State of Oregon
DEQ Department of Environmental Quality

Total Maximum Daily Loads for the Middle Columbia-Hood (Miles Creeks) Subbasin

Technical Support Document

Appendix A: Model Report

Date: (EQC adoption meeting month and year)



Document information

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1 Overview

This document, the Technical Support Document Appendix A of the replacement Middle Columbia-Hood (Miles Creeks) Subbasin 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.

The Heat Source model was used to simulate both stream temperatures and shade conditions on Fifteenmile Creek, and shade conditions only on Eightmile Creek and Ramsey Creek (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. Wasteload allocations will be developed for all NPDES permittees that were determined to be thermal sources.

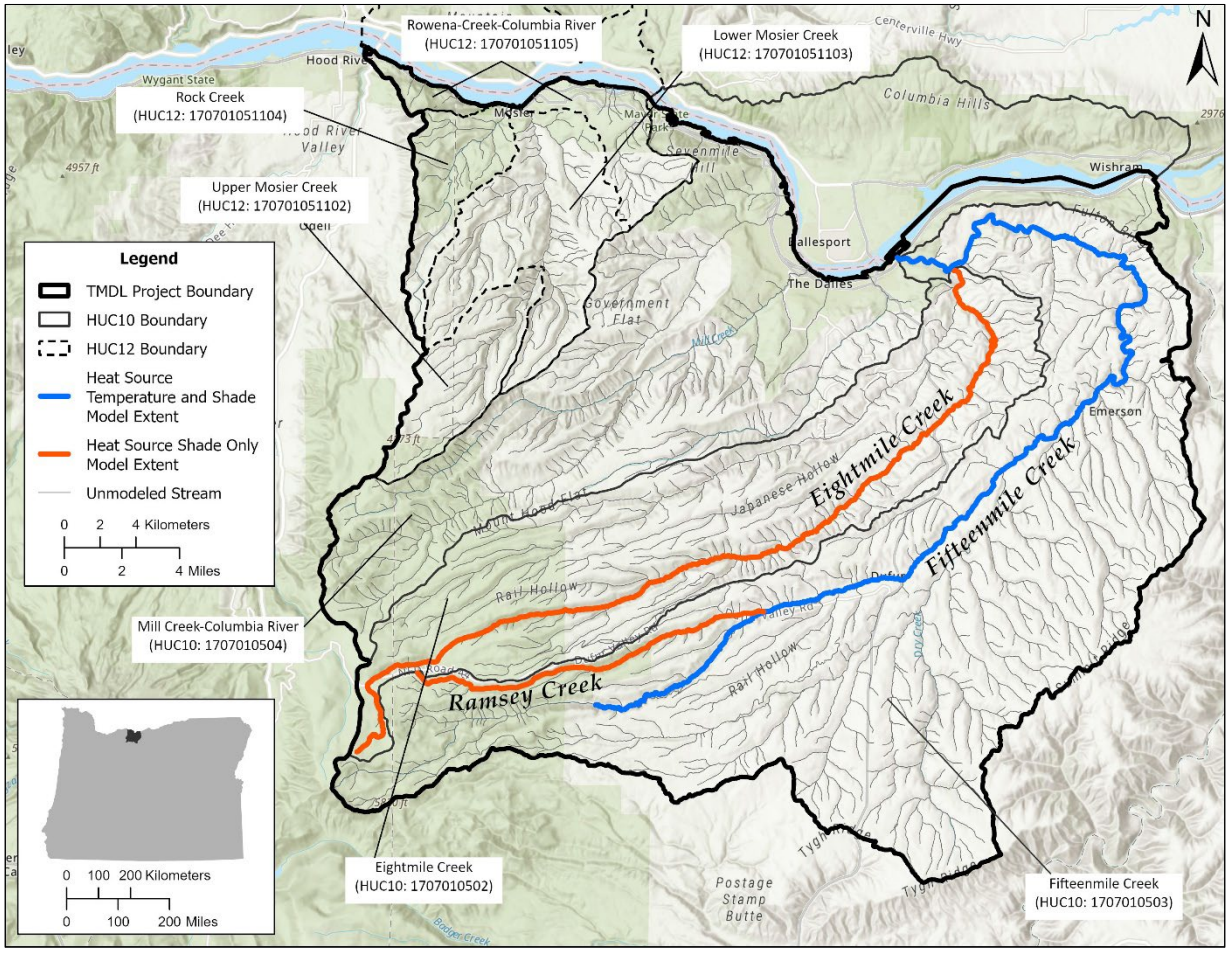


Figure 1-1: Overview of the Middle Columbia-Hood (Miles Creeks) Subbasin TMDL project area with model extents.

2 Available data

2.1 Field data

2.1.1 Meteorology

Meteorological data required for model development include air temperature, relative humidity, and wind speed. Climate and meteorological data was collected from seven sites during the summer of 2002, and the data sources for the parameters used to support model development are listed in Table 2-1. This data was used to establish climate and meteorological conditions in the temperature and effective shade models. Figure 2-1 shows the locations of climate stations used to establish meteorological conditions for model simulations.

Table 2-1. Meteorological data sources used in model development.

Station	Data Source	Latitude	Longitude	Measurement Parameters
Emerson Bridge	Wasco SWCD	45.5455	-120.98	Air Temperature

Station	Data Source	Latitude	Longitude	Measurement Parameters
Watermaster Larry Toll's House	Larry Toll (watermaster)	45.5881	-121.181	Air temperature, wind speed/direction, relative humidity
KDLS, The Dalles Municipal Airport	NOAA/NNDC	45.6167	-121.1667	Air temperature, wind speed/direction, relative humidity, cloudiness
Hwy 197 near auction yard	IFPnet	45.59002	-121.12498	Air temperature, wind speed, relative humidity, solar radiation
RAWS (Pollywog Site)	RAWS	45.4586	-121.446	Air temperature, wind speed/direction, relative humidity, solar radiation
Dufur City intake	Wasco SWCD	45.39582049	-121.2786149	Air Temperature
Dufur COOP	COOP	45.4538	-121.13	Air Temperature

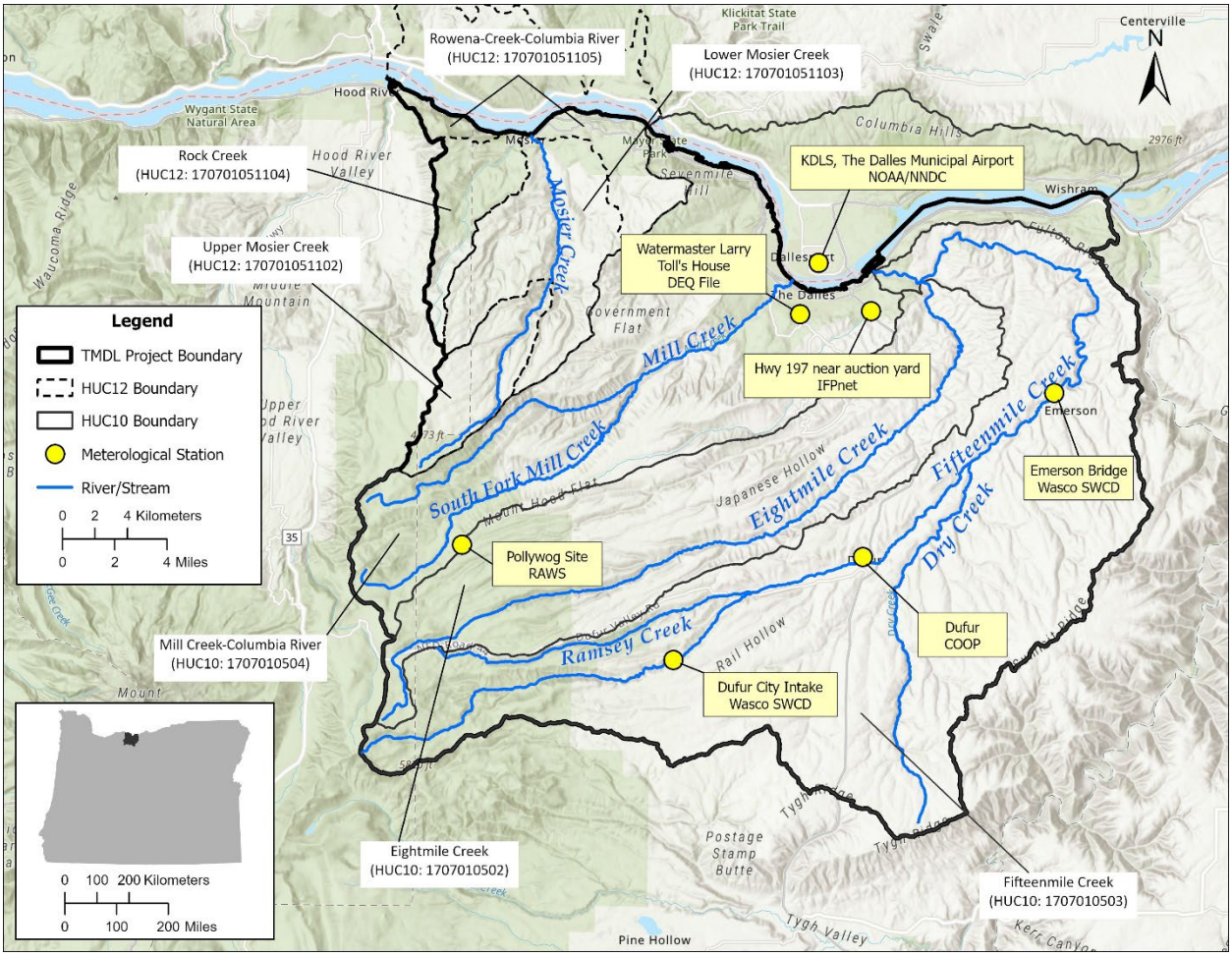


Figure 2-1: Location of climate stations providing meteorological data for model simulations.

2.1.2 Stream temperature

Continuous stream temperature data were used:

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

Temperature data used in this analysis were collected by the Oregon Department of Environmental Quality (DEQ) and other organizations, and most of the data is available in DEQ's Ambient Water Quality Monitoring System (AWQMS) database.

The data retrieval period for continuous stream temperature data was January 1, 1999 to December 31, 2024. 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. Continuous stream temperature monitoring sites supporting TMDL model development are summarized in Table 2-2.

Table 2-2: Stream temperature monitoring sites supporting Fifteenmile Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
No Station ID	Temperature data from Fifteenmile downstream of Lyda	45.3859	-121.3368	DEQ File
FM200	Fifteenmile at Petersburg upstream of Eightmile Creek	45.6113	-121.0750	ODFW
28972-ORDEQ	Fifteenmile downstream of Big Spring Gulch	45.6198	-120.9912	Wasco County SWCD
28968-ORDEQ	Fifteenmile downstream of Standard Hollow	45.5453	-120.9800	Wasco County SWCD
FM900	Fifteenmile upstream of Standard Hollow	45.5455	-120.9799	ODFW
No Station ID	Fifteenmile upstream of Dry Creek	45.5049	-121.0486	Wasco County SWCD
28973-ORDEQ	Fifteenmile upstream of Pine Creek	45.4502	-121.1185	Wasco County SWCD
FM1200	Fifteenmile at Ashbrook pump	45.4499	-121.1366	ODFW
28975-ORDEQ	Fifteenmile upstream of Underhill's Diversion	45.4391	-121.1860	Wasco County SWCD
28976-ORDEQ	Fifteenmile upstream of Ramsey	45.4309	-121.2250	Wasco County SWCD
28977-ORDEQ	Fifteenmile at Dufur Reservoir Intake	45.3958	-121.2786	Wasco County SWCD
FM2100	Fifteenmile downstream of Lyda	45.3866	-121.3395	DEQ
No Station ID	Eightmile Creek	45.6064	-121.0851	DEQ File
DC1300	Dry Creek	45.5052	-121.0464	ODFW

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
No Station ID	Ramsey Creek	45.4337	-121.2178	ODFW

2.1.3 Stream flow rate – continuous and instantaneous measurements

DEQ and other agencies measured instantaneous flow rate at multiple stream survey sites during the critical stream temperature period in the summers of 2000 and 2002. In addition to instantaneous flow rate, the surveys included measurements of flow velocity, wetted width, and average depth, and maximum depth. DEQ also obtained continuous flow rate measurements from various United States Geological Survey (USGS) and Oregon Water Resources Department (OWRD) monitoring sites. These instream measurements were used to develop flow inputs into the model, support flow mass balance analysis, and calibrate the temperature models. Flow monitoring sites supporting TMDL model development are summarized in Table 2-3 through Table 2-5.

Table 2-3: Continuous flow measurements available from USGS flow gaging stations in the Middle Columbia-Hood (Miles Creeks) Subbasin.

Station ID	Station	Latitude/Longitude
14105700	Columbia River At The Dalles, OR	45.60828/-121.1899
14113200	Mosier Creek Near Mosier, OR	45.64901/-121.3773

Table 2-4: Continuous flow measurements available from OWRD flow gaging stations in the Middle Columbia-Hood (Miles Creeks) Subbasin.

Station ID	Station	Latitude/Longitude
14104190	Fifteenmile Cr Bl Pine Cr Nr Dufur, OR	45.4589/-121.109
14104700	Fifteenmile Cr Nr Moody, OR	45.5955/-120.946
14104800	Fifteenmile Cr At Kaser Ranch Nr The Dalles, OR	45.6304/-121.055
14105545	Eightmile Cr At Petersburg, OR	45.6052/-121.08
14105550	Fifteenmile Cr Nr The Dalles	45.6061/-121.087
14113210	Mosier Cr Ab Dry Cr, Nr Mosier	45.6633/-121.381
28976-ORDEQ	Fifteenmile upstream Ramsey Creek	45.4331/-121.218
No Station ID	Fifteenmile at ISCO site	45.6308/-121.055

Table 2-5: Instantaneous flow measurements by DEQ and others in the Middle Columbia-Hood (Miles Creeks) Subbasin.

Station ID	Station	Latitude/Longitude	Data Source
28977-ORDEQ	Fifteenmile downstream Dufur City intake	45.3957/-121.279	DEQ
FM2100	Fifteenmile downstream Lyda Diversion	45.3859/-121.337	DEQ
No Station ID	Boundary Condition	45.3859/ -121.3368	DEQ
No Station ID	Eightmile Creek	45.6064/ -121.0851	DEQ
No Station ID	Fifteenmile downstream Underhills diversion	45.4393/-121.185	DEQ
No Station ID	Ramsey Creek at mouth	45.4337/ -121.218	OWRD

Station ID	Station	Latitude/Longitude	Data Source
FM900	Fifteenmile at Emerson Loop Rd. (upstream Standard Hollow)	45.5455/-120.98	ODFW
No Station ID	Fifteenmile at Dufur City Park	45.4511/-121.126	ODFW
No Station ID	Fifteenmile upstream mouth	45.6112/-121.119	ODFW

2.1.4 Vegetation and habitat surveys

Habitat data was collected at a number of locations in the Fifteenmile watershed in a coordinated monitoring effort by DEQ, ODFW, MHNF, and Wasco SWCD staff (Figure 2-2) during the summers of 2000-2002. Vegetation descriptions, effective shade measurements, channel width/depth and substrate information were collected at these sites. This data was used for stream simulation validation and temperature model inputs on Fifteenmile Creek. On Eightmile Creek and Ramsey Creek, effective shade measurements were used to corroborate the shade simulations. In addition, habitat data was collected along the length of Fifteenmile Creek by ODFW in 2001 as part of their Aquatic Inventory Project (AIP) (ODFW, 2001). This data was used as verification for temperature model input.

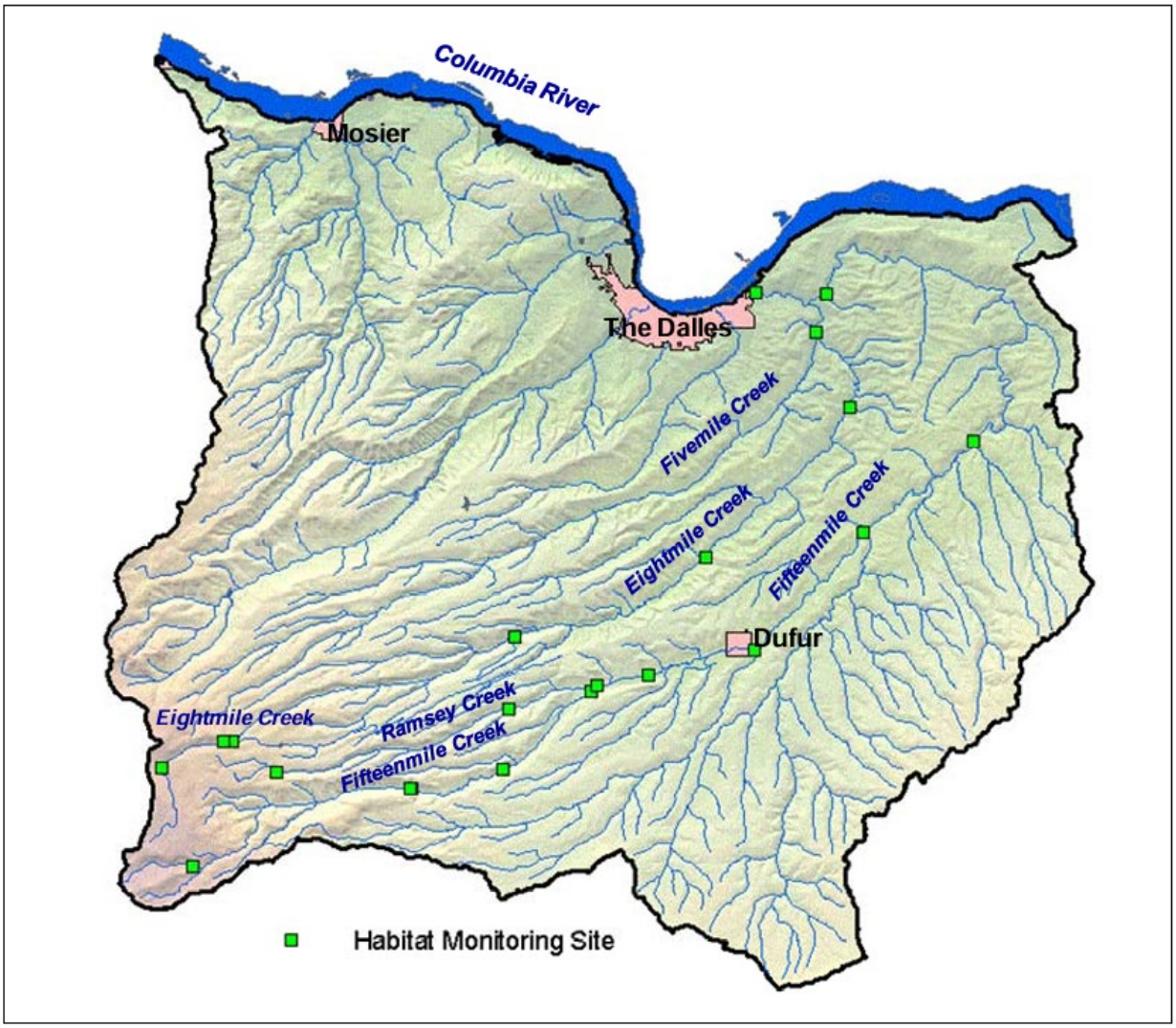


Figure 2-2: Habitat measurement locations in 2000 – 2002 (does not include AIP sites).

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 (Solar Pathfinder, Linden, TN) 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). Effective shade measurement collection locations and results are listed in Table 2-6, with collection locations shown in Figure 2-3. All results represent the effective shade on a cloud free day in August 2002.

Table 2-6: Effective shade data collected in the Middle Columbia-Hood (Miles Creeks) Subbasin.

Station ID	Station	Latitude/Longitude	Effective Shade (%)	Data Source
No Station ID	Fifteenmile at forest boundary	45.3866/-121.34	92	USFS

Station ID	Station	Latitude/Longitude	Effective Shade (%)	Data Source
28973-ORDEQ	Fifteenmile upstream Pine Creek/Hwy 97	45.4506/-121.121	72	DEQ
28975-ORDEQ	Fifteenmile upstream Underhill's diversion near river mile 34	45.4391/-121.186	62	Wasco SWCD
28976-ORDEQ	Fifteenmile upstream Ramsey Creek	45.4331/-121.218	76	DEQ
28977-ORDEQ	Fifteenmile downstream Dufur City intake	45.3957/-121.279	82	Wasco SWCD
FM200	Fifteenmile at Petersburg upstream of Eightmile Creek	45.6113/-121.075	95	ODFW
FM2100	Fifteenmile downstream Lyda Diversion	45.3859/-121.337	51	ODFW
FM900	Fifteenmile at Emerson Loop Rd. (u/s Standard Hollow)	45.5455/-120.98	7	ODFW
No Station ID	Fifteenmile at Dufur City Park	45.4511/-121.126	11	DEQ
No Station ID	Fifteenmile at ISCO site	45.6308/-121.055	5	DEQ
No Station ID	Fifteenmile downstream Underhills diversion near river mile 34	45.4393/-121.185	43	DEQ
No Station ID	Fifteenmile upstream Dry Creek	45.5049/-121.049	7	Wasco SWCD
No Station ID	Fifteenmile upstream mouth	45.6112/-121.119	10	DEQ
No Station ID	Eightmile Creek upstream Fifteenmile Rd	45.6055/-121.084	82	ODFW
No Station ID	Eightmile Creek downstream Fivemile Creek	45.5933/-121.081	81	Wasco SWCD
No Station ID	Eightmile Creek downstream county bridge	45.5603/-121.059	87	Wasco SWCD
No Station ID	Eightmile Creek upstream Endersby bridge	45.4918/-121.152	47	ODFW
No Station ID	Eightmile Creek at River Mile 19	45.4558/-121.272	87	ODFW
No Station ID	Eightmile Creek downstream Road 4430	45.4068/-121.452	74	USFS
No Station ID	Eightmile Creek upstream Road 4430	45.4067/-121.458	100	USFS
No Station ID	Eightmile Creek upstream Road 44	45.3944/-121.499	88	USFS
No Station ID	Ramsey Creek at mouth	45.4337/-121.218	100	ODFW
No Station ID	Ramsey Creek at Ramsey Rd. (new forest boundary)	45.4231/-121.275	55	USFS
No Station ID	Ramsey downstream Road 4450	45.3934/-121.425	89	ODFW

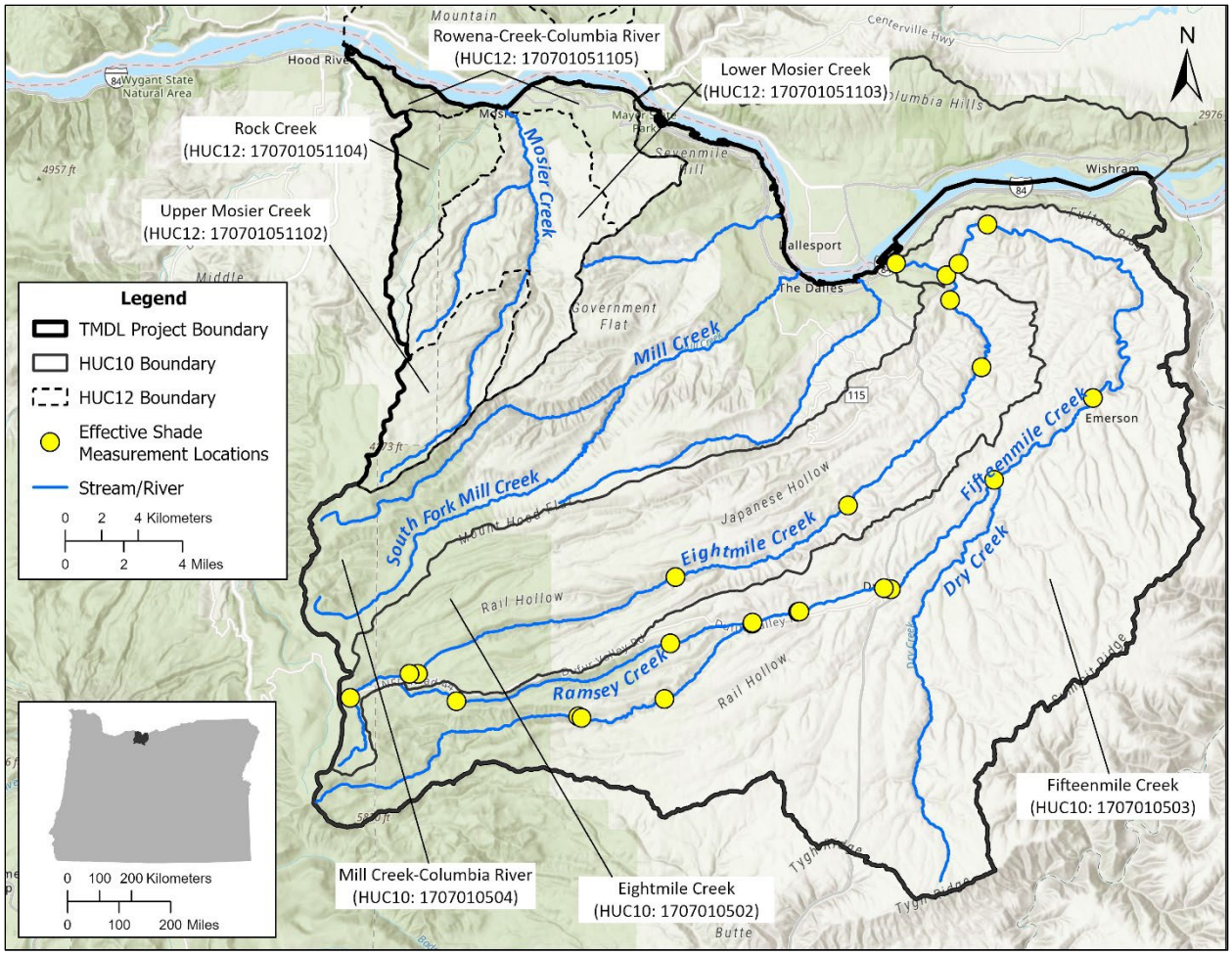


Figure 2-3: Effective shade measurement locations in the Middle Columbia-Hood (Miles Creeks) Subbasin TMDL project area.

2.2 GIS and remotely sensed data

[add information for LiDAR]

2.2.1 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 Middle Columbia-Hood (Miles Creeks) Subbasin in 2002 (Figure 2-4). TIR data are used to characterize stream thermal regimes and habitat quality. Table 2-7 summarizes TIR collection dates for all streams.

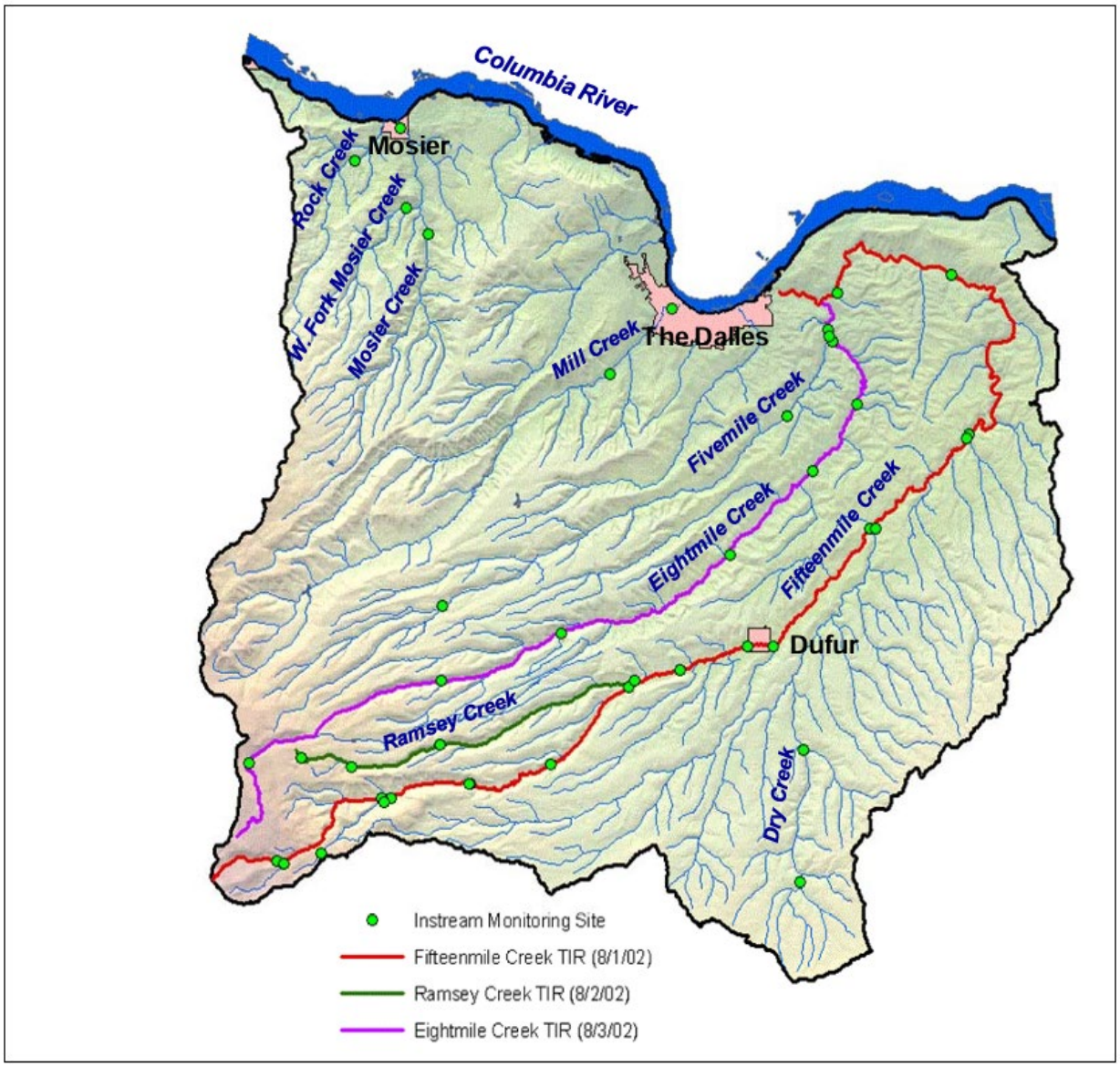


Figure 2-4: TIR flight paths in the Middle Columbia-Hood (Miles Creeks) Subbasin.

TIR stream temperature data were used to:

- Measure surface temperatures,
- Develop longitudinal temperatures profiles,
- Develop flow mass balances,
- Map/identify significant thermal features;
- Indicate subsurface hydrology, groundwater inflow and/or springs, and
- Validate simulated stream temperatures.

Table 2-7: Middle Columbia-Hood (Miles Creeks) Subbasin model development: TIR survey extents and collection dates.

Stream	Survey extent	Date	Time	Survey distance
Eightmile Creek	Mouth to headwaters	2002-08-03	13:28-14:54	53.8 km

Stream	Survey extent	Date	Time	Survey distance
Fifteenmile Creek	Mouth to headwaters	2002-08-01	13:54-15:33	84.1 km
Ramsey Creek	Mouth to headwaters	2002-08-02	13:19-13:54	21.1 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 so 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 were deployed 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.

2.2.2 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 X). 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.

2.2.3 Aerial imagery: Digital orthophoto quads

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. The digital orthophotos used in this report were black and white with one-

meter pixels covering a USGS quarter quadrangle. The images were collected in May through July of 1994, 1995 and 1996, and were provided through the Natural Resources Conservation Service National Cartography and Geospatial Center.

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.

2.2.4 Land ownership and jurisdiction mapping

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 **Error! Reference source not found.**.

2.3 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/shade analyses were:

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

Most of these parameters were derived using TTools (Boyd and Kasper, 2003). TTools is a set of ArcGIS tools that are designed to automatically sample spatial data sets and assemble an input database for Heat Source modeling. The methodologies used for deriving this data in the Middle Columbia-Hood (Miles Creeks) Subbasin TMDL analysis are described below.

In addition to derived landscape parameters, stream flows were derived using a mass balance method. Stream flow measurements were taken at a limited number of locations, and the mass balance method was used to calculate stream flows in areas where field measurements were not collected.

2.3.1 Stream position and aspect

Stream position was assessed by digitizing the stream centerline. This polyline was segmented into 50-meter reaches, separated by nodes. The latitude/longitude and aspect (downstream direction) were calculated at each node (Figure 2-5). An aspect of zero would be north, 90 (east), 180 (south), and 270 (west).

2.3.2 Stream elevation and gradient

Stream elevation was sampled from the 10-meter DEM at each of the segmented TTools nodes (Figure 2-6). Gradients were calculated from the elevation of the stream node and the distance between nodes.

2.3.3 Topographic shade angle

A topographic 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. On Fifteenmile Creek, the sampling routine extended 32.3 km (20 miles) in each direction. On Eightmile Creek and Ramsey Creek, the sampling routine extended 20 km (12.4 miles). The difference in sampling routine was a function of different TTools versions used. Topographic shade angle was calculated using **Equation 2-1** as implemented in a python script called TTools. Elevations were sampled from the 10-meter DEM. The maximum topographic shade angles to the west, south and east for each node was found by sampling every raster cell out as far as necessary, typically 10 km at each of the segmented nodes (Figure 2-7).

$$\theta_T = \tan^{-1}\left(\frac{Z_T - Z_S}{d}\right) \qquad \textbf{Equation 2-1}$$

where,

$\theta_T =$ The topographic shade angle (degrees).

$Z_T =$ The elevation (meters) at the topographic feature.

$Z_S =$ The elevation (meters) at the stream node.

$d =$ Horizontal distance (meters) from the stream node to the topographic feature.

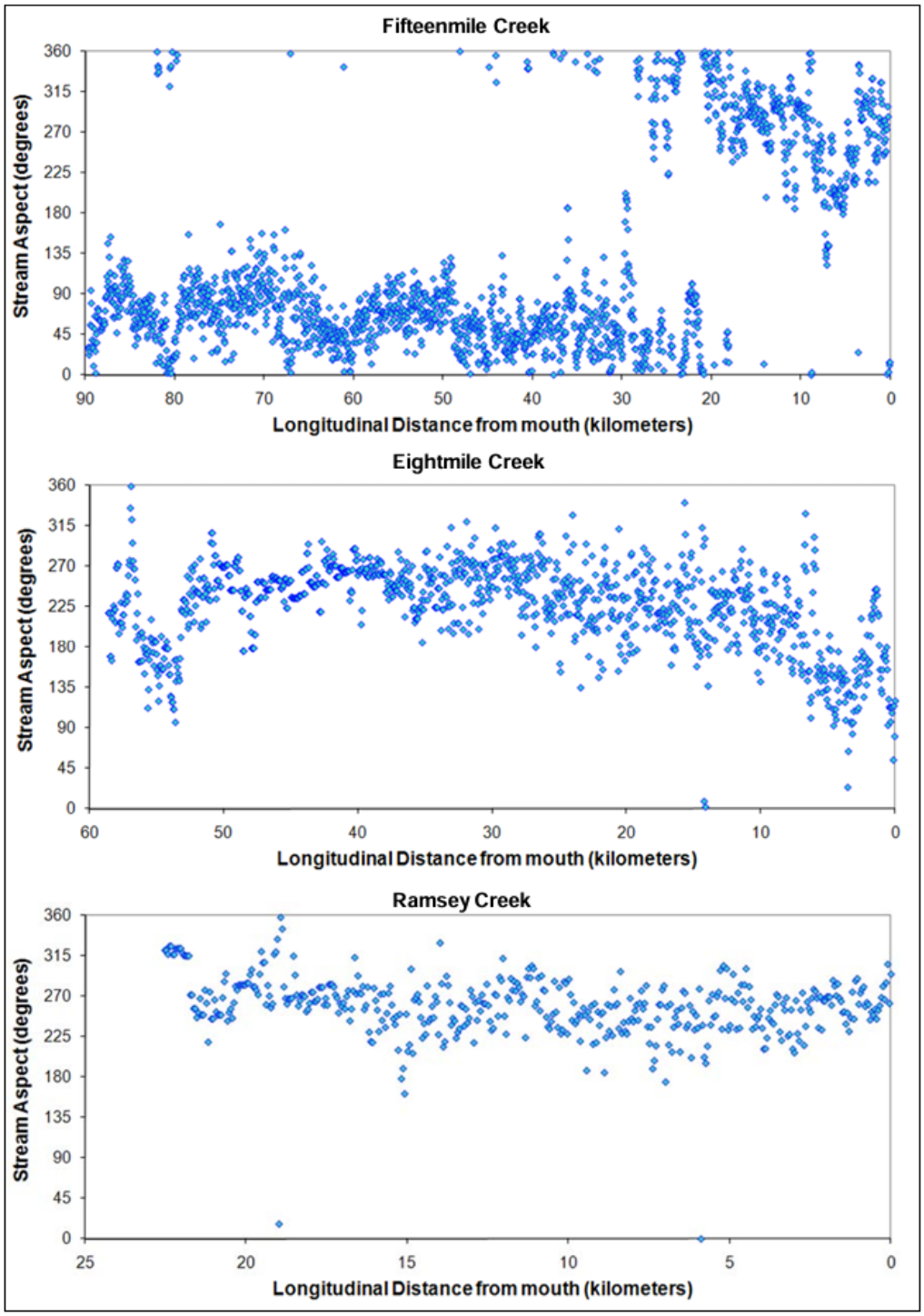


Figure 2-5: Stream aspects (direction of flow).

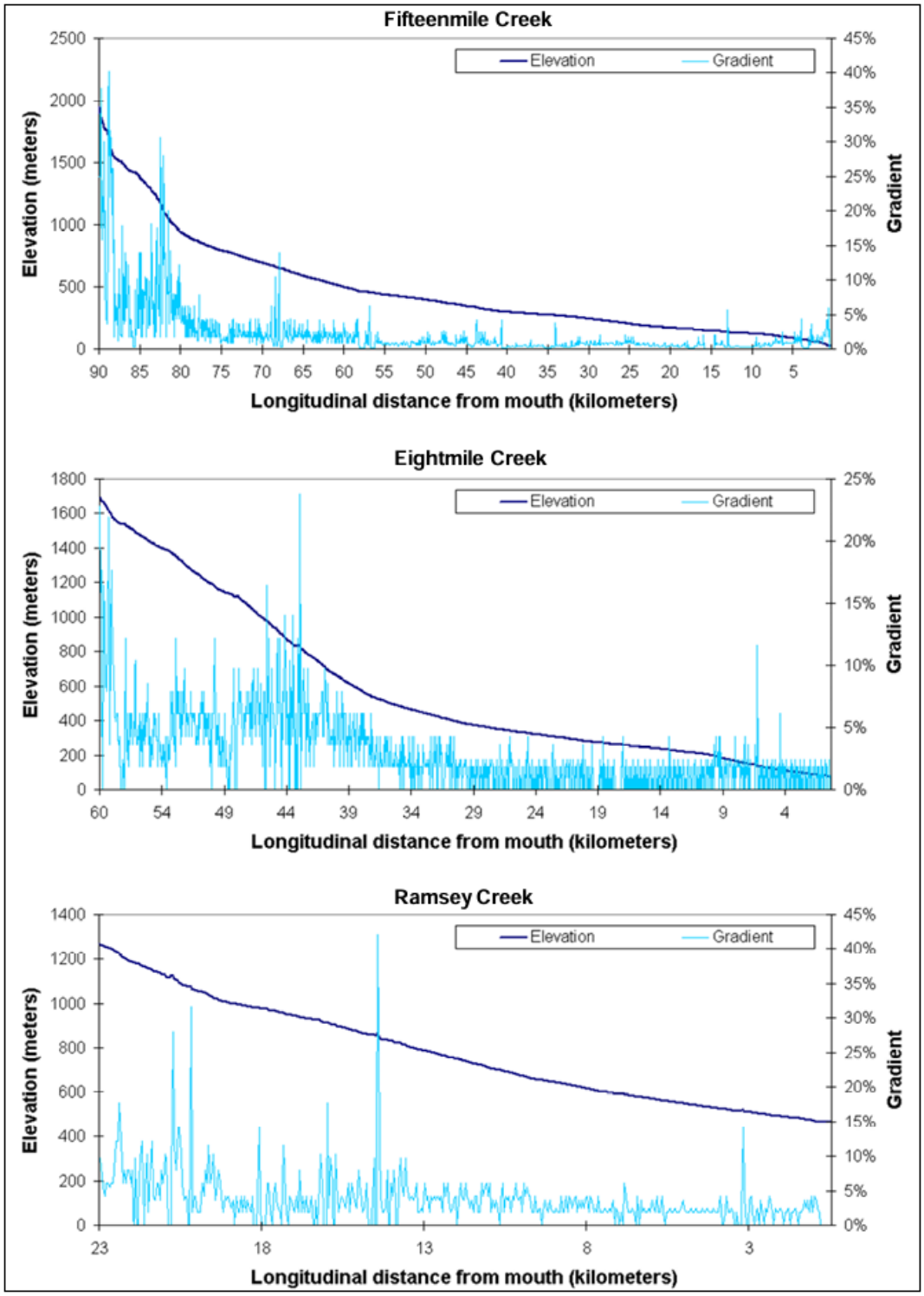


Figure 2-6: Stream elevations and gradients.

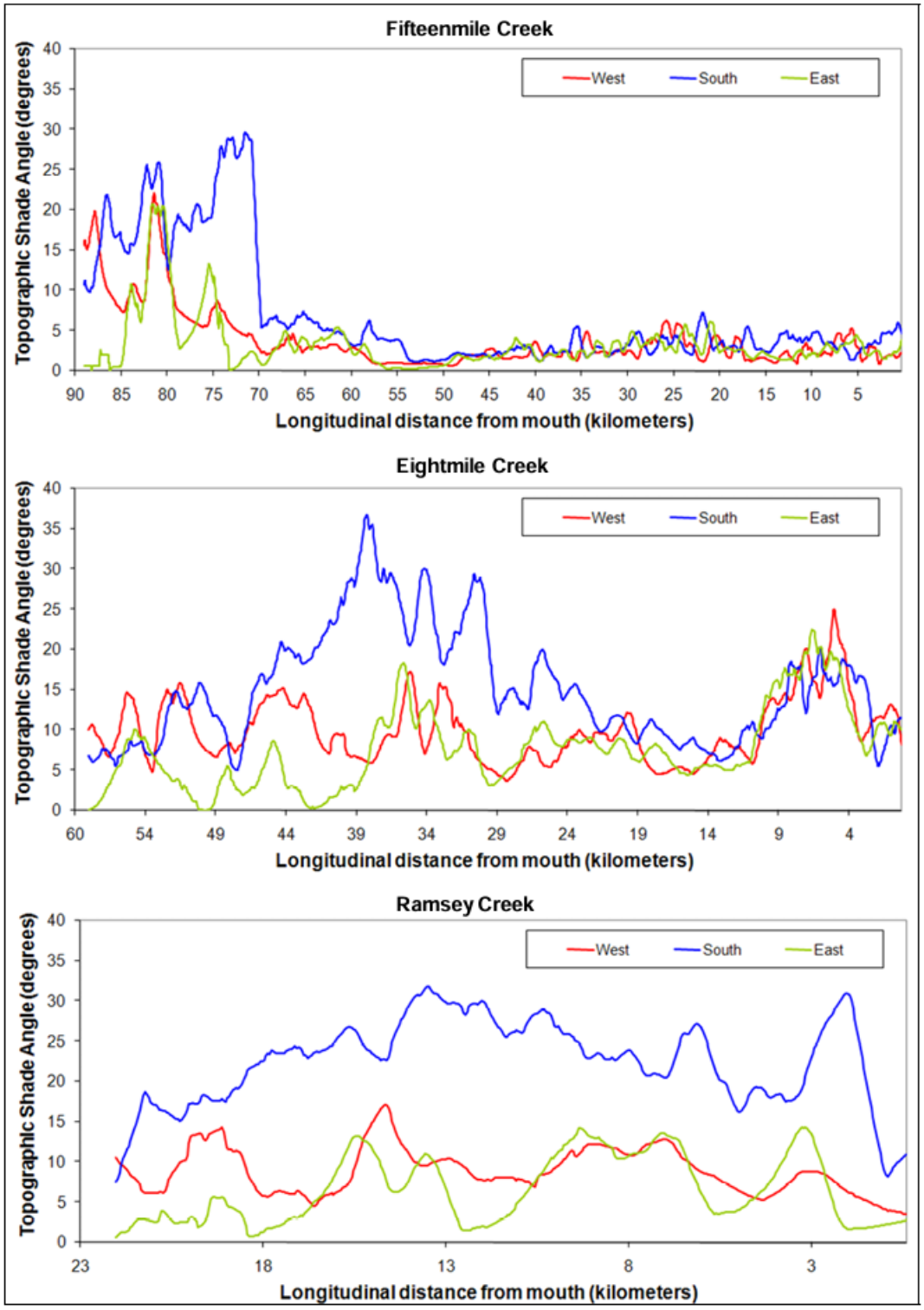


Figure 2-7: Topographic shade angles (1-kilometer moving averages).

2.3.4 Channel width

Channel width is an important component in stream heat transfer and mass transfer processes. Effective shade, stream surface area, wetted perimeter, stream depth and stream hydraulics are all highly sensitive to channel width. Accurate measurement of channel width across the stream network, coupled with other derived data, allows a comprehensive analytical methodology for assessing channel morphology. The steps listed below were used for determining channel widths in Fifteenmile Creek, Eightmile Creek and Ramsey Creek.

1. Using the DOQs, the right and left banks (looking in the downstream direction) for each of the creeks were digitized. In some reaches, the creeks were either too narrow or too vegetated to digitize the channel edges. In such cases, the channel widths were estimated based on field data or upstream and downstream comparisons. All digitized line work was completed at a 1:5,000 map scale or less.

2. The distance between each of the digitized banks (perpendicular to the stream aspect) was then measured at each of the segmented TTools nodes. Figure 2-8 shows the digitized stream and channel edges for Fifteenmile Creek at Boyd Loop Rd as an example of the digitizing process.

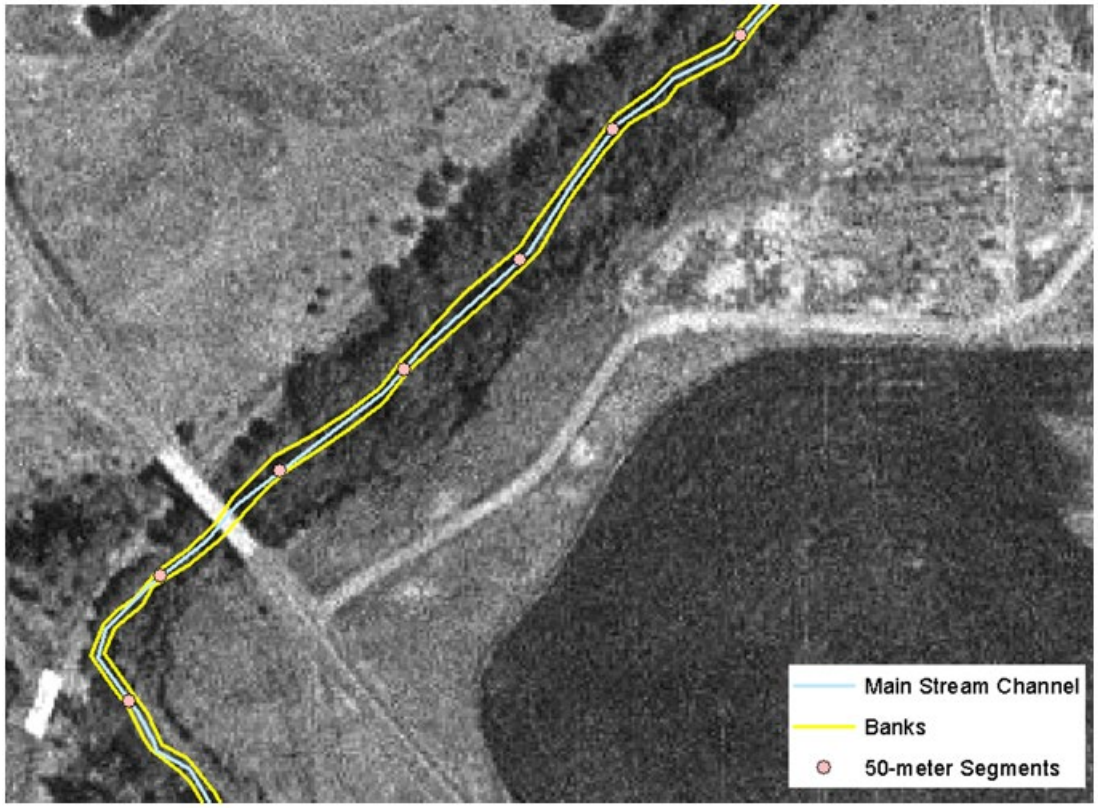


Figure 2-8: Digitized stream channels and banks.

2.3.5 Land cover mapping

The role of vegetation in maintaining a healthy stream condition and water quality is well documented and accepted in scientific literature (Beschta et al. 1987). The list of important

impacts that near stream vegetation has upon the stream and the surrounding environment is long and warrants listing.

- Near stream vegetation plays an important role in regulating radiant heat in stream thermodynamic regimes.
- Channel morphology is often highly influenced by vegetation type and condition by affecting flood plain and instream roughness, contributing coarse woody debris, and influencing sedimentation, stream substrate compositions and stream bank stability.
- Near stream vegetation creates a thermal microclimate that generally maintains cooler air temperatures, higher relative humidity and lower wind speeds along stream corridors.
- Riparian and instream nutrient cycles are affected by near stream vegetation.

With the recognition that near stream vegetation is an important parameter in influencing water quality, detailed mapping of land cover is a high priority in TMDL development.

Variable vegetation conditions require a higher resolution mapping than is currently available with existing GIS data sources. To meet this need, DEQ mapped current condition near stream vegetation along Fifteenmile Creek, Eightmile Creek, and Ramsey Creek using the DOQs at a 1:5,000 scale. The following mapping protocol was used:

Step 1. Using the digitized stream channel, vegetation was mapped 100 meters from each channel edge. Within this zone, polygons were drawn to capture visually alike vegetation features. All digitized line work was completed at a 1:5,000 map scale or less.

Step 2. Basic vegetation types were categorized and assigned to individual polygons. Vegetation types were classified as riparian, upland, deciduous, coniferous, grass, (and other general descriptions) by Ecoregion. Ecoregions of Oregon (Thorson et. al., 2003) was used for the designation of the ecoregions.

Table 2-8 summarizes the numeric codes and descriptions used to uniquely identify each of the digitized land cover polygons. Height values and densities were estimated based on field measurements taken during the habitat surveys, as well as the input of local expertise.

Step 3. Automated sampling was conducted on the classified vegetation spatial data set in 2-dimensions using TTools. At each node along the stream centerline, the vegetation polygons were sampled. For Fifteenmile Creek, the polygons were sampled in a radial pattern, using a 15-meter outwards step, up to 60 meters from the stream centerline. For Eightmile Creek and Ramsey Creek, the polygons were sampled in a star pattern using a 7-meter outward step, up to 28 meters from the stream centerline. All streams were sampled every 50 meters longitudinally along the stream path which resulted in 928 radial vegetation samples per stream mile.

Figure 2-9 summarizes the vegetation classification steps. Boyd and Kasper (2003) provide detailed methodological information.

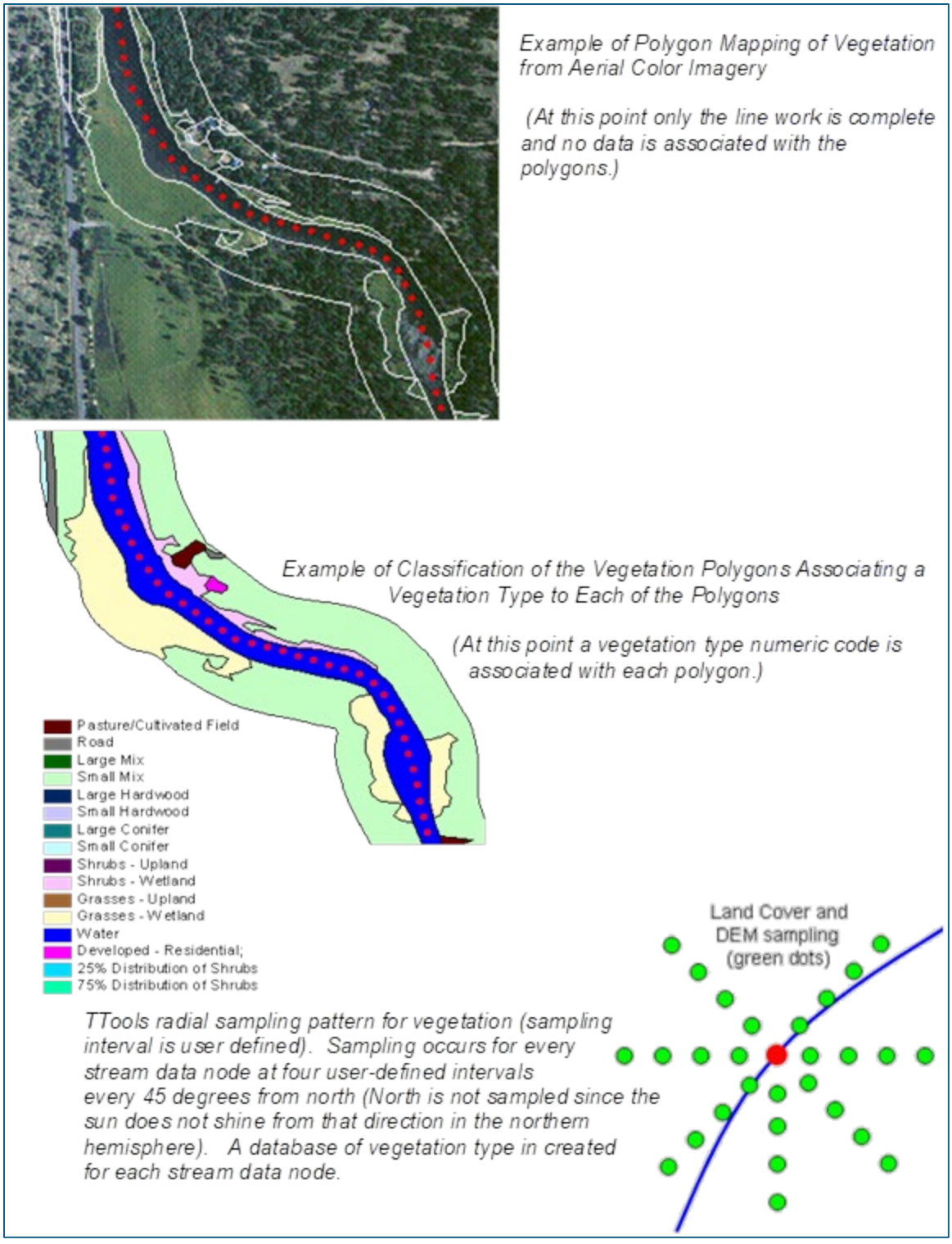


Figure 2-9: Visual summary: vegetation digitization and classification steps.

Table 2-8: Land cover codes used in land cover mapping. [populate]

Code	Description	Height (m)	Density (%)	Overhang (m)

2.3.6 Derived data 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 2-9 summarizes the data derivation methods used to address data gaps and 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 2-9: Methods to derive model parameters for data gaps.

[table on next page, troubleshoot formatting issue with this page to move table up**]**

Method	Possible Parameters	Description
Direct surrogate	Tributary temperatures, meteorological inputs, sediment	Often neighboring or nearby tributary watersheds share climatological and landscape features. Model parameters that have an incomplete record or no data may be parameterized using data from a neighboring or nearby location where data is available.
Calibration adjustment	All inputs	In some instances, a significant input may be required for appropriate representation in the modeling, however little may be known about the nature of that input. An example of this is groundwater influx and temperature. Datasets for these inputs can be estimated by adjusting the necessary values within acceptable ranges during the calibration process.
Literature-based values	All inputs	Literature values are often used for model parameters or unquantified model inputs when little is known about the site-specific nature of those inputs. Examples of these types of parameters include stream bed 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	On modeled reaches, tributary stream flow or temperature can be estimated using a mass balance approach assuming either flow or temperature data for the tributary are known. If estimating temperature, flow is required, and if estimating flow, temperature is required. 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 can also be used (without temperature data) to estimate flow rates. The approach relies on having some flow measurements available in order estimate the flow between contributed from tributaries between the measured points.
Simple linear regression	Tributary temperature and flow	Parameters such as flow and temperature in neighboring or nearby tributaries often demonstrate similar diurnal patterns or hydrographs which allow for the development of suitable mathematical relationships (simple linear regression) in order to fill the data gaps for those inputs. This method requires at least some data exist for the incomplete dataset in order to develop the relationship.
Drainage area ratio	Tributary flow	For ungaged tributaries, flows can be estimated using the ratio between the watershed drainage areas of the ungaged location and from a nearby gaged tributary (Ries et al., 2017; Risley, 2009; Gianfagna, 2015). For example, if the watershed area upstream of a gaged tributary is 10 square kilometers, and the watershed area of an ungaged tributary is 5, the flows in the ungaged tributary are estimated to be half of those in the gaged tributary. The method is typically used to calculate low flow or flood frequency statistics. In that context a weighting factor is recommended when the drainage area ratio of the two sites is between 0.5 and 1.5. Weighting factors can be evaluated if instantaneous observed flows are available at the ungaged location.

Method	Possible Parameters	Description
Adiabatic adjustment	Air temperature	Air temperature can vary significantly throughout a watershed, particularly with large differences in elevation from headwaters to the mouth of the drainage. To account for these differences, air temperatures can be adjusted using an equation that relates air temperature measured at a meteorological station to a location of a given elevation using the dry adiabatic lapse rate of 9.8 °C/km and the differences in elevation.
GIS Data	Channel position, Channel width, Landcover, Gradient, Elevation, Topographic shade angles	Several landscape scale GIS data sets can be used to derive a number of model parameters. 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. A DEM consists of digital information that provides a uniform matrix of terrain elevation values. It provides basic quantitative data for deriving surface elevation, stream gradient, and maximum topographic shade angles.

TIR sampled stream temperature data can be used to develop a mass balance for stream flow using minimal ground level data collection points. Simply identifying mass transfer areas is an important step in quantifying heat transfer within a stream network. For example, using TIR temperature data, DEQ identified mass transfer areas occurring in the Willamette subbasin streams. Several of the subsurface mass transfer areas were unmapped and the relative thermal and hydrologic impact to the stream system was not previously quantified.

All stream temperature changes that result from mass transfer processes (i.e., tributary confluence, point source discharge, groundwater inflow, etc.) can be described mathematically using Equation 2-2.

$$T_{mix} = \frac{(Q_{up} \cdot T_{up}) + (Q_{in} \cdot T_{in})}{(Q_{up} + Q_{in})}$$ **Equation 2-2**

where,

$T_{mix} =$ Stream temperature from mass transfer process assuming complete mix.

$Q_{up} =$ Stream flow rate upstream from mass transfer process.

$Q_{in} =$ Inflow volume or flow rate.

$Q_{mix} =$ Resulting volume or flow rate from mass transfer process.

$T_{up} =$ Stream temperature directly upstream from mass transfer process.

$T_{in} =$ Temperature of inflow.

All water temperatures (i.e., T_{up}, T_{in} and T_{mix}) can be derived from the TIR sampled stream temperature data. Provided that at least one instream flow rate is known, the other flow rates can be calculated.

Water volume losses are sometimes visible in TIR imagery since diversions and water withdrawals usually contrast with the surrounding thermal signature of landscape features.

Highly managed stream flow regimes can become complicated where multiple diversions and return flows mix or where flow diversions and returns are unmapped and undocumented. In such cases it becomes important to establish the direction of flow (i.e., influent or effluent). With the precision afforded by TIR sampled stream temperatures, effluent flows can be determined when temperatures are the same. Temperature differences indicate that the flow is influent. This holds true even when observed temperature differences are very small. The rate of water loss from diversions or withdrawals cannot be easily calculated. DEQ estimates water withdrawal flow rates from the water right information maintained by Oregon Water Resources Department (OWRD) and with discussion with the subbasin water master.

In this fashion, a mass balance can be developed from relatively few instream measurements, TIR stream temperature data and water rights data.

3 Model setup and calibration

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 3.1 to 3.3) 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 0.3°C above the applicable BBNC, cumulatively at the point of maximum impact (POMI). Modeling helps determine the portion of the human use allowance (HUA) assigned to each source in the TMDL. Certain HUA portions were translated into numeric 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 days to months and at a no greater than 500 m longitudinal resolution.

2) Prediction of hourly solar radiation flux and daily effective shade at a no greater than 100 m longitudinal resolution.

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

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

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

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

3.1 Fifteenmile Creek

The Fifteenmile Creek model is a temperature and shade model developed by DEQ using Heat Source 7.0.

3.1.1 Model extent

The model domain extends 70.5 kilometers, from Fifteenmile Creek downstream of N South Road to the mouth at the Columbia River (Figure 3-1).

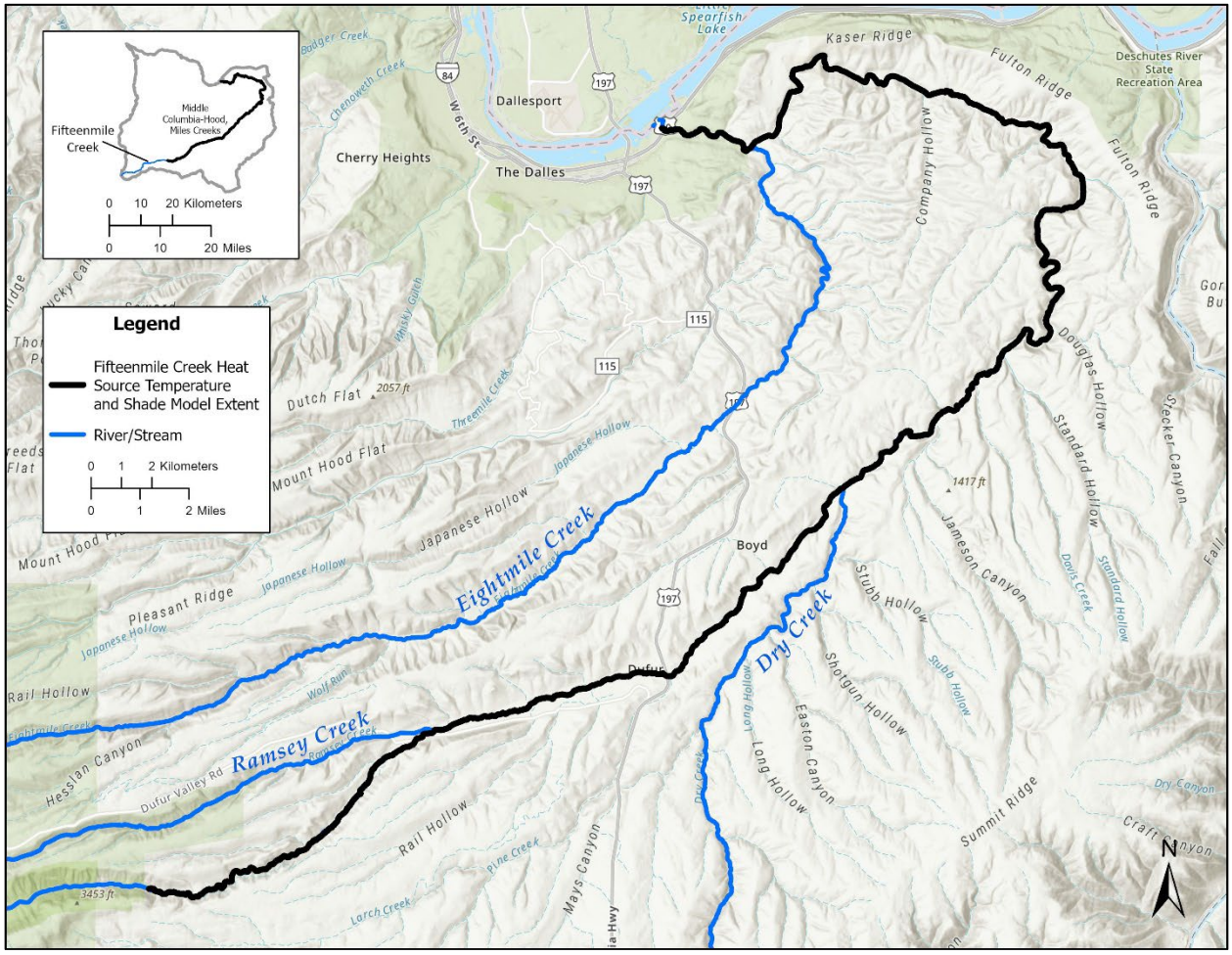


Figure 3-1: Extent of the Fifteenmile Creek temperature and shade model.

3.1.2 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.

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each DMA.

3.1.3 Time frame of simulation

The model period is July 17, 2002 to August 5, 2002.

3.1.4 Meteorological inputs

Hourly meteorological inputs included air temperature, relative humidity, and wind speed.

[add additional narrative/plots/table]

3.1.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup. Figure 3-2 shows the various stream temperature monitoring locations used in model setup or calibration.

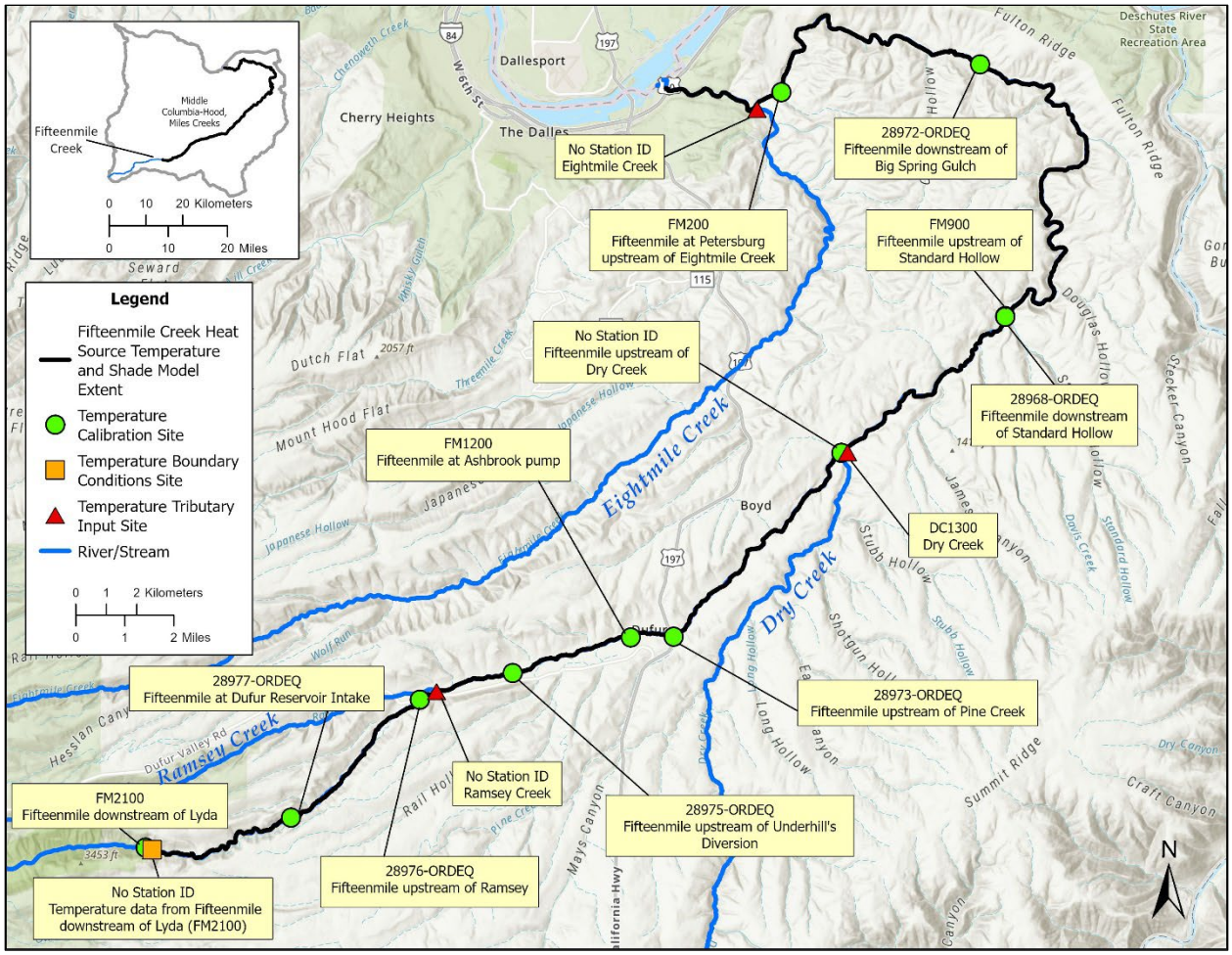


Figure 3-2: Temperature monitoring locations used for Fifteenmile Creek model setup and calibration.

Table 3-1: Boundary condition and tributary water temperature inputs to the Fifteenmile Creek model.

Model Location Name	Model Location (km)	Input Type	Data Source
Fifteenmile downstream of Lyda	70.5	Boundary Condition	DEQ file
Eightmile Creek	3.9	Tributary	DEQ file
Dry Creek	39.45	Tributary	DC1300
Ramsey Creek	57.55	Tributary	ODFW

3.1.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup. Figure 3-3 shows the locations of the various stream flow monitoring locations that were used for model setup or calibration.

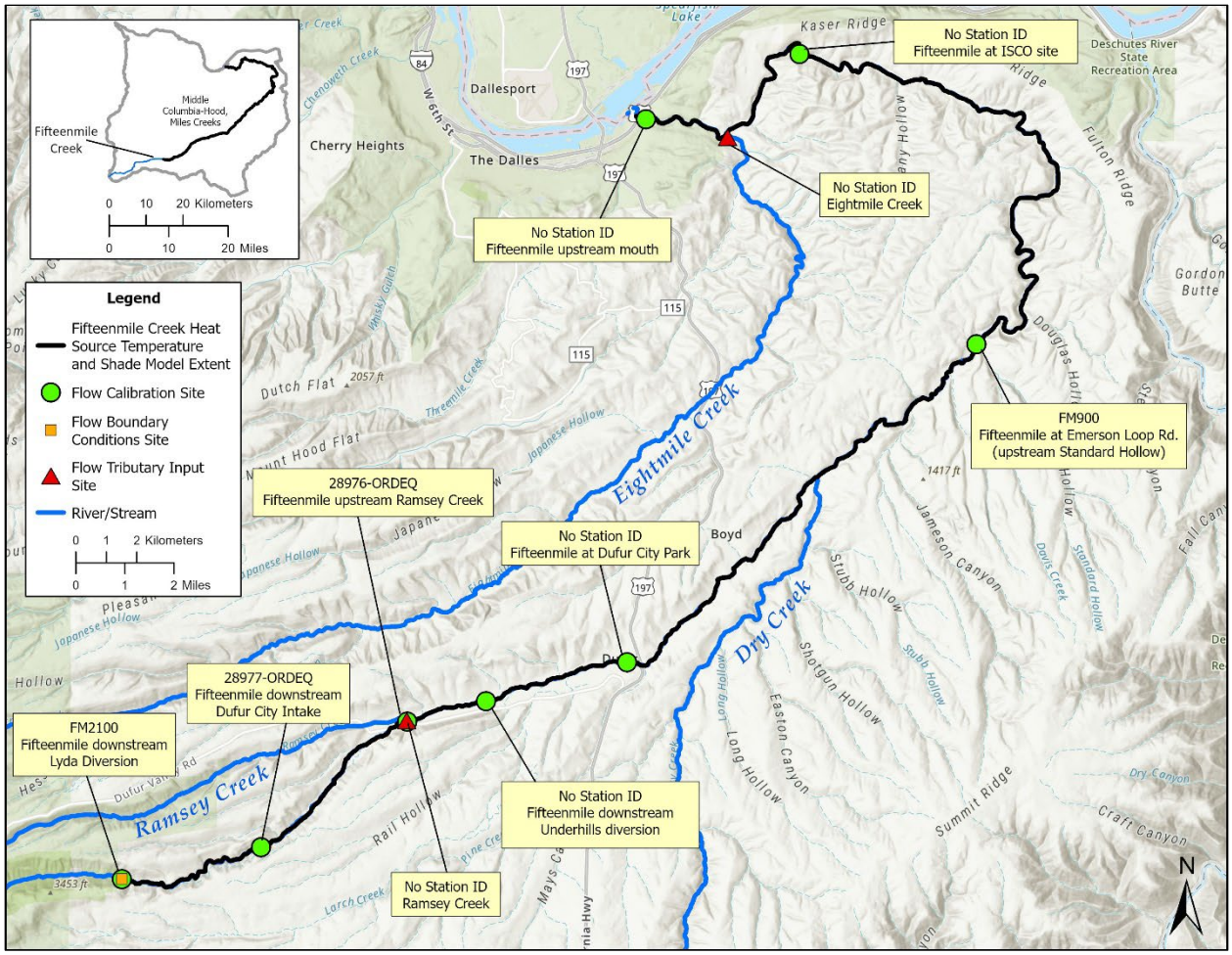


Figure 3-3: Flow monitoring locations used for Fifteenmile Creek model setup and calibration.

Table 3-2: Boundary condition and tributary flow temperature inputs to the Fifteenmile Creek model.

Model Location Name	Model Location (km)	Input Type	Data Source
Fifteenmile downstream of Lyda	70.5	Boundary Condition	DEQ
Eightmile Creek	3.9	Tributary	DEQ file
Ramsey Creek	57.55	Tributary	DEQ file

3.1.7 Point source inputs

There are no point source discharges within the model extent.

3.1.8 Landcover and topographic shade inputs

Average land cover height inputs to the Fifteenmile Creek model are shown in Figure 3-4, with topographic shade angle inputs shown in Figure 3-5.

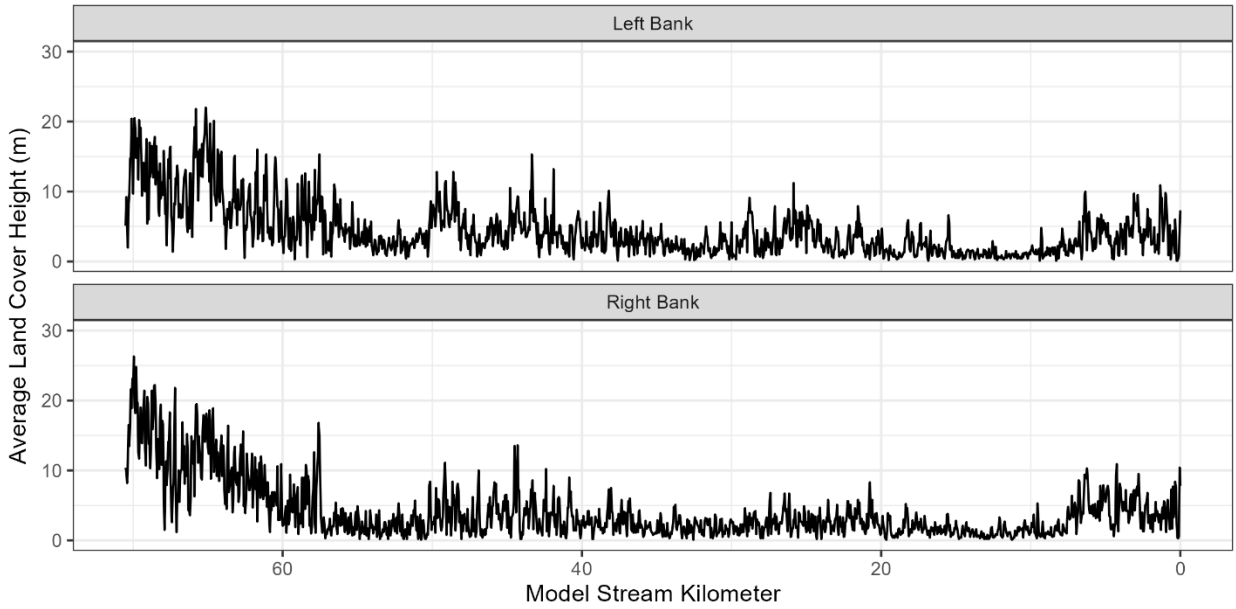


Figure 3-4: Average land cover height inputs to the Fifteenmile Creek model.

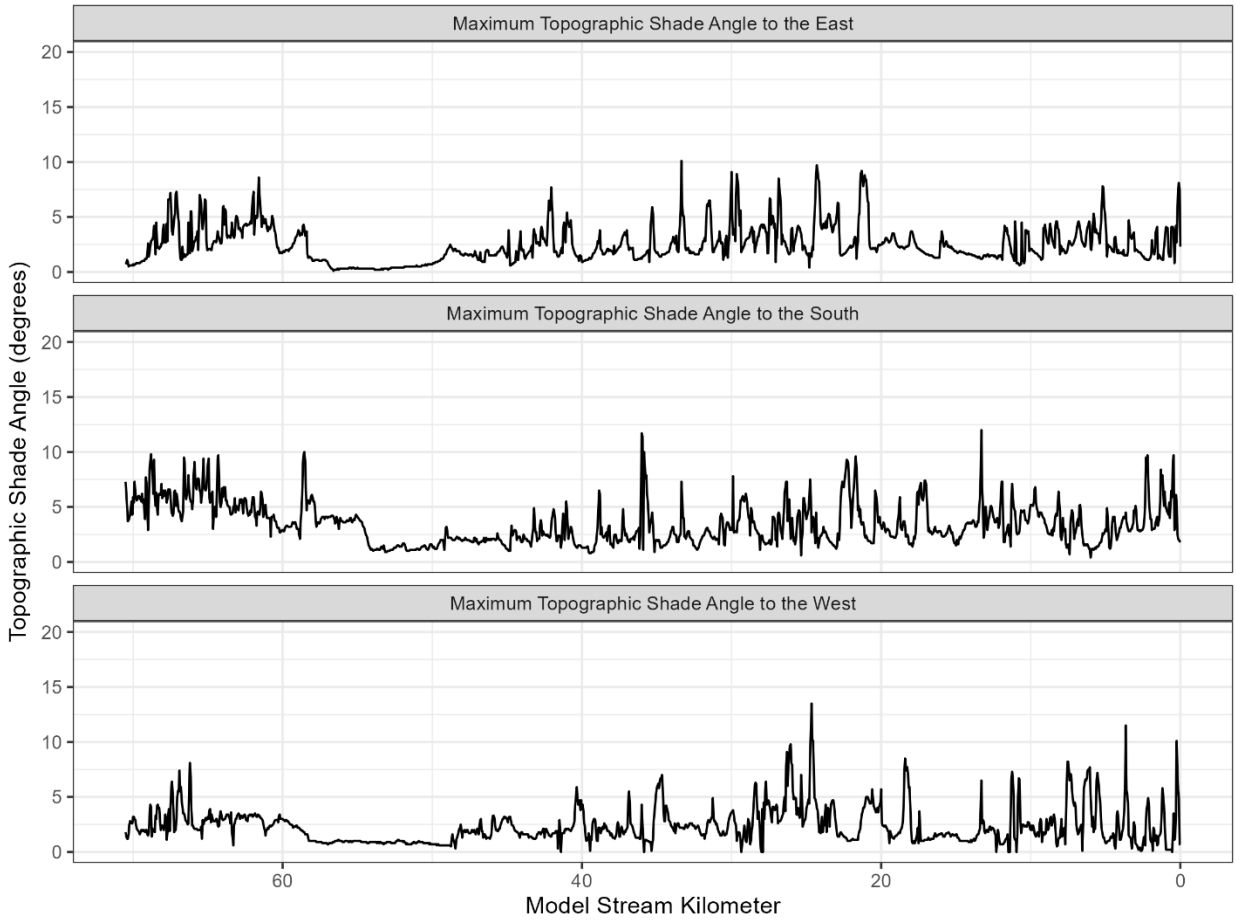
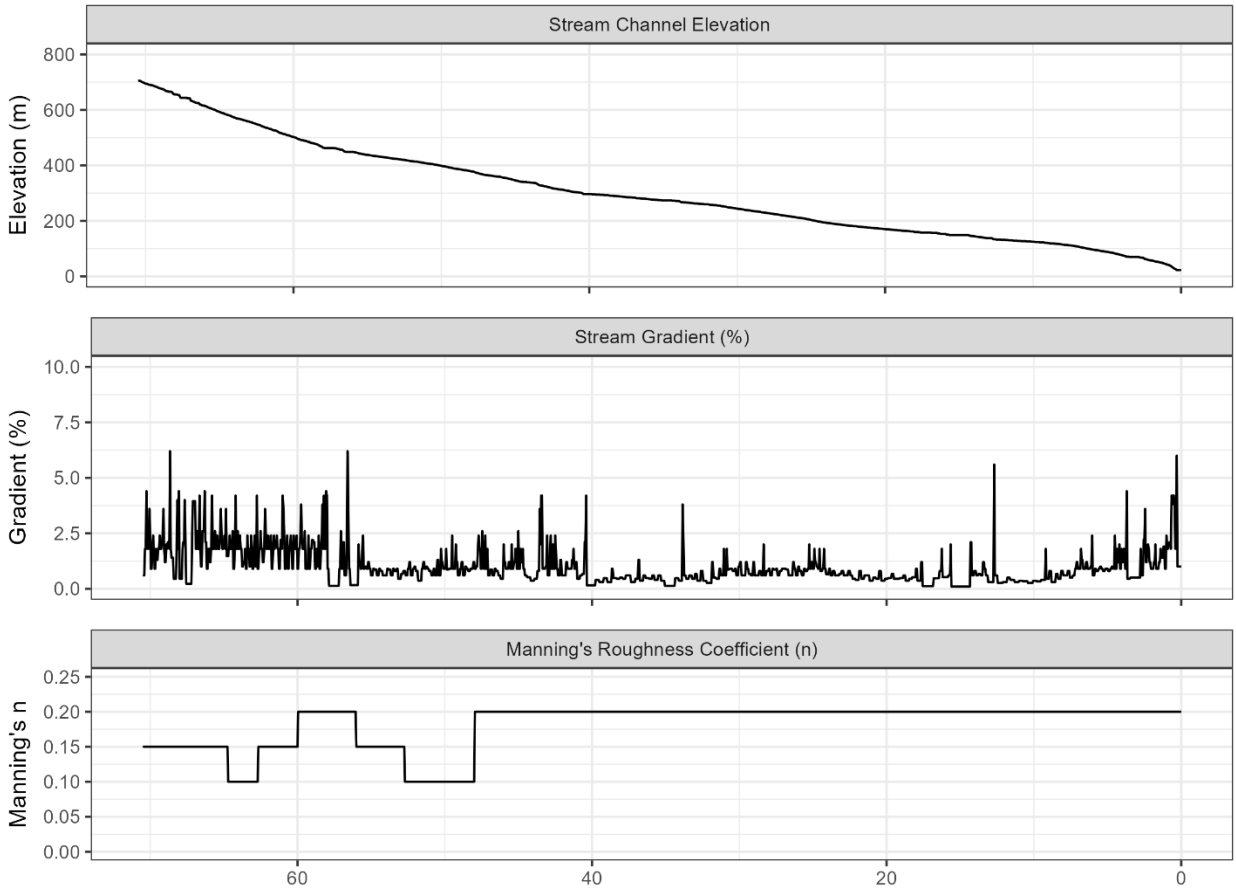


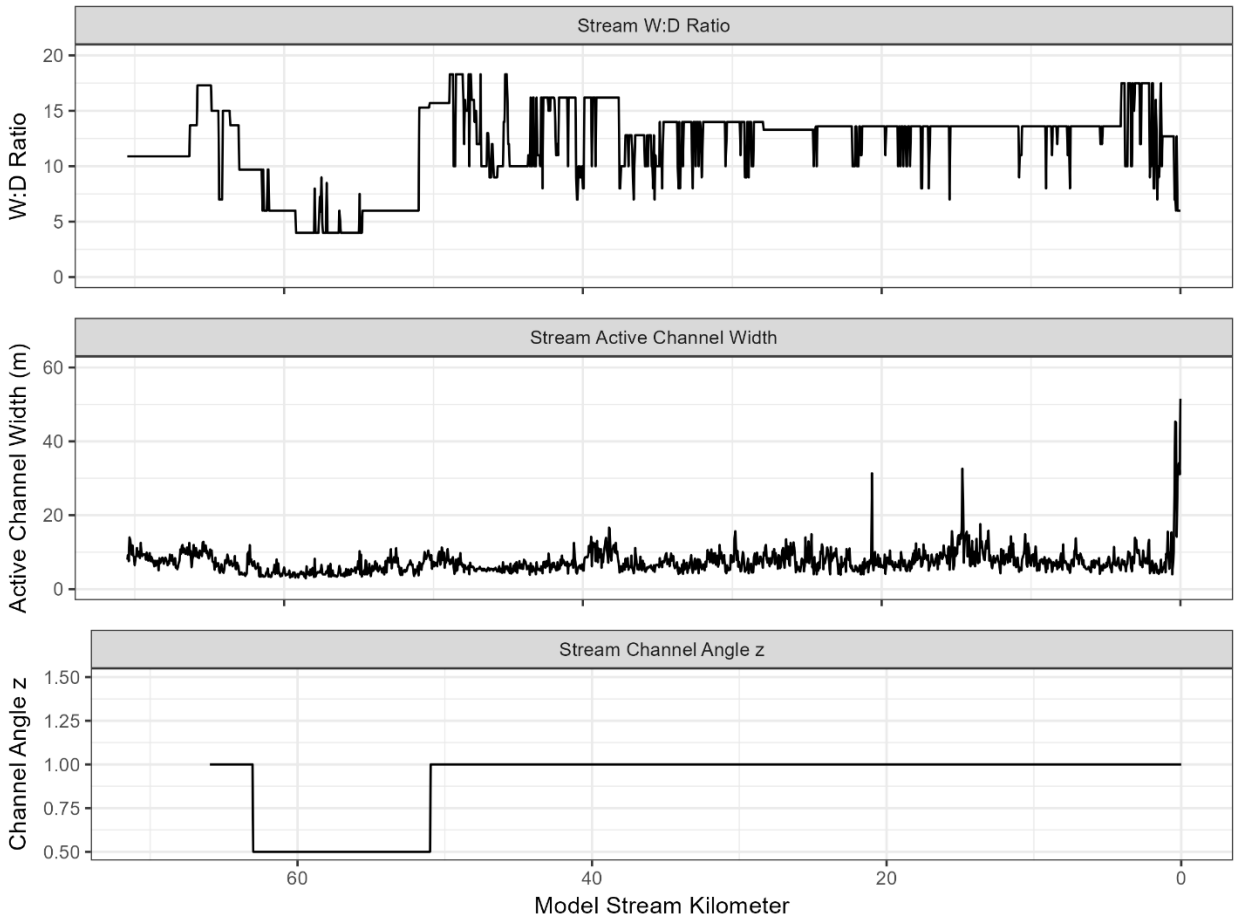
Figure 3-5: Topographic shade angle inputs to the Fifteenmile Creek model.

3.1.9 Channel setup

The channel setup for the Fifteenmile Creek model is shown in Figure 3-6 (A) and (B).



(A)



(B)

Figure 3-6 (A) and (B): Channel setup in the Fifteenmile Creek model.

3.1.10 Other model parameters

Other model parameters, including horizontal bed conductivity, bed particle size, and embeddedness, are displayed in Figure 3-7. The horizontal bed conductivity values used in the model were 15 and 30 mm/s, while the bed particle sizes ranged from 20 to 75 mm. Embeddedness in the model ranged between 11% and 24%.

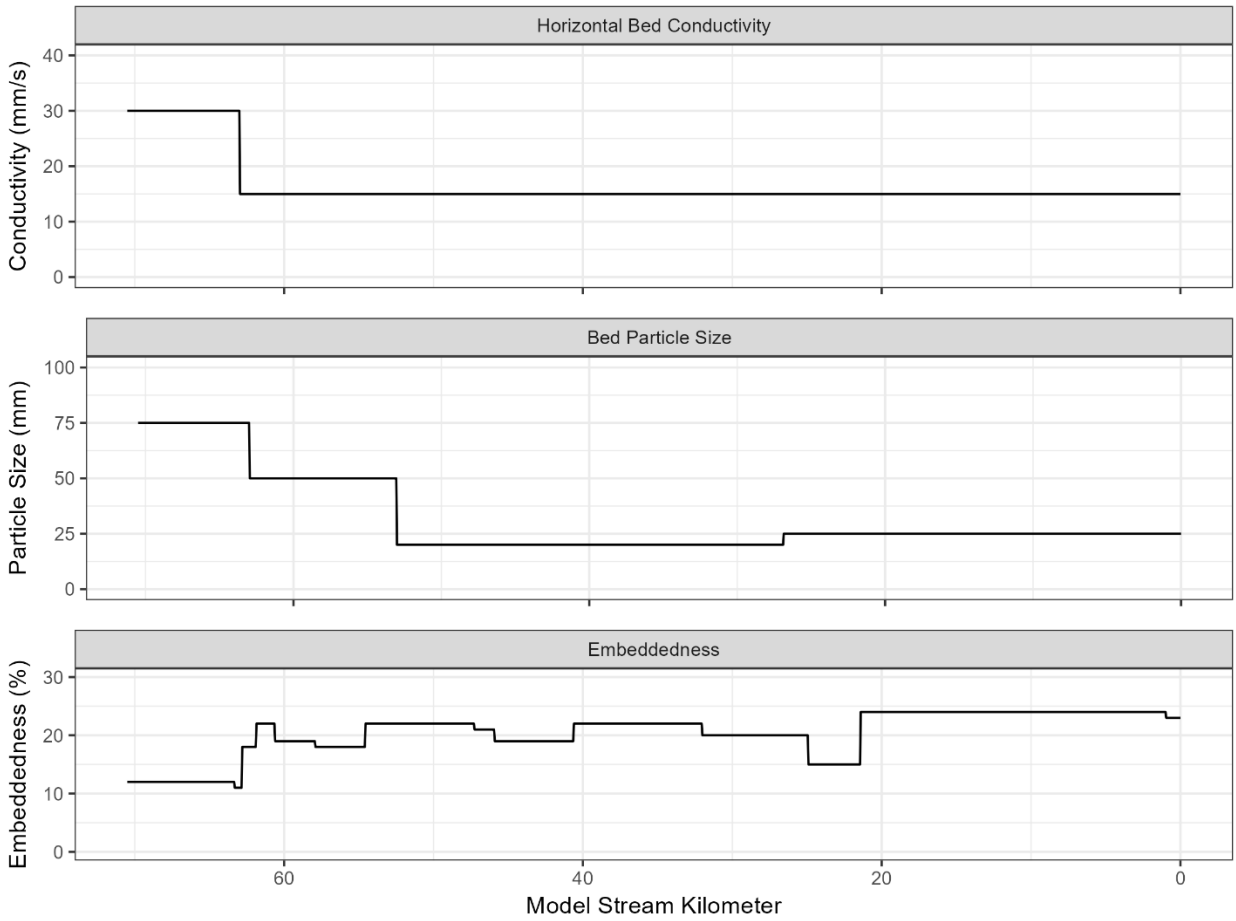


Figure 3-7: Other model parameters used for channel setup in the Fifteenmile Creek model.

3.1.11 Calibration results

3.2 Eightmile Creek

The Eightmile Creek model is a shade model developed by DEQ using Heat Source 7.0.

3.2.1 Model extent

The model domain extends 58.6 kilometers, from the headwaters of Eightmile Creek to its confluence with Fifteenmile Creek (Figure 3-8).

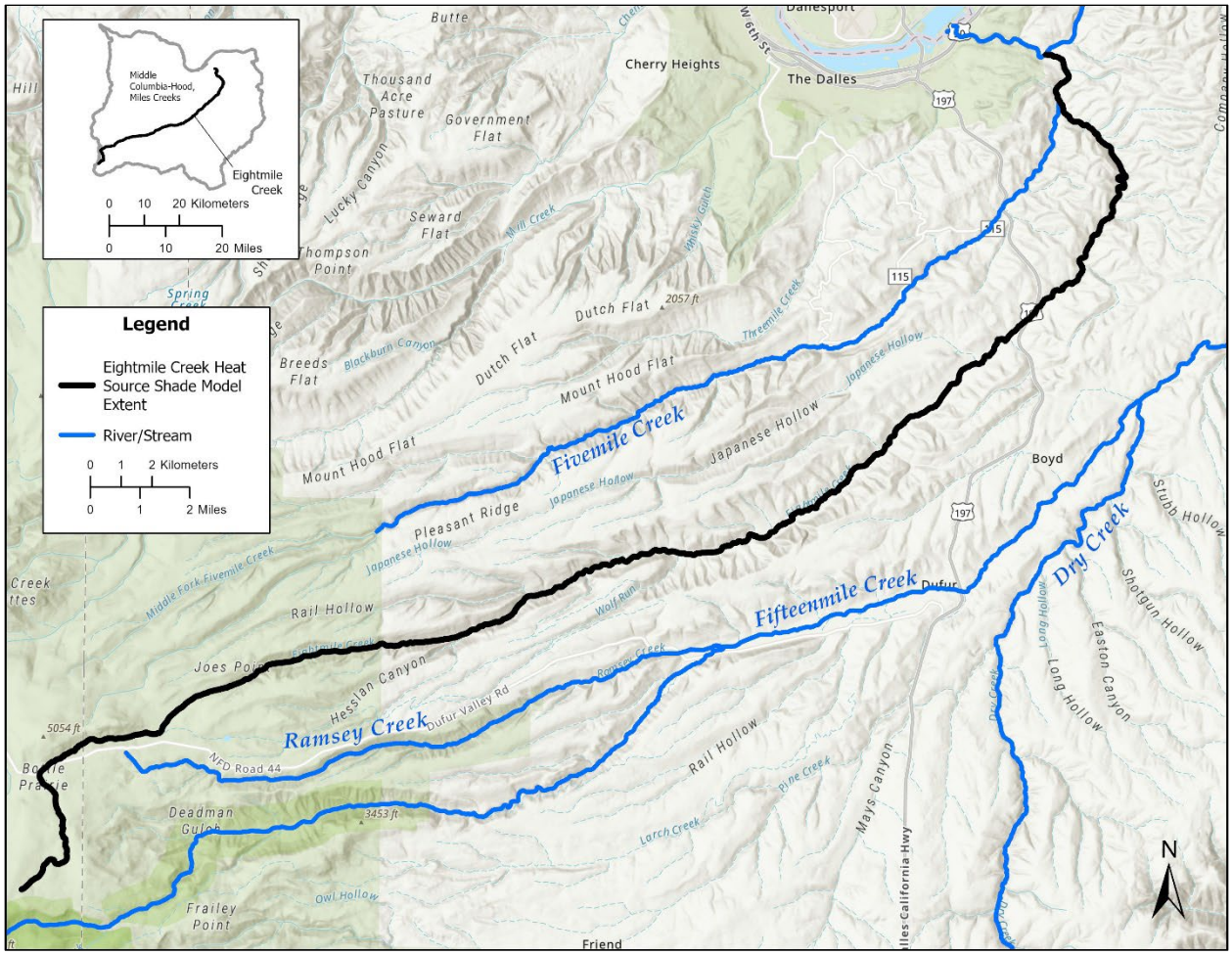


Figure 3-8: Extent of the Eightmile Creek shade model.

3.2.2 Spatial and temporal resolution

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

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each designated management agency (DMA).

3.2.3 Time frame of simulation

The model period is for a single day: July 17, 2002.

3.2.4 Meteorological inputs

[add details]

3.2.5 Point sources

There are no point source discharges within the model extent.

3.2.6 Landcover and topographic shade inputs

Near-stream vegetation input parameters include height, width, density, and overhang.

[add plots]

3.2.7 Channel setup

[add details]

3.3 Ramsey Creek

The Ramsey Creek model is a shade model developed by DEQ using Heat Source 7.0.

3.3.1 Model extent

The model domain extends 22.5 kilometers, from the headwaters of Ramsey Creek to its confluence with Fifteenmile Creek (Figure 3-9).

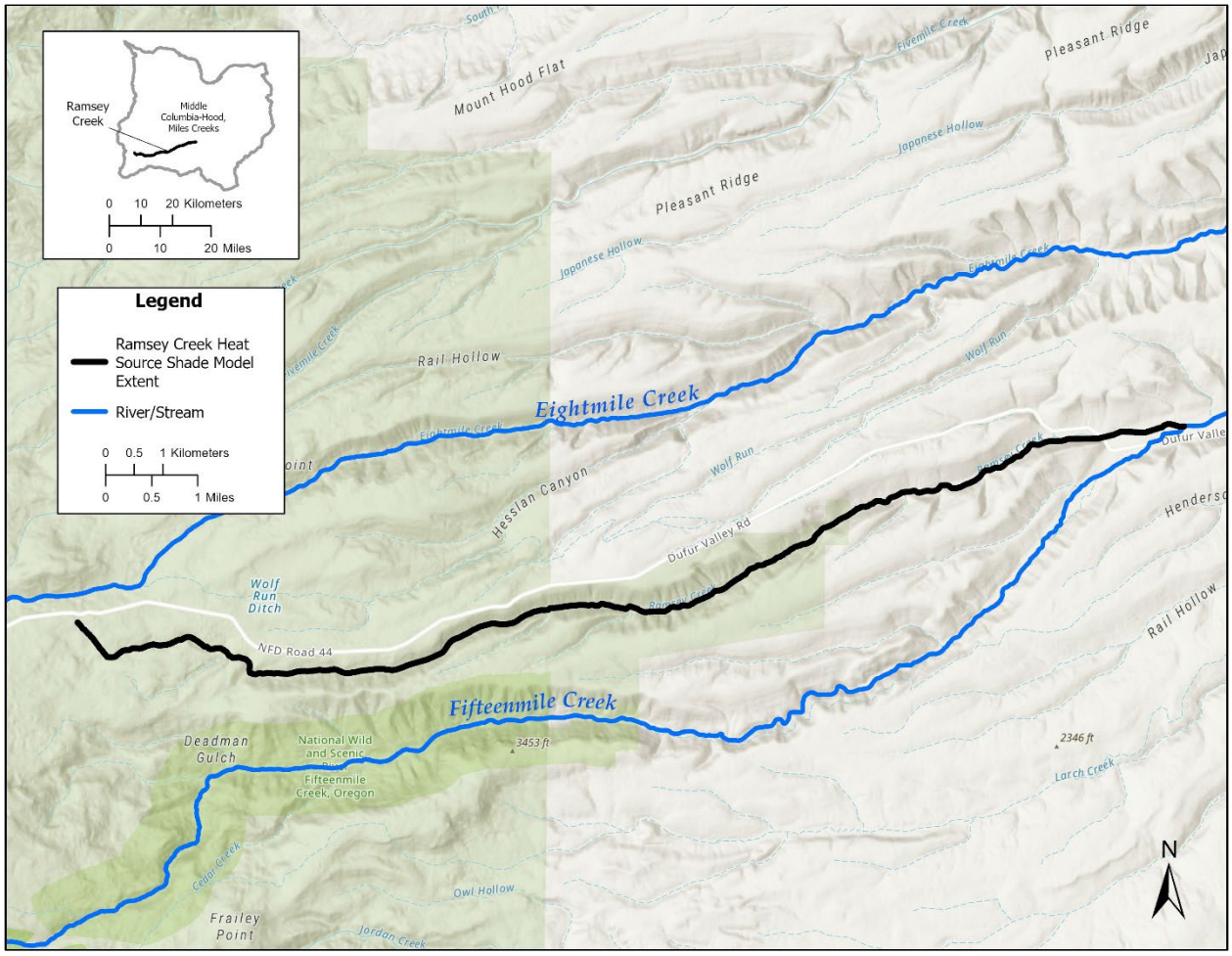


Figure 3-9: Extent of the Ramsey Creek shade model.

3.3.2 Spatial and temporal resolution

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

A *dx* of 50 meters was chosen to capture the range of solar flux input caused by the varied vegetation conditions along the length of the stream. The high resolution *dx* will allow evaluation of multiple vegetation management scenarios for each DMA.

3.3.3 Time frame of simulation

The model period is for a single day: July 17, 2002.

3.3.4 Meteorological inputs

[add details]

3.3.5 Point sources

There are no point source discharges within the model extent.

3.3.6 Landcover and topographic shade inputs

[add plots]

3.3.7 Channel setup

[add details]

4 Model scenario set up

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 condition

For this replacement TMDL, a Current Condition model scenario was created for all modeled streams, which is distinct from the Calibrated Current Condition model. This scenario was developed to reflect vegetation conditions that are more representative of current conditions.

The Current Condition model scenario was used to develop other model scenarios and to evaluate temperature and shade effects due to management strategies.

Except for this change, all other current conditions model inputs are identical to the Calibrated Current Condition models for the modeled streams.

4.2 Vegetation scenarios

Site potential vegetation refers to the vegetation landcover which can grow and reproduce on a site given the natural plant biology, site elevation, soil characteristics, climate, and natural disturbance regime. Potential near stream vegetation is essentially the mature species composition, height, and density of vegetation that would occur in the absence of human disturbances. Potential near stream vegetation does not include considerations for resource management, human use or other legacy human disturbances.

Since near stream vegetation is a controlling factor in stream temperature regimes, the condition and health of vegetation is considered a primary parameter in the TMDL. Potential vegetation is a key condition targeted in the TMDL. DEQ worked with members of the Miles Creeks TMDL Technical Committee to determine site potential vegetation by TMDL vegetation zones (Figure 4-1). The vegetation zones were developed from ecoregions of Oregon (Thorson et.al., 2003, Figure 4-2), with further modification based on a consensus process using the local expertise of the Technical Committee (including local staff from ODF, Wasco SWCD, ODFW, the Mt. Hood National Forest and city of The Dalles). Table 4-2 summarizes the numeric codes and descriptions used to uniquely identify each of the digitized land cover polygons. Height values and densities were estimated based on field measurements taken during the habitat surveys, as well as the input of local expertise.

Each zone was subdivided into categories, based on location within the zone (riparian or upland) and aspect (south/west or north/east facing). The zone numbers are not sequential because of revisions to the map as the TMDL was developed. Changing the numbers after each revision would have been difficult and labor-intensive because the modeling setup and the zones are intricately linked. Table 4-1 provides detailed information about the vegetation characteristics associated with each zone. It should be noted that the species listed in a particular Vegetation Zone below may vary somewhat on different streams within that zone. The lists provide an indication of the species you might find in that zone.

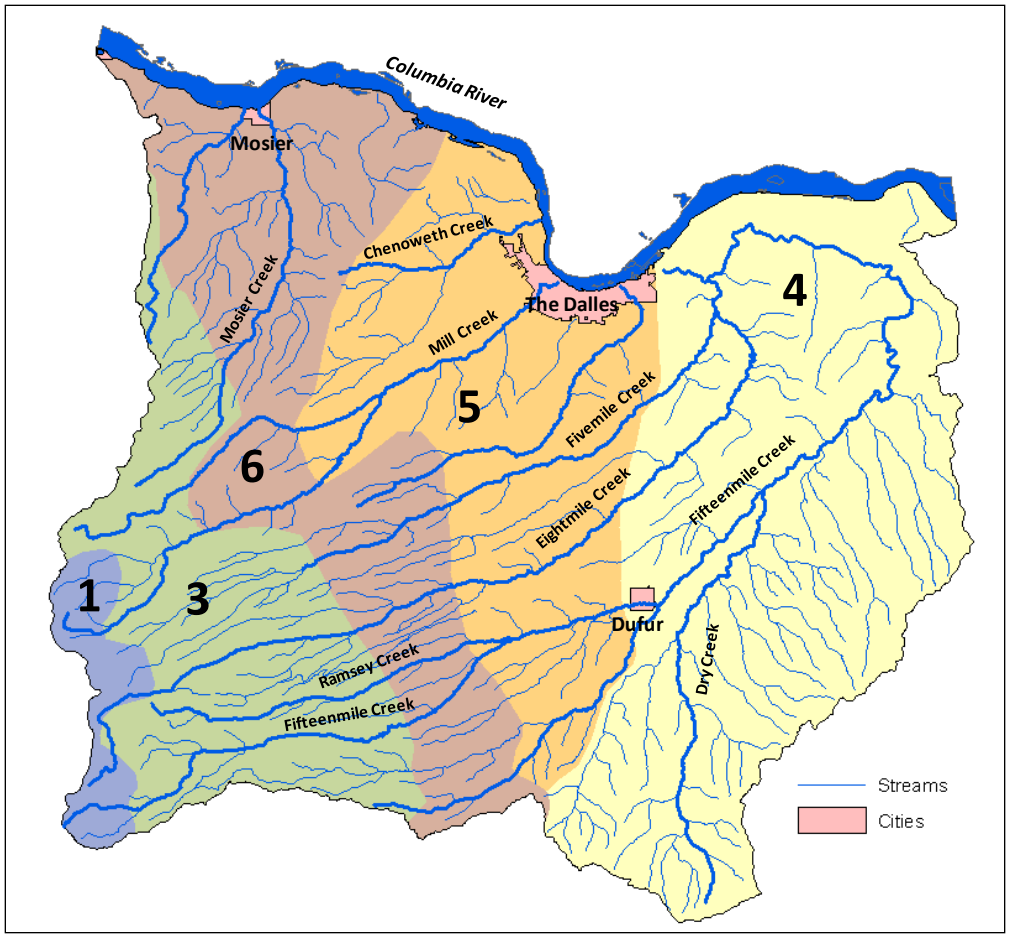


Figure 4-1: Middle Columbia-Hood (Miles Creeks) Subbasin TMDL vegetation zones.

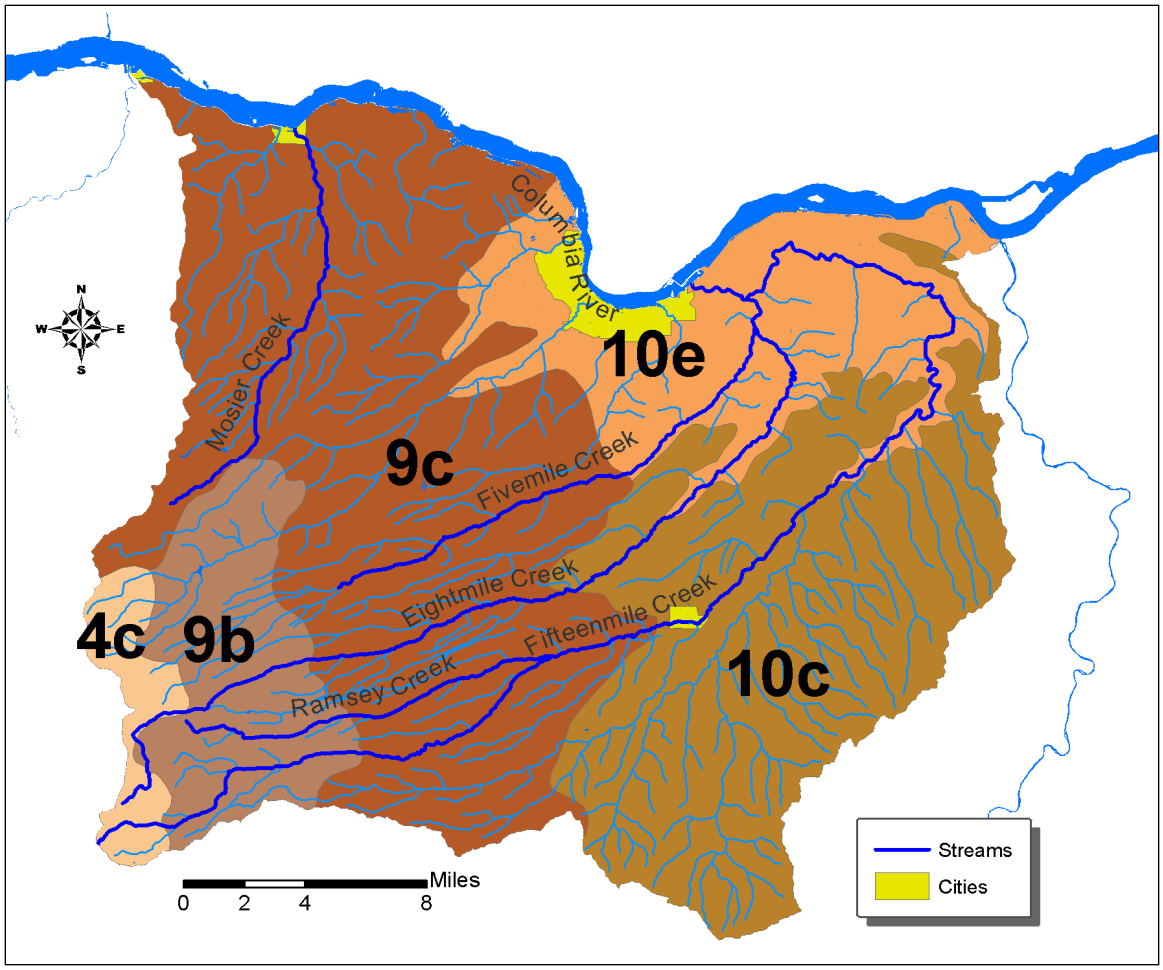


Figure 4-2: Ecoregions in the Middle Columbia-Hood (Miles Creeks) Subbasin (Thorson et al., 2003).

Table 4-1: Summary of characteristics of site potential vegetation by TMDL vegetation zone.
[Insert table – Table A-6 TMDL App. A]

Table 4-2: Digitized land cover polygon codes and descriptions.
[Insert table – Table A-5 TMDL App. A]

4.2.1 Restored Vegetation A (RV_A)

In the restored vegetation A (RV-A) scenario transportation corridors (such as roads and highways) and urban, residential, commercial or industrial development (buildings) are removed and replaced with system potential vegetation based on Ecoregion-physiographic (EP) Types.

This scenario quantifies the impacts of nonpoint source solar radiation loads and is used to develop the HUA.

4.2.2 Restored Vegetation B (RV_B)

The restored vegetation B (RV_B) scenario does not remove transportation corridors (such as roads and highways) and urban, residential, commercial or industrial development (buildings).

All other vegetation is restored to system potential vegetation and uses the same approach in the RV_A scenario.

This scenario quantifies the impacts of nonpoint source solar radiation loads and is used to develop the HUA for solar loading from existing transportation corridors, buildings, and utility infrastructure.

4.3 Natural flow

This scenario evaluates Fifteenmile Creek stream temperature response by changing permitted water withdrawals to instream flow and then comparing its results to those of the Current Condition 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.

To simulate natural potential flow for Fifteenmile Creek, all water withdrawals were set to zero and boundary condition and tributary flows were set to natural (information on natural tributary flows came from the Fifteenmile Watershed Assessment (Wasco SWCD, 2003).

In the simulated reach of Fifteenmile Creek, there are four tributaries which contribute flow to Fifteenmile Creek, either as surface or subsurface flows. These are Ramsey Creek, Pine Creek, Dry Creek and Eightmile Creek. Under the current condition only Dry Creek enters Fifteenmile Creek as subsurface flow. Under natural conditions, Dry Creek would have small surface flow in to Fifteenmile Creek and Eightmile Creek and Ramsey Creek would have much higher flows than under current conditions. Under natural conditions in late July/early August, average flows in Eightmile Creek would be approximately 7.2 cfs, as compared to 1.2 cfs in 2002 and average natural flows in Ramsey Creek would be 1.2 cfs as compared to 0.6 cfs in 2002.

4.4 Consumptive use

This scenario evaluates the stream temperature response to consumptive use water withdrawals. It is identical to the natural stream flow model setup except that all boundary, tributary, and hence instream flows are modified iteratively to reflect various rates of consumptive water withdrawals. The purpose of this scenario is to determine the maximum consumptive withdrawal rate (as a percentage of natural flow) that will attain both the TMDL load allocation and any HUA assigned for permitted withdrawals. The percent consumptive withdrawal rate is globally adjusted for the boundary condition, the four tributaries contributing flow to Fifteenmile Creek, and points of diversion along Fifteenmile Creek. The percent consumptive withdrawal rate is also based on the flow rate at the OWRD reference gage 14105500 (Fifteenmile Cr Nr The Dalles).

Tributary flow reductions were applied only to tributaries with flows that differ between the Current Condition and Natural Flow scenarios. These include Eightmile Creek, Dry Creek, Pine Creek, and Ramsey Creek. Consumptive use scenario tributary and boundary condition flows were calculated using Equation 4-1, and point of diversion withdrawals were calculated using Equation 4-2. The flow rates at OWRD gage 14105550, located near the mouth of Fifteenmile Creek, was used as the reference site in Equation 4-1 and Equation 4-2.

The consumptive use model scenario tributary flow rate at timestep *i.*

$$Q_{CUi_trib} = Q_{Ni_trib} - CU_{Si_trib}$$ **Equation 4-1**

where,

$Q_{CUi_trib} =$ The consumptive use flow scenario input tributary flow rate at timestep *i.*

$Q_{Ni_trib} =$ The natural flow scenario tributary flow rate at timestep *i.*

$Q_{CCi_trib} =$ The current existing condition tributary flow rate at timestep *i.*

$CU_{Si_trib} =$ The consumptive flow being withdrawn from the tributary at timestep *i.*

$$CU_{Si_trib} = \left(Q_{Ni_trib} - Q_{CCi_trib}\right) \times \frac{CU_{Si}}{CU_{CCi}}$$

$CU_{Si} =$ The consumptive use flow scenario consumptive use percent at the reference site at timestep *i.*

$CU_{CCi} =$ The current existing condition consumptive use percent at the reference site at timestep *i.*

The consumptive use model scenario point of diversion withdrawal rate at timestep *i*.

$$Q_{CUi_pod} = Q_{CCi_pod} \times \frac{CU_{Si}}{CU_{CCi}}$$ **Equation 4-2**

where,

$Q_{CUi_pod} =$ The consumptive use flow scenario withdrawal rate at the point of diversion at timestep *i.*

$Q_{CCi_pod} =$ The current existing condition withdrawal rate at the point of diversion at timestep *i.*

$CU_{Si} =$ The consumptive use flow scenario consumptive use percent at the reference site at timestep *i.*

$CU_{CCi} =$ The current existing condition consumptive use percent at the reference site at timestep *i.*

4.5 Tributary temperatures

4.5.1 Tributary temperatures A

The Tributary Temperatures A scenario is used to evaluate the temperature impacts in Fifteenmile Creek resulting from elevated tributary temperatures that exceed applicable criteria. For this scenario, tributaries were set to attain the applicable temperature criteria at their mouths. For tributaries that exceed the water quality standard, the maximum temperatures for the tributary were reduced to equal the standard. All other model inputs, including tributary flow, are the same as the Current Condition model.

4.5.2 Tributary temperatures B

The Tributary Temperatures B scenario evaluates stream temperature warming or cooling in Fifteenmile Creek from sources on upstream tributaries attaining their HUA assignment. Tributary temperatures are increased by the assigned HUA allocations at their mouths. Each tributary was assigned a temperature increase of 0.30°C to include all HUA source categories as well as the reserve capacity. All other model inputs, including tributary flow, are the same as the Current Condition model.

4.6 Background

This scenario evaluates the stream temperature response on Fifteenmile Creek 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 another 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. This scenario essentially combines the following model scenarios: restored vegetation A and natural stream flow. The background scenario is compared to the current condition model scenario to determine the point of maximum impact, and the amount of cumulative warming originating from human activities. The background scenario is also used to determine the portion of temperature increases above the temperature criteria that are attributable to background sources.

4.7 HUA attainment

The HUA attainment scenario evaluates attainment of the cumulative HUA (0.30°C) based on point and nonpoint sources being set at their respective allocations. In this scenario, tributary temperatures are assigned a temperature increase of 0.30°C to include all HUA source categories as well as the reserve capacity. Tributary flows are equivalent to those in the Current Condition scenario. The HUA attainment scenario is compared to a baseline scenario that is equivalent to the Restored Vegetation A scenario.

5 Model scenario results

Each model scenario was compared to a baseline scenario (often the Current Condition scenario) to evaluate its impacts on stream temperatures and/or effective shade.

Table 5-1 summarizes the various model comparisons and identifies the topic or question addressed by each.

Table 5-1: Middle Columbia-Hood (Miles Creeks) temperature TMDL scenarios and explanation of comparisons. Note that all comparisons were conducted for Fifteenmile Creek, while only the top three were evaluated for Eightmile and Ramsey Creeks.

Baseline Scenario	Model Scenario	Question/topic addressed
Current Condition	Restored Veg A	Effect of fully restored vegetation.
Restored Veg B	Restored Veg A	Effect of existing infrastructure (e.g., roads, buildings)
Topographic Shade	Current Condition	Evaluates the amount of effective shade associated with current vegetation.
Topographic Shade	Restored Veg A	Evaluates the amount of effective shade associated with restored vegetation.
Current Condition	Natural Flow	Effect of permitted water withdrawals.
Consumptive Use	Natural Flow	Effect of specific rate of water withdrawal that meets the HUA.
Current Condition	Tributary Temps A	Effect of tributary temperature criteria exceedances.
Current Condition	Tributary Temps B	Effect of tributary temperatures set at their respective TMDL allocations.
Current Condition	Background	Effect of anthropogenic sources that were quantified and represented in the model.
Attainment	Background	Effect of point and nonpoint sources set at their respective TMDL 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 7th 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 7th 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 of the 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 X was used to assess cumulative warming and HUA assignments for point sources and tributary sources. With this approach, there is no assumption of heat dissipation, so the cumulative warming represents the total sum of the calculated temperature increases from all sources combined.

$$\Delta T_{ps} = \left(\frac{Q_E}{Q_E + Q_R}\right) \cdot (T_E - T_C) \qquad \textbf{Equation 5-1}$$

where,

$\Delta T_{ps} =$ The river temperature increase (°C) above the applicable river temperature 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)

$$\Delta T_R = \left(\frac{Q_{in}}{Q_{in} + Q_{up}}\right) \cdot (T_{in} - T_{up}) \qquad \textbf{Equation 4-2a}$$

$$T_{mix} = T_{up} + \left(\frac{Q_{in}}{Q_{in} + Q_{up}}\right) \cdot (T_{in} - T_{up}) \qquad \textbf{Equation 4-2b}$$

where,

$\Delta T_R =$ The change in river temperature (°C) after complete mixing with an inflowing tributary.

$T_{mix} =$ The river temperature (°C) downstream after complete mixing with an inflowing tributary.

$Q_{in} =$ The river flow rate of the inflowing tributary (cfs).

$Q_{up} =$ The river flow rate upstream of the tributary (cfs).

$T_{in} =$ The river temperature of the inflowing tributary (°C).

$T_{up} =$ The river temperature upstream of the inflowing tributary (°C).

5.2 Fifteenmile Creek

Table 5-2 describes the different model scenarios used to simulate stream temperature and effective shade for Fifteenmile Creek.

Table 5-3 and Table 5-4 summarize the maximum 7DADM stream temperature predicted at the mouth of Fifteenmile Creek and at the POMI, respectively, for all model scenarios over the entire model period.

Figure 5-1 shows the predicted maximum 7DADM stream temperature for all Fifteenmile Creek model scenarios.

Table 5-2: Fifteenmile Creek model scenario descriptions.

Scenario Name	Description
Current Condition	The Fifteenmile Creek Current Condition scenario model has the following update from the calibrated model created to support the original 2008 Middle Columbia-Hood (Miles Creeks) Subbasin TMDL: Vegetation heights, density, and overhang were updated based on recently collected LiDAR (2018).
Restored Vegetation A	This scenario evaluates the stream temperature response from setting near stream land cover to system potential vegetation conditions.

Scenario Name	Description
Restored Vegetation B	This scenario is identical to the Restored Vegetation A scenario, except that areas associated with residential and industrial/commercial development, roads, and bridges are left unchanged and retain the same landcover heights and densities as the Current Condition scenario.
Topographic Shade	This scenario evaluates the stream temperature response from removing all near stream land cover.
Natural Flow	This scenario evaluates the stream temperature response from removing consumptive use withdrawals entirely.
Consumptive Use Flow	This scenario evaluates the stream temperature response to various consumptive use water withdrawals.
Tributary Temperatures A	This scenario evaluates the stream temperature response when the temperature of tributaries that exceed applicable temperature standards are set to temperatures that attain those standards.
Tributary Temperatures B	This scenario evaluates stream temperature warming or cooling in Fifteenmile Creek from sources on upstream tributaries attaining their HUA assignment.
Attainment	This scenario evaluates the stream temperature response from setting near stream land cover to system potential vegetation conditions and from increasing hourly tributary temperatures by the portion of the HUA assigned on those tributaries.
Background	This scenario evaluates the stream temperature response from removing consumptive uses and setting near stream land cover to system potential vegetation conditions.

Table 5-3: Summary of maximum 7DADM stream temperatures at the mouth of Fifteenmile Creek for all model scenarios over the entire model period.

Model KM	Scenario	Stream temperature (°C)	Location
0	Current Condition	24.94	outlet
0	Restored Vegetation A	21.06	outlet
0	Restored Vegetation B	21.09	outlet
0	Topographic Shade	27.79	outlet
0	Natural Flow	24.57	outlet
0	Consumptive Use	24.57	outlet
0	Tributary Temps A	24.66	outlet
0	Tributary Temps B	24.97	outlet
0	Attainment	21.09	outlet
0	Background	20.43	outlet

Table 5-4: Summary of maximum 7DADM stream temperatures in Fifteenmile Creek at the POMI for all model scenarios over the entire model period.

Model KM	Scenario	Stream temperature (°C)	Location
27	Current Condition	30.14	POMI
26.9	Restored Vegetation A	21.66	POMI
26.9	Restored Vegetation B	21.77	POMI
27	Topographic Shade	31.19	POMI
10.8	Natural Flow	27.09	POMI
10.9	Consumptive Use	27.10	POMI
27	Tributary Temps A	30.14	POMI
27	Tributary Temps B	30.14	POMI

Model KM	Scenario	Stream temperature (°C)	Location
3.8	Attainment	21.67	POMI
3.8	Background	22.03	POMI

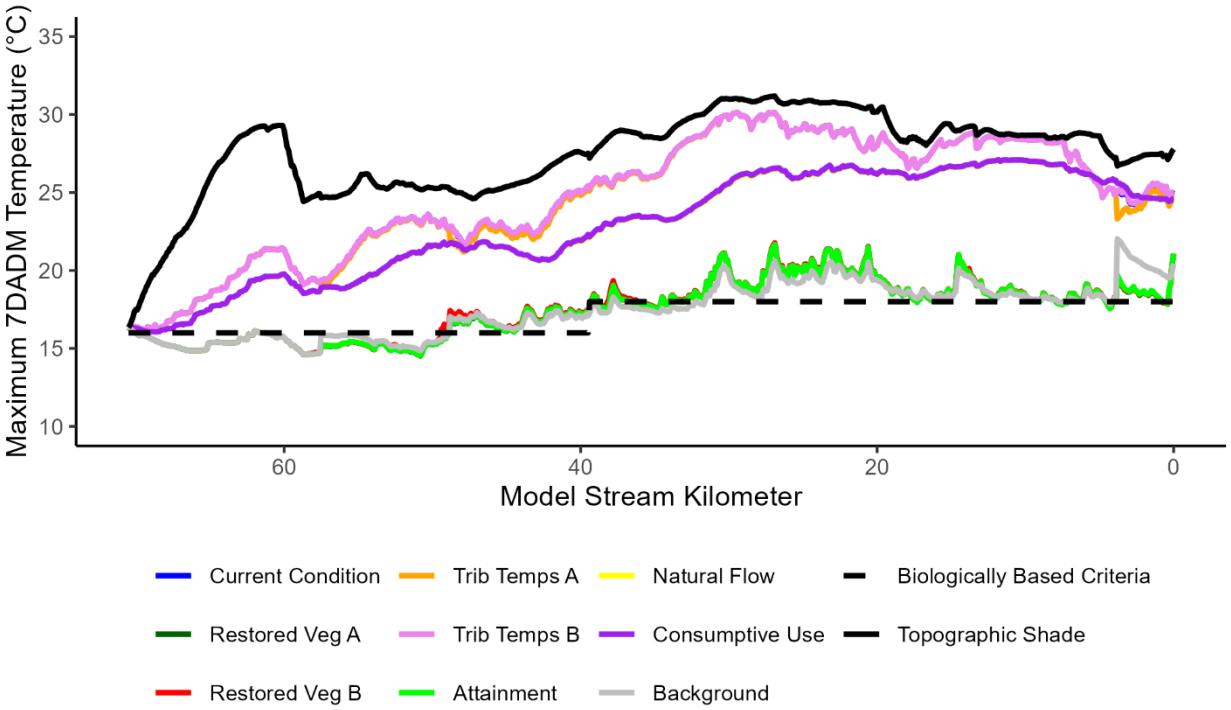


Figure 5-1: Maximum 7DADM stream temperature for all model scenarios for Fifteenmile Creek.

5.2.1 Current Condition Scenario

The Current Condition scenario is identical to the calibrated model developed to support the 2008 Middle Columbia-Hood (Miles Creeks) Subbasin TMDL, with the following exception: vegetation heights, density, and overhang were updated based on LiDAR data collected in 2018.

As the calibrated model included vegetation data from X, the Current Condition scenario was compared to the calibrated model to evaluate the change in vegetation over the last X years.

Mean effective shade was calculated for the Current Condition and original calibrated model scenarios and is summarized in

Table 5-5. The difference in mean effective shade between the calibrated model and Current Condition scenarios is equal to about 2 percentage points. This result indicates that mean effective shade along the model extent has decreased over time.

Figure 5-2 compares effective shade predictions from the Current Condition and original calibrated model scenarios for Fifteenmile Creek.

Figure 5-3 shows the difference in effective shade predictions between the Current Condition and original calibrated model scenarios for Fifteenmile Creek.

Table 5-5: Summary of mean effective shade between the Current Condition and original calibrated model scenarios for Fifteenmile Creek.

Scenario	Mean Effective Shade (%)
Current Condition	27
Original calibrated model	30
Shade Gap (Restored – Current)	2

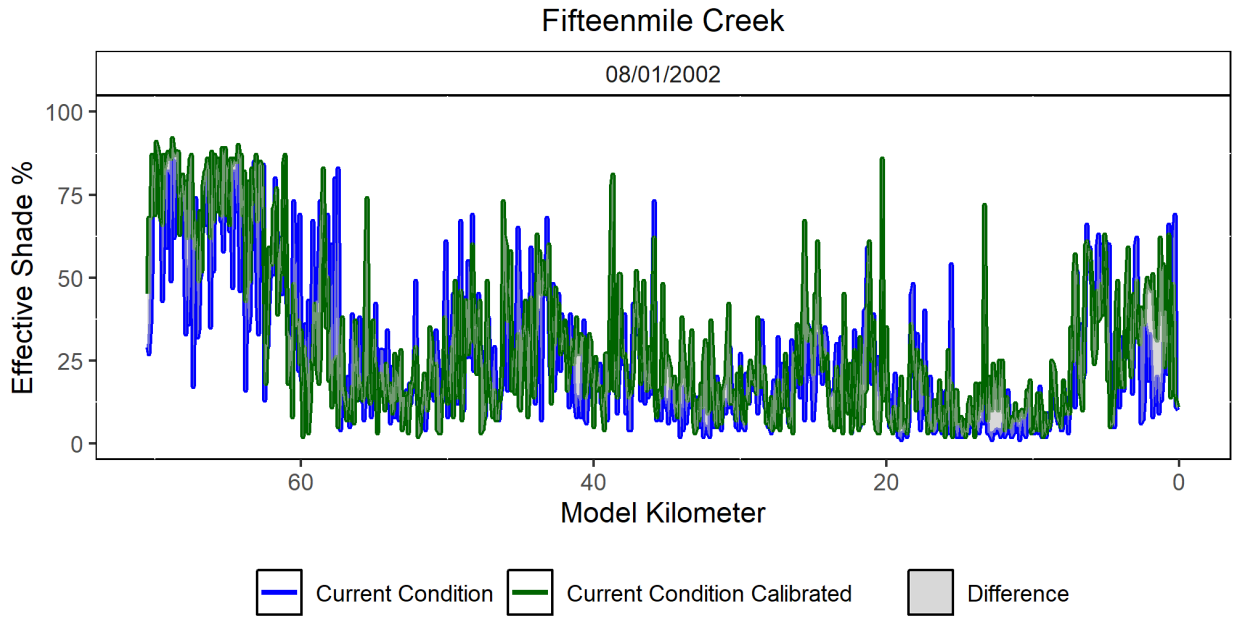


Figure 5-2: Comparison of effective shade from the Current Condition and original calibrated model scenarios for Fifteenmile Creek.

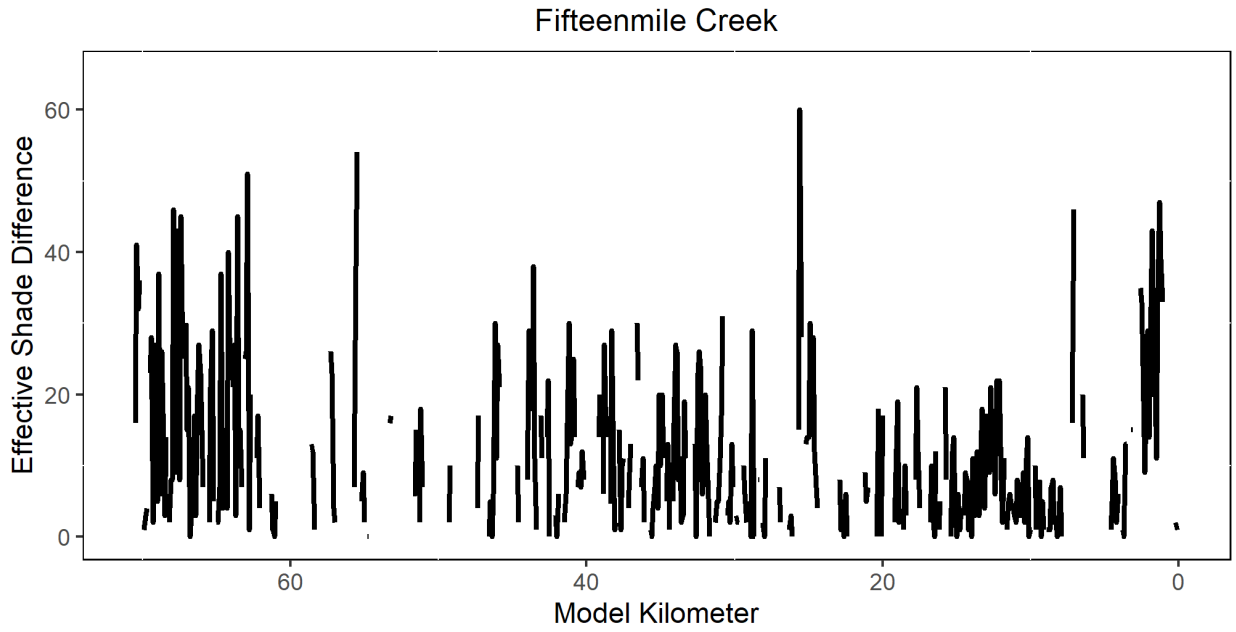


Figure 5-3: Percentage point difference between effective shade from the Current Condition and original calibrated model scenarios on 8/1/2002 for Fifteenmile Creek. Missing values indicate that the shade difference is negative due to instances of higher effective shade in the Current Condition scenario versus the original calibrated model scenario.

5.2.2 Vegetation Scenarios

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

The Restored Vegetation A scenario represents system potential vegetation conditions that are unaltered by anthropogenic activities, and can be used to evaluate stream temperature changes due to the removal of streamside vegetation.

Restored Vegetation A was compared to the Current Condition scenario to evaluate the impact of fully restored vegetation on stream temperatures and effective shade in Fifteenmile Creek. Table 5-6 summarizes the maximum 7DADM stream temperature change between the Current Condition and Restored Vegetation A scenarios. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 3.93°C. In addition, the greatest 7DADM temperature difference between the two scenarios (the POMI) is equal to 11.93°C and occurs at stream model km 27.8.

These results indicate that current vegetation conditions contribute to a nearly 12°C increase in stream temperatures compared to temperatures under system potential vegetation conditions.

Figure 5-4 shows the change in the maximum 7DADM stream temperatures between the Current Condition and Restored Vegetation A model scenarios for Fifteenmile Creek over the entire model period.

Table 5-6: Summary of maximum 7DADM stream temperature change between Current Condition and Restored Vegetation A model scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	3.93	outlet
27.8	11.93	POMI

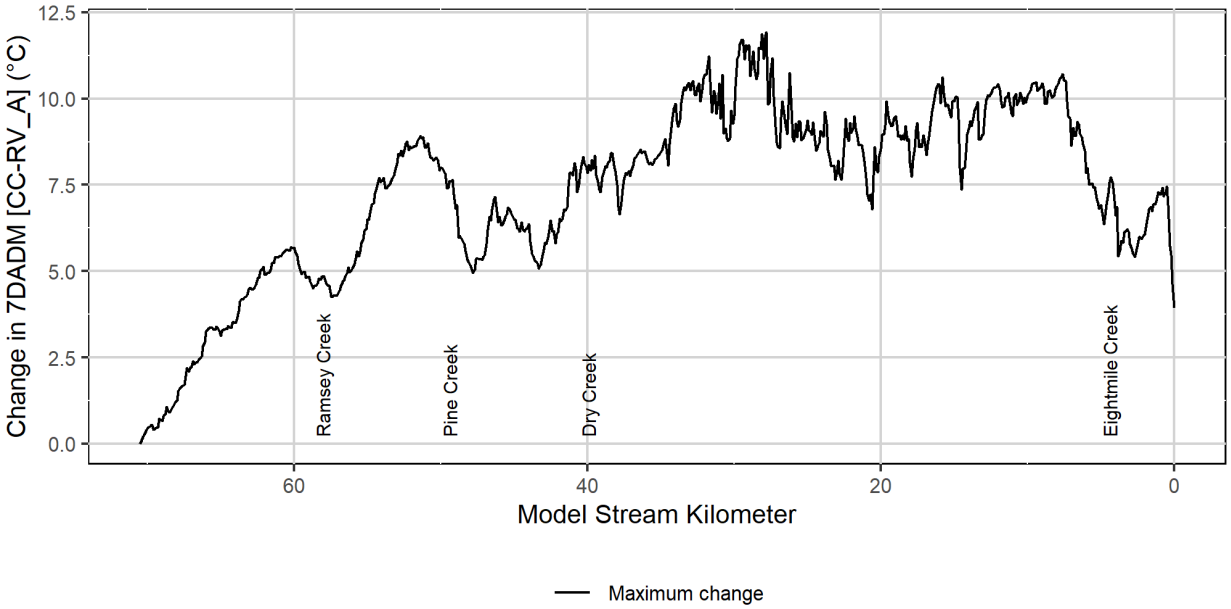


Figure 5-4: Change in the maximum stream temperatures between Current Condition and Restored Vegetation A scenarios for Fifteenmile Creek over the entire model period.

Restored Vegetation B is identical to Restored Vegetation A, with the exception that areas associated with existing infrastructure (i.e., roads, buildings, houses) are not set to system potential vegetation conditions but instead to current conditions (in this case, land cover codes associated with newly acquired LiDAR data). This scenario acknowledges that the removal of such infrastructure is highly unlikely.

Restored Vegetation B was compared to Restored Vegetation A to evaluate the impact of existing infrastructure on stream temperatures and effective shade in Fifteenmile Creek. Table 5-7 summarizes the maximum 7DADM stream temperature change between the Restored Vegetation B and Restored Vegetation A scenarios for Fifteenmile Creek. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 0.03°C. In addition, the greatest 7DADM temperature difference between the two scenarios (the POMI) is equal to 0.97°C and occurs at stream model km 49.2.

This comparison indicates that infrastructure such as roads, buildings, and houses contributes to an approximately 1°C increase in Fifteenmile Creek temperatures.

Figure 5-5 shows the change in the maximum 7DADM stream temperatures between the Restored Vegetation A and Restored Vegetation B model scenarios for Fifteenmile Creek over the entire model period.

Table 5-7: Summary of maximum 7DADM stream temperature change between Restored Vegetation A and Restored Vegetation B model scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	0.03	outlet
49.2	0.97	POMI

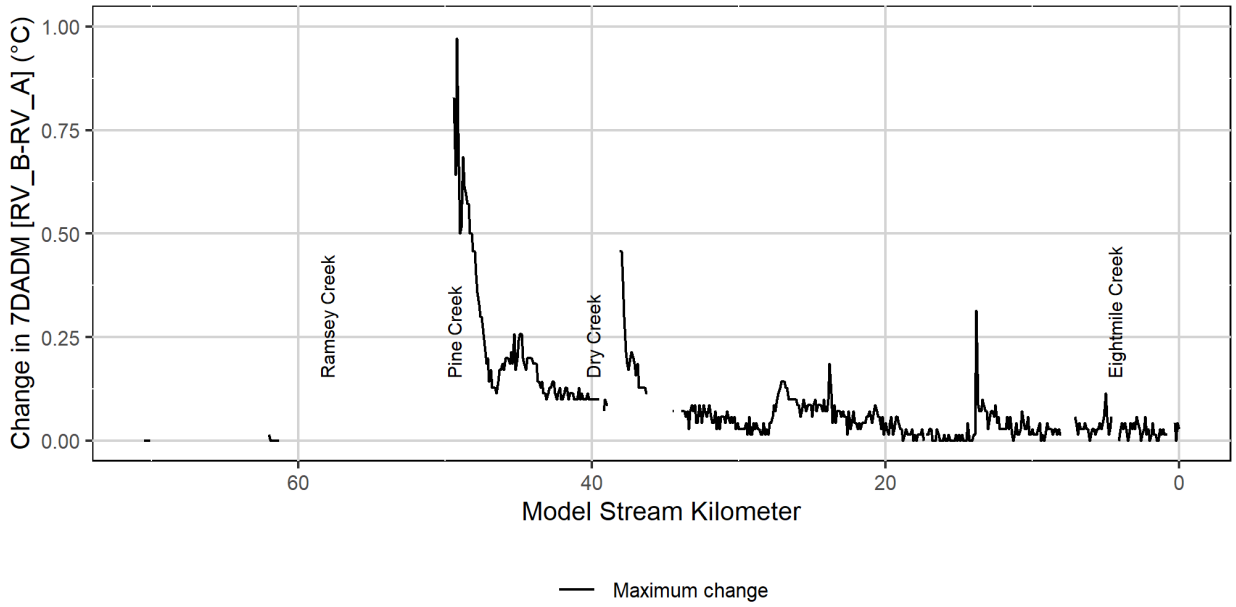


Figure 5-5: Change in the maximum stream temperatures between the Restored Vegetation A and Restored Vegetation B scenarios for Fifteenmile Creek over the entire model period.

The Topographic Shade scenario represents the effective shade provided only from the stream bank and distant topographic features, excluding any shade from vegetation and anthropogenic landcover such as houses and buildings.

The Topographic Shade scenario was compared to the Current Condition scenario to evaluate the impacts on stream temperatures of removing all near stream land cover. Table 5-8 summarizes the maximum 7DADM stream temperature change between the Current Condition and Topographic Shade scenarios for Fifteenmile Creek. It shows the 7DADM temperature difference at the most downstream model node (the outlet) is equal to 2.91°C. In addition, the greatest 7DADM temperature difference between the two scenarios (the POMI) is equal to 9.10°C and occurs at stream model km 63.1.

The results of this comparison indicate that without the current vegetative shading, maximum stream temperatures would be over 9°C warmer than current temperatures at the point of maximum impact (Table 5-8), illustrating the need to maintain and protect existing vegetation.

Figure 5-6 shows the change in the maximum 7DADM stream temperatures between the Current Condition and Topographic Shade model scenarios for Fifteenmile Creek over the entire model period.

Table 5-8: Summary of maximum 7DADM stream temperature change between the Topographic Shade and Current Condition model scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	2.91	outlet
63.1	9.10	POMI

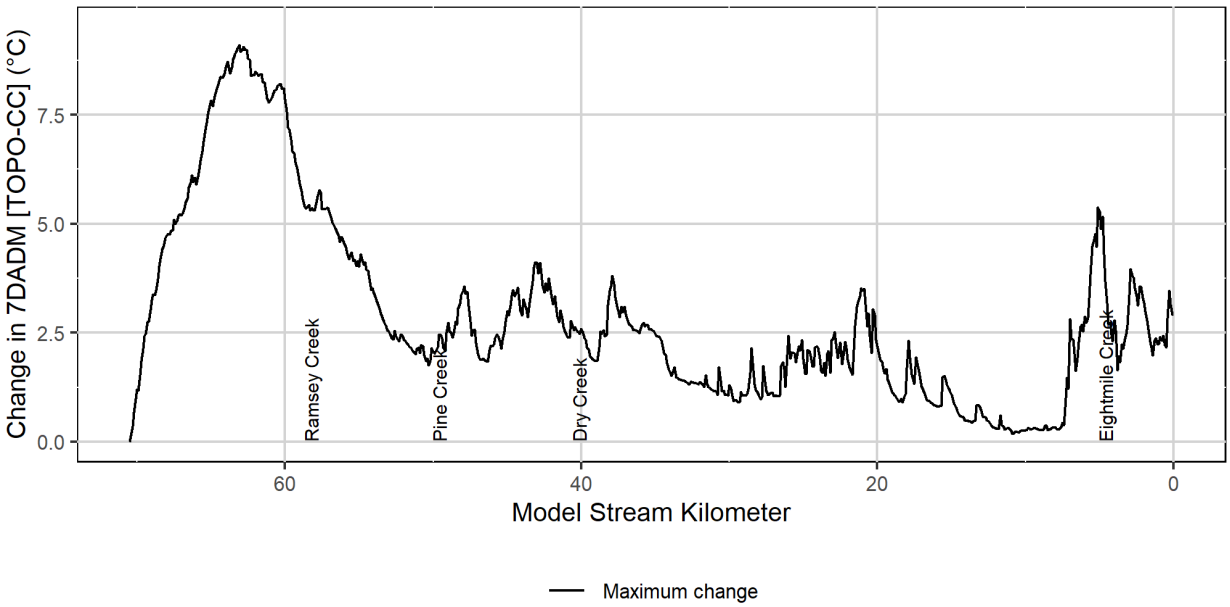


Figure 5-6: Change in the maximum 7DADM stream temperatures between the Current Condition and Topographic Shade scenarios for Fifteenmile Creek over the entire model period.

The Topographic Shade scenario was also compared to the Restored Vegetation A scenario to evaluate the temperature response from removing all restored vegetation leaving only shade provided by the stream bank and distant topographic features. Table 5-9 summarizes the maximum 7DADM stream temperature change between the Restored Vegetation A and Topographic Shade scenarios for Fifteenmile Creek. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 6.73°C. In addition, the greatest 7DADM temperature difference between the two scenarios (the POMI) is equal to 13.60°C and occurs at stream model km 60.5.

The results of this comparison indicate that temperatures would increase over 13°C relative to temperatures that result from full restored vegetation.

Figure 5-7 shows the change in the maximum 7DADM stream temperatures between the Restored Vegetation A and Topographic Shade model scenarios for Fifteenmile Creek over the entire model period.

Table 5-9: Summary of maximum 7DADM stream temperature change between the Topographic Shade and Restored Vegetation A model scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	6.73	outlet
60.5	13.60	POMI

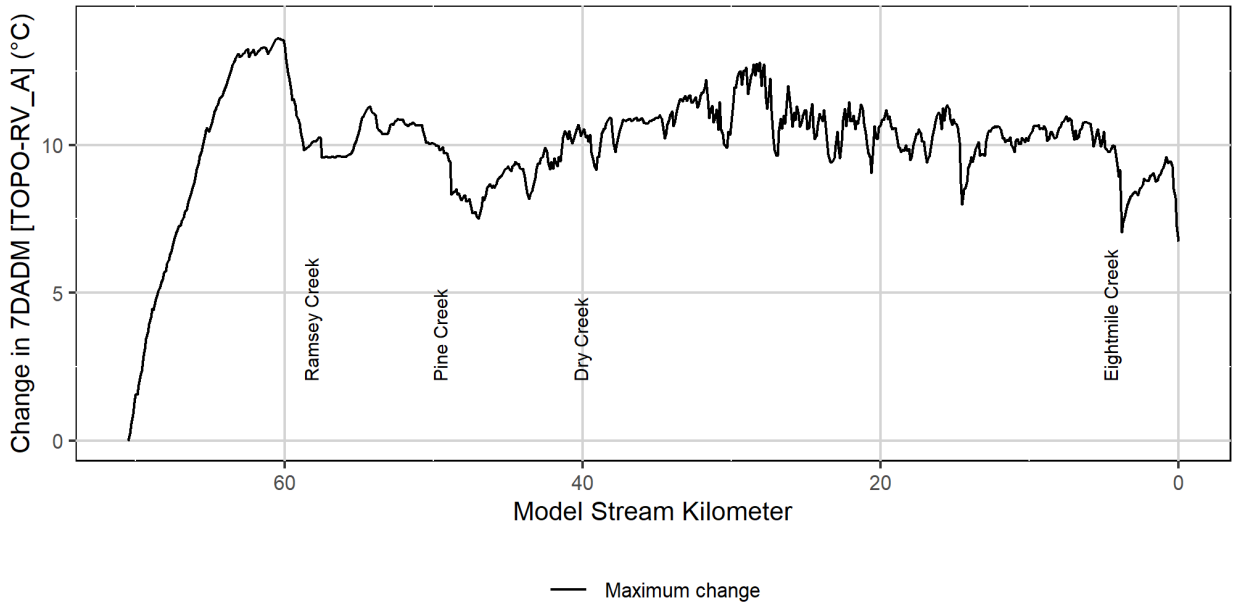


Figure 5-7: Change in the maximum 7DADM stream temperatures between the Restored Vegetation A and Topographic Shade scenarios for Fifteenmile Creek over the entire model period.

Mean effective shade was calculated for the Current Condition, Restored Vegetation A, and Topographic Shade scenarios and is summarized in Table 5-10. The difference in mean effective shade between the Current Condition and Restored Vegetation A scenarios is equal to 50 percentage points.

Figure 5-8 compares effective shade predictions from the Current Condition, Restored Vegetation A, and Topographic Shade scenarios for Fifteenmile Creek.

Figure 5-9 shows the difference in effective shade predictions between the Current Condition and Restored Vegetation A scenarios for Fifteenmile Creek.

Figure 5-10 shows the difference in effective shade predictions between the Current Condition and Topographic Shade scenarios for Fifteenmile Creek.

Table 5-10: Summary of mean effective shade between the Current Condition, Restored Vegetation A, and Topographic Shade scenarios for Fifteenmile Creek.

Scenario	Mean Effective Shade (%)
Current Condition	27
Restored Vegetation A	77
Shade Gap (Restored – Current)	50
Topographic Shade	3

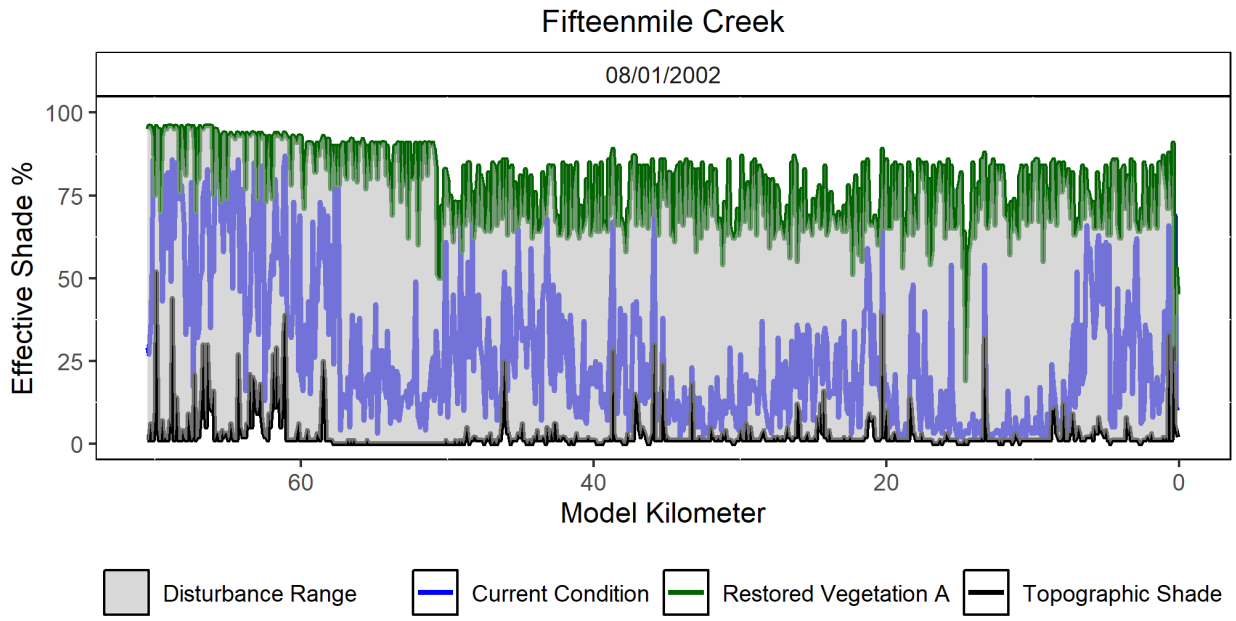


Figure 5-8: Comparison of effective shade from the Current Condition, Restored Vegetation A, and Topographic Shade scenarios for Fifteenmile Creek.

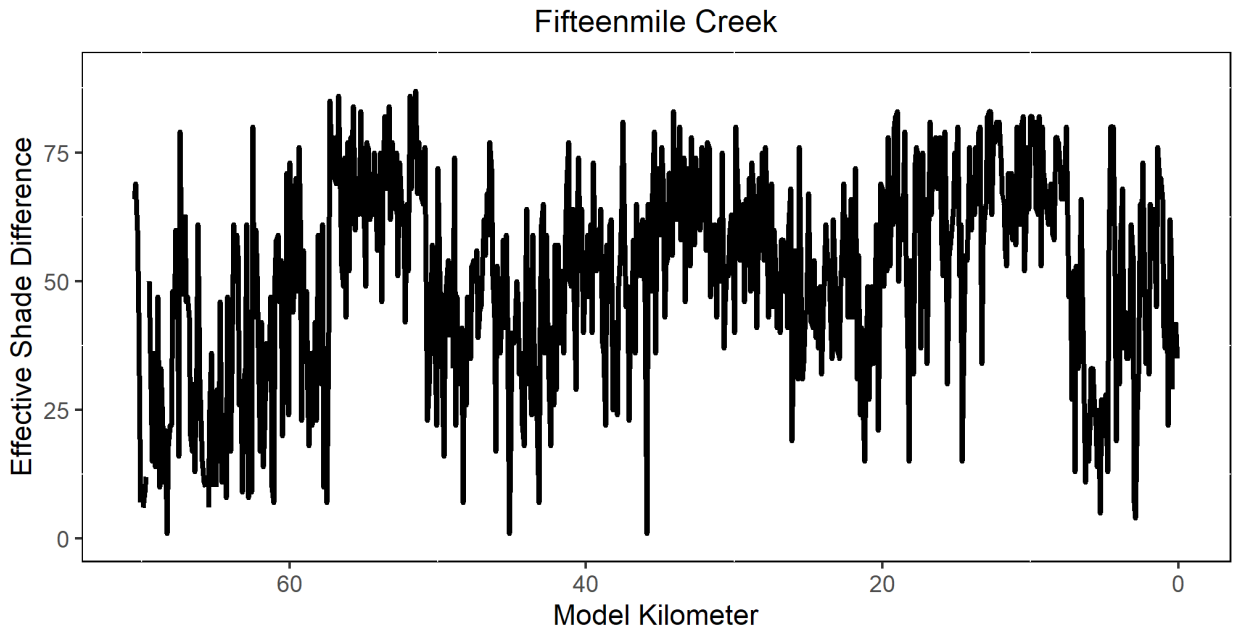


Figure 5-9: Percentage point difference between effective shade from the Current Condition and Restored Vegetation A scenarios on 8/1/2002 for Fifteenmile Creek. Missing values indicate that the shade difference is negative due to instances of higher effective shade in the Current Condition scenario versus the Restored Vegetation scenario.

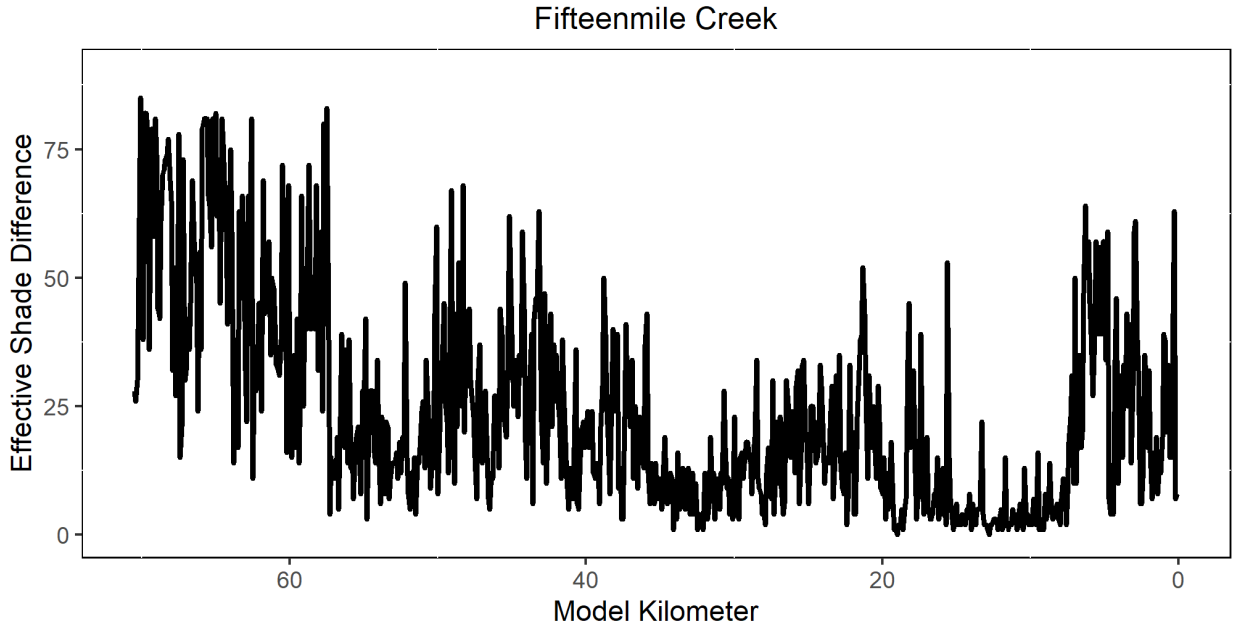


Figure 5-10: Percentage point difference between effective shade from the Current Condition and Topographic Shade scenarios on 8/1/2002 for Fifteenmile Creek.

5.2.3 Natural Flow

This section summarizes the temperature impacts of removing all consumptive use withdrawals and setting flows to their natural conditions.

In the Natural Flow scenario, both boundary condition and tributary flows are set to natural, based on hydrologic modeling at the mouth of perennial streams by the Oregon Water Resources Department. These flows represent conditions in the absence of water withdrawals.

The Natural Flow scenario was compared to the Current Condition scenario to evaluate the impact on stream temperatures of keeping permitted water withdrawals as instream flow. Table 5-11 summarizes the maximum 7DADM stream temperature change between the Natural Flow and Current Condition scenarios for Fifteenmile Creek. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 0.51°C. In addition, the greatest daily maximum temperature difference between the two scenarios (the POMI) is equal to 4.67°C and occurs at stream model km 30.8.

These results indicate that current flow reductions from instream water withdrawals have raised Fifteenmile Creek stream temperatures by nearly 5°C.

Figure 5-11 shows the change in the maximum 7DADM stream temperatures between the Natural Flow and Current Condition model scenarios for Fifteenmile Creek over the entire model period.

Table 5-11: Summary of maximum 7DADM stream temperature change between the Natural Flow and Current Condition scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	0.51	outlet
30.8	4.67	POMI

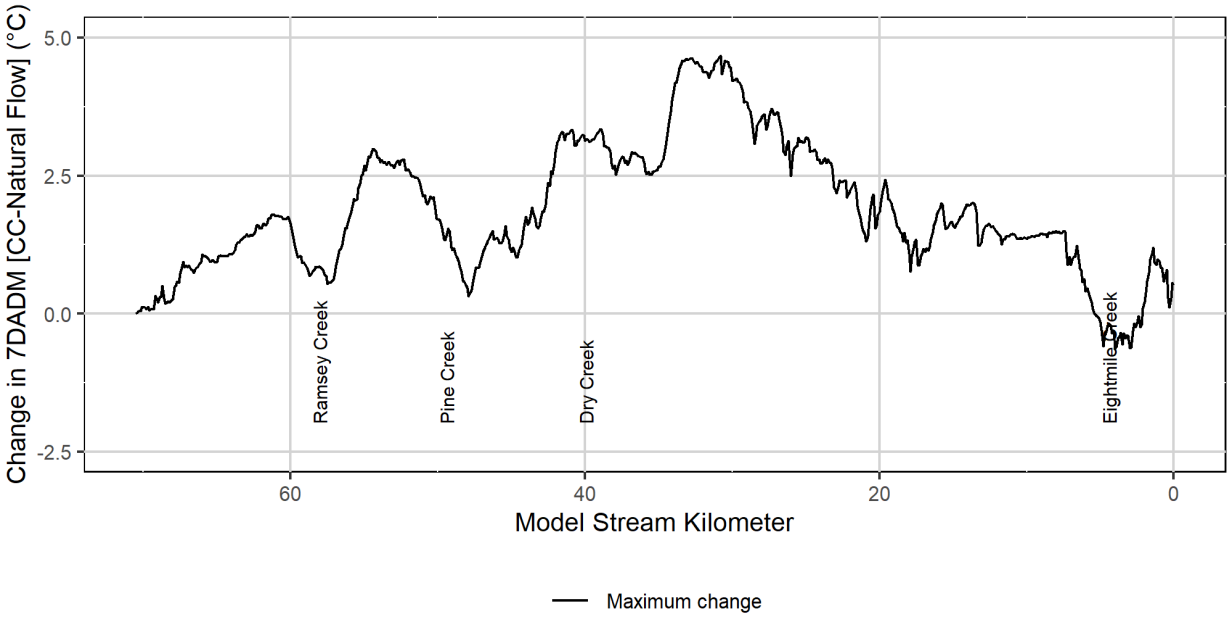


Figure 5-11: Change in maximum 7DADM stream temperatures between the Natural Flow and Current Condition scenarios for Fifteenmile Creek over the entire model period.

5.2.4 Consumptive Use

This section summarizes the model scenario assessing the temperature impacts of consumptive uses.

To determine the current existing consumptive use percent, DEQ calculated the average existing percent consumptive use during the model period and applied this value in Equation 4-1 and Equation 4-2. The estimated average percent current consumptive use during the model period at OWRD gage 14105550 was 33.7 percent.

Results showed that the portion of the HUA that is allocated to water withdrawals (0.10°C) is attained at the flow reference site on Fifteenmile Creek when natural flows are reduced by 0.6%. The flow reference site is located at OWRD gage 14105550 (Fifteenmile Cr Nr The Dalles).

The Consumptive Use scenario was compared to the Natural Flow scenario to evaluate the impact on stream temperatures of consumptive use water withdrawals resulting from a 0.6% reduction in natural flows. Table 5-12 summarizes the maximum 7DADM stream temperature change between the Consumptive Use and Natural Flow scenarios for Fifteenmile Creek. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 0.01°C. In addition, the greatest daily maximum temperature difference between the two scenarios (the POMI) is equal to 0.10°C and occurs at stream model km 32.4.

Flows at the reference gage for each day in the model period were extracted from the 0.6% Consumptive Use scenario and compared to natural flows at the reference gage. The reductions in flow between the Natural Flow and Consumptive use scenarios at the reference gage closely approximate 0.6% (Table 5-13).

Table 5-12: Summary of maximum 7DADM stream temperature change between the Consumptive Use and Natural Flow scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	0.01	outlet
32.4	0.10	POMI

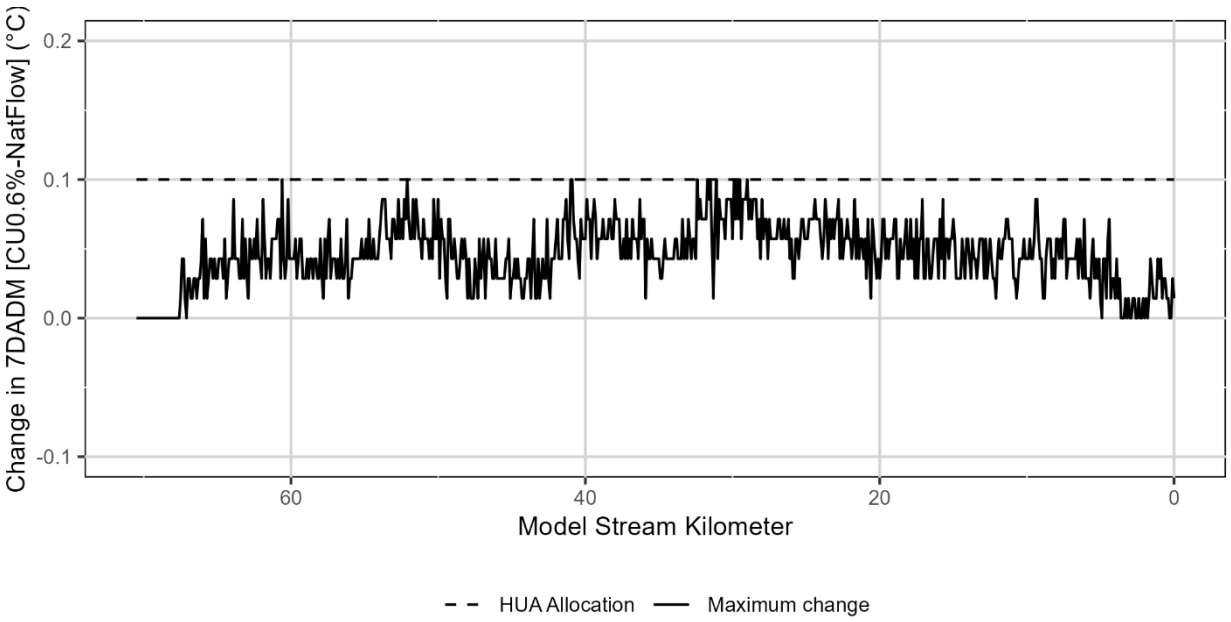


Figure 5-12: Change in maximum 7DADM stream temperatures between the Consumptive Use and Natural Flow scenarios for Fifteenmile Creek over the entire model period.

Table 5-13: Consumptive use flows and natural flows at the reference gage (OWRD 14105550).

Model date	Natural flow (cms)	0.6% Consumptive use flow (cms)	Percent reduction
7/17/2002	0.421	0.419	0.5
7/18/2002	0.418	0.416	0.5
7/19/2002	0.415	0.413	0.5
7/20/2002	0.412	0.409	0.7
7/21/2002	0.408	0.406	0.5
7/22/2002	0.405	0.403	0.5
7/23/2002	0.402	0.400	0.5
7/24/2002	0.399	0.397	0.5
7/25/2002	0.396	0.394	0.5
7/26/2002	0.393	0.390	0.8
7/27/2002	0.390	0.387	0.8
7/28/2002	0.387	0.384	0.8
7/29/2002	0.383	0.381	0.5
7/30/2002	0.380	0.378	0.5
7/31/2002	0.377	0.375	0.5
8/1/2002	0.374	0.372	0.5
8/2/2002	0.371	0.369	0.5
8/3/2002	0.368	0.366	0.5
8/4/2002	0.365	0.362	0.8
8/5/2002	0.362	0.359	0.8

5.2.5 Tributary Temperatures

This section summarizes the temperature impacts of restored tributary temperatures.

In the Tributary Temperatures A scenario, any tributary temperatures that exceed the applicable temperature standard are adjusted to meet that standard. This scenario is used to assess the impact of tributary temperature exceedances.

The Tributary Temperatures A scenario was compared with the Current Condition scenario to evaluate the contribution of tributary inflows to stream warming in Fifteenmile Creek by quantifying the effects of tributary temperatures that exceed the standard. Table 5-14 summarizes the maximum 7DADM stream temperature change between the Tributary Temperatures A and Current Condition scenarios for Fifteenmile Creek. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 0.29°C. In addition, the greatest daily maximum temperature difference between the two scenarios (the POMI) is equal to 1.79°C and occurs at stream model km 3.8, at the mouth of Eightmile Creek.

These results indicate that tributary temperature exceedances of the standard contribute to higher temperatures in Fifteenmile Creek, resulting in an increase of nearly 2°C. In particular, Eightmile Creek appears to be the primary contributor to warming in Fifteenmile Creek as a function of tributary temperature exceedances.

Figure 5-13 shows the change in the maximum 7DADM stream temperatures between the Tributary Temperatures A and Current Condition model scenarios for Fifteenmile Creek over the entire model period.

Table 5-14: Summary of maximum 7DADM stream temperature change between the Tributary Temperatures A and Current Condition scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	0.29	outlet
3.8	1.79	POMI

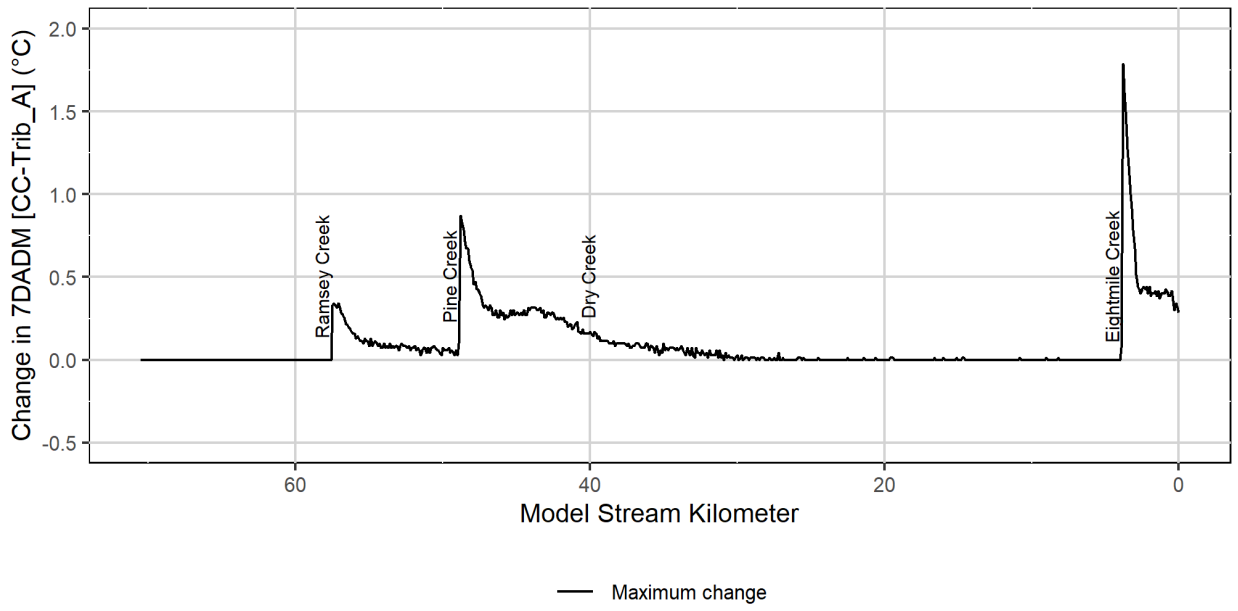


Figure 5-13: Change in maximum 7DADM stream temperatures between the Tributary Temperatures A and Current Condition scenarios for Fifteenmile Creek over the entire model period.

In the Tributary Temperatures B scenario, tributary temperatures were modified to meet the assigned human use allowance (HUA). This scenario enables the HUA to be properly assigned and accounted for on the mainstem independent of other source categories. Assigning an HUA of 0.3°C to the tributaries, and therefore increasing tributary temperatures by 0.3°C, did not result in exceedance of the HUA. This indicates that the assigned value fully accounts for the warming contribution from tributaries. Therefore, the full HUA is accounted for on each tributary, including reserve capacity.

Table 5-15 summarizes the maximum 7DADM stream temperature change between the Tributary Temperatures B and Current Condition scenarios for Fifteenmile Creek. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 0.03°C. In addition, the greatest daily maximum temperature difference between the two scenarios (the POMI) is equal to 0.10°C and occurs at stream model km 3.8.

These results indicate that an HUA of 0.10°C for warming from tributaries is appropriate for Fifteenmile Creek.

Figure 5-14 shows the change in the maximum 7DADM stream temperatures between the Tributary Temperatures B and Current Condition model scenarios for Fifteenmile Creek over the entire model period.

Table 5-15: Summary of maximum 7DADM stream temperature change between the Tributary Temperatures B and Current Condition scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	0.03	outlet
3.8	0.10	POMI

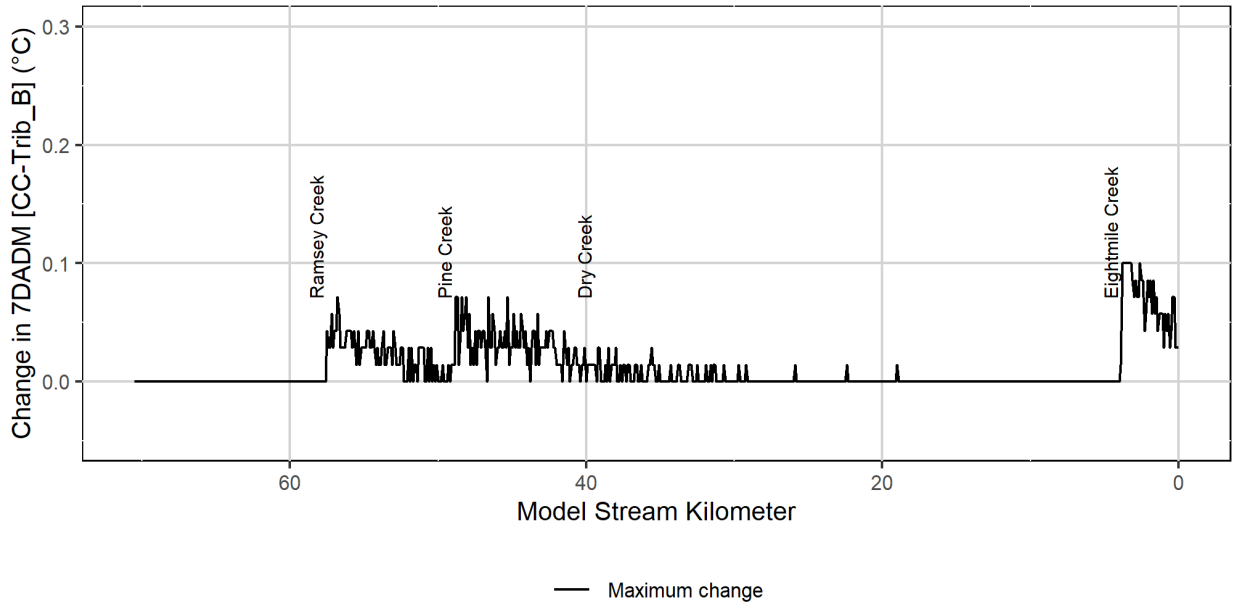


Figure 5-14: Change in maximum 7DADM stream temperatures between the Tributary Temperatures B and Current Condition scenarios for Fifteenmile Creek over the entire model period.

5.2.6 Background

This section summarizes the temperature impacts of background conditions.

The Background scenario evaluates stream temperature response from background sources, which include all sources of thermal loading not originating from human activities. This scenario was developed to estimate the magnitude of background excess load relative to anthropogenic load. The Background scenario is equivalent to the Current Conditions scenario with the exception that vegetation is set to system potential conditions (as in the RV_A scenario) and water withdrawals have been removed (as in the Natural Flow scenario).

The Background scenario was compared to the Current Condition scenario to evaluate the impact of anthropogenic activities on stream temperatures in Fifteenmile Creek. Table 5-16 summarizes the maximum 7DADM stream temperature change between the Current Condition and Background scenarios. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 4.60°C. In addition, the greatest 7DADM temperature difference between the two scenarios (the POMI) is equal to 11.97°C and occurs at stream model km 27.8.

These results indicate that anthropogenic activities account for nearly 12°C of warming in Fifteenmile Creek.

Figure 5-15 shows the change in the maximum 7DADM stream temperatures between the Current Condition and Background model scenarios for Fifteenmile Creek over the entire model period.

Table 5-16: Summary of maximum 7DADM stream temperature change between the Background and Current Condition scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	4.60	outlet
27.8	11.97	POMI

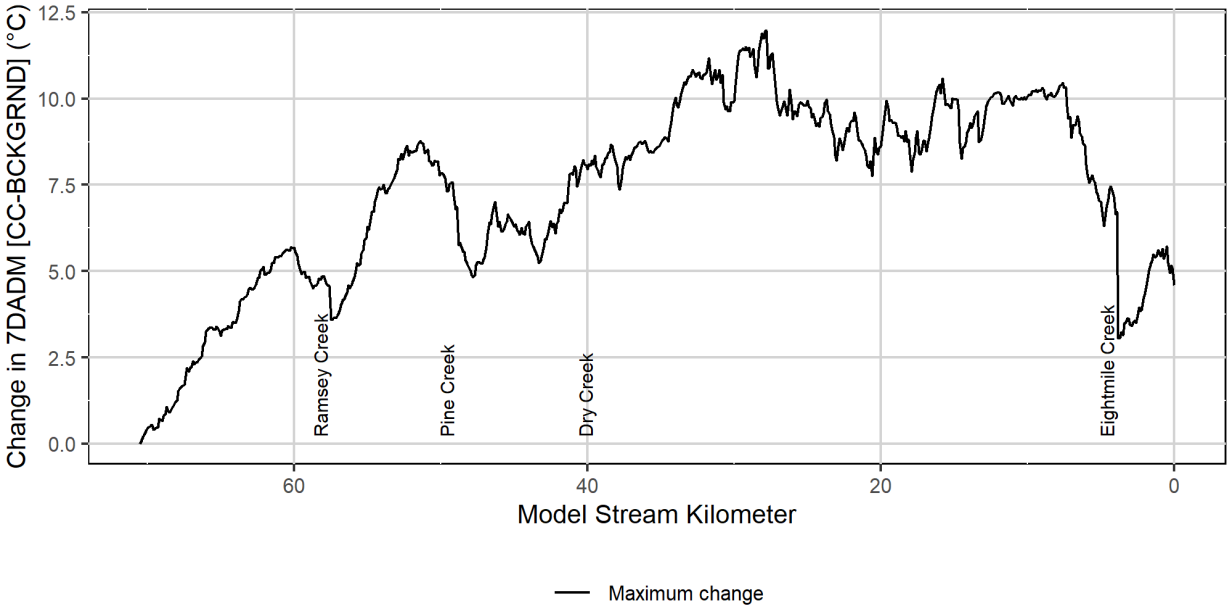


Figure 5-15: Change in maximum 7DADM stream temperatures between the Background and Current Condition scenarios for Fifteenmile Creek over the entire model period.

The Background scenario was also compared to the applicable biologically based numeric criteria (BBNC) to identify the extent and magnitude of temperature exceedances that would occur in the absence of anthropogenic activities (i.e., exceedances due to background factors).

Table 5-17 summarizes the maximum 7DADM stream temperature change between the Background scenario and the BBNC. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 2.43°C. In addition, the greatest 7DADM temperature difference between the two scenarios (the POMI) is equal to 4.03°C and occurs at stream model km 3.8.

These results indicate that in the absence of anthropogenic activities, background sources (i.e., all sources of pollution or pollutants not originating from human activities) contribute over 4°C warming in Fifteenmile Creek.

Figure 5-16 shows the change in the maximum 7DADM stream temperatures between the Background scenario and the BBNC for Fifteenmile Creek over the entire model period.

Table 5-17: Summary of maximum 7DADM stream temperature change between the Background scenario and BBNC for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	2.43	outlet
3.8	4.03	POMI

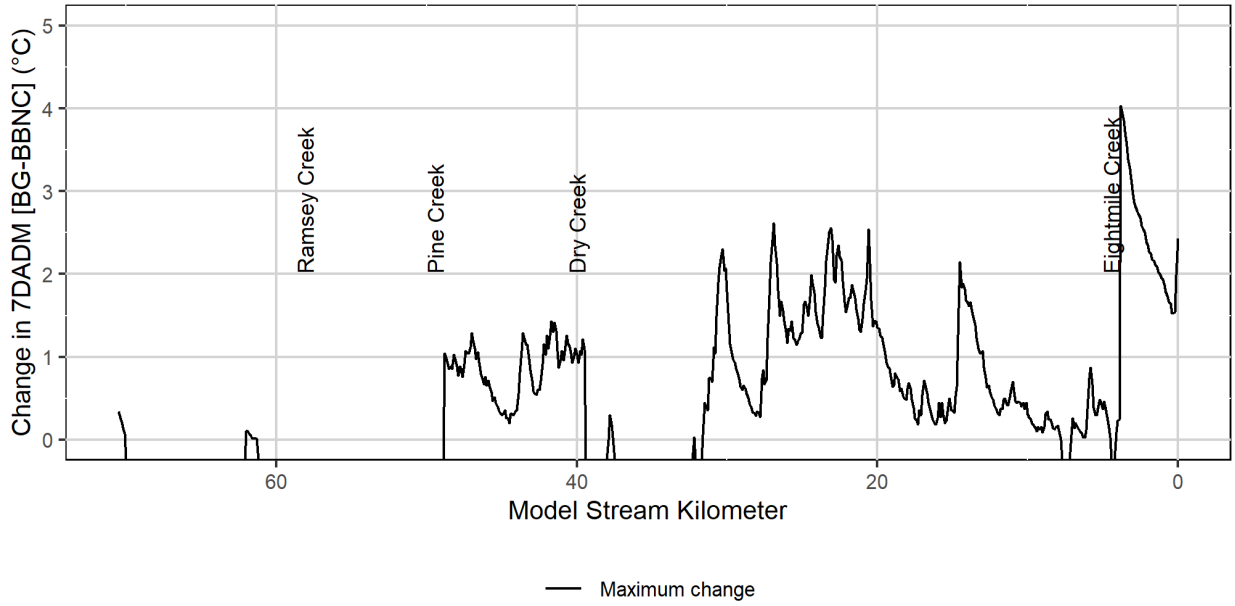


Figure 5-16: Change in maximum 7DADM stream temperatures between the Background scenario and BBNC for Fifteenmile Creek over the entire model period.

5.2.7 HUA Attainment

This section summarizes the temperature impacts of the proposed allocation to warming from tributaries on Fifteenmile Creek. 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 Attainment-Baseline scenario (which is equivalent to the Restored Vegetation A scenario). Table 5-18 describes how the HUA Attainment model scenario was set up.

Table 5-18: HUA Attainment model scenario set up description for Fifteenmile Creek.

Model input variable	HUA Attainment scenario set up description
Riparian landcover	Set to system potential vegetation conditions.
Tributary temperatures	Tributary temperatures were increased by the portion of the HUA assigned to sources of warming on each tributary (0.3°C).

Model input variable	HUA Attainment scenario set up description
Withdrawals	Set to current flows.

Table 5-19 summarizes the maximum 7DADM stream temperature change between the Attainment-Baseline and HUA Attainment scenarios for Fifteenmile Creek. It shows the 7DADM temperature difference at the most downstream node (the outlet) is equal to 0.04°C. In addition, the greatest daily maximum temperature difference between the two scenarios (the POMI) is equal to 0.10°C and occurs at stream model km 3.8.

The comparison of the HUA Attainment scenario to the Attainment-Baseline scenario supports that Fifteenmile Creek warming from tributaries is equal to 0.10°C. The TMDL allocation is 0.10 to warming from tributaries on Fifteenmile Creek. The HUA Attainment analysis results support that the portion of the HUA assigned to modeled sources will be achieved on Fifteenmile Creek.

Figure 5-17 shows the change in the maximum 7DADM stream temperatures between the Attainment-Baseline and HUA Attainment scenarios for Fifteenmile Creek over the entire model period.

Table 5-19: Summary of maximum 7DADM stream temperature change between the Attainment-Baseline and HUA Attainment scenarios for Fifteenmile Creek over the entire model period.

Model KM	Stream temperature change (°C)	Location
0	0.04	outlet
3.8	0.10	POMI

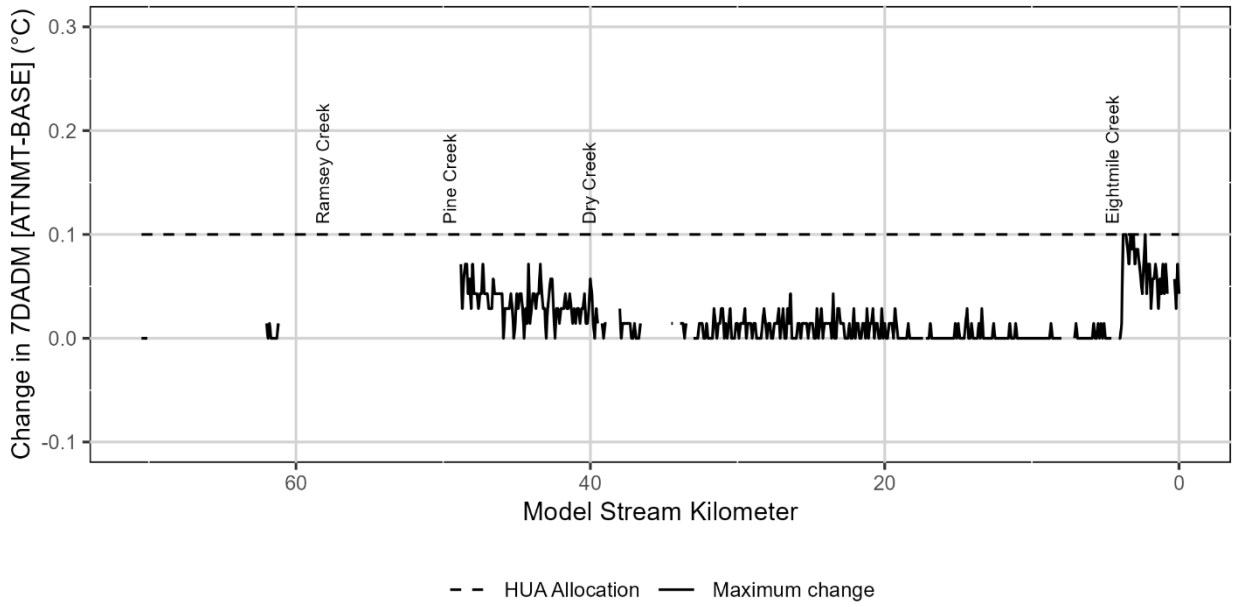


Figure 5-17: Change in maximum 7DADM stream temperatures between the Background and HUA Attainment scenarios for Fifteenmile Creek over the entire model period.

5.3 Eightmile Creek

Table 5-20 describes the different model scenarios used to simulate effective shade for Eightmile Creek.

Table 5-20: Eightmile Creek model scenario descriptions.

Scenario Name	Description
Current Condition	Effective shade response to conditions on August 1, 2002.
Restored Vegetation A	This scenario evaluates the stream temperature response from setting near stream land cover to system potential vegetation conditions.
Restored Vegetation B	This scenario is identical to the Restored Vegetation A scenario, except that areas associated with residential and industrial/commercial development, roads, and bridges are left unchanged and retain the same landcover heights and densities as the Current Condition scenario.
Topographic Shade	Near stream land cover set to zero to evaluate the portion of effective shade contributed by topographic features only.

5.3.1 Current Condition Scenario

The Current Condition scenario is identical to the calibrated model developed to support the 2008 Middle Columbia-Hood (Miles Creeks) Subbasin TMDL, with the following exception: vegetation heights, density, and overhang were updated based on LiDAR data collected in 2018.

As the calibrated model included vegetation data from X, the Current Condition scenario was compared to the calibrated model to evaluate the change in vegetation over the last X years.

Mean effective shade was calculated for the Current Condition and original calibrated model scenarios and is summarized in Table 5-21. The difference in mean effective shade between the Current Condition and calibrated model scenarios is equal to about 8 percentage points. This result indicates that mean effective shade along the model extent has increased over time.

Figure 5-18 compares effective shade predictions from the Current Condition and original calibrated model scenarios for Eightmile Creek.

Figure 5-19 shows the difference in effective shade predictions between the Current Condition and original calibrated model scenarios for Eightmile Creek.

Table 5-21: Summary of mean effective shade between the Current Condition and original calibrated model scenarios for Eightmile Creek.

Scenario	Mean Effective Shade (%)
Current Condition	68
Original calibrated model	60
Shade Gap (Restored – Current)	8

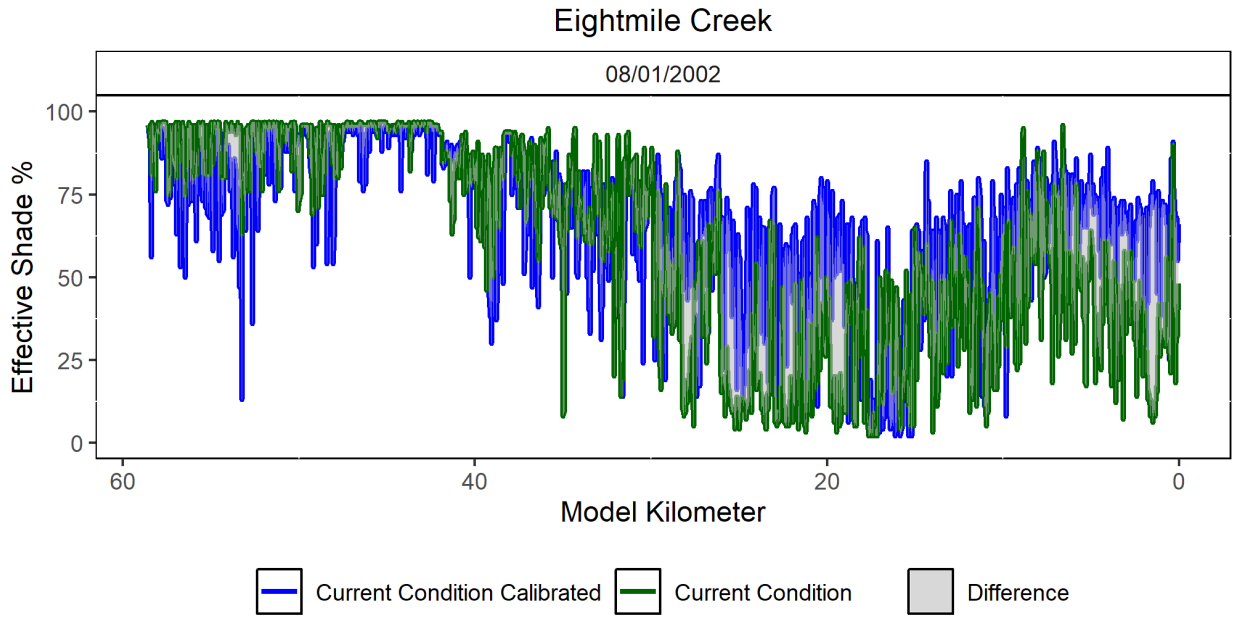


Figure 5-18: Comparison of effective shade from the Current Condition and original calibrated model scenarios for Eightmile Creek.

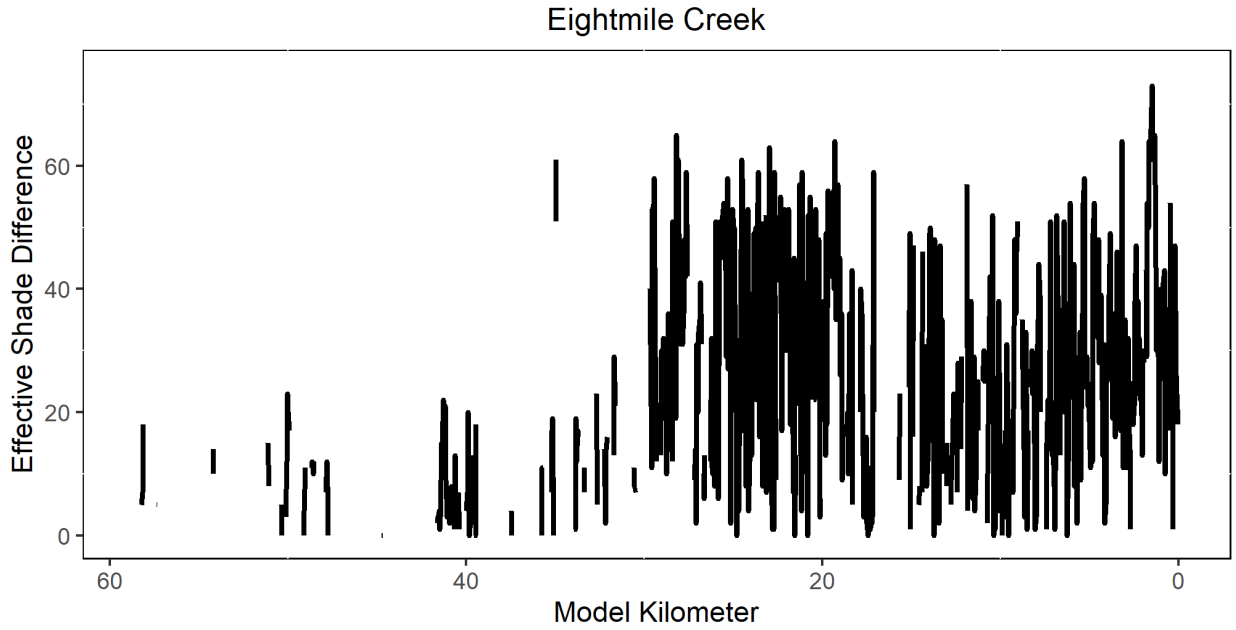


Figure 5-19: Percentage point difference between effective shade from the Current Condition and original calibrated model scenarios on 8/1/2002 for Eightmile Creek. Missing values indicate that the shade difference is negative due to instances of higher effective shade in the original calibrated model scenario versus the Current Condition scenario.

5.3.2 Vegetation Scenarios

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

The Restored Vegetation A scenario represents system potential vegetation conditions that are unaltered by anthropogenic activities, and can be used to evaluate the impact of fully restored vegetation on effective shade in Eightmile Creek.

Restored Vegetation B is identical to Restored Vegetation A, with the exception that areas associated with existing infrastructure (i.e., roads, buildings, houses) are not set to system potential vegetation conditions but instead to current conditions (in this case, land cover codes associated with newly acquired LiDAR data). This scenario acknowledges that the removal of such infrastructure is highly unlikely.

The Topographic Shade scenario represents the effective shade from natural topography by removing all vegetation and anthropogenic landcover such as houses and buildings.

Mean effective shade was calculated for the Current Condition, Restored Vegetation A, and Topographic Shade scenarios and is summarized in Table 5-22. The difference in mean effective shade between the Current Condition and Restored Vegetation A scenarios is equal to about 16 percentage points.

Figure 5-20 compares effective shade predictions from the Current Condition, Restored Vegetation A, and Topographic Shade scenarios for Eightmile Creek.

Figure 5-21 shows the difference in effective shade predictions between the Current Condition and Restored Vegetation A scenarios for Eightmile Creek.

Figure 5-22 shows the difference in effective shade predictions between the Current Condition and Topographic Shade scenarios for Eightmile Creek.

Table 5-22: Summary of mean effective shade between the Current Condition, Restored Vegetation A, and Topographic Shade scenarios for Eightmile Creek.

Scenario	Mean Effective Shade (%)
Current Condition	68
Restored Vegetation A	83
Shade Gap (Restored – Current)	16
Topographic Shade	15

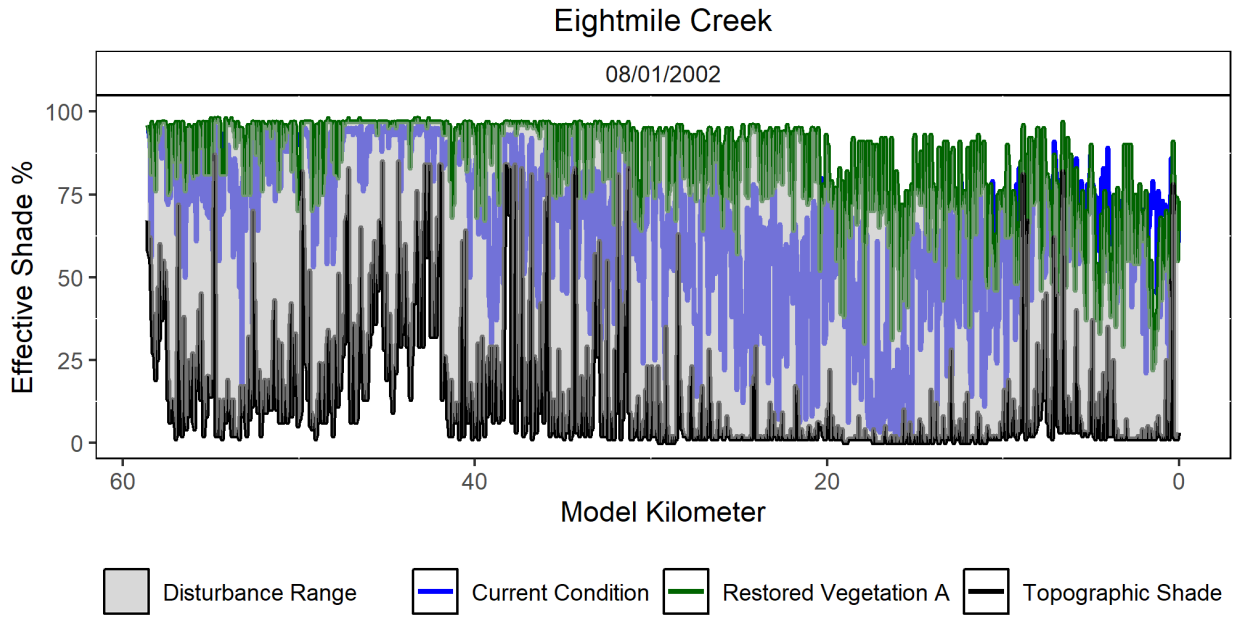


Figure 5-20: Comparison of effective shade from the Current Condition, Restored Vegetation A, and Topographic Shade scenarios for Eightmile Creek.

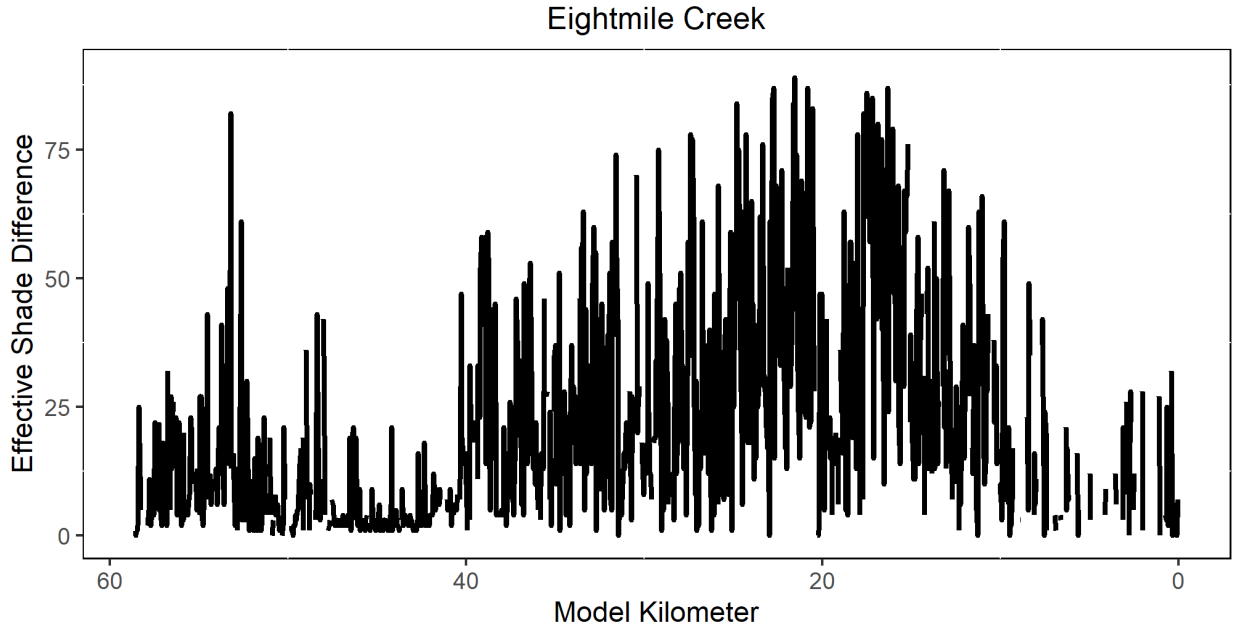


Figure 5-21: Percentage point difference between effective shade from the Current Condition and Restored Vegetation A scenarios on 8/1/2002 for Eightmile Creek. Missing values indicate that the shade difference is negative due to instances of higher effective shade in the Current Condition scenario versus the Restored Vegetation scenario.

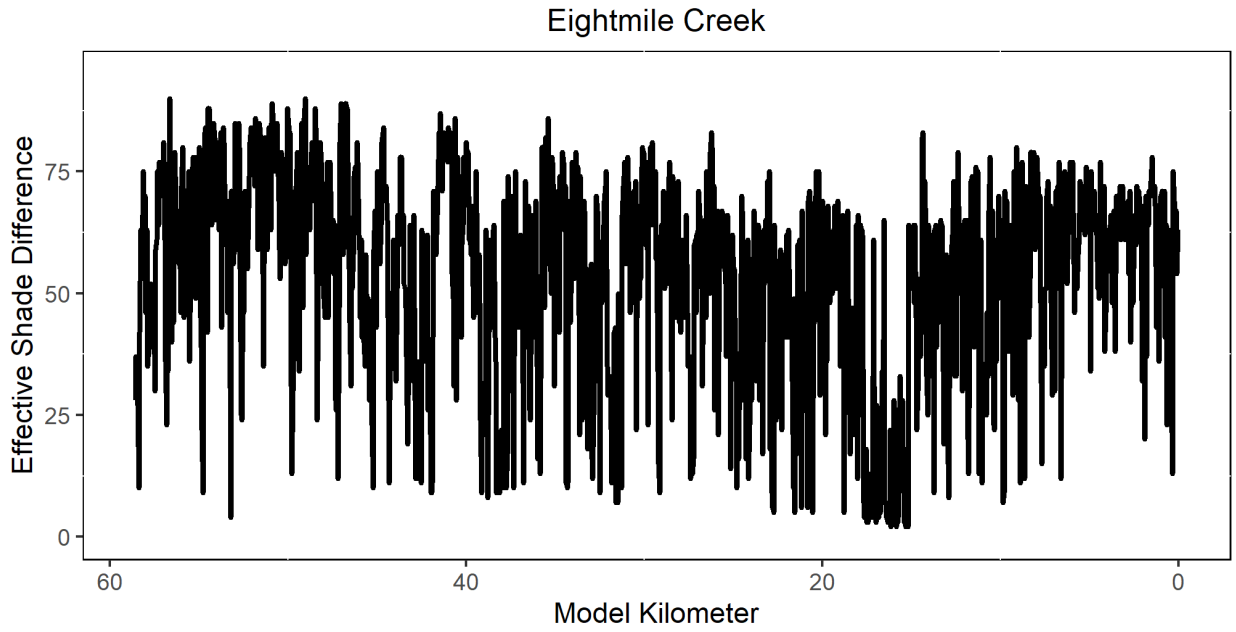


Figure 5-22: Percentage point difference between effective shade from the Current Condition and Topographic Shade scenarios on 8/1/2002 for Eightmile Creek.

5.4 Ramsey Creek

Table 5-23 describes the different model scenarios used to simulate effective shade for Eightmile Creek.

Table 5-23: Ramsey Creek model scenario descriptions.

Scenario Name	Description
Current Condition	Effective shade response to conditions on August 1, 2002.
Restored Vegetation A	This scenario evaluates the stream temperature response from setting near stream land cover to system potential vegetation conditions.
Restored Vegetation B	This scenario is identical to the Restored Vegetation A scenario, except that areas associated with residential and industrial/commercial development, roads, and bridges are left unchanged and retain the same landcover heights and densities as the Current Condition scenario.
Topographic Shade	Near stream land cover set to zero to evaluate the portion of effective shade contributed by topographic features only.

5.4.1 Current Condition Scenario

The Current Condition scenario is identical to the calibrated model developed to support the 2008 Middle Columbia-Hood (Miles Creeks) Subbasin TMDL, with the following exception: vegetation heights, density, and overhang were updated based on LiDAR data collected in 2018.

As the calibrated model included vegetation data from X, the Current Condition scenario was compared to the calibrated model to evaluate the change in vegetation over the last X years.

Mean effective shade was calculated for the Current Condition and original calibrated model scenarios and is summarized in Table 5-24. The difference in mean effective shade between the calibrated model and Current Condition scenarios is equal to about 2 percentage points. This result indicates that mean effective shade along the model extent has increased over time.

Figure 5-23 compares effective shade predictions from the Current Condition and original calibrated model scenarios for Ramsey Creek.

Figure 5-24 shows the difference in effective shade predictions between the Current Condition and original calibrated model scenarios for Ramsey Creek.

Table 5-24: Summary of mean effective shade between the Current Condition and original calibrated model scenarios for Ramsey Creek.

Scenario	Mean Effective Shade (%)
Current Condition	78
Original calibrated model	76
Shade Gap (Restored – Current)	2

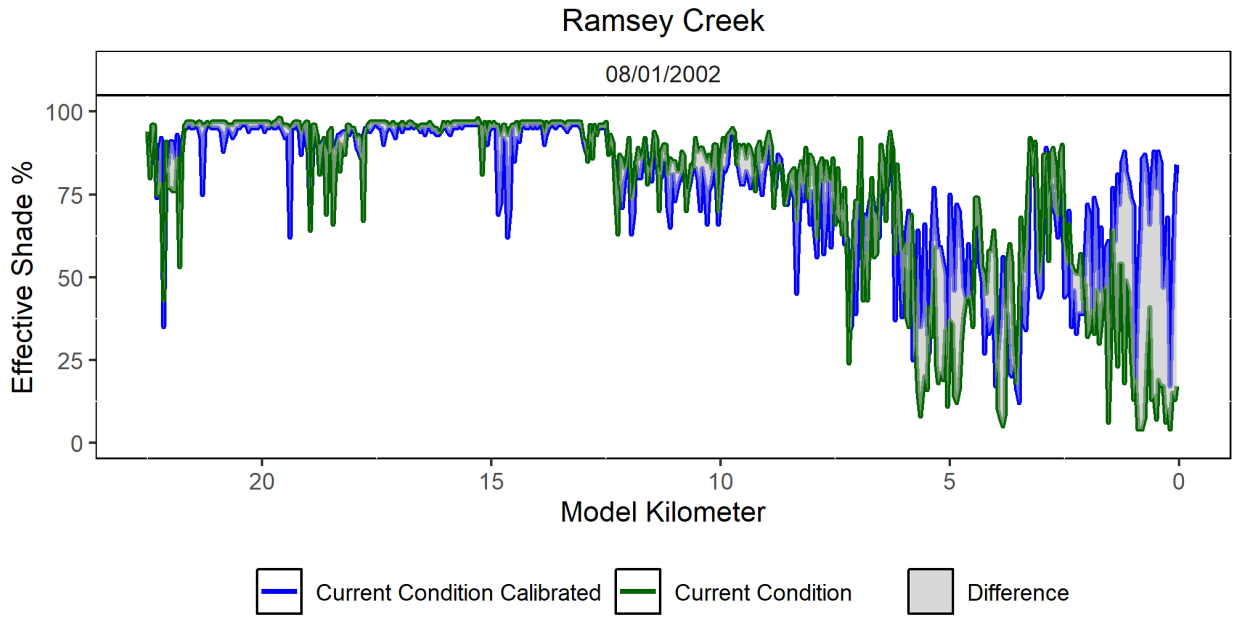


Figure 5-23: Comparison of effective shade from the Current Condition and original calibrated model scenarios for Ramsey Creek.

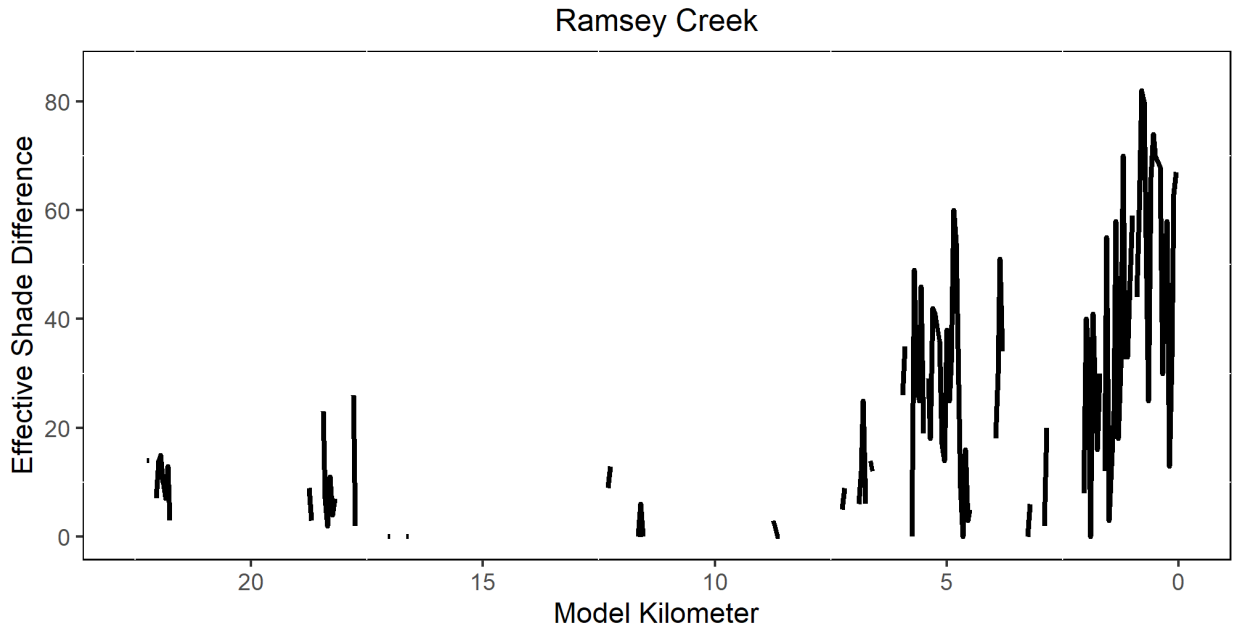


Figure 5-24: Percentage point difference between effective shade from the Current Condition and original calibrated model scenarios on 8/1/2002 for Ramsey Creek. Missing values indicate that the shade difference is negative due to instances of higher effective shade in the original calibrated scenario versus the Current Condition scenario.

5.4.2 Vegetation scenarios

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

The Restored Vegetation A scenario represents system potential vegetation conditions that are unaltered by anthropogenic activities, and can be used to evaluate the impact of fully restored vegetation on effective shade in Eightmile Creek.

Restored Vegetation B is identical to Restored Vegetation A, with the exception that areas associated with existing infrastructure (i.e., roads, buildings, houses) are not set to system potential vegetation conditions but instead to current conditions (in this case, land cover codes associated with newly acquired LiDAR data). This scenario acknowledges that the removal of such infrastructure is highly unlikely.

The Topographic Shade scenario represents the effective shade from natural topography by removing all vegetation and anthropogenic landcover such as houses and buildings.

Mean effective shade was calculated for the Current Condition, Restored Vegetation A, and Topographic Shade scenarios and is summarized in Table 5-25. The difference in mean effective shade between the Current Condition and Restored Vegetation A scenarios is equal to about 15 percentage points.

Figure 5-25 compares effective shade predictions from the Current Condition, Restored Vegetation A, and Topographic Shade scenarios for Ramsey Creek.

Figure 5-26 shows the difference in effective shade predictions between the Current Condition and Restored Vegetation A scenarios for Ramsey Creek.

Figure 5-27 shows the difference in effective shade predictions between the Current Condition and Topographic Shade scenarios for Ramsey Creek.

Table 5-25: Summary of mean effective shade between the Current Condition, Restored Vegetation A, and Topographic Shade scenarios for Ramsey Creek.

Scenario	Mean Effective Shade (%)
Current Condition	78
Restored Vegetation A	93
Shade Gap (Restored – Current)	15
Topographic Shade	32

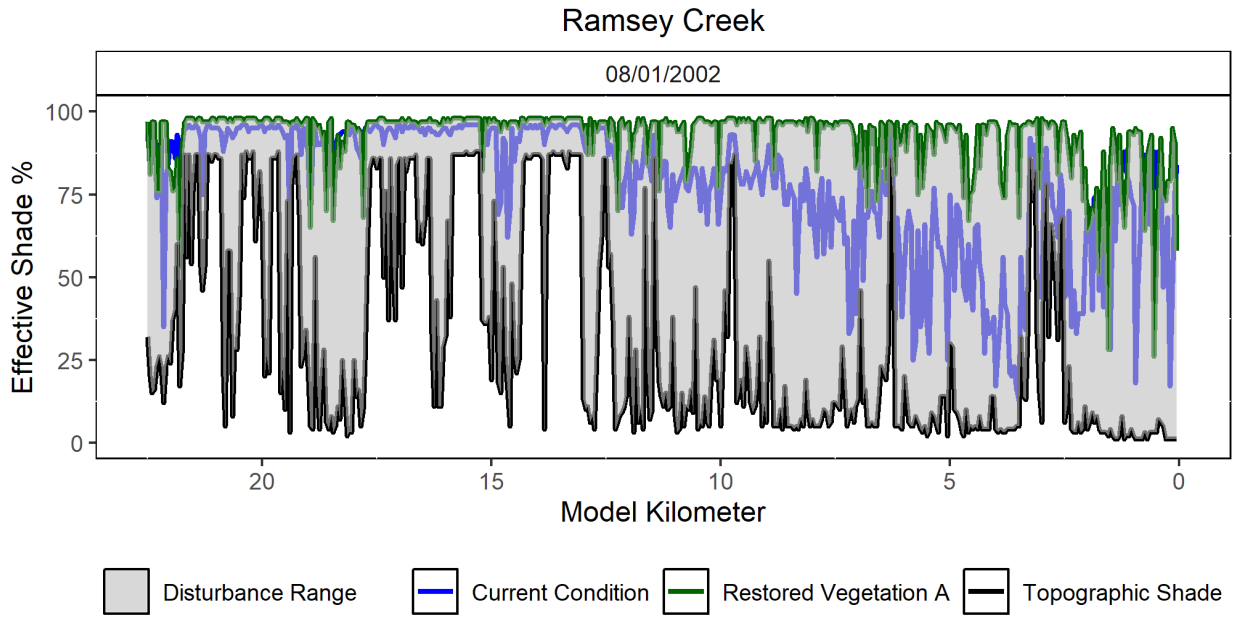


Figure 5-25: Comparison of effective shade from the Current Condition, Restored Vegetation A, and Topographic Shade scenarios for Ramsey Creek.

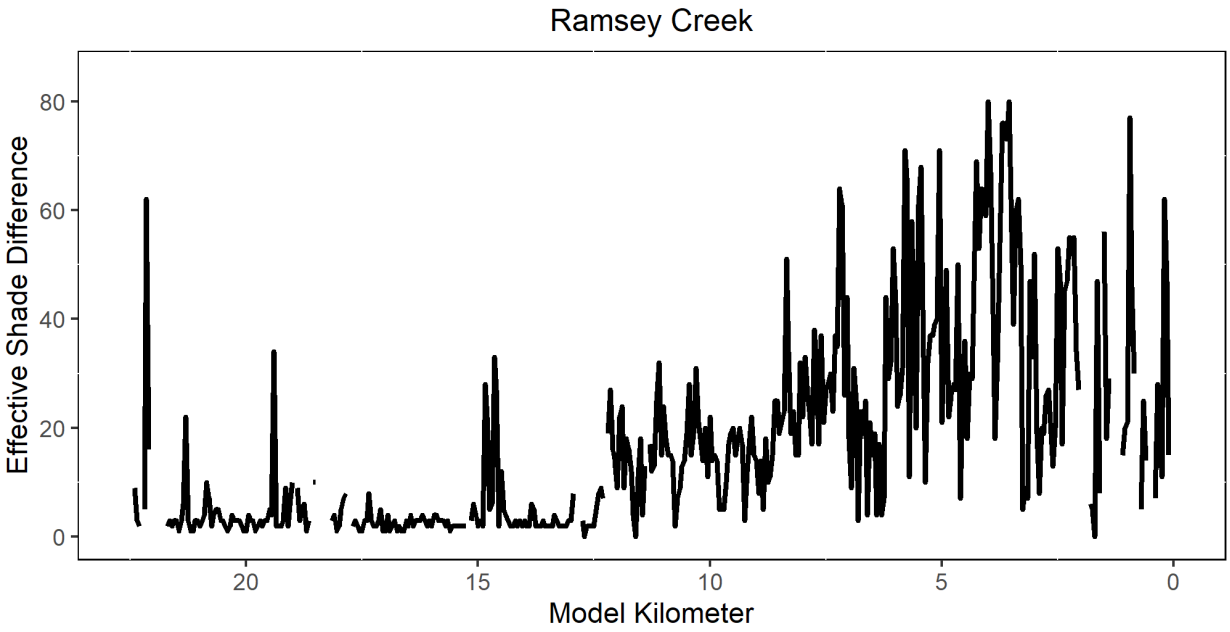


Figure 5-26: Percentage point difference between effective shade from the Current Condition and Restored Vegetation A scenarios on 8/1/2002 for Ramsey Creek. Missing values indicate that the shade difference is negative due to instances of higher effective shade in the Current Condition scenario versus the Restored Vegetation scenario.

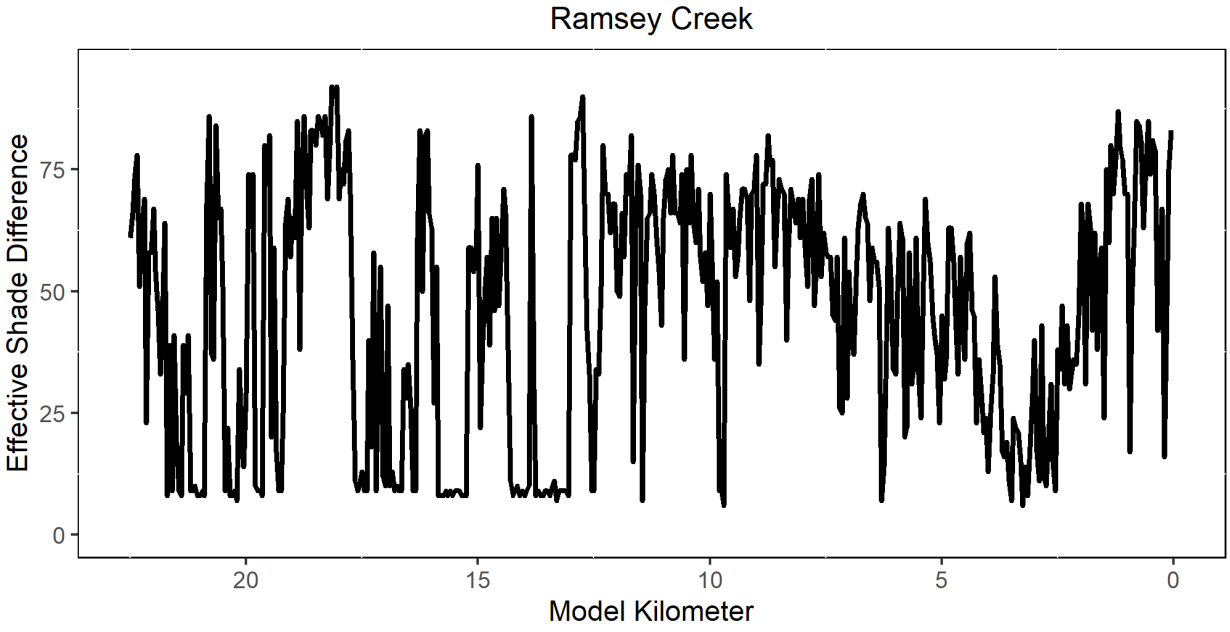


Figure 5-27: Percentage point difference between effective shade from the Current Condition and Topographic Shade scenarios on 8/1/2002 for Ramsey Creek.

6 References

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