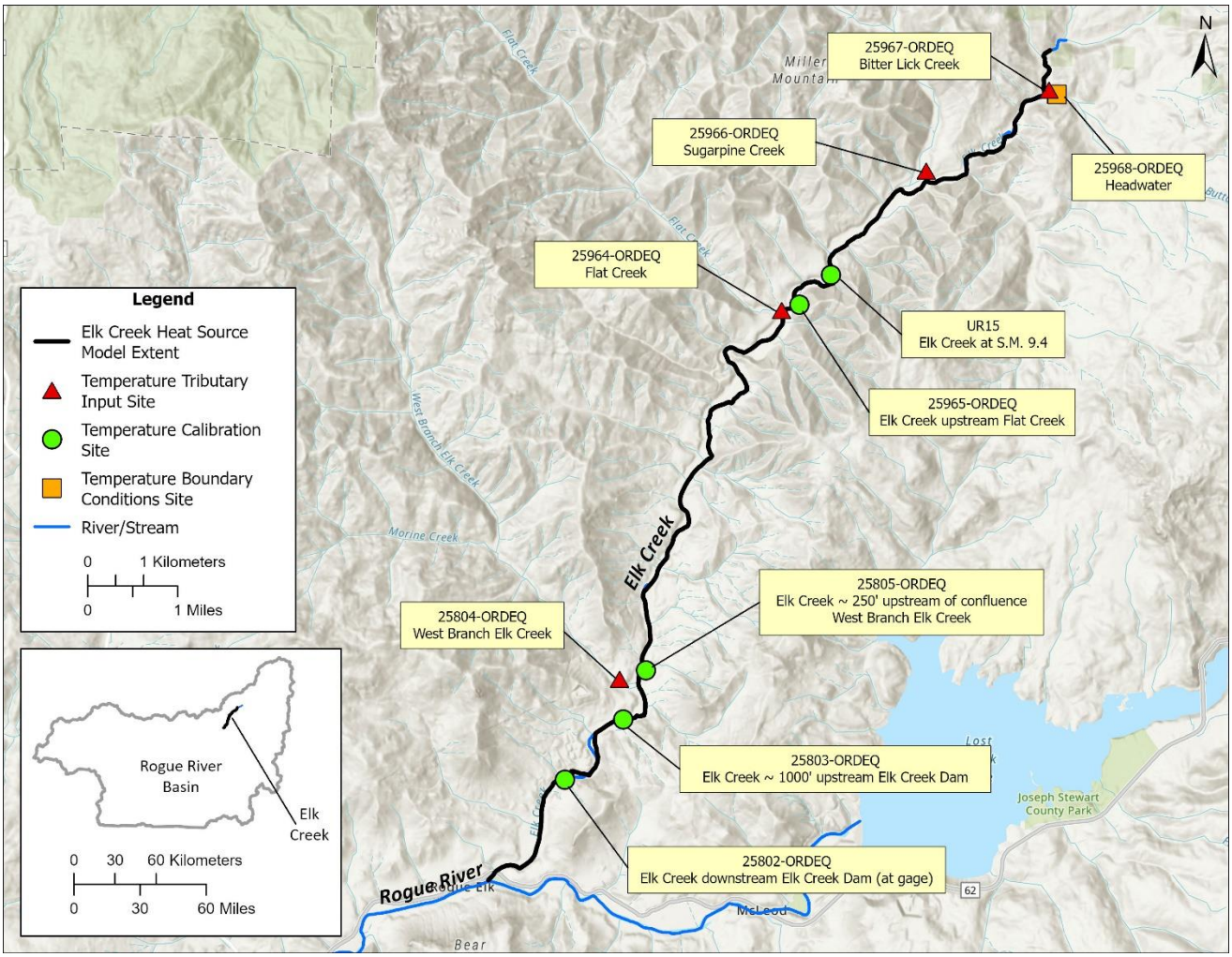


Figure 3-26: Temperature monitoring locations used for Elk Creek model setup and calibration.

Table 3-30: Elk Creek model: source of tributary and boundary condition temperature inputs.

Model Location Name	Stream km	Source of temperature data
Headwater	22.5	Station DEQ-25968

Model Location Name	Stream km	Source of temperature data
Bitter Lick Creek	22.4	Station DEQ-25967
Sugarpine Creek	17.85	Station DEQ-25966
Flat Creek	14.3	Station DEQ-25964
West Branch Elk Creek	5.65	Station DEQ-25804

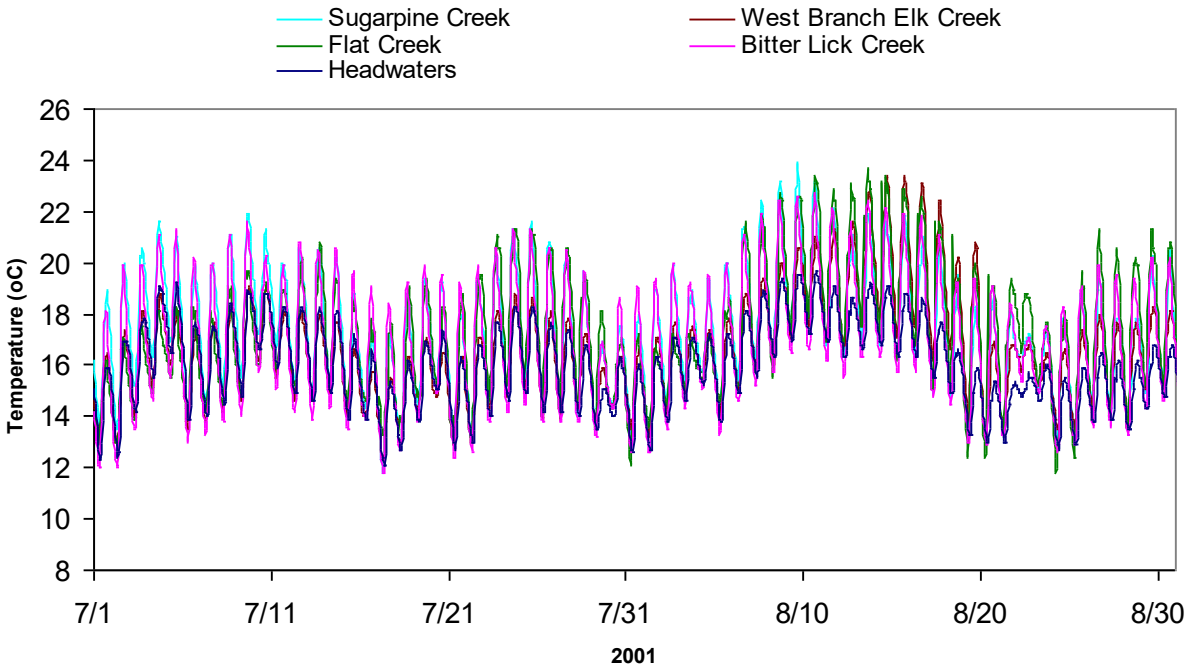


Figure 3-27: Elk Creek model tributary temperature inputs.

3.6.8 Flow inputs

Continuous discharge data were available in 2001 on Elk Creek near Trail, OR (USGS 14338000) at river km 2.5. Figure 3-28 shows the stream flow monitoring locations used for model setup or calibration. DEQ also collected instantaneous flow measurements from 7 sites within the model reach and from major tributaries (Table 3-31 and Figure 3-29**).** To match instream flows, water loss estimation was necessary from river km 5 - 19, which corresponds with consumptive use information provided by OWRD (Figure 3-30). Elk Creek flow diversions were estimated as shown in Table 3-32.

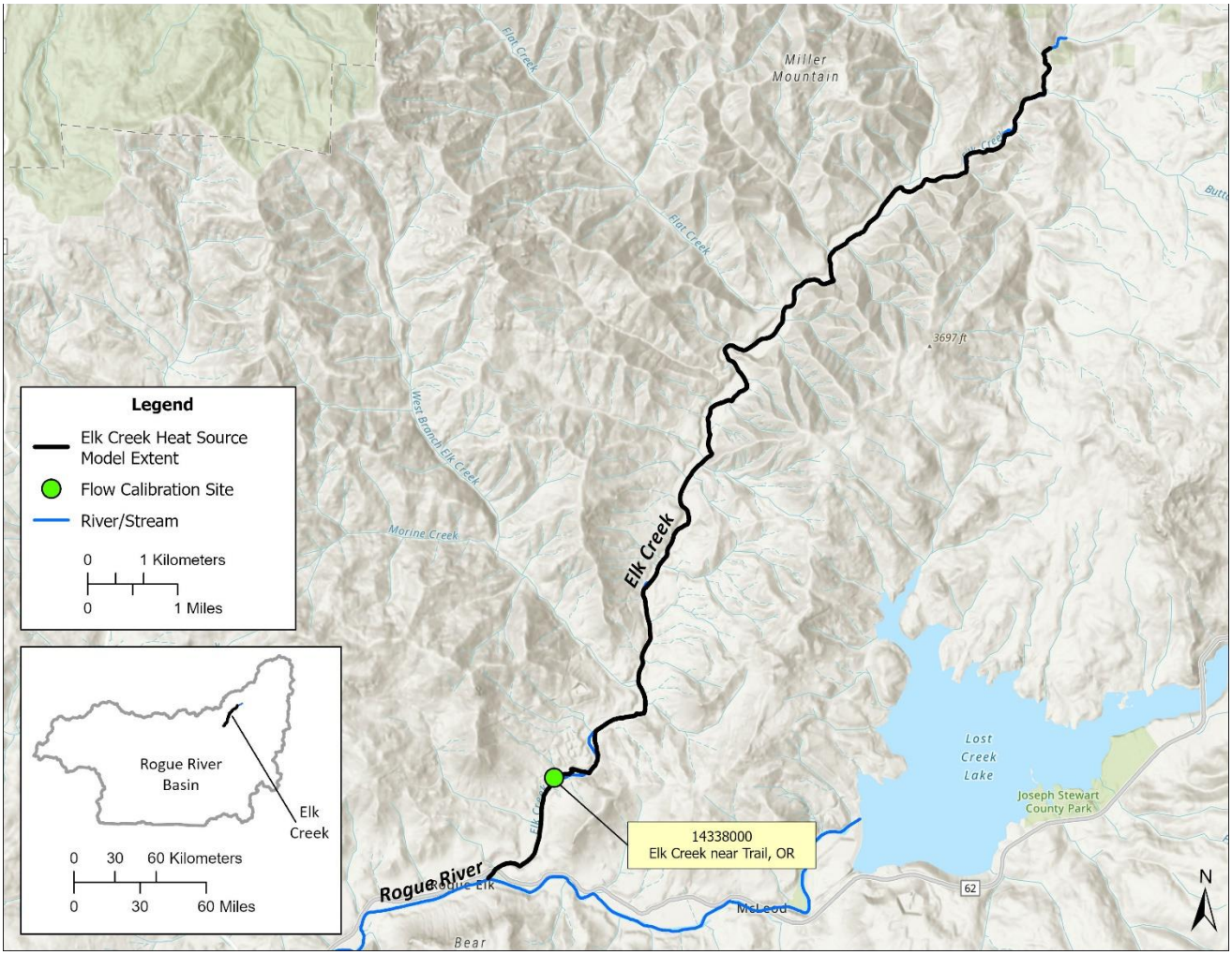


Figure 3-28: Flow monitoring locations used for Elk Creek model setup or calibration.

Table 3-31: Flow input information for Elk Creek model.

Model Location Name (Station ID)	Stream km	Source/notes
Headwater	22.5	Derived by proportioning flows based on an instantaneous flow measurement plus the aerial relationship to the gage
Bitter Lick Creek	22.4	Same method as Headwater site.
Sugarpine Creek	17.85	Same method as Headwater site.
Flat Creek	14.3	Same method as Headwater site.
West Branch Elk Creek	5.65	Same method as Headwater site.

Table 3-32: Flow diversion information for Elk Creek model.

Stream km	Source/notes
14.45 to 19.3	Derived data (OWRD). Applied as distributed diversion of 0.047 cfs total along the reach.
5.35 to 14.45	Derived data (OWRD). Applied as distributed diversion of 0.036 cfs total along the reach.

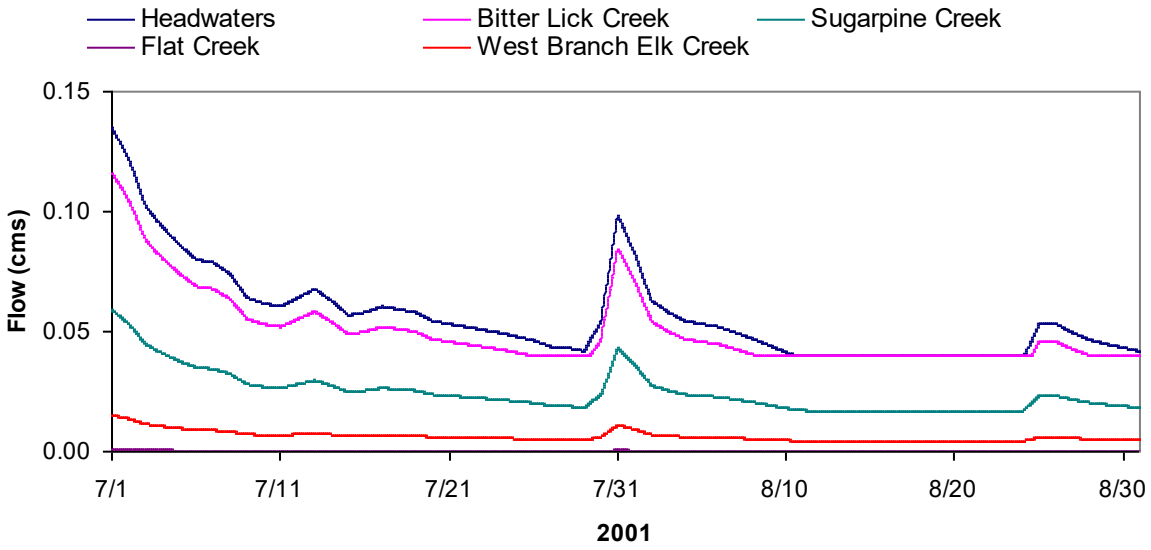


Figure 3-29: Elk Creek model tributary and headwater flow conditions.

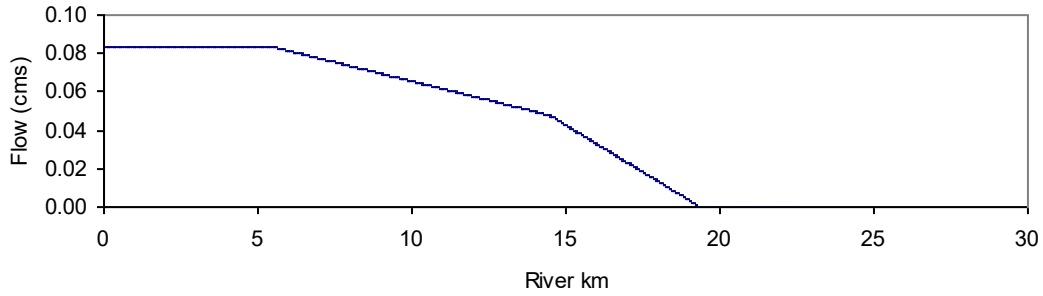


Figure 3-30: Elk Creek model, sum of withdrawals in the downstream direction.

3.6.9 Point source inputs

There are no permitted individual NPDES point sources along the model extent.

3.6.10 Landcover and topographic shade inputs

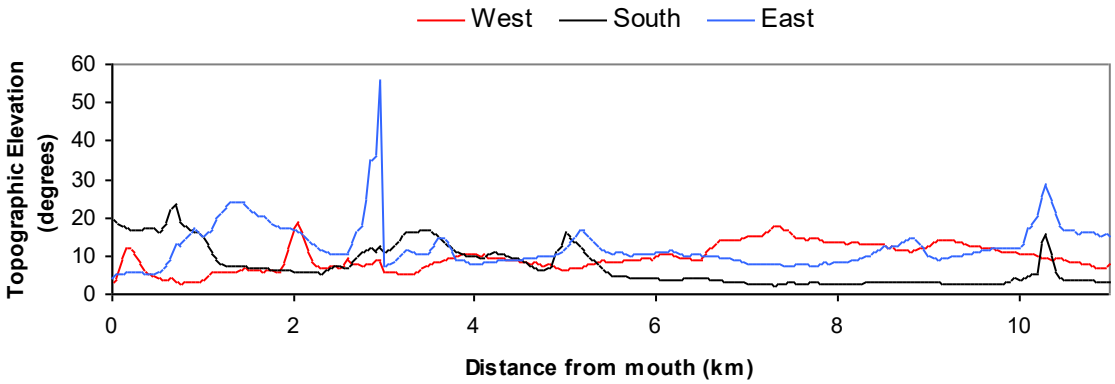


Figure 3-31: Elk Creek model setup for topographic angle.

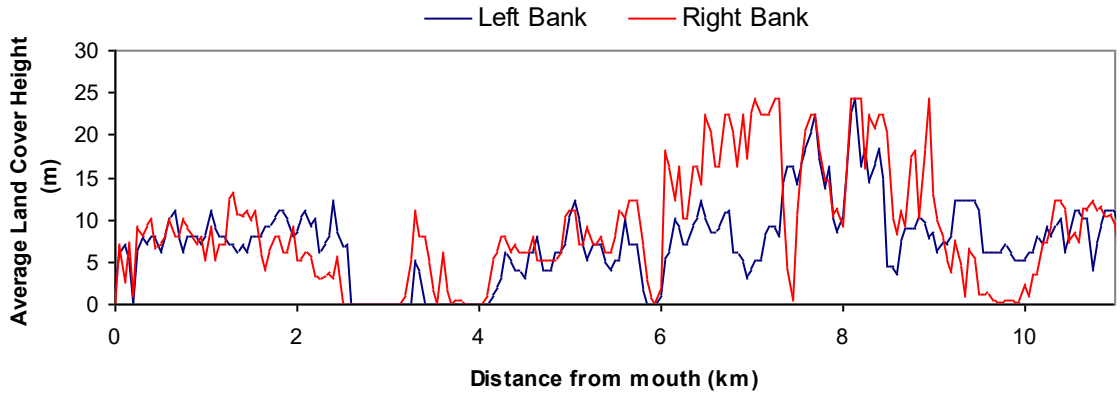


Figure 3-32: Elk Creek model setup for streamside vegetation height.

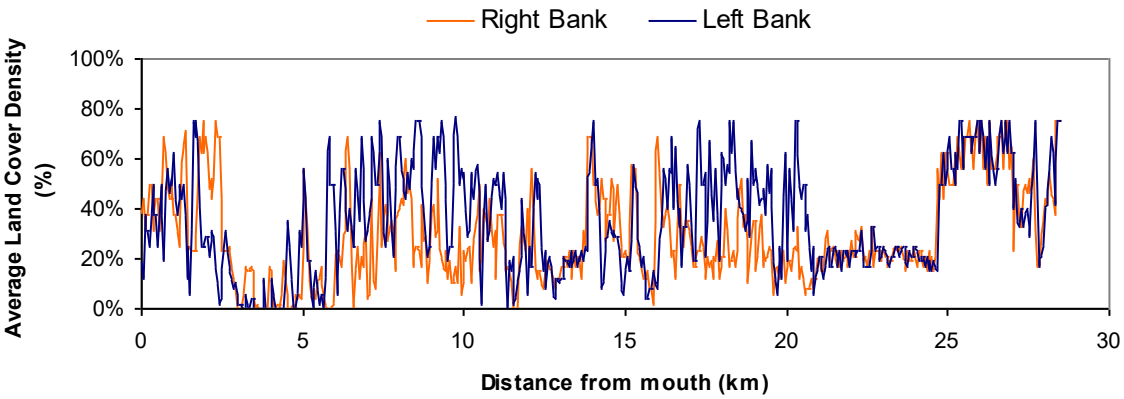


Figure 3-33: Elk Creek model setup for streamside vegetation density.

3.6.11 Channel setup

The channel properties were determined using the methodology documented previously in this report (see Section 2.2.3). The available digital elevation models (DEMs) represented a large reach of Elk Creek as the elevation of the pool behind the future dam, which was never completed (Figure 3-34). Therefore, an average slope was applied to this reach. The bottom width was derived using the active channel width measured from aerial photographs. Bottom width and channel angle (Figure 3-35) were estimated by assuming a trapezoidal channel with variable side slopes and a constant width-to-depth ratio of 8:1 as determined through model calibration. Non-spatially varying coefficients are presented in Table 3-33. Manning's n, substrate thickness and hyporheic exchange were iteratively altered so that the model temperatures approximately reproduced measured temperatures (Table 3-34 and Figure 3-42). Topographic shade angle (Figure 3-31) and riparian vegetation heights (Figure 3-32) were determined through GIS analysis. Using these channel and vegetation inputs, the performance of the Elk Creek model in predicting shade is shown in Figure 3-40.

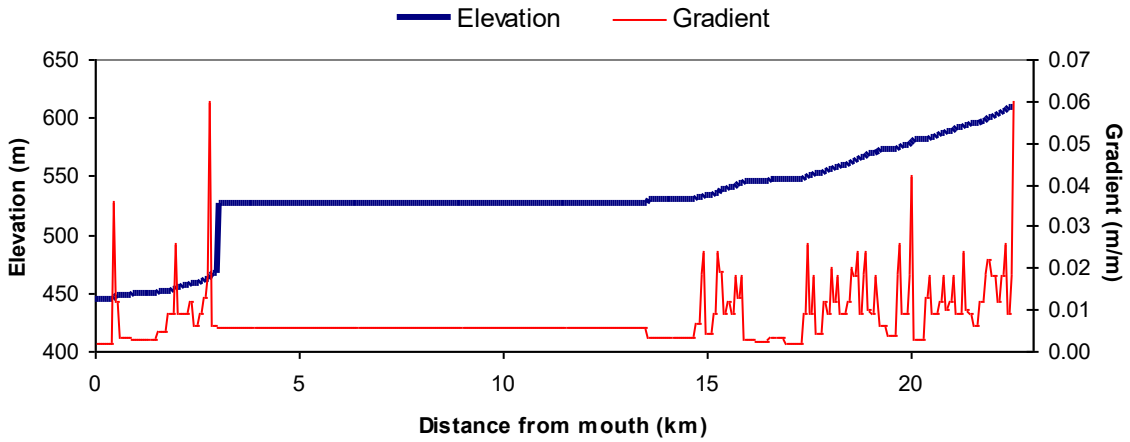


Figure 3-34: Elk Creek model setup channel elevation and gradient.

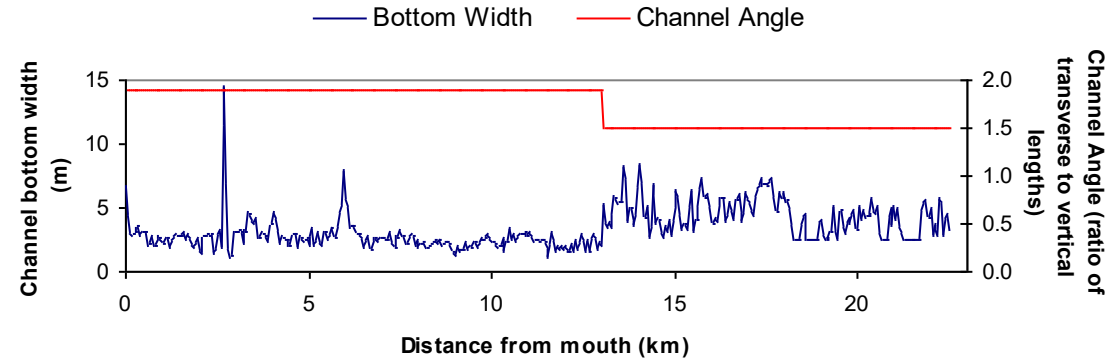


Figure 3-35: Elk Creek model setup for channel bottom width and channel angle.

Table 3-33: Elk Creek model coefficients for non-spatially varying parameters.

Parameter name (units)	Value
Wind Function, coefficient a	1.51×10^{-9}
Wind Function, coefficient b	1.60×10^{-9}
Sediment Thermal Conductivity (W/m/°C)	1.57
Sediment Thermal Diffusivity (cm2/sec)	0.0064
Porosity	30%

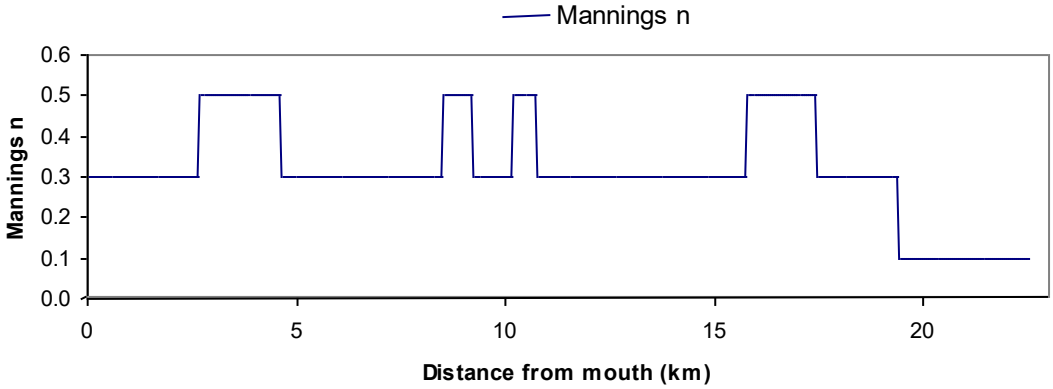


Figure 3-36: Elk Creek: model setup for roughness coefficient.

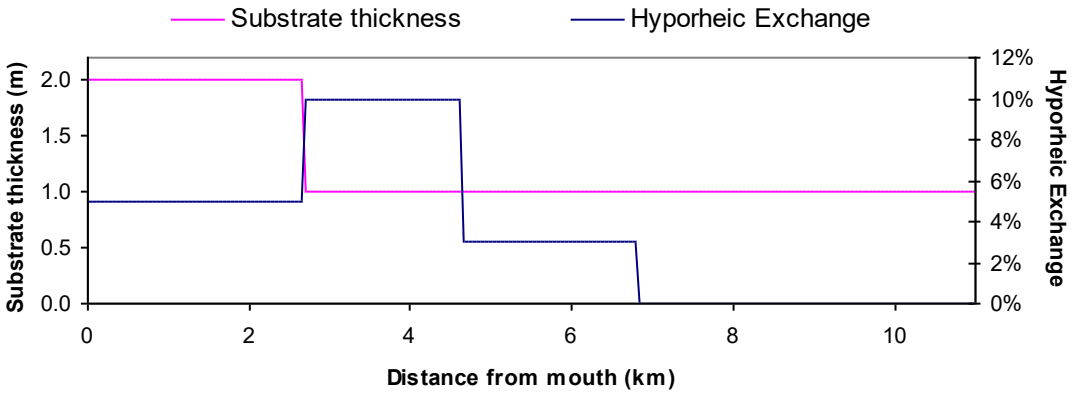


Figure 3-37: Elk Creek: model setup for substrate parameters.

3.6.12 Calibration results

The flow prediction performance of the Elk Creek model at several locations and times is shown in Figure 3-38 and Figure 3-39**.** The temporal shift between measured flow and model results is due to derivation of the dynamic boundary condition flow inputs that were based on a downstream gage. The derivation did not account for travel time between the locations.

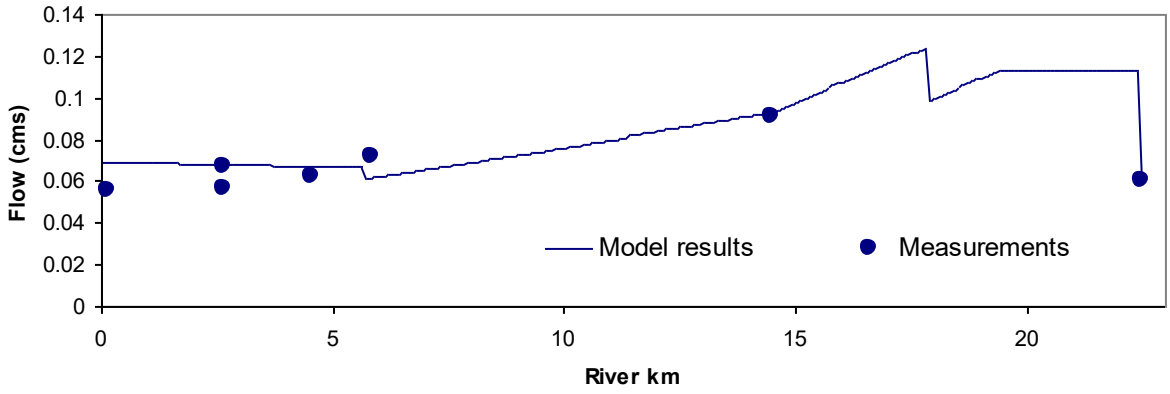


Figure 3-38: Elk Creek: longitudinal profile of measured vs. modeled flow results.

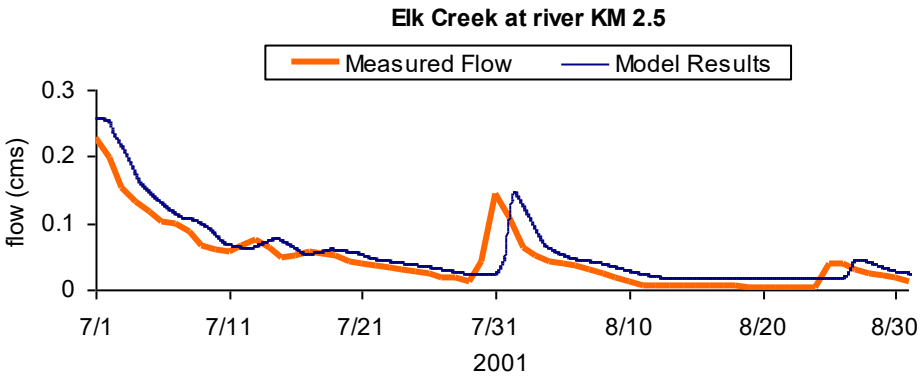


Figure 3-39: Elk Creek: timeseries of measured vs. modeled flow results.

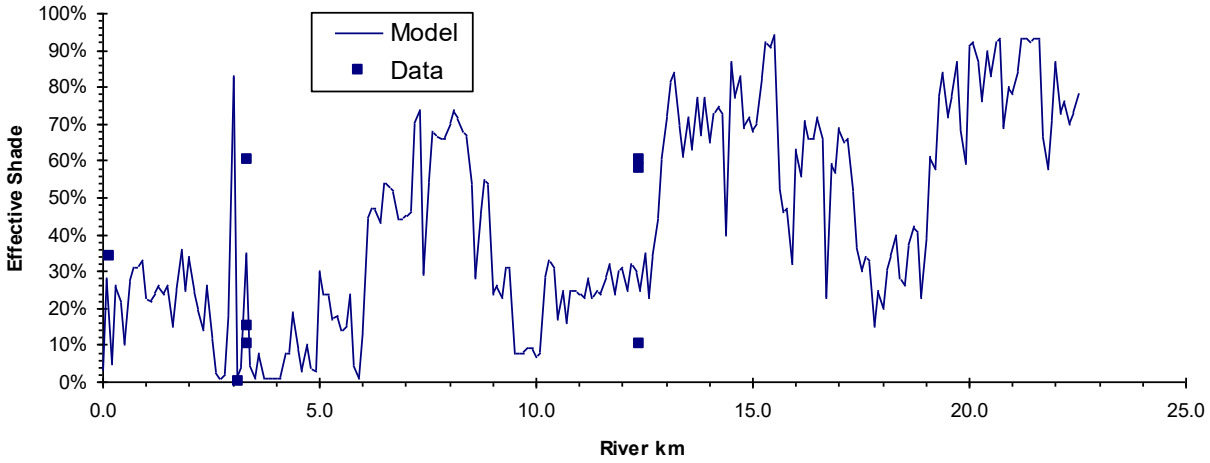


Figure 3-40: Elk Creek: measured vs. modeled shade.

The model outputs generally reproduced spatially and temporally varying temperature measurements (Table 3-34, Figure 3-41, and Figure 3-42). However, there were some deviations between TIR data and model results. Part of this deviation was likely due to the assumed slopes between river kms 3 and 14; the DEM represented elevations of a reservoir behind the dam that was never completed. Without an accurate representation of hydraulics, the temperature calibration suffered. See previous statistics discussion in Section 3.1.3.1 for definitions.

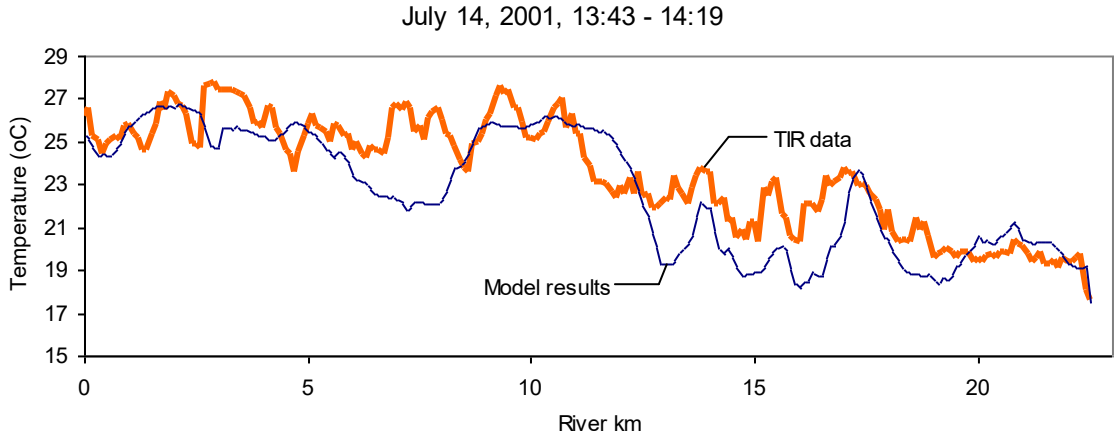


Figure 3-41: Elk Creek: longitudinal profile of TIR-measured temperatures and model results.

Table 3-34: Elk Creek model: continuous and TIR measurement error statistics

Monitoring location	Model km	Temp. Statistic	ME	MAE	RMSE	NSE	n
All Stations		Daily Maximum	-0.34	1.38	1.70		
All Stations		Hourly	-0.77	1.64	1.98	0.37	
Elk Creek at RM 9.4 (UR15) (A)	15.7	Daily Maximum	-0.33	0.83	1.03		62
Elk Creek u/s Flat Creek (25965-ORDEQ) (B)	14.5	Daily Maximum	-0.96	1.11	1.27		62
Elk Creek ~250' u/s West Branch (25805-ORDEQ) (C)	5.85	Daily Maximum	-0.09	1.67	2.19		62
Elk Creek ~1000' u/s Elk Creek Dam (25803-ORDEQ) (D)	4.55	Daily Maximum	0.03	1.66	2.05		62

Monitoring location	Model km	Temp. Statistic	ME	MAE	RMSE	NSE	n
Elk Creek d/s Elk Cr. Dam at gage (25802-ORDEQ) (E)	2.65	Daily Maximum	-0.35	1.63	1.93		62
Elk Creek @ S.M. 9.4	15.7	Hourly	0.43	1.23	1.50	0.56	1488
Elk Creek u/s Flat Creek	14.5	Hourly	-0.27	1.51	1.84	0.24	1488
Elk Creek ~250' u/s West Branch	5.85	Hourly	-1.61	2.02	2.42	0.38	1488
Elk Creek ~1000' u/s Elk Creek Dam	4.55	Hourly	-0.98	1.48	1.81	0.64	1488
Elk Creek d/s Elk Cr. Dam at gage (E)	2.65	Hourly	-1.43	1.98	2.31	0.04	1488
TIR	Model extent		-0.88	1.45	1.83	0.49	

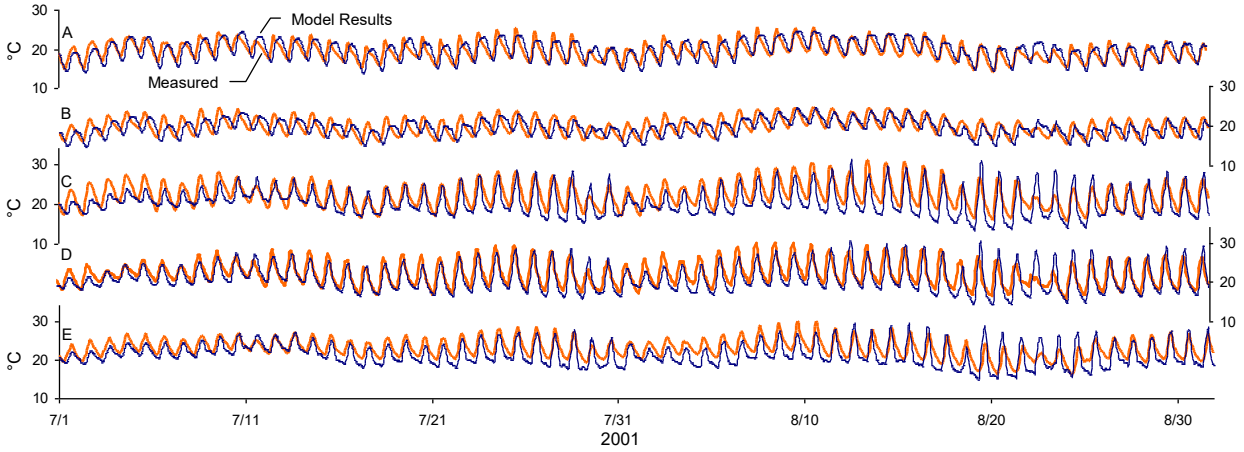


Figure 3-42: Elk Creek: measured vs. modeled steam temperatures.

3.7 Evans Creek and West Fork Evans Creek

The Evans Creek and West Fork Evans Creek model is a water temperature model developed by DEQ using Heat Source 8.0.8.

3.7.1 Model extent

The extent of the model domain is 59.9km, from the mouth of Evans Creek to the West Fork Evans Creek near its headwaters. The model extent is shown in the HTML interactive map that accompanies this TMDL and in Figure 3-43.

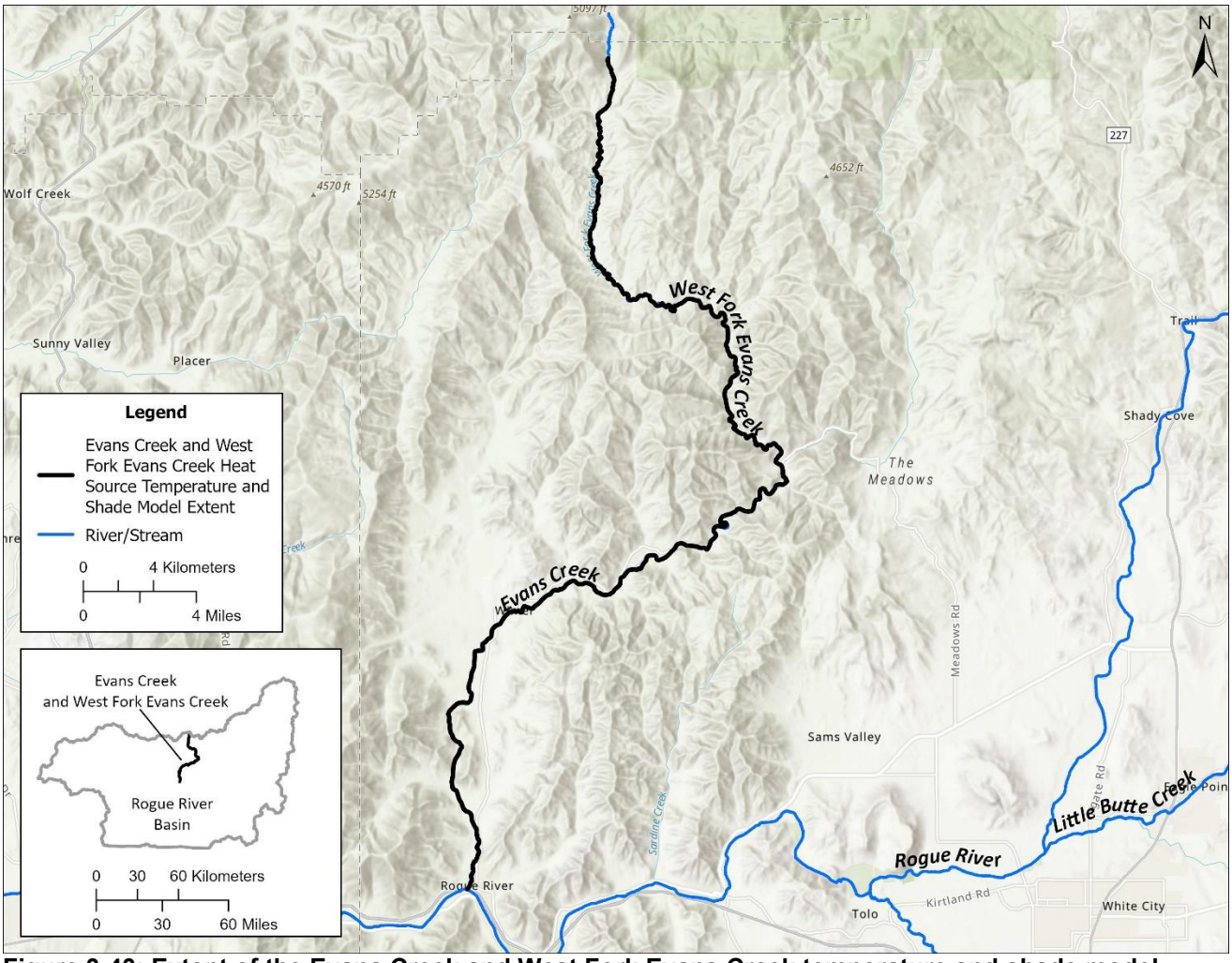


Figure 3-43: Extent of the Evans Creek and West Fork Evans Creek temperature and shade model.

3.7.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 50m. Outputs are generated every 100m. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.7.3 Source characteristics

The primary sources of thermal loading contributing to temperatures exceedances in Evans Creek and West Fork Evans Creek include increases in solar radiation loading from the disturbance or removal of near-stream vegetation and background sources (DEQ, 2008). Other potential sources include channel modification and widening, reductions to stream flow rate, and warming caused by climate change. There are no permitted individual NPDES point sources along the model extent. The majority land use along Evans Creek and West Fork Evans Creek is forestry accounting for about 69 percent of the near-stream area. Table 3-35 summarizes all the land uses within 100 meters of the digitized Evans Creek and West Fork Evans Creek centerline. Land uses were summarized using the 2016 National Land Cover Database (Yang et al., 2018). Note that

Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.

Table 3-35: Summary of land uses along the model extent within 100 meters of the digitized Evans Creek and West Fork Evans Creek centerline based on the 2016 National Land Cover Database (Yang et al., 2018).

2016 NLCD Land Cover	Acres	Percent of Total Acres
Evergreen Forest	1315.0	45.1
Hay/Pasture	426.1	14.6
Shrub/Scrub	338.7	11.6
Developed, Open Space	220.6	7.6
Woody Wetlands	200.6	6.9
Emergent Herbaceous Wetlands	143.7	4.9
Mixed Forest	133.7	4.6
Developed, Low Intensity	86.1	3
Herbaceous	24.2	0.8
Developed, Medium Intensity	11.3	0.4
Deciduous Forest	9.6	0.3
Cultivated Crops	2.4	0.1
Barren Land	1.8	0.1
Developed, High Intensity	1.3	<0.05

Table 3-36 summarizes the designated management agencies and responsible persons along Evans Creek and West Fork Evans Creek model extent.

Table 3-36: Summary of designated management agencies (DMAs) or responsible persons along the model extent within 100 meters of the digitized Evans Creek and West Fork Evans Creek centerline.

DMA or Responsible Person	Acres	Percent of Total Acres
Oregon Department of Forestry - Private Forestland	1025.8	34.7
U.S. Bureau of Land Management	813.4	27.5
Jackson County	550.1	18.6
Oregon Department of Agriculture	496.4	16.8
City of Rogue River	60.4	2
Oregon Department of Transportation	8.8	0.3
Oregon Department of Fish and Wildlife	0.1	<0.05

3.7.4 Time frame of simulation

The model period is from July 1, 2003, to August 31, 2003.

3.7.5 Important assumptions

The effort described here references existing models. Key calibration assumptions made during the model setup and calibration process were documented in the original Rogue River Basin TMDL (DEQ, 2008) and the model user guide (Boyd and Kasper, 2003); those documents should be used as reference for questions about the representation provided in this document.

3.7.6 Meteorological inputs

The model used air temperature, relative humidity, wind speed and cloudiness data collected at the Medford airport. These data are presented in the Little Butte Creek and North Fork Little Butte Creek section of this Appendix. Multiplicative wind sheltering coefficients were applied to the wind speed for calibration (Table 3-37).

Table 3-37: Evans Creek model: applicable wind sheltering coefficients.

Range (river km)	Wind sheltering coefficient
59.7 - 25.2	1.0
25.2 - 6.5	0.5
6.5 - 0.0	1.0

3.7.7 Temperature inputs

Figure 3-44 shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration. Table 3-38 and Figure 3-45 document the temperatures and data sources of the tributaries used in the model. There were no continuous temperature data for the tributaries to Evans Creek, so the West Fork Evans Creek headwater data (Vemco 2700) were applied.

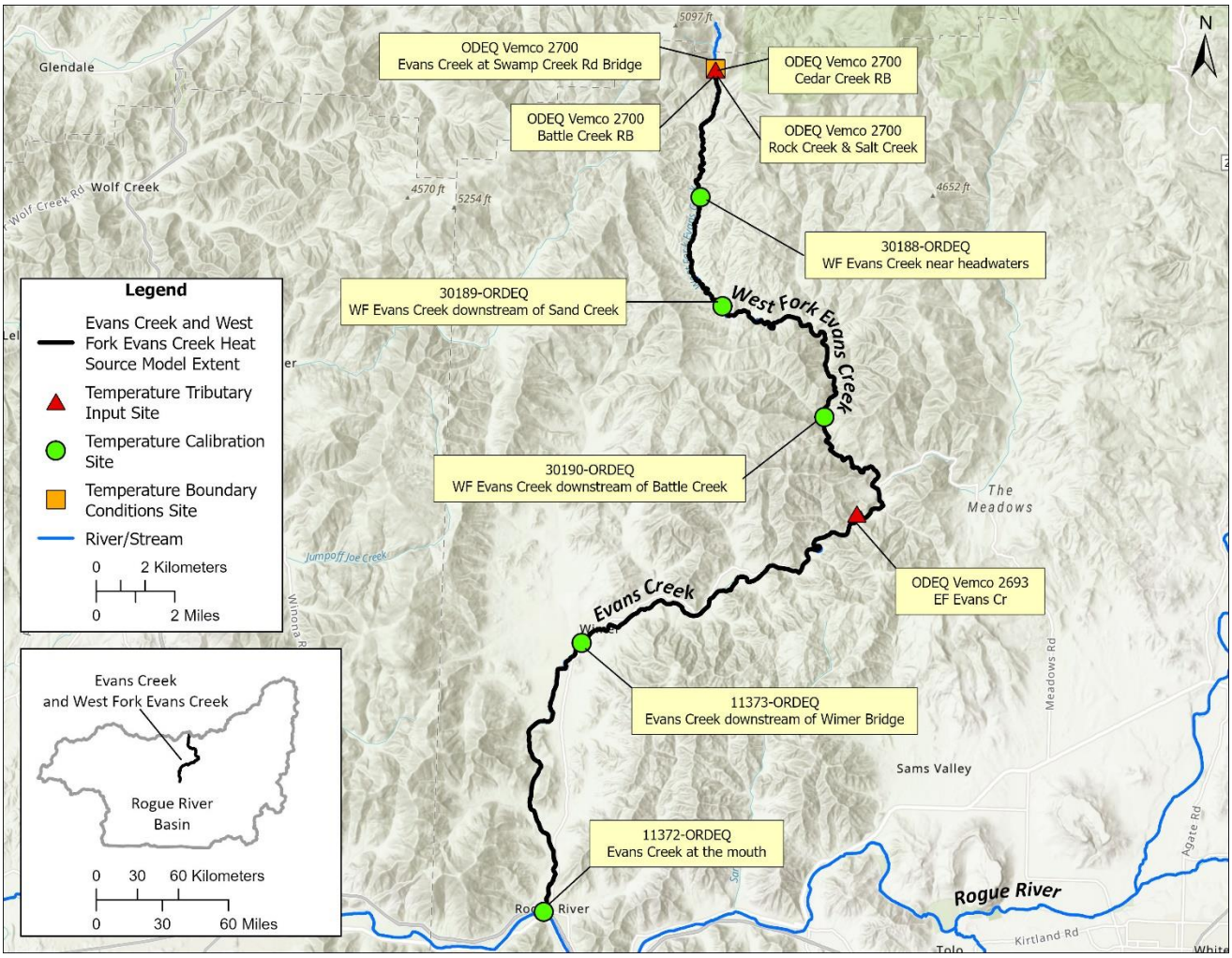


Figure 3-44: Temperature monitoring locations used for Evans Creek and West Fork Evans Creek model setup and calibration.

Table 3-38: Source of tributary and boundary condition temperature inputs for the Evans Creek/West Fork Evans Creek model.

Model Location Name	Stream km	Temperature data source
W. Fork Evans Creek Headwaters at Swamp Creek Rd Bridge	59.7	ODEQ Vemco 2700
Cedar Creek	56.75	ODEQ Vemco 2700
Rock Creek and Salt Creek	45.0	ODEQ Vemco 2700
Battle Creek	37.15	ODEQ Vemco 2700
E. Fork Evans Creek	31.65	ODEQ Vemco 2693

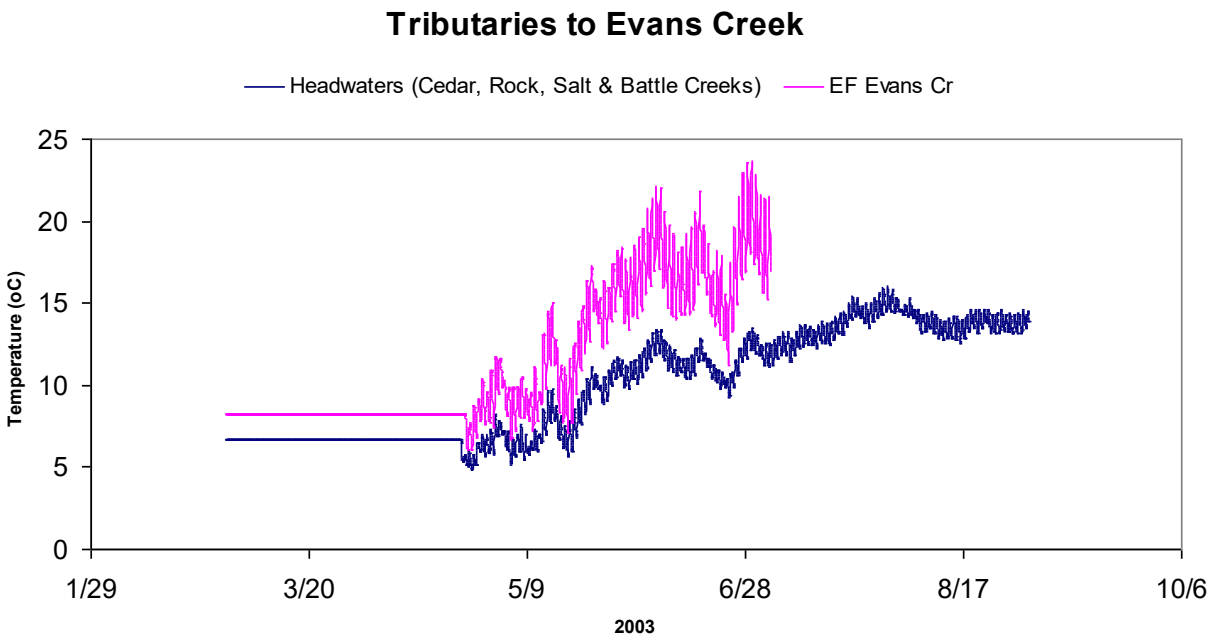


Figure 3-45: Boundary condition and tributary temperatures used in Evans Creek/West Evans Creek model.

3.7.8 Flow inputs

No continuous gage data for Evans Creek were available for 2003, so flows were based on instantaneous flow measurements (Table 3-39). Tributary inflow rates were held constant over the modeling season (Table 3-40). Stream withdrawal rates assumed no water withdrawal upstream of river kilometer 37.1 and were held constant over reach segments to reproduce flow measurements (Table 3-32, Figure 3-47).

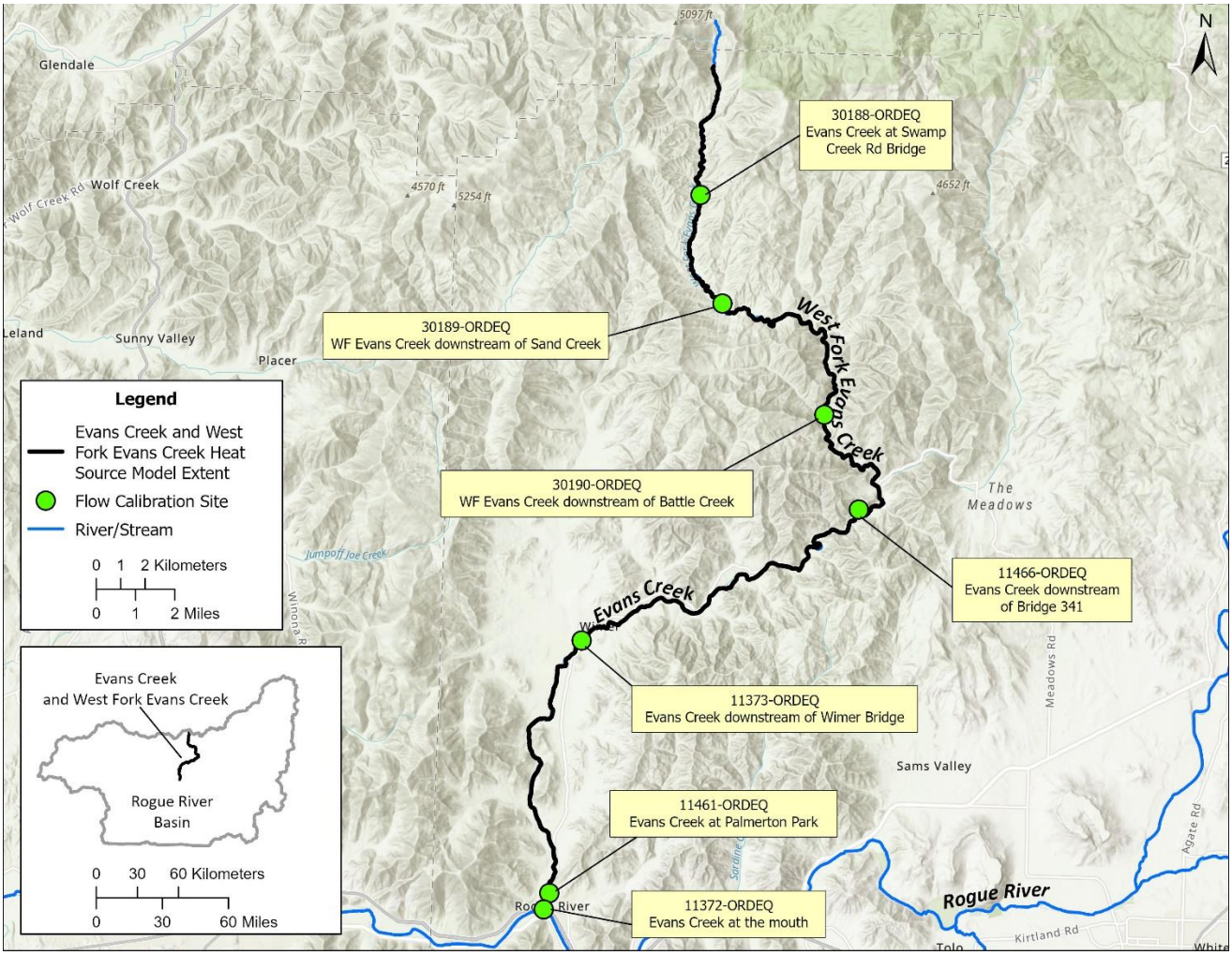


Figure 3-46: Flow monitoring locations used for Evans Creek and West Fork Evans Creek model setup and calibration.

Table 3-39: Source of flow information for Evans Creek/West Evans Creek model.

Inflow	Stream km	Flow data source
WF Evans Creek at Swamp Cr Rd Bridge	53.7	Instantaneous measurement. Applied as a constant (0.075 cms) based on instantaneous flow measurements during modeling period
West Fork Evans Creek d/s of Sand Creek	47.45	Instantaneous flow measurement
West Fork Evans Creek d/s of Battle Creek	37.05	Instantaneous flow measurement
Evans Creek @ Bridge 341	29.5	Instantaneous flow measurement
Evans Creek D/S Wimer Bridge	13.3	Instantaneous flow measurement
Evans Creek @ Palmerton Park	0.8	Instantaneous flow measurement
Evans Creek at Mouth	0.05	Instantaneous flow measurement

Table 3-40: Constant flow conditions based on instantaneous flow measurements during the Evans Creek model period.

Model inflow	Stream km	Flow rate (cms)
Headwaters	59.7	0.075
Cedar Creek	56.75	0.055

Model inflow	Stream km	Flow rate (cms)
Rock Creek and Salt Creek	45.0	0.050
Battle Creek	37.15	0.050
EF Evans Creek	31.65	0.015

Table 3-41: Flow diversion information for Evans Creek model.

Stream km	Source/notes
31.7 to 37.15	Derived data (OWRD). Applied as distributed diversion of 1.925 cfs total along the reach.
13.35 to 31.65	Derived data (OWRD). Applied as distributed diversion of 1.81 cfs total along the reach.
0.85 to 13.3	Applied as a distributed diversion of 0.176 cfs total along the reach.
0.1 to 0.8	Applied as a distributed diversion of 1.73 cfs total along the reach.

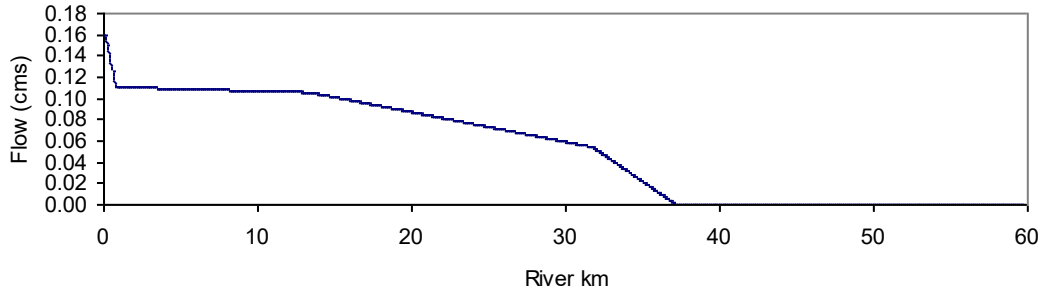


Figure 3-47: Evans Creek model: sum of withdrawals in the downstream direction.

3.7.9 Point source inputs

There are no point source discharges within the model extent.

3.7.10 Landcover and topographic shade inputs

Topographic angle (Figure 3-48) and riparian vegetation heights (Figure 3-49) and densities (Figure 3-50) were determined through GIS analysis. Using these channel and vegetation inputs, the performance of the Evans Creek model in predicting shade is shown in Figure 3-51.

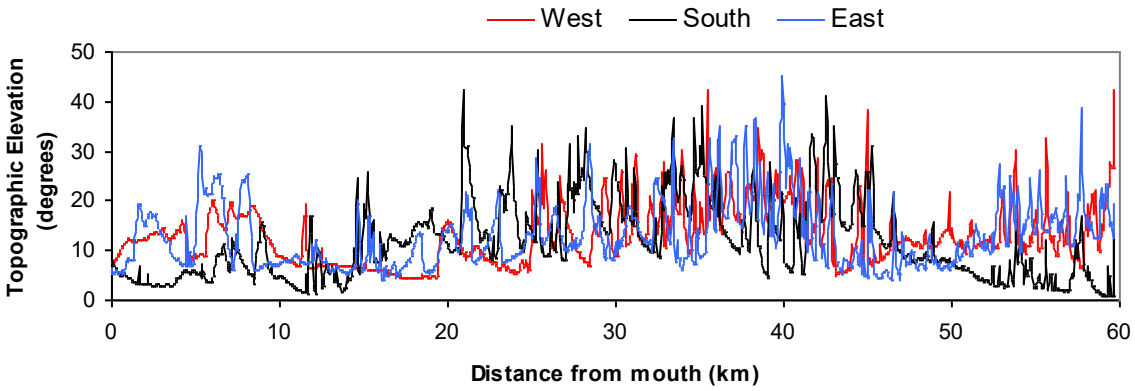


Figure 3-48: Evans Creek model setup for topographic angle.

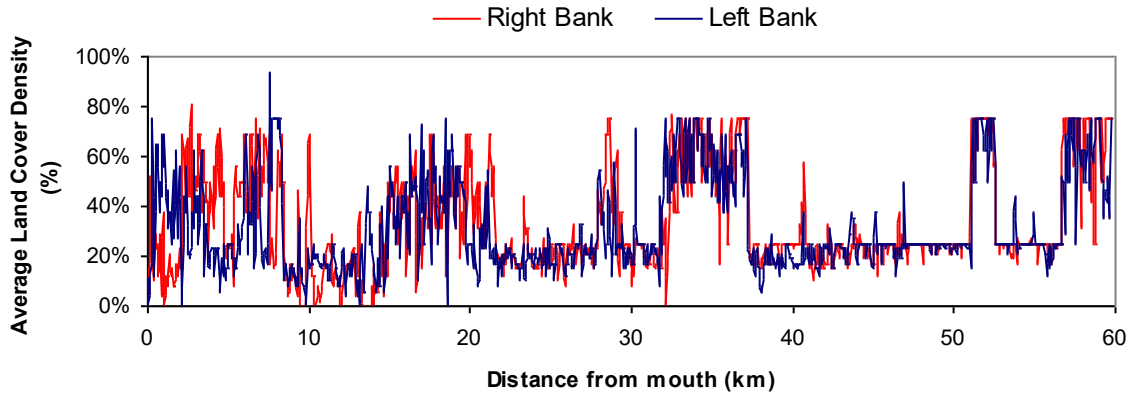


Figure 3-49: Evans Creek model setup for height of streamside vegetation.

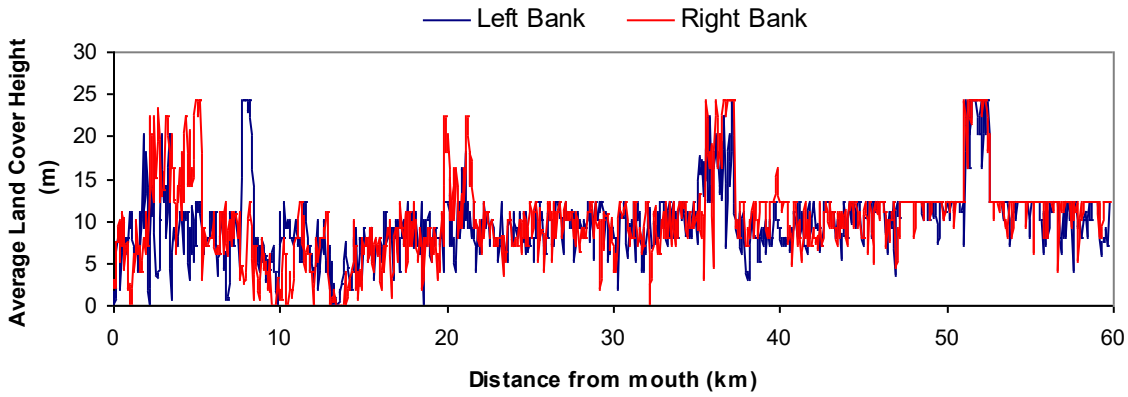


Figure 3-50: Evans Creek model setup for density of streamside vegetation.

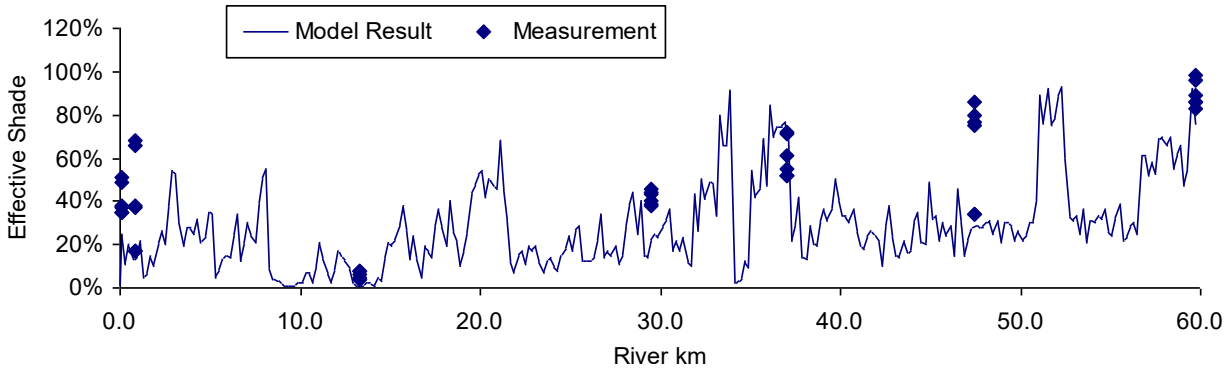


Figure 3-51: Evans Creek model: predicted vs. measured effective shade.

3.7.11 Channel setup

The channel properties were determined using the methodology documented previously in this document (see Section 2.2.3). Figure 3-52 shows the elevation and reach gradient profiles. Bottom widths were derived using active channel widths measured from aerial photographs. Bottom widths (Figure 3-53) were estimated by assuming a trapezoidal channel with 45° side slopes and a constant width-to-depth ratio of 8:1 as determined through model calibration. Non-spatially varying coefficients are presented in Table 3-42. Manning's n (Figure 3-54) and sediment thermal conductivity and diffusivity (Figure 3-55) were iteratively altered so that the model temperatures approximately reproduced measured temperatures (Figure 3-57, Figure 3-58, Figure 3-59).

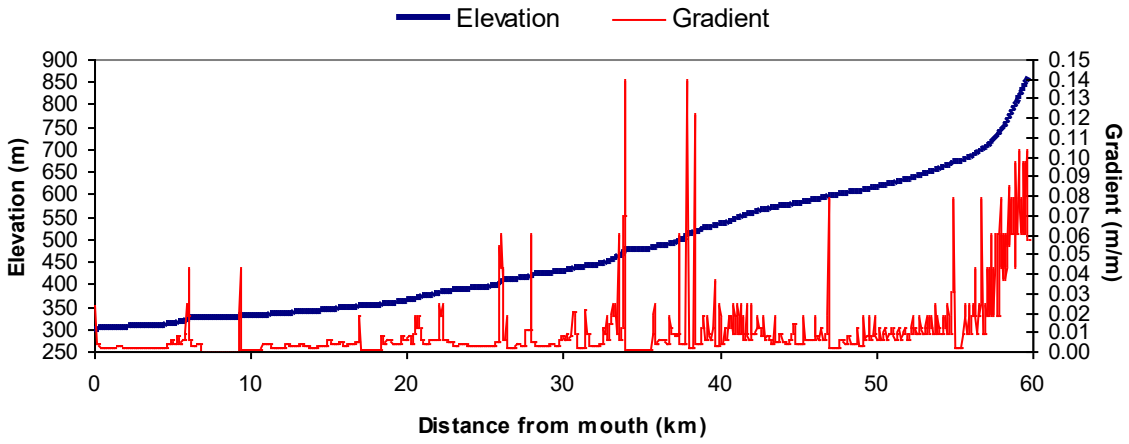


Figure 3-52: Evans Creek model setup channel elevation and gradient.

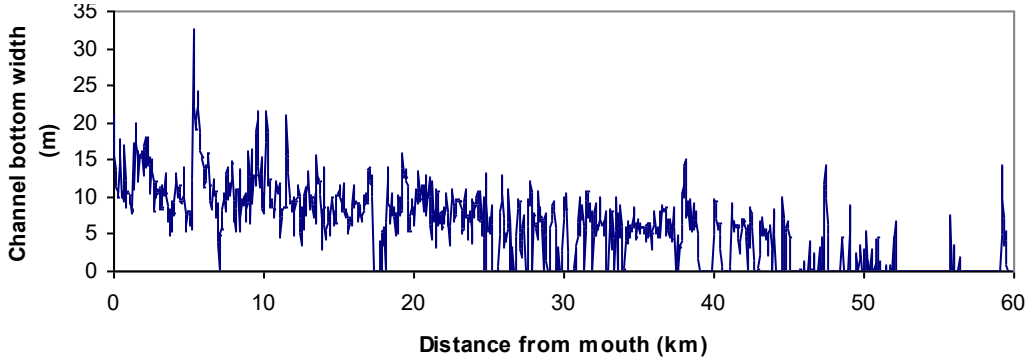


Figure 3-53: Evans Creek model setup for channel bottom width.

Table 3-42: Evans Creek model coefficients for non-spatially varying parameters.

Parameter name (units)	Value
Wind Function, coefficient a	1.51×10^{-9}
Wind Function, coefficient b	1.60×10^{-9}
Channel Angle	1.0
Sediment / hyporheic zone thickness (m)	0.5
Percent hyporheic exchange	0%
Porosity	30%

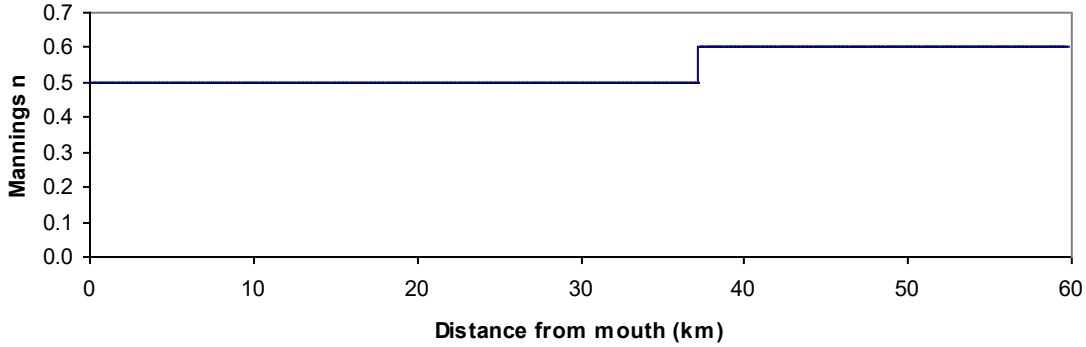


Figure 3-54: Evans Creek model setup for roughness coefficient.

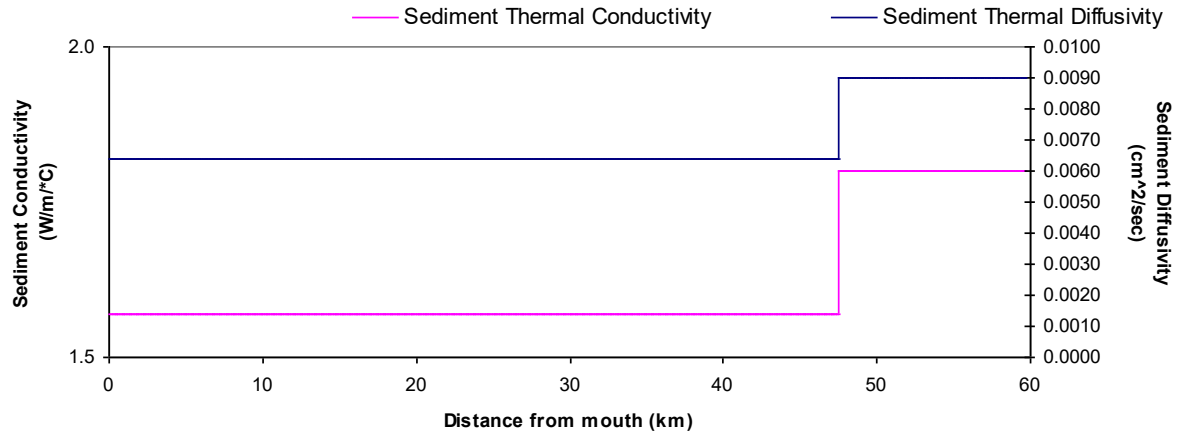


Figure 3-55: Evans Creek model setup for substrate parameters.

3.7.12 Calibration results

Figure 3-56 shows the flow-prediction performance of the Evans Creek model at several locations.

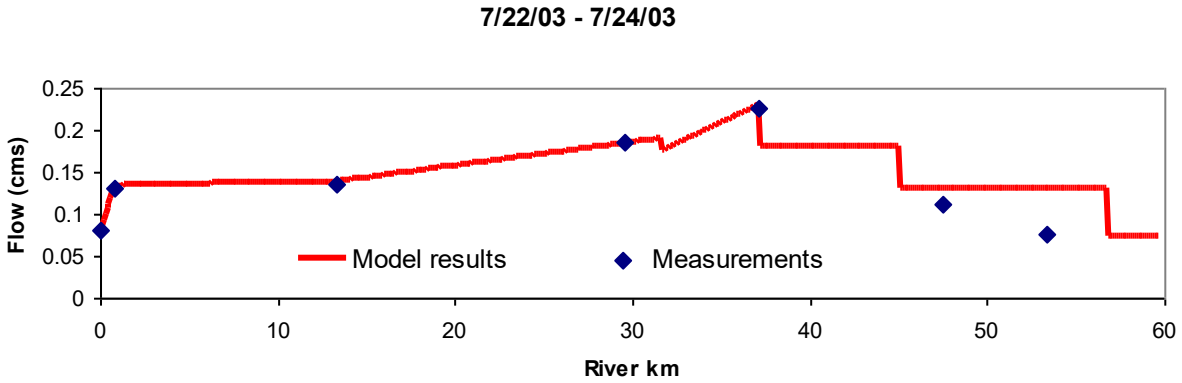


Figure 3-56: Evans Creek model: longitudinal profile of measured flow vs. model results.

The temperature model was calibrated to TIR data (Figure 3-57) and to continuous temperature data collected at several locations along the model extent throughout the modeled period (Figure 3-59). Goodness-of-fit statistical results of comparisons between field-observed and model-predicted temperatures are summarized in Table 3-43. Comparison of the TIR data with the Evans Creek and West Fork Evans Creek model simulation did not meet the MAE target of <1.0°C.

The model outputs generally reproduced spatially and temporally varying temperature measurements between river kilometers 13.3 – 59.7 (Table 3-43, Figure 3-57, Figure 3-59). See previous statistics discussion in Section 3.1.3.1 for definitions. Between river kilometers 0.05 and 13.3, the model overpredicted maximum temperatures (Figure 3-57). This may be due to stratification of water at different temperatures, cold-water influence from groundwater, or the Rogue River. The TIR data, which represents the surface water temperatures, also recorded higher temperatures than the continuous data loggers, which represent subsurface water temperatures, in this reach (compare Figure 3-57 and Figure 3-58 on August 1 at Evans Creek mouth). Rogue River temperatures measured just upstream of Evans Creek compare closely with temperatures measured at the Evans Creek mouth (Figure 3-58), though Evans Creek temperatures are slightly warmer and shifted temporally from the Rogue River temperatures. Thus, DEQ determined that temperature measurements near the Evans Creek mouth were influenced by Rogue River water, and these locations were omitted from the calibration results and statistical summaries.

Table 3-43: Evans Creek and West Fork Evans Creek model goodness-of-fit statistics from comparison of field-measured and model-simulated temperatures. Gray-shaded sites were near the mouth and determined as influenced by Rogue River water and thus omitted from calibration and summaries.

Monitoring location	Model km	Temperature statistic	ME	MAE	RMSE	NSE	n
All Stations		Daily Maximum	-0.93	1.59	2.69	NA	274
All Stations		Hourly	-0.15	1.13	1.83	0.78	6543
30188 (A)	59.70	Daily Maximum	0.00	0.00	0.00	NA	62
30189 (B)	47.45	Daily Maximum	-0.54	0.73	0.94	NA	50
30190 (C)	37.05	Daily Maximum	1.83	1.83	1.97	NA	39

Monitoring location	Model km	Temperature statistic	ME	MAE	RMSE	NSE	n
11373 (D)	13.30	Daily Maximum	-0.40	0.77	1.01	NA	61
11372 (E)	0.05	Daily Maximum	0.36	0.76	0.99	NA	62
11372 (F)	0.05	Daily Maximum	-4.44	4.52	5.27	NA	62
30188	59.70	Hourly	0.00	0.00	0.00	1.00	1488
30189	47.45	Hourly	-0.37	0.77	0.99	0.71	1180
30190	37.05	Hourly	1.25	1.39	1.62	0.47	923
11373	13.30	Hourly	-0.13	0.89	1.13	0.81	1464
11372	0.05	Hourly	0.99	2.61	3.32	-2.39	1488
11372	0.05	Hourly	1.69	2.64	3.45	-4.90	1488
TIR	Model extent		0.35	1.38	1.82	0.54	

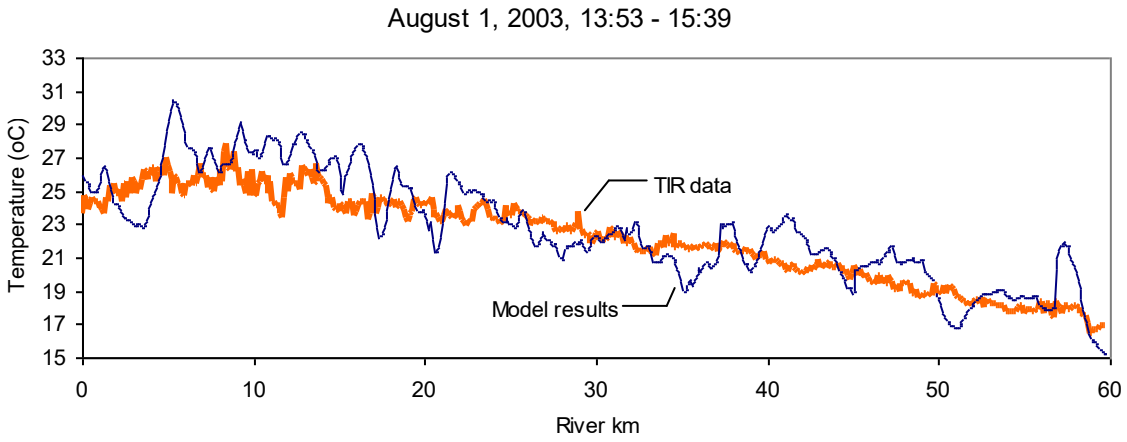


Figure 3-57: Longitudinal profile of Evans Creek and West Fork Evans Creek TIR and simulated stream temperatures. Periodic temperature decreases may indicate the influence of cooler tributaries, springs, seeps, or groundwater.

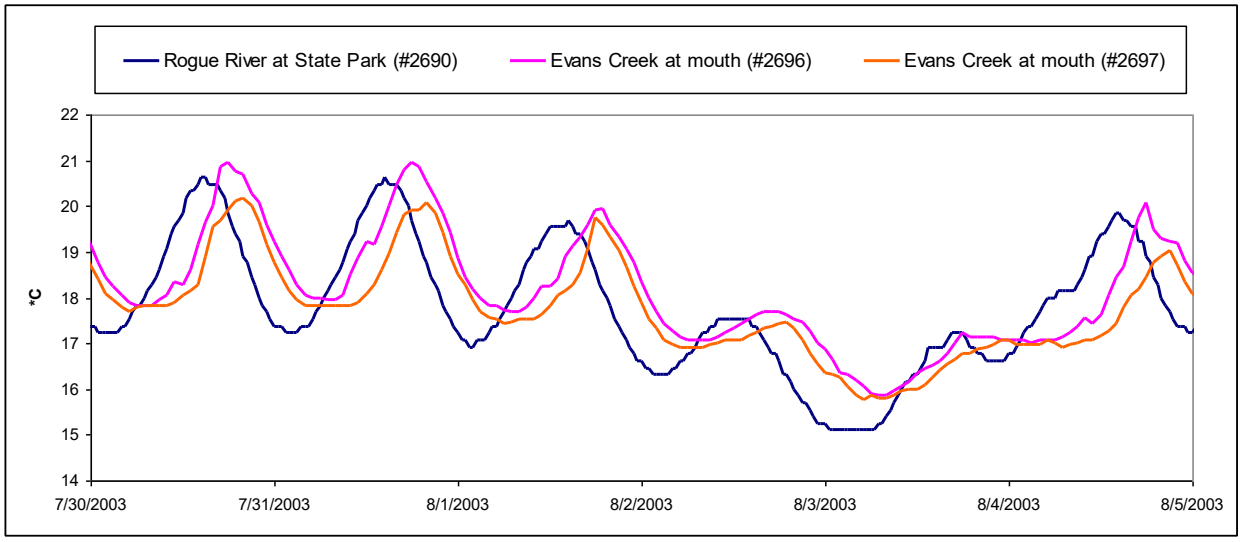


Figure 3-58: Comparison of temperature measurements from the mouth of Evans Creek and the mainstem of the Rogue River upstream of the confluence with Evans Creek.

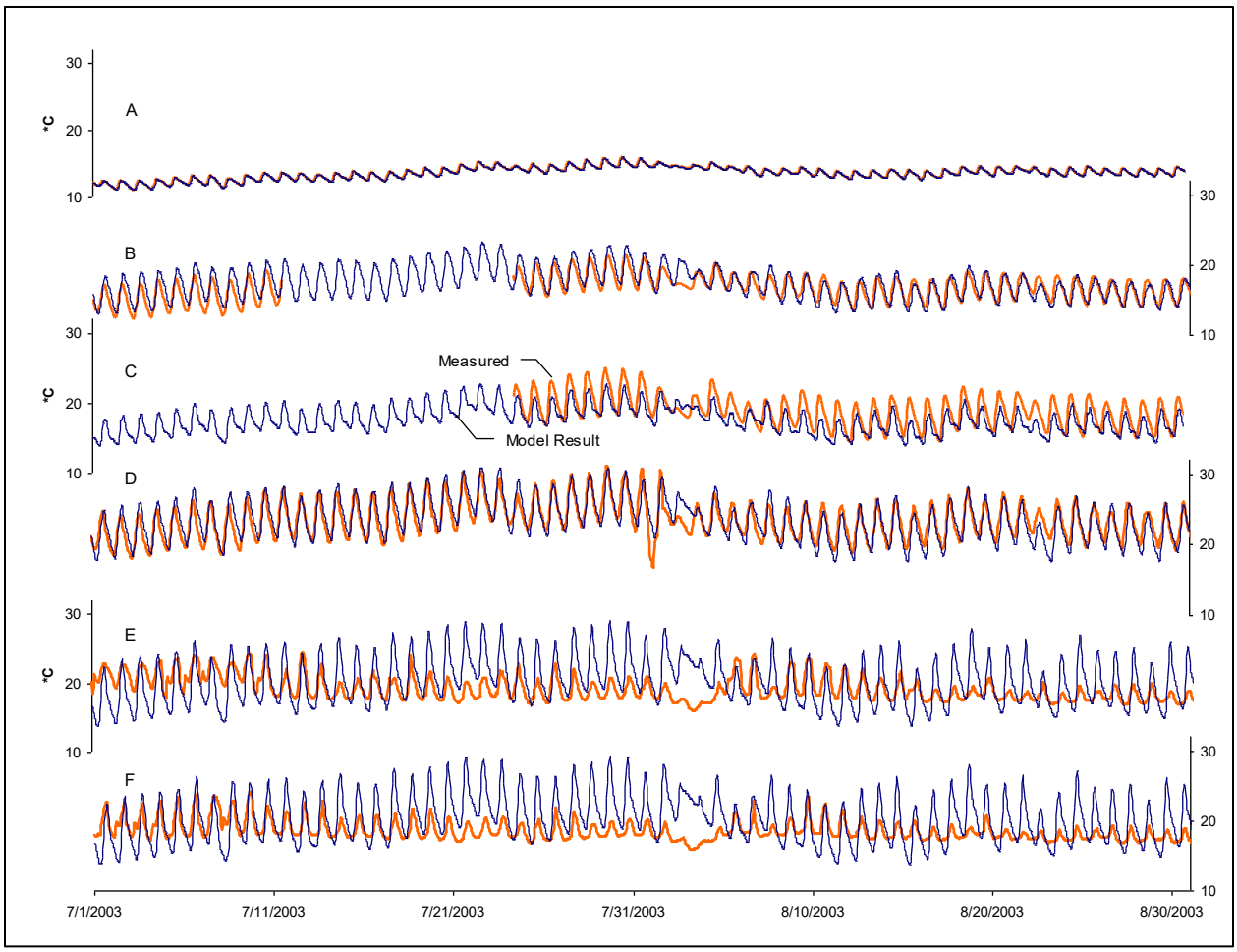


Figure 3-59: Measured and modeled hourly stream temperatures at Evans Creek and West Fork Evans Creek monitoring stations.

3.8 Little Butte Creek and North Fork Little Butte Creek

3.8.1 Model extent

The extent of the model domain is 54.1km, from the mouth of Little Butte Creek at its confluence with the Rogue River to the North Fork Little Butte Creek at Fish Lake (Figure 3-60).

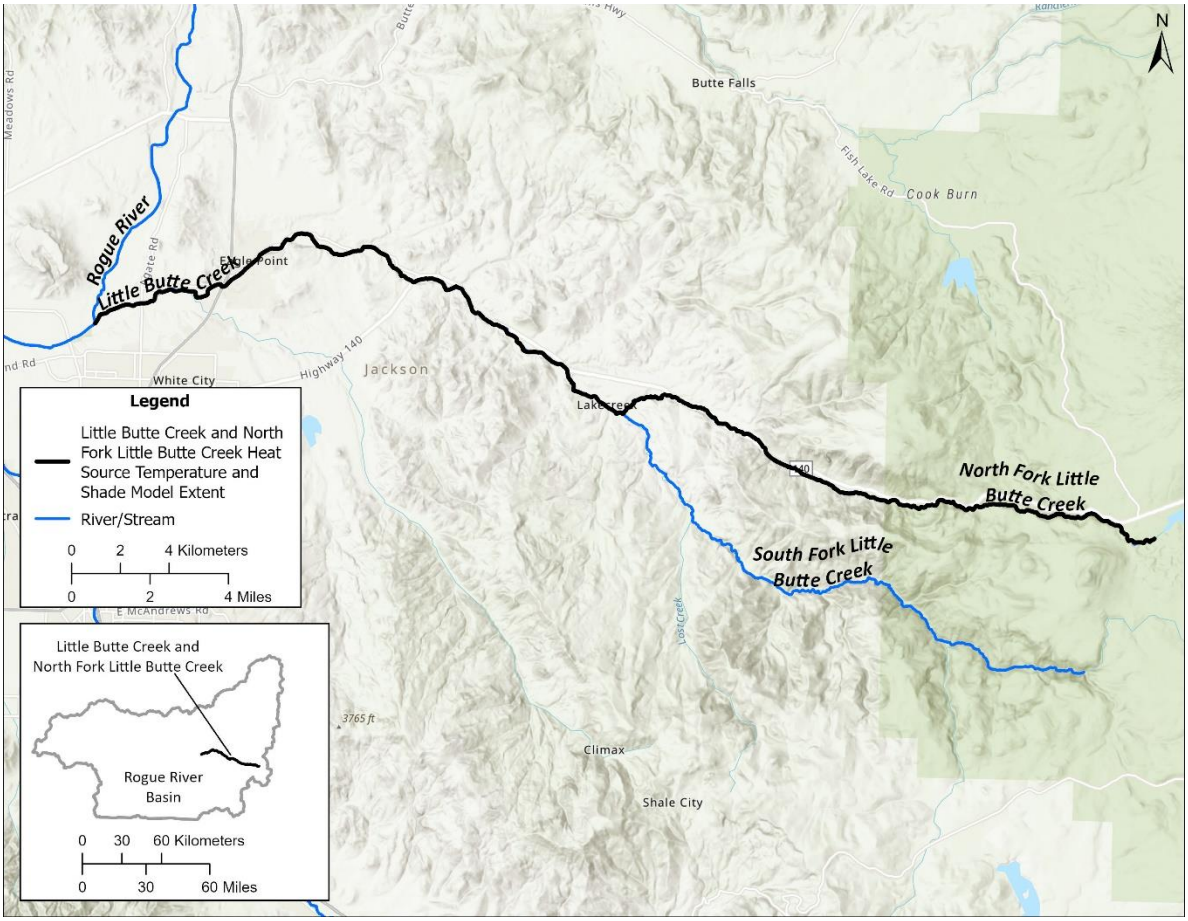


Figure 3-60: Extent of the Little Butte and North Fork Little Butte temperature and shade model.

3.8.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is x m. Outputs are generated every x m. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.8.3 Time frame of simulation

The model period is from July 1, 2001 to August 31, 2001.

3.8.4 Meteorological inputs

The model used air temperature measurements from Fish Lake (USBR 2008) and temperature, relative humidity, wind speed and cloudiness from the Medford airport. The 2-hour Fish Lake data were linearly interpolated hourly, and missing data were filled in using a regression with Medford airport data. The meteorological inputs varied by stream kilometer based on proximity to the weather station (Table 3-44). A multiplicative wind sheltering coefficient was applied to the wind speed for calibration. The meteorological observations are presented in Figure 3-61, Figure 3-62, Figure 3-63, and Figure 3-64.

Table 3-44: Source of meteorological inputs into Little Butte Creek model.

Range (river km)	Cloudiness	Relative Humidity	Air Temperature	Wind Speed	Wind sheltering Coefficient
54 - 45	Medford	Medford	Fish Lake	Medford	0.1
45 - 32	Medford	Medford	Average of Fish Lake and Medford	Medford	0.1
32 - 9	Medford	Medford	Medford	Medford	0.1
9 - 4	Medford	Medford	Medford	Medford	0.3
4 - 0	Medford	Medford	Medford	Medford	0.5

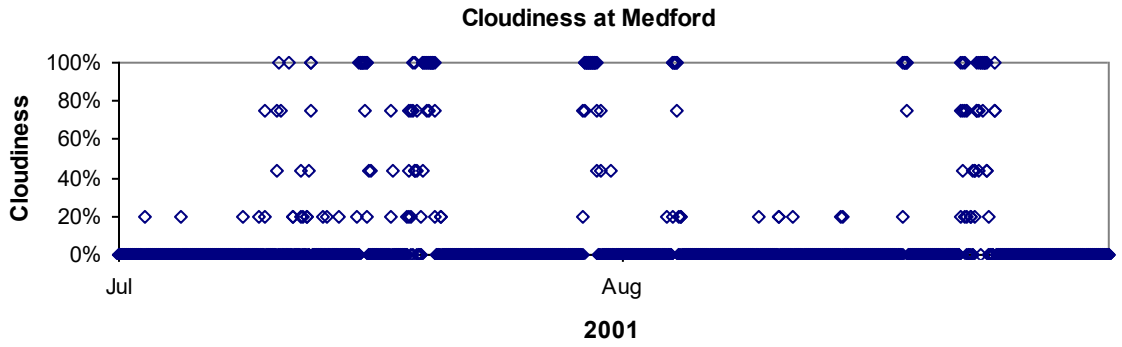


Figure 3-61: Cloud cover data used for Little Butte Creek model setup. The intervals represent residuals from reported measurements.

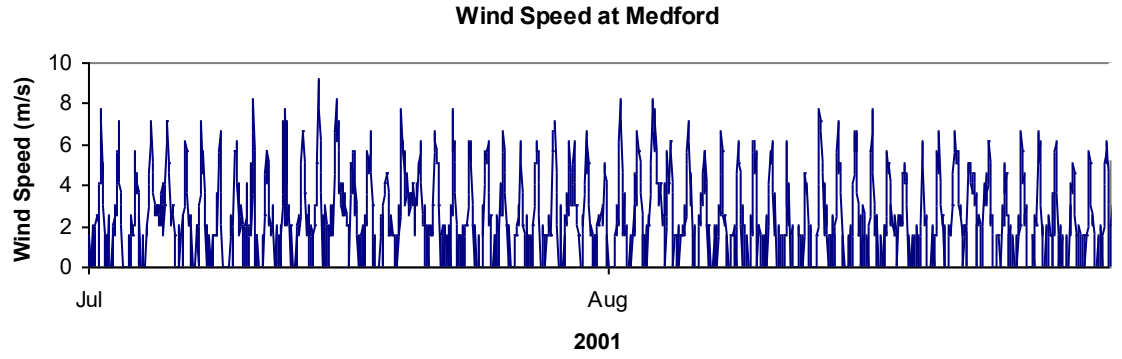


Figure 3-62: Wind speed data used for Little Butte Creek model setup.

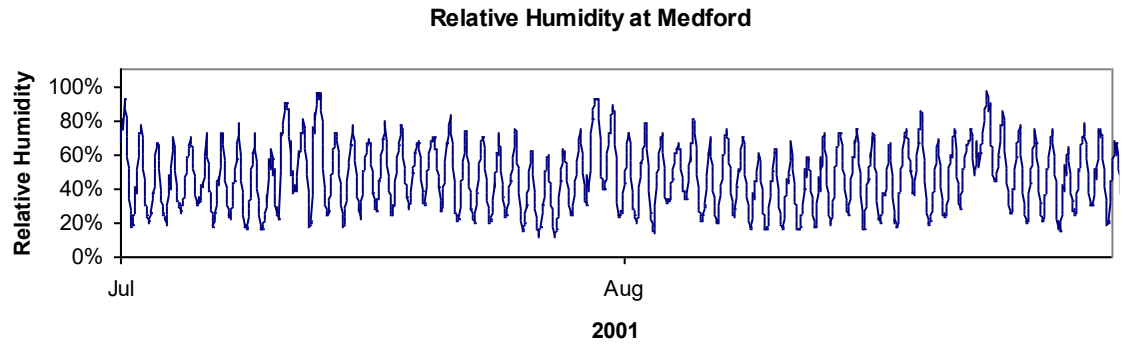


Figure 3-63: Relative humidity data used for Little Butte Creek model setup.

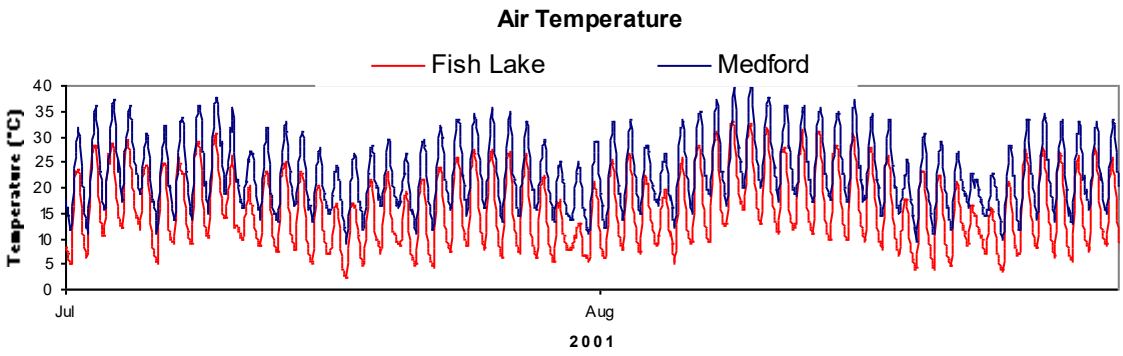


Figure 3-64: Air temperature data used for Little Butte Creek model setup.

3.8.5 Temperature inputs

Figure 3-65 shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration. Table 3-45 and Figure 3-66 document the data sources and temperature data for the tributaries, springs and canal returns included in the Little Butte Creek model.

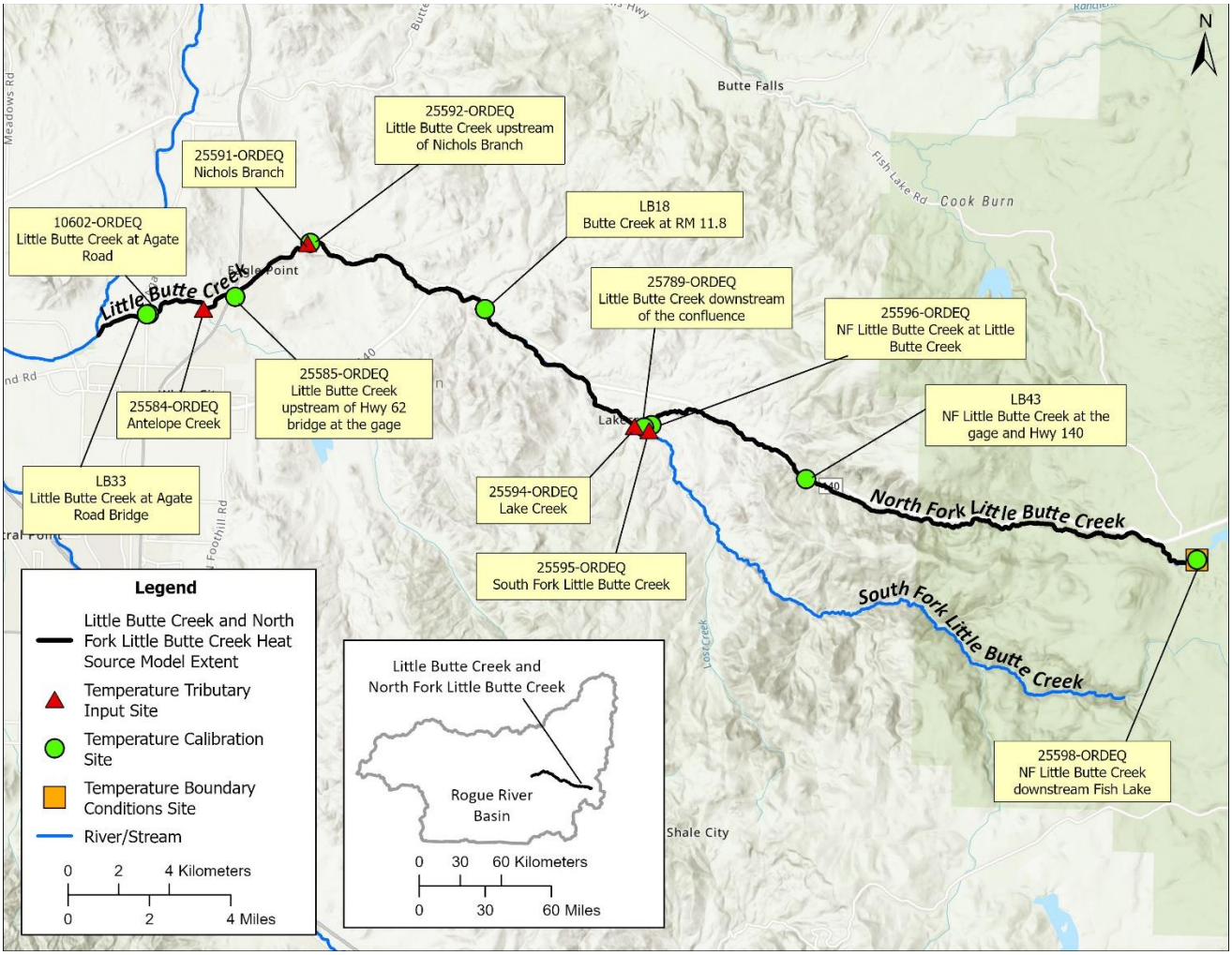


Figure 3-65: Temperature monitoring locations used for Little Butte Creek and North Fork Little Butte Creek model setup and calibration.

Table 3-45: Source of tributary and boundary condition temperature inputs for Little Butte Creek model.

Inflow	Stream km	Source of temperature data
Fish Lake outlet	54.1	DEQ data site #25598
Springs	52 - 47	Estimate based on average annual air temperature (8 °C)
SF Little Butte	27.9	DEQ data site #25595
Lake Creek	27.23	DEQ data site #25594
Salt Creek	23.55	Estimate
Nichols Branch	10.3	DEQ data site #25591
Return flow from Buchanan Ditch	6.95	Estimate (22 °C)
Return flow from EPID Ditch	6.9	Estimate (22 °C)
Antelope Creek	4.5	DEQ data site #25584

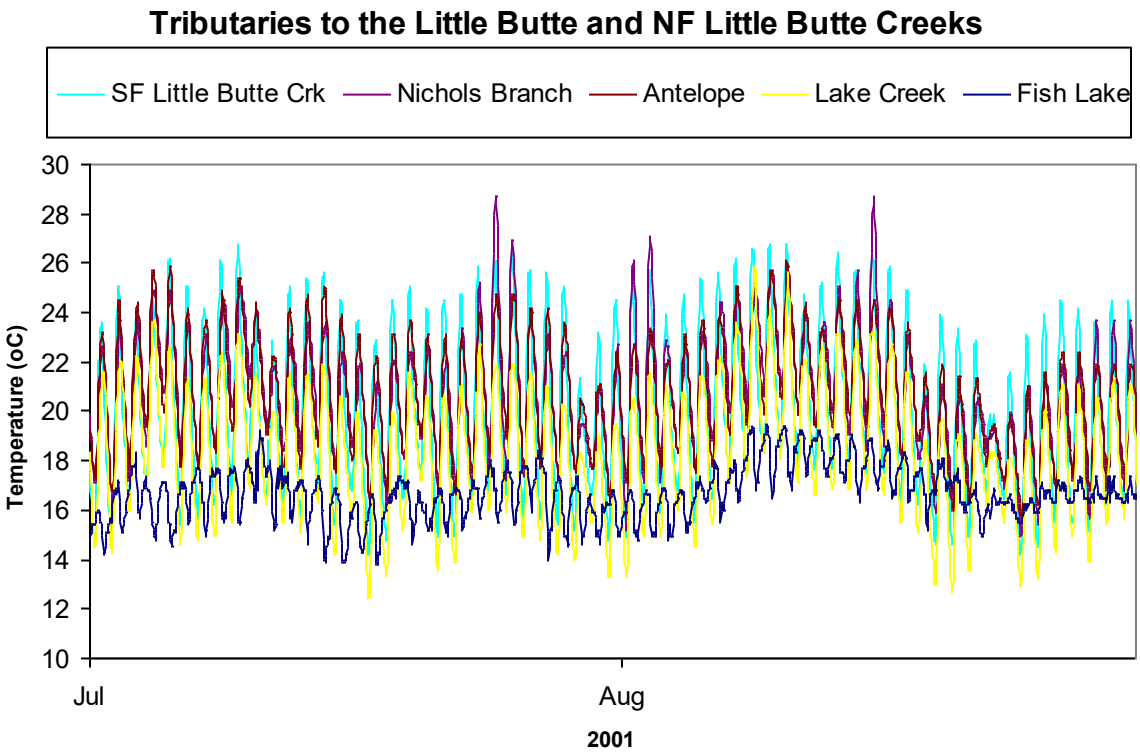


Figure 3-66: Temperature inputs of tributaries to the Little Butte Creek model.

3.8.6 Flow inputs

When available, flow measurements taken in the Little Butte Creek watershed were used to generate model input. Figure 3-67 shows the locations of the various stream flow monitoring locations that were used for model setup or calibration. Otherwise, relationships with other gages were used (Table 3-46, Figure 3-68). Discharge inputs at the model headwater (Fish Lake) were acquired from USBR (2007). Data from one additional flow gage in 2001 were available for the model reach: Little Butte Creek at Lake Creek. Instantaneous flow measurements were collected at various places and times during the model period. A flow balance was derived through various methods including use of the TIR temperatures and upstream flows. Maximum consumptive use is based on information provided by OWRD (Figure 3-69). Withdrawals were based on the OWRD points of diversion GIS layer described in 2.2.3. To match observed flows, the maximum withdrawal rate was used on the North Fork and half the maximum rate was used on Little Butte Creek. Using these flow inputs, the performance of the Little Butte Creek model at several times and locations is shown in Figure 3-70 and Figure 3-71.

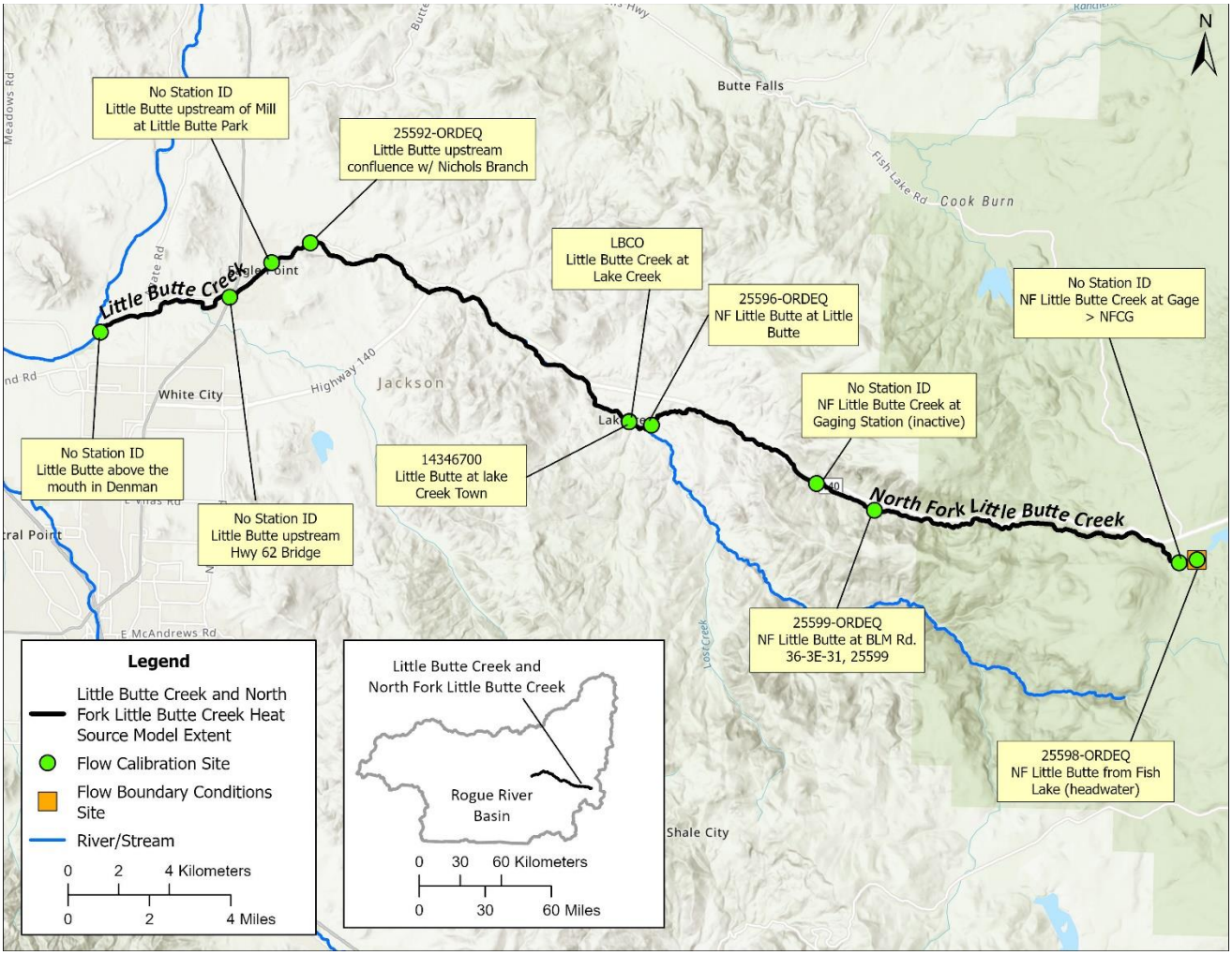


Figure 3-67: Flow monitoring locations used for Little Butte Creek and North Fork Little Butte Creek model setup and calibration.

Table 3-46: Source of flow information for the Little Butte Creek model. EPID refers to Eagle Point Irrigation District.

Inflow / Outflow	Stream km	Source
Fish Lake outlet	54.1	USBR gage
Springs	52 - 47	Flow balance
Diversion to Joint System Canal	29.3	Flow balance
SF Little Butte	27.9	Flow and temperature balance
Lake Creek	27.23	Average of 3 instantaneous flow measurements
Salt Creek	23.55	Average of 2 instantaneous flow measurements
Diversion to Crater Canal	13.3	Flow balance
Nichols Branch	10.3	Linear interpolation of 3 instantaneous measurements
Return flow from Buchanan Ditch	6.95	Average of 2 instantaneous flow measurements
Return flow from EPID Ditch	6.9	Average of 2 instantaneous flow measurements
Antelope Creek	4.5	Linear interpolation of 2 instantaneous measurements

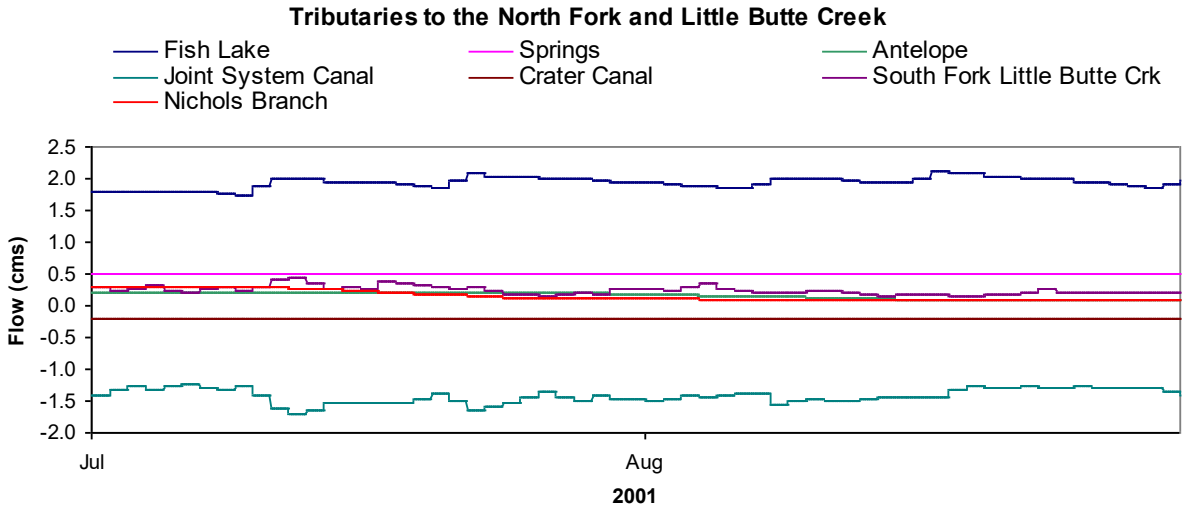


Figure 3-68: Little Butte Creek model: tributary flows and irrigation system withdrawals. Lake Creek and Salt Creek are not shown (<0.008 cms).

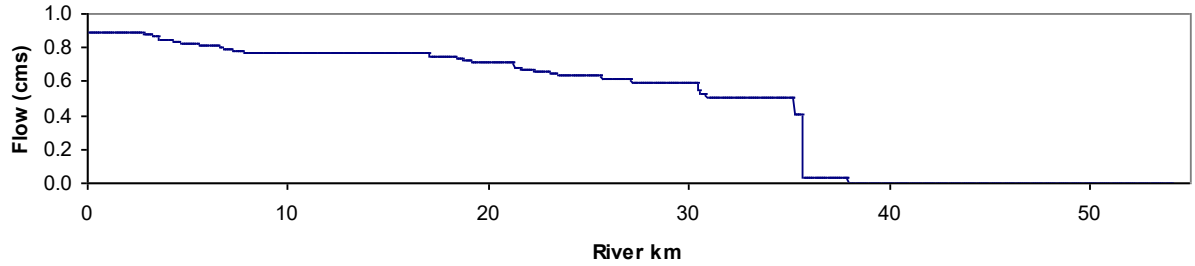


Figure 3-69: Little Butte Creek: sum of the withdrawals in the downstream direction not including the two diversions presented in Table X because they are dynamic.

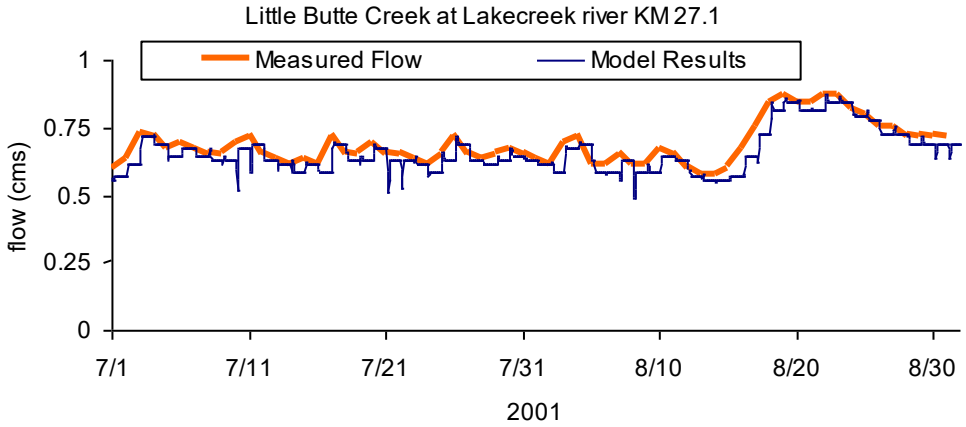


Figure 3-70: Little Butte Creek: time-series of measured flow vs. model results.

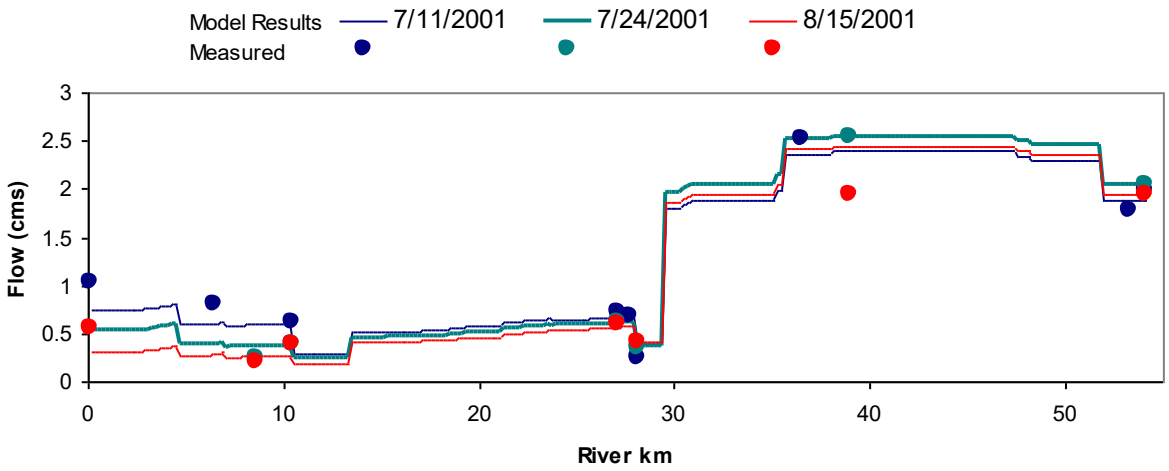


Figure 3-71: Little Butte Creek: longitudinal profile of measured vs. modeled flow results. Lines represent model results and points represent measurements. Different colors represent different days.

3.8.7 Point source inputs

There are no point source discharges within the model extent. There is one point source in a tributary upstream of the model extent.

3.8.8 Landcover and topographic shade inputs

Topographic and riparian vegetation heights were determined through a GIS analysis (Figure 3-72, Figure 3-73, Figure 3-74).

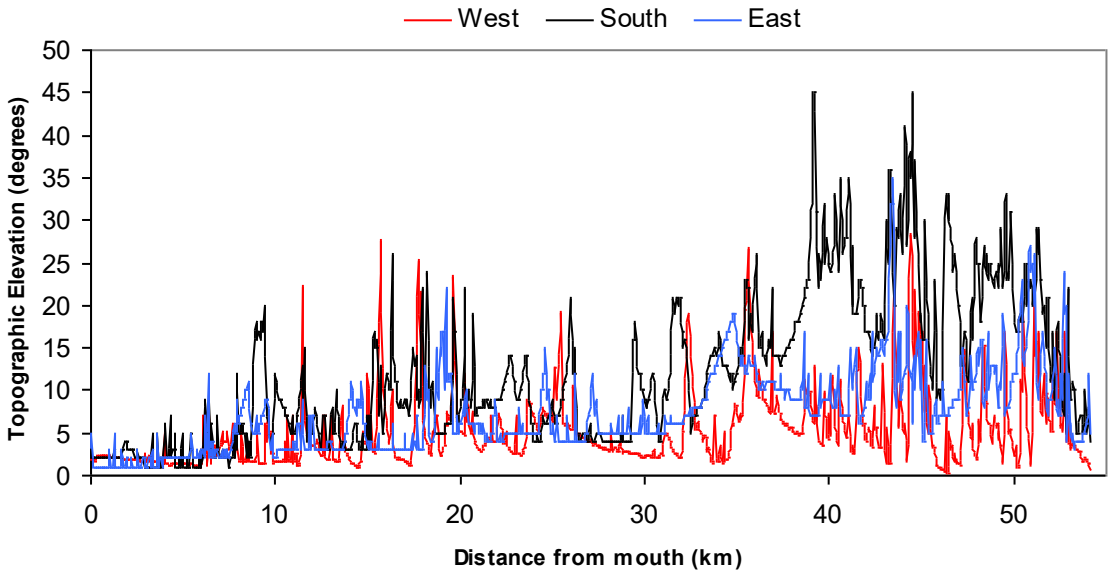


Figure 3-72: Little Butte Creek model setup for topographic angle.

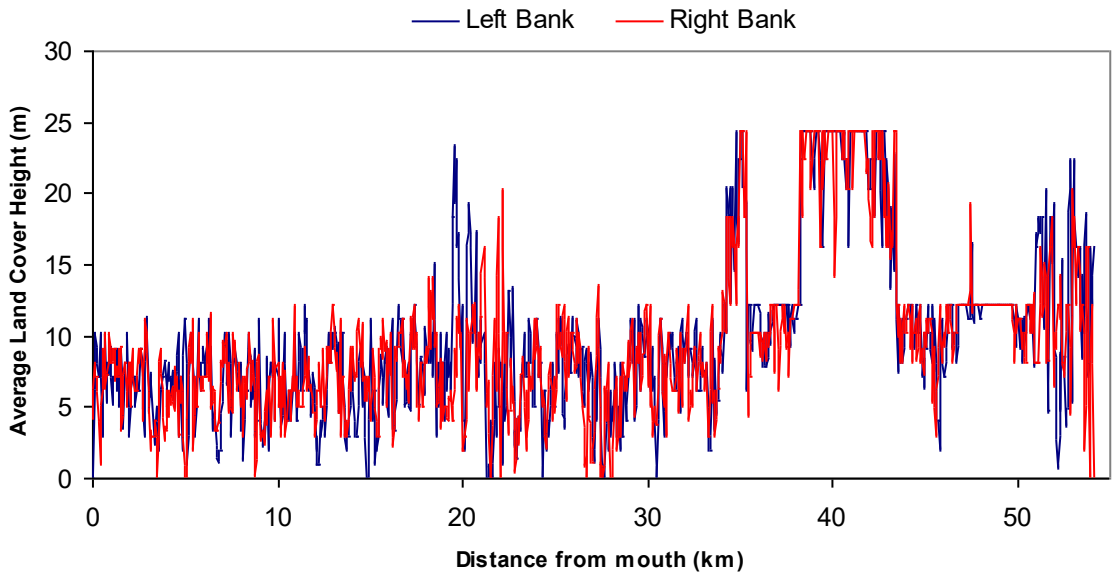


Figure 3-73: Little Butte Creek model setup for height of streamside vegetation.

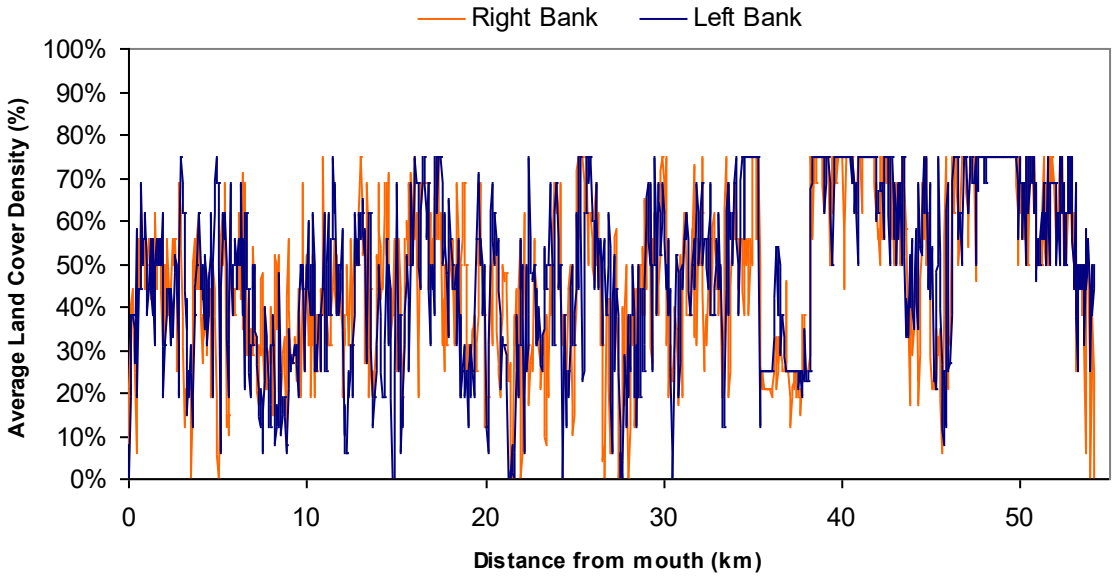


Figure 3-74: Little Butte Creek model setup for density of streamside vegetation.

3.8.9 Channel setup

The channel properties were determined using the methodology documented previously in this report (see Section 2.2.3). Figure 3-75 shows the elevation profile and reach gradient. The bottom width was derived using the active channel width measured from aerial photographs. Bottom width was estimated by assuming a trapezoidal channel with 3:1 (length:height) side slopes and a variable width-to-depth ratio determined through model calibration (Figure 3-76). The active channel width from creek kilometers 23.0-4.6 and percent hyporheic exchange values were modified based on information from project consultant TetraTech (see Appendix C). Non-spatially varying coefficients are presented in Table 3-47. Manning's n values were iteratively altered so that the model temperatures approximately reproduced measured temperatures (Figure 3-77).

Using these channel and vegetation inputs, the performance of the Little Butte and North Fork Little Butte Creek model in predicting shade is shown in Figure 3-78.

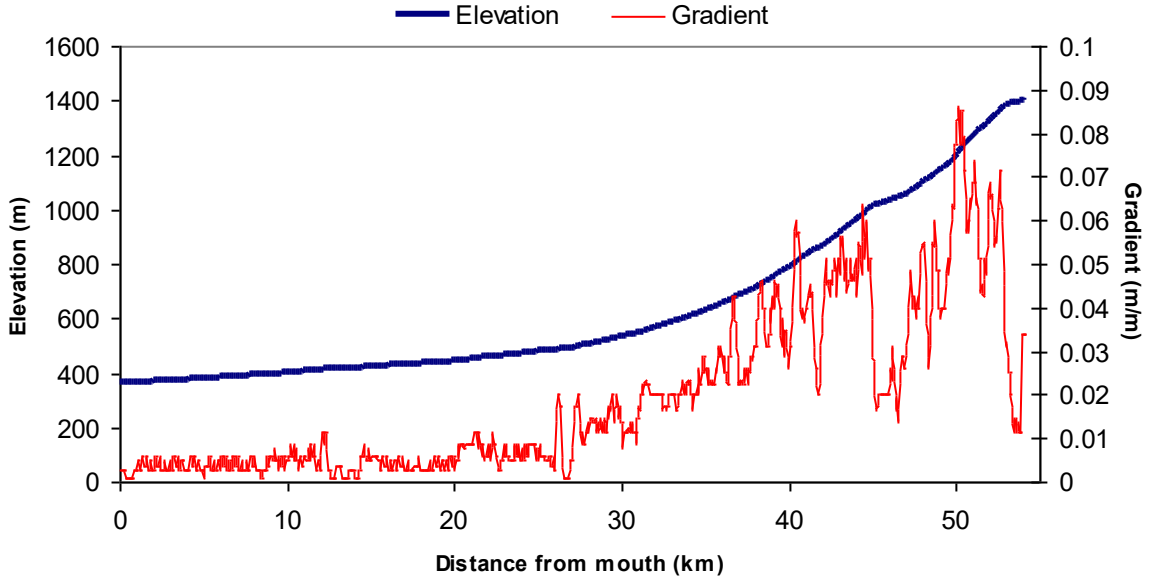


Figure 3-75: Little Butte Creek model setup channel elevation and gradient.

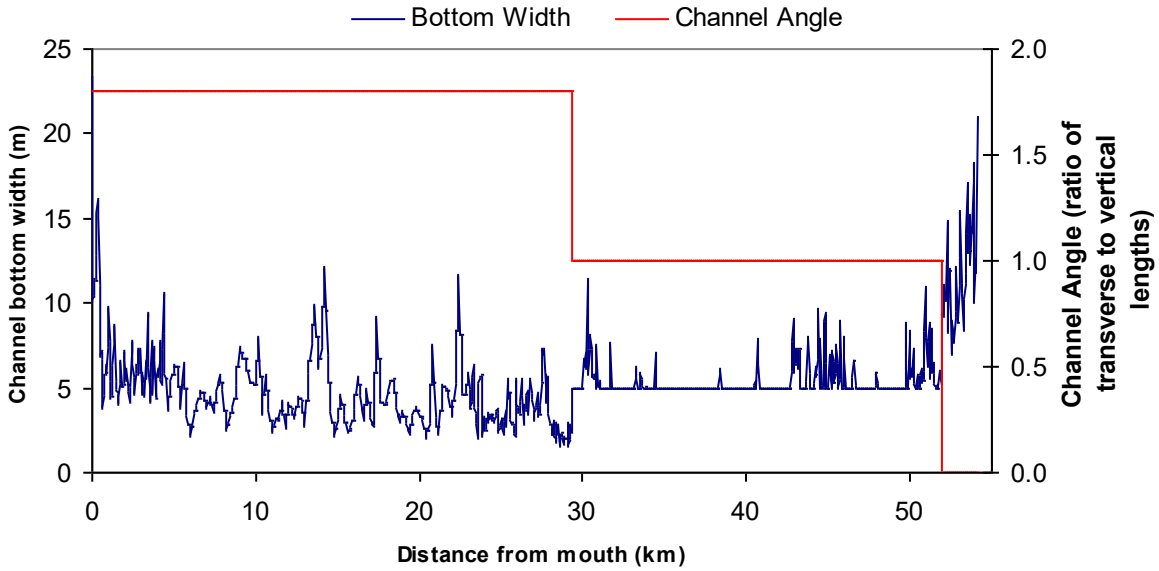


Figure 3-76: Little Butte Creek model setup for channel bottom width and channel angle.

Table 3-47: Little Butte Creek model coefficients for non-spatially varying parameters.

Parameter name (units)	Value
Wind Function, coefficient a	1.51 x 10^{-9}
Wind Function, coefficient b	1.60 x 10^{-9}
Sediment Thermal Conductivity (W/m/°C)	1.57
Sediment Thermal Diffusivity (cm^2/sec)	0.0064
Sediment / hyporheic zone thickness (m)	0.5
Porosity	30%

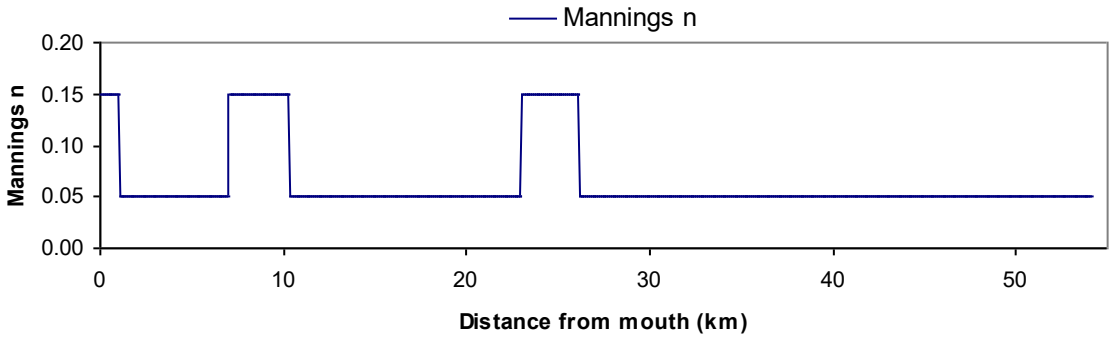


Figure 3-77: Little Butte Creek model setup for roughness coefficient.

3.8.10 Calibration results

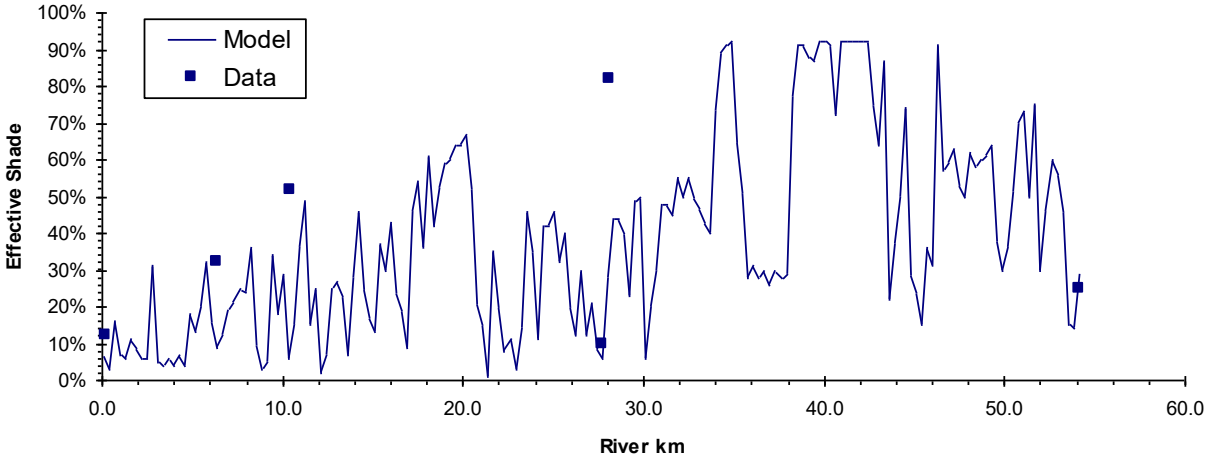


Figure 3-78: Little Butte Creek: modeled vs. measured shade.

The model outputs generally reproduced spatially and temporally varying temperature measurements (Table 3-48, Figure 3-79, Figure 3-80). See previous statistics discussion in Section 3.1.3.1 for definitions.

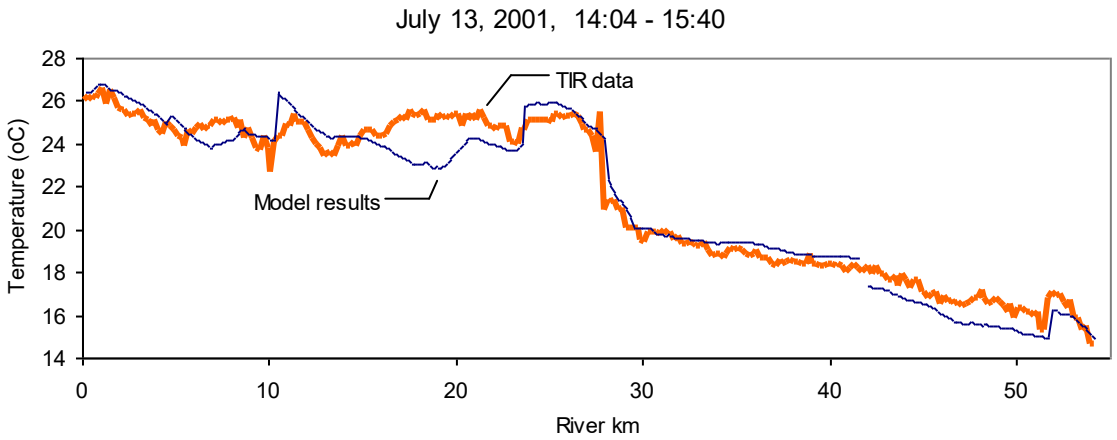


Figure 3-79: Little Butte Creek: longitudinal profile of modeled vs. TIR-measured temperatures. Staggered model results occur near river km 42 because hourly model output changes stepwise.

Table 3-48: Little Butte Creek continuous monitoring error statistics.

Monitoring location	Model km	Temp. statistic	ME	MAE	RMSE	NSE	n
All Stations, average		Daily max.	0.46	1.05	1.27		
All Stations, average		Hourly	-0.88	1.37	1.62	0.43	
N. Fork Little Butte Cr., Hwy 140 gage (LB43) (A)	36.45	Daily max.	0.48	0.81	1.00	N/A	52
N. Fork Little Butte Cr. at Little Butte RM 0.1 (25596) (B)	28	Daily max.	1.00	1.22	1.49	N/A	59
Little Butte Cr. d/s forks' confluence RM 19.1 (25789) (C)	27.78	Daily max.	0.91	0.98	1.12	N/A	59
Little Butte Cr. at RM 11.8 (LB18) (D)	19.23	Daily max.	-0.09	1.00	1.21	N/A	62
Little Butte Cr. u/s Nichols Branch (25592) (E)	10.48	Daily max.	1.01	1.57	1.82	N/A	59
Little Butte Cr. gage u/s Hwy 62 bridge (25585) (F)	6.58	Daily max.	0.48	0.87	1.05	N/A	59
Little Butte Cr. at Agate Rd (10602) (G)	2.3	Daily max.	-0.19	0.99	1.24	N/A	59
Little Butte Cr. at Agate Rd Bridge (LB33) (H)	2.2	Daily max.	0.13	0.98	1.23	N/A	62
N. Fork Little Butte Cr., Hwy 140 gage (LB43) (A)	36.45	Hourly	-0.57	1.35	1.65	-0.06	1224
N. Fork Little Butte Cr. at Little Butte RM 0.1 (25596) (B)	28	Hourly	-1.58	1.92	2.24	-0.33	1430
Little Butte Cr. d/s forks' confluence RM 19.1 (25789) (C)	27.78	Hourly	-0.97	1.22	1.42	0.62	1430
Little Butte Cr. at RM 11.8 (LB18) (D)	19.23	Hourly	-1.55	1.72	1.92	0.57	1488
Little Butte Cr. u/s Nichols Branch (25592) (E)	10.48	Hourly	-0.83	1.58	1.94	0.34	1426
Little Butte Cr. gage u/s Hwy 62 bridge (25585) (F)	6.58	Hourly	-0.06	0.87	1.08	0.81	1426
Little Butte Cr. at Agate Rd (10602) (G)	2.3	Hourly	-0.76	0.97	1.17	0.83	1424
Little Butte Cr. at Agate Rd Bridge (LB33) (H)	2.2	Hourly	-0.70	1.32	1.55	0.66	1488
TIR	Model extent		-0.23	0.78	1.41	0.85	

* Sites labeled as LB were reported by Medford Water Commission. All other data were collected by DEQ.

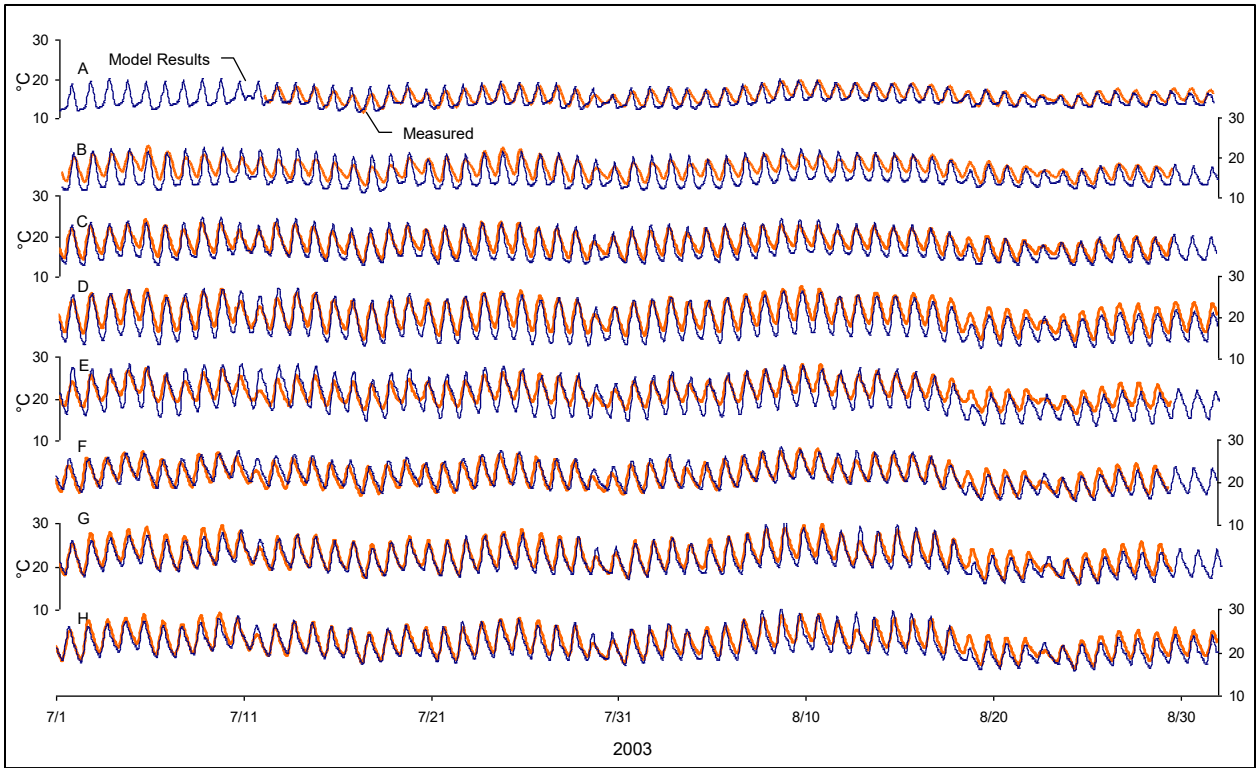


Figure 3-80: Little Butte Creek: modeled vs. measured steam temperature. See Table 3-48 for monitoring locations linked to letter codes in this plot.

3.9 Lobster Creek

Lobster Creek was modeled for temperature by DEQ with Heat Source 6.0.

3.9.1 Model extent

The extent of the Lobster Creek model domain is 9.6 miles (15.3km), from its mouth at the Rogue River upstream just past Lost Valley Creek. The model extent is shown in the HTML interactive map that accompanies this TMDL and in Figure 3-81.

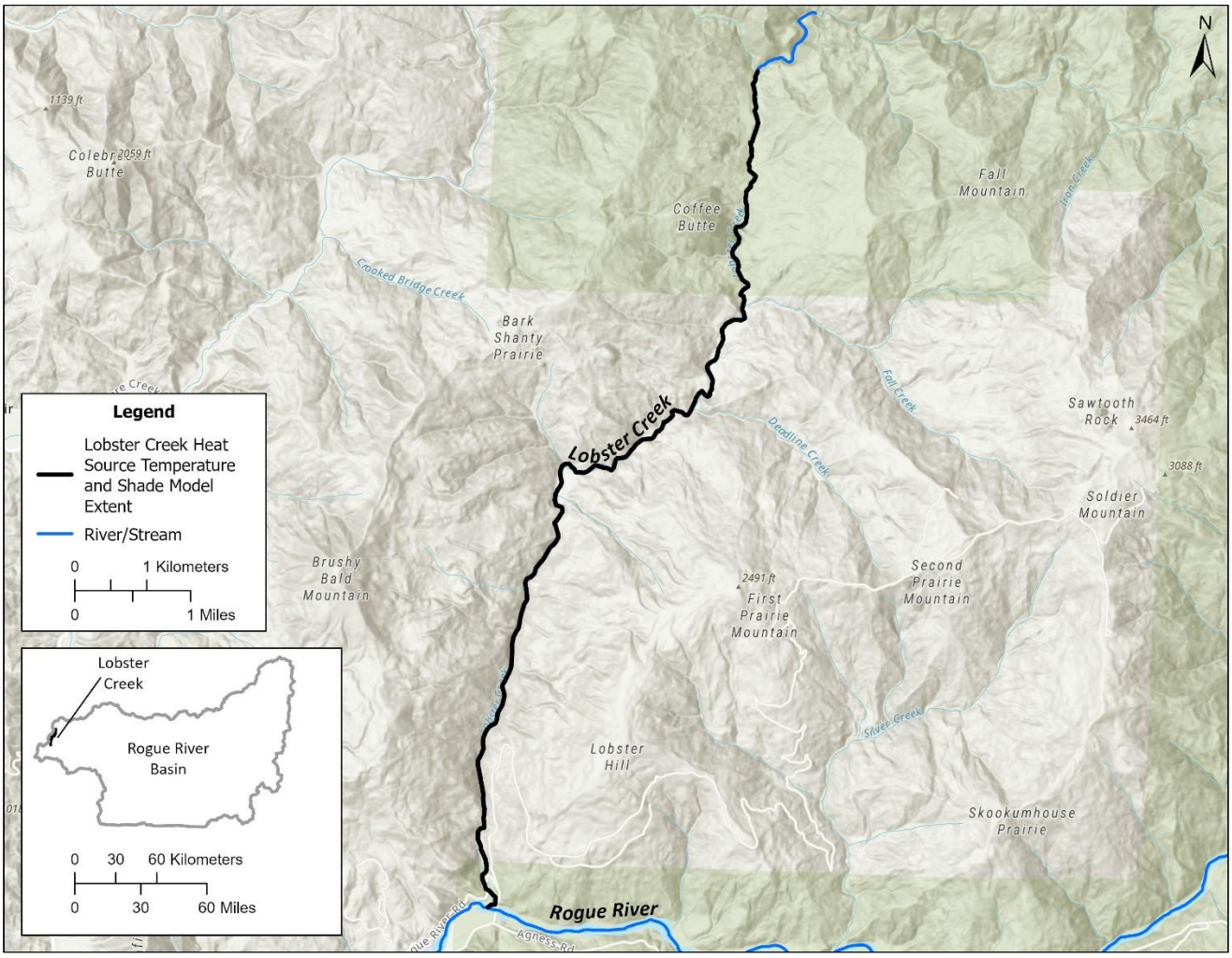


Figure 3-81: Extent of the Lobster Creek temperature and shade model.

3.9.2 Spatial and temporal resolution

The model input spatial resolution (dx) is 100 meters. Outputs are generated every 100 meters. The model time step (dt) is 1 minute and outputs are generated every hour.

3.9.3 Time frame of simulation

The model period is one day: July 22nd, 1999.

3.9.4 Meteorological inputs

The model used air temperature data from the “Gorge” site (the most downstream temperature logging site), and used humidity and wind speed data from the Agness RAWS reporting site.

3.9.5 Temperature inputs

Hourly temperature measurements on July 22nd, 1999, at five sites were used as model inputs. Figure 3-82 shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

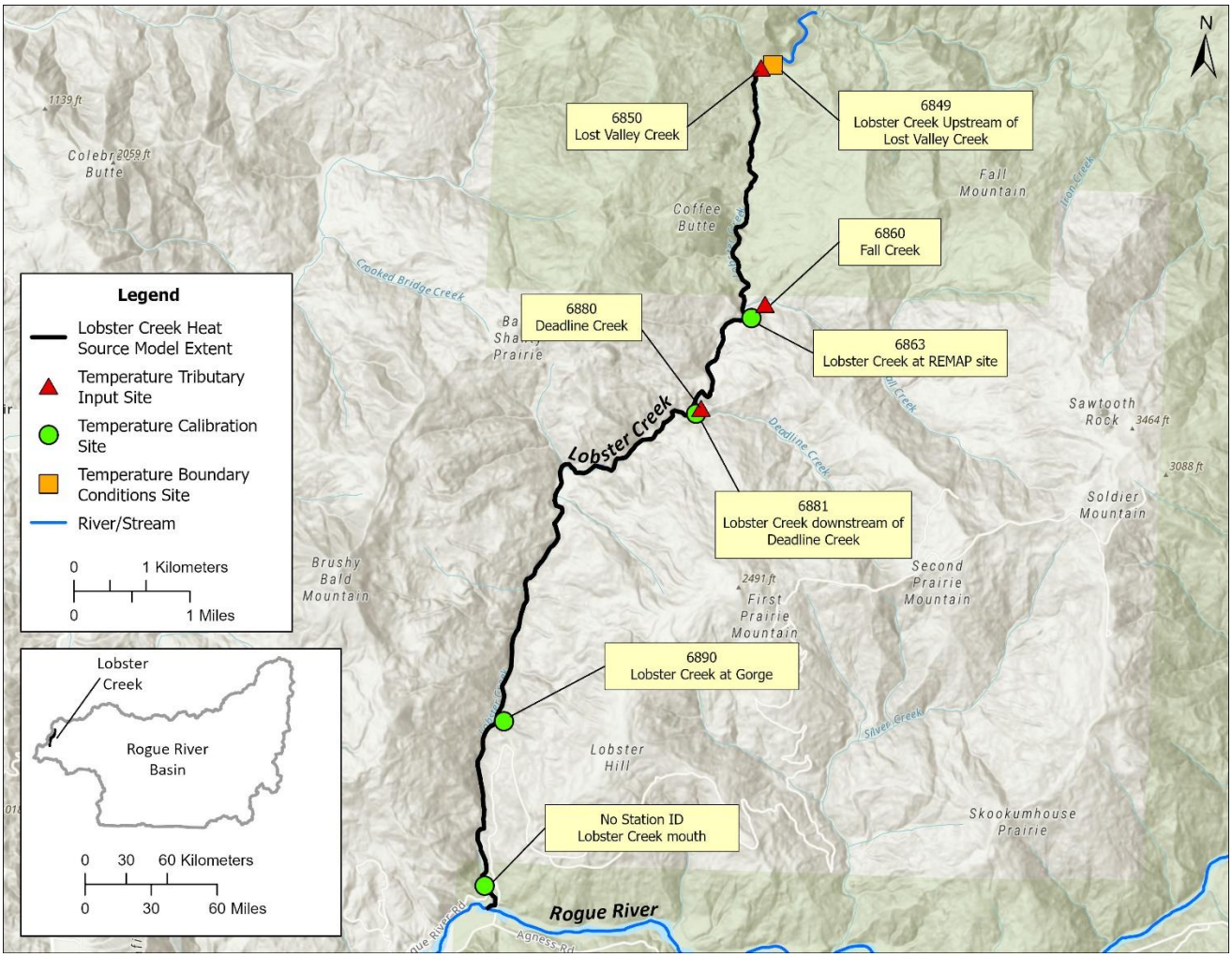


Figure 3-82: Temperature monitoring locations used for Lobster Creek model setup and calibration.

3.9.6 Flow inputs

Figure 3-83 shows the locations of the various stream flow monitoring locations that were used for model setup or calibration. In Figure 3-84, flow measurements on mainstem sites are depicted as solid dots while flow measurements at tributary mouths are depicted as open diamonds. Flows downstream of each tributary were calculated by adding the mainstem flow to the tributary flow. Intervening flow was extrapolated so that a complete flow profile could be constructed. No water rights are allocated in the entire Lobster Creek watershed. These values remained unchanged for the future condition simulations. Groundwater inputs were added to the model at the locations shown. The location and magnitude of these inputs were estimated.

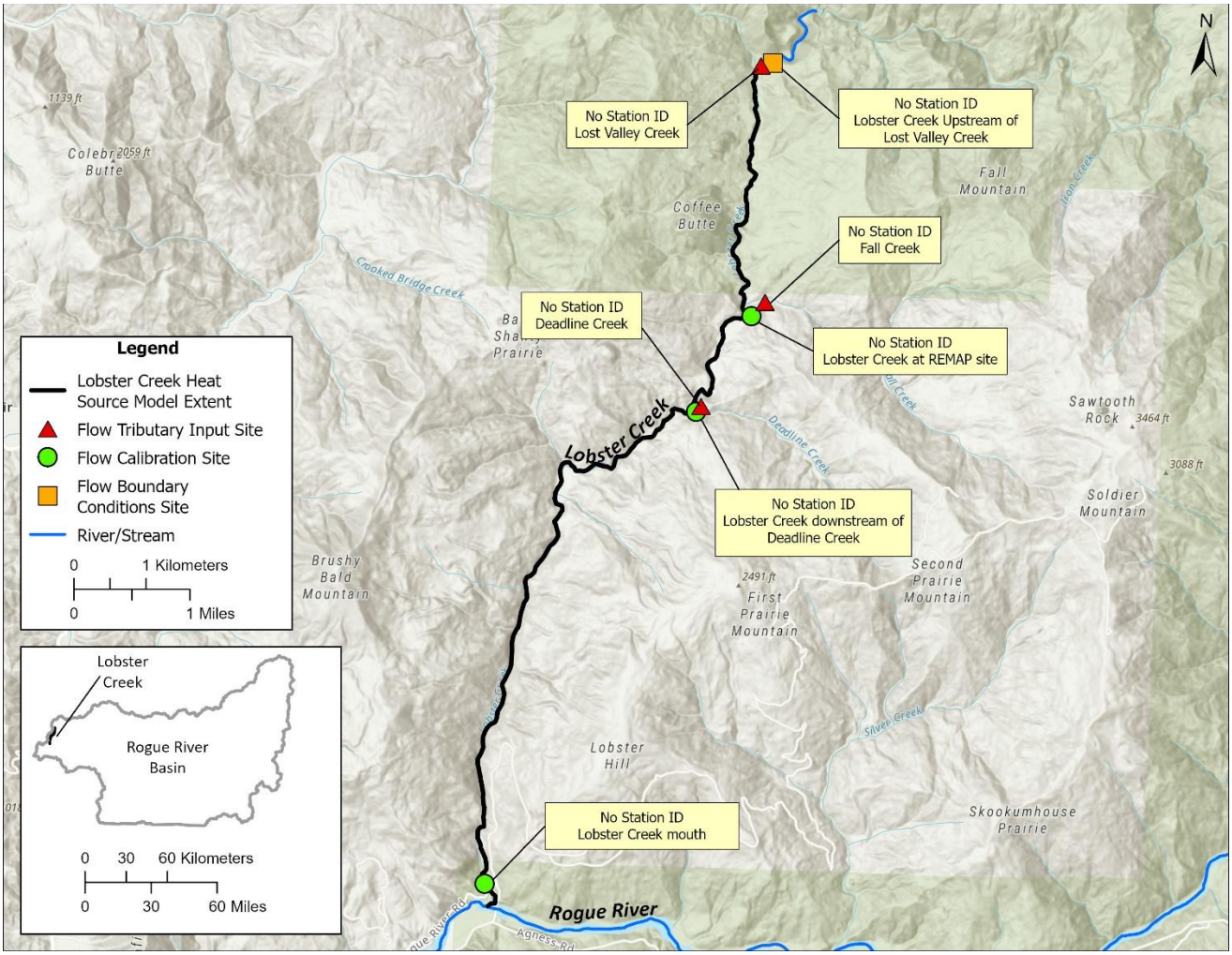


Figure 3-83: Flow monitoring locations used for Lobster Creek model setup and calibration.

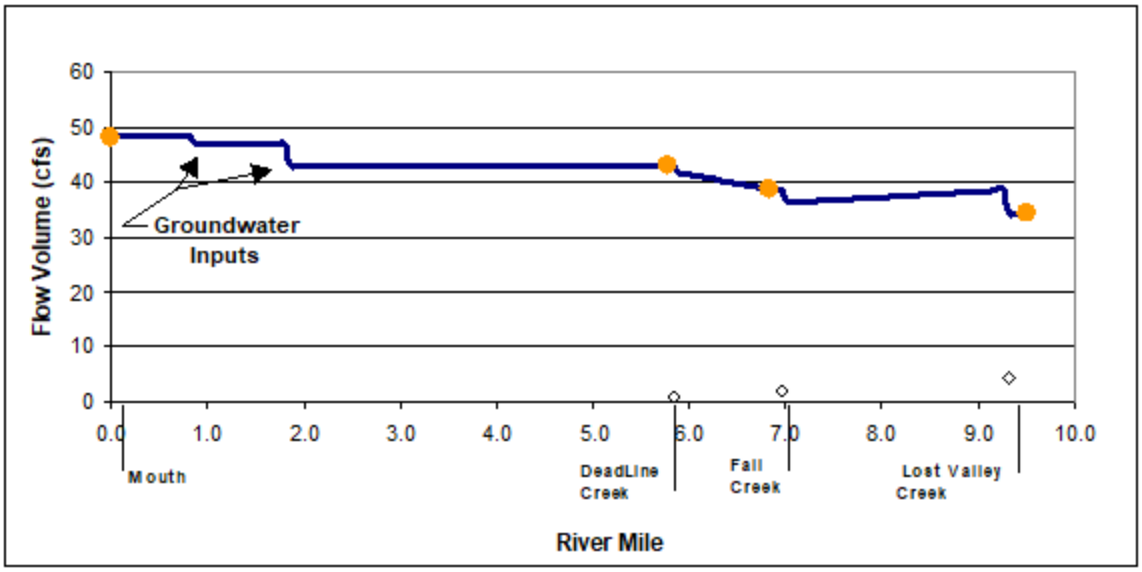


Figure 3-84: Measured and calculated flows in Lobster Creek and its tributaries. Orange circles represent mainstem measurements, hollow diamonds represent tributary measurements, and blue line represents total calculated flow along longitudinal extent.

3.9.7 Point source inputs

There are no permitted individual NPDES point sources along the model extent.

3.9.8 Landcover and topographic shade inputs

Riparian characteristics relating to shade quality and quantity were measured from aerial photography, digital imagery and on-site field measurements. The shading values so calculated were: shade height (Figure 3-86), shade density (Figure 3-87), and shade overhang (Figure 3-88).

Figure 3-85 shows the percentages of studied Lobster Creek mainstem reaches oriented in these general compass headings.

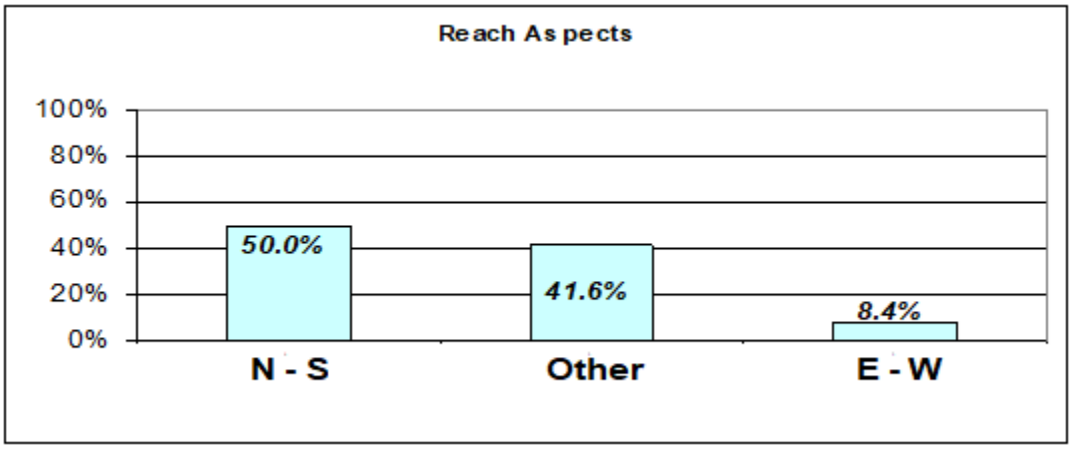


Figure 3-85: Proportion of modeled Lobster Creek reaches with various aspects.

In Figure 3-86, the red line represents the calibration condition for shade height, based on field measurements. The blue line represents assumed future conditions at management and restored vegetation. Figure 3-86 shows the average gradients for left and right streambanks by segment.

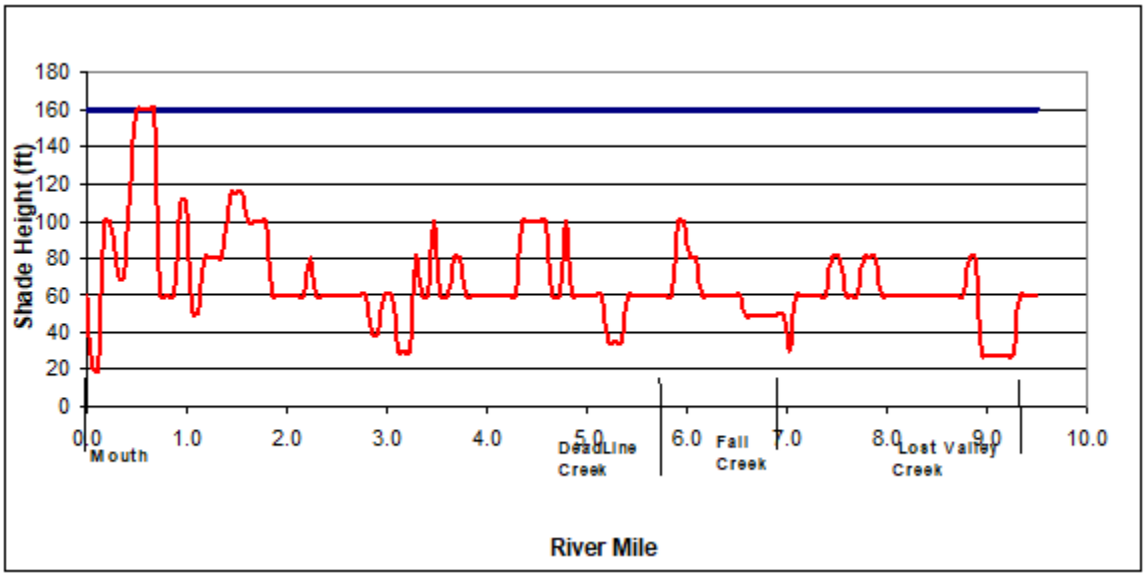


Figure 3-86: Lobster Creek stream gradients used in Heat Source model. The red line represents current condition values based on field measurements. The blue line represents restored vegetation condition estimates.

In Figure 3-87, the red line represents current condition field-measured shade densities. The blue line represents assumed restored vegetation shade densities. Figure 3-87 shows the average densities for left and right streambanks by segment. The model calculates the total effective shade by segment using both the left bank and right banks values.

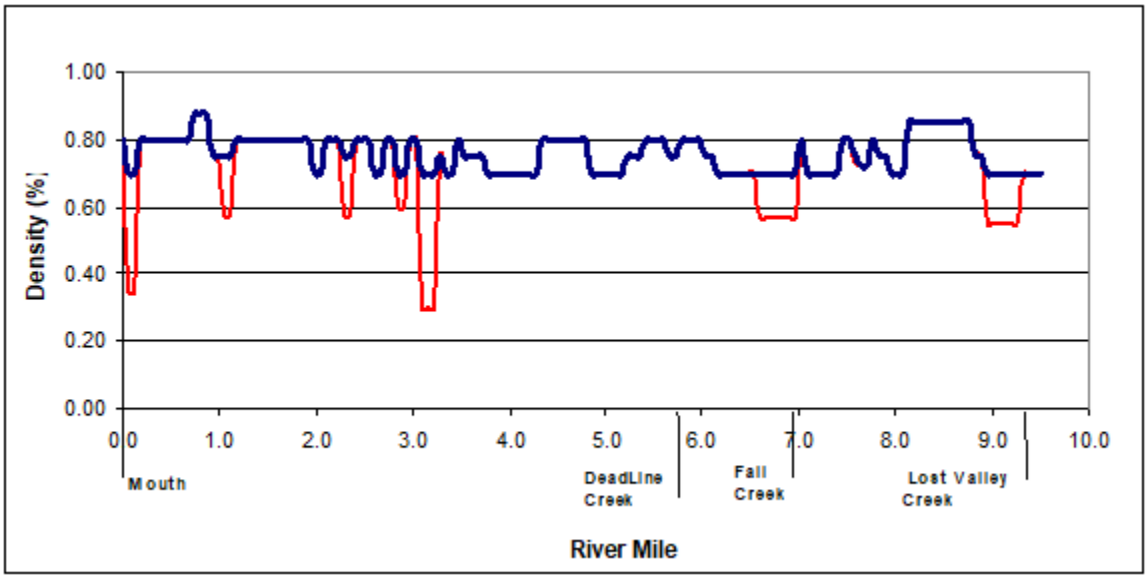


Figure 3-87: Lobster Creek stream densities used in Heat Source model. The red line represents current condition values based on field measurements. The blue line represents restored vegetation condition estimates.

Shade Width. The width of the shade–producing riparian area is assumed to be 100’ under current and management potential future conditions. This width was assumed to be 300’ under the restored vegetation scenario.

Shade Overhang. Figure 3-88 shows the shade overhang profile used in both calibration and restored conditions simulations. This graph shows the average of the left and right bank measurements for each segment. The model calculates the total shade production in a segment using both the left bank and right bank values.

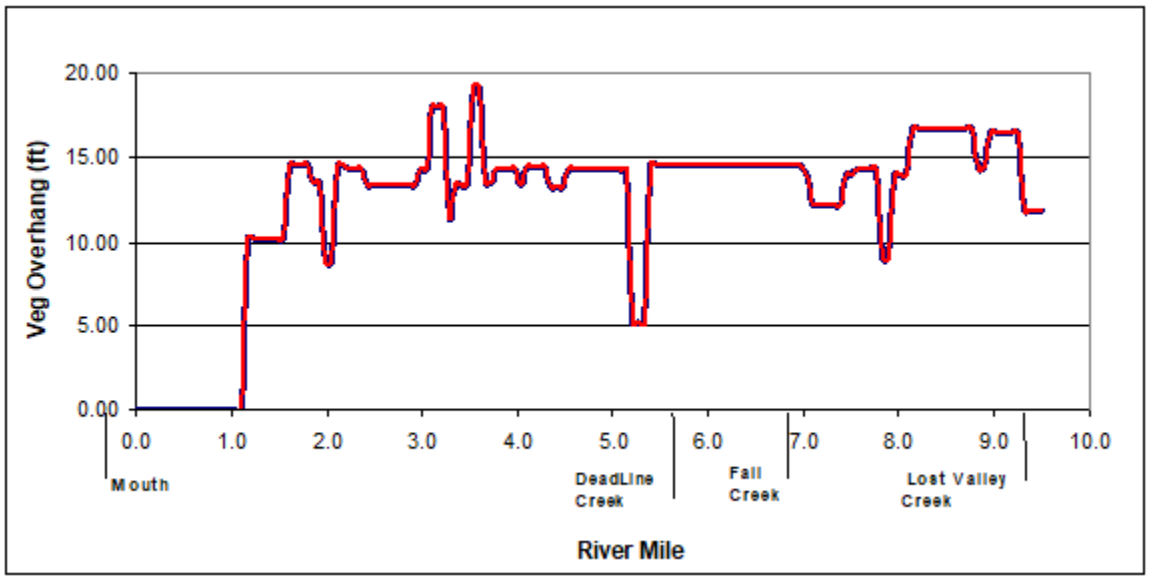


Figure 3-88: Lobster Creek vegetation overhang values used in Heat Source model.

3.9.9 Channel setup

Channel wetted width was measured via field observations.

Wetted channel widths (dark red line) and near stream disturbance zone widths (NSDZ – dark blue line) were scaled from aerial photos and field measurements. The near stream disturbance zone is defined as the distance across the stream from one the shade-producing area to the one on the opposite bank. Figure 3-91 shows the width profiles used in the model. These values remained unchanged for the future condition simulations

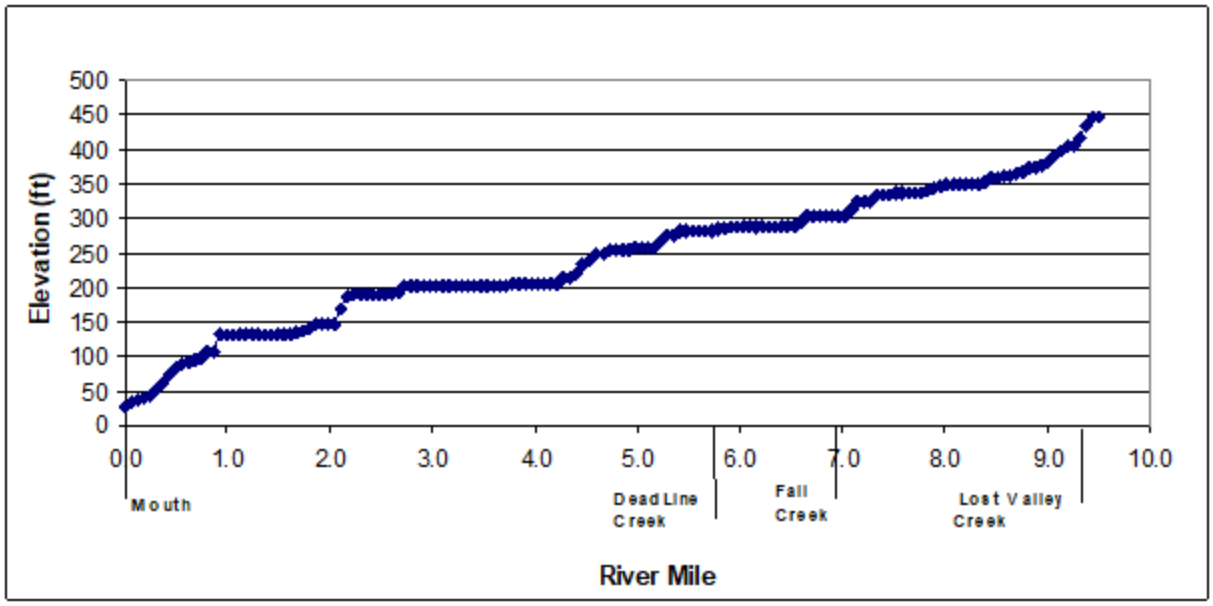


Figure 3-89: Lobster Creek channel elevations used in Heat Source model.

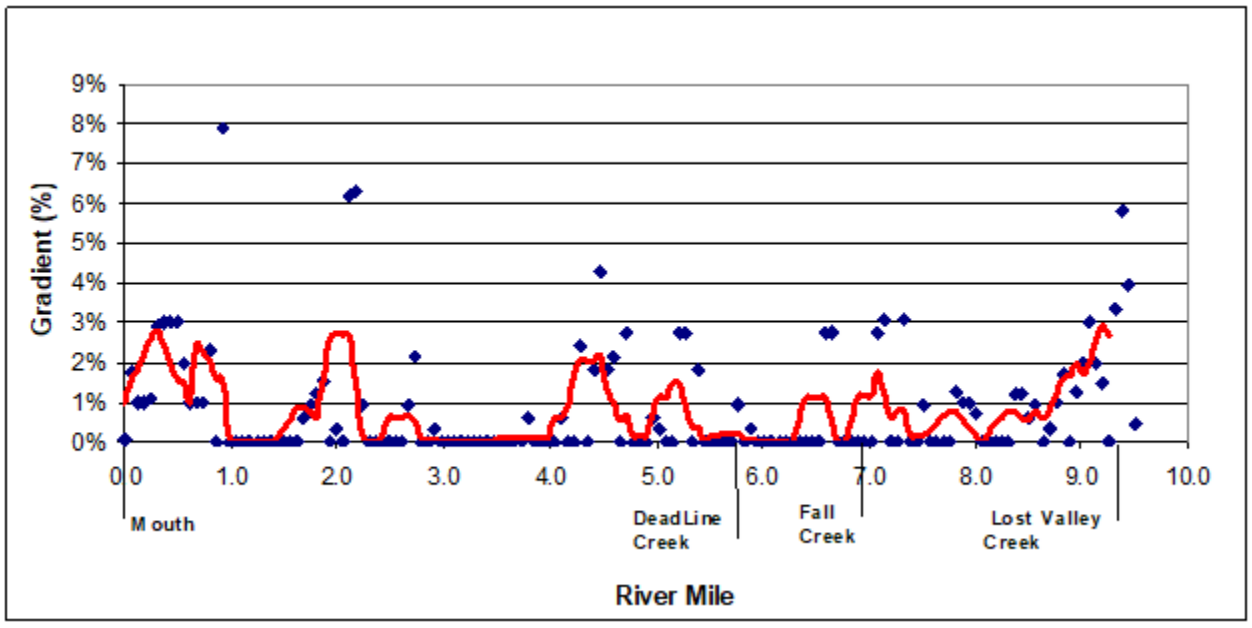


Figure 3-90: Lobster Creek stream gradients used in Heat Source model.

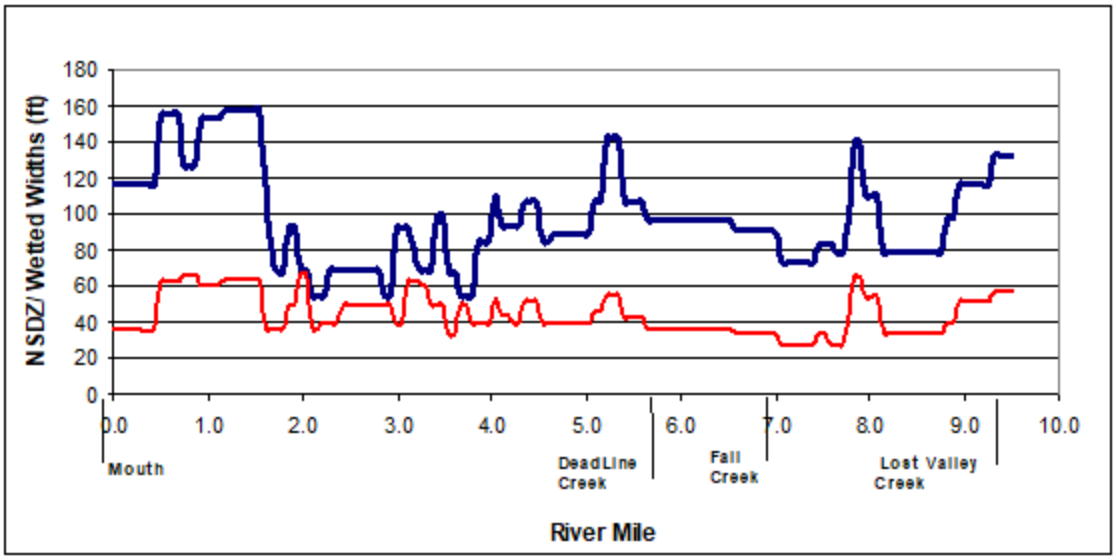


Figure 3-91: Lobster Creek near-stream disturbance zone (blue line) and wetted channel widths (red line) used in Heat Source model.

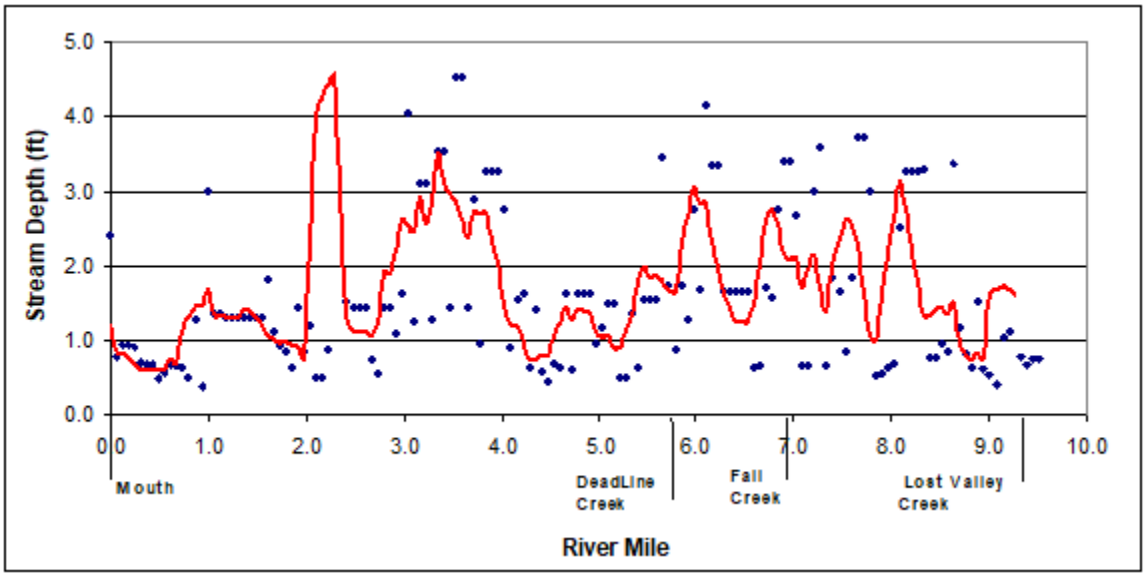


Figure 3-92: Lobster Creek stream depths used in Heat Source model.

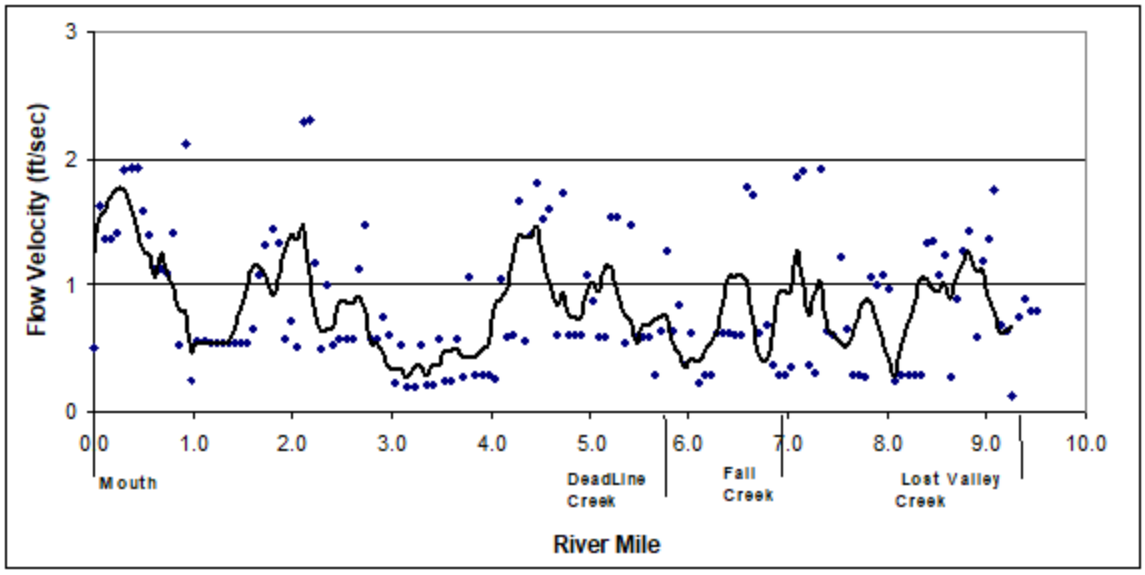


Figure 3-93: Lobster Creek flow velocities used in Heat Source model.

Topographic Shading. Topographic shading is defined as the shading provided to the stream by ridgelines or hills. It is extremely localized and unique for each system. Southern shading can result in an appreciable lowering of solar energy during the day. East/West shading effectively shortens the amount of daylight hours by delaying local sunrise or hastening local sunset. Figure 3-94 shows that some parts of Lobster Creek get a generous amount of topographic shading to the south.

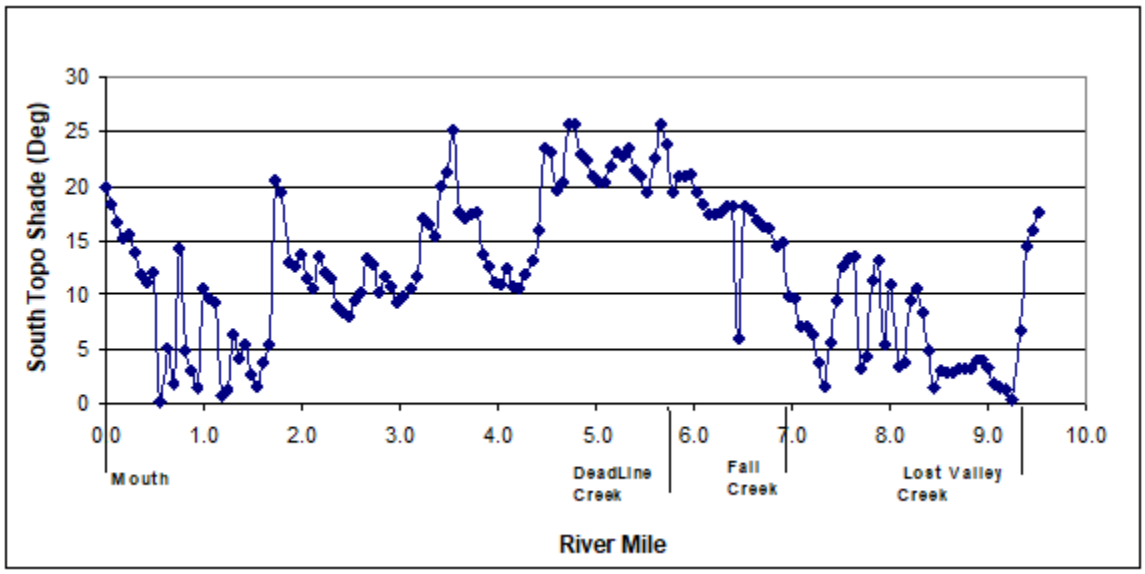


Figure 3-94: Lobster Creek topographic shade angles used in Heat Source model.

3.9.10 Calibration results

Field measured data (collected on 7/22/1999) was used to calibrate the stream temperature model. For this series of Heat Source simulations, the parameters that were adjusted for the calibration process were Manning's “n”, average channel width, and average channel depth.

Except for riparian shade width, humidity, and wind speed, all data obtained from field measurements or scaled from photos were used as recorded. Calibration parameter adjustments ceased when the simulated output agreed with observed field data within error targets.
For this study, the Lobster Creek mainstem had five data loggers where simulated and observed data could be compared. Table 3-49 summarizes the variation between modeled and measured results. Each logger summary is based on 24 data pairs (one pair for each hour of the model day).

Table 3-49: Lobster Cr. Heat Source temperature model, goodness-of-fit results.

Measurement location	River mile	r-squared	Standard Error (°C)
Upstream of Lost Valley Cr.	9.6	1.000	0.00
REMAP Site	6.9	0.945	0.30
Downstream of Deadline Cr.	5.8	0.935	0.40
At Gorge	1.8	0.954	0.20
At Mouth	0.0	0.939	0.20
Average		0.955	0.22

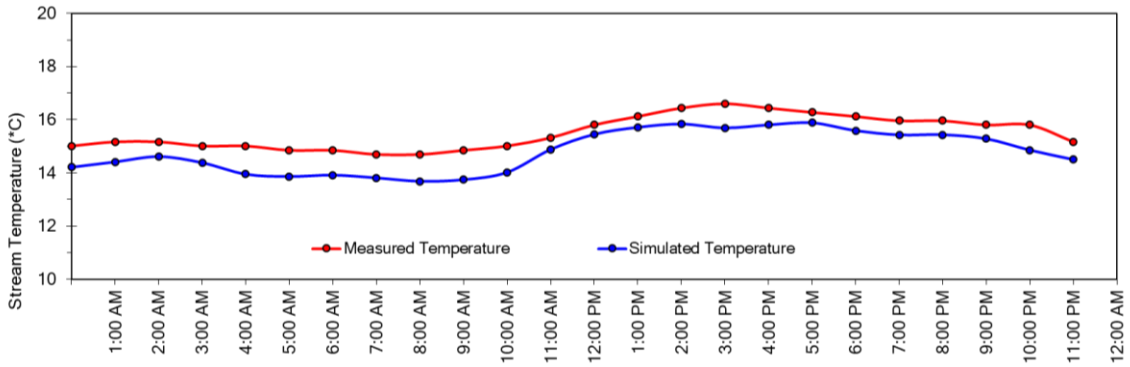


Figure 3-95: Measured vs. modeled water temperatures, Lobster Creek mouth.

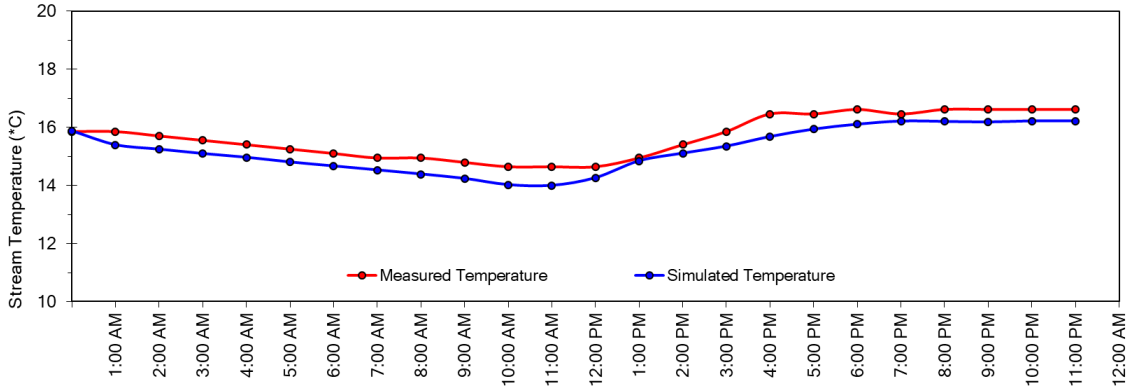


Figure 3-96: Measured vs. modeled water temperatures, Lobster Creek "Gorge" site (model km 3.1).

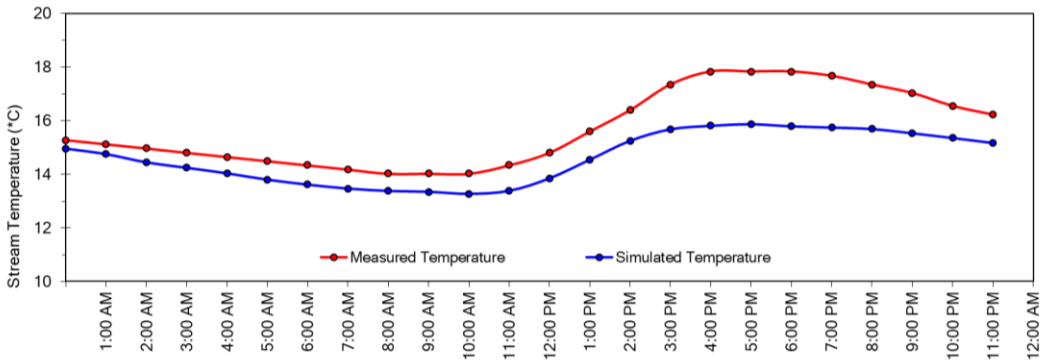


Figure 3-97: Measured vs. modeled water temperatures, Lobster Creek downstream of Deadline Cr. (model km 8.7).

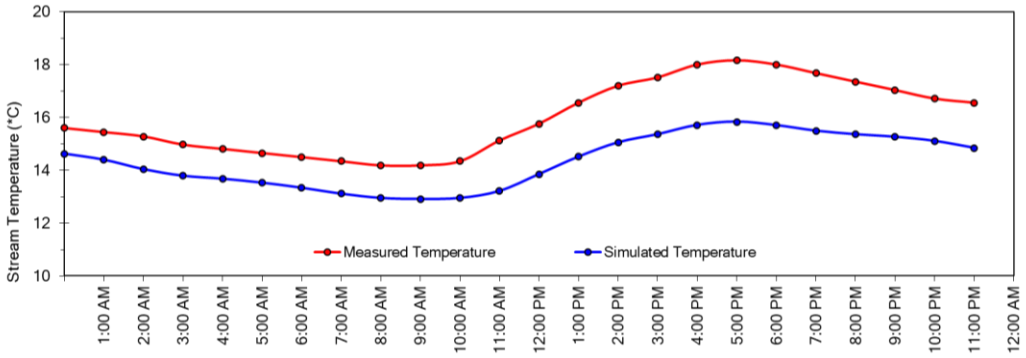


Figure 3-98: Measured vs. modeled water temperatures, Lobster Creek "REMAP" site (model km 11.0).

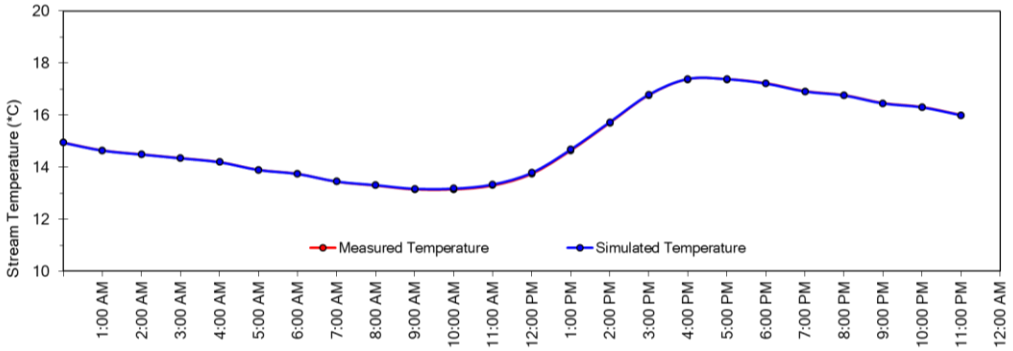


Figure 3-99: Measured vs. modeled water temperatures, Lobster Cr. upstream of Lost Valley Cr. (model km 15.3).

3.10 Lobster Creek Watershed

The Lobster Creek Watershed SHADOW models are shade models developed by the USFS and Lower Rogue Watershed Council. DEQ did not update these models. The model setup is described in the original Lobster Creek Watershed TMDL (DEQ, 2002a).

3.10.1 Model extent

The extent of the model domain is Lobster Creek and select tributaries to Lobster Creek in the Lobster Creek Watershed (1710031007). Select tributaries include Lost Valley Creek, North Fork Lobster Creek, South Fork Lobster Creek, Boulder Creek, Fall Creek, and Deadline Creek. The model extent is shown in the HTML interactive map that accompanies this TMDL

Perennial streams were defined as those that appear as lines on the USGS 1:24000 7.5' maps, with lines extended to any point that drains 60 acres (based on Watershed Council assumptions). Only those perennial streams that contribute 5% or more of the flow at their confluence with the next larger stream were analyzed (based on methods established for the Sucker-Grayback WQMP).

3.10.2 Spatial and temporal resolution

This information was generated with a GIS layer, which was derived from imagery at 30m resolution.

3.10.3 Time frame of simulation

The Shadow model determines shading on August 1 of any given year. August was selected for this exercise because it is a peak solar loading month for this region

3.10.4 Landcover and topographic shade inputs

Aerial photos and field reconnaissance were used to quantify shade values, recovery potential, and recovery time frame. Input variables used to analyze and develop shade curves (Figure 5-64**,** Figure 5-65, and Figure 5-66) include low-flow wetted stream width, riparian tree height, shade density (80%), and stream orientation. For modeling purposes, these curves assumed a common hillslope gradient (60%) and offsets (5') from wetted channel edges to beginning of riparian vegetation. Lobster Creek was then divided into representative reaches based on orientation and riparian condition. Tributaries that account for ≥5% of the mainstem drainage area were assumed to influence mainstem temperatures and were included in the assessment. For private lands, the mainstem and primary tributaries accounted for approximately 240 evaluation reaches. Field measurements at 23 sites included bankfull and low flow channel width, streambank slope, distance from bankfull to riparian vegetation, tree heights, and percent overhang and shade density. Federal Land Managers evaluated approximately 225 reaches.

Maps and aerial photos were used to divide streams into 230 segments based on differences in riparian vegetation, orientation, and tributary confluences. Field measurements at 15 sites included bankfull and low flow channel width, streambank slope, distance from bankfull to riparian vegetation, tree heights, percent overhang, and shade density. For each stream reach, we used our map/photo information along with the field measurements to estimate a bankfull channel width and existing tree height.

To assess present stream shade condition on perennial streams for the 1999 Lobster Creek Watershed Assessment, the age of riparian vegetation throughout the watershed was estimated based on information available in the Siskiyou National Forest GIS. Within the National Forest and the State of Oregon land, riparian vegetation age was interpreted from satellite imagery (PMR). On Lincoln Timber LLC and BLM land, the stand origin dates were used. On other privately owned land, age estimates were based on the overall vegetation appearance in the 1997 aerial photos. These estimates are general, inconsistent between ownerships, and intended only to give a rough indication of streamside vegetation.

Table 3-50 summarizes the successional stages of vegetation throughout the basin. The riparian area widths considered for this GIS data were the interim riparian widths from the Northwest Forest Plan ROD for National Forest lands (USDA and USDI, 1994). For other ownerships, a width of 100' on each side of Lobster Creek and 50' on each side of its tributaries was used to approximate Oregon Forest Practices riparian widths.

Table 3-50: Riparian Successional Stages From GIS Data[1].

Seventh Field WS	Riparian Acres	% Late Successional	% Mid Successional	% Early Successional	% Pioneer	% Rock	% Mid & Late Successional
20L01F	140	4	11	64	16	6	15
20L02W	38	5		95			5
20L03F	86			88	12		
20L04W	48			96			
20L05F	131			94	6		
20L06W	63			89	10		
20L07F	93	3	2	86	9		5
20L08W	67	3	3	94			6
20L09F	225	8	4	77	11	1	12
20L10W	624	37	5	25	33		42
20N01F	543	45	4	30	21		49
20N02W	392	40	3	30	26		43
20N03W	345	33	1	39	26	1	34
20N04W	333	56	5	15	24		61
20N05W	244	63	4	13	19	1	67
20N06W	263	76	2	10	13		78
20N07F	309	64	3	21	12		67
20S01F	635	37	10	24	28	1	47
20S02W	51	16	2	75	6		18
20S03W	62	47	2	39	13		49
20S04W	803	33	7	19	39	2	40
20S05W	462	56	6	19	19	1	62
20S06W	317	50	5	15	28	2	55
20S07W	446	57	2	26	15		59
20S08W	402	35	2	43	20		37
20S09F	248	56	5	13	25		61

[1] Successional categories were developed based on tree height: Pioneer (0 - 10 yrs), Early (11 - 60 yrs), Mid (61 - 100 yrs), Late (>100 yrs)

Potential tree heights and shade densities were based on measured and estimated tree heights in adjacent, undisturbed areas. Douglas Firs in the watershed can grow to 160' high and 80% shade density. Potential shade differed from existing shade in riparian areas that had been harvested, or where it was deemed reasonable to assume that future and current vegetation would differ based on natural growth.

Existing shade values were calculated from existing shade densities, stream wetted widths, and tree heights. Forest Service personnel determined values for Lost Valley Creek, North Fork Lobster, and South Fork Lobster stream segments except for the first tributary above the mouth of the South Fork. Watershed Council personnel determined values for stream segments on Lincoln Timber LLC land ownership. "Target" shade values were also predicted for each reach based on expected future riparian tree type and shade characteristics. Reference sites were examined to restored vegetation conditions. The SHADOW model was used to project future condition shade values. The difference between these two values represents the target shade increase. Effective shade and solar radiation

loading were simulated for various bankfull channel widths. Restored vegetation was determined to be late successional Douglas fir, with Hemlock and Port Orford cedar present. Coniferous and mixed hardwood stands are common based upon watershed reference sites' evaluation. This vegetative condition was used to define effective shade potential. Restored vegetation shading was used to predict solar loading without anthropogenic effects. Restored vegetation defines the solar load while effective shade is the surrogate target. It is possible that effective shade targets will be achieved in given channel types without restored vegetation.

In the Lobster Creek Watershed, undisturbed riparian areas generally progress towards late successional woody vegetation communities (i.e., conifer-dominated, mixed hardwood). Few, if any, Lobster Creek Watershed riparian areas are unable to support either late successional woody vegetation or tall herbaceous vegetation. Further, the climate and topography are well-suited for growth and maintenance of large woody vegetative species in the riparian areas.

3.11 Rogue River

The Rogue River model is a Heat Source 8.0.8 water temperature model developed by DEQ.

3.11.1 Model extent

The extent of the model domain is 239.6km, from the estuary at river km 9.3 to Lost Creek Reservoir at river km 248.9 (Figure 3-100).

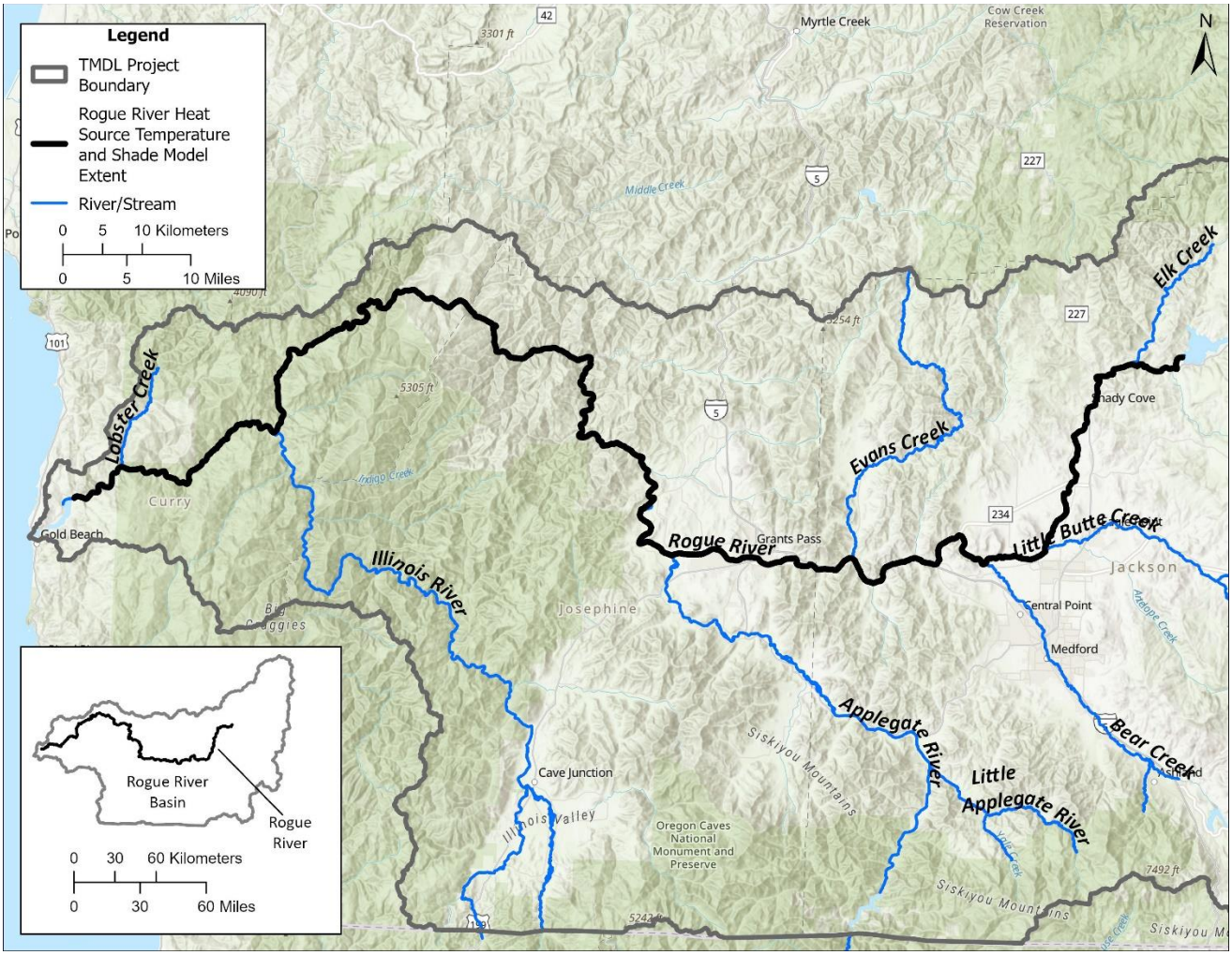


Figure 3-100: Extent of the Rogue River temperature model.

3.11.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is x m. Outputs are generated every x m. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.11.3 Time frame of simulation

The model period is from March 1, 2003, to October 31, 2003.

3.11.4 Meteorological inputs

The model used air temperature, relative humidity, wind speed and cloudiness from various sites (Table A4 and Table A5). The meteorological observations are presented in Figure A20 - Figure A24. A sine wave function was used to calculate hourly air temperatures for stations with only daily minimum and maximum air temperatures. At the Brookings station, cloudiness was calculated from solar radiation observations. The meteorological inputs varied by stream kilometer based on

proximity to the weather station. A multiplicative wind sheltering coefficient was applied to the wind speed for calibration.

Table 3-51: Rogue River model: meteorological data sources.

Site	Source	Meteorological Parameters
Medford Airport	NCDC	Cloudiness, wind speed, relative humidity, air temp.
Lost Creek Reservoir	US Army Corp of Engineers	Daily minimum and maximum temperature
Grants Pass	Oregon Climate Service	Daily minimum and maximum temperature
Brookings	Agrimet	Solar radiation, wind speed, relative humidity, air temp.

Table 3-52: Data inputs to Rogue River model by river km.

Range (river km)	Cloudiness	Relative Humidity	Air temperature	Wind speed	Wind sheltering coefficient
249 - 210	Medford	Medford	Lost Creek *	Medford	0.0
210 - 203	Medford	Medford	Medford	Medford	0.0
203 - 119	Medford	Medford	Grants Pass**	Medford	0.0
119 - 55	Medford	Medford	Grants Pass**	Medford	0.25
55 - 0	Brookings	Brookings	Brookings	Brookings	0.5

*missing data filled in with Medford data.
**missing data filled in with a regression with Medford.

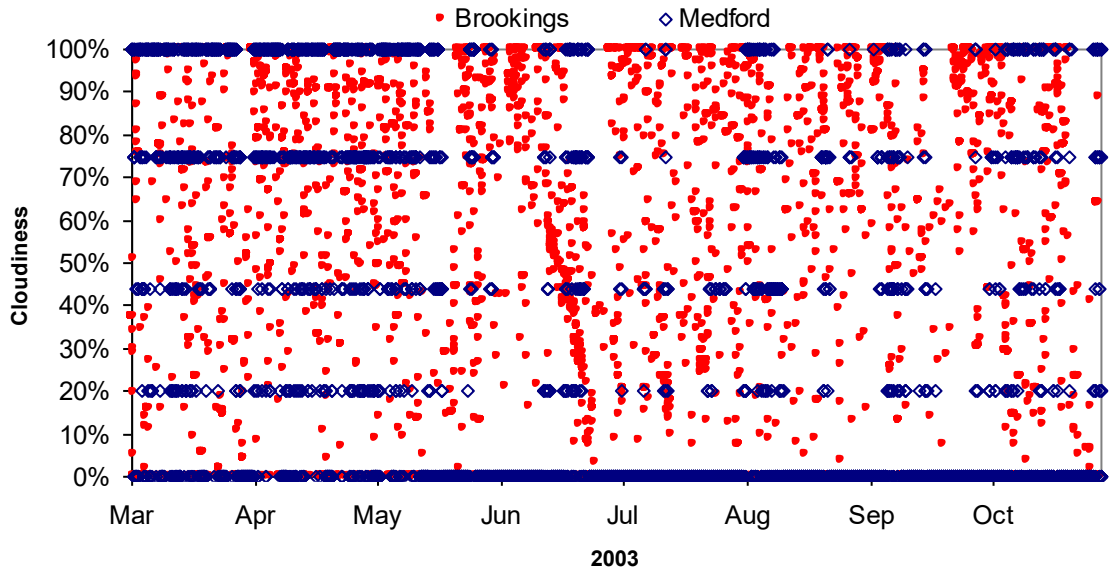


Figure 3-101: Rogue River model setup: cloudiness data. Intervals are residuals of reported Medford station measurements.

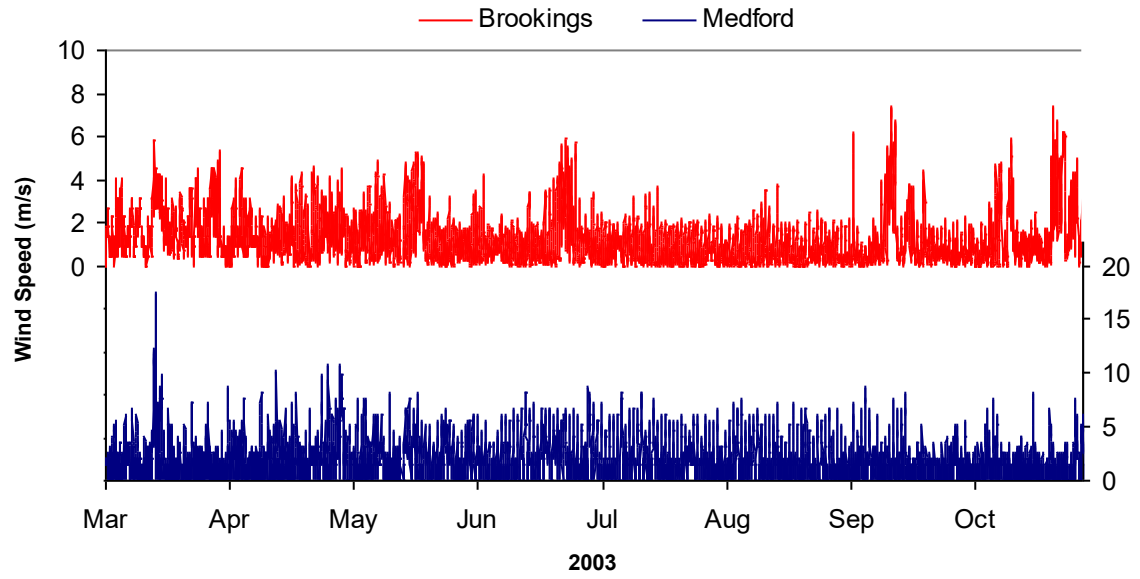


Figure 3-102: Wind speed data used in Rogue River model setup.

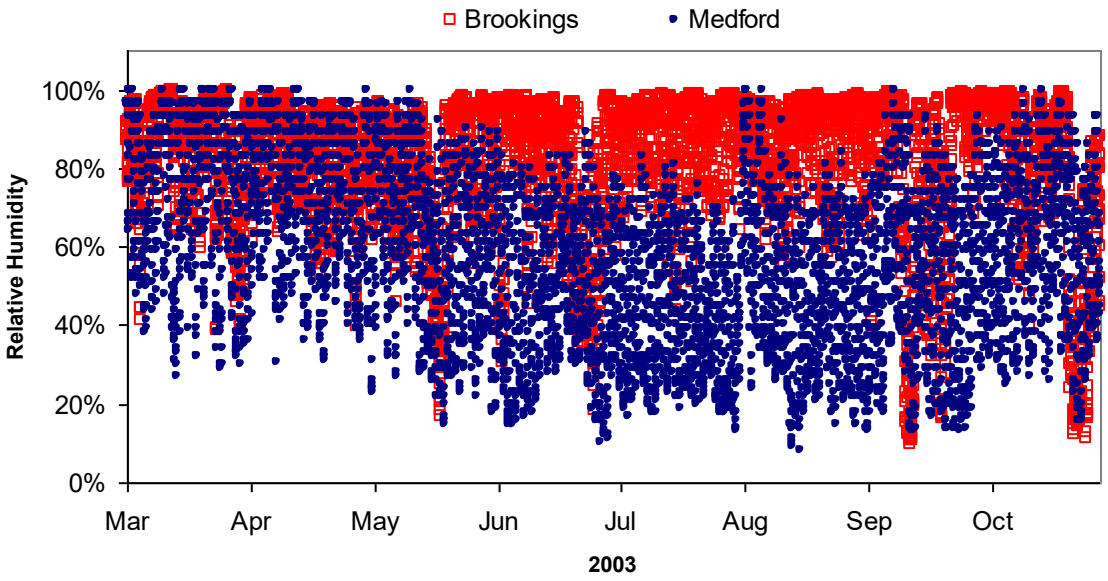


Figure 3-103: Relative humidity data used in Rogue River model setup.

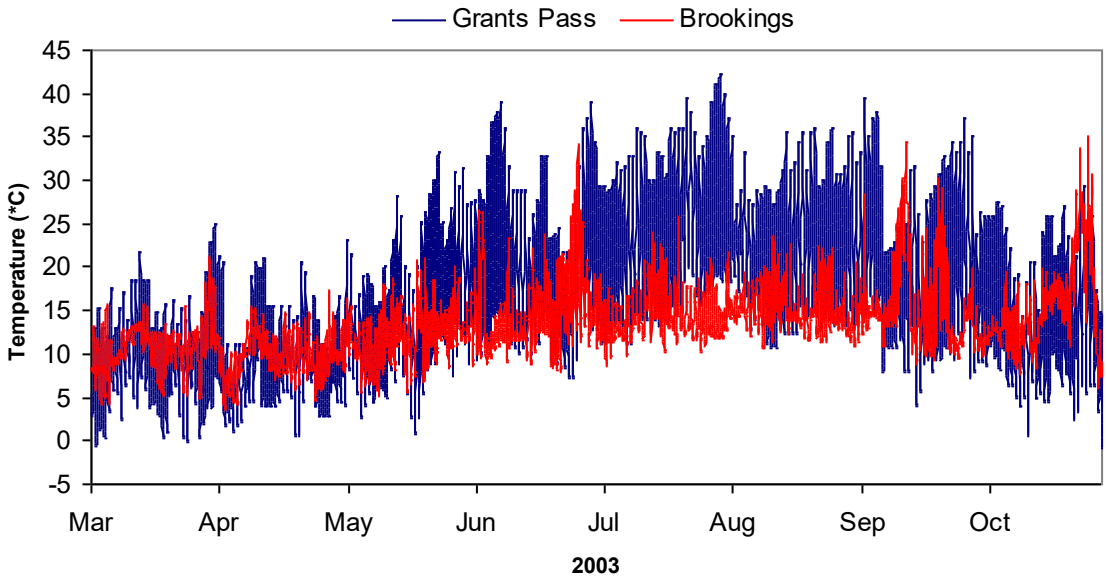


Figure 3-104: Air temperature used in Rogue River model setup (1 of 2).

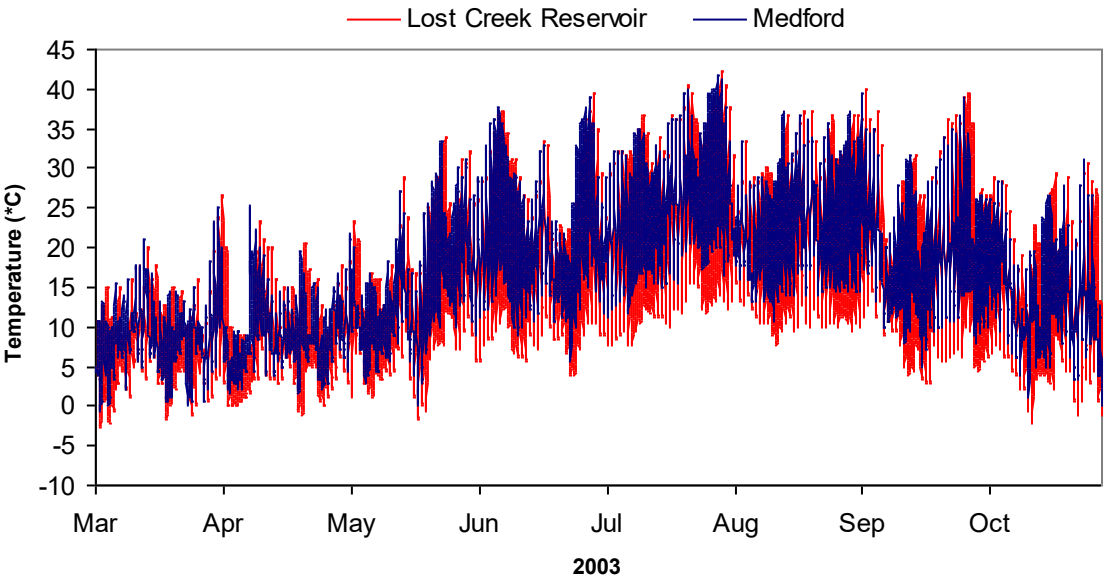


Figure 3-105: Air temperature used in Rogue River model setup (2 of 2).

3.11.5 Temperature inputs

Figure 3-106 shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration. Figure 3-107, Figure 3-108, Figure 3-109, Table 3-53, and Table 3-54 document the temperature inputs for the headwaters, tributaries, and NPDES point sources in the model. Because three NPDES permittees discharge to Military Slough, a mixing assessment was completed with permittees' discharge data to estimate Military Slough's flow and temperature at its confluence with the Rogue River. In the current condition model, Military Slough is represented with a constant 0.020 cms flow and 23.86°C temperature.

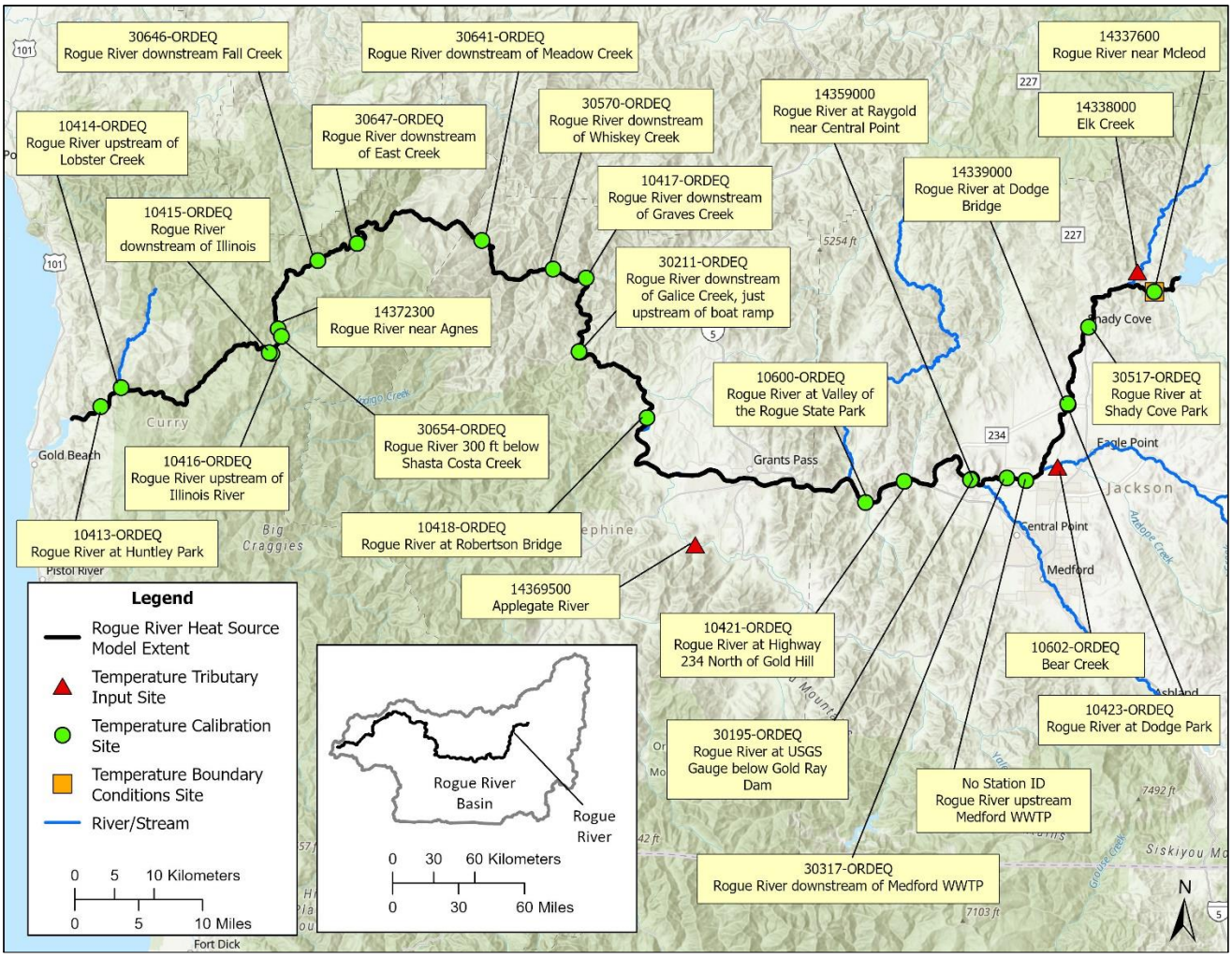


Figure 3-106: Rogue River model setup and calibration: temperature monitoring locations.

Table 3-53: Rogue River model: tributary and boundary condition temperature data sources.

Inflow	Stream km	Source
Headwater: Rogue R. at McLeod	249	USGS #14335075
Elk Creek	245.1	USGS #14338000
Trail Creek	239.8	5/7 - 9/16: DEQ-24477; other dates: linear regression w/Elk Cr
Little Butte Creek	213.5	5/7 – 6/30: DEQ-10602; 7/1 – 9/15: Medford Water Commission; other dates: linear regression w/Elk Cr.
Bear Creek	203.8	No 2003 data; Little Butte Creek used as surrogate.
Derived flow (d/s of Bear Cr.)	200	Big Butte Cr. data (Medford Water Commission, Elk Cr. regression w/5°C min.
Derived flow (at Evans Cr.)	178.8	4/23 – 9/16: DEQ-11372; other dates: regression w/Applegate R.
Applegate River	153.3	USGS # 14369500
Derived Flow (at Foster Cr.)	55.1	7/11 – 9/24: DEQ-30369, other dates: Evans Cr.
Illinois River	44.5	7/17 – 10/13: DEQ-10425), other dates: regression w/Applegate R.
Lobster Creek	18.4	7/17 – 10/13: DEQ-30194, other dates: used Illinois R.

Table 3-54: Rogue River model: NPDES temperature input sources.

Point source inflow	Stream km	Source
Butte Falls STP	u/s boundary (248.90)	DMRs (Mar-Apr 2019)
USACE, William L. Jess Dam Project	248.80	Permit application
ODFW, Cole M. Rivers Hatchery	248.25	DMR 2016 (Apr-Oct)
Country View Mobile Home Estates	238.35	Sporadic grabs, DMRs 2019-2023
Shady Cove STP	233.55	Daily grab, DMRs 2016-2020
Cascade Wood (Military Slough)	213.25	Monthly grab, DMRs 2018-2020
Biomass One, LLC (Military Slough)	213.25	DMRs 2021-2024
ODVA S. OR Rehabilitation Center & Clinics (Military Slough)	213.25	Permit application
Duff WTP (Medford)	212.75	General permittees do not submit DMRs; estimated.
Medford RWRF	210.55	Hourly data provided by permittee, DMRs 2016-2020
Gold Hill WWTP	190.20	Daily grab, DMRs 2016-2020
Rogue River STP	177.95	Daily grab, DMRs 2016-2020
Grants Pass WTP	164.90	Personal communication data
Grants Pass STP	162.80	Daily grab, DMRs 2016-2020
Riveria Mobile Park	155.20	Daily grab, DMRs 2016-2020

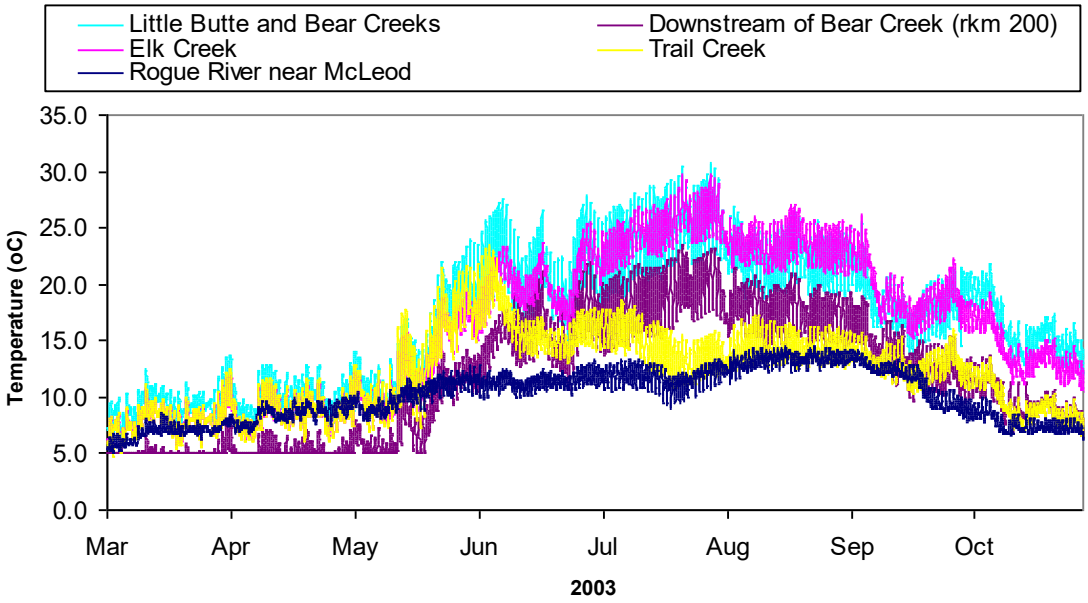


Figure 3-107: Rogue River model: tributary temperature inputs (1 of 2).

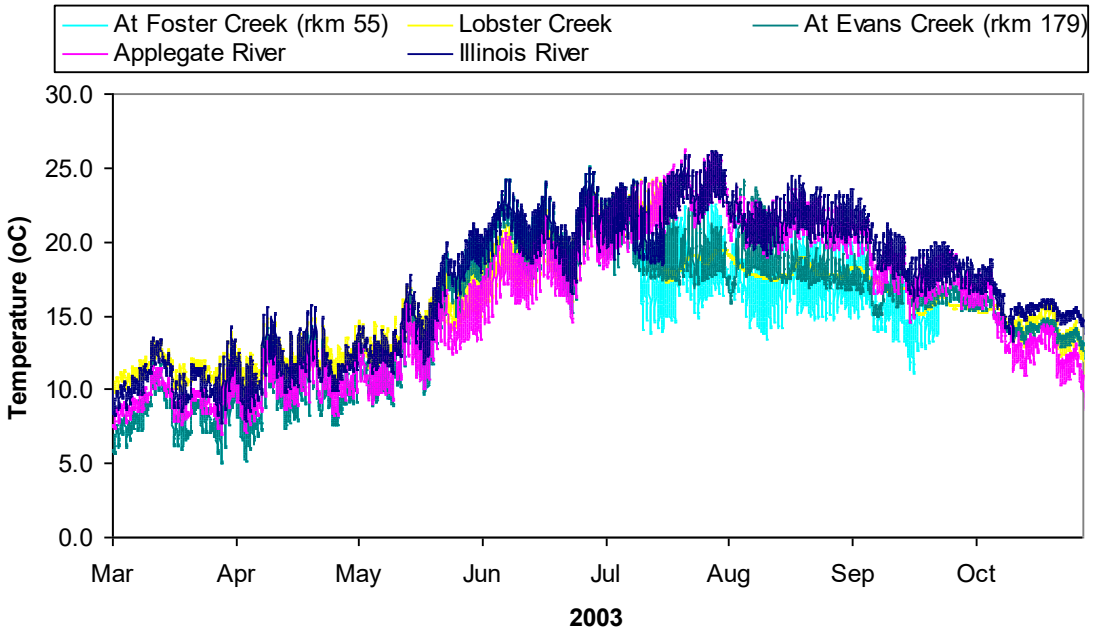


Figure 3-108: Rogue River model: tributary temperature inputs (2 of 2).

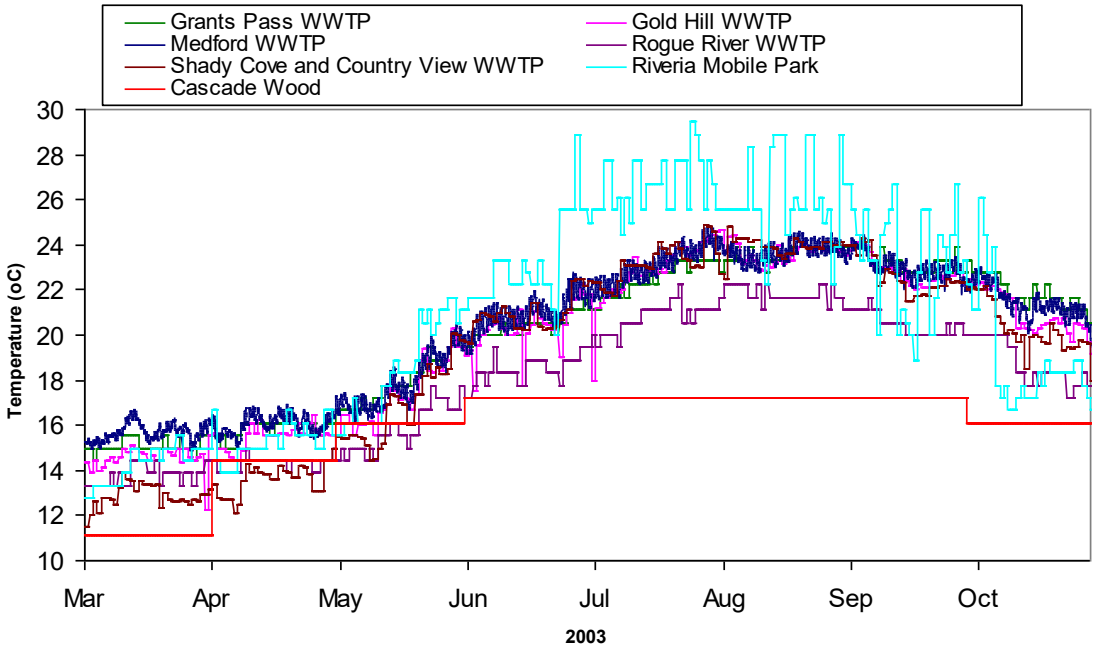


Figure 3-109: Rogue River model: point source temperature inputs.

3.11.6 Flow inputs

Figure 3-110 shows the locations of the various stream flow monitoring locations that were used for model setup or calibration. Discharge inputs at the model headwater (Rogue River near McLeod) and tributaries used field measurements when available and relationships with other gages were used otherwise (Table 3-55, Figure 3-111). At three locations, additional flow and/or withdrawal was necessary to reproduce observed flows (Table 3-55, Figure 3-112). The discharge rates of the eight

NPDES point sources were based on discharge monitoring reports (Figure 3-113, Figure 3-114). Maximum consumptive use is based on information provided by OWRD (Figure 3-115). The temporal component of consumptive use was estimated based on the irrigation season.

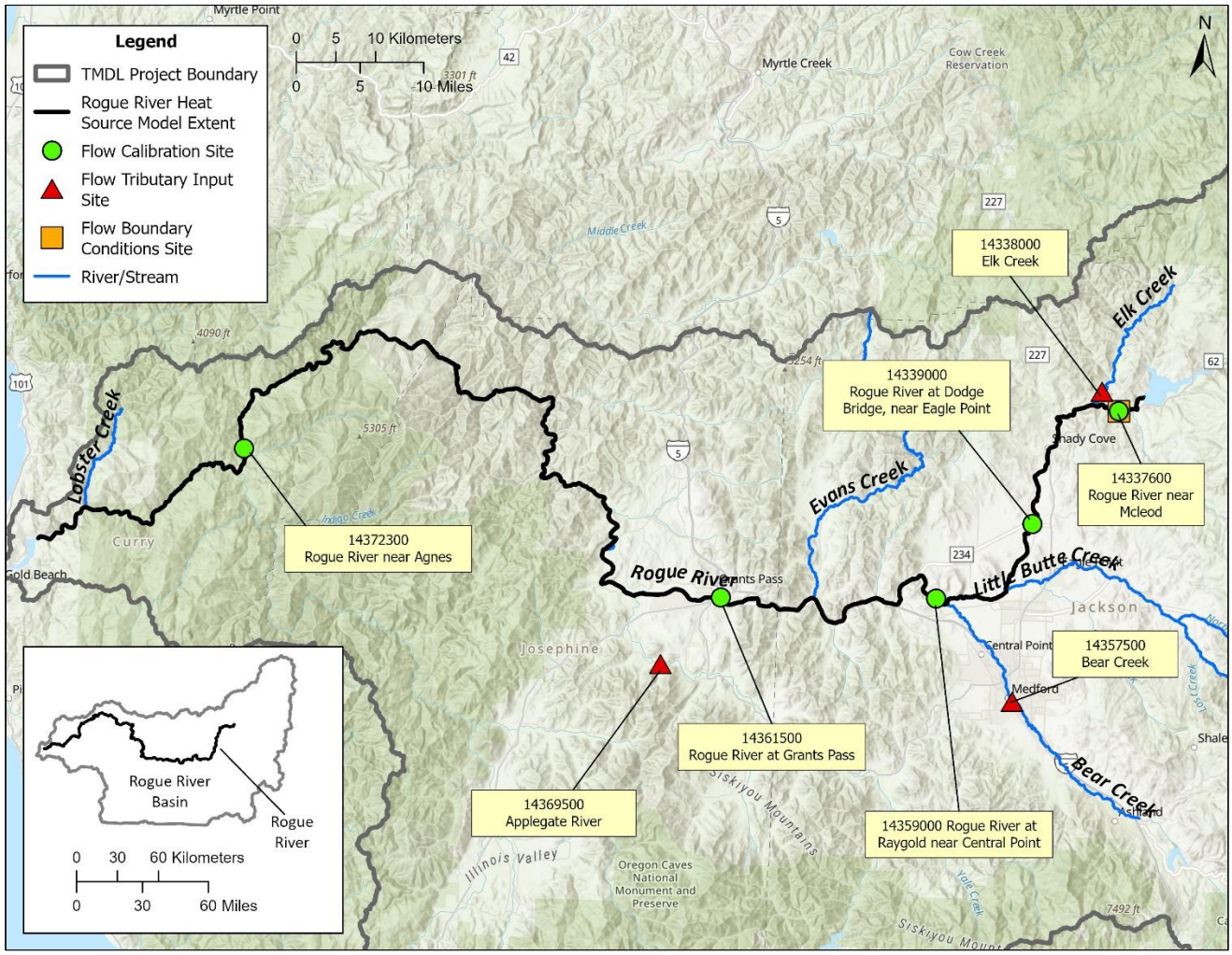


Figure 3-110: Rogue River model setup and calibration: flow monitoring locations.

Table 3-55: Rogue River model: flow data sources.

Inflow	Stream km	Source
Boundary condition: Rogue R. at McLeod	249	USGS #14337600
Elk Creek	245.1	USGS #14338000
Trail Creek	239.8	No gage, Elk Cr. relative drainage area (0.442) used to compute flow
Little Butte Creek	213.5	No current gage, used historical regression with Elk Cr. gage below Eagle Cr. (1945-1950)
Bear Creek	203.8	USGS #14357500
Derived flow, d/s of Bear Cr.	200	Added to reproduce USGS #14361500 observed flows (rkm 164.8)
Derived flow, Evans Cr.	178.8	No gage, derived via mass balance with USGS #14361500 (rkm 164.8)
Applegate River	153.3	USGS #14369500 (RM 7.6)
Derived Flow (Foster Cr.)	55.1	No gage, added to reproduce USGS #14372300 observed flows

Inflow	Stream km	Source
Illinois River	44.5	Regressed Illinois R. USGS #14377100 (rm 50) and Illinois R. near Agness (rm 5), 1961-1983 data
Lobster Creek	18.4	No gage, S. Fork Coquille R. at Powers relative drainage area (0.41) used to compute flow

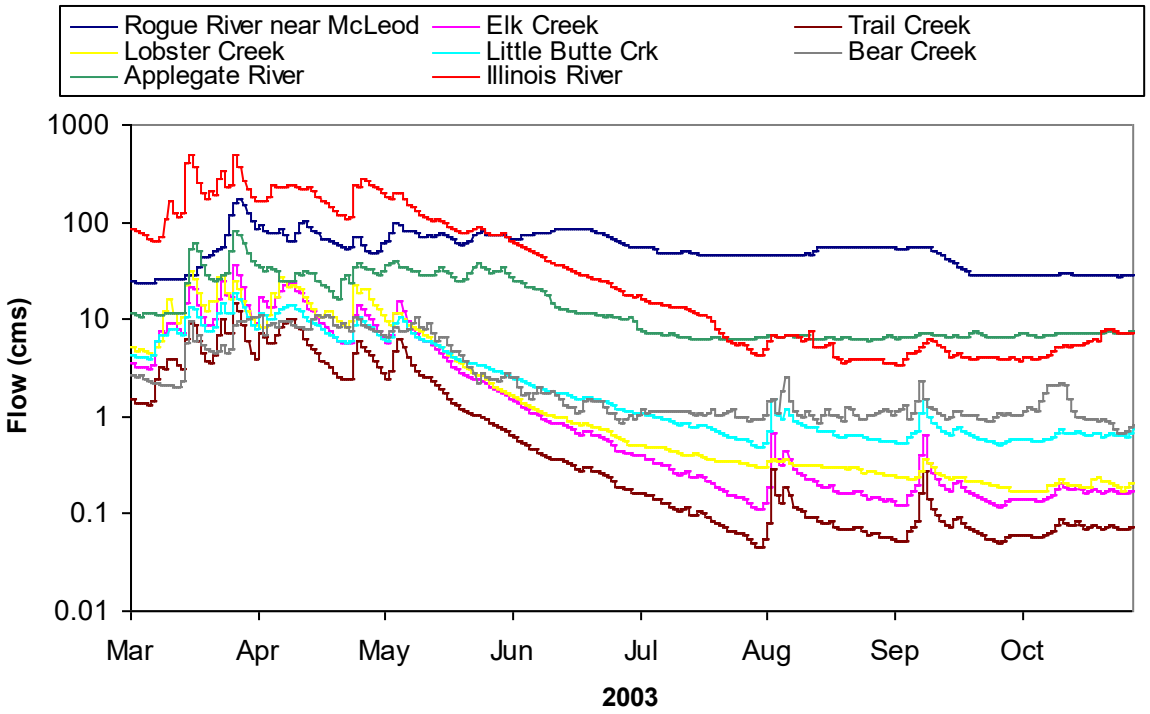


Figure 3-111: Rogue River model: tributary flow boundary conditions.

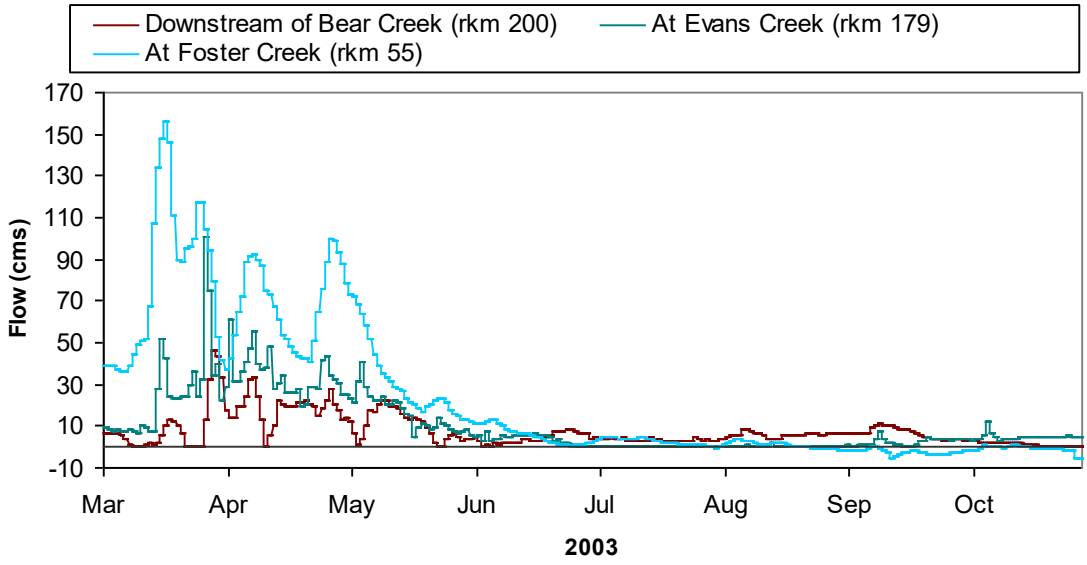


Figure 3-112: Rogue River model: tributary flows derived from mass balance with mainstem gages.

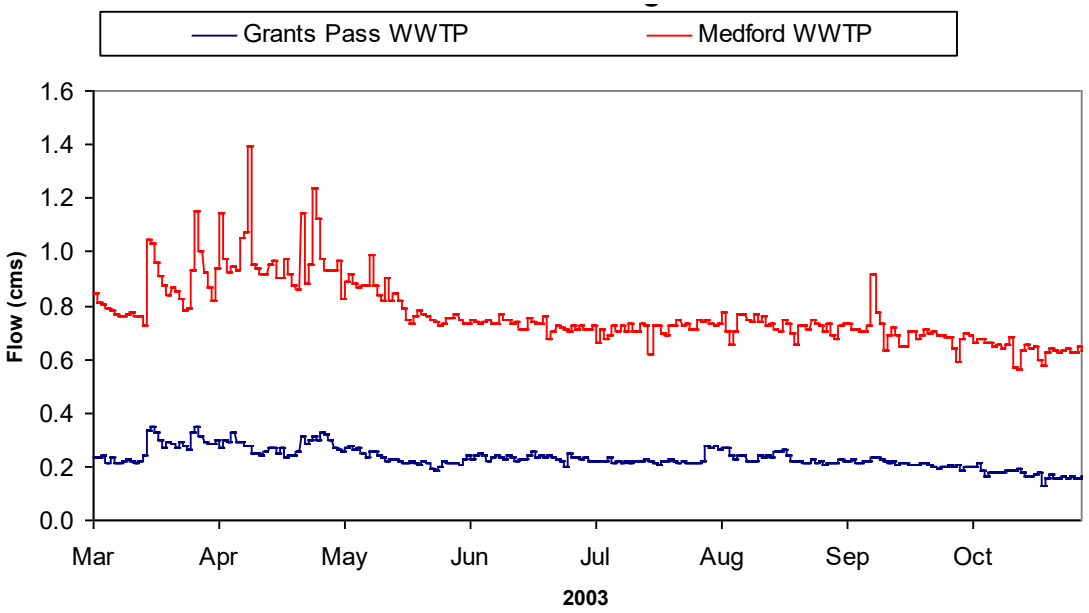


Figure 3-113: Rogue River model: point sources flows for the two largest sources.

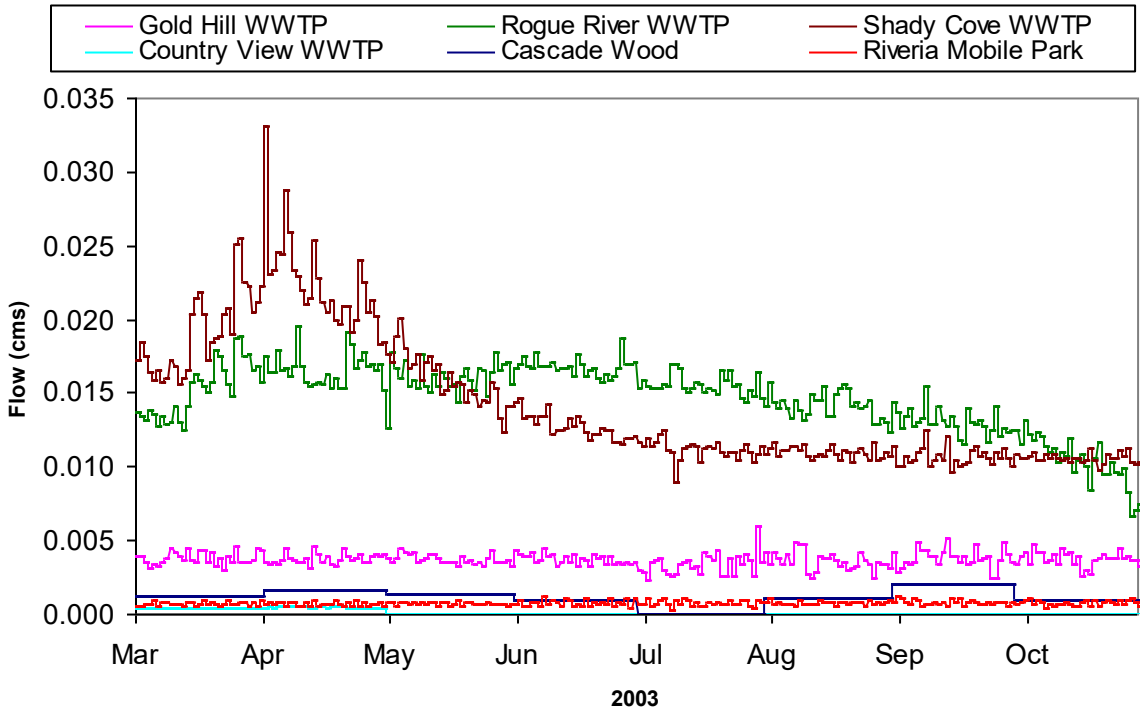


Figure 3-114: Rogue River model: point source flows for the six smaller sources.

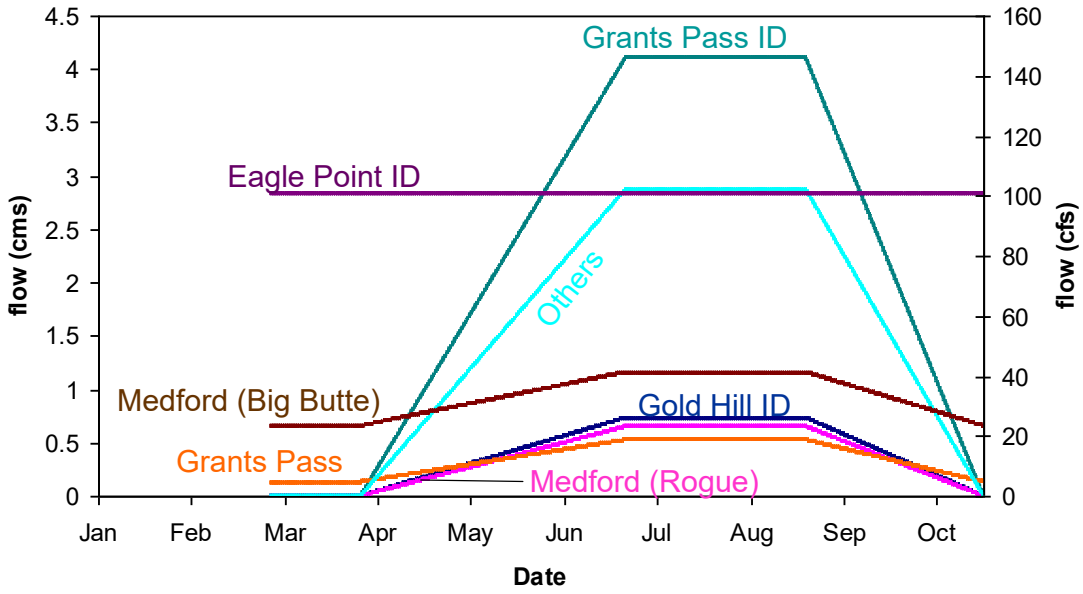


Figure 3-115: Rogue River model: water withdrawals from model reach and Big Butte Creek.

3.11.7 Point source inputs

There are 16 NPDES permitted point sources within the Rogue River model extent that were deemed potential thermal sources that could contribute to Rogue River temperature standard exceedances. These include 11 NPDES Individual permittees, 2 100J General Permit registrants, 2 200J General Permit registrants, and 1 300J General Permit registrant. TSD Sections 7.1.1 and 9.1.6.1 provide details on Individual NPDES permittees, while TSD Sections 7.1.2 and 9.1.6.2 provide details for General Permitees.

Figure 3-116 shows the individual NPDES point source locations on the Rogue River model extent.

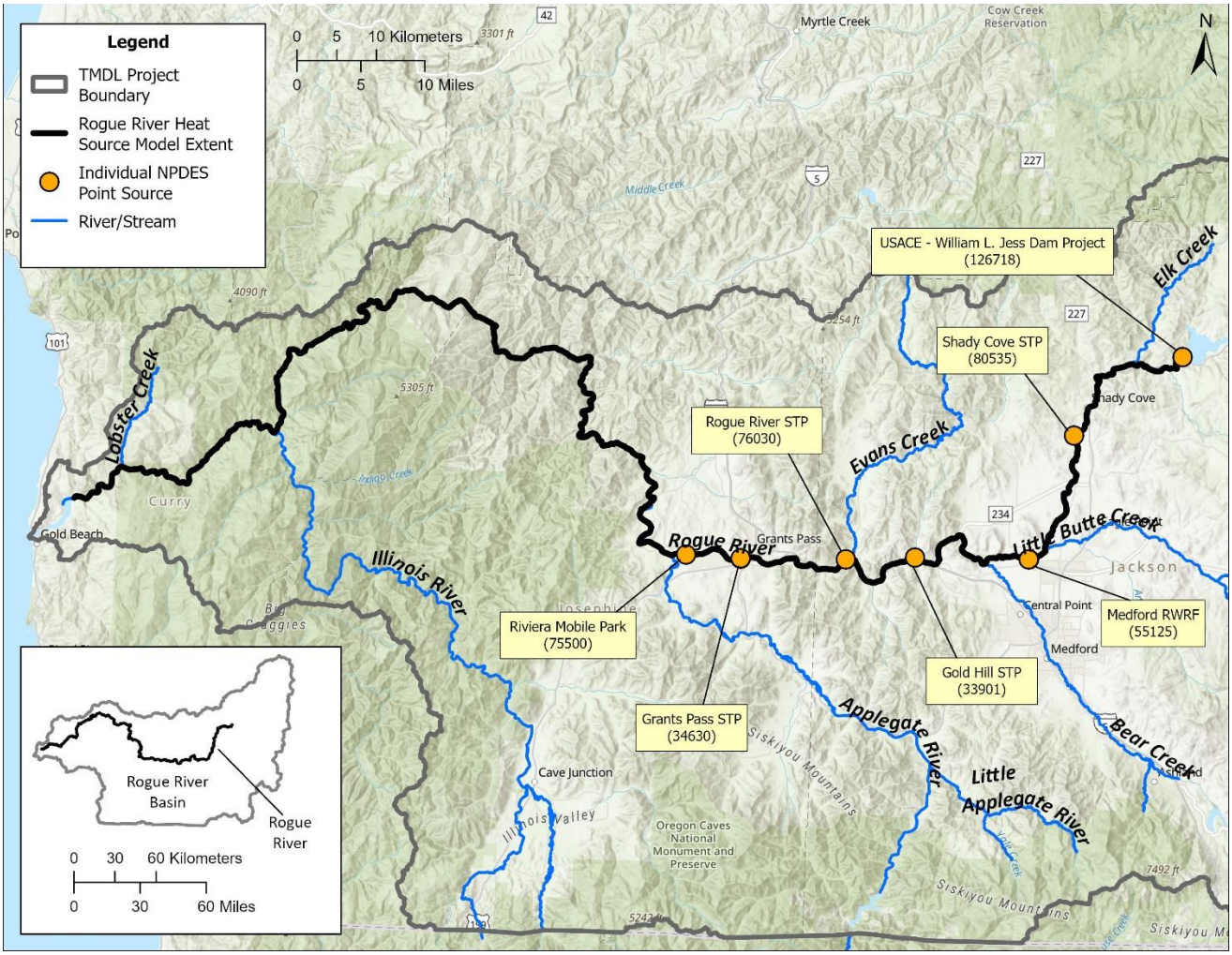


Figure 3-116: Rogue River model: Individual NPDES permittee outfall locations.

3.11.8 Landcover and topographic shade inputs

Topographic and riparian vegetation heights were determined through a GIS analysis (Figure 3-117, Figure 3-118, Figure 3-119). Shade measurements from the middle of the Rogue River were not available to corroborate the shade predicted using the channel and vegetation inputs.

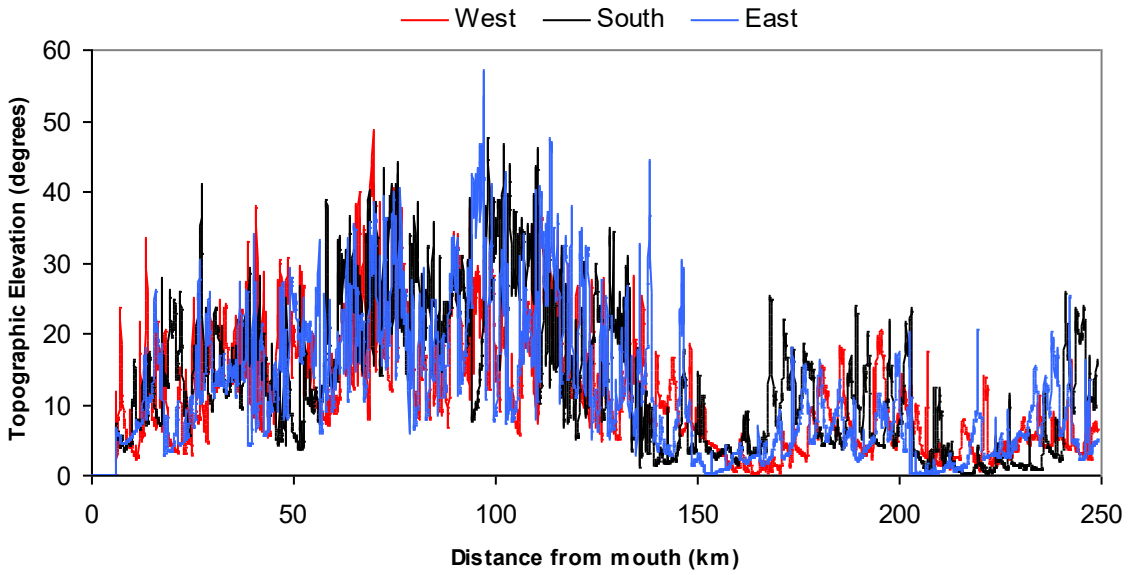


Figure 3-117: Rogue River model setup: topographic shade angle.

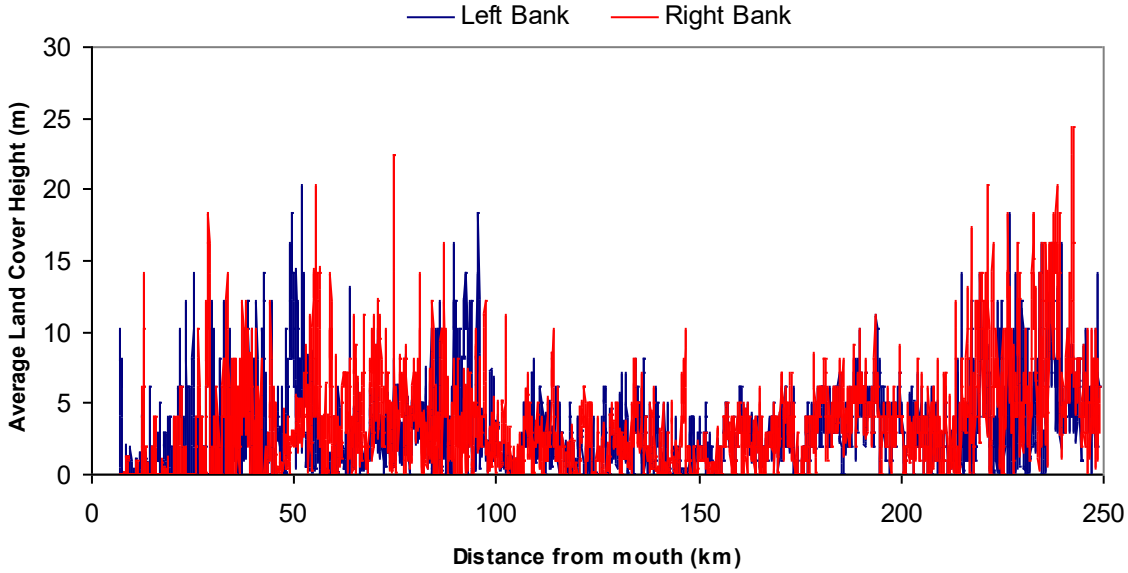


Figure 3-118: Rogue River model setup: streamside vegetation height.

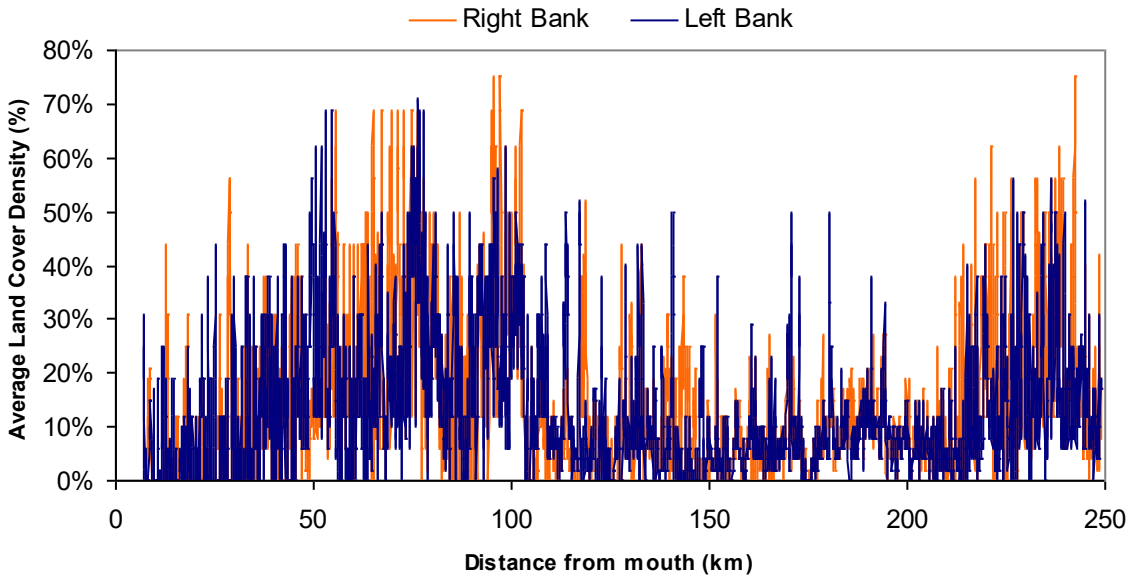


Figure 3-119: Rogue River model setup: streamside vegetation density.

3.11.9 Channel setup

Channel properties were determined using the methodology documented previously in this report (see Section 2.2.3). Figure 3-120 shows the elevation profile and reach gradient. Bottom widths were derived using active channel widths measured from aerial photographs. Bottom widths were estimated by assuming a trapezoidal channel with 3:1 (length:width) side slopes and 100:1 width:depth ratio (Figure 3-121). The width:depth ratio was based on measurements at the USGS gage sites. Non-spatially varying coefficients are presented in Table 3-56.

During calibration, Manning's n was iteratively altered so that the model temperatures approximately reproduced measured temperatures. Since the model does not have the capability to represent dams, Manning's n was increased in each dam's pooled area to represent a hydraulically equivalent reach (Figure 3-122). The temperature profile of Hellgate Canyon area was not initially well-represented using Manning's n literature values. The canyon morphology is controlled by bedrock that forms deep pools. Again, Manning's n was increased to reproduce observed temperatures.

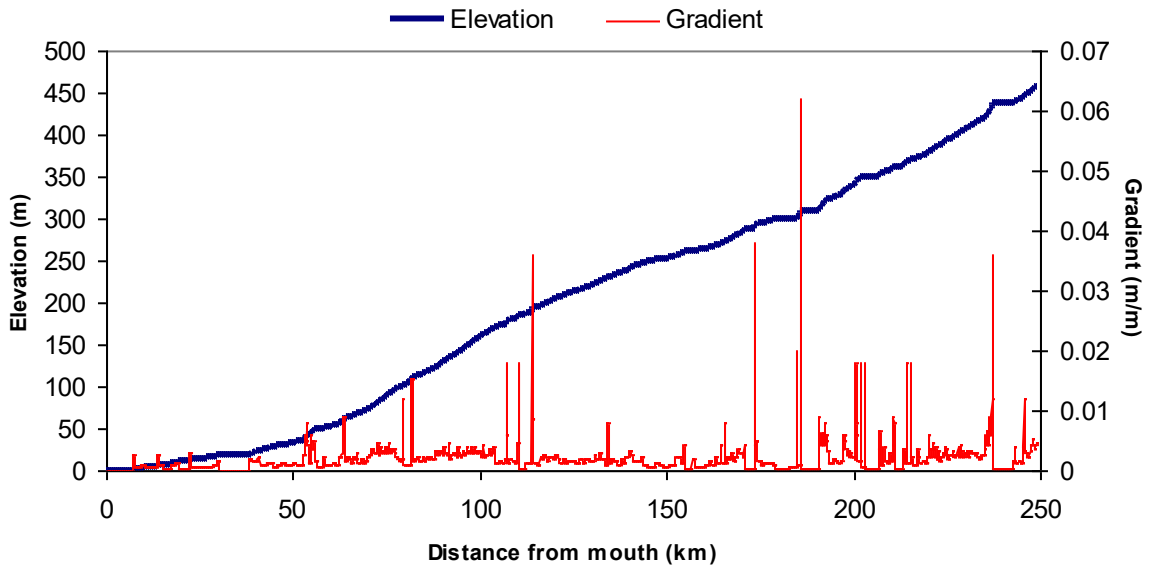


Figure 3-120: Rogue River model setup: channel elevation and gradient.

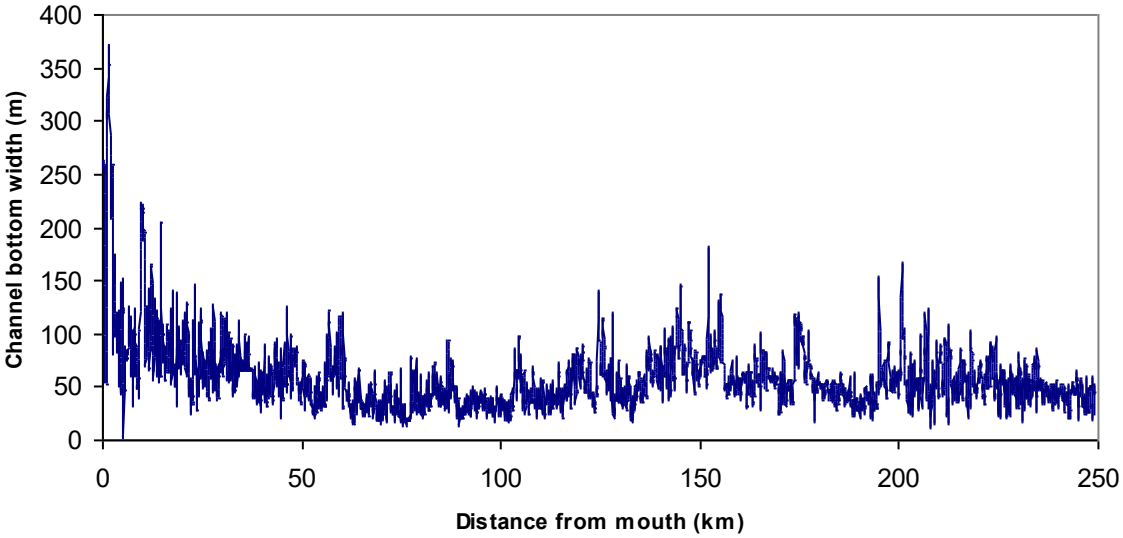


Figure 3-121: Rogue River model setup: channel bottom width.

Table 3-56: Rogue River model coefficients for non-spatially varying parameters.

Parameter name (units)	Value
Wind Function, coefficient a	1.51×10^{-9}
Wind Function, coefficient b	1.60×10^{-9}
Channel angle (ratio of transverse to vertical lengths)	3.0*
Sediment Thermal Conductivity (W/m/°C)	1.57
Sediment Thermal Diffusivity (cm^2/sec)	0.0064
Sediment / hyporheic zone thickness (m)	0.5
Percent Hyporheic Exchange	0%
Porosity	33%

* Except for the reach impacted by Gold Ray dam, where channel angle = 6 to account for volume in side channels and backwaters.

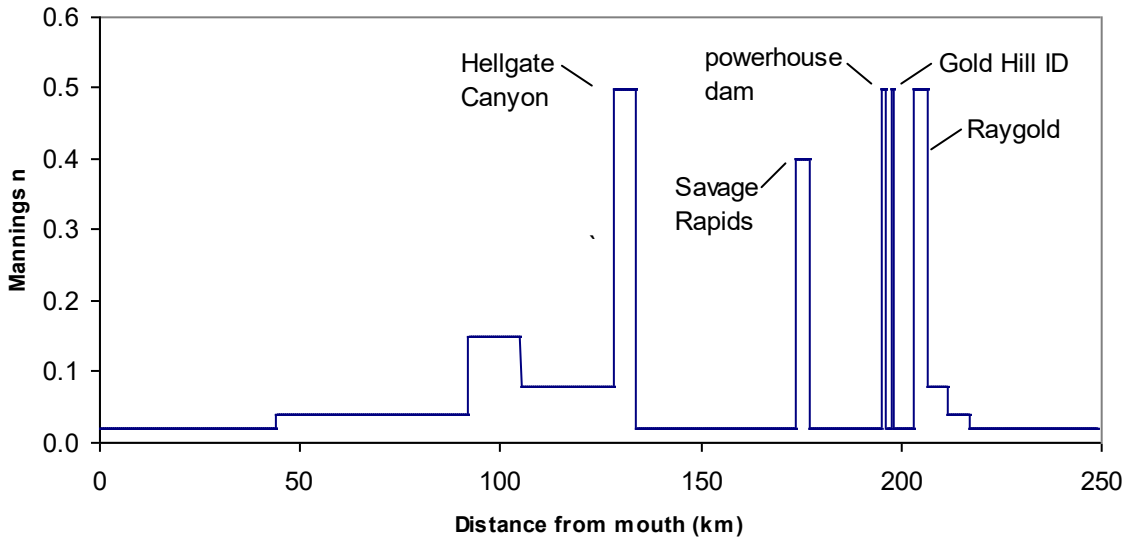


Figure 3-122: Rogue River model setup for roughness coefficient.

3.11.10 Calibration results

3.11.10.1 Flow calibration

The flow-prediction performance of the Rogue River model at several locations is shown in Figure 3-123 through Figure 3-127.

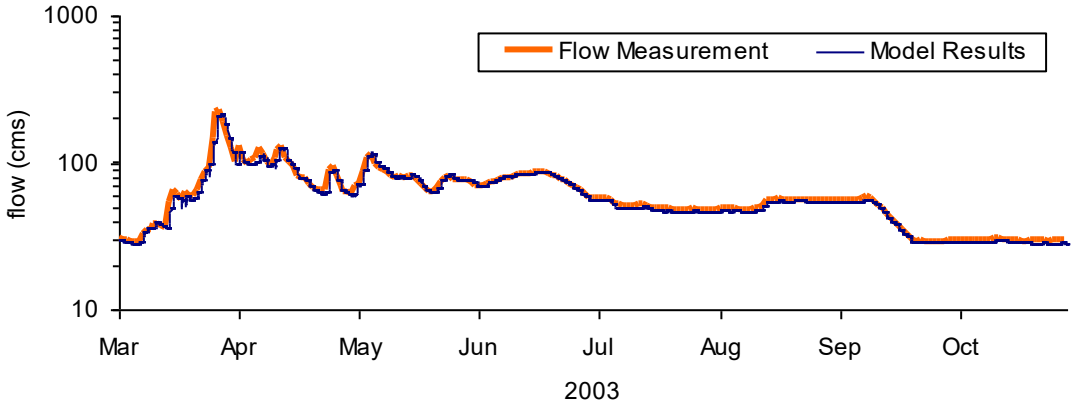


Figure 3-123: Rogue River: modeled vs. measured flows at Dodge Park (USGS #14339000).

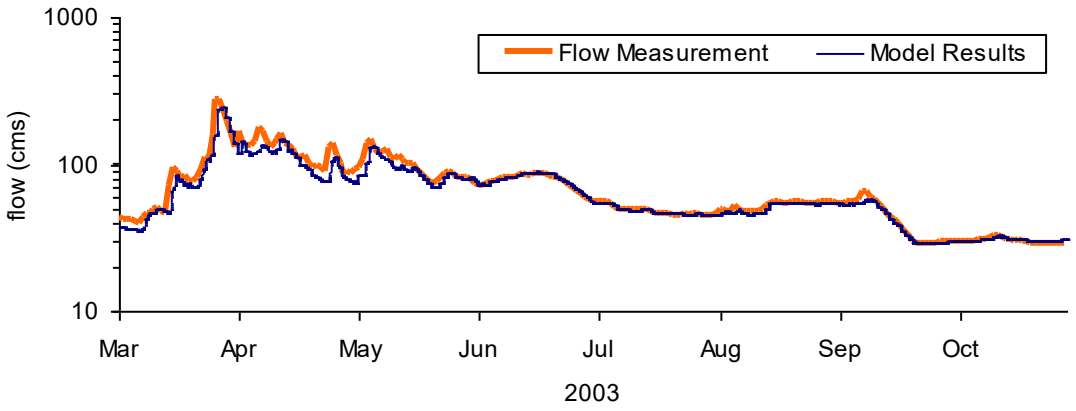


Figure 3-124: Modeled vs. measured flows, Rogue R. at Raygold Dam (DEQ-30195).

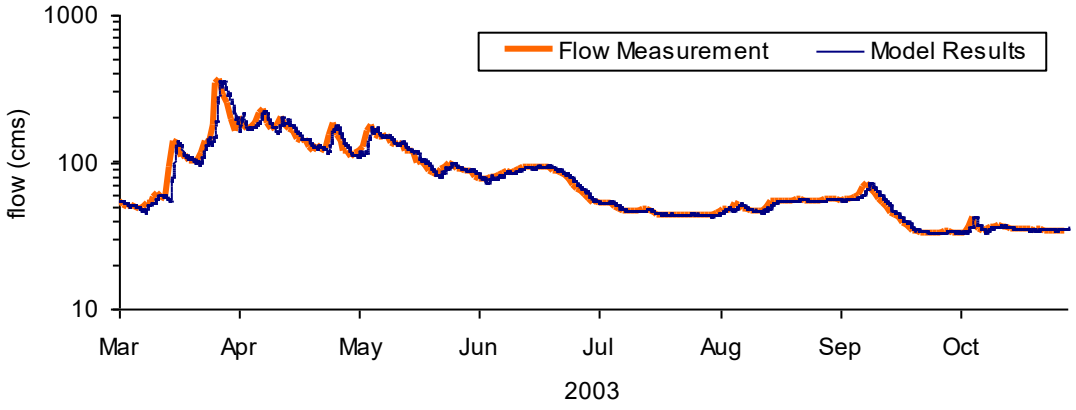


Figure 3-125: Modeled vs. measured flows, Rogue R. at Grants Pass (rkm 164.65).

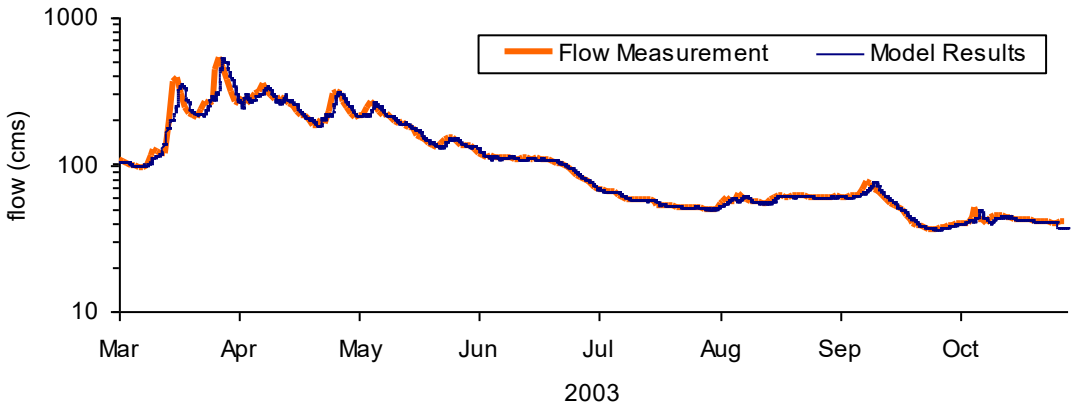


Figure 3-126: Modeled vs. measured flows, Rogue R. at Agness (USGS #14372300).

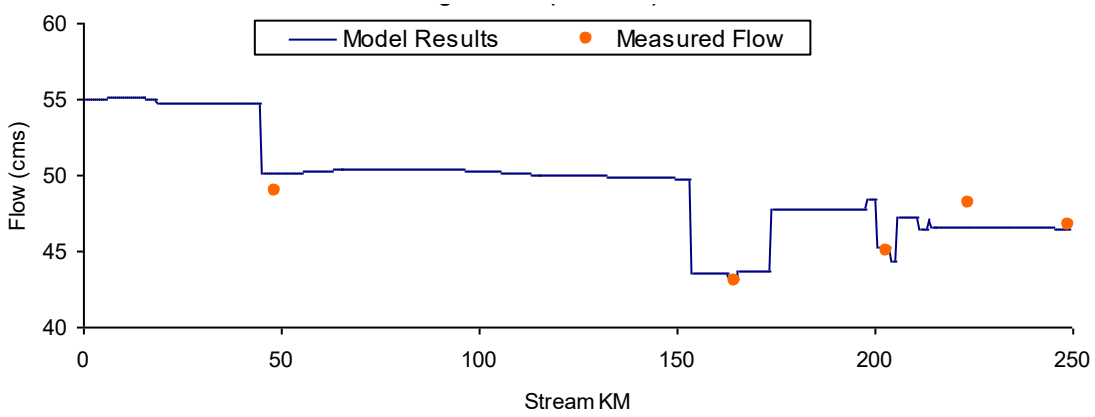


Figure 3-127: Modeled vs. measured flows, Rogue R. model longitudinal extent on 7/31/2003.

3.11.10.2 Temperature Calibration

The model outputs generally reproduced spatially and temporally varying temperature measurements (Table 3-57, Table 3-58, and Figure 3-128 through Figure 3-175). For statistics definitions, see Section 3.1.3.1.

Table 3-57: Rogue R. temperature model goodness-of-fit results. Headwaters not included in averages.

Monitoring location	Model km	Time increment	ME	MAE	RMSE	NSE	n
All Stations, average		Hourly	-0.08	0.63	0.80	0.86	
Rogue R. near McLeod (headwaters) (14337600)	248.9	Hourly	0.00	0.00	0.00	1.00	5874
Rogue R. @ Shady Cove Park (DEQ-30517)	235.6	Hourly	-0.02	0.25	0.32	0.96	3166
Rogue R. @ Dodge Bridge (14339000)	223.9	Hourly	-0.16	0.55	0.70	0.95	5829
Rogue R. @ Dodge Park (DEQ-10423)	223.8	Hourly	-0.24	0.60	0.75	0.88	3069
Rogue R. u/s Medford WWTP	211.0	Hourly	-0.45	0.76	0.96	0.91	4581
Rogue R. d/s of Medford WWTP (DEQ-30317)	208.5	Hourly	-0.35	0.61	0.78	0.95	5879
Rogue R. @ Raygold (14359000)	202.7	Hourly	-0.23	0.57	0.71	0.94	5830
Rogue R. @ d/s Gold Ray Dam (DEQ-30195)	202.6	Hourly	-0.51	0.93	1.21	0.81	2122
Rogue R. @ Highway 234 (DEQ-10421)	189.2	Hourly	-0.26	0.83	1.02	0.82	3140
Rogue R. @ Valley of the Rogue (DEQ-10600)	182.8	Hourly	-0.22	0.72	0.89	0.88	3266
Rogue R. @ Robertson Bridge (DEQ-10418)	140.1	Hourly	-0.52	0.67	0.83	0.92	2531
Rogue R. d/s of Galice Cr. (DEQ-30211)	126.9	Hourly	-0.34	0.74	0.96	0.90	2458
Rogue R. d/s of Graves Cr. (DEQ-10417)	110.5	Hourly	-0.23	0.67	0.83	0.92	3352
Rogue R. d/s of Whiskey Cr. (DEQ-30570)	105.7	Hourly	0.44	0.65	0.85	0.82	1822
Rogue R. d/s of Meadow Cr. (DEQ-30641)	92.0	Hourly	0.17	0.60	0.77	0.86	1823
Rogue R. d/s of East Cr. (DEQ-30647)	68.2	Hourly	0.29	0.63	0.77	0.86	1824
Rogue R. d/s of Fall Cr. (DEQ-30646)	61.5	Hourly	0.14	0.53	0.67	0.90	1822
Rogue R. near Agness (14372300)	48.7	Hourly	-0.08	0.58	0.72	0.98	5880
Rogue R. d/s Shasta Costa Cr. (DEQ-30654	47.4	Hourly	0.29	0.57	0.73	0.92	2111
Rogue R. u/s of Illinois R. (DEQ-10416)	44.9	Hourly	0.07	0.53	0.68	0.94	2111
Rogue R. d/s of Illinois R. (DEQ-10415)	44.5	Hourly	-0.01	0.54	0.68	0.93	2111
Rogue R. u/s of Lobster Cr. (DEQ-10414)	18.7	Hourly	0.00	0.77	0.93	0.86	2110
Rogue R. @ Huntley Park (DEQ-10413)	14.3	Hourly	0.54	0.67	0.78	0.09	169
TIR	Model extent		-0.11	0.50	0.63	0.97	

Table 3-58: Rogue R. temperature model goodness-of-fit results, Jul-Aug. Headwaters not averaged.

Monitoring location	Model km	Time increment	ME	MAE	RMSE	NSE	n
All Stations, average		Daily max.	0.01	0.55	0.68		
All Stations, average		Hourly	-0.17	0.65	0.81	0.50	
Rogue R. near McLeod (headwaters) (14337600)	248.9	Daily max.	0.00	0.00	0.00		62
Rogue R. @ Shady Cove Park (DEQ-30517)	235.6	Daily max.	0.00	0.21	0.33		62
Rogue R. @ Dodge Bridge (14339000)	223.9	Daily max.	-0.38	0.55	0.70		62
Rogue R. @ Dodge Park (DEQ-10423)	223.8	Daily max.	-0.19	0.43	0.64		62
Rogue R. u/s Medford WWTP	211.0	Daily max.	-0.18	0.39	0.50		26
Rogue R. d/s of Medford WWTP (DEQ-30317)	208.5	Daily max.	-0.04	0.33	0.51		62
Rogue R. @ Raygold (14359000)	202.7	Daily max.	0.06	0.28	0.39		62
Rogue R. @ d/s Gold Ray Dam (DEQ-30195)	202.6	Daily max.	-1.31	1.31	1.38		42
Rogue R. @ Highway 234 (DEQ-10421)	189.2	Daily max.	0.37	0.44	0.56		58
Rogue R. @ Valley of the Rogue (DEQ-10600)	182.8	Daily max.	0.30	0.46	0.65		54
Rogue R. @ Robertson Bridge (DEQ-10418)	140.1	Daily max.	-0.43	0.50	0.61		41
Rogue R. d/s of Galice Cr. (DEQ-30211)	126.9	Daily max.	-0.23	0.47	0.60		41
Rogue R. d/s of Graves Cr. (DEQ-10417)	110.5	Daily max.	0.19	0.45	0.57		62
Rogue R. d/s of Whiskey Cr. (DEQ-30570)	105.7	Daily max.	0.84	0.86	0.98		54
Rogue R. d/s of Meadow Cr. (DEQ-30641)	92.0	Daily max.	0.44	0.46	0.60		53
Rogue R. d/s of East Cr. (DEQ-30647)	68.2	Daily max.	0.50	0.55	0.69		52
Rogue R. d/s of Fall Cr. (DEQ-30646)	61.5	Daily max.	0.27	0.38	0.50		52
Rogue R. near Agness (14372300)	48.7	Daily max.	-0.58	0.69	0.77		62
Rogue R. d/s Shasta Costa Cr. (DEQ-30654)	47.4	Daily max.	-0.09	0.52	0.67		46
Rogue R. u/s of Illinois R. (DEQ-10416)	44.9	Daily max.	-0.34	0.57	0.67		46
Rogue R. d/s of Illinois R. (DEQ-10415)	44.5	Daily max.	-0.23	0.57	0.70		46
Rogue R. u/s of Lobster Cr. (DEQ-10414)	18.7	Daily max.	0.61	0.83	0.99		46
Rogue R. @ Huntley Park (DEQ-10413)	14.3	Daily max.	0.72	0.72	0.90		8
Rogue R. near McLeod (headwaters) (14337600)	248.9	Hourly	0.00	0.00	0.00	1.00	1488
Rogue R. @ Shady Cove Park (DEQ-30517)	235.6	Hourly	-0.11	0.30	0.37	0.94	1488
Rogue R. @ Dodge Bridge (14339000)	223.9	Hourly	-0.45	0.75	0.90	0.79	1475
Rogue R. @ Dodge Park (DEQ-10423)	223.8	Hourly	-0.36	0.76	0.91	0.79	1488
Rogue R. u/s Medford WWTP	211.0	Hourly	-0.90	1.15	1.35	0.43	609
Rogue R. d/s of Medford WWTP (DEQ-30317)	208.5	Hourly	-0.75	0.88	1.07	0.68	1488
Rogue R. @ Raygold (14359000)	202.7	Hourly	-0.19	0.55	0.70	0.38	1488
Rogue R. @ d/s Gold Ray Dam (DEQ-30195)	202.6	Hourly	-0.79	1.26	1.54	-0.78	994
Rogue R. @ Highway 234 (DEQ-10421)	189.2	Hourly	-0.31	0.76	0.94	-0.88	1370
Rogue R. @ Valley of the Rogue (DEQ-10600)	182.8	Hourly	-0.26	0.60	0.77	0.45	1275
Rogue R. @ Robertson Bridge (DEQ-10418)	140.1	Hourly	-0.46	0.65	0.84	0.75	971
Rogue R. d/s of Galice Cr. (DEQ-30211)	126.9	Hourly	-0.39	0.61	0.77	0.56	976
Rogue R. d/s of Graves Cr. (DEQ-10417)	110.5	Hourly	-0.24	0.56	0.69	0.64	1488
Rogue R. d/s of Whiskey Cr. (DEQ-30570)	105.7	Hourly	0.29	0.55	0.71	0.61	1281
Rogue R. d/s of Meadow Cr. (DEQ-30641)	92.0	Hourly	0.00	0.53	0.66	0.71	1260
Rogue R. d/s of East Cr. (DEQ-30647)	68.2	Hourly	0.15	0.57	0.70	0.55	1237
Rogue R. d/s of Fall Cr. (DEQ-30646)	61.5	Hourly	-0.01	0.46	0.59	0.72	1234
Rogue R. near Agness (14372300)	48.7	Hourly	-0.01	0.49	0.61	0.82	1488
Rogue R. d/s Shasta Costa Cr. (DEQ-30654	47.4	Hourly	0.28	0.53	0.67	0.75	1094
Rogue R. u/s of Illinois R. (DEQ-10416)	44.9	Hourly	-0.01	0.46	0.59	0.83	1093
Rogue R. d/s of Illinois R. (DEQ-10415)	44.5	Hourly	0.02	0.50	0.63	0.81	1093
Rogue R. u/s of Lobster Cr. (DEQ-10414)	18.7	Hourly	0.15	0.78	0.94	0.31	1091
Rogue R. @ Huntley Park (DEQ-10413)	14.3	Hourly	0.54	0.67	0.78	0.09	169
TIR	Model extent		-0.11	0.50	0.63	0.97	

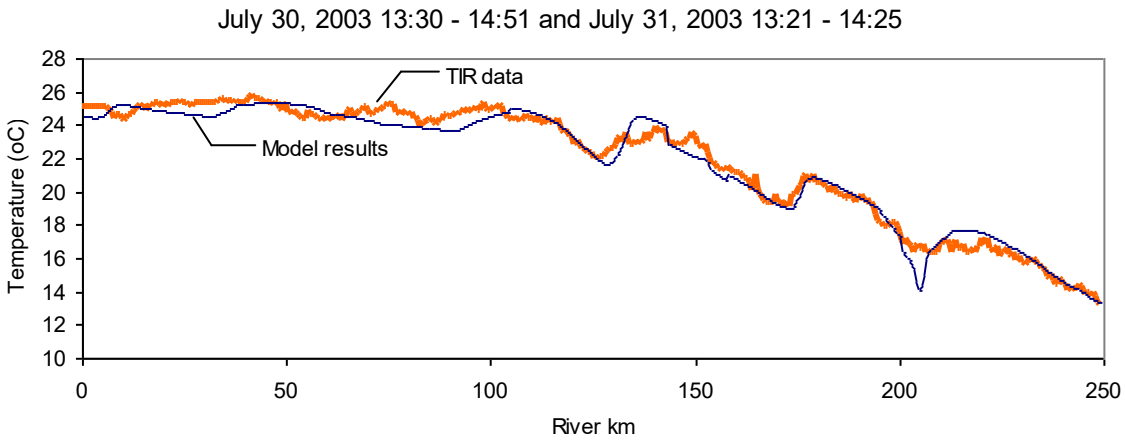


Figure 3-128: Rogue River temperatures: Longitudinal profile of model results vs. TIR measurements.

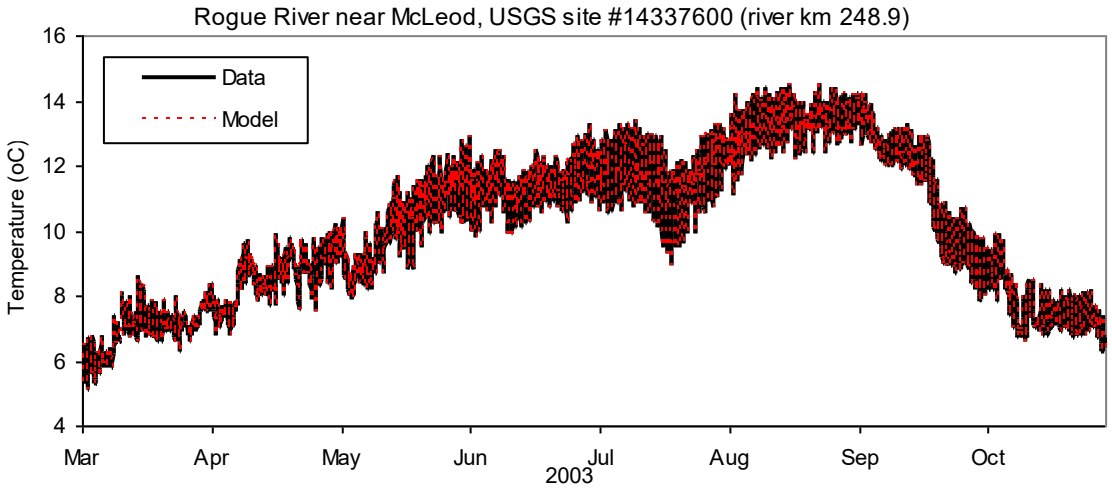


Figure 3-129: Rogue River temperatures: Measured vs. modeled, entire model period near McLeod (USGS #14337600).

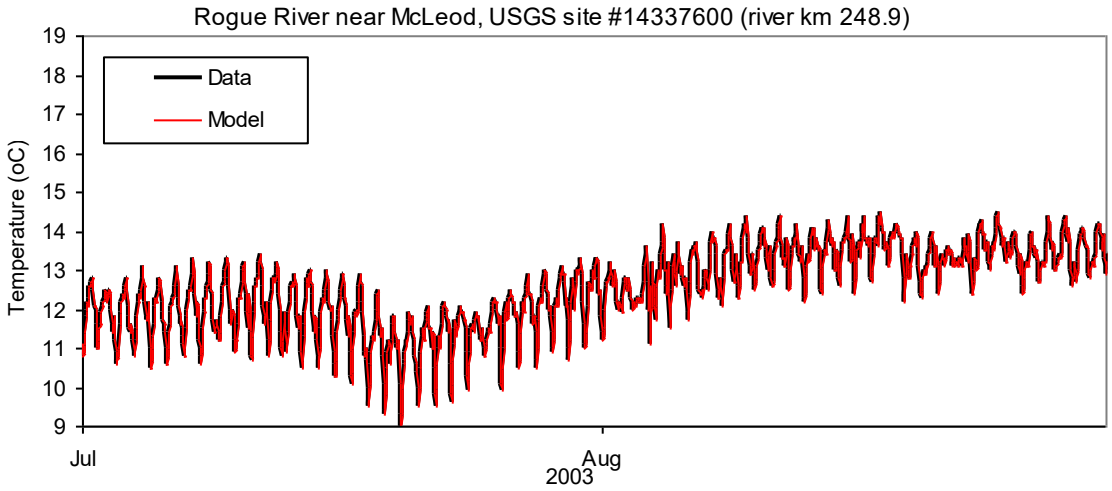


Figure 3-130: Rogue River temperatures Measured vs. modeled, Jul-Aug critical season near McLeod (USGS #14337600).

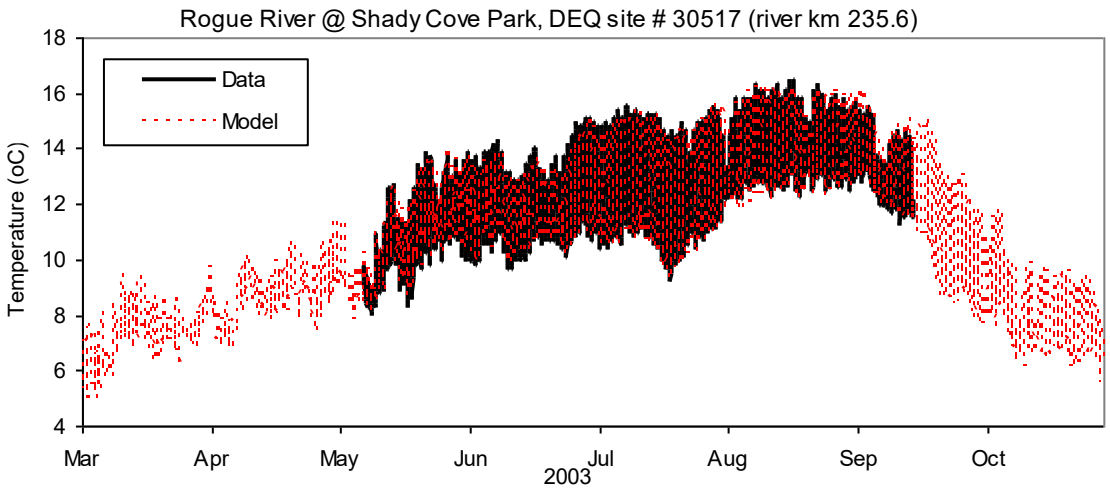


Figure 3-131: Rogue River temperatures: measured vs. modeled, entire model period, Shady Cove Park (DEQ-30517).

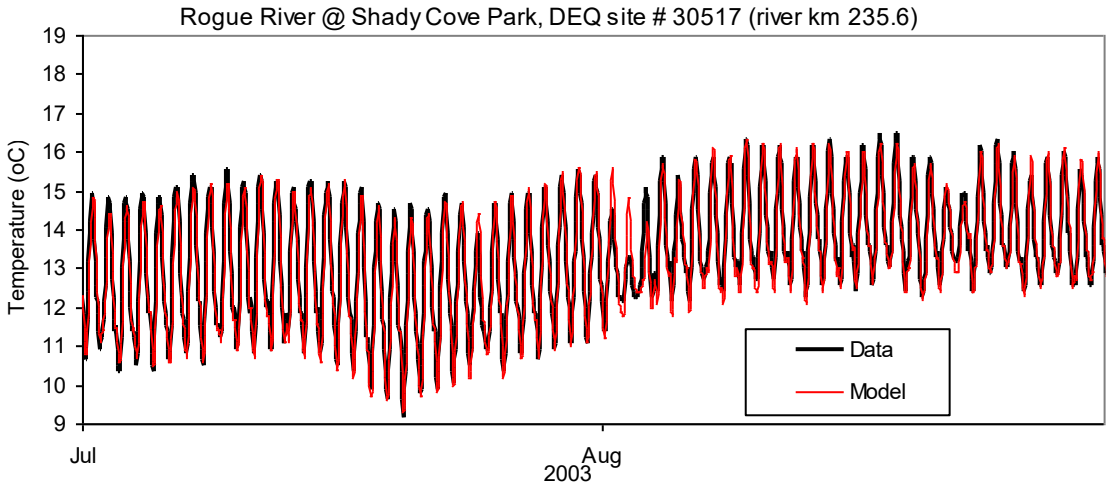


Figure 3-132: Rogue River temperatures: Measured vs. modeled, Jul-Aug critical season, Shady Cove Park (DEQ-30517).

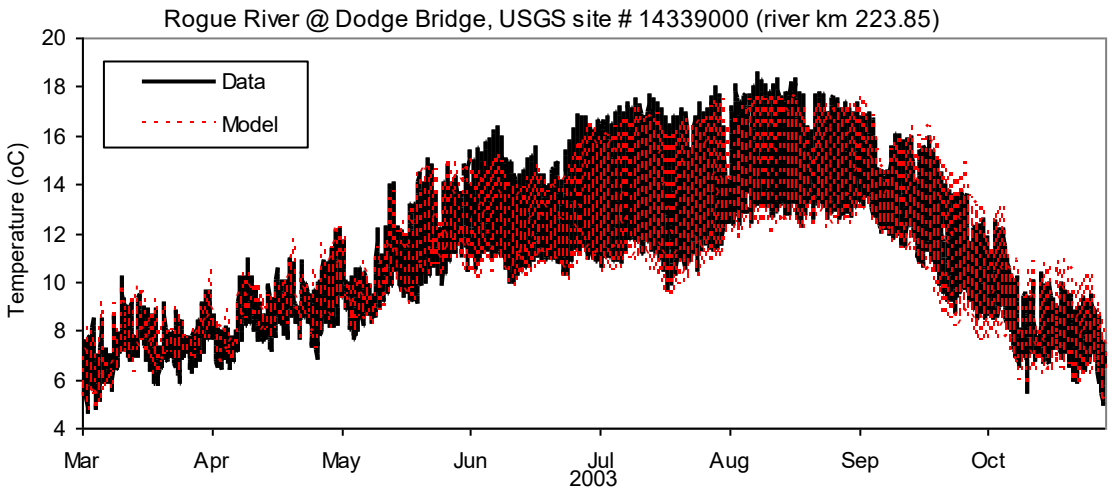


Figure 3-133: Rogue River temperatures: Measured vs. modeled, entire model period, Dodge Bridge (USGS #14339000).

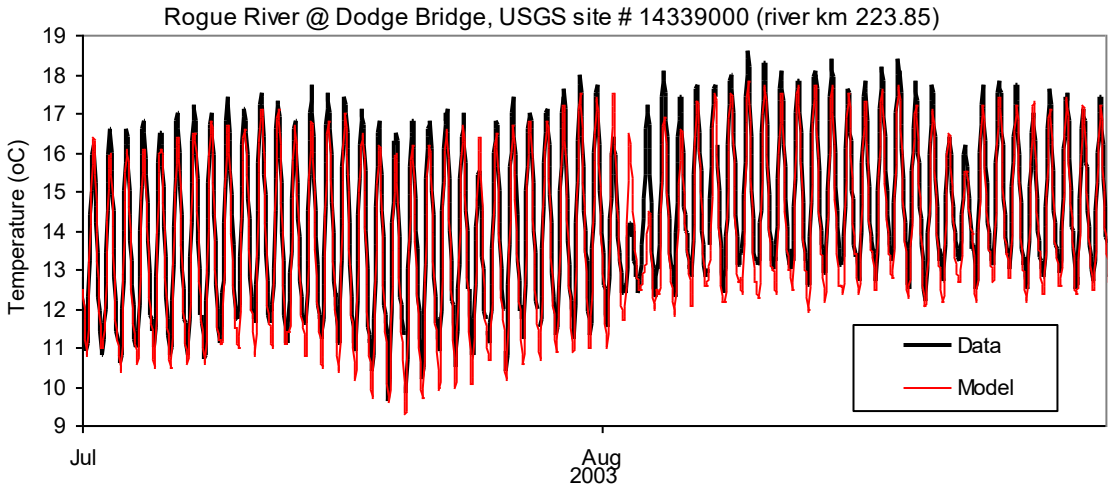


Figure 3-134: Rogue River temperatures: Measured vs. modeled, Jul-Aug critical season, Dodge Bridge (USGS #14339000).

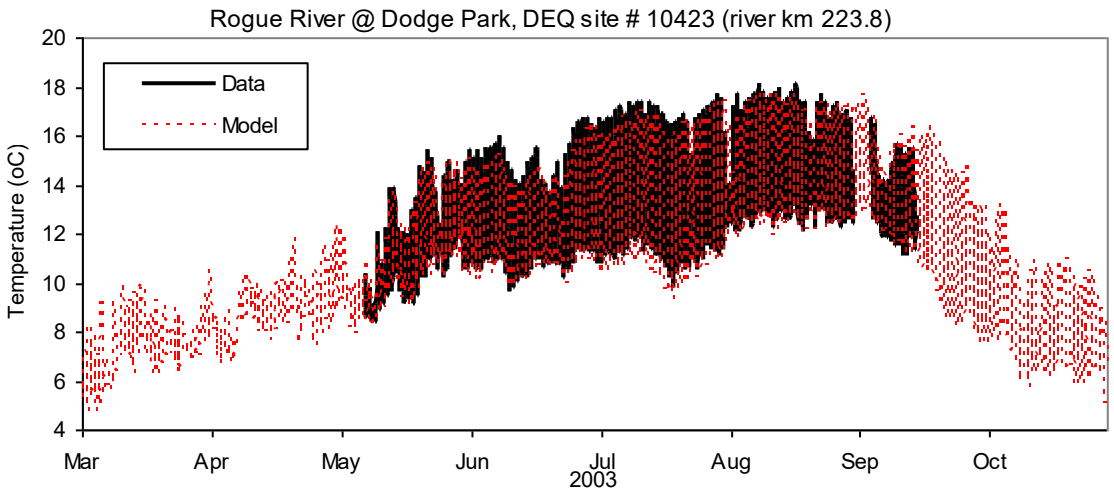


Figure 3-135: Rogue River temperatures: Measured vs. modeled, entire model period, Dodge Park (DEQ-10423).

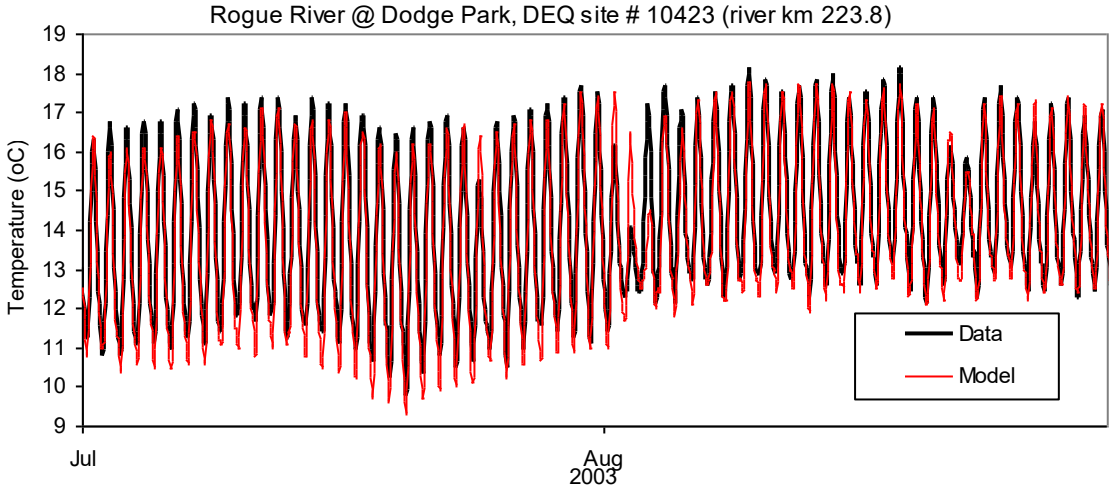


Figure 3-136: Rogue River temperatures: Measured vs. modeled, Jul-Aug critical season, Dodge Park (DEQ-10423).

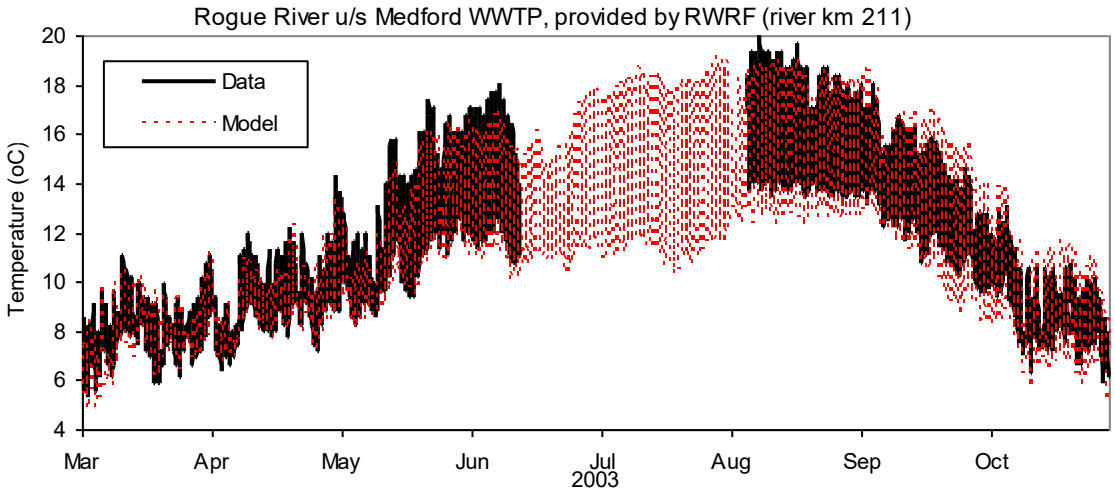


Figure 3-137: Rogue River temperatures: measured vs. modeled, entire model period u/s of Medford RWRF.

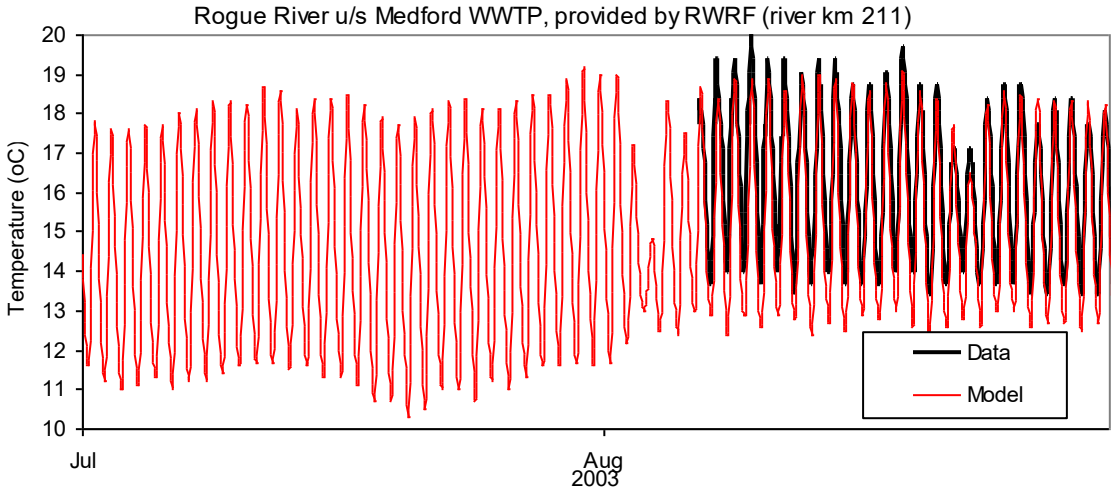


Figure 3-138: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season u/s of Medford RWRF.

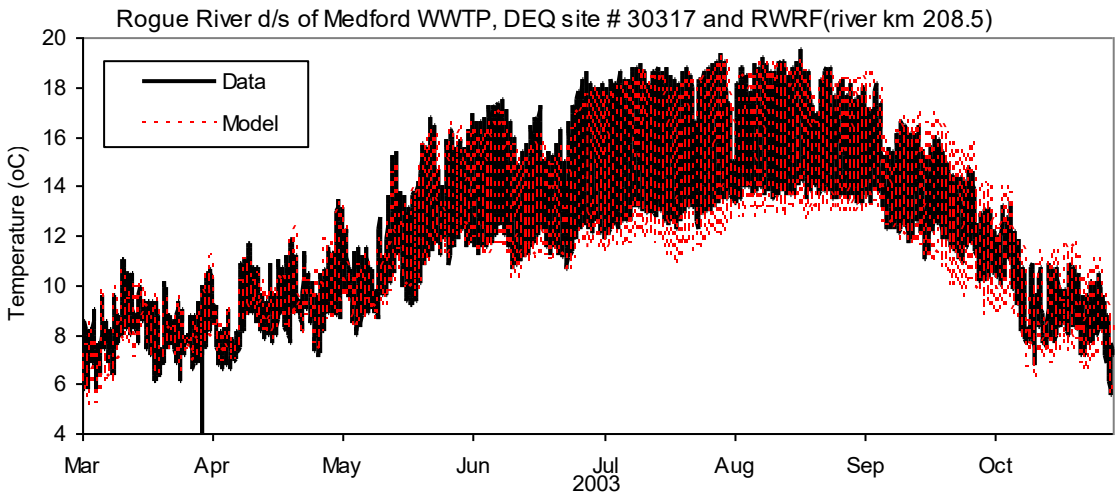


Figure 3-139: Rogue River temperatures: measured vs. modeled, entire model period d/s of Medford RWRF (DEQ-30317).

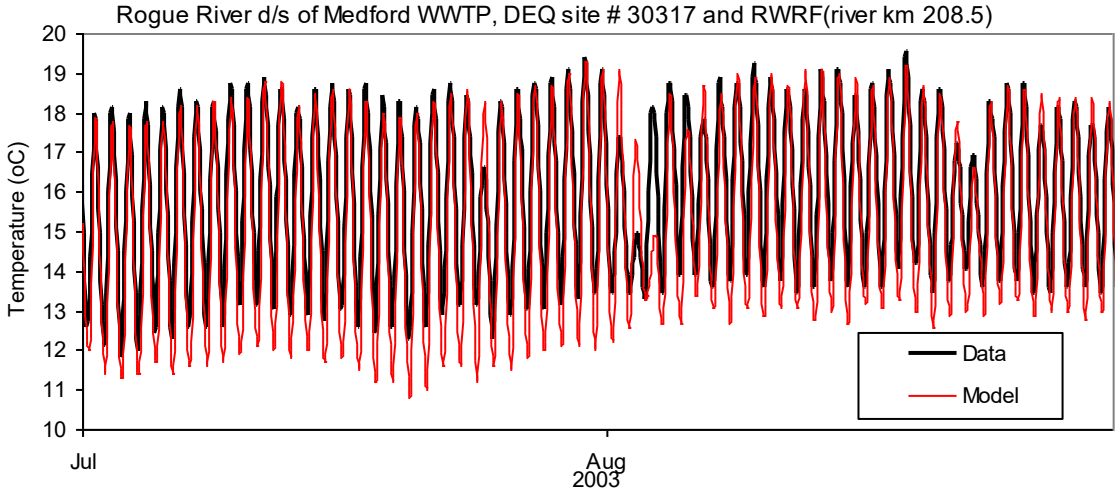


Figure 3-140: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of Medford RWRF (DEQ-30317).

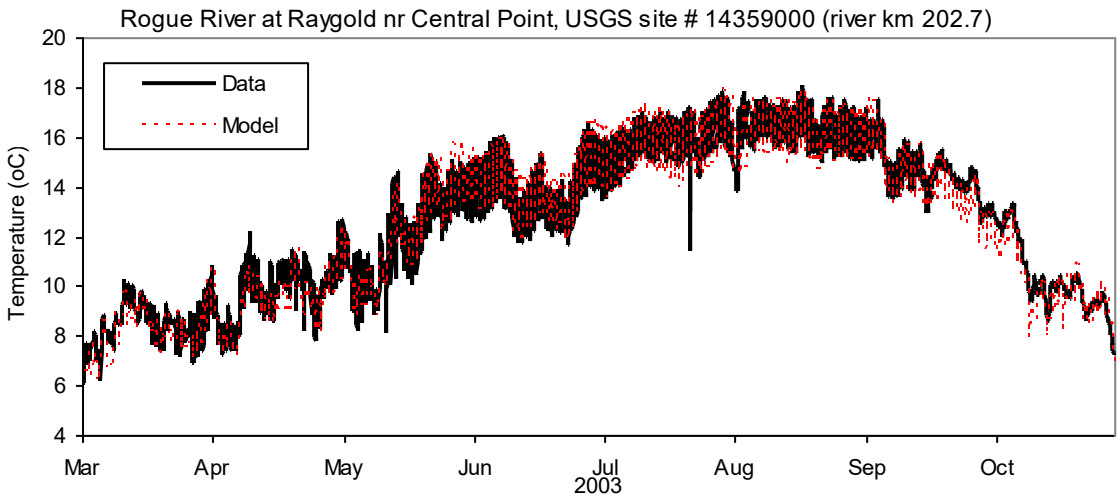


Figure 3-141: Rogue River temperatures: measured vs. modeled, entire model period, Raygold Dam (USGS #14359000).

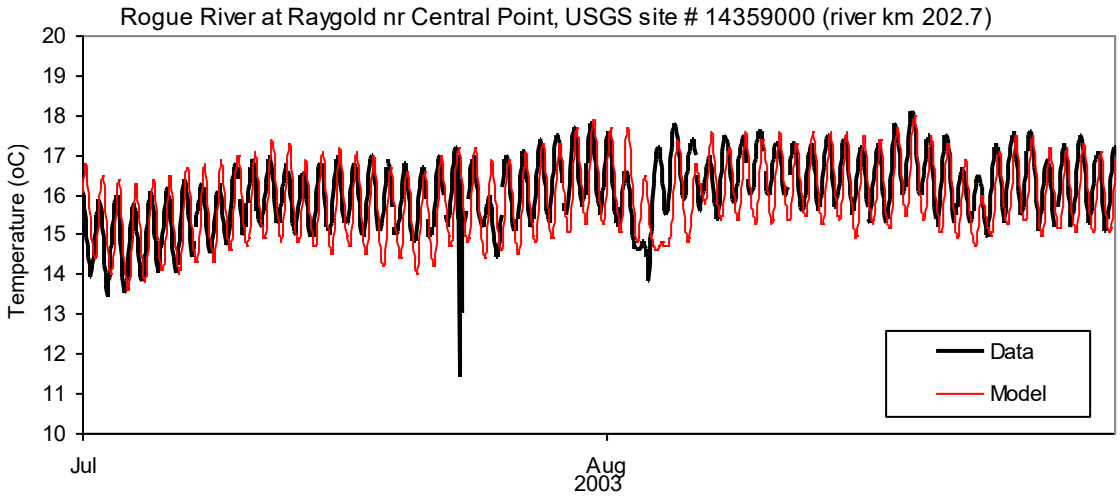


Figure 3-142: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season, Raygold Dam (USGS #14359000).

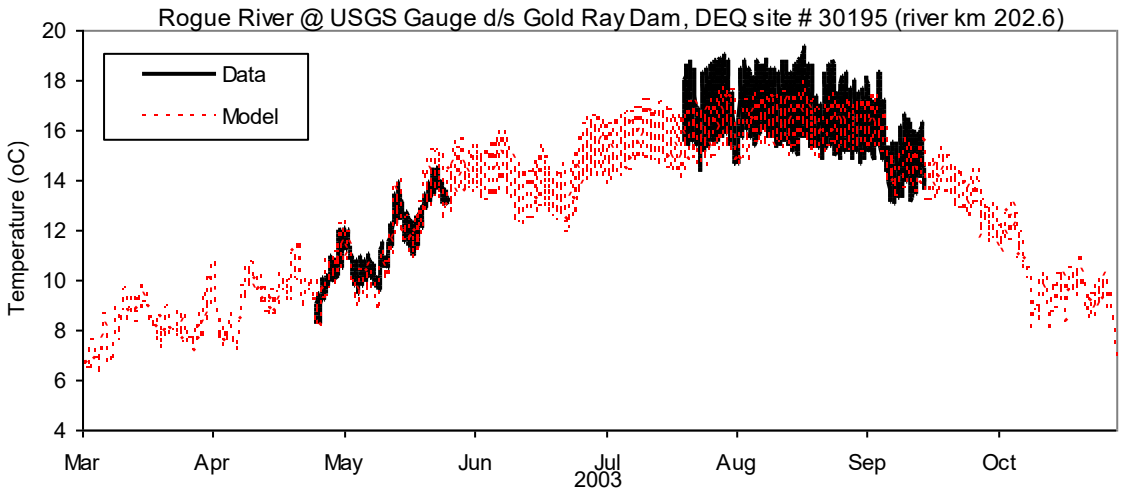


Figure 3-143: Rogue River temperatures: measured vs. modeled, entire model period d/s of Raygold Dam (DEQ-30195).

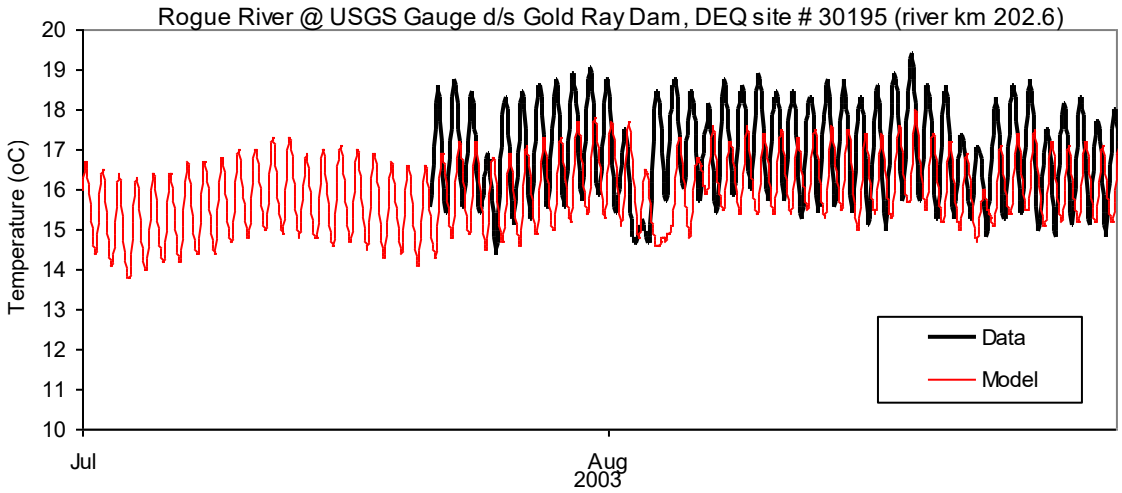


Figure 3-144: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of Raygold Dam (DEQ-30195).

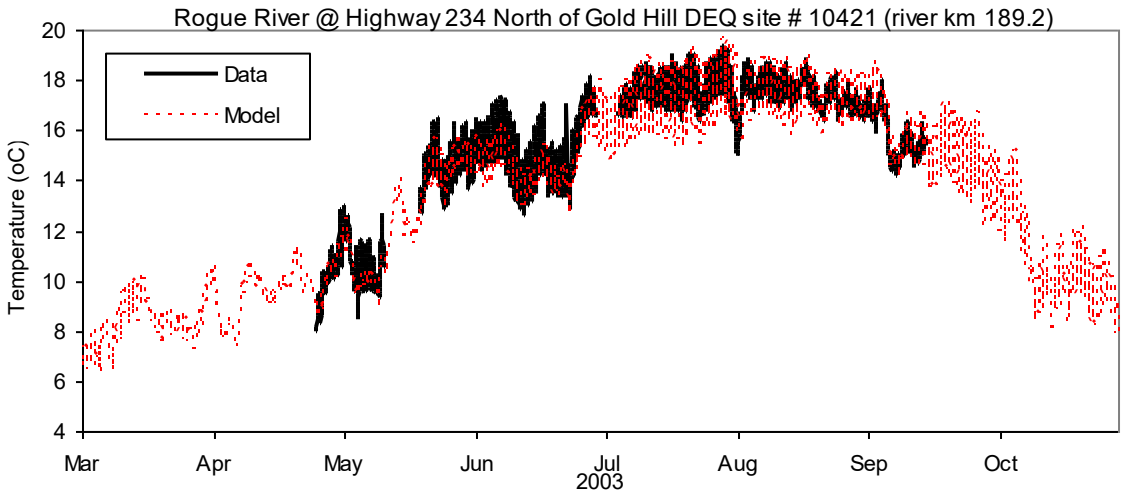


Figure 3-145: Rogue River temperatures: measured vs. modeled, entire model period at Highway 234 (DEQ-10421).

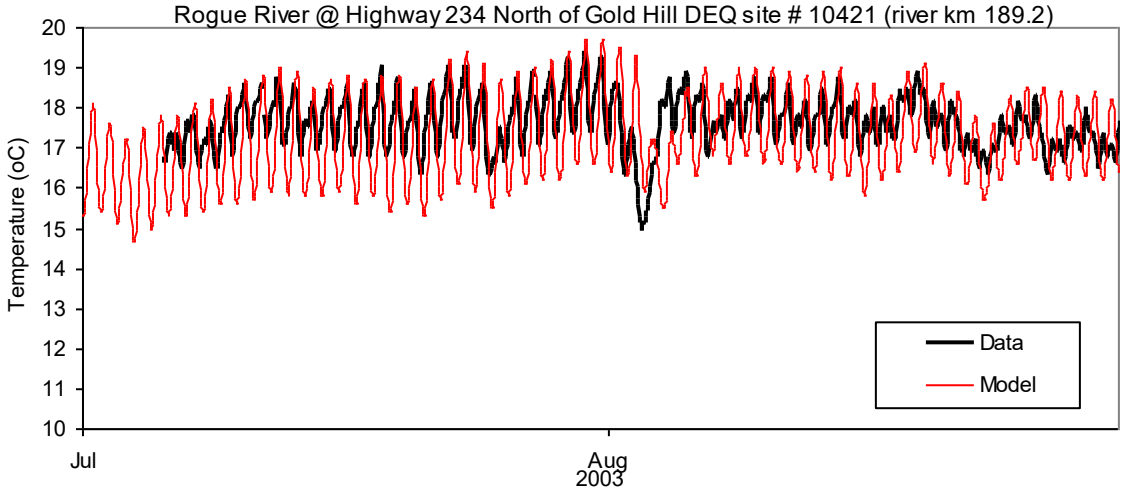


Figure 3-146: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season, Hwy 234 (DEQ-10421).

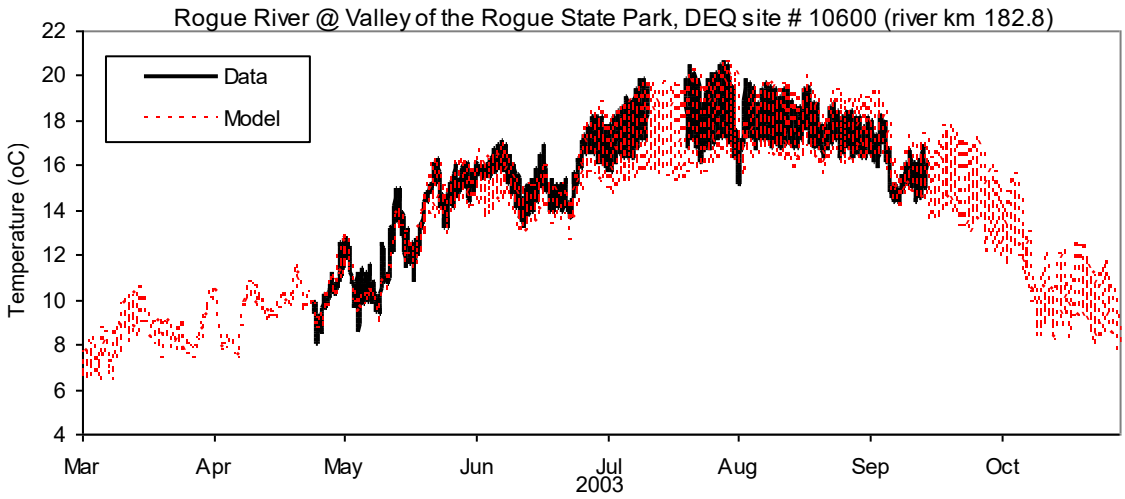


Figure 3-147: Rogue River temperatures: measured vs. modeled, entire model period, Valley of the Rogue (DEQ-10600).

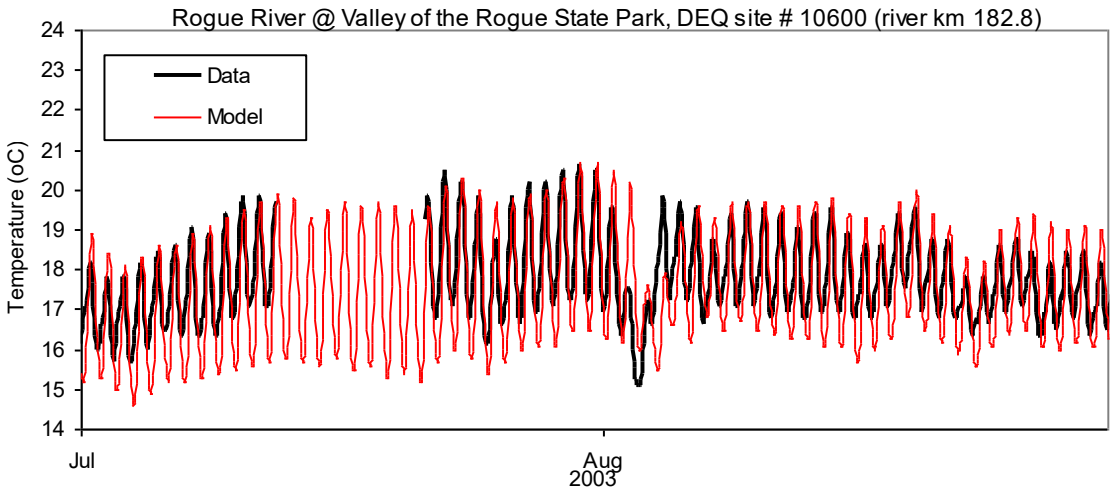


Figure 3-148: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season, Valley of the Rogue (DEQ-10600).

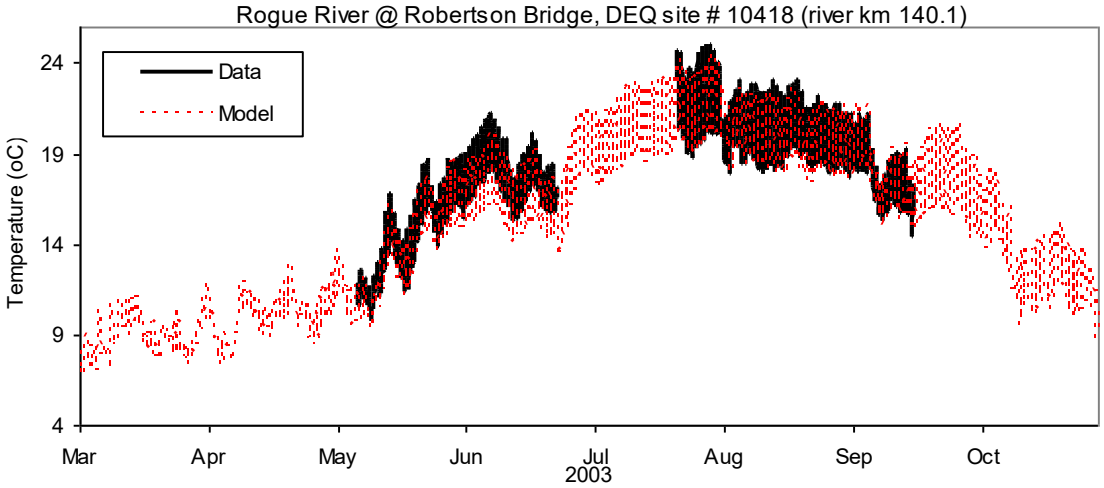


Figure 3-149: Rogue River temperatures: measured vs. modeled, entire model period, Robertson Bridge (DEQ-10418).

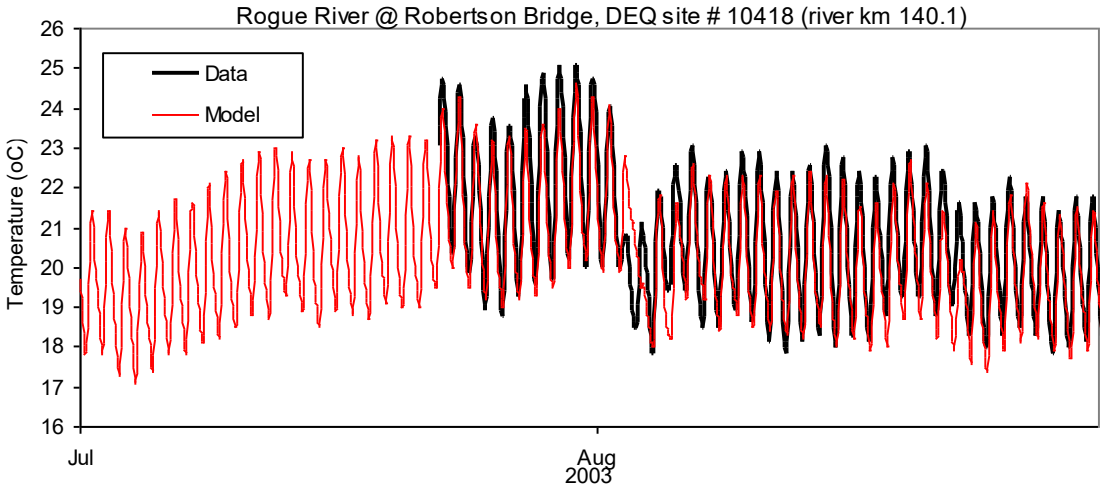


Figure 3-150: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season, Robertson Bridge (DEQ-10418).

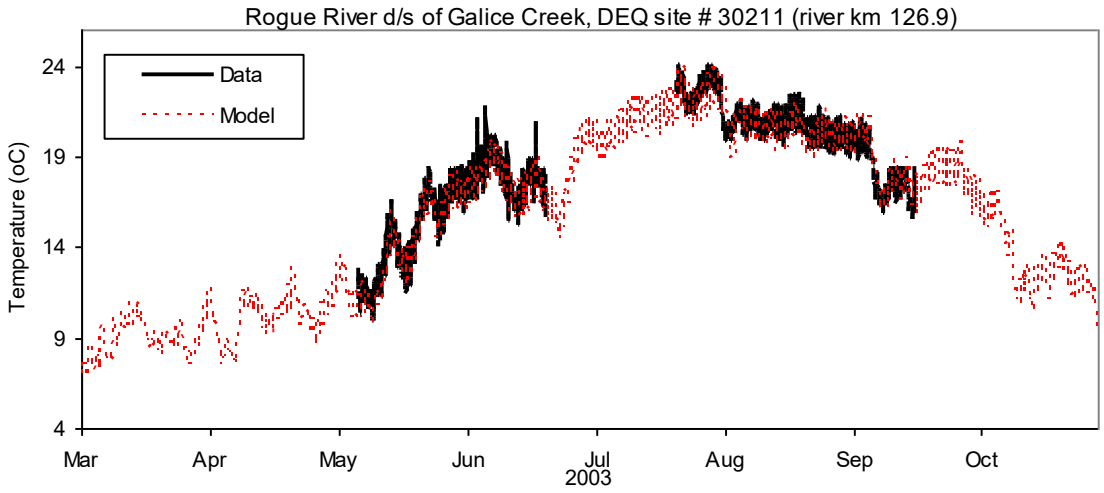


Figure 3-151: Rogue River temperatures: measured vs. modeled, entire model period d/s of Galice Cr. (DEQ-30211).

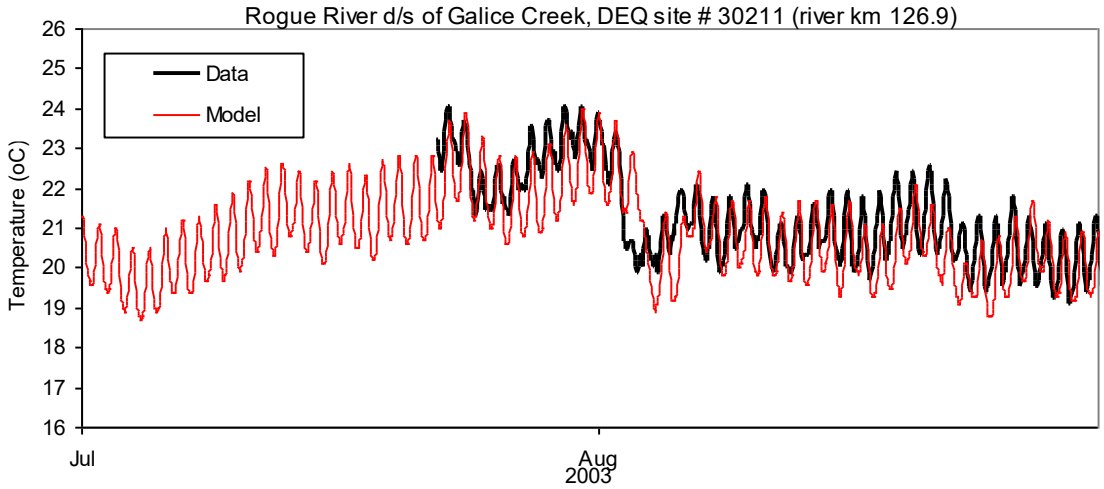


Figure 3-152: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of Galice Cr. (DEQ-30211).

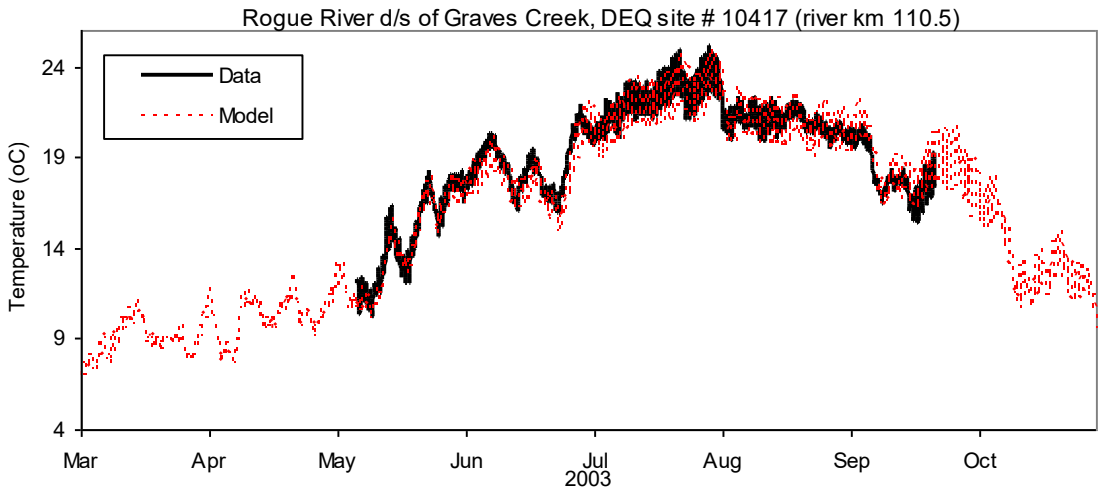


Figure 3-153: Rogue River temperatures: measured vs. modeled, entire model period d/s of Graves Cr. (DEQ-10417).

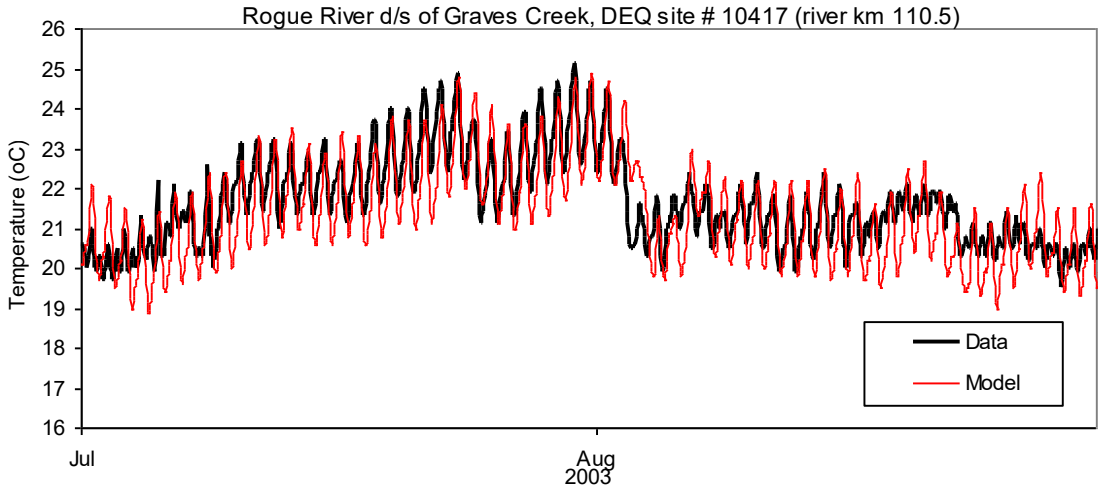


Figure 3-154: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of Graves Cr. (DEQ-10417).

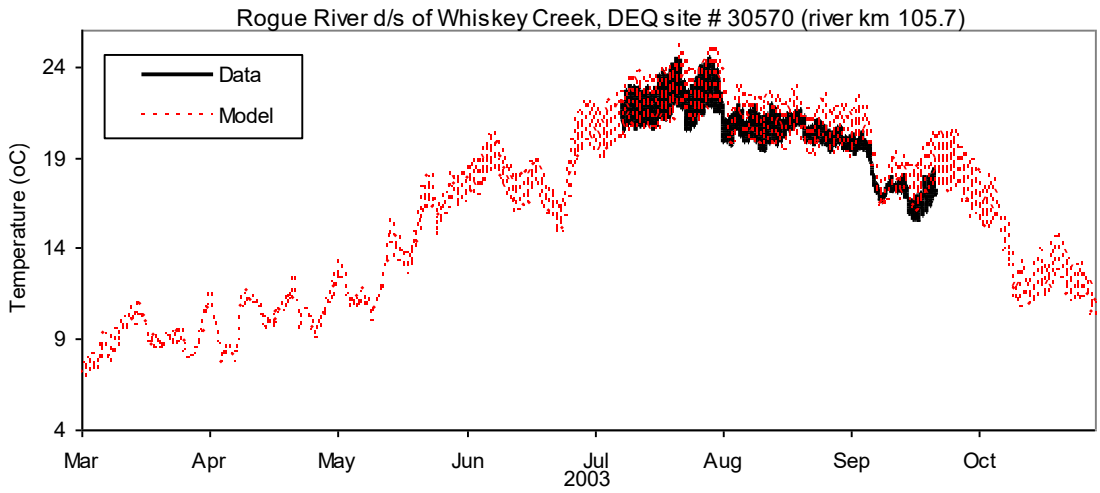


Figure 3-155: Rogue River temperatures: measured vs. modeled, entire model period d/s of Whiskey Cr. (DEQ-30570).

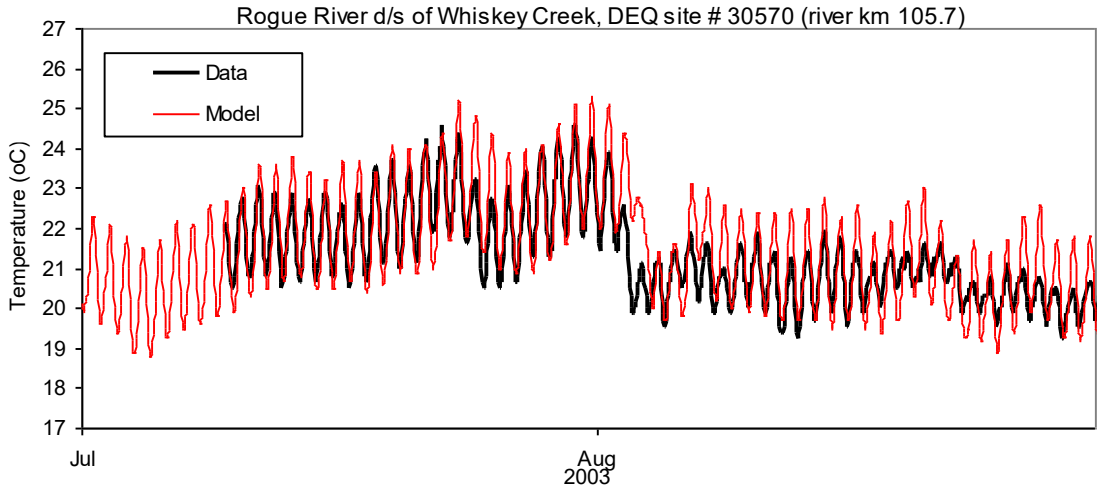


Figure 3-156: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of Whiskey Cr. (DEQ-30570).

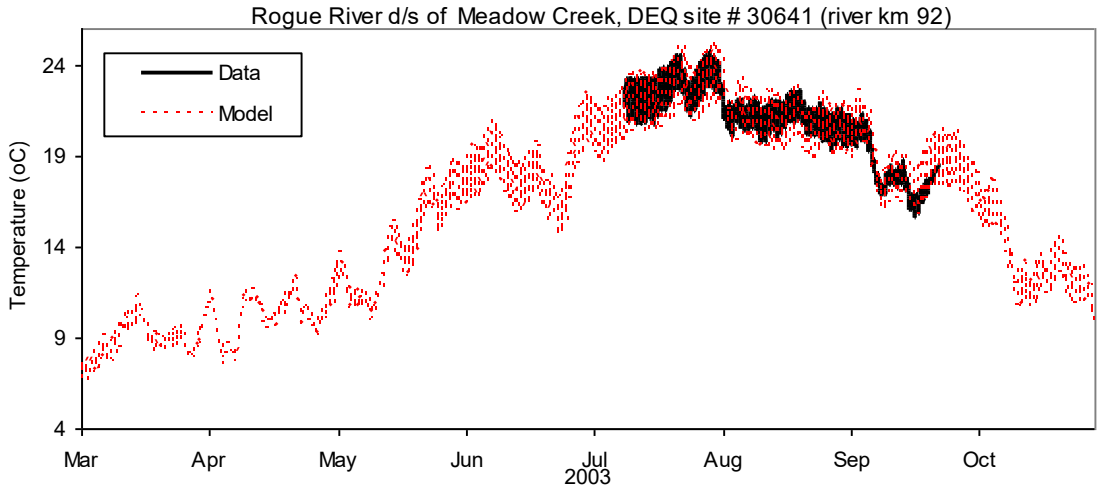


Figure 3-157: Rogue River temperatures: measured vs. modeled, entire model period d/s of Meadow Cr. (DEQ-30641).

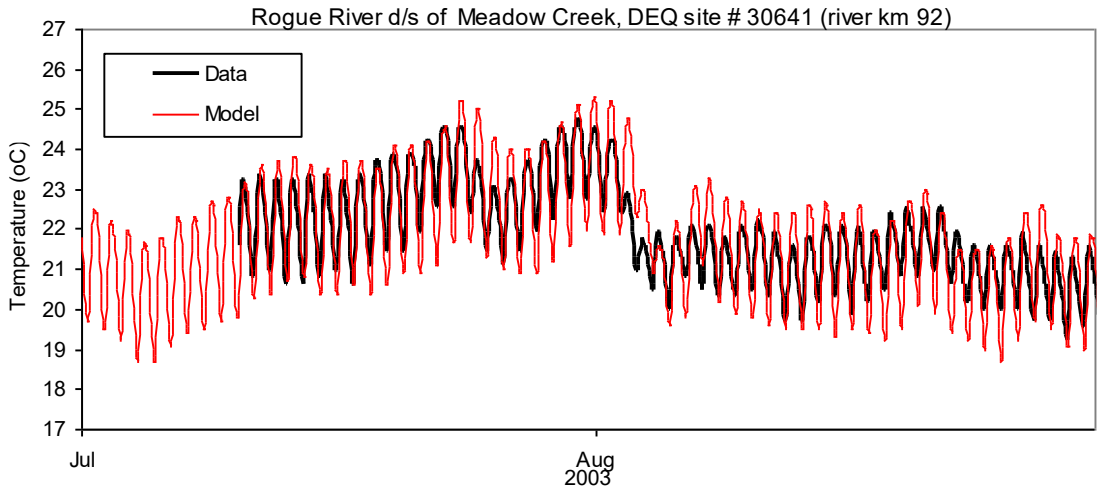


Figure 3-158: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of Meadow Cr. (DEQ-30641).

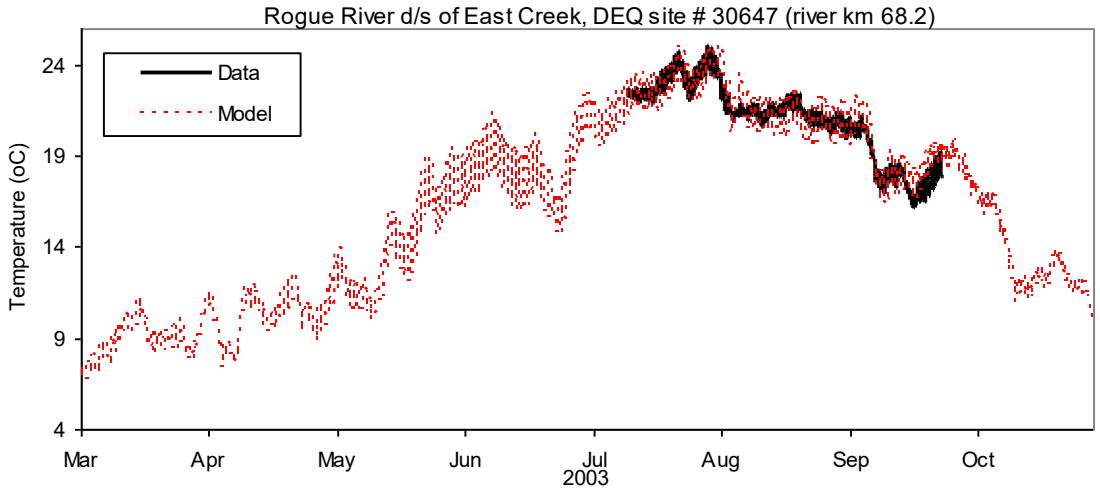


Figure 3-159: Rogue River temperatures: measured vs. modeled, entire model period d/s of East Cr. (DEQ-30647).

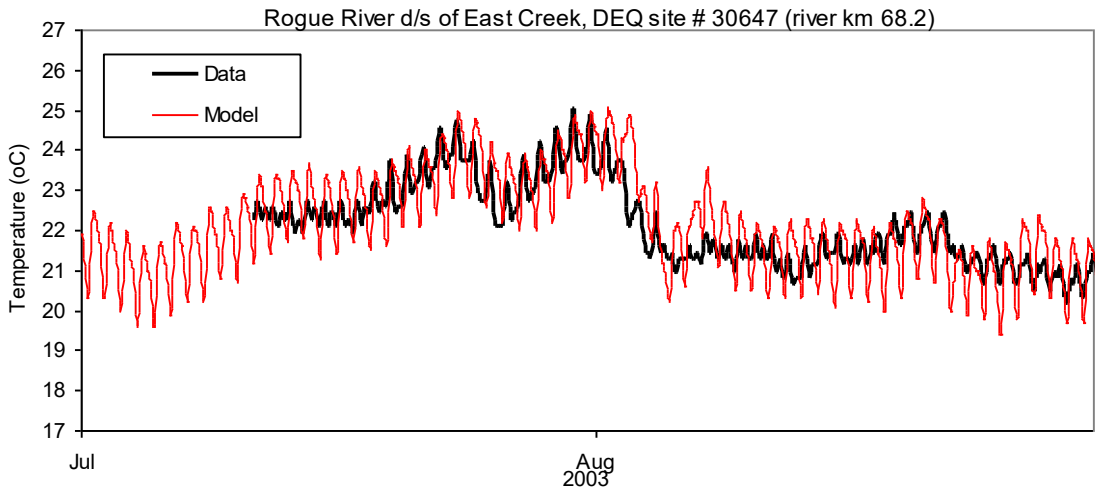


Figure 3-160: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of East Cr. (DEQ-30647).

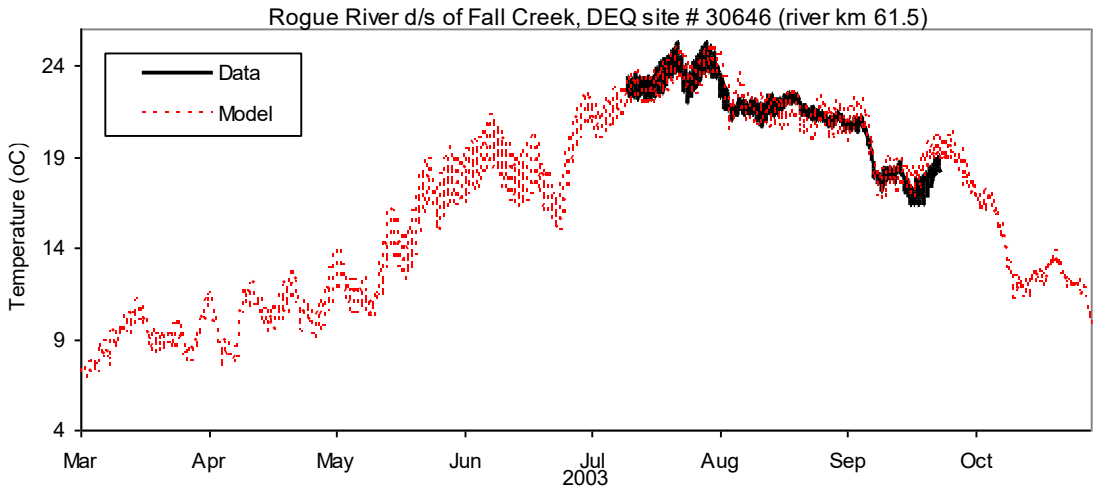


Figure 3-161: Rogue River temperatures: measured vs. modeled, entire model period d/s of Fall Cr. (DEQ-30646).

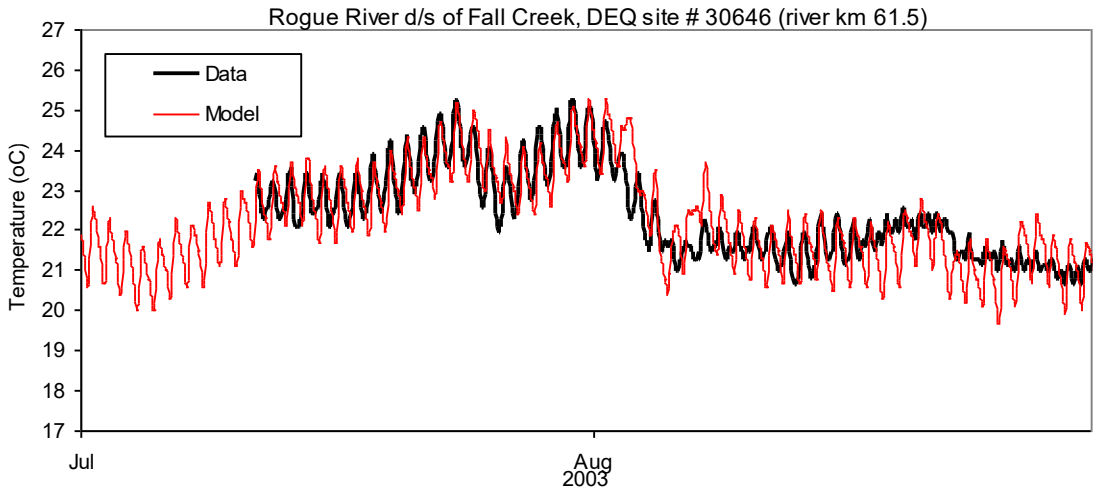


Figure 3-162: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of Fall Cr. (DEQ-30646).

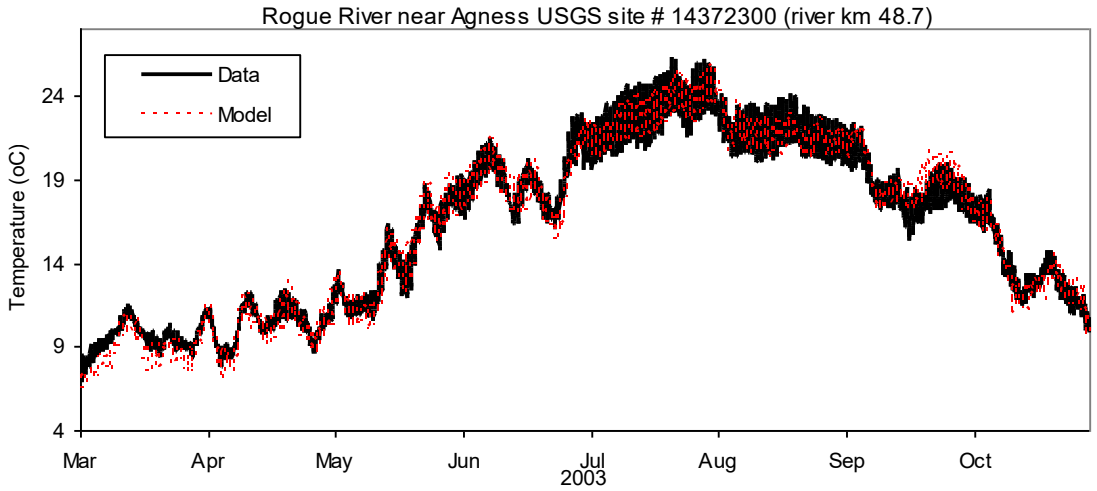


Figure 3-163: Rogue River temperatures: measured vs. modeled, entire model period near Agness (USGS #14372300).

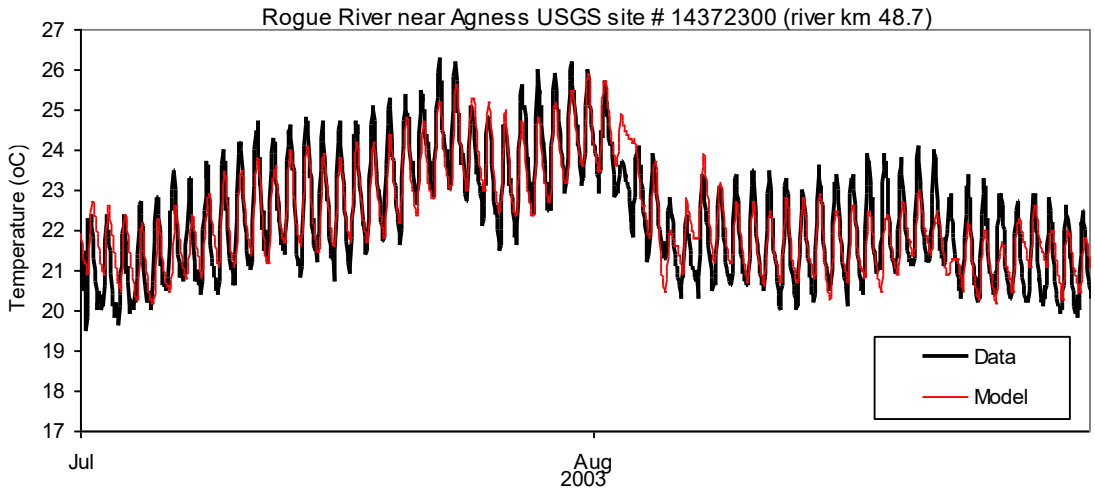


Figure 3-164: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season near Agness (USGS #14372300).

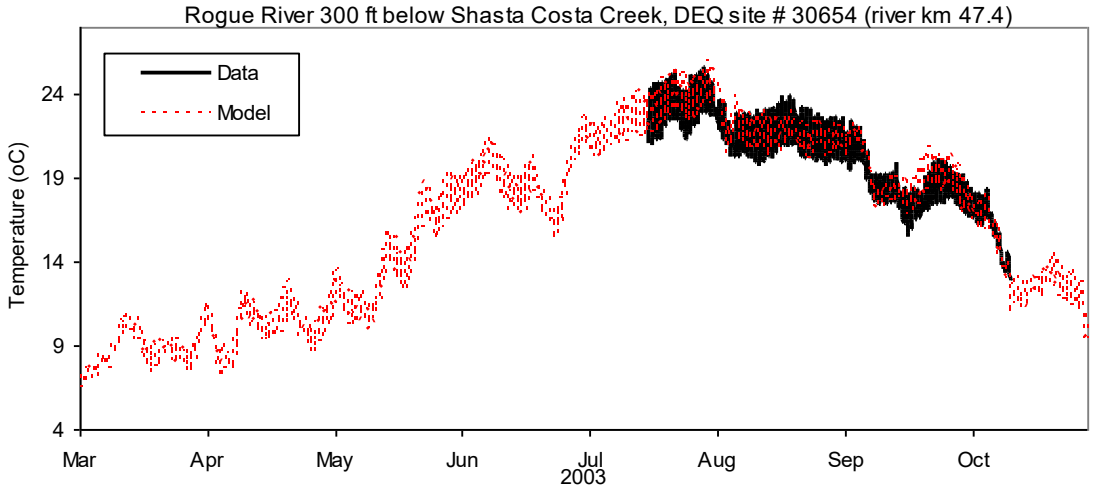


Figure 3-165: Rogue River temperatures: measured vs. modeled, entire model period d/s of Shasta Costa Cr. (DEQ-30654).

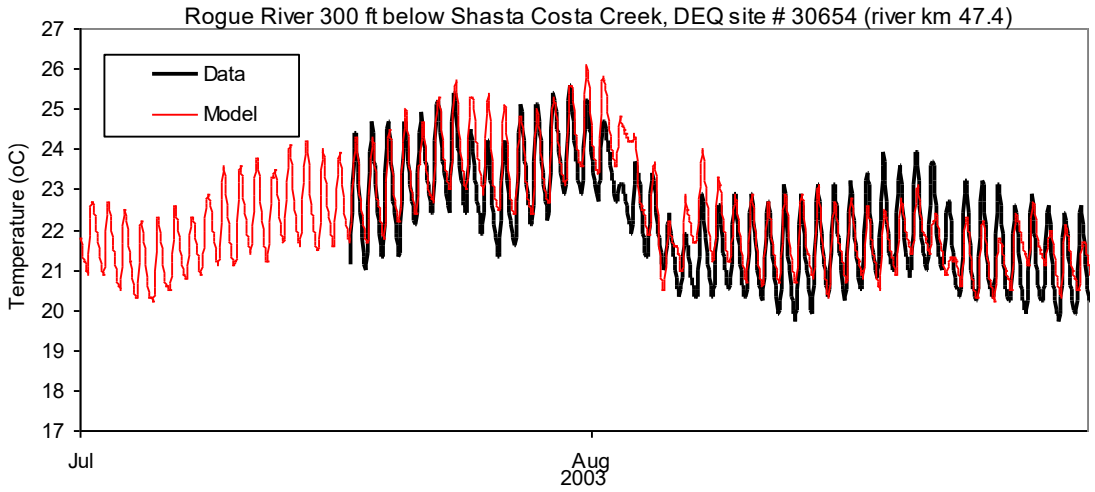


Figure 3-166: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of Shasta Costa Cr. (DEQ-30654).

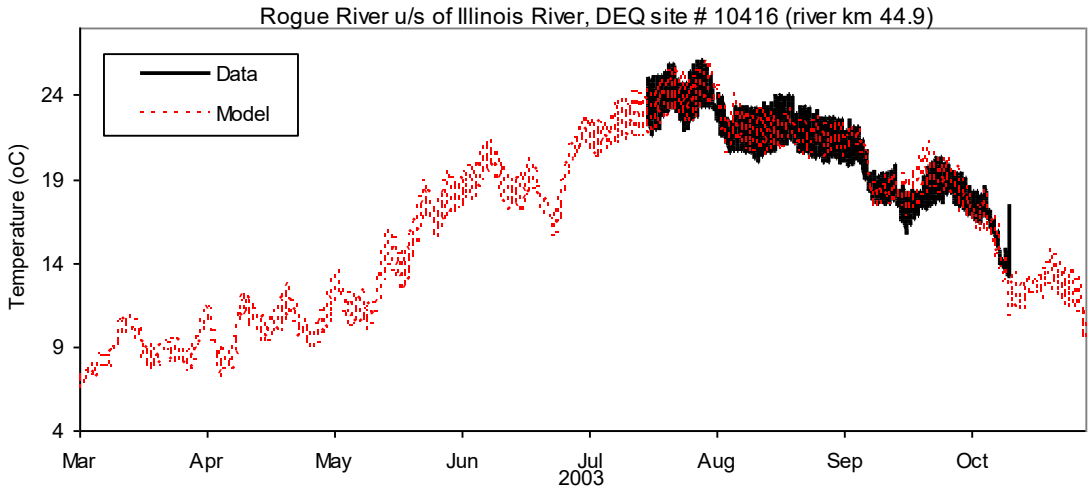


Figure 3-167: Rogue River temperatures: measured vs. modeled, entire model period u/s of Illinois R. (DEQ-10416).

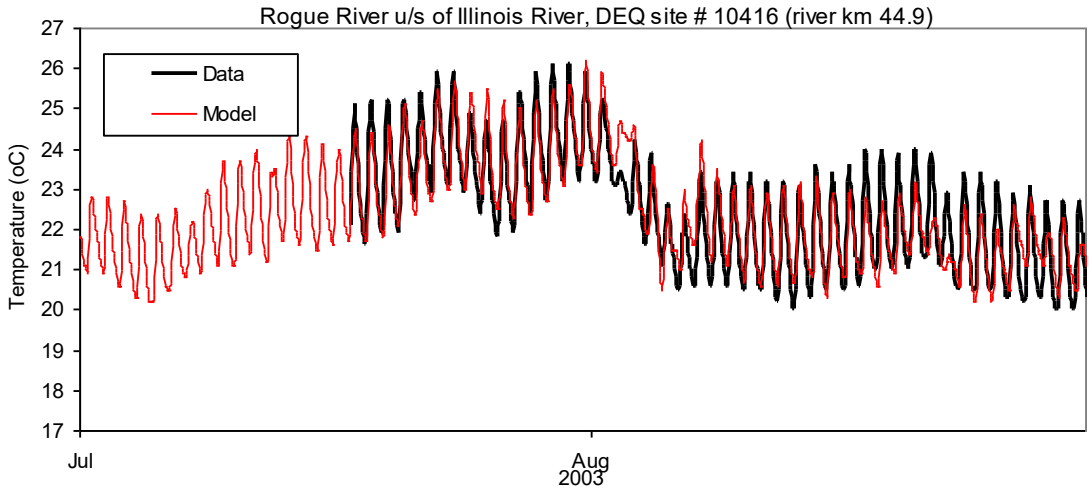


Figure 3-168: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season u/s of Illinois R. (DEQ-10416).

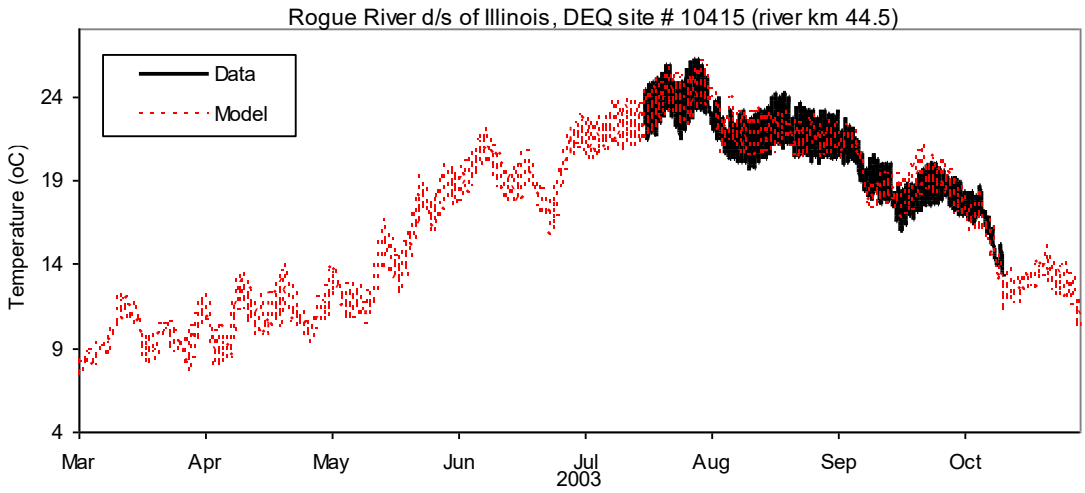


Figure 3-169: Rogue River temperatures: measured vs. modeled, entire model period d/s of Illinois R. (DEQ-10415).

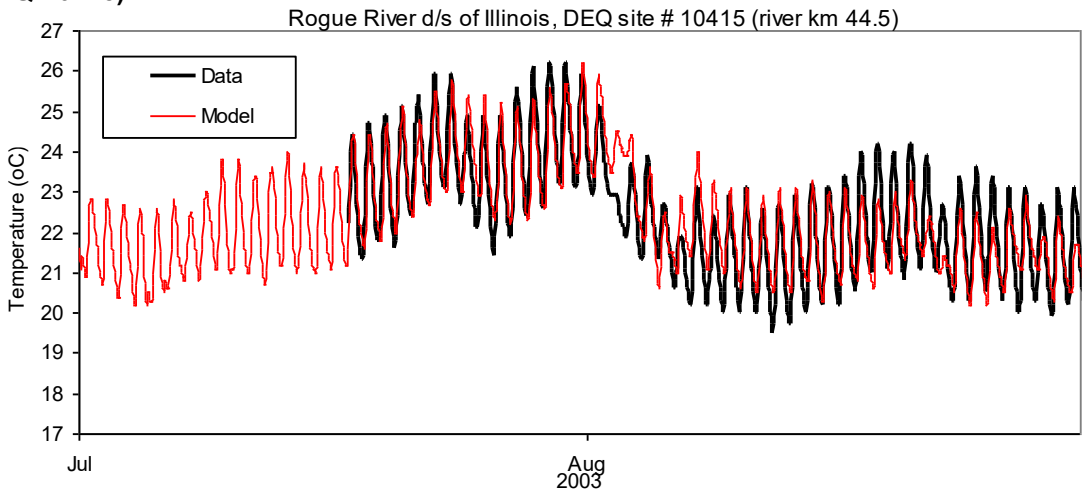


Figure 3-170: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season d/s of Illinois R. (DEQ-10415).

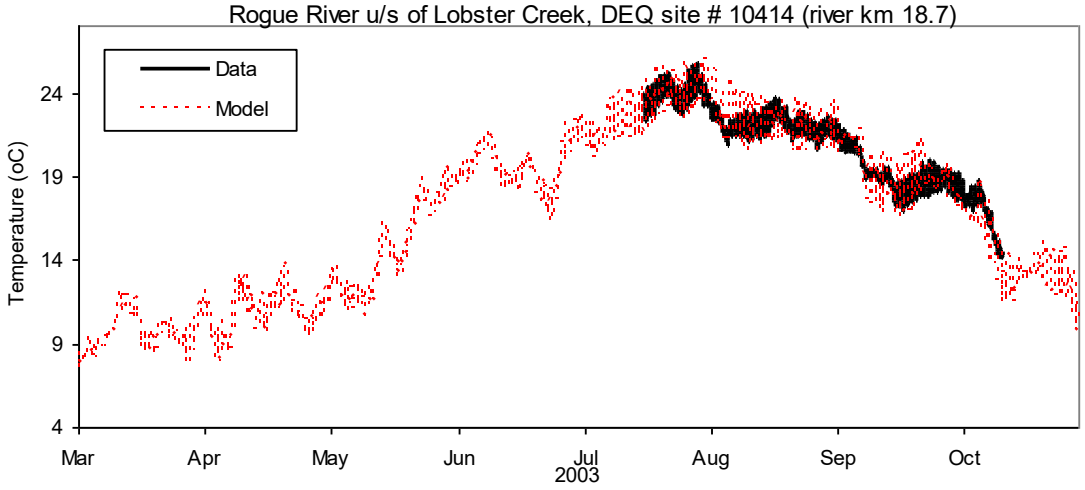


Figure 3-171: Rogue River temperatures: measured vs. modeled, entire model period u/s of Lobster Cr. (DEQ-10414).

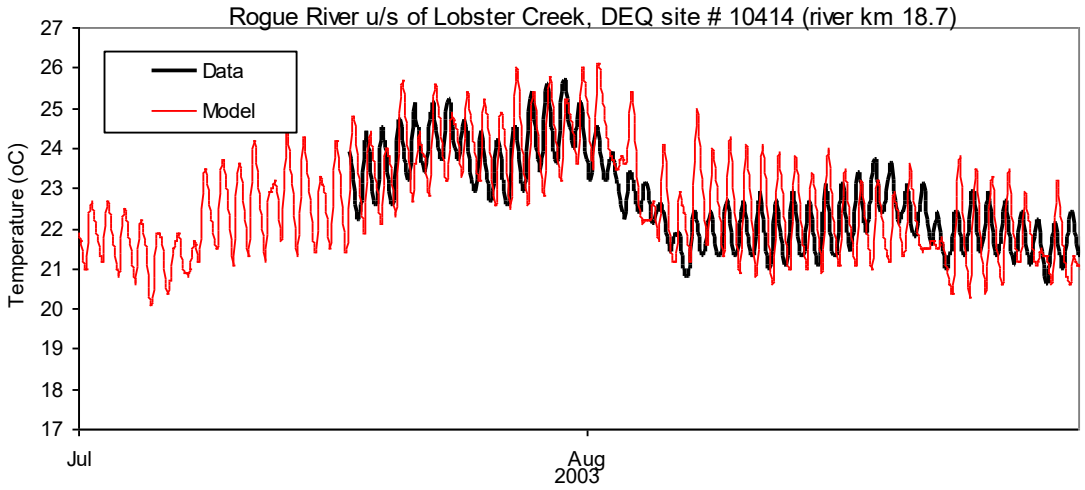


Figure 3-172: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season u/s of Lobster Cr. (DEQ-10414).

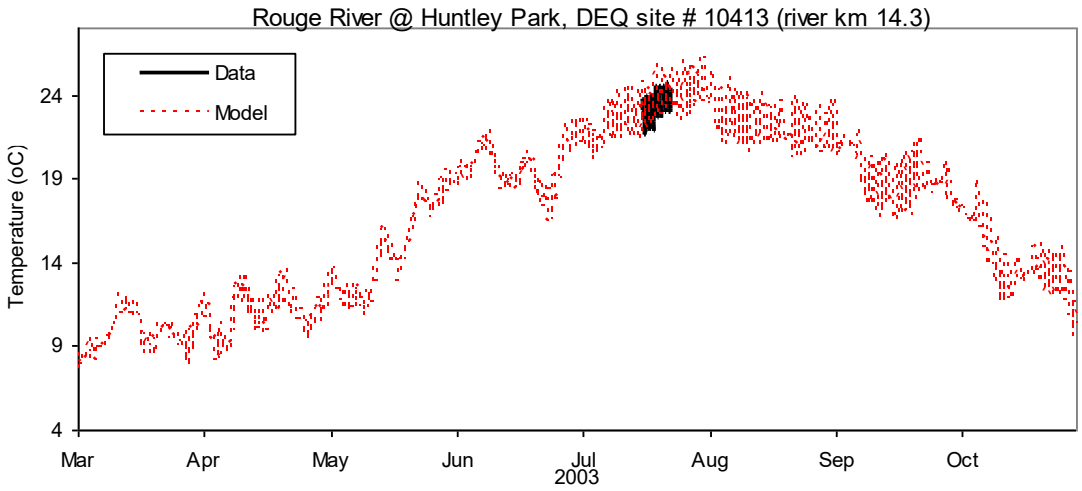


Figure 3-173: Rogue River temperatures: measured vs. modeled, entire model period at Huntley Park (DEQ-10413).

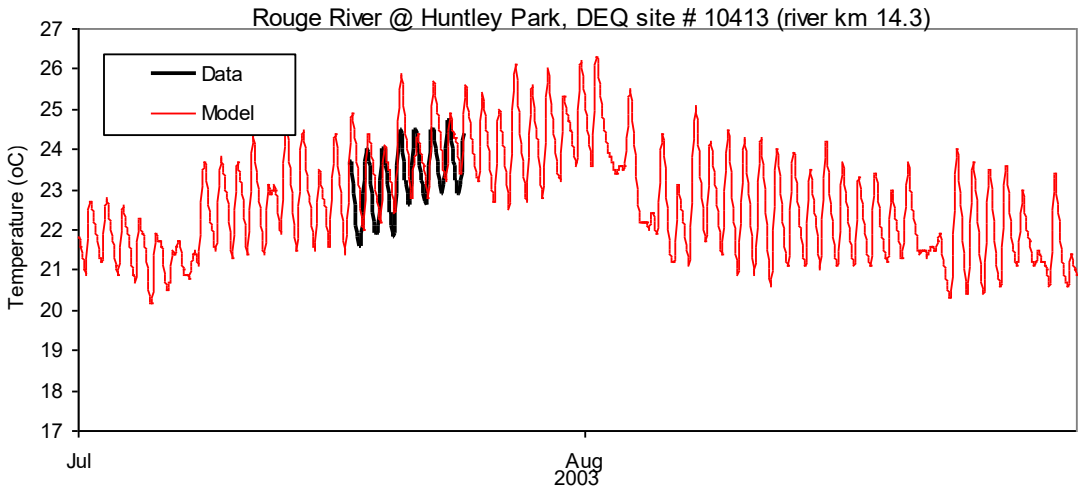


Figure 3-174: Rogue River temperatures: measured vs. modeled, Jul-Aug critical season at Huntley Park (DEQ-10413).

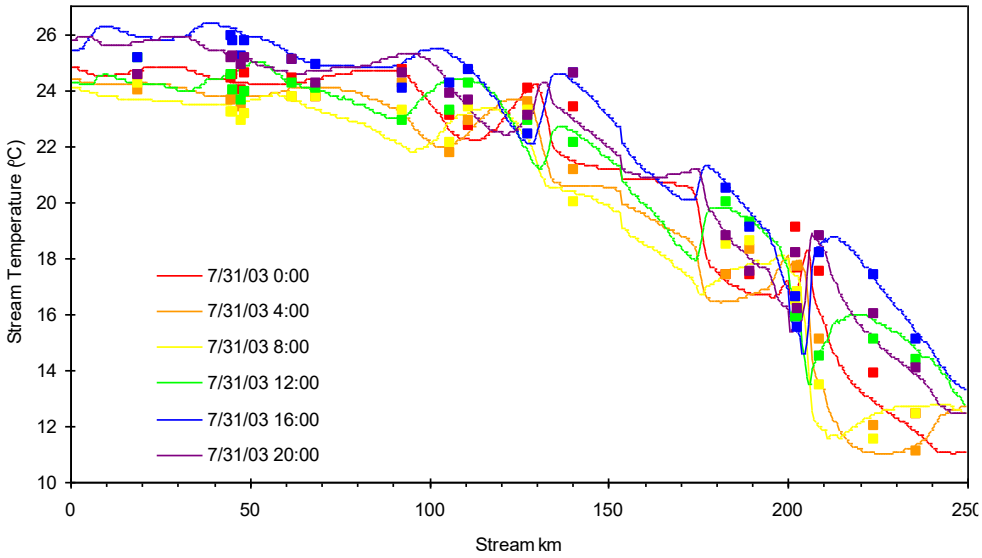


Figure 3-175: Rogue River temperatures: Longitudinal profile, measured vs. modeled, various times on July 31, 2003.

3.12 South Fork Little Butte Creek

3.12.1 Model extent

The extent of the model domain is 28.5km, from the mouth of South Fork Little Butte Creek at its confluence with Little Butte Creek to just upstream of Beaver Dam Creek (Figure 3-176).

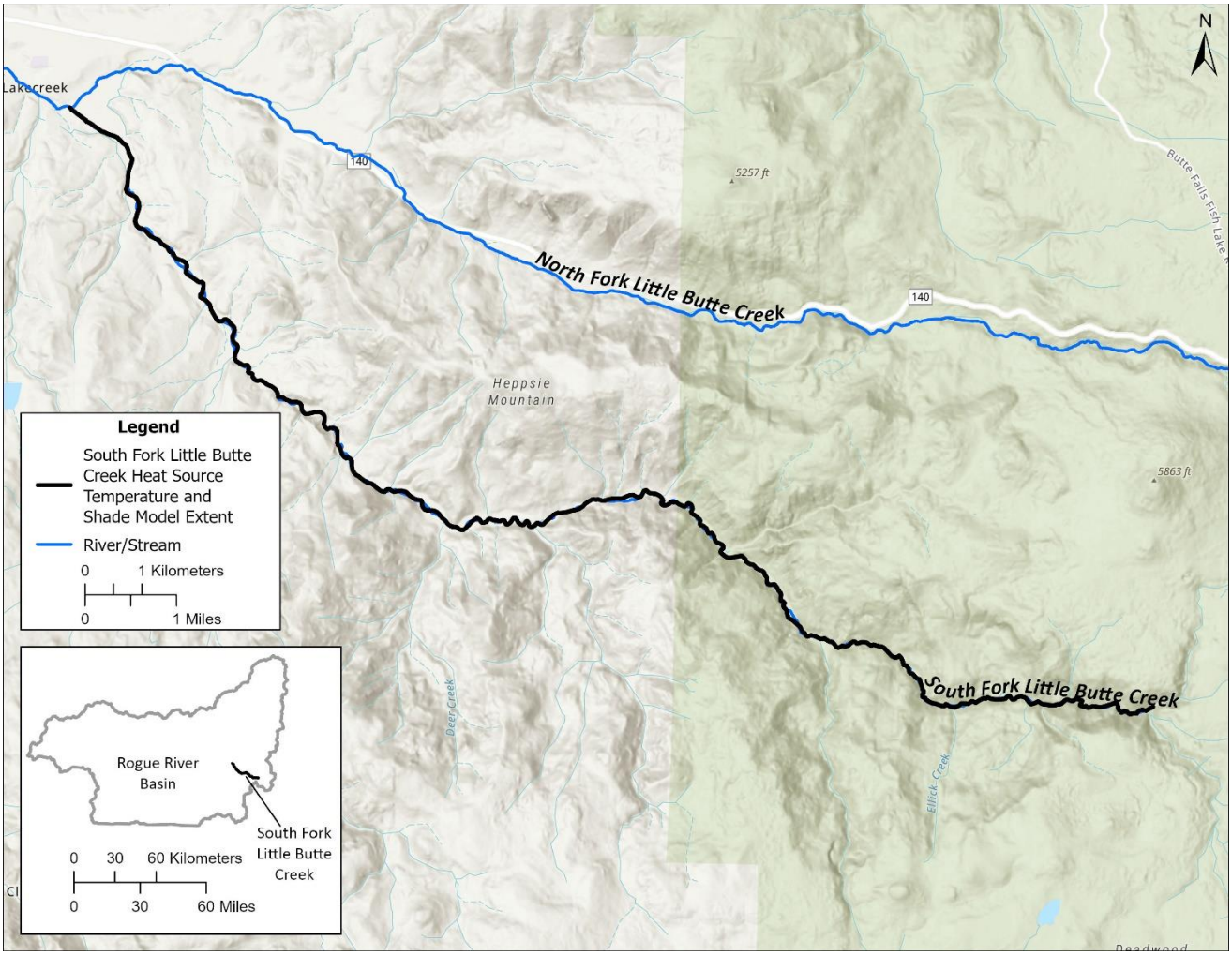


Figure 3-176: Extent of the South Fork Little Butte temperature model.

3.12.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 50m. Outputs are generated every 200m. The model time step (*dt*) is 30 sec and outputs are generated every hour.

3.12.3 Time frame of simulation

The model period is from July 1, 2001 to August 31, 2001.

3.12.4 Meteorological inputs

The model used air temperature, relative humidity, wind speed and cloudiness data from the Medford airport. These data are presented in Section 3.8.4. The meteorological inputs varied by stream kilometer based on proximity to the weather station (Table 3-59). A multiplicative wind sheltering coefficient was applied to the wind speed for calibration.

Table 3-59: Source of meteorological inputs for model. See Little Butte Creek model setup for data.

Range (river km)	Cloudiness	Relative humidity	Air temperature	Wind speed	Wind sheltering coefficient
28 -18	Medford	Medford	Medford	Medford	0.5
18 - 0	Medford	Medford	Medford	Medford	0.1

3.12.5 Temperature inputs

Figure 3-177 shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration. Table 3-60 and Figure 3-178 document the temperatures of the tributaries and canal spills incorporated in the model.

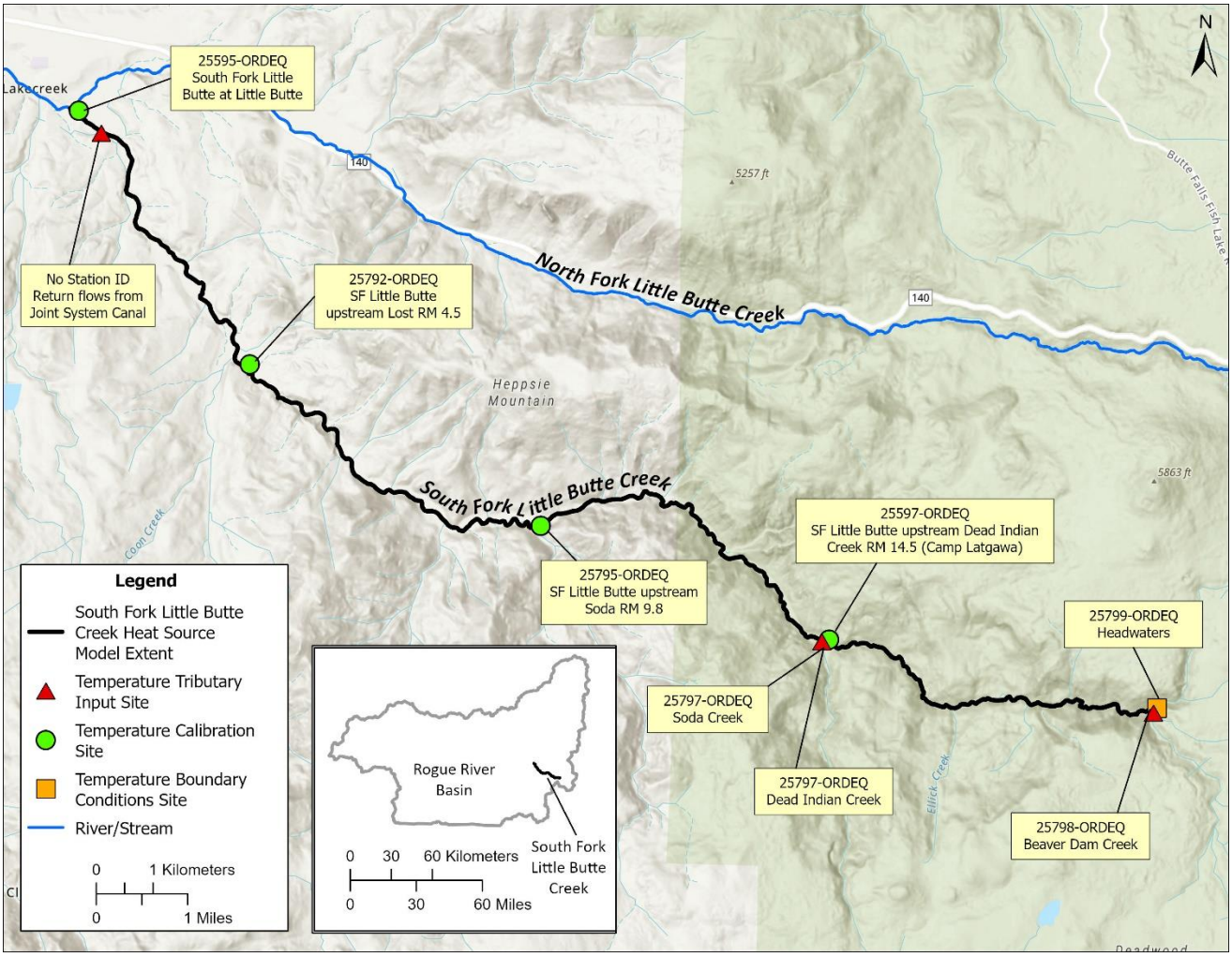


Figure 3-177: South Fork Little Butte Creek model: temperature monitoring locations.

Table 3-60: South Fork Butte Creek model: tributary and boundary condition temperature sources.

Inflow	Stream km	Source
Headwaters	28.45	DEQ-25799
Beaver Dam Creek	28.3	DEQ-25798
Dead Indian Creek	20.9	DEQ-25797

Inflow	Stream km	Source
Soda Creek	13.8	Used Dead Indian Creek as a surrogate
Spill from canal	0.7	N. Fork Little Butte Creek at mouth measurements (canal water originates near this location)

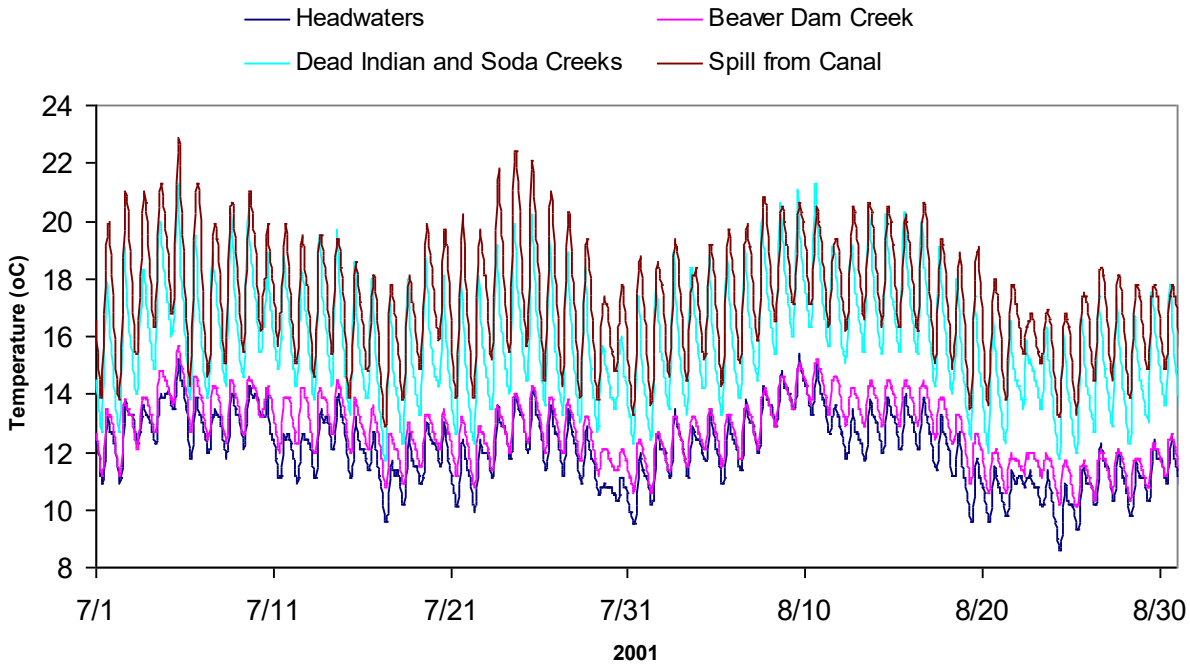


Figure 3-178: South Fork Little Butte Creek model: tributary temperature inputs.

3.12.6 Flow inputs

Figure 3-179 shows the locations of the various stream flow monitoring locations that were used for model setup or calibration. No continuous gage data for were available for 2001, so flows were based on instantaneous flow measurements and mass balance derived from temperature data (Table 3-61 and Figure 3-180). The flow balance was derived via various methods including use of TIR temperatures and upstream flows. To match measured instream flows, additional water loss was necessary from river km 21-25. There were limited reported agricultural withdrawals in this reach. Thus, DEQ deemed it likely that this is a losing reach and the reduced flow is non-anthropogenic. Water losses further downstream correspond with OWRD-provided consumptive use data (Figure 3-181). DEQ estimated the temporal component of consumptive use based on the irrigation season.

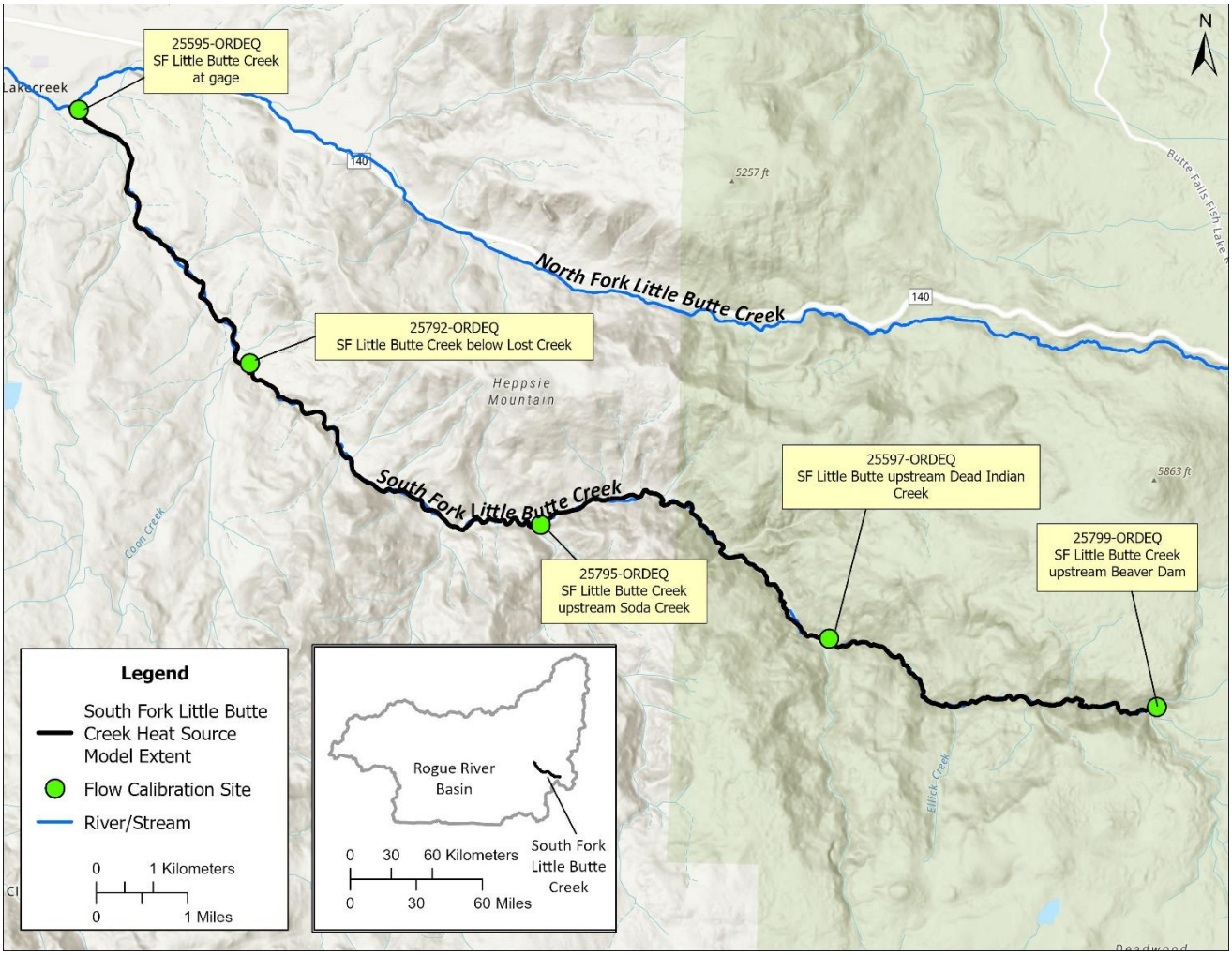


Figure 3-179: South Fork Little Butte Creek model setup and calibration: flow monitoring locations.

Table 3-61: Source of flow information for South Fork Little Butte Creek model.

Inflow/outflow	Stream km	Source
Headwaters	28.45	Instantaneous flow measurement
Beaver Dam Creek	28.3	Instantaneous flow measurement
Dead Indian Creek	20.9	Instantaneous flow measurement
Soda Creek	13.8	Instantaneous flow measurement
Diversion to Joint System Canal	1.75	Temperature and flow balance
Spill from canal	0.7	Temperature and flow balance

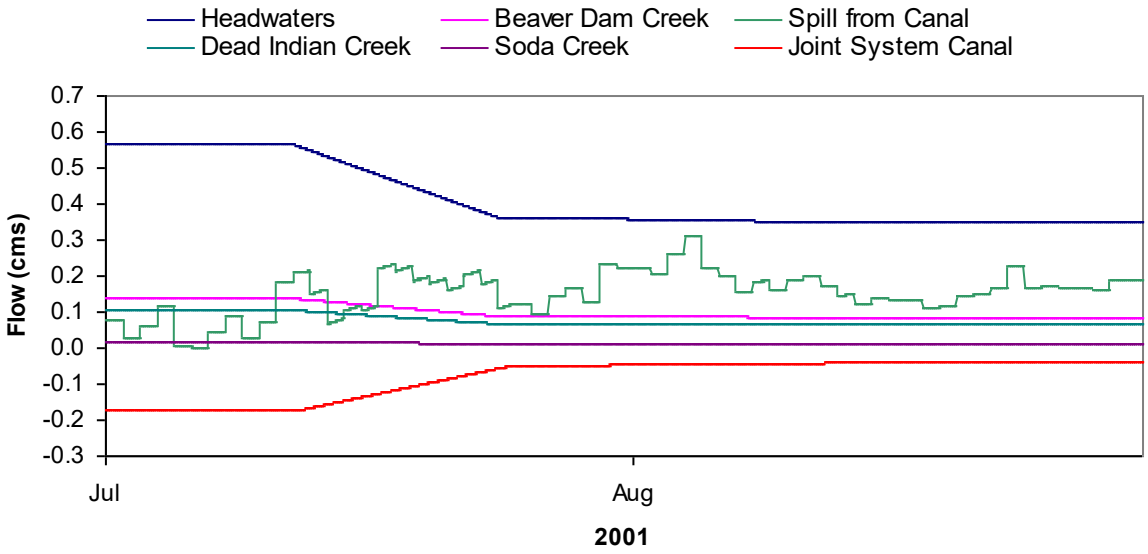


Figure 3-180: South Fork Little Butte Creek model: tributary flows and irrigation system withdrawals.

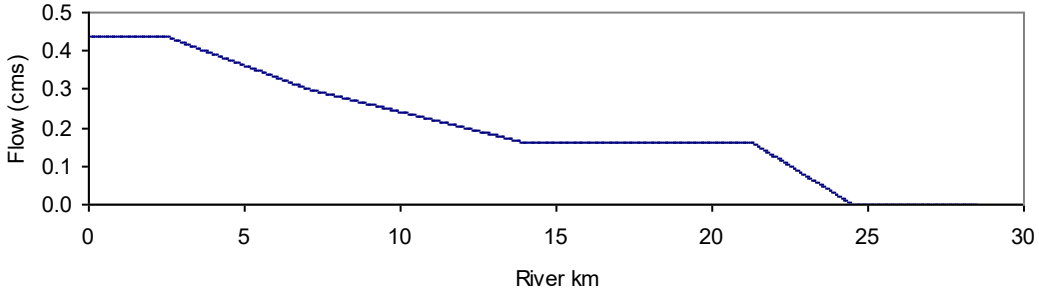


Figure 3-181: South Fork Little Butte Creek model: longitudinal cumulative withdrawals not shown in Figure 3-180.

3.12.7 Point source inputs

3.12.8 Landcover and topographic shade inputs

Topographic shade angle (Figure 3-182) and riparian vegetation heights (Figure 3-183) and densities (Figure 3-184) were determined through GIS analysis.

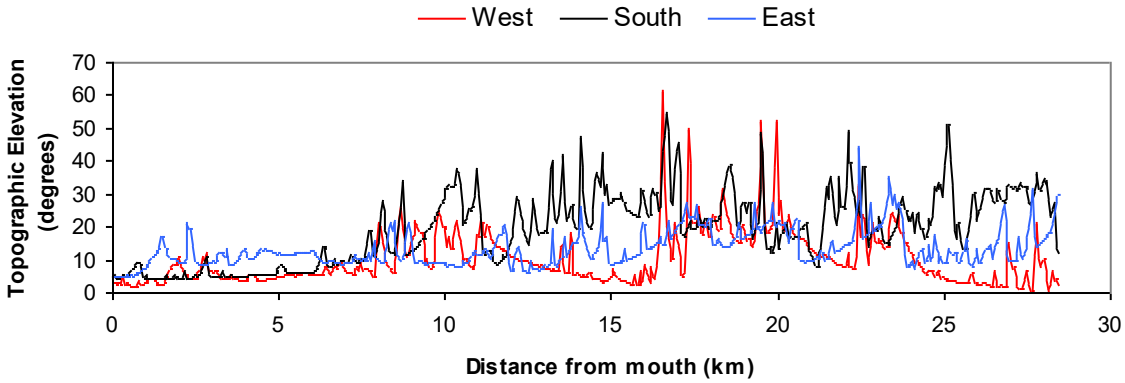


Figure 3-182: South Fork Little Butte Creek model setup for topographic angle.

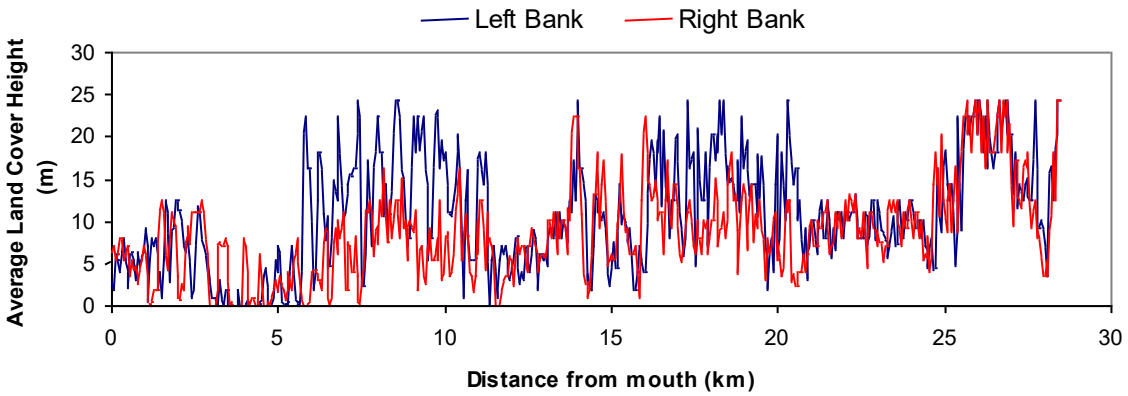


Figure 3-183: South Fork Little Butte Creek model setup for height of streamside vegetation.

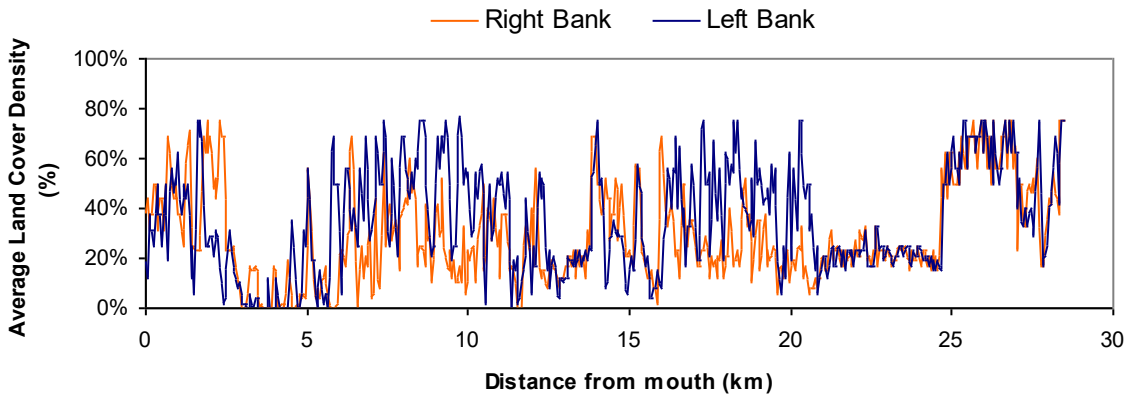


Figure 3-184: South Fork Little Butte Creek model setup for density of streamside vegetation.

3.12.9 Channel setup

The channel properties were determined using the methodology documented previously in this report (see Section 2.2.3). Figure 3-185 shows the elevation profile and reach gradient. The bottom width was derived using the active channel width measured from aerial photographs. Bottom widths (Figure 3-186) were estimated by assuming a trapezoidal channel with 3:1 (length:width) side slopes and a variable width:depth ratio determined through model calibration. Non-spatially varying coefficients are presented in Table 3-62. Manning's n was iteratively altered so that the model temperatures approximately reproduced measured temperatures (Figure 3-187). Percent hyporheic exchange values (Figure 3-188) were modified based on information from project consultant TetraTech (see Appendix **C**).

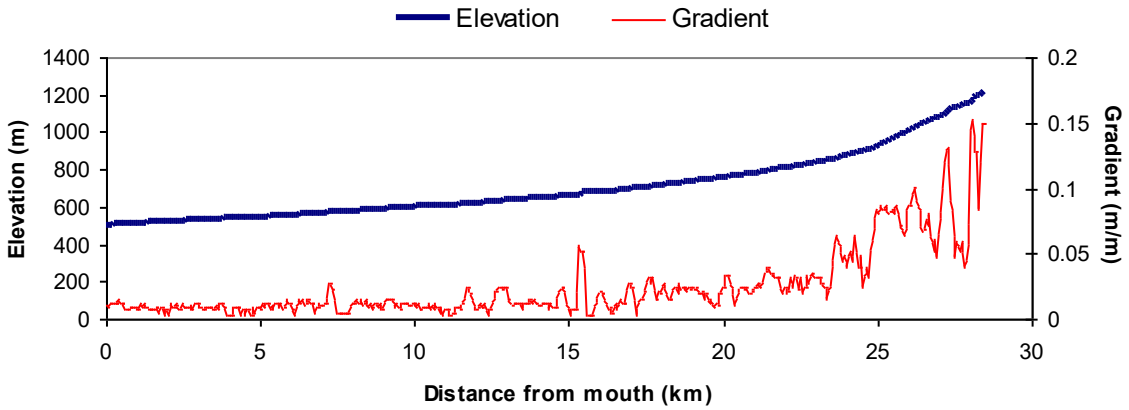


Figure 3-185: South Fork Little Butte Creek model setup channel elevation and gradient.

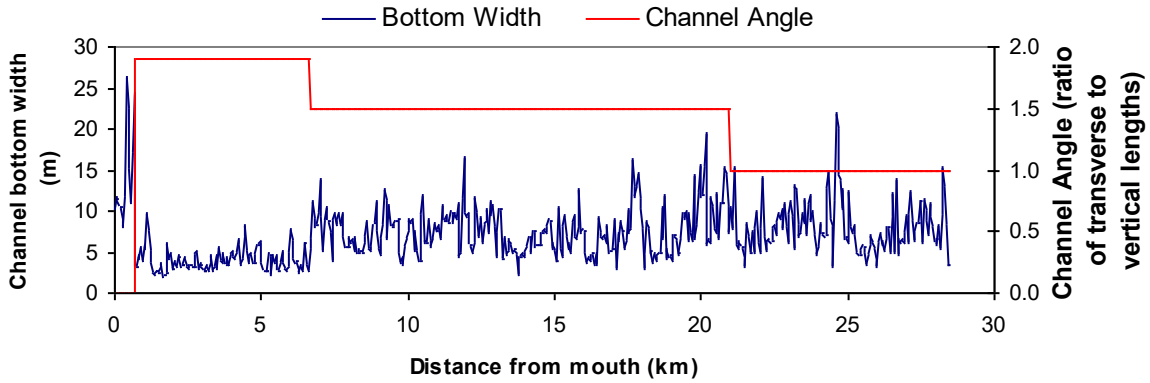


Figure 3-186: South Fork Little Butte Creek model setup for channel bottom width and channel angle.

Table 3-62: South Fork Little Butte Creek model coefficients for non-spatially varying parameters.

Parameter name (units)	Value
Wind Function, coefficient a	1.51×10^{-9}
Wind Function, coefficient b	1.60×10^{-9}
Sediment Thermal Conductivity (W/m/°C)	1.57
Sediment Thermal Diffusivity (cm^2/sec)	0.0064
Porosity	30%

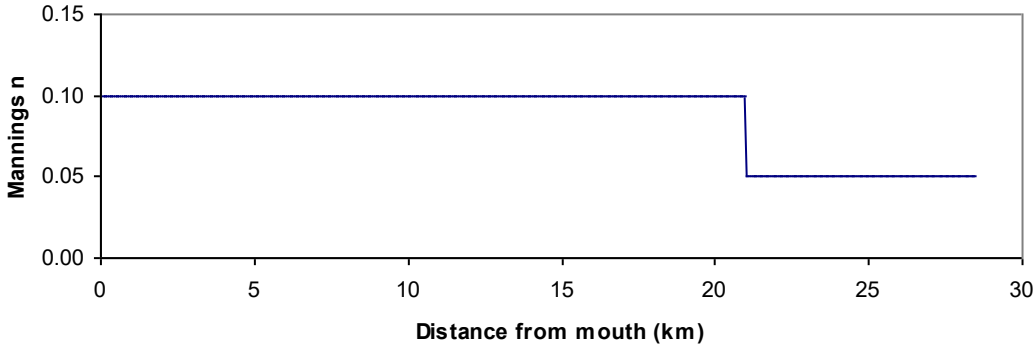


Figure 3-187: South Fork Little Butte Creek model setup for Manning's roughness coefficient.

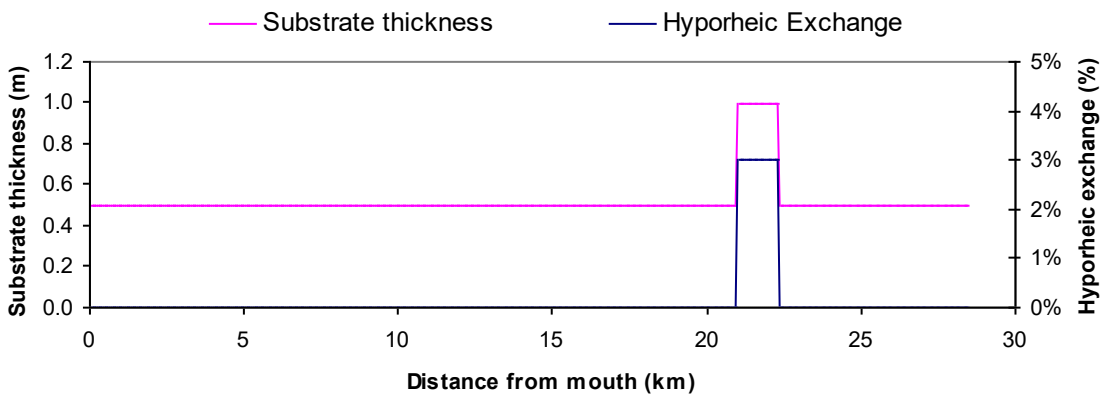


Figure 3-188: South Fork Little Butte Creek model setup for substrate thickness and hyporheic exchange.

3.12.10 Calibration results

Figure 3-189 shows the shade prediction performance of the South Fork Little Butte Creek model.

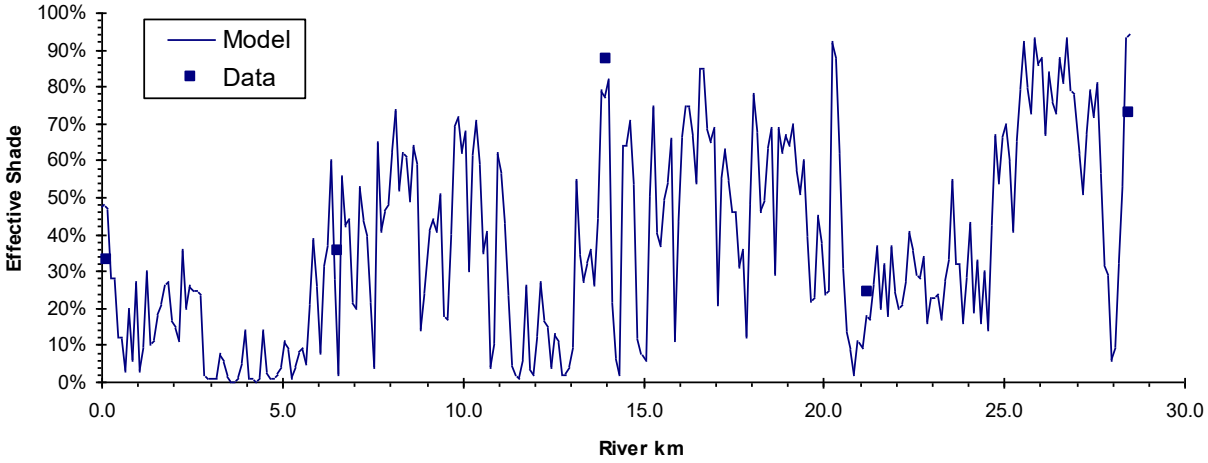


Figure 3-189: South Fork Little Butte Creek model-predicted vs. measured effective shade.

Figure 3-190 shows the flow prediction performance of the South Fork Little Butte Creek model at several locations.

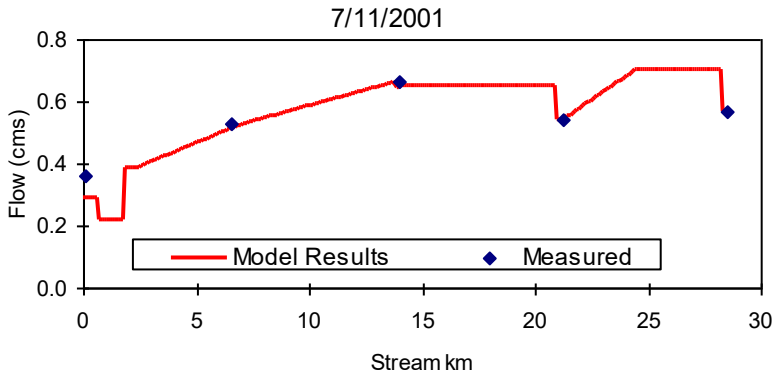


Figure 3-190: South Fork Little Butte Creek: Longitudinal profile of measured flow vs. model results.

Table 3-63, Figure 3-191, and Figure 3-192 indicate that the calibrated model generally reproduced the spatially and temporally varying temperature measurements. See previous statistics discussion in Section 3.1.3.1 for definitions.

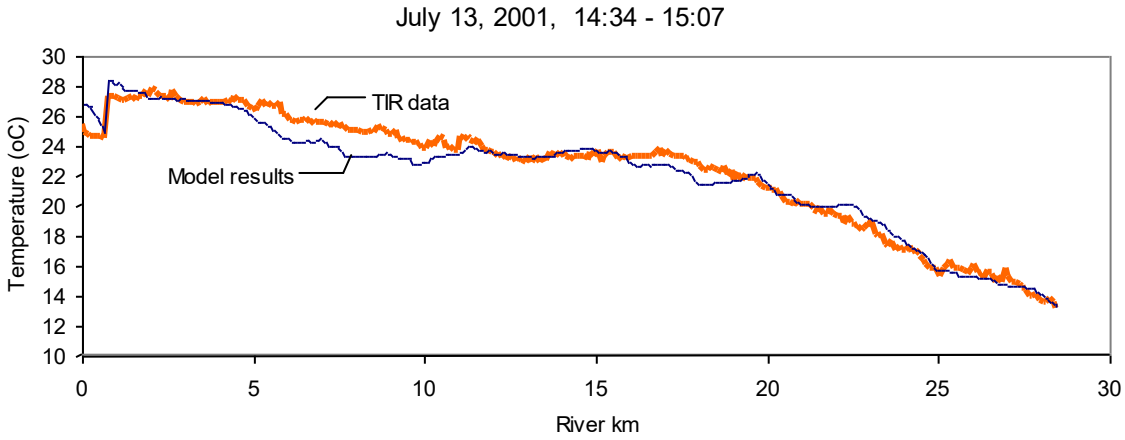


Figure 3-191: South Fork Little Butte Creek: Longitudinal profile of TIR-measured vs. modeled temperatures.

Table 3-63: Continuous monitoring error statistics.

Site Name	rkm	Time increment	ME	MAE	RMSE	NSE	n
Average		Daily Maximum	1.21	1.28	1.53		
Average		Hourly	-0.21	1.40	1.66	0.62	
S. Fork Little Butte Cr. u/s Dead Indian Cr. (DEQ-25597) (A)	21.23	Daily Maximum	1.20	1.27	1.51		62
S. Fork Little Butte Cr. u/s Soda Cr. (DEQ-25795) (B)	13.98	Daily Maximum	2.50	2.58	2.80		62
S. Fork Little Butte Cr. u/s Lost Cr. (DEQ-25792) (C)	6.53	Daily Maximum	1.39	1.90	2.38		59
S. Fork Little Butte Cr. @ Little Butte Cr. (DEQ-25595) (D)	0.13	Daily Maximum	2.01	2.56	4.64		62
S. Fork Little Butte Cr. u/s Dead Indian Cr. (DEQ-25597) (A)	21.23	Hourly	-0.26	1.13	1.34	0.52	1488
S. Fork Little Butte Cr. u/s Soda Cr. (DEQ-25795) (B)	13.98	Hourly	-0.67	1.57	1.81	0.64	1430
S. Fork Little Butte Cr. u/s Lost Cr. (DEQ-25792) (C)	6.53	Hourly	0.15	1.54	1.84	0.62	1488
S. Fork Little Butte Cr. @ Little Butte Cr. (DEQ-25595) (D)	0.13	Hourly	-0.06	1.35	1.66	0.71	1431
TIR			-0.29	0.67	0.86	0.95	

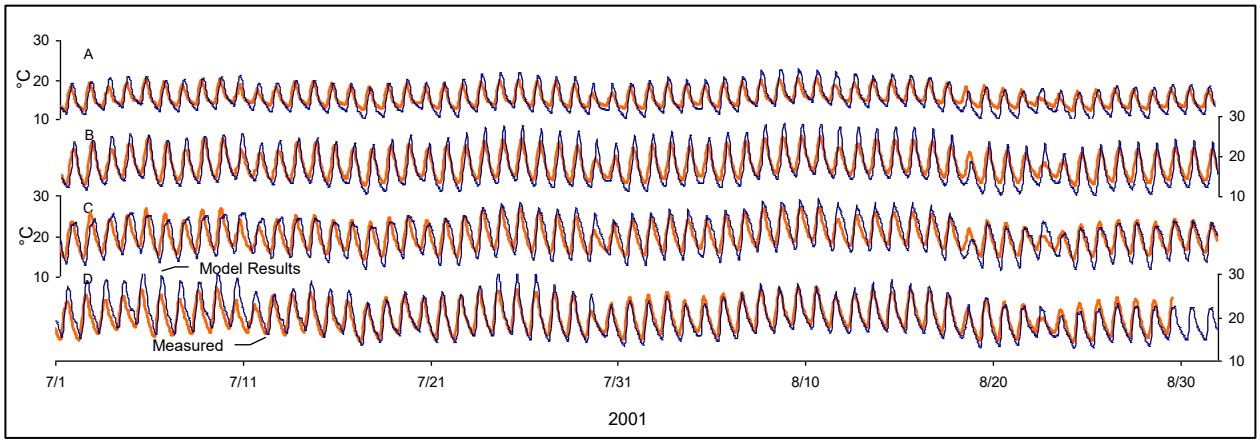


Figure 3-192: South Fork Little Butte Creek: Measured steam temperature vs. model results.

4 Model scenario setups

Management scenarios described in this section summarize how thermal sources and different management alternatives were evaluated. In some cases, the management scenario was developed as part of a previous TMDL.

4.1 Current conditions

This scenario evaluates the stream temperature response under current existing conditions. This scenario is similar to the calibrated model except that some sources conditions may be modified, added, or removed to reflect current conditions or loads if they differ significantly from the calibrated model. Elements of this scenario or scenarios may include model updates to reflect current discharges from NPDES-permitted point sources.

4.2 Background

This scenario evaluates the stream temperature response from background sources only. Background sources include all sources of pollution or pollutants not originating from human activities. Background sources may also include anthropogenic sources of a pollutant that DEQ or other Oregon state agency does not have authority to regulate, such as pollutants emanating from another state, tribal lands, or sources otherwise beyond the jurisdiction of the state (OAR 340-042-0030(1)). This scenario essentially combines the following model scenarios: restored vegetation, restored streamflow, and no point sources. Specific model adjustments made for each modeled stream are described in the stream-specific model scenario results (see Sections 5.2 through 5.12).

The Background scenario is compared to:

- The BBNC to determine the extent of temperature standard exceedances that occur with the aforementioned anthropogenic sources removed,
- The Current Conditions model to determine the combined temperature effects of those anthropogenic sources,
- The WLA scenario to determine the cumulative temperature effects of all mainstem-located point sources when each discharges according to its assigned WLA or LA,

- The Tributary Temperatures scenario to determine the temperature effects of tributaries' discharges reflecting the cumulative assigned HUA portions on those tributaries, and
- The HUA Attainment scenario to determine the cumulative temperature effects of that tributary warming and warming from various modeled sources on the mainstem.

4.3 Topographic shade

This scenario evaluates the effective shade produced by topographic features only and the stream temperature response from removing all near-stream landcover. The stream temperature effects of complete landcover removal are evaluated by comparing this scenario to the Current Conditions model. For this scenario, all landcover height, density and overhang inputs are set to 0.

4.4 Restored vegetation

Restored vegetation is essentially the mature species vegetation composition, height, and density that would occur absent human disturbances. Restored vegetation conditions were used in stream temperature model scenarios to quantify the impacts of nonpoint source solar radiation loads, and ultimately to develop nonpoint source load allocations for the TMDL. This scenario evaluates the stream temperature response with streamside vegetation set to restored conditions by comparing its results to those of the Current Condition model.

The Rogue River Basin is large and consists of a variety of unique ecosystems. Restored vegetation height and density for Bear Creek and Lobster Creek model scenarios were based on EPA Level IV Ecoregions (Thorson et al. 2003). Each ecoregion can support different vegetation types (Figure 4-1). Ecoregions are classified based on multiple parameters including elevation, climate, soils, vegetative communities, geology, physiography, hydrology, land use, etc.. Restored vegetation characteristics for Antelope Creek, Elk Creek, Evans Creek and West Fork Evans Creek, Litle Butte Creek and North Fork Little Butte Creek, Rogue River, and South Fork Little Butte Creek model scenarios were also based on ecoregion and informed by vegetation descriptions in the Oregon Watershed Assessment Manual (1999) and BLM-provided average restored vegetation tree heights by watershed (Laurie Lindell 2008, personal communication). Restored vegetation characteristics for each ecoregion are summarized in Table 4-1.

The application method for restored vegetation in the temperature models was based on the following general rules:

- Existing tree stands were assigned their restored heights and densities. Existing mature trees were left as-is, while immature tree stands were assigned the appropriate restored (mature) heights.
- Non-forested areas that are capable of supporting trees (i.e., clear cuts, fields, recently disturbed areas) were assigned the appropriate mature species composition type.
- Areas that are naturally incapable of supporting trees or other shade-producing vegetation were left as-is (i.e., barren steep rocky slopes, bedrock outcrops, etc.). Notably, this includes portions of the riparian area along the Rogue River in the "Wild and Scenic" reach identified by the TMDL technical committee that are currently identified as grasses and shrubs. These areas that have not been actively managed and due to hillside slope, soil, and other factors are not predicted to support forests.

- Developed areas (i.e., roads, buildings, rail, dams, etc.) were assigned the appropriate mature species composition type.

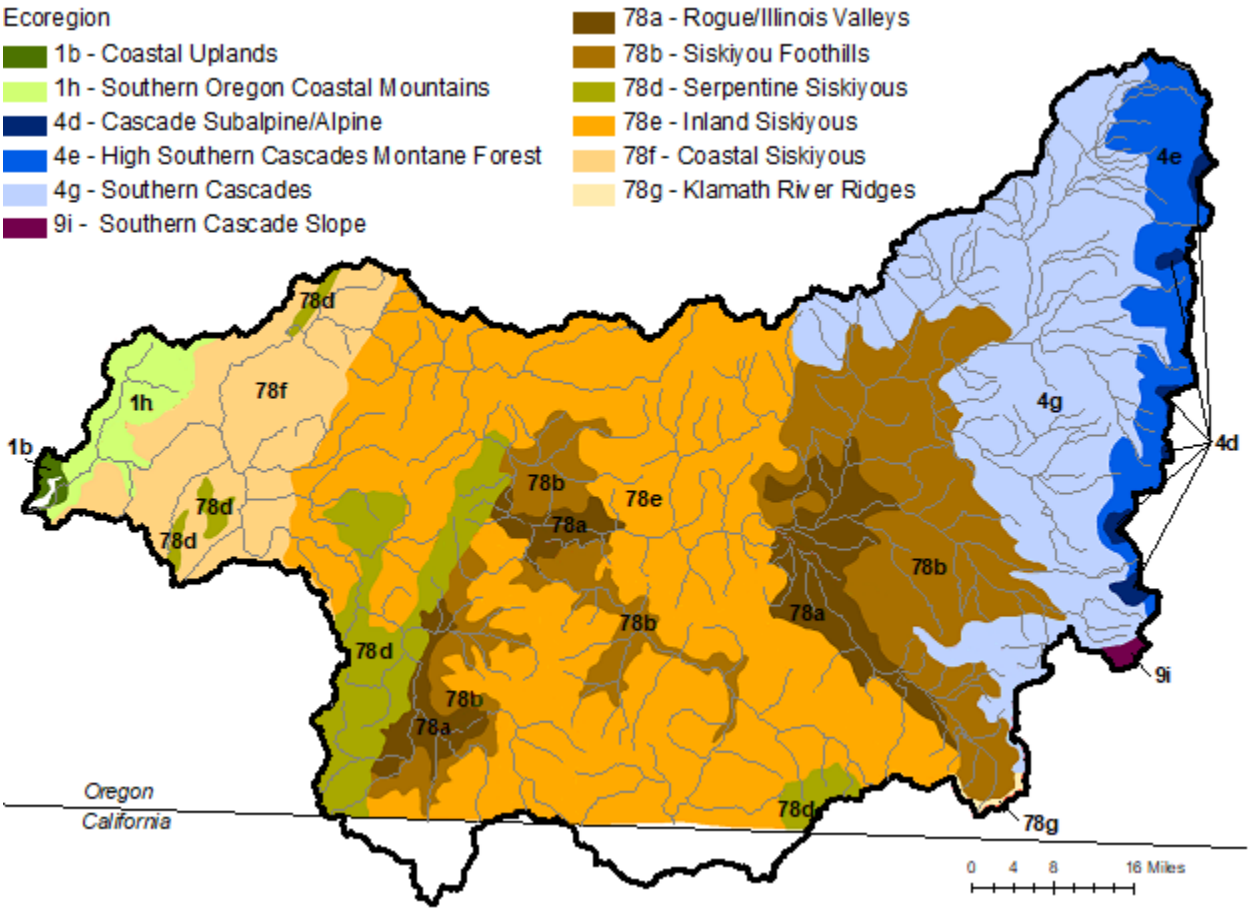


Figure 4-1: EPA Level IV Ecoregions in the Rogue River Basin.

Table 4-1: Summary of restored vegetation species compositions, heights, and densities for each Level IV Ecoregion. Ecoregions 9i and 78g were not included as they represent a small portion of the basin.

Ecoregion	Vegetation type	Examples from Oregon Watershed Assessment Manual (1999)	Height (m)	Density
1b	Conifer	Spruce, hemlock	41.1	80%
1b	Hardwood	Alder dominant with maple	27.4	70%
1b	Mixed		30.5	75%
1h	Mixed	Western hemlock, western redcedar, Port-Orford cedar, grand fir, tanoak, myrtle, red alder	48.8	70%
4d	Herbaceous plants	Arrowleaf groundsel, red mountain heath	0.2	50%
4e	Conifer	True fir, mountain hemlock and lodgepole pine	42.7	70%
4e	Mixed	Mountain alder and some conifers	14.9	80%
4g	Conifer	Douglas fir, true fir, and incense cedar	56.4	70%
4g	Hardwood	Mountain alder	14.9	80%
4g	Mixed		35.7	75%
78a	Conifer	Douglas fir, ponderosa pine	46.0	80%
78a	Hardwood	Red alder, cottonwood	28.2	70%

Ecoregion	Vegetation type	Examples from Oregon Watershed Assessment Manual (1999)	Height (m)	Density
78a	Mixed		37.1	75%
78b	Conifer	Douglas fir, incense cedar	51.8	80%
78b	Hardwood	Cottonwood, oak, madrone	29.3	85%
78b	Mixed		42.1	70%
78d	Mixed	Jeffery pine, tanoak, Douglas fir, white fir	36.0	52%
78d	Willows	Willows, azalea, shrubs	4.6	90%
78e	Conifer	Douglas fir, ponderosa pine, incense cedar, white fir	53.6	80%
78e	Hardwood	Oak, madrone	29.3	85%
78e	Mixed		42.1	70%
78f	Conifer	Sitka spruce, western hemlock, Douglas fir, Port Orford cedar and Jeffery pine	57.0	70%
78f	Hardwood	Alder, myrtle and bigleaf maple	27.4	70%
78f	Mixed		42.2	70%

4.5 Restored flow

This scenario evaluates stream temperature response by changing permitted water withdrawals to instream flow and then comparing its results to those of the Current Conditions model scenario. Elements of this scenario typically include maintaining all currently permitted water withdrawals on the model stream as instream flows and increasing boundary condition flows to reflect the removal of water withdrawals upstream of the model extent. Specific model adjustments made for each modeled stream are described in the stream-specific model scenario results (see Sections 5.2 through 5.12).

4.6 Tributary temperatures

This scenario evaluates the stream temperature response from TMDL allocations on tributaries. For this scenario, each tributary's temperatures are increased by the total HUA assigned to point and nonpoint sources on that tributary. HUA held as reserve capacity is not included. This scenario is compared to a baseline scenario that includes tributaries at unadjusted temperatures. Specific model adjustments made for each modeled stream are described in the stream-specific model scenario results (see Sections 5.2 through 5.12).

4.7 No point sources

This scenario evaluates the stream temperature response from removing point source heat loads. For this scenario, all NPDES-permitted inputs are removed from the model. The stream temperature effects due to the current heat loads from permitted NPDES point sources are evaluated by comparing the results of this scenario to those of the Current Conditions model.

4.8 Wasteload allocations

This scenario evaluates stream temperature effects of NPDES-permitted point sources discharging at their assigned TMDL wasteload allocations. This scenario is compared to the Background scenario (a) to evaluate cumulative attainment of the categorical HUA allocation to NPDES point

sources and (b) to evaluate the instream temperature effects of each point source albeit at a coarser scale. For this scenario, all NPDES permitted point source discharges are modified to reflect the proposed TMDL WLAs. Note that the specific WLAs proposed for various permittees were derived primarily from a separate warming analysis; this WLA scenario was used to confirm and in some cases adjust the proposed WLAs but not as the primary method of WLA derivation.

4.9 Dams

Multiple Rogue River model scenarios were developed to evaluate stream temperature response from removing dams. The first no dam model scenario was also developed to simulate removal of the William L. Jess Dam ("No Lost Creek Reservoir scenario"), and the second was developed to simulate the removal of multiple low head dams on the Rogue River ("No small dams"). The low head dams have been removed and no longer affect Rogue River temperatures. The stream temperature response from removing small dams is evaluated by comparing the No Small Dams scenario to the 2008 current conditions scenario, which included the small dams. The stream temperature response from removing the William L. Jess Dam is evaluated by comparing the No Lost Creek Reservoir scenario to the updated current conditions scenario completed for the replacement (2027) TMDL.

4.10 Hyporheic

This scenario evaluates stream temperature response to natural, pre-development hyporheic flow exchange conditions in the Little Butte Creek Watershed with the Little Butte Creek and North Fork Little Butte Creek model, and the South Fork Little Butte Creek model. The stream temperature effects due to natural hyporheic flow are evaluated by comparing this scenario to the current conditions model scenario. Assumptions and methods used to estimate natural hyporheic flow were documented in the 2008 Rogue River Temperature TMDL Technical Support Document.

4.11 HUA attainment

4.11.1 Explicitly assessed (modeled) sources

The HUA Attainment scenario setup is adapted from the Background scenario for each modeled river. The only model inputs changed for the Attainment scenario were those related to thermal sources explicitly assessed by this scenario; the specific source categories assessed differed among modeled streams for this TMDL, as presented in Section 5. Typically, elements of this scenario include point source discharges set to reflect individual proposed WLA flows and temperatures, restored vegetation (representing no temperature increase HUA from excessive solar radiation), and tributary temperatures increased by the HUA portion assigned to point and nonpoint sources on each tributary.

For sources explicitly assessed in each stream's HUA Attainment model, the model setup included those sources' inputs set to reflect their assigned HUA portion; comparison of the Attainment scenario to the Background scenario results thus explicitly assessed the cumulative thermal impacts of those specific sources attaining their assigned TMDL allocations. In the Rogue River HUA Attainment model, for example, the discharge flows and temperatures of each NPDES permittee in the model extent were the same as in the Rogue River WLA scenario. Likewise, model tributary

inputs were the same as in the Rogue River Tributary Temperatures scenario. All other Rogue River Attainment scenario inputs were identical to those of the Background scenario.

4.11.2 Cumulative HUA attainment assessment

Results of this scenario were also used to assess attainment of the total (sum) assigned portion of the maximum allowable HUA (0.3°C). The assigned portion of the HUA is equal to the sum assigned to all categories not including Reserve Capacity; another way to say this is that the assigned portion of the HUA is equal to 0.3°C minus the amount held for Reserve Capacity.

Thermal source categories that were not *explicitly* included in the Attainment scenario were *implicitly* included in this cumulative HUA attainment assessment. If these sources were assigned part of the HUA for a given modeled stream, then the target maximum temperature difference for the stream was adjusted accordingly. That is, the target maximum temperature difference between the HUA Attainment and Background scenarios for that stream equaled 0.3°C minus the Reserve Capacity minus the sum of implicitly included assignments. So, if warming due to solar loading from existing infrastructure and warming from consumptive uses were not assessed by comparison of the HUA Attainment scenario to the Background scenario results, but each category was assigned a categorical HUA of 0.05°C, and 0.05°C was held for RC, then the target maximum temperature difference between the HUA Attainment and Background scenarios was 0.3°C – 0.05°C (infrastructure) – 0.05°C (consumptive uses) – 0.05°C (reserve capacity) = 0.15°C. Section 9.1 of the main TMDL provides the category-specific HUA assignments for each AU in the TMDL scope. The results of the cumulative HUA attainment assessment for each modeled stream are presented in Section 5 of this appendix.

5 Model scenario results

Ten different comparisons were made using both the calibration and background scenarios. Each comparison scenario was designed to address a specific question. The questions or topics addressed by each comparison scenario are summarized in Table 5-1. Not all scenarios and comparisons were completed for all modeled rivers; e.g., if there were no permitted point sources on a given modeled stream, then that stream did not have a “No point source” scenario developed. See Section 5.2 through Section 5.12 for the comparisons and results specific to each modeled stream.

Table 5-1: Rogue River Temperature TMDL scenarios: explanation of comparisons.

Scenario baseline	Scenario comparison	Question/topic addressed
Calibration	No point source	Effect of NPDES-permitted point source discharges.
Calibration	No dams	Effect of existing dams and reservoir operations.
Calibration	Restored vegetation	Effect of fully restored vegetation along the model mainstem.
Calibration	Topographic shade	Effect of shade produced by topographic features only.
Calibration	Restored flow	Effect of maintaining water withdrawals as instream flow.
Calibration	Hyporheic	Effect of pre-development hyporheic flow exchange conditions.
Background	Calibration	Effect of anthropogenic sources that were quantified and represented in the model.
Background	Tributary temperatures	Effect of model tributary temperatures increased by their respective TMDL allocations.
Background	Wasteload allocations	Effect of point source discharges at WLA levels.
Background	HUA attainment	Effect of point and nonpoint sources set at their respective TMDL HUA allocations.

5.1 Analysis and interpretation methods

5.1.1 Significant digits and rounding

The TMDL analysis and interpretation of all model and scenario results accounted for significant digits and rounding. To evaluate human use allowance (HUA) attainment, DEQ calculates and records values to the hundredths (0.01°C). Because DEQ assigns some source sector HUAs to the hundredths, attainment is tracked with equal precision. The TMDL analysis follows the rounding procedures outlined in a DEQ permit-related internal management directive (IMD) on rounding and significant digits (DEQ, 2013b). This IMD says that for "calculated values" (which includes model results), if the digit being dropped is a "5," it is rounded up. For example, if an HUA allocation is set at 0.05°C and the model shows warming equal to 0.054°C, the value is rounded down to 0.05°C and the result is attainment. If the model shows warming equal to 0.055°C, the value is rounded up to 0.06°C and the result is non-attainment.

5.1.2 Calculating the 7-Day Average Daily Maximum temperature

For each scenario the 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 this IMD, the 7DADM temperature is calculated by (i) calculating the daily maximum for each day and each location, then (ii) calculating a 7-day rolling average of the daily maximums, the result for which lands on the 7^{th} day and is considered the 7DADM for that day. Following transition to a new fish use designation (such as spawning), the first day that the 7DADM is reported occurs on the 7^{th} day after the new fish use designation begins. For example, if spawning begins October 15, the first 7-day period would be October 15 to 21, with the first 7DADM temperature reported on October 21.

5.1.3 Comparing temperature between two scenarios

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

1. Calculate the 7DADM or daily maximum temperatures for scenario 1 at every model output location for every day of the model period.

2. Calculate the 7DADM or daily maximum temperatures for scenario 2 at every model output location for every day of the model period.

3. For allocation scenarios, the HUA is defined as the maximum allowable increase above the applicable biologically-based numeric criteria (BBNC). Thus, to determine the maximum temperature change in relation to HUAs, only days when the BBNC was exceeded were considered and thus days when 7DADM or daily maximum river temperatures did not exceed the BBNC were excluded. Note that the BBNC varied spatially and temporally and this was accounted for in the assessment.

4. Compute the difference between the 7DADM or daily maximum temperatures of scenario 1 and scenario 2 only for days when one or both scenarios exceed the BBNC.

5. Round the differences to two decimals Celsius, based on the adopted rounding procedure discussed in Section 4.1.1.

The 7DADM is the preferred temperature metric for comparing two scenarios. If the model period or available data were less than 7 days, the daily maximum temperature metric was used instead. It was assumed that the daily maximum temperatures approximate 7DADM results.

5.1.4 Calculating change in temperature

On unmodeled streams, a mass balance approach utilizing Equation 5-1 and Equation 5-2 was used to assess cumulative warming and HUA assignments for point sources and tributary sources. This approach does not assume instream heat dissipation, so the cumulative warming result is the sum total of calculated temperature increases from all sources combined.

$\Delta T_{ps} = \left(\frac{Q_E}{Q_E + Q_R}\right) \cdot (T_E - T_C)$	***Equation 5-1***
where,	
$\Delta T_{ps} =$	The river temperature increase (°C) above the applicable criterion using 100% of river flow.
$Q_E =$	The daily mean effluent flow (cfs). When effluent flow is in million gallons per day (MGD) convert to cfs: $\frac{1 \text{ million } gallons}{1\ day} \cdot \frac{1.5472\ ft^3}{1 \text{ million gallons}} = 1.5472$
$Q_R =$	The daily mean river flow rate, upstream (cfs). When river flow is <= 7Q10, Q_R = 7Q10. When river flow > 7Q10, Q_R is equal to the daily mean river flow, upstream.
$T_E =$	The daily maximum effluent temperature (°C)
$T_C =$	The point of discharge applicable river temperature criterion (°C)
$T_{up} =$	The river temperature upstream of a tributary inflow (°C).

$\Delta T_R = \left(\frac{Q_{in}}{Q_{in} + Q_{up}}\right) \cdot (T_{in} - T_{up})$	***Equation 5-2a***
$T_{mix} = T_{up} + \left(\frac{Q_{in}}{Q_{in} + Q_{up}}\right) \cdot (T_{in} - T_{up})$	***Equation 5-2b***
where,	
$\Delta T_R =$	The river temperature change (°C) after complete mixing with a tributary inflow.
$T_{mix} =$	The river temperature (°C) downstream after complete mixing with a tributary inflow.
$Q_{in} =$	The flow rate of the tributary inflow (cfs).
$Q_{up} =$	The river flow rate upstream of the tributary inflow (cfs).
$T_{in} =$	The temperature of the tributary inflow (°C).
$T_{up} =$	The river temperature upstream of the tributary inflow (°C).

5.2 Antelope Creek

Table 5-2 describes the different model scenarios used to simulate stream temperature and effective shade for Antelope Creek. Table 5-3 and Figure 5-1 summarize the maximum predicted 7DADM stream temperatures for all model scenarios over the entire model period end extent.

Table 5-2: Antelope Creek model scenario descriptions.

Scenario Name	Description
Restored Vegetation	Evaluates stream temperature and shade responses with fully restored near-stream vegetation.
Topographic Shade	Evaluates stream temperature and shade responses with no near-stream land cover.
Restored Flow	Evaluates stream temperature responses with all consumptive use withdrawals removed. For Antelope Creek, OWRD reported 2.5 cfs total withdrawal. Thus, boundary condition flows were increased by 2.5 cfs in this scenario.
Tributary Temperatures	Evaluates stream temperature responses with fully restored near-stream vegetation, all consumptive use withdrawals removed, and tributary temperatures increased by the total HUA allocations on those tributaries; Dry Creek and Quarter Branch temperatures were both increased by 0.175°C.
HUA Attainment	Identical to the Tributary Temperatures scenario for Antelope Creek.
Background	Evaluates stream temperature responses with consumptive uses removed, fully restored near-stream vegetation, and model headwater temperatures decreased to account for upstream riparian disturbance. The boundary condition headwater temperature was set to S. Fork Little Butte Creek measurements (upstream of Beaver Dam Cr.), which is in an adjacent watershed, at a point of minimum upstream disturbance. The boundary condition headwater flow was increased by 2.5 cfs to simulate removal of consumptive uses. No other adjustments were made.

Table 5-3: Antelope Creek: summary of maximum 7DADM stream temperatures for all model scenarios over the entire model extent.

Scenario	Max. 7DADM temp., mouth (°C)	Max. 7DADM temp., POMI (°C)	POMI (model km)
Current Condition	26.18	31.08	8.3
Restored Vegetation	20.45	23.26	10.1
Topographic Shade	29.87	33.79	7.9
Restored Flow	25.14	27.06	8.3
Attainment	18.32	18.32	0.0
Background	18.29	18.29	0.0

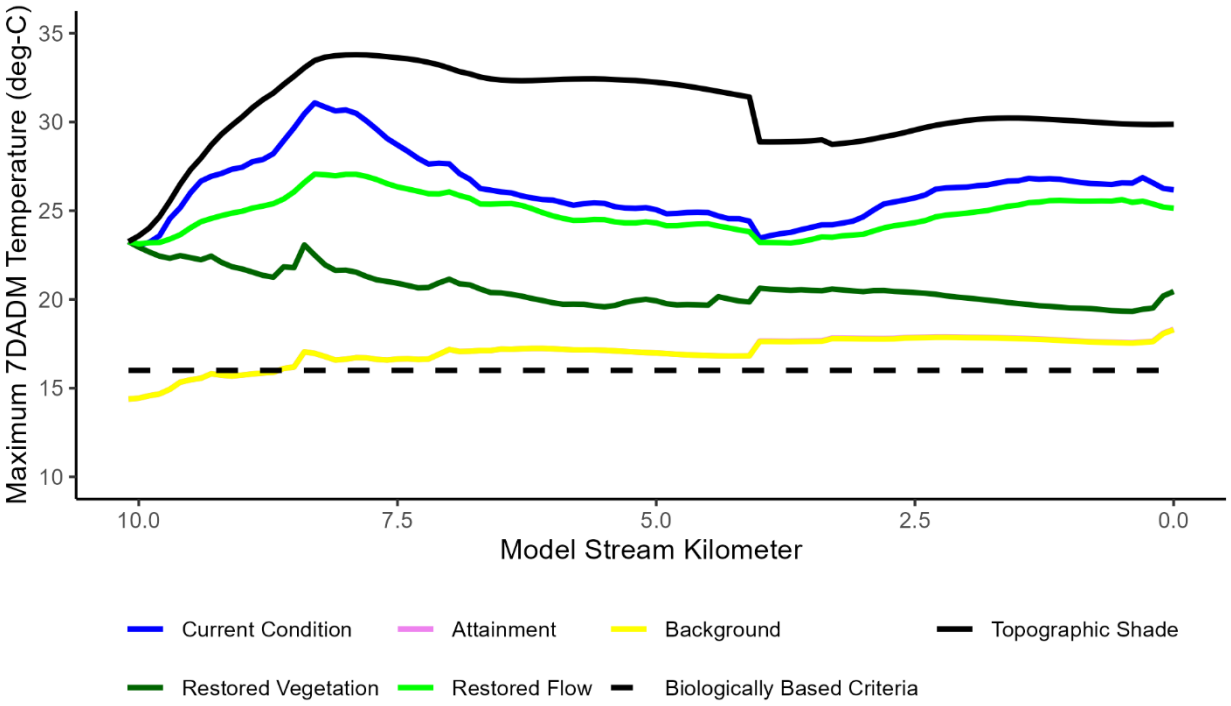


Figure 5-1: Antelope Creek: maximum 7DADM stream temperature, all model scenarios.

5.2.1 Vegetation scenarios

This section summarizes the temperature impacts of current vegetation conditions, restored vegetation conditions, and topographic shading.

Table 5-4 and Figure 5-2 summarize the maximum 7DADM stream temperature changes between the Antelope Creek Current Condition and Restored Vegetation scenarios over the entire model period and extent. The maximum 7DADM temperature difference was 6.22°C at the most downstream node (the mouth) and 10.79°C at the POMI (model km 8.3).

Table 5-4: Antelope Creek: maximum 7DADM stream temperature change between Restored Vegetation and Current Condition model scenarios over the entire model period.

Model km	Stream temperature change (°C)	Location
0	6.22	Outlet
8.3	10.79	POMI



Figure 5-2: Antelope Creek: maximum 7DADM stream temperatures changes between Current Condition and Restored Vegetation scenarios over the entire model period when scenario temperatures exceed the BBNC.

Table 5-5 and Figure 5-3 summarize the maximum Antelope Creek 7DADM stream temperature changes between the Current Condition and Topographic Shade scenarios over the entire model period and extent. The maximum 7DADM temperature difference was 4.25°C at the most downstream node (the mouth) and 10.12°C at the POMI (model km 5.2).

Table 5-5: Antelope Creek: maximum 7DADM stream temperature change between Topographic Shade and Current Condition model scenarios over the entire model period.

Model km	Stream temperature change (°C)	Location
0	4.25	Outlet
5.2	10.12	POMI

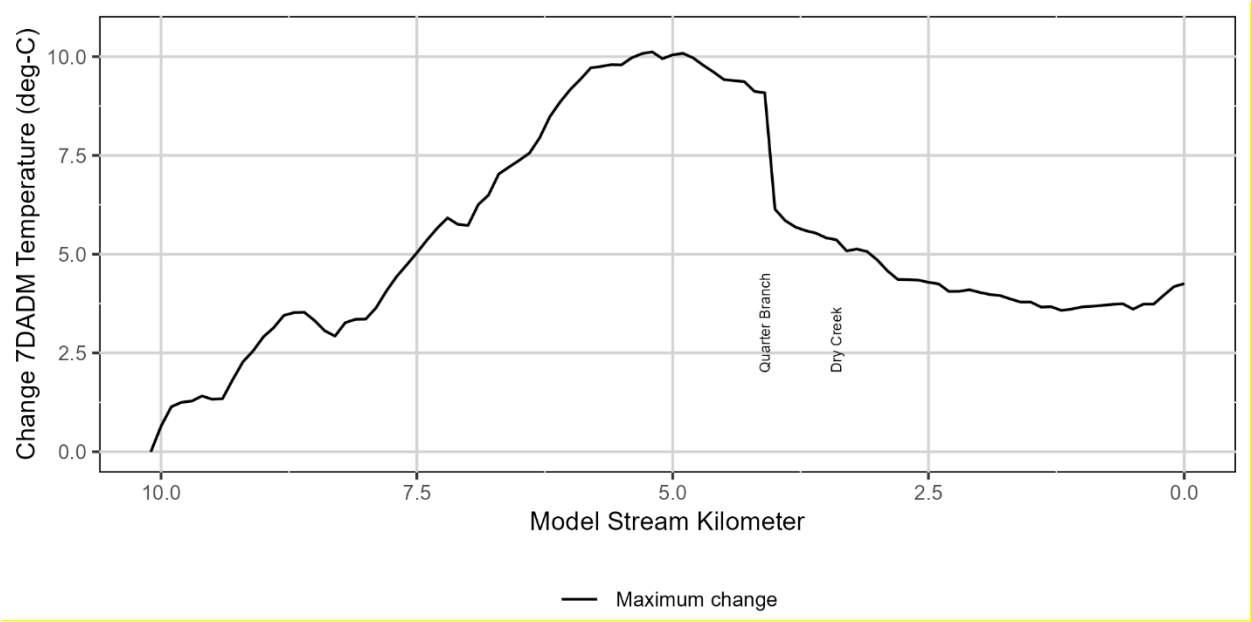


Figure 5-3: Antelope Creek: maximum 7DADM stream temperature change between Topographic Shade and Current Condition scenarios over the entire model period when temperatures exceed the BBNC.

Table 5-6 summarizes the mean effective shade for the Antelope Creek Current Condition, Restored Vegetation, and Topographic Shade scenarios. The mean effective shade difference between the Current Condition and Restored Vegetation scenarios is 40%.

For Antelope Creek, Figure 5-4 and Figure 5-5 compare effective shade predictions for the Current Condition and Restored Vegetation scenarios, while Figure 5-6 shows the predicted effective shade differences (gaps) between the Current Conditions and Topographic Shade scenarios. Figure 5-7 shows the shade gaps between the Restored Vegetation and Current Condition scenarios along the mapped model extent.

Table 5-6: Antelope Creek: Mean effective shade summaries for the Current Condition, Restored Vegetation, and Topographic Shade scenarios.

Scenario	Mean effective shade (%)
Current Condition	42
Restored Vegetation	82
Shade Gap (Restored – Current)	40
Topographic Shade	2

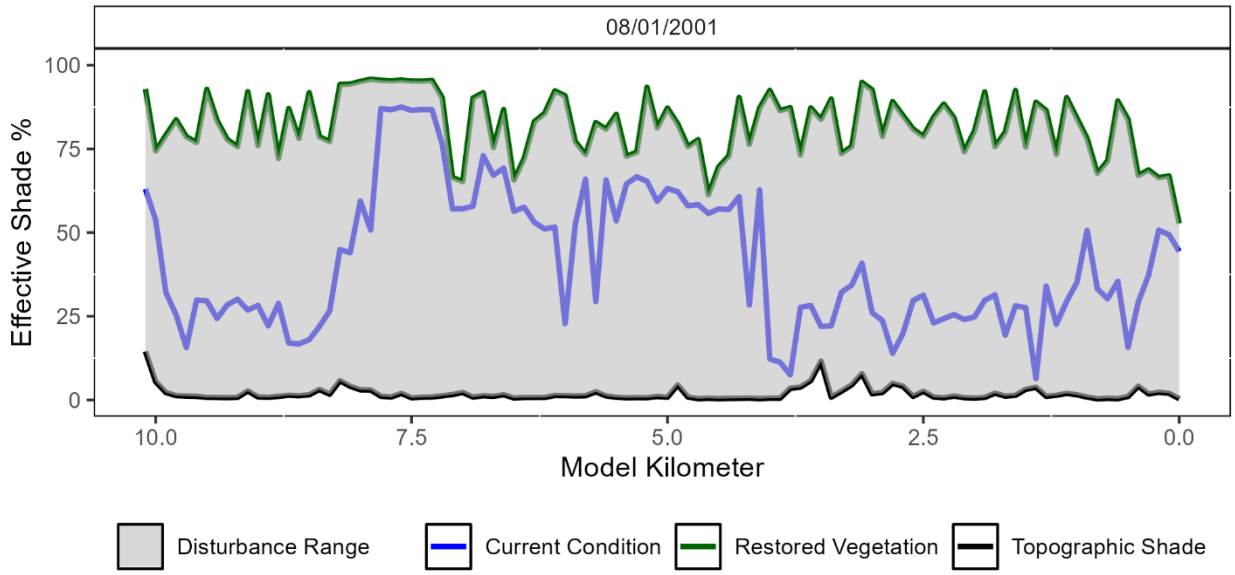


Figure 5-4: Antelope Creek: Effective shade comparisons among the Restored Vegetation, Current Condition, and Topographic Shade scenarios.

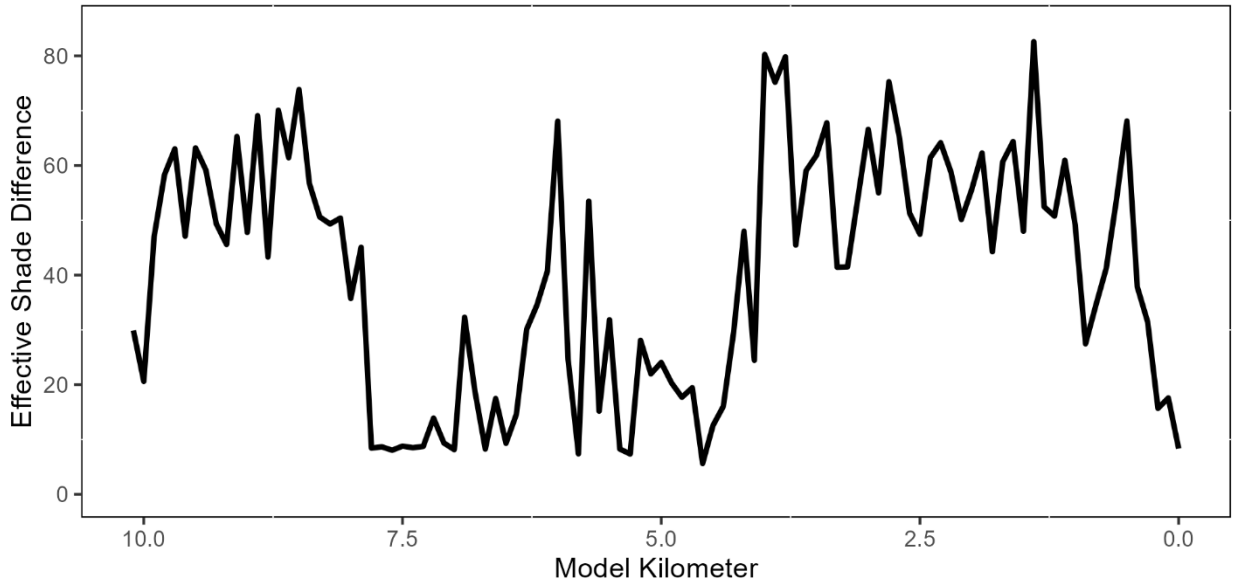


Figure 5-5: Antelope Creek: Effective shade differences (%) between Restored Vegetation and Current Condition scenarios.

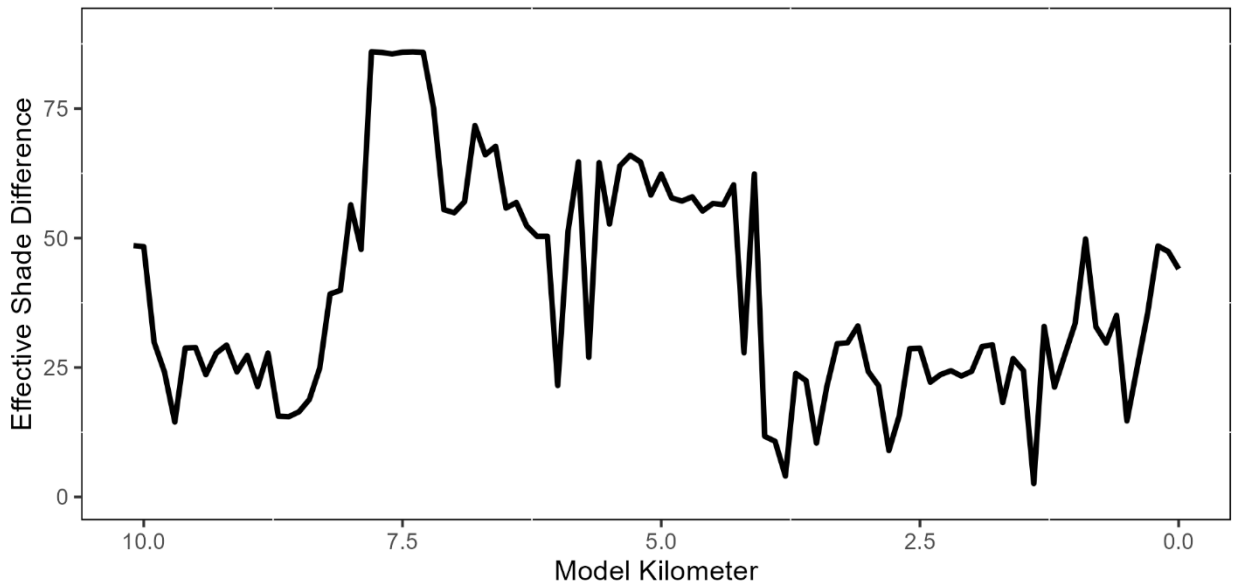


Figure 5-6: Antelope Creek: Effective shade differences (%) between Current Condition and Topographic Shade scenarios.

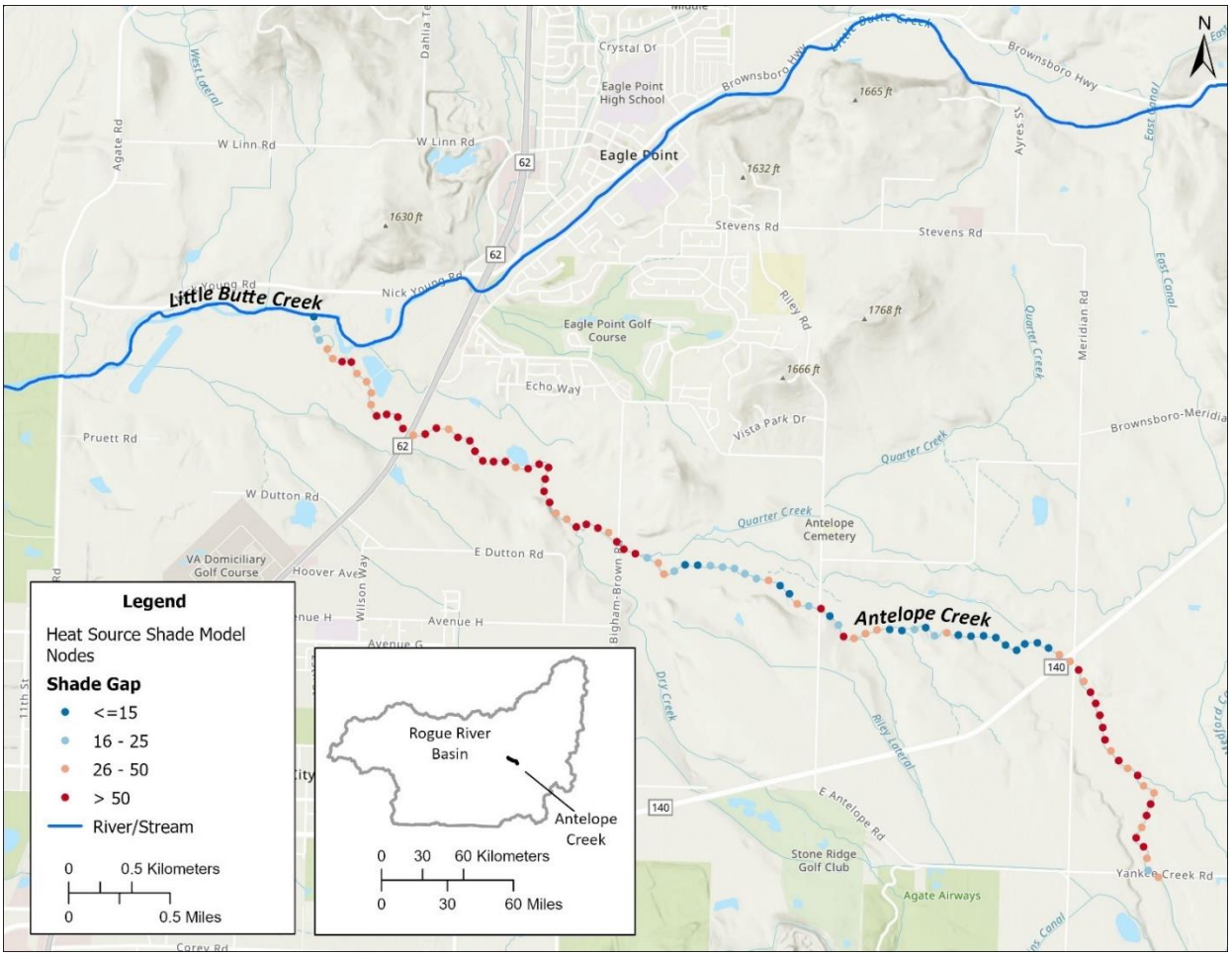


Figure 5-7: Antelope Creek shade gaps (%) between the Restored Vegetation and Current Condition scenarios.

5.2.2 Restored flow

This section summarizes the temperature impacts of restored flow conditions. Table 5-7 and Figure 5-8 summarize the maximum 7DADM stream temperature changes between the Current Condition and Restored Flow scenarios for Antelope Creek over the entire model period and extent when the temperatures exceeded the BBNC. The maximum 7DADM temperature differences were 1.36°C at the most downstream node (the mouth) and 4.25°C at the POMI (model km 8.3).

Table 5-7: Antelope Creek: Maximum 7DADM stream temperature changes between Current Condition and Restored Flow model scenarios over the entire model extent.

Model km	Stream temperature change (°C)	Location
0	1.36	outlet
8.3	4.25	POMI

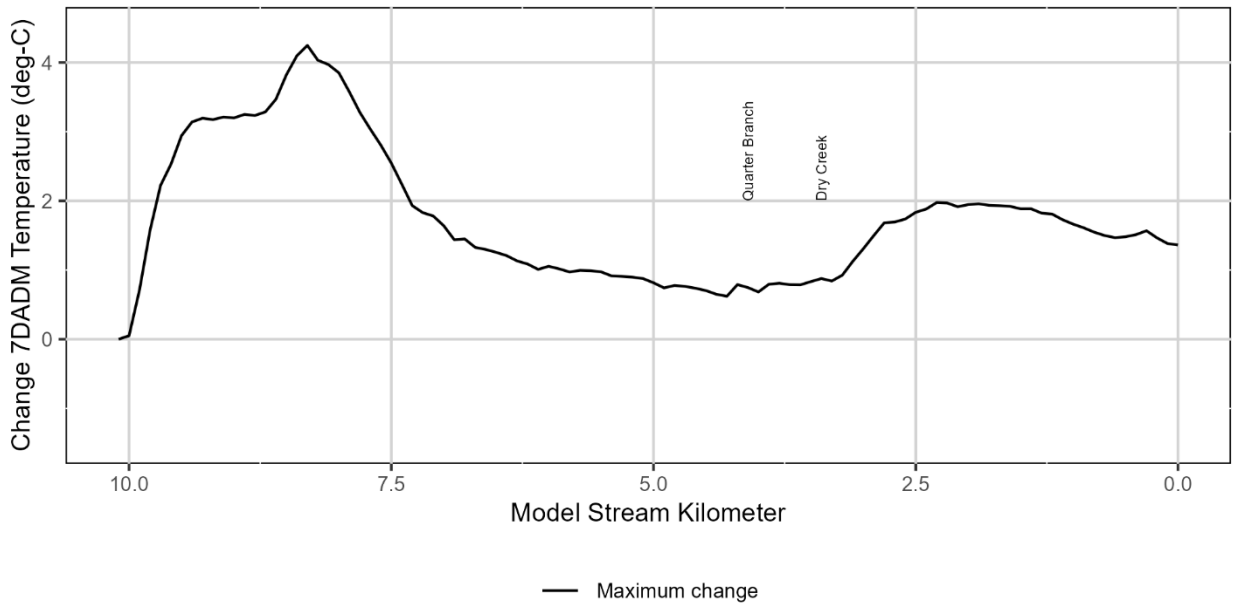


Figure 5-8: Antelope Creek: Maximum 7DADM stream temperature changes between the Current Condition and Restored Flow scenarios over the model extent when temperatures exceed the BBNC.

5.2.3 Tributary temperatures

For Antelope Creek, the Tributary Temperatures and HUA Attainment scenarios' results were identical because the models were identical. Refer to Section 5.2.4 for the Tributary Temperatures scenario results. Table 5-8 shows the HUA portion assigned to thermal sources on each Antelope Creek tributary included in the HUA Attainment analysis.

Table 5-8: Antelope Creek model tributaries: HUA assignments to thermal sources.

Tributary name	HUA portion assigned to thermal sources (°C)
Dry Creek	0.175
Quarter Branch Creek	0.175

5.2.4 HUA Attainment

This section summarizes the temperature impacts to Antelope Creek of the proposed thermal allocations on the mainstem and its tributaries. The HUA Attainment scenario determines if the modeled thermal sources together achieve their total (sum) allocated portion of the HUA. To determine this, results from the HUA Attainment and the Background scenarios were compared to ascertain if the maximum temperature difference was within a maximum target difference.

Table 5-9 describes the HUA Attainment model scenario set-up. Table 9-5 of the main TMDL includes the category-specific HUA assignments for Antelope Creek. Some source categories were explicitly assessed by the model comparison; i.e., the two scenarios had different setups for these categories (i.e., tributary temperatures). Other sources were not explicitly assessed by the model comparison; for these categories, the two scenarios had identical setups, but the maximum target difference was reduced by each category's applicable categorical HUA assignment. For example, consumptive use water withdrawals were identical in the two scenarios, but the HUA assignment (0.5C) was accounted for by reducing the target maximum difference accordingly (by 0.5°C).

Table 5-9: Antelope Creek HUA Attainment model scenario set up description.

Model input variable	HUA Attainment scenario set up description
Riparian landcover	Equal to Background scenario (restored vegetation conditions).
Tributary temperatures	Hourly tributary temperatures were increased by the assigned allocations on each tributary; Dry Creek and Quarter Branch temperatures were both increased by 0.175°C.
Tributary flow	Equal to Background scenario tributary flows.
Boundary condition temperature	Equal to Background scenario boundary condition temperatures.
Boundary condition flow	Equal to Background scenario boundary condition flows.
Withdrawals	Equal to Background scenario withdrawals.
NPDES point sources	No NPDES point source discharges are in the model extent (equal to Background scenario).
Nonpoint source dam and reservoir operations	No dam or reservoir operations are in the model extent (equal to Background scenario).
Solar loading from existing infrastructure	Not modeled, though this source is assigned an allocation.

Table 5-10 and Figure 5-9 summarize the maximum 7DADM stream temperature changes between the Antelope Creek Background and HUA Attainment scenarios over the entire model period and extent. The maximum 7DADM temperature difference was 0.035°C at the most downstream node (the outlet) and 0.042°C at the POMI (model km 3.3).

Table 5-10: Antelope Creek: Maximum 7DADM temperature change between Background and HUA Attainment model scenarios for over the model extent.

Model km	Stream temperature change (°C)	Location
0	0.035	Outlet
3.3	0.042	POMI

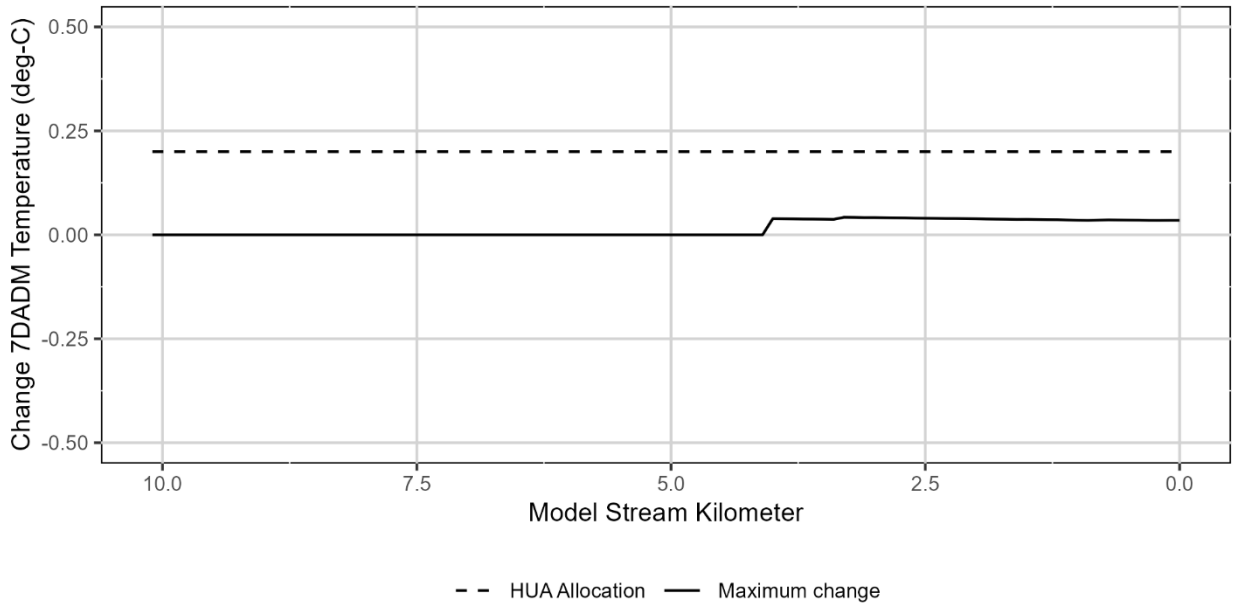


Figure 5-9: Antelope Creek: Maximum 7DADM stream temperature changes between the Background and HUA Attainment scenarios over the model period when temperatures exceed the BBNC.

For Antelope Creek, the HUA Attainment scenario and Background scenario results comparison shows that tributaries warm the mainstem by 0.042°C (max. 7DADM). Thus, the TMDL allocation to warming from tributaries on Antelope Creek is 0.042°C. For Antelope Creek, the total allocation to all thermal source categories is 0.092°C; the remainder of the maximum allowable HUA (0.3°C) is assigned to Reserve Capacity (0.208°C). This analysis indicates that the HUA portion assigned to modeled sources will be achieved on Antelope Creek and that all assessed anthropogenic sources plus reserve capacity will not exceed the maximum allowable cumulative 0.3°C HUA.

5.2.5 Background

This section summarizes the temperature impacts of background conditions. Table 5-11 and Figure 5-10 summarize the maximum 7DADM stream temperature changes between the Current Condition and Background scenarios for Antelope Creek over the entire model period and extent. The maximum 7DADM temperature difference between these scenarios was 8.39°C at the most downstream node (the mouth) and 15.54°C at the POMI (model km 8.3). Table 5-12 summarizes the maximum 7DADM stream temperature change between the Background scenario and the BBNC. The greatest 7DADM temperature difference between the Background scenario and the BBNC was 2.29°C at the most downstream outlet (the mouth), which was also the POMI.

Table 5-11: Antelope Creek: Maximum 7DADM stream temperature change between Background and Current Condition model scenarios over the entire model period.

Model km	Stream temperature change (°C)	Location
0	8.39	Outlet
8.3	15.54	POMI

Table 5-12: Antelope Creek: Maximum 7DADM stream temperature change between the Background model scenario and BBNC over the entire model period.

Model km	Stream temperature change (°C)	Location
0	2.29	Outlet
0	2.29	POMI

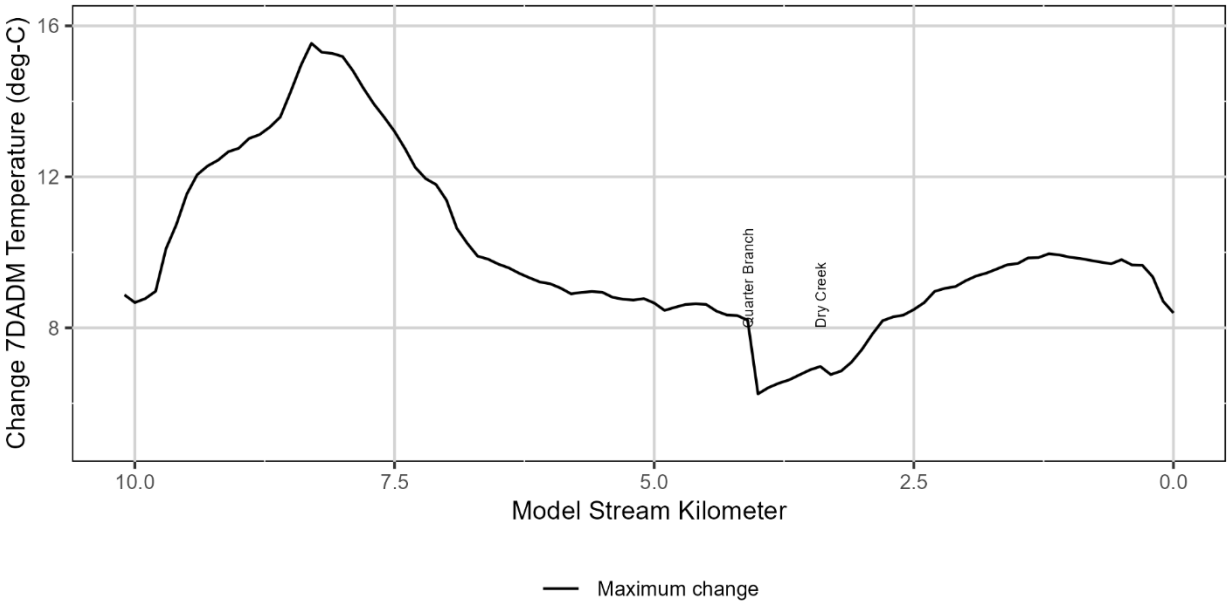


Figure 5-10: Antelope Creek: Maximum 7DADM stream temperature changes between the Background and Current Condition model scenarios over the model extent when scenario temperatures exceed the BBNC.

5.3 Applegate Subbasin

5.3.1 Williams Creek, Star/Boaz, Beaver, Palmer, Powell, Little Applegate, Glade, Sterling, and Yale Creeks

The following tables display the SHADOW model results for Williams Creek watershed (Table 5-13**),** the Applegate-Star/Boaz watershed (Table 5-14**),** the Beaver-Palmer watersheds (Table 5-15), Sterling Creek (Table 5-16**),** and Yale, Little Applegate, Sterling, and Glade Creeks (Table 5-17).

Table 5-13: Williams Cr. watershed summary: Solar TMDL as percent shade (all reaches).

Stream	Area (ac) / % above stream[1]	Existing shade[2] (%)	Restored shade[2] (%)	Shade gap (%)	Years to recovery [2]	Pvt land non-fish stream (mi.)	Pvt land non-fish stream (%)	Disturbance[3]
Williams Ck (mouth to Forks)	20,600 / 40	56	73	17	6			Ag; roads; unstable banks
Powell	7,625 / 15	71	90	19	66			Ag: hvst/road
Wallow	1,225 / 32	92	96	4	65			
Honeysuckle	825 / 17	91	91	3	81			
West Fork Williams	21,375 / 68	75	85	10	64	0.8	1.1	Ag: hvst

Stream	Area (ac) / % above stream[1]	Existing shade[2] (%)	Restored shade[2] (%)	Shade gap (%)	Years to recovery [2]	Pvt land non-fish stream (mi.)	Pvt land non-fish stream (%)	Disturbance[3]
Munger	4,600 / 27	83	93	10	78			Ag: hvst/road
North Fork Munger	725 / 41	76	92	16	80			Hvst
Goodwin	725 / 6	89	96	7	67	0.5	0.7	Hvst/road
Lone	1,400 / 14	89	96	7	78	0.4	0.5	Hvst
Tree Branch	525 / 40	88	94	6	83	1.3	1.8	Hvst/road
Bill	5,950 / 71	76	95	21	87	0.3	0.4	Hvst/road
Rt. Hand Fk, WF Williams	2,250 / 27	87	92	5	88			Hvst
Bear Wallow	1,350 / 28	80	95	15	88	0.8	1.1	Hvst/road
East Fork Williams	9,975 / 32	85	91	6	45			Ag; unstable banks; hvst/road
Clapboard	1,625 / 17	91	93	2	69	0.8	1.1	Hvst
Sugarloaf	725 / 54	89	95	6	73	0.8	1.1	Hvst/road
Rock	3,275 / 45	87	92	5	66	0.8	1.1	Hvst/road
Rt Hand Fk, Rock	975 / 42	89	97	8	70			Hvst/road
Glade	1,075 / 31	94	97	3	35			Hvst/road
Basin totals	~ 52,000	80	90	10	63	5.8	7.6	

1 – Area of sub-watershed / percentage of sub-watershed area relative to the remaining Williams Creek drainage above this tributary.
2 – Calculated by averaging reach values weighted by reach length.
3 – Disturbance: noted if it has a negative effect on present or future riparian vegetation.
Ag: Harvest (hvst): within 100' of stream on non-federal land or 300' on federal land.
Roads: riparian roads that parallel the stream for any distance (not stream crossings).

Table 5-14: Applegate-Star/Boaz watershed summary, Solar TMDL as percent shade (all reaches).

Stream	Area (ac) / % above stream[1]	Existing shade[2] (%)	Restored shade[2] (%)	Shade gap (%)	Years to recovery [2]	Pvt land non-fish stream (mi.)	Pvt land non-fish stream (%)	Disturbance[3]
Applegate River		8	41	33	37	0	0	Highway/roads, rural residential, ag/pasture, harvest
Star Gulch	10830/ 87[4]	60	86	26	74	0	0	Harvest, roads, rural residential, highway
Benson Gulch	715/ 8	64	94	30	103	0	0	Harvest
Lightning Gulch	1330/ 17	82	93	11	59	0	0	Harvest, roads
1918 Gulch	640/ 11	62	90	28	83	0	0	Harvest, roads
1917 Gulch	210/ 5	63	89	26	76	0	0	Harvest, roads
Ladybug Gulch	925/ 23	70	92	22	125	0	0	Harvest, roads
Alexander Gulch	705/ 24	75	92	17	72	0	0	Harvest, roads
Deadman Gulch	235/12	94	97	3	40	0	0	No disturbance
Applegate-Star/Boaz Watershed	**17,651**	**65**	**86**	**21**	**73**	**0**	**0**	

Stream	Area (ac) / % above stream[1]	Existing shade[2] (%)	Restored shade[2] (%)	Shade gap (%)	Years to recovery [2]	Pvt land non-fish stream (mi.)	Pvt land non-fish stream (%)	Disturbance[3]

1 – Watershed considered is from the Little Applegate River to just above China Gulch (Sect 33 T39S R2W).
2 – Calculated by averaging reach values weighted by reach length.
3 – Disturbance: noted if it has a negative effect on present or future riparian vegetation.
Harvest, pasture, rural residential: within 100' of stream on non-federal land or 300' on federal land.
Roads: riparian roads that parallel the stream for any distance, generally for forest or local access.
Highway: paved Federal, State, or county routes.
4 – Watershed area of the Applegate River above the Little Applegate River is approximately 200,370 ac. Star Gulch encompasses 6% of this area.

Table 5-15: Beaver-Palmer SHADOW models, Summary of Analysis and Ownership.

Modeled region and ownership	Length (ft)	RM	Ht	Den	Current shade (%)	Restored vegetation shade (%)	Estimated time to recovery (yr)
Applegate River							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	11500	2.2	41.0	35.1	51.4	81.1	141.4
Private	13100	2.5	47.2	46.8	56.6	79.4	134.9
Total	24600	4.7	44.3	41.3	54.2	80.2	137.9
Armstrong Gulch							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	5,400	1.0	80.0	83.3	90.8	93.8	88.7
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5,400	1.0	80.0	83.3	90.8	93.8	88.7
Bailey Gulch							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	8200	1.6	72.6	77.2	94.2	96.8	102.6
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	8200	1.6	72.6	77.2	94.2	96.8	102.6
Bailey Gulch Trib							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	1600	0.3	110.0	90.0	93.0	92.0	33.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	1600	0.3	110.0	90.0	93.0	92.0	33.0
Beaver Cr							
BLM	6200	1.2	87.1	89.5	90.5	91.7	82.2
USFS	24000	4.5	80.9	87.0	84.5	90.2	89.5
Private	13400	2.5	58.2	64.9	76.8	90.8	122.9
Total	43,600	8.3	74.8	80.6	83.0	90.6	98.7
Brushy Gulch							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	9600	1.8	77.5	81.7	95.3	98.0	95.9
Private	600	0.1	25.0	30.0	52.0	98.0	157.0
Total	10200	1.9	74.4	78.6	92.8	98.0	99.5
Charlie Buck Gulch							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	3400	0.6	79.1	90.0	92.5	94.4	80.4
Private	0	0.0	0.0	0.0	0.0	0.0	0.0

Modeled region and ownership	Length (ft)	RM	Ht	Den	Current shade (%)	Restored vegetation shade (%)	Estimated time to recovery (yr)
Total	3400	0.6	79.1	90.0	92.5	94.4	80.4
Hanley Gulch							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	10800	2.0	96.5	86.7	92.2	92.7	59.3
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	10800	2.0	96.5	86.7	92.2	92.7	59.3
Hanley Trib							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	10000	1.9	88.2	83.8	95.0	95.4	80.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	10000	1.9	88.2	83.8	95.0	95.4	80.0
Haskins Gulch							
BLM	400	0.1	100.0	90.0	93.0	92.0	58.0
USFS	9000	1.7	68.1	83.6	91.9	92.0	100.0
Private	2800	0.5	65.7	81.4	90.1	92.0	106.0
Total	12200	2.3	68.6	83.3	91.6	92.0	100.0
Kinney Cr							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	13000	2.5	46.3	64.2	76.4	98.0	130.1
Private	400	0.1	75.0	65.0	90.0	96.0	102.0
Total	13400	2.5	47.2	64.2	76.8	97.9	129.3
Lime Gulch							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	4200	0.8	60.0	65.0	91.0	92.0	121.0
Private	2000	0.4	65.0	70.0	92.0	92.0	115.0
Total	6200	1.2	61.6	66.6	91.3	92.0	119.1
Mule Cr							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	16600	3.1	82.8	66.3	85.8	92.7	87.6
Private	1600	0.3	60.0	30.0	74.0	91.0	121.0
Total	18200	3.4	80.8	63.1	84.8	92.6	90.5
Mule Cr Trib							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	3200	0.6	110.0	80.0	93.0	92.0	33.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	3200	0.6	110.0	80.0	93.0	92.0	33.0
Nine Dollar Gulch							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	2800	0.5	110.0	90.0	93.0	92.0	33.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	2800	0.5	110.0	90.0	93.0	92.0	33.0
Nine Dollar Gulch Trib							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	5200	1.0	110.0	90.0	96.1	95.1	33.0
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5200	1.0	110.0	90.0	96.1	95.1	33.0

Modeled region and ownership	Length (ft)	RM	Ht	Den	Current shade (%)	Restored vegetation shade (%)	Estimated time to recovery (yr)
Palmer Cr							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	28200	5.3	54.8	63.7	80.6	93.9	126.1
Private	1200	0.2	30.0	30.0	45.0	92.0	153.0
Total	29400	5.6	53.7	62.3	79.1	93.8	127.2
Palmer Trib							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	15200	2.9	75.4	84.5	95.7	96.6	99.1
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	15200	2.9	75.4	84.5	95.7	96.6	99.1
Petes Camp Cr							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	1800	0.3	110.0	90.0	93.0	92.0	33.0
Private	7000	1.3	70.6	83.1	90.9	94.4	107.4
Total	8800	1.7	78.6	84.5	91.3	93.9	92.2
Rock Gulch							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	0	0.0	0.0	0.0	0.0	0.0	0.0
Private	1800	0.3	70.0	50.0	86.0	96.0	109.0
Total	1800	0.3	70.0	50.0	86.0	96.0	109.0
Waters Gulch							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	9400	1.8	56.9	50.5	84.5	97.6	121.4
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	9400	1.8	56.9	50.5	84.5	97.6	121.4
Waters Gulch Trib							
BLM	0	0.0	0.0	0.0	0.0	0.0	0.0
USFS	5000	0.9	83.0	55.0	95.0	98.0	90.2
Private	0	0.0	0.0	0.0	0.0	0.0	0.0
Total	5000	0.9	83.0	55.0	95.0	98.0	90.2

Table 5-16: Sterling Cr. SHADOW Model Results. S1 is located at Sterling Creek's headwater and S21 is at the confluence with the Little Applegate River.

Reach	Existing shade (%)	Potential shade (%)	Shade difference (%)	Years to Recovery
S1	51	96	46	50
S2	58	96	38	50
S3	70	89	20	40
S4	87	90	04	20
S5	72	91	19	40
S6	70	93	22	40
S7	79	89	11	25
S8	48	88	40	50
S9	89	91	1	10
S10	79	88	9	30
S11	59	87	28	40
S12	75	88	13	30

Reach	Existing shade (%)	Potential shade (%)	Shade difference (%)	Years to Recovery
S13	87	91	4	20
S14	91	93	2	10
S15	72	88	16	30
S16	64	85	21	30
S17	84	92	9	25
S18	27	87	60	50
S19	27	87	60	50
S20	94	96	2	25
S21	74	85	11	20

Table 5-17: Shadow Model Results by ownership for Little Applegate River, Sterling Creek, Yale Creek, and Glade Creek

Modeled region and ownership	Miles	Height	Density	Current shade (%)	Restored vegetation shade (%)	Shade gap (%)
Little Applegate						
BLM	6.3	89.3	75.5	93.7	95.8	2.1
USFS	10.7	109.7	71.6	92.7	96.2	3.5
Private	18.4	79.3	62.8	87.7	94.8	7.1
Total	**20.1**	**100.6**	**71.7**	**92.9**	**95.9**	**2.9**
Glade Creek						
BLM	0.0	0.0	0.0	0.0	0.0	0.0
USFS	12.0	103.1	67.7	91.7	95.5	3.8
Private	2.8	100.8	70.5	92.6	94.4	1.8
Total	**14.8**	**102.6**	**68.2**	**91.9**	**95.3**	**3.4**
Sterling Creek						
BLM	1.0	70.3	56.8	86.7	94.9	8.2
USFS	0.0	0.0	0.0	0.0	0.0	0.0
Private	12.6	59.2	52.7	85.2	95.7	10.5
Total	**13.6**	**60.0**	**53.0**	**85.3**	**95.6**	**10.3**
Yale Creek						
BLM	3.3	128.3	77.5	98.0	98.2	0.2
USFS	6.3	114.3	69.0	95.5	97.4	1.9
Private	7.5	97.6	72.1	95.6	97.1	1.5
Total	**17.0**	**109.7**	**72.0**	**96.0**	**97.4**	**1.4**

5.3.2 Stream reaches basin not covered by prior sections

In the Applegate TMDL (2007), general effective shade curves were developed for some areas (Figure 5-11) under a method called “Tier 4” analysis in that TMDL. For field use, the user must identify the applicable soil zone (Figure 5-11) and dominant vegetation to identify the appropriate shade curve and restored vegetation height (Table 5-18), and then use a field-measured NSDZ to identify the associated percent shade from the appropriate shade curve (Figure 5-12 through Figure 5-16; tabular data that correspond to the shade curve figures are presented in

Table 5-19, Table 5-20, and Table 5-21). Results based on these SHADOW-based shade curves may differ from results based on Heat Source modeled shade curves presented in the main TMDL.

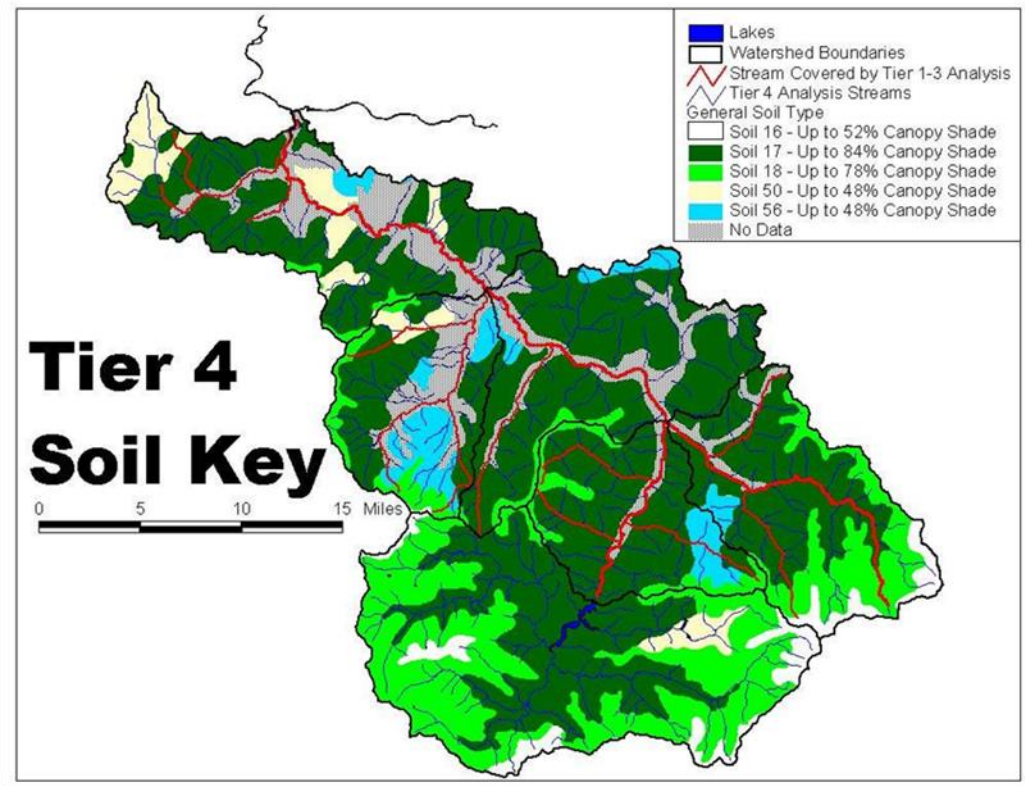


Figure 5-11: Tier 4 SHADOW modeling soil key for relevant Applegate Subbasin areas.

Table 5-18: Shade parameters of Tier 4 areas of Applegate River watershed (see Figure 5-11 map).

Soil type	Typical canopy shade (%)	Dominant species	Species site index	Restored vegetation height (ft)	Shade curve figure
16	52	Douglas Fir	95	105	Figure 5-12
Crannler-Bigelow-Woodseye	52	White Fir	70	130	Figure 5-12
17	84	Douglas Fir	65-94	105-145	Figure 5-13
Beekman-Josephine-Vannoy	84	Ponderosa Pine	75-115	140-190	Figure 5-13
18	78	Douglas Fir	60-95	105-145	Figure 5-14
Jayer-Althouse-Woodseye	78	White Fir	70-80	130	Figure 5-14
50	48	Douglas Fir	76-90	105-145	Figure 5-15
Pearsoll-Dubakella-Cornutt	48	Ponderosa Pine	60	120	Figure 5-15
	48	Jeffery Pine	60	70	Figure 5-15
	48	Incense Cedar	60	95	Figure 5-15
56	48	Douglas Fir	60-110	105-185	Figure 5-16
Tallowbox-Siskiyou-Shefflein	48	Ponderosa Pine	90-114	160-190	Figure 5-16

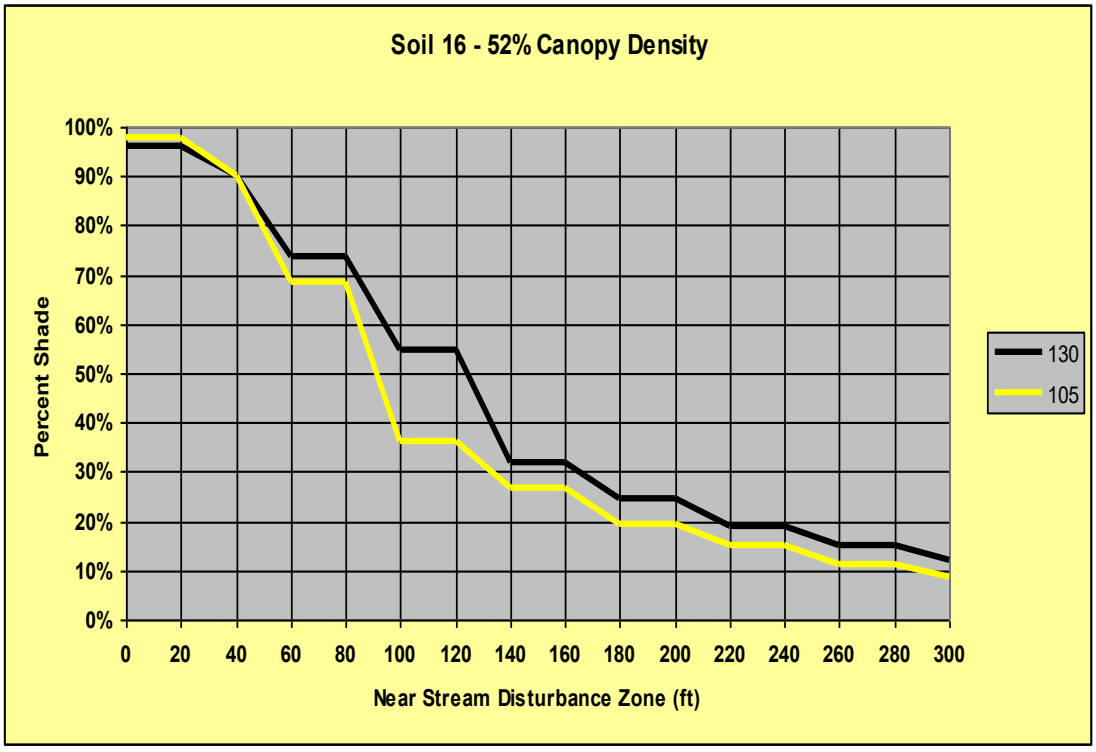


Figure 5-12: Applegate River watershed Tier 4 areas: Soil type 16 shade curve (see Table 5-18).

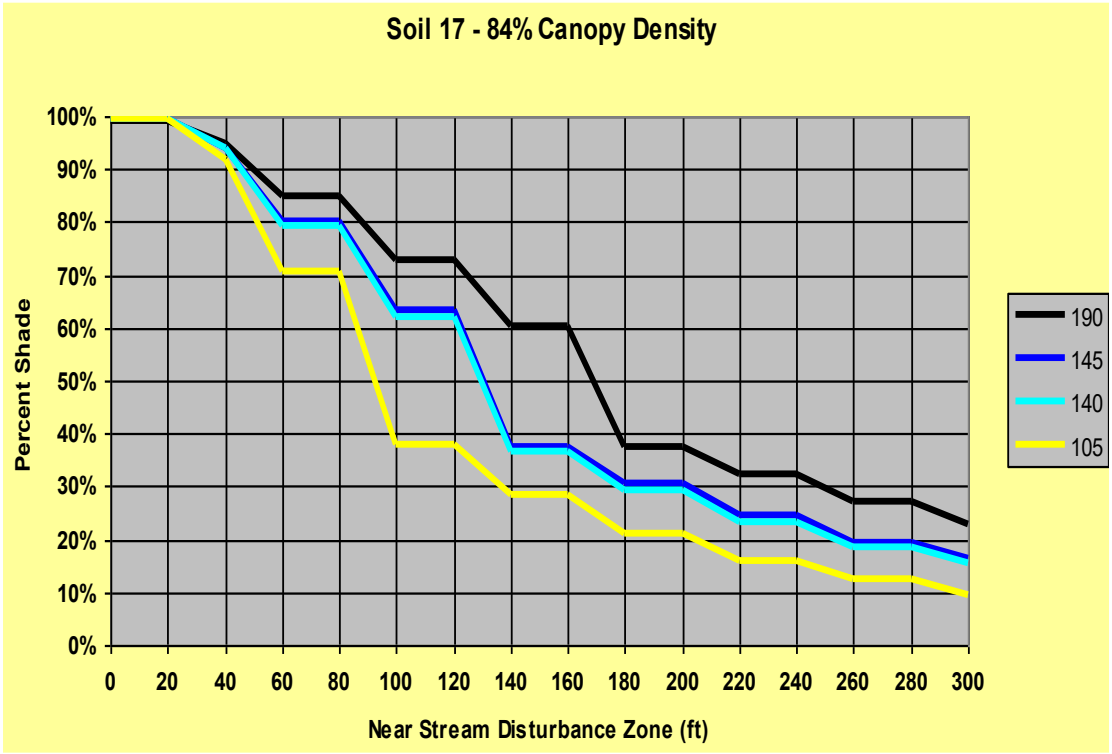


Figure 5-13: Applegate River watershed Tier 4 areas: Soil type 17 shade curve (see Table 5-18).

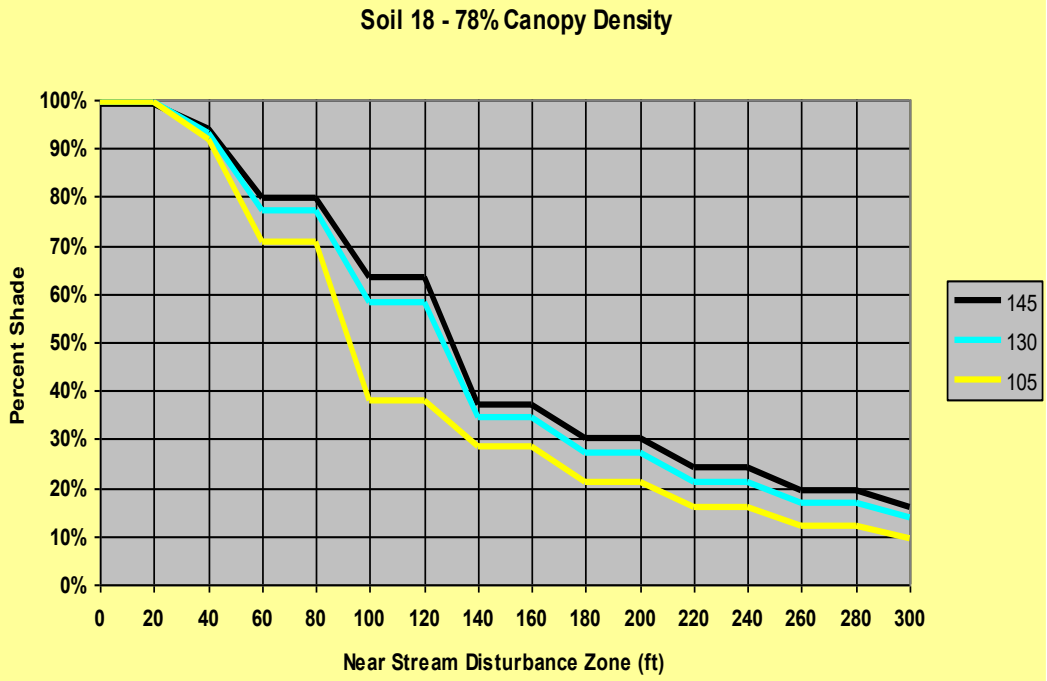


Figure 5-14: Applegate River watershed Tier 4 areas: Soil type 18 shade curve (see Table 5-18)

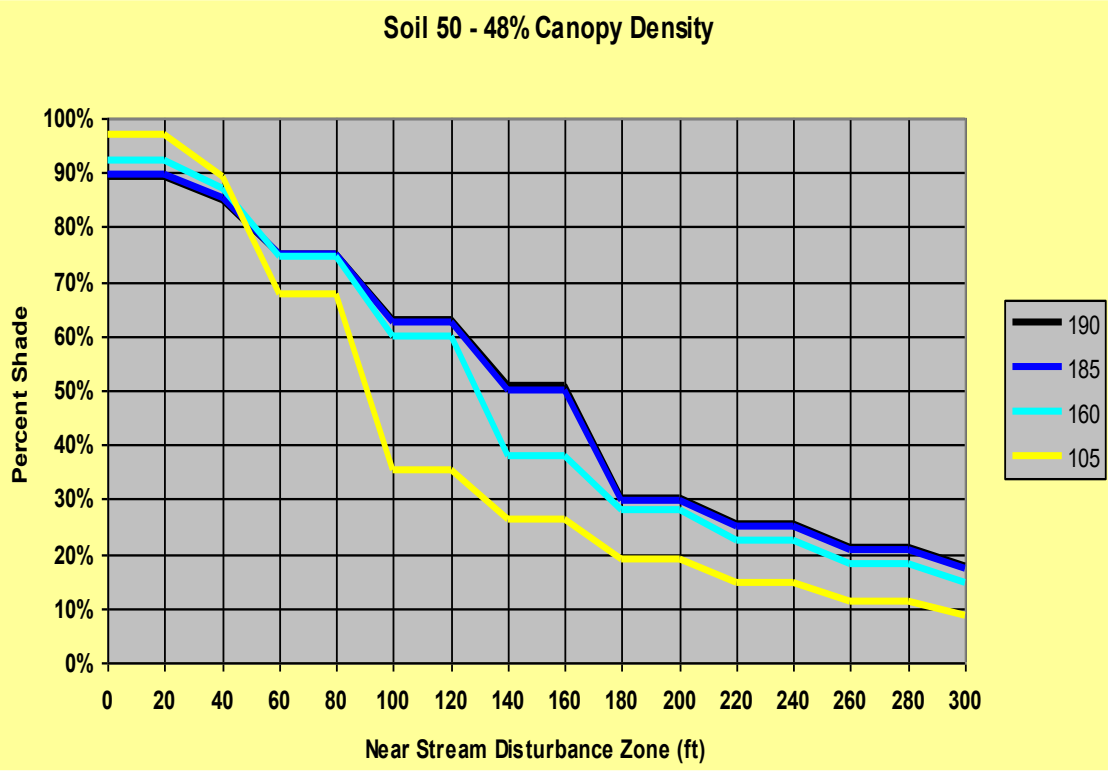


Figure 5-15: Applegate River watershed Tier 4 areas: Soil type 50 shade curve (see Table 5-18)

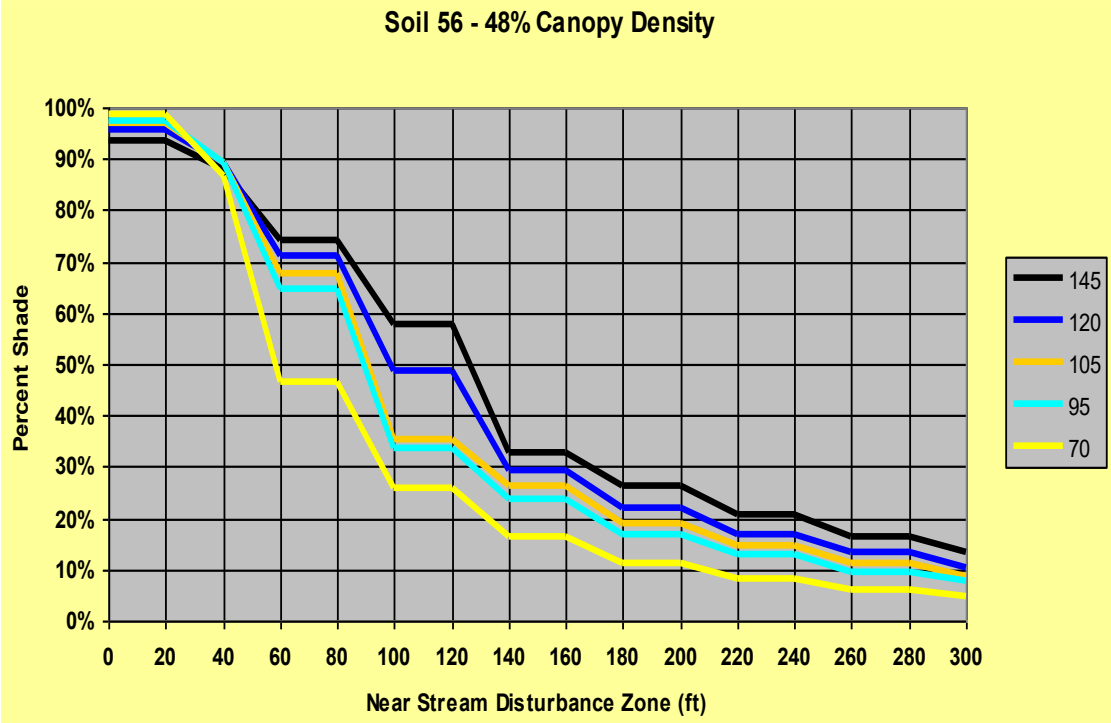


Figure 5-16: Applegate River watershed Tier 4 areas: Soil type 56 shade curve (see Table 5-18).

Table 5-19: Applegate Subbasin SHADOW models: effective shade results for all combinations of soil, vegetation, aspect, and NZDZ.

	Soil Type 16	SP Height 105	SP Density 52	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.5%	97.4%	96.3%	**99.7%**
20	99.5%	97.4%	96.3%	**99.7%**
40	94.5%	88.3%	87.3%	**90.1%**
60	78.4%	58.1%	69.5%	**68.7%**
80	78.4%	58.1%	69.5%	**68.7%**
100	4.7%	49.5%	53.9%	**36.0%**
120	4.7%	49.5%	53.9%	**36.0%**
140	3.7%	35.5%	41.4%	**26.9%**
160	3.7%	35.5%	41.4%	**26.9%**
180	2.9%	24.1%	31.8%	**19.6%**
200	2.9%	24.1%	31.8%	**19.6%**
220	2.4%	17.6%	24.7%	**14.9%**
240	2.4%	17.6%	24.7%	**14.9%**
260	1.9%	12.6%	19.4%	**11.3%**
280	1.9%	12.6%	19.4%	**11.3%**
300	1.4%	9.4%	15.6%	**8.8%**

	Soil Type 17	SP Height 140	SP Density 84	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.5%	99.4%	**99.6%**
20	99.9%	99.5%	99.4%	**99.6%**
40	96.3%	92.7%	92.7%	**93.9%**
60	86.7%	72.0%	79.0%	**79.2%**
80	86.7%	72.0%	79.0%	**79.2%**
100	65.7%	54.3%	66.3%	**62.1%**
120	65.7%	54.3%	66.3%	**62.1%**
140	4.6%	50.8%	55.1%	**36.8%**
160	4.6%	50.8%	55.1%	**36.8%**
180	3.8%	39.1%	45.5%	**29.5%**
200	3.8%	39.1%	45.5%	**29.5%**
220	3.2%	29.4%	37.6%	**23.4%**
240	3.2%	29.4%	37.6%	**23.4%**
260	2.7%	22.3%	31.1%	**18.7%**
280	2.7%	22.3%	31.1%	**18.7%**
300	2.3%	18.2%	25.9%	**15.5%**

	Soil Type 16	SP Height 130	SP Density 52	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	98.8%	95.7%	94.0%	**96.2%**
20	98.8%	95.7%	94.0%	**96.2%**
40	94.8%	88.3%	86.8%	**90.0%**
60	84.0%	65.4%	72.1%	**73.8%**
80	84.0%	65.4%	72.1%	**73.8%**
100	56.3%	49.8%	58.8%	**55.0%**
120	56.3%	49.8%	58.8%	**55.0%**
140	4.3%	43.9%	47.3%	**31.9%**
160	4.3%	43.9%	47.3%	**31.9%**
180	3.5%	32.3%	38.0%	**24.6%**
200	3.5%	32.3%	38.0%	**24.6%**
220	2.9%	23.5%	30.6%	**19.0%**
240	2.9%	23.5%	30.6%	**19.0%**
260	2.5%	17.9%	24.8%	**15.0%**
280	2.5%	17.9%	24.8%	**15.0%**
300	2.1%	14.4%	20.3%	**12.3%**

	Soil Type 17	SP Height 145	SP Density 84	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.5%	99.3%	**99.6%**
20	99.9%	99.5%	99.3%	**99.6%**
40	96.4%	92.9%	92.8%	**94.1%**
60	87.3%	73.1%	79.6%	**80.0%**
80	87.3%	73.1%	79.6%	**80.0%**
100	68.6%	54.6%	67.3%	**63.5%**
120	68.6%	54.6%	67.3%	**63.5%**
140	4.7%	51.3%	56.3%	**37.4%**
160	4.7%	51.3%	56.3%	**37.4%**
180	3.9%	40.7%	46.8%	**30.5%**
200	3.9%	40.7%	46.8%	**30.5%**
220	3.3%	31.0%	38.9%	**24.4%**
240	3.3%	31.0%	38.9%	**24.4%**
260	2.8%	23.5%	32.4%	**19.6%**
280	2.8%	23.5%	32.4%	**19.6%**
300	2.4%	19.1%	27.1%	**16.2%**

	Soil Type 17	SP Height 105	SP Density 84	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.6%	99.6%	**99.7%**
20	99.9%	99.6%	99.6%	**99.7%**
40	94.9%	90.5%	90.6%	**92.0%**
60	78.9%	60.2%	72.7%	**70.6%**
80	78.9%	60.2%	72.7%	**70.6%**
100	4.7%	51.6%	57.1%	**37.8%**
120	4.7%	51.6%	57.1%	**37.8%**
140	3.7%	37.4%	44.3%	**28.5%**
160	3.7%	37.4%	44.3%	**28.5%**
180	2.9%	25.6%	34.4%	**21.0%**
200	2.9%	25.6%	34.4%	**21.0%**
220	2.4%	15.9%	26.9%	**16.1%**
240	2.4%	18.9%	26.9%	**16.1%**
260	1.9%	13.6%	21.4%	**12.3%**
280	1.9%	13.6%	21.4%	**12.3%**
300	1.6%	10.1%	17.2%	**9.6%**

	Soil Type 17	SP Height 190	SP Density 84	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.1%	98.6%	**99.2%**
20	99.9%	99.1%	98.6%	**99.2%**
40	97.2%	94.1%	93.6%	**95.0%**
60	91.0%	80.6%	83.4%	**85.0%**
80	91.0%	80.6%	83.4%	**85.0%**
100	81.7%	63.3%	73.6%	**72.9%**
120	81.7%	63.3%	73.6%	**72.9%**
140	62.5%	53.4%	64.5%	**60.1%**
160	62.5%	53.4%	64.5%	**60.1%**
180	4.7%	51.0%	56.2%	**37.3%**
200	4.7%	51.0%	56.2%	**37.3%**
220	4.1%	43.6%	48.7%	**32.2%**
240	4.1%	43.6%	48.7%	**32.2%**
260	3.6%	35.5%	42.2%	**27.1%**
280	3.6%	35.5%	42.2%	**27.1%**
300	3.2%	28.7%	36.6%	**22.8%**

Table 5-20: Applegate Subbasin SHADOW models: effective shade results for all combinations of soil, vegetation, aspect, and NZDZ (cont.).

	Soil Type 18	SP Height 105	SP Density 78	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.5%	99.4%	**99.6%**
20	99.9%	99.5%	99.4%	**99.6%**
40	94.9%	90.4%	90.5%	**91.9%**
60	78.9%	60.1%	72.6%	**70.5%**
80	78.9%	60.1%	72.6%	**70.5%**
100	4.7%	51.5%	57.0%	**37.7%**
120	4.7%	51.5%	57.0%	**37.7%**
140	3.7%	37.4%	44.2%	**28.4%**
160	3.7%	37.4%	44.2%	**28.4%**
180	2.9%	25.5%	34.3%	**20.9%**
200	2.9%	25.5%	34.3%	**20.9%**
220	2.4%	18.8%	26.8%	**16.0%**
240	2.4%	18.8%	26.8%	**16.0%**
260	1.9%	13.5%	21.3%	**12.2%**
280	1.9%	13.5%	21.3%	**12.2%**
300	1.6%	10.1%	17.2%	**9.6%**

	Soil Type 50/56	SP Height 70	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.7%	98.6%	98.1%	**98.8%**
20	99.7%	98.6%	98.1%	**98.8%**
40	91.9%	82.9%	84.7%	**86.5%**
60	28.4%	51.9%	59.9%	**46.6%**
80	28.4%	51.9%	59.5%	**46.6%**
100	65.7%	33.3%	40.4%	**25.7%**
120	65.7%	33.3%	40.4%	**25.7%**
140	3.5%	19.6%	27.5%	**16.5%**
160	3.5%	19.6%	27.5%	**16.5%**
180	2.5%	11.9%	19.4%	**11.0%**
200	1.8%	11.9%	19.4%	**11.0%**
220	1.3%	8.7%	14.2%	**8.1%**
240	1.3%	8.7%	14.2%	**8.1%**
260	0.9%	7.0%	10.8%	**6.2%**
280	0.9%	7.0%	10.8%	**6.2%**
300	0.6%	5.7%	8.5%	**4.9%**

	Soil Type 18	SP Height 130	SP Density 78	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.4%	99.1%	**99.5%**
20	99.9%	99.4%	99.1%	**99.5%**
40	96.0%	92.0%	91.9%	**93.3%**
60	85.1%	69.1%	77.2%	**77.1%**
80	85.1%	69.1%	77.2%	**77.1%**
100	57.2%	53.4%	63.8%	**58.1%**
120	57.2%	53.4%	63.8%	**58.1%**
140	4.3%	47.4%	52.1%	**34.6%**
160	4.3%	47.4%	52.1%	**34.6%**
180	3.6%	35.3%	42.3%	**27.1%**
200	3.6%	35.3%	42.3%	**27.1%**
220	3.0%	25.9%	34.4%	**21.1%**
240	3.0%	25.9%	34.4%	**21.1%**
260	2.5%	19.9%	28.2%	**16.9%**
280	2.5%	19.9%	28.2%	**16.9%**
300	2.1%	16.1%	23.2%	**13.8%**

	Soil Type 50/56	SP Height 95	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.4%	97.3%	96.1%	**97.6%**
20	99.4%	97.3%	96.1%	**97.6%**
40	93.9%	87.0%	86.2%	**89.1%**
60	73.7%	53.7%	66.7%	**64.7%**
80	73.7%	53.7%	66.7%	**64.7%**
100	4.4%	46.5%	50.2%	**33.7%**
120	4.4%	46.5%	50.2%	**33.7%**
140	3.4%	30.6%	37.4%	**23.8%**
160	3.4%	30.6%	37.4%	**23.8%**
180	2.6%	20.2%	28.0%	**16.9%**
200	2.6%	20.2%	28.0%	**16.9%**
220	2.1%	15.0%	21.3%	**12.8%**
240	2.1%	15.0%	21.3%	**12.8%**
260	1.6%	9.9%	16.6%	**9.4%**
280	1.6%	9.9%	16.6%	**9.4%**
300	1.3%	8.2%	13.2%	**7.6%**

	Soil Type 18	SP Height 145	SP Density 78	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.9%	99.2%	98.8%	**99.3%**
20	99.9%	99.2%	98.8%	**99.3%**
40	96.4%	92.6%	92.3%	**93.8%**
60	87.3%	72.8%	79.1%	**79.7%**
80	87.3%	72.8%	79.1%	**79.7%**
100	68.6%	54.3%	66.8%	**63.2%**
120	68.6%	54.3%	66.8%	**63.2%**
140	4.7%	51.0%	55.8%	**37.2%**
160	4.7%	51.0%	55.8%	**37.2%**
180	3.9%	40.5%	46.4%	**30.2%**
200	3.9%	40.5%	46.4%	**30.2%**
220	3.3%	30.8%	38.4%	**24.2%**
240	3.3%	30.8%	38.4%	**24.2%**
260	2.8%	23.3%	32.0%	**19.4%**
280	2.8%	23.3%	32.0%	**19.4%**
300	2.4%	18.9%	26.7%	**16.0%**

	Soil Type 50/56	SP Height 105	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	Avg
0	99.2%	96.5%	95.1%	**96.9%**
20	99.2%	96.5%	95.1%	**96.9%**
40	94.2%	87.4%	86.2%	**89.3%**
60	78.1%	57.2%	68.3%	**67.9%**
80	78.1%	57.2%	68.3%	**67.9%**
100	4.7%	48.6%	52.8%	**35.4%**
120	4.7%	48.6%	52.8%	**35.4%**
140	3.7%	34.8%	40.4%	**26.3%**
160	3.7%	34.8%	40.4%	**26.3%**
180	2.9%	23.5%	30.9%	**19.1%**
200	2.9%	23.5%	30.9%	**19.1%**
220	2.3%	17.2%	23.9%	**14.5%**
240	2.3%	17.2%	23.9%	**14.5%**
260	1.9%	12.3%	18.8%	**11.0%**
280	1.9%	12.3%	18.8%	**11.0%**
300	1.5%	9.1%	15.1%	**8.6%**

Table 5-21: Applegate Subbasin SHADOW models: effective shade results for all combinations of soil, vegetation, aspect, and NZDZ (cont.).

	Soil Type 50/56	SP Height 120	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	**Avg**
0	98.6%	95.3%	93.5%	**95.8%**
20	98.6%	95.3%	93.5%	**95.8%**
40	94.3%	87.3%	85.6%	**89.1%**
60	81.9%	61.9%	69.9%	**71.2%**
80	81.9%	61.9%	69.9%	**71.2%**
100	41.1%	48.7%	55.8%	**48.5%**
120	41.1%	48.7%	55.8%	**48.5%**
140	4.0%	40.0%	44.0%	**29.4%**
160	4.0%	40.0%	44.0%	**29.4%**
180	3.3%	28.5%	34.7%	**22.1%**
200	3.3%	28.5%	34.7%	**22.1%**
220	2.7%	20.2%	27.4%	**16.8%**
240	2.7%	20.2%	27.4%	**16.8%**
260	2.2%	15.9%	22.0%	**13.4%**
280	2.2%	15.9%	22.0%	**13.4%**
300	1.9%	11.6%	17.8%	**10.4%**

	Soil Type 50/56	SP Height 185	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	**Avg**
0	94.4%	88.9%	85.7%	**89.7%**
20	94.4%	88.9%	85.7%	**89.7%**
40	91.6%	83.8%	80.6%	**85.3%**
60	85.1%	69.8%	70.2%	**75.0%**
80	85.1%	69.8%	70.2%	**75.0%**
100	75.4%	52.4%	60.4%	**62.7%**
120	75.4%	52.4%	60.4%	**62.7%**
140	55.1%	43.8%	51.5%	**50.1%**
160	55.1%	43.8%	51.5%	**50.1%**
180	4.4%	41.5%	43.8%	**29.9%**
200	4.4%	41.5%	43.8%	**29.9%**
220	3.8%	34.1%	37.1%	**25.0%**
240	3.8%	34.1%	37.1%	**25.0%**
260	3.3%	27.1%	31.5%	**20.6%**
280	3.3%	27.1%	31.5%	**20.6%**
300	2.9%	21.5%	26.8%	**17.1%**

	Soil Type 50/56	SP Height 145	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	**Avg**
0	97.3%	92.9%	90.6%	**93.6%**
20	97.3%	92.9%	90.6%	**93.6%**
40	93.7%	86.4%	84.1%	**88.0%**
60	84.6%	66.6%	70.8%	**74.0%**
80	84.6%	66.6%	70.8%	**74.0%**
100	66.1%	48.3%	58.7%	**57.7%**
120	66.1%	48.3%	58.7%	**57.7%**
140	4.6%	45.1%	48.1%	**32.6%**
160	4.6%	45.1%	48.1%	**32.6%**
180	3.8%	35.2%	39.3%	**26.1%**
200	3.8%	35.2%	39.3%	**26.1%**
220	3.2%	26.4%	32.1%	**20.6%**
240	3.2%	26.4%	32.1%	**20.6%**
260	2.7%	19.7%	26.4%	**16.3%**
280	2.7%	19.7%	26.4%	**16.3%**
300	2.3%	15.9%	21.8%	**13.3%**

	Soil Type 50/56	SP Height 190	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	**Avg**
0	94.0%	88.4%	85.1%	**89.2%**
20	94.0%	88.4%	85.1%	**89.2%**
40	91.3%	83.4%	80.2%	**84.9%**
60	85.0%	70.0%	70.0%	**75.0%**
80	85.0%	70.0%	70.0%	**75.0%**
100	75.8%	53.0%	60.4%	**63.1%**
120	75.8%	53.0%	60.4%	**63.1%**
140	57.6%	43.6%	51.7%	**51.0%**
160	57.6%	43.6%	51.7%	**51.0%**
180	4.4%	41.3%	44.1%	**30.0%**
200	4.4%	41.3%	44.1%	**30.0%**
220	3.8%	34.8%	37.6%	**25.4%**
240	3.8%	34.8%	37.6%	**25.4%**
260	3.3%	27.8%	32.0%	**21.1%**
280	3.3%	27.8%	32.0%	**21.1%**
300	2.9%	22.2%	27.3%	**17.5%**

	Soil Type 50/56	SP Height 160	SP Density 48	
NSDZ(ft)	%Shade E-W (90)	%Shade 45 Deg	%Shade N-S (0)	**Avg**
0	96.3%	91.4%	88.7%	**92.1%**
20	96.3%	91.4%	88.7%	**92.1%**
40	93.1%	85.5%	82.8%	**87.1%**
60	85.2%	68.3%	70.8%	**74.8%**
80	85.2%	68.3%	70.8%	**74.8%**
100	71.4%	48.1%	59.7%	**59.7%**
120	71.4%	48.1%	59.7%	**59.7%**
140	19.3%	44.7%	49.8%	**37.9%**
160	19.3%	44.7%	49.8%	**37.9%**
180	4.0%	38.4%	41.4%	**27.9%**
200	4.0%	38.4%	41.4%	**27.9%**
220	3.4%	29.7%	34.3%	**22.5%**
240	3.4%	29.7%	34.3%	**22.5%**
260	2.9%	22.7%	28.6%	**18.1%**
280	2.9%	22.7%	28.6%	**18.1%**
300	2.5%	17.7%	23.9%	**14.7%**

5.4 Bear Creek

Table 5-22 describes the different model scenarios used to simulate effective shade for Bear Creek. The Bear Creek Heat Source version 6.0 model scenario used to simulate stream temperature needed additional work and updates that were infeasible given project time constraints. For these reasons, the Bear Creek temperature effects from point source wasteload allocations, tributary allocations, and HUA allocation attainment were assessed using Equation 5-1 and Equation 5-2.

Table 5-22: Bear Creek model scenario descriptions.

Scenario name	Description
Restored Vegetation	Evaluates the effective shade response with fully restored near-stream land cover.
Topographic Shade	Evaluates the effective shade response with no near-stream land cover.
Tributary Temperatures	This scenario was not modeled; instead, a thermal mass balance was completed to evaluate stream temperature responses with each tributary's temperatures increased by the total HUA allocations on each tributary.
HUA Attainment	This scenario was not modeled; instead, a thermal mass balance was completed to evaluate stream temperature responses with the NPDES point source discharging at its proposed WLA and tributary temperatures increased by the total HUA allocations on each tributary.

5.4.1 Vegetation scenarios

This section summarizes the effective shade impacts of current vegetation conditions, restored vegetation conditions, and topographic shading on Bear Creek. Table 5-23 summarizes the mean effective shade results for the Current Condition, Restored Vegetation and Topographic Shade scenarios. The mean effective shade difference between the Current Condition and Restored Vegetation scenarios was 47%. The mean effective shade difference between the Current Condition and Topographic Schade scenarios was 27%

For the longitudinal Bear Creek model extent, Figure 5-17 compares effective shade predictions from the Current Condition, Restored Vegetation, and Topographic Shade scenarios. Figure 5-18 shows the effective shade difference between the Current Condition and Restored Vegetation model scenarios. Figure 5-19 shows the effective shade differences (gaps) between the Current Condition and Topographic Shade model scenarios. Finally, Figure 5-20 shows the effective shade differences (gaps) between the Restored Vegetation and Current Condition scenarios.

Table 5-23: Bear Creek: Mean effective shade for Current Condition, Restored Vegetation, and Topographic Shade scenarios.

Scenario	Mean effective shade (%)
Current Condition	27
Restored Vegetation	74
Shade Gap (Restored – Current)	47
Topographic Shade	0

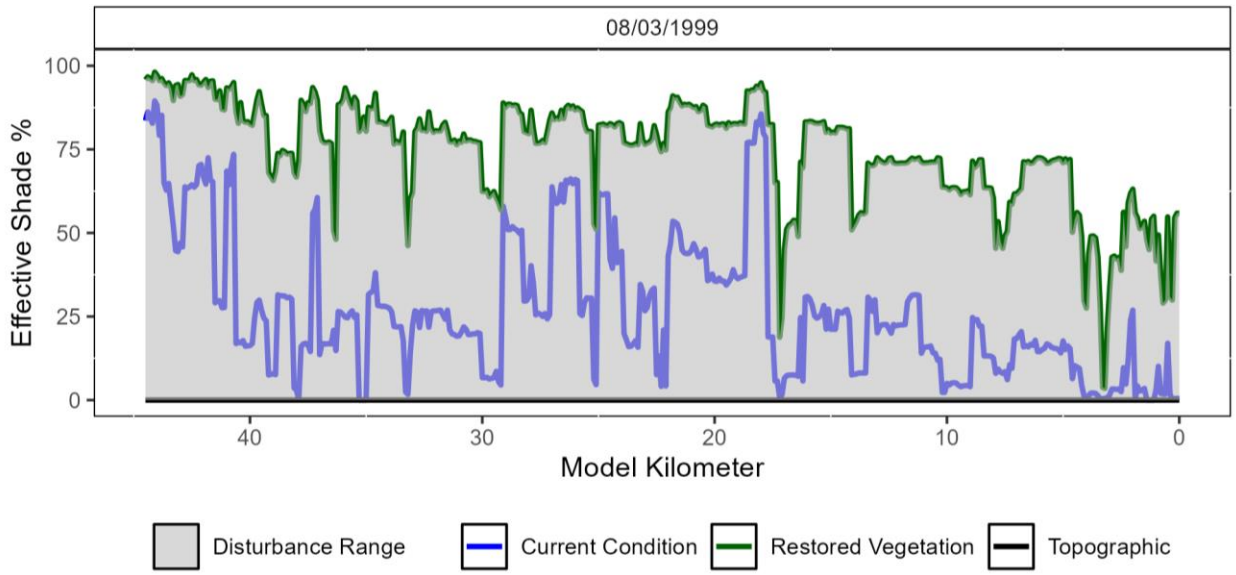


Figure 5-17: Bear Creek: Effective shade summary for Current Condition, Restored Vegetation and Topographic Shade scenarios.

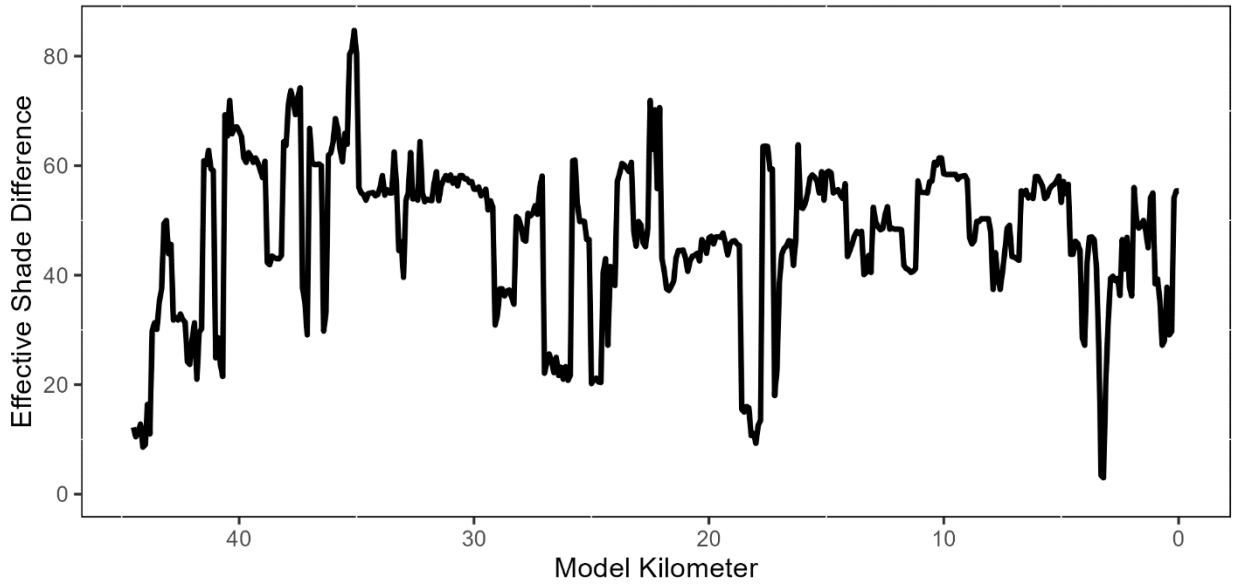


Figure 5-18: Bear Creek: Effective shade differences (%) between the Current Condition and Restored Vegetation scenarios.

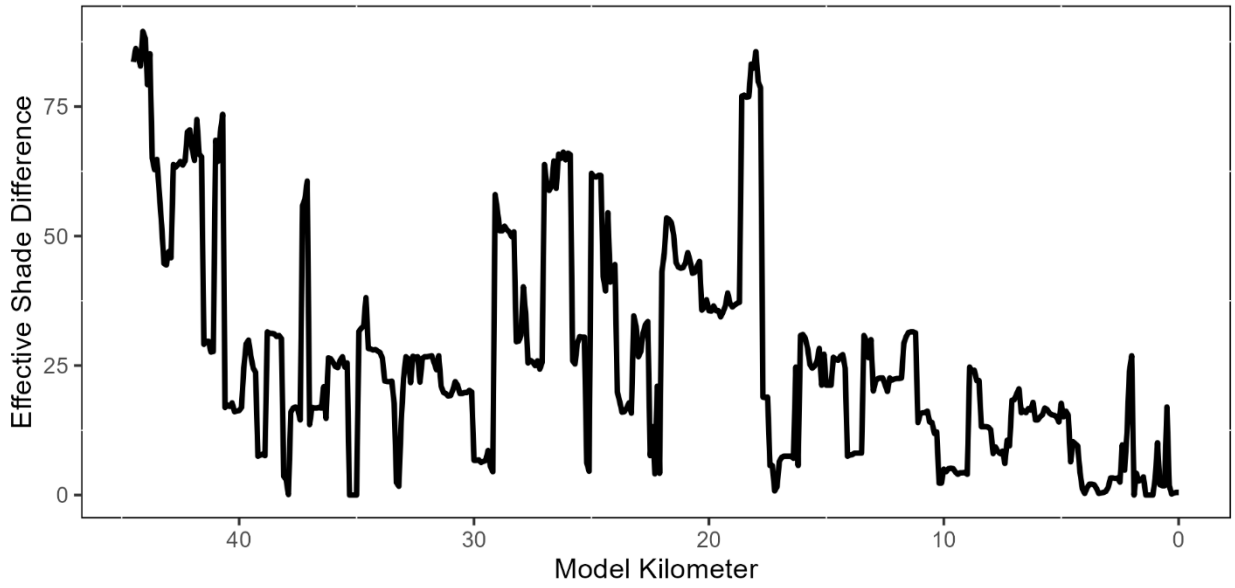


Figure 5-19: Bear Creek: Effective shade differences (%) between the Current Condition and Topographic Shade scenarios.

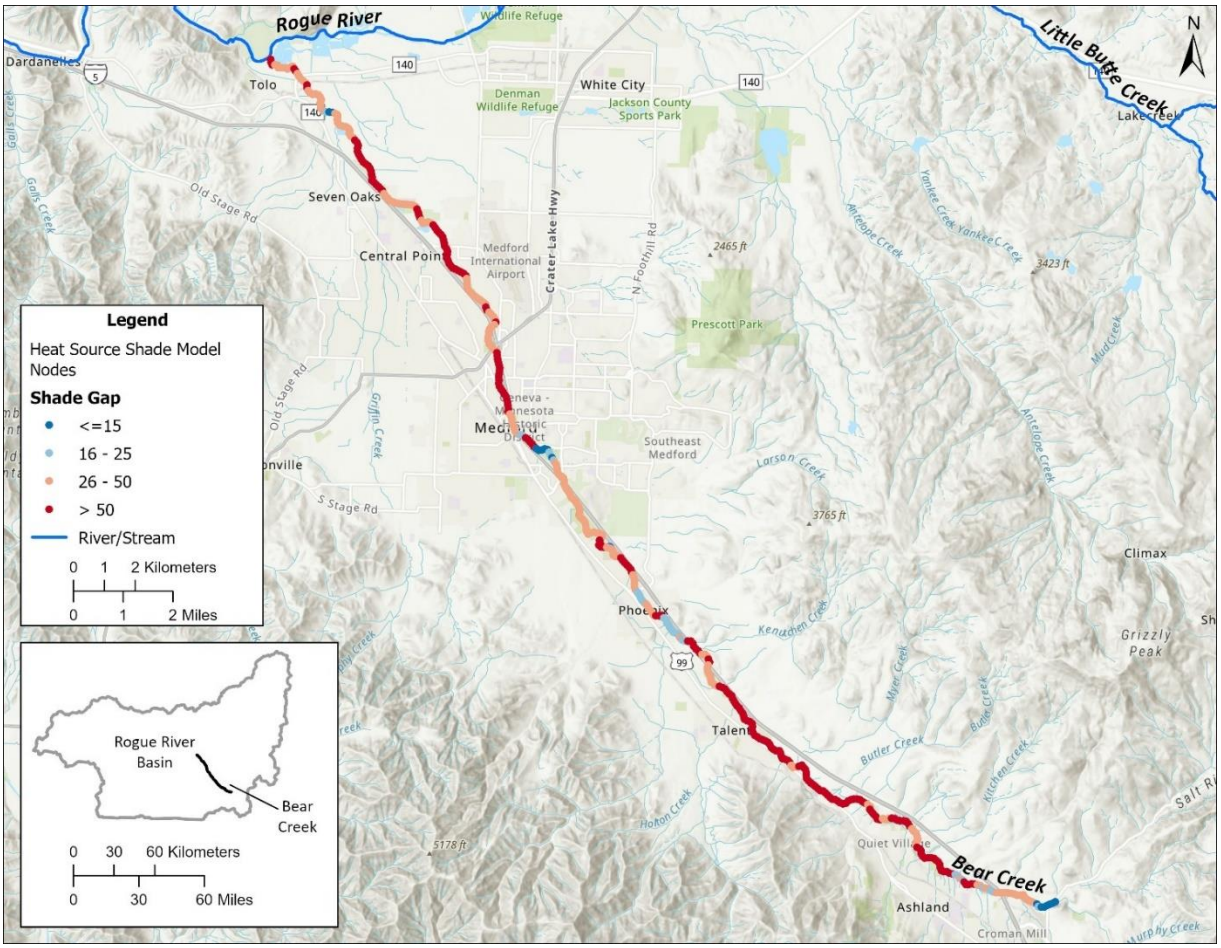


Figure 5-20: Bear Creek shade gaps (%) between the Restored Vegetation and Current Condition scenarios.

5.4.2 Wasteload allocations

This section summarizes the temperature impacts of wasteload allocations. Ashland STP is the only point source on Bear Creek and it discharges through Outfall 002, which is located on Bear Creek just downstream of its confluence with Ashland Creek.

Equation 5-1 was used to calculate instream temperature change based on the Ashland STP point source effluent discharge, river flow, and the applicable temperature criteria. For this calculation, Bear Creek flow was assumed equal to the 7Q10. Table 5-24 summarizes the Equation 5-1 inputs to calculate the Bear Creek temperature increase above the applicable criterion when the point source on Bear Creek discharges at its wasteload allocation.

Table 5-24: Bear Creek: Summary of Equation 5-1 variable specifications to calculate stream temperature change due to point sources discharging at wasteload allocations.

Variable	Value	Unit	Note
Q_E	3.559	cfs	Average dry weather design flow for Ashland STP.
Q_R	4.73	cfs	Bear Creek 7Q10 flow upstream of Ashland Creek confluence calculated with USGS station 1435420 data.
T_E	18.46	°C	Effluent temperature from Ashland STP Outfall 002 was set to the temperature that achieves the wasteload allocation.
T_C	18.00	°C	Applicable temperature criteria on Bear Creek during the critical period.
ΔT_{ps}	0.20	°C	Bear Creek temperature increase due to Ashland STP Outfall 002 discharging at its wasteload allocation.

The calculated warming of Bear Creek when Ashland STP Outfall 002 discharges at its wasteload allocation is 0.20°C (Table 5-24). The point sources HUA assignment on Bear Creek is thus 0.20°C, and since Ashland STP is the only such point source, it is assigned the entire point source HUA assignment. This analysis supports that the wasteload allocation assigned to Ashland STP Outfall 002 achieves the portion of the HUA assigned to point sources on Bear Creek: 0.20°C and that .

5.4.3 Tributary temperatures

This section summarizes the temperature impacts of increasing model tributary temperatures by the HUA assignments to thermal sources on those tributaries.

Bear Creek temperature changes due to tributary HUA assignments were assessed with Equation 5-2. For this calculation, it was assumed that Bear Creek and all tributary inputs were at 7Q10 levels: that there was no heat dissipation from point source discharges; and that Bear Creek's temperature upstream of its tributary inputs was equal to the 18.0°C non-spawning criteria. Table 5-25 lists the HUA portions assigned to thermal sources on each relevant Bear Creek tributary. Table 5-26 summarizes the values used in Equation 5-2 to calculate the Bear Creek temperature increase above the applicable criterion due to TMDL allocations on tributaries.

In Bear Creek, the calculated cumulative warming from sources on upstream tributaries set at their allocations is 0.06°C. The HUA portion assigned to tributary warming on Bear Creek is thus 0.06°C.

Table 5-25: Bear Creek: Summary of HUA assignments to thermal sources on tributaries.

Tributary name	HUA portion assigned to thermal sources (°C)
Neil Creek	0.175

Tributary name	HUA portion assigned to thermal sources (°C)
Gaerky Creek	0.175
Ashland Creek	0.100
Butler Creek	0.175
Myer Creek	0.175
Wagner Creek	0.175
Payne Creek	0.175
Larson Creek	0.175
Lazy Creek	0.175
Lone Pine Creek	0.175
Griffin Creek	0.175
Jackson Creek	0.175

Table 5-26: Bear Creek: Summary of Equation 5-2 variables input to calculate stream temperature change due to warming from HUA assignments on tributaries.

Variable	Value	Unit	Note
Q_{in}	4.88	cfs	Total discharge from all tributaries at 7Q10 levels, plus total effluent flow from the two point sources that discharge to Ashland Creek (~0.5 MGD).
Q_{up}	6.12	cfs	Bear Creek 7Q10 flow at mouth estimated using StreamStats.
T_{in}	18.133	°C	Temperature of mixed discharge from all tributaries when the temperature of each tributary was increased by the HUA portion assigned to thermal sources on that tributary (Table 5-25) above the applicable criteria (18.0°C).
T_{up}	18.00	°C	The applicable temperature criteria on Bear Creek during the critical period.
ΔT_R	0.06	°C	Bear Creek temperature increase due to warming from tributaries' HUA assignments.

5.4.4 HUA Attainment

This section summarizes the cumulative temperature impacts in Bear Creek of the proposed allocations to warming from tributaries and point sources. The HUA Attainment analysis determines if the assessed thermal sources achieve their allocated portion of the HUA and do not exceed the maximum cumulative allowable 0.3°C HUA. Table 5-27 describes the setup of this analysis.

Table 5-27: Bear Creek HUA Attainment analysis set up summary.

Model input variable	HUA Attainment analysis set up description
Tributary temperatures	Tributary temperatures were set to the applicable temperature criterion during the critical period (18.0°C), then increased by the HUA portion assigned to thermal sources on each tributary. See Table 5-25 for details.
Tributary flows	Tributary flows were set to 7Q10 for this analysis.
Mainstem flow	Bear Creek flow was set to 7Q10 for this analysis.
NPDES point sources	Three (3) point source discharges were included: Ashland STP Outfall 001, Ashland STP 002, and Ashland WTP. Effluent flows and temperatures were set to wasteload allocations for each point source.

The cumulative Bear Creek temperature change due to allocations to tributary warming and point sources was assessed with Equation 5-1 and Equation 5-2. For these calculations, it was assumed that Bear Creek and tributary flows were at 7Q10 levels; that there was no heat dissipation from point source discharges; and that the Bear Creek temperature upstream of proposed allocation impacts equaled the 18.0°C non-spawning criteria.

Warming from NPDES point source allocations on Bear Creek was calculated as 0.20°C; these results are summarized in Section 5.4.2. Warming from allocations to Bear Creek tributaries was calculated as 0.06°C; these results are summarized in Section 5.4.3.

The calculated cumulative warming in Bear Creek from all sources set at their TMDL allocations is 0.26°C (Equation 5-2). The total HUA portion assigned to anthropogenic thermal sources on Bear creek is thus 0.26°C. The HUA portion assigned to reserve capacity is 0.04°C. The HUA Attainment analysis results indicate that the HUA portion assigned to assessed sources will be achieved on Bear Creek and the maximum allowable cumulative 0.3°C HUA will not be exceeded.

5.5 Bear Creek Watershed

Effective shade is defined as the percent of available solar flux intercepted before reaching the stream. The Heat Source-calculated Bear Creek mainstem longitudinal effective shade is shown in Figure 5-21 for the current conditions model and Figure 5-22 for restored vegetation. The current conditions and restored vegetation results are compared in Figure 5-23 (longitudinally) and Figure 5-24 (as cumulative frequencies). Table 5-28 presents SHADOW model results for the same reaches. The two methods' results are not necessarily comparable, as Heat Source measures shade within the wetted width while SHADOW measures shade within the near-stream disturbance zone.

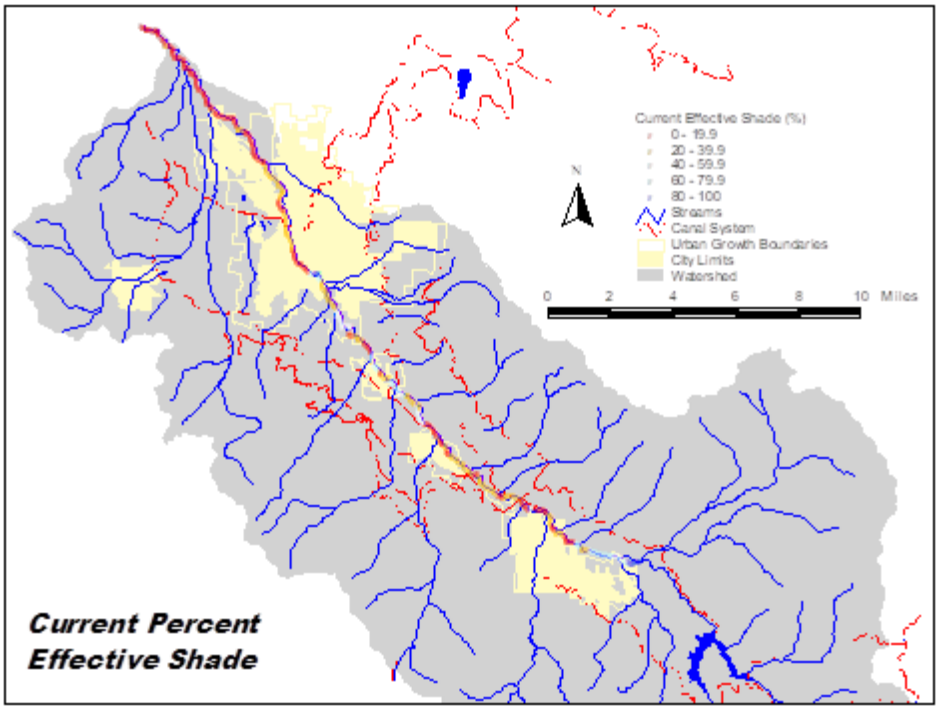


Figure 5-21: Bear Creek mainstem current conditions estimated shade (%).

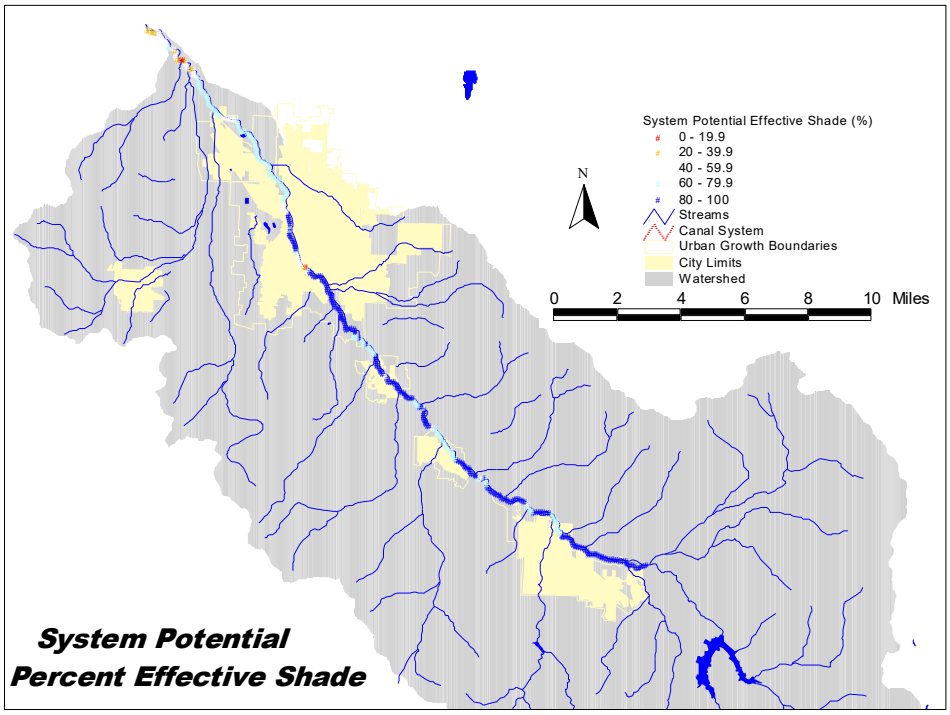


Figure 5-22: Bear Creek mainstem restored vegetation estimated shade (%).

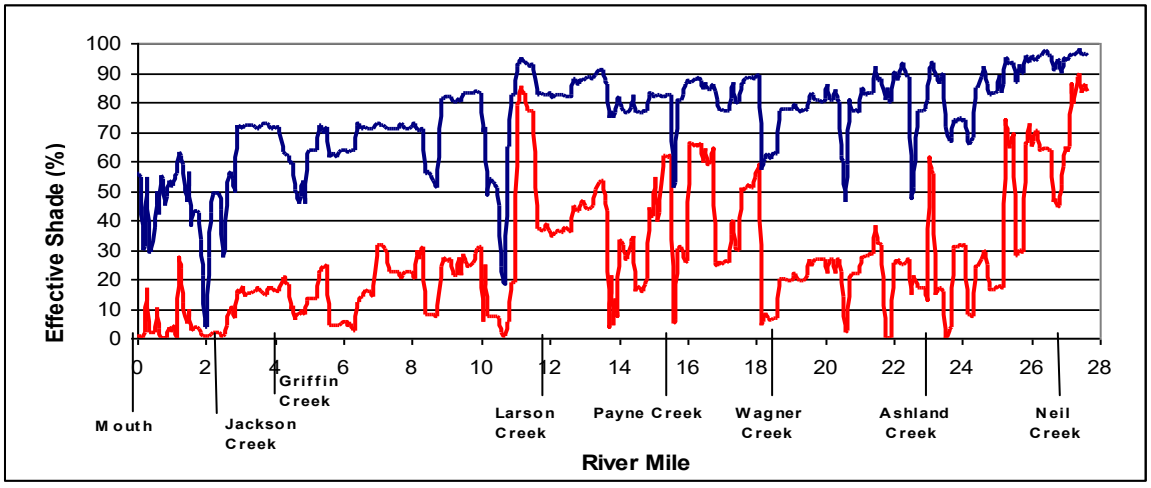


Figure 5-23: Bear Creek mainstem effective shade (%): current (red line) and potential (blue line).

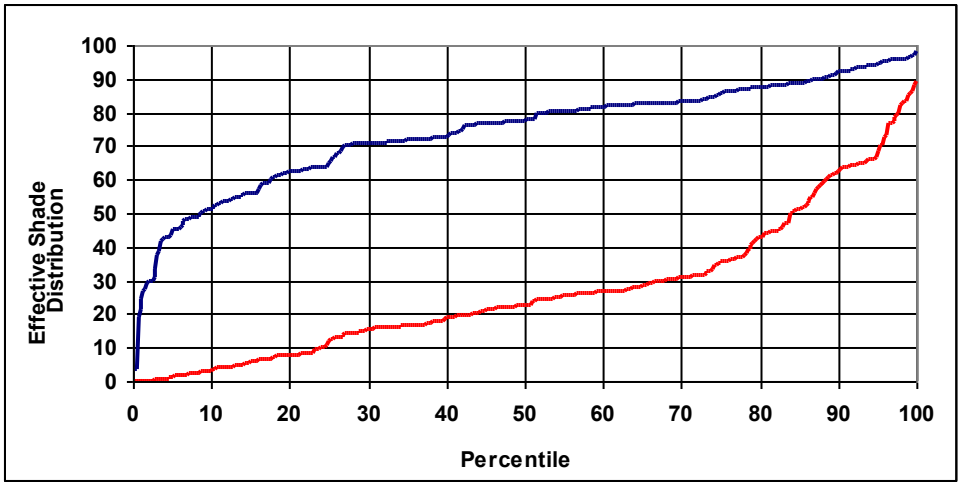


Figure 5-24: Bear Creek effective shade (%) cumulative frequency plots, current (red) and potential (blue).

Table 5-28: Shade results for Bear Creek and tributaries.

Waterbody	Area (ac)	Current effective shade (%)	TMDL shade target[1] (%)	Shade gap (%)
Bear Creek Mainstem	140,758	15	54	39
Jackson Creek	122,477	46	88	42
Griffin Creek	91,715	47	85	38
Lazy Creek	22,939 (no res.?)	26	82	56
Coleman Creek	33,075	67	89	21
Wagner Creek	28,874	70	91	21
Myer Creek	25,351	40	83	42
Butler Creek	21,800	21	84	63
Ashland Creek[2]	229,508 (no res.)	66	82	16
Neil Creek	21,800	71	88	17
Walker Creek	25,580	41	86	37
Emigrant Creek	84,238 (no res.)	54	85	31
TOTAL	**TBD, address comment 1st**	**TBD, address comment 1st**	**TBD, address comment 1st**	**TBD, address comment 1st**

5.6 Elk Creek

Table 5-29 describes the different model scenarios used to simulate stream temperature and effective shade for Elk Creek. Table 5-30 summarizes the maximum 7DADM stream temperature predicted at the mouth of Elk Creek for all model scenarios over the entire model period. Figure 5-25 shows the predicted maximum 7DADM stream temperature for all Elk Creek model scenarios.

Table 5-29: Elk Creek model scenario descriptions.

Scenario Name	Description
Restored Vegetation	Evaluates stream temperature and shade responses with fully restored near-stream vegetation.
Topographic Shade	Evaluates stream temperature and shade responses with no near-stream land cover.
Restored Flow	Evaluates the stream temperature response with points of diversion removed. Withdrawal flows included in the calibrated model from model km 5.35 to 19.3 were removed for this scenario.

Scenario Name	Description
Tributary Temperatures	Evaluates the stream temperature response with fully restored near-stream vegetation, points of diversion removed as in the Restored Flow scenario, and tributary temperatures increased by the total HUA allocations on those tributaries; Bitter Lick Creek, Sugarpine Creek, Flat Creek, and West Branch Creek hourly temperatures were increased by 0.175°C.
HUA Attainment	This scenario is identical to the Tributary Temperatures scenario for Elk Creek.
Background	Evaluates the stream temperature response with points of diversion removed as in the Restored Flow scenario, fully restored near-stream vegetation, and model boundary condition temperatures reduced to that of an upstream location on Elk Creek with minimal disturbance (Elk Creek at Al Serena Buzzard Mine).

Table 5-30: Summary of maximum 7DADM stream temperatures on Elk Creek for all model scenarios over the entire model period.

Scenario	Stream temperature at mouth (°C)	Stream temperature at POMI (°C)	POMI location (Model km)
Current Condition	26.93	30.27	10.2
Restored Vegetation	20.99	26.27	5.8
Topographic Shade	29.32	37.74	12.4
Restored Flow	24.99	27.44	10.2
Attainment	21.90	22.69	5.8
Background	21.89	22.67	5.8

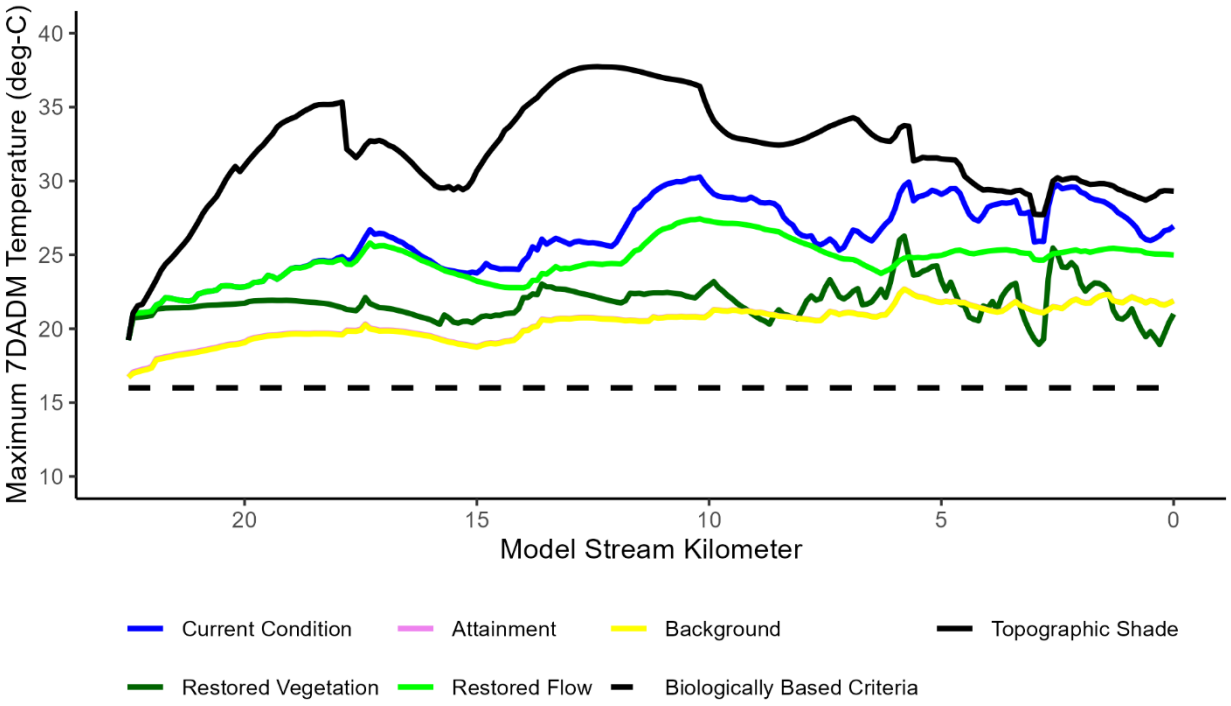


Figure 5-25: Elk Creek: Maximum 7DADM stream temperature for all model scenarios.

5.6.1 Vegetation scenarios

This section summarizes the temperature impacts of restored vegetation. Table 5-31 and Figure 5-26 summarize the maximum 7DADM stream temperature change between the Current Condition

and Restored Vegetation scenarios for Elk Creek over the entire model extent when scenario temperatures exceeded the BBNC. The maximum 7DADM temperature difference at the most downstream node (the outlet) was 7.33°C and was 10.90°C at the POMI (model km 8.7).

Table 5-32 and Figure 5-27 summarize the maximum 7DADM stream temperature changes between the Current Condition and Topographic Shade scenarios for Elk Creek over the entire model extent when scenario temperatures exceeded the BBNC. The 7DADM temperature difference at the most downstream node (the outlet) was 2.84°C and was 14.31°C at the POMI (model km 12.5).

Table 5-31: Summary of maximum 7DADM stream temperature change between Restored Vegetation and Current Condition model scenarios for Elk Creek over the entire model period.

Model km	Stream temperature change (°C)	Location
0	7.33	Outlet
8.7	10.90	POMI

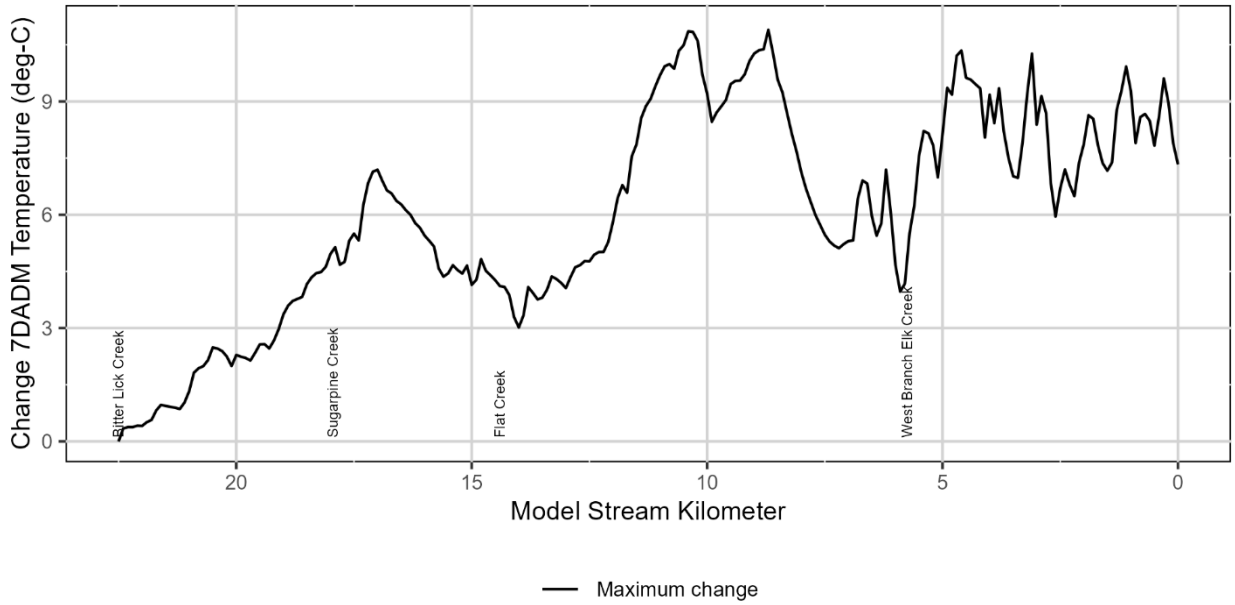


Figure 5-26: Elk Creek: Maximum 7DADM stream temperature changes between Current Condition and Restored Vegetation scenarios over the model extent when scenario temperatures exceed the BBNC.

Table 5-32: Elk Creek: Maximum 7DADM stream temperature changes between Topographic Shade and Current Condition model scenarios over the model period.

Model km	Stream temperature (°C)	Location
0	2.84	outlet
12.5	14.31	POMI

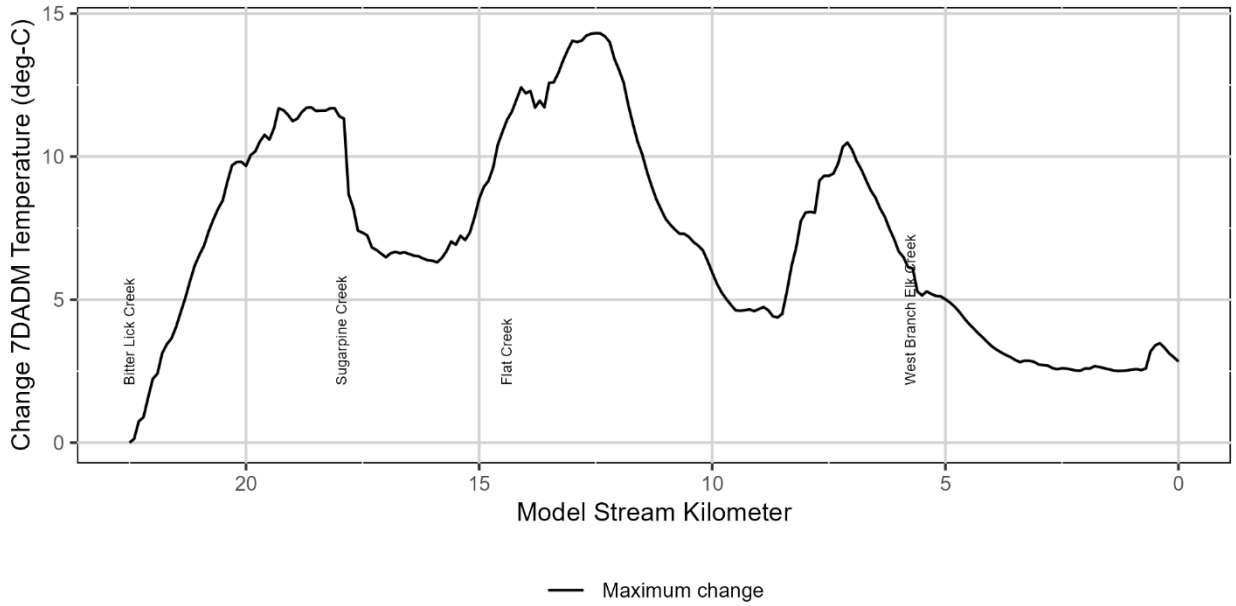


Figure 5-27: Elk Creek: Maximum 7DADM stream temperature changes between Current Condition and Topographic Shade scenarios over the model extent when scenario temperatures exceed the BBNC.

Table 5-33 summarizes the mean effective shade for the Current Condition, Restored Vegetation, and Topographic Shade scenarios for Elk Creek over the entire model extent. The difference in mean effective shade between the Restored Vegetation and Current Condition scenarios is 35%.

Figure 5-28 shows longitudinal effective shade predictions for the Current Condition, Restored Vegetation, and Topographic Shade scenarios. Figure 5-29 shows the difference between effective shade predictions for the Current Conditions and Restored Vegetation scenarios, while Figure 5-30 shows the difference in effective shade predictions between the Current Conditions and Topographic Shade scenarios. Figure 5-31 shows the shade gaps between the Restored Vegetation and Current Condition scenarios along the Elk Creek model extent.

Table 5-33: Elk Creek: Mean effective shade for the Current Condition, Restored Vegetation, and Topographic Shade scenarios.

Scenario	Mean effective shade (%)
Current Condition	46
Restored Vegetation	81
Shade Gap (Restored – Current)	35
Topographic Shade	9

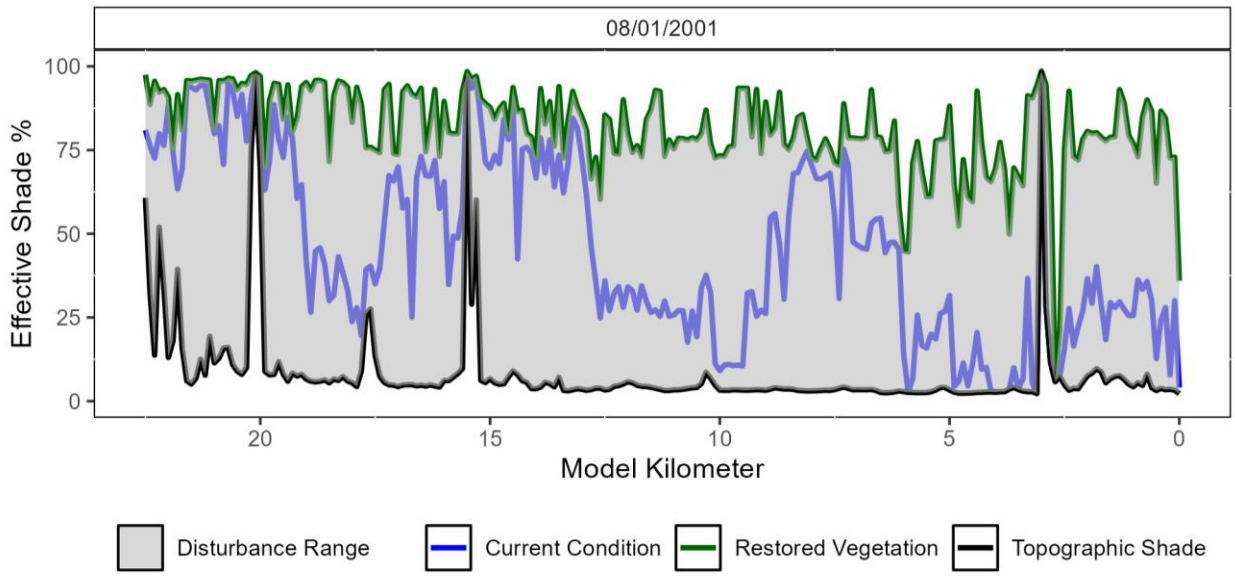


Figure 5-28: Elk Creek: Longitudinal effective shade for Current Condition, Restored Vegetation, and Topographic Shade scenarios.

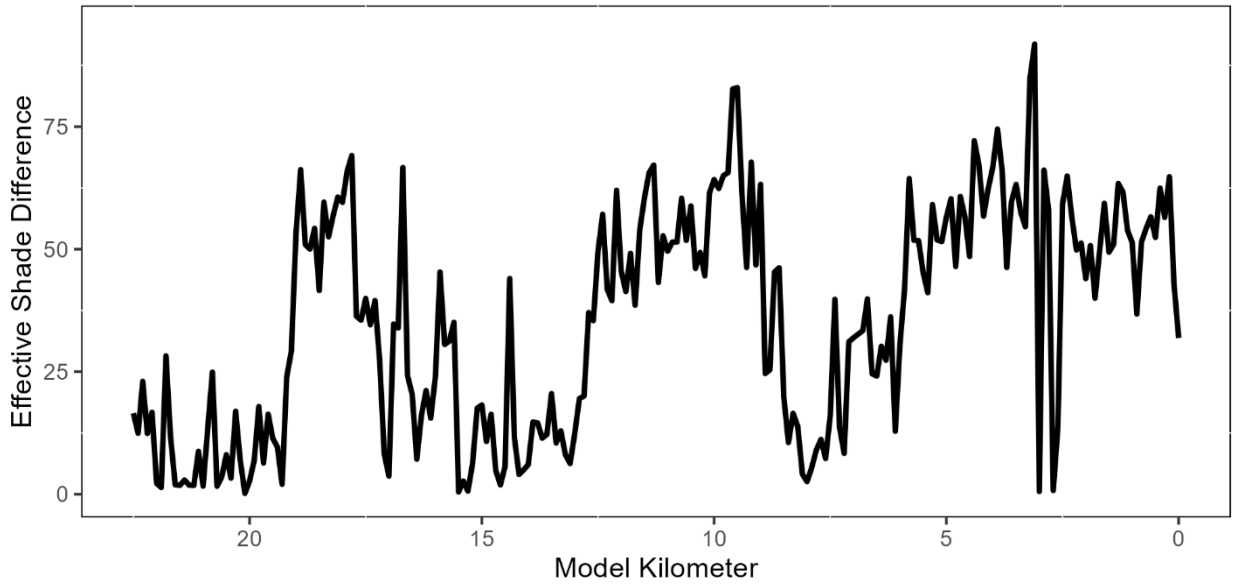


Figure 5-29: Elk Creek: Effective shade differences (%) between Restored Vegetation and Current Condition scenarios.

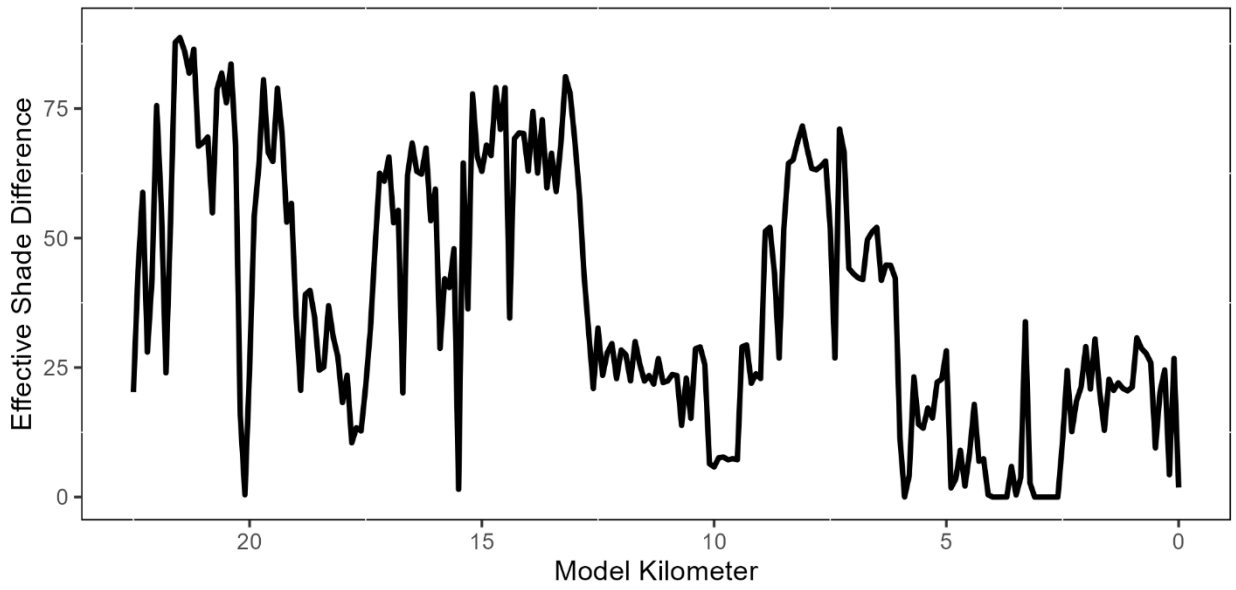


Figure 5-30: Elk Creek: Effective shade differences (%) between Current Condition and Topographic Shade scenarios.

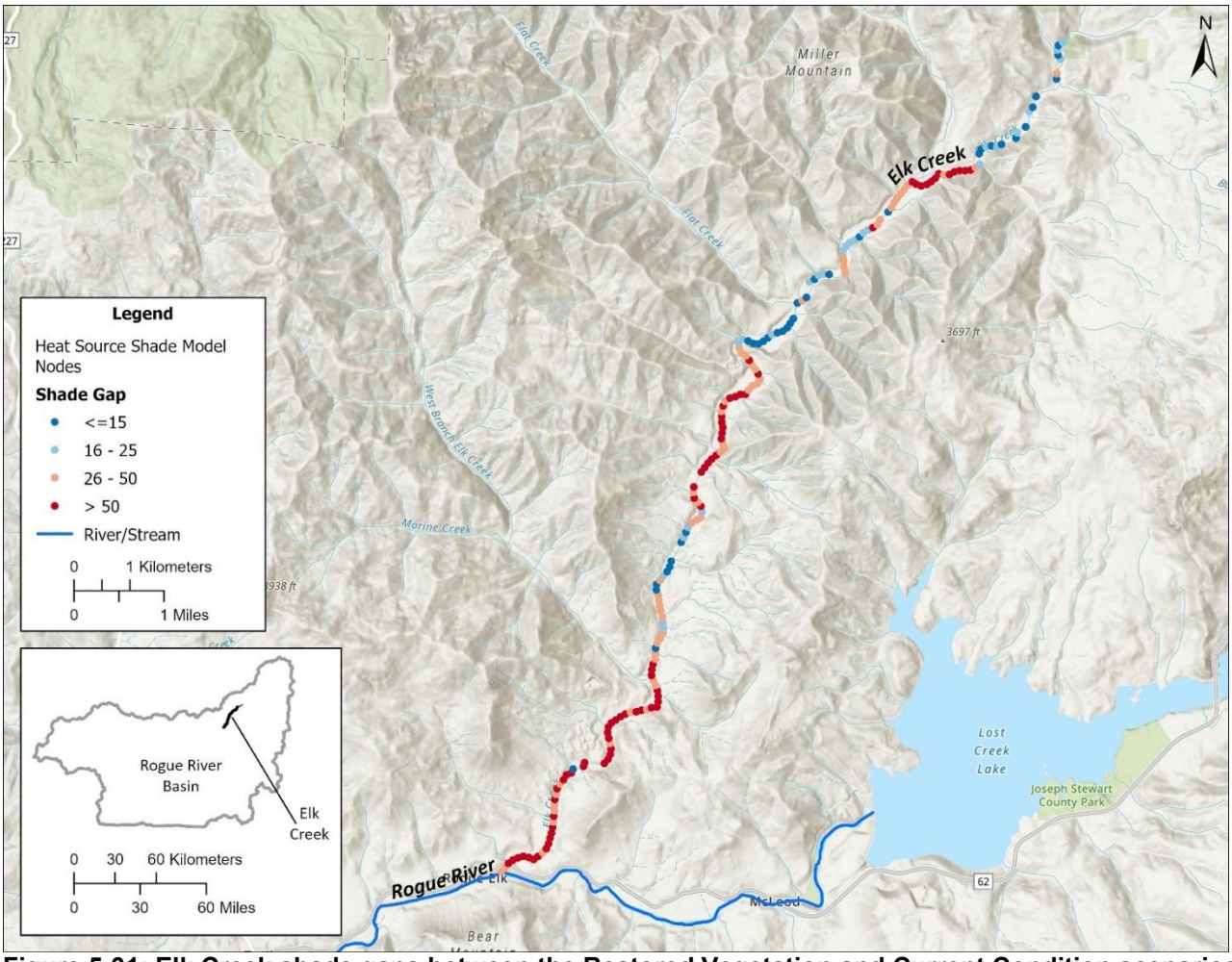


Figure 5-31: Elk Creek shade gaps between the Restored Vegetation and Current Condition scenarios.

5.6.2 Restored flow

This section summarizes the temperature impacts of restored flow. Table 5-34 and Figure 5-32 summarize the maximum 7DADM stream temperature changes between the Current Condition and Restored Flow scenarios for Elk Creek over the entire model period and extent. The maximum 7DADM temperature difference was 3.53°C at the most downstream node (the outlet) and was 6.81°C at the POMI (model km 5.7).

Table 5-34: Summary of maximum 7DADM stream temperature change between Restored Flow and Current Condition model scenarios for Elk Creek over the entire model period.

Model km	Stream temperature change (°C)	Location
0	3.53	outlet
5.7	6.81	POMI

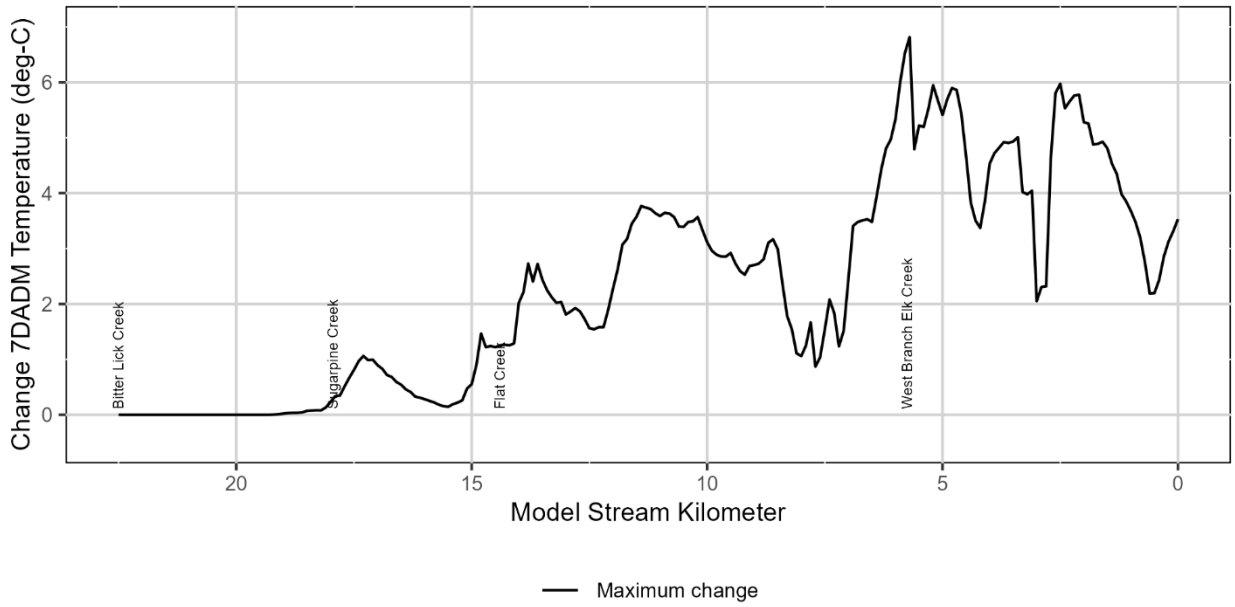


Figure 5-32: Elk Creek: Maximum 7DADM stream temperature changes between Current Condition and Restored Flow scenarios over the model extent when scenario temperatures exceed the BBNC.

5.6.3 Tributary temperatures

For Elk Creek, the Tributary Temperatures and HUA Attainment scenarios are identical. See Section 5.6.4 for results.

5.6.4 HUA Attainment

This section summarizes the temperature impacts on Elk Creek of the proposed load allocations and wasteload allocations, as applicable. The HUA Attainment scenario determines if the modeled sources of warming achieve their allocated portion of the HUA. To make this determination, results from the HUA Attainment scenario were compared to results from the Background scenario. Table 5-35 describes the HUA Attainment model scenario set up.

Table 5-35: HUA Attainment model scenario set up description for Elk Creek.

Model input variable	Attainment scenario set up description
Riparian landcover	Set to restored vegetation conditions as in the Background scenario.
Tributary temperatures	Hourly tributary temperatures were increased by the assigned allocations on each tributary; Bitter Lick Creek, Sugarpine Creek, Flat Creek, and West Branch Elk Creek hourly temperatures were increased by 0.175°C.
Tributary flow	Equal to tributary flows used in the Background model scenario.
Boundary condition temperature	Equal to boundary condition temperatures used in the Background model scenario.
Boundary condition flow	Equal to boundary condition flows used in the Background model scenario.
Withdrawals	Equal to withdrawals used in the Background model scenario.
NPDES point sources	There are no NPDES point source discharges within the model extent.
Nonpoint source dam and reservoir operations	There are no dam or reservoir operations within the model extent.
Solar loading from existing infrastructure	Solar loading from existing infrastructure was not modeled.

Table 5-36 shows the HUA portion assigned to thermal sources on each of the Elk Creek tributaries included in the HUA Attainment analysis.

Table 5-36: Summary of HUA assignments to sources of warming on tributaries to Elk Creek.

Tributary name	HUA portion assigned to thermal sources (°C)
Bitter Lick Creek	0.175
Sugarpine Creek	0.175
Flat Creek	0.175
West Branch Elk Creek	0.175

Table 5-37 and Figure 5-33 summarize the maximum 7DADM stream temperature changes between the Attainment and Background scenarios for Elk Creek over the entire model extent when scenario temperatures exceeded the BBNC. The maximum 7DADM temperature difference was 0.037°C at the most downstream node (the outlet) and was 0.086°C at the POMI (model km 22.4).

Table 5-37: Elk Creek: Maximum 7DADM temperature changes between HUA Attainment and Background model scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
0	0.037	Outlet
22.4	0.086	POMI

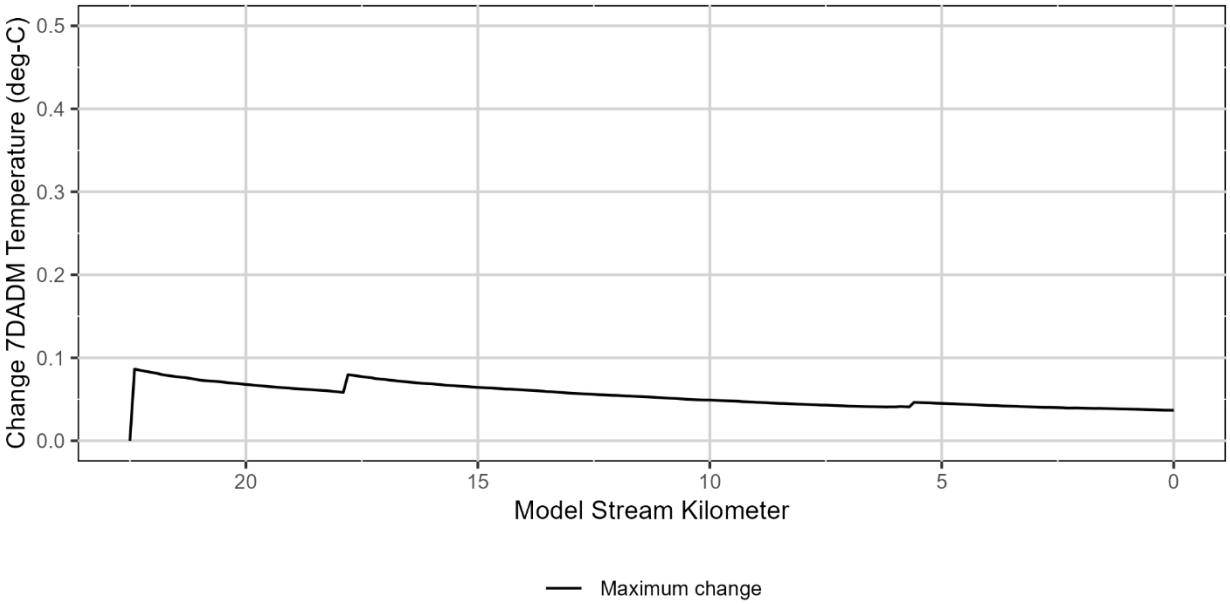


Figure 5-33: Elk Creek: Maximum 7DADM stream temperature changes between the Attainment and Background model scenarios over the model extent when scenario temperatures exceed the BBNC.

The comparison of the HUA Attainment scenario to the Background indicates that Elk Creek warming from tributaries is 0.086°C. The TMDL allocation to warming from tributaries on Elk Creek is 0.086°C. The HUA Attainment analysis results support that the HUA portion assigned to modeled sources will be achieved on Elk Creek.

5.6.5 Background

This section summarizes the temperature impacts of background conditions. Table 5-38 and Figure 5-34 summarize the maximum 7DADM stream temperature changes between the Current Condition and Background scenarios for Elk Creek over the entire model extent. The maximum 7DADM temperature difference was 7.78°C at the most downstream node (the outlet) and was 12.39°C at the POMI (model km 10.2)

Table 5-39 summarizes the maximum 7DADM stream temperature changes between the Elk Creek Background scenario and BBNC over the entire model extent. The maximum 7DADM temperature difference between Background and the BBNC was 5.89°C at the most downstream node (the outlet) and was 6.67°C at the POMI (model km 5.8).

Table 5-38: Elk Creek: Maximum 7DADM stream temperature changes between Current Condition and Background model scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
0	7.78	outlet
10.2	12.39	POMI

Table 5-39: Elk Creek: Maximum 7DADM stream temperature changes between Background model scenario and the BBNC over the model extent.

Model km	Stream temperature change (°C)	Location
0	5.89	outlet
5.8	6.67	POMI

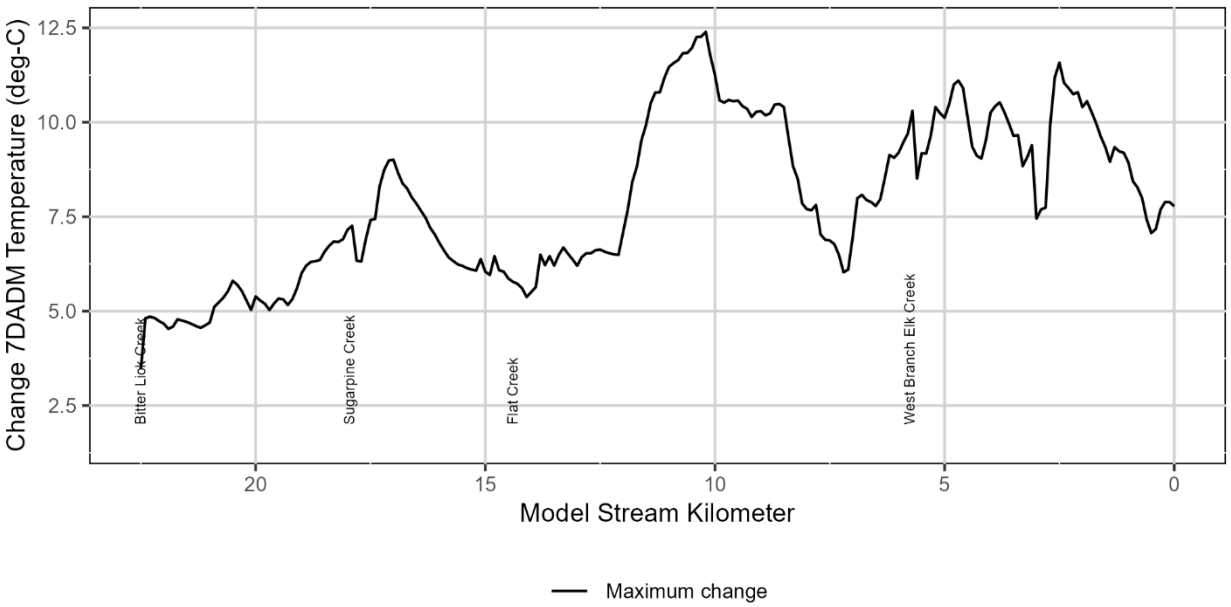


Figure 5-34: Elk Creek: Maximum 7DADM stream temperature changes between the Background and Current Condition scenarios over the model extent when scenario temperatures exceed the BBNC.

5.7 Evans Creek and West Fork Evans Creek

Table 5-40 describes the different model scenarios used to simulate stream temperature and effective shade for Evans Creek and West Fork Evans Creek. Table 5-41 and Figure 5-35 summarize the maximum 7DADM stream temperatures predicted for all Evans Creek and West Fork Evans Creek model scenarios over the entire model period and extent.

Table 5-40: Evans Creek and West Fork Evans Creek model scenario descriptions.

Scenario Name	Description
Restored Vegetation	Evaluates the effective shade and temperature responses with fully restored near-stream land cover.
Topographic Shade	Evaluates the effective shade and temperature responses with no near-stream land cover.
Restored Flow	Evaluates the stream temperature response with points of diversion removed.
Background	Evaluates the effective shade and temperature responses with fully restored near-stream land cover and points of diversion removed.
Tributary Temperatures	Evaluates stream temperature responses with fully restored near-stream vegetation, points of diversion removed, and each tributary's temperatures increased by the total HUA allocations on that tributary. Cedar Creek (RB); Battle Creek (RB); EF Evans Cr; Pleasant Cr; and Rock Creek & Salt Creek were all increased by 0.10°C from their Background scenario temperatures.
Attainment	Identical to the Tributary Temperatures scenario for this model extent.

Table 5-41: Evans Creek: Maximum 7DADM stream temperatures at the mouth for all model scenarios over the model extent .

Scenario	Stream temperature (°C), mouth	Stream temperature (°C), POMI
Current Condition	28.24	31.27
Topographic Shade	29.35	32.76

Scenario	Stream temperature (°C), mouth	Stream temperature (°C), POMI
Attainment	24.41	26.64
Background	24.41	26.64
Restored Vegetation	24.41	26.64
Restored Flow	27.21	30.29

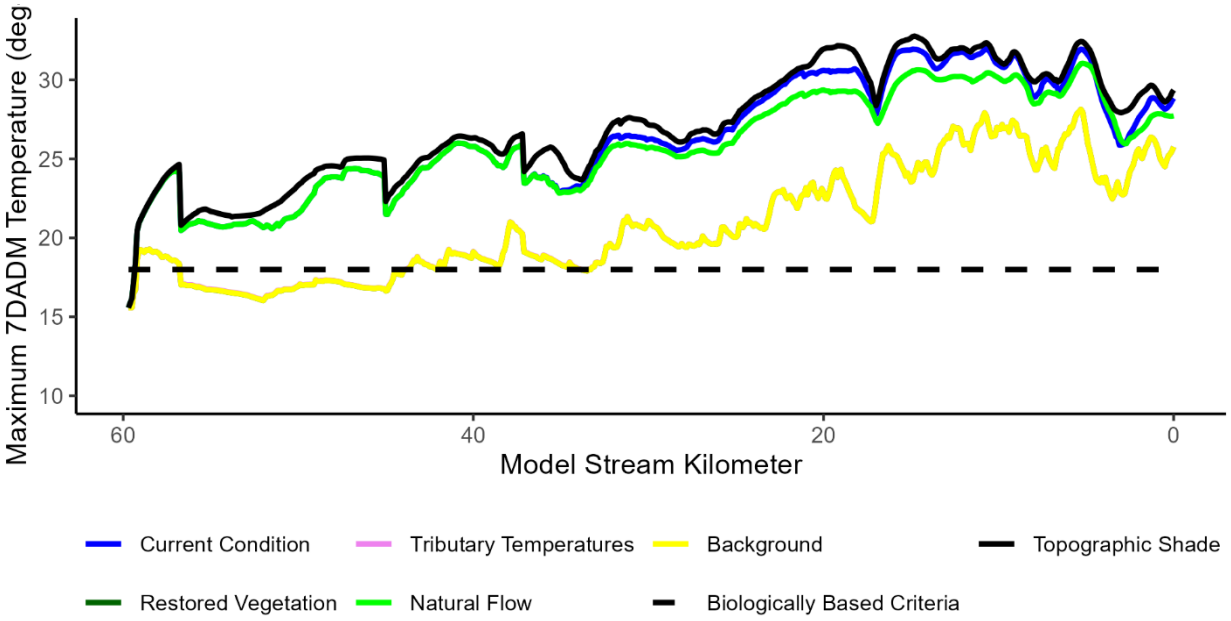


Figure 5-35: Maximum 7DADM stream temperature for all model scenarios for Evans Creek and West Fork Evans Creek. HUA Attainment results are the same as Tributary Temperature results.

5.7.1 Vegetation scenarios

This section summarizes the temperature impacts of current vegetation conditions, restored vegetation conditions and topographic shading. Table 5-42 and Figure 5-36 summarize the maximum 7DADM stream temperature changes between the Current Condition and Restored Vegetation scenarios for Evans Creek and West Fork Evans Creek over the entire model extent. The maximum 7DADM temperature difference was 4.20°C at the most downstream node and was is 4.20°C at the POMI (model km 15.9).

Table 5-42: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature changes between Restored Vegetation and Current Condition model scenarios over the entire model period.

Model km	Stream temperature change (°C)	Location
0.00	4.20	Downstream boundary
15.9	9.26	POMI

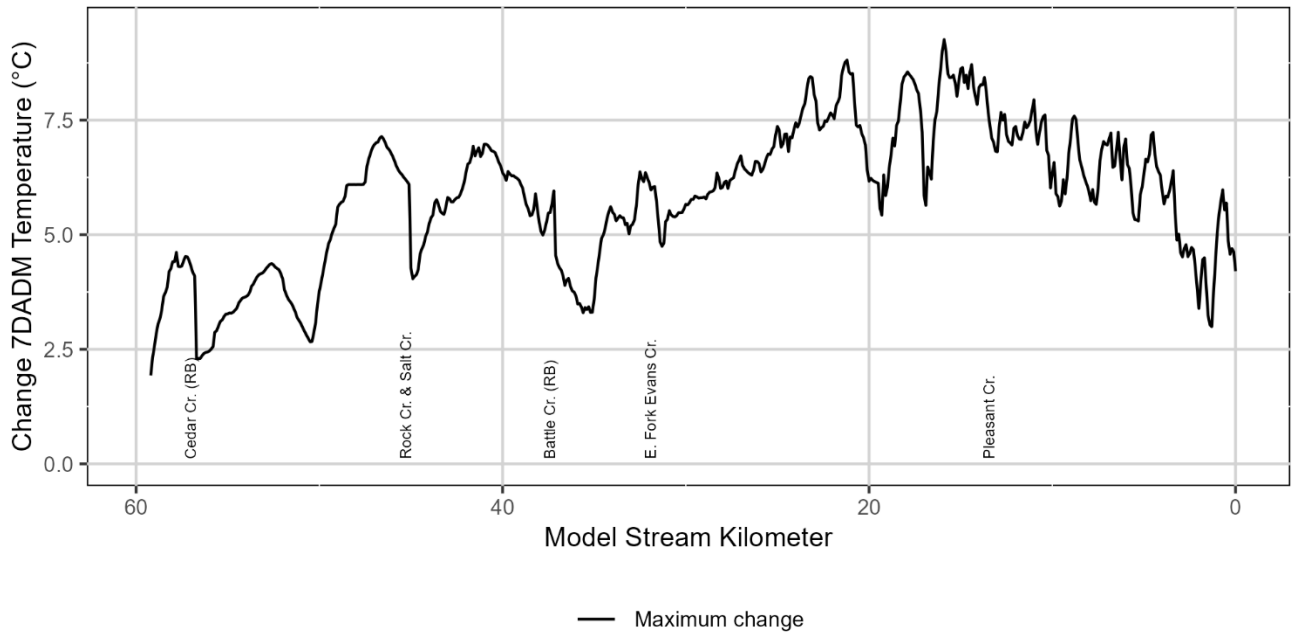


Figure 5-36: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature changes between Current Condition and Restored Vegetation scenarios over the model extent when scenario temperatures exceed the BBNC.

Table 5-43 and Figure 5-37 summarize the maximum 7DADM stream temperature changes between the Topography and Current Condition scenarios for Evans Creek and West Fork Evans Creek over the entire model period and extent. The maximum 7DADM temperature difference was 1.16°C at the most downstream node and was 6.88°C at the POMI (km 19.6).

Table 5-43: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature change between Topography and Current Condition model scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
0.00	1.16	Downstream boundary
19.6	6.88	POMI

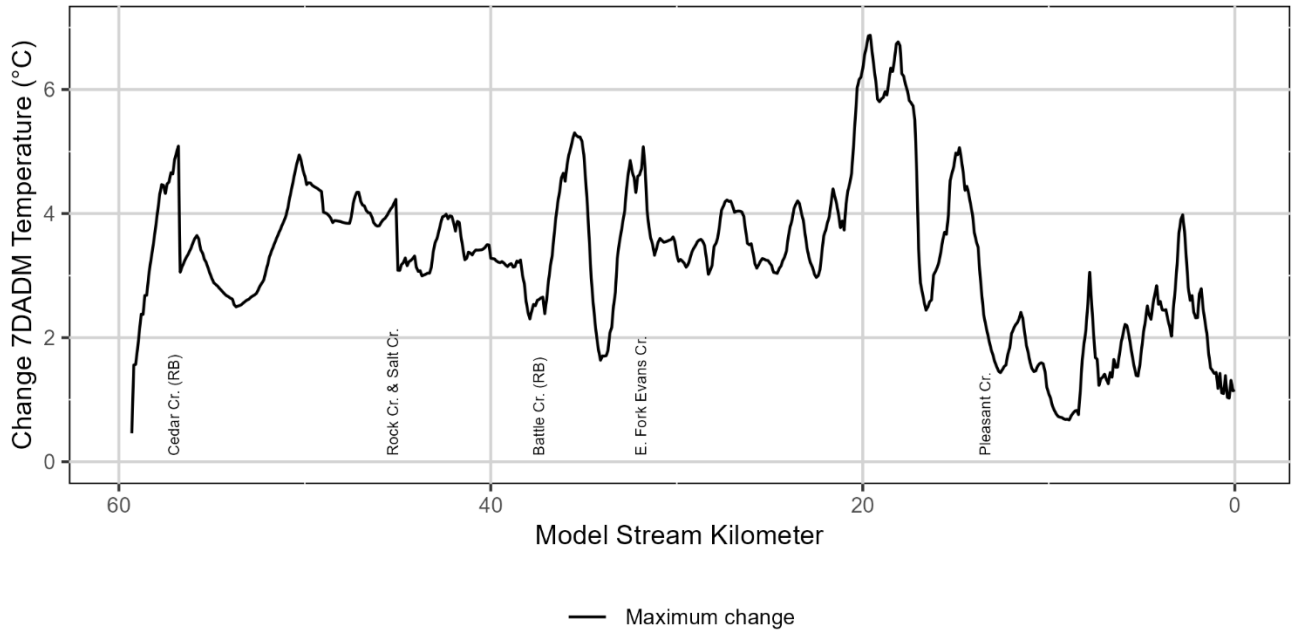


Figure 5-37: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature changes between Topography and Current Condition scenarios over the model extent when scenario temperatures exceed the BBNC.

Table 5-44 summarizes the mean effective shade results for the Current Condition, Restored Vegetation, and Topographic Shade scenarios for Evans Creek and West Fork Evans Creek. The difference (i.e., shade gap) in mean effective shade between scenarios is in percentage point units.

Table 5-44: Evans Creek and West Fork Evans Creek mean effective shade for Current Condition, Restored Vegetation, and Topographic Shade scenarios.

Scenario	Mean effective shade (%)
Current Condition	42
Restored Vegetation	82
Shade Gap (Restored – Current)	40
Topographic Shade	7.1

Figure 5-38 compares effective shade predictions under the Current Condition, Restored Vegetation, and Topographic Shade scenarios for Evans Creek and West Fork Evans Creek. Figure 5-39 shows the difference in effective shade predictions between the Restored Vegetation and Current Conditions scenarios for Evans Creek and West Fork Evans Creek. Figure 5-40 shows the difference in effective shade predictions between the Current Conditions and Topographic Shade scenarios for Evans Creek and West Fork Evans. The difference in mean effective shade between the scenarios is in percentage point units.

Figure 5-41 shows the shade gaps between the Restored Vegetation and Current Condition scenarios along the Evans Creek and West Fork Evans Creek model extent.

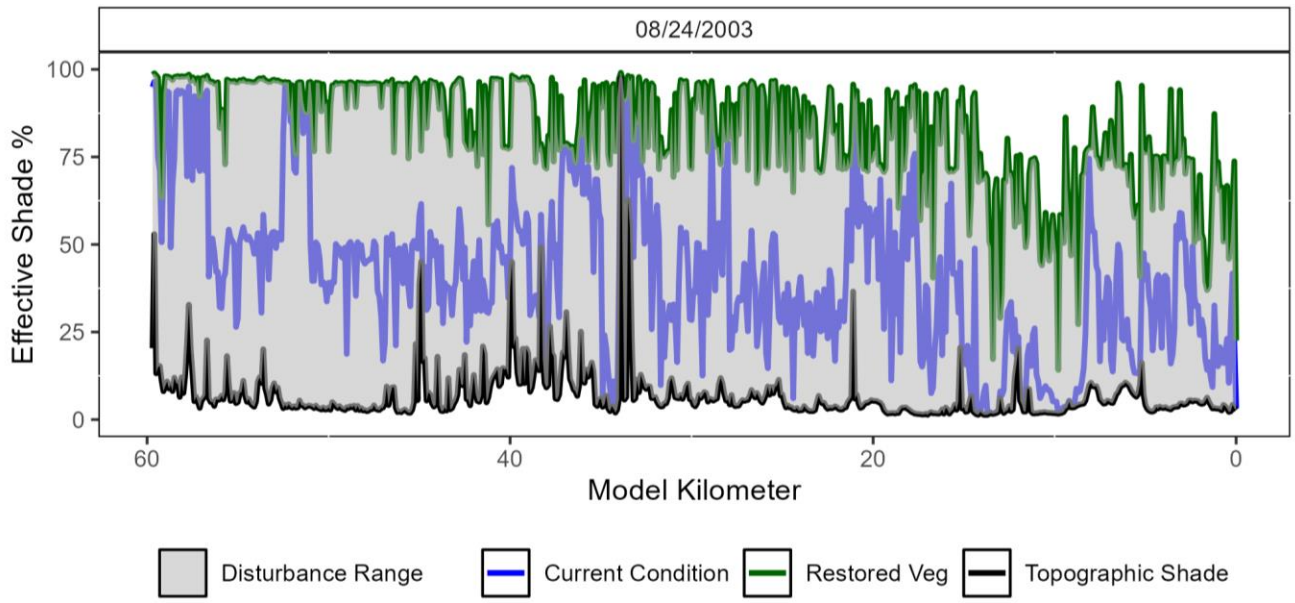


Figure 5-38: Comparison of longitudinal effective shade results of Evans Creek and West Fork Evans Creek Current Condition, Restored Vegetation, and Topographic Shade scenarios.

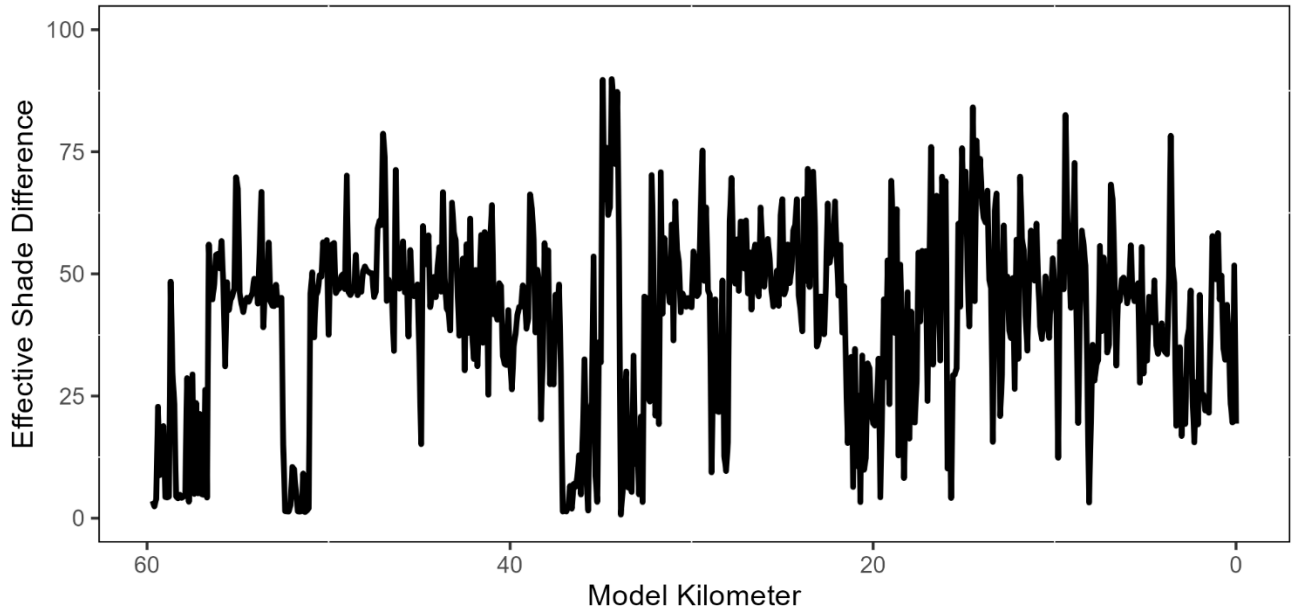


Figure 5-39: Evans Creek and West Fork Evans Creek: Longitudinal effective shade (%) differences between the Restored Vegetation and Current Condition scenarios.

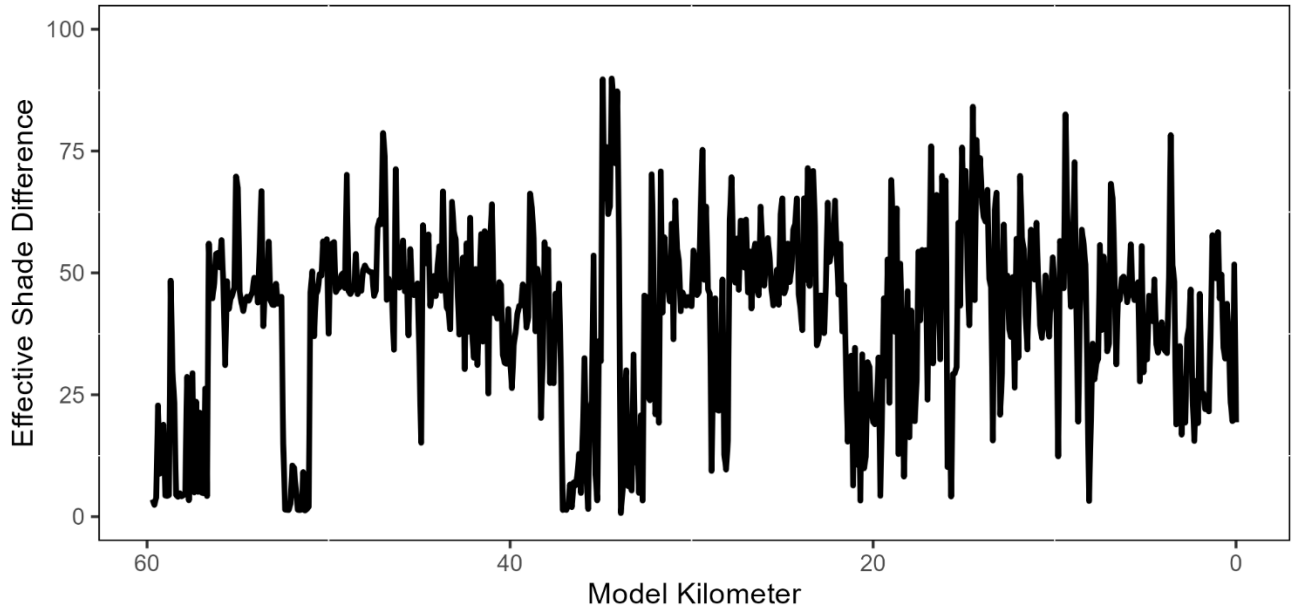


Figure 5-40: Evans Creek and West Fork Evans Creek: Longitudinal effective shade (%) differences between the Current Condition and Topographic Shade scenarios.

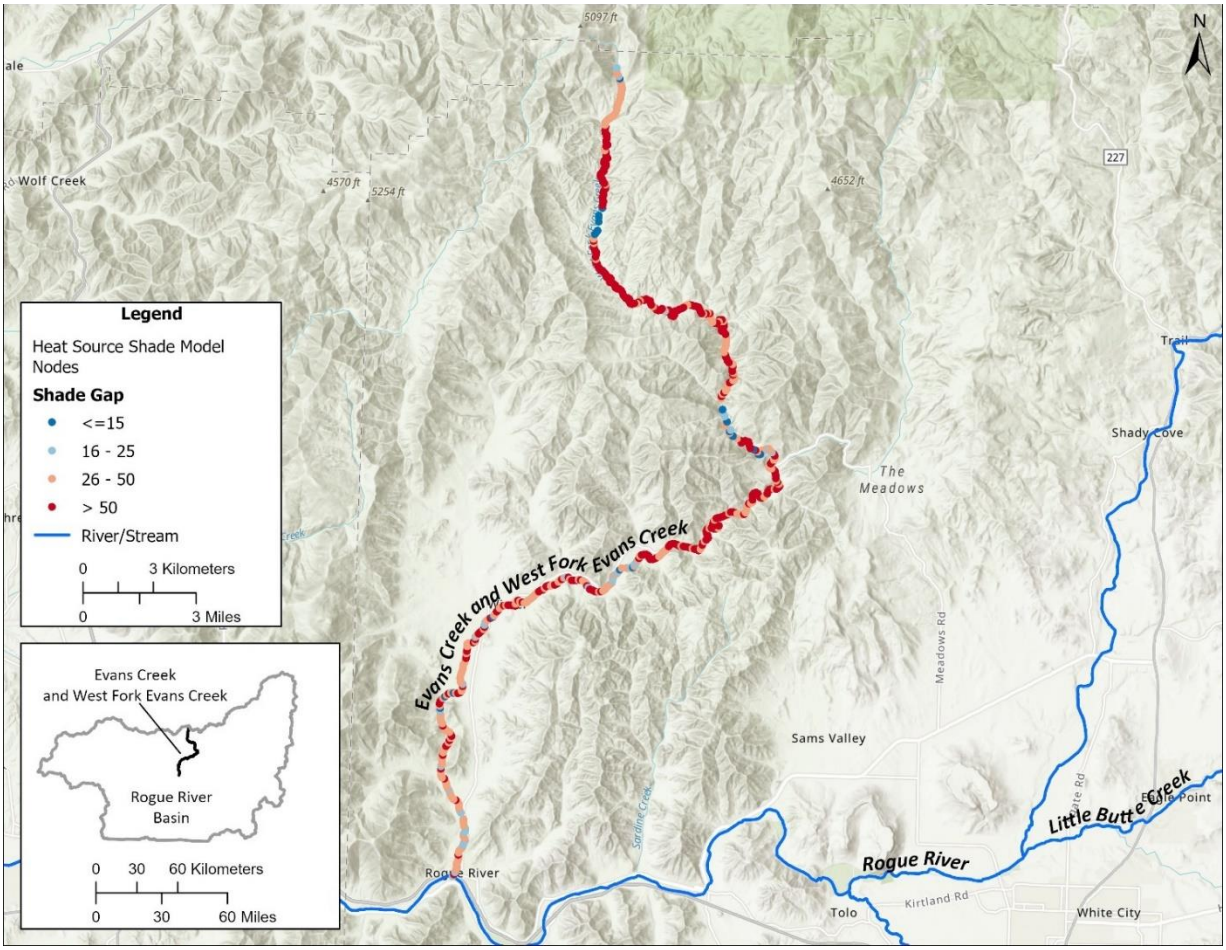


Figure 5-41: Evans Creek and West Fork Evans Creek shade gaps (%) between the Restored Vegetation and Current Condition scenarios.

5.7.2 Restored flow

This section summarizes the temperature impacts of altered flow. Table 5-45 and Figure 5-42 summarize the maximum 7DADM stream temperature changes between the Current Condition and Restored Flow scenarios for Evans Creek and West Fork Evans Creek over the model extent. The maximum 7DADM temperature difference was 0.67°C at the most downstream node and 1.11°C at the POMI (model km 9.2).

Table 5-45: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature change between Current Condition and Restored Flow scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
0.00	0.67	Downstream boundary
9.2	1.11	POMI

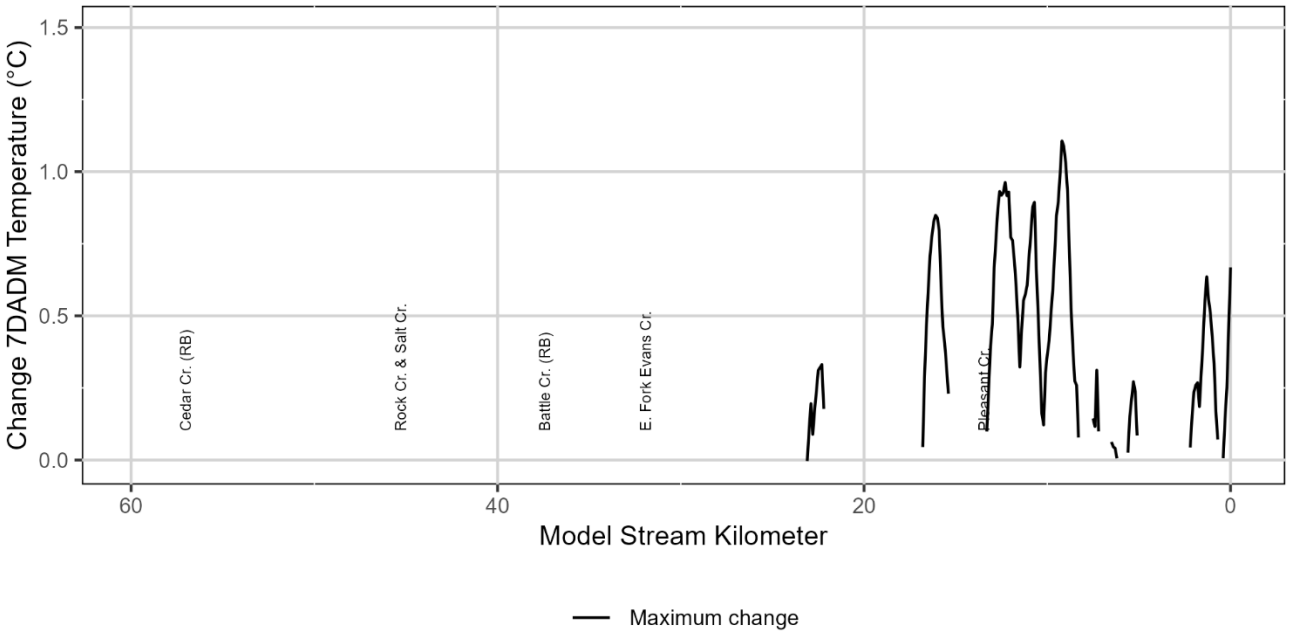


Figure 5-42: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature changes between Current Condition and Restored Flow scenarios over the model extent when scenario temperatures exceed the BBNC.

5.7.3 Tributary temperatures

For Evans Creek and West Fork Evans Creek, the Tributary Temperatures and HUA Attainment scenarios are identical. Refer to Section 5.7.4 for results.

5.7.4 HUA Attainment

This section summarizes the temperature impacts on Evans Creek and West Fork Evans Creek of the proposed load allocations and wasteload allocations, as applicable. The HUA Attainment scenario determines if the modeled thermal sources achieve their allocated portion of the HUA. To

determine this, results from the HUA Attainment scenario and from the Background scenario were compared. Table 5-46 describes the HUA Attainment model scenario set up.

Table 5-46: Evans Creek and West Fork Evans Creek: HUA Attainment scenario setup description.

Model input variable	Attainment scenario set up description
Riparian landcover	Equal to Background scenario setup (restored vegetation conditions), though this source is assigned an allocation.
Tributary temperatures	Tributary temperatures were increased by the assigned allocations on each tributary: Cedar Creek; Battle Creek; EF Evans Cr; Pleasant Cr; and Rock Creek/Salt Creek were all +0.100°C
Tributary flow	Equal to Background model scenario setup.
Boundary condition temperature	Equal to Background model scenario setup.
Boundary condition flow	Equal to Background model scenario setup.
Withdrawals	Equal to Background model scenario setup, though this source is assigned an allocation.
NPDES point sources	There are no NPDES point source discharges within the model extent.
Nonpoint source dam and reservoir operations	There are no dam or reservoir operations within the model extent.
Solar loading from existing infrastructure	Solar loading from existing infrastructure was not modeled, though this source is assigned an allocation.

Table 5-47 and Figure 5-43 summarize the maximum 7DADM stream temperature changes on Evans Creek and West Fork Evans Creek between the Background and Attainment scenarios over the model extent. The maximum 7DADM temperature difference was 0.00°C at the most downstream node and was 0.03°C at the POMI (model km 37.1).

The comparison of the HUA Attainment scenario to the Background indicated that Evans Creek and West Fork Evans Creek warming from tributaries is 0.03°C. The TMDL allocation to warming from tributaries on Evans Creek and West Fork Evans Creek is 0.03°C. The HUA Attainment analysis results support that the HUA portion assigned to modeled sources will be achieved on Evans Creek and West Fork Evans Creek.

Table 5-47: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature changes between Background and Attainment model scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
0.00	0.00	Downstream boundary
37.1	0.03	POMI

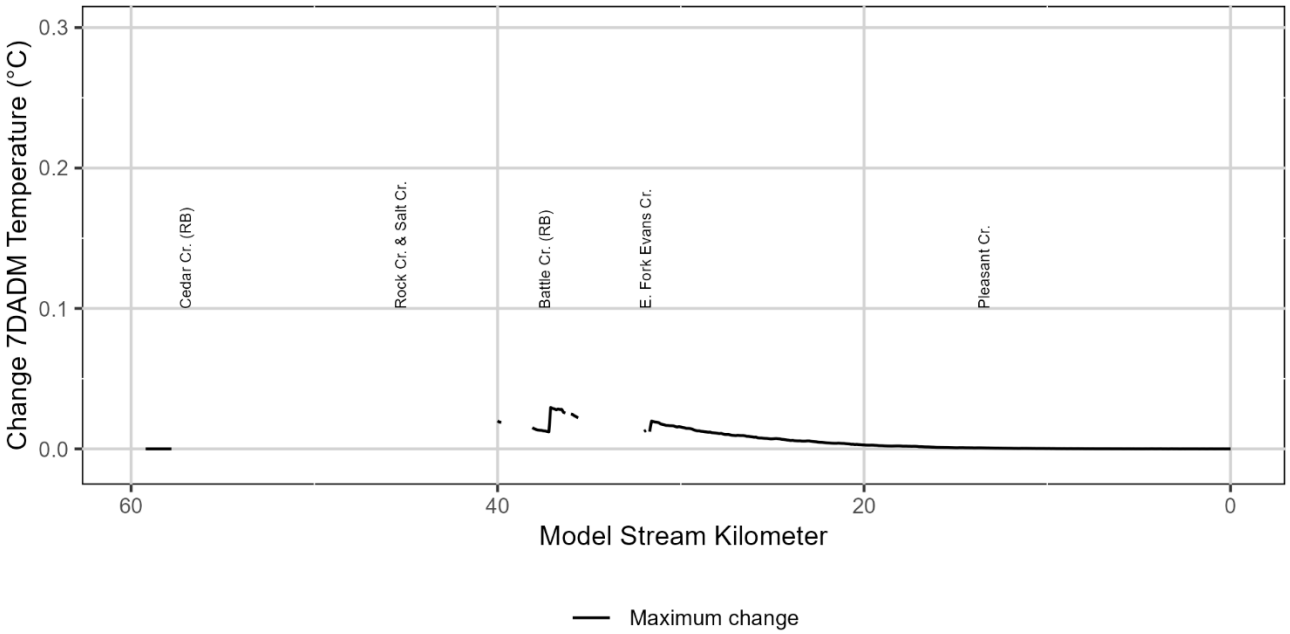


Figure 5-43: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature changes between Attainment and Background scenarios over the model extent when scenario temperatures exceed the BBNC.

5.7.5 Background

This section summarizes the temperature impacts of background conditions. The temperature and effective shade results for the Background scenario are identical to those of the Restored Vegetation scenario for Evans Creek and West Fork Evans Creek because the two scenarios' setups were identical. Likewise, the temperature and shade comparison results between the Background scenario and the Current Condition scenario are equal to those between the Restored Vegetation scenario and the Current Condition scenario. Please refer to those results in section 5.7.1.

Table 5-48 and Figure 5-44 summarize the maximum 7DADM stream temperature changes between the Background scenario and applicable BBNC for Evans Creek and West Fork Evans Creek over the model extent. The maximum 7DADM temperature difference between the Background scenario and the BBNC was 6.41°C at the most downstream node and 8.64°C at the POMI (model km 5.3).

Table 5-48: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature changes between the Background scenario and BBNC over the model extent.

Model km	Stream temperature change (°C)	Location
0.00	6.41	Downstream boundary
5.30	8.64	POMI

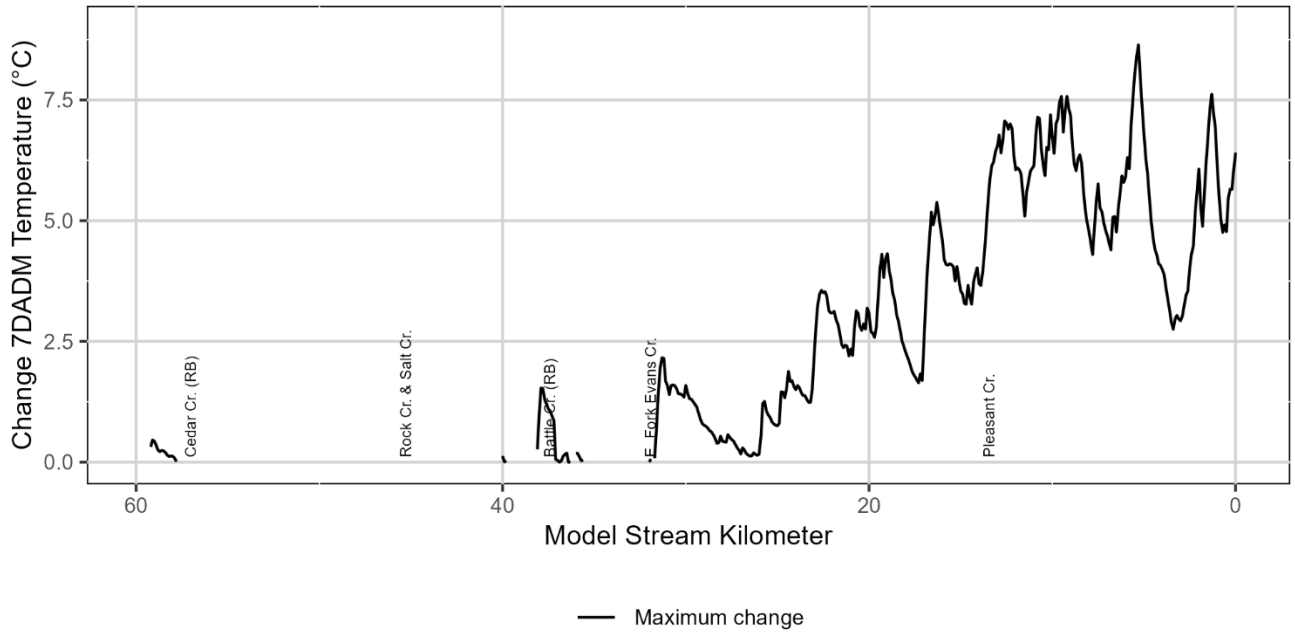


Figure 5-44: Evans Creek and West Fork Evans Creek: Maximum 7DADM stream temperature changes between the Background scenario and the BBNC over the model extent when Background scenario temperatures exceeded the BBNC.

5.8 Little Butte Creek and North Fork Little Butte Creek

Table 5-49 describes the different model scenarios used to simulate stream temperature and effective shade for Little Butte Creek and North Fork Little Butte Creek. Table 5-50 and Figure 5-45 summarize the daily maximum stream temperatures predicted by the various Little Butte Creek and North Fork Little Butte Creek model scenarios over the model extent.

Table 5-49: Little Butte Creek and North Fork Little Butte Creek model scenario descriptions.

Scenario Name	Description
Restored Vegetation	Evaluates effective shade and temperature responses with fully restored near-stream land cover.
Topographic Shade	Evaluates effective shade and temperature responses with no near-stream land cover.
Restored Flow	Evaluates temperature responses with all consumptive use withdrawals removed.
Restored Flow 2	Identical to the Restored Flow scenario but without Fish Lake reservoir. Natural flows were estimated by predicting spring flow into Fish Lake. This was done by subtracting lake outflow from the change in storage and inflow from Cascade Canal (trans-basin transfer via shallow groundwater), averaged over July - August. This method predicted a natural flow of 0.51 cms (18 cfs). Stream temperatures at the (removed) Fish Lake outfall location were assumed equal to spring inflow temperatures (8°C) as the lake is entirely spring-fed. This is a conservative estimate as some warming would have occurred between the springs' inlets and the current lake outlet.
Background	Evaluates the effective shade and stream temperature responses with fully restored near-stream land cover and all consumptive use withdrawals removed.

Scenario Name	Description
Tributary Temperatures	Evaluates stream temperature responses with fully restored near-stream vegetation, points of diversion removed, and each tributary's temperatures increased by the total HUA allocations on that tributary. Thus, temperature were increased from their Background scenario temperatures by 0.13°C for S. Fork Little Butte Creek, 0.094°C for Antelope Creek, and 0.100°C for all other modeled tributary streams. Note: temperatures of springs, canals, and ditches were not adjusted.
Attainment	Identical to the Tributary Temperatures scenario for Little Butte Creek and North Fork Little Butte Creek.

Table 5-50: Summary of maximum 7DADM stream temperature at the mouth of Little Butte Creek for all model scenarios over the entire model period.

Scenario	Stream temperature (°C), mouth	Stream temperature (°C), POMI
Current Condition	30.60	30.60
Topographic Shade	32.41	32.43
Background	18.55	19.63
Restored Vegetation	24.29	24.36
Restored Flow	21.24	22.27
Restored Flow 2	21.68	21.75
Attainment	18.58	19.63

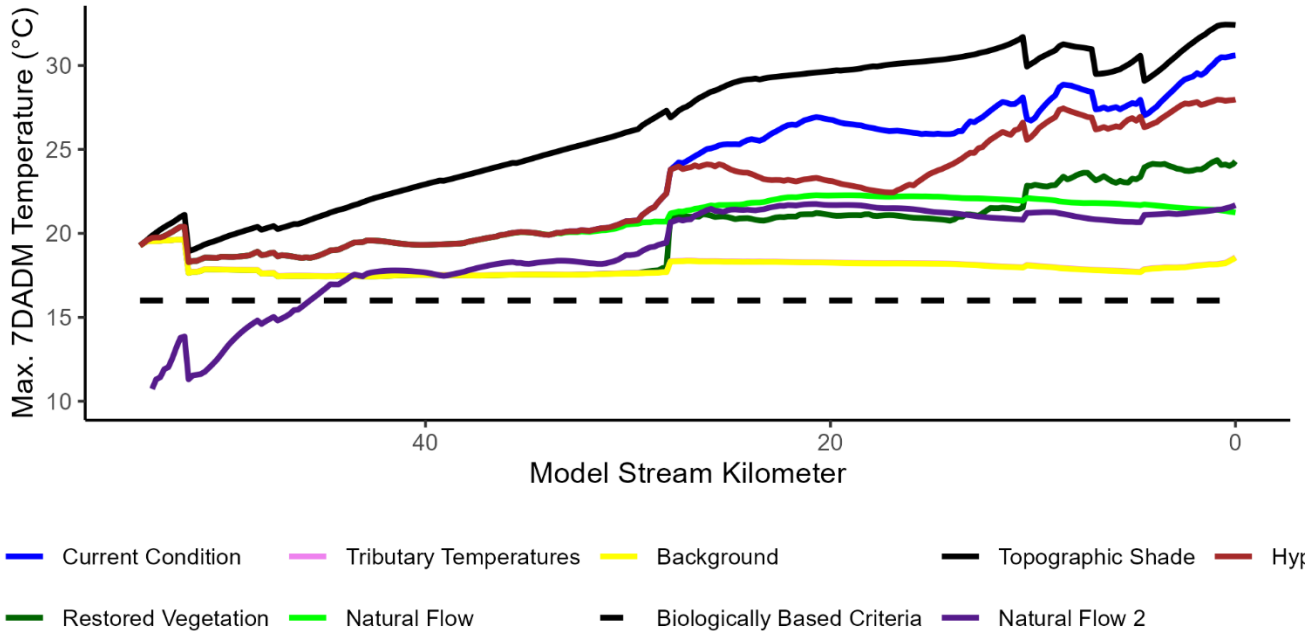


Figure 5-45: Maximum 7DADM stream temperature for all Little Butte Creek and North Fork Little Butte Creek model scenarios over the model extent.

5.8.1 Vegetation scenarios

This section summarizes the temperature and shade impacts of restored vegetation, current conditions, and topographic shade on Little Butte Creek and North Fork Little Butte Creek. Table 5-51 and Figure 5-46 summarize the maximum 7DADM stream temperature changes between the Current Condition and Restored Vegetation scenarios for Little Butte Creek and North Fork Little Butte Creek over the model extent when temperatures exceed the BBNC. The maximum 7DADM

temperature difference was 6.40°C at the most downstream node and 6.74°C at the POMI (model km 0.50).

Table 5-51: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Restored Vegetation and Current Condition model scenarios over the model extent when temperatures exceeded the BBNC.

Model km	Stream temperature change (°C)	Location
0.00	6.40	Downstream boundary
0.40	6.74	POMI

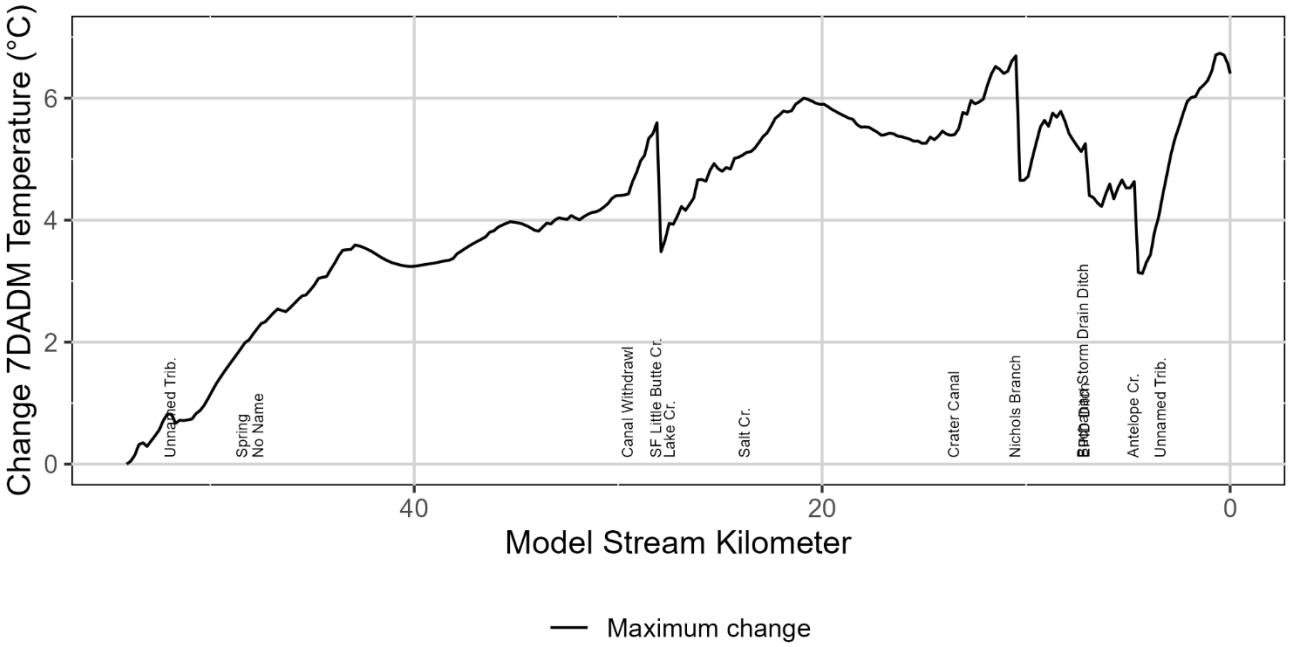


Figure 5-46: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Current Condition and Restored Vegetation scenarios over the model extent when scenario temperatures exceed the BBNC.

Table 5-52 and Figure 5-47 summarize the maximum 7DADM stream temperature changes between the Topographic Shade and Current Condition scenarios for Little Butte Creek and North Fork Little Butte Creek over the entire model extent. The maximum 7DADM temperature difference at the most downstream node is 0.65°C. In addition, the greatest 7DADM temperature difference between the two scenarios (the POMI) is 3.04°C and occurs at stream model km 3.04

Table 5-52: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Current Condition and Topography model scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
0.00	3.96	Downstream boundary
28.10	6.77	POMI

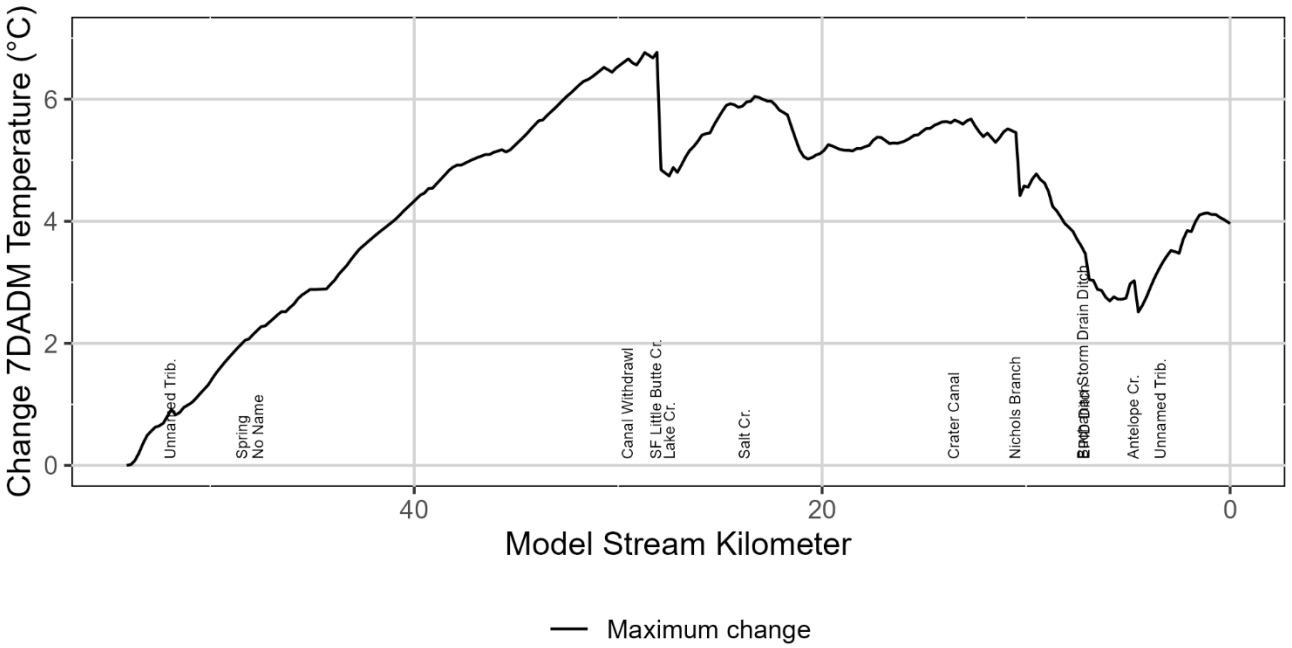


Figure 5-47: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Topographic Shade and Current Condition scenarios over the model extent when scenario temperatures exceed the BBNC.

Table 5-53 summarizes the mean effective shade results for the Current Condition, Restored Vegetation, and Topographic Shade scenarios for Evans Creek and West Fork Evans Creek. The difference (i.e., shade gap) in mean effective shade between scenarios is in percentage point units.

Figure 5-48 compares effective shade predictions under the Current Condition, Restored Vegetation, and Topographic Shade scenarios for Evans Creek and West Fork Evans Creek. Figure 5-49 shows the difference in effective shade predictions between the Restored Vegetation and Current Conditions scenarios for Evans Creek and West Fork Evans Creek. Figure 5-50 shows the difference in effective shade predictions between the Current Conditions and Topographic Shade scenarios for Evans Creek and West Fork Evans. The difference in mean effective shade between scenarios is in percentage point units.

Figure 5-51 shows the shade gaps between the Restored Vegetation and Current Condition scenarios along the Little Butte Creek and North Fork Little Butte Creek model extent.

Table 5-53: Little Butte Creek and North Fork Little Butte Creek: Mean effective shade for the Current Condition, Restored Vegetation, and Topographic Shade scenarios.

Scenario	Mean effective shade (%)
Current Condition	57
Restored Vegetation	83
Shade Gap (Restored – Current)	26
Topographic Shade	5

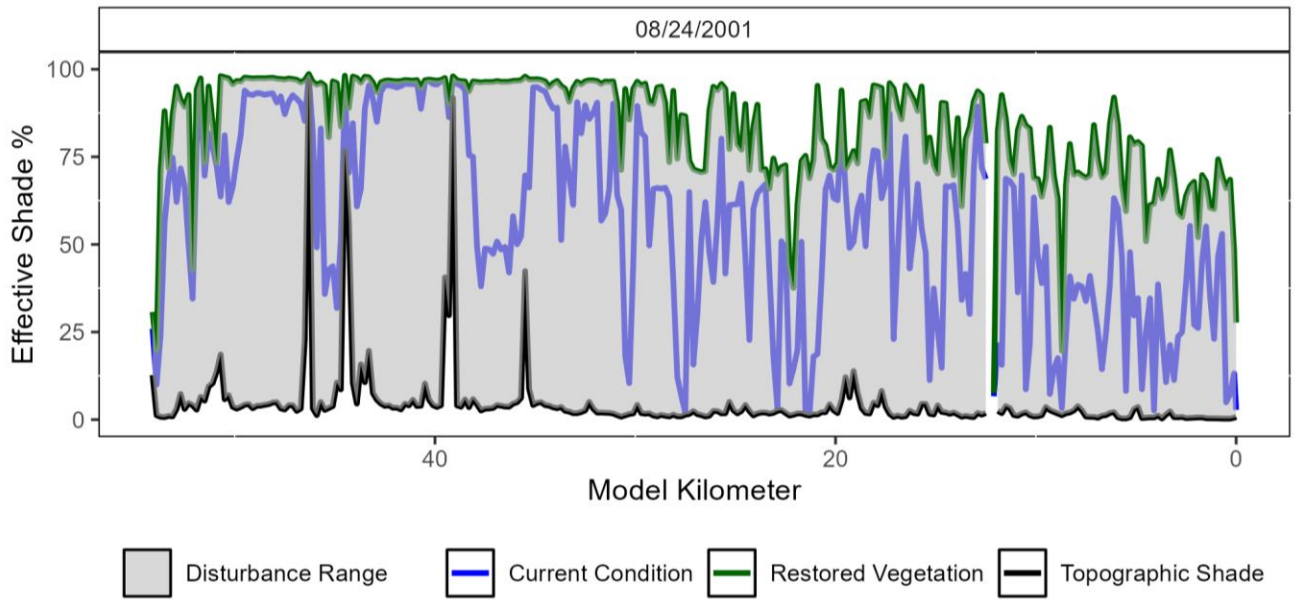


Figure 5-48: Little Butte Creek and North Fork Little Butte Creek: Longitudinal effective shade results for Current Condition, Restored Vegetation, and Topographic Shade scenarios.

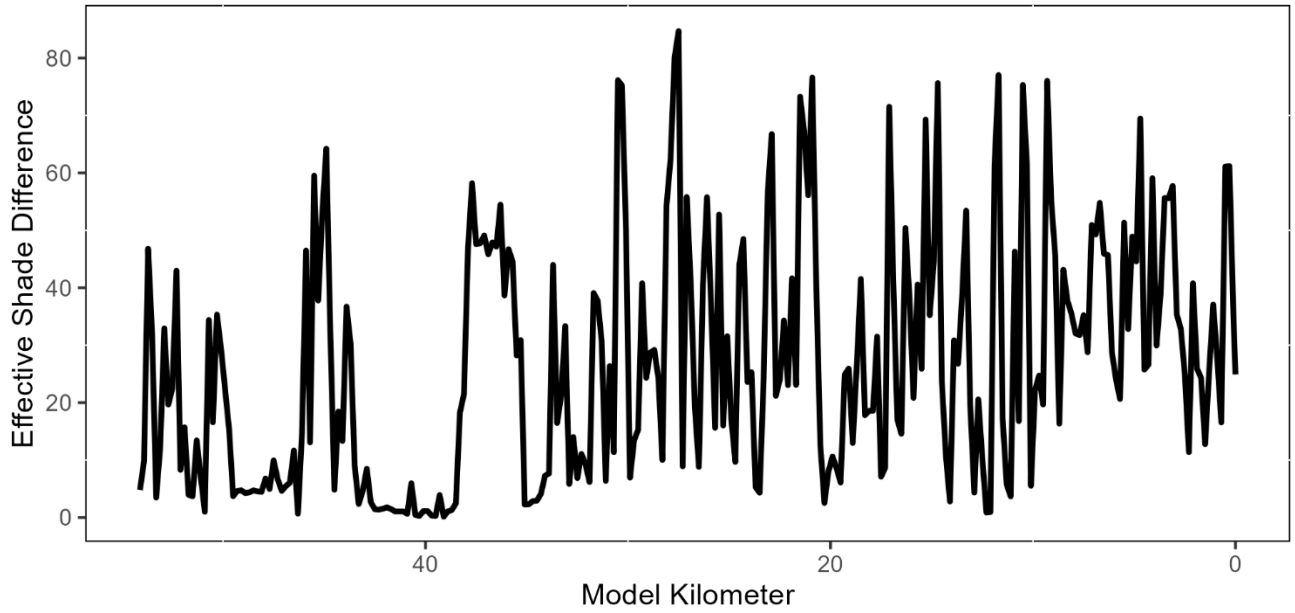


Figure 5-49: Little Butte Creek and North Fork Little Butte Creek: Longitudinal effective shade (%) differences between Restored Vegetation and Current Condition scenarios.

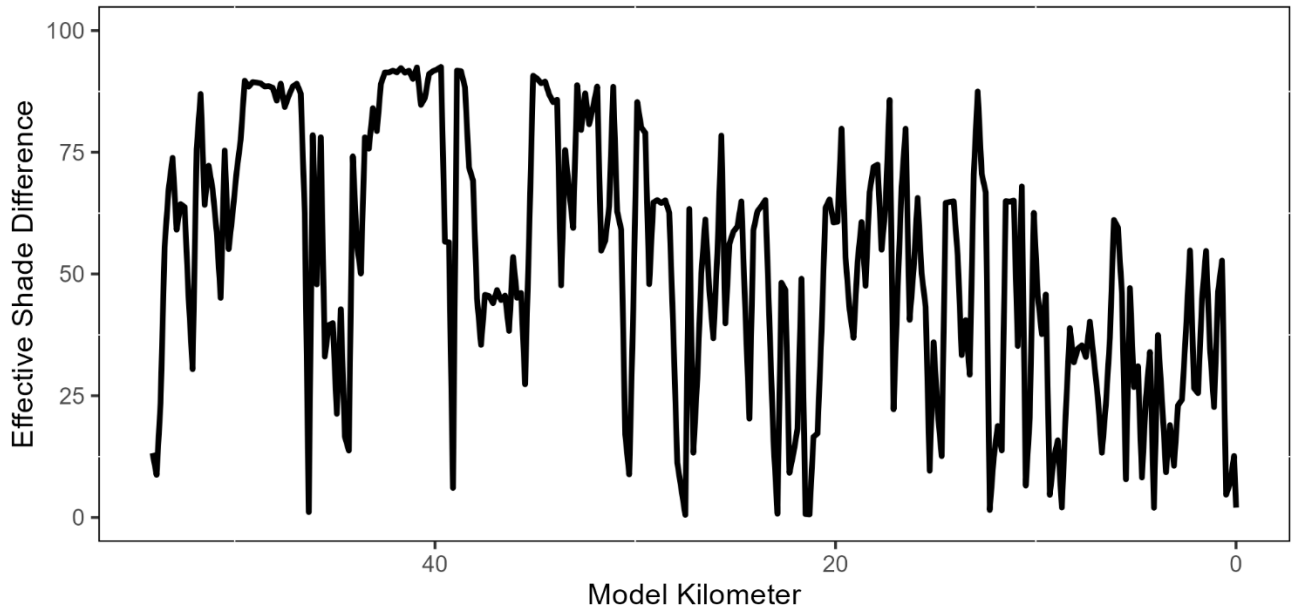


Figure 5-50: Little Butte Creek and North Fork Little Butte Creek: Longitudinal effective shade (%) differences between Current Condition and Topographic Shade scenarios.

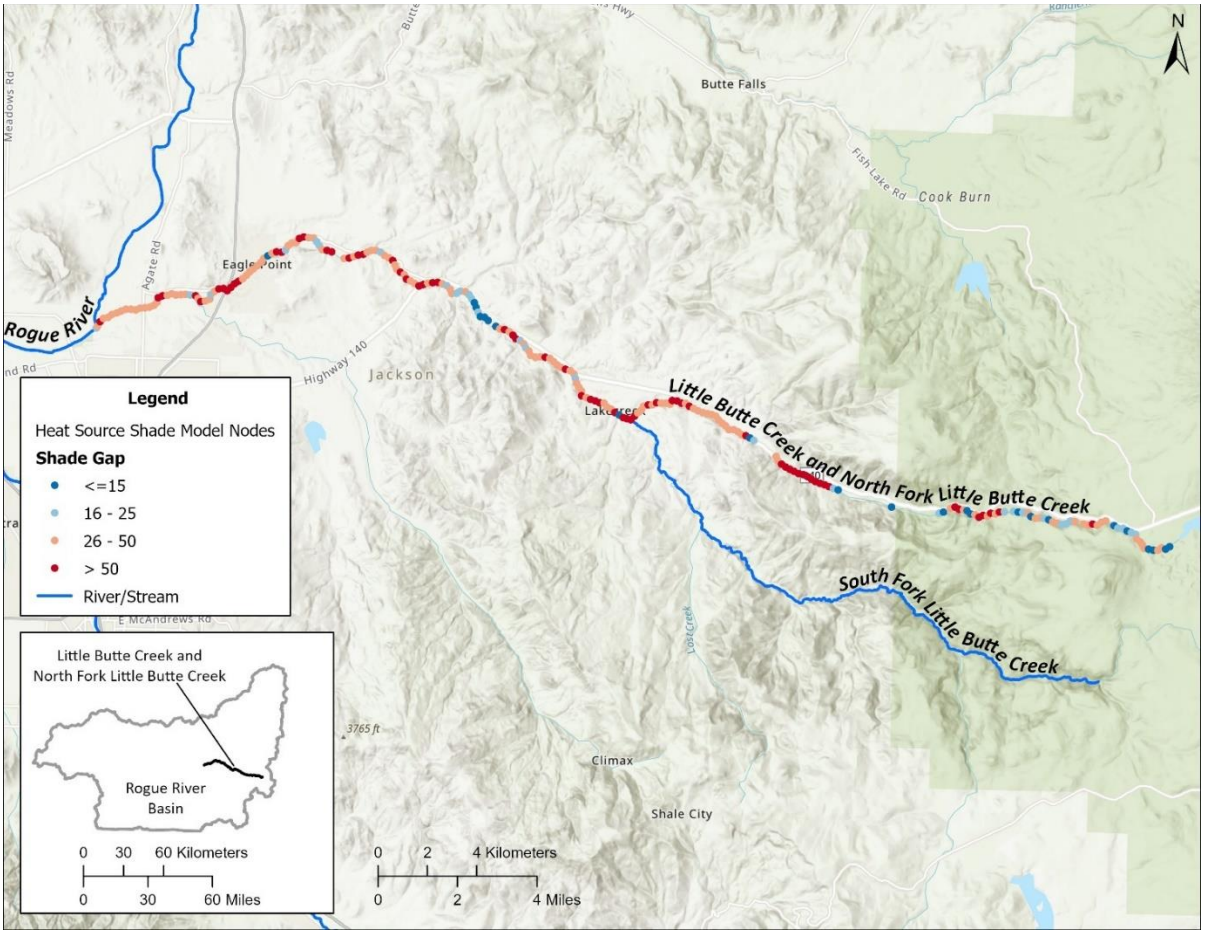


Figure 5-51: Little Butte Creek and North Fork Little Butte Creek shade gaps (%) between Restored Vegetation and Current Condition scenarios.

5.8.2 Restored flow 1

This section summarizes the temperature impacts of altered flow. Table 5-54 and Figure 5-52 summarize the maximum 7DADM stream temperature changes between the Current Condition and Restored Flow 1 scenarios for Little Butte Creek and North Fork Little Butte Creek over the model extent when scenario temperatures exceed the BBNC. The maximum 7DADM temperature difference was 9.67°C at the most downstream node (model km 0.00), which was also the POMI.

Table 5-54: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature change between Current Condition and Restored Flow scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
0.00	9.67	Downstream boundary
0.00	9.67	POMI

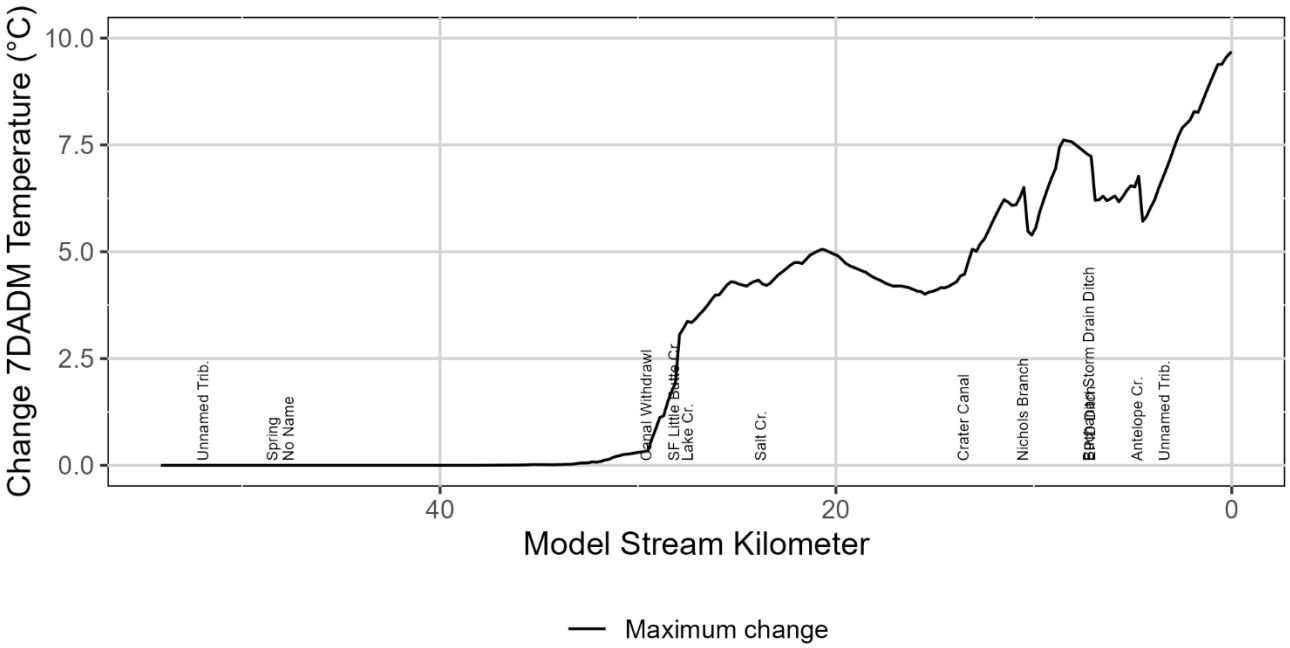


Figure 5-52: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Restored Flow 1 and Current Condition scenarios over the model extent when scenario temperatures exceed the BBNC.

5.8.3 Restored flow 2

This section summarizes the temperature impacts of altered flow. Table 5-55 and Figure 5-53 summarize the maximum 7DADM stream temperature change between the Current Condition and Restored Flow scenarios for Little Butte Creek and North Fork Little Butte Creek over the entire model period and extent. The maximum 7DADM temperature difference at the most downstream node is 9.83°C. In addition, the greatest 7DADM temperature difference between the two scenarios (the POMI) is 11.27°C and occurs at stream model km 54.1.

Table 5-55: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Current Condition and Restored Flow scenarios over the model extent when scenario temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
0.00	9.78	Downstream boundary
54.1	11.27	POMI

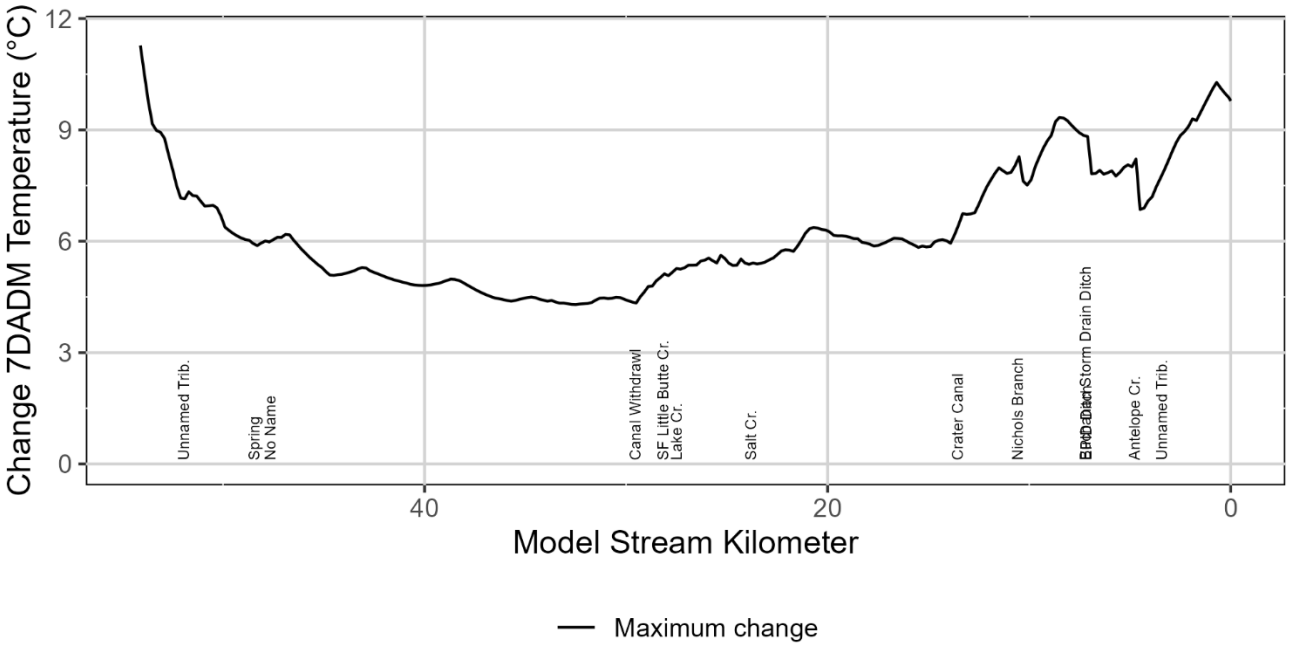


Figure 5-53: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Restored Flow 2 and Current Condition scenarios over the model extent when scenario temperatures exceed the BBNC.

5.8.4 Tributary Temperatures

For Little Butte Creek and North Fork Little Butte Creek, the Tributary Temperatures and HUA Attainment scenarios are identical. Refer to Section 5.8.5 for results.

5.8.5 HUA Attainment

This section summarizes the temperature impacts on Little Butte Creek and North Fork Little Butte Creek of the proposed load allocations and wasteload allocations, as applicable. The HUA Attainment scenario determines if the modeled thermal sources achieve their allocated portion of the HUA. To determine this, results from the HUA Attainment scenario and Background scenario were compared. Table 5-56 describes the HUA Attainment model scenario setup.

Table 5-56: Little Butte Creek and North Fork Little Butte Creek: HUA Attainment scenario setup.

Model input variable	Attainment scenario set up description
Riparian landcover	Equal to the Background scenario setup (restored vegetation conditions), though this source is assigned an allocation.
Tributary temperatures	Tributary temperatures were increased by the assigned allocations on each tributary: 0.13°C for S. Fork Little Butte Creek, 0.094°C for Antelope Creek, and 0.100°C for all other modeled tributary streams. Note: temperatures of springs, canals, and ditches were not adjusted
Tributary flow	Equal to the Background scenario setup.
Boundary condition temperature	Equal to the Background scenario setup.

Model input variable	Attainment scenario set up description
Boundary condition flow	Equal to the Background scenario setup
Withdrawals	Equal to the Background scenario setup
NPDES point sources	There are no NPDES point source discharges within the model extent.
Nonpoint source dam and reservoir operations	There are no dam or reservoir operations within the model extent.
Solar loading from existing infrastructure	Solar loading from existing infrastructure was not modeled, though this source is assigned an allocation.

Table 5-57 and Figure 5-54 summarize the maximum 7DADM stream temperature changes between the Attainment and Background scenarios for Little Butte Creek and North Fork Little Butte Creek. The maximum 7DADM temperature difference was 0.03°C at the most downstream node and 0.04°C at the POMI (model km 4.30).

This comparison indicates that the maximum Little Butte Creek and North Fork Little Butte Creek warming from tributaries is 0.04°C. The TMDL allocation to warming from tributaries on Evans Creek and West Fork Evans Creek is 0.04°C. The HUA Attainment analysis results support that the HUA portion assigned to modeled sources will be achieved on Evans Creek and West Fork Evans Creek.

Table 5-57: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Attainment and Background model scenarios over the model extent.

Model km	Stream temperature (°C)	Location
0.00	0.03	Downstream boundary
4.30	0.04	POMI

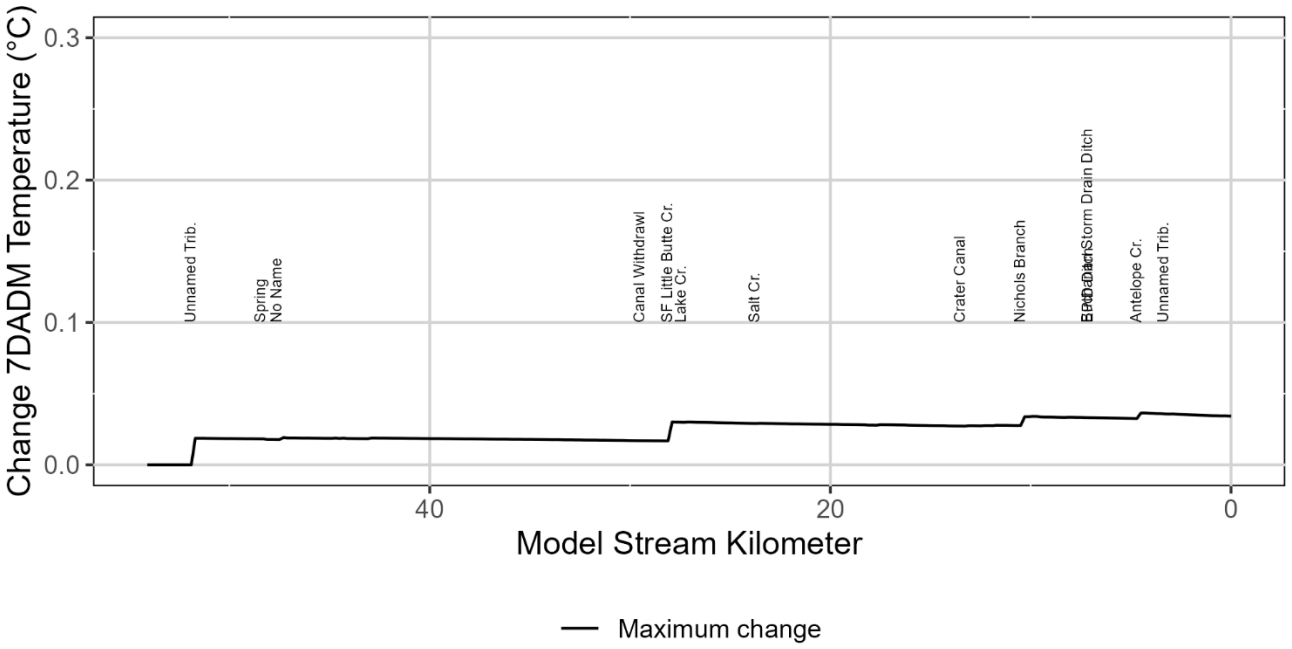


Figure 5-54: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Attainment and Background scenarios over the model extent when scenario temperatures exceed the BBNC.

5.8.6 Hyporheic

This section summarizes the temperature impacts of altered hyporheic flow. Table 5-58 and Figure 5-55 summarize the maximum 7DADM stream temperature changes between the Current Condition and Hyporheic scenarios for Little Butte Creek and North Fork Little Butte Creek over the model extent when scenario temperatures exceed the BBNC. The maximum 7DADM temperature difference was 2.68°C at the most downstream node and was 3.93°C at the POMI (model km 18.3).

Table 5-58: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Current Condition and Hyporheic scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
0.00	2.68	Downstream boundary
18.30	3.93	POMI

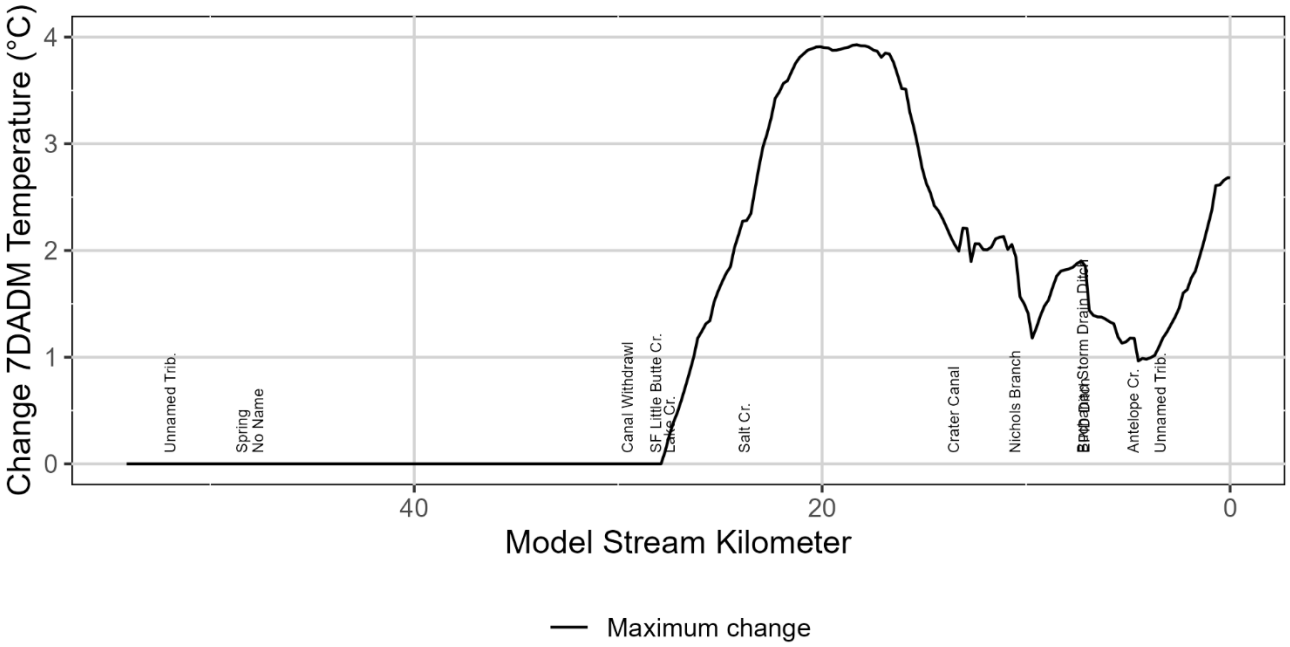


Figure 5-55: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Current Condition and Hyporheic scenarios over the model extent when scenario temperatures exceed the BBNC.

5.8.7 Background

This section summarizes the temperature impacts of background conditions. For Little Butte Creek and North Fork Little Butte Creek, the Background scenario temperature and effective shade results are identical to those of the Restored Vegetation scenario because the two scenarios' setups were identical. Likewise, the results of temperature and shade comparisons between the Background and Current Condition scenarios are the same as between the Restored Vegetation and Current Condition scenarios. Please see the results in Section 5.8.1.

Table 5-59 and Figure 5-56 summarize the maximum 7DADM stream temperature changes between the Background scenario and the BBNC for Little Butte Creek and North Fork Little Butte Creek over the model extent. The maximum 7DADM temperature difference between the Background scenario and the BBNC was 2.55°C at the most downstream node and 3.63°C at the POMI (model km 51.90).

Table 5-59: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between the Background scenario and BBNC over the model extent.

Model km	Stream temperature change (°C)	Location
0.00	2.55	Downstream boundary
51.90	3.63	POMI

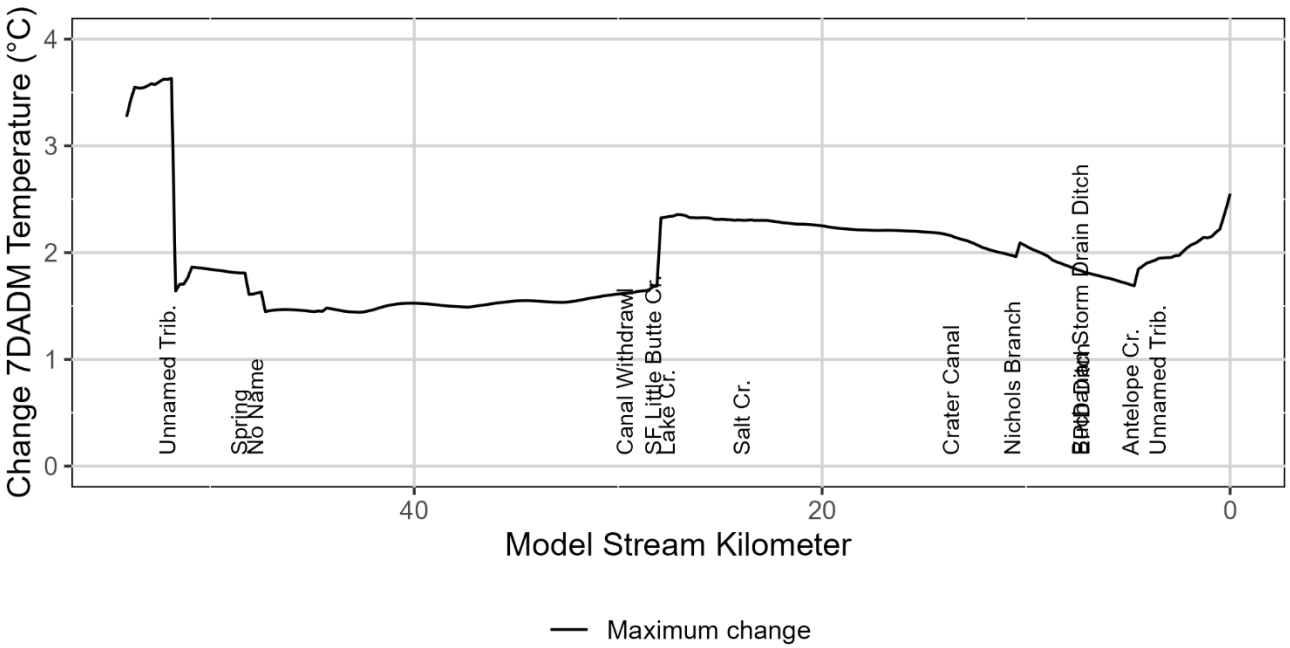


Figure 5-56: Little Butte Creek and North Fork Little Butte Creek: Maximum 7DADM stream temperature changes between the Background scenario and the BBNC over the model extent.

5.9 Lobster Creek

In 1999, seasonal 7DADM water temperatures were recorded for the period of August 23 - August 30. The Heat Source modeling date (July 22, 1999) was selected due to its proximity to the field flow measurement collection date (July 15, 1999) and because the diurnal temperature curve appeared to indicate a lack of coastal fog. Flow measurements were collected during adverse conditions, near the peak solar loading period, and during a period of staff availability. As Table 5-61 indicates, however, during the one-day model period, neither the Current Condition nor the Restored Vegetation model scenarios results exceeded the BBNC (18.0°C). Also, field-collected stream temperature data for the selected model day did not exceed the BBNC. Lobster Creek did not exceed the BBNC in the summer of 1999.

The 2022 Integrated Report assessed Lobster Creek and concluded it was temperature-impaired from Fall Creek to the confluence of the Rogue River due to 120 valid excursions of criteria (DEQ 2022). This assessment confirmed that Lobster Creek is temperature impaired and has exceeded numeric criteria, but these conditions were not observed in the model period.

Given the above circumstances, model scenarios were not used to assess TMDL allocations in Lobster Creek. A model scenario was not ideal for this assessment, as the model was calibrated to a period when Lobster Creek was attaining the water temperature criteria. As described in Section 5.1.3, water temperature change results between scenarios are typically presented only when one or both scenarios exceed the BBNC; this is to ensure that reported water temperature results represent

conditions when the HUA applies. Model scenarios are tools used to identify how to achieve water temperature standards when the HUA applies. Since the HUA does not apply to Lobster Creek under modeled conditions, it was not appropriate to assess attainment of the HUA, or portions of the HUA with a model scenario. Accordingly, warming from allocations on tributaries and the mainstem was assessed with a mass balance (Equation 5-2a) as detailed in Sections 5.9.2 and 5.9.3.

Table 5-60 describes the different model scenarios used to simulate stream temperature and effective shade for Lobster Creek. Table 5-61 and Figure 5-57 summarize the daily maximum stream temperatures predicted for all model scenarios over the model extent.

Table 5-60: Lobster Creek model scenario descriptions.

Scenario Name	Description
Restored Vegetation	Evaluates effective shade and temperature responses with fully restored near-stream land cover.
Topographic Shade	Evaluates effective shade and temperature responses with no near-stream land cover.
Tributary Temperatures	This scenario was not modeled; instead, a thermal mass balance was completed to evaluate stream temperature responses with each tributary's temperatures increased by the total HUA assigned to point and nonpoint sources on that tributary (0.175°C).
Background	Identical to the Restored Vegetation scenario for Lobster Creek.
Attainment	Identical to the Tributary Temperatures scenario for Lobster Creek.

Table 5-61: Lobster Creek: Daily maximum stream temperatures for all model scenarios over the model extent.

Scenario	Stream temperature, mouth (°C)	Stream temperature, POMI (°C)	POMI (model km)
Current Condition	15.88	17.53	15.1
Restored Vegetation	15.02	17.46	15.1
Topographic Shade	17.55	19.85	3.9
Background	15.02	17.46	15.1

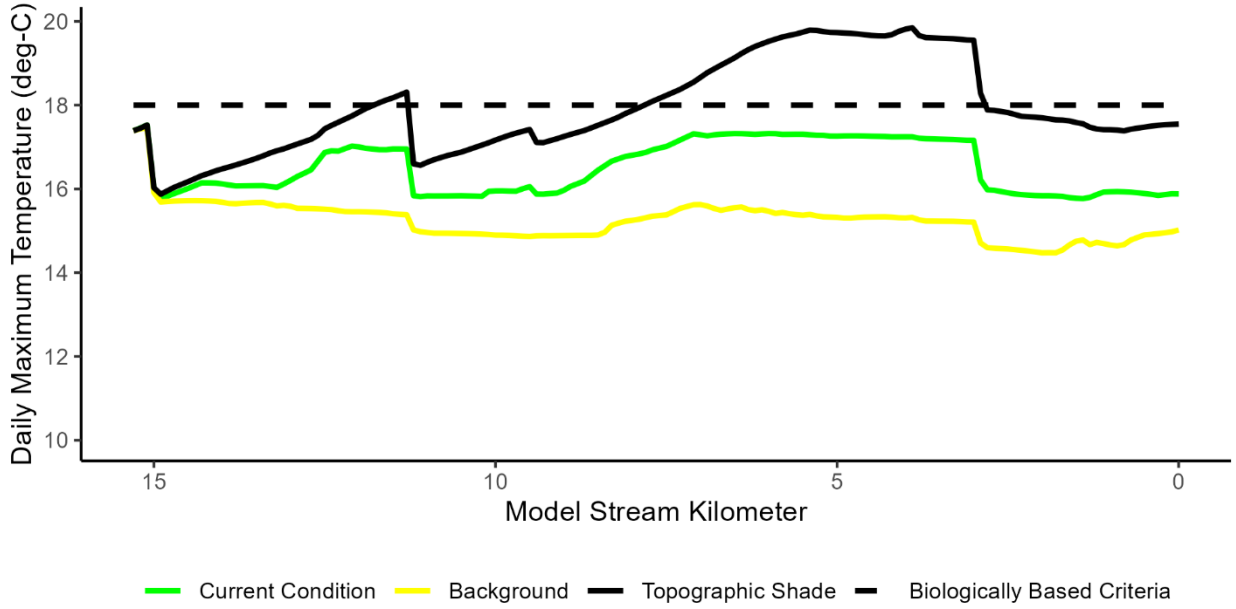


Figure 5-57: Lobster Creek: Daily maximum stream temperature for all model scenarios.

5.9.1 Vegetation scenarios

This section summarizes the effective shade and stream temperature impacts of current vegetation conditions, restored vegetation conditions and topographic shading for Lobster Creek. Table 5-62 and Figure 5-58 summarize the daily maximum stream temperature changes between the Current Condition and Restored Vegetation scenarios. The daily maximum temperature difference was 0.86°C at the most downstream node (the outlet) and 1.97°C at the POMI (model km 3.7).

Table 5-62: Lobster Creek: Daily maximum stream temperature changes between Restored Vegetation and Current Condition model scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
0	0.86	outlet
3.7	1.97	POMI

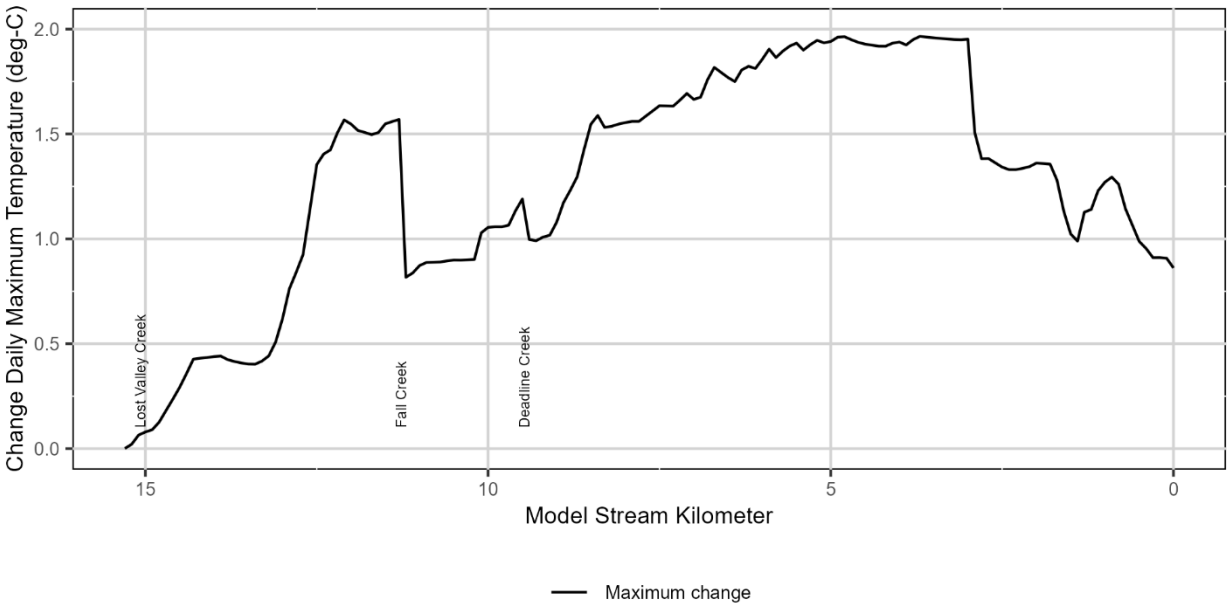


Figure 5-58: Lobster Creek: Daily maximum stream temperature changes between the Restored Vegetation and Current Condition model scenarios over the model extent.

Table 5-63 and Figure 5-59 summarizes the daily maximum stream temperature changes between the Current Condition and Topographic Shade scenarios over the model extent. The daily maximum temperature difference was 1.67°C at the most downstream node (the outlet) and 2.60°C at the POMI (model km 3.9).

Table 5-63: Summary of daily maximum stream temperature change between Current Condition and Topographic Shade model scenarios for Lobster Creek over the entire model period.

Model km	Stream temperature change (°C)	Location
0	1.67	outlet
3.9	2.60	POMI

Table 5-64: Lobster Creek: Daily maximum stream temperature change between Topographic Shade scenario and the BBNC over the model extent.

Model km	Stream temperature change (°C)	Location
3.9	1.85	POMI

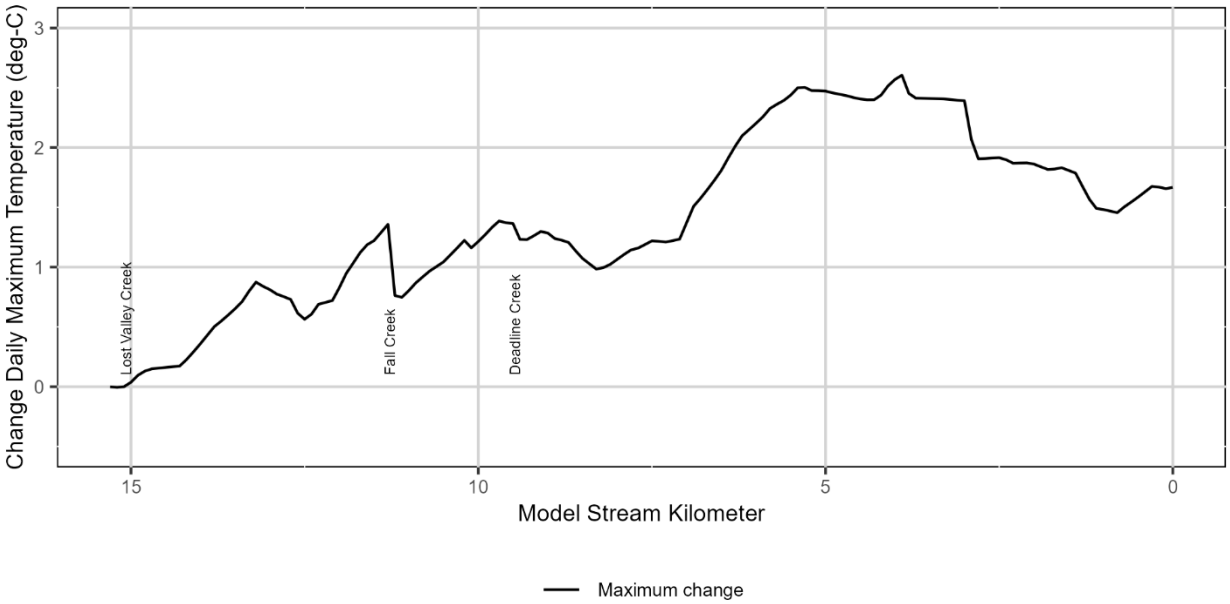


Figure 5-59: Lobster Creek: Daily maximum stream temperature changes between the Current Condition and Topographic Shade model scenarios over the model extent.

Table 5-65 and Figure 5-60 summarize mean effective shade (%) results for the Current Condition, Restored Vegetation, and Topographic Shade model scenarios.

Figure 5-61 shows the effective shade (%) differences between the Restored Vegetation and Current Condition model scenarios, while Figure 5-62 shows effective shade (%) differences between the Current Condition and Topographic Shade model scenarios.

Figure 5-63 shows the effective shade (%) differences (gaps) between the Restored Vegetation and Current Condition scenarios along the mapped Lobster Creek model extent.

Table 5-65: Lobster Creek: Mean effective shade for Current Condition, Restored Vegetation, and Topographic Shade scenarios.

Scenario	Mean effective shade (%)
Current Condition	42
Restored Vegetation	73
Change (Restored – Current)	31
Topographic Shade	0

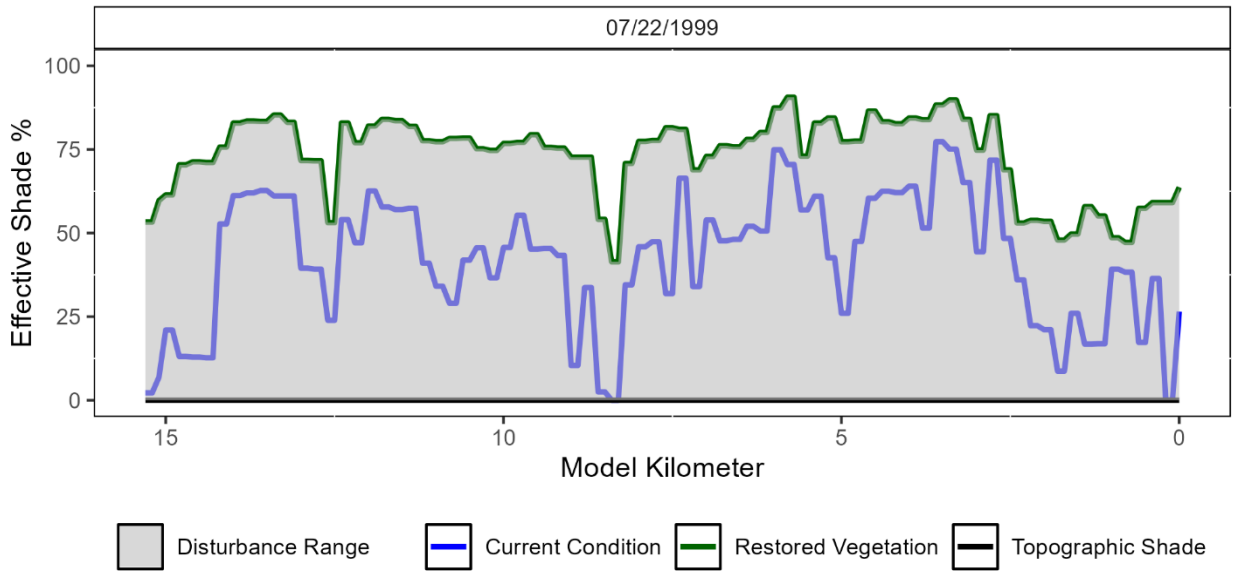


Figure 5-60: Lobster Creek: Effective shade results for Current Condition, Restored Vegetation, and Topographic Shade scenarios.

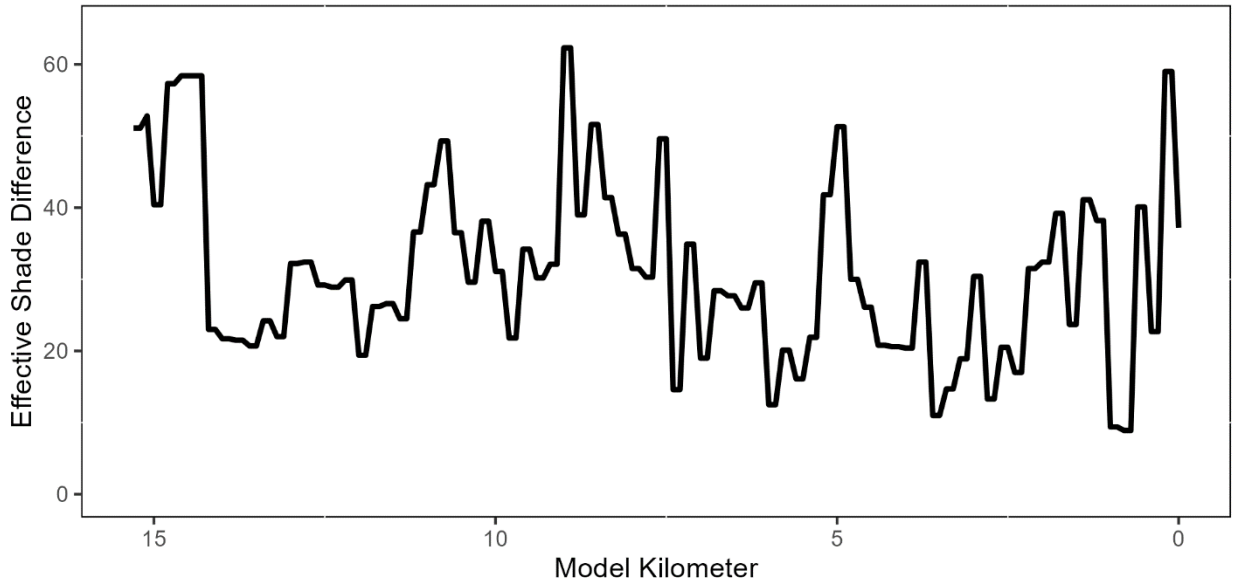


Figure 5-61: Lobster Creek: Effective shade (%) differences between Current Condition and Restored Vegetation scenarios.

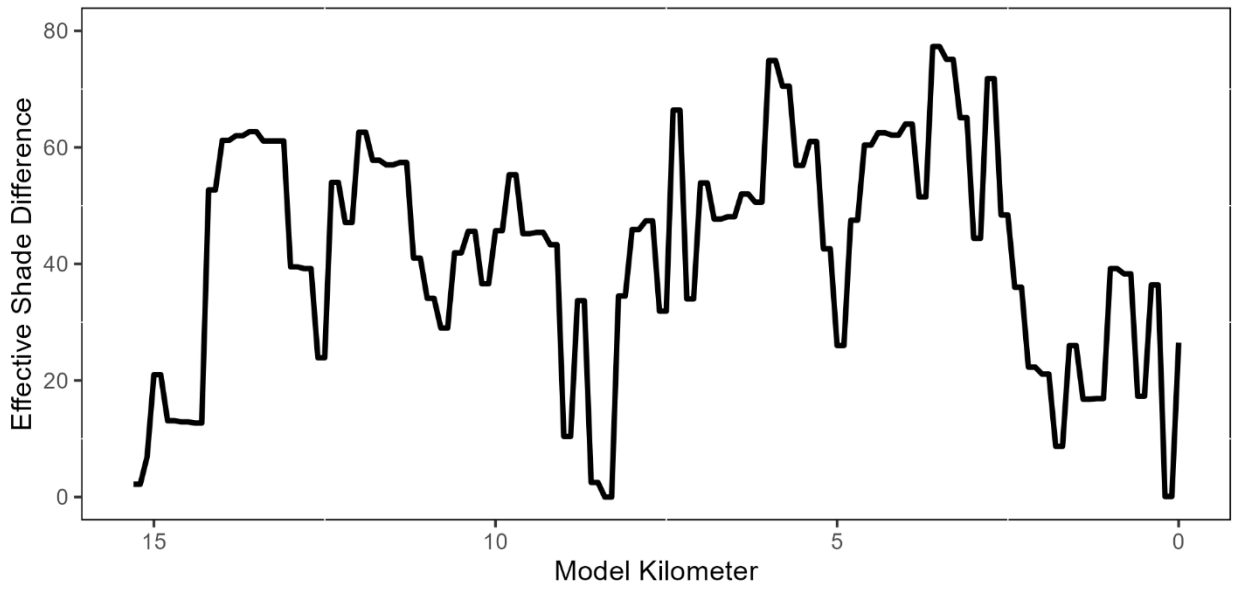


Figure 5-62: Lobster Creek: Effective shade (%) differences between Current Condition and Topographic Shade scenarios.

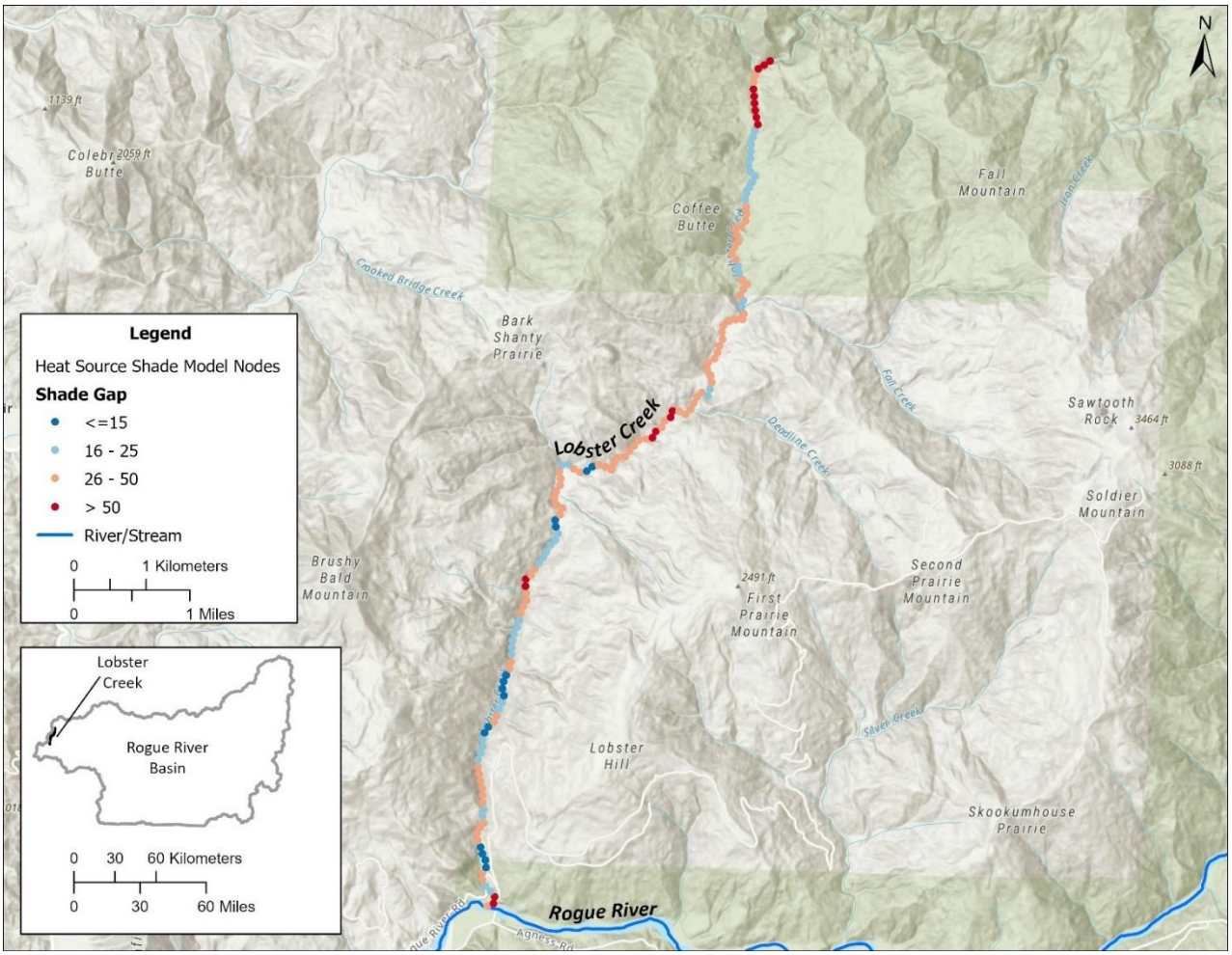


Figure 5-63: Lobster Creek shade gaps (%), Restored Vegetation vs. Current Condition scenarios.

5.9.2 Tributary temperatures

This section summarizes the temperature impacts of increasing model tributary temperatures by the proposed allocations on those tributaries. Lobster Creek temperature change due to tributary HUA assignments was assessed using Equation 5-2a. For this calculation, it was assumed that Lobster Creek and all tributary flows were at 7Q10 levels, and that Lobster Creek temperature upstream of tributary impacts was equal to the 18.0°C non-spawning criteria. Table 5-66 describe the setup of this analysis. Table 5-67 shows the HUA portions assigned to thermal sources on each Lobster Creek tributary included in this analysis. For this analysis, it was assumed that Lobster Creek and tributary flows were at 7Q10 levels, that there was no dissipation of heat, and that Lobster Creek temperature upstream of allocation impacts was equal to the 18.0°C non-spawning criteria.

Table 5-66: Lobster Creek: HUA Attainment analysis setup description.

Model input variable	HUA Attainment analysis setup description
Tributary temperatures	Tributary temperatures were set to the applicable temperature criteria during the critical period (18.0°C), then increased by the portion of the HUA assigned to sources of warming on each tributary. See Table 5-67 for details.
Tributary flows	Tributary flows were set to 7Q10 for this analysis.
Mainstem flow	Lobster Creek flow was set to 7Q10 for this analysis.

Table 5-67: HUA assignments to thermal sources on Lobster Creek tributaries.

Tributary name	HUA portion assigned to thermal sources (°C)
Lost Valley Creek	0.175
Deadline Creek	0.175
Fall Creek	0.175

Table 5-68 summarizes the values used in Equation 5-2a to calculate the Lobster Creek temperature increase above the applicable river temperature criterion due to TMDL allocations on tributaries. Table 5-68 also shows the calculated cumulative warming in Lobster Creek from sources set at their allocations on upstream tributaries; this is 0.03°C. The portion of the HUA assigned to tributary warming on Lobster Creek is therefore set at 0.03°C.

Table 5-68: Lobster Creek: Summary of variables input to Equation 5-2 to calculate the stream temperature change due to warming from HUA assignments on its tributaries.

Variable	Value	Unit	Note
Q_{in}	2.33	cfs	Total discharge from all tributaries at 7Q10 levels.
Q_{up}	12.3	cfs	Lobster Creek 7Q10 flow at mouth estimated using StreamStats.
T_{in}	18.175	°C	Temperature of discharge from all tributaries mixed when the temperature of each tributary has been warmed by the potion of the HUA assigned to source of warming on that tributary (Table 5-67) above the applicable criteria (18.0 °C).
T_{up}	18.00	°C	The applicable temperature criteria on Lobster Creek during the critical period.
ΔT_R	0.03	°C	Lobster Creek temperature increase due to warming from HUA assignments on tributaries.

5.9.3 HUA Attainment

For Lobster Creek, the HUA Attainment analysis was identical to the Tributary Temperatures analysis. See Section 5.9.2 for details and results. The HUA Attainment analysis results support that the portion of the HUA assigned to assessed sources will be achieved on Lobster Creek.

5.9.4 Background

Table 5-69: Lobster Creek: Summary of daily maximum stream temperature difference between the BBNC and Background model scenario over the model extent.

Model km	Stream temperature difference (°C)	Location
0	2.98	outlet

5.10 Lobster Creek Watershed

This section summarizes results of SHADOW modeling of effective shade in the Lobster Creek watershed that was completed for the Lobster Creek Watershed TMDL (DEQ, 2002a).

Table 5-70 summarizes the effective shade results for various streams in the modeled area. Table 5-71 summarizes the effective shade results by DMA.

Table 5-70: Lobster Creek Watershed SHADOW models: Effective shade (%) results summaries.

Location	Current Shade (%)	Potential Shade (%)	Shade Gap (%)	Stream Miles	% Area at confluence	Historical disturbances
South Fork Lobster Cr.	89	91	2	1.7		Road/harvest/ mining
South Fork Lobster Cr. above Boulder Cr	93	96	3		74	Road/harvest/ mining
SF Lobster below Boulder Cr	73	74	1		62	Road/harvest/ mining
North Fork Lobster Cr.	94	96	2		38	Road/harvest
Boulder Cr.	87	92	5		26	Road/harvest/ mining
Lost Valley Cr.	93	96	3		9	Road/harvest
Fall Cr.	88	93	4	10.2		tbd
Deadline Cr.	90	93	3	4.6		Tbd
Mainstem Lobster Cr.	80	88	9	25.1		tbd

Table 5-71: Lobster Creek watershed: Effective shade (%) results by DMA.

Management Entity	Target Shade (%)	Potential Shade (%)	Shade Gap (%)
USFS	93%	91%	2%
Lincoln Timber LLC	90%	83%	7%
All lands (watershed)	92%	88%	4%

Figure 5-64, Figure 5-65, and Figure 5-66 provide effective shade curves three different stream aspects at various channel widths and riparian vegetation heights. These curves allow shade assessments in unmodeled areas for a variety of riparian vegetation, channel widths, and stream aspect conditions. Assumptions include 80% shade density, 60% terrain slope, 5' tree-to-channel distance, and that overhang varies inversely with channel width.

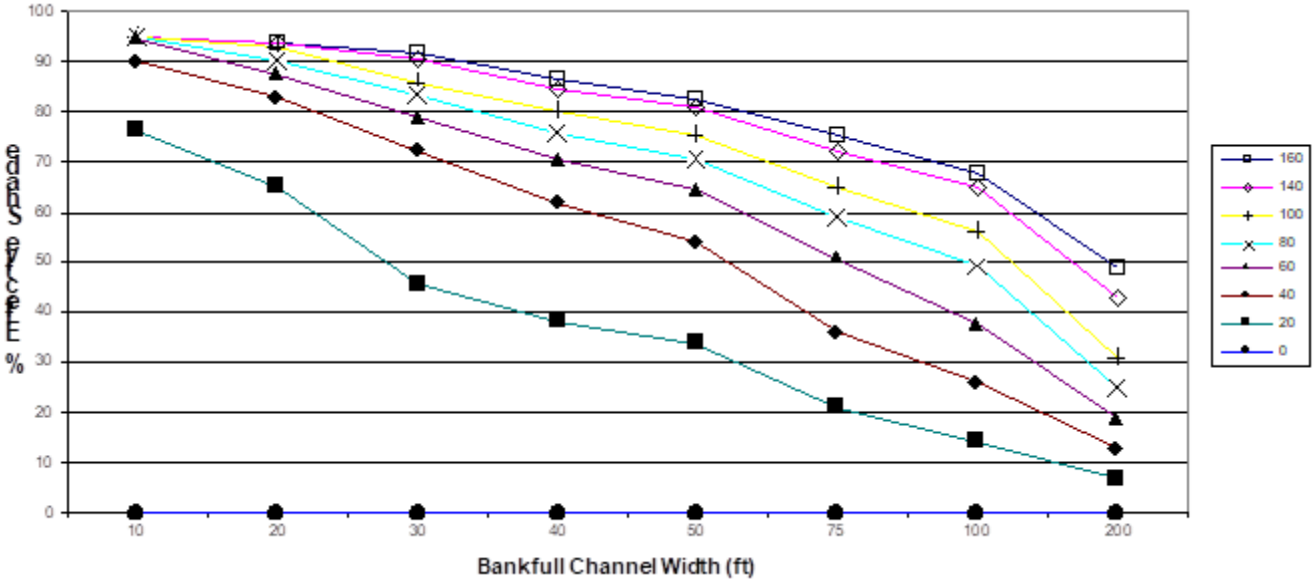


Figure 5-64: Lobster Creek watershed shade curves for N-S stream aspects. Lines represent various tree heights (ft).

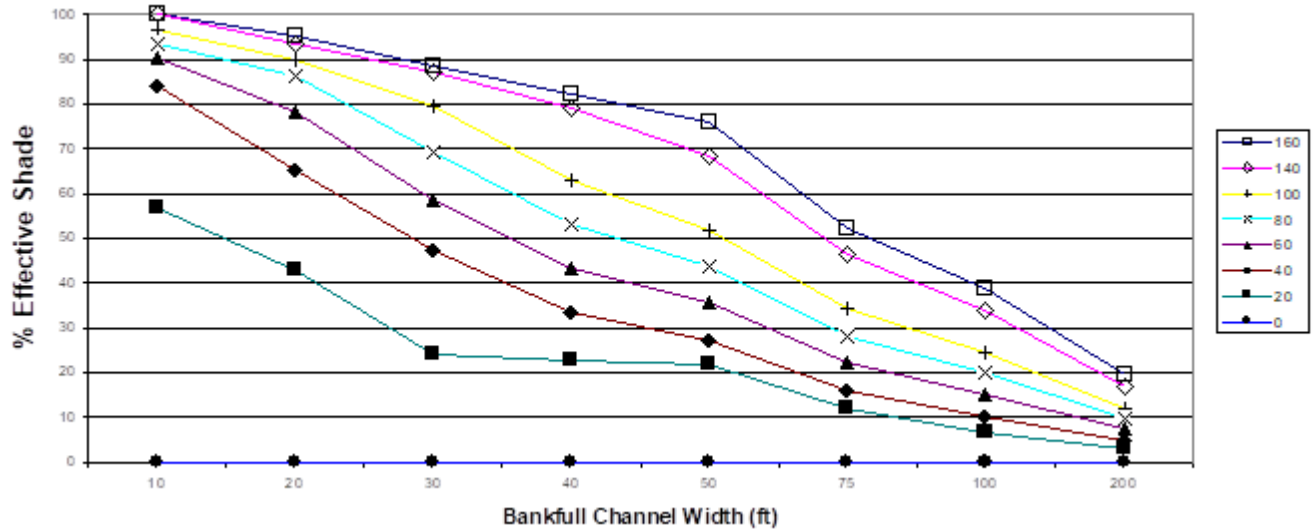


Figure 5-65: Lobster Creek watershed shade curves for E-W stream aspects. Lines represent various tree heights (ft).

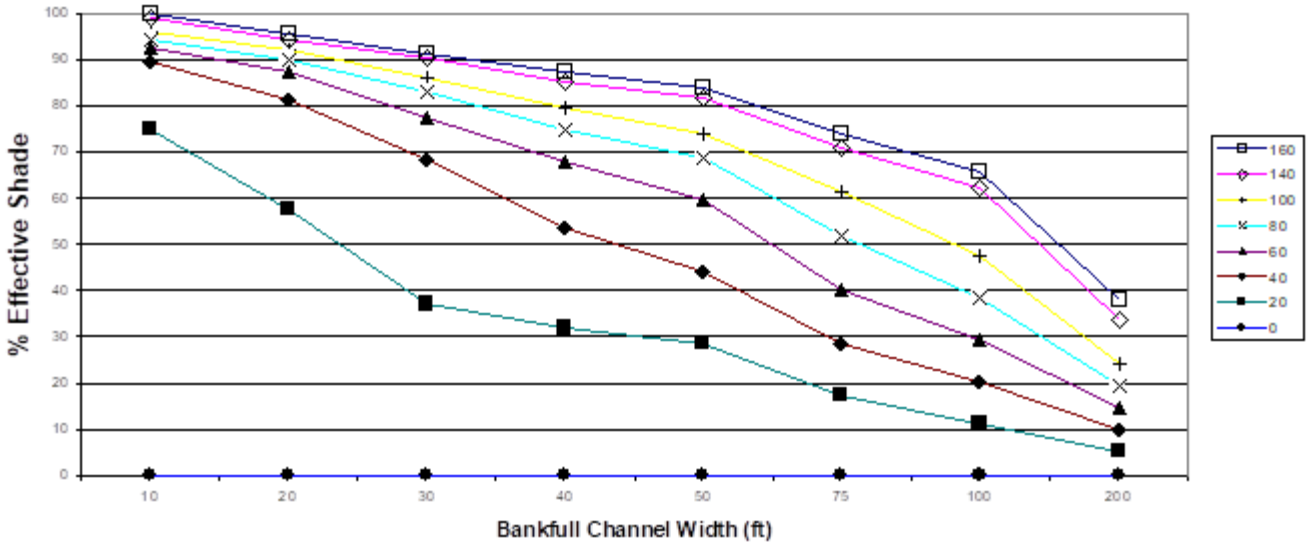


Figure 5-66: Lobster Creek watershed shade curves for diagonally stream aspects. Lines represent various tree heights (ft).

5.11 Rogue River

Table 5-72 describes the different model scenarios used to simulate stream temperature and effective shade for the Rogue River. Table 5-73 summarizes the maximum 7DADM stream temperature predicted at the downstream boundary of the Rogue River model for all model scenarios over the entire model period. Figure 5-67 shows the predicted maximum 7DADM stream temperature for the Rogue River model scenarios. For many scenarios, the POMI occurred at the downstream model boundary (river km 9.25). The model boundary was set at river km 9.25 due to confounding tidal influences that occur between this location and its mouth at the Pacific Ocean.

Table 5-72: Rogue River model scenario descriptions.

Scenario Name	Description
Restored Vegetation	Evaluates temperature and effective shade responses with fully restored near-stream land cover.
Topographic Shade	Evaluates temperature and effective shade responses with no near-stream land cover.
No Point Sources	Evaluates temperature responses with all NPDES-permitted point sources removed.
Wasteload Allocations	Evaluates temperature responses with all NPDES-permitted point sources discharging at their proposed WLAs.
Restored Flow	Evaluates temperature responses with all consumptive uses removed.
Small Dams included	Evaluates temperature responses of previous removal of small dams. This scenario is identical to the current conditions model except that previously removed small dams are reincluded. This scenario was compared to the current conditions model.
No Lost Creek Reservoir	Evaluates temperature responses of removal of the Lost Creek Reservoir.
No Lost Creek Reservoir or ODFW Fish Hatchery	Evaluates temperature responses of removal of the Lost Creek Reservoir and the ODFW Cole M. Rivers Fish Hatchery.
Background	Evaluates temperature responses with fully restored near-stream land cover, all consumptive uses removed, and no point source discharges.

Scenario Name	Description
Tributary Temperatures	Identical to the Background scenario but with each tributary's temperatures increased by the total HUA allocations on that tributary: 0.13°C for Lobster Cr, 0.10°C for Trail Cr., 0.06°C for Applegate R., 0.15°C for Illinois R., 0.26°C for Bear Cr., 0.136°C for Elk Cr., 0.13 for Evans Cr., and 0.136°C for L. Butte Cr..
Attainment	Identical to the Rogue River Tributary Temperatures scenario but with all NPDES-permitted point sources discharging at their proposed WLAs.

Table 5-73: Rogue River: Maximum 7DADM stream temperatures at the downstream boundary (river km 9.25) and POMI for all model scenarios over the model extent.

Scenario	Stream temperature (°C), rkm 9.25	Stream temperature (°C), POMI
Current Condition	25.94	25.94
Attainment	24.18	24.18
Topographic Shade	26.01	26.01
Background	24.25	24.25
Restored Vegetation	25.31	25.31
No Point Sources	25.84	25.84
Wasteload Allocations	24.16	24.16
Restored Flow	24.91	24.91
Tributary Temperatures	24.27	24.27
Small Dams included	26.05	26.05
No Lost Creek Reservoir	28.99	30.50
No Lost Creek Reservoir or ODFW Fish Hatchery	29.02	30.54

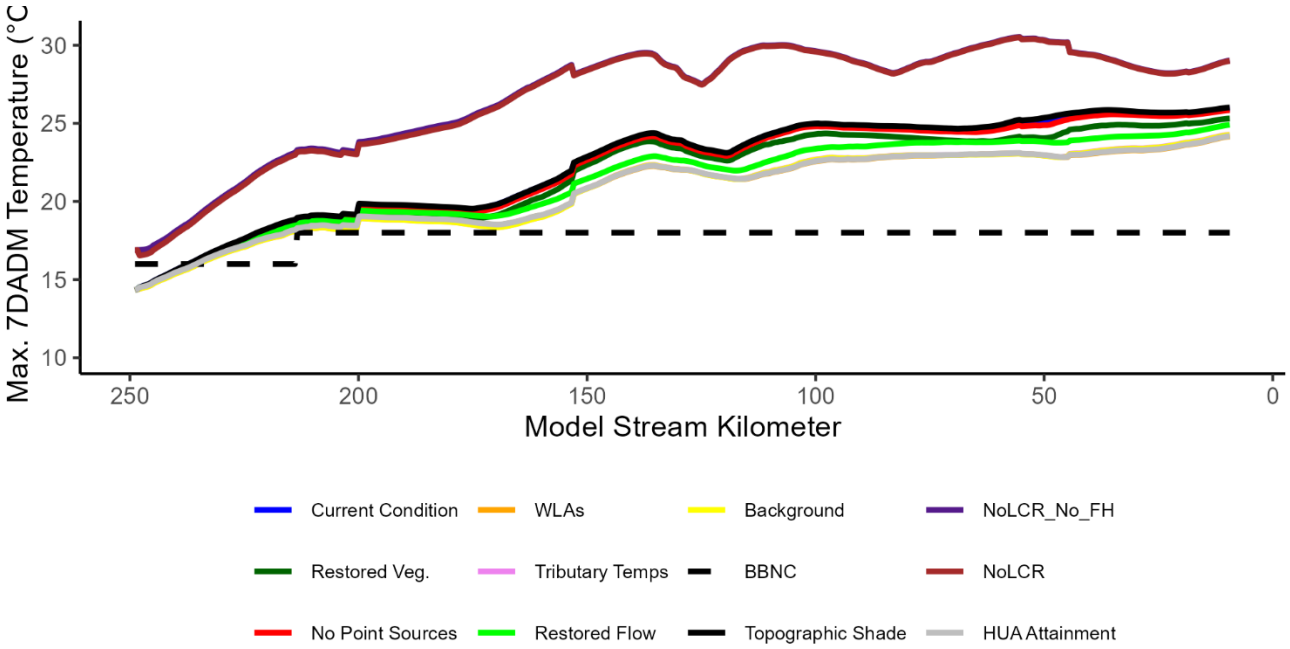


Figure 5-67: Rogue River: Maximum 7DADM temperatures for all model scenarios over model extent.

5.11.1 Vegetation scenarios

This section summarizes the temperature impacts of restored vegetation, current conditions, and topographic shade on the Rogue River. Table 5-74 and Figure 5-68 show the maximum 7DADM stream temperature changes between the Current Condition and Restored Vegetation scenarios

over the model extent when scenario temperatures exceed the BBNC. The maximum 7DADM temperature difference was 1.70°C at the most downstream node and was 3.19°C at the POMI (model km 153.4).

Table 5-74: Rogue River: Maximum 7DADM stream temperature changes between Restored Vegetation and Current Condition model scenarios for the over the model period.

Model km	Stream temperature change (°C)	Location
9.25	1.70	Downstream boundary
153.4	3.19	POMI

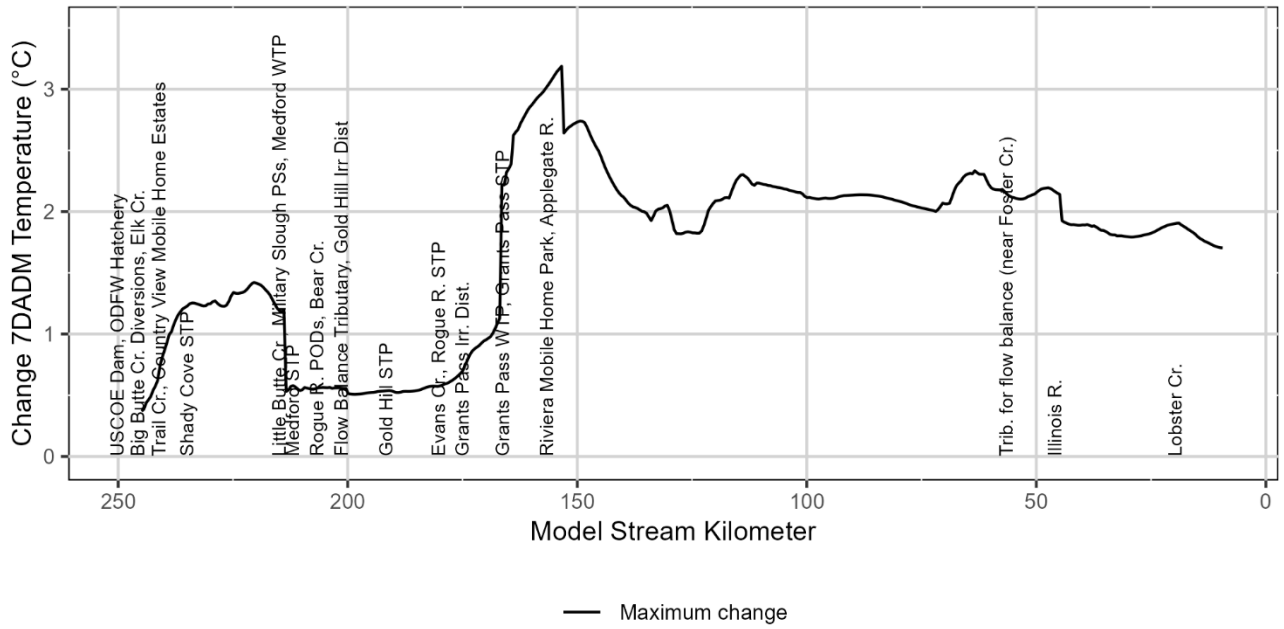


Figure 5-68: Rogue River: Maximum 7DADM temperature changes between Current Condition and Restored Vegetation scenarios over the model period when scenario temperatures exceed the BBNC.

Table 5-75 and Figure 5-69 summarize the maximum 7DADM stream temperature changes between the Topography and Current Condition scenarios for the Rogue River over the model extent when scenario temperatures exceed the BBNC. The maximum 7DADM temperature difference was 0.34°C at the most downstream node and 0.89°C at the POMI (model km 60.9).

Table 5-75: Rogue River: Maximum 7DADM stream temperature changes change between Topography and Current Condition model scenarios over the model period.

Model km	Stream temperature change (°C)	Location
9.25	0.34	Downstream boundary
60.9	0.89	POMI

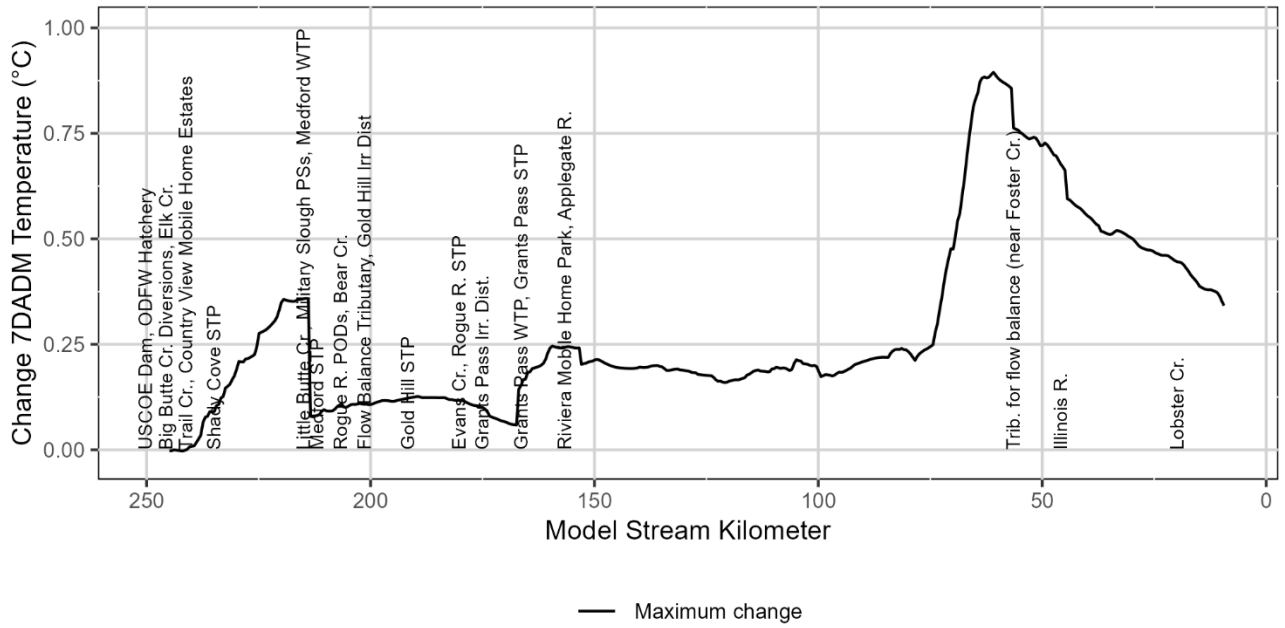


Figure 5-69: Rogue River: Maximum 7DADM stream temperature changes between Topography and Current Condition scenarios over the model period when scenario temperatures exceed the BBNC.

Table 5-76 and Figure 5-70 summarize and compare the mean effective shade for the Current Condition, Restored Vegetation, and Topographic Shade scenarios. The mean effective shade (%) difference between the Current Condition and Restored Vegetation scenarios is 15.

Figure 5-71 shows the longitudinal shade gaps between the Restored Vegetation and Current Condition scenarios, while Figure 5-72 shows the longitudinal shade gaps between the Current Condition and Topographic Shade scenarios.

Figure 5-73 shows the shade gaps between the Restored Vegetation and Current Condition scenarios in a map view of the Rogue River model extent.

Table 5-76: Rogue River: Mean effective shade (%) for Current Condition, Restored Vegetation, and Topographic Shade scenarios.

Scenario	Mean effective shade (%)
Current Condition	9
Restored Vegetation	24
Shade Gap	15
Topo	6

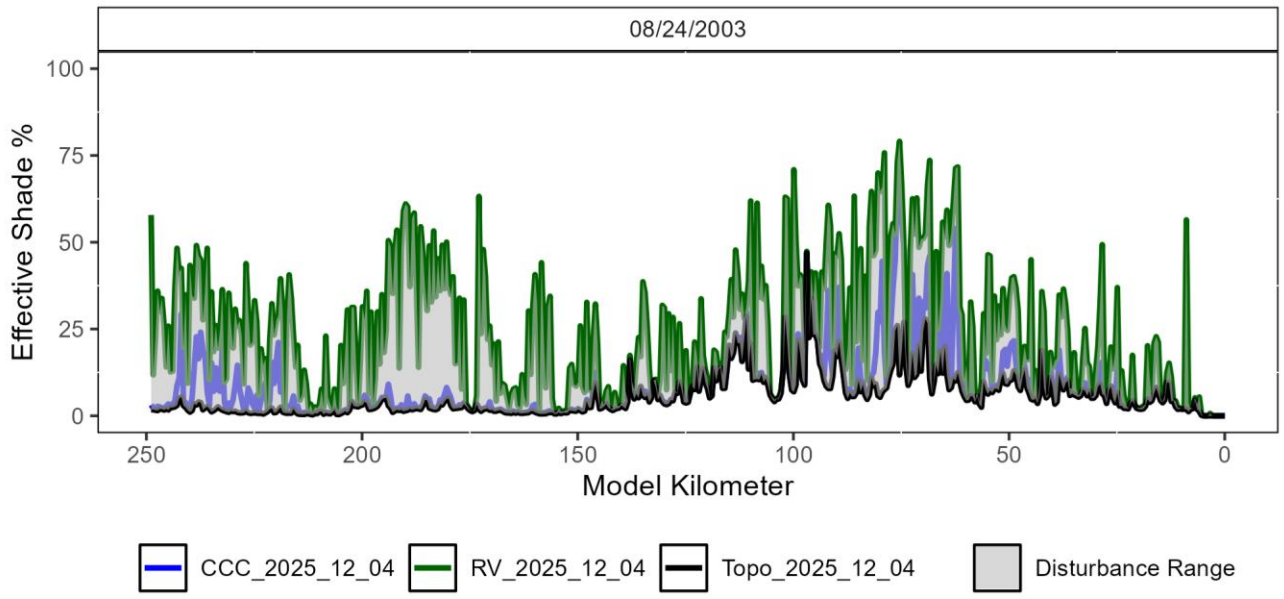


Figure 5-70: Rogue River: Longitudinal effective shade (%) results of the Current Condition, Restored Vegetation, and Topographic Shade scenarios.

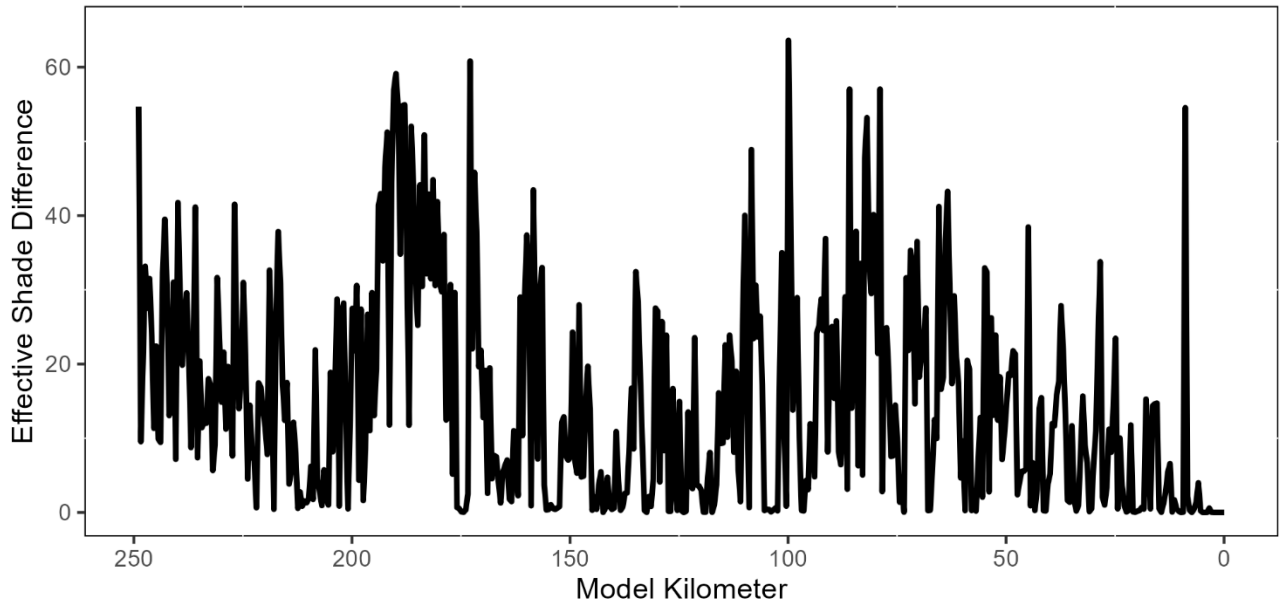


Figure 5-71: Rogue River: Longitudinal effective shade (%) differences between Restored Vegetation and Current Condition scenarios.

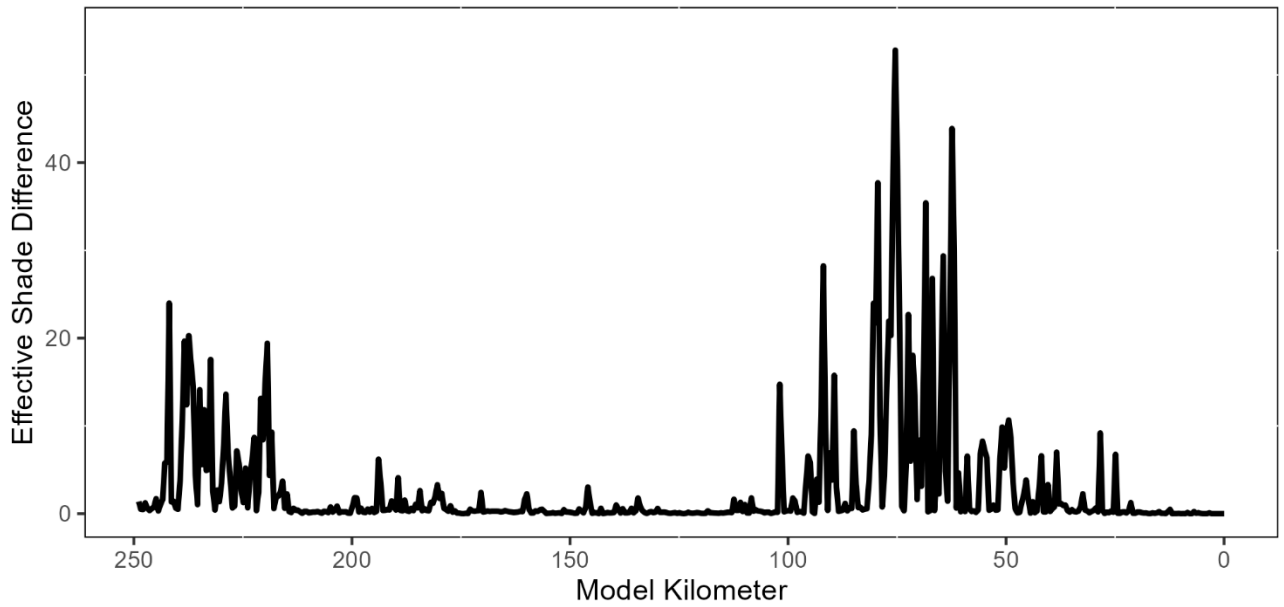


Figure 5-72: Rogue River: Longitudinal effective shade (%) differences between Current Condition and Topographic Shade scenarios.

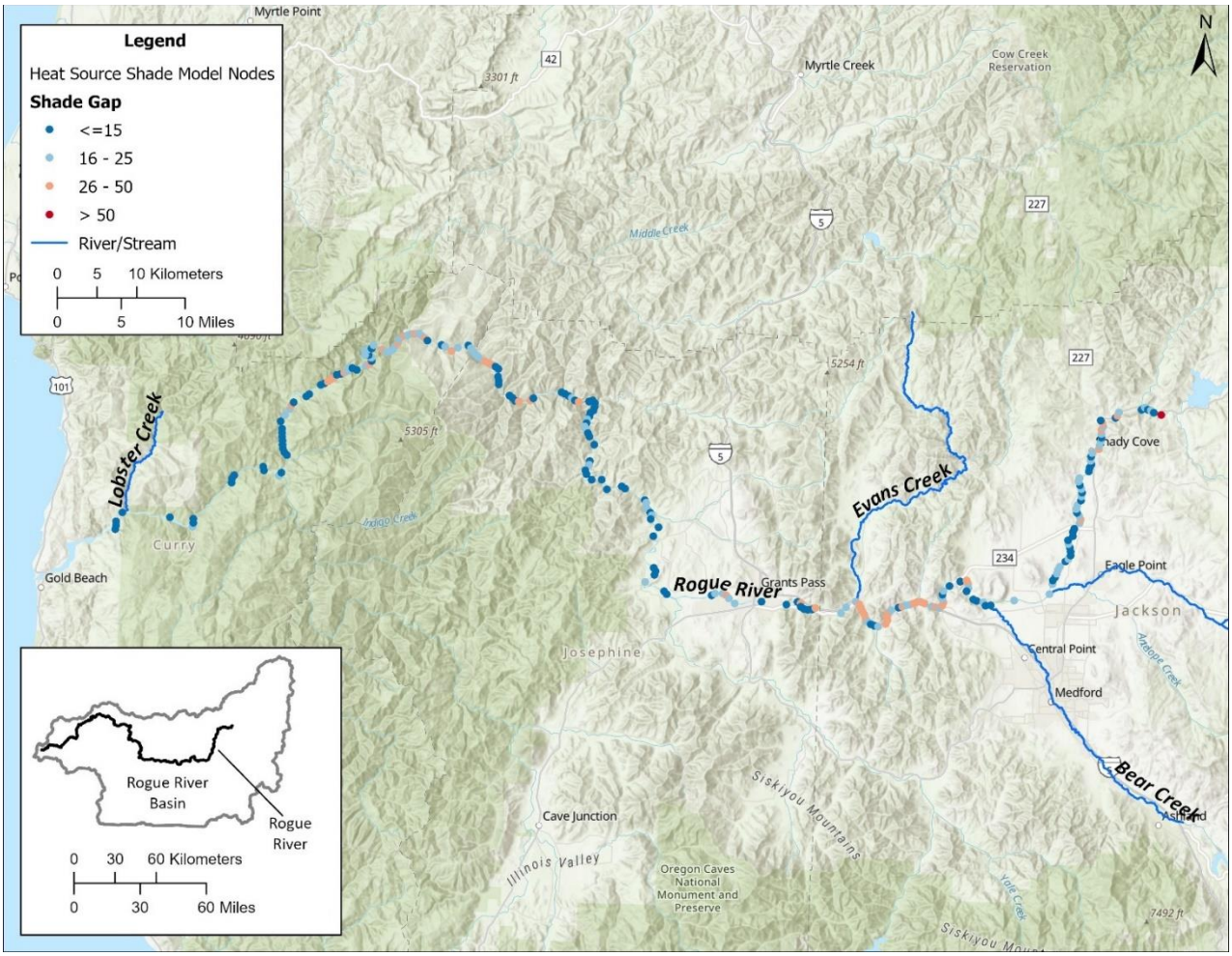


Figure 5-73: Rogue River shade gaps (%) map, Restored Vegetation vs. Current Condition scenarios.

5.11.2 No point sources

This section summarizes the temperature impacts of point sources operating at current conditions. Table 5-77 and Figure 5-74 summarize the maximum 7DADM stream temperature changes between the Current Condition and No Point Source scenarios for the Rogue River over the model extent when scenario temperatures exceed the BBNC. The maximum 7DADM temperature difference was 0.10°C at the most downstream node and was 0.25°C at the POMI (model km 162.4).

Table 5-77: Rogue River: Maximum 7DADM stream temperature changes between Current Condition and No Point Source scenarios over the model extent when scenario temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
9.25	0.10	Downstream boundary
162.4	0.25	POMI

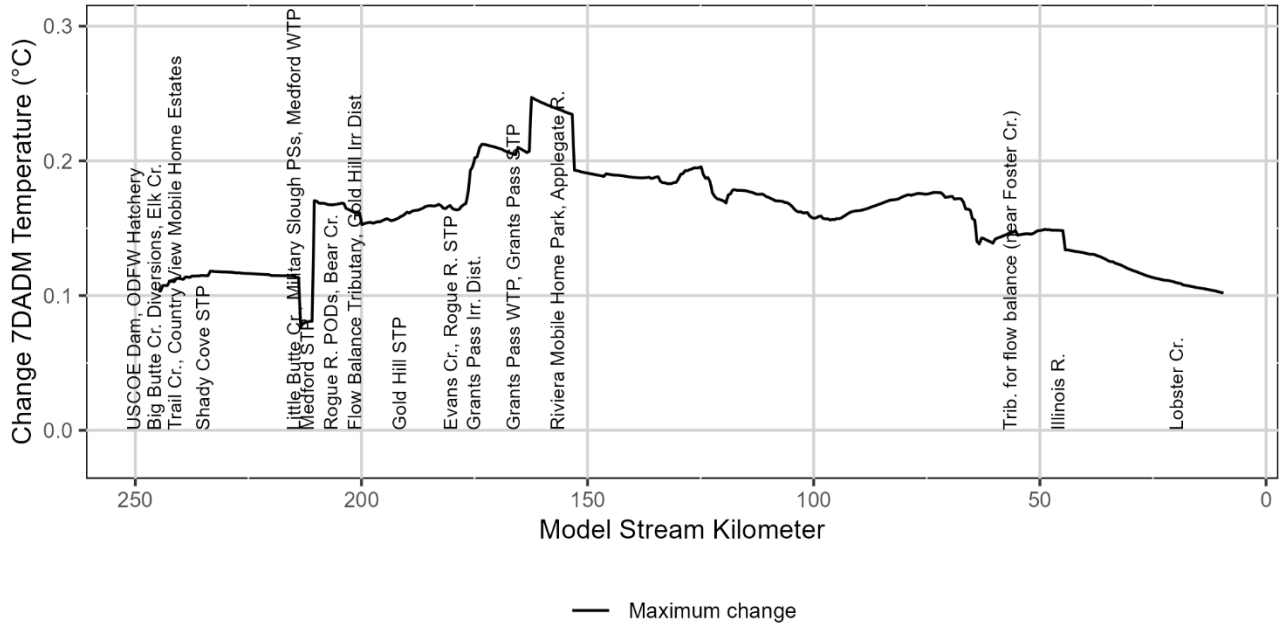


Figure 5-74: Rogue River: Maximum 7DADM stream temperature changes between Current Condition and No Point Source scenarios over the model extent when scenario temperatures exceed the BBNC.

5.11.3 Wasteload allocations

This section summarizes the temperature impacts of point sources operating in attainment of proposed wasteload allocations. Table 3-54 lists the points sources relevant to the Rogue River WLA model; their WLAs are listed in Section 9.2 of the main TMDL document.

Table 5-78 and Figure 5-75 summarize the maximum 7DADM stream temperature changes between the Wasteload Allocations and Background scenarios over the model extent when temperatures exceed the BBNC. The maximum 7DADM temperature difference was 0.07°C at the most downstream node and was 0.21°C at the POMI (model km 161.4).

Table 5-78: Rogue River: Maximum 7DADM stream temperature changes between Wasteload Allocations and Background scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
9.25	0.07	Downstream boundary
161.4	0.21	POMI

Table 5-79: Rogue River: Maximum 7DADM stream temperature changes between WLA and Background scenarios by AU and seasonal period when scenario temperatures exceed the BBNC.

AU	AU extent, model km	Stream temperature (°C), 3/1-5/31	Stream temperature (°C), 6/1-10/31
OR_SR_1710030703_04_105475	247.8 - 248.9	N/A	N/A
OR_SR_1710030707_04_105506	245.1 - 247.8	N/A	N/A
OR_SR_1710030707_04_105507	213.5 - 245.1	0.06	0.11
OR_SR_1710030802_04_105816	178.8 - 213.5	0.15	0.17
OR_SR_1710030804_04_106341	153.3 - 178.8	0.18	0.21
OR_SR_1710031002_04_104794	109.6 - 153.3	0.15	0.16
OR_SR_1710031004_04_104821	77.2 - 109.6	0.14	0.14
OR_SR_1710031005_04_106305	55.2 - 77.2	0.14	0.14
OR_SR_1710031006_04_104637	44.5 - 55.2	N/A	0.14
OR_SR_1710031008_04_104646	9.25 - 44.5	0.05	0.11

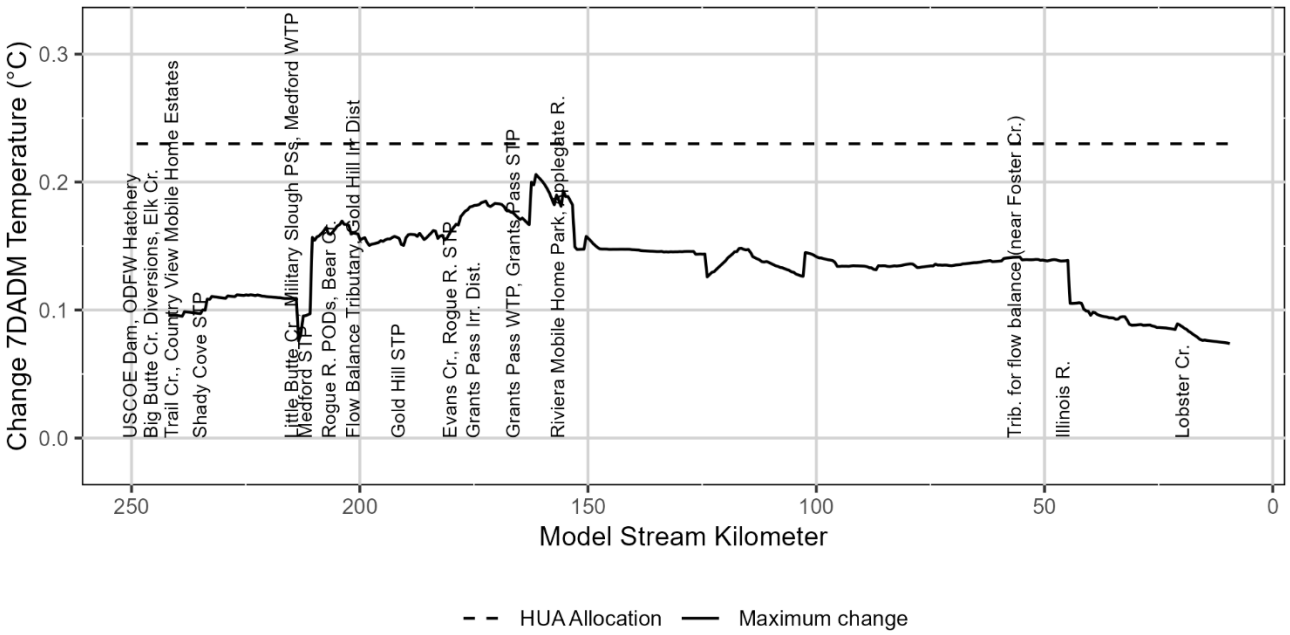


Figure 5-75: Rogue River: Maximum 7DADM stream temperature changes between Wasteload Allocations and Background scenarios over the model extent when temperatures exceed the BBNC.

5.11.4 Restored flow

This section summarizes the temperature impacts of altered flow. Table 5-80 and Figure 5-76 summarize the maximum 7DADM stream temperature changes between the Current Condition and Restored Flow scenarios over the model extent when scenario temperatures exceed the BBNC. The maximum 7DADM temperature difference was 1.09°C at the most downstream node and was 1.79°C at the POMI (model km 110.9).

Table 5-80: Rogue River: Maximum 7DADM stream temperature changes between Current Condition and Restored Flow scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
9.25	1.09	Downstream boundary
110.9	1.79	POMI

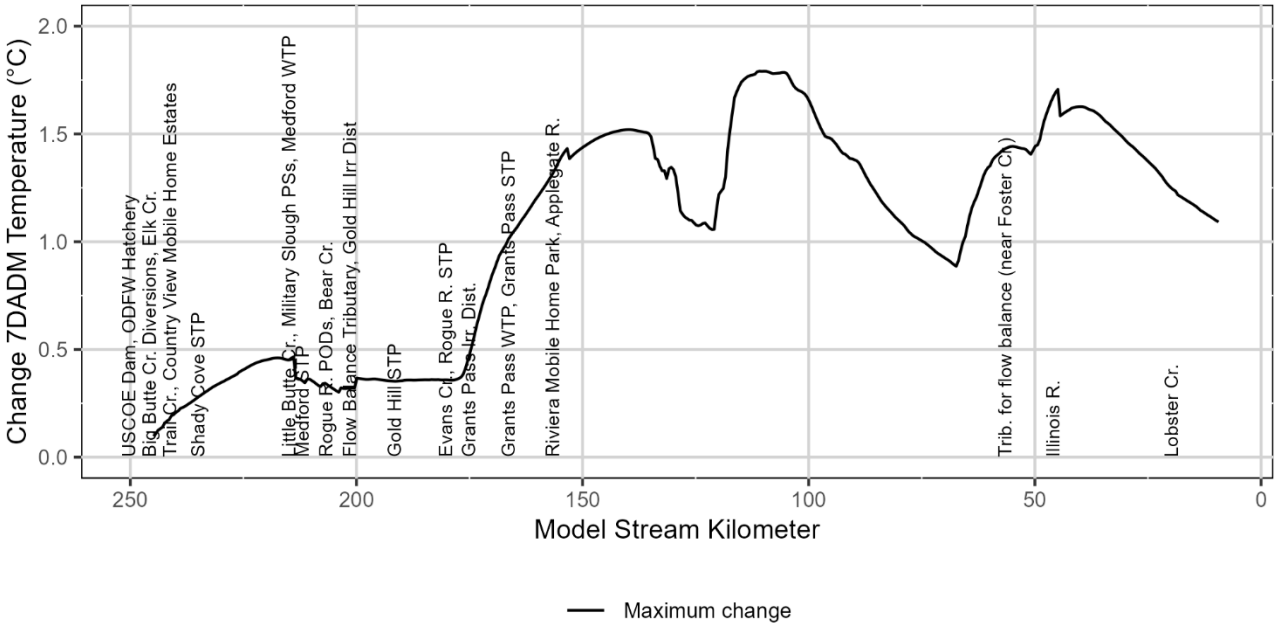


Figure 5-76: Rogue River: Maximum 7DADM stream temperatures change between Current Condition and Restored Flow scenarios over the model extent when temperatures exceed the BBNC.

5.11.5 Tributary temperatures

This section summarizes the Rogue River temperature impacts of the proposed thermal allocations on its tributaries. Table 5-81 lists these allocations. Table 5-82 and Figure 5-77 summarize the maximum 7DADM stream temperature changes between the Tributary Temperature and Background scenarios. The maximum 7DADM temperature difference was 0.07°C at the most downstream node and was 0.08°C at the POMI (model km 44.4).

Table 5-81: HUA assignments to thermal sources on Rogue River tributaries.

Tributary name	HUA portion assigned to thermal sources (°C)
Lobster Creek	0.13
Trail Creek	0.10
Applegate River	0.06
Illinois River	0.15
Bear Creek	0.26
Elk Creek	0.136
Evans Creek	0.13
Litte Butte Creek	0.136

Table 5-82: Rogue River: Maximum 7DADM stream temperature changes between Tributary Temperature and Background scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
9.25	0.07	Downstream boundary
44.4	0.08	POMI

Table 5-83: Rogue River: Maximum 7DADM stream temperature changes between Tributary Temperature and Background scenarios by AU and seasonal period.

AU	AU extent, model km	Stream temperature (°C), 3/1-5/31	Stream temperature (°C), 6/1-10/31
OR_SR_1710030703_04_105475	247.8 - 248.9	N/A	N/A
OR_SR_1710030707_04_105506	245.1 - 247.8	N/A	N/A
OR_SR_1710030707_04_105507	213.5 - 245.1	0.01	N/A
OR_SR_1710030802_04_105816	178.8 - 213.5	N/A	0.01
OR_SR_1710030804_04_106341	153.3 - 178.8	0.05	0.01
OR_SR_1710031002_04_104794	109.6 - 153.3	0.06	0.03
OR_SR_1710031004_04_104821	77.2 - 109.6	N/A	0.04
OR_SR_1710031005_04_106305	55.2 - 77.2	0.05	0.04
OR_SR_1710031006_04_104637	44.5 - 55.2	N/A	0.04
OR_SR_1710031008_04_104646	9.25 - 44.5	0.08	0.07

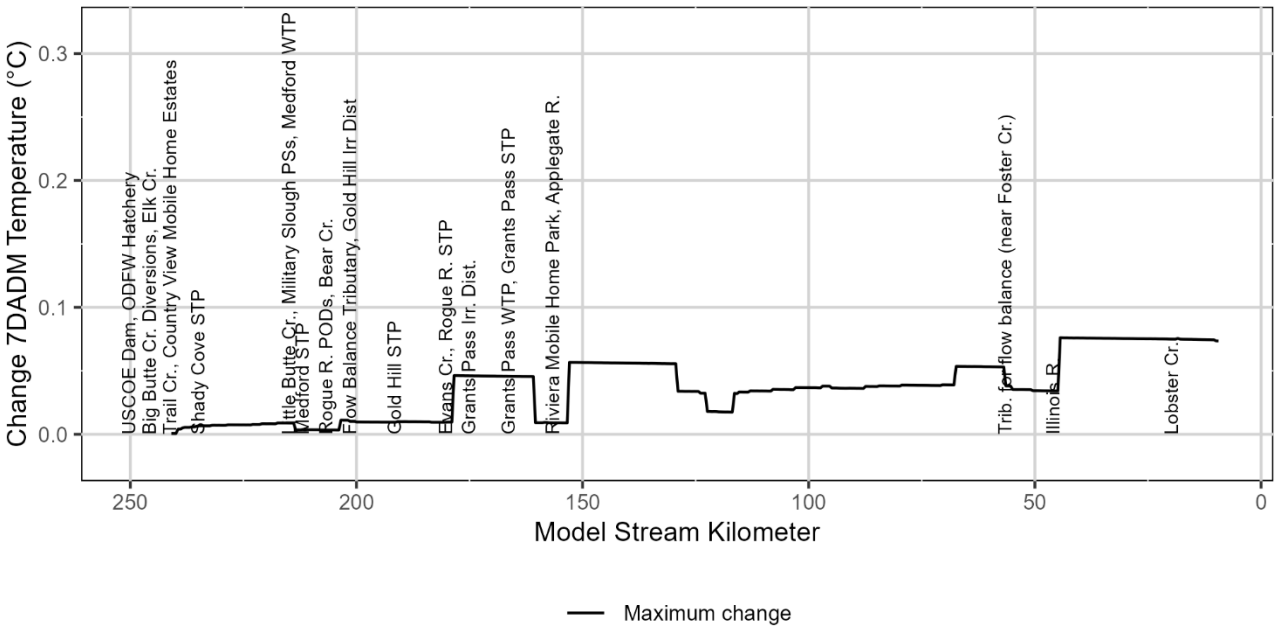


Figure 5-77: Rogue River: Maximum 7DADM stream temperature changes between Tributary Temperature and Background scenarios over the model extent when temperatures exceed the BBNC.

The TMDL allocations to warming from Rogue River tributaries are presented in the main TMDL report (see Tables 9-3, 9-4, and 9-5). The Tributary Temperature model analysis results supports that the categorical HUA portions assigned to thermal sources on modeled Rogue River tributaries will be achieved when those sources attain their applicable Load Allocations and Wasteload Applications.

5.11.6 HUA Attainment

This section summarizes the temperature impacts of attainment of the proposed Load Allocations and Wasteload Allocations on the Rogue River and its modeled tributaries. The HUA Attainment scenario also determines if the modeled thermal source categories achieve their categorically-allocated HUA portions. To determine this, results from the HUA Attainment scenario and

Background scenario were compared. Table 5-84 describes the Rogue River HUA Attainment model scenario setup.

Table 5-84: Rogue River: HUA Attainment scenario setup.

Model input variable	Attainment scenario set up description
Riparian landcover	Equal to the Background scenario setup (restored vegetation conditions), though this source is assigned an allocation.
Tributary temperatures	Each tributary's temperatures were increased from Background scenario values by the total HUA allocations on that tributary: 0.13°C for Lobster Cr, 0.10°C for Trail Cr., 0.06°C for Applegate R., 0.15°C for Illinois R., 0.26°C for Bear Cr., 0.136°C for Elk Cr., 0.13 for Evans Cr., and 0.136°C for L. Butte Cr..
Tributary flows	Equal to the Background scenario setup.
Boundary condition temperature	Equal to the Background scenario setup.
Boundary condition flow	Equal to the Background scenario setup
Withdrawals	Equal to the Background scenario setup
NPDES point sources	Equal to the Wasteload Allocation scenario setup.
Nonpoint source dam and reservoir operations	Loading from this category was not modeled, though this source is assigned an allocation.
Solar loading from existing infrastructure	Solar loading from existing infrastructure was not modeled, though this source is assigned an allocation.

Table 5-85 and Figure 5-78 summarize the maximum 7DADM stream temperature changes between the Attainment and Background scenarios over the model extent when scenario temperatures exceed the BBNC. The maximum 7DADM temperature difference was 0.13°C at the most downstream node and 0.23°C at the POMI (model km 155.4).

The TMDL allocations to thermal source categories on the Rogue River mainstem and tributaries are presented in the main TMDL report (see Tables 9-3, 9-4, and 9-5). The Rogue River HUA Attainment model analysis results supports that the applicable categorical HUA assignments will be achieved when those sources attain their applicable Load Allocations and Wasteload Applications, and that cumulative warming in the Rogue River will not exceed the cumulative HUA assignments in its modeled AUs.

Table 5-85: Rogue River: Maximum 7DADM stream temperature changes between Background and Attainment scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature (°C)	Location
9.25	0.13	Downstream boundary
155.4	0.23	POMI

Table 5-86: Rogue River: Maximum 7DADM stream temperature changes between Attainment and Background scenarios by AU and seasonal period.

AU	AU extent, model km	Stream temperature change (°C), 3/1-5/31	Stream temperature change (°C), 6/1-10/31
OR_SR_1710030703_04_105475	247.8 - 248.9	N/A	N/A
OR_SR_1710030707_04_105506	245.1 - 247.8	N/A	N/A
OR_SR_1710030707_04_105507	213.5 - 245.1	0.08	0.12
OR_SR_1710030802_04_105816	178.8 - 213.5	0.19	0.18
OR_SR_1710030804_04_106341	153.3 - 178.8	0.23	0.22
OR_SR_1710031002_04_104794	109.6 - 153.3	0.21	0.18
OR_SR_1710031004_04_104821	77.2 - 109.6	0.20	0.17

AU	AU extent, model km	Stream temperature change (°C), 3/1-5/31	Stream temperature change (°C), 6/1-10/31
OR_SR_1710031005_04_106305	55.2 - 77.2	0.20	0.16
OR_SR_1710031006_04_104637	44.5 - 55.2	N/A	0.16
OR_SR_1710031008_04_104646	9.25 - 44.5	0.13	0.15

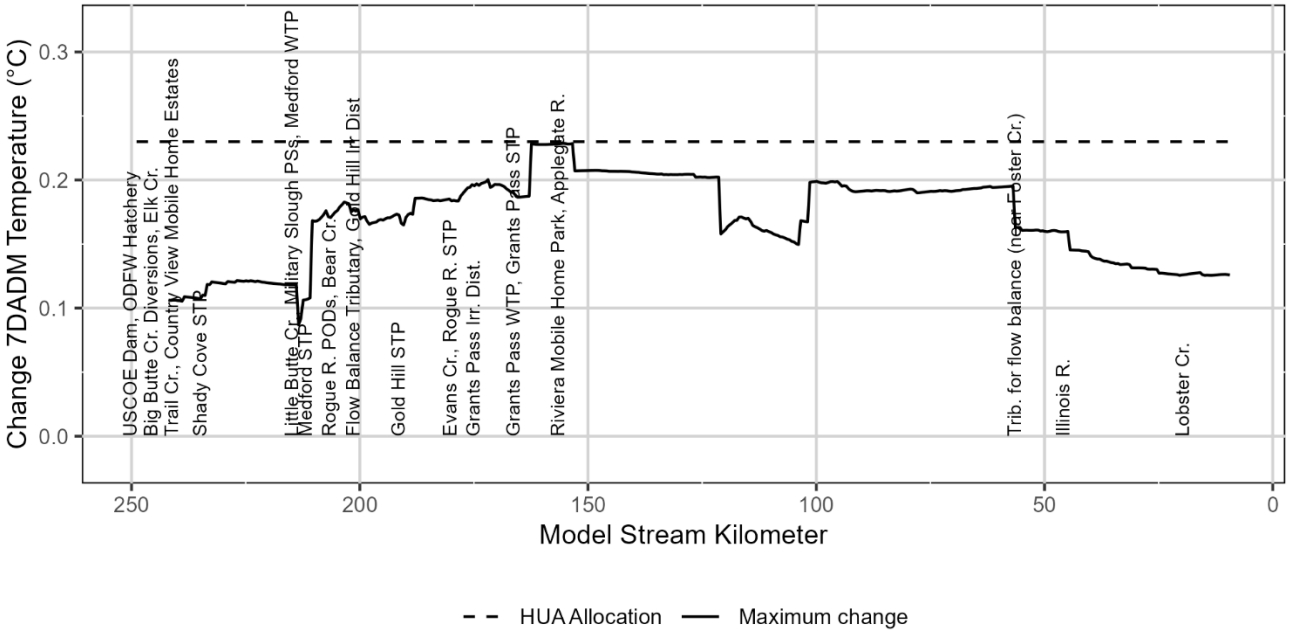


Figure 5-78: Rogue River: Maximum 7DADM stream temperature changes between Background and Attainment scenarios over the model extent when scenario temperatures exceed the BBNC.

5.11.7 Small dams

This section summarizes the temperature impacts of previously completed removal of small dams. Table 5-87 and Figure 5-79 summarize the maximum 7DADM stream temperature changes between the 2008 No Small Dams and 2008 CCC scenarios. The maximum 7DADM temperature difference was 0.19°C at the most downstream node and 1.70°C at the POMI (model km 222.4). These results indicate that in general, Rogue River temperatures decreased following these small dam removals.

Table 5-87: Rogue River: Maximum 7DADM stream temperature changes between the 2008 No Small Dams and 2008 CC scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
9.25	0.19	Downstream boundary
222.4	1.70	POMI

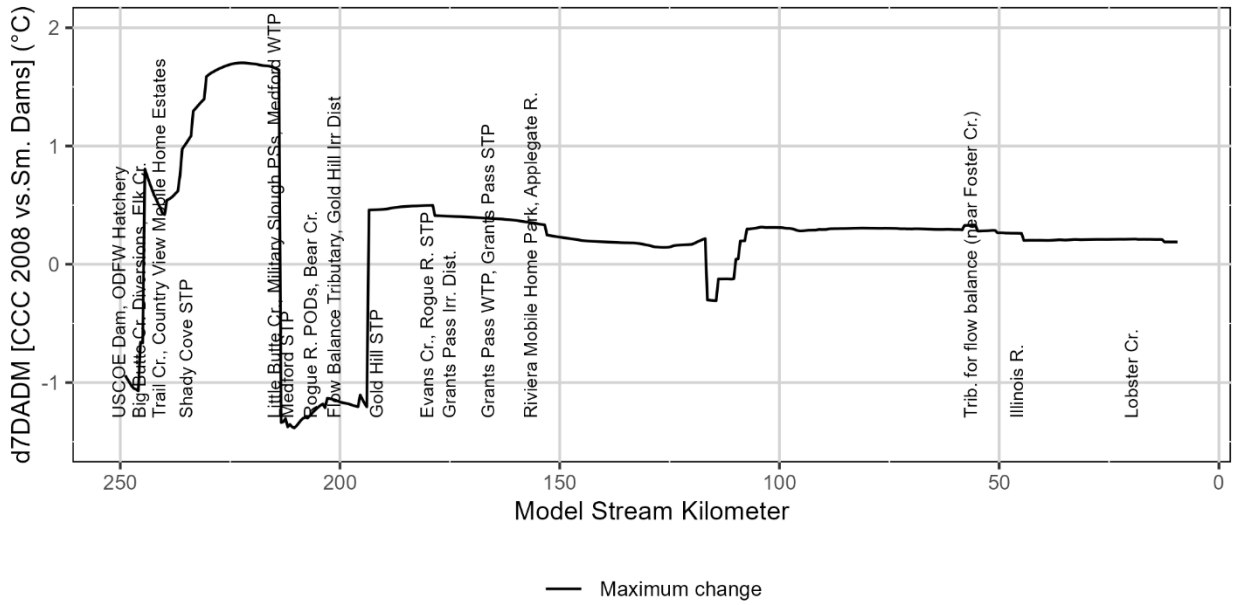


Figure 5-79: Rogue River: Maximum 7DADM stream temperature changes between the 2008 No Small Dams and 2008 CCC scenarios over the model extent when temperatures exceed the BBNC.

5.11.8 No Lost Creek Reservoir

This section summarizes the temperature impacts of the Lost Creek Reservoir. Table 5-88 and Figure 5-80 summarize the maximum 7DADM stream temperature changes between the No Lost Creek Reservoir and Current Condition scenarios. The maximum 7DADM temperature difference (i.e., No Lost Creek dam scenario minus Current Condition scenario temperature) was 0.18°C at the most downstream node and 1.64°C at the POMI (model km 222.4). Thus, the model results indicate that the river temperatures would be warmer under the No Lost Creek Dam scenario than under Current Conditions; i.e., the river temperatures are typically cooler with the dam and reservoir present than if they were not present.

Table 5-88: Rogue River: Maximum 7DADM stream temperature changes between No Lost Creek Reservoir and Current Condition scenarios over the model extent.

Model km	Stream temperature change (°C)	Location
9.25	0.18	Downstream boundary
222.4	1.64	POMI

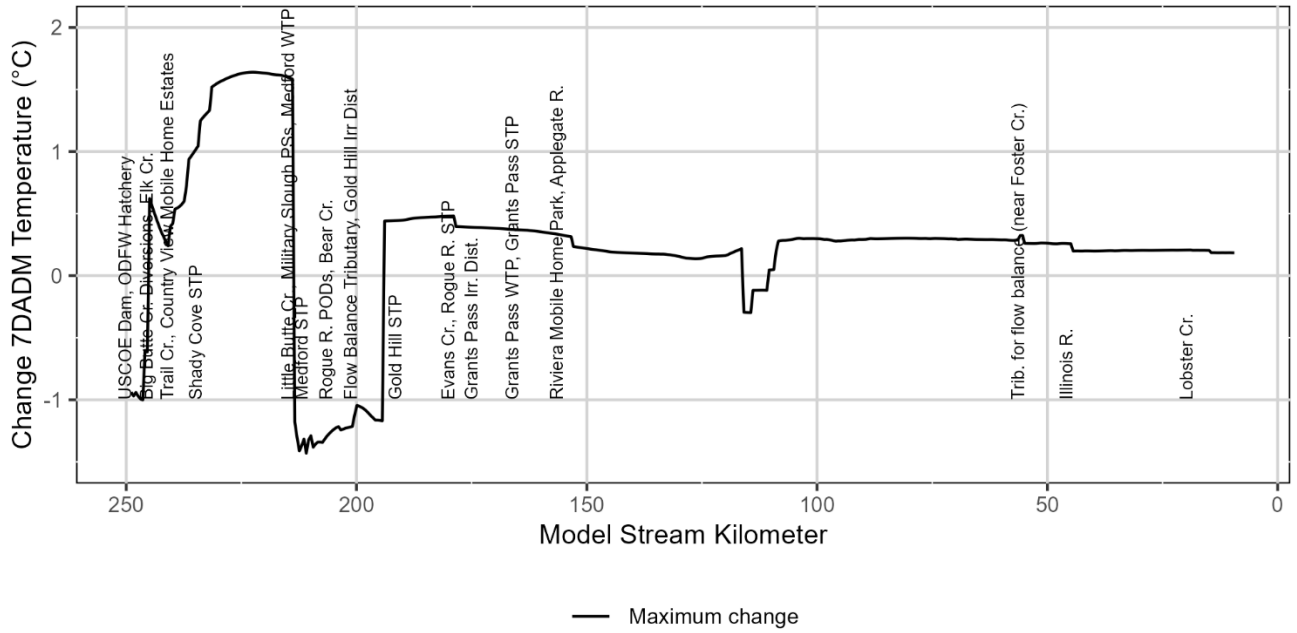


Figure 5-80: Rogue River: Maximum 7DADM stream temperature changes between No Lost Creek Reservoir and Current Condition scenarios over the model extent when temperatures exceed the BBNC.

5.11.9 Background

This section summarizes the temperature impacts of background conditions. Table 5-89 and Figure 5-81 summarize the maximum 7DADM stream temperature changes between the Current Condition and Background scenarios over the model extent. The maximum 7DADM temperature difference between the two scenarios was 2.24°C at the most downstream node and 3.73°C at the POMI (model km 153.4). The greatest 7DADM temperature difference between the Background scenario and the BBNC was 6.25°C at the most downstream node, which was also the POMI for this comparison (Table 5-90, Figure 5-82).

Table 5-89: Rogue River: Maximum 7DADM stream temperature changes between Background and Current Condition scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
9.25	2.24	Downstream boundary
153.4	3.73	POMI

Table 5-90: Rogue River: Maximum 7DADM stream temperature changes between Background scenario and the BBNC over the model extent.

Model km	Stream temperature change (°C)	Location
9.25	6.25	Downstream boundary
9.25	6.25	POMI

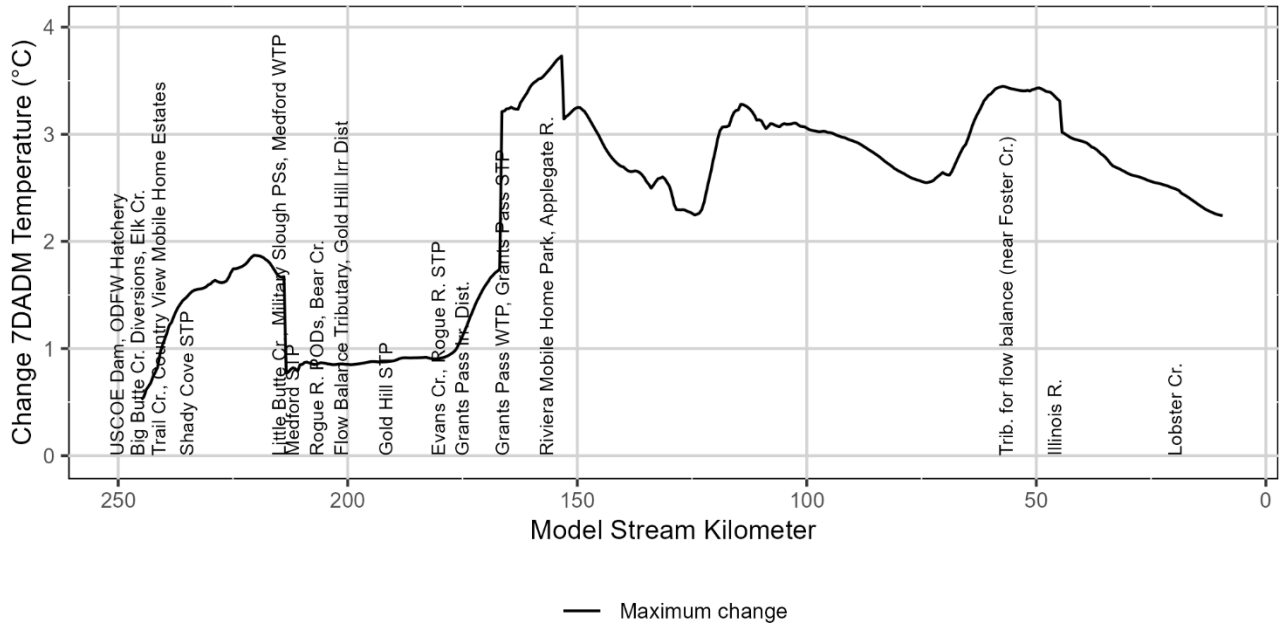


Figure 5-81: Rogue River: Maximum 7DADM stream temperature changes between Background and Current Condition scenarios over the model extent when scenario temperatures exceed the BBNC.

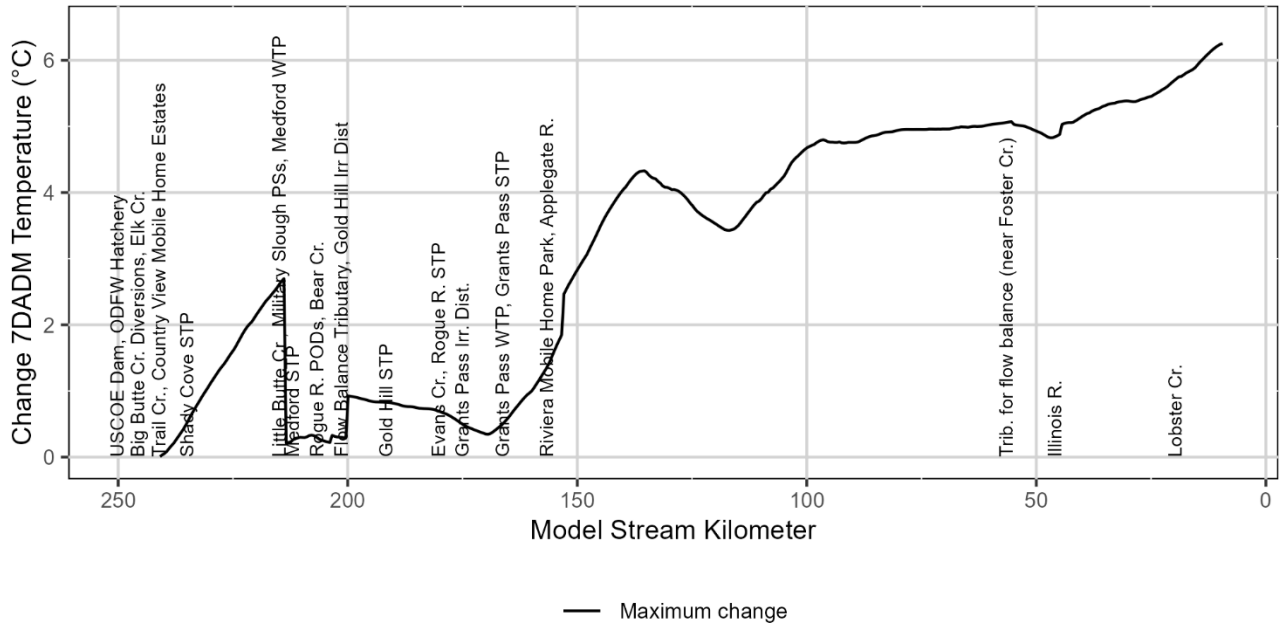


Figure 5-82: Rogue River: Maximum 7DADM stream temperature changes between Background scenario and the BBNC over the model extent.

The effective shade results for the Background and Restored Vegetation scenarios are identical as their vegetation inputs were identical. Thus, the shade comparison results between the Background and Current Condition scenarios are the same as between the Restored Vegetation and Current Condition scenarios. Please refer to the corresponding results in Section 5.11.1.

5.12 South Fork Little Butte Creek

Table 5-91 describes the different model scenarios used to simulate stream temperatures and effective shade for South Fork Little Butte Creek. Table 5-92 and Figure 5-83 summarize the maximum model-predicted 7DADM stream temperatures at the downstream model boundary and the POMI for all model scenarios over the model extent.

Table 5-91: South Fork Little Butte Creek model scenario descriptions.

Scenario Name	Description
Restored Vegetation	Evaluates stream temperature and shade responses with fully restored near-stream land cover.
Topographic Shade	Evaluates stream temperature and shade responses with no near-stream land cover.
Restored Flow	Evaluates stream temperature responses with points of diversion removed.
Hyporheic	Evaluates stream temperature responses to natural, pre-development hyporheic flow exchange conditions
Tributary Temperatures	Evaluates stream temperature responses with fully restored near-stream vegetation, points of diversion removed, and each tributary's temperatures increased by the total HUA allocations on that tributary (+0.10°C). Note that canal and diversion temperatures were not adjusted.
Background	Evaluates stream temperature and shade responses with fully restored near-stream land cover and points of diversion removed.
Attainment	Identical to the Tributary Temperatures scenario for South Fork Little Butte Creek.

Table 5-92: Summary of maximum 7DADM stream temperature at the downstream South Fork Little Butte Creek model boundary (river km 0.00) for all model scenarios over the entire model period.

Scenario	Max. stream temperature (°C), mouth	Max. stream temperature (°C), POMI
Current Condition	29.73	39.01
Attainment	22.22	23.25
Tributary Temps.	22.22	23.25
Background	22.21	23.24
Restored Vegetation	24.18	29.81
Topographic Shade	31.45	42.49
Restored Flow	31.05	31.46
Hyporheic	29.51	38.79

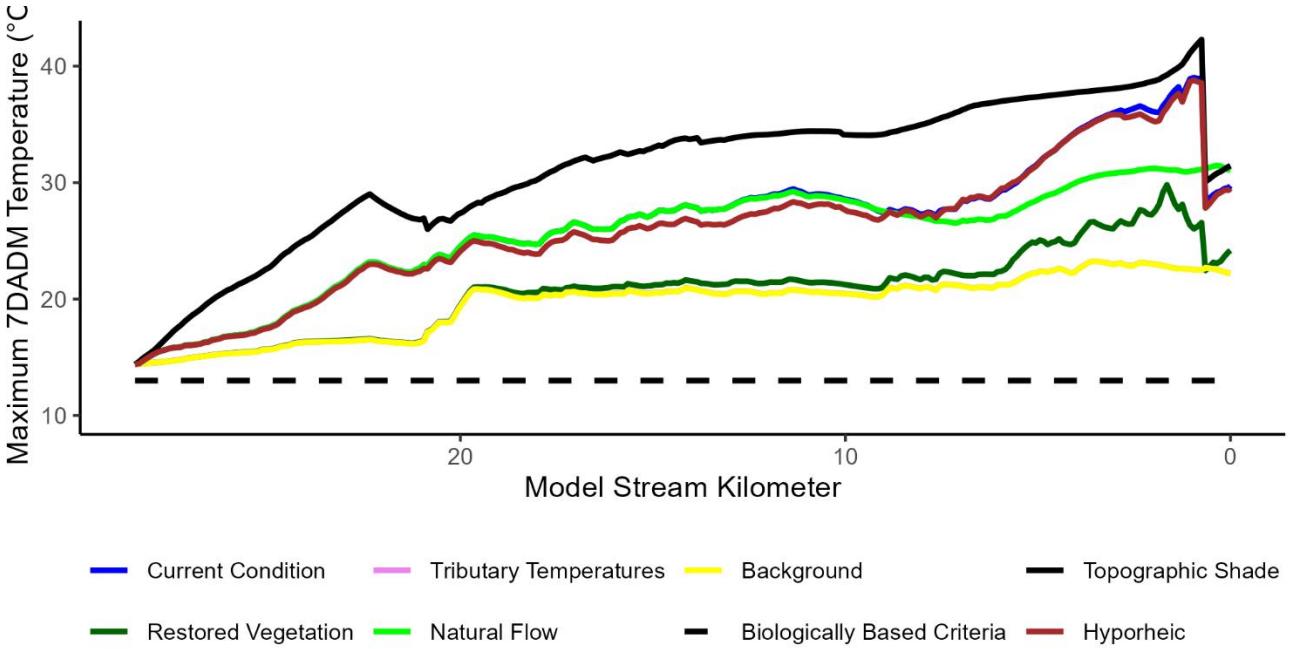


Figure 5-83: South Fork Little Butte Creek: Longitudinal maximum 7DADM temperatures, all scenarios.

5.12.1 Vegetation scenarios

This section summarizes the temperature impacts of restored vegetation, current conditions, and topographic shade on South Fork Little Butte Creek. Table 5-93 and Figure 5-84 summarize the maximum 7DADM stream temperature changes between the Current Condition and Restored Vegetation scenarios over the model extent when scenario temperatures exceed the BBNC. The maximum 7DADM temperature difference was 7.23°C at the most downstream node and 13.09°C at the POMI (model km 0.95).

Table 5-93: South Fork Little Butte Creek: Maximum 7DADM temperature changes between Restored Vegetation and Current Condition scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
0.00	7.23	Downstream boundary
0.95	13.09	POMI

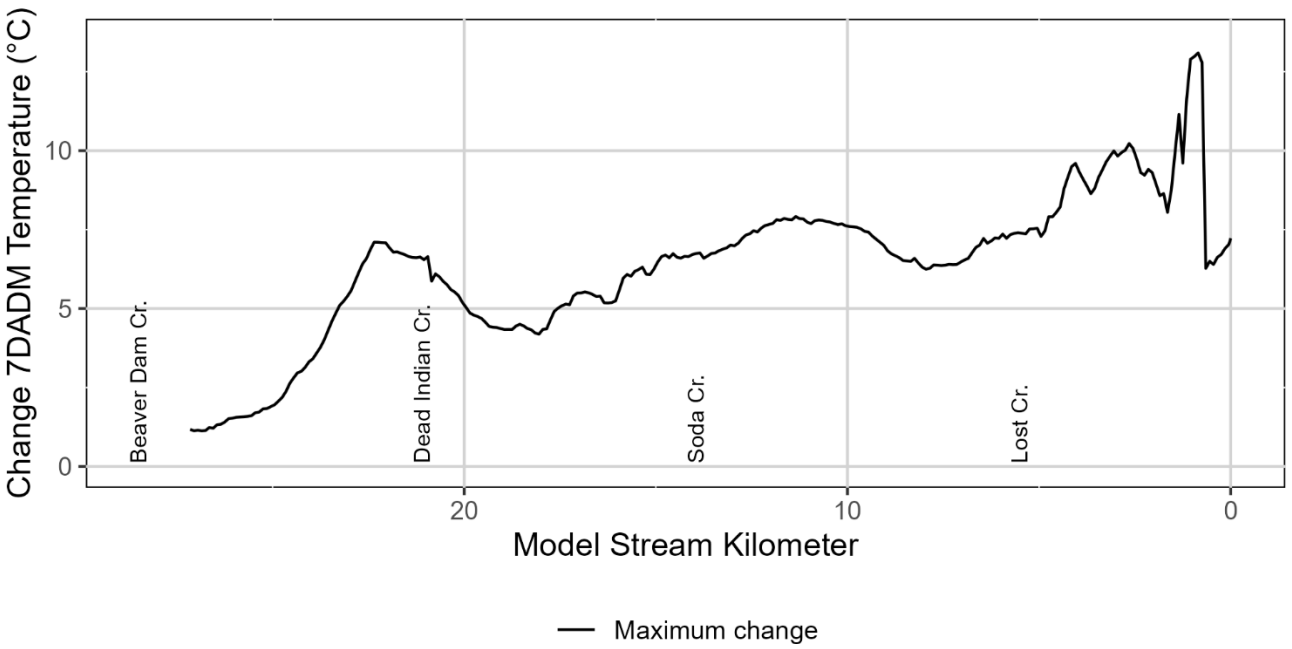


Figure 5-84: South Fork Little Butte Creek: Maximum 7DADM temperature changes between Restored Vegetation and Current Condition scenarios over the model extent when temperatures exceed the BBNC.

Table 5-94 and Figure 5-85 summarize the maximum 7DADM stream temperature changes between the Topographic Shade and Current Condition scenarios. The maximum 7DADM temperature difference was 3.34°C at the most downstream node and was 10.50°C at the POMI (model km 6.25).

Table 5-94: South Fork Little Butte Creek: Maximum 7DADM stream temperature between Topographic Shade and Current Condition scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
0.00	3.34	Downstream boundary
6.25	10.50	POMI

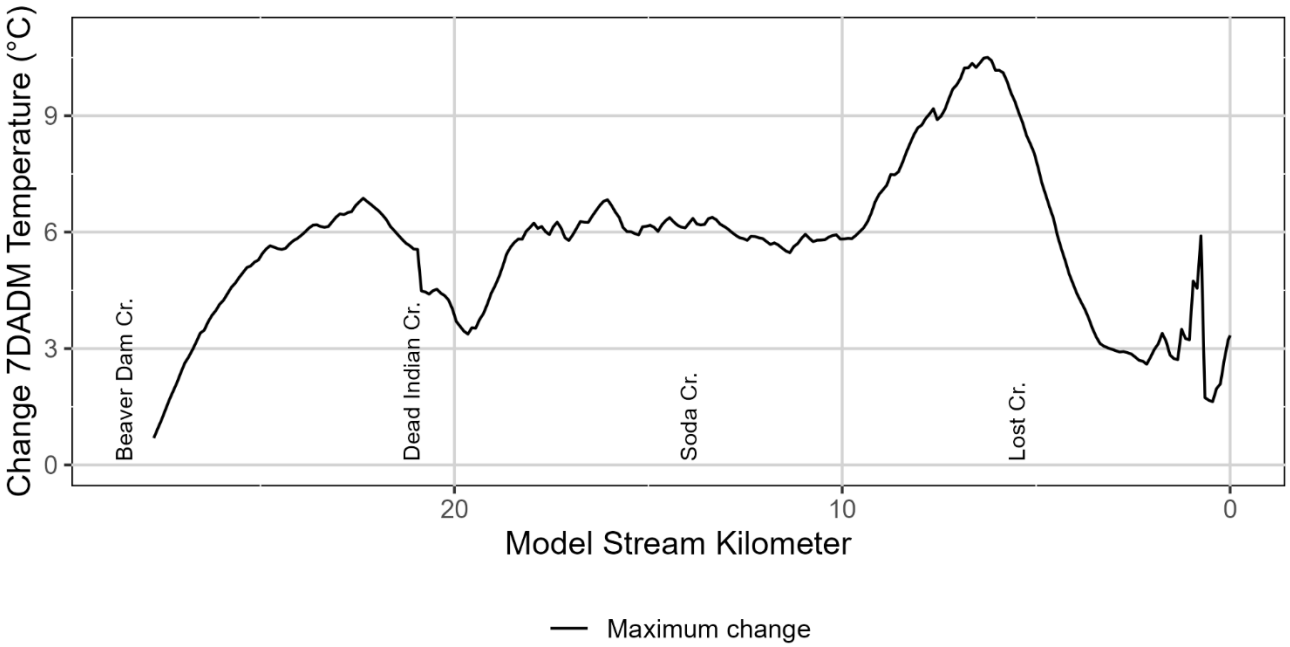


Figure 5-85: South Fork Little Butte Creek: Maximum 7DADM temperature changes between Topographic Shade and Current Condition scenarios over the model extent when temperatures exceed the BBNC.

Table 5-95 and Figure 5-86 summarize the mean effective shade (%) for the Current Condition, Restored Vegetation, and Topographic Shade scenarios. The mean effective shade difference between the Restored Vegetation and Current Condition scenarios was 33%.

Figure 5-87 shows longitudinal effective shade gaps (%) between Restored Vegetation and Current Condition scenarios, while Figure 5-88 shows longitudinal effective shade gaps (%) between Restored Vegetation and Current Condition scenarios

Table 5-95: South Fork Little Butte Creek: Mean effective shade (%) for the Current Condition, Restored Vegetation, and Topographic Shade scenarios.

Scenario	Mean effective shade (%)
Current Condition	47
Restored Vegetation	79
Shade Gap (Restored – Current)	33
Topographic Shade	13

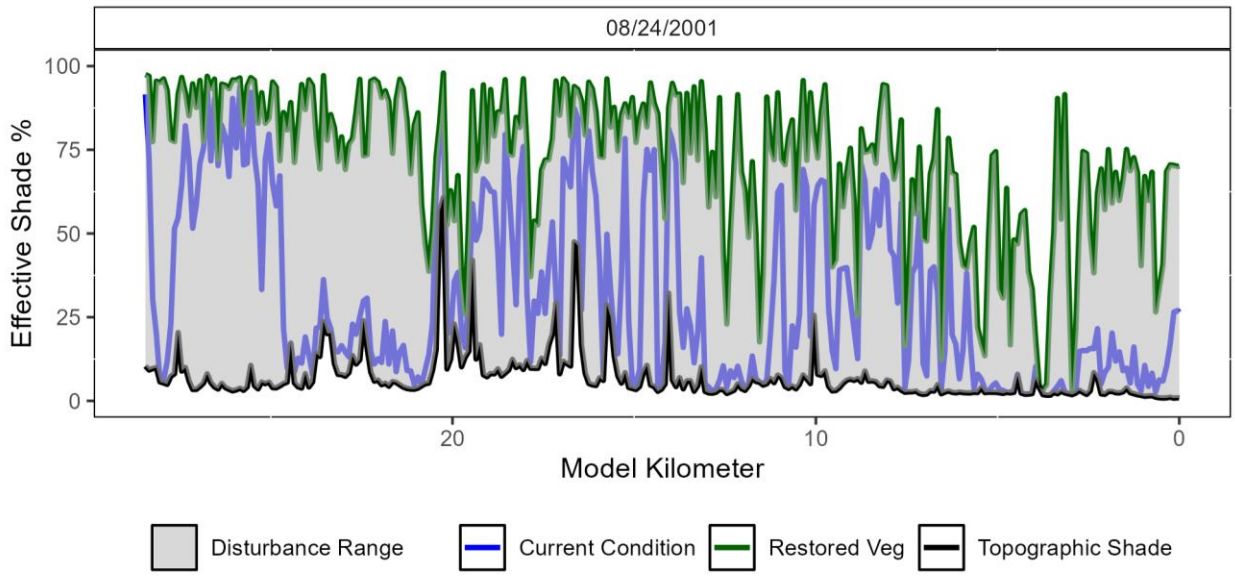


Figure 5-86: South Fork Little Butte Creek: Longitudinal effective shade results (%) for Current Condition, Restored Vegetation, and Topographic Shade scenarios.

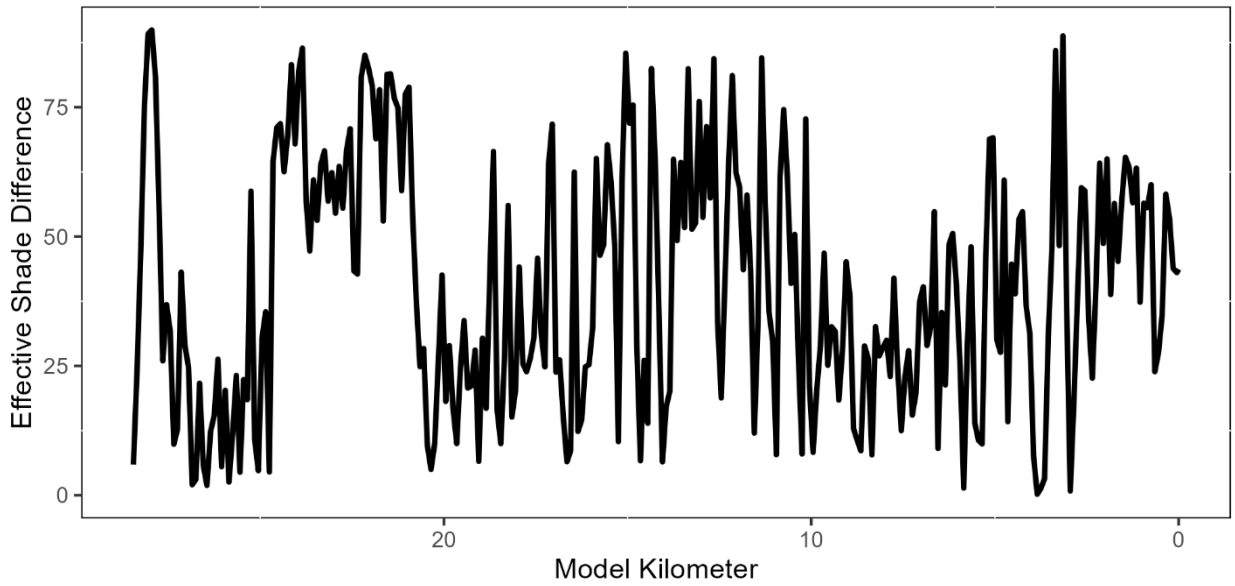


Figure 5-87: South Fork Little Butte Creek: Longitudinal effective shade (%) gaps between Restored Vegetation and Current Condition scenarios.

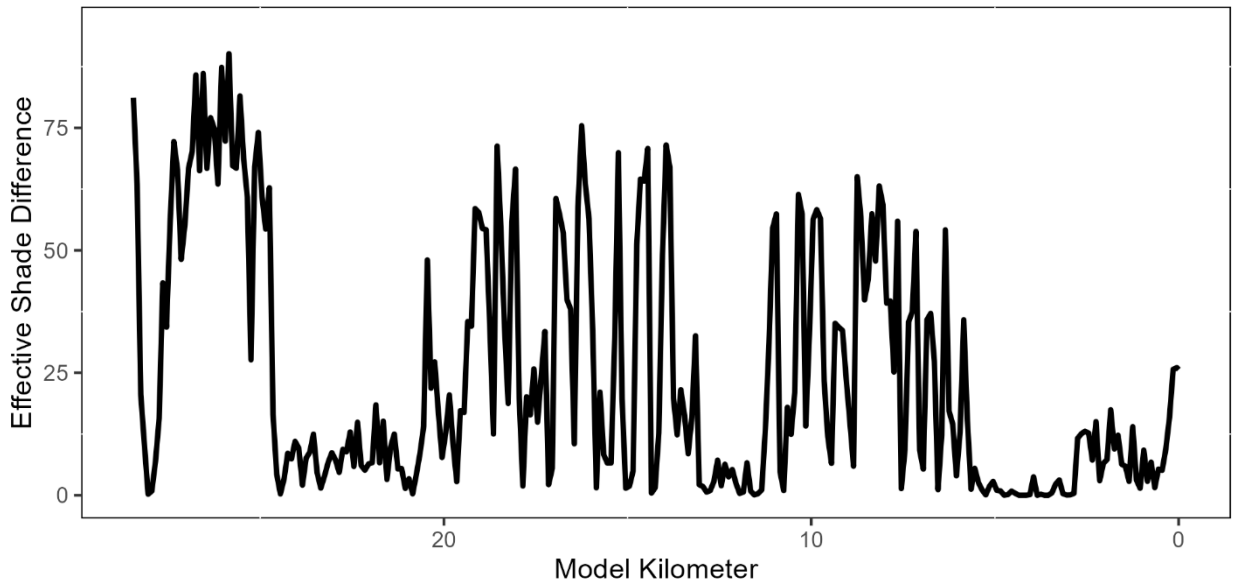


Figure 5-88: South Fork Little Butte Creek: Longitudinal effective shade (%) gaps between Topographic Shade and Current Condition scenarios.

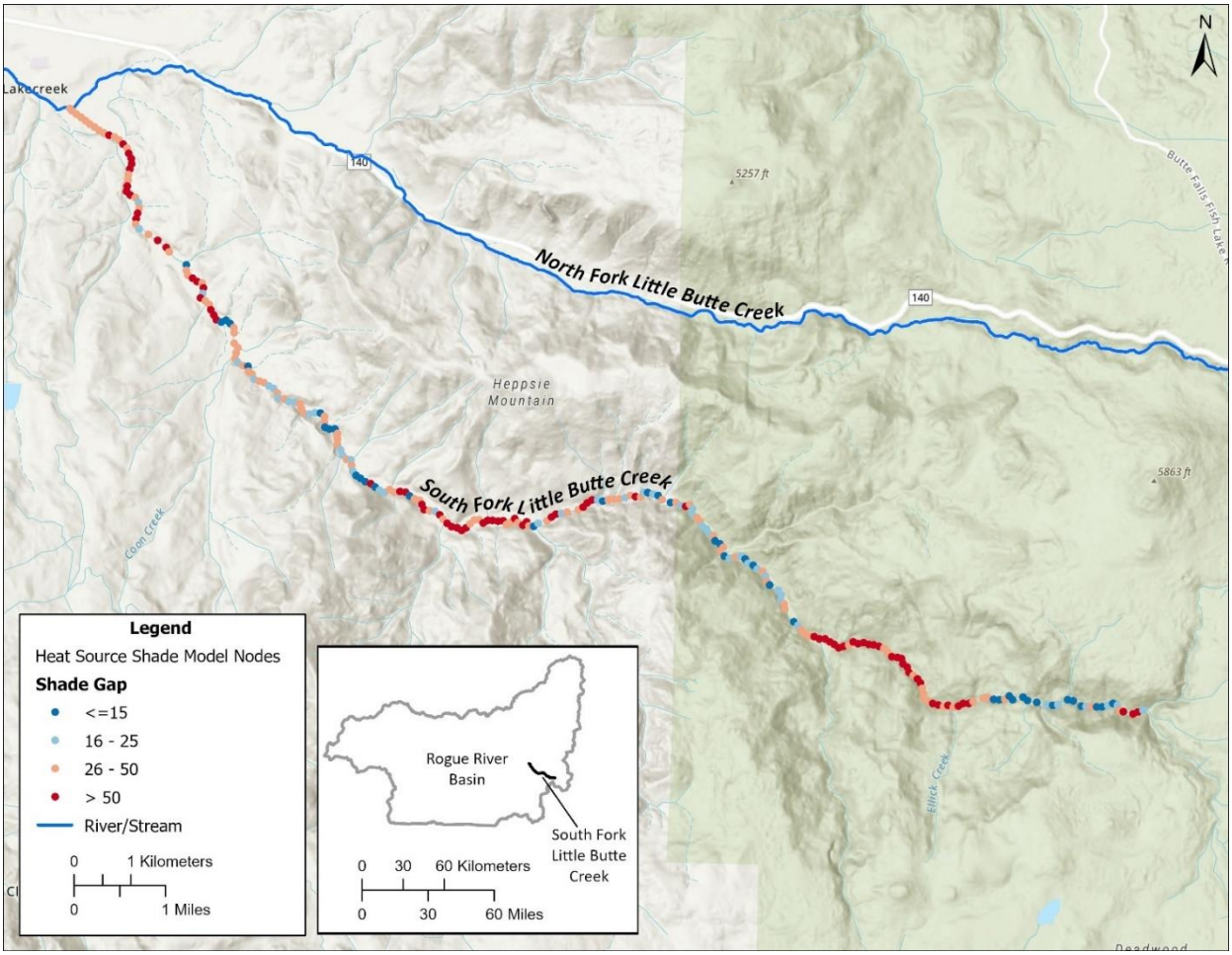


Figure 5-89: South Fork Little Butte Creek map: shade gaps (%) between Restored Vegetation and Current Condition scenarios.

5.12.2 Restored flow

This section summarizes the temperature impacts of altered flow. Table 5-96 and Figure 5-90 summarize the maximum 7DADM stream temperature changes between the Current Condition and Restored Flow scenarios. The maximum 7DADM temperature difference was 2.15°C at the most downstream node and 8.81°C at the POMI (model km 1.05).

Table 5-96: South Fork Little Butte Creek: Maximum 7DADM temperature changes between Current Condition and Restored Flow scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
0.00	2.15	Downstream boundary
1.05	8.81	POMI

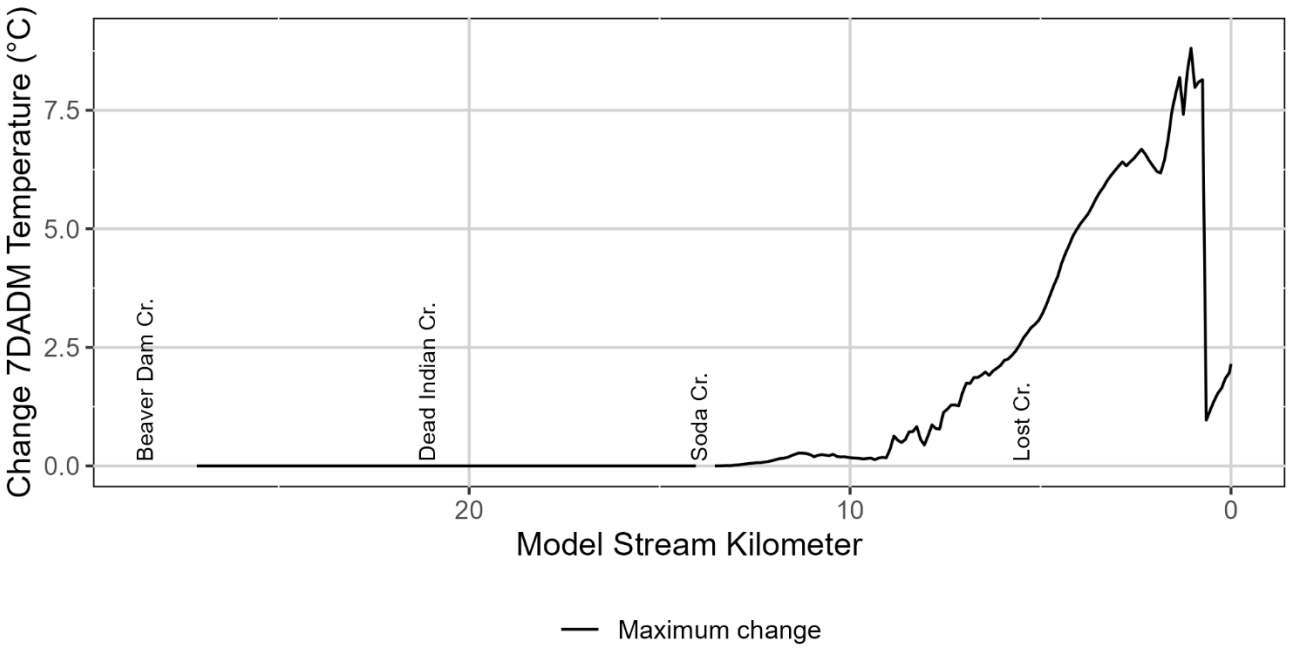


Figure 5-90: South Fork Little Butte Creek: Maximum 7DADM temperature changes between Current Condition and Restored Flow scenarios over the model extent when temperatures exceed the BBNC.

5.12.3 Tributary temperatures

The Tributary Temperatures scenario setup was identical to the HUA Attainment scenario setup for South Fork Little Butte Creek. Refer to Section 5.12.4 for results.

5.12.4 HUA Attainment

This section summarizes the temperature effects of proposed load allocations on the mainstem and modeled tributaries. Table 5-97 describes the South Fork Little Butte Creek HUA Attainment model scenario setup.

Table 5-97: South Fork Little Butte Creek: HUA Attainment scenario setup.

Model input variable	Attainment scenario set up description
Riparian landcover	Equal to the Background scenario setup (restored vegetation conditions), though this source is assigned an allocation.
Tributary temperatures	Each tributary's temperatures were increased from Background scenario values by the total HUA allocations on that tributary (+0.10°C). Note that canal and diversion temperatures were not adjusted.
Tributary flows	Equal to the Background scenario setup.
Boundary condition temperature	Equal to the Background scenario setup.
Boundary condition flow	Equal to the Background scenario setup
Withdrawals	Equal to the Background scenario setup, though this source is assigned an allocation.
NPDES point sources	No point sources exist in the model extent.
Nonpoint source dam and reservoir operations	Loading from this category was not modeled, though this source is assigned an allocation.
Solar loading from existing infrastructure	Solar loading from existing infrastructure was not modeled, though this source is assigned an allocation.

The TMDL allocations to thermal source categories on the South Fork Little Butte Creek mainstem and tributaries are presented in the main TMDL report (Table 9-5).

Table 5-98 and Figure 5-91 summarize the maximum 7DADM stream temperature changes between the Attainment and Background scenarios. The maximum 7DADM temperature difference was 0.02°C at the most downstream node and 0.03°C at the POMI (model km 20.75).

The South Fork Little Butte Creek HUA Attainment model analysis results indicate that when sources attain their applicable Load Allocations, that the applicable categorical HUA assignments will be achieved and cumulative warming will not exceed the cumulative HUA assignment in South Fork Little Butte Creek.

Table 5-98: South Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Attainment and Background scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
0.00	0.02	Downstream boundary
20.75	0.03	POMI

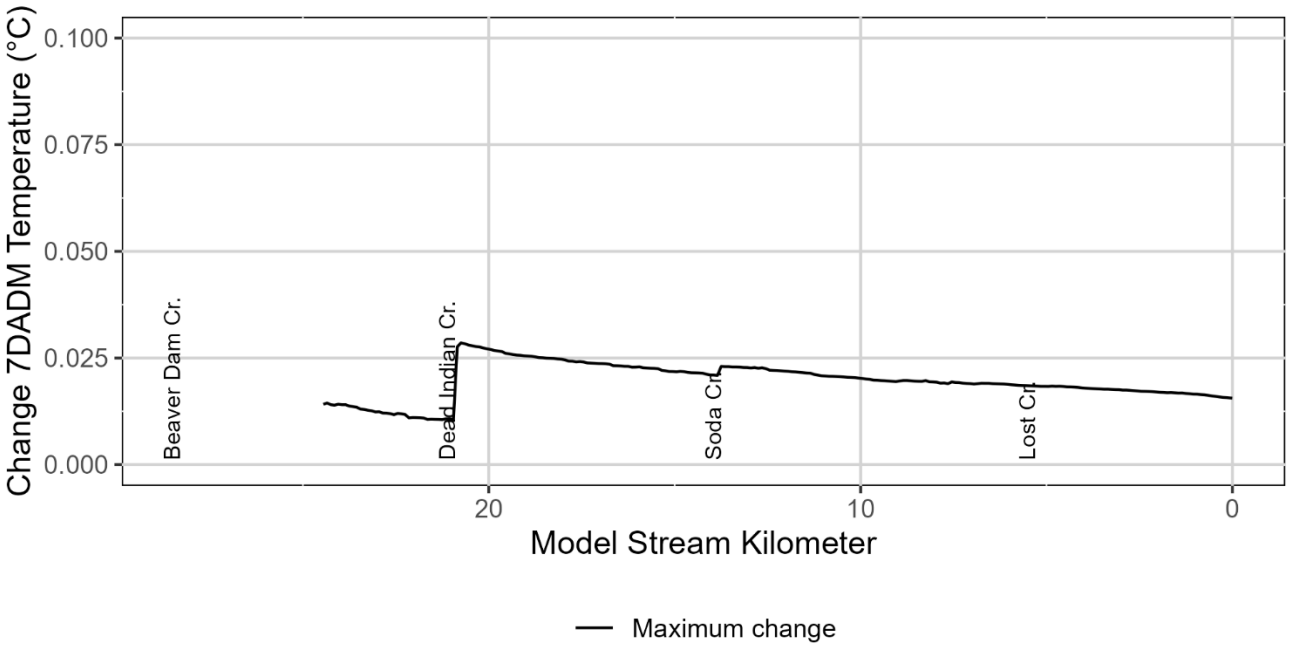


Figure 5-91: South Fork Little Butte Creek: Maximum 7DADM stream temperature changes between Attainment and Background scenarios over the model extent when temperatures exceed the BBNC.

5.12.5 Hyporheic

This section summarizes the temperature impacts of altered Hyporheic flow. Table 5-99 and Figure 5-92 summarize the maximum 7DADM stream temperature changes between the Current Condition and Hyporheic scenarios. The maximum 7DADM temperature difference was 0.51°C at the most downstream node and 1.84°C at the POMI (model km 8.35).

Table 5-99: South Fork Little Butte Creek: Maximum 7DADM temperature changes between Current Condition and Hyporheic scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
0.00	0.51	Downstream boundary
8.35	1.84	POMI

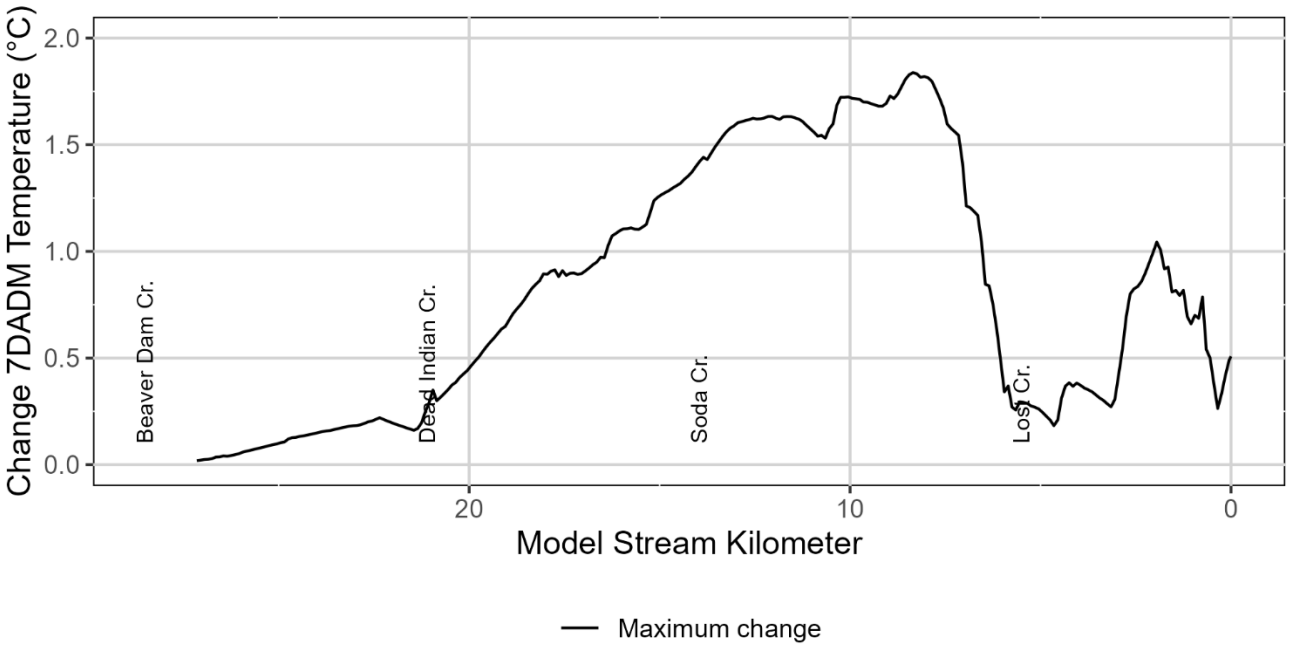


Figure 5-92: South Fork Little Butte Creek: Maximum 7DADM temperature changes between Current Condition and Hyporheic scenarios over the model extent when temperatures exceed the BBNC.

5.12.6 Background

This section summarizes the temperature impacts of background conditions.

Table 5-100 and Figure 5-93 summarize the maximum 7DADM stream temperature changes between the Current Condition and Background scenarios. The maximum 7DADM temperature difference between the two scenarios was 9.32°C at the most downstream node and 16.97°C at the POMI (model km 0.75).

Table 5-101 and Figure 5-94 summarize the maximum 7DADM stream temperature changes between the Background scenario and the BBNC. The maximum 7DADM temperature difference between the Background scenario and the BBNC was 6.21°C at the most downstream node and 7.24°C at the POMI (model km 3.55).

Table 5-100: South Fork Little Butte Creek: Maximum 7DADM temperature changes between Current Condition and Background scenarios over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature (°C)	Location
0.00	9.32	Downstream boundary
0.75	16.97	POMI

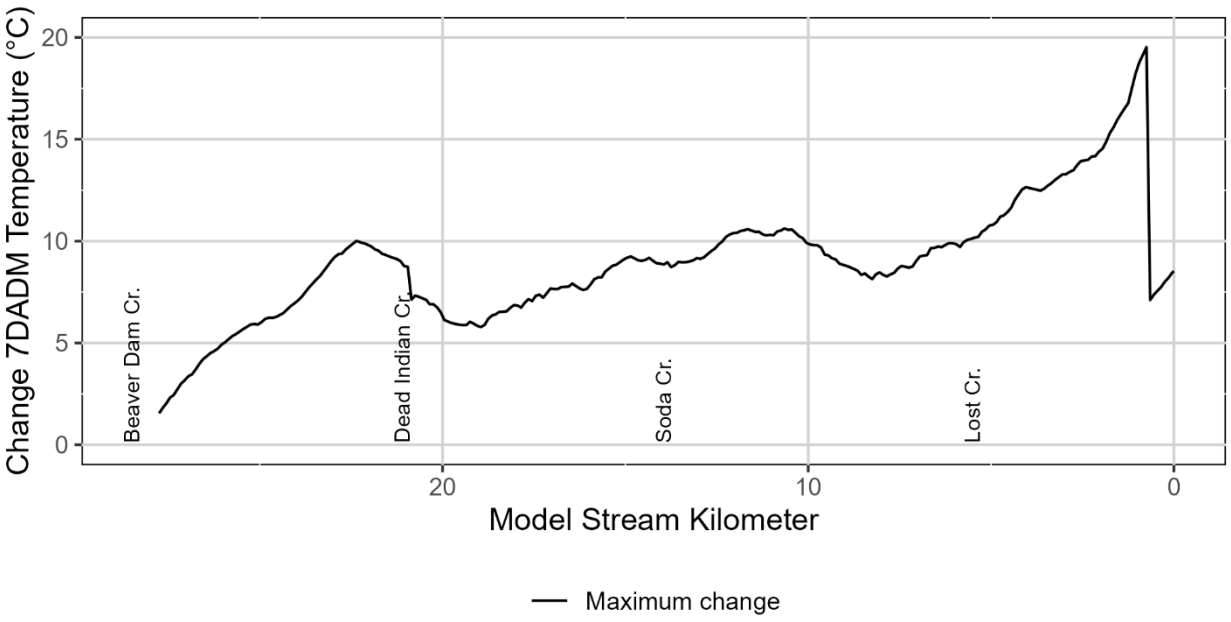


Figure 5-93: South Fork Little Butte Creek: Maximum 7DADM temperature changes between Current Condition and Background scenarios over the model extent when temperatures exceed the BBNC.

Table 5-101: South Fork Little Butte Creek: Maximum 7DADM temperature changes between the Background scenario and the BBNC over the model extent when temperatures exceed the BBNC.

Model km	Stream temperature change (°C)	Location
0.00	6.21	Downstream boundary
3.55	7.24	POMI

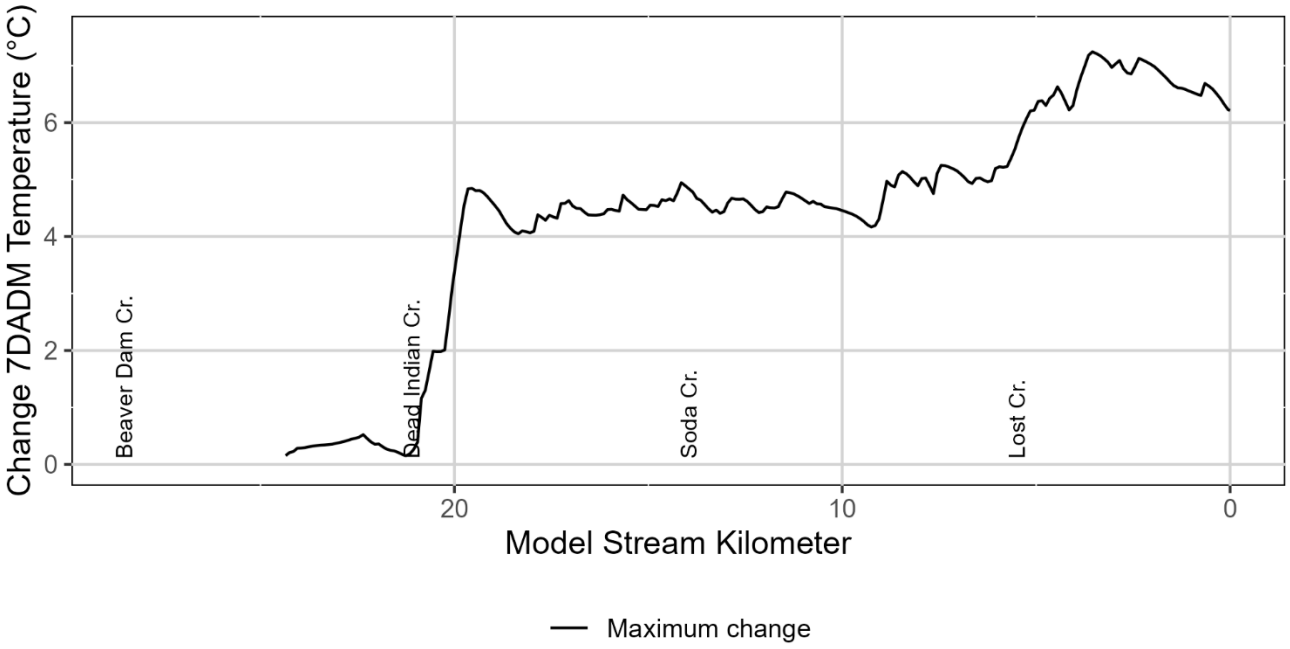


Figure 5-94: South Fork Little Butte Creek: Maximum 7DADM temperature changes between the Background scenario and the BBNC over the model extent when temperatures exceed the BBNC.

6 References

Boyd and Kasper (2003). *Analytical Methods for Dynamic Open Channel Heat and Mass Transfer: Methodology for Heat Source Model Version 7.0.*

DEQ (Oregon Department of Environmental Quality). 1999. “Upper Sucker Creek TMDL and WQMP.”

DEQ (Oregon Department of Environmental Quality). 2002a. “Lobster Creek Watershed TMDL and WQMP.”
DEQ (Oregon Department of Environmental Quality). 2002b. “Lower Sucker Creek TMDL and WQMP.”

DEQ (Oregon Department of Environmental Quality). 2004. “Applegate Subbasin TMDL and WQMP.”

DEQ (Oregon Department of Environmental Quality). 2007. “Bear Creek Watershed TMDL and WQMP.”

DEQ (Oregon Department of Environmental Quality). 2008. “Rogue Basin TMDL and WQMP.”

DEQ (Oregon Department of Environmental Quality). 2013b. “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.

DEQ (Oregon Department of Environmental Quality). 2022. “2022 EPA Approved Integrated Report.”
OWEB (Oregon Watershed Enhancement Board). 1999. Oregon Watershed Assessment Manual, Appendix A – Ecoregion Descriptions, Salem, Oregon.

Thorson, T. D., Bryce, S. A., Lammers, D. A., Wood, A. J., Omernik, J. M., Kagan, J., … Comstock, J.A. (Cartographers). 2003. Color poster with map, descriptive text, summary tables, and photographs. [Ecoregions of Oregon]. Reston, VA: U.S. Geological Survey

USFS (U.S. Forest Service). 1993. “SHADOW v. 2.3 - Stream Temperature Management Program. Prepared by Chris Park USFS, Pacific Northwest Region.”

“Log Scaling & Timber Cruising” (Bell and Dillworth, OSU Press,1988), pages 225-236.

“Field Guide to Forested Plant Associations of Southwest Oregon” (USDA/USFS, 1996)