Technical Support Document

Willamette River Subbasins TMDL - DRAFT

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State of Oregon
DEQ Department of Environmental Quality

This document was prepared by
Oregon Department of Environmental Quality
Program Name
700 NE Multnomah Street, Suite 600
Portland Oregon, 97232
Contact: Contact
Phone: 503-555-5555
www.oregon.gov/deq

State of Oregon
DEQ Department of Environmental Quality

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800-452-4011 | TTY: 711 | deqinfo@deq.oregon.gov

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1 Introduction

1.1 Document purpose and organization

This document provides comprehensive supporting information on technical analyses completed for the Total Maximum Daily Load and Water Quality Management Plan for addressing temperature impairments in the waters of the Willamette River Subbasins. This document provides explanation of TMDL concepts and analysis and support for conclusions and requirements included in the Willamette River Subbasins TMDL and WQMP, which are proposed for adoption by Oregon's Environmental Quality Commission, by reference, into rule [add OAR 340-042-0090(xx) post adoption].

This document is organized into sections with titles reflective of the TMDL elements required by OAR 340-042-0040(4) in the Willamette River Subbasins TMDL for temperature. This organization is intended to assist readers to readily access the information relied on for TMDL element-specific determinations.

1.2 Overview of TMDL elements

According to OAR 340-042-0030 Definitions (15): Total Maximum Daily Load means a written quantitative plan and analysis for attaining and maintaining water quality standards and includes the elements described in OAR 340-042-0040. Determinations on each element are presented in the Willamette River Subbasins TMDL for temperature. Technical and policy information supporting those determinations are presented in this report at the section headings that correspond to the TMDL elements for which complex analysis was undertaken.

In plain language, a TMDL is a water quality budget plan to ensure that the receiving water body can attain water quality standards that protect beneficial uses of the water. This budget calculates and assigns pollutant loads for discharges of point (end of pipe) and non-point (landscape) sources, in consideration of natural background levels, along with determination of a margin of safety and reserve capacity.

A margin of safety takes into account the uncertainty in predicting how well pollutant reductions will result in meeting water quality standards and can be expressed either explicitly, as a portion of the allocations, or implicitly, by incorporating conservative assumptions in the analyses. Reserve capacity sets aside some portion of the loading capacity for use for pollutant discharges that may result from future growth and new or expanded sources.

A key element of analysis is the amount of pollutant that a waterbody can receive and still meet the applicable water quality standard is referred to as the "loading capacity" of a waterbody. Because the loading capacity must not be exceeded by pollutant loads from all existing sources plus the margin of safety and reserve capacity, it can be considered the maximum load. Hence, the loading capacity is often referred to as the TMDL.

Another key element of analysis is allocating portions of the loading capacity or TMDL to known sources. Allocations are quantified measures that assure water quality standards will be met and may distribute the pollutant loads between nonpoint and point sources. "Load allocations" are portions of the loading capacity that are attributed to: 1) non-point sources such as urban, agriculture, rural residential or forestry activities; and 2) natural background sources such as soils or wildlife. “Wasteload allocations” are portions of the total load that are allotted to point sources of pollution, such as permitted discharges from sewage treatment plants, industrial wastewater or stormwater. As noted above, allocations can also be reserved for future uses, termed “reserve capacity.”

This general TMDL concept is represented by the following equation:

TMDL = ∑Wasteload Allocations + ∑Load Allocations + Reserve Capacity + Margin of Safety

Together, these elements establish the pollutant loads necessary to meet the applicable water quality standards for impaired pollutants and protect beneficial uses.

2 Location

The Willamette Subbasins Temperature TMDL includes all perennial and intermittent streams, located in the Middle Fork Willamette Subbasin (HUC 17090001), Coast Fork Willamette Subbasin (HUC 17090002), Upper Willamette Subbasin (HUC 17090003), McKenzie Subbasin (HUC 17090004), North Santiam Subbasin (HUC 17090005), the South Santiam Subbasin (HUC 17090006), Middle Willamette Subbasin (HUC 17090007), Molalla-Pudding Subbasin (HUC 17090009), Clackamas Subbasin (HUC 17090011), and Lower Willamette Subbasin (HUC 17090012). Waters excluded from the Willamette Subbasins TMDLs (Table 2.2) include the Willamette River, Multnomah Channel, and tributaries to the Willamette River downstream of the following dams: River Mill Dam, Detroit Dam, Foster Dam, Fern Ridge Dam, Cougar Dam, Blue River Dam, Dexter Dam, Fall Creek Dam, Cottage Grove Dam. The temperature TMDLs also do not include the section of the Columbia River that flows through the Lower Willamette Subbasin (HUC 17090012).

The map in Figure 1 provides an overview of where the temperature TMDLs are applicable. Appendix E of the Willamette Subbasin Technical support document, provides a list of all assessment units addressed by the TMDL.

The Willamette Subbasins is comprised of ten 10-digit subbasins as listed in Table 2.1.

Table 2.0.1 The Willamette Subbasins.

HU10 code	Subbasin Name
17090001	Middle Fork Willamette
17090002	Coast Fork Willamette
17090003	Upper Willamette
17090004	McKenzie
17090005	North Santiam
17090006	South Santiam
17090007	Middle Willamette
17090009	Molalla-Pudding
17090011	Clackamas
17090012	Lower Willamette

Table 2.0.2 Waters not included in the Willamette Subbasins Temperature TMDLs.

Waterbody	Extent
Willamette River	From the confluence of the Columbia River upstream to the confluence of Coast Fork of the Willamette and Middle Fork of the Willamette Rivers.
Multnomah Channel	From the confluence of the Columbia River upstream to The Willamette River.
Clackamas River	From the confluence with the Willamette River upstream to River Mill Dam.
Clackamas River	From the confluence with the Willamette River upstream to River Mill Dam.
Santiam River	From the confluence with the Willamette River upstream to the confluence of the North and South Santiam Rivers.
North Santiam River	From the confluence with the Santiam River upstream to Detroit Dam.
South Santiam River	From the confluence with the Santiam River upstream to Foster Dam.
Long Tom River	From the confluence with the Willamette River upstream to Fern Ridge Dam.
McKenzie River	From the confluence with the Willamette River upstream to the confluence with the South Fork McKenzie River.
South Fork McKenzie River	From the confluence with the McKenzie River upstream to Cougar Dam.
Blue River	From the confluence with the McKenzie River upstream to Blue River Dam.
Middle Fork Willamette River	From the confluence with the Willamette River upstream to Dexter Dam.
Fall Creek	From the confluence with the Middle Fork Willamette River upstream to Fall Creek Dam.
Coast Fork Willamette River	From the confluence with the Willamette River upstream to Cottage Grove Dam.
Row River	From the confluence with the Coast Fork Willamette River upstream to Dorena Dam.

2.1 Climate

The Willamette Basin has a temperate maritime climate with mild, wet winters and warm, dry summers. According to PRISM normals of annual conditions over the past 30 years (1991-2020), the average annual precipitation in the Willamette Basin ranges from around 985 mm (38”) in the lower elevations of the Willamette Valley to over 4,160 mm (160”) in the higher elevations of the Cascade Range (PRISM Climate Group, 2022) (Figure 2.1). The highest precipitation levels are typically seen during the winter months, with November to January being the wettest months. In contrast, the summer months are generally drier, with July and August being the driest months of the year.

In terms of temperature, the PRISM normals show that the average annual temperature in the Willamette Basin is around 15.3°C (59.6°F). However, temperatures can vary greatly depending on elevation and the time of year. The average annual maximum temperatures in the Willamette Basin range from 2.7°C (37°F) in the Willamette Valley to about 18°C (64°F) at the Cascade Range (Figure 2.2). The summer months are typically warm, with average temperatures of 26°C (78.8°F) in July and August. On the other hand, the winter months are cooler, with average temperatures of 6°C (42.8°F) in December and January.

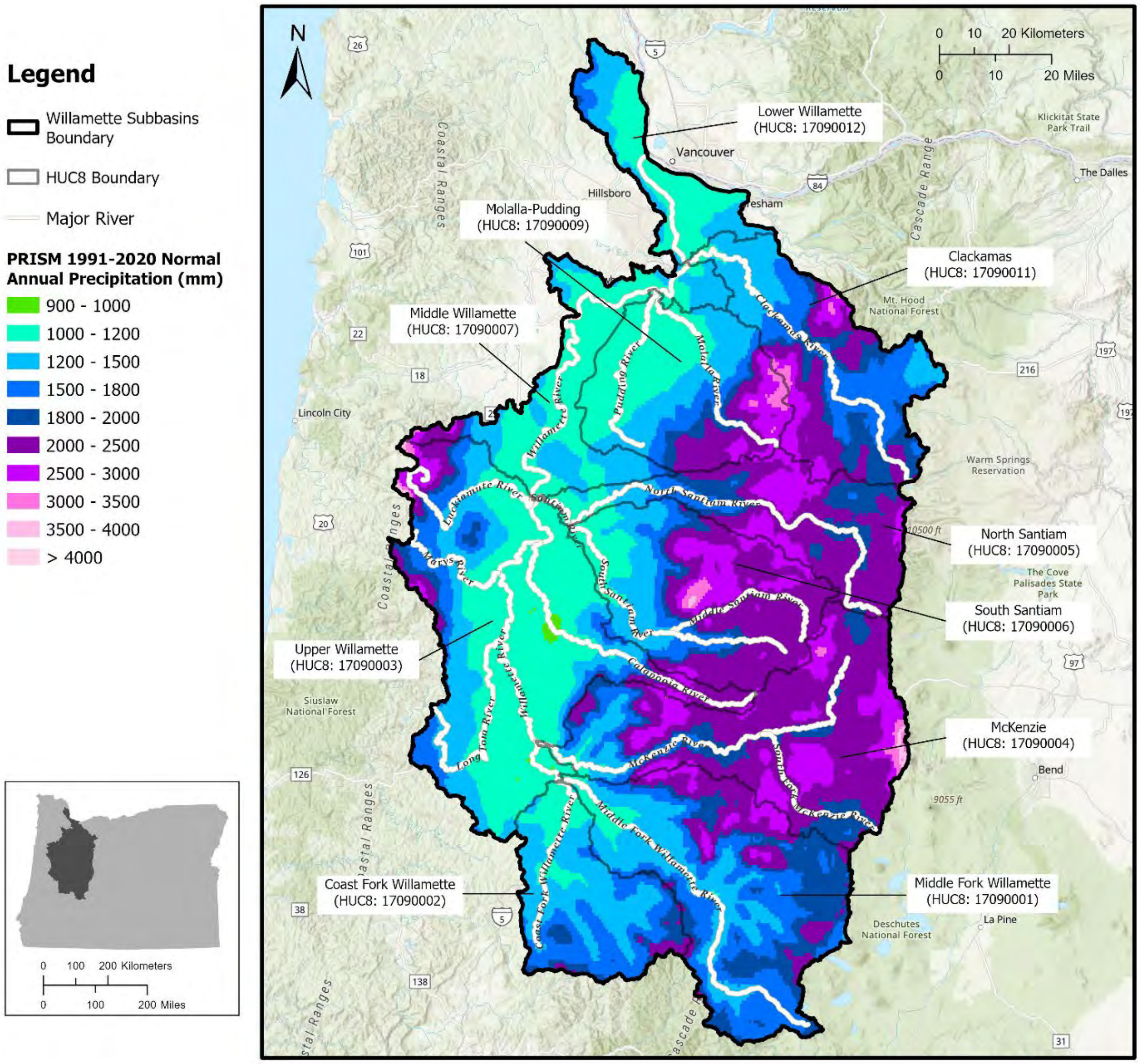


Figure 2.1 PRISM 1991-2020 Normal Annual Precipitation in the Willamette Subbasins TMDL project area (Data Source: PRISM Climate Group, 2022).

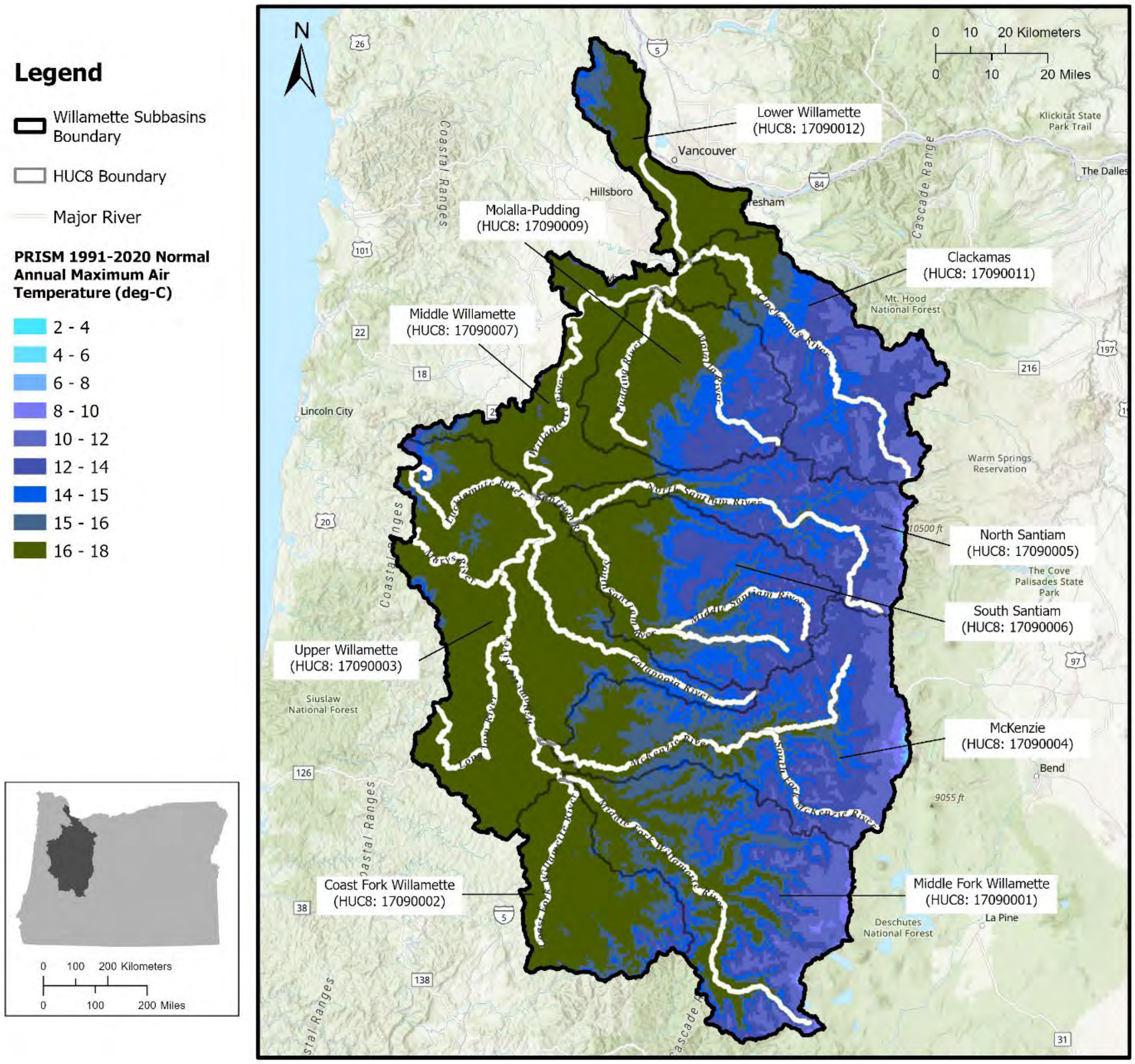


Figure 2.2 PRISM 1991-2020 Normal Annual Maximum Air Temperature in the Willamette Subbasins TMDL project area (Data Source: PRISM Climate Group, 2022).

2.2 Hydrology

The Willamette Basin drains approximately 29,785 km^2 (11,500 mi^2) in northwestern Oregon between the Cascade and Coast Ranges (Figure 2.3). The Willamette River is formed by the confluence of two major tributaries, the Coast Fork Willamette River and the Middle Fork Willamette River. The Coast Fork originates in the foothills of the Cascade Mountains, while the Middle Fork originates in the high Cascades. These two rivers merge near the city of Eugene, Oregon, to form the Willamette River, which then travels about 187 miles before flowing into the Columbia River at River Mile 101, at Portland.

The Willamette Basin includes numerous major tributaries, including the Coast Fork Willamette River, the Middle Fork Willamette River, the McKenzie River, the Long Tom River, the Calapooia River, the Santiam River, and the Clackamas River. The Willamette River mainstem and lower reaches of major tributaries downstream from dams are not included in this TMDL; instead, they are covered by the Willamette River Mainstem and Major Tributaries TMDL.

The Willamette Basin also has many smaller tributaries, where small streams flow into larger ones, which ultimately flow into the Willamette River. The smaller tributaries in the Willamette Basin include the Pudding River, Molalla River, Little North Santiam River, Luckiamute River, and Mohawk River, which are covered in this TMDL.

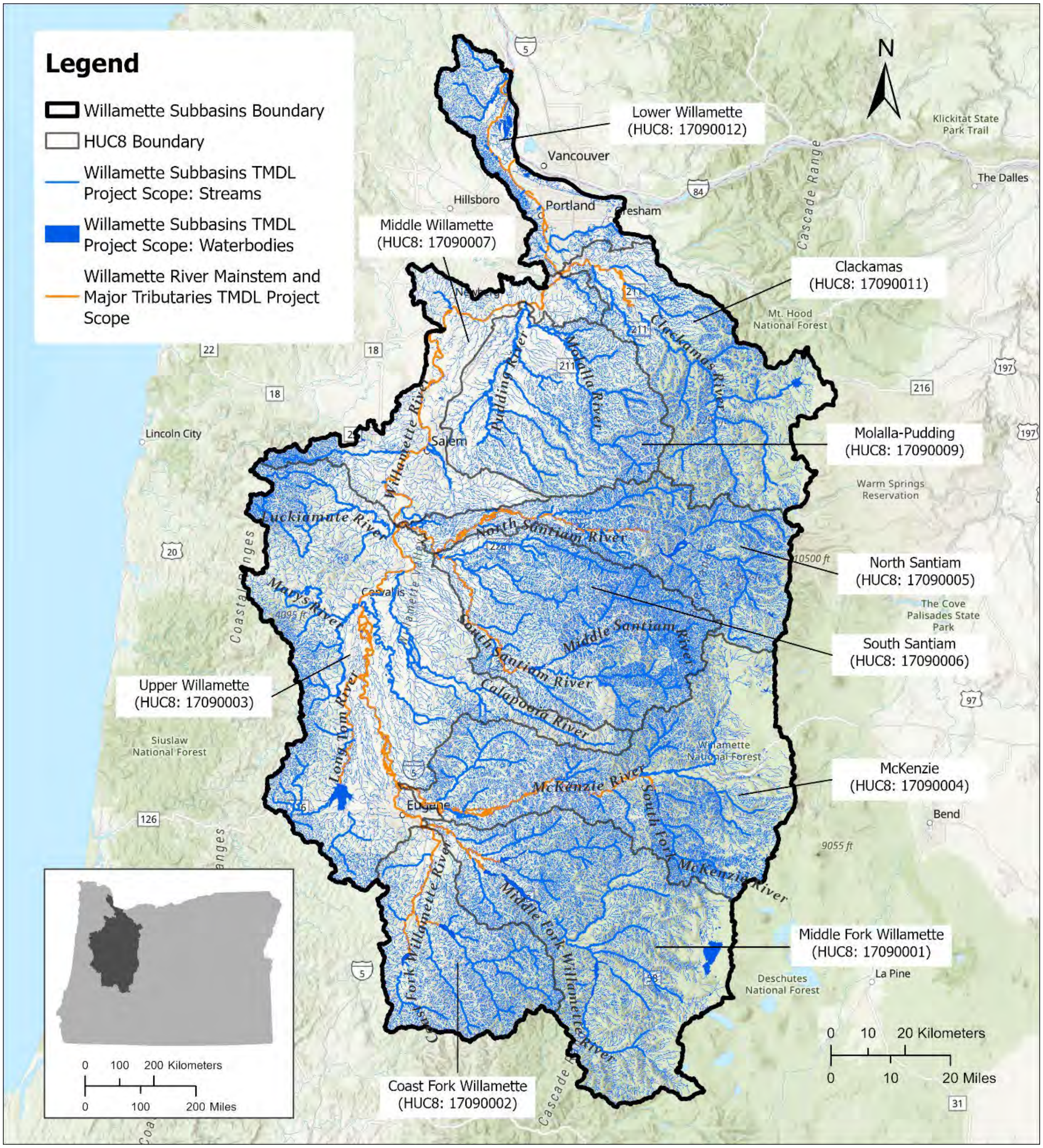


Figure 2.3 Waterbodies in the Willamette Subbasins temperature TMDLs project area.

Dams and reservoirs have a significant influence on the hydrology in the Willamette Basin. The U.S. Army Corps of Engineers (USACE) constructed a series of 11 dams with reservoirs and 2 re-regulating dams on major tributaries in the basin between 1941 and 1969, known as the Willamette Valley Project (Table 2.2). USACE operates the Willamette Valley Project based on the purposes authorized by Congress with the Flood Control Act of 1938. Flood control is the highest priority of the Willamette Project, but other purposes include flow augmentation for navigation, irrigation, hydroelectric power production, fisheries, recreation, and water quality. The project provides the capacity of seasonal storage of nearly 1.6 million acre feet of water and a production capacity of 2,100 megawatts (MW) of electric power (USACE, 2019).

In addition to these large federal dams, there are Portland General Electric (PGE)'s dams and reservoirs on the Clackamas River, Eugene Water and Electric Board (EWEB) operated projects in the McKenzie Subbasin, and over 350 smaller dams and reservoirs throughout the basin that are operated by local irrigation districts, municipalities, and private companies.

[map of dams and reservoirs in the Willamette Subbasins]

Table 2.0.3 Summary of USACE dams in the Willamette Basin.

Dam & Reservoir	Tributary Location	Year Complete	Total Storage in acre-feet	Summary Storage	# of Rec Areas	Power Generators	Drawdown Priority
Blue River	Blue River	1969	89,500	78,800	3	None	3rd
Cottage Grove	Coast Fork Willamette River	1942	32,900	28,700	5	None	5th
Fern Ridge	Long Tom River	1941	116,800	93,900	5	None	Last
Dexter	MF Willamette River	1954	NA, Reregulating	NA	2	1	NA
Lookout Point	MF Willamette River	1954	455,800	324,200	6	3	1st
Hills Creek	MF Willamette River	1961	355,500	194,000	5	2	4th
Fall Creek	MF Willamette River	1966	125,000	108,200	5	None	5th
Green Peter	Middle Santiam River	1968	428,100	249,900	3	2	5th
Big Cliff	North Santiam River	1953	NA, Reregulating	NA	None	1	NA
Detroit	North Santiam River	1953	455,100	281,000	7	2	Last
Dorena	Row River	1949	77,600	65,000	5	None	5th
Cougar	SF McKenzie River	1963	219,000	143,900	6	2	2nd

Dam & Reservoir	Tributary Location	Year Complete	Total Storage in acre-feet	Summary Storage	# of Rec Areas	Power Generators	Drawdown Priority
Foster	South Santiam River	1968	60,700	24,800	6	2	Last

Willamette Project reservoirs attenuate flood flows and hold spring runoff from the Coast Range and Cascade Mountains. Stored water is released when reservoir capacity is met or to augment stream flows during the dry months of summer and early fall. As currently constructed and operated the release of water from Willamette Project reservoirs modifies natural temperature patterns downstream during late summer and early fall, but also during spring and early summer as well. The temperature seasonal shifts occur because stored water in reservoirs stratifies and the reservoirs were constructed with regulating outlets near the bottom of each structure. The only exception to bottom released water outlets is Cougar reservoir which has been structurally modified to allow “selective withdrawal” of stratified waters.

Seasonal pattern shifts are of concern because water temperature triggers aquatic life activities such as spawning, length of time needed for incubation and fry emergence. The food supplies (macroinvertabrates) salmonids rely on are also affected by seasonal temperature shifts. In late summer and into autumn, the reservoirs are drawn down to provide flood storage capacity for the coming winter precipitation. During this time, thermal stratification in the reservoirs breaks down but reservoir water temperatures remain warmer than inflowing upstream tributary temperatures. This is also the season when fall spawning fish have moved into reaches below the reservoirs to wait for spawning. Salmon and trout will hold in the coldest water they can find to wait for stream temperatures to cool enough to trigger their spawning migration.

Alternately, colder, winter waters are released during spring and into early summer when inflowing upstream tributary temperatures are warmer than stored reservoir waters. This is the season when fall spawned fry should be emerging but the colder water shifts their emergence timing. Spring spawning is also delayed until winter water temperatures warm enough to trigger spawning. Late spring spawning can mean that fry emergence occurs when summer water temperatures are too warm for emerging fry.

In 2008, the U.S. Fish and Wildlife Service and National Oceanic and Atmospheric Administration Fisheries issued the Willamette River basin Biological Opinion (BiOp) in consultation with the US Army Corps of Engineers, the Bonneville Power Administration and the Bureau of Reclamation to address the impacts of federal projects on listed species of fish in the Willamette Basin, including chinook salmon and steelhead. The BiOp includes measures to improve fish habitat, manage water flows, and reduce the impact of dams and other infrastructure on fish populations. The goal of the BiOp is to ensure that federal projects in the Willamette Basin do not jeopardize the survival and recovery of listed species. The BiOp is periodically updated to reflect new information and changes in project operations, and it is an important tool for protecting and restoring endangered fish populations in the Willamette Basin. The BiOp was updated in 2019 to include additional measures to address climate change and improve fish passage at dams (USACE, 2019).

2.3 Land Use

Forestry, agriculture and urban uses dominate land use in the Willamette Subbasins TMDL project area, which are summarized in Table 2.3 and Figure 2.4 based on the 2019 National Land Cover Database (Dewitz and USGS, 2021). The majority of the basin is forestry accounting for about 68% of the land in the basin. Forests are mainly located from the higher elevations to the foothills of the Coast and Cascade mountain ranges. These forests are primarily composed of Douglas fir and other conifers, and provide important habitat for a variety of wildlife, including salmon and steelhead. The land cover of the lower elevations of the basin is more heavily influenced by agriculture and urbanization. Agricultural land covers about 19% of the basin, including pasture and crops. Urban areas are prominent, with a total of 75 cities, including the three largest cities in the state (Portland, Eugene, and Salem). According to the 2010 census data, more than two million individuals, which accounts for over 50% of Oregon's overall population, reside in the Willamette Basin. This region is also identified as the most rapidly developing area in the state.

Table 2.0.4 Summary of land uses in the Willamette Subbasins TMDL project area based on the 2019 National Land Cover Database.

2019 NLCD Land Cover	Acres	Percent of Total Area
Evergreen Forest	3723099.4	58.30
Hay/Pasture	817292.4	12.80
Cultivated Crops	404290.1	6.30
Shrub/Scrub	346706.4	5.40
Mixed Forest	197931.8	3.10
Herbaceous	165112.3	2.60
Developed, Low Intensity	156196.8	2.40
Developed, Open Space	142817.1	2.20
Developed, Medium Intensity	130316.7	2.00
Open Water	75347.9	1.20
Woody Wetlands	63695.8	1.00
Developed, High Intensity	55271.5	0.90
Emergent Herbaceous Wetlands	54148.8	0.80
Barren Land	31091.2	0.50
Deciduous Forest	25684.6	0.40
Perennial Snow/Ice	2126.5	0.03

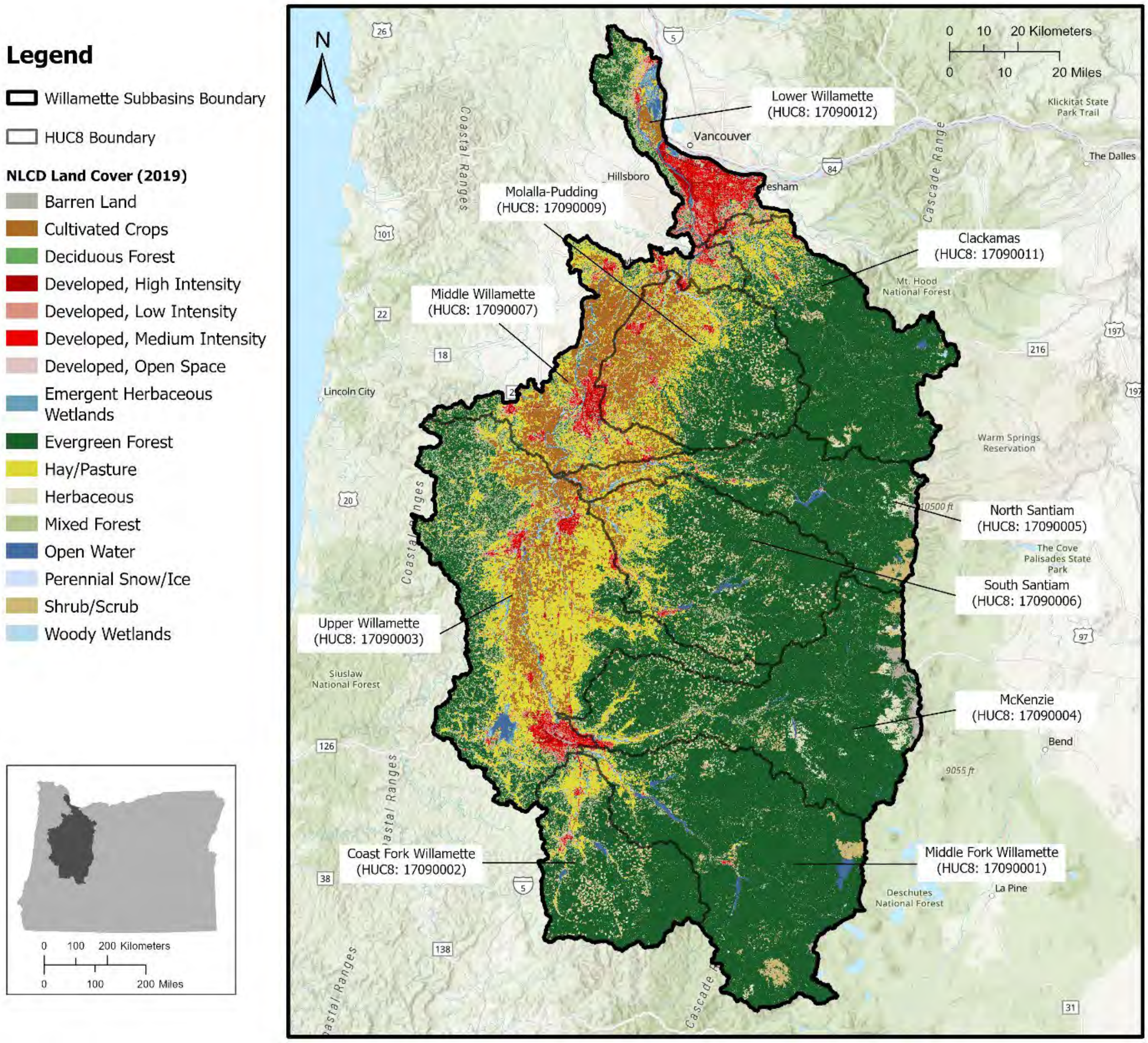


Figure 2.4 Land uses in the Willamette Subbasins TMDL project area based on the 2019 National Land Cover Database. (*Note: Shrub/Scrub and Herbaceous land uses can be areas where forest clearcuts have occurred and would be classified as forest after regrowth.)*

2.4 Land Ownership and Jurisdiction

The Willamette Subbasins TMDL project area is a complex landscape with a variety of landowners and jurisdictions (Figure 2.5). Land ownership within the subbasins includes private individuals, corporations, state and federal agencies, and tribal governments. Private individuals and corporations own the majority of the land in the basin, accounting for about 56%, particularly in the Willamette Valley where agriculture and urbanization are more prevalent. Federal agencies, such as the U.S. Forest Service and the Bureau of Land Management, own and manage those portions of forested lands, accounting for about 34.4% and 5.5% of the basin, respectively. The Oregon Department of Forestry manages about 27% of the land in the basin, including both private and public lands. Tribal governments also have important land ownership and management roles within the basin. The Confederated Tribes of Warm Springs has land holdings within the basin and have treaty rights to fish and hunt in the area.

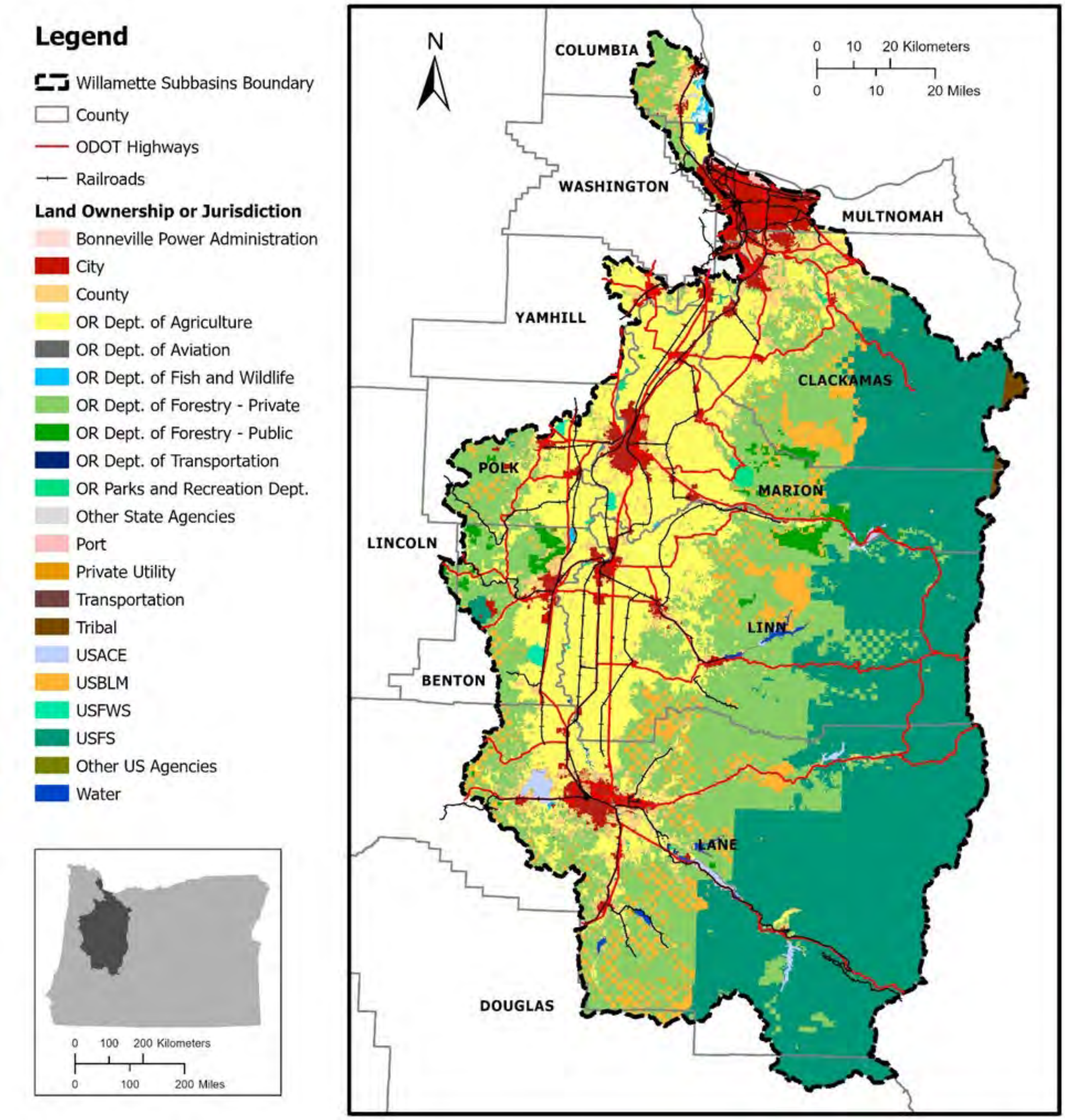


Figure 2.5 Designated management agencies (DMAs) in the Willamette Subbasins temperature TMDL project area.

3 Temperature water quality standards and beneficial uses

Temperature water quality standards are set to protect the most sensitive beneficial uses for fish and aquatic life. The temperature water quality standards for the Willamette Subbasins are based on the rolling seven-day average daily maximum (7DADM) and include the following numeric criteria:

- Bull trout spawning and juvenile rearing: 12°C (53.6°F) (OAR 340-041-0028(4)(f))
- Salmon and steelhead spawning: 13.0°C (55.4°F) (OAR 340-041-0028(4)(a))
- Core cold water habitat: 16.0°C (60.8°F) (OAR 340-041-0028(4)(b))
- Salmon and trout rearing and migration: 18.0°C (64.4°F) (OAR 340-041-0028(4)(c))
- Salmon and steelhead migration corridors: 20.0°C (68.0°F) (OAR 340-041-0028(4)(d))

[Cool water species narrative]

The locations and periods of criteria applicability are determined from designated fish use maps in OAR 340-041-0340 Figure 340A and Figure 340B. For the rivers and streams in the Willamette River Subbasins, Figure 3.1 shows various designated fish uses and applicable criteria, while Figure 3.2 specifically shows salmon and steelhead spawning use designation, based on the National Hydrography Dataset (NHD).

The temperature standard authorizes insignificant anthropogenic heat additions in waters that exceed applicable temperature criteria as follows: following a temperature TMDL or other cumulative effects analysis, the Human Use Allowance (HUA) will restrict all NPDES point sources and nonpoint sources to a cumulative increase of ≥0.3°C (OAR 340-041-0028(12)(b)).

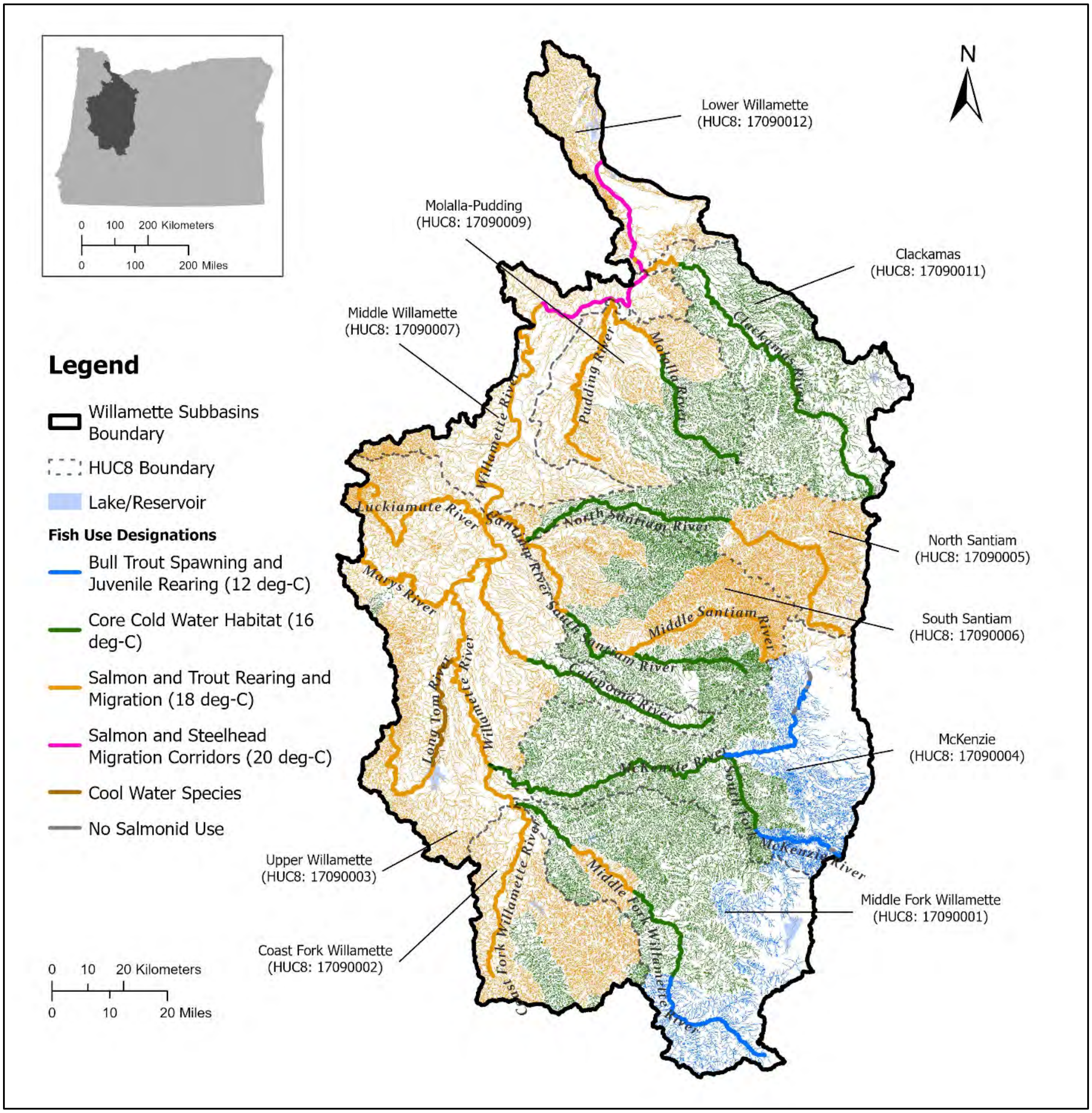


Figure 3.1 Fish use designations in the Willamette Subbasins TMDL project area.

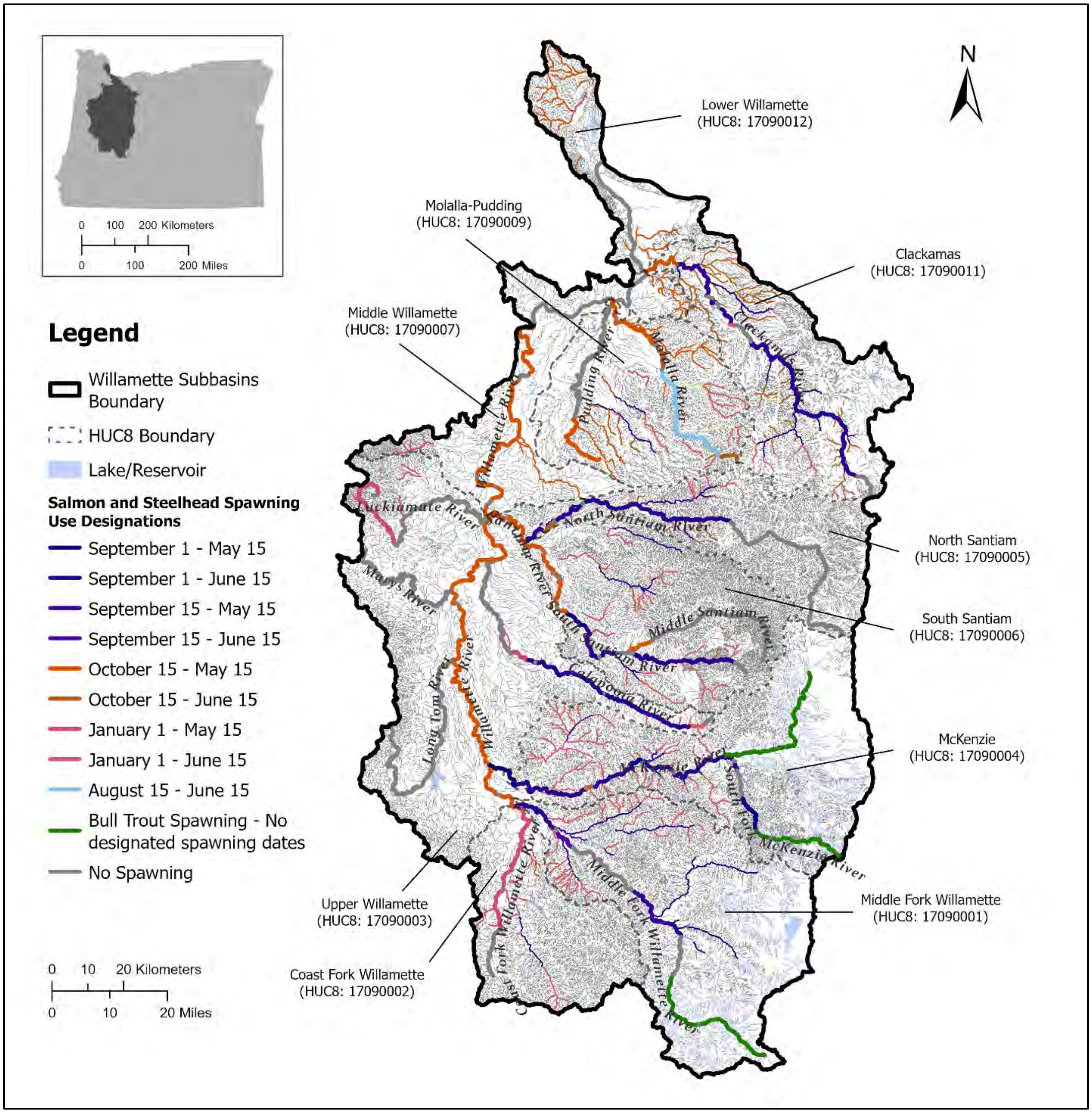


Figure 3.2 Salmon & steelhead spawning use designations in the Willamette Subbasins TMDL project area.

4 Water Quality Data Evaluation and Analyses

A critical TMDL element is water quality data evaluation and analysis to the extent that existing data allow. To understand the water quality impairment, quantify the loading capacity, and assess the ability of various possible scenarios to achieve the TMDL and applicable water quality standards, the analysis requires a predictive component. Certain models provide a means to evaluate potential stream warming sources and, to the extent existing data allow, their current and potential pollutant loads. Heat Source model was used in this effort and is described in Appendix B.

4.1 Analysis overview

The modeling framework needs for this project included the abilities to predict/evaluate hourly:

1. Stream temperatures spanning months at ≤500m longitudinal resolution.
2. Solar radiation fluxes and daily effective shade at ≤100m longitudinal resolution.
3. Stream temperature responses due to changes in:
    a. Streamside vegetation,
    b. Water withdrawals and upstream tributaries' stream flow,
    c. Channel morphology in the upstream catchment,
    d. Effluent temperature and flow discharge from NPDES permitted facilities.

To function properly, water quality models have specific input and calibration data requirements. Data collected for this TMDL analysis are summarized in Figure 4.1 and Table 4.1 and described more fully in Appendix B. All data are available upon request. Figure 4.1 also provides an overview of the analyses completed for this TMDL, which are described in the remaining sections of this TSD.

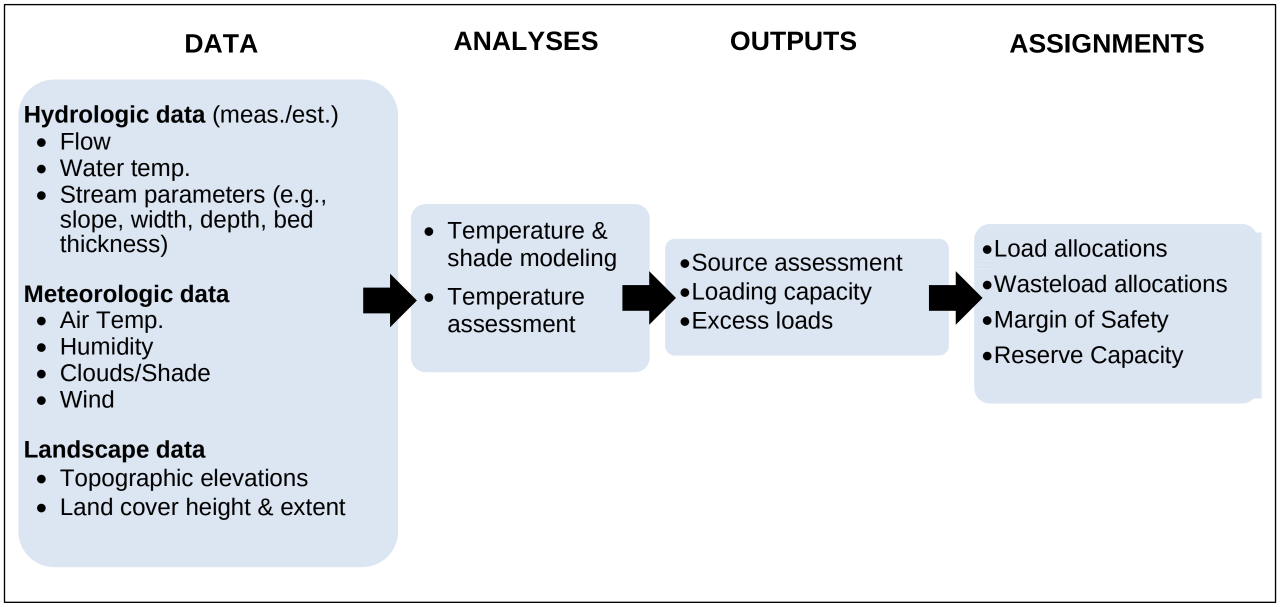


Figure 4.1 Willamette River Subbasins temperature analysis overview.

4.2 Data overview

As illustrated in Figure 4.1, data for numerous hydrologic, meteorologic, and landscape/ geographic parameters within the spatial and temporal boundaries of the TMDL are required to conduct effective analysis for TMDL development. Section 2 of Appendix B to this document describes these parameters, their applications in this TMDL development, and provides information on the specific datasets and sources utilized for this effort. All data are available upon request.

Table 4.0.1 Data types used in the Willamette River Subbasins Temperature TMDL modeling.

Data Source Type	Dataset Types	Data Sources
Field-acquired	• Continuous stream temperature • Stream flow rate: continuous & instantaneous • Point source discharge temperatures & flows	DEQ Ambient Water Quality Monitoring System (AWQMS); USGS National Water Information System (NWIS); DEQ data solicitation responses; Portland Water Bureau; 2016 NPDES Discharge Monitoring Reports
GIS and/or remotely sensed	• 3-ft Digital Elevation Model (DEM) • Light Detection and Ranging (LiDAR) • Aerial imagery: Digital Orthophoto Quads (DOQs) • Thermal Infrared Radiometry (TIR) temperature data	Oregon Department of Geology and Mineral Industries (DOGAMI); Oregon LiDAR Consortium (OLC); Watershed Sciences, Inc.
Derived from above data types via: (a) quantitative methods or (b) proxy substitution (for certain tributary flows & temps.)	• Stream position, channel width, channel bottom width, elevation, gradient • Topographic shade angles • Land cover mapping • Tributary flows & temperatures	DEMs, LiDAR, DOQs (for stream morphology, land cover, topography, & geography); USGS StreamStats, historical data, proxy site data, estimated (constant) data (for tributary flows & temperatures if direct 2016 monitoring data were unavailable)

4.1.1 The 7Q10 low-flow statistic

The “7Q10” is a summary low-flow statistic equal to the lowest seven-day average flow that occurs once every ten years (on average). For the Willamette River Subbasins temperature TMDL, estimated 7Q10s used to calculate numeric loading capacities and allocations. DEQ calculated annual 7Q10s for temperature-impaired streams in the Willamette River Subbasins (Table 4.2), and for the receiving waterbodies that have NPDES permitted discharges with a waste load allocation (Table 4.3).

The 7Q10 estimates were based on the following approaches:

1) If sufficient daily mean flow data from USGS or OWRD gaging stations were available for a given waterbody, 7Q10 estimates were calculated using these data. Available flow data were retrieved for up to a 30-year period (October 1, 1992 to September 31, 2022). DEQ relied on quality control protocols implemented by USGS and OWRD. Only data with a result status of “Approved” (USGS) or “Published” (OWRD) were included in 7Q10 calculations. 7Q10s were calculated by the method of EPA’s DFLOW program (Rossman, 1990), which computes extreme design flows using the log-Pearson Type III probability distribution. A minimum of 10 years of flow data were used with some exceptions. For ungaged locations, if there were sufficient gage data from confluent streams, 7Q10 were estimated from (a) the sum of mean daily flows (for upstream

gages), or (b) the difference of mean daily flows (for downstream gages), prior to application of the DFLOW procedure.

2) If insufficient daily mean flow data from USGS and OWRD stream flow gaging stations were available, the web-based tool StreamStats (USGS) was used to estimate 7Q10s. Details of StreamStats are described below.

3) 7Q10s calculated and reported elsewhere (e.g. consultant studies, water quality permits, TMDLs) may have been used. In such cases, DEQ relied on the source's data quality.

4) For tidally-influenced streams, DEQ reviewed each situation and made 7Q10 estimates based on the best available data from the relevant gaging stations. Methods are described for each case.

StreamStats version 4 is a web-based geographic information system (GIS) application developed by the USGS (https://streamstats.usgs.gov/ss/). StreamStats has a map-based interface that allows the user to determine drainage area delineations, basin characteristics, and estimates of stream flow statistics for user-selected locations along available streams. The program also provides users with access to stream monitoring data by selecting USGS data-collection stations in the map application and providing access to flow statistics and other information for the stations. StreamStats provides estimates of various stream flow statistics for user-selected sites by solving site-specific regression equations. The regression equations were developed through a process, known as regionalization, which involves use of regression analysis to relate stream flow statistics computed for a group of selected stream gages (usually within a state) to basin characteristics measured for the stream gages. Basin characteristics are used to obtain estimates of the stream flow statistics for ungaged sites.

StreamStats regression equations for Oregon were developed by Cooper (2005) and Risley et al. (2008). These equations were based on basin characteristics and flow statistics (e.g., historical percentile flow-exceedance values and annual and monthly 7Q10). Flow statistics were computed at 466 gaging stations across Oregon and proximal out-of-states areas. This study area was divided into 10 regions based on ecological, topographic, geologic, hydrologic, and climatic criteria. StreamStats includes 910 annual and monthly regression equations to estimate 7Q10s for ungaged stream sites in the 10 aforementioned regions. These equations were developed for unregulated streams (without major dams, constructed reservoirs, catchment development, or significant diversions/withdrawals). If the equations are applied to ungaged streams subject to such influences, the resultant estimates may require adjustment to approximate actual flows.

The StreamStats user selects a stream location of interest and the program estimates the associated drainage area and summary flow statistics. For this TMDL, DEQ's procedure specified that selected stream locations should be the most downstream location on each stream for which DEQ required flow estimates; the exception was if DEQ required 7Q10 estimates for NPDES-permitted point source receiving waters, in which case the selected stream location was immediately upstream of the point source outfall. StreamStats also estimates basin characteristics for the selected catchment, including drainage area, mean annual precipitation, mean slope, and climactic characteristics (Cooper, 2005; Risley et al., 2008). If estimates are outside suggested parameter ranges, the warning message "extrapolated with uncertainty" appears in the StreamStats report.

Table 4.0.2 The 7Q10 low-flow estimates for modeled temperature-impaired rivers in the Willamette River Subbasins.

Assessment Unit Name	Assessment Unit ID	Estimated 7Q10 (cfs)	Flow Estimation Method	Flow Estimation Latitude/Longitude	Gage Period
Coyote Creek	OR_SR_1709000301_02_103796	5.9	StreamStats	44.052, -123.269	
Crabtree Creek	OR_SR_1709000606_02_103978	25.4	StreamStats	44.673, -122.946	
Johnson Creek	OR_SR_1709001201_02_104170	11.3	USGS: 14211550	45.453, -122.643	1992-10-01 ~ 2020-11-08
Little North Santiam River	OR_SR_1709000505_02_104564	21.1	USGS: 14182500	44.792, -122.579	1992-10-01 ~ 2021-10-19
Luckiamute River	OR_SR_1709000305_02_103829	16.3	USGS: 14190500	44.783, -123.235	1992-10-01 ~ 2022-09-30
Mohawk River	OR_SR_1709000406_02_103870	4.26	StreamStats	44.191, -122.84	
Mohawk River	OR_SR_1709000406_02_103871	15.9	USGS: 14165000	44.093, -122.957	1992-10-01 ~ 2020-10-15
Mohawk River	OR_SR_1709000406_02_103877	3.04	StreamStats	44.213, -122.827	
Molalla River	OR_SR_1709000904_02_104086	38.1	StreamStats	45.083, -122.488	
Mosby Creek	OR_SR_1709000201_02_103752	10.7	StreamStats	43.779, -123.011	
Pudding River	OR_SR_1709000901_02_104067	3.13	StreamStats	45, -122.842	
Pudding River	OR_SR_1709000905_02_104088	10.1	USGS: 14202000	45.233, -122.75	1993-06-21 ~ 2021-10-26
Thomas Creek	OR_SR_1709000607_02_103988	6.8	USGS: 14188800	44.712, -122.77	2002-10-01 ~ 2021-10-13
Thomas Creek	OR_SR_1709000607_02_103991	12.5	StreamStats	44.713, -122.719	

Table 4.0.3 The 7Q10 low-flow estimates for NPDES permitted discharges receiving a numeric waste load allocation in this TMDL.

Facility Name (Facility Number)	Stream	Estimated 7Q10 (cfs)	Flow Estimation Method	Flow Estimation Latitude/Longitude	Gage Period
Albany Water Treatment Plant (66584)	Calapooia River	24	StreamStats	44.635, -123.114	
Alpine Community (100101)	Muddy Creek	0.446	StreamStats	44.33, -123.352	
Americold Logistics, LLC (87663)	Claggett Creek	0	StreamStats	44.976, -123.001	
Arclin (16037)	28th Street Canal	0	StreamStats	44.058, -122.986	
Arclin (81714)	Columbia Slough	0	USGS: 14211820	45.639, -122.763	1992-10-01 ~ 2022-09-30
ATI Albany Operations (64300)	Oak Creek	1.38	StreamStats	44.602, -123.107	

Facility Name (Facility Number)	Stream	Estimated 7Q10 (cfs)	Flow Estimation Method	Flow Estimation Latitude/Longitude	Gage Period
Aumsville STP (4475)	Beaver Creek	0.659	StreamStats	44.852, -122.872	
Aurora STP (110020)	Pudding River	10.1	USGS: 14202000	45.233, -122.75	1993-06-21 ~ 2022-09-30
Blount Oregon Cutting Systems Division (63545)	Minthorne Creek	0	StreamStats	45.436, -122.612	
Boeing of Portland - Fabrication Division (9269)	Osburn Creek	0	StreamStats	45.541, -122.446	
Brownsville STP (11770)	Calapooia River	14.4	StreamStats	44.396, -122.998	
Coburg Wastewater Treatment Plant (115851)	Muddy Creek	0	StreamStats	44.152, -123.058	
Coffin Butte Landfill (104176)	Roadside ditch to Soap Creek tributary	0	StreamStats	44.698, -123.23	
Columbia Helicopters (100541)	Unnamed Stream RM 1.8 (Trib to Pudding River)	0	Assumed zero		
Corvallis Rock Creek WTP (20160)	Marys River	0	StreamStats	44.51, -123.456	
Creswell STP (20927)	Camas Swale Creek	0	StreamStats	43.928, -123.037	
Dallas STP (22546)	Rickreall Creek	4.2	StreamStats	44.92, -123.258	
Dallas WTP (22550)	Rickreall Creek	3.3	StreamStats	44.928, -123.363	
Duraflake (97047)	Murder Creek	0	StreamStats	44.664, -123.066	
Estacada STP (27866)	River Mill Reservoir	317	StreamStats	45.296, -122.347	
EWEB Carmen-Smith (28393)	McKenzie River Outfall 001A/B	146	StreamStats	44.2878, 122.0350	
EWEB Carmen-Smith (28393)	McKenzie River Outfall 002A/B	497.5	USGS: 14158850	44.268, -122.05	1992-10-01 ~ 2022-09-30
Falls City STP (28830)	Little Luckiamute River	5.34	StreamStats	44.865, -123.43	
Forrest Paint Co. (100684)	Amazon Creek	0	StreamStats	44.046, -123.128	

Facility Name (Facility Number)	Stream	Estimated 7Q10 (cfs)	Flow Estimation Method	Flow Estimation Latitude/Longitude	Gage Period
Foster Farms (97246)	Camas Swale Creek	0	StreamStats	43.93, -123.027	
Fujimi Corporation - SW Commerce Circle (107178)	Coffee Lake Creek	0	StreamStats	45.338, -122.779	
Georgia-Pacific Chemicals LLC (32864)	Amazon Creek	0	StreamStats	44.121, -123.19	
Gervais STP (33060)	Pudding River	33	StreamStats	45.108, -122.839	
GP Millersburg Resin Plant (32650)	Murder Creek	0	StreamStats	44.661, -123.069	
Halsey STP (36320)	Muddy Creek	4.99	StreamStats	44.383, -123.136	
Holiday Plaza (108298)	Unknown				
Hubbard STP (40494)	Mill Creek	0	StreamStats	45.186, -122.814	
Hull-Oakes Lumber Co. (107228)	Oliver Creek	0	StreamStats	44.36, -123.412	
International Paper Springfield Paper Mill (96244)	Outfall 003 - Storm Ditch near 42nd St.	0	StreamStats. Discharge point is not well represented on StreamStats network. Used nearest location on Q Street Canal	44.0623, -123.0069	
J.H. Baxter & Co., Inc. (6553)	Amazon Diversion Canal	0.597	StreamStats	44.062, -123.196	
JLR, LLC (32536)	Pudding River	6.7	USGS: 14201340	45.151, -122.804	1997-10-01 ~ 2022-09-30
Junction City STP (44509)	Flat Creek	0	StreamStats	44.218, -123.23	
Kingsford Manufacturing Company - Springfield Plant (46000)	Patterson Slough	0	StreamStats	44.062, -123.063	
Knoll Terrace Mhc (46990)	Mountain View Creek	0	StreamStats	44.625, -123.227	
Lakewood Utilities, Ltd (96110)	Mill Creek	0	StreamStats	45.206, -122.789	
Lane Community College (48854)	Russel Creek	0	StreamStats	44.009, -123.037	
Malarkey Roofing (52638)	Columbia Slough	0	StreamStats	45.593, -122.699	
Mcfarland Cascade Pole & Lumber Co (54370)	Storm Ditch to Amazon Creek	0	StreamStats	44.092, -123.198	
Miller Paint Company (103774)		0	StreamStats	45.562, -122.53	

Facility Name (Facility Number)	Stream	Estimated 7Q10 (cfs)	Flow Estimation Method	Flow Estimation Latitude/Longitude	Gage Period
Molalla Municipal Water Treatment Plant (109846)	Molalla River	55.5	StreamStats	45.129, -122.54	
Molalla STP (57613)	Molalla River	55.8	StreamStats	45.15, -122.544	
Mt. Angel STP (58707)	Pudding River	31.6	StreamStats	45.067, -122.828	
Murphy Veneer, Foster Division (97070)	Wiley Creek	4.2	USGS: 14187000	44.372, -122.623	1992-10-01 ~ 2022-09-30
Norpac Foods- Plant #1, Stayton (84820)	Salem Ditch	0	StreamStats	44.799, -122.806	
Norpac Foods - Brooks Plant No. 5 (84791)	Fitzpatrick Creek	0	StreamStats	45.056, -122.955	
Oakridge STP (62886)	Middle Fork Willamette River	449.8	USGS: 14148000 - 14147500	43.801, -122.561	1987-10-01 ~ 1994- 09-30
ODC - Oregon State Penitentiary (109727)	Mill Creek	6.53	StreamStats	44.931, -123.007	
ODFW - Marion Forks Hatchery (64495)	Horn Creek	6.3	DEQ permit renewal fact sheet, Appendix D. (DEQ, 2022)		
ODFW - Roaring River Hatchery (64525)	Roaring River	0.523	StreamStats	44.627, -122.719	
ODFW - Willamette Fish Hatchery (64585)	Salmon Creek	110	StreamStats	43.748, -122.444	
Owens-Brockway Glass Container Plant (65610)		0	StreamStats	45.563, -122.564	
PCC Structurals, Inc. - (71920)	Mount Scott Creek	0	StreamStats	45.427, -122.569	
Philomath WTP (100048)	Marys River	6.6	USGS: 14171000	44.525, -123.334	2000-10-01 ~ 2022-09-30
Philomath WWTP (103468)	Marys River	6.6	USGS: 14171000	44.525, -123.334	2000-10-01 ~ 2022-09-30
Portland International Airport (107220)	Columbia Slough	0	StreamStats	45.575, -122.604	
RSG Forest Products - Liberal (72596)	Molalla River	0	StreamStats	45.191, -122.592	
Sandy WWTP (78615)	Tickle Creek	0.195	StreamStats	45.405, -122.347	
SCIO STP (79633)	Thomas Creek	6.8	USGS: 14188800	44.712, -122.77	2002-10-01 ~ 2022-09-30
Seneca Sawmill Company (80207)	Ditch to A-1 Amazon Channel	0	StreamStats	44.116, -123.174	
SFPP, L.P. (103159)	Flat Creek	0	StreamStats	44.092, -123.149	

Facility Name (Facility Number)	Stream	Estimated 7Q10 (cfs)	Flow Estimation Method	Flow Estimation Latitude/Longitude	Gage Period
Sherman Bros. Trucking (36646)	Little Muddy Creek	0.194	StreamStats	44.285, -123.06	
Silverton STP (81395)	Silver Creek	14	StreamStats	45.008, -122.803	
Spinnaker II Office Building (110603)	Unknown				
Sundance Lumber Company, Inc. (107401)	Stream without a name	0	StreamStats	44.053, -122.981	
Sunstone Circuits (26788)	Milk Creek	10.5	Using 7Q10 reported in 2008 TMDL		
Tangent STP (87425)	Calapooia River	20.3	StreamStats	44.553, -123.147	
Timberlake STP (90948)	Clackamas River	254	StreamStats	45.087, -122.065	
USFW - Eagle Creek National Fish Hatchery (91035)	Eagle Creek	21.3	StreamStats	45.278, -122.196	
Veneta STP (92762)	Long Tom River	6.3	USGS: 14166500	44.05, -123.426	1992-10-01 ~ 2022-09-30
Ventura Foods, LLC (103832)		0	StreamStats	45.567, -122.57	
WES (Boring STP) (16592)	North Fork Deep Creek	0.65	Clackamas County reports the estimated North Fork Deep Creek 7Q10 flow (0.65 cfs) in the temperature management plan for the Boring WWTP (DEQ, 2006).		
Westfir STP (94805)	N Fk Middle Fk Willamette R	174	StreamStats	43.759, -122.522	
Willamette Leadership Academy (34040)	Wild Hog Creek	0	StreamStats	43.991, -123.007	
Woodburn WWTP (98815)	Pudding River	6.7	USGS: 14201340	45.151, -122.804	1997-10-01 ~ 2022-09-30

4.3 Model setup and application overview

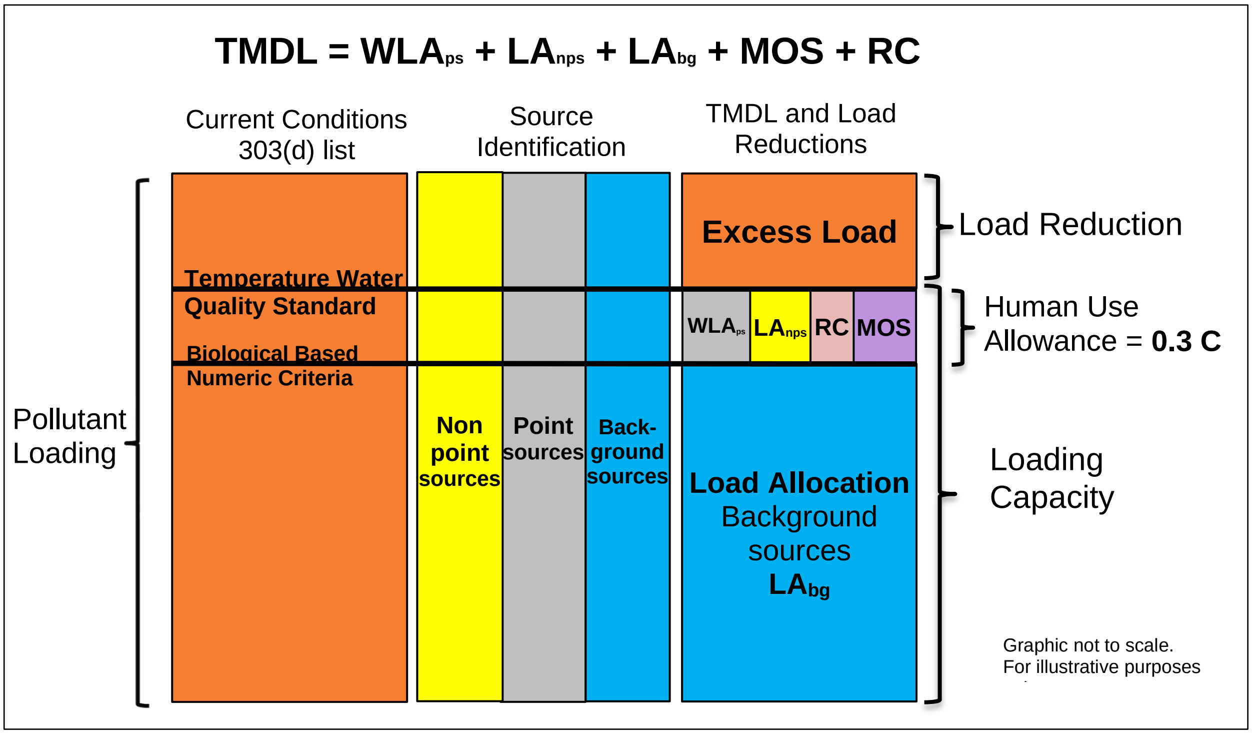
As described in the model report appendices (Appendix A and Appendix B), DEQ and partners setup and calibrated temperature and shade models for numerous streams in the Willamette Subbasins. The models were adjusted iteratively until acceptable goodness-of-fit was achieved relative to the observed current conditions. These results are provided in the appendices and were used in tandem with applicable water quality standard data to predict (7DADM) standard exceedances, effective shade levels, and derive the loading capacities, excess loads, and allocations presented in the TMDL report. To predict the effects of various changes in riparian conditions and other and management scenarios, the model parameters were adjusted and the results evaluated. The results of these model scenarios were then evaluated to determine if those management strategies would result in attainment of water quality standards.

5 Source Assessment and Load Contributions

[provide supporting info/tables/figures for source assessment summary in TMDL]

6 Allocation Approach

Figure 6.1 provides three separate conceptual representations of the total load to a temperature-impaired water. The left (completely orange) block shows the total load, with the bisecting lines representing the load that would meet the biologically-based numeric criteria plus the human use allowance (the temperature standard). The middle block represents the portions of the total load contributed by the different source categories (point, nonpoint, and background). The right block illustrates how the loading capacity element of the TMDL defines the various allocations.



Graphic not to scale.
For illustrative purposes

Figure 6.1 Conceptual representation and breakdown of total pollutant loading to a temperature-impaired waterbody.

Wasteload allocations (shown as WLAps) are the portion of the TMDL loading capacity allocated to point sources and load allocations (shown as LAnps and LAbg) are the portion distributed to nonpoint sources, including background sources. OAR 340-042-0040(6) identifies the factors that DEQ or EQC may consider when distributing wasteload and load allocations.

The factors include:

a) Contributions from sources;
b) Costs of implementing measures;
c) Ease of implementation;
d) Timelines for attainment of water quality standards;
e) Environmental impacts of allocations;
f) Unintended consequences;
g) Reasonable assurances of implementation.
h) Any other relevant factor.

Oregon's temperature standard provides a framework for how the loading capacity is distributed between human sources of warming and background sources. The human use allowance at OAR 340-041-0028(12)(b)(B) identifies the portion of the loading capacity reserved for human uses. The rule requires wasteload and load allocations restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.3 degrees Celsius (0.5 Fahrenheit) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact. DEQ allocated a thermal load equivalent to 0.3 degrees to human sources and the remainder of the loading capacity to background sources.

When distributing the thermal loads associated with a 0.3 degrees Celsius increase, DEQ considered the magnitude of the thermal load contributed from known sources, ease of implementing the allocations, the environmental impact of those contributions including where the impact occurs and how the source contribution impacts cumulative warming.

6.1 Loading capacity

As described in the TMDL report, the pollutant load that a waterbody can receive and still meet water quality standards is called the loading capacity (LC). For temperature, thermal loading capacity is calculated using **Equation 1**.

Equation 1 $$LC = (T_C + \mathrm{HUA}) \cdot Q_R \cdot C_F$$

where,

$LC =$ Loading Capacity (kcal/day).

$T_C =$ The applicable river temperature criterion (°C).

$\mathrm{HUA} =$ The 0.3°C human use allowance allocated to point sources, nonpoint sources, margin of safety, or reserve capacity.

$Q_R =$ The daily mean river flow rate (cfs).
When river flow is <= 7Q10, Q_R = 7Q10. When river flow > 7Q10, Q_R is equal to the daily mean river flow.

$C_F =$ Conversion factor using flow in cubic feet per second (cfs): 2,446,665

$$\frac{1\,m^3}{35.31\,ft^3} \cdot \frac{1000\,kg}{1\,m^3} \cdot \frac{86400\,sec}{1\,day} \cdot \frac{1\,kcal}{1\,kg\,\cdot 1℃} = 2{,}446{,}665$$

The TMDL report Table 8.1 presents minimum LCs for certain assessment units with an NPDES discharge or that were modeled for the TMDL analysis. Minimum LCs are calculated based on the 7Q10 low flow.

6.2 Point source waste load allocations (WLAs)

DEQ's approach to point sources allocations was to distribute an equal portion of the human use allowance (0.075 degrees Celsius) to each point source except when the point source is not authorized to discharge in the current NPDES permit (maximum effluent flow = 0) or analysis indicated current thermal loads are less 0.075 degrees Celsius and the allocation could be reduced to minimize cumulative effects. In some cases DEQ increased the allocation above 0.075 when analysis indicated the waste load allocation would result in immediate noncompliance. Cumulative effects were also considered on streams that had more than one discharge.

6.2.1 Wasteload allocation equation

The following equation was used to calculate the thermal waste load allocations.

$$WLA = (\Delta T) \cdot (Q_E + Q_R) \cdot C_F$$ **Equation 2**

where,

$WLA =$ Waste load allocation (kilocalories/day).

$\Delta T =$ The maximum temperature increase (ºC) above the applicable temperature criterion using 100% of river flow not to be exceeded by each individual source from all outfalls combined.

$Q_E =$ The daily mean effluent flow (cfs).
When effluent flow is in million gallons per day (MGD) convert to cfs:

$$\frac{1{,}000{,}000\ gallons}{1\ day} \cdot \frac{0.13368 ft^3}{1\ \text{gallon}} \cdot \frac{1\ day}{86{,}400\ sec} = 1.5472\ ft^3/sec$$

$Q_R =$ The daily mean river flow rate, upstream (cfs).
When flow is <= 7Q10, Q_R = 7Q10. When flow is > 7Q10, Q_R equals the daily mean river flow, upstream.

$C_F =$ Conversion factor using flow in cubic feet per second (cfs): 2,446,665

$$\frac{1\ m^3}{35.31\ ft^3} \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1℃} = 2{,}446{,}665$$

Table 6.0.1 Summary of effluent discharge flow rates used for calculation waste load allocations.

NPDES Permittee WQ File# : EPA Number	Effluent discharge (cfs)	Effluent discharge data source	Notes
Albany Water Treatment Plant 66584 : ORG383501	0.77	Assumed 0.5 MGD	
Alpine Community 100101 : OR0032387	0.03	Effluent flow is ADWDF from permit (0.02 MGD).	NPDES Permit: April 16 - Nov 30 No Discharge
Americold Logistics, LLLC 87663 : ORG253544	0.77	Set at maximum allowed by permit (0.5 MGD)	

NPDES Permittee WQ File# : EPA Number	Effluent discharge (cfs)	Effluent discharge data source	Notes
Arclin 16037 : OR0021857	1.55	Effluent Flow is based on maximum allowed in permit (1.00 MGD)	
Arclin 81714 : OR0000892	0.93	Effluent discharge recorded on Permit Evaluation and Fact Sheet. Prepared 7/21/2009.	
ATI Albany Operations 64300 : OR0001716	0.46	Effluent flow from Permit Evaluation and Fact Sheet, dated 11/30/2005	
Aumsville STP 4475 : OR0022721	0.52	Effluent flow is ADWDF from permit (0.335 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge
Aurora STP 110020 : OR0043991	0.1	Effluent flow is ADWDF from permit (0.087 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge.
Forrest Paint Co. 100684 : ORG253508	0.77	Set at maximum allowed by permit (0.5 MGD)	
Boeing Of Portland - Fabrication Division 9269 : OR0031828	0.46	Effluent flow from Permit Evaluation Report prepared 6/18/2012. Average combined discharge flow for 2012.	
SFPP 103159 : OR0044661	0.02	Effluent flow reported in Permit Evaluation Report received 8/19/09	
City of Silverton Drinking WTP 81398 : ORG383527	0.095	Using design effluent flow reported in 2008 TMDL	
Coburg Wastewater Treatment Plant 115851 : OR0044628	0.68	Effluent flow is ADWDF from permit (0.44 MGD).	
Coffin Butte Landfill 104176 : OR0043630	0.0	Based on review of DMRs showing no discharge	
Columbia Helicopters 100541 : OR0033391	0.01	Effluent flow from peak design flow listed in Permit Evaluation Report received 2/6/2007 (expired 3/19/2019)	
Brownsville STP 11770 : OR0020079	0.0		NPDES Permit: May 1 - Oct 31 No Discharge
Tangent STP 87425 : OR0031917	0.17	Effluent flow is ADWDF from permit (0.11 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge
Creswell STP 20927 : OR0027545	0.31	Effluent flow is ADWDF from permit (0.20 MGD).	NPDES Permit: June 1 - Oct 31 No Discharge

NPDES Permittee **WQ File# : EPA Number**	**Effluent discharge (cfs)**	**Effluent discharge data source**	**Notes**
Foster Farms 97246 : OR0026450	0.0		NPDES Permit: May 1 - Oct 31 No Discharge
Duraflake 97047 : OR0000426	0.55	Using 95th percentile effluent flow from permit which is 0.248604 MGD for outfall 002 and 0.108250 MGD for outfall 003. (combined 0.356854 MGD)	
Estacada STP 27866 : OR0020575	0.84	Effluent discharge is recorded on the Permit Evaluation Form from May 1 to October 2009.	
EWEB Carmen-Smith (Outfalls 001A and 001B) 28393 : OR0000680	2.68	Effluent flow based on current permit requirement limiting outfall 001 flow to maximum of 1.73 MGD.	
EWEB Carmen-Smith (Outfalls 002A and 002B) 28393 : OR0000680	0.93	Effluent flow based on current permit requirement limiting outfall 002 flow to maximum of 0.6 MGD.	
Falls City STP 28830 : OR0032701	0.0		NPDES Permit: June 1 - Oct 31 No Discharge
First Premier Properties 110603 : ORG253511	0.77	Set at maximum allowed by permit (0.5 MGD)	
Portland International Airport 107220 : OR0040291	0.0		No discharge for Outfall CS-001 May 1 - Oct 31. Other Columbia Slough outfalls are stormwater.
Corvallis Rock Creek WTP 20160 : ORG383513	0.77	Assumed 0.5 MGD	
Fujimi Corporation - SW Commerce Circle 107178 : OR0040339	0.2	Effluent discharge recorded on Permit Evaluation and Fact Sheet. Finalized 9/4/2012.	
Georgia-Pacific Chemicals LLC 32864 : OR0002101	0.0	No effluent discharge reported on May 2019 and 2020 DMR for Outfall 001	NPDES Permit: June 1 - Oct 31 No Discharge
Georgia-Pacific Chemicals LLC 32864 : OR0002101	0.0	No Discharge	NPDES Permit: June 1 - Oct 31 No Discharge

NPDES Permittee **WQ File# : EPA Number**	**Effluent discharge (cfs)**	**Effluent discharge data source**	**Notes**
Gervais STP 33060 : OR0027391	0.34	Effluent flow is ADWDF from permit (0.22 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge.
GP Millersburg Resin Plant 32650 : OR0032107	0.0		NPDES Permit: April 1 - Oct 31 No Discharge
Philomath WTP 100048 : ORG383536	0.77	Assumed 0.5 MGD	
Herbert Malarkey Roofing Company 52638 : ORG250024	0.77	Set at maximum allowed by permit (0.5 MGD)	
Holiday Retirement Corp 108298 : ORG253504	0.77	Set at maximum allowed by permit (0.5 MGD)	
Hubbard STP 40494 : OR0020591	0.53	Effluent flow is ADWDF from permit (0.34 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge
Hull-Oakes Lumber Co. 107228 : OR0038032	0.08	Outfall 001 (Log Pond) no discharge July 1 - Oct 31. Outfall 002 max flow of 0.05 MGD. Using 0.05 MGD as effluent flow.	Outfall 001 (Log Pond) no discharge July 1 - Oct 31.
International Paper - Springfield (Outfall 003) 96244 : OR0000515	3.09	Effluent is the maximum discharge (2.0 MGD) at Outfall 003 reported on DMRs May-Oct 2013-2017.	Allocation is only for Outfall 003. Outfalls 001 and 002 are currently addressed in the 2006 Willamette Basin TMDL.
J.H. Baxter & Co 6553 : OR0021911	0.12	Effluent flow from average listed in Permit Evaluation from 9/13/2010	
JLR 32536 : OR0001015	0.5	Effluent discharge from April-October of 2018-2020 NetDMR data	HUA from 2008 TMDL.
Junction City STP 44509 : OR0026565	0.0		NPDES Permit: May 1 - Oct 31 No Discharge (unless authorized)
Kingsford Manufacturing Company - Springfield Plant 46000 : OR0031330	0.08	Using maximum effluent flow (133300 gallons/day) reported on April 2020 DMR.	NPDES Permit: June 1 - Oct 31 No Discharge (unless authorized by DEQ)
Kingsford Manufacturing Company - Springfield Plant 46000 : OR0031330	0	No discharge	NPDES Permit: June 1 - Oct 31 No Discharge (unless authorized by DEQ)

NPDES Permittee **WQ File# : EPA Number**	**Effluent discharge (cfs)**	**Effluent discharge data source**	**Notes**
Knoll Terrace Mhc 46990 : OR0026956	0.09	Effluent flow is ADWDF from permit (0.06 MGD)	NPDES Permit: May 1 - Oct 31 No Discharge
Philomath WWTP 103468 : OR0032441	0.0		NPDES Permit: May 1 - Oct 31 No Discharge
Lane Community College 48854 : OR0026875	0.22	Effluent flow is ADWDF from permit (0.142 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge unless authorized by DEQ
Mcfarland Cascade Pole & Lumber Co 54370 : OR0031003	0.0		Effluent temperature may not exceed 17.8 C NPDES Permit: May 1 - Oct 31 No Discharge unless authorized by DEQ
Miller Paint Co Inc 103774 : ORG250040	0.77	Set at maximum allowed by permit (0.5 MGD)	
Molalla Municipal Drinking WTP 109846 : ORG380014	0.08	Using effluent flow reported in 2008 TMDL	
Molalla STP 57613 : OR0022381	3.46	Effluent discharge is max effluent flow recorded from March-October in NetDMR data. 2.234 MGD recorded on 4/24/2020.	NPDES Permit: No discharge June 1 - October 31 (unless permitted by state). Current di
Mt. Angel STP 58707 : OR0028762	0.87	Effluent flow is ADWDF from permit (0.56 MGD).	No discharge May 1 - October 31 (unless permitted by state).
Murphy Veneer, Foster Division 97070 : OR0021741	1.11	Effluent flow reported in Permit Evaluation Report from July 1, 2010. 7 day average flow occurring between June 1st-15th during past 3 years (2007-2010?)	
Norpac Foods - Brooks Plant No. 5 84791 : OR0021261	0.0		NPDES Permit: May 1 - Oct 31 No Discharge
Lakewood Utilities, Ltd 96110 : OR0027570	0.0		NPDES Permit: May 1 - Oct 31 No Discharge
Oakridge STP 62886 : OR0022314	0.73	Effluent flow is ADWDF from permit (0.47 MGD).	

NPDES Permittee WQ File# : EPA Number	Effluent discharge (cfs)	Effluent discharge data source	Notes
Norpac Foods- Plant #1, Stayton 84820 : OR0001228	6.19	Effluent flow is the peak processing flow reported in the permit evaluation report.	
ODFW - Marion Forks Hatchery 64495 : OR0027847	18.6	Effluent flow is maximum from data submitted by ODFW	
ODFW - Roaring River Hatchery 64525 : ORG133506	14.2	Effluent flow is maximum from data submitted by ODFW	
ODFW - Willamette Fish Hatchery 64585 : ORG133507	79.0	Effluent flow is the maximum of the combined discharge from outfalls 001 and 002 as summarized from data submitted by ODFW.	
Owens-Brockway Glass Container Inc. 65610 : ORG250029	0.77	Set at maximum allowed by permit (0.5 MGD)	
ODC - Oregon State Penitentiary 109727 : OR0043770	2.48	Used maximum flow of 1.6 MGD (2.48 cfs) authorized by NPDES permit.	
Blount Oregon Cutting Systems Division 63545 : OR0032298	0.19	Effluent discharge from Permit Evaluation Report, prepared 8/19/2010. Maximum flow from August 2009-July 2010.	
PCC Structurals, Inc. 71920 : ORG250015	0.77	Set at maximum allowed by permit (0.5 MGD)	
Halsey STP 36320 : OR0022390	0.30	Effluent flow is ADWDF from permit (0.197 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge
Row River Valley Water District 100075 : ORG383534	0.77	Assumed 0.5 MGD, needs confirmation	
RSG Forest Products - Liberal 72596 : OR0021300	1.24	Effluent flow is maximum reported on DMRs May - Oct 2018 - 2021. 0.8 MGD in September 2020.	
Sandy WWTP 78615 : OR0026573	0.00		NPDES Permit: May 1 - Oct 31 No Discharge
Scio STP 79633 : OR0029301	0.14	Effluent flow is ADWDF from permit (0.09 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge

NPDES Permittee **WQ File# : EPA Number**	**Effluent discharge (cfs)**	**Effluent discharge data source**	**Notes**
Seneca Sawmill Company 80207 : OR0022985	1.19	Effluent flow from Permit Evaluation and Fact Sheet, dated 6/15/2006	Effluent temperature may not exceed 18.0 C as weekly average May 1 - Oct 31 per NPDES permit.
Dallas STP 22546 : OR0020737	3.09	Effluent flow is ADWDF from permit (2.0 MGD).	
Sherman Bros. Trucking 36646 : OR0021954	0.02	Effluent flow is ADWDF from permit (.014 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge
Silverton STP 81395 : OR0020656	3.87	Effluent flow is ADWDF from permit (2.5 MGD).	
Sundance Lumber Company, Inc. 107401 : ORG253618	0.77	Set at maximum allowed by permit (0.5 MGD)	
Sunstone Circuits 26788 : OR0031127	0.065	Using design effluent flow reported in 2008 TMDL	Using same HUA from 2008 TMDL
Dallas WTP 22550 : ORG383529	0.77	Assumed 0.5 MGD, needs confirmation	
Timberlake STP 90948 : OR0023167	0.22	Effluent flow is ADWDF from permit (0.144 MGD).	NPDES Permit: May 1 - Oct 31 no discharge for outfall 002.
USFW - Eagle Creek National Fish Hatchery 91035 : OR0000710	52.6	Effluent flow from 2006 TMDL.	
Veneta STP 92762 : OR0020532	0.81	Effluent flow is average design wet weather flow from permit (0.524 MGD).	NPDES Permit: June 1 - Sep 31 No Discharge unless authorized by DEQ
Veneta STP 92762 : OR0020532	0.00	No Discharge	NPDES Permit: June 1 - Sep 31 No Discharge unless authorized by DEQ
Ventura Foods, LLLC 103832 : ORG250005	0.77	Set at maximum allowed by permit (0.5 MGD)	
WES - Boring STP 16592 : OR0031399	0.03	Using effluent flow from 2006 TMDL as reported in the WES temperature management plan. Permit says ADWDF is 0.02 MGD.	
Westfir STP 94805 : OR0028282	0.05	Effluent flow is ADWDF from permit (0.030 MGD).	
Willamette Leadership Academy 34040 : OR0027235	0.01	Effluent flow is ADWDF from permit (0.007 MGD).	NPDES Permit: May 1 - Oct 31 No Discharge

NPDES Permittee **WQ File# : EPA Number**	**Effluent discharge (cfs)**	**Effluent discharge data source**	**Notes**
Woodburn WWTP 98815 : OR0020001	7.79	Effluent flow is ADWDF from permit (5.037 MGD).	

6.2.2 WLA permit compliance equation.

When evaluating current discharge, DEQ used to determine compliance with the waste load allocation (WLA).

$$ETL = (T_E - T_C) \cdot Q_E \cdot C_F$$ **Equation 3**

where,

$ETL =$ The daily excess thermal load (kilocalories/day) used to evaluate compliance with the waste load allocation (WLA) from Equation 1.

$T_{C,i} =$ The point of discharge applicable river temperature criterion (°C) (T_c); or when the minimum duties provision at OAR 340-041-0028(12)(a) applies $T_{C,i}$ = the 7DADM measured at the facility intake (T_i). Use Equation 7 to determine if the minimum duties provision applies.

$T_E =$ The daily maximum effluent temperature (°C)

$Q_E =$ The daily mean effluent flow (cfs or MGD)

$C_F =$ Conversion factor for flow in cubic feet per second (cfs): 2,446,665

$$\frac{1\, m^3}{35.31\, ft^3} \cdot \frac{1000\, kg}{1\, m^3} \cdot \frac{86400\, sec}{1\, day} \cdot \frac{1\, kcal}{1\, kg\ \cdot 1℃} = 2{,}446{,}665$$

Conversion factor for flow in millions of gallons per day (MGD): 3,785,411

$$\frac{1\, m^3}{264.17\, gal} \cdot \frac{1000\, kg}{1\, m^3} \cdot \frac{1000000\, gal}{1\, million\, gal} \cdot \frac{1\, kcal}{1\, kg\ \cdot 1℃} = 3{,}785{,}441$$

6.2.3 Calculating current change in temperature

The following equation is used to determine compliance with the allowed ΔT allocated in the TMDL

$$\Delta T_{Current} = \left(\frac{Q_E}{Q_E + Q_R}\right) \cdot (T_E - T_C)$$ **Equation 4**

where,

$\Delta T_{Current} =$ The current 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) covert 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 (ºC). When the minimum duties provision at OAR 340-041-0028(12)(a) applies TC = the 7DADM measured at the facility intake.

6.2.4 Calculating acceptable effluent temperatures

The daily maximum effluent temperatures (ºC) acceptable under the allowed ΔT and the waste load allocation (WLA).

$$T_{E\_WLA} = \frac{(Q_E + Q_R) \cdot (T_C + \Delta T) - (Q_R \cdot T_C)}{Q_E}$$ **Equation 5a** (using ΔT)

$$T_{E\_WLA} = \frac{(WLA)}{Q_E \cdot \ C_F} + \ T_C$$ **Equation 6b** (using WLA)

where,

$T_{E\_WLA} =$ Daily maximum effluent temperature (ºC) allowed under the waste load allocation. When T_{E_WLA} is > 32 deg-C, T_{E_WLA} = 32 deg-C as required by the thermal plume limitations in OAR 340-041-0053(2)(d)(B).

$WLA =$ Waste load allocation (kilocalories/day) from Equation 1.

$\Delta T =$ The maximum temperature increase (ºC) above the applicable river temperature criterion using 100% of river flow not to be exceeded by each individual source from all outfalls combined. When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ΔT = 0.0.

$Q_E =$ The daily mean effluent flow (cfs). When effluent flow is in million gallons per day (MGD) covert 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.

$T_{C,i} =$ The point of discharge applicable river temperature criterion (ºC) (T_c); or when the minimum duties provision at OAR 340-041-0028(12)(a) applies $T_{C,i}$ = the 7DADM measured at the facility intake (T_i).

$C_F =$ Conversion factor for flow in cubic feet per second (cfs): 2,446,665

$$\frac{1 \ m^3}{35.31 \ ft^3} \cdot \frac{1000 \ kg}{1 \ m^3} \cdot \frac{86400 \ sec}{1 \ day} \cdot \frac{1 \ kcal}{1 \ kg \ \cdot 1℃} = 2{,}446{,}665$$

6.2.5 Calculating acceptable effluent flows

The daily mean effluent flow (cfs) acceptable under the allowed ΔT and the waste load allocation (WLA).

$$Q_{E\_WLA} = \frac{(Q_R \cdot T_C) - ((T_C + \Delta T) * Q_R)}{T_C + \Delta T - T_E}$$ **Equation 6a** (using ΔT)

$$Q_{E\_WLA} = \frac{(WLA)}{(T_E - T_C) * C_F}$$ **Equation 6b** (using WLA)

where,

$Q_{E\_WLA} =$ Daily mean effluent flow (cfs) allowed under the waste load allocation.

$WLA =$ Waste load allocation (kilocalories/day) from Equation 1.

$\Delta T =$ The maximum temperature increase (ºC) above the applicable river temperature criterion using 100% of river flow not to be exceeded by each individual source from all outfalls combined. When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ΔT = 0.0.

$T_E =$ The daily maximum effluent temperature (°C).

$Q_R =$ 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.

$T_{C,i} =$ The point of discharge applicable river temperature criterion (°C) (T_c); or when the minimum duties provision at OAR 340-041-0028(12)(a) applies $T_{C,i}$ = the 7DADM measured at the facility intake (T_i).

$C_F =$ Conversion factor for flow in cubic feet per second (cfs): 2,446,665

$$\frac{1\ m^3}{35.31\ ft^3} \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1°\mathrm{C}} = 2{,}446{,}665$$

6.2.6 Determination of when minimum duties applies

DEQ may apply the minimum duties provision at OAR 340-041-0028(12)(a) if a facility operation meets acceptable operation and design requirements in regard to flow pass through. Generally, the facility must be operated as a “flow through” facility where intake water moves through the facility and is not processed.

In the Willamette River Subbasins, DEQ determined that ODFW’s fish hatchery facilities, including Marion Forks Hatchery, Roaring River Hatchery, and Willamette Fish Hatchery, and USFW’s Eagle Creek National Fish Hatchery operate as a flow through facility.

The minimum duties provision applies on days when $T_{E\_WLA} < T_i$.

When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ΔT = 0.0.

where,

$T_{E\_WLA} =$ Daily maximum effluent temperature (°C) allowed under the waste load allocation as calculated using Equation 5a or Equation 5b.

$T_i =$ The daily maximum influent temperature (°C) measured at the facility intake.

7 Water quality management plan support

7.1.1 Adequacy of Agricultural Water Quality Management programs in attaining TMDL load allocations and effective shade surrogate measures

The Oregon Legislature passed the Agricultural Water Quality Management Act in 1993, which directed Oregon Department of Agriculture to adopt rules as necessary and to develop plans to prevent water pollution from agricultural activities (ORS 568.900 to 568.933 and ORS 561.191 and OAR chapter 603, divisions 90 and 95). Subsequently, ODA worked with Local Advisory Committees and Soil and Water Conservation Districts to develop Agricultural Water Quality Area Rules and Area Plans for 38 watershed-based management areas across the state.

The Willamette Subbasins TMDL includes eight management areas: North Coast, Lower Willamette, Clackamas, Middle Willamette, Molalla-Pudding/French Prairie/ North Santiam, South Santiam, Southern Willamette, and Upper Willamette/ Upper Siuslaw. Each management area has agricultural water quality regulatory requirements, called Area Rules. Each management area also has an Agricultural Water Quality Management Area Plan, which is not regulatory but guides landowners in how to protect water quality from agricultural activities.

Oregon Administrative Rules 603-095 requires agricultural activities to allow streamside vegetation to establish and grow to provide shade on perennial and some intermittent streams. Table 1. summarizes the streamside management measures required by state law for the seven management areas included in this TMDL. Specific requirements differ depending on the management area; however, most management areas identify vegetation goals based on site capability; site capability is not clearly defined However, in OAR 603-095 there are no requirements to require streamside vegetation to be established on agricultural lands when streamside vegetation deficiency is not caused by an agricultural activity.

Table 1. Summary of Oregon Administrative Rules (OAR 603-095) for streamside management in seven management areas within the Willamette Subbasins Temperature TMDL project area.

Agricultural Water Quality Management Area	**Prevention and Control Measures***
North Coast	Allow the natural and managed regeneration and growth of riparian vegetation trees, shrubs, grasses, and sedges along natural waterways to provide shade to moderate water temperatures and bank stability to maintain erosion near background levels. Management activities minimize the degradation of established native vegetation while allowing for the presence of nonnative vegetation. Management activities maintain at least 50% of each year’s new growth of woody vegetation -- both trees and shrubs.
Clackamas Subbasin	Allow the establishment, growth, and/or maintenance of native or non-native riparian vegetation appropriate to site capability, sufficient to encourage shade, protect streamside area during high stream flow events expected to occur in a 25-year, 24- hour storm event.
Lower Willamette	Allow the development of riparian vegetation along streams to provide shade for minimizing solar heating of the stream, streambank stability from flows in a 25-year, 24-hour storm event, filtration, settlement, and biological uptake of sediment, organic

	material, nutrients, and pesticides in surface runoff by intercepting or slowing overland flow, improvement to water storage capacity of the riparian zone, protection of streams from flashy flows by infiltrating runoff and overland flow. Riparian vegetation includes grasses, sedges, shrubs and trees that are consistent with site capability, and site development can be through allowing natural processes or active management. Management within the riparian area is allowed, and sufficient riparian width is site specific, and may vary by soil type, hydrology, climate, geology, and man-made limitations, and other factors. Drainage and irrigation ditches are not subject to these prevention control measures.
Molalla-Pudding/French Prairie/ North Santiam	Allow natural or managed development of riparian vegetation and riparian function over time along all streams. Riparian width is site specific, and may vary, for example by soil type, size of stream, and agricultural use. Natural or managed establishment and maintenance includes riparian vegetation, such as grasses, sedges, shrubs, and trees, appropriate to site capability, that in the normal course of time will provide shade and protect streambank stability from flows at or below those expected in a 25-year, 24-hour storm event.
South Santiam	Allow establishment and maintenance of riparian vegetation consistent with site capability that promotes infiltration of overland flows, moderation of solar heating, and streambank stability. Management within the riparian area is allowed, and minimal breaks in shade vegetation for essential management activities are considered appropriate.
Southern Willamette	Allow establishment and maintenance of vegetation along perennial streams consistent with capability of the site to provide riparian functions necessary to help moderate solar heating and for streambanks to withstand flows in a 25-year, 24-hour storm event.
Upper Willamette/ Upper Siuslaw	Allow establishment and development of riparian vegetation along perennial and

	intermittent streams for streambank stability, shading, and proper riparian function, consistent with site capability. Legally constructed drainage and irrigation ditches are exempt.
Yamhill	Allow the establishment, growth, and/or maintenance of riparian vegetation appropriate to the site. Vegetation must provide shade, protect the streamside area to maintains its integrity during high stream flow events in a 25-year, 24-hour storm event. Any agricultural activity that degrades riparian vegetation will be replanted or restored as soon as practical. Indicator of non-compliance is active streambank sloughing or erosion from tillage, grazing, or destruction of vegetation by landowner or occupier.

*Prevention and Control Measures are identified in OAR for each management area for various agricultural activities. The ones summarized in this table are specific to streamside management.

Each management area has an Area Plan, which is not regulatory and does not establish prohibitions on agricultural activities that may impact water quality or require active restoration on agricultural lands. Instead, Area Plans rely on outreach and education, and voluntary landowner actions to implement conservation and management activities that protect water quality. ODA continues to work with LACs, SWCDs, DEQ and other watershed partners to implement, evaluate, and update Area Plans through their Biennial Review process for each of the management areas included in this TMDL.

As part of the biennial review process, DEQ prepares and submits to ODA specific feedback about water quality in the management areas. DEQ's assessments also address land conditions, agricultural activities, and implementation gaps that likely contribute to water quality impairments. DEQ has identified that a high priority for many management areas is to protect and reestablish riparian vegetation. The Area Plans for the eight management areas included in this TMDL have all been reviewed by DEQ within the last three years. Some of these reviews were completed as part of ODA's light biennial review process; during light reviews ODA convenes members of the LAC to report out on restoration and land management accomplishments and water quality status and trends within the management area, but ODA does not change or update plans during a light review. Table 2 is a summary of the most recent updates for these Area Plans. Updates to Area Plans typically occur during the full biennial review process.

Table 2. Summary of the most recent updates to Area Plans, which occur during ODA's full biennial review process.

Agricultural Water Quality Management Area	Date of most recent Area Plan update
North Coast	2018
Clackamas	2022
Lower Willamette	2020
Middle Willamette	2020
Molalla-Pudding/French Prairie/North Santiam	2018
South Santiam	2019
Southern Willamette	2019
Upper Willamette/Upper Siuslaw	2023

ODA, through coordination with agency and local partners, identifies geographic areas of focus, called Strategic Implementation Areas, for targeted outreach to landowners, land condition assessment and enforcement. The SIA process includes an assessment and compliance evaluation of agricultural lands, outreach to landowners, technical assistance, monitoring of water quality and land conditions, and landowner follow up as needed. ODA identified 12 SIAs in the TMDL project area between 2014 and 2021. While ODA has conducted initial landowner outreach and facilitated local SIA planning meetings for some of these SIAs, as of 2023 ODA has reported limited restoration or enhancement projects as an outcome of the SIA process in this TMDL project area.

There continue to be water quality impairments in all seven of the management areas included in this TMDL. Specifically, water temperatures continue to be identified as impaired on Oregon’s Section 303d list. In addition, results from the modeling and shade gap analyses DEQ completed for this TMDL indicate that extensive riparian areas are deficient in providing shade along streams. The shade gap results for the Southern Willamette model area and the Lower Willamette model area on land managed for agriculture is 53 percent and 20 percent, respectively. However, the shade gaps of specific HUC 12 watersheds within the model area represent a broad range.

ODA assesses riparian vegetation against the Area Rules for streamside management. The Area Rules are regulatory requirements limited to agricultural activities and are not consistent with and do not include specific reference to the TMDL load allocations for temperature and surrogate shade measures. Area Rules do not apply to agricultural land conditions that are not directly impacted by agricultural activities. It is unclear what steps can be taken when landowners are in compliance with Area Rules, yet land conditions contribute to water quality standard exceedances and are unable to meet TMDL load allocations. There has been a lack of implementation of area plans to achieve TMDL allocations and there are no or few assurances that voluntary landowner action will be able to bridge the gap between current and needed riparian condition and function. ODA has also not been able to adequately incorporate or implement water quality priorities as identified in the 2006 TMDL or as part of the Biennial Review process. Therefore, ODA is required to develop a temperature TMDL implementation plan to be submitted to DEQ for review and approval.

8 Acknowledgements

9 References

US Army Corps of Engineers Portland District (USACE). 2019. “Willamette Basin Review Feasibility Study Final Integrated Feasibility Report and Environmental Assessment”.

Appendix A: Model Report

Willamette River Subbasins Temperature TMDL - DRAFT

March 2023

State of Oregon
DEQ Department of Environmental Quality

This document was prepared by
Oregon Department of Environmental Quality
Program Name
700 NE Multnomah Street, Suite 600
Portland Oregon, 97232
Contact: Contact
Phone: 503-555-5555
www.oregon.gov/deq

State of Oregon
DEQ Department of Environmental Quality

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800-452-4011 | TTY: 711 | deqinfo@deq.oregon.gov

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1. Overview

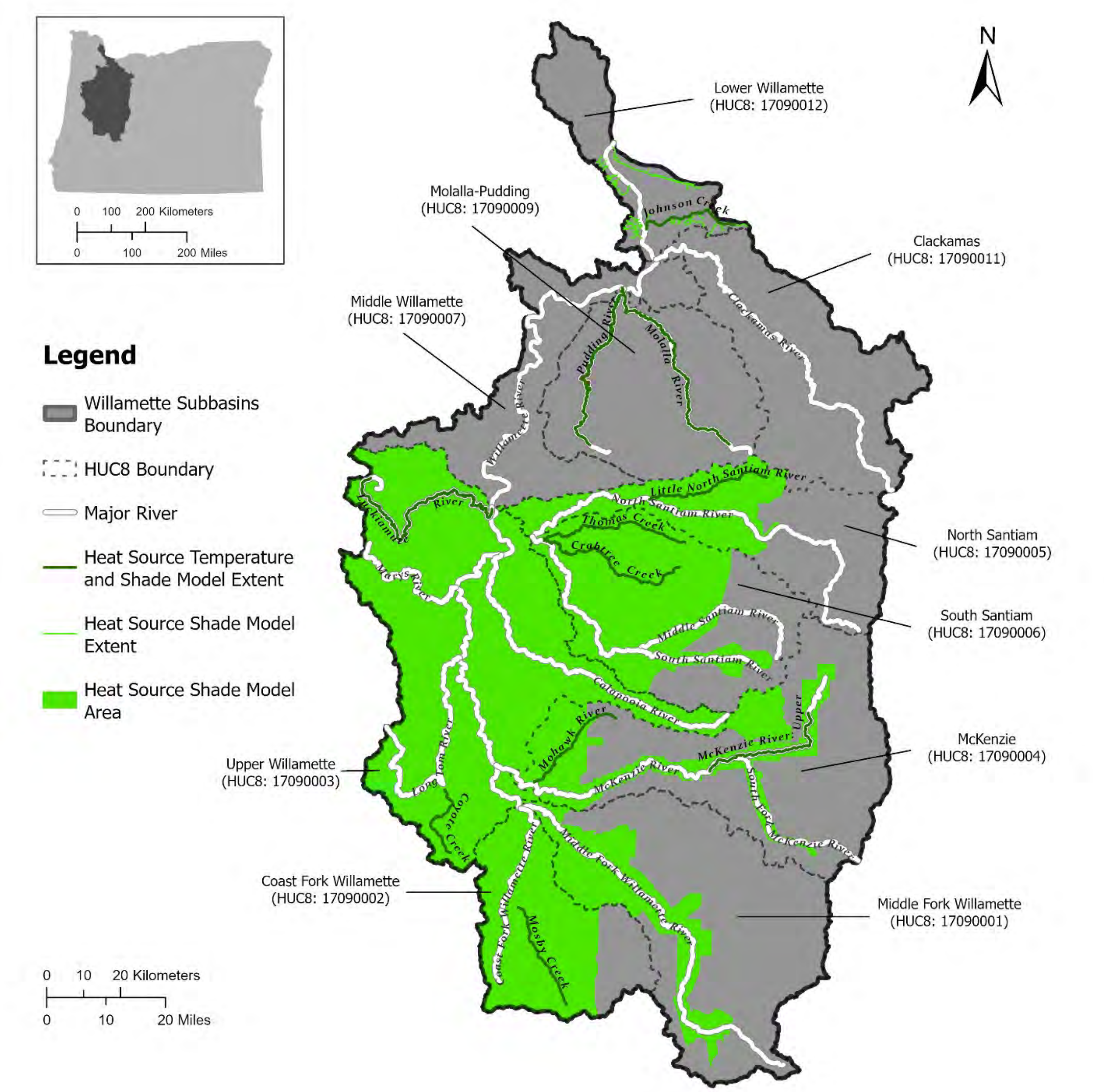


Figure 1.1. Overview of TMDL project area with model extents.

2. Available Data

2.1 Field Data

2.1.1 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 the observed stream temperature data to the predicted stream temperature data.

In some cases, grab temperature data were used as model input for tributary inflows or the upstream boundary condition.

Temperature data retrieved from DEQ's AWQMS database had 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). For TMDL development, only temperature results with a data quality level of A, B, or E are used (DEQ, 2021). Data of unknown quality were used after careful review.

Table 2.1. Stream temperature monitoring sites supporting Johnson Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
No ID	Errol Creek	45.4638	-122.6178	City of Portland Parks & Recreation (Grab)
10853-ORDEQ	Johnson Creek at 92nd Avenue near Flavel	45.4678	-122.568	DEQ
10856-ORDEQ	Johnson Creek at 122nd and Leach Botanical Gardens	45.4737	-122.536	DEQ
11321-ORDEQ	Johnson Creek at 17th Avenue	45.4467	-122.643	DEQ
11323-ORDEQ	Johnson Creek at 45th Avenue Footbridge	45.4617	-122.616	DEQ
11326-ORDEQ	Johnson Creek at Pleasant View / 190th Ave.	45.488	-122.468	DEQ
11327-ORDEQ	Johnson Creek at Regner Gage	45.4867	-122.421	DEQ
11329-ORDEQ	Crystal Springs Creek	45.4615	-122.642	DEQ
11626-ORDEQ	Johnson Creek at Palmblad Road	45.4728	-122.403	DEQ
14211550	Johnson Creek at Milwaukie Gage	45.453	-122.643	USGS
14211499	Kelley Creek	45.4768	-122.498	USGS
28729-ORDEQ	Johnson Creek at Revenue Road	45.4617	-122.337	DEQ
28730-ORDEQ	Johnson Creek at Short Road	45.4627	-122.358	DEQ
28731-ORDEQ	Johnson Creek at SE Circle Avenue	45.4864	-122.488	DEQ
28732-ORDEQ	Johnson Creek at Bell Road and Johnson Creek Blvd	45.4556	-122.593	DEQ

Table 2.2. Stream temperature monitoring sites in the Molalla River supporting model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
No Station ID	Molalla at Locked Gate HW			DEQ
10636-ORDEQ	Molalla at the mouth	45.29960184	-122.7213653	DEQ
32059-ORDEQ	Molalla at 22nd	45.28053237	-122.7112837	DEQ
10637-ORDEQ	Molalla River at Knights Bridge Road (Canby)	45.26749645	-122.7103007	DEQ
32058-ORDEQ	Molalla at Goods Br. USGS	45.24426737	-122.6875281	DEQ
32061-ORDEQ	Molalla abv Milk Cr	45.23771299	-122.6578146	DEQ
No Station ID	Molalla at Kraxberger			DEQ
10881-ORDEQ	Molalla at HWY 213	45.1999142	-122.5809614	DEQ
No Station ID	Molalla at HWY 211			DEQ
No Station ID	Molalla abv N. Fork			DEQ
32051-ORDEQ	Molalla above Pine Cr USGS	45.01207266	-122.4847353	DEQ
32049-ORDEQ	Molalla above Horse Cr	44.96215	-122.4325	DEQ
No Station ID	Molalla at Locked Gate HW			DEQ
10362-ORDEQ	Pudding River at Arndt Road (Barlow)	45.2599	-122.738	DEQ
No Station ID	North Fork Molalla			DEQ
32048-ORDEQ	Table Rock Fork	44.96807471	-122.4036666	DEQ
32047-ORDEQ	Copper Creek	44.92421333	-122.3393682	DEQ

Table 2.3. Stream temperature monitoring sites supporting Pudding River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
32055-ORDEQ	Pudding River at State Street	44.9144	-122.8175	DEQ
10362-ORDEQ	Pudding River at Arndt Road (Barlow)	45.2599	-122.738	DEQ
10917-ORDEQ	Pudding River at Hwy 99 (Aurora)	45.2338	-122.749	DEQ
10640-ORDEQ	Pudding River at Hwy 211 (Woodburn)	45.1504	-122.7925	DEQ
10641-ORDEQ	Pudding River at Hwy 214 (downstream of cannery outfall)	45.1264	-122.8193	DEQ
11530-ORDEQ	Pudding River at Monitor-McKee Road	45.1008	-122.83	DEQ
31877-ORDEQ	Pudding River at Saratoga Road	45.0631	-122.8287	DEQ
PR1-5808	Pudding River at Hazel Green Rd.	45.0094	-122.8434	Marion SWCD
NPDES-98815	Woodburn WWTP	45.15087851	-122.8040241	DEQ
NPDES-32536	JLR, LLC	45.12609132	-122.8207567	DEQ
31876-ORDEQ	Mill Creek	45.2336	-122.7558	DEQ
RC1-70	Rock Creek	45.1879	-122.7446	Marion SWCD
BC1-67	Butte Creek	45.1477	-122.7804	Marion SWCD
ZC1-72	Zollner Creek	45.1004	-122.8225	Marion SWCD

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
LPR1-71	Little Pudding R Node 385	45.0458	-122.8948	Marion SWCD
AC1-5406	Abiqua Creek	45.0323	-122.798	Marion SWCD
10646-ORDEQ	Silver Creek	45.0066	-122.8242	DEQ

Table 2.4. Stream temperature monitoring sites supporting Little North Santiam River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
S68509	Little North Santiam at Fawn Creek			Watershed Sciences (2001)
No Station ID	Elk Horn Park			BLM
S349766	Node 3			Watershed Sciences (2001)
S88442	Node 4			Watershed Sciences (2001)
No Station ID	North Fork County Park			BLM
14182500	Little North Santiam River near Mehama	44.791667	-122.577778	USGS
No Station ID	Fish Creek			DEQ
No Station ID	Elkhorn Creek	44.802775	-122.4386194	BLM
No Station ID	Sinker Creek	44.8093	-122.4167778	BLM
No Station ID	Wonder Creek			DEQ
No Station ID	Big Creek			DEQ
No Station ID	Cougar Creek			DEQ
No Station ID	Canyon Creek	44.80160278	-122.47945	BLM
No Station ID	Beaver Creek			DEQ
No Station ID	Cox Creek			DEQ

Table 2.5. Stream temperature monitoring sites supporting Thomas Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
tho31a01	Upper Thomas Creek BLM Site	44.6823	-122.4827	BLM
tho25a01	Lower Thomas Creek BLM Site	44.7025	-122.5589	BLM
23779-ORDEQ	Thomas Creek at bridge at Willamette Industries Gate	44.71217	-122.6087	DEQ
23780-ORDEQ	Thomas Creek downstream Jordon Creek	44.72647	-122.6995	DEQ
23781-ORDEQ	Thomas Creek at Hannah Covered Bridge	44.71225	-122.7182	DEQ
23783-ORDEQ	Thomas Creek at old USGS Gage at Shindler Bridge Drive	44.71155	-122.7665	DEQ
23784-ORDEQ	Thomas Creek at Shimanek Covered Bridge	44.71621	-122.8045	DEQ
23785-ORDEQ	Thomas Creek at 0.6 miles west of Scio off of NW 1st	44.70381	-122.8588	DEQ
10783-ORDEQ	Thomas Creek at Kelly Road	44.690666	-122.936888	DEQ
23782-ORDEQ	Neal Creek at Lulay Bridge near Hannah Covered Bridge	44.70761	-122.7124	DEQ

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
23787-ORDEQ	Sucker Slough at Robinson Road	44.70586	-122.917	DEQ

Table 2.6. Stream temperature monitoring sites supporting McKenzie River: Upper model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
No Station ID	McKenzie River at Olallie (RM 75.43)			DEQ
14158850	McKenzie River at Belknap Springs Resort	44.268059	-122.048615	USGS
14159000	McKenzie River at McKenzie Bridge	44.17917	-122.12917	USGS
No Station ID	McKenzie River at Quartz Creek Bridge			DEQ
No Station ID	Deer Creek			DEQ
No Station ID	South Fork McKenzie River			DEQ

Table 2.7. Stream temperature monitoring sites supporting Crabtree Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
No Station ID	Crabtree Creek upstream of BLM site	44.61447	-122.52109	BLM
23742-ORDEQ	Crabtree Creek at Main Line Bridge	44.59453	-122.5567	DEQ
23743-ORDEQ	Crabtree Creek at Road 311 Bridge	44.57808	-122.5816	DEQ
23766-ORDEQ	Crabtree Creek at Willamette Main Line Road	44.58831	-122.6373	DEQ
23767-ORDEQ	Crabtree Creek at swinging foot bridge	44.59833	-122.6872	DEQ
23768-ORDEQ	Crabtree Creek at Larwood Bridge	44.62944444	-122.7410556	DEQ
23769-ORDEQ	Crabtree Creek at Richardson Gap Road	44.65808	-122.8045	DEQ
23771-ORDEQ	Crabtree Creek at Hoffman Covered Bridge	44.65336	-122.8903	DEQ
10784-ORDEQ	Crabtree Creek at Riverside School Road	44.67338889	-122.9178056	DEQ
No Station ID	White Rock Creek	44.59156	-122.50968	BLM
No Station ID	SF Crabtree Creek			DEQ
21834-ORDEQ	Roaring River	44.630311	-122.73781	DEQ
23770-ORDEQ	Beaver Creek	44.63358	-122.8549	DEQ

Table 2.8. Stream temperature monitoring sites supporting Luckiamute River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
25494-ORDEQ	Luckiamute River at Road 1430 crossing (Roadmile 3)	44.8158	-123.56667	DEQ
25493-ORDEQ	Luckiamute River at Road 1440 crossing	44.794	-123.59248	DEQ
25490-ORDEQ	Luckiamute River at Boise Roadmile 4	44.7717	-123.57954	DEQ
25488-ORDEQ	Luckiamute River at Boise Roadmile 1	44.7476	-123.53346	DEQ
25486-ORDEQ	Luckiamute River at Gaging Site	44.6817	-123.46775	DEQ
11111-ORDEQ	Luckiamute River at Hoskins	44.6817	-123.46775	DEQ

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
25483-ORDEQ	Luckiamute River just upstream Ritner Creek	44.7281	-123.44109	DEQ
25480-ORDEQ	Luckiamute River at Ira Hooker Rd.	44.74653725	-123.415898	DEQ
25477-ORDEQ	Luckiamute River at Airlie Rd. Bridge	44.7761	-123.34322	DEQ
10659-ORDEQ	Luckiamute River at Helmick State Park	44.7828	-123.23533	DEQ
25475-ORDEQ	Luckiamute River at Corvallis Rd.	44.7567	-123.1814	DEQ
10658-ORDEQ	Luckiamute River at Lower Bridge (Buena Vista Rd.)	44.73024478	-123.1623338	DEQ
25492-ORDEQ	Miller Creek at the mouth (Trib to Luckiamute RM 50.5)	44.7762	-123.5966	DEQ
25491-ORDEQ	Rock Pit Creek at the mouth (trib to Luckiamute RM 49.8)	44.7727	-123.58502	DEQ
25489-ORDEQ	Slick Creek at the mouth (Trib to Luckiamute RM 48.6)	44.7625	-123.5669	DEQ
25485-ORDEQ	Price Creek at HWY 223 (Trib to Luckiamute RM 35.2)	44.68580005	-123.433875	DEQ
25484-ORDEQ	Maxfield Creek at HWY 223 (Trib to Luckiamute RM 34.0)	44.69482848	-123.4322279	DEQ
25482-ORDEQ	Ritner Creek at Ritner Wayside (Trib to Luckiamute RM 31.2)	44.72824679	-123.4418425	DEQ
25481-ORDEQ	Pedee Creek at Kings Highway (Trib to Luckiamute RM 30.2)	44.74450381	-123.4391258	DEQ
25478-ORDEQ	McTimmonds Creek at State HWY 223 (Trib to Luckiamute RM 27.7)	44.7601	-123.41066	DEQ
11114-ORDEQ	Little Luckiamute River at Elkins Rd. (Trib to Luckiamute RM 18.2)	44.7972	-123.2915	DEQ
25474-ORDEQ	Soap Creek at Buena Vista Rd. (Trib to Luckiamute RM 2.31)	44.7264	-123.16283	DEQ

Table 2.9. Stream temperature monitoring sites supporting Mohawk River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
25608-ORDEQ	Mohawk River on Easy Street below Road 2201	44.24805	-122.7035	DEQ
25607-ORDEQ	Mohawk River at WEYCO shop	44.25872	-122.7319	DEQ
22651-ORDEQ	Mohawk River at WEYCO Gate	44.2542	-122.75605	DEQ
25502-ORDEQ	Mohawk River at Paschelke Road	44.2014	-122.83678	DEQ
22654-ORDEQ	Mohawk River at Wendling Road	44.1729	-122.85408	DEQ
25498-ORDEQ	Mohawk River at Sunderman Road	44.1414	-122.9073	DEQ
25496-ORDEQ	Mohawk River at Old Mohawk Road	44.1042	-122.94029	DEQ
10663-ORDEQ	Mohawk River at Hill Road	44.0923	-122.95934	DEQ
25506-ORDEQ	Unnamed Creek at model meter 5821.68	44.2537	-122.7626	DEQ
25504-ORDEQ	Shotgun Creek	44.2128	-122.82927	DEQ
25503-ORDEQ	Cash Creek	44.2059	-122.83348	DEQ
25501-ORDEQ	Mill Creek	44.1884	-122.83401	DEQ
25500-ORDEQ	Cartwright Creek	44.1712	-122.85729	DEQ
25499-ORDEQ	Parsons Creek	44.1691	-122.87664	DEQ
No Station ID	McGowan Creek			DEQ

Table 2.10. Stream temperature monitoring sites supporting Coyote Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
25627-ORDEQ	Coyote Creek at Gillespie	43.9081	-123.25045	DEQ
25626-ORDEQ	Coyote Creek at Powell Rd	43.92503	-123.27126	DEQ
11148-ORDEQ	Coyote Creek Crow Rd	43.9872	-123.3114	DEQ
10151-ORDEQ	Coyote Creek Petzold Rd	44.00457	-123.27023	DEQ
10150-ORDEQ	Coyote Creek Centrell Rd	44.04158	-123.26766	DEQ
No Station ID	Spencer Creek	43.9081	-123.25045	DEQ

Table 2.11. Stream temperature monitoring sites supporting Mosby Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
28102-ORDEQ	Mosby Creek Above West Fork Mosby Creek	43.5551	-122.8501	BLM
28101-ORDEQ	Mosby Creek Above Cedar Creek	43.6486	-122.9201	BLM
28799-ORDEQ	Mosby Creek at Blue Mountain Park (upstream Perkins Creek)	43.7278	-122.9769	DEQ
30368-ORDEQ	Mosby Creek at Layng Road	43.7779	-122.0045	DEQ
28103-ORDEQ	Mosby Creek below Row River Trail	43.7779	-123.0071	BLM
No Station ID	Miles Creek			DEQ
17090002_LI1380	Lilly Creek			BLM
17090002_BD1160	Big Dry Creek			BLM
17090002_ST1120	Stell Creek			BLM
17090002_CE1060	Cedar Creek (Spring 1)			BLM
No Station ID	Palmer Creek			DEQ
No Station ID	Rock Creek			DEQ
No Station ID	Short Creek			DEQ
No Station ID	Smith Creek			DEQ
No Station ID	Kennedy Creek			DEQ
17090002_PE1235	Perkins Creek			BLM
No Station ID	Unnamed Creek at model meter 26883.36			DEQ
No Station ID	Carolina Creek			DEQ

2.1.2 Stream flow rate– continuous and instantaneous measurements

During the summers of 2000, 2001, and 2002 Oregon DEQ collected ground-level habitat data at many sites in the Willamette subbasins. Stream survey data focuses on near stream land cover classification and measurements, channel morphology measurements, and stream shade measurements.

Flow volume data was collected at stream survey sites and from existing flow gages during the critical stream temperature period in summer of 2000, 2001, and 2002 by the Oregon DEQ and other agencies as stated in the subbasin TMDLs. These instream measurements were used to develop flow mass balances for the streams that were modeled for temperature.

Continuous and instantaneous stream flow rates were collected at several sites during the model period. The measurements at these sites (Table A2 and Table A3) were used to support flow mass balances, tributary inputs, and flow calibrations for the temperature models. **Error! Reference source not found.** shows the location of each site.

Table 2.12. Continuous flow rate measurements supporting Johnson Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source
14211400	Johnson Creek at Regner Gage	45.48647314	-122.4218	USGS
14211499	Kelley Creek At SE 159th Drive at Portland, OR	45.47679	-122.4984	USGS
14211500	Johnson Creek at Sycamore, OR	45.47746	-122.508	USGS
14211550	Johnson Creek at Milwaukie Gage	45.45305	-122.6434	USGS
14211542	Crystal Springs Creek at Bybee St	45.474166	-122.6408	USGS

Table 2.13. Instantaneous flow rate measurements supporting Johnson Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)
10856-ORDEQ	Johnson Creek at SE 122nd	45.4737	-122.536	2002-07-30	2.08
11326-ORDEQ	Johnson Creek at Pleasant View / 190th Ave.	45.488	-122.468	2002-07-29	1.09
11329-ORDEQ	Crystal Springs Creek at Johnson Creek Park	45.4613	-122.642	2002-07-30	8.87
28728-ORDEQ	Johnson Creek at SE 327th Ave.	45.4605	-122.326	2002-07-29	0.42
28729-ORDEQ	Johnson Creek at Revenue Road	45.4617	-122.337	2002-07-29	1.01
28732-ORDEQ	Johnson Creek at Bell Road and Johnson Creek Blvd.	45.4556	-122.593	2002-07-30	1.38

Table 2.14. Continuous flow rate measurements supporting Molalla River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.15. Instantaneous flow rate measurements supporting Molalla River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)
	Molalla R. at HWY 213				88.6
	Molalla R. at Feyrer Park				50.2
	Molalla R. upstream Nork Fork Molalla				67.1
	Molalla R. upstream Pine Cr.				59.7
	Molalla R. above Horse Cr.				46.2
	Molalla R. at Locked Gate				9.6
	North Fork Molalla R. at mouth				44.6
	Table Rock Fork at river mile 1				26.9

Table 2.16. Continuous flow rate measurements supporting Pudding River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.17. Instantaneous flow rate measurements supporting Pudding River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)
	Pudding R. at Arndt Rd.				69

Table 2.18. Continuous flow rate measurements supporting Little North Santiam model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.19. Instantaneous flow rate measurements supporting Little North Santiam model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)

Table 2.20. Continuous flow rate measurements supporting Thomas Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.21. Instantaneous flow rate measurements supporting Thomas Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)

Table 2.22. Continuous flow rate measurements supporting Crabtree Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.23. Instantaneous flow rate measurements supporting Crabtree Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)

Table 2.24. Continuous flow rate measurements supporting Luckiamute River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.25. Instantaneous flow rate measurements supporting Luckiamute River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)

Table 2.26. Continuous flow rate measurements supporting Mohawk River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.27. Instantaneous flow rate measurements supporting Mohawk River model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)

Table 2.28. Continuous flow rate measurements supporting McKenzie River (Upper) model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.29. Instantaneous flow rate measurements supporting McKenzie River (Upper) model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)

Table 2.30. Continuous flow rate measurements supporting Coyote Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.31. Instantaneous flow rate measurements supporting Coyote Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)

Table 2.32. Continuous flow rate measurements supporting Mosby Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Source

Table 2.33. Instantaneous flow rate measurements supporting Mosby Creek model development.

Monitoring Location ID	Monitoring Location Name	Latitude	Longitude	Date	Flow (cfs)

2.1.3 Point Source discharges

2.1.4 Vegetation and habitat surveys

Oregon DEQ and partners collected ground-level habitat data to support model development. Stream survey data focused on near stream land cover classification and height canopy measurements, and channel morphology measurements, and effective shade measurements (Section 2.1.5).

2.1.5 Effective shade measurements

Effective shade is the percent of potential daily solar radiation flux that is blocked by vegetation and topography. A Solar Pathfinder (Solar Pathfinder, Linden, TN) instrument was used to collect effective shade measurements in the field. The effective shade measurement methods and quality control procedures used are outlined in the Water Quality Monitoring Technical Guide Book (OWEB, 1999) and the Solar Pathfinder manual (Solar Pathfinder, 2016). Table 2.34 lists the effective shade measurement collection locations and results, which is shown in Figure 2.1. All results represent the effective shade on a cloud free day during the model period for each stream.

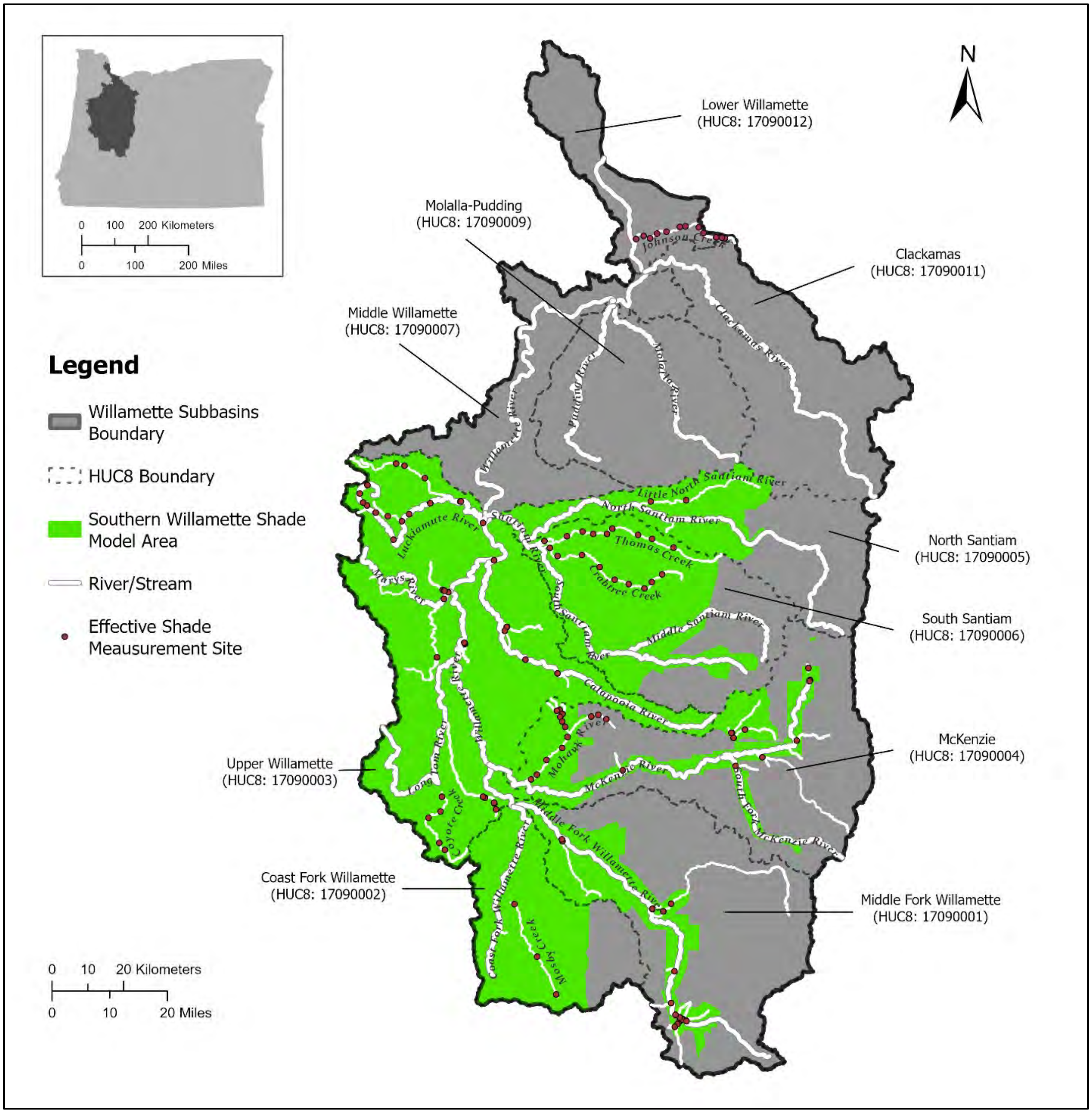


Figure 2.1 Effective shade measurement collection locations in the Willamette Subbasins project area.

Table 2.34: Effective shade measurements on Johnson Creek.

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Johnson Creek at SE 327th Avenue	45.4605	-122.3264	100%	DEQ
Johnson Creek at Revenue Road	45.4617	-122.3368	100%	DEQ
Johnson Creek at Short Road	45.4627	-122.3575	93%	DEQ
Johnson Creek at Palmblad Road	45.4728	-122.4035	91%	DEQ

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Johnson Creek at Regner USGS Gage	45.4867	-122.4206	90%	DEQ
Johnson Creek at Pleasant View / 190th Ave.	45.4880	-122.4676	82%	DEQ
Johnson Creek at SE Circle Avenue	45.4864	-122.4880	77%	DEQ
Johnson Creek at SE 122nd Avenue (Portland)	45.4737	-122.5358	79%	DEQ
Johnson Creek at 92nd Avenue near Flavel	45.4678	-122.5683	20%	DEQ
Johnson Creek at Bell Road and Johnson Creek Blvd	45.4557	-122.5927	67%	DEQ
Johnson Creek at 45th Avenue Footbridge	45.4617	-122.6161	63%	DEQ
Johnson Creek at Milwaukie Gage	45.4531	-122.6434	71%	DEQ

Table 2.35: Effective shade measurements on the Little North Santiam River.

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Little North Santiam at Elk Horn Park	44.8018	-122.4428	51	BLM
Little North Santiam at North Fork County Park	44.7964	-122.5673	24	BLM

Table 2.36: Effective shade measurements on Thomas Creek.

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Thomas Creek at Kelly Road	44.6907	-122.9369	4%	DEQ
Thomas Creek at 0.6 miles west of Scio off of NW 1st	44.7038	-122.8588	44%	DEQ
Thomas Creek at Shimanek Covered Bridge	44.7162	-122.8045	18%	DEQ
Thomas Creek at old USGS Gage at Shindler Bridge Drive	44.7116	-122.7665	37%	DEQ
Thomas Creek at Hannah Covered Bridge	44.7123	-122.7182	31%	DEQ
Thomas Creek downstream Jordon Creek	44.7265	-122.6995	28%	DEQ
Thomas Creek at bridge at Willamette Industries Gate	44.7122	-122.6087	62%	DEQ
Lower Thomas Creek BLM Site	44.7025	-122.5589	55%	DEQ
Upper Thomas Creek BLM Site	44.6823	-122.4827	87%	DEQ

Table 2.37: Effective shade measurements on Crabtree Creek.

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Crabtree Creek at Riverside School Road	44.6734	-122.9178	55%	DEQ
Crabtree Creek at Hoffman Covered Bridge	44.6534	-122.8903	30%	DEQ
Crabtree Creek at Richardson Gap Road	44.6581	-122.8045	13%	DEQ
Crabtree Creek at Larwood Bridge	44.6294	-122.7411	7%	DEQ
Crabtree Creek at swinging foot bridge	44.5983	-122.6872	34%	DEQ
Crabtree Creek at Willamette Main Line Road	44.5883	-122.6373	43%	DEQ
Crabtree Creek at Road 311 Bridge	44.5781	-122.5816	55%	DEQ
Crabtree Creek at Main Line Bridge	44.5945	-122.5567	41%	DEQ
Crabtree Creek at BLM site	44.6145	-122.5211	56%	BLM

Table 2.38: Effective shade measurements on the Luckiamute River.

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Luckiamute River at Road 1430 crossing (Roadmile 3)	44.8158	-123.5667	93%	DEQ
Luckiamute River at Road 1440 crossing	44.7940	-123.5925	76%	DEQ
Luckiamute River at Boise Roadmile 4	44.7717	-123.5795	84%	DEQ
Luckiamute River at Boise Roadmile 1	44.7476	-123.5335	77%	DEQ
Luckiamute River at Gaging Site	44.6817	-123.4678	84%	DEQ
Luckiamute River at Hoskins	44.6817	-123.4678	34%	DEQ
Luckiamute River just upstream Ritner Creek	44.7281	-123.4411	78%	DEQ
Luckiamute River at Ira Hooker Rd.	44.7465	-123.4159	15%	DEQ
Luckiamute River at Airlie Rd. Bridge	44.7761	-123.3432	31%	DEQ
Luckiamute River at Helmick State Park	44.7828	-123.2353	46%	DEQ

Table 2.39: Effective shade measurements on the Mohawk River.

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Mohawk River at Hill Road	44.0923	-122.9593	52%	DEQ
Mohawk River at Old Mohawk Road	44.1042	-122.9403	59%	DEQ
Mohawk River at Sunderman Road	44.1414	-122.9073	50%	DEQ
Mohawk River at Wendling Road	44.1729	-122.8541	42%	DEQ
Mohawk River at Paschelke Road	44.2014	-122.8368	71%	DEQ
Mohawk River at WEYCO Gate	44.2542	-122.7561	77%	DEQ
Mohawk River at WEYCO shop	44.2587	-122.7319	20%	DEQ
Mohawk River on East Street	44.2481	-122.7035	96%	DEQ

Table 2.40: Effective shade measurements on Coyote Creek.

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Coyote Creek at Gillespie	43.9081	-123.2505	56%	DEQ
Coyote Creek at Powell Rd	43.9250	-123.2713	55%	DEQ
Coyote Creek at Crow Road	43.9872	-123.3114	15%	DEQ
Coyote Creek at Petzold Road	44.0046	-123.2702	64%	DEQ
Coyote Creek at Centrell Road	44.0416	-123.2677	63%	DEQ

Table 2.41: Effective shade measurements on Mosby Creek.

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Mosby Creek Above West Fork Mosby Creek	43.5551	-122.8501	50%	DEQ
Mosby Creek Above Cedar Creek	43.6486	-122.9201	54%	DEQ
Mosby Creek at Layng Road	43.7779	-123.0045	45%	DEQ

Table 2.42: Effective shade measurements supporting the Southern Willamette shade model.

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Amazon Creek near East 39th Ave	44.0141	-123.0780	57%	DEQ
Amazon Creek near East 27th Ave	44.0288	-123.0840	63%	DEQ
Amazon Creek near East 26th Ave	44.0307	-123.0855	53%	DEQ
Amazon Creek upstream of Chambers Street	44.0423	-123.1170	21%	DEQ
Amazon Creek downstream of Arthur Street	44.0445	-123.1250	13%	DEQ
Blue River upstream of Blue River Road (NF 15)	44.2210	-122.2634	64%	DEQ
Boulder Creek upstream of OR highway 126	44.2054	-122.0375	92%	DEQ
Buck Creek upstream of Railroad tracks	43.7751	-122.5255	91%	DEQ
Buck Creek downstream of Road	43.7755	-122.5262	94%	DEQ
Butte Creek 100 feet downstream of bridge	44.4721	-123.0599	86%	DEQ
Butte Creek 300 feet downstream of bridge	44.4725	-123.0602	91%	DEQ
Calapooia River at McKercher Park	44.3598	-122.8782	33%	DEQ
Calapooia River 300 feet upstream of playground downstream end of side channel	44.3917	-122.9913	26%	DEQ
Calapooia River near mouth	44.6375	-123.1124	26%	DEQ
Coal Creek downstream NF Road 201	43.4947	-122.4230	73%	DEQ
Coal Creek near mouth	43.5045	-122.4226	70%	DEQ
Cogswell Creek near mouth	44.1210	-122.6409	95%	DEQ
Cougar Creek near mouth	44.1388	-122.2478	90%	DEQ
Deadhorse Creek upstream of road	43.5013	-122.4112	95%	DEQ
Fish Lake Creek upstream of Eno Road (NF 2676)	44.3879	-122.0005	93%	DEQ
Horse Creek downstream of Horse Creek Road (NF 2638)	44.1617	-122.1554	71%	DEQ
Lake Creek 40 feet north of bridge	44.4261	-123.2049	68%	DEQ
Lake Creek at first right turn	44.4284	-123.2058	68%	DEQ
Lake Creek 100 feet upstream of Lake	44.4294	-123.2068	56%	DEQ
Little Luckiamute River at George Gerlinger Park	44.8721	-123.4687	55%	DEQ
Little Luckiamute River upstream Falls	44.8671	-123.4388	76%	DEQ
Little Luckiamute River downstream of 223 bridge	44.8380	-123.3648	34%	DEQ
Lookout Creek downstream of Forest Road 1506	44.2306	-122.2181	22%	DEQ
Lookout Creek near river mile 0.3	44.2092	-122.2576	86%	DEQ
Lost Creek at Elijah Bristow State Park downstream of bridge	43.9395	-122.8441	52%	DEQ
Lost Creek at Elijah Bristow State Park	43.9444	-122.8468	82%	DEQ
Luckiamute River at Helmick State Park	44.7824	-123.2374	21%	DEQ
Luckiamute River at river mile 2.1	44.7306	-123.1550	3%	DEQ
Mary's River in the Mary's River natural area	44.5375	-123.2838	7%	DEQ
Mary's River upstream of railroad bridge	44.5542	-123.2695	51%	DEQ
McKenzie River downstream of Clear Lake at river mile 84.3	44.3578	-121.9945	69%	DEQ
McKenzie River downstream of Clear Lake at river mile 84.1	44.3550	-121.9961	63%	DEQ
Middle Fork Willamette River upstream of bridge	43.4977	-122.4017	52%	DEQ

Monitoring Location Name	Latitude	Longitude	Effective Shade	Source
Middle Fork Willamette River at Campers Flat	43.5007	-122.4131	64%	DEQ
Middle Fork Willamette River upstream of Coal Creek	43.5050	-122.4226	6%	DEQ
Muddy Creek 50 meters downstream of Bruce Road	44.3900	-123.3015	18%	DEQ
Muddy Creek 135 meters downstream of Bruce Road	44.3906	-123.3018	8%	DEQ
North Fork Middle Fork Willamette River upstream of NF road 1910	43.7897	-122.4618	42%	DEQ
North Fork Middle Fork Willamette River at river mile 2.52	43.7701	-122.4873	43%	DEQ
North Fork Middle Fork Willamette River at river mile 2.43	43.7695	-122.4883	43%	DEQ
Oak Creek 90 feet downstream of the 35th Street bridge	44.5602	-123.2894	76%	DEQ
Oak Creek 200 feet downstream of the 30th St bridge	44.5587	-123.2837	89%	DEQ
Oak Creek 100 feet upstream of Western Blvd	44.5574	-123.2821	96%	DEQ
Owl Creek at gate about 0.06 miles from Shotgun Creek Road	44.2685	-122.8676	93%	DEQ
Ritner Creek at Ritner Creek Park	44.7398	-123.4906	89%	DEQ
Seeley Creek 50 feet downstream of Seeley Cr Road	44.2587	-122.8567	90%	DEQ
Shotgun Creek 0.2 miles north of Owl Creek Road	44.2654	-122.8767	95%	DEQ
Shotgun Creek 30 feet downstream of logjam	44.2508	-122.8645	96%	DEQ
Shotgun Creek 120 feet upstream of bridge	44.2389	-122.8562	96%	DEQ
Shotgun Creek at sewage lagoons	44.2258	-122.8451	95%	DEQ
Simpson Creek downstream of Road 21	43.4962	-122.3987	88%	DEQ
Slick Creek upstream of road	44.7642	-123.5656	94%	DEQ
Snake Creek downstream of bridge	43.5404	-122.4535	98%	DEQ
Sodom Ditch 50 feet north of Boston Mill Dr	44.4618	-123.0669	74%	DEQ
Tibits Creek near mouth	44.2215	-122.2655	64%	DEQ
Unnamed Tributary of Hills Creek Lake	43.6209	-122.4442	97%	DEQ
Unnamed Tributary of Coal Creek upstream of FS road 2133-210	43.4881	-122.4293	96%	DEQ
Unnamed Tributary of Coal Creek at the end of FS road 2133-210	43.4815	-122.4382	97%	DEQ
Unknown Tributary of M.F. Willamette R near mouth (Young or What Creek)	43.5110	-122.4364	97%	DEQ
Youngs Creek near mouth	43.5113	-122.4374	98%	DEQ

2.2 GIS and Remotely Sensed Data

2.2.1 10-Meter Digital Elevation Model (DEM)

The Digital Elevation Model (DEM) data files are representations of cartographic information in a raster form. DEMs consist of a sampled array of elevations for a number of ground positions at regularly spaced intervals. The U.S. Geological Survey, as part of the National Mapping Program, produces these digital cartographic/geographic data files. DEM grid data are rounded to the nearest meter for ten-meter pixels. DEMs are used to determine stream elevation, stream gradient, valley gradient, valley shape/landform and topographic shade angles

2.2.2 Light Detection and Ranging (LiDAR)

Light Detection and Ranging (LiDAR) is a remote sensing method that uses pulses of light to calculate the elevation of ground and surface features with a high degree of accuracy and resolution. LiDAR data is used to develop high resolution digital surface models (DSM) and DEMs which can then be used to derive canopy height. The Oregon Department of Geology and Mineral Industries oversees the Oregon LiDAR Consortium (OLC), which develops cooperative agreements for LiDAR collection. LiDAR collected through the OLC is made available for free and can be downloaded at https://www.oregongeology.org/lidar. LIDAR was used to characterize vegetation height and ground elevations.

2.2.3 Aerial Imagery – Digital Orthophoto Quads

Aerial imagery was used to:

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

A digital orthophoto quad (DOQ) is a digital image of an aerial photograph in which displacements caused by the camera angle and terrain have been removed. In addition, DOQs are projected in map coordinates combining the image characteristics of a photograph with the geometric qualities of a map.

2.2.4 Thermal Infrared Radiometry (TIR) temperature data

TIR temperature data were used to:

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

TIR imagery measures the surface temperature of waterbodies or objects captured in the TIR image (i.e., ground, vegetation, and stream). TIR data was gathered through a sensor mounted on a helicopter that collected digital data directly to an on-board computer at a rate that insured the imagery maintained a continuous image overlap of at least [40%]. The TIR detected emitted radiation at wavelengths from [8-12] microns (long-wave) and recorded the level of emitted radiation as a digital image across the full 12-bit dynamic range of the sensor. Each image pixel contained a measured value that was directly converted to a temperature. Each thermal image has a spatial resolution of less than one-half meter/pixel. Visible video sensor captured the same field-of-view as the TIR sensor. GPS time was encoded on the imagery.

Data collection was timed to capture maximum daily stream temperatures, which typically occur between 14:00 and 18:00 hours. The helicopter was flown longitudinally over the center of the stream channel with the sensors in a vertical (or near vertical) position. In general, the flight altitude was selected so that the stream channel occupied approximately 20-40% of the image frame. A minimum altitude of approximately 300 meters was used both for maneuverability and for 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 distributed prior to the survey to ground truth the radiant temperatures measured by the TIR. 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 directly to specific sources (i.e., water withdrawal, tributary confluence, vegetation patterns, etc.). Areas with stream water mixing 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 specific change in stream temperature or a stream temperature gradient that results in a temperature change over a specified distance.

Longitudinal river temperatures were sampled using thermal infrared radiometry (TIR) in separate flights for each stream. Temperature data sampled from the TIR imagery revealed spatial patterns that are variable due to localized stream heating, tributary mixing, and groundwater influences. Figure 2.4Figure 3.1 through Figure 2.7 display plots of TIR-sampled temperatures in the Willamette subbasins Tributary and spring temperatures identified on the plots are sampled from TIR imagery.

Thermal stratification was identified in TIR imagery and by comparison with the instream temperatures loggers. For example, the imagery may reveal a sudden cooling at a riffle or downstream of an instream structure, where water was rather stagnant or deep just upstream. All streams and the TIR collection dates are summarized in Table 2.43.

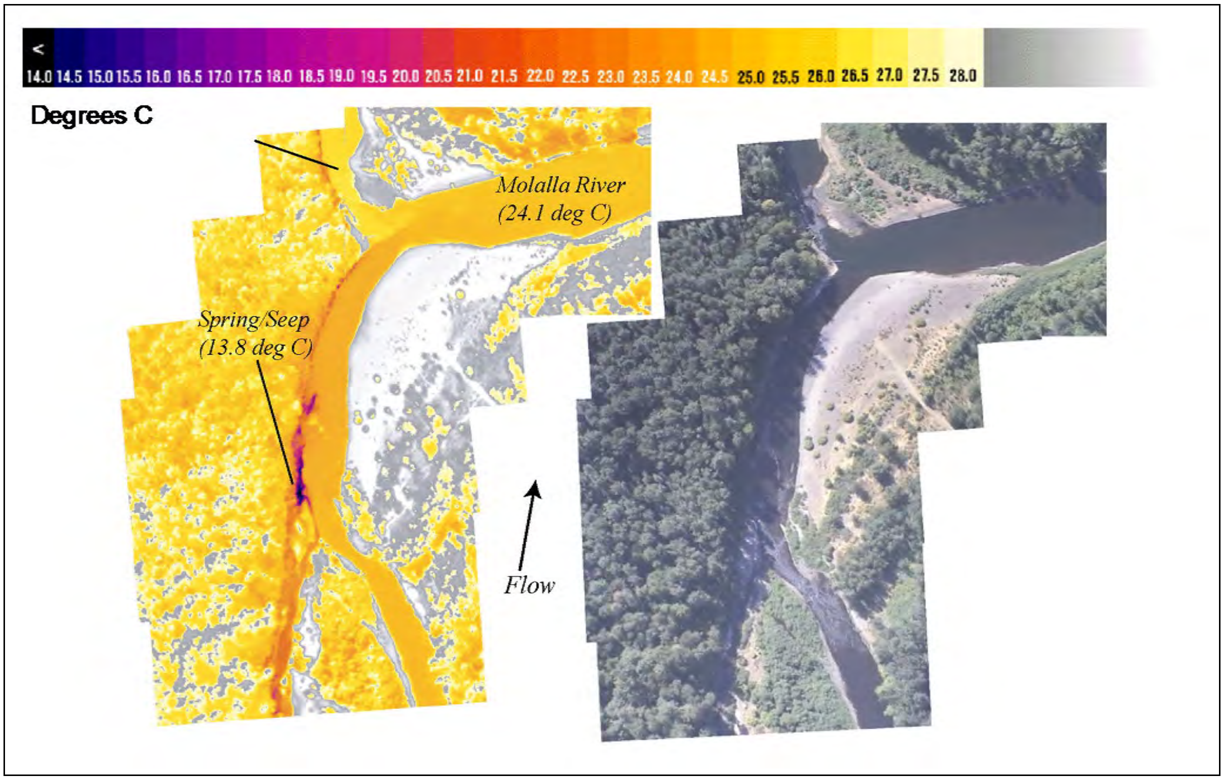


Figure 2.2 TIR/color video image pair showing the location of a spring or seep near the confluence of the Molalla and Pudding Rivers, July 26, 2004.

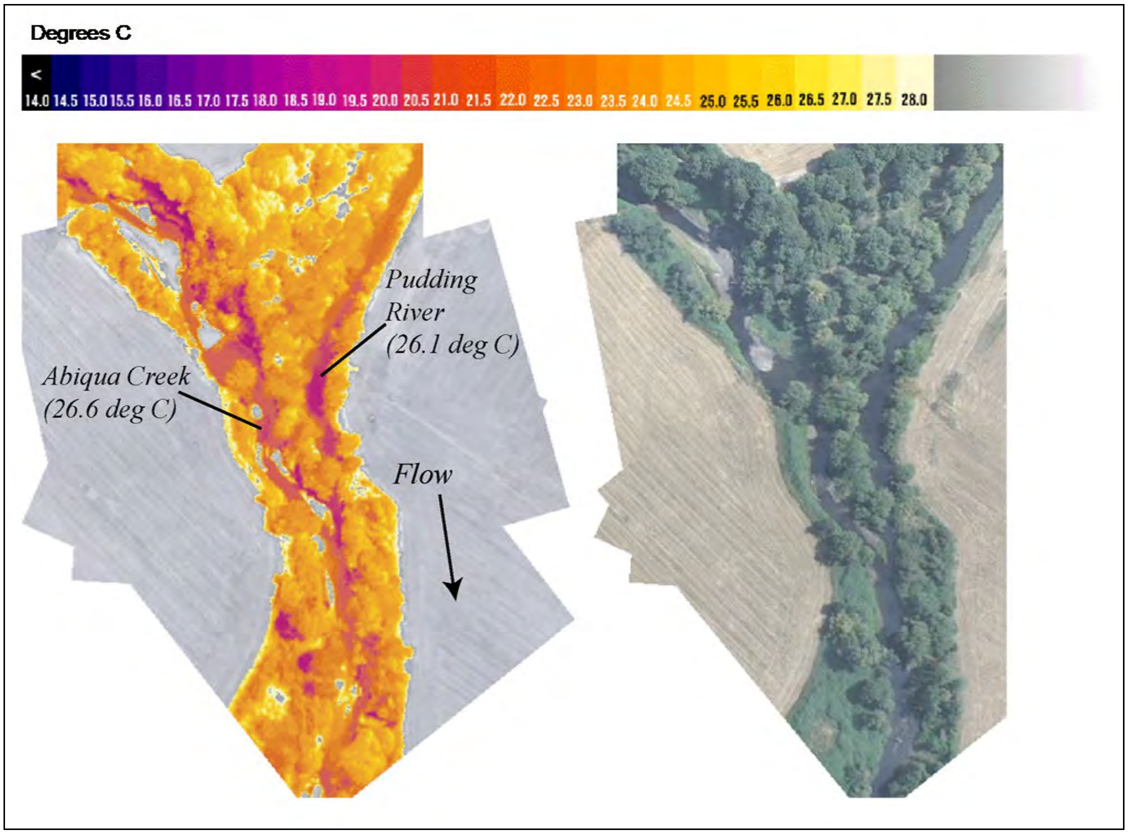


Figure 2.3 TIR/color video image pair showing Pudding River and Abiqua Creek temperatures on August 11, 2004.

Table 2.43. TIR survey extents and collection dates in the Willamette Subbasins.

Stream	Survey Extent	Survey Date	Time	Survey Distance
Johnson Creek	Mouth to headwaters	7/31/2002	13:32-14:35	21.5 mi
Beverly Creek	Mouth to headwaters	8/2/2000	15:24-15:31	2.3 mi
Bonnie Creek	Mouth to headwaters	8/3/2000	14:38-14:41	2.0 mi
Boulder Creek	Mouth to headwaters	8/2/2000	14:51-14:57	2.9 mi
Canal Creek	Mouth to Elk Creek	8/2/2000	15:59-16:04	2.7 mi
Crabtree Creek	River mile 30.6 to downstream of Crabtree Lake	8/2/2000	16:13-16:25	6.1 mi
Elkhorn Creek	Mouth to river mile 3.3	8/1/2000	15:04-15:10	3.3 mi
Hamilton Creek	Deer Creek to headwaters	8/3/2000	13:38-13:51	3.8 mi
Hamilton Creek South Branch	Mouth to headwaters	8/3/2000	13:54-14:05	2.5 mi
Little North Fork Santiam River	Mouth to Henline Creek	8/1/2000	14:33-15:00	16.8 mi
Molalla River	Mouth to headwaters	7/26/2004	14:36-16:23	47.1 mi
Packers Gulch	Mouth to headwaters	8/2/2000	15:05-15:14	3.0 mi

Stream	Survey Extent	Survey Date	Time	Survey Distance
Pat Creek	Mouth to headwaters	8/2/2000	15:34-15:37	1.4 mi
Pudding River	Mouth to Little Pudding River	8/11/2004	16:01-17:59	36.7 mi
Pudding River	Little Pudding River to heatwaters	8/12/2004	14:07-15:48	26.8 mi
Quartzville Creek	Green Peter Reservoir to Canal Creek	8/2/2000	15:43-15:59	8.9 mi
Schafer Creek	Mouth to headwaters	8/2/2000	16:13-16:25	1.2 mi
South Fork Packers Gulch	Mouth to headwaters	8/2/2000	15:01-15:05	1.8 mi
South Fork Scott Creek	Mouth to headwaters	8/3/2000	13:22-13:33	5.3 mi
South Santiam River	Confluence with the North Santiam River to Foster Reservoir	8/1/2000	15:32 - 16:16	35.9 mi
Thomas Creek	Mouth to Neal Creek	8/3/2000	16:16-16:43	16.0 mi
Thomas Creek	River mile 22.2 to River mile 35.8	8/3/2000	16:50-17:08	10.0 mi
Unnamed Tributary to Crabtree Creek	Mouth to headwaters	8/3/2000	14:11-14:18	2.6 mi
Unnamed Tributary to Quartzville Ck	Mouth to headwaters	8/2/2000	14:19-14:22	1.1 mi
Unnamed Tributary to Unnamed Trib of Crabtree Creek	Mouth to headwaters	8/3/2000	14:20-14:24	1.1 mi
Unnamed Tributary to Yellowstone Creek	Mouth to headwaters	8/2/2000	14:35-14:37	0.7 mi
Unnamed Tributary to Yellowstone Creek	Mouth to headwaters	8/2/2000	14:40-14:48	1.5 mi
West Fork Packers Gulch	Mouth to headwaters	8/2/2000	15:14-15:19	1.5 mi
White Rock Creek	Mouth to headwaters	8/3/2000	14:26-14:35	2.7 mi
Yellowstone Creek	Mouth to headwaters	8/2/2000	14:27-14:34	3.0 mi
Bear Creek	Mouth to river mile 1.0	7/31/2002	16:25-16:34	1.0 mi
Big River	Mouth to river mile 7.5	7/21/2002	16:27-16:43	7.5 mi
Deer Creek	Mouth upstream 8.7 km	9/3/1999	16:30 –16:31	8.7 km
Eagle Creek	Mouth to Wilderness Bnd.	7/31/2002	15:14-15:54	16.5 mi
Mosby Creek	Mouth to headwaters	7/21/2002	15:06-15:52	22.0 mi
North Fork Eagle Creek	Mouth to river mile 5.0	7/31/2002	16:01-16:20	5.0 mi
Sharps Creek	Mouth to Rivermile 11.0	7/21/2002	13:44-14:15	11.0 mi
South Fork McKenzie River	Mouth to Cougar Dam	9/3/1999	16:24 –16:25	7.0 km

The TIR survey reports contain detailed flight information, results discussions, sample imagery, and longitudinal temperature profiles. Actual TIR data is available upon request from DEQ.

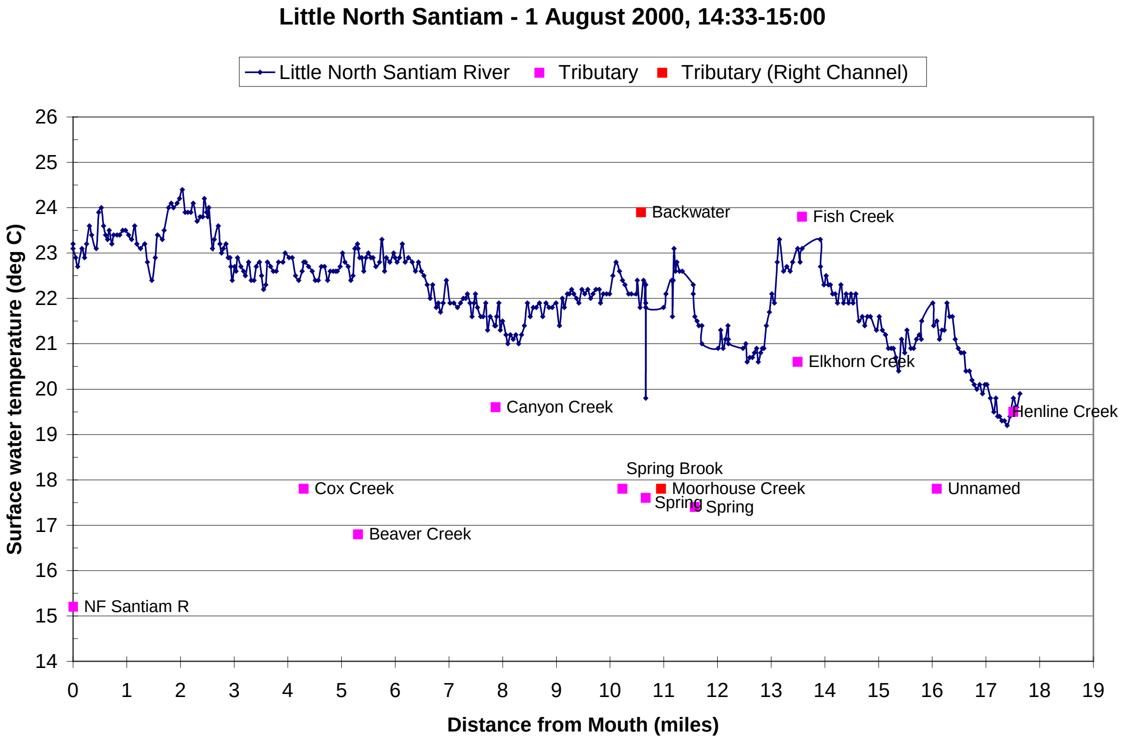


Figure 2.4 TIR temperatures on the Little North Santiam River, North Santiam Subbasin.

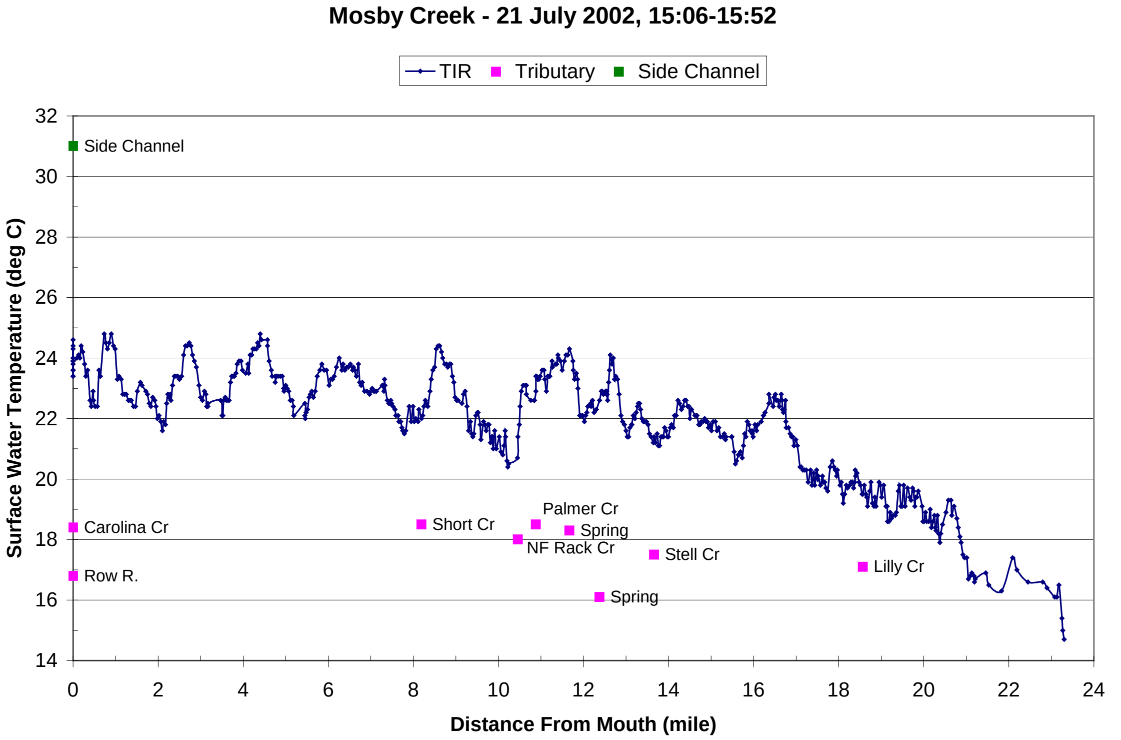


Figure 2.5 TIR temperatures on Mosby Creek, Coast Fork Willamette Subbasin.

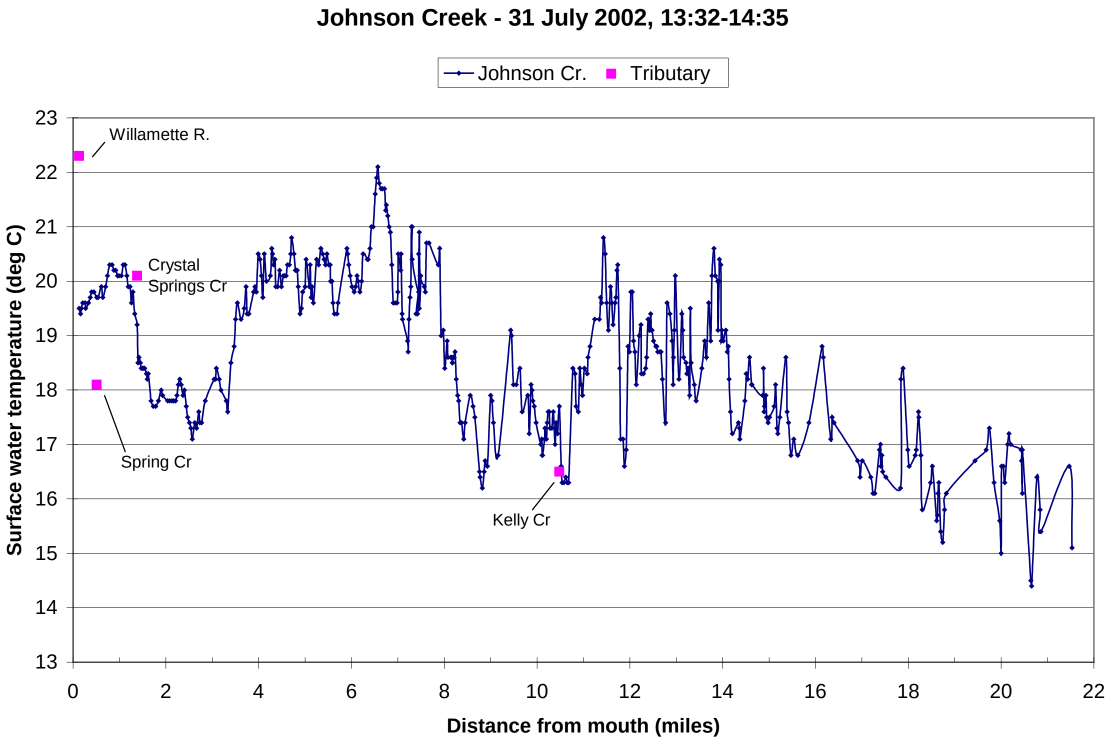


Figure 2.6 TIR temperatures on Johnson Creek, Lower Willamette Subbasin.

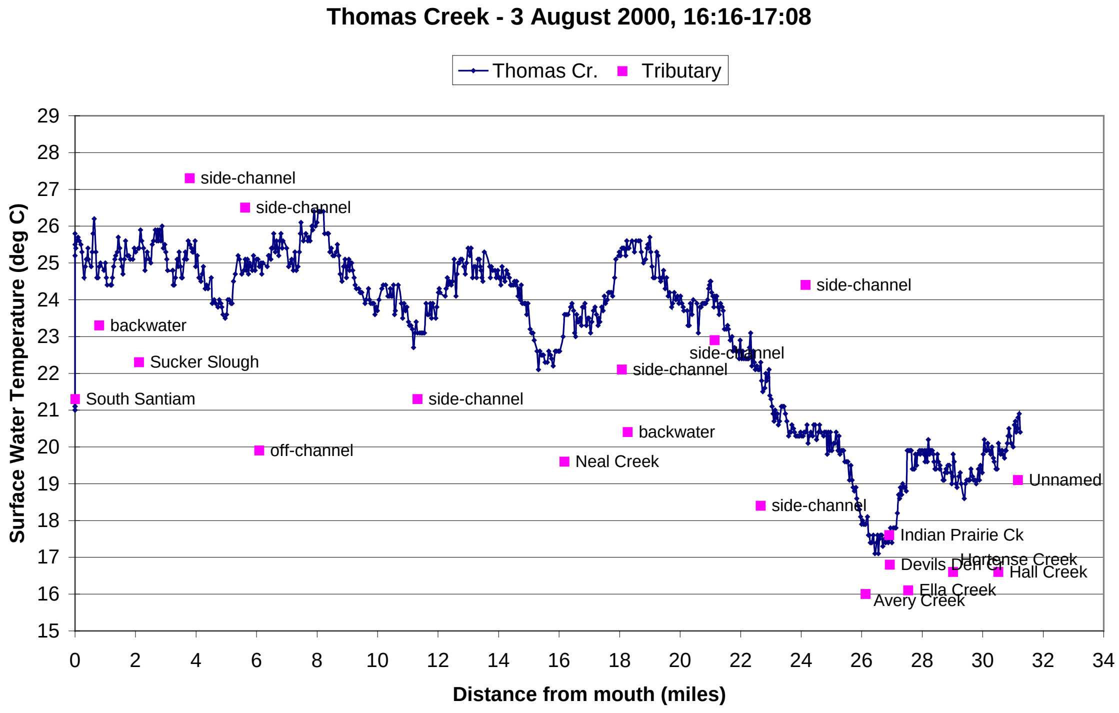


Figure 2.7 TIR Temperatures on Thomas Creek, South Santiam Subbasin

2.3 Derived Data

Several datasets used for model setup were derived or sampled from landscape scale GIS data. Sampling density was user-defined and generally matched any GIS data resolution and accuracy. The derived parameters used in the stream temperature analysis were:

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

2.3.1 Stream Position and Channel Width

Stream position and active channel width were estimated using the following steps:

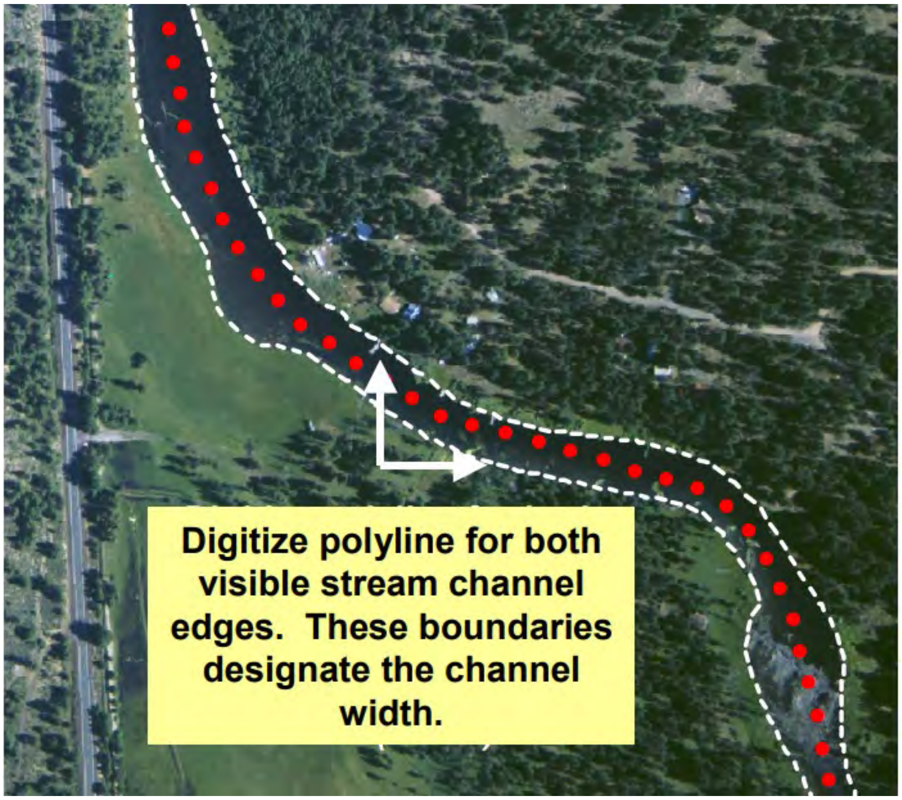
Step 1. Stream right and left banks (looking in the downstream direction) were digitized at a 1:2,000 or smaller map scale using a combination of [aerial imagery from the USDA National Agricultural Imagery Program (NAIP) and hillshade rasters derived from high resolution LiDAR ground elevation data (Figure A3). Channel boundaries were digitized to correspond to the active channel width, which is defined as the width between shade producing near stream vegetation, the low flow channel terrace edge, or down cut banks were interpreted from the available datasets.

Step 2. The stream center flowline was digitized at a 1:2,000 or smaller map scale by following the center of the wetted stream area. At bifurcations the stream flowline was digitized along the largest channel.

Step 3. The stream flowline was segmented into reaches no greater than 100 meters, with a node separating each reach (

Figure 2.8). These nodes determine the location and flow path for modeling. Stream segmentation was completed using a python script called TTools.

Figure 2.8. Example of digitized channel, flowline, and stream nodes.

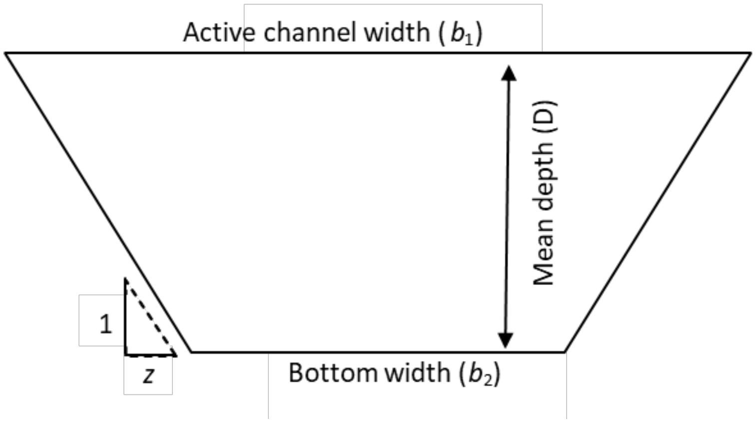


Digitize polyline for both visible stream channel edges. These boundaries designate the channel width.

2.3.2 Channel Bottom Width

The heat source model assumes a trapezoidal channel shape and model versions 8 and newer require input of channel bottom width depicted as b_2 in Figure 2.9. In the Willamette Subbasins, the Pudding River was the only stream modeled with a version 8 heat source temperature model. Bottom width is estimated using Equation A1. The active channel width (b_1) is the GIS digitized channel width. Mean depth was calculated as the active channel width divided by an estimated width-to-depth ratio| or the measured width-to-depth ratio at each instantaneous flow site. Channel angle z and the width-to-depth ratios are estimated model calibration parameters.

Figure 2.9. Conceptual diagram of trapezoidal channel and terms used in Equation A1.



$$b_2 = b_1 - 2 \cdot \mathrm{z} \cdot \mathrm{D}$$ **Equation A1**

where,

$b_2 =$ Bottom width (meters)

$b_1 =$ Active channel width (meters)

$D =$ Mean active channel depth (meters). Estimated as b1 / the width to depth ratio.

$z =$ Channel angle z defined as the change in horizontal distance (meters) for every unit rise in vertical distance (meters) of the channel side slope.

2.3.3 Stream Elevation and Gradient

Stream elevation and stream gradient were derived at each stream node from 10-Meter Digital Elevation Model (DEM) data files for the Molalla River, Pudding River, Johnson Creek (2002) models, and from 3 foot resolution LiDAR bare earth elevation data for the Southern Willamette shade models. Stream gradients were calculated from the elevation of the stream node using the distance between nodes. Stream elevation and gradient derivation for models completed by agencies other than DEQ are described in their respective model reports.

2.3.4 Topographic Shade Angles

The topographic shade angle represents the vertical angle to the highest topographic feature as measured from a flat horizon. At this angle and smaller the topographic feature will cast a shadow over the stream node as the sun moves behind it. Topographic shade angle was calculated using **Equation A2** as implemented in python script called TTools. Elevations were sampled from the DEM. The maximum topographic shade angle in each direction for each stream node was found by sampling every raster cell out as far necessary, typically 10km in three directions (west, south, east) from each stream node.

$$\theta_T = \tan^{-1}\left(\frac{Z_T - Z_S}{d}\right)$$ **Equation A2**

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.

2.3.5 Land Cover Mapping

Near stream land cover is an important parameter influencing water quality. Oregon DEQ has mapped near stream land cover using Digital Orthophoto Quads (DOQs) at a 1:5,000 scale, ODFW's Willamette Valley Land Use/Land Cover GIS database (ODWF, 1998), and PNWERC's Willamette River Basin Landuse and Landcover ca. 1990 GIS dataset (PNWERC/ISE, 1999). Land cover features were mapped 300 feet in the transverse direction from each stream bank. Land cover data are developed by ODEQ in successive steps.

Step 1. Land cover polygons and stream polylines are digitized from DOQs and integrated with ODFW and PNWERC datasets. All digitized polygons are drawn to capture visually like land cover features. All ODEQ digitized line work is verified at 1:5,000 or less.

Step 2. Basic land cover types are developed and assigned to individual polygons. The land cover types used in this effort are aggregate land cover groups, such as: conifers, hardwoods, shrubs, etc., and as defined by ODFW's Willamette Valley database (ODFW, 1998) and PNWERC's Willamette River Basin Land Use and Land Cover ca 1990 dataset (PNWERC/ISE, 1999). See **Table #** for landcover classifications and attributes used to describe current condition near stream landcover.

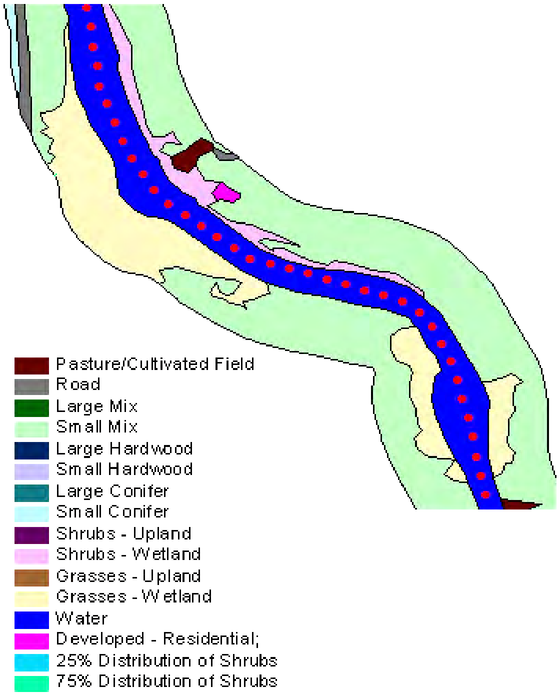
Step 3. Automated sampling is conducted on classified land cover spatial data sets in 2-dimensions. Every 100 feet along the stream (i.e., in the longitudinal direction), the near stream land cover is sampled every 15 meters in a transverse direction; starting at the channel center, out to 60 meters.

Step 4. Ground level land cover data are statistically summarized and sorted by land cover type.

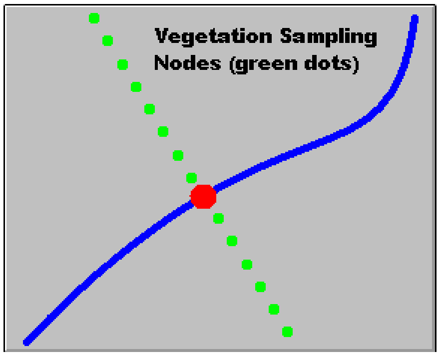
Step 5. Land cover physical attributes can then be described in 2-dimensions since automated sampling occurs in both the longitudinal and transverse directions.

The following images in **Figure #** summarize the steps followed for near stream land cover classification.

Example of Polygon Mapping of Near Stream Land Cover



Example of Classification of the Land Cover Polygons Associating a Land Cover Type to Each of the Polygons (At this point a land cover type numeric code is associated with each polygon.)



TTools longitudinal sampling pattern for near stream land cover (sampling interval is user defined). Sampling occurs for every stream data node at 9 user-defined intervals at 90 degrees from the stream centerline. A database of land cover type is created for each stream data node

Figure 2.10. Examples of classifying near stream land cover.

Table 2.44. Current condition land cover classifications and attributes.

ODFW Landcover Code	PNWERC Landcover Code	ODEQ Landcover Code	Landcover Type	Height (ft)	Density
9	32 , 33	**3011**	Water	0	0%
N/A	N/A	**304**	Barren - Rock	0	0%
N/A	N/A	**308**	Barren - Clearcut	0	0%
N/A	N/A	**400**	Barren - Road	0	0%
N/A	N/A	**401**	Barren - Forest Road	0	0%

N/A	N/A	**402**	Barren - Railroad	0	0%
N/A	N/A	**403**	Barren - Ag. Road	0	0%
N/A	N/A	**3011**	River Bottom - Floodplain	0	0%
N/A	N/A	**3248**	Developed - Residential	20	100%
3	N/A	**3249**	Urban Industrial	30	100%
N/A	N/A	**3249**	Developed - Industrial	30	100%
N/A	N/A	**3252**	Dam	0	0%
N/A	N/A	**3254**	WWTP	0	0%
2.1	N/A	**21**	Annual Row Crops	0	0%
2.2	N/A	**22**	Annual Grass	3	75%
2.3	N/A	**23**	Perennial Grass	3	75%
2.4	N/A	**24**	Orchards, Vineyards, Berries, Christmas Trees, Nursery Stock	10	75%
2.4	N/A	**28**	Orchards, Vineyards, Berries, Christmas Trees, Nursery Stock	40	75%
2.5	N/A	**25**	Unmanaged Pasture	0	0%
2.6	N/A	**26**	Parks and Cemeteries	0	0%
3	N/A	**3248**	Urban Residential	20	100%
20	N/A	**202**	Black Hawthorn, Hedgerows, Brushy Fields	19	25%
20	N/A	**204**	Black Hawthorn, Hedgerows, Brushy Fields	26	25%
20	N/A	**206**	Black Hawthorn, Hedgerows, Brushy Fields	19	75%
20	N/A	**208**	Black Hawthorn, Hedgerows, Brushy Fields	26	75%
21	N/A	**212**	Cottonwood	75	25%
21	N/A	**214**	Cottonwood	105	25%
21	N/A	**216**	Cottonwood	75	75%
21	N/A	**218**	Cottonwood	105	75%
22	N/A	**222**	Willow	28	25%
22	N/A	**224**	Willow	43	25%
22	N/A	**226**	Willow	28	75%
22	N/A	**228**	Willow	43	75%
30	N/A	**30**	Reed Canary Grass	6	75%
30	N/A	**35**	Reed Canary Grass	6	25%
31	N/A	**31**	Cattial, Bulrush	5	75%
31	N/A	**315**	Cattial, Bulrush	5	25%
463	N/A	**4632**	Ash, Cottonwood - Bottomland Pasture Mosaic	33	25%
463	N/A	**4634**	Ash, Cottonwood - Bottomland Pasture Mosaic	93	25%
463	N/A	**4636**	Ash, Cottonwood - Bottomland Pasture Mosaic	33	75%
463	N/A	**4638**	Ash, Cottonwood - Bottomland Pasture Mosaic	93	75%
476	N/A	**4762**	Oak, Douglas Fir - >50% Oak	53	25%
476	N/A	**4764**	Oak, Douglas Fir - >50% Oak	93	25%
476	N/A	**4766**	Oak, Douglas Fir - >50% Oak	53	75%
476	N/A	**4768**	Oak, Douglas Fir - >50% Oak	93	75%
505	N/A	**5052**	Douglas Fir, Oak - < 50% Oak	53	25%
505	N/A	**5054**	Douglas Fir, Oak - < 50% Oak	91	25%
505	N/A	**5056**	Douglas Fir, Oak - < 50% Oak	53	75%
505	N/A	**5058**	Douglas Fir, Oak - < 50% Oak	91	75%
506	N/A	**5062**	Oak, Madrone, Douglas Fir	50	25%
506	N/A	**5064**	Oak, Madrone, Douglas Fir	87	25%
506	N/A	**5066**	Oak, Madrone, Douglas Fir	50	75%
506	N/A	**5068**	Oak, Madrone, Douglas Fir	87	75%
510	N/A	**5102**	Maple, Alder, Fir	65	25%
510	N/A	**5104**	Maple, Alder, Fir	93	25%
510	N/A	**5106**	Maple, Alder, Fir	65	75%
510	N/A	**5108**	Maple, Alder, Fir	93	75%
512	N/A	**5122**	Douglas Fir or any Conifer	102	25%
512	N/A	**5124**	Douglas Fir or any Conifer	160	25%
512	N/A	**5126**	Douglas Fir or any Conifer	102	75%
512	N/A	**5128**	Douglas Fir or any Conifer	160	75%
999	N/A	**999**	Gravel and Sand	0	0%
1000	N/A	**1002**	Unclassified Forest	56	25%
1000	N/A	**1004**	Unclassified Forest	89	25%
1000	N/A	**1006**	Unclassified Forest	56	75%
1000	N/A	**1008**	Unclassified Forest	89	75%

2.3.6 Derived Tributary Stream Flow

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, Oregon 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 the following relationship:

$$T_{mix} = \frac{(Q_{up} \cdot T_{up}) + (Q_{in} \cdot T_{in})}{(Q_{mix})} = \frac{(Q_{up} \cdot T_{up}) + (Q_{in} \cdot T_{in})}{(Q_{up} + Q_{in})}$$

where,

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 (Q_{up} + Q_{in})
T_{up}: Stream temperature directly upstream from mass transfer process
T_{in}: Temperature of inflow
T_{mix}: Resulting stream temperature from mass transfer process assuming complete mix

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. Oregon 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.

2.3.7 Derived Tributary Temperatures

Non-steady state stream models typically require a significant amount of data because of the large spatial and temporal extents the models typically encompass. As the model size or modeling period increase, the amount of information needed to parameterize it also increases. Often it is not possible to parameterize a model entirely from field data because it can be resource intensive or impractical to collect everything that is needed. In general, these data gaps may be considered and addressed in a number of ways. Table 11 summarizes methods that are used to derive the data needed to parameterize the model.

To the greatest extent possible, the method used to derive the model parameters for the existing TMDL models have been summarized in the boundary conditions and tributary inputs tables in the sections of model inputs in the current Chapter 6.

Table 2.45. Methods to derive model parameters for data gaps.

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	Tributary temperature and flow	On main stem 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).

Method	**Possible Parameters**	**Description**
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.
Flow-probability-probability-flow (QPPQ)	Tributary flow	The flow-probability-probability-flow (QPPQ) method makes use of relating flow duration curves between a gaged tributary and an ungaged tributary (Lorenz and Ziegeweid, 2016). The flow duration curve at ungaged sites is estimated using regression approaches (Risley et al., 2008) and the online USGS tool StreamStats (Ries et al., 2017).
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.

Method	Possible Parameters	Description
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 digital elevation model (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.

3. Model setup and calibration

3.1 Johnson Creek

The Johnson Creek model is a water temperature model developed using Heat Source 6.5.1. The model was developed by Oregon DEQ.

3.1.1 Model extent

The extent of the model domain is Johnson Creek at Revenue Road to the mouth of Johnson Creek at the confluence with the Willamette River (

Figure 3.1).

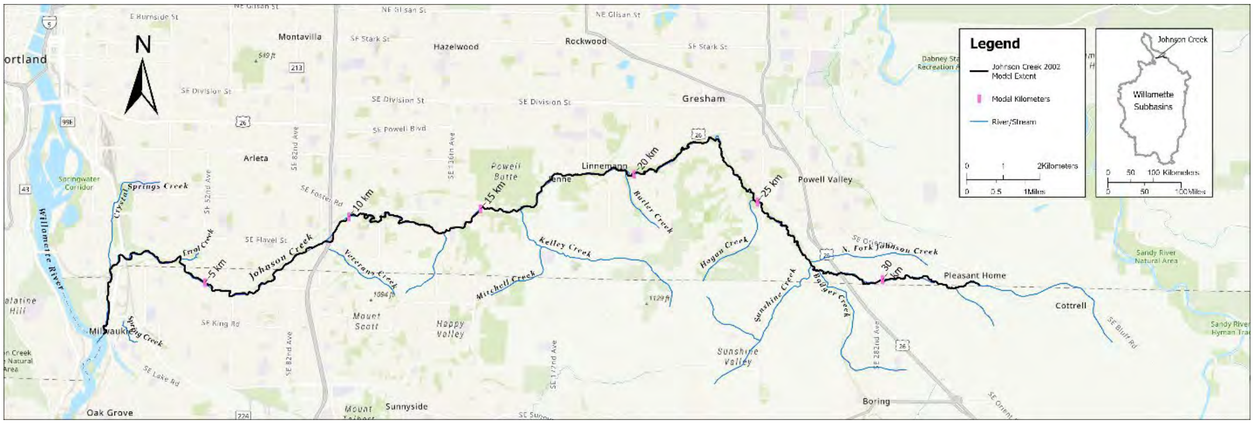


Figure 3.1. Johnson Creek temperature model extent.

3.1.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.1.3 Time frame of simulation

The model period is for a single day: July 31, 2002.

3.1.4 Meteorological inputs

The model used air temperature, relative humidity, and wind speed from various sites (**Table A5 and A6**). The meteorological observations are presented in **Figure A5-A7**. A multiplicative wind sheltering coefficient was applied to the wind speed for calibration.

Table 3.1. Meteorology data sources for the Johnson Creek model.

Site ID	Site	Source
POBO	Powell Butte	AgriMet
10009634	Portland International Airport	NCDC

Table 3.2. Meteorology inputs to Johnson Creek model.

Model Location Name	Model Location (km)	Relative Humidity	Air Temperature	Wind Speed	Wind Sheltering Coefficient
Johnson Creek at Revenue Road	0.00	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at Short Road	2.03	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at Palmblad Avenue	7.24	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at Regner Road	10.06	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at Pleasant View/190th Avenue	15.80	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at SE Circle Avenue	17.55	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at SE 122nd Avenue	22.83	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at SE 92nd Avenue	27.213	Portland International Airport	Portland International Airport	Powell Butte	0.07

Model Location Name	Model Location (km)	Relative Humidity	Air Temperature	Wind Speed	Wind Sheltering Coefficient
Johnson Creek at SE 72nd Avenue and Bell	29.94	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at SE 45th Avenue	32.49	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at Milwaukie Gage	36.42	Portland International Airport	Portland International Airport	Powell Butte	0.07
Johnson Creek at SE 17th Avenue	37.18	Portland International Airport	Portland International Airport	Powell Butte	3

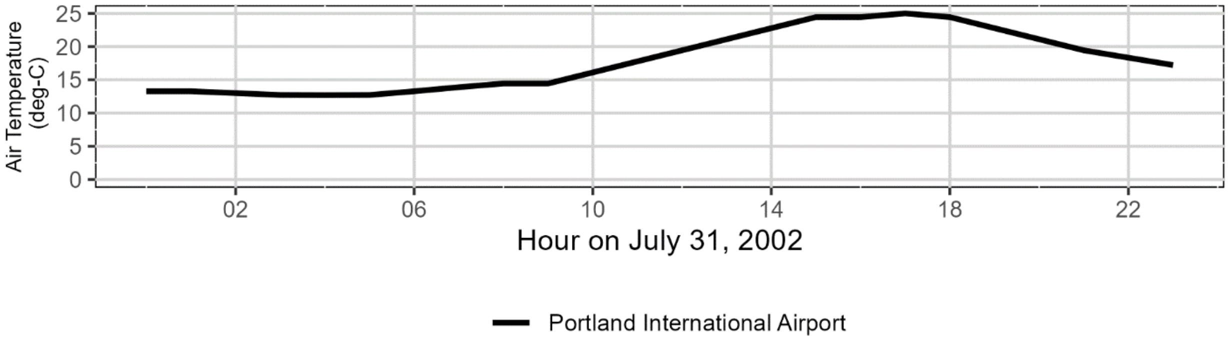


Figure 3.2. Johnson Creek model setup for air temperatures.

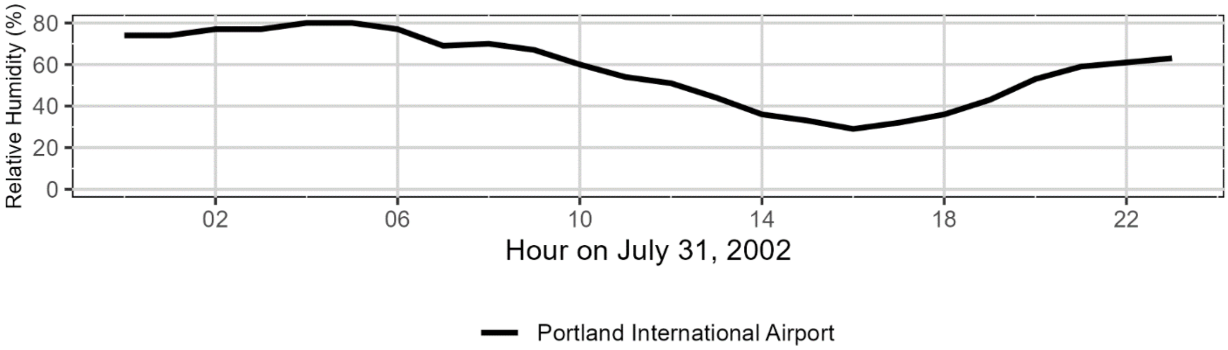


Figure 3.3. Johnson Creek model setup for relative humidity.

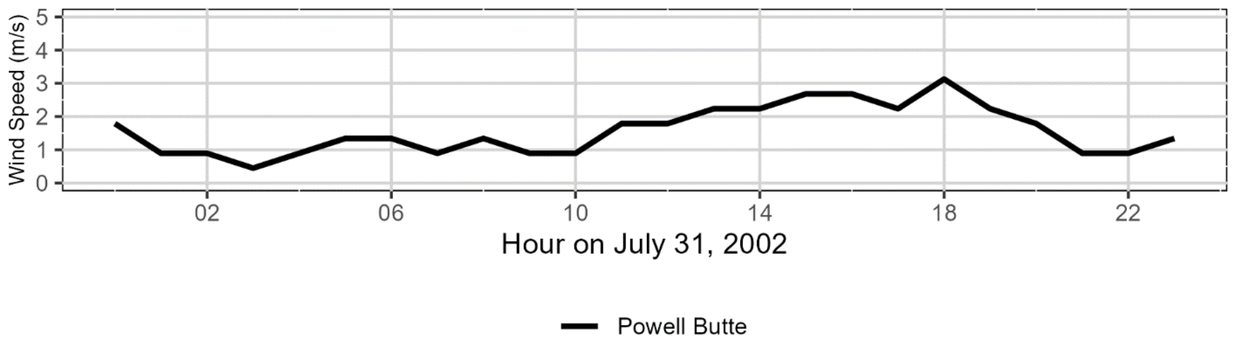


Figure 3.4. Johnson Creek model setup for wind speed.

3.1.5 Temperature inputs

Table A7 and Figure A8 document the water temperature inputs to the model at the boundary condition (Johnson Creek at Revenue Road) and tributaries.

Table 3.3. Tributary and boundary condition water temperature inputs to the Johnson Creek model.

Model Location Name	Model Location (km)	Input Type	Data Source
Johnson Creek at Revenue Road	37.552	Boundary Condition	28729-ORDEQ
Sunshine Creek	31.569	Tributary	Same as Kelley Creek.
Butler Creek	22.365	Tributary	Same as Kelley Creek.
Kelley Creek	18.469	Tributary	USGS 14211499
Veterans Creek	10.646	Tributary	Same as Kelley Creek.
Errol Creek	4.816	Tributary	Grab data collected by City of Portland.
Crystal Springs Creek	2.055	Tributary	11329-ORDEQ
Spring Creek	0.613	Tributary	Same as Kelley Creek.

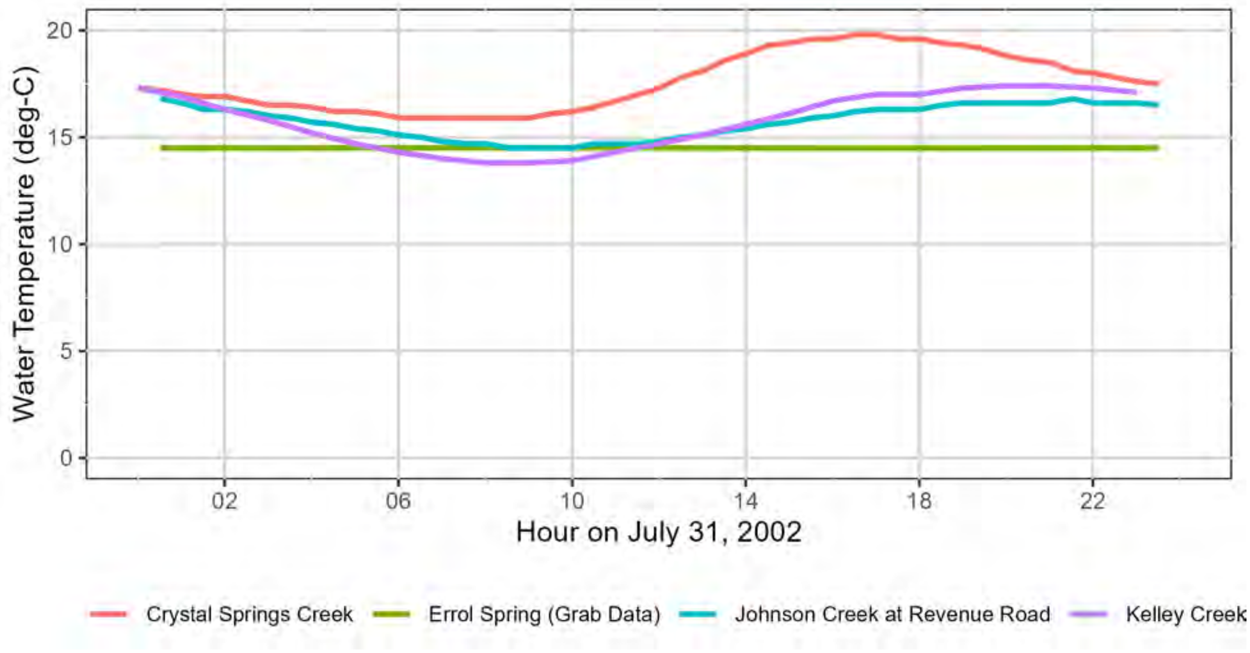


Figure 3.5. Johnson Creek model setup for tributary and boundary condition water temperatures.

3.1.6 Flow inputs

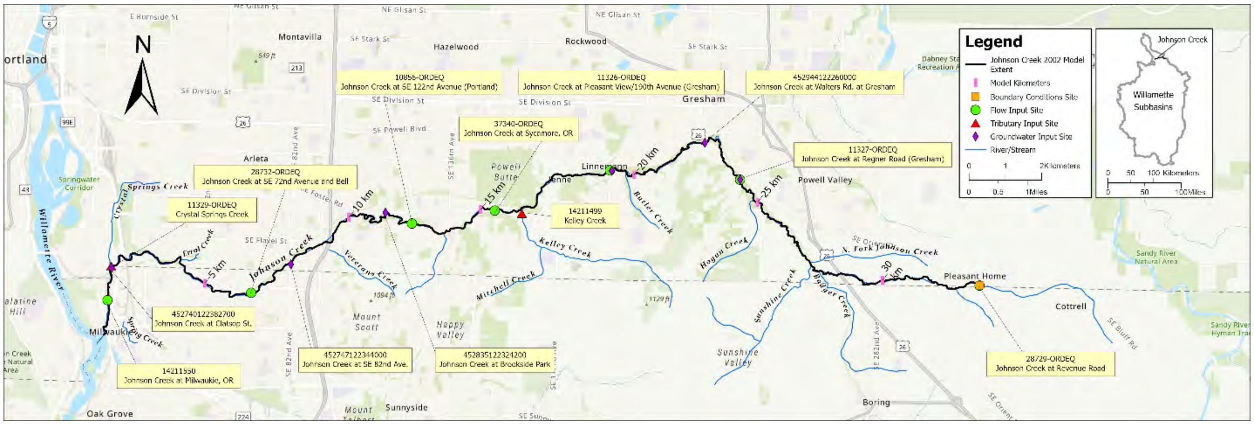


Figure 3.6. Flow monitoring locations used for Johnson Creek model setup and calibration.

Table 3.4 summarizes the boundary condition and tributary flow inputs to the model. Table A2 and Figure A7 document mainstem model flow setup and measured mainstem flow data. Table A9 documents groundwater flow inputs to the model.

Table 3.4. Boundary condition and tributary flow inputs to the Johnson Creek model.

Model Location Name	Model Location (km)	Source
Johnson Creek at Revenue Road	37.552	
Sunshine Creek	31.569	80% of Kelley Creek flow
Butler Creek	22.365	24% of Kelley Creek flow.
Kelley Creek	18.469	USGS 14211499
Veterans Creek	10.646	15% of Kelley Creek flow.
Errol Creek	4.816	Estimated using a flow mass balance based on measured flow and TIR.
Crystal Springs Creek	2.055	
Spring Creek	0.613	15% of Kelley Creek flow.

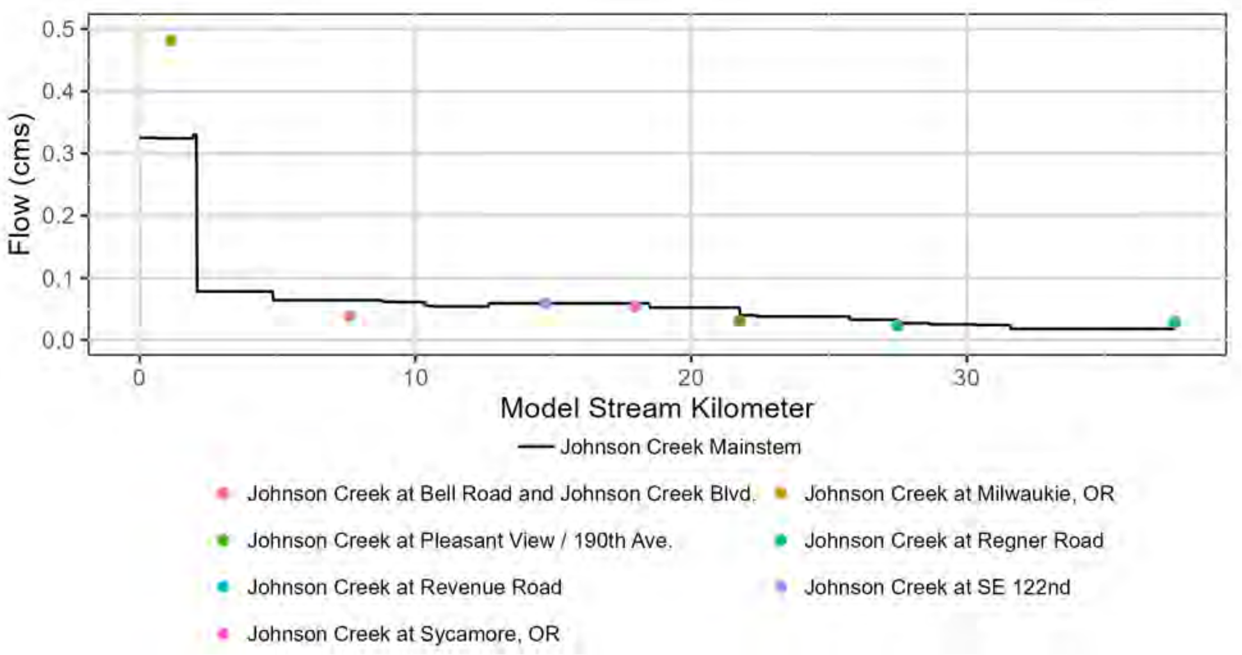


Figure 3.7. Boundary condition and mainstem flow inputs to the Johnson Creek model.

Table 3.5. Groundwater flow inputs to the Johnson Creek model.

Model Location Name	Model Location (km)	Note
Johnson Creek at Regner Gage	27.489	Estimated from USGS Seepage Investigation.
Johnson Creek at Walters Rd.	25.740	Estimated from USGS Seepage Investigation.
Johnson Creek at SE 190th Ave.	21.752	Estimated from USGS Seepage Investigation.
Johnson Creek at Brookside Park	12.64	Estimated from USGS Seepage Investigation.
Johnson Creek at SE 82nd Ave.	9.296	Estimated from USGS Seepage Investigation.
Johnson Creek at Clatsop St.	1.933	Estimated from USGS Seepage Investigation.

3.1.7 Landcover and topographic shade inputs

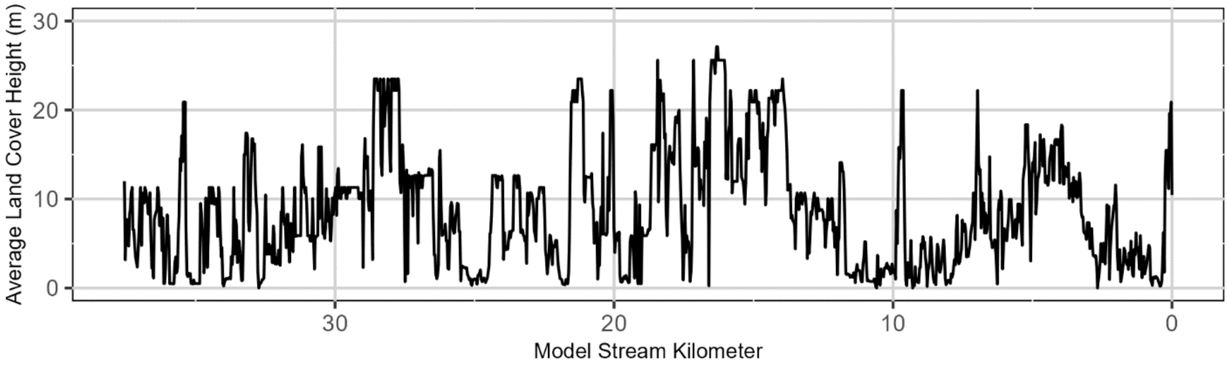


Figure 3.8. Model setup average land cover height (m).

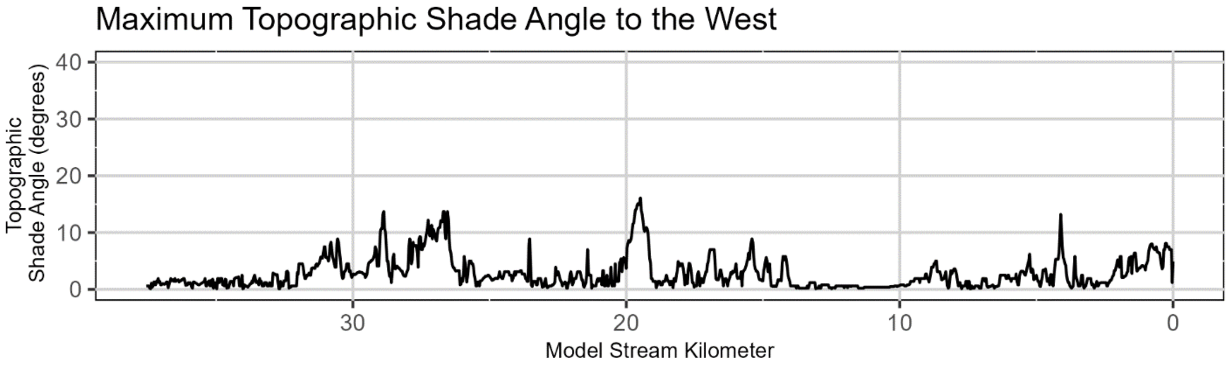


Figure 3.9. Model setup topographic shade angles.

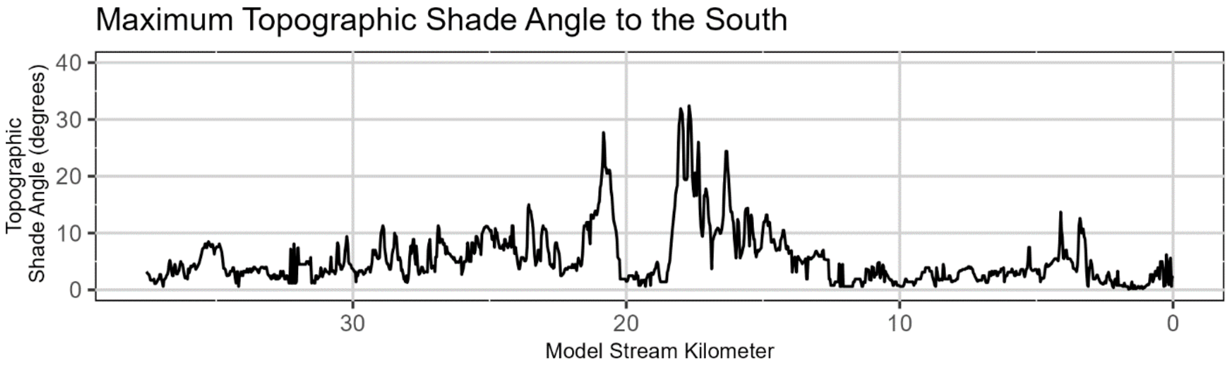


Figure 3.10. Model setup topographic shade angles.

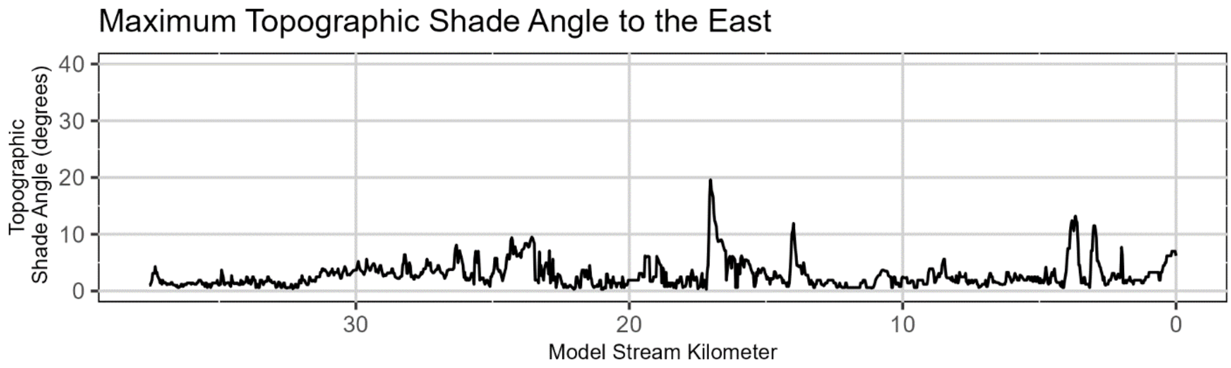
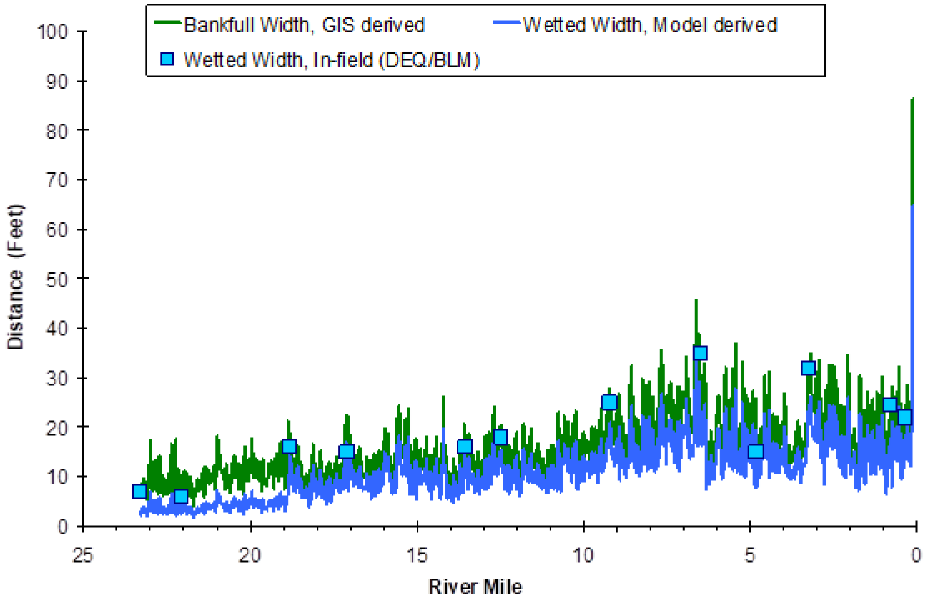


Figure 3.11. Model setup topographic shade angles.

3.1.8 Channel setup

Channel widths on Johnson Creek, Lower Willamette Subbasin



The model was setup with a constant channel incision of 0.5 m.

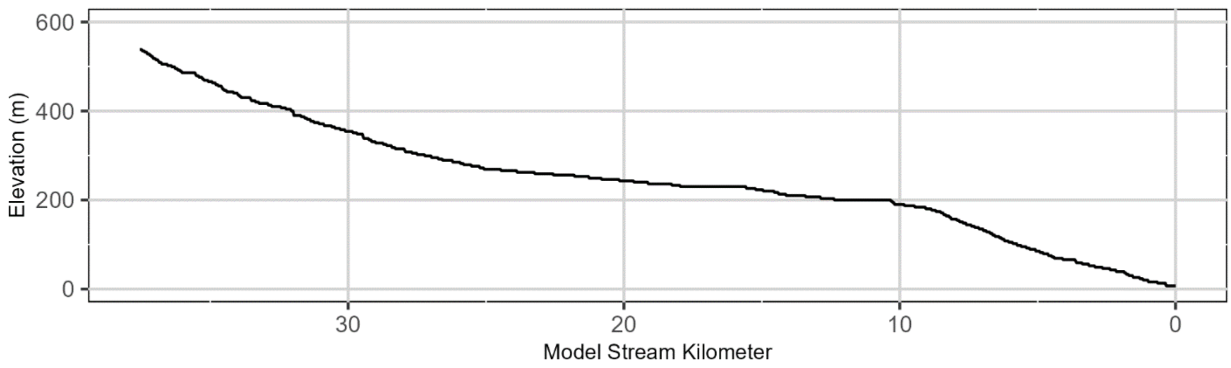


Figure 3.12. Johnson Creek model setup for stream channel elevation (m).

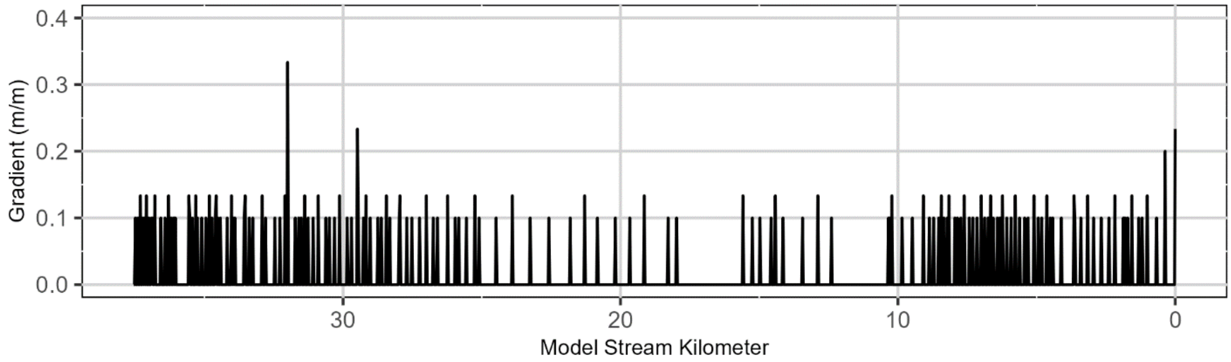


Figure 3.13. Johnson Creek model setup for stream gradient (m/m).

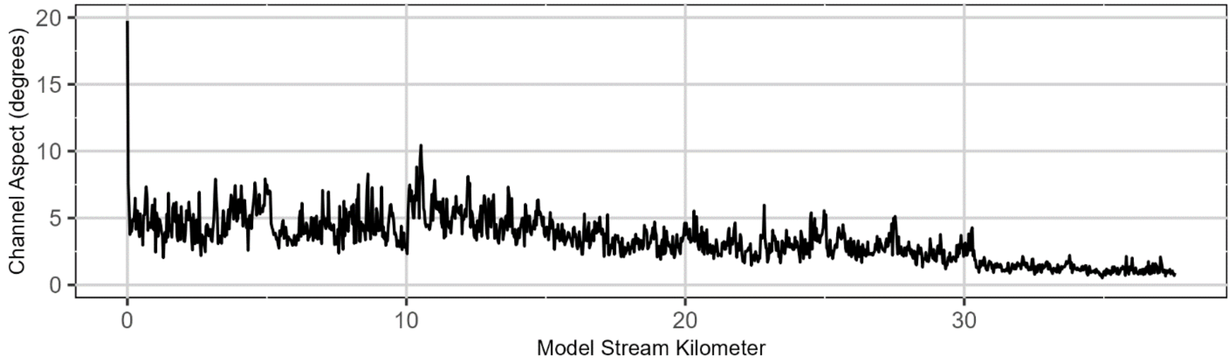


Figure 3.14. Johnson Creek model setup stream wetted width (m)

3.1.9 Calibration results

3.1.9.1 Temperature

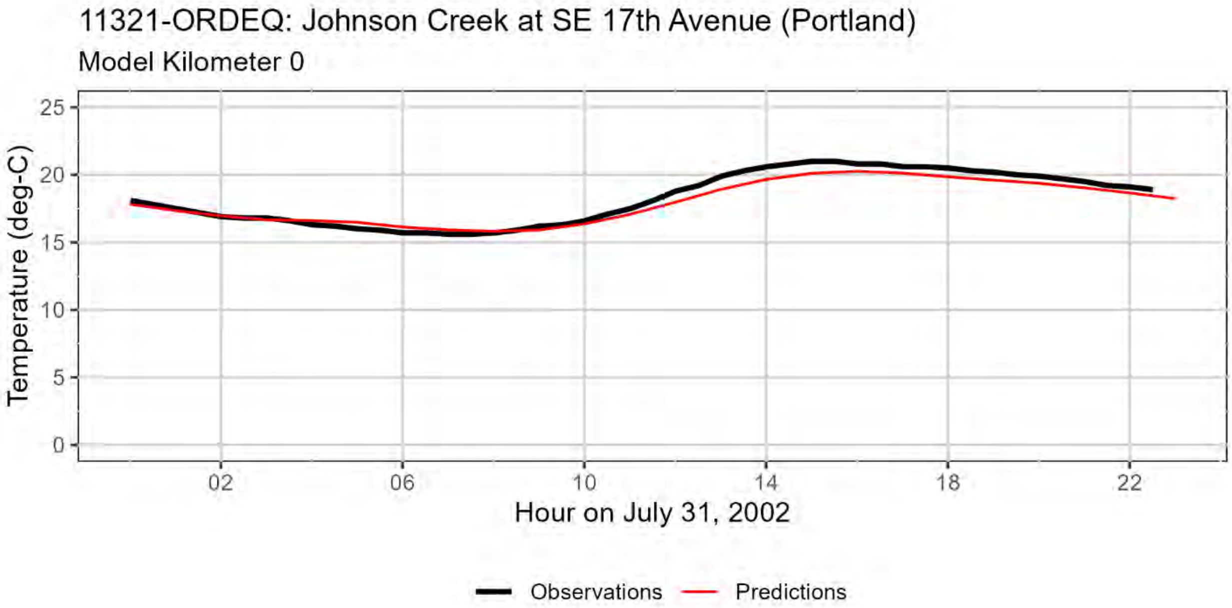


Figure 3.15. Measured and model predicted hourly temperatures at monitoring station 11321-ORDEQ.

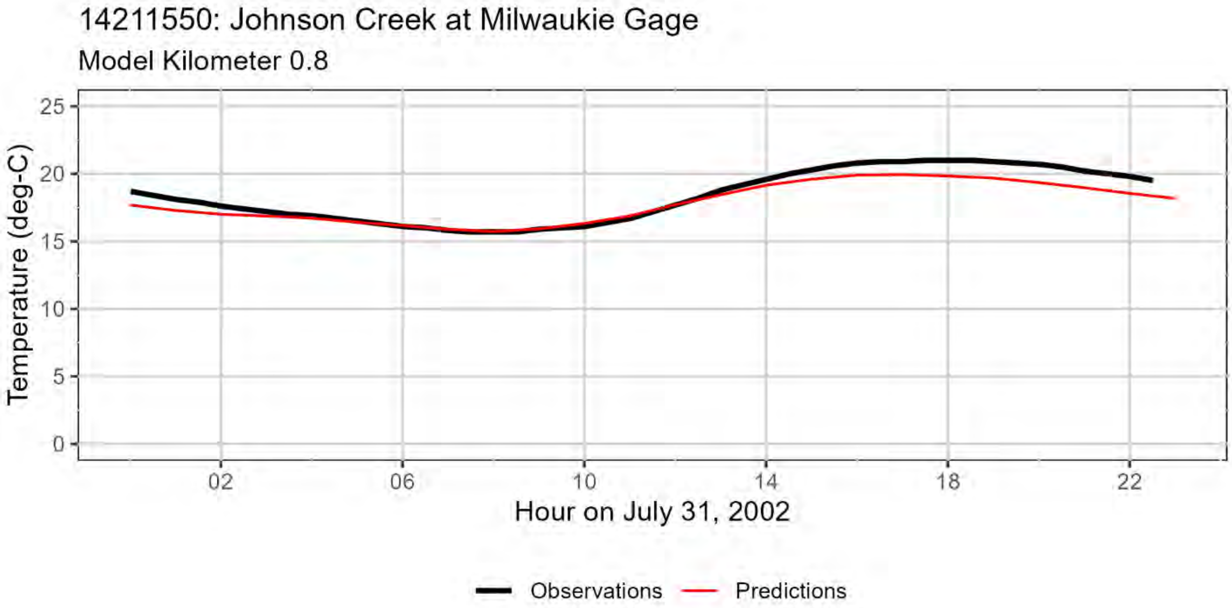


Figure 3.16. Measured and model predicted hourly temperatures at USGS monitoring station 14211550.

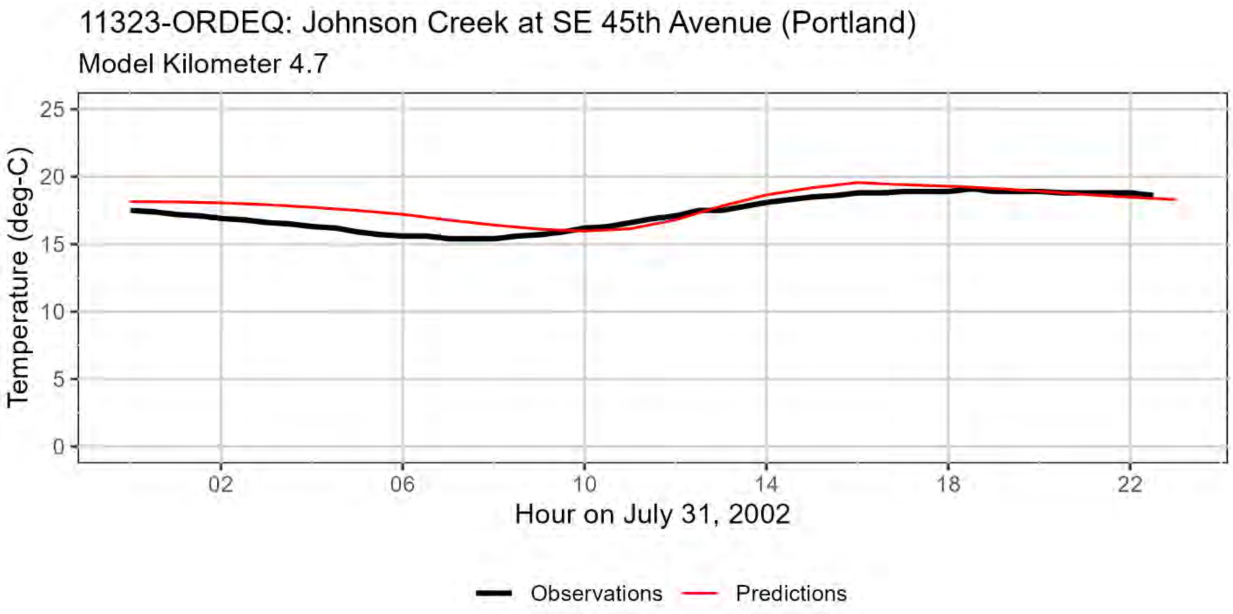


Figure 3.17. Measured and model predicted hourly temperatures at monitoring station 11323-ORDEQ.

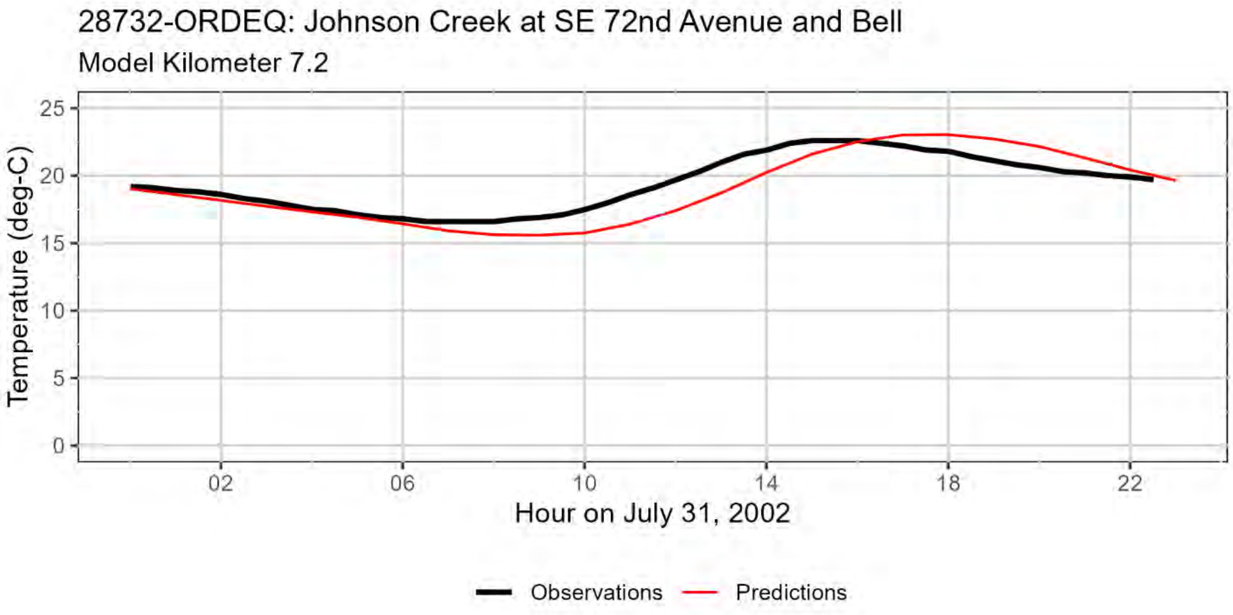


Figure 3.18. Measured and model predicted hourly temperatures at monitoring station 28732-ORDEQ.

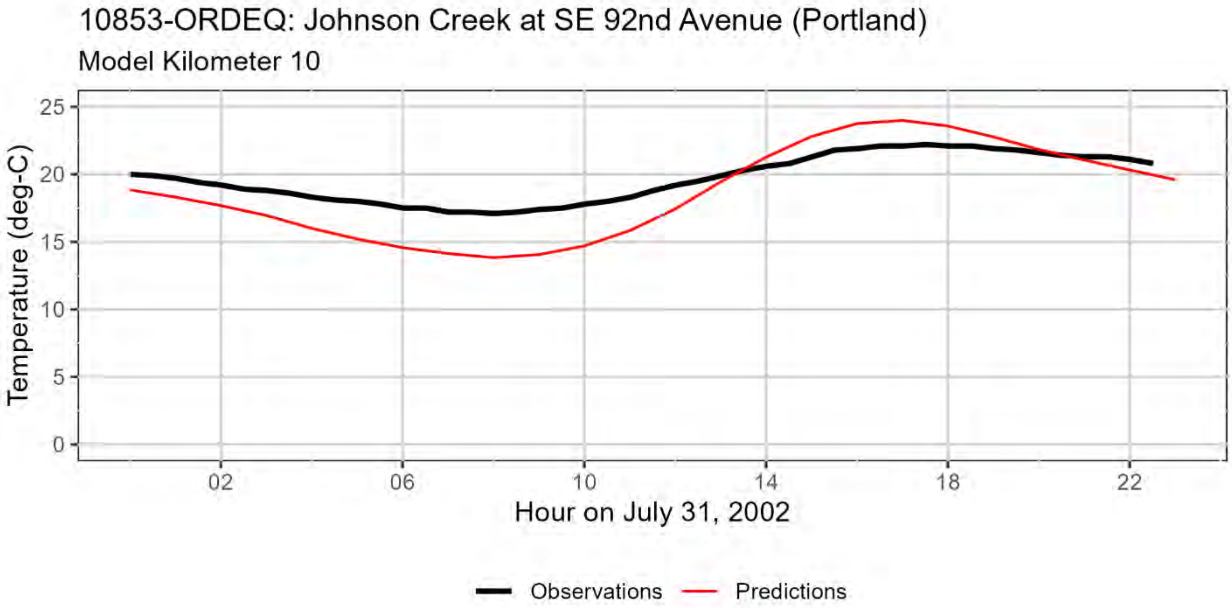


Figure 3.19. Measured and model predicted hourly temperatures at monitoring station 10853-ORDEQ.

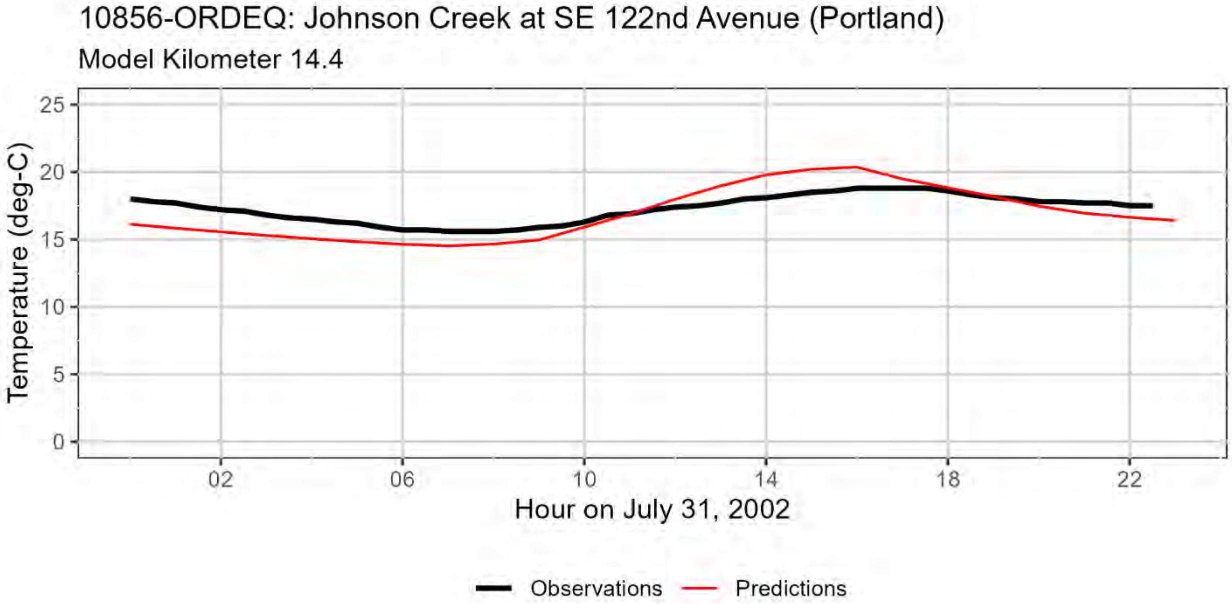


Figure 3.20. Measured and model predicted hourly temperatures at monitoring station 10856-ORDEQ.

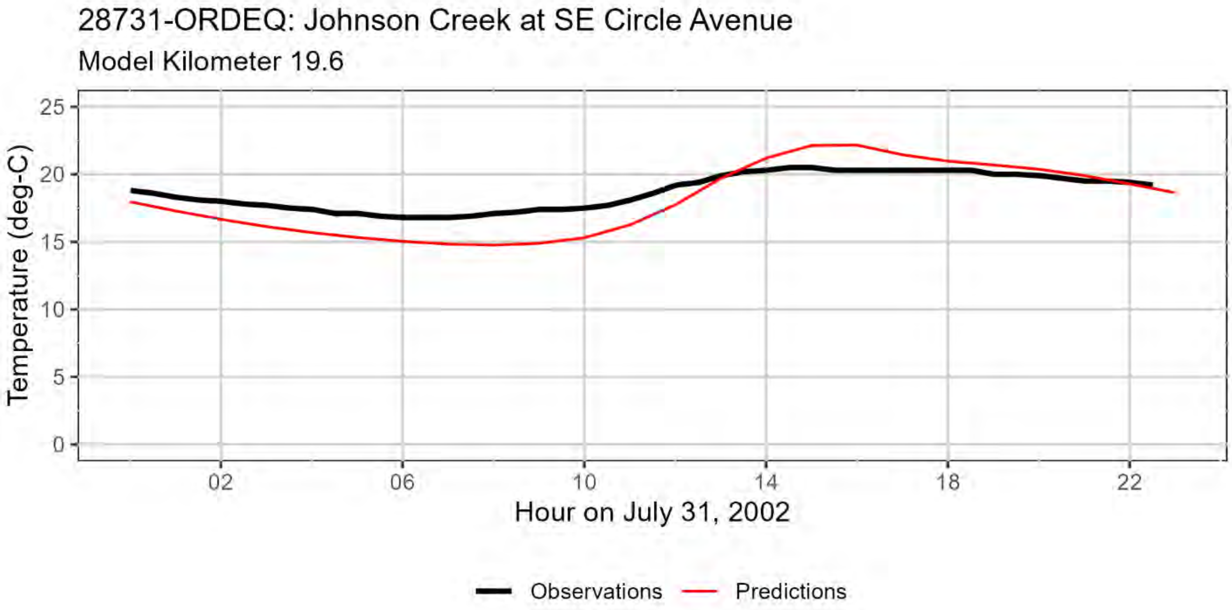


Figure 3.21. Measured and model predicted hourly temperatures at monitoring station 28731-ORDEQ.

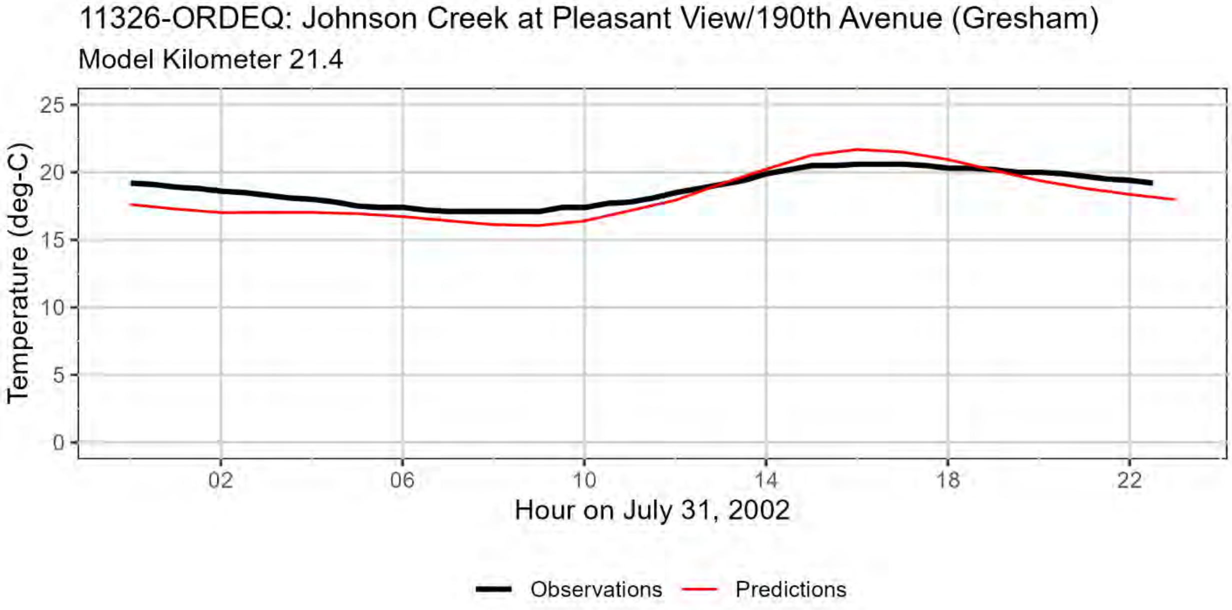


Figure 3.22. Measured and model predicted hourly temperatures at monitoring station 11326-ORDEQ.

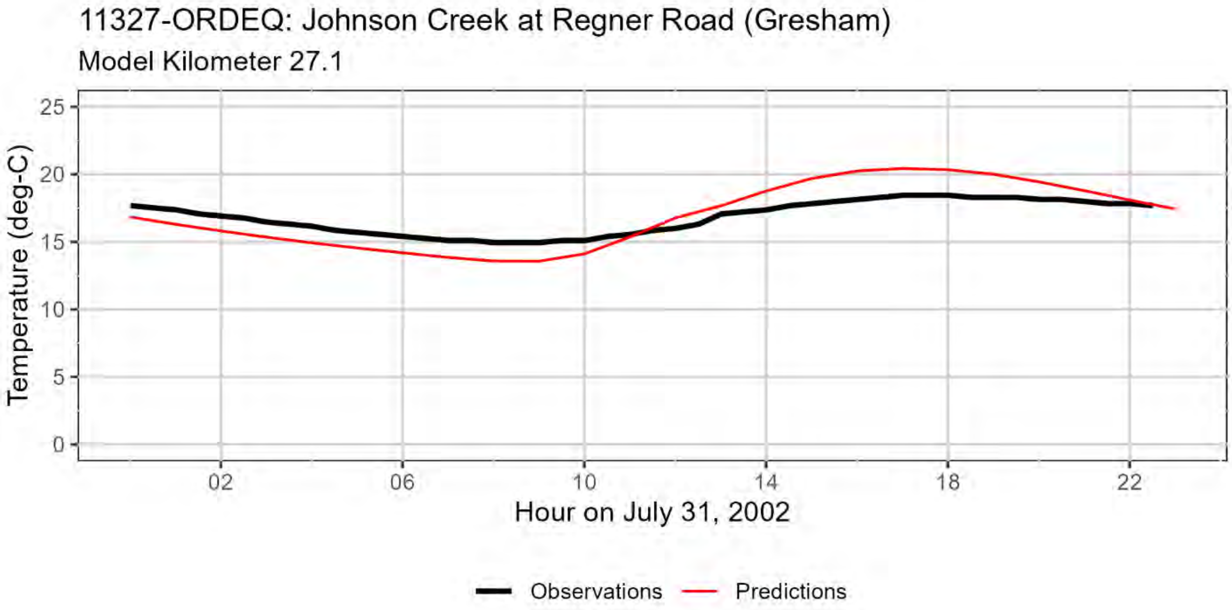


Figure 3.23. Measured and model predicted hourly temperatures at monitoring station 11327-ORDEQ.

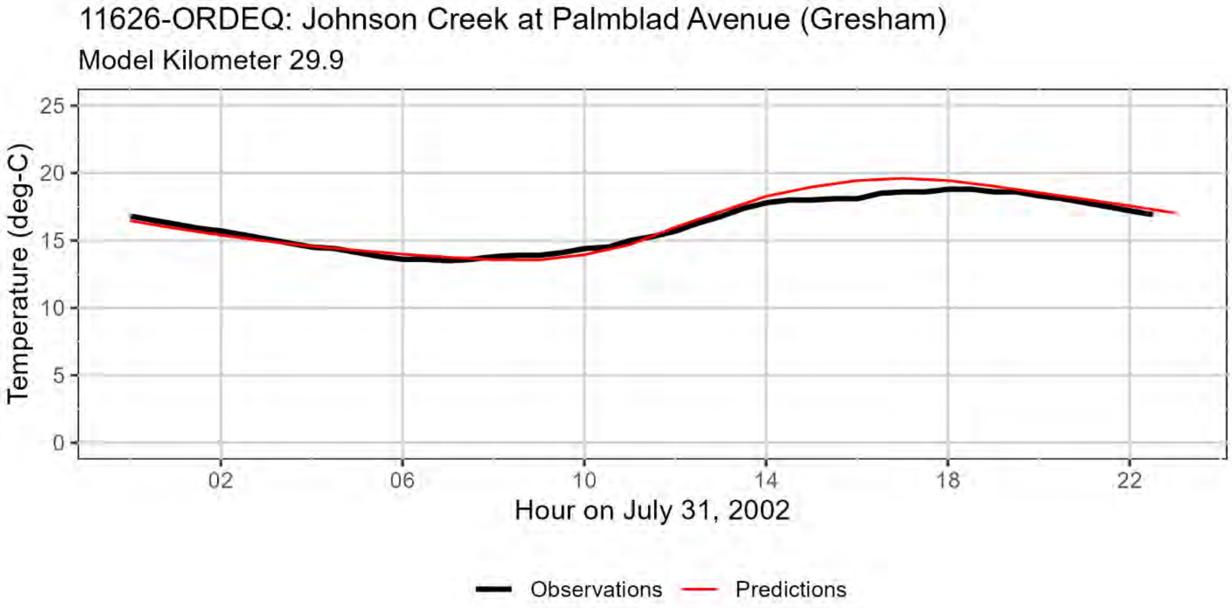


Figure 3.24. Measured and model predicted hourly temperatures at monitoring station 11629-ORDEQ.

Figure 3.25. Measured and model predicted hourly temperatures at monitoring station 28730-ORDEQ.

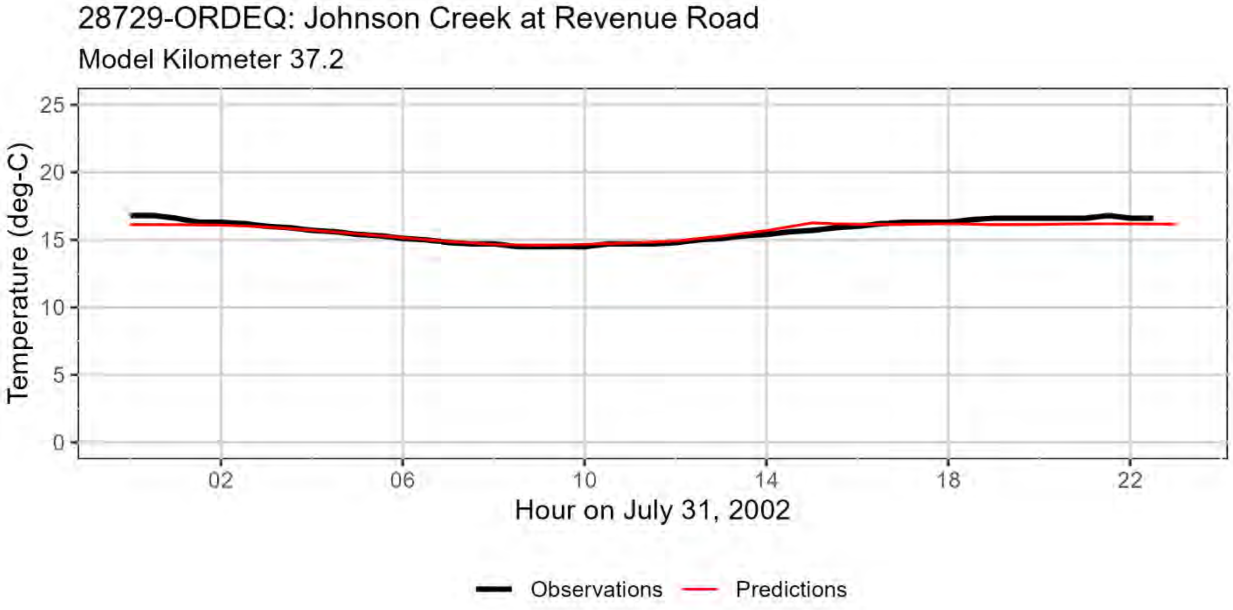


Figure 3.26. Measured and model predicted hourly temperatures at monitoring station 28729-ORDEQ.

Table 3.6. Stream temperature goodness of fit statistics comparing field observed and model predicted temperatures.

Monitoring Location	Constituent	ME	MAE	RMSE	NSE	R2	n
All Stations	Daily Maximum Temperature	0.72	1.11	1.23	0.44	0.73	12
All Stations	Hourly Temperature	-0.27	0.89	1.13	0.66	0.77	288
10853-ORDEQ	Hourly Temperature	-1.04	1.75	1.99	-0.39	0.98	24
10856-ORDEQ	Hourly Temperature	-0.39	1.04	1.18	-0.4	0.76	24
11321-ORDEQ	Hourly Temperature	-0.32	0.46	0.53	0.92	0.98	24
11323-ORDEQ	Hourly Temperature	0.56	0.69	0.84	0.56	0.75	24
11326-ORDEQ	Hourly Temperature	-0.54	0.86	0.95	0.36	0.88	24
11327-ORDEQ	Hourly Temperature	0.07	1.15	1.27	-0.09	0.88	24
11626-ORDEQ	Hourly Temperature	0.21	0.41	0.5	0.92	0.97	24
14211400	Hourly Temperature	-0.54	0.6	0.76	0.84	0.97	24
28729-ORDEQ	Hourly Temperature	-0.09	0.24	0.31	0.85	0.89	24
28730-ORDEQ	Hourly Temperature	-0.11	1.25	1.42	-0.03	0.65	24
28731-ORDEQ	Hourly Temperature	-0.64	1.29	1.46	-0.32	0.96	24
28732-ORDEQ	Hourly Temperature	-0.38	0.97	1.2	0.62	0.81	24
Johnson Creek TIR	Grab Temperature	0.78	1.09	1.34	N/A	0.92	1670

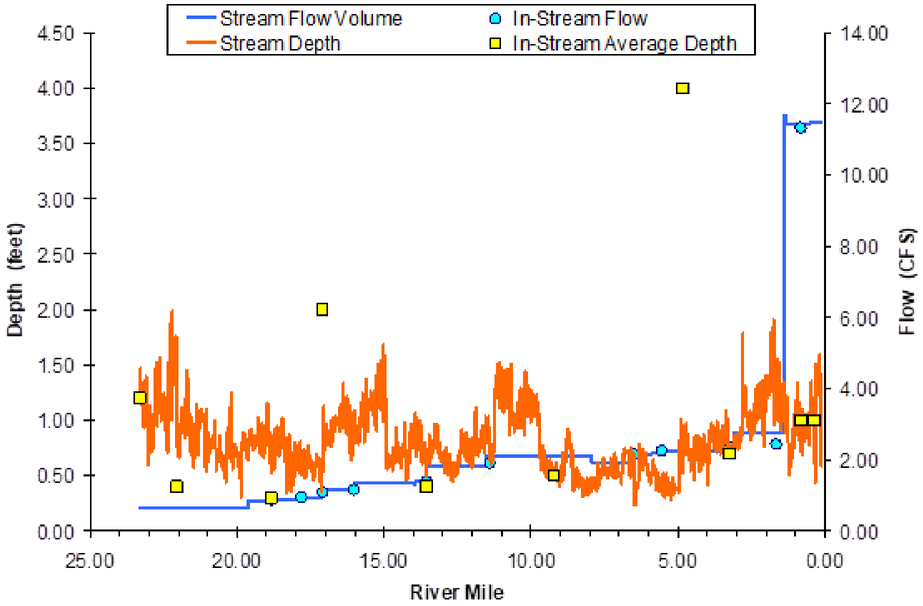


Figure x. Longitudinal flow mass balance for Johnson Creek, Lower Willamette Subbasin

3.2 Molalla River

The Molalla River model is a temperature model developed using Heat Source 7.0. The model was developed by DEQ.

3.2.1 Model extent

The extent of the model domain is the Molalla River from the mouth to river mile 44 (Figure 3.27).

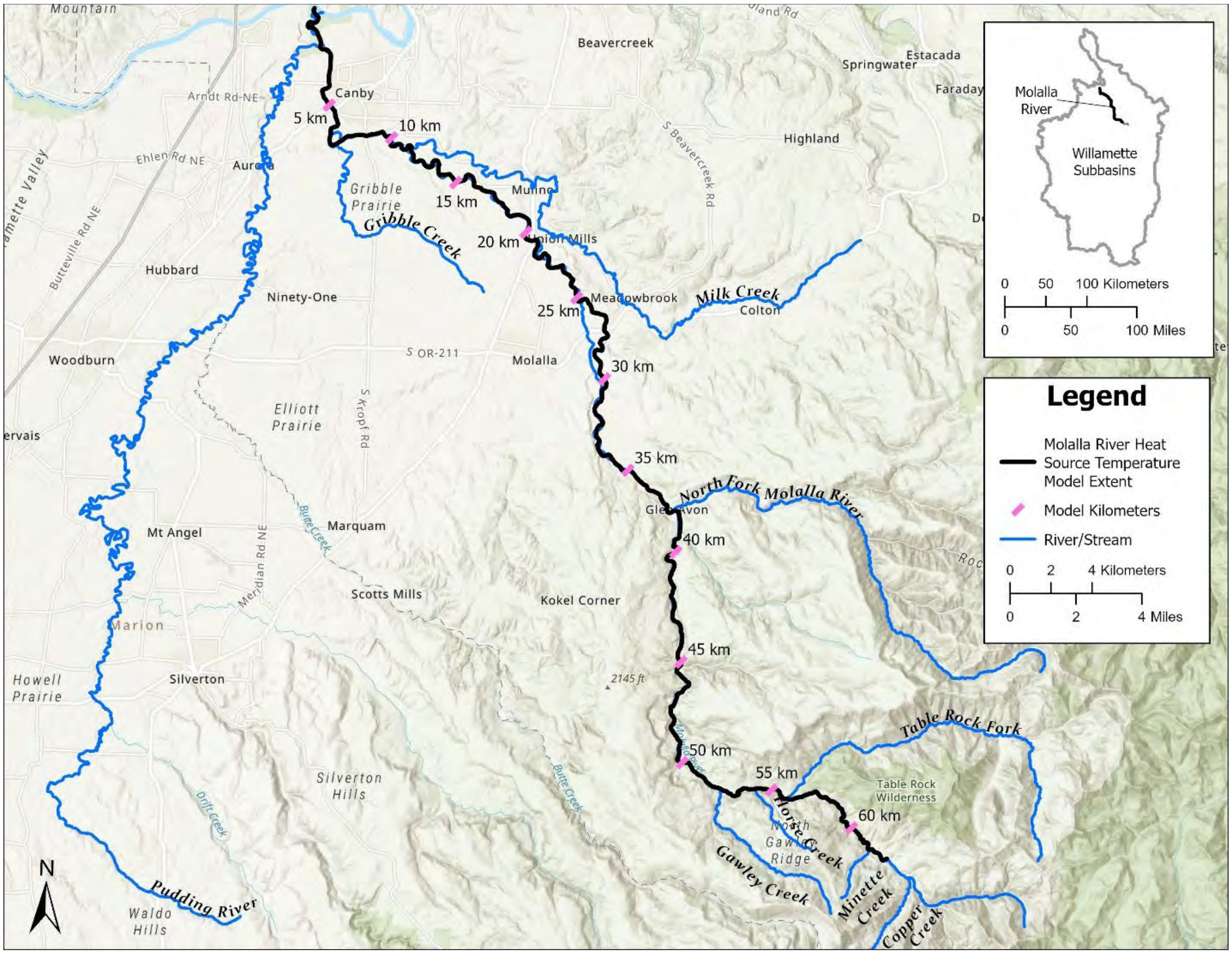


Figure 3.27. Molalla River model extent.

3.2.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.2.3 Time frame of simulation

The model period is July 20, 2004 to August 02, 2004.

3.2.4 Meteorological inputs

The model was set up using hourly air temperature, relative humidity, and wind speed measurements from a DEQ site (No Station ID). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using a wind-sheltering coefficient to represent difference in wind speed between the measurement location and above the stream within the riparian area.

FIGURE

Figure A3.28. Model setup cloudiness.

FIGURE

Figure A3.29. Model setup air temperatures.

FIGURE

Figure A3.30. Model setup relative humidity

FIGURE

Figure A3.31. Model setup solar radiation.

3.2.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.7). Figure 3.32 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

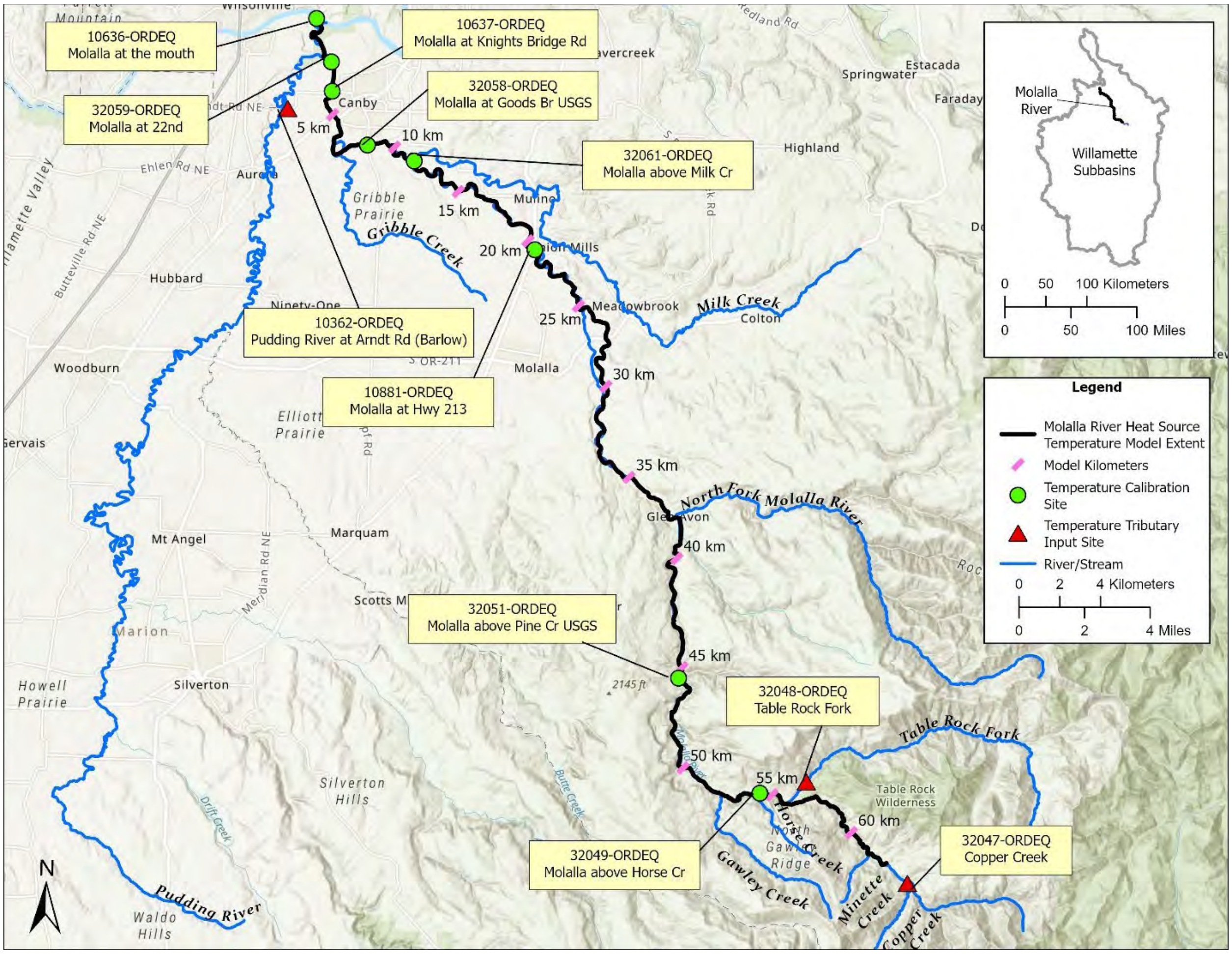


Figure 3.32. Location of temperature monitoring sites used for setup and calibration of the Molalla River model.

Table 3.7. Molalla River tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (kilometers)	Input Type	Data Source
Molalla at Locked Gate HW	75.36	Boundary Condition	DEQ File
Copper Creek	75.33	Tributary	32047-ORDEQ
Spring at model kilometer 75.3	75.3	Tributary	Derived from TIR. Constant temperature of 14.3 deg-C. Watershed Sciences (2005)
unnamed tributary 6	74.6	Tributary	Derived from TIR. Constant temperature of 15.5 deg-C. Watershed Sciences (2005)
Spring at model kilometer 74.2	74.2	Tributary	Derived from TIR. Constant temperature of 15.3 deg-C. Watershed Sciences (2005)
Spring at model kilometer 73.77	73.77	Tributary	Derived from TIR. Constant temperature of 14.7 deg-C. Watershed Sciences (2005)
Spring at model kilometer 73.4	73.4	Tributary	Derived from TIR. Constant temperature of 9.3 deg-C. Watershed Sciences (2005)

Model Location Name	Model Location (kilometers)	Input Type	Data Source
Minette Creek	72.69	Tributary	Derived from TIR. Constant temperature of 13.2 deg-C. Watershed Sciences (2005)
Table Rock Fork	66.54	Tributary	32048-ORDEQ
Horse Creek	64.65	Tributary	Derived from TIR. Constant temperature of 17.1 deg-C. Watershed Sciences (2005)
Spring at model kilometer 63.33	63.33	Tributary	Derived from TIR. Constant temperature of 14.7 deg-C. Watershed Sciences (2005)
Gawley Creek	62.52	Tributary	Derived from TIR. Constant temperature of 16.3 deg-C. Watershed Sciences (2005)
Spring at model kilometer 60.84	60.84	Tributary	Derived from TIR. Constant temperature of 18.9 deg-C. Watershed Sciences (2005)
unnamed tributary 5	59.91	Tributary	Derived from TIR. Constant temperature of 18.9 deg-C. Watershed Sciences (2005)
North Fork Molalla	44.94	Tributary	DEQ File
Spring at model kilometer 39.12	39.12	Tributary	Derived from TIR. Constant temperature of 20.3 deg-C. Watershed Sciences (2005)
Seep at model kilometer 38.16	38.16	Tributary	Derived from TIR. Constant temperature of 19.3 deg-C. Watershed Sciences (2005)
Seep/Spring at model kilometer 35.88	35.88	Tributary	Derived from TIR. Constant temperature of 21.1 deg-C. Watershed Sciences (2005)
Spring at model kilometer 35.07	35.07	Tributary	Derived from TIR. Constant temperature of 22.2 deg-C. Watershed Sciences (2005)
Spring at model kilometer 32.7	32.7	Tributary	Derived from TIR. Constant temperature of 16.9 deg-C. Watershed Sciences (2005)
Spring at model kilometer 30.63	30.63	Tributary	Derived from TIR. Constant temperature of 20.7 deg-C. Watershed Sciences (2005)
Spring at model kilometer 30.54	30.54	Tributary	Derived from TIR. Constant temperature of 21 deg-C. Watershed Sciences (2005)
Seep at model kilometer 29.88	29.88	Tributary	Derived from TIR. Constant temperature of 20.8 deg-C. Watershed Sciences (2005)
Spring at model kilometer 25.59	25.59	Tributary	Derived from TIR. Constant temperature of 22.2 deg-C. Watershed Sciences (2005)
Spring at model kilometer 22.29	22.29	Tributary	Derived from TIR. Constant temperature of 22.5 deg-C. Watershed Sciences (2005)
Spring at model kilometer 18.33	18.33	Tributary	Derived from TIR. Constant temperature of 19.7 deg-C. Watershed Sciences (2005)
Spring at model kilometer 16.89	16.89	Tributary	Derived from TIR. Constant temperature of 18.2 deg-C. Watershed Sciences (2005)
unnamed tributary 2	15.75	Tributary	Derived from TIR. Constant temperature of 23.2 deg-C. Watershed Sciences (2005)
Spring at model kilometer 13.71	13.71	Tributary	Derived from TIR. Constant temperature of 21.3 deg-C. Watershed Sciences (2005)
Milk Creek	12.9	Tributary	Derived from TIR. Constant temperature of 23.5 deg-C. Watershed Sciences (2005)
Spring at model kilometer 12.69	12.69	Tributary	Derived from TIR. Constant temperature of 22.6 deg-C. Watershed Sciences (2005)
Spring at model kilometer 12.03	12.03	Tributary	Derived from TIR. Constant temperature of 19.8 deg-C. Watershed Sciences (2005)

Model Location Name	Model Location (kilometers)	Input Type	Data Source
unnamed tributary 1	11.88	Tributary	Derived from TIR. Constant temperature of 24.4 deg-C. Watershed Sciences (2005)
Spring at model kilometer 11.58	11.58	Tributary	Derived from TIR. Constant temperature of 19.8 deg-C. Watershed Sciences (2005)
Spring at model kilometer 11.19	11.19	Tributary	Derived from TIR. Constant temperature of 19.8 deg-C. Watershed Sciences (2005)
Spring at model kilometer 10.59	10.59	Tributary	Derived from TIR. Constant temperature of 24.7 deg-C. Watershed Sciences (2005)
Gribble Creek	8.46	Tributary	Derived from TIR. Constant temperature of 19.1 deg-C. Watershed Sciences (2005)
Spring at model kilometer 2.67	2.67	Tributary	Derived from TIR. Constant temperature of 13.8 deg-C. Watershed Sciences (2005)
Pudding River at Arndt Road (Barlow)	2.55	Tributary	10362-ORDEQ
Spring at model kilometer 0.87	0.87	Tributary	Derived from TIR. Constant temperature of 19.1 deg-C. Watershed Sciences (2005)

Figure A3.33. Model setup tributary and boundary condition temperatures.

3.2.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (Table 3.8).

Table 3.8. Molalla River tributary and boundary condition flow model setup.

Model Location Name	Model Location (kilometers)	Input Type	Data Source
Molalla at Locked Gate HW	75.36	Boundary Condition	DEQ
Copper Creek	75.33	Tributary	DEQ
Spring at model kilometer 75.3	75.3	Tributary	DEQ
unnamed tributary 6	74.6	Tributary	DEQ
Spring at model kilometer 74.2	74.2	Tributary	DEQ
Spring at model kilometer 73.77	73.77	Tributary	DEQ
Spring at model kilometer 73.4	73.4	Tributary	DEQ
Minette Creek	72.69	Tributary	DEQ
Table Rock Fork	66.54	Tributary	DEQ
Horse Creek	64.65	Tributary	DEQ
Spring at model kilometer 63.33	63.33	Tributary	DEQ
Gawley Creek	62.52	Tributary	DEQ
Spring at model kilometer 60.84	60.84	Tributary	DEQ
unnamed tributary 5	59.91	Tributary	DEQ
North Fork Molalla	44.94	Tributary	DEQ

Model Location Name	Model Location (kilometers)	Input Type	Data Source
Spring at model kilometer 39.12	39.12	Tributary	DEQ
Seep at model kilometer 38.16	38.16	Tributary	DEQ
Seep/Spring at model kilometer 35.88	35.88	Tributary	DEQ
Spring at model kilometer 35.07	35.07	Tributary	DEQ
Spring at model kilometer 32.7	32.7	Tributary	DEQ
Spring at model kilometer 30.63	30.63	Tributary	DEQ
Spring at model kilometer 30.54	30.54	Tributary	DEQ
Seep at model kilometer 29.88	29.88	Tributary	DEQ
Spring at model kilometer 25.59	25.59	Tributary	DEQ
Spring at model kilometer 22.29	22.29	Tributary	DEQ
Spring at model kilometer 18.33	18.33	Tributary	DEQ
Spring at model kilometer 16.89	16.89	Tributary	DEQ
unnamed tributary 2	15.75	Tributary	DEQ
Spring at model kilometer 13.71	13.71	Tributary	DEQ
Milk Creek	12.9	Tributary	DEQ
Spring at model kilometer 12.69	12.69	Tributary	DEQ
Spring at model kilometer 12.03	12.03	Tributary	DEQ
unnamed tributary 1	11.88	Tributary	DEQ
Spring at model kilometer 11.58	11.58	Tributary	DEQ
Spring at model kilometer 11.19	11.19	Tributary	DEQ
Spring at model kilometer 10.59	10.59	Tributary	DEQ
Gribble Creek	8.46	Tributary	DEQ
Spring at model kilometer 2.67	2.67	Tributary	DEQ
Pudding River	2.55	Tributary	DEQ
Spring at model kilometer 0.87	0.87	Tributary	DEQ

Figure 3.34. Model setup tributary and boundary condition flow rates.

FIGURE

Figure 3.35. Model setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.36. Model setup for withdrawal flow rates.

3.2.7 Point source inputs

There are two permitted individual NPDES point sources along the model extent. Detail about each point source is summarized in Table 3.9.

Table 3.9. NPDES point sources located along the Molalla River model extent.

Facility Name (Facility Number)	Latitude/Longitude	Permit Type and Description	Stream/River Mile
Molalla STP (57613)	45.15/-122.541	NPDES-DOM-Db: Sewage - less than 1 MGD with discharging lagoons	Molalla River RM 8.2
Rsg Forest Products - Liberal (72596)	45.192/-122.592	NPDES-IW-B19: Timber and Wood Products - Sawmills, log storage, instream log storage.	Unnamed ditch to Molalla River RM 9.8 (Molalla River) RM 9.8

FIGURE

Figure 3.37. Model setup up point source effluent temperatures.

FIGURE

Model setup point source effluent flow rates.

3.2.8 Landcover and topographic shade inputs

FIGURE

Figure 3.38. Model setup landcover height (m).

FIGURE

Figure 3.39. Model setup topographic shade angles.

3.2.9 Channel setup

FIGURE

Figure 3.40. Model setup stream channel elevation (m) and gradient.

FIGURE

Figure 3.41. setup channel angle z.

FIGURE

Figure 3.42. Model setup bottom width (m).

FIGURE

Figure 3.43. Model setup for manning roughness coefficient.

FIGURE

3.2.10 Other model parameters

3.2.11 Calibration results

DEQ adjusted input variables such as channel width-to-depth ratio, Manning's roughness coefficient (*n*) (which affects stream velocity), amount of groundwater/surface water interaction, and wind speed (which affects evaporation) in order to improve calibration.

The temperature model was calibrated to the TIR data collected on July 26, 2004 as well as the continuous temperature data collected at several locations (Table 3.10) throughout the modeled period. Simulations were performed for a total of 44 stream miles (76 km).

Table 3.10. Monitoring locations used as calibration sites in the Molalla River model.

Model Location Name	Model Location (kilometers)	Calibration Parameter	Data Source
Molalla at Locked Gate HW	75.36	Water Temperature	DEQ
Molalla above Horse Cr	64.8	Water Temperature	32049-ORDEQ
Molalla above Pine Cr USGS	54.45	Water Temperature	32051-ORDEQ
Molalla abv N. Fork	45	Water Temperature	DEQ
Molalla at HWY 211	32.16	Water Temperature	DEQ
Molalla at HWY 213	24.4	Water Temperature	10881-ORDEQ
Molalla at Kraxberger	20.49	Water Temperature	DEQ
Molalla abv Milk Cr	13.65	Water Temperature	32061-ORDEQ
Molalla at Goods Br. USGS	10.41	Water Temperature	32058-ORDEQ
Molalla River at Knights Bridge Road (Canby)	4.8	Water Temperature	10637-ORDEQ
Molalla at 22nd	3.18	Water Temperature	32059-ORDEQ
Molalla at the mouth	0.3	Water Temperature	10636-ORDEQ
Model extent	Model extent	Water Temperature (TIR)	Watershed Sciences (2005)

3.2.11.1 Flow and Channel

The Molalla River modeled longitudinal stream discharge based on measured flows, OWRD points of diversion data, and mass balance estimates is presented with measured discharge points in Figure 3.44. Stream discharge measurements were collected on July 20 and 22, 2004. The model simulates stream discharge on July 26.

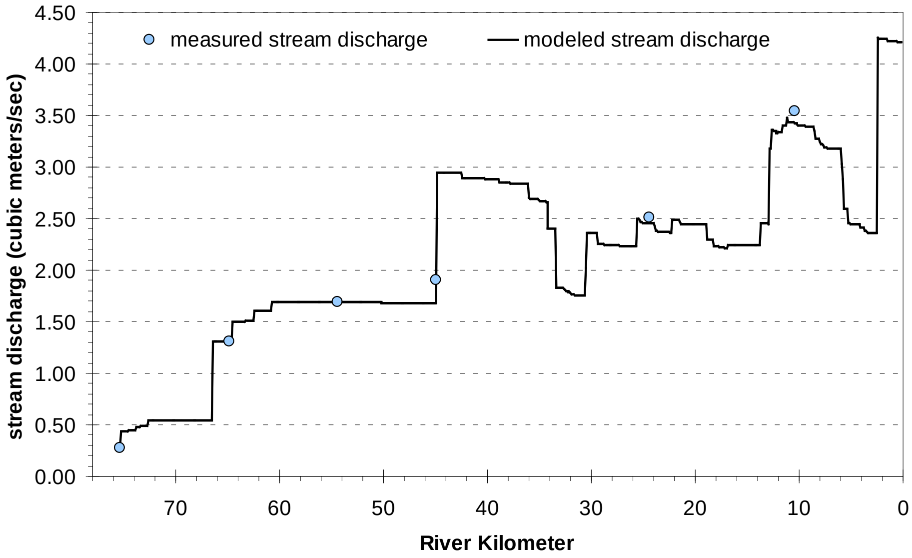


Figure 3.44 Molalla River field observed and model predicted flow rates.

Table 3.11 Flow rate goodness of fit statistics comparing field observed and model flow rates

TBA

DEQ verified model output by comparing model simulated characteristics with measurements of wetted depth, wetted width, and bankfull width. The average stream depth at a site is the average of each of the depth measurements (usually 10 to 20, depending on the width of the channel) recorded during the cross-sectional stream discharge measurements. The average depth measurements for the Molalla River compared with the modeled depths are shown in Figure 3.45. The measured depths are shown with bars that represent the range of depth measurements across the channel at that site.

Results comparing channel widths derived from GIS and modeling to those measured in the field are presented in Figure 3.46. The wetted width measurements agree with the simulated measurements reasonably well.

DEQ verified those remote measurements of bankfull width with four field measurements (Figure 3.47). The agreement is reasonable and the discrepancy between remotely measured and field measured bankfull width near the headwaters is likely because the more dense vegetation obscures the stream banks in the aerial photographs. The discrepancy may also result from the GIS measurement and the field measurement occurring at slightly different locations on the stream.

Figure 3.48 illustrates a comparison of the GIS-measured bankfull width with the simulated wetted width. The wetted width is a model-calculated characteristic based on the channel shape and the amount of stream flow. One would expect the wetted width to be less than the bankfull width, but follow a similarly varying pattern. **Error! Reference source not found.** indicates this is generally the case and that the model's calculations of wetted width are realistic.

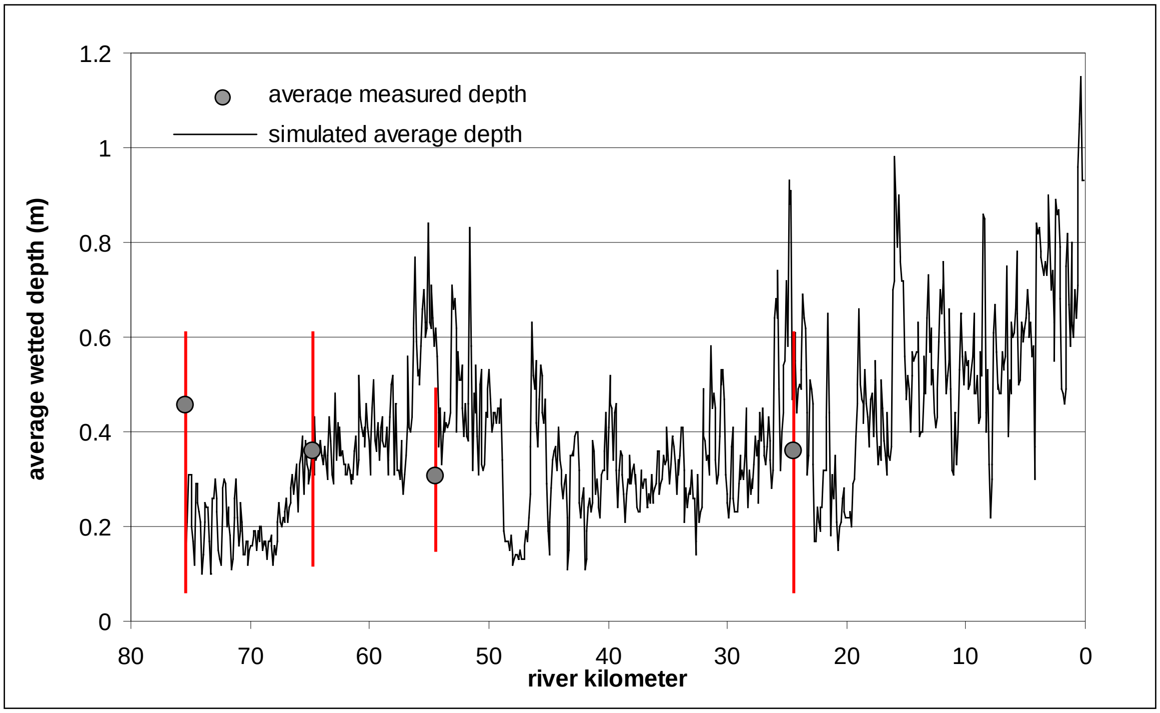


Figure 3.45 Molalla River simulated wetted depth and field measured average depth.

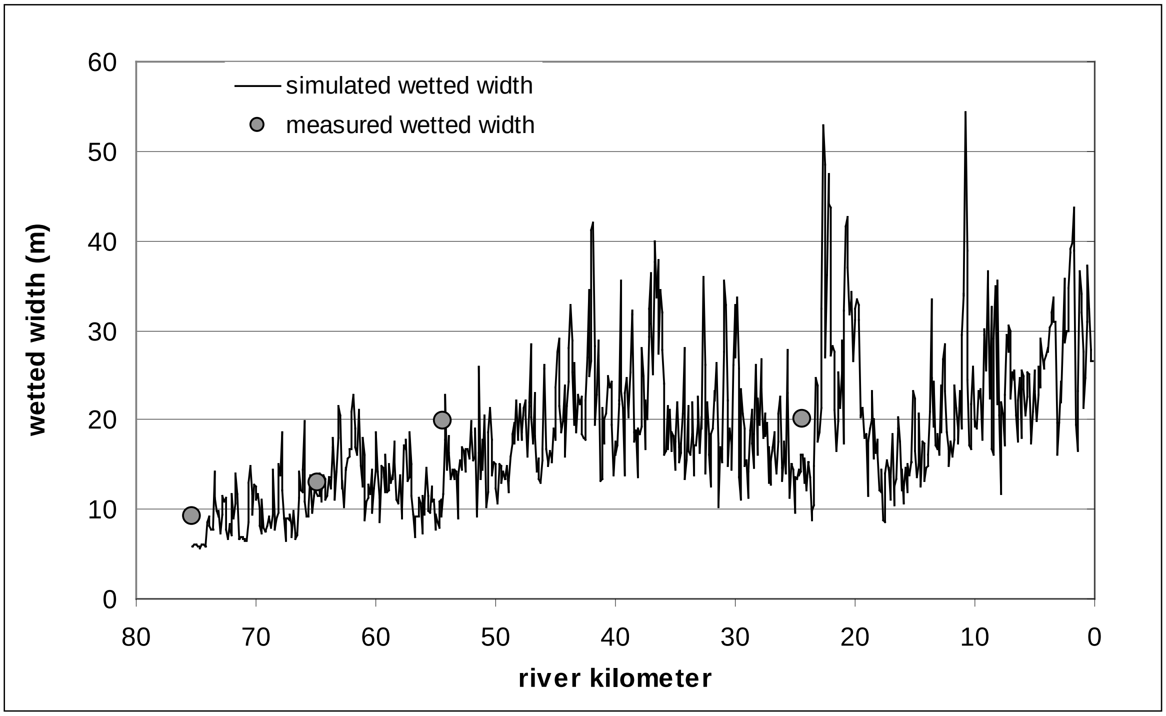


Figure 3.46 Molalla River simulated wetted width and field measured wetted width.

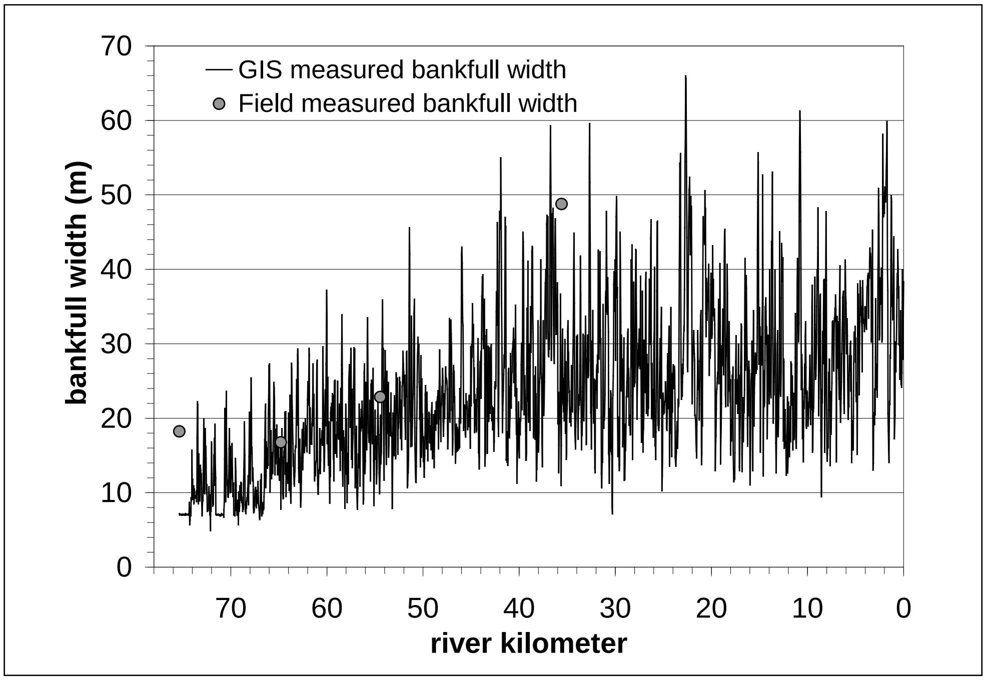


Figure 3.47 Molalla River remotely measured bankfull width and field measured bankfull width.

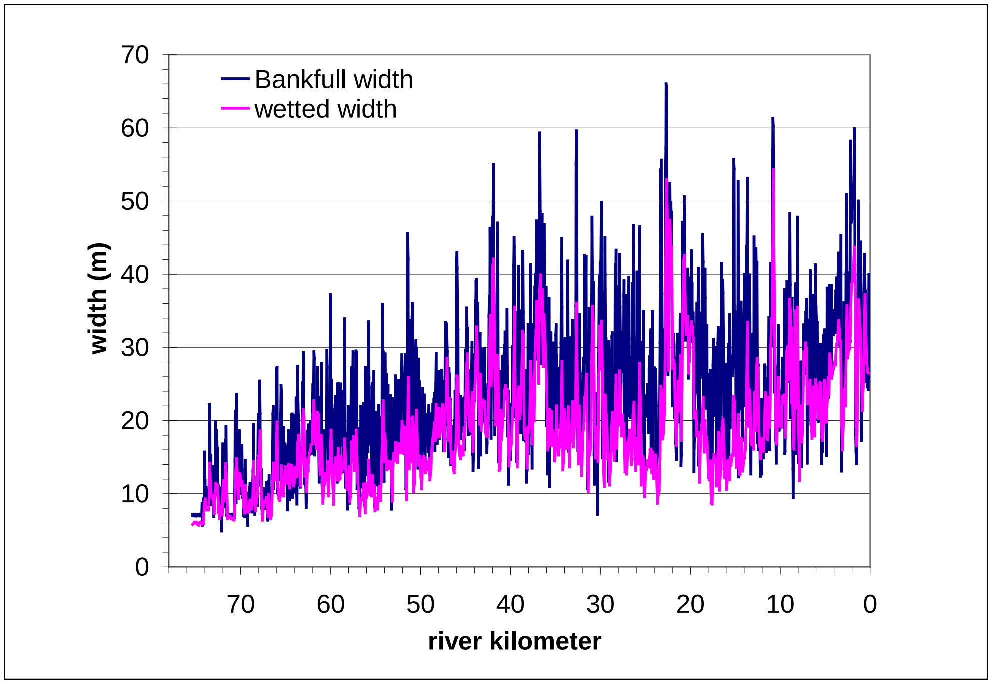


Figure 3.48 Comparison of bankfull width and simulated wetted width of the Molalla River

3.2.11.2 Effective Shade

Figure coming soon.

Figure 3.49 Molalla River model predicted effective shade.

Table 3.12 Molalla River effective shade summary.

Table coming soon.

3.2.11.3 Temperature

Modeling results comparing simulated current condition for the Molalla River to the TIR data are presented in Figure 3.50. Comparison of the TIR data with the Molalla River model simulation meets the target of errors less than 1.0ºC (Table 3.13).

For the purposes of this analytical effort, validation refers to the statistical comparison of measured field data and the Heat Source model simulated current condition. Standard goodness of fit statistics are calculated for instream measured continuous temperature data sets (Table 3.14). Since TIR temperature data sets are robust spatially, there is a possibility that the simulation could be calibrated to the specific time when TIR data was obtained, yet perform poorly for other periods of the day. The model’s simulation of continuous temperature for stations upstream of river mile 6 generally meets the standard error target of <1.0 ºC, but the agreement between model simulated temperatures and continuously measured temperatures decreases somewhat for stations between river mile 6 and the mouth.

Statistics for the Molalla River model calibration and validation are presented in graphical comparisons of modeled temperature and measured temperature at the continuously monitored locations are presented in Figure 3.51 through Figure 3.61. The figures show that the greatest discrepancy between simulated and measured temperatures, especially at stations 10 and 11, occurs in the first week of the model period when measured stream temperatures are higher than simulated stream temperatures. Air temperatures during this first week (July 20 – 26) were higher than the second week of the model period (July 27 – August 2). In particular, maximum measured air temperatures on July 23, 24, and 25 were near or exceeding 38ºC (100 ºF). Possibly, the model is not as sensitive to spikes in air temperature as is the stream itself. The wide stream conditions in the lower river may respond more rapidly to increases in air temperature than does the simulation.

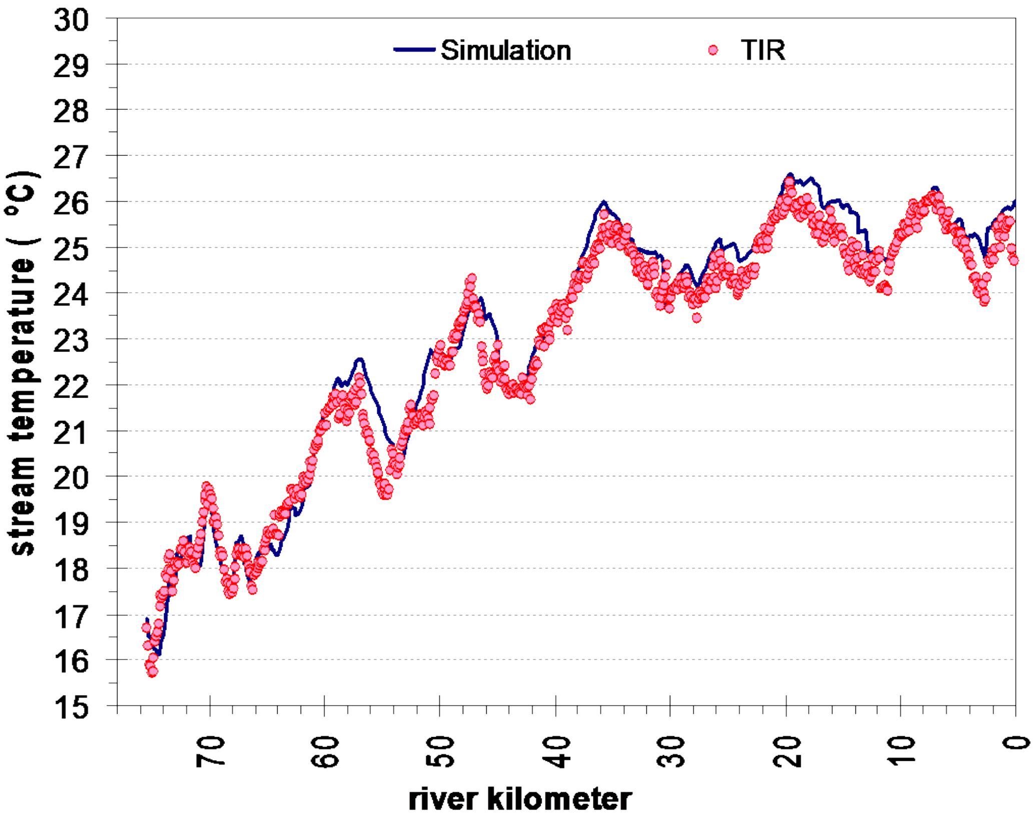


Figure 3.50 Molalla River Thermal Infrared Radiometry measured temperature compared with model simulated temperatures. Periodic temperature decreases may indicate the influence of cooler tributaries, springs, seeps, and groundwater interaction.

Table 3.13 Goodness of fit statistics for Molalla River model versus TIR data.

	Entire River **(ºC)**
Mean Error	0.32
Mean Absolute Error	0.44
RMS Error	0.56

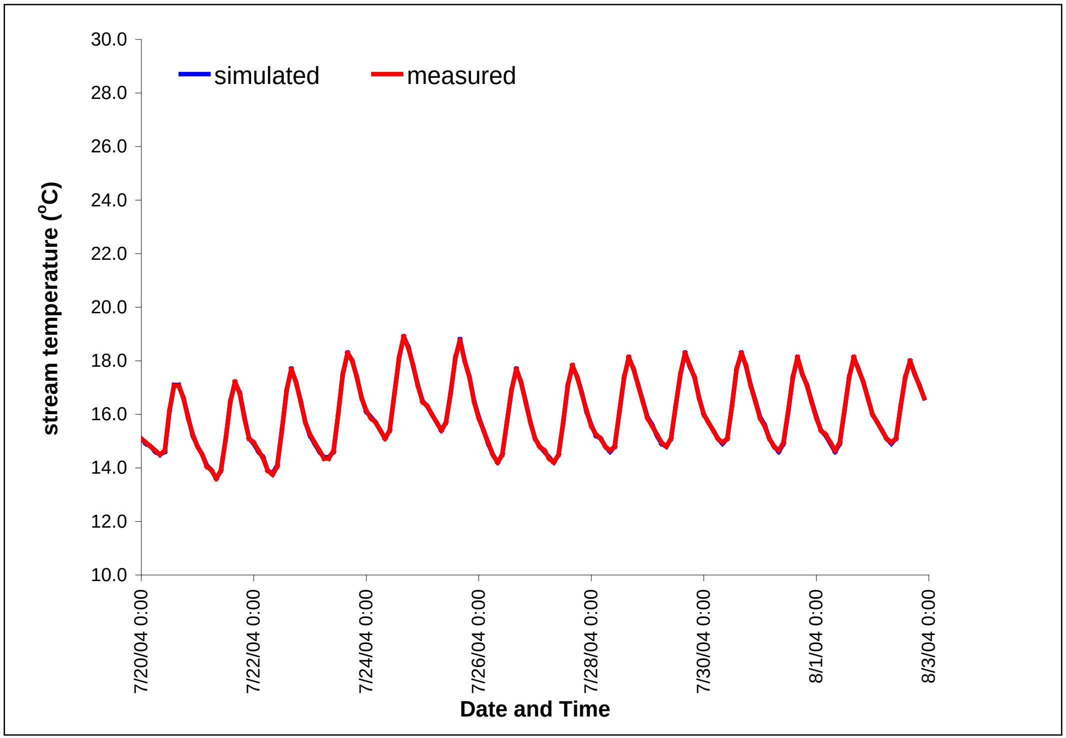


Figure 3.51 Continuous temperature measured and simulated at Molalla River at Locked Gate, river kilometer 75.4 (46.8 river miles).

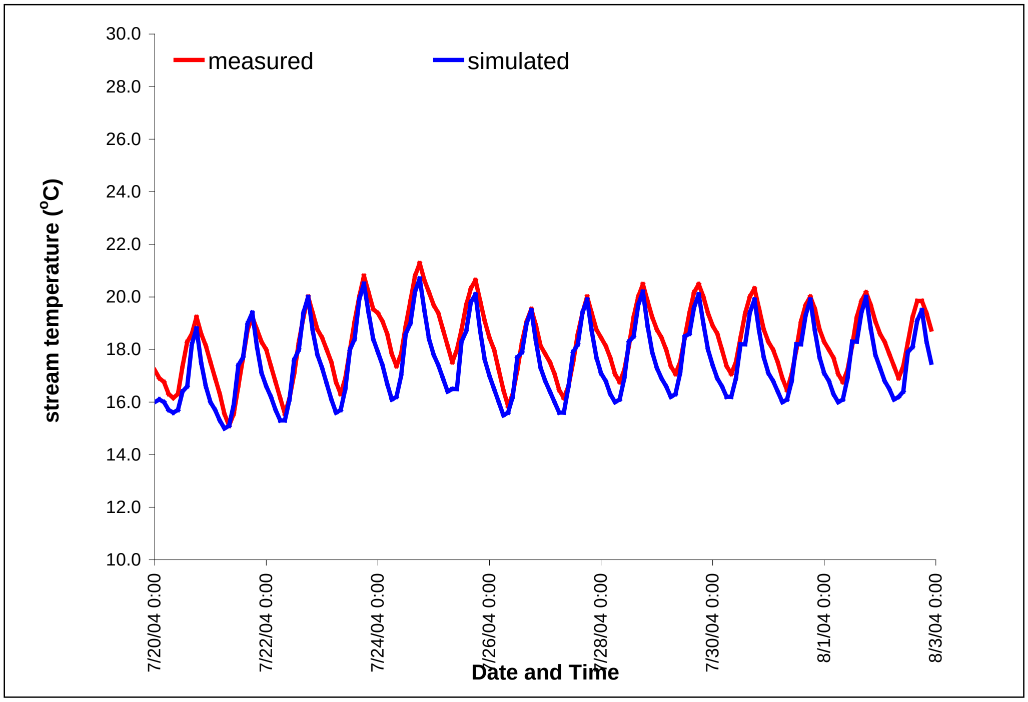


Figure 3.52 Continuous temperature measured and simulated at Molalla River upstream of Horse Creek, river kilometer 64.8 (40.3 river miles).

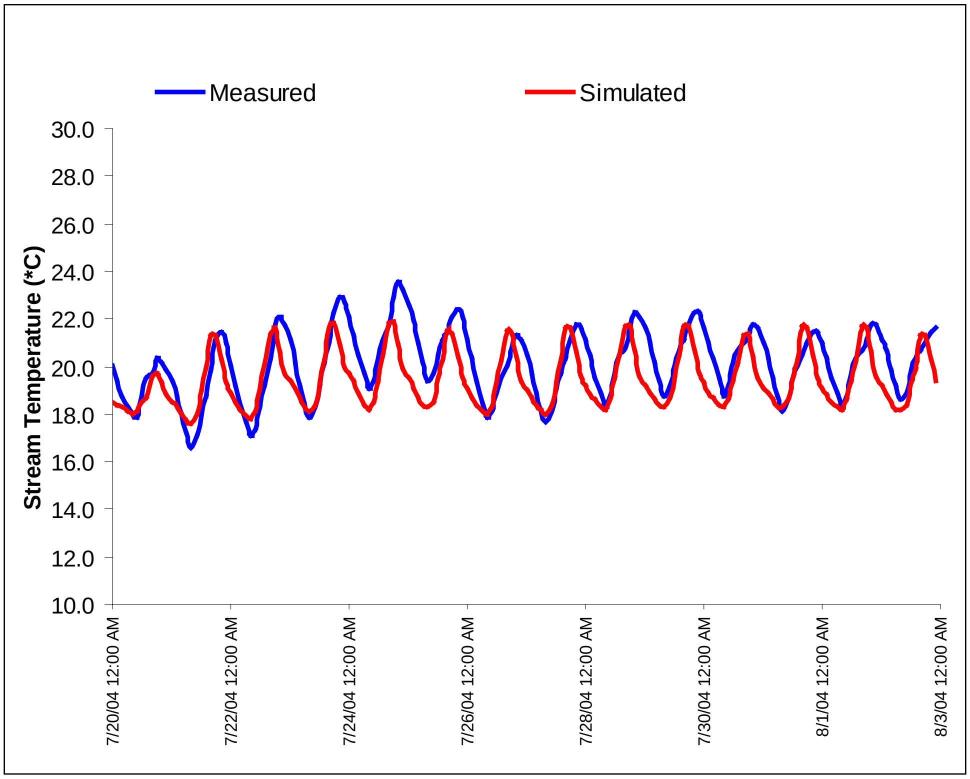


Figure 3.53 Continuous temperature measured and simulated at Molalla River upstream of Pine Creek, river kilometer 54.4 (33.8 river miles).

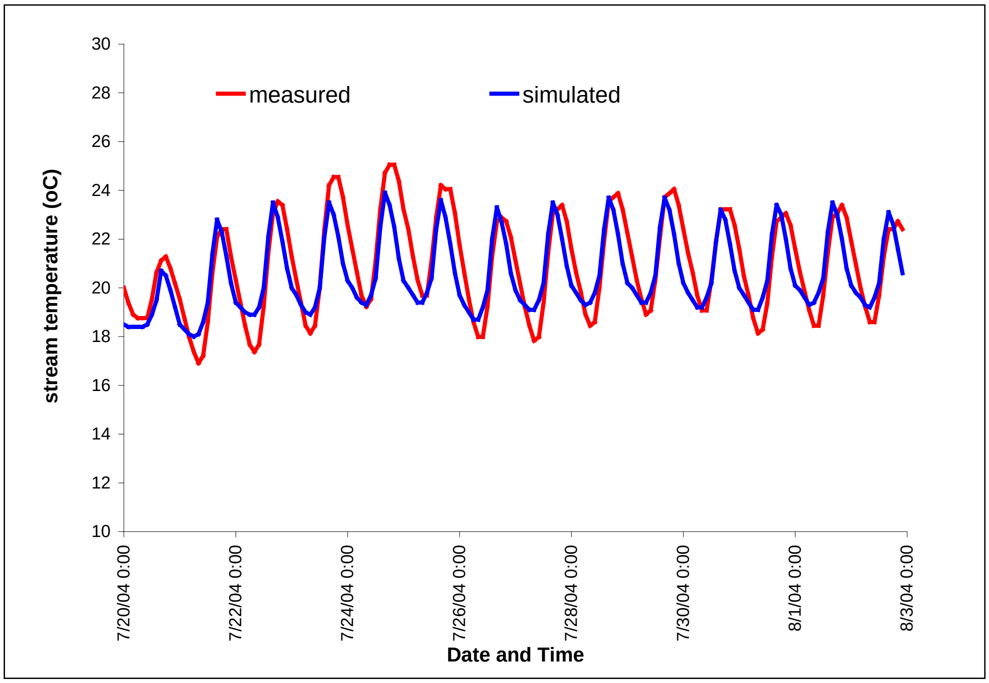


Figure 3.54 Continuous temperature measured and simulated at Molalla River upstream of North Fork Molalla River, river kilometer 45 (28 river miles).

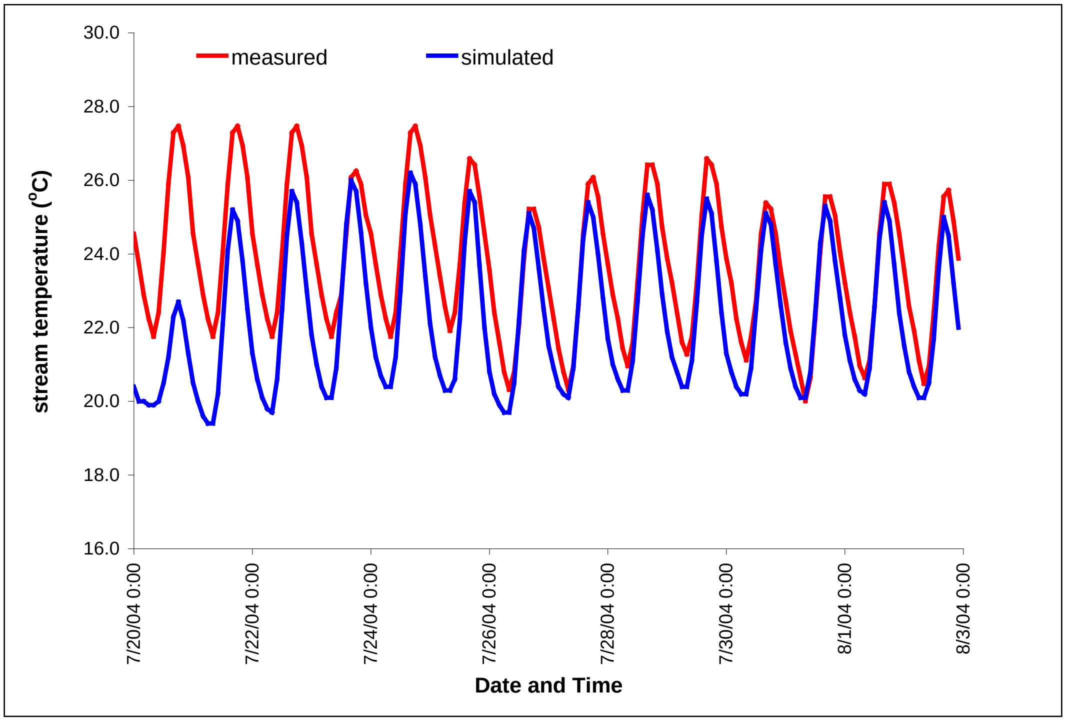


Figure 3.55 Continuous temperature measured and simulated at Molalla River at Highway 213, river kilometer 24.4 (15.2 river miles).

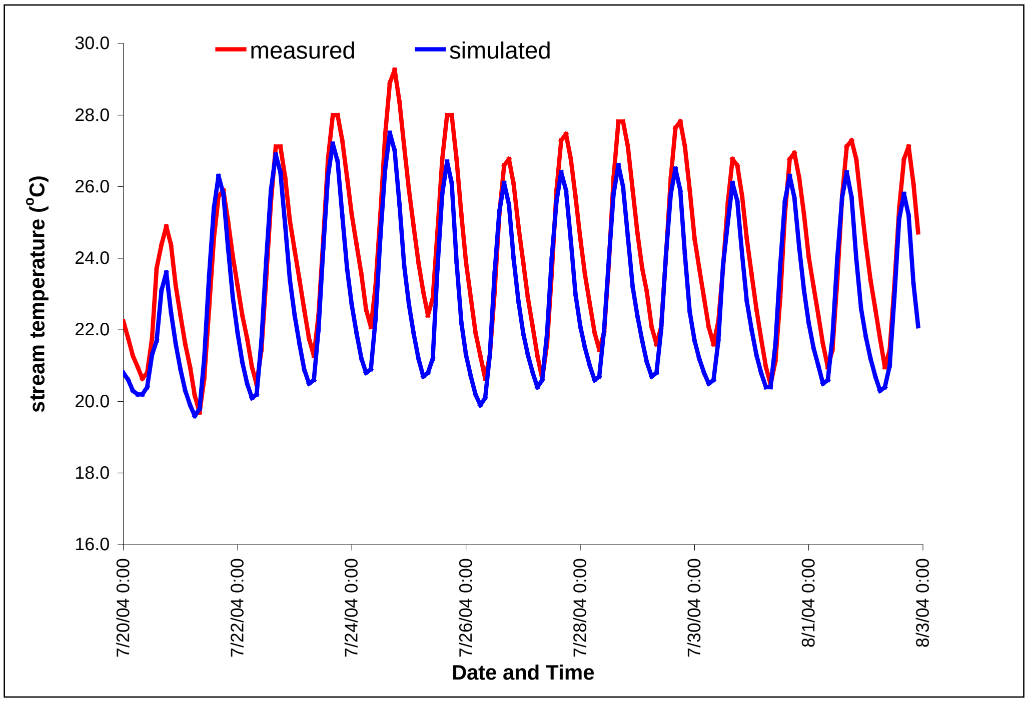


Figure 3.56 Continuous temperature measured and simulated at Molalla River at Kraxberger Rd., river kilometer 20.5 (12.7 river miles).

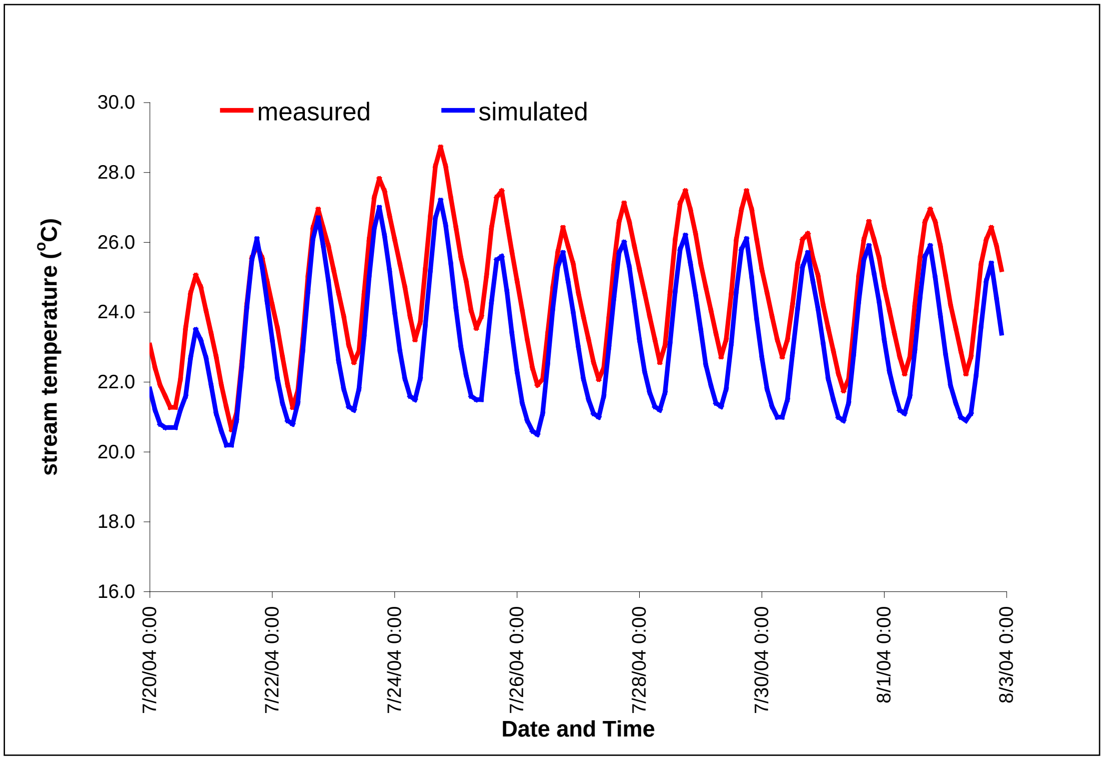


Figure 3.57 Continuous temperature measured and simulated at Molalla River upstream of Milk Creek, river kilometer 13.6 (8.5 river miles).

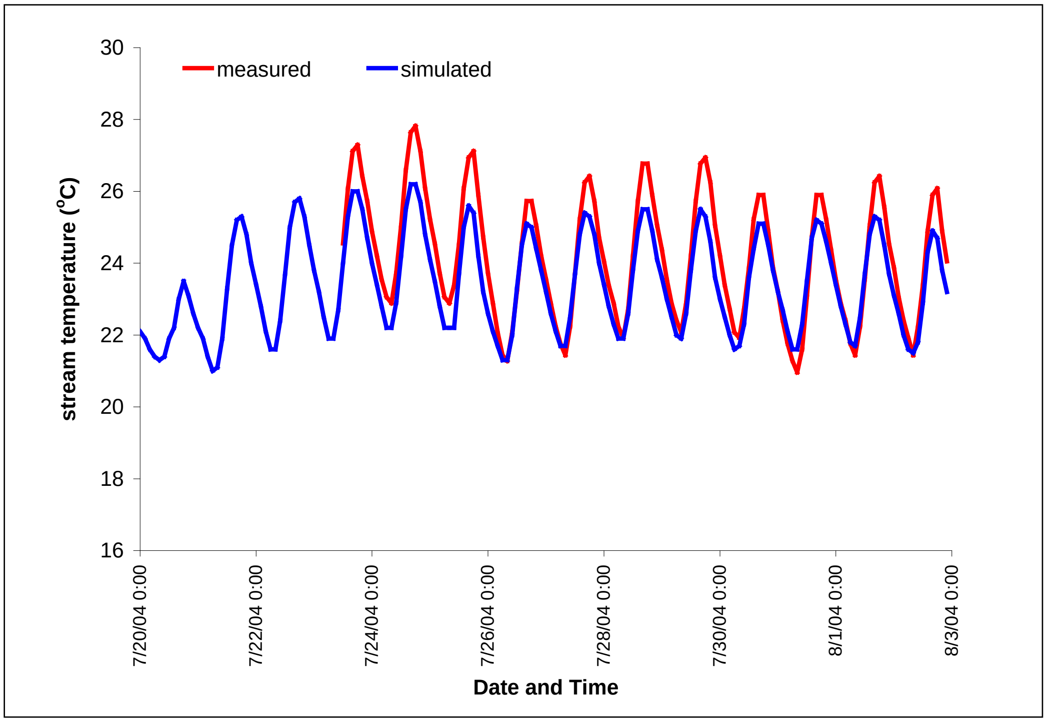


Figure 3.58 Continuous temperature measured and simulated at Molalla River at Goods Bridge, river kilometer 10.4 (6.5 river miles).

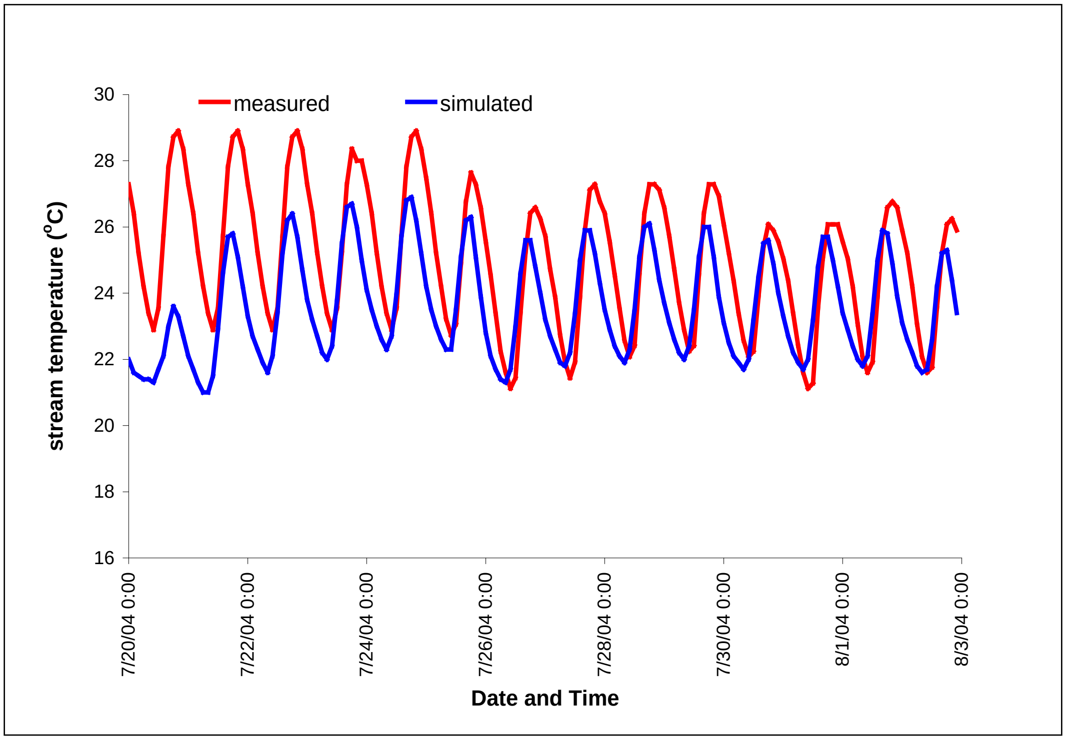


Figure 3.59 Continuous temperature measured and simulated at Molalla River at Knights Bridge Rd., river kilometer 4.8 (3 river miles).

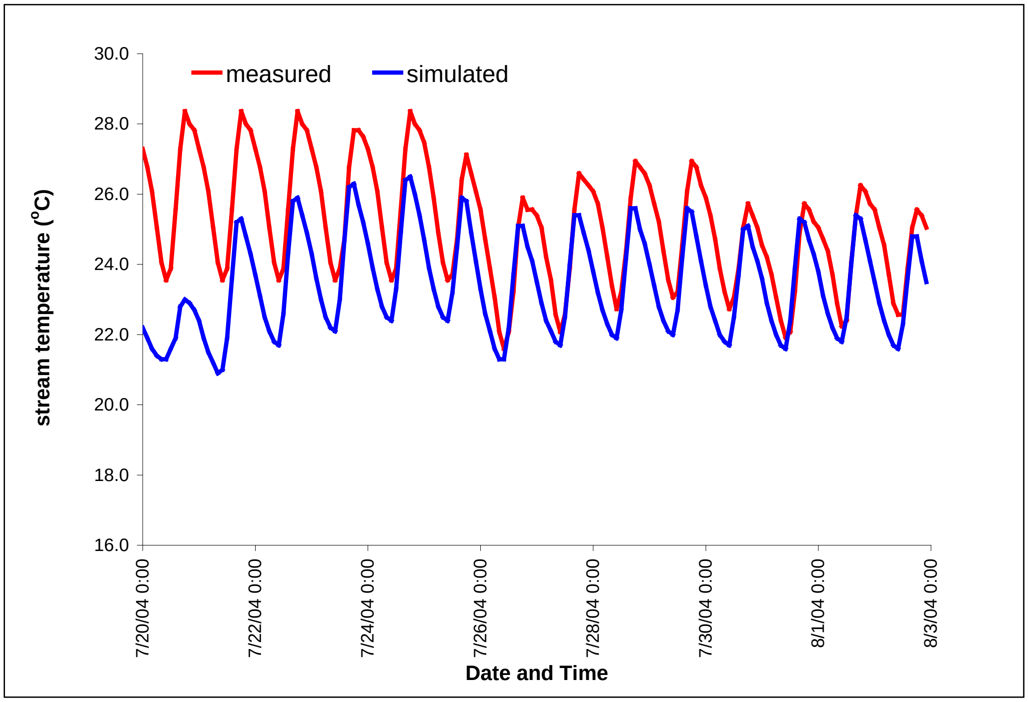


Figure 3.60 Continuous temperature measured and simulated at Molalla River at 22nd, river kilometer 3.2 (2 river miles).

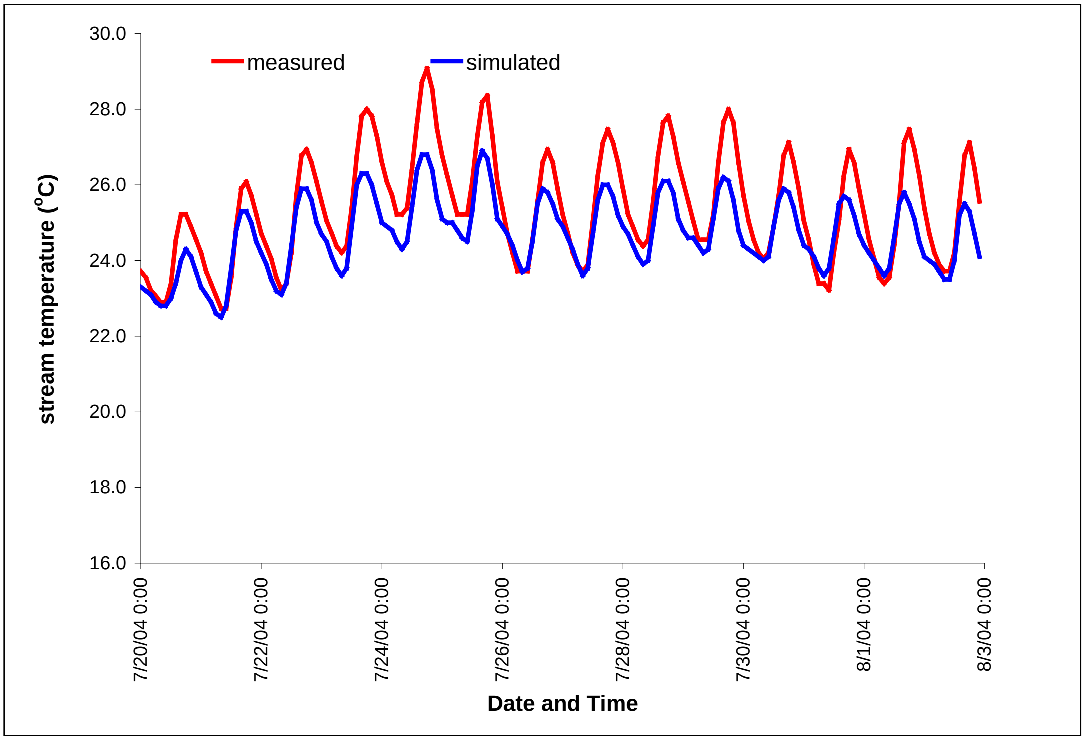


Figure 3.61 Continuous temperature measured and simulated at Molalla River at mouth, river kilometer 0.3 (0.2 river miles).

Table 3.14 Molalla River model goodness of fit statistics comparing field measured and model simulated temperatures.

Temperature measurement location	River Km	River Mile	SE	R^2	RMSE	ME	MAE
1	75.4	46.8	0.03	1.00	0.03	0.00	0.02
2	64.8	40.3	0.53	0.83	0.99	-0.79	0.83
3	54.5	33.8	1.02	0.48	**1.24**	-0.68	0.99
4	45.0	28.0	**1.07**	0.72	**1.15**	-0.41	0.93
6	24.4	15.2	**1.08**	0.69	**1.94**	**-1.58**	**1.59**
7	20.5	12.7	1.00	0.81	**1.59**	**-1.24**	**1.34**
8	13.7	8.5	0.61	0.88	**1.55**	**-1.42**	**1.43**
9	10.4	6.5	0.91	0.73	**1.35**	-0.99	**1.04**
10	4.8	3.0	**1.59**	0.42	**2.19**	**-1.51**	**1.79**
11	3.2	2.0	**1.23**	0.45	**2.15**	**-1.74**	**1.77**

12	0.3	0.2	0.50	0.88	0.96	-0.72	0.77
July 26 TIR			0.41	0.98	0.56	0.32	0.44

3.3 Pudding River

The Pudding River model is a temperature model developed using Heat Source 8.0. The model was developed by DEQ.

3.3.1 Model extent

The extent of the model domain is the Pudding River from the mouth to upstream of the confluence with Drift Creek at river kilometer 84.5 (Figure 3.62).

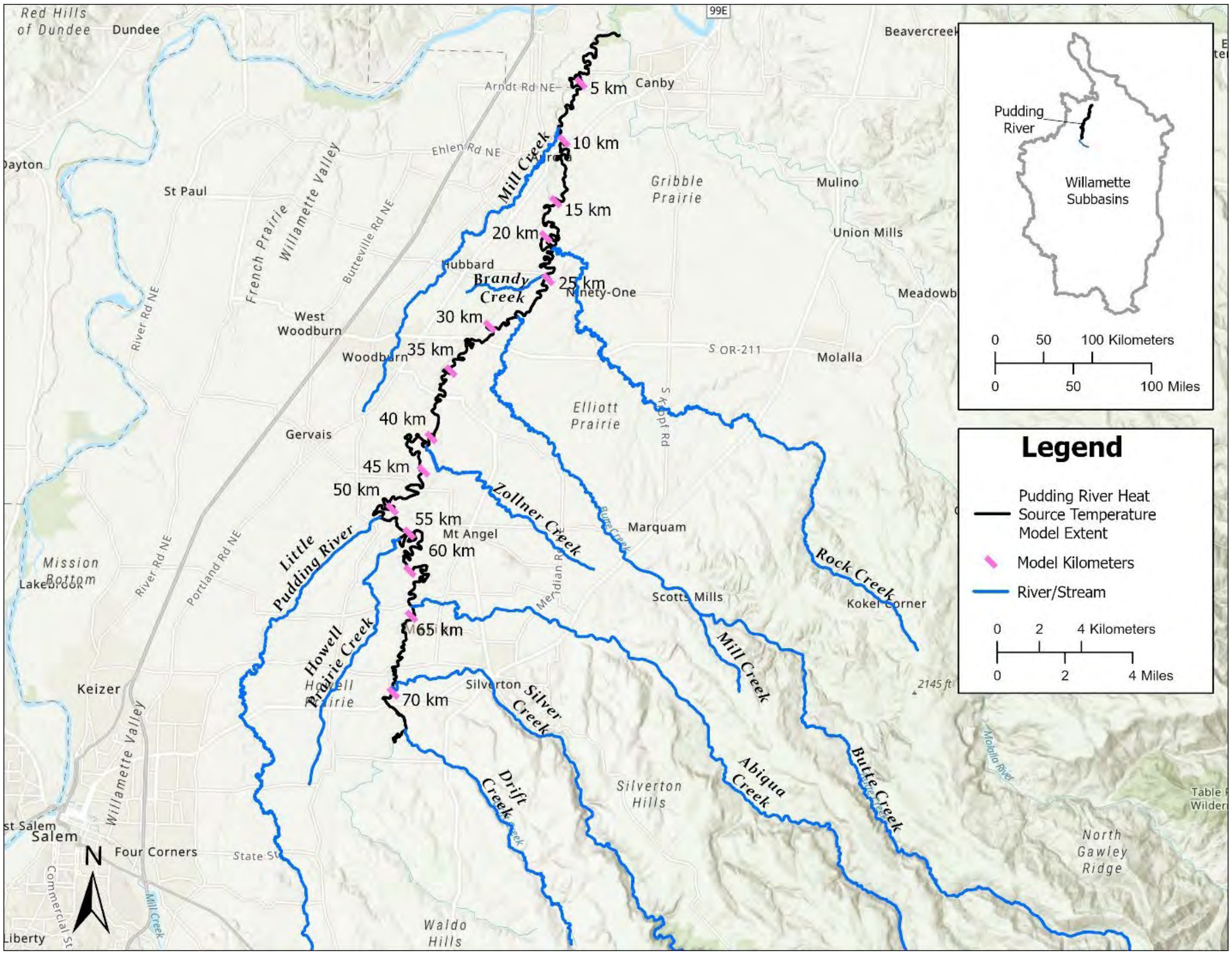


Figure 3.62. Pudding River model extent.

3.3.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 4 minute and outputs are generated every hour.

3.3.3 Time frame of simulation

The model period is August 01, 2004 to August 14, 2004.

3.3.4 Meteorological inputs

The model was set up using hourly air temperature, cloudiness, relative humidity, and wind speed (Table 3.15). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using a wind-sheltering coefficient to represent difference in wind speed between the measurement location and above the stream within the riparian area.

Table 3.15. Meteorological inputs used in the setup of the Pudding River model.

Model Location Name	Model Location (kilometers)	Model Input	Data Source
arao - Aurora	7.7, 12.4, 36.2, 43.7, 51.7, 66.3, 79.6	Air Temperature, Relative Humidity, Wind Speed	Oregon AgriMet Weather Station
KUAO - Aurora State Airport	7.7, 12.4, 36.2, 43.7, 51.7, 66.3, 79.6	Cloudiness	NWS

FIGURE

Figure 3.63 Pudding River model setup for cloudiness.

FIGURE

Figure 3.64 Pudding River model setup for air temperatures.

FIGURE

Figure 3.65 Pudding River model setup for relative humidity.

3.3.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.16). Figure 3.66 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

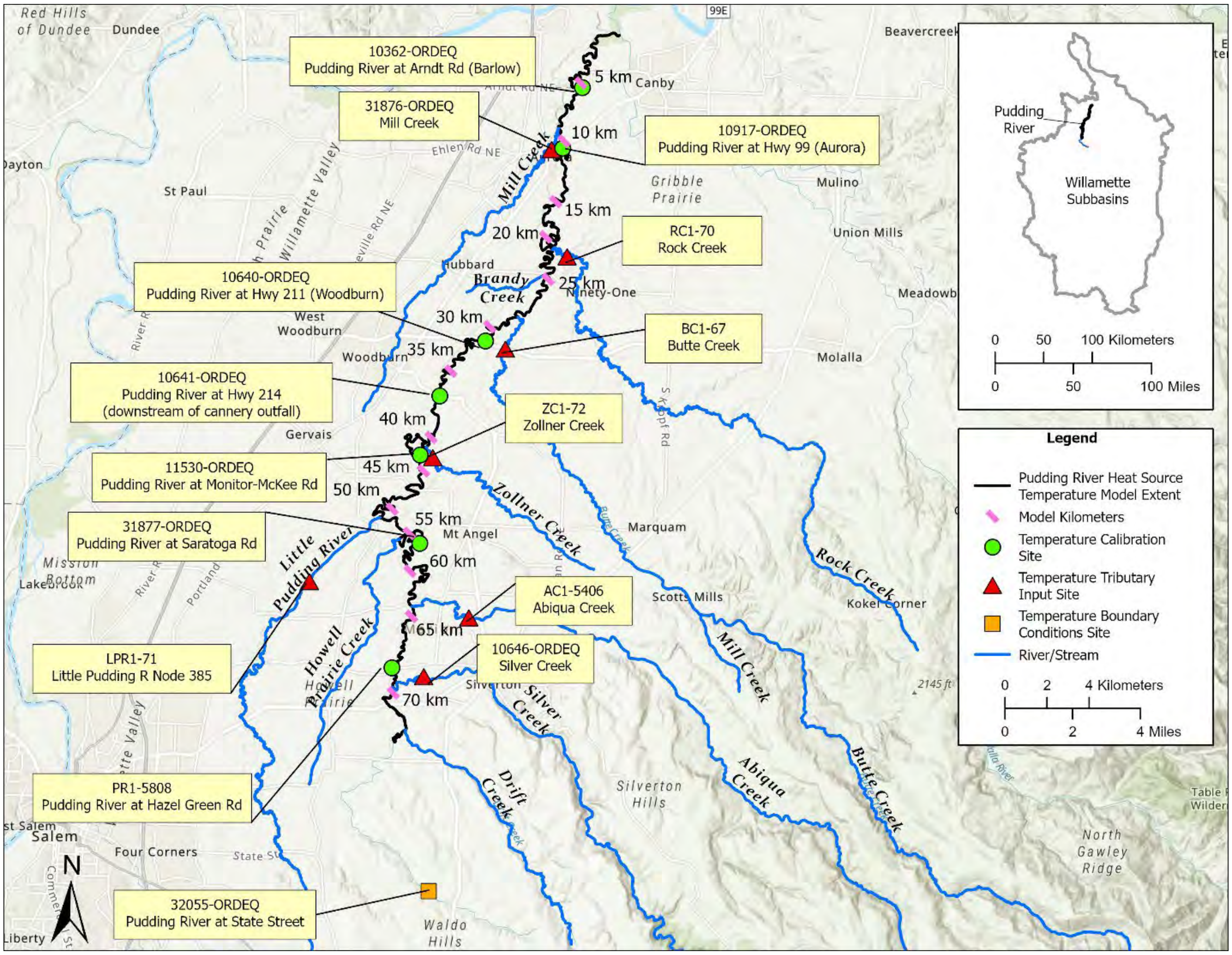


Figure 3.66. Location of temperature monitoring sites used for the setup and calibration of the Pudding River model.

Table 3.16. Pudding River tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (kilometers)	Input Type	Data Source
Pudding River at State Street	84.6	Boundary Condition	32055-ORDEQ
Drift Cr	84.5	Tributary	Derived from a linear interpolation between Marion County SWCD station DC2 and DEQ temperature station 32057-ODEQ.
Lower Pudding R / Howell Prairie Catchment 1 (blw Drift Cr)	82.3	Tributary	Estimated data*
Silver Creek	81.2	Tributary	10646-ORDEQ
Lower Pudding R / Howell Prairie Catchment 2 (Silver to Abiqua) Node 180	80.9	Tributary	Estimated data*

Model Location Name	Model Location (kilometers)	Input Type	Data Source
Abiqua Creek	75.1	Tributary	Marion SWCD (AC1-5406)
Lower Pudding R / Howell Prairie Catchment 3 (upstream Mt. Angel gage) Node 278	71.1	Tributary	Estimated data*
Howell Prairie Cr Node 360	62.9	Tributary	Estimated data*
Little Pudding R Node 385	60.4	Tributary	Marion SWCD (LPR1-71)
Unnamed Trib (Sacred Heart Cr) to the Pudding at Monitor-McKee Rd Node 478	51.1	Tributary	Estimated data*
Zollner Creek	47.6	Tributary	Marion SWCD (ZC1-72)
Unnmd Trib Node 580 inflow (19% of 6th field)	40.9	Tributary	Estimated data*
Butte Creek	32.9	Tributary	Marion SWCD (BC1-67)
Brandy Creek Node 703	28.6	Tributary	Estimated data*
Rock Creek	24.9	Tributary	Marion SWCD (RC1-70)
DA between Mill Cr and Pudding R to Node 794	19.5	Tributary	Estimated data*
DA Rt side Pudding upstream Mill to Node 837	15.2	Tributary	Estimated data*
Mill Creek	10.8	Tributary	31876-ORDEQ
DA Lt side Pudding ds Mill to Arndt Rd Node 894	9.5	Tributary	Estimated data*
DA Rt side Pudding ds Mill to Arndt Rd Node 907	8.2	Tributary	Estimated data*
DA Rt side ds Arndt Rd Node 967	2.2	Tributary	Estimated data*
DA Lt side ds Arndt Rd Node 971	1.8	Tributary	Estimated data*

* Temperature data from a mix of Mill Creek (31876-ODEQ), Zollner Creek (ZC1-72-Marion SWCD), Upper Pudding Creek and groundwater data.

FIGURE

Figure 3.67 Pudding River model setup for tributary and boundary condition temperatures.

3.3.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (Table 3.17). Figure 3.68 **Error! Reference source not found.**shows the locations of the various stream flow monitoring locations that were used for model setup or calibration.

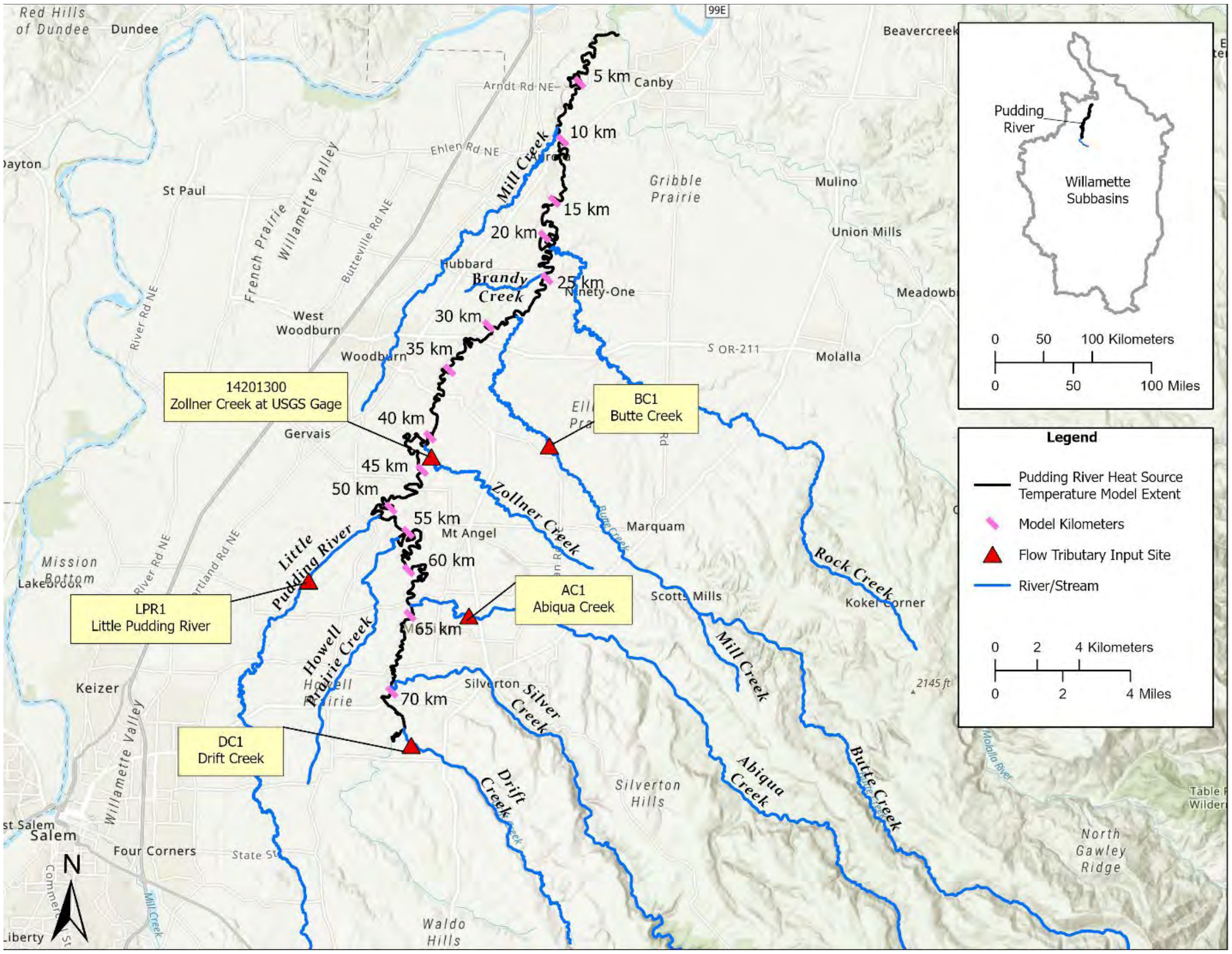


Figure 3.68. Location of flow monitoring sites used for setup and calibration of the Pudding River model.

Table 3.17. Pudding River tributary and boundary condition flow model setup.

Model Location Name	Model Location (kilometers)	Input Type	Data Source
Pudding River upstream of Drift Creek	84.6	Boundary Condition	OWRD
Drift Creek	84.5	Tributary	Marion SWCD (DC1)
Lower Pudding R / Howell Prairie Catchment 1 (blw Drift Cr)	82.3	Tributary	DEQ File
Silver Creek	81.2	Tributary	DEQ File
Lower Pudding R / Howell Prairie Catchment 2 (Silver to Abiqua) Node 180	80.9	Tributary	DEQ File
Abiqua Creek	75.1	Tributary	Marion SWCD (AC1)
Lower Pudding R / Howell Prairie Catchment 3 (upstream Mt. Angel gage) Node 278	71.1	Tributary	DEQ File
Howell Prairie Cr Node 360	62.9	Tributary	DEQ File
Little Pudding River	60.4	Tributary	Marion SWCD (LPR1)

Model Location Name	**Model Location (kilometers)**	**Input Type**	**Data Source**
Unnamed Trib (Sacred Heart Cr) to the Pudding at Monitor-McKee Rd Node 478	51.1	Tributary	DEQ File
Zollner Creek at USGS Gage	47.6	Tributary	USGS (14201300)
Unnmd Trib Node 580 inflow (19% of 6th field)	40.9	Tributary	DEQ File
Butte Creek	32.9	Tributary	Marion SWCD (BC1)
Brandy Creek Node 703	28.6	Tributary	DEQ File
Rock Creek	24.9	Tributary	DEQ File
DA between Mill Cr and Pudding R to Node 794	19.5	Tributary	DEQ File
DA Rt side Pudding upstream Mill to Node 837	15.2	Tributary	DEQ File
Mill Creek	10.8	Tributary	DEQ File
DA Lt side Pudding ds Mill to Arndt Rd Node 894	9.5	Tributary	DEQ File
DA Rt side Pudding ds Mill to Arndt Rd Node 907	8.2	Tributary	DEQ File
DA Rt side ds Arndt Rd Node 967	2.2	Tributary	DEQ File
DA Lt side ds Arndt Rd Node 971	1.8	Tributary	DEQ File

FIGURE

Figure 3.69 Pudding River model setup for tributary and boundary condition flow rates.

FIGURE

Figure 3.70 Pudding River model setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.71 Pudding River model setup for withdrawal flow rates.

3.3.7 Point source inputs

There are six permitted individual NPDES point sources along the model extent. Detail about each point source is summarized in Table 3.18.

Table 3.18. NPDES point sources located along the Pudding River model extent.

Facility Name (Facility Number)	**Latitude/Longitude**	**Permit Type and Description**	**Stream/River Mile**
Aurora STP (110020)	45.2291/-122.753	NPDES-DOM-Db: Sewage - less than 1 MGD with discharging lagoons	Pudding River RM 8.8
Columbia Helicopters (100541)	45.2776/-122.733	NPDES-IW-B16: All facilities not elsewhere classified which dispose of non-process wastewaters	Unnamed Stream (tributary to Pudding River RM 1.8) RM 2

Facility Name (Facility Number)	**Latitude/Longitude**	**Permit Type and Description**	**Stream/River Mile**
Gervais STP (33060)	45.1079/-122.84	NPDES-DOM-Db: Sewage - less than 1 MGD with discharging lagoons	Pudding River RM 28.2
JLR, LLC (32536)	45.1261/-122.821	NPDES-IW-B05: Food/beverage processing - Large and complex. Flow greater than or equal to 1 MGD for 180 days/year or more	Pudding River RM 27
Mt. Angel STP (58707)	45.0678/-122.828	NPDES-DOM-Da: Sewage - less than 1 MGD	Pudding River RM 37.5
Woodburn WWTP (98815)	45.1509/-122.804	NPDES-DOM-C1a: Sewage - 2 MGD or more but less than 5 MGD	Pudding River RM 21.4

FIGURE

Figure 3.72 Pudding River model setup up for point source effluent temperatures.

FIGURE

Figure 3.73 Model setup point source effluent flow rates.

3.3.8 Landcover and topographic shade inputs

FIGURE

Figure 3.74 Pudding River model setup for landcover height (m).

FIGURE

Figure 3.75 Pudding River model setup for topographic shade angles.

3.3.9 Channel setup

FIGURE

Figure 3.76 Pudding River model setup for stream channel elevation (m) and gradient.

FIGURE

Figure 3.77 Pudding River model setup for channel angle z.

FIGURE

Figure 3.78 Pudding River model setup for bottom width (m).

FIGURE

Figure 3.79 Pudding River model setup for manning roughness coefficient.

3.3.10 Other model parameters

3.3.11 Calibration results

Table 3.19. Monitoring locations used as calibration sites in the Pudding River model.

Model Location Name	Model Location (kilometers)	Calibration Parameter	Data Source
Pudding River at Hazel Green Rd.	79.6	Water Temperature	Marion SWCD (PR1-5808)
Pudding River at Saratoga Road	66.3	Water Temperature	31877-ORDEQ
Pudding River at Monitor-McKee Road	51.7	Water Temperature	11530-ORDEQ
Pudding River at Hwy 214 (downstream of cannery outfall)	43.7	Water Temperature	10641-ORDEQ
Pudding River at Hwy 211 (Woodburn)	36.2	Water Temperature	10640-ORDEQ
Pudding River at Hwy 99 (Aurora)	12.4	Water Temperature	10917-ORDEQ
Pudding River at Arndt Road (Barlow)	7.7	Water Temperature	10362-ORDEQ
Model extent	Model extent	Water Temperature (TIR)	Watershed Sciences (2005)

3.3.11.1 Flow

Comparisons of model calculated flow rates at Woodburn to values measured by the USGS gage are shown in Figure 3.80. As shown, the flow calibration at this gage is quite good. The flow calibration at the Aurora gage is not nearly as good as at the Woodburn gage (Figure 3.81). The model does a relatively poor job of replicating the large fluctuations in flow at this gage. As shown by Figure 3.80 and Figure 3.81, peak flows nearly double from Woodburn to Aurora. Two major tributaries enter between these sites, Butte Creek and Rock Creek, which implies that much of the large flow increase is due to these two tributaries. Unfortunately, neither of these tributaries is currently gauged, so flow rates cannot be accurately determined. The poor performance may also be partially due to longitudinal dispersion provided by the model. The longitudinal dispersion coefficient, which is not available to users for adjustment, may be larger than is appropriate for the Pudding River.

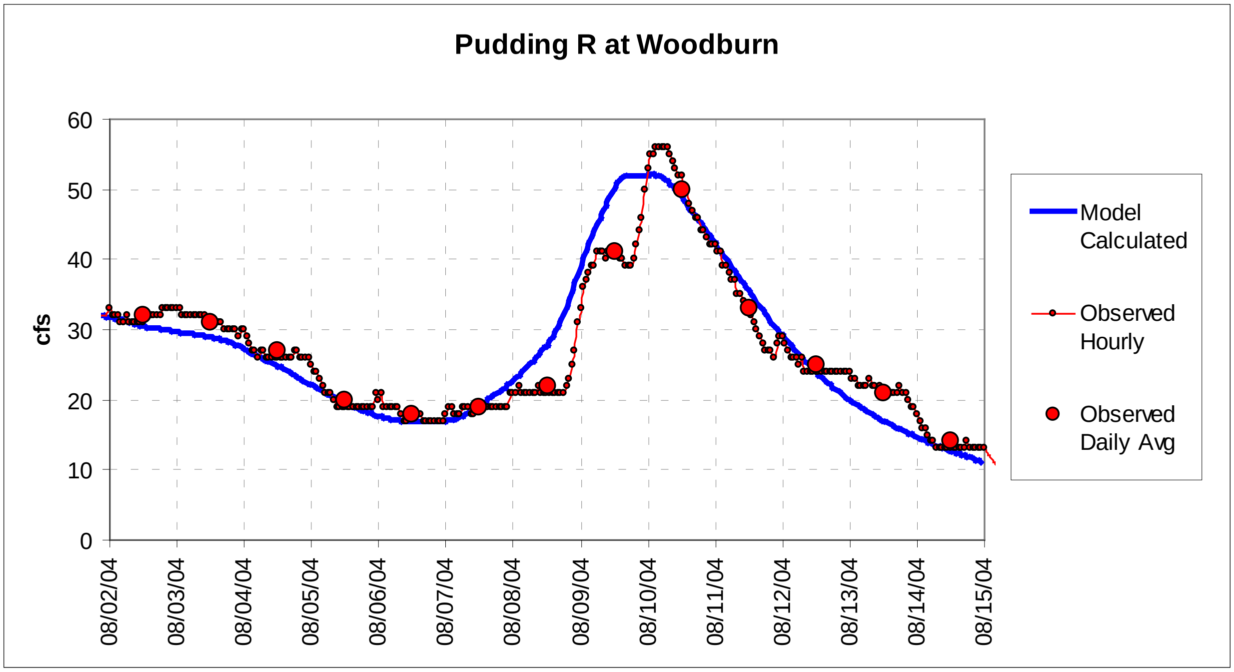


Figure 3.80. Pudding River field observed and model calculated flow rates at Aurora, model km 13 (river mile 8.1).

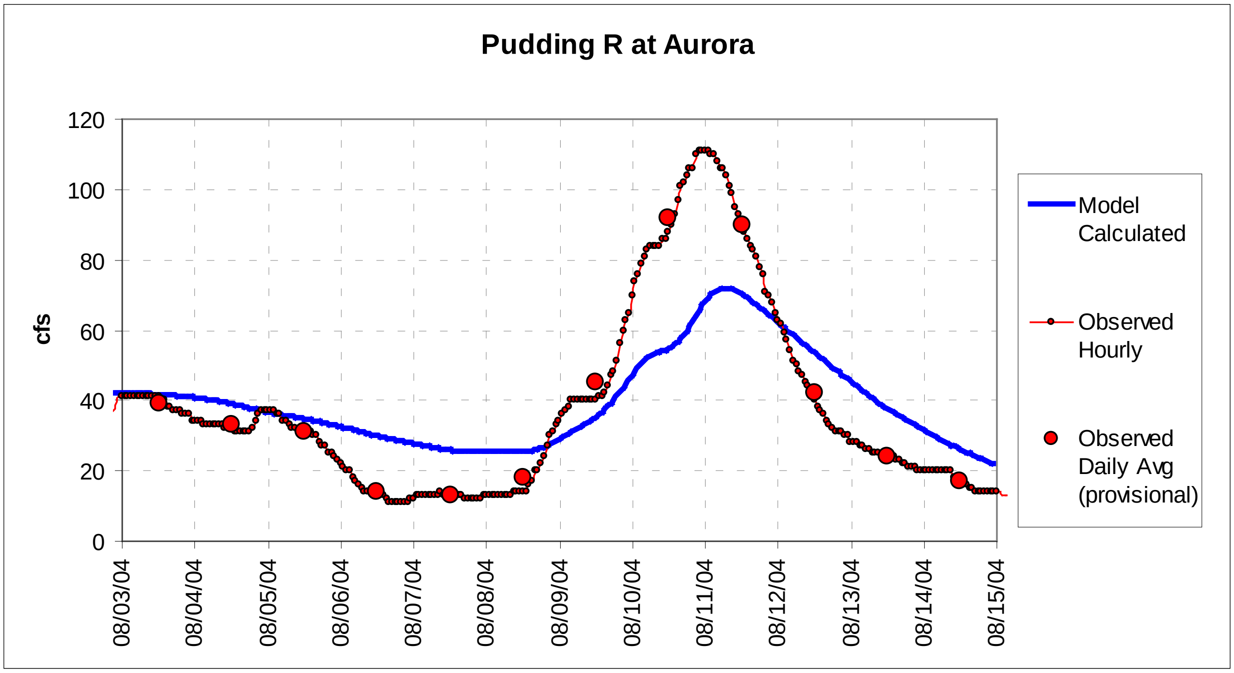


Figure 3.81. Pudding River field observed and model calculated flow rates near Woodburn, model km 37.5 (river mile 23.3).

Table 3.20. Flow rate goodness of fit statistics comparing field observed and model flow rates

TABLE

3.3.11.2 Bathymetry and velocity

A QUAL2E model of the Pudding River was developed by ODEQ in the 1990's using data collected in the early 1990's (Brown and Barnwell, 1987). While the extensive dataset collected to calibrate the model could not be located, the QUAL2E model, which includes calibrated width, depth, and velocity relationships, was available. The model used relationships in which velocity, depth, and width are functions of flow, as follows:

Velocity = aQ^b

Depth = cQ^d

Width = eQ^e

Bottom widths, side angles, and Manning's roughness coefficient (*n*) were adjusted to produce surface widths which matched GIS measured widths and QUAL2E model depths, cross-sectional areas and velocities. Note that the coefficients and exponents for the QUAL2E velocity, depth and width equations were constant for each QUAL2E model reach, so the values for each QUAL2E reach are nearly constant, with variations within each reach only due to variations in flow. The ten QUAL2E reaches, reaches 1, 3, 5, 7, 9, 10, 11, 13, 14, 16 and 17, are identified in the following figures. Reaches 6, 8, 12, etc., are tributary reaches and hence do not appear in the following figures. Reaches 17 and 18 were not modeled by QUAL2E, only Heat Source.

Average flow rates for August 1 to 20, as calculated by the model, are similar to flow conditions for which the QUAL2E model was calibrated. Average flow rates for this 20-day period are shown on **Error! Reference source not found.**. As shown, these flow rates are slightly greater than the 7Q10 rates of 15 cfs at the Woodburn gage and 25 cfs at the Aurora gage. Also shown on the plot are gage and instantaneous flow measurements from July 31 to August 3, 2007. As shown, these flows for these dates were similar to flows during the August, 2004 model calibration period.

Calculated widths, depths, cross-sectional areas and velocities (based on the 20-day average flow rates) compared to QUAL2E and GIS measured values are shown in Figure 3.82 to Figure 3.86. Note that the QUAL2E width, depth, and velocities are reach average values which apply for reaches that extend for large distances. Therefore, values for some Heat Source segments will be greater than QUAL2E values and for others will be less. The goal of the calibration was to reproduce the QUAL2E values on average. As shown by the plots, the Heat Source values generally reproduce the QUAL2E values quite well.

The goal of the hydraulics calibration was for reach average velocities, depths, and cross-sectional areas to be within +/- 10% of reach average values for the QUALE model and for reach average surface widths to not exceed reach average GIS measured channel widths by more than 10%. As shown in Table 3.21, the model meets these specifications.

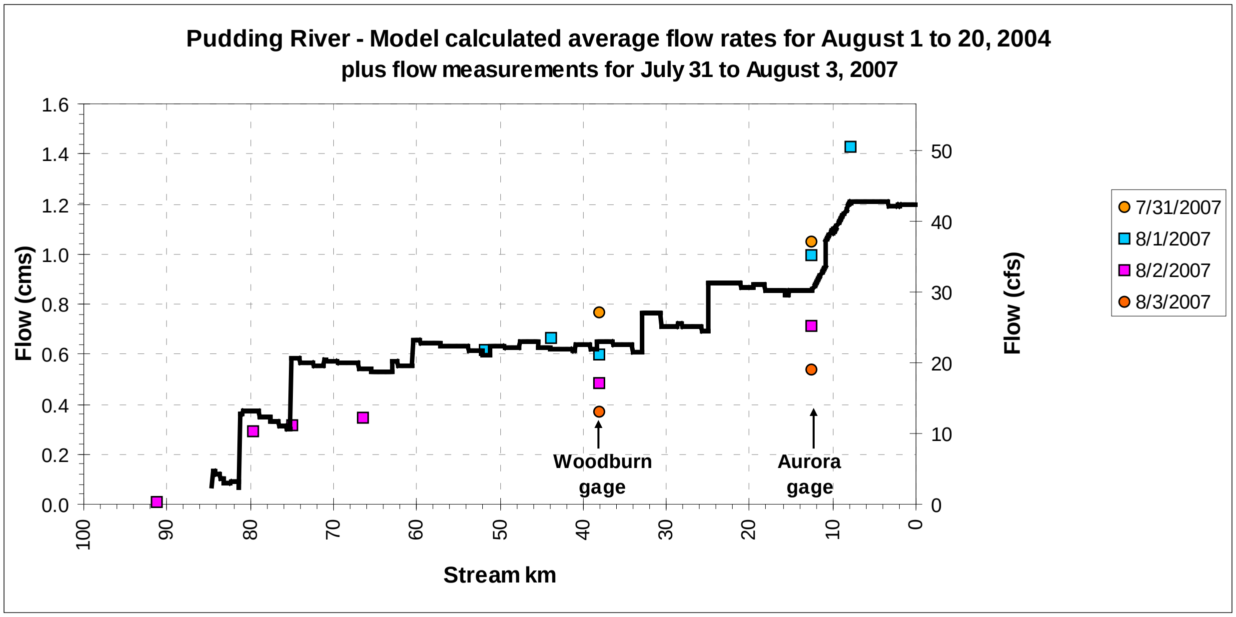


Figure 3.82 Flow rates used for hydraulics calibration and comparisons to Pudding River QUAL2E model

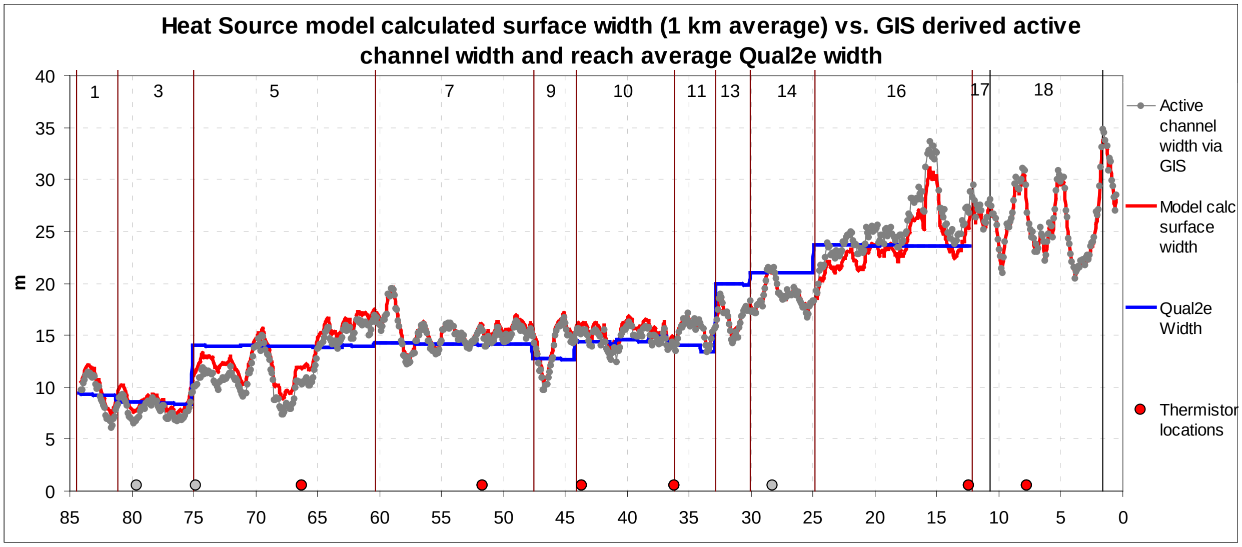


Figure 3.83 Pudding River model width calibration.

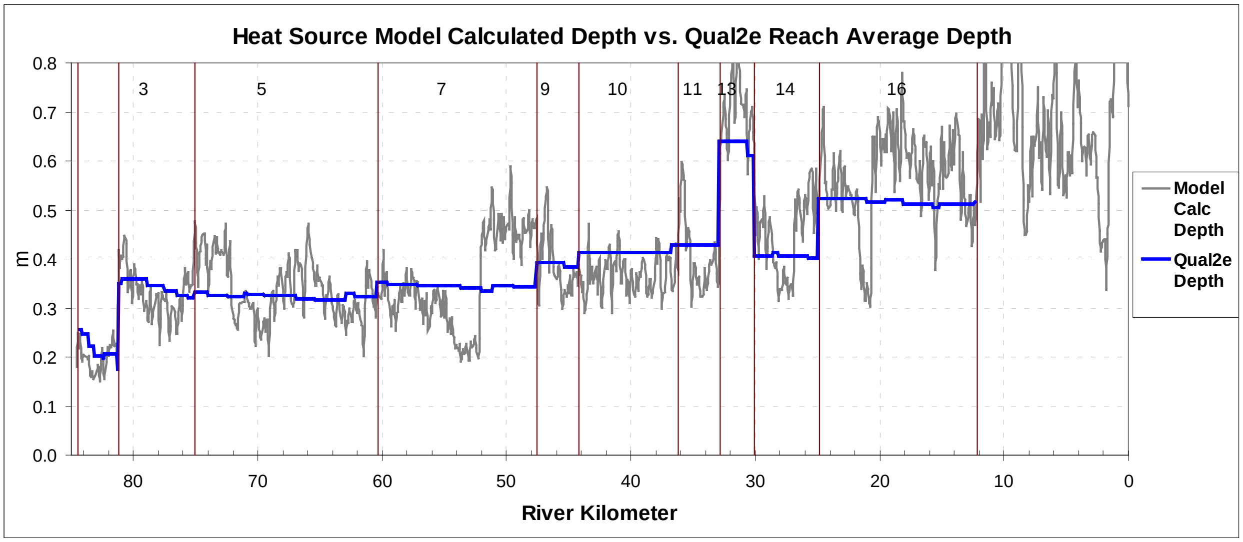


Figure 3.84 Pudding River model depth calibration.

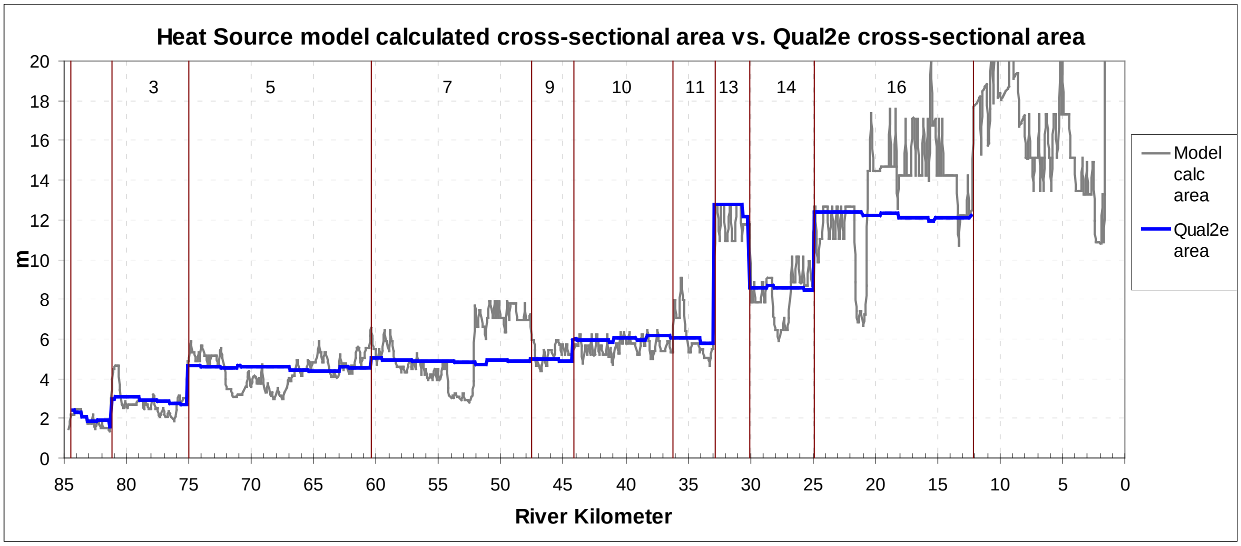


Figure 3.85 Pudding River model cross-sectional area calibration.

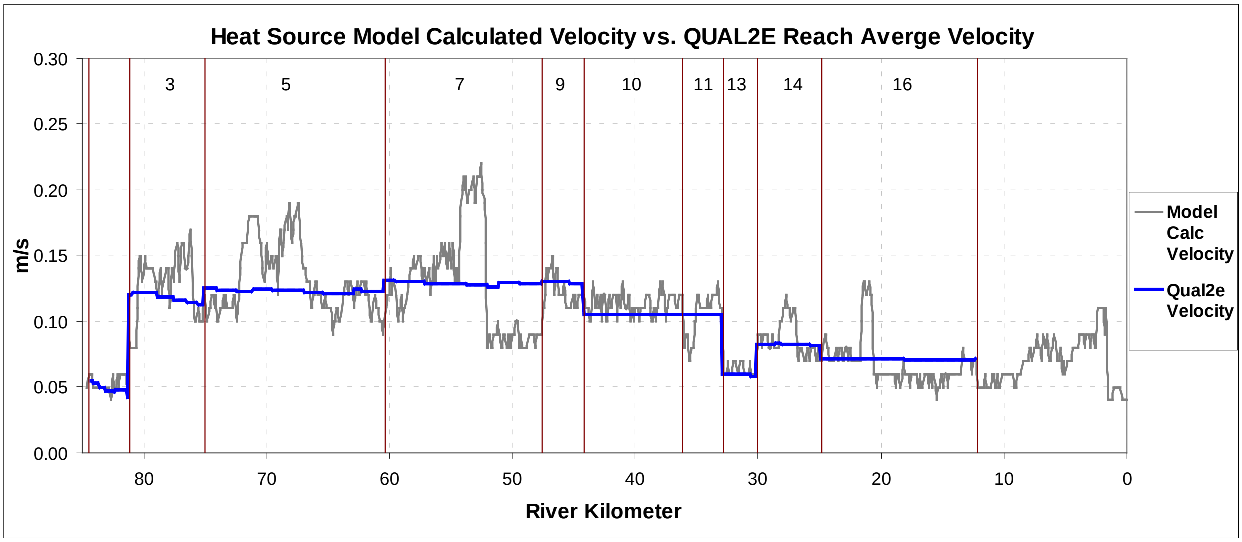


Figure 3.86 Pudding River model velocity calibration.

Table 3.21 Comparison of Pudding River Heat Source velocity, depth, area and width to target values.

Reach	Average Heat Source to QUAL2E Velocity	Average Heat Source to QUAL2E Depth	Average Heat Source to QUAL2E Width	Average Heat Source to QUAL2E Area	Ratio Model Calc Surface Width to Active Channel Width
0					1.08
1	108%	90%	106%	93%	1.09
3	108%	95%	101%	96%	1.09
5	107%	104%	96%	97%	1.09
7	99%	102%	109%	110%	1.03
9	94%	99%	113%	108%	1.05
10	107%	90%	106%	94%	1.05
11	100%	94%	111%	104%	1.01
13	109%	109%	87%	93%	1.01
14	106%	110%	89%	97%	1.00

16	96%	110%	101%	109%	0.94
17					0.98
18					0.99
19					0.99

3.3.11.3 Effective Shade

FIGURE

Figure 3.87 Pudding River model predicted effective shade.

Table 3.22. Pudding River effective shade summary.

TABLE

3.3.11.4 Temperature

A comparison of model calculated temperature to TIR measured temperatures for the Pudding River is shown in Figure 3.88. Goodness of fit statistics are shown in Table 3.23. A reasonable target for model calibration is an RMS error of no more than 1.0^{o}C and a mean error in the range +/- 1.0^{o}C. These statistics are met for most of the river from the historic Mt. Angel Gage at model km 66.3 to the confluence of Mill Creek at river km 10.8, which are of most interest to point sources, particularly the Woodburn WWTP which discharges at model km 38.3. However, for the entire river the RMSE specification is slightly exceeded.

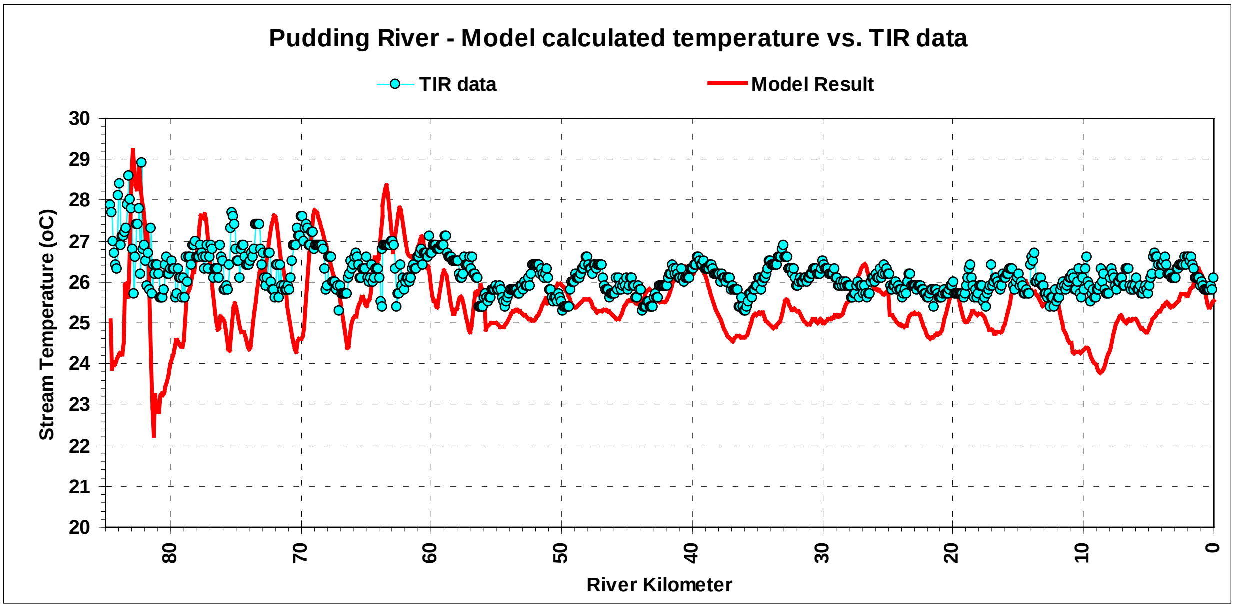


Figure 3.88 Pudding River TIR temperature and model predicted temperatures for August 11 and 12.

Table 3.23 Pudding River stream temperature goodness of fit statistics comparing TIR measured and model predicted temperatures.

	Entire River (ºC)	**Mt. Angel Gage at model km 66.3 to Mill Creek at model km 10.8 (ºC)**
Mean Error	-0.7	-0.5
Mean Absolute Error	0.9	0.7
RMS Error	1.1	0.8

Comparisons of model calculated temperatures to continuous temperature data collected at monitoring locations where data was successfully retrieved is presented in Figure 3.89 through Figure 3.94. Mainstem Pudding River thermisters upon which the model was calibrated were deployed by ODEQ. Tributary temperatures monitoring for the calibration period were measured and deployed by the Marion Soil and Water Conservation District and ODEQ.

The Pudding River model closely matches DEQ continuous monitoring data at most locations. Error statistics for hourly values are presented in Table 3.24 and statistics for 7-day average daily maximum values are presented in Table 3.25. Comparisons of calculated hourly values to observed data are presented in Figure 3.89 through Figure 3.94. Note that no data is available for Node 7 since the thermister failed at this location during the time period modeled. Note also that the thermister for Node 3 (Saratoga Road, 31877-ORDEQ) occasionally generated some erratic temperatures (not shown on plot) and may not be reliable.

Root Mean Squared error (RMSE) is commonly used to evaluate model performance. A value of 1.0 was specified as a good calibration. Nodes 4 through 8 meet this specification, but Node 9 exceeds it, with an RMSE error of 1.2.

Mean Error (ME) is a useful measure of model bias. If ME is positive, the model shows a positive bias (i.e., it over calculates temperature). If ME is negative, it shows a negative bias. Generally, ME values within the range +/- 1.0 are considered acceptable. ME for Nodes 4 to 9 meet this specification, although a slightly negative bias is exhibited.

For 7-day average daily maximum temperatures, all stations are within the desired ranges for the three statistics, except for Node 5, which slightly exceeds the desired values (RMSE = 1.1°C and an ME = -1.1°C). Error statistics and visual observations of simulated compared to observed temperatures indicate that the model is sufficiently well calibrated to use to evaluate the sensitivity of river temperatures to various heat loads, including point source impacts.

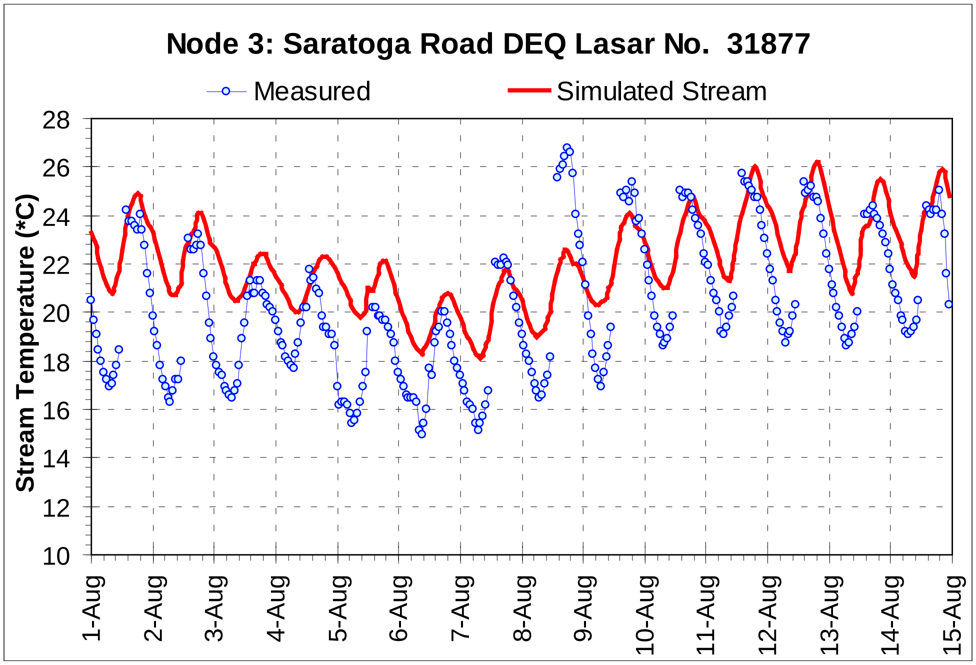


Figure 3.89 Pudding River field observed and model predicted hourly temperatures. – model km km 66.3 (river mile 41.2).

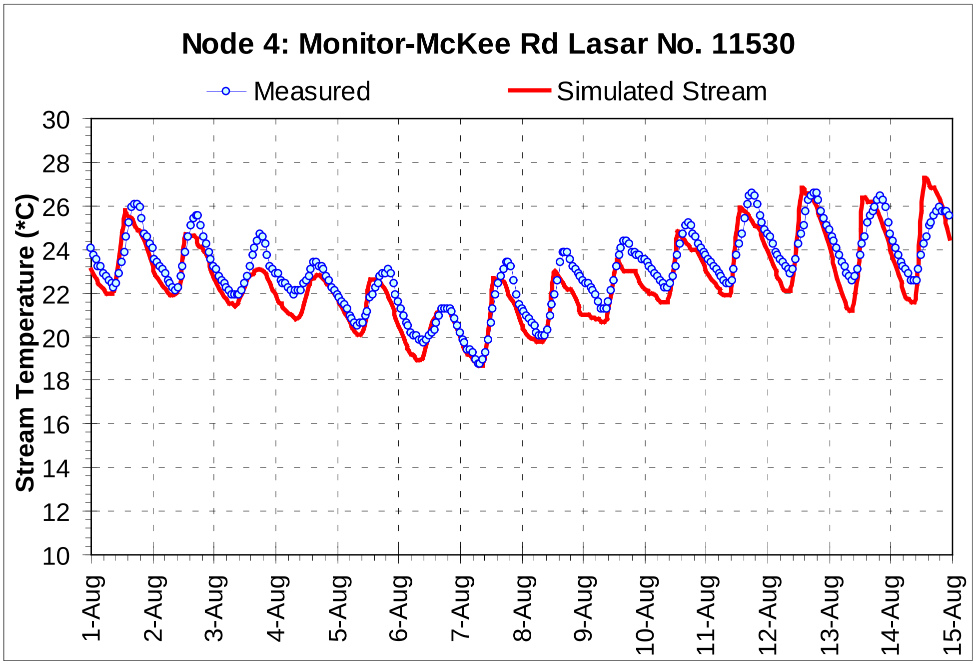


Figure 3.90 Pudding River field observed and model predicted hourly temperatures. – model km 51.7 (river mile 32.1).

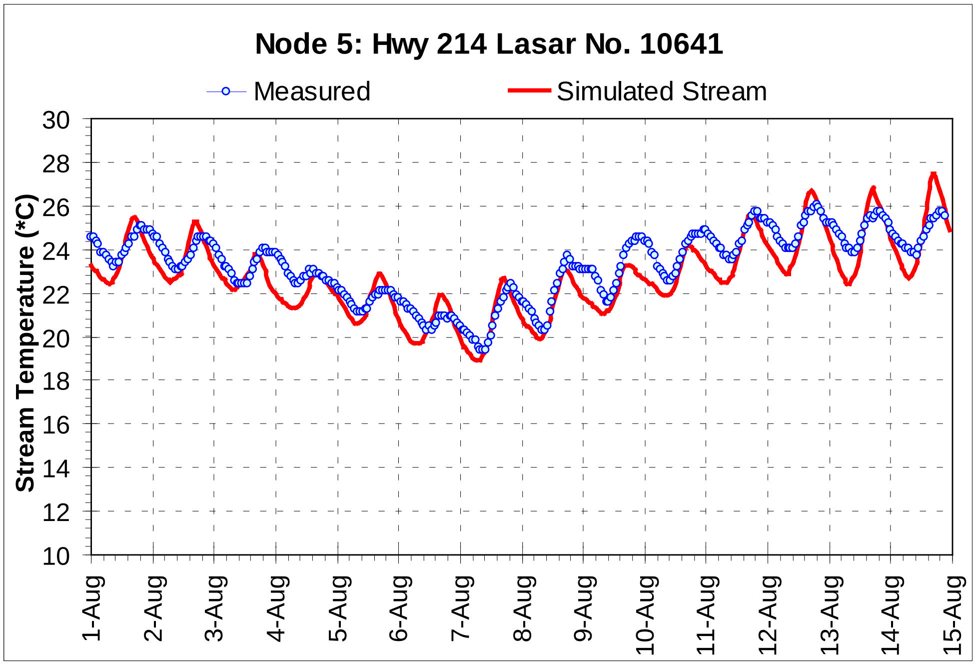


Figure 3.91 Pudding River field observed and model predicted hourly temperatures. – model km 43.7 (river mile 27.1)

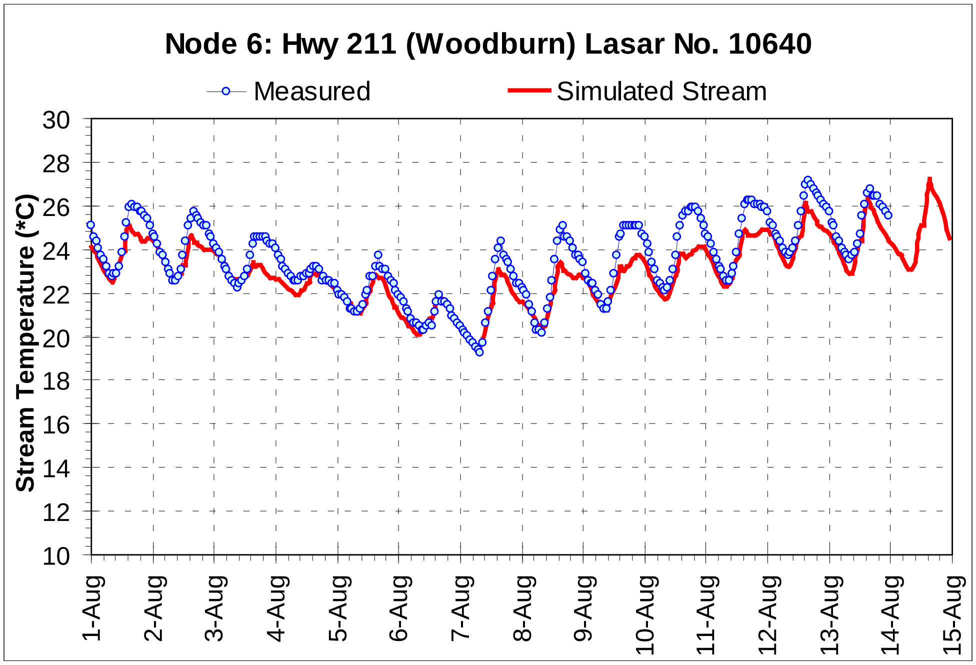


Figure 3.92 Pudding River field observed and model predicted hourly temperatures. – model km 36.2 (river mile 22.5).

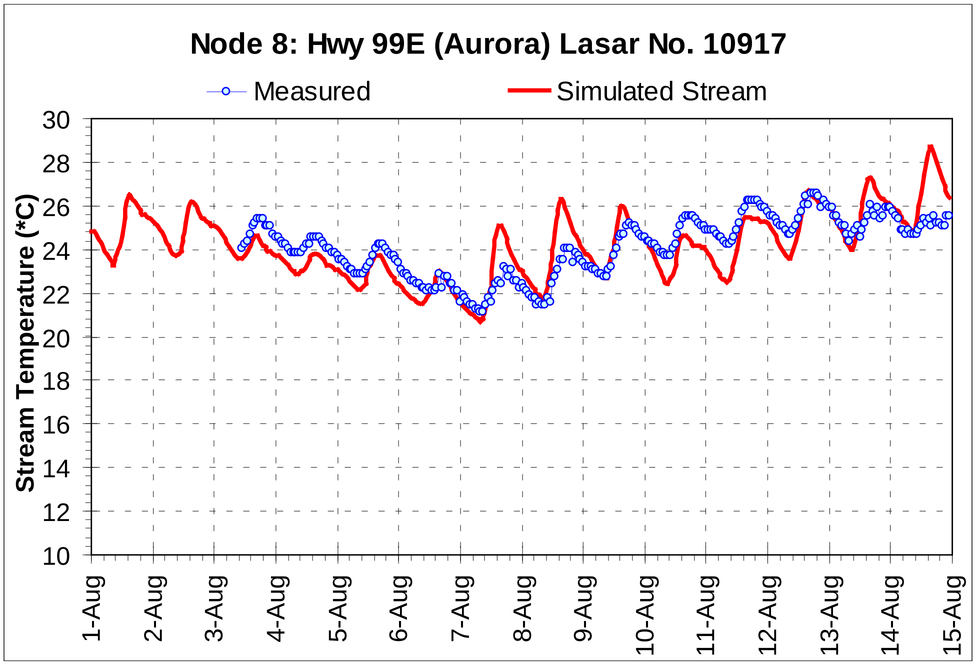


Figure 3.93 Pudding River field observed and model predicted hourly temperatures. – model km 12.4 (river mile 7.7).

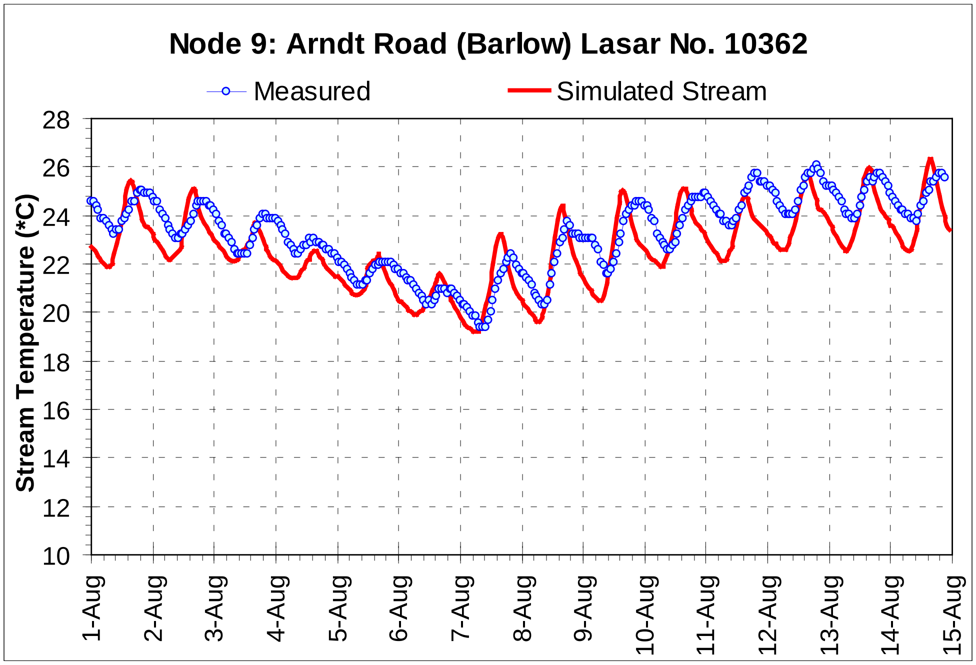


Figure 3.94 Pudding River field observed and model predicted hourly temperatures. – model km 7.7 (river mile 4.8).

Table 3.24 Pudding River hourly stream temperature goodness of fit statistics comparing field measured and model predicted temperatures.

Monitoring Location	Model kilometer	Mean Error (deg-C)	Mean Absolute Error (deg-C)	RMSE (deg-C)
Node 3: Saratoga Road, 31877-ORDEQ	66.3	1.8	2.1	2.5
Node 4: Monitor-McKee Rd, 11530-ORDEQ	51.7	-0.5	0.8	0.9
Node 5: Hwy 214, 10641-ORDEQ	43.7	-0.5	0.8	0.9
Node 6: Hwy 211 (Woodburn), 10640-ORDEQ	36.2	-0.6	0.7	0.8
Node 8: Hwy 99E (Aurora), 10917-ORDEQ	12.4	-0.1	0.8	1.0
Node 9: Arndt Road (Barlow), 10362-ORDEQ	7.7	-0.7	1.0	1.2

Table 3.25 Pudding River 7DADM stream temperature goodness of fit statistics comparing field measured and model predicted temperatures.

Monitoring Location	Model kilometer	Mean	Mean	RMSE (deg-C)

		Error (deg-C)	Absolute Error (deg-C)	
Node 3: Saratoga Road, 31877-ORDEQ	66.3	-0.1	0.5	0.5
Node 4: Monitor-McKee Rd, 11530-ORDEQ	51.7	-0.6	0.6	0.6
Node 5: Hwy 214, 10641-ORDEQ	43.7	-0.1	0.2	0.2
Node 6: Hwy 211 (Woodburn), 10640-ORDEQ	36.2	-1.1	1.1	1.1
Node 8: Hwy 99E (Aurora), 10917-ORDEQ	12.4	0.5	0.5	0.5
Node 9: Arndt Road (Barlow), 10362-ORDEQ	7.7	0.1	0.1	0.1

3.4 Little North Santiam River

The Little North Santiam River model is a temperature model developed using Heat Source 6.5.1. The model was developed by DEQ.

3.4.1 Model extent

The extent of the model domain is the Little North Santiam River from the mouth to river mile 15 (Figure 3.95).

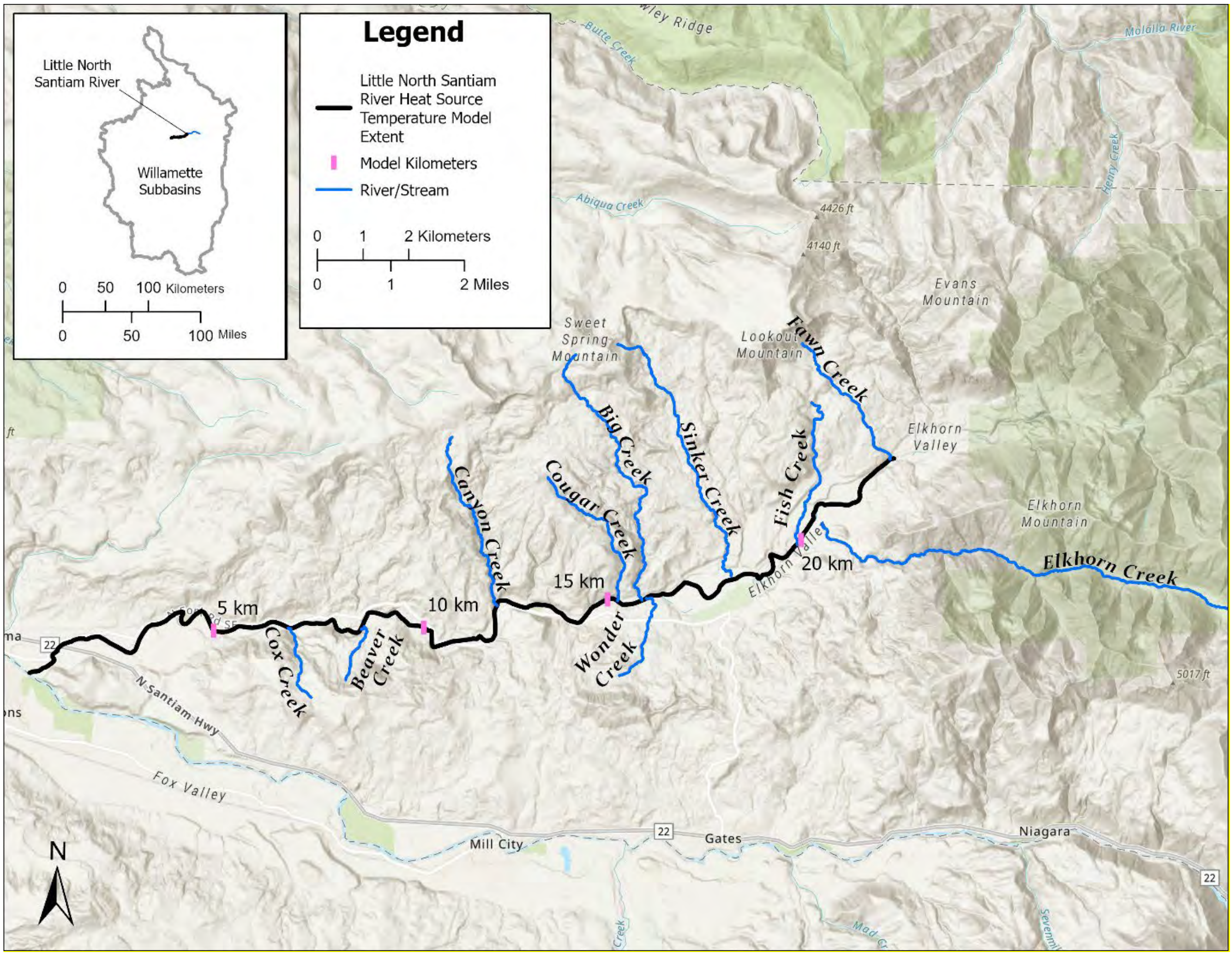


Figure 3.95. Little North Santiam model extent.

3.4.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.4.3 Time frame of simulation

The model period is for a single day: August 01, 2000.

3.4.4 Meteorological inputs

The model was set up using hourly air temperature, relative humidity, and wind speed measurements from AirNav at the McNary Field Airport (KSLE). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using a wind-sheltering coefficient of 0.25 to represent difference in wind speed between the measurement location and above the stream within the riparian area.

FIGURE

Figure 3.96. Model setup cloudiness.

FIGURE

Figure 3.97. Model setup air temperatures.

FIGURE

Figure 3.98. Model setup relative humidity

3.4.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.26). Figure 3.99 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

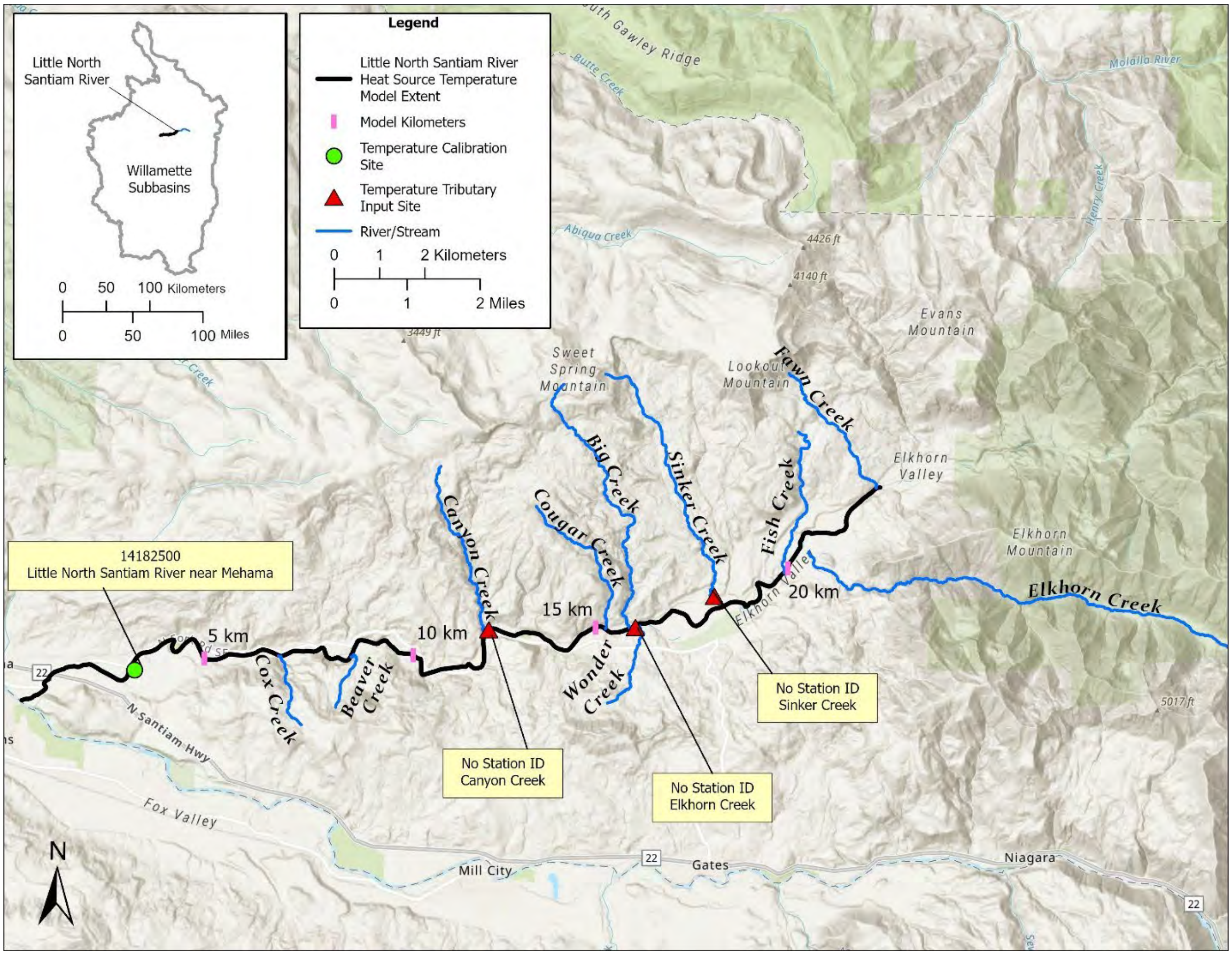


Figure 3.99. Location of temperature monitoring sites used for setup and calibration of the Little North Santiam River model.

Table 3.26. Little North Santiam River tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Little North Santiam at Fawn Creek	0	Boundary Condition	Watershed Sciences (2001) (S68509)
Cox Creek	17374	Tributary	DEQ File
Beaver Creek	15728	Tributary	DEQ File
Canyon Creek	11217	Tributary	BLM
Cougar Creek	8108	Tributary	DEQ File
Big Creek	7559	Tributary	DEQ File
Wonder Creek	7498	Tributary	DEQ File
Sinker Creek	5304	Tributary	BLM
Elkhorn Creek	2560	Tributary	BLM
Fish Creek	2195	Tributary	DEQ File

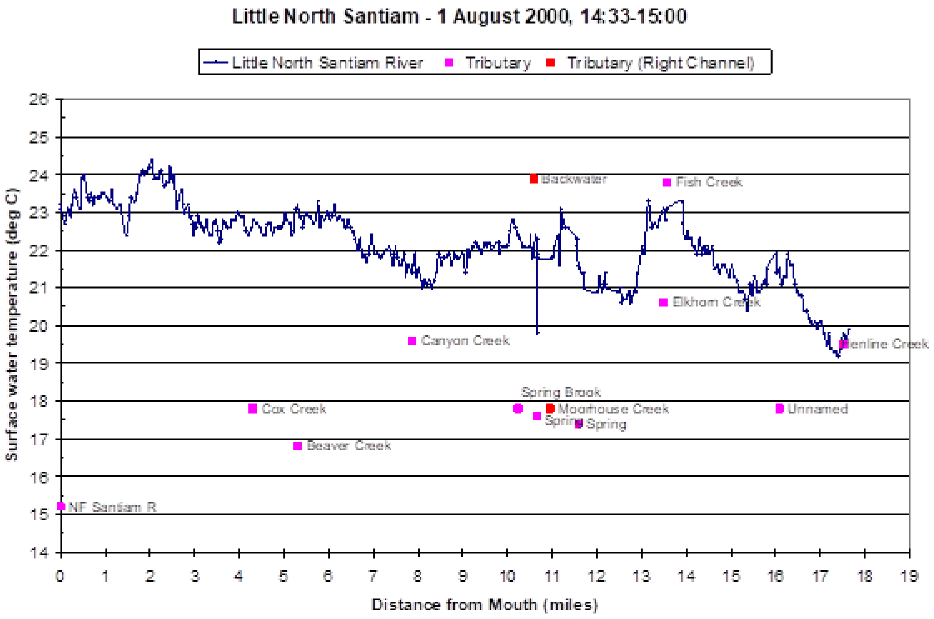


Figure 3.100. TIR Temperatures on the Little North Santiam River, North Santiam Subbasin

FIGURE

Figure 3.101. Model setup tributary and boundary condition temperatures.

3.4.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (). Figure 3.102 **Error! Reference source not found.**shows the locations of the various stream flow monitoring locations that were used for model setup or calibration.

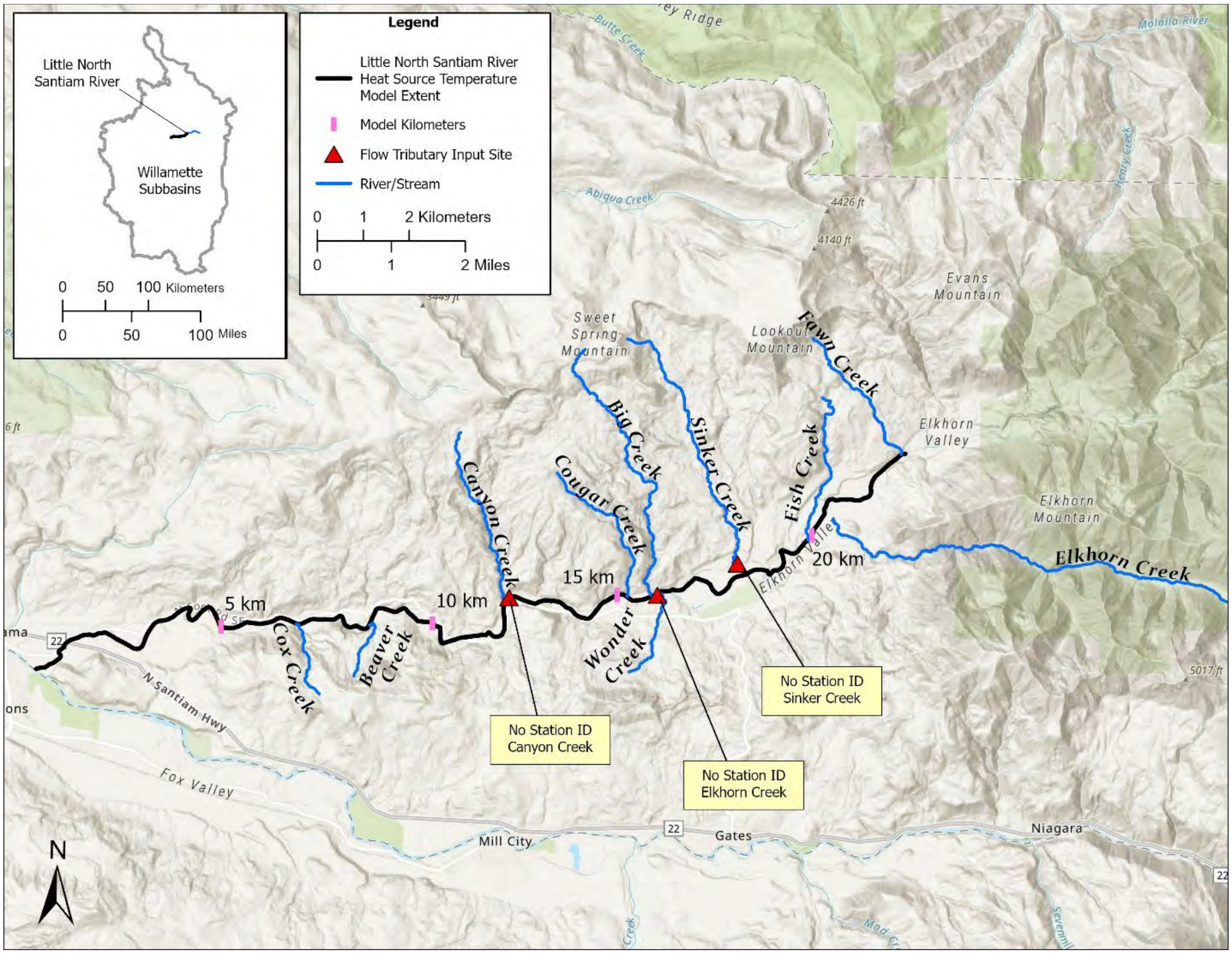


Figure 3.102. Location of flow monitoring sites used for setup and calibration of the Little North Santiam River model.

Table 3.27. Little North Santiam River tributary and boundary condition flow model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Little North Santiam at Fawn Creek	0	Boundary Condition	Derived from flow mass balance (S68509)
Cox Creek	17374	Tributary	Derived from TIR using flow mass balance
Beaver Creek	15728	Tributary	Derived from TIR using flow mass balance
Canyon Creek	11217	Tributary	BLM
Cougar Creek	8108	Tributary	Derived from TIR using flow mass balance
Big Creek	7559	Tributary	Derived from TIR using flow mass balance
Wonder Creek	7498	Tributary	Derived from TIR using flow mass balance
Sinker Creek	5304	Tributary	BLM

Model Location Name	Model Location (meters)	Input Type	Data Source
Elkhorn Creek	2560	Tributary	BLM
Fish Creek	2195	Tributary	Derived from TIR using flow mass balance

Figure 3.103. Model setup tributary and boundary condition flow rates.

FIGURE

Figure 3.104. Model setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.105. Model setup for withdrawal flow rates.

FIGURE

3.4.7 Point source inputs

There are no point sources discharging within the model extent.

Figure 3.106. Model setup up point source effluent temperatures.

FIGURE

Model setup point source effluent flow rates.

FIGURE

3.4.8 Landcover and topographic shade inputs

Figure 3.107. Model setup landcover height (m).

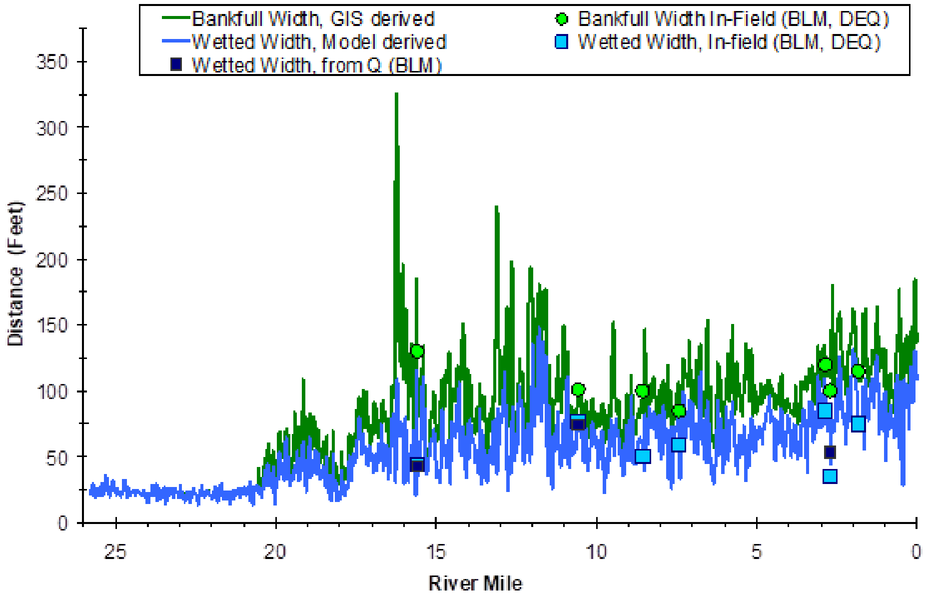
FIGURE

Figure 3.108. Model setup topographic shade angles.

FIGURE

3.4.9 Channel setup

Channel widths on Little North Santiam River, North Santiam Subbasin



FIGURE

Figure 3.109. Model setup stream channel elevation (m) and gradient.

FIGURE

Figure 3.110. setup channel angle z.

FIGURE

Figure 3.111. Model setup bottom width (m).

FIGURE

Figure 3.112. Model setup for manning roughness coefficient.

3.4.10 Other model parameters

3.4.11 Calibration results

Table 3.28. Monitoring locations used as calibration sites in the Little North Santiam model.

Model Location Name	Model Location (meters)	Calibration Parameter	Data Source
Little North Santiam River near Mehama	21854.16	Water Temperature	USGS (14182500)
Little North Santiam at North Fork County Park	20452.08	Effective Shade	BLM
North Fork County Park	20452.08	Water Temperature, Flow	BLM
Node 4	17251.68	Water Temperature	Watershed Sciences (2001) (S88442)

Model Location Name	Model Location (meters)	Calibration Parameter	Data Source
Node 3	11216.64	Water Temperature	Watershed Sciences (2001) (S349766)
Elk Horn Park	7802.88	Water Temperature, Flow	BLM
Little North Santiam at Elk Horn Park	7802.88	Effective Shade	BLM

3.4.11.1 Flow

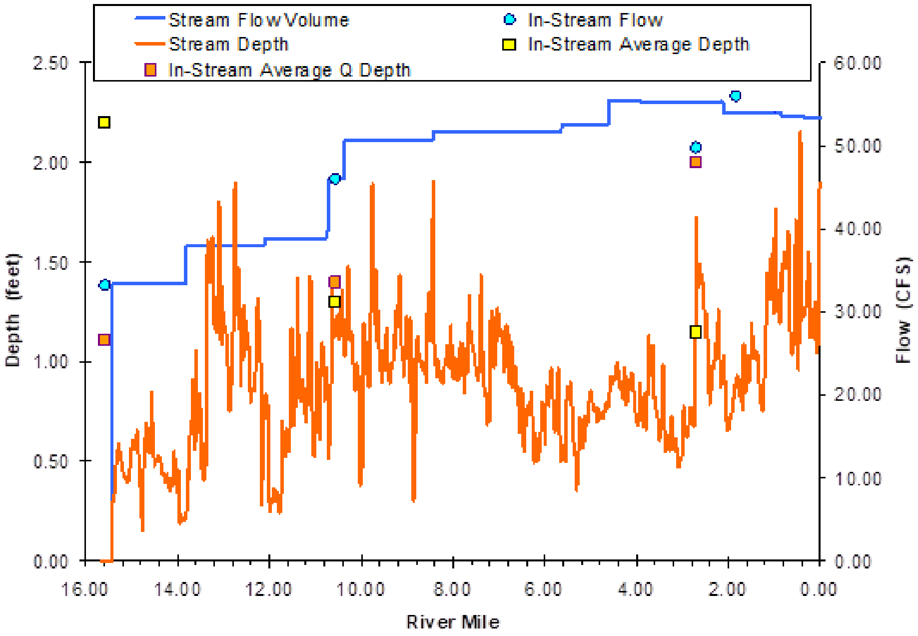


Figure x. Longitudinal flow mass balance for Little North Santiam River, North Santiam Subbasin

Figure 3.113. Field observed and model predicted mean daily flow rates.

FIGURE

Table 3.29. Flow rate goodness of fit statistics comparing field observed and model flow rates

TABLE

3.4.11.2 Effective Shade

Figure 3.114. Field observed and model predicted effective shade.

FIGURE

Table 3.30. Effective shade goodness of fit statistics comparing field observed and model values.

TABLE

3.4.11.3 Temperature

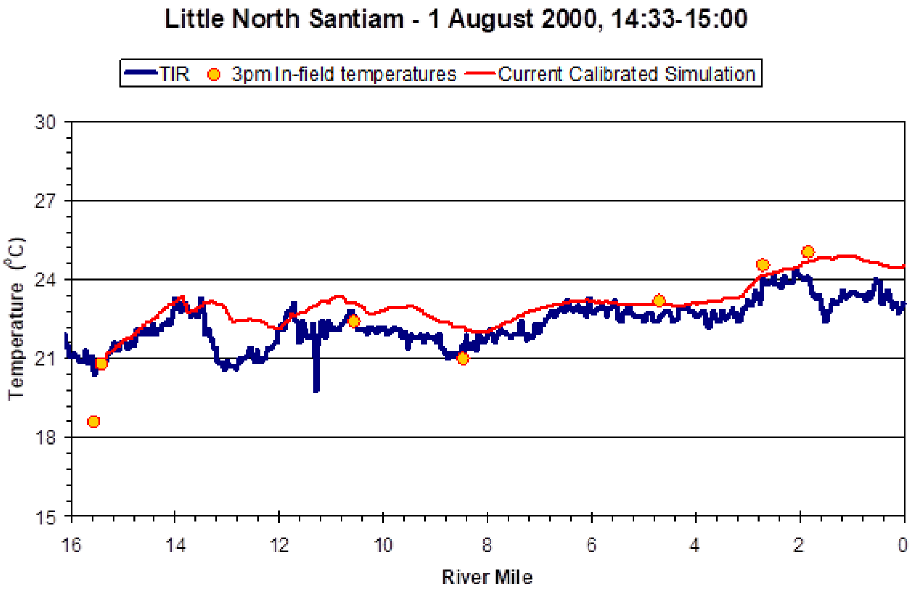


Figure 3.115 TIR and simulated current stream temperatures, Little North Santiam R., North Santiam Subbasin

Table 3.31. Stream temperature goodness of fit statistics comparing field observed and model predicted temperatures.

Monitoring Location	ME	MAE	RMSE	R2	N
Little N. Santiam @ RM 15.4	0.01	0.02	0.02	1.00	24
Little N. Santiam @ Elk Horn Park	-0.24	0.38	0.46	0.98	24
Little N. Santiam @ RM 8.5	-0.28	0.81	0.93	0.76	24
Little N. Santiam @ RM 4.7	-0.99	1.02	1.16	0.96	24
Little N. Santiam @ North Fork County Park	-0.83	0.85	0.98	0.94	24
Little N. Santiam @ USGS site 14182500	-0.78	0.78	0.87	0.95	24
Little North Santiam River TIR	0.71	0.73	0.90	0.60	815

3.5 Thomas Creek

The Thomas Creek model is a temperature model developed using Heat Source 6.5.1. The model was developed by DEQ.

3.5.1 Model extent

The extent of the model domain is Thomas Creek from the mouth to river mile 32 (Figure 3.116).

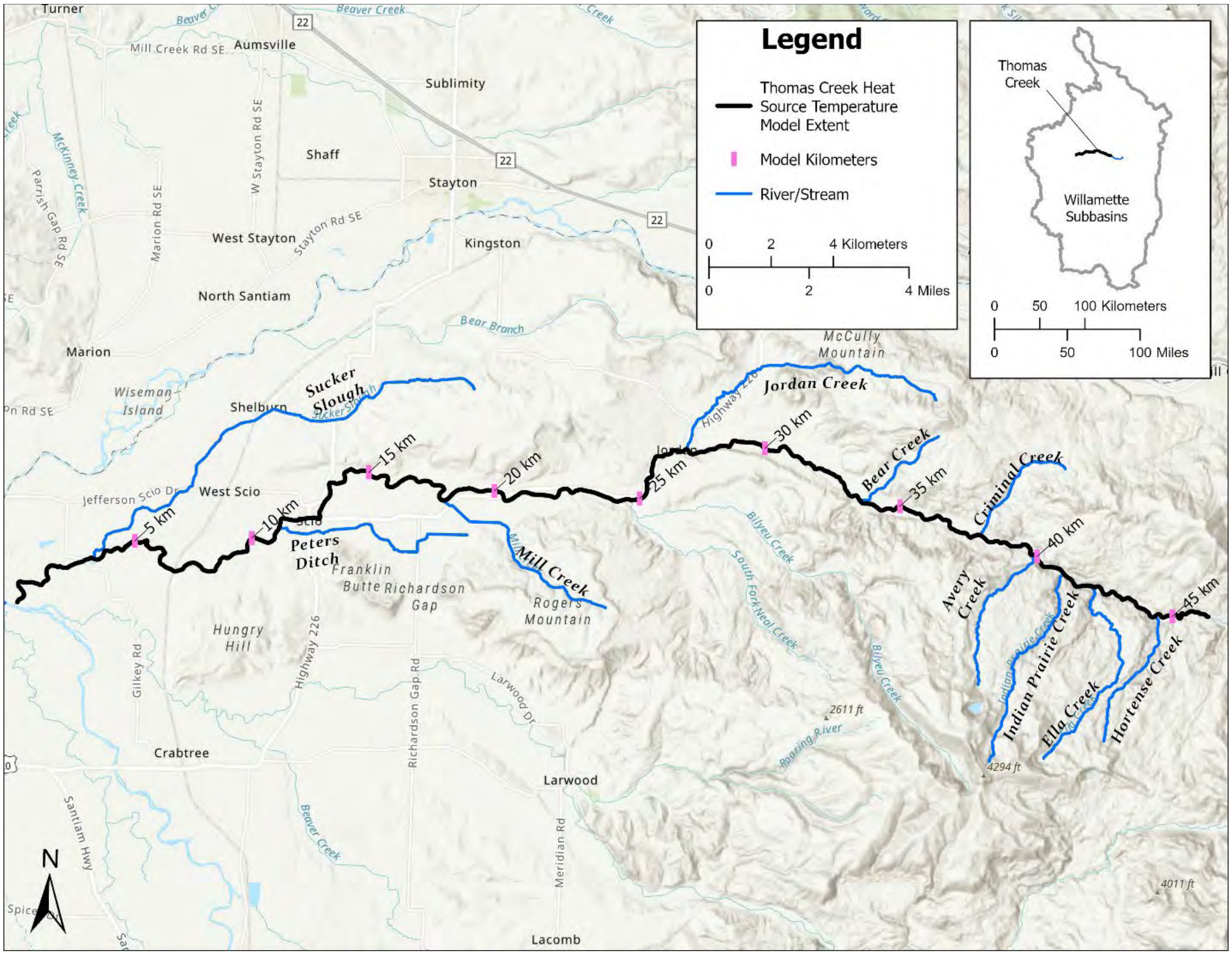


Figure 3.116. Thomas Creek model extent.

3.5.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.5.3 Time frame of simulation

The model period is for a single day: August 03, 2000.

3.5.4 Meteorological inputs

Figure 3.117. Model setup cloudiness.

The model was set up using hourly air temperature, relative humidity, and wind speed measurements from the Corvallis AgriMet site (crvo). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using a wind-sheltering coefficient to represent difference in wind speed between the measurement location and above the stream within the riparian area.

Figure 3.118. Model setup air temperatures.

FIGURE

Figure 3.119. Model setup relative humidity

FIGURE

Figure 3.120. Model setup solar radiation.

3.5.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.32). Figure 3.121 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

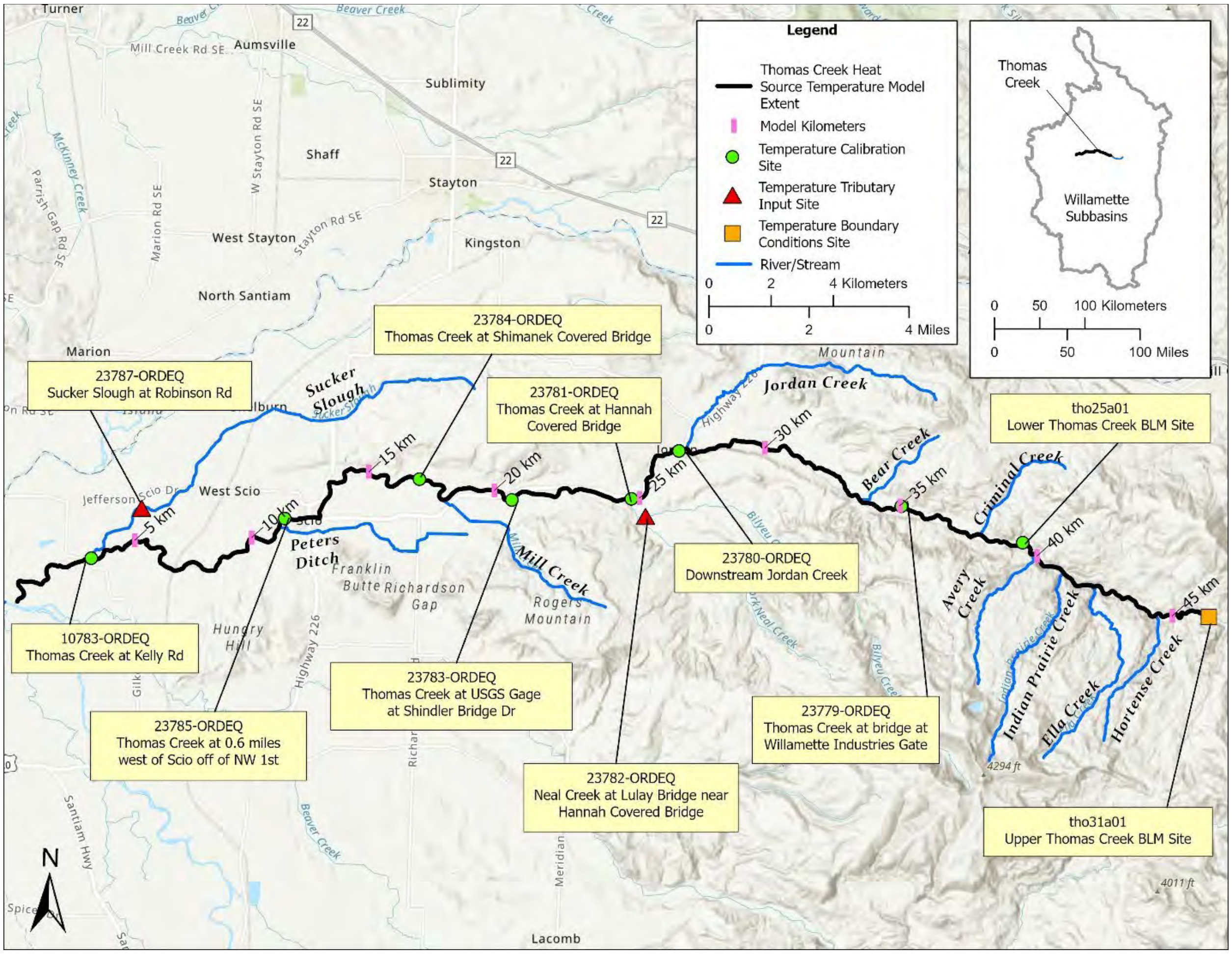


Figure 3.121. Location of temperature monitoring sites used for setup and calibration of the Thomas Creek model.

Table 3.32. Thomas Creek tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Upper Thomas Creek BLM Site	0	Boundary Condition	BLM (tho31a01)
Sucker Slough at Robinson Road	46817.28	Tributary	23787-ORDEQ
Small Trib	39288.72	Tributary	Derived from TIR. Watershed Sciences (2001)
Peters Ditch	38374.32	Tributary	Derived from TIR. Watershed Sciences (2001)
Mill Creek	30297.12	Tributary	Derived from TIR. Watershed Sciences (2001)
Small Trib	29992.32	Tributary	Derived from TIR. Watershed Sciences (2001)
Neal Creek at Lulay Bridge near Hannah Covered Bridge	23652.48	Tributary	23782-ORDEQ
Jordon Creek	20543.52	Tributary	Derived from TIR. Watershed Sciences (2001)

Model Location Name	Model Location (meters)	Input Type	Data Source
Spring Brook	20330.16	Tributary	Derived from TIR.* Watershed Sciences (2001)
Bear Creek	13776.96	Tributary	Derived from TIR. Watershed Sciences (2001)
Criminal Creek	9174.48	Tributary	Derived from TIR. Watershed Sciences (2001)
Avery Creek	7040.88	Tributary	Derived from TIR. Watershed Sciences (2001)
Indian Prairie / Devils Den	5760.72	Tributary	Derived from TIR. Watershed Sciences (2001)
Ella Creek	4815.84	Tributary	Derived from TIR. Watershed Sciences (2001)
Hortense Creek	1920.24	Tributary	Derived from TIR. Watershed Sciences (2001)

* Constant temperature of 18.8 deg-C.

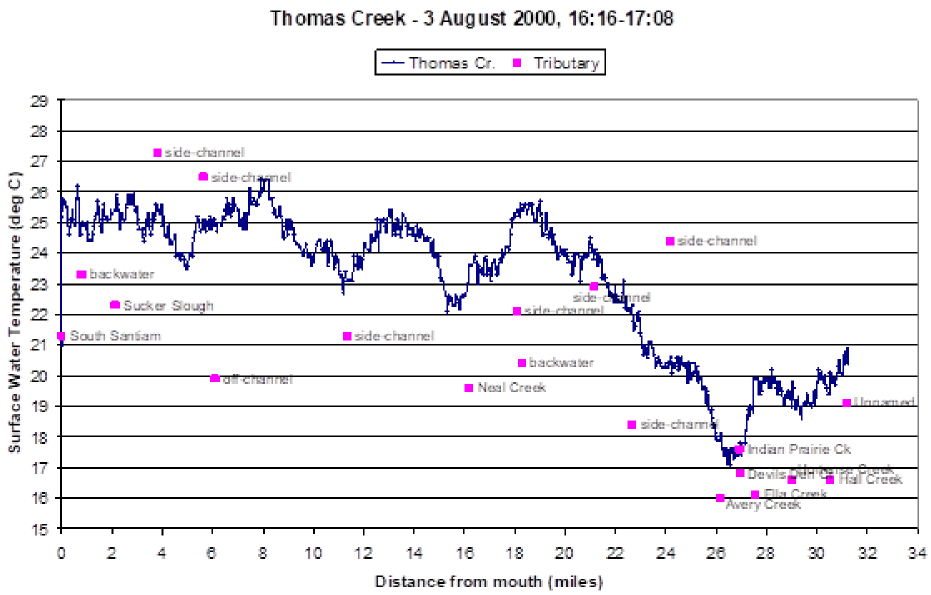


Figure x. TIR Temperatures on Thomas Creek, South Santiam Subbasin

Figure 3.122. Model setup tributary and boundary condition temperatures.

FIGURE

3.5.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (Table 3.33). Figure 3.123 **Error! Reference source not found.**shows the locations of the various stream flow monitoring locations that were used for model setup or calibration.

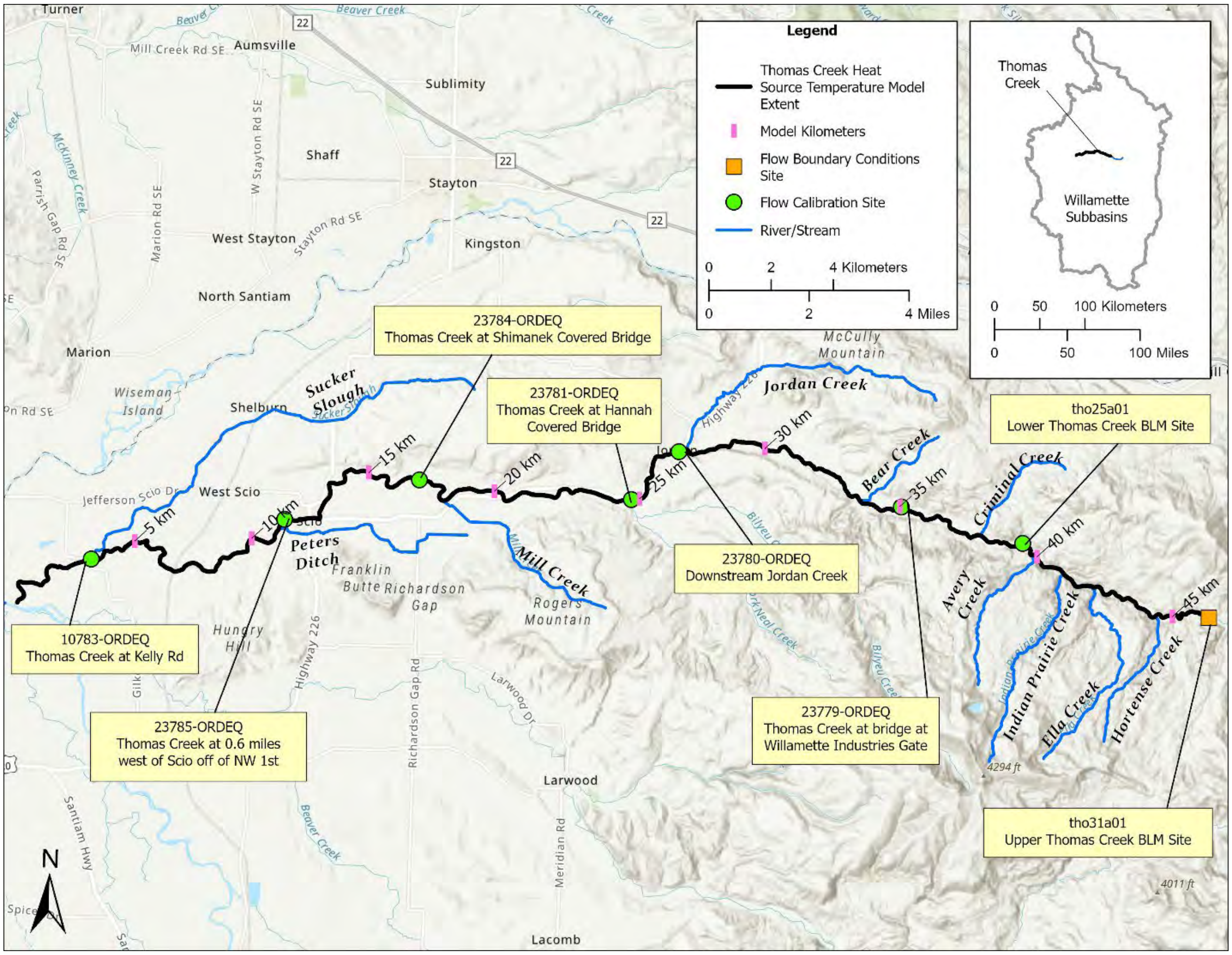


Figure 3.123. Location of flow monitoring sites used for setup and calibration of the Thomas Creek model.

Table 3.33. Thomas Creek tributary and boundary condition flow model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Upper Thomas Creek BLM Site	0	Boundary Condition	BLM (tho31a01)
Sucker Slough at Robinson Road	46817.28	Tributary	Derived using flow mass balance
Small Trib	39288.72	Tributary	Derived using flow mass balance
Peters Ditch	38374.32	Tributary	Derived using flow mass balance
Mill Creek	30297.12	Tributary	Derived using flow mass balance
Small Trib	29992.32	Tributary	Derived using flow mass balance

Model Location Name	Model Location (meters)	Input Type	Data Source
Neal Creek at Lulay Bridge near Hannah Covered Bridge	23652.48	Tributary	DEQ File
Jordon Creek	20543.52	Tributary	Derived using flow mass balance
Spring Brook	20330.16	Tributary	Derived using flow mass balance
Bear Creek	13776.96	Tributary	Derived using flow mass balance
Criminal Creek	9174.48	Tributary	BLM
Avery Creek	7040.88	Tributary	Derived using flow mass balance
Indian Prairie / Devils Den	5760.72	Tributary	Derived using flow mass balance
Ella Creek	4815.84	Tributary	Derived using flow mass balance
Hortense Creek	1920.24	Tributary	Derived using flow mass balance

FIGURE

Figure 3.124. Model setup tributary and boundary condition flow rates.

FIGURE

Figure 3.125. Model setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.126. Model setup for withdrawal flow rates.

3.5.7 Point source inputs

There is one permitted individual NPDES point source along the model extent. Detail about the point source is summarized in Table 3.34.

Table 3.34. NPDES point source located along the Thomas Creek model extent.

Facility Name (Facility Number)	Latitude/Longitude	Permit Type and Description	Stream/River Mile
Scio STP (79633)	44.7001/-122.862	NPDES-DOM-Db: Sewage - less than 1 MGD with discharging lagoons	Thomas Creek RM 7.2

Figure 3.127. Model setup up point source effluent temperatures.

FIGURE

Model setup point source effluent flow rates.

FIGURE

3.5.8 Landcover and topographic shade inputs

Figure 3.128. Model setup landcover height (m).

FIGURE

Figure 3.129. Model setup topographic shade angles.

FIGURE

3.5.9 Channel setup

Channel widths on Thomas Creek, South Santiam Subbasin

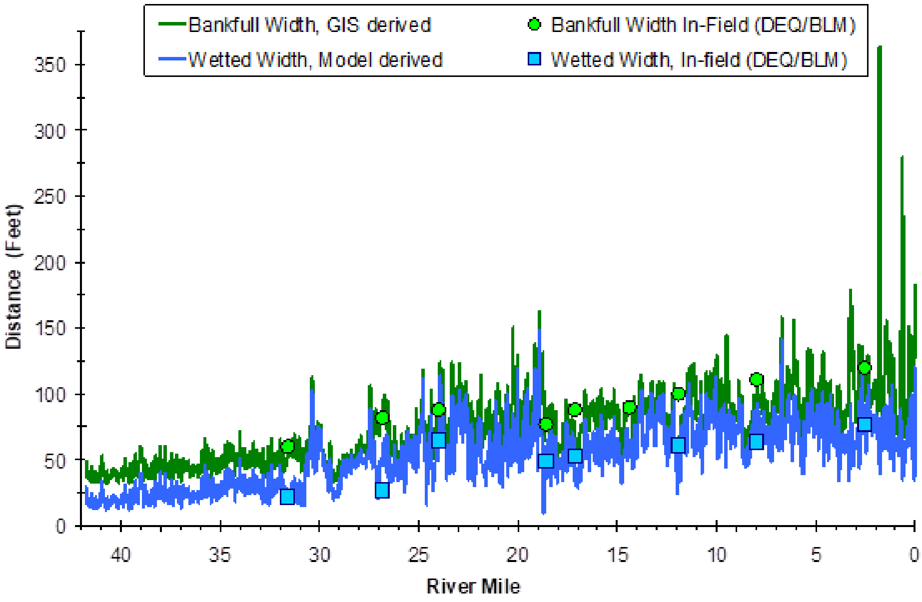


Figure 3.130. Model setup stream channel elevation (m) and gradient.

FIGURE

Figure 3.131. setup channel angle z.

FIGURE

Figure 3.132. Model setup bottom width (m).

FIGURE

Figure 3.133. Model setup for manning roughness coefficient.

FIGURE

3.5.10 Other model parameters

3.5.11 Calibration results

Table 3.35. Monitoring locations used as calibration sites in the Thomas Creek model.

Model Location Name	Model Location (meters)	Calibration Parameter	Data Source
Thomas Creek at Kelly Road	46787	Water Temperature, Flow, Effective Shade	10783-ORDEQ
Thomas Creek at 0.6 miles west of Scio off of NW 1st	38039	Water Temperature, Flow, Effective Shade	23785-ORDEQ
Thomas Creek at Shimanek Covered Bridge	31699	Water Temperature, Flow, Effective Shade	23784-ORDEQ
Thomas Creek at old USGS Gage at Shindler Bridge Drive	27706	Water Temperature, Effective Shade	23783-ORDEQ
Thomas Creek at Hannah Covered Bridge	23987	Water Temperature, Flow, Effective Shade	23781-ORDEQ
Downstream Jordon Creek	20940	Flow	23780-ORDEQ
Thomas Creek downstream Jordon Creek	20940	Water Temperature, Effective Shade	23780-ORDEQ
Thomas Creek at bridge at Willamette Industries Gate	12223	Water Temperature, Flow, Effective Shade	23779-ORDEQ
Lower Thomas Creek BLM Site	7681	Water Temperature, Flow, Effective Shade	BLM (tho25a01)
Upper Thomas Creek BLM Site	0	Effective Shade	BLM (tho31a01)

3.5.11.1 Flow

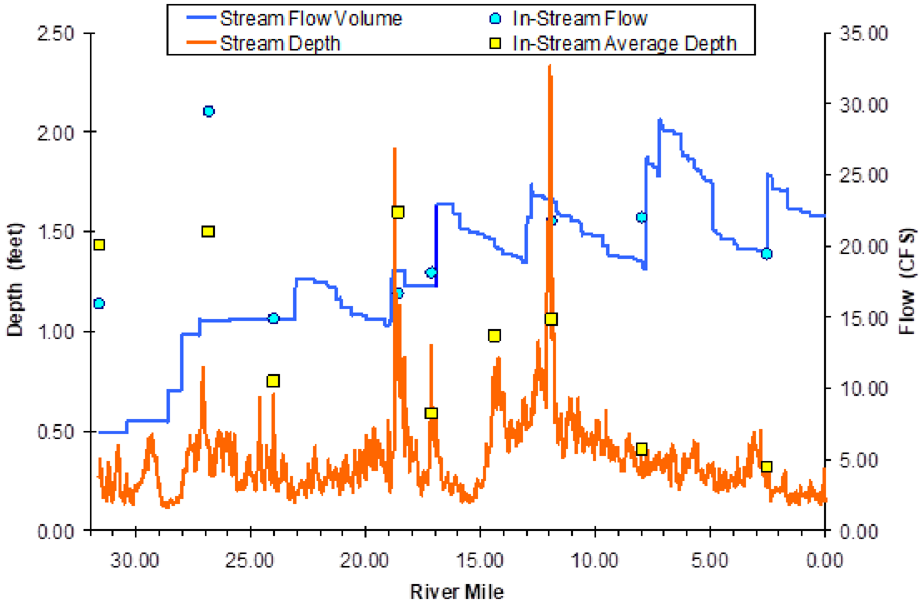


Figure x. Longitudinal flow mass balance for the Thomas Creek, South Santiam Subbasin

Figure 3.134. Field observed and model predicted mean daily flow rates.

FIGURE

Table 3.36. Flow rate goodness of fit statistics comparing field observed and model flow rates

TABLE

3.5.11.2 Effective Shade

Figure 3.135. Field observed and model predicted effective shade.

FIGURE

Table 3.37. Effective shade goodness of fit statistics comparing field observed and model values.

TABLE

3.5.11.3 Temperature

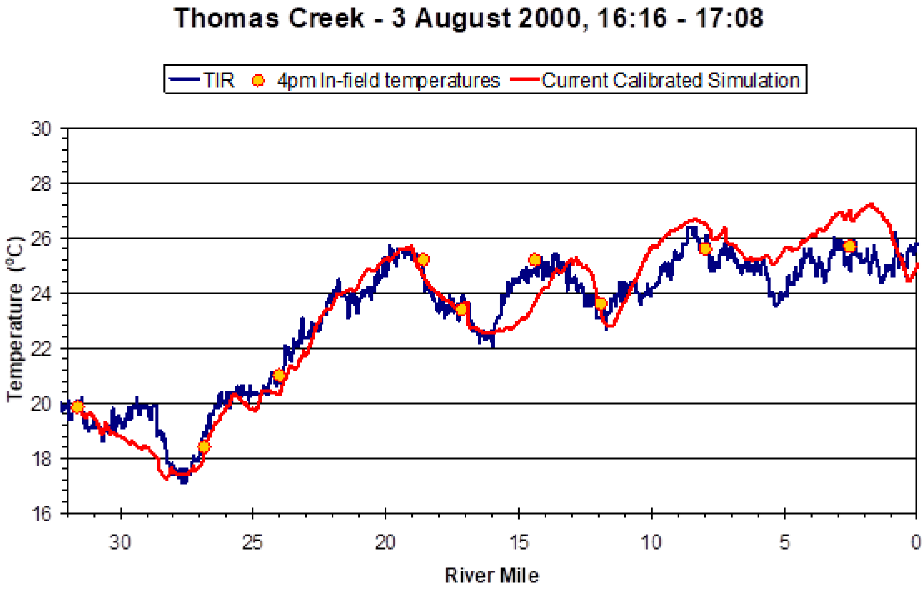


Figure 3.136 TIR and simulated current stream temperatures, Thomas Creek, South Santiam Subbasin.

FIGURE

Figure 3.137. Field observed and model predicted [hourly/daily maximum] temperatures.

Table 3.38. Stream temperature goodness of fit statistics comparing field observed and model predicted temperatures.

Monitoring Location	ME	MAE	RMSE	R2	N
Thomas Creek @ RM 31.6 BLM Site U/S	0.00	0.01	0.01	1.00	24
Thomas Creek @ RM 26.8 BLM Site D/S	-0.74	0.88	1.02	0.76	24
Thomas Creek @ RM 24.0 Willamette Industries Gate	-1.45	1.45	1.56	0.96	24
Thomas Creek @ RM 18.6 D/S Jordon Creek	-1.04	1.04	1.13	0.97	24
Thomas Creek @ RM 17.1 Hannah Covered Bridge	-0.48	0.85	1.03	0.93	24
Thomas Creek @ RM 14.4 Old USGS Gage	-0.62	0.82	1.17	0.89	24
Thomas Creek @ RM 11.9 Shimanek Bridge	-1.19	1.30	1.49	0.80	24
Thomas Creek @ RM 8.0 West of Scio	-0.15	0.62	0.70	0.90	24
Thomas Creek @ RM 2.5 Kelly Road	-0.22	0.80	0.90	0.91	24
Thomas Creek TIR	-0.21	0.55	0.68	0.92	1670

3.6 Crabtree Creek

The Crabtree Creek model is a temperature model developed using Heat Source 6.5.1. The model was developed by DEQ.

3.6.1 Model extent

The extent of the model domain is Crabtree Creek from the mouth to river mile 35 (Figure 3.138).

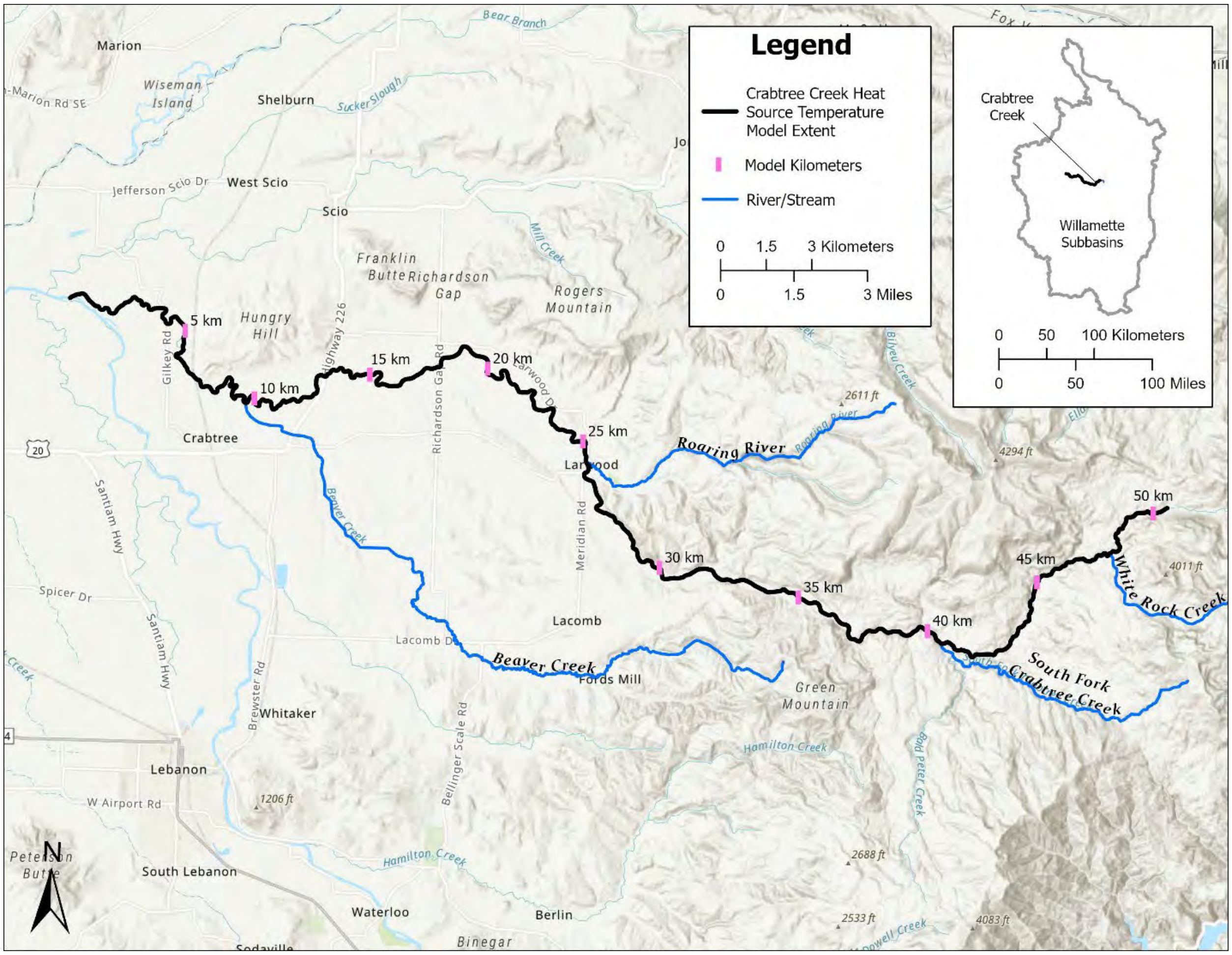


Figure 3.138. Crabtree Creek model extent.

3.6.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.6.3 Time frame of simulation

The model period is for a single day: August 02, 2000.

3.6.4 Meteorological inputs

The model was set up using hourly air temperature, relative humidity, and wind speed measurements from a DEQ site (No Station ID). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using a wind-sheltering coefficient to represent difference in wind speed between the measurement location and above the stream within the riparian area.

FIGURE

Figure 3.139. Model setup cloudiness.

FIGURE

Figure 3.140. Model setup air temperatures.

FIGURE

Figure 3.141. Model setup relative humidity

3.6.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.39). Figure 3.142 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

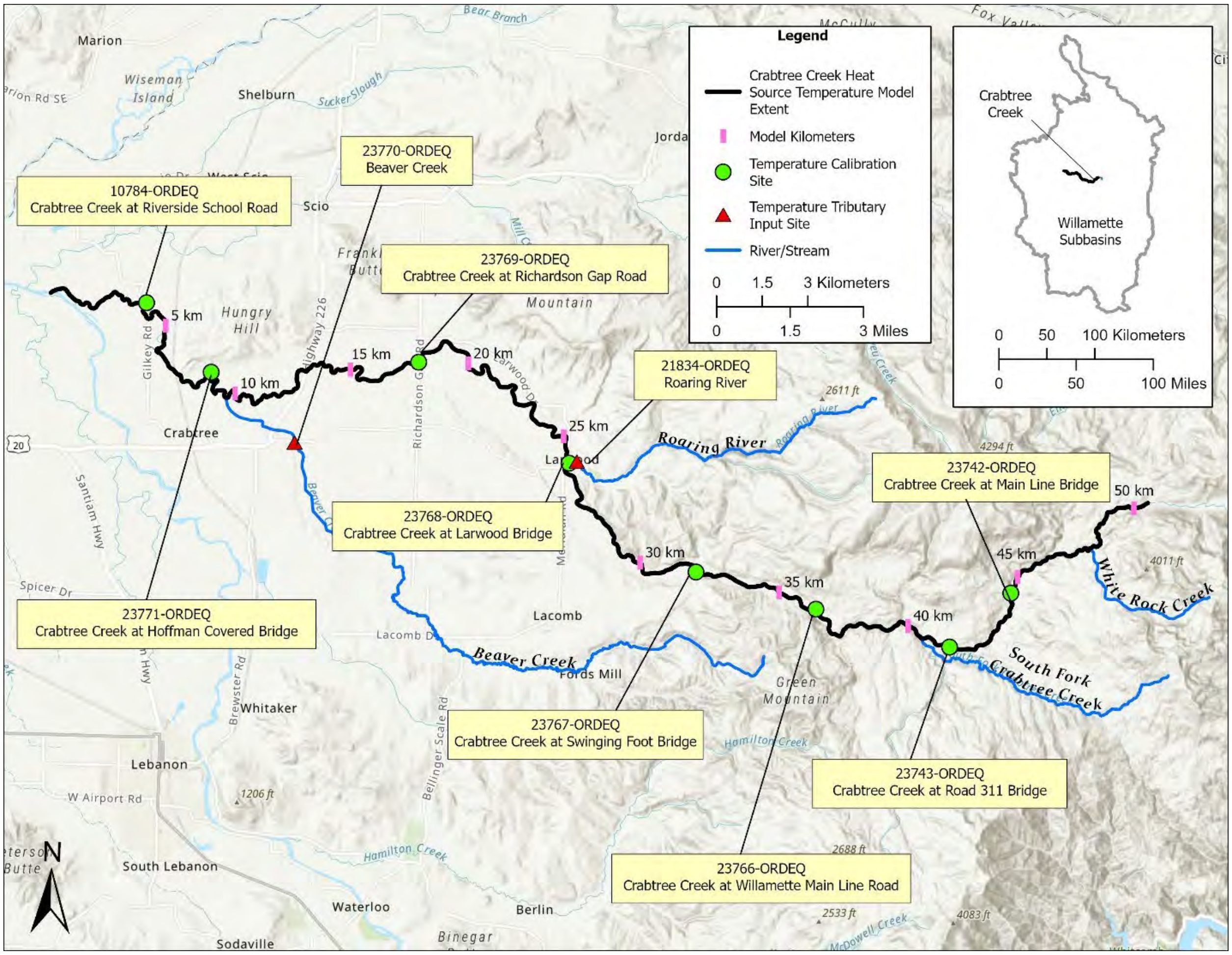


Figure 3.142. Location of temperature monitoring sites used for setup and calibration of the Crabtree Creek model.

Table 3.39. Crabtree Creek tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Crabtree Creek upstream of BLM site	0	Boundary Condition	BLM
Beaver Creek	44318	Tributary	23770-ORDEQ
Roaring River	25817	Tributary	21834-ORDEQ
SF Crabtree Creek	9296	Tributary	DEQ File
White Rock Creek	1036	Tributary	BLM

Figure 3.143. Model setup tributary and boundary condition temperatures.

FIGURE

3.6.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (). Figure 3.144 **Error! Reference source not found.**shows the locations of the various stream flow monitoring locations that were used for model setup or calibration.

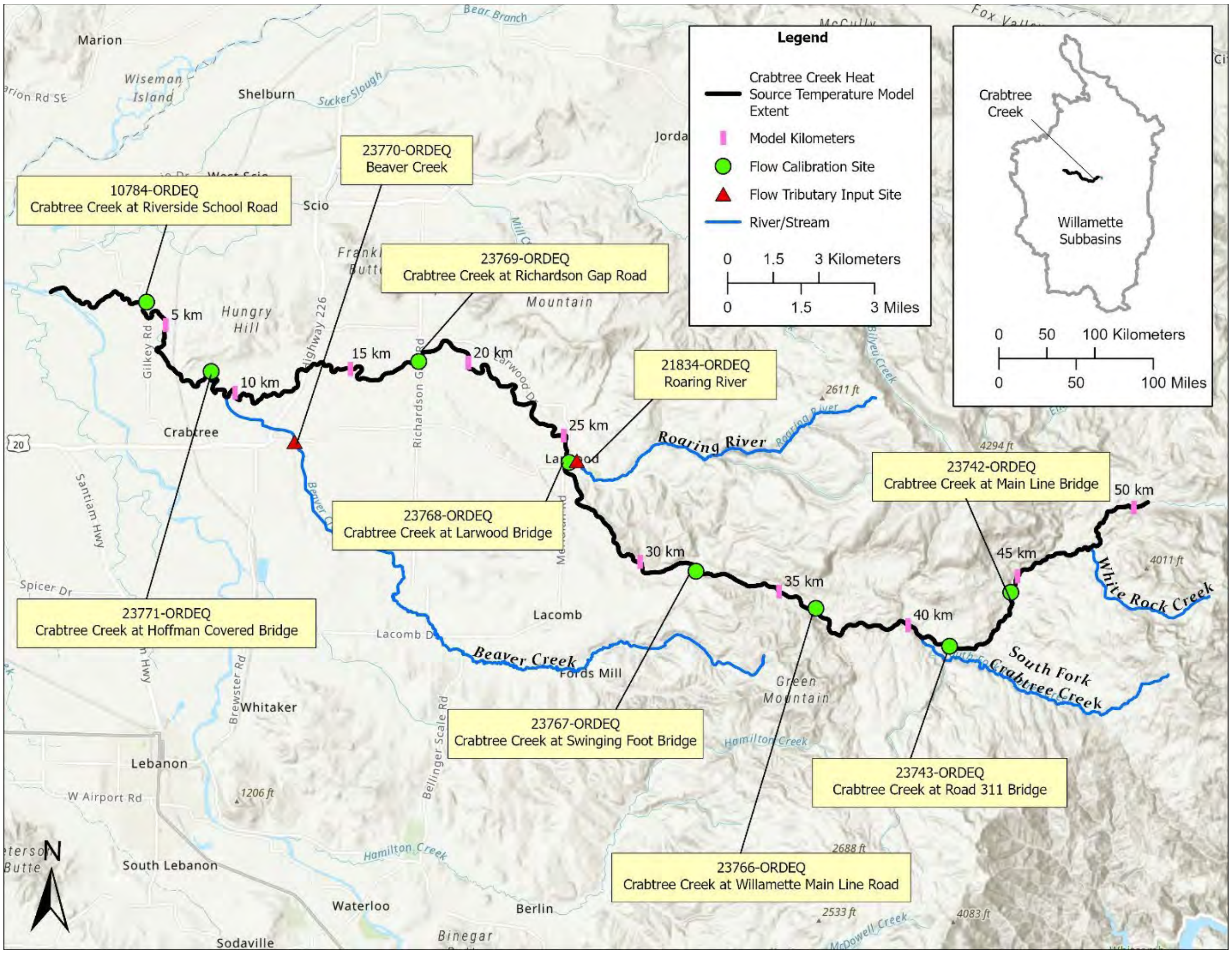


Figure 3.144. Location of flow monitoring sites used for setup and calibration of the Crabtree Creek model.

Table 3.40. Crabtree Creek tributary and boundary condition flow model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Crabtree Creek upstream of BLM site	0	Boundary Condition	BLM
Beaver Creek	44318	Tributary	23770-ORDEQ
Roaring River	25817	Tributary	21834-ORDEQ
SF Crabtree Creek	9296	Tributary	DEQ File
White Rock Creek	1036	Tributary	BLM

Figure 3.145. Model setup tributary and boundary condition flow rates.

FIGURE

Figure 3.146. Model setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.147. Model setup for withdrawal flow rates.

FIGURE

3.6.7 Point source inputs

There are no point sources discharging within the model extent.

Figure 3.148. Model setup up point source effluent temperatures.

FIGURE

Model setup point source effluent flow rates.

FIGURE

3.6.8 Landcover and topographic shade inputs

Figure 3.149. Model setup landcover height (m).

FIGURE

Figure 3.150. Model setup topographic shade angles.

FIGURE

3.6.9 Channel setup

Channel widths on Crabtree Creek, South Santiam Subbasin

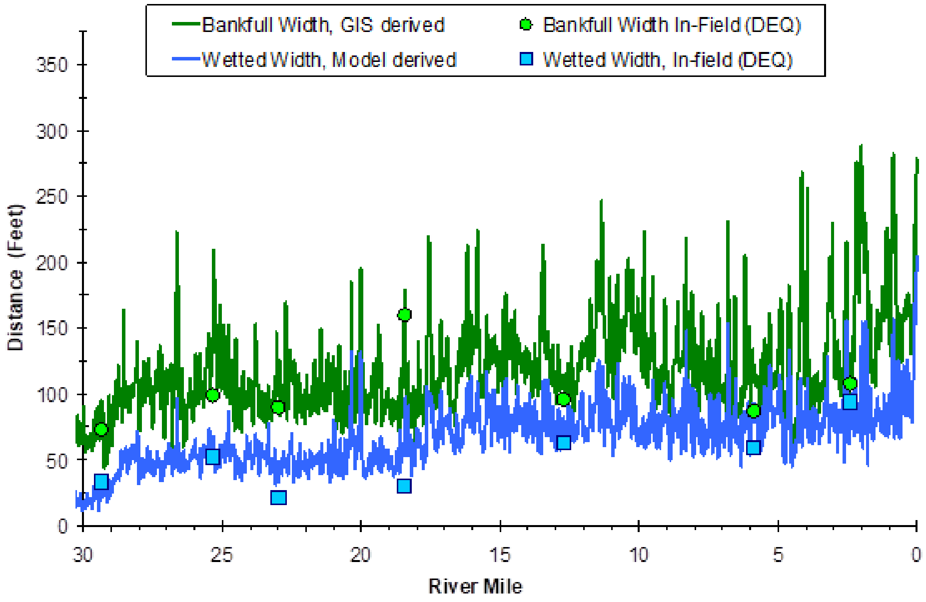


Figure 3.151. Model setup stream channel elevation (m) and gradient.

FIGURE

Figure 3.152. setup channel angle z.

FIGURE

Figure 3.153. Model setup bottom width (m).

FIGURE

Figure 3.154. Model setup for manning roughness coefficient.

FIGURE

3.6.10 Other model parameters

3.6.11 Calibration results

Table 3.41. Monitoring locations used as calibration sites in the Crabtree Creek model.

Model Location Name	Model Location (meters)	Calibration Parameter	Data Source
Crabtree Creek at Riverside School Road	51603	Water Temperature, Flow, Effective Shade	10784-ORDEQ
Crabtree Creek at Hoffman Covered Bridge	46025	Water Temperature, Flow, Effective Shade	23771-ORDEQ
Crabtree Creek at Richardson Gap Road	34991	Water Temperature, Flow, Effective Shade	23769-ORDEQ
Crabtree Creek at Larwood Bridge	25786	Water Temperature, Flow, Effective Shade	23768-ORDEQ
Crabtree Creek at swinging foot bridge	18471	Water Temperature, Flow, Effective Shade	23767-ORDEQ
Crabtree Creek at Willamette Main Line Road	14691	Water Temperature, Flow, Effective Shade	23766-ORDEQ
Crabtree Creek at Road 311 Bridge	8230	Water Temperature, Flow, Effective Shade	23743-ORDEQ
Crabtree Creek at Main Line Bridge	4724	Water Temperature, Flow, Effective Shade	23742-ORDEQ
Crabtree Creek upstream of BLM site	0	Effective Shade	BLM

3.6.11.1 Flow

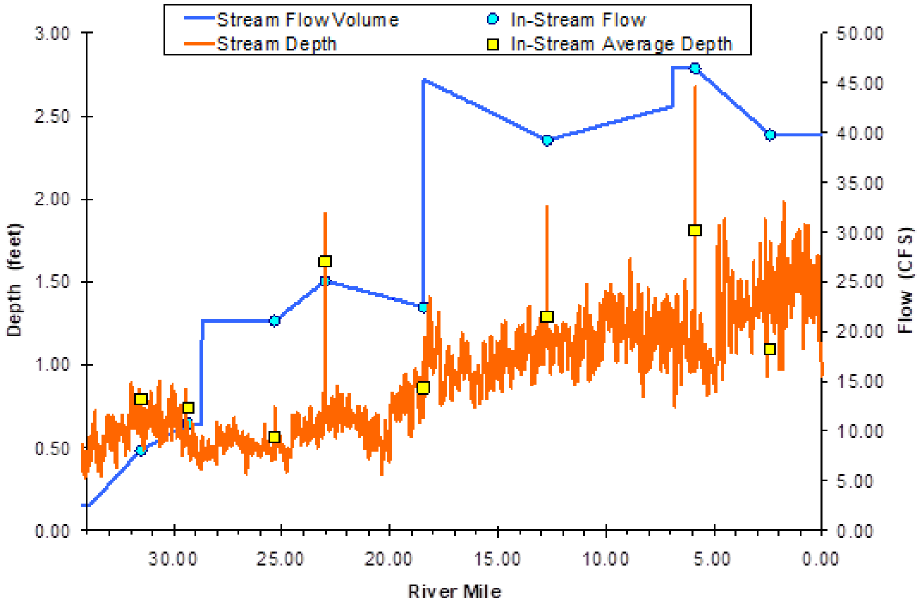


Figure x. Longitudinal flow mass balance for the Crabtree Creek, South Santiam Subbasin

Figure 3.155. Field observed and model predicted mean daily flow rates.

FIGURE

Table 3.42. Flow rate goodness of fit statistics comparing field observed and model flow rates

TABLE

3.6.11.2 Effective Shade

Figure 3.156. Field observed and model predicted effective shade.

FIGURE

Table 3.43. Effective shade goodness of fit statistics comparing field observed and model values.

TABLE

3.6.11.3 Temperature

Figure 3.157. Field observed and model predicted [hourly/daily maximum] temperatures.

FIGURE

Table 3.44. Stream temperature goodness of fit statistics comparing field observed and model predicted temperatures.

Monitoring Location	ME	MAE	RMSE	R2	N
Crabtree Creek @ RM 34.5 25608-ORDEQ	0.01	0.01	0.02	1.00	24
Crabtree Creek @ RM 31.5 25607-ORDEQ	0.36	1.84	2.08	0.68	24
Crabtree Creek @ RM 29.4 22651-ORDEQ	-0.30	1.15	1.41	0.76	24
Crabtree Creek @ RM 25.3 25502-ORDEQ	0.44	0.65	0.74	0.95	24
Crabtree Creek @ RM 23.0 22654-ORDEQ	-0.41	0.80	0.88	0.99	24
Crabtree Creek @ RM 18.4 25498-ORDEQ	-0.92	1.00	1.52	0.83	24
Crabtree Creek @ RM 12.7 25496-ORDEQ	0.07	0.86	1.02	0.76	24
Crabtree Creek @ RM 5.9 L10663-ORDEQ	-0.35	0.47	0.57	0.92	24
Crabtree Creek @ RM 2.4	-0.74	0.91	1.08	0.96	24

3.7 Luckiamute River

The Luckiamute River model is a temperature model developed using Heat Source 6.5.1. The model was developed by DEQ.

3.7.1 Model extent

The extent of the model domain is the Luckiamute River from the mouth upstream to Road 1430 at river mile 57 (Figure 3.158).

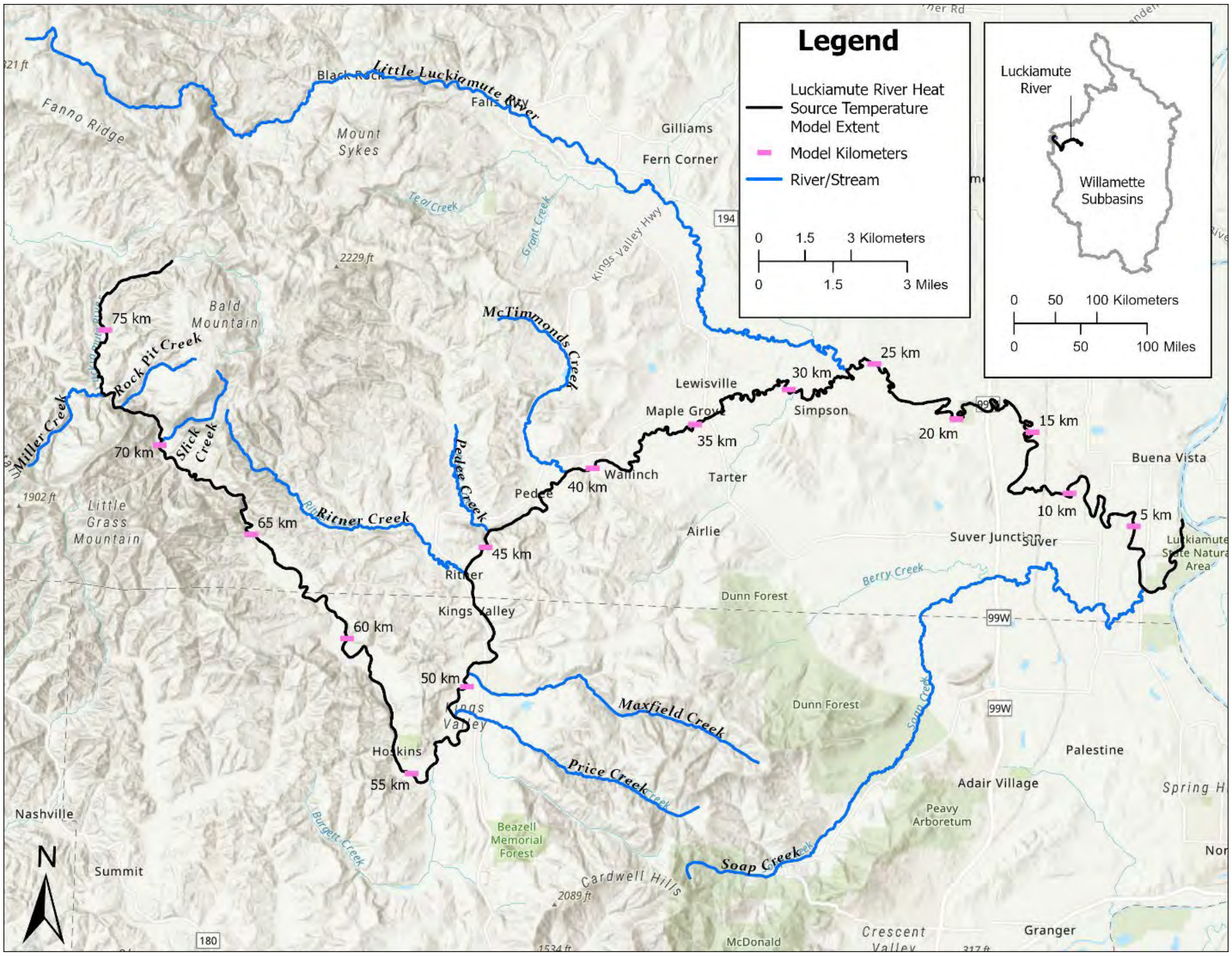


Figure 3.158. Luckiamute River model extent.

3.7.2 Spatial and temporal resolution

The model input spatial resolution (dx) is 30 meters. Outputs are generated every 100 meters. The model time step (dt) is 1 minute and outputs were generated every hour.

3.7.3 Time frame of simulation

The model period is for a single day: August 12, 2001.

3.7.4 Meteorological inputs

The model was set up using hourly air temperature, relative humidity, and wind speed measurements from the Corvallis AgriMet site (crvo). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using a wind-sheltering coefficient of 0.25 to represent differences in wind speed between the measurement location and above the stream within the riparian area.

FIGURE

Figure 3.159. Luckiamute River model setup for cloudiness.

FIGURE

Figure 3.160. Luckiamute River model setup for air temperatures.

FIGURE

Figure 3.161. Luckiamute River model setup for relative humidity.

3.7.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.45). Figure 3.162 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

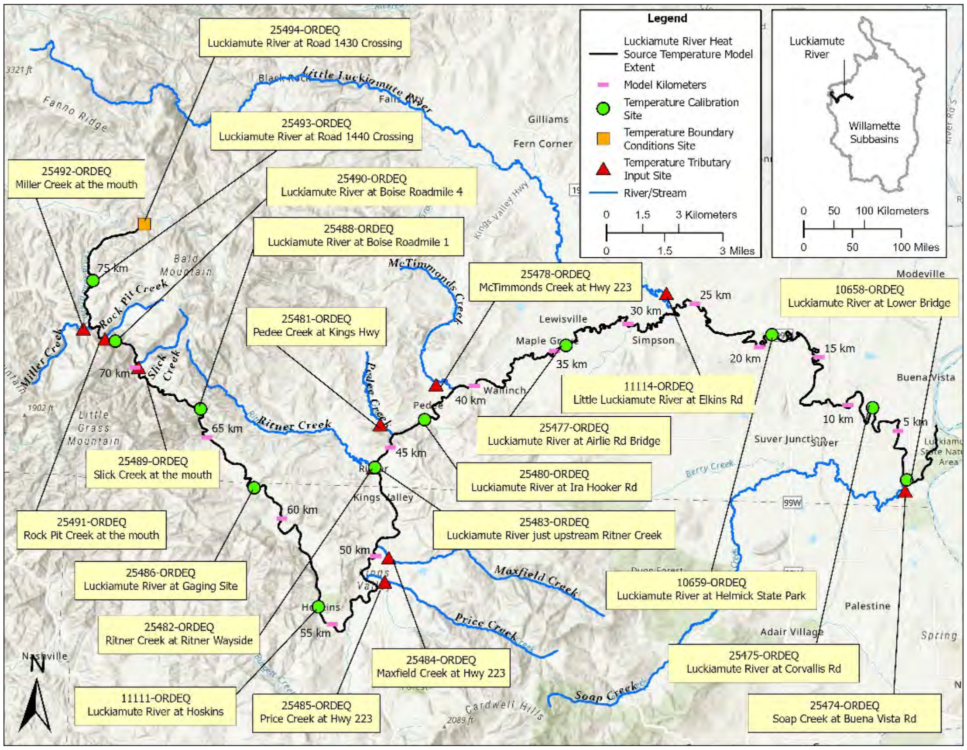


Figure 3.162. Location of temperature monitoring sites used for setup and calibration of the Luckiamute River model.

Table 3.45. Luckiamute River tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Luckiamute River at Road 1430 crossing (Roadmile 3)	0	Boundary Condition	25494-ORDEQ
Miller Creek	6522.72	Tributary	25492-ORDEQ
Rock Pit	7559.04	Tributary	25491-ORDEQ
Slick Creek	9723.12	Tributary	25489-ORDEQ
Price Creek	32034.48	Tributary	25485-ORDEQ
Maxfield Creek	33985.2	Tributary	25484-ORDEQ
Ritner Creek	38496.24	Tributary	25482-ORDEQ
Pedee Creek	40172.64	Tributary	25481-ORDEQ
McTimmonds Creek	44256.96	Tributary	25478-ORDEQ
Little Luckiamute River	60868.56	Tributary	11114-ORDEQ
Soap Creek	87843.36	Tributary	25474-ORDEQ

FIGURE

Figure 3.163. Luckiamute River model setup for tributary and boundary condition temperatures.

3.7.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (Table 3.46). Figure X **Error! Reference source not found.**shows the locations of the various stream flow monitoring locations that were used for model setup or calibration.

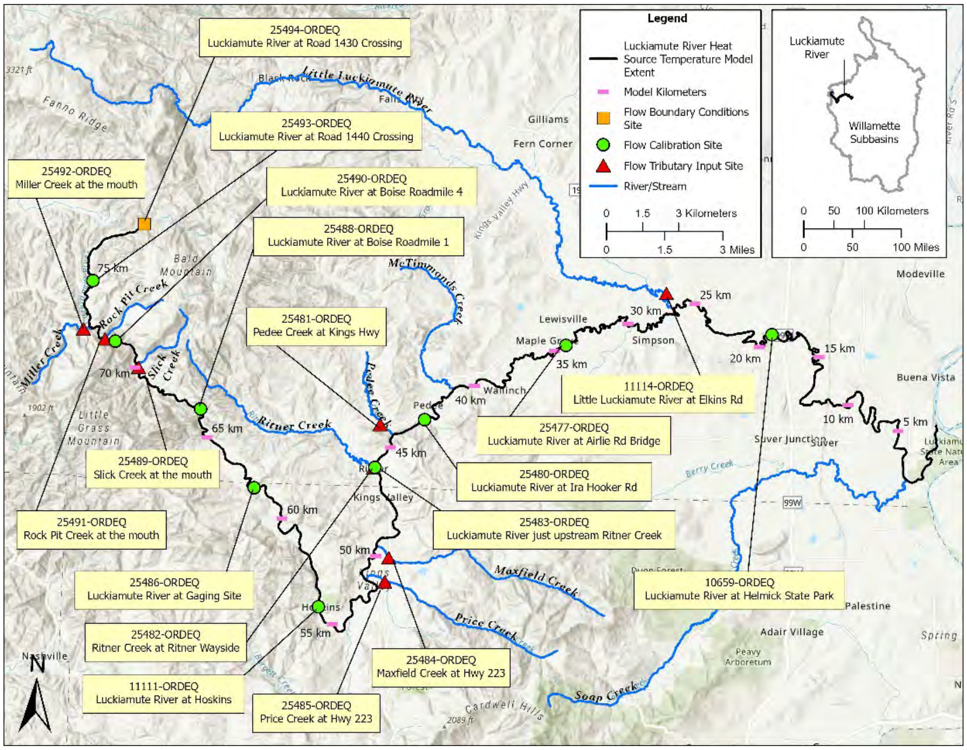


Figure 3.164. Location of flow monitoring sites used for setup and calibration of the Luckiamute River model.

Table 3.46. Luckiamute River tributary and boundary condition flow model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Luckiamute River at Road 1430 crossing (Roadmile 3)	0	Boundary Condition	25494-ORDEQ
Miller Creek	6522.72	Tributary	25492-ORDEQ
Rock Pit	7559.04	Tributary	25491-ORDEQ
Slick Creek	9723.12	Tributary	25489-ORDEQ
Price Creek	32034.48	Tributary	25485-ORDEQ
Maxfield Creek	33985.2	Tributary	25484-ORDEQ
Ritner Creek	38496.24	Tributary	25482-ORDEQ
Pedee Creek	40172.64	Tributary	25481-ORDEQ
McTimmonds Creek	44256.96	Tributary	Mass balance estimated
Little Luckiamute River	60868.56	Tributary	11114-ORDEQ
Soap Creek	87843.36	Tributary	Mass balance estimated

Figure 3.165. Luckiamute River model setup for tributary and boundary condition flow rates.

FIGURE

Figure 3.166. Luckiamute River model setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.167. Luckiamute River model setup for withdrawal flow rates.

FIGURE

3.7.7 Point source inputs

There are no point sources discharging within the model extent.

3.7.8 Landcover and topographic shade inputs

FIGURE

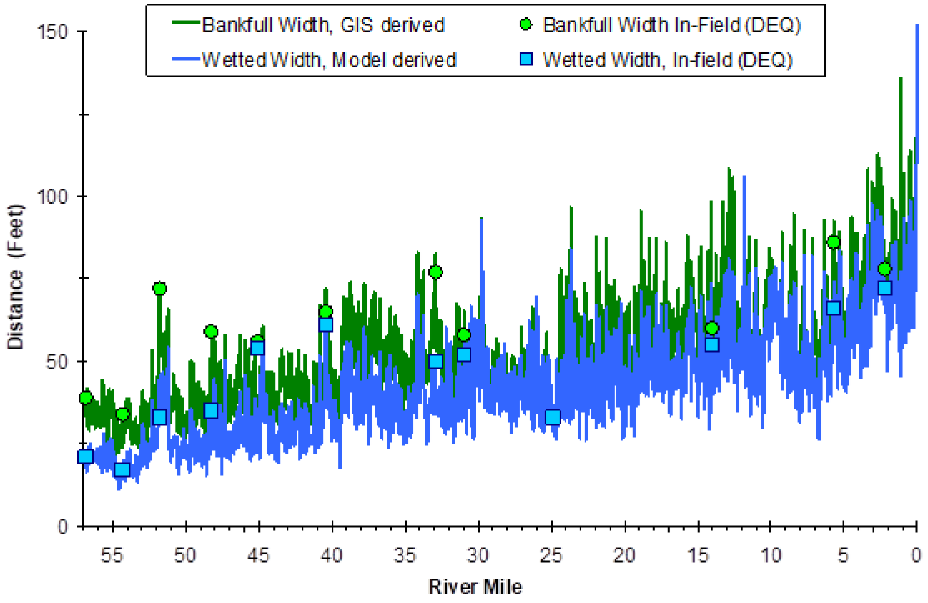
Figure 3.168. Luckiamute River model setup for landcover height (m).

FIGURE

Figure 3.169. Luckiamute River model setup for topographic shade angles.

3.7.9 Channel setup

Channel widths on Luckiamute River, Upper Willamette Subbasin



FIGURE

Figure 3.170. Model setup stream channel elevation (m) and gradient.

FIGURE

Figure 3.171. setup channel angle z.

FIGURE

Figure 3.172. Model setup bottom width (m).

FIGURE

Figure 3.173. Model setup for manning roughness coefficient.

3.7.10 Other model parameters

3.7.11 Calibration results

Table 3.47. Monitoring locations used as calibration sites in the Luckiamute River model.

Monitoring Location	Model Location (meters)	Calibration Parameter	Data Source
Luckiamute River at Lower Bridge (Buena Vista Rd.)	87904.32	Water Temperature	10658-ORDEQ
Luckiamute River at Corvallis Rd.	82296.00	Water Temperature	25475-ORDEQ
Luckiamute River at Helmick State Park	68884.80	Water Temperature, Flow, Effective Shade	10659-ORDEQ
Luckiamute River at Airlie Rd. Bridge	51389.28	Water Temperature, Flow, Effective Shade	25477-ORDEQ
Luckiamute River at Ira Hooker Rd.	41635.68	Water Temperature, Flow, Effective Shade	25480-ORDEQ
Luckiamute River just upstream Ritner Creek	38465.76	Water Temperature, Flow, Effective Shade	25483-ORDEQ
Luckiamute River at Hoskins	26395.68	Water Temperature, Flow, Effective Shade	11111-ORDEQ
Luckiamute River at Gaging Site	18867.12	Water Temperature, Flow, Effective Shade	25486-ORDEQ
Luckiamute River at Boise Roadmile 1	13807.44	Water Temperature, Flow, Effective Shade	25488-ORDEQ
Luckiamute River at Boise Roadmile 4	8107.68	Water Temperature, Flow, Effective Shade	25490-ORDEQ

Monitoring Location	Model Location (meters)	Calibration Parameter	Data Source
Luckiamute River at Road 1440 crossing	4023.36	Water Temperature, Flow, Effective Shade	25493-ORDEQ
Luckiamute River at Road 1430 crossing (Roadmile 3)	0.00	Effective Shade	25494-ORDEQ

3.7.11.1 Flow

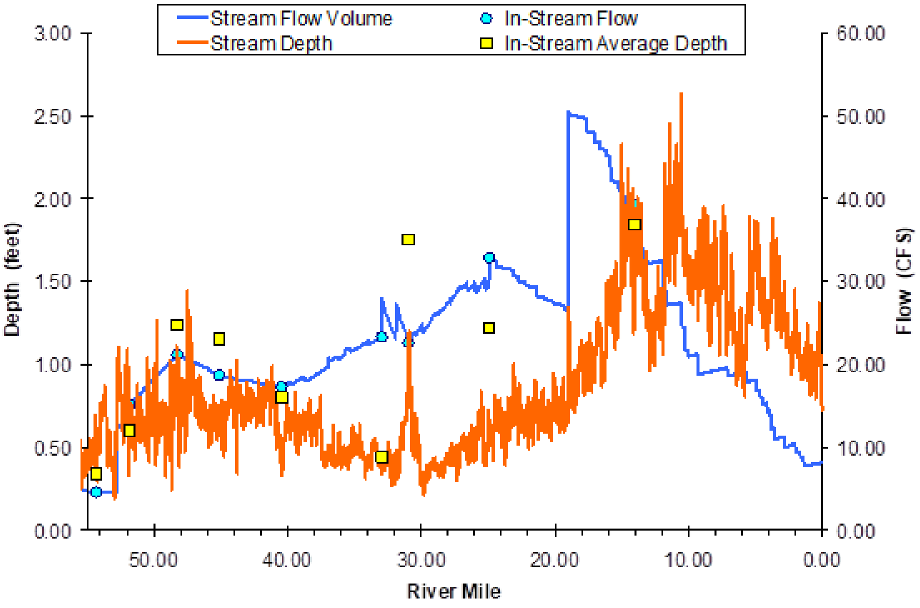


Figure 3.174. Longitudinal flow mass balance for the Luckiamute River, Upper Willamette Subbasin

Table 3.48. Flow rate goodness of fit statistics comparing field observed and model flow rates

TABLE

3.7.11.2 Effective Shade

FIGURE

Figure 3.175. Field observed and model predicted effective shade.

Table 3.49. Effective shade goodness of fit statistics comparing field observed and model values.

TABLE

3.7.11.3 Temperature

FIGURE

Figure 3.176. Field observed and model predicted [hourly/daily maximum] temperatures.

Table 3.50. Stream temperature goodness of fit statistics comparing field observed and model predicted temperatures.

Monitoring Location	ME	MAE	RMSE	R2	N
Lukiamute @ RM 56.8 25494-ORDEQ	0.01	0.01	0.02	1.00	24
Lukiamute @ RM 54.3 25493-ORDEQ	-1.99	2.24	2.46	0.88	24
Lukiamute @ RM 51.8 25490-ORDEQ	-0.77	0.92	1.21	0.95	24
Lukiamute @ RM 48.3 25488-ORDEQ	-0.30	0.50	0.72	0.94	24
Lukiamute @ RM 45.1 25486-ORDEQ	-0.54	0.54	0.73	0.95	24
Lukiamute @ RM 40.1 11111-ORDEQ	-1.01	1.01	1.17	0.97	24
Lukiamute @ RM 32.9 25483-ORDEQ	-0.95	1.43	1.65	0.96	24
Lukiamute @ RM 31.0 25480-ORDEQ	-0.58	1.05	1.20	1.00	24
Lukiamute @ RM 24.9 25477-ORDEQ	-2.25	2.52	2.96	0.93	24
Lukiamute @ RM 14.0 10659-ORDEQ	-1.28	1.30	1.66	0.70	24
Lukiamute @ RM 5.7 25475-ORDEQ	-1.15	1.48	1.77	0.92	24
Lukiamute @ RM 2.2 10658-ORDEQ	-0.72	1.21	1.35	0.86	24

3.8 Mohawk River

The Mohawk River model is a temperature model developed using Heat Source 6.5.1. The model was developed by DEQ.

3.8.1 Model extent

The extent of the model domain is the Mohawk River from the mouth to river mile 24.7 (Figure 3.177).

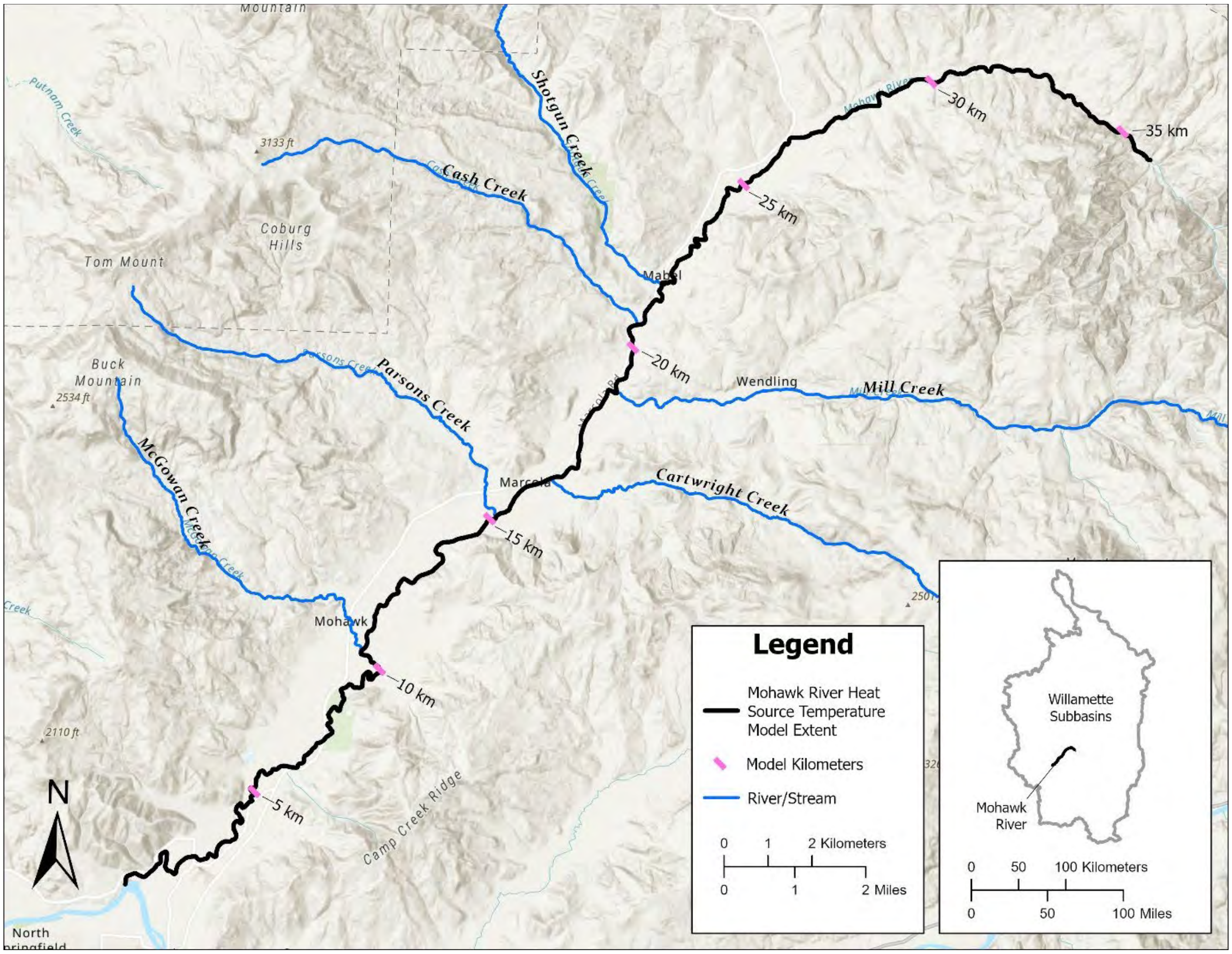


Figure 3.177. Mohawk River model extent.

3.8.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.8.3 Time frame of simulation

The model period is for a single day: August 09, 2001.

3.8.4 Meteorological inputs

The model was set up using hourly air temperature, relative humidity, and wind speed measurements from the NCDC site at the Eugene Airport (KEUG). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using a wind-sheltering coefficient of 0.25 to represent differences in wind speed between the measurement location and above the stream within the riparian area.

FIGURE

Figure 3.178. Mohawk River model setup for cloudiness.

FIGURE

Figure 3.179. Mohawk River model setup air temperatures.

FIGURE

Figure 3.180. Mohawk River model setup relative humidity.

3.8.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.51). Figure 3.181 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

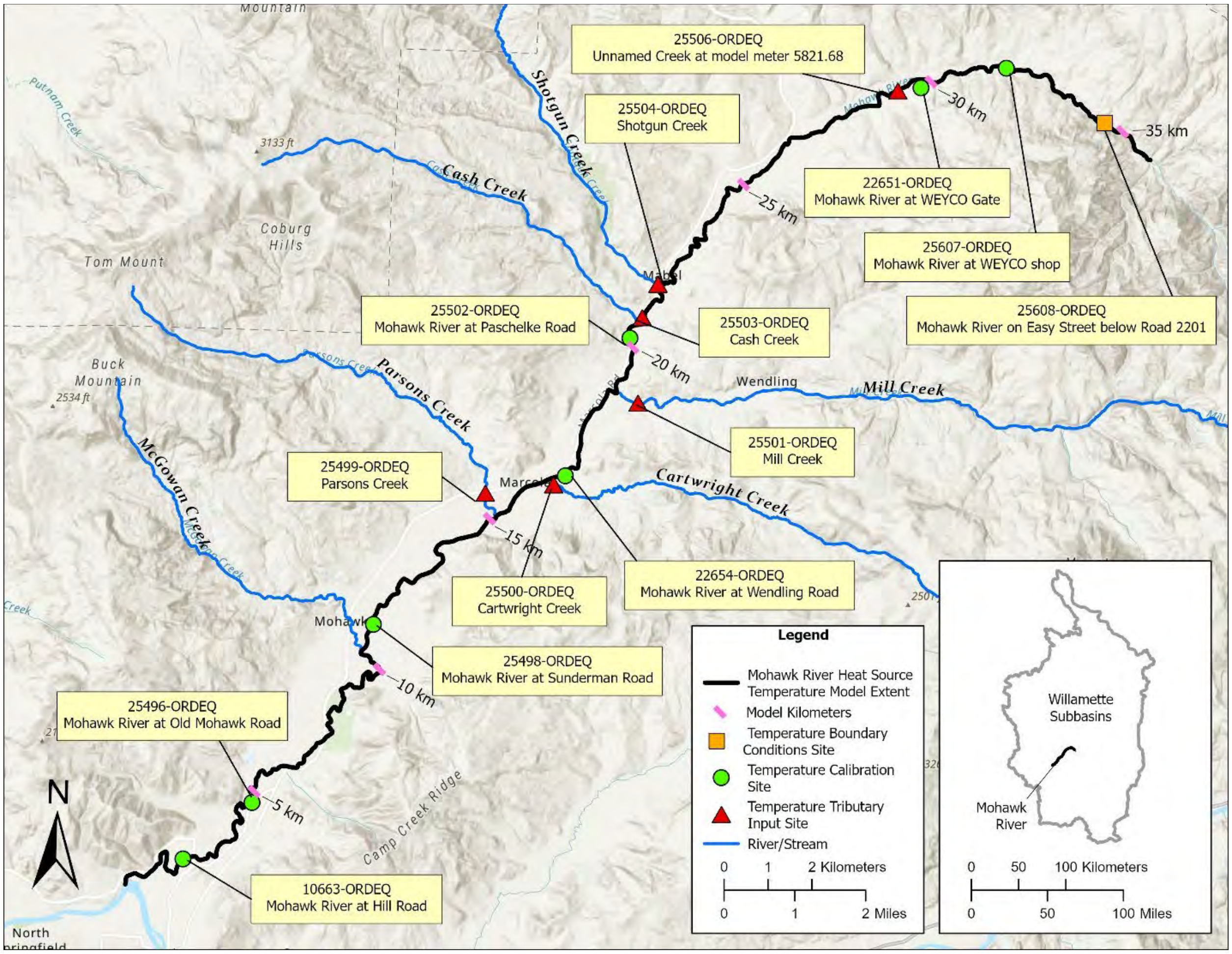


Figure 3.181. Location of temperature monitoring sites used for setup and calibration of the Mohawk River model.

Table 3.51. Mohawk River tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Mohawk River on Easy Street below Road 2201	0	Boundary Condition	25608-ORDEQ
McGowan Creek	27553.92	Tributary	DEQ File
Parsons Creek	22372.32	Tributary	25499-ORDEQ
Cartwright Creek	20604.48	Tributary	25500-ORDEQ
Mill Creek	17647.92	Tributary	25501-ORDEQ
Cash Creek	15453.36	Tributary	25503-ORDEQ
Shotgun Creek	14386.56	Tributary	25504-ORDEQ
Unnamed Creek at model meter 5821.68	5821.68	Tributary	25506-ORDEQ

FIGURE

Figure 3.182. Mohawk River model setup tributary and boundary condition temperatures.

3.8.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (Table 3.52). Figure 3.183 **Error! Reference source not found.**shows the locations of the various stream flow monitoring locations that were used for model setup or calibration.

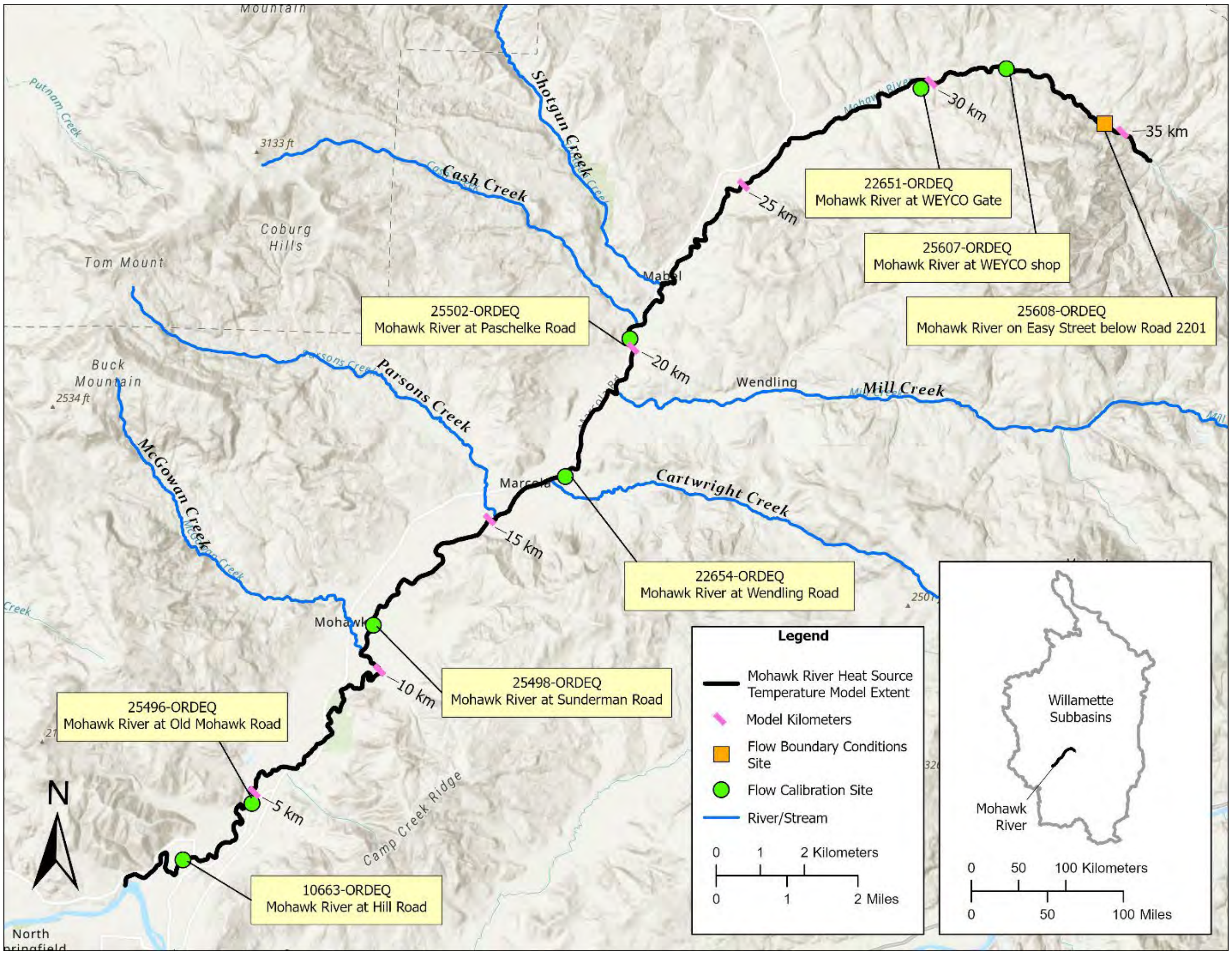


Figure 3.183. Location of flow monitoring sites used for setup and calibration of the Mohawk River model.

Table 3.52. Mohawk River tributary and boundary condition flow model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Mohawk River on Easy Street below Road 2201	0	Boundary Condition	25608-ORDEQ
McGowan Creek	27553.92	Tributary	DEQ File
Parsons Creek	22372.32	Tributary	DEQ File
Cartwright Creek	20604.48	Tributary	DEQ File

Model Location Name	Model Location (meters)	Input Type	Data Source
Mill Creek	17647.92	Tributary	DEQ File
Cash Creek	15453.36	Tributary	DEQ File
Shotgun Creek	14386.56	Tributary	DEQ File
Unnamed Creek at model meter 5821.68	5821.68	Tributary	DEQ File

Figure 3.184. Model setup tributary and boundary condition flow rates.

FIGURE

Figure 3.185. Model setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.186. Model setup for withdrawal flow rates.

3.8.7 Point source inputs

There are no point sources discharging within the model extent.

3.8.8 Landcover and topographic shade inputs

FIGURE

Figure 3.187. Model setup landcover height (m).

FIGURE

Figure 3.188. Model setup topographic shade angles.

3.8.9 Channel setup

Channel widths on Mohawk River, McKenzie Subbasin

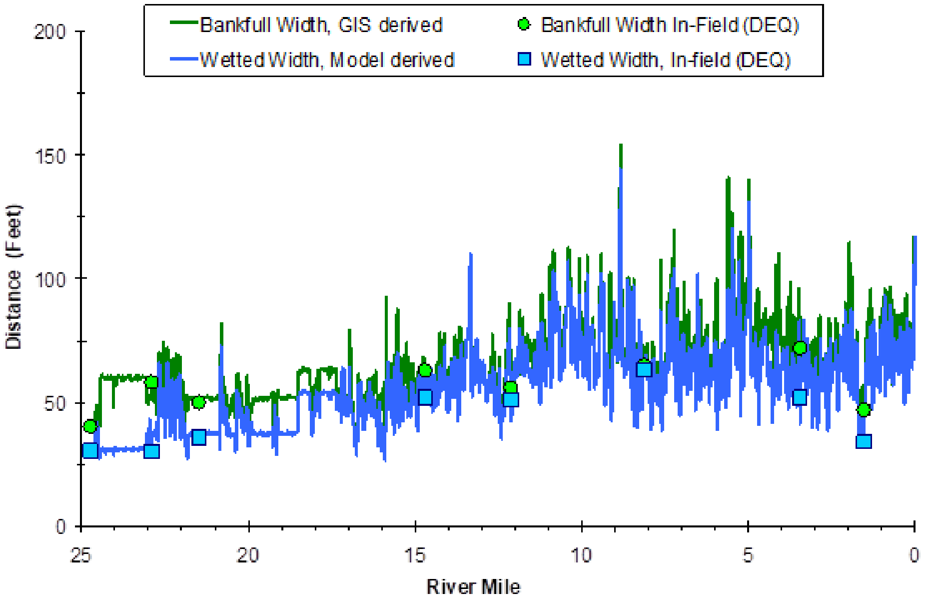


Figure 3.189. Model setup stream channel elevation (m) and gradient.

FIGURE

Figure 3.190. setup channel angle z.

FIGURE

Figure 3.191. Model setup bottom width (m).

FIGURE

Figure 3.192. Model setup for manning roughness coefficient.

FIGURE

3.8.10 Other model parameters

3.8.11 Calibration results

Table 3.53. Monitoring locations used as calibration sites in the Mohawk River model.

Model Location Name (Station ID)	Model Location (meters)	Calibration Parameter	Data Source
Mohawk River at Hill Road	37338.00	Water Temperature, Flow, Effective Shade	10663-ORDEQ
Mohawk River at Old Mohawk Road	34259.52	Water Temperature, Flow, Effective Shade	25496-ORDEQ
Mohawk River at Sunderman Road	26730.96	Water Temperature, Flow, Effective Shade	25498-ORDEQ
Mohawk River at Wendling Road	20299.68	Water Temperature, Flow, Effective Shade	22654-ORDEQ

Model Location Name (Station ID)	Model Location (meters)	Calibration Parameter	Data Source
Mohawk River at Paschelke Road	16154.40	Water Temperature, Flow, Effective Shade	25502-ORDEQ
Mohawk River at WEYCO Gate	5242.56	Water Temperature, Flow, Effective Shade	22651-ORDEQ
Mohawk River at WEYCO shop	2956.56	Water Temperature, Flow, Effective Shade	25607-ORDEQ
Mohawk River on Easy Street below Road 2201	0.00	Effective Shade	25608-ORDEQ

3.8.11.1 Flow

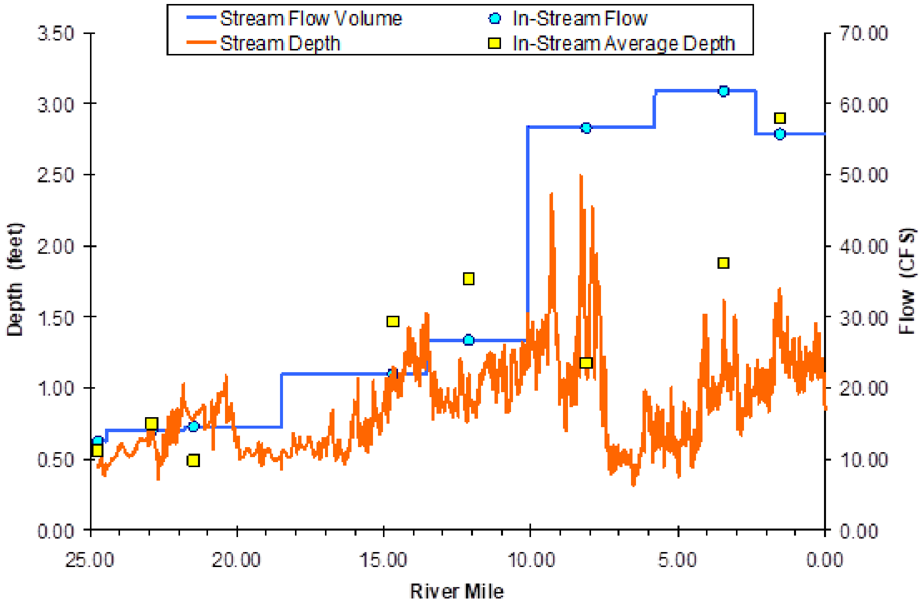


Figure x. Longitudinal flow mass balance for the Mohawk River, McKenzie Subbasin

Figure 3.193. Field observed and model predicted mean daily flow rates.

FIGURE

Table 3.54. Flow rate goodness of fit statistics comparing field observed and model flow rates

TABLE

3.8.11.2 Effective Shade

Figure 3.194. Field observed and model predicted effective shade.

FIGURE

Table 3.55. Effective shade goodness of fit statistics comparing field observed and model values.

TABLE

3.8.11.3 Temperature

Figure 3.195. Field observed and model predicted [hourly/daily maximum] temperatures.

FIGURE

Table 3.56. Stream temperature goodness of fit statistics comparing field observed and model predicted temperatures.

Monitoring Location	ME	MAE	RMSE	R2	N
Mohawk River @ RM 24.7 25608-ORDEQ	0.00	0.01	0.01	1.00	24
Mohawk River @ RM 22.9 25607-ORDEQ	-0.43	0.50	0.64	0.97	24
Mohawk River @ RM 21.5 22651-ORDEQ	-0.66	0.69	0.87	0.96	24
Mohawk River @ RM 14.7 25502-ORDEQ	-0.38	0.44	0.55	0.95	24
Mohawk River @ RM 12.1 22654-ORDEQ	-0.24	0.59	0.68	0.83	24
Mohawk River @ RM 8.1 25498-ORDEQ	-0.78	0.78	0.95	0.92	24
Mohawk River @ RM 3.4 25496-ORDEQ	-1.30	1.30	1.43	0.96	24
Mohawk River @ RM 1.5 10663-ORDEQ	-1.35	1.35	1.54	0.97	24

3.9 McKenzie River: Upper

The McKenzie River: Upper model is a temperature model developed using Heat Source 6.0. The model was developed by DEQ.

3.9.1 Model extent

The extent of the model domain is the McKenzie River from Olallie Campground to the confluence of Quartz Creek (Figure 3.196).

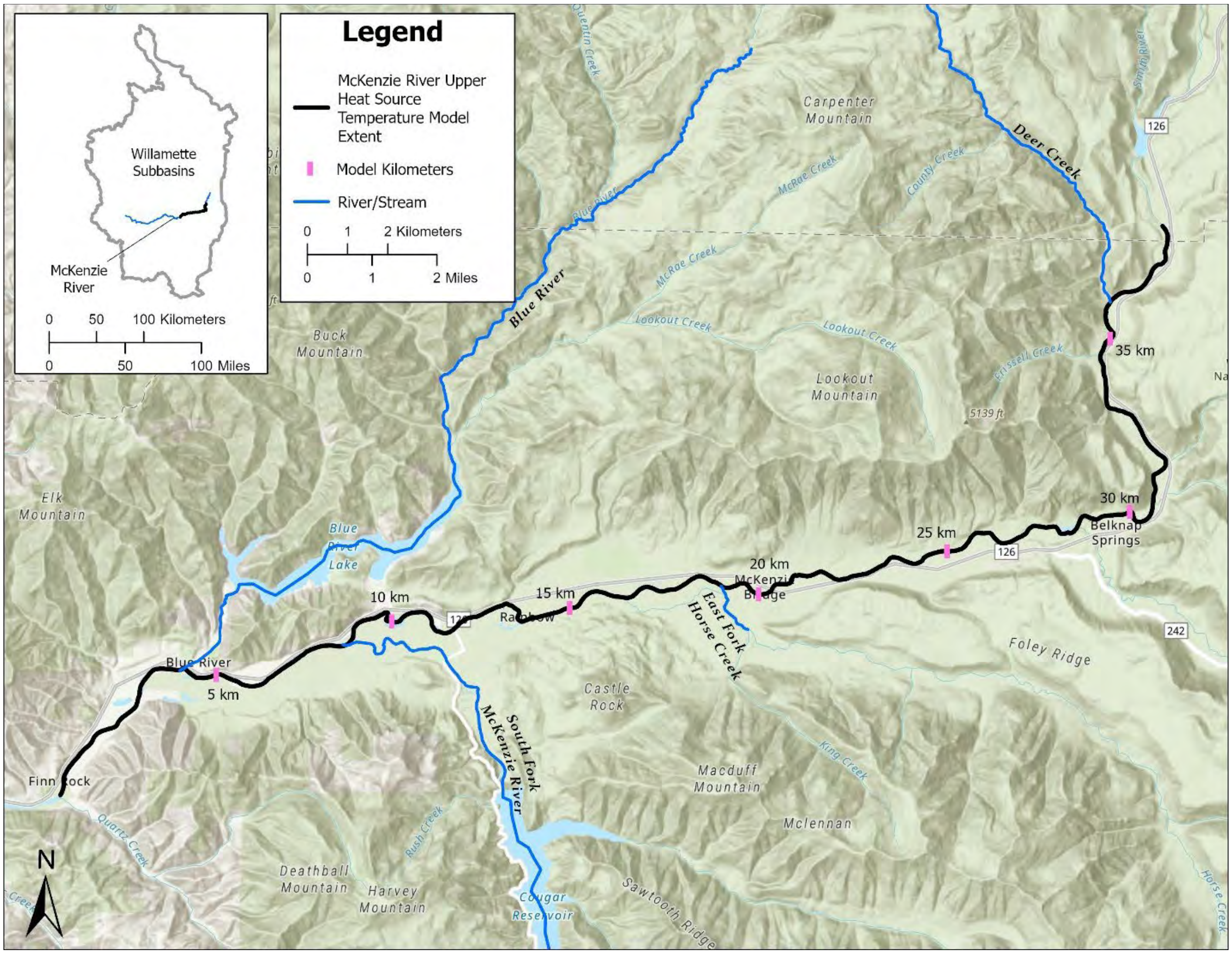


Figure 3.196. McKenzie River: Upper model extent.

3.9.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.9.3 Time frame of simulation

The model period is for a single day: September 03, 1999.

3.9.4 Meteorological inputs

The model was set up using hourly air temperature, relative humidity, and wind speed measurements from a DEQ site at the H.J. Andrews Experimental Forest Meteorological Station. Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using a wind-sheltering coefficient to represent differences in wind speed between the measurement location and above the stream within the riparian area.

Figure 3.197. Model setup cloudiness.

FIGURE

Figure 3.198. Model setup air temperatures.

FIGURE

Figure 3.199. Model setup relative humidity

FIGURE

Figure 3.200. Model setup solar radiation.

FIGURE

3.9.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.57). Figure 3.201 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

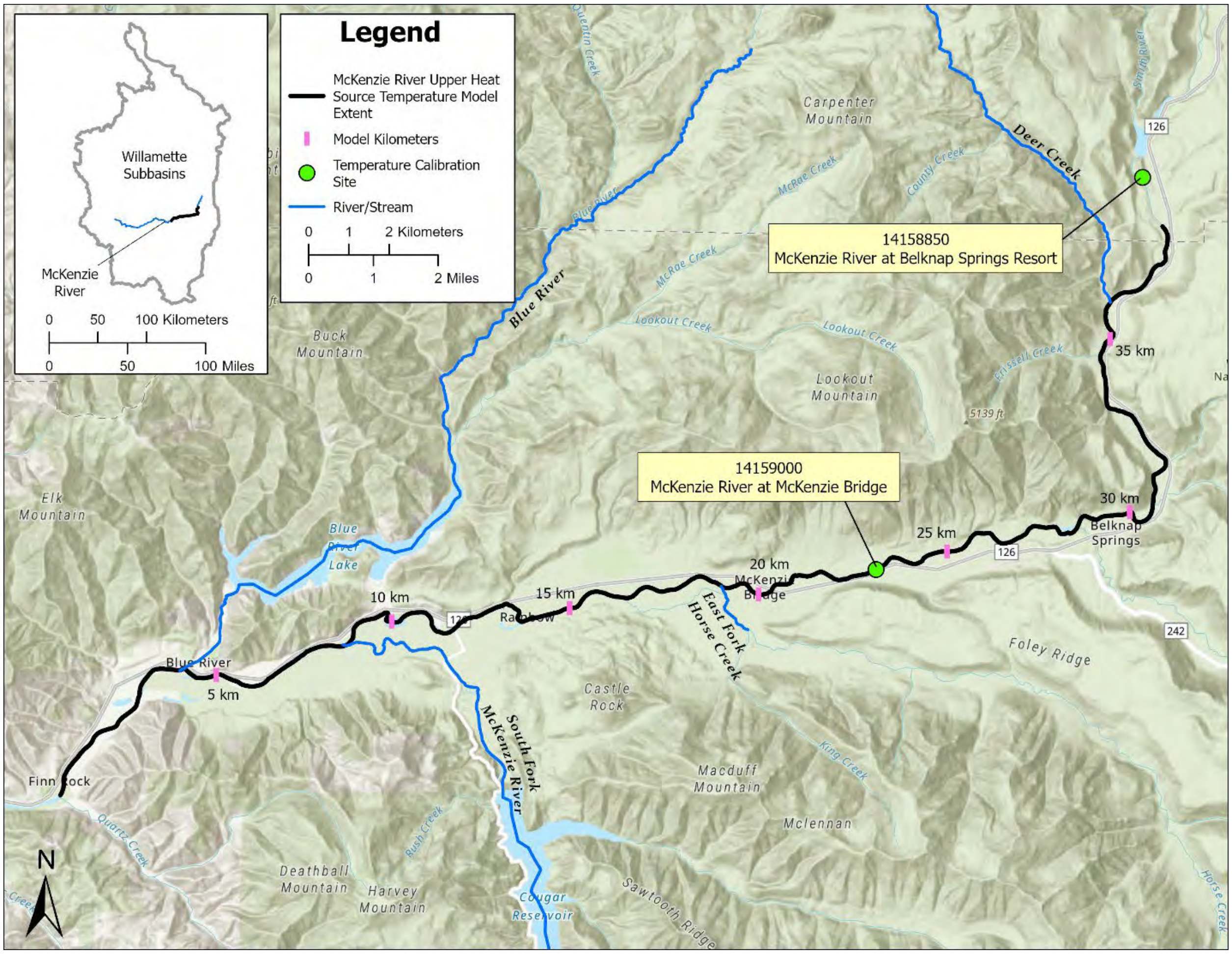


Figure 3.201. Location of temperature monitoring sites used for setup and calibration of the McKenzie River: Upper model.

Table 3.57. McKenzie River: Upper tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
McKenzie River at Olallie (RM 75.43)	0	Boundary Condition	DEQ File
Blue River	38857	Tributary	Estimated 1 degree warmer than South Fork Mckenzie temp data.
South Fork McKenzie River	33184	Tributary	DEQ File
East Fork Horse Creek	22112.5	Tributary	Estimated 1 degree warmer than South Fork Mckenzie temp data.
Groundwater (warm)	16012.5	Tributary	Estimated 1 degree warmer than South Fork Mckenzie temp data.
Groundwater (warm)	13999.5	Tributary	Estimated 1 degree warmer than South Fork Mckenzie temp data.
Deer Creek	3203	Tributary	DEQ File

Figure 3.202. Model setup tributary and boundary condition temperatures.

FIGURE

3.9.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (Table 3.58).

There are no flow input sites along the model extent.

Table 3.58. McKenzie River: Upper tributary and boundary condition flow model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
McKenzie River at Olallie (RM 75.43)	0	Boundary Condition	Estimated based on nearby USGS gage
Blue River	38857	Tributary	Estimated based on nearby USGS gage
South Fork McKenzie River	33184	Tributary	Estimated based on nearby USGS gage
East Fork Horse Creek	22112.5	Tributary	USFS Measurement in Horse Creek
Groundwater (warm)	16012.5	Tributary	Estimated data
Groundwater (warm)	13999.5	Tributary	Estimated data
Deer Creek	3203	Tributary	Estimated based on nearby USGS gage

Figure 3.203. Model setup tributary and boundary condition flow rates.

FIGURE

Figure 3.204. Model setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.205. Model setup for withdrawal flow rates.

FIGURE

3.9.7 Point source inputs

There are no point sources discharging within the model extent.

Figure 3.206. Model setup up point source effluent temperatures.

FIGURE

Model setup point source effluent flow rates.

FIGURE

3.9.8 Landcover and topographic shade inputs

Figure 3.207. Model setup landcover height (m).

FIGURE

Figure 3.208. Model setup topographic shade angles.

FIGURE

3.9.9 Channel setup

Channel widths on Upper McKenzie River, McKenzie Subbasin

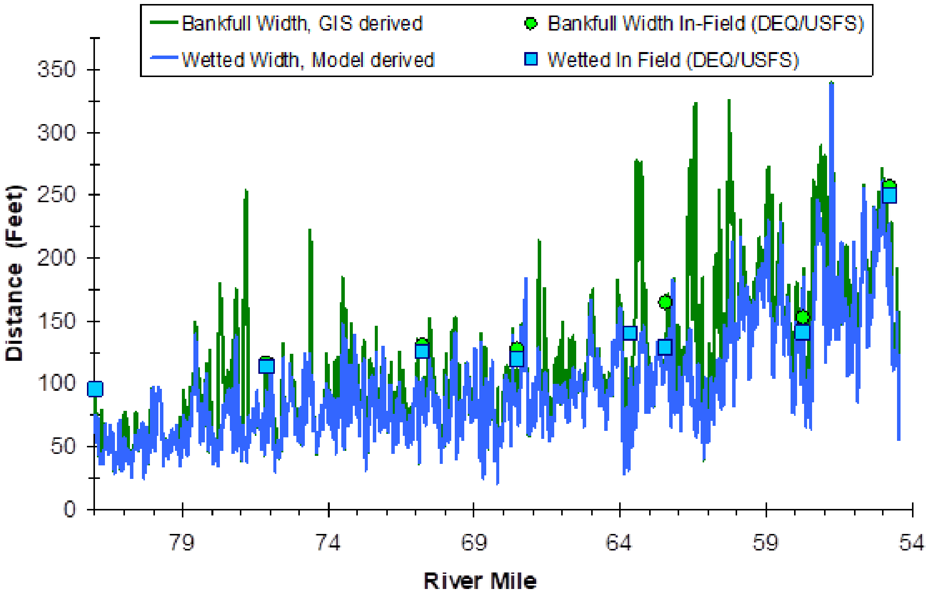


Figure 3.209. Model setup stream channel elevation (m) and gradient.

FIGURE

Figure 3.210. setup channel angle z.

FIGURE

Figure 3.211. Model setup bottom width (m).

FIGURE

Figure 3.212. Model setup for manning roughness coefficient.

FIGURE

3.9.10 Other model parameters

3.9.11 Calibration results

Table 3.59. Monitoring locations used as calibration sites in the McKenzie River: Upper model.

Model Location Name	Model Location (meters)	Calibration Parameter	Data Source
McKenzie River at Quartz Creek Bridge	43157.5	Water Temperature	DEQ
McKenzie River at McKenzie Bridge	18818.5	Water Temperature	USGS (14159000)
McKenzie River at Belknap Springs Resort	9699.0	Water Temperature	USGS (14158850)

3.9.11.1 Flow

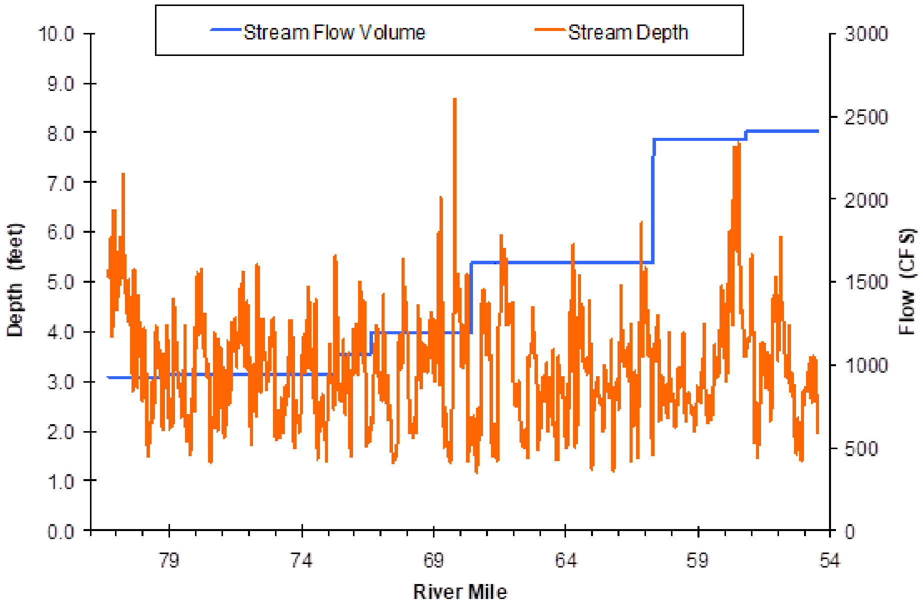


Figure 3.213 Longitudinal flow mass balance for the McKenzie River (Upper), McKenzie Subbasin.

Table 3.60. Flow rate goodness of fit statistics comparing field observed and model flow rates

TABLE

3.9.11.2 Effective Shade

FIGURE

Figure 3.214. Field observed and model predicted effective shade.

Table 3.61. Effective shade goodness of fit statistics comparing field observed and model values.

TABLE

3.9.11.3 Temperature

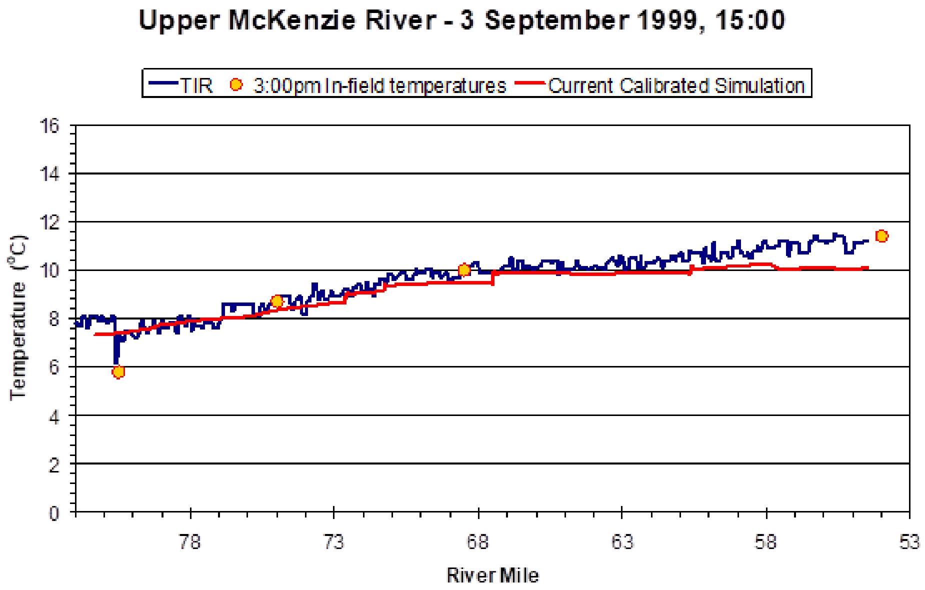


Figure 3.215 TIR and simulated current stream temperatures, McKenzie River (upper), McKenzie Subbasin.

FIGURE

Figure 3.216. Field observed and model predicted [hourly/daily maximum] temperatures.

Table 3.62. Stream temperature goodness of fit statistics comparing field observed and model predicted temperatures.

Monitoring Location	ME	MAE	RMSE	R2	N
McKenzie River @ RM 75.4 Ollalie	0.00	0.00	0.00	1.00	24
McKenzie River @ Belknap Springs Resort	-0.99	0.99	1.11	0.91	24
McKenzie River @ McKenzie Bridge	-0.19	0.38	0.54	0.67	24
McKenzie River @ Quartz Cr. Bridge	0.02	0.39	0.50	0.82	24
McKenzie River TIR	-0.23	0.33	0.39	0.93	1418

3.10 Coyote Creek

The Coyote Creek model is a temperature model developed using Heat Source 6.5.1. The model was developed by DEQ.

3.10.1 Model extent

The extent of the model domain is Coyote Creek from Gillespie Corners to the mouth at the Fern Ridge Reservoir (Figure 3.217).

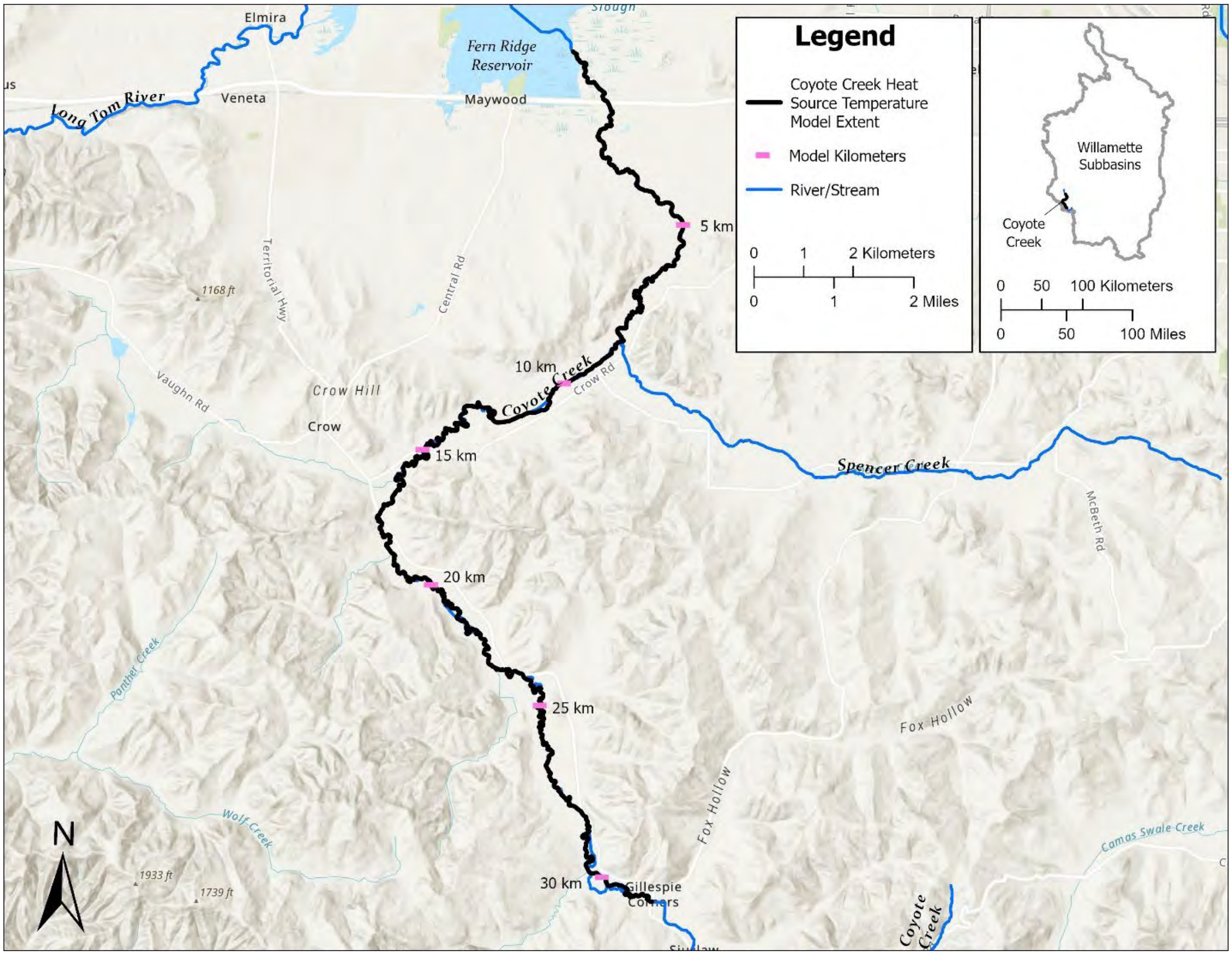


Figure 3.217. Coyote Creek model extent.

3.10.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.10.3 Time frame of simulation

The model period is for a single day: July 11, 2002.

3.10.4 Meteorological inputs

The model was set up using hourly air temperature, relative humidity, and wind speed measurements from the NCDC site at the Eugene Airport (KEUG). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using wind-sheltering coefficients of 0.75 and 0.90 to represent differences in wind speed between the measurement location and above the stream within the riparian area.

FIGURE

Figure 3.218. Coyote Creek model setup for cloudiness.

FIGURE

Figure 3.219. Coyote Creek model setup for air temperatures.

FIGURE

Figure 3.220. Coyote Creek model setup for relative humidity.

3.10.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.63). Figure 3.221 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

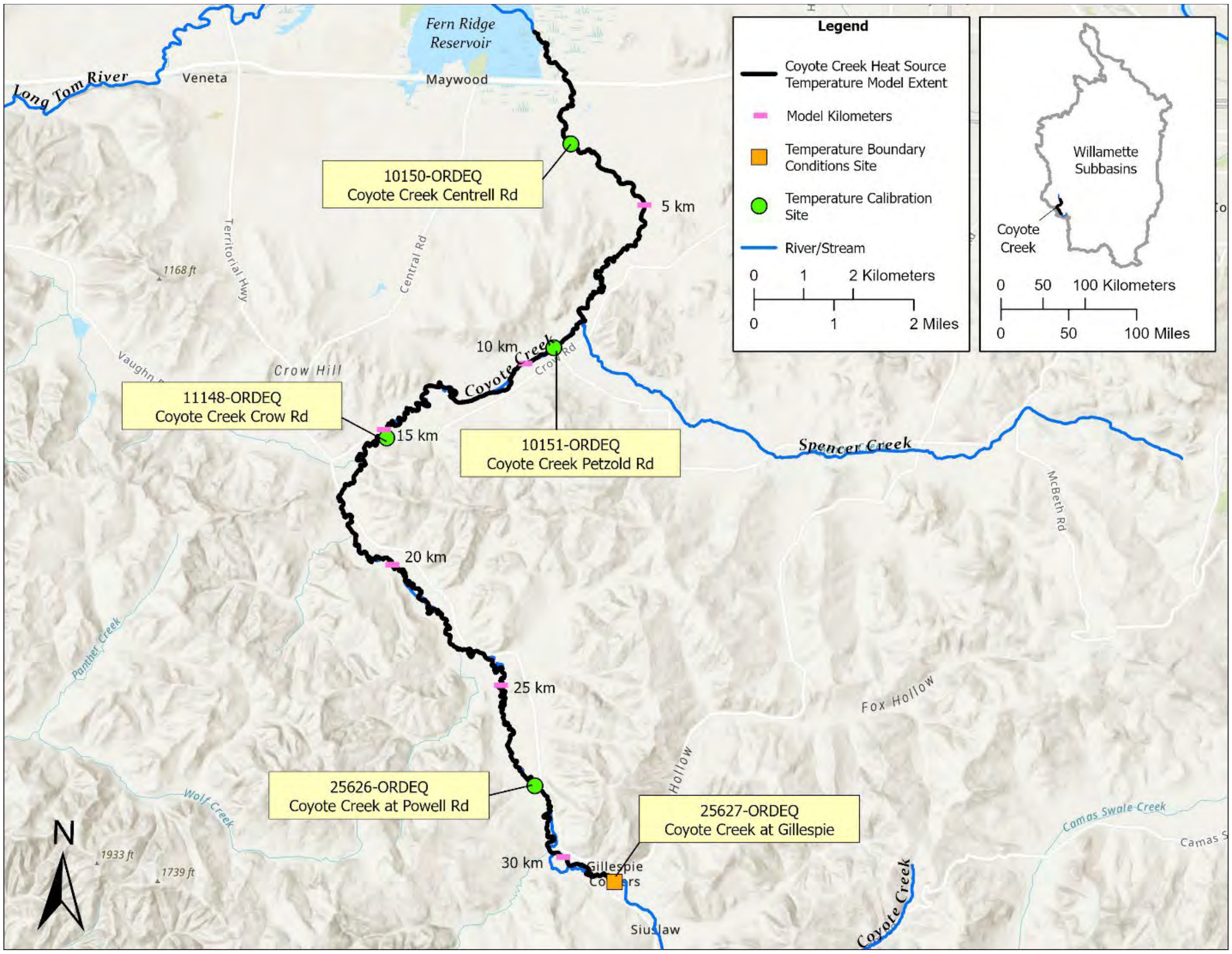


Figure 3.221. Location of temperature monitoring sites used for setup and calibration of the Coyote Creek model.

Table 3.63. Coyote Creek tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Coyote Creek at Gillespie	0	Boundary Condition	25627-ORDEQ
Spencer Creek	26365	Tributary	DEQ File

FIGURE

Figure 3.222. Coyote Creek model setup tributary and boundary condition temperatures.

3.10.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (Table 3.64). Figure 3.223 **Error! Reference source not found.**shows the locations of the various stream flow monitoring locations that were used for model setup or calibration.

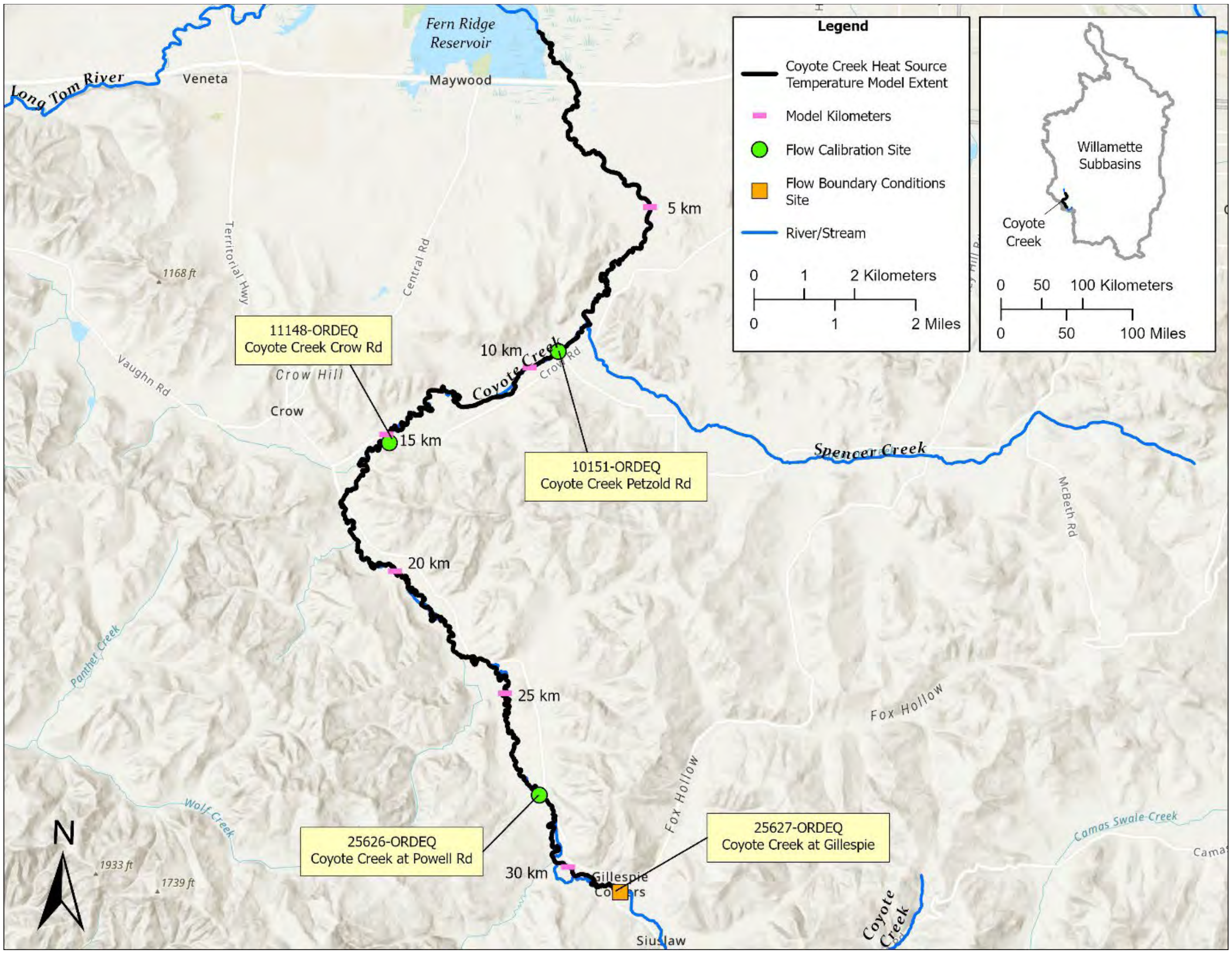


Figure 3.223. Location of flow monitoring sites used for setup and calibration of the Coyote Creek model.

Table 3.64. Coyote Creek tributary and boundary condition flow model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Coyote Creek at Gillespie	0	Boundary Condition	25627-ORDEQ
Spencer Creek	26365	Tributary	DEQ File

FIGURE

Figure 3.224. Coyote Creek model setup tributary and boundary condition flow rates.

FIGURE

Figure 3.225. Coyote Creek model I setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.226. Coyote Creek model setup for withdrawal flow rates.

3.10.7 Point source inputs

There are no point sources discharging within the model extent.

3.10.8 Landcover and topographic shade inputs

FIGURE

Figure 3.227. Coyote Creek model setup landcover height (m).

FIGURE

Figure 3.228. Coyote Creek model setup topographic shade angles.

3.10.9 Channel setup

Channel widths on Coyote Creek, Upper Willamette Subbasin

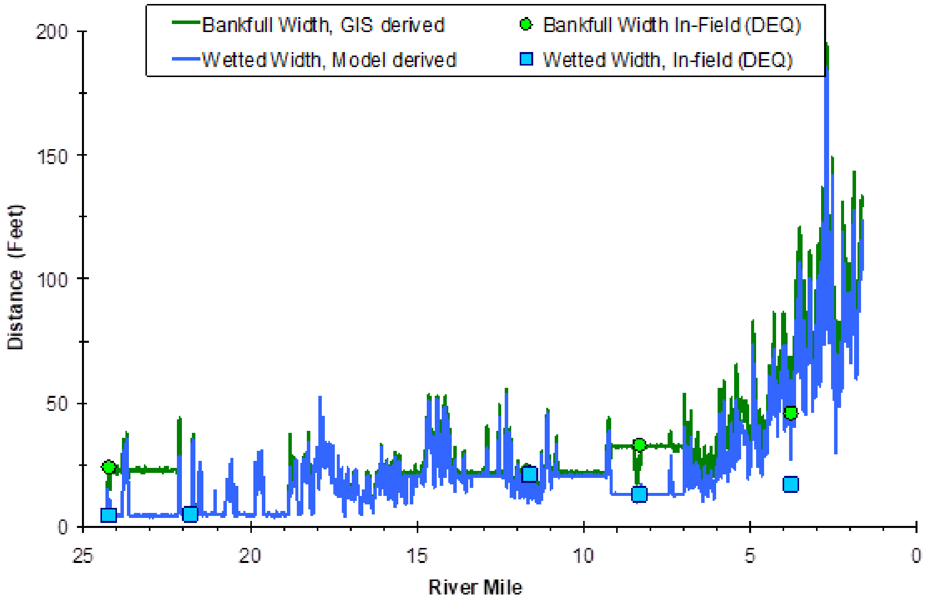


Figure 3.229. Coyote Creek model setup stream channel elevation (m) and gradient.

FIGURE

Figure 3.230. Coyote Creek model setup channel angle z.

FIGURE

Figure 3.231. Coyote Creek model setup bottom width (m).

FIGURE

Figure 3.232. Coyote Creek model setup for manning roughness coefficient.

3.10.10 Other model parameters

3.10.11 Calibration results

Table 3.65. Monitoring locations used as calibration sites in the Coyote Creek model.

Model Location Name	Model Location (meters)	Calibration Parameter	Data Source
Coyote Creek Centrell Rd	32918.40	Water Temperature, Effective Shade	10150-ORDEQ
Coyote Creek Petzold Rd	25603.20	Water Temperature, Flow, Effective Shade	10151-ORDEQ
Coyote Creek Crow Rd	19141.44	Water Temperature, Flow, Effective Shade	11148-ORDEQ
Coyote Creek at Powell Rd	3931.92	Water Temperature, Flow, Effective Shade	25626-ORDEQ
Coyote Creek at Gillespie	0.00	Effective Shade	25627-ORDEQ

3.10.11.1 Flow

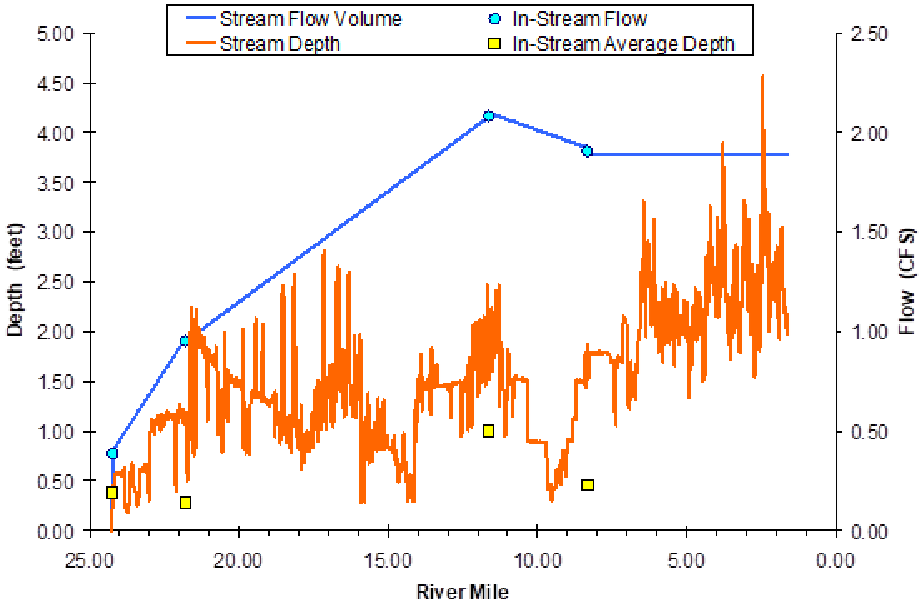


Figure 3.233. Longitudinal flow mass balance for Coyote Creek, Upper Willamette Subbasin.

Table 3.66. Flow rate goodness of fit statistics comparing field observed and model flow rates

TABLE

3.10.11.2 Effective Shade

FIGURE

Figure 3.234. Coyote Creek field observed and model predicted effective shade.

Table 3.67. Coyote Creek effective shade goodness of fit statistics comparing field observed and model values.

TABLE

3.10.11.3 Temperature

FIGURE

Figure 3.235. Coyote Creek field observed and model predicted [hourly/daily maximum] temperatures.

Table 3.68. Coyote Creek stream temperature goodness of fit statistics comparing field observed and model predicted temperatures.

TABLE

3.11 Mosby Creek

The Mosby Creek model is a temperature model developed using Heat Source 6.5.1. The model was developed by DEQ.

3.11.1 Model extent

The extent of the model domain is Mosby Creek from the confluence of the East and West Forks to the confluence with the Row River (Figure 3.236).

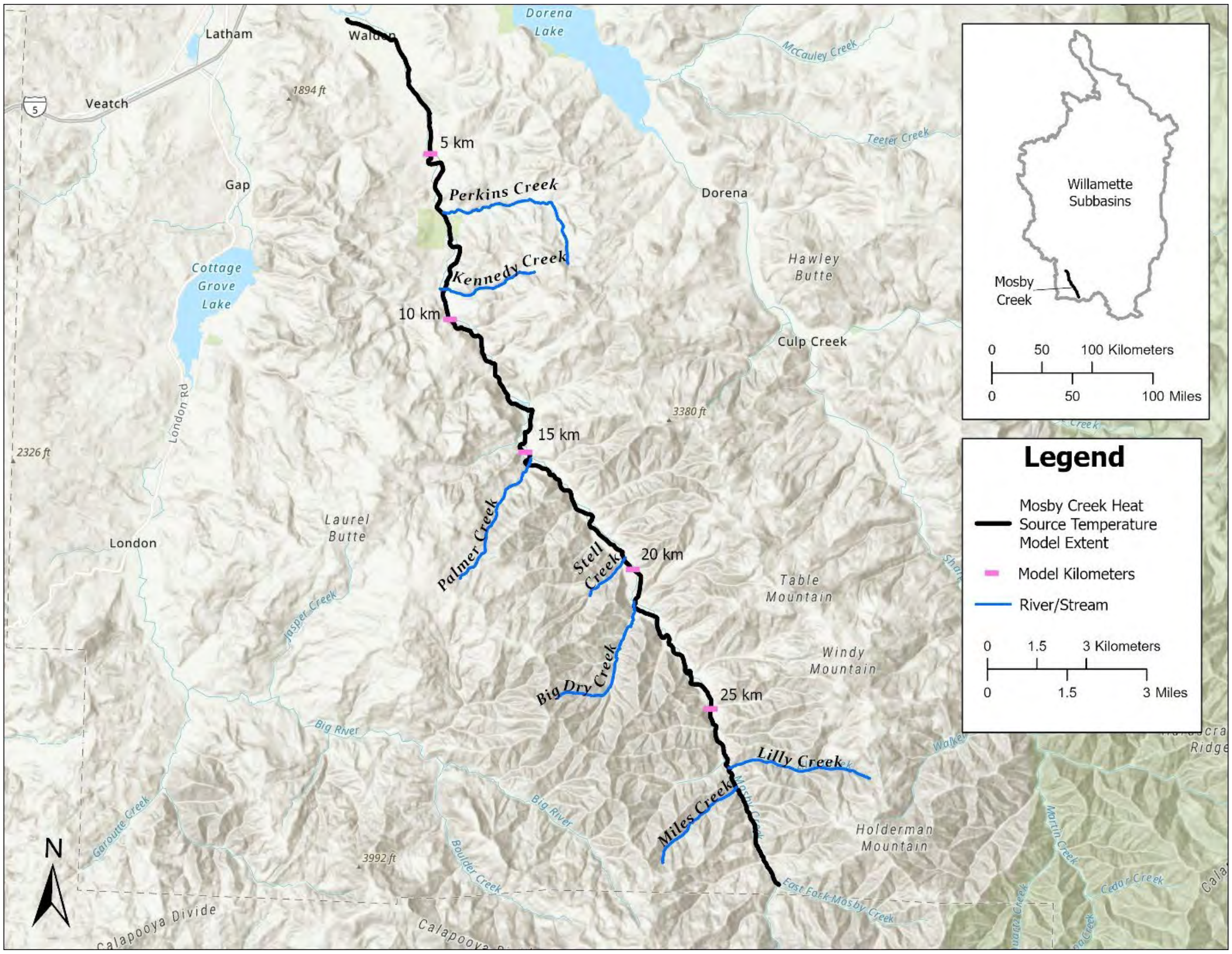


Figure 3.236. Mosby Creek model extent.

3.11.2 Spatial and temporal resolution

The model input spatial resolution (*dx*) is 30 meters. Outputs are generated every 100 meters. The model time step (*dt*) is 1 minute and outputs are generated every hour.

3.11.3 Time frame of simulation

The model period is for a single day: July 21, 2002.

3.11.4 Meteorological inputs

The model was set up using hourly air temperature, relative humidity, and wind speed measurements from the NCDC site at the Eugene Airport (KEUG). Air temperature data were modified using the dry adiabatic lapse rate to adjust for differences in elevation between the measurement location and the model input location. Wind speeds were adjusted to improve the calibration using a wind-sheltering coefficient to represent differences in wind speed between the measurement location and above the stream within the riparian area.

FIGURE

Figure 3.237. Mosby Creek model setup for cloudiness.

FIGURE

Figure 3.238. Mosby Creek model setup for air temperatures.

FIGURE

Figure 3.239. Mosby Creek model setup for relative humidity

3.11.5 Temperature inputs

Hourly water temperature time series data were used to support tributary and boundary condition model setup (Table 3.69). Figure 3.240 **Error! Reference source not found.**shows the locations of the various stream temperature monitoring locations that were used for model setup or calibration.

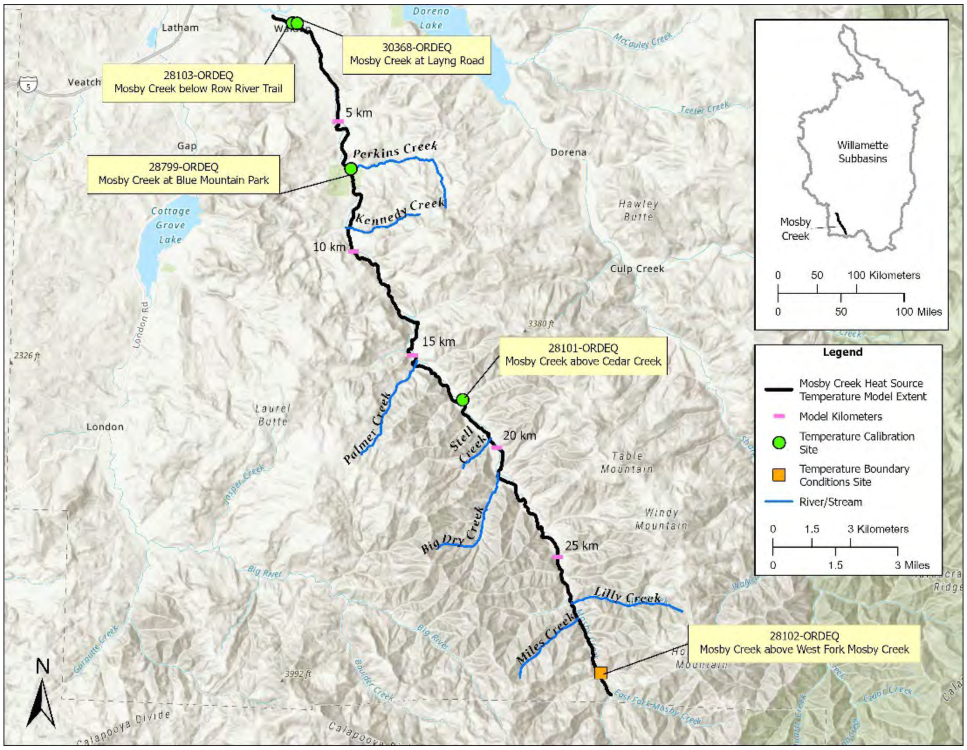


Figure 3.240. Location of temperature monitoring sites used for setup and calibration of the Mosby Creek model.

Table 3.69. Mosby Creek tributary and boundary condition water temperature model setup.

Model Location Name	Model Location (meters)	Input Type	Data Source
Mosby Creek Above West Fork Mosby Creek	0	Boundary Condition	BLM 28102-ORDEQ
Carolina Creek	34350.96	Tributary	DEQ File
Unnamed Creek at model meter 26883.36	26883.36	Tributary	DEQ File
Perkins Creek	26548.08	Tributary	BLM (17090002_PE1235)
Kennedy Creek	23652.48	Tributary	DEQ File
Smith Creek	23622	Tributary	DEQ File
Short Creek	20878.8	Tributary	DEQ File
Rock Creek	17160.24	Tributary	DEQ File
Palmer Creek	15849.6	Tributary	DEQ File
Cedar Creek (Spring 1)	13716	Tributary	BLM (17090002_CE1060)
Stell Creek	11582.4	Tributary	BLM (17090002_ST1120)*
Big Dry Creek	9906	Tributary	BLM (17090002_BD1160)
Lilly Creek	2926.08	Tributary	BLM (17090002_LI1380)
Miles Creek	2225.04	Tributary	DEQ File

* Constant temperature of 16.1.

Figure 3.241. Model setup tributary and boundary condition temperatures.

FIGURE

3.11.6 Flow inputs

Hourly stream flow time series data were used to support tributary and boundary condition model setup (Table 3.70). Figure 3.242 **Error! Reference source not found.**shows the locations of the various stream flow monitoring locations that were used for model setup or calibration.

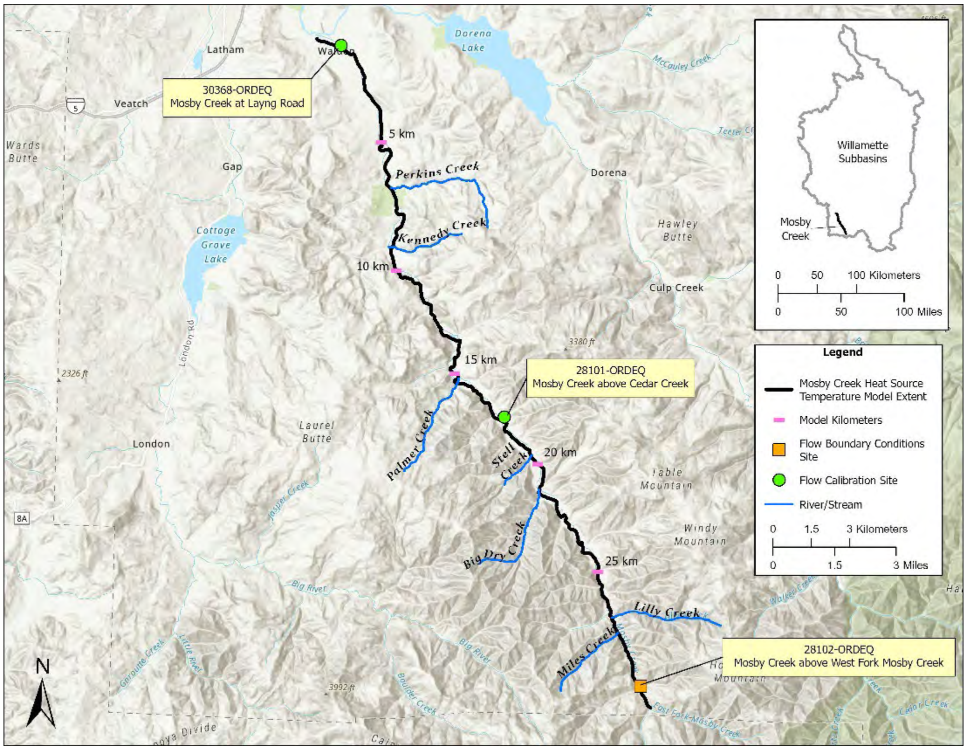


Figure 3.242. Location of flow monitoring sites used for setup and calibration of the Mosby Creek model.

Table 3.70. Mosby Creek tributary and boundary condition flow model setup.

Model Location Name (Station ID)	Model Location (meters)	Input Type	Data Source
Mosby Creek Above West Fork Mosby Creek	0	Boundary Condition	28102-ORDEQ
Carolina Creek	34350.96	Tributary	Derived using TIR and flow mass balance
Unnamed Creek at model meter 26883.36	26883.36	Tributary	Derived using TIR and flow mass balance
Perkins Creek	26548.08	Tributary	Derived using TIR and flow mass balance

Model Location Name (Station ID)	Model Location (meters)	Input Type	Data Source
Kennedy Creek	23652.48	Tributary	DEQ
Smith Creek	23622	Tributary	Derived using TIR and flow mass balance
Short Creek	20878.8	Tributary	Derived using TIR and flow mass balance
Rock Creek	17160.24	Tributary	Derived using TIR and flow mass balance
Palmer Creek	15849.6	Tributary	Derived using TIR and flow mass balance
Cedar Creek (Spring 1)	13716	Tributary	Derived using TIR and flow mass balance
Stell Creek	11582.4	Tributary	DEQ
Big Dry Creek	9906	Tributary	DEQ
Lilly Creek	2926.08	Tributary	Derived using TIR and flow mass balance
Miles Creek	2225.04	Tributary	DEQ

FIGURE

Figure 3.243. Model setup tributary and boundary condition flow rates.

FIGURE

Figure 3.244. Model setup for groundwater/accretion/distributed flow rates.

FIGURE

Figure 3.245. Model setup for withdrawal flow rates.

3.11.7 Point source inputs

There are no point sources discharging within the model extent.

3.11.8 Landcover and topographic shade inputs

FIGURE

Figure 3.246. Model setup landcover height (m).

FIGURE

Figure 3.247. Model setup topographic shade angles.

FIGURE

3.11.9 Channel setup

Channel widths on Mosby Creek, Coast Fork Willamette Subbasin

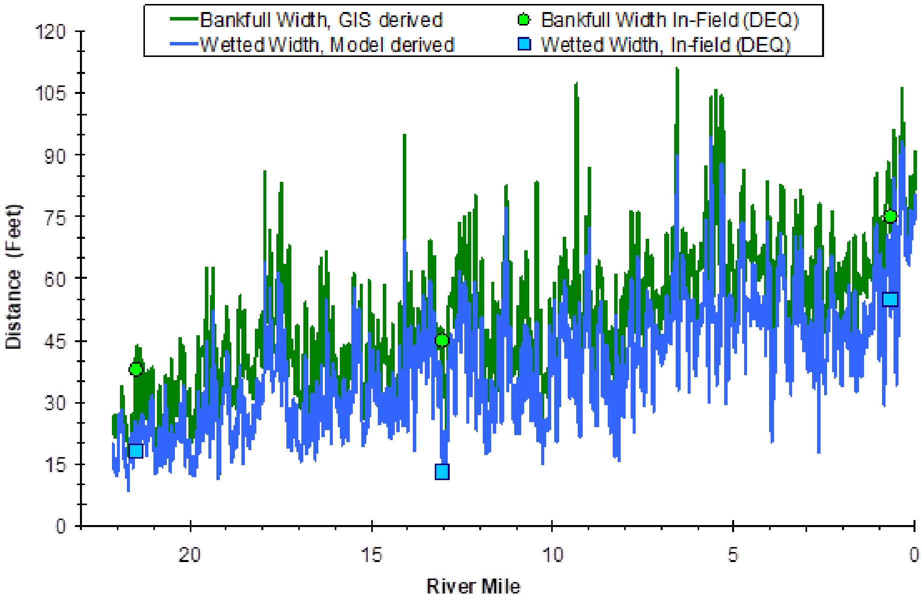


Figure 3.248. Model setup stream channel elevation (m) and gradient.

FIGURE

Figure 3.249. setup channel angle z.

FIGURE

Figure 3.250. Model setup bottom width (m).

FIGURE

Figure 3.251. Model setup for manning roughness coefficient.

3.11.10 Other model parameters

3.11.11 Calibration results

Table 3.71. Monitoring locations used as calibration sites in the Mosby Creek model.

Model Location Name	Model Location (meters)	Calibration Parameter	Data Source
Mosby Creek below Row River Trail	33771.84	Water Temperature	BLM 28103-ORDEQ
Mosby Creek at Layng Road	33497.52	Water Temperature, Flow, Effective Shade	30368-ORDEQ
Mosby Creek at Blue Mountain Park (upstream Perkins Creek)	26365.2	Water Temperature	28799-ORDEQ
Mosby Creek Above Cedar Creek	13594.08	Water Temperature, Flow, Effective Shade	BLM 28101-ORDEQ
Mosby Creek Above West Fork Mosby Creek	0	Effective Shade	28102-ORDEQ
Model extent	Model extent	Water Temperature (TIR)	Watershed Sciences (2003)

3.11.11.1 Flow

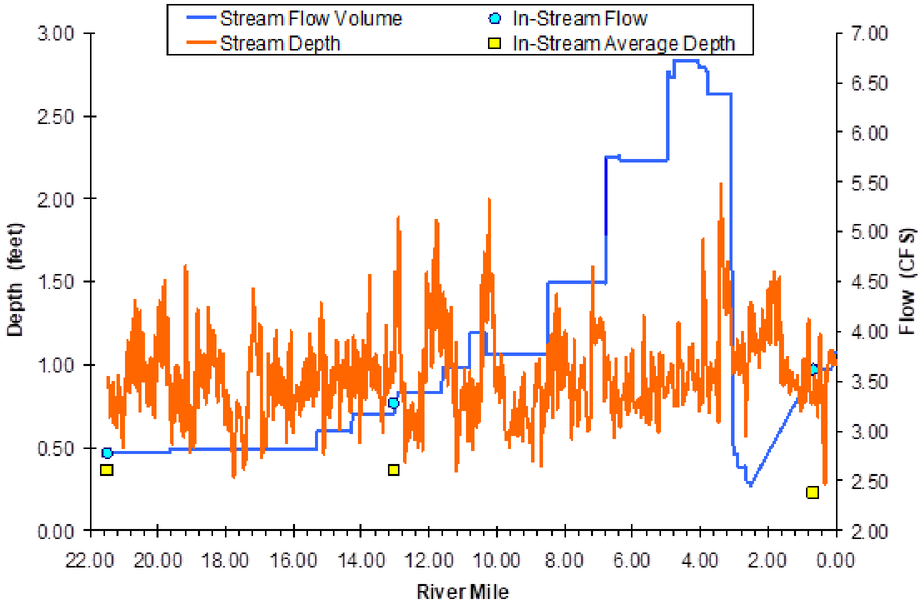


Figure 3.252 Longitudinal flow mass balance for Mosby Creek, Coast Fork Willamette Subbasin

Table 3.72. Flow rate goodness of fit statistics comparing field observed and model flow rates

TABLE

3.11.11.2 Effective Shade

FIGURE

Figure 3.253. Field observed and model predicted effective shade.

Table 3.73. Effective shade goodness of fit statistics comparing field observed and model values.

TABLE

3.11.11.3 Temperature

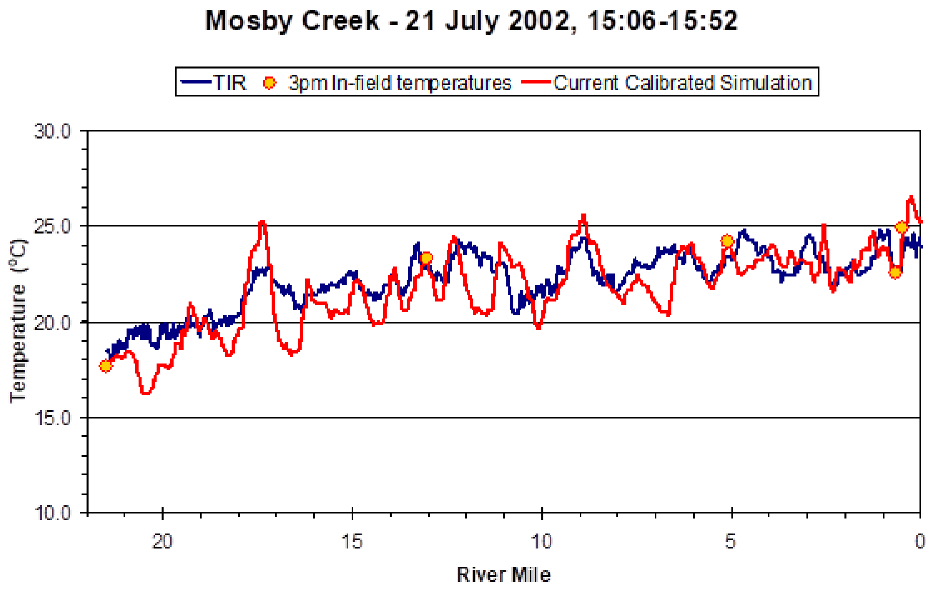


Figure 3.254 TIR and simulated current stream temperatures, Mosby Creek, Coast Fork Willamette Subbasin

Table 3.74. Stream temperature goodness of fit statistics comparing field observed and model predicted temperatures.

Monitoring Location	ME	MAE	RMSE	R2	N
Mosby Creek @ RM 21.5 30165-ORDEQ	0.00	0.00	0.01	1.00	24
Mosby Creek @ RM 13.0 28101-ORDEQ	0.14	0.86	1.06	0.80	24

Mosby Creek @ RM 5.1 28799-ORDEQ	-0.25	0.81	1.15	0.79	24
Mosby Creek @ RM 0.7 30368-ORDEQ	0.44	0.67	0.89	0.82	24
Mosby Creek @ RM 0.5 28103-ORDEQ	0.55	0.89	1.08	0.84	24
Mosby Creek TIR	-0.72	1.22	1.50	0.62	1136

3.12 Southern Willamette Shade

Between 2014 and 2018 DEQ developed a Heat Source version 9 shade model for streams in the southern portion of the Willamette Basin. The primary purpose of these models was to characterize the status of effective shade on project area streams and the gap between the current shade and the TMDL effective shade targets identified in the Willamette Basin TMDL (ODEQ, 2006). Effective shade is a surrogate for solar radiation loading caused by the disturbance or removal of near-stream vegetation. The model was developed and calibrated using high resolution LiDAR and sixty-five field based effective shade measurements collected throughout the study area. Results were stratified by Designated Management Agencies (DMAs), HUC10 watersheds, and HUC12 subwatetersheds.

Several data sets used for model setup were derived using a GIS, associated spatial data, and a set of python based scripting tools called TTools (Boyd and Kasper 2003). The scale and resolution of the derived data sets generally matched the resolution and accuracy of the input GIS data. The derived data sets include:

- Stream position
- Stream and ground elevation
- Topographic shade angles
- Land cover height

3.12.1 Model extent

Effective shade was modeled along all streams mapped in the National Hydrography Dataset high resolution v2.2 database where LiDAR data was available in the Middle Fork Willamette (17090001), Coast Fork Willamette (17090002), Upper Willamette (17090003), McKenzie (17090004), North Santiam (17090005), and South Santiam (17090006) Subbasins. These subbasins are all located in the southern half of the Willamette Basin (170900). The model area is shown in Figure 3.255.

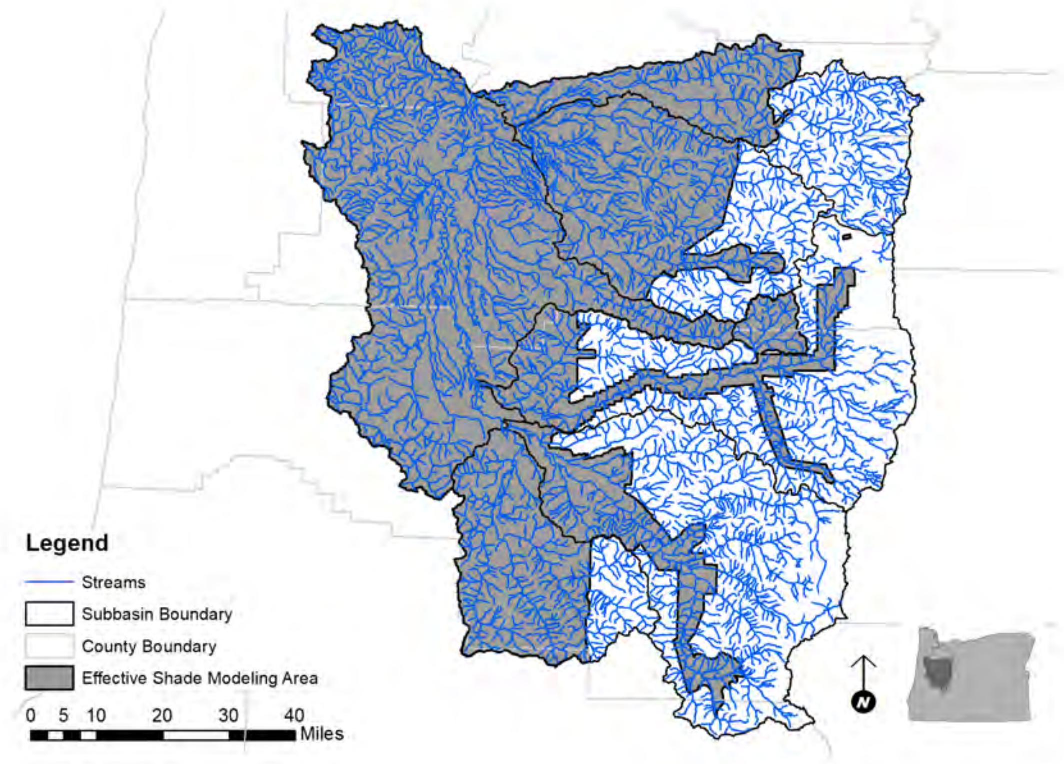


Figure 3.255 Effective shade and solar flux modeling area in the southern portion of the Willamette Basin (170900).

3.12.2 Spatial and temporal resolution

The model input spatial resolution (dx) is 200 meters. Outputs were generated every 200 meters. The model time step (dt) is 1 minute, and outputs are generated every hour. There is a total of 149500 nodes in the model.

3.12.1 Time frame of simulation

The model period is for a single day: August 15, 2014.

3.12.1 Meteorological inputs

The only meteorological input to the shade model is cloudiness. The model was setup to assume no cloud cover. This was done to isolate the solar radiation flux blocked by vegetation and topography only.

3.12.2 Spatial data

Multiple spatial GIS datasets were used to support model setup and configuration. Table 3.75 identifies the GIS datasets used for the model setup and a brief summary of the application or derived data.

Table 3.75 Spatial data used to support model setup and configuration.

Spatial Data	Source	Application
LiDAR Bare Earth (DEM), LiDAR Highest Hit (DSM)	Watershed Sciences 2009, 2010, 2012a, 2012b; WSI 2012a, 2012b, 2013, and 2015	The LiDAR bare earth DEM is used to estimate topographic shading angles and land surface elevation. The difference between the bare earth DEM and highest hit DSM was used to derive vegetation canopy height.
National Hydrography Dataset high resolution v2.2	USGS 2014	Mapping stream position and location.
National Wetland Inventory	USFWS 2004	The national wetland inventory was used to identify the location of open water and wetlands for development of the site potential vegetation model scenario.
Quaternary Geologic Units	O'Connor et al 2001	The Quaternary geologic units were used to map and derive the appropriate site potential vegetation types identified in the Willamette Basin TMDL (DEQ, 2006).

Light Detection and Ranging (LiDAR) is a remote sensing method that uses pulses of light to calculate the elevation of ground and surface features with a high degree of accuracy and resolution. LiDAR data is used to develop high resolution DEMs and digital surface models (DSM) which can then be used to derive canopy height. The Oregon Department of Geology and Mineral Industries oversees the Oregon LiDAR Consortium (OLC), which develops cooperative agreements for LiDAR collection. LiDAR collected through the OLC is made available for free and can be downloaded at https://www.oregongeology.org/lidar/. LIDAR was used to characterize vegetation canopy height and ground elevations.

The LiDAR bare earth DEM was used to estimate topographic shading angles and land surface elevation. The difference between the bare earth DEM and highest hit DSM was used to derive and characterize vegetation canopy height. All LiDAR datasets used in this study had a uniform three foot horizontal resolution.

The LiDAR datasets utilized in this study were collected between 2008 and 2014. In locations where there was overlapping LiDAR datasets collected in different years the most recent LiDAR were used. Figure 3 shows the location of existing LiDAR in the Southern Willamette Basin and the year of acquisition.

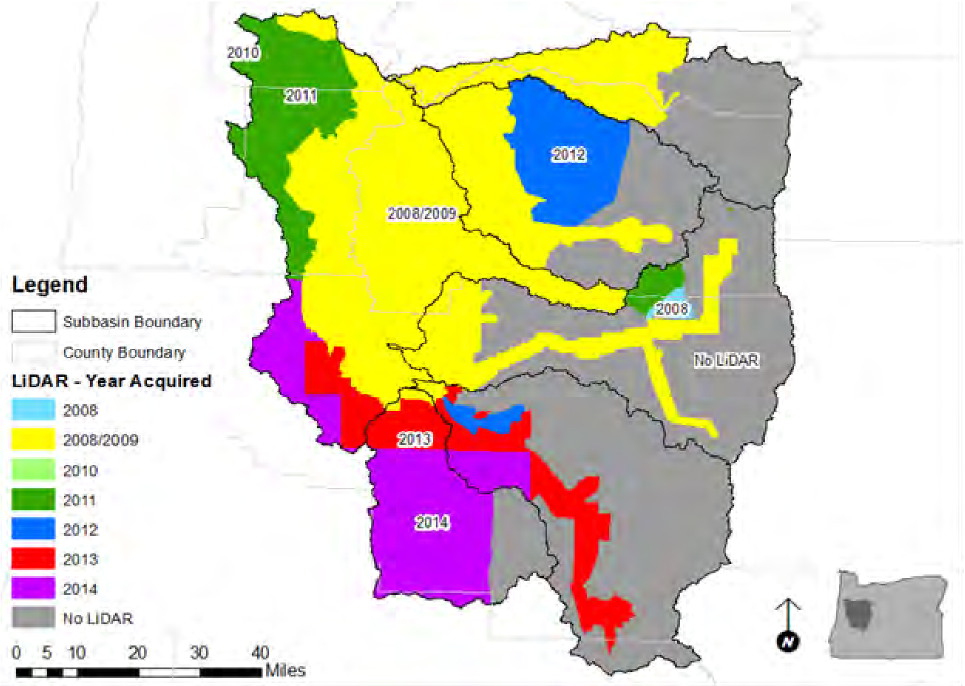


Figure 3.256 Location and year of LiDAR acquisition.

3.12.3 Stream Position

The stream position was determined using the National Hydrography Dataset high resolution v2.2 database. The NHD flowlines were segmented into 200 meter reaches with a node separating each 200 meter reach. These nodes determine the location for shade modeling. Stream segmentation was completed using a python script called TTools.

The stream flowlines in this version of NHD were primarily digitized from aerial photographs using a similar method that DEQ has used for other TMDLs including the 2006 TMDL effort. In places where the stream is masked by forest cover, it is often hard to “see” the stream channel and this can result in the digitized line not always matching the true location of the stream. DEQ considered remapping the stream locations by modeling the flow path using the LiDAR bare earth DEMs. This approach has shown to improve accuracy. The limitation with this approach is that it requires significant effort to identify and correct the DEM in places where road culverts occur. Because of the large project area and number of road crossings, it was determined that remapping the stream locations required an effort and timeline that did not align with the project schedule or available resources. As a result, in forested areas where the stream is not visible, the position of the stream is less certain.

3.12.4 Stream Elevation

The elevation at each stream node was derived from three-foot resolution LiDAR bare earth elevation DEMs.

3.12.5 Topographic Shade Angles

The topographic shade angle represents the vertical angle to the highest topographic feature as measured from a flat horizon. When the sun's altitude is equal to or less than the maximum topographic shade angle the topographic feature will cast a shadow over the stream node. The topographic shade angle is calculated using Equation 3. The TTools script uses Equation 3 to find maximum topographic shade angle in three directions (west, south, and east). The script samples the elevation from every LiDAR bare earth DEM raster cell from the stream node out to a distance of 10 kilometers (6.2 miles)

$$\theta_T = \tan^{-1}\left(\frac{Z_T - Z_S}{d}\right)$$ **Equation 3**

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.

3.12.6 Canopy Height

A three foot resolution land cover height raster was derived by subtracting the LiDAR bare earth elevation rasters from the LiDAR highest hit elevation rasters. The canopy height raster was used to characterize the vegetation and other land cover height along the stream. The characterization was completed using TTools. At each stream node TTools samples the canopy height along a set of eight transects that form a star pattern around the node (Figure 3.257). The transects radiate around the node toward the northeast, east, southeast, south, southwest, west, northwest, and north. Along each transect the canopy height was sampled every five meters starting at the channel center out to 75 meters. This sampling rate resulted in 120 samples per node.

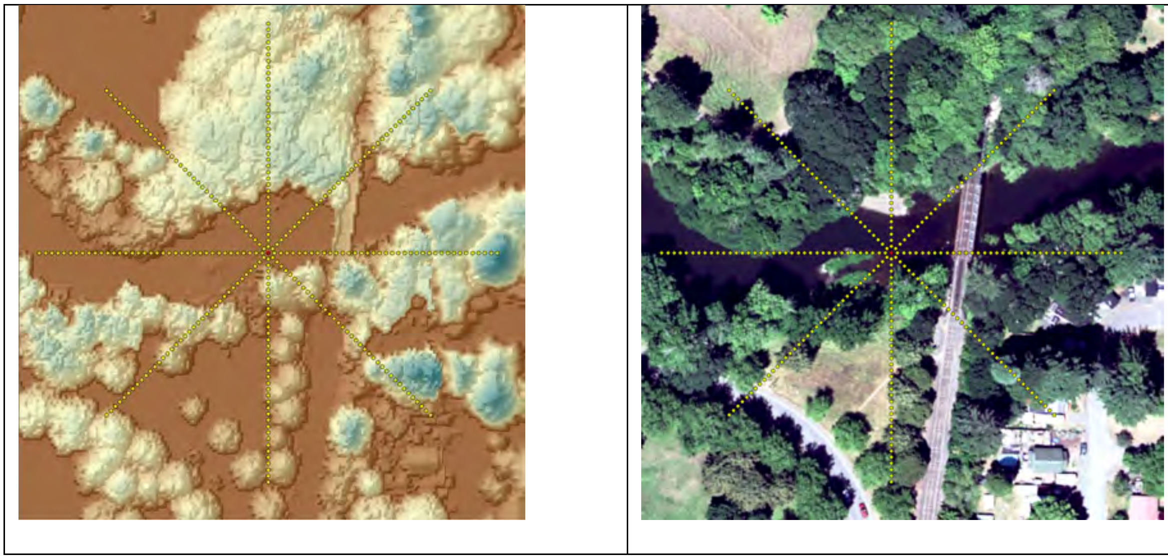


Figure 3.257. Example of the star pattern canopy height sampling at the MAR1 sample site. LiDAR derived height on the left and the same location as depicted in 2018 aerial imagery on the right. The stream node is depicted in red at the center.

3.12.1 Calibration results

The model was calibrated primarily by comparing the model effective shade predictions to the field measured effective shade values summarized in Table 2.42. To improve the calibration results global changes to the canopy cover parameter were made iteratively. Canopy cover was the only calibration parameter adjusted. The final calibrated canopy cover value was 0.80 (80%). Other potential calibration parameters (landcover height and landcover overhang) were determined directly from LiDAR and were not adjusted.

Goodness of fit statistics were calculated to compare the model predicted shade results to the associated observed shade measurements. The statistics calculated include the coefficient of determination, mean error, mean absolute error, and root mean squared error. Results are presented in Table 3.76. A scatter plot of the measured and model predicted results are shown in Figure 3.258. Overall, these results were good and the bias is near zero.

Table 3.76 Southern Willamette effective shade model goodness of fit statistics.

N	R^2	ME	MAE	RMSE
65	0.87	0.9	7.7	11

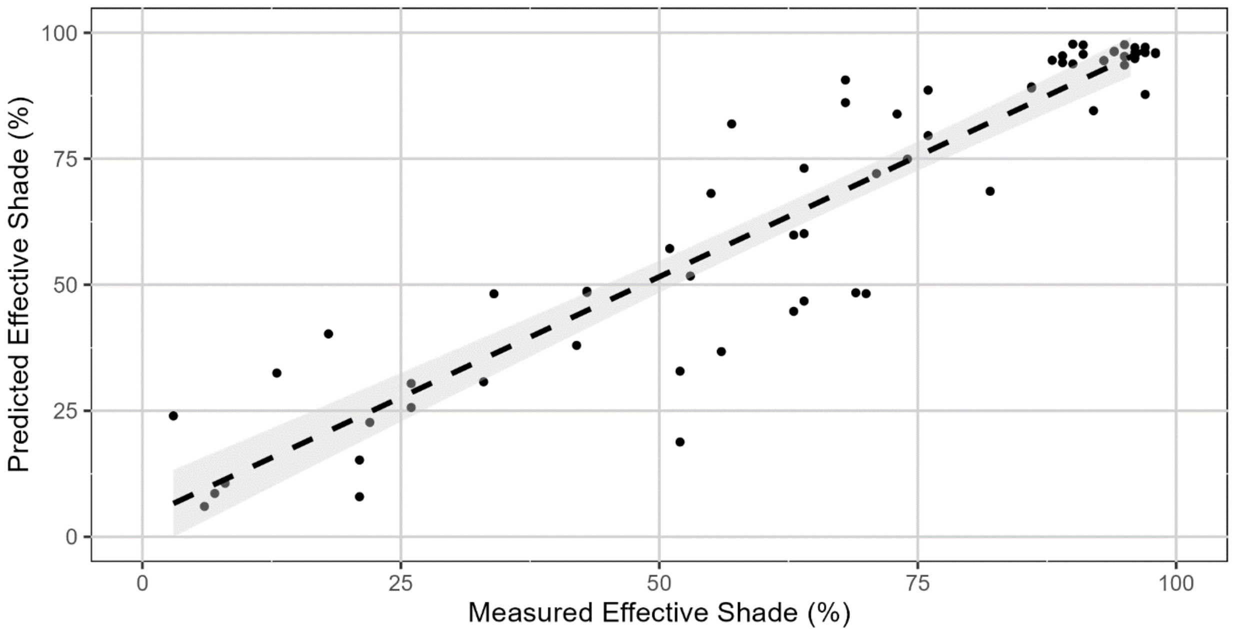


Figure 3.258 Southern Willamette measured and predicted effective shade. The dashed line is the best fit line and the grey area represents the confidence interval.

4. Model scenarios results

4.1 Johnson Creek

Table A# describes the different simulation scenarios for Johnson Creek.

Figure A# displays the longitudinal water temperature profiles of the different simulation scenarios for Johnson Creek. Though they are plotted on the same figure, the three restored stream flow simulation scenarios are not comparable to the other simulation scenarios, as they are based on different flow regimes. Current conditions, background, and restored tributary temperature simulation scenarios are based on observed Johnson Creek stream flow from July 31, 2002. The discharge at the mouth of Johnson Creek on this day was 0.32515 cubic meters per second (11.48 cfs), which is roughly equivalent to the 25% exceedance flow for August as estimated by the USGS Stream Stats tool. The restored flow simulation scenarios were based on the 50% exceedance flow for August at the mouth of Johnson Creek, which was 0.134 cubic meters per second (4.75 cfs).

Table 4.1. Johnson Creek model scenario descriptions.

Scenario Name	Description
Current Condition	This is the calibrated model scenario that evaluates the stream temperature response to Johnson Creek conditions on July 31, 2002.
Background	This scenario evaluates the stream temperature response from background sources only. Background sources include all sources of pollution or pollutants not originating from human activities. Model inputs for land cover height, canopy density and overhang were modified to reflect restored conditions. Tributary temperature inputs were reduced to meet temperature standards. In Johnson Creek, Crystal Springs hourly tributary temperature inputs were reduced by 1.8°C.
Restored Stream Flow	This scenario evaluates the stream temperature response when the USGS Stream Stats estimated August median flow is the assumed restored flow condition for the mainstem. Model boundary and tributary flows are set to achieve mainstem restored flows. This flow condition maintains all currently permitted water withdrawals as instream flow.
Restored Stream Flow with 20% Flow Reduction	This scenario evaluates the stream temperature response when the mainstem flow is set to restored flows reduced by 20%. Model boundary and tributary flows are set to achieve mainstem restored flows reduced by 20%. This flow condition represents the consumptive use rate above which OWRD assumes water quality impacts due to water withdrawals.
Restored Stream Flow with HUA Attaining Flow Reduction	This scenario evaluates the stream temperature response when the mainstem flow is set to restored flows reduced by the percent flow withdrawal that results in a 0.05°C water temperature increase at the flow reference site. In Johnson Creek, a 4% reduction of the mainstem restored flow conditions achieved HUA warming.
Tributary Temperatures	This scenario evaluates the stream temperature response when tributary temperature inputs were reduced to meet temperature standards. In Johnson Creek, Crystal Springs hourly tributary temperature inputs were reduced by 1.8°C. Crystal Springs was the only tributary altered because it was the only tributary with water temperatures that exceeded the standard of 18°C.

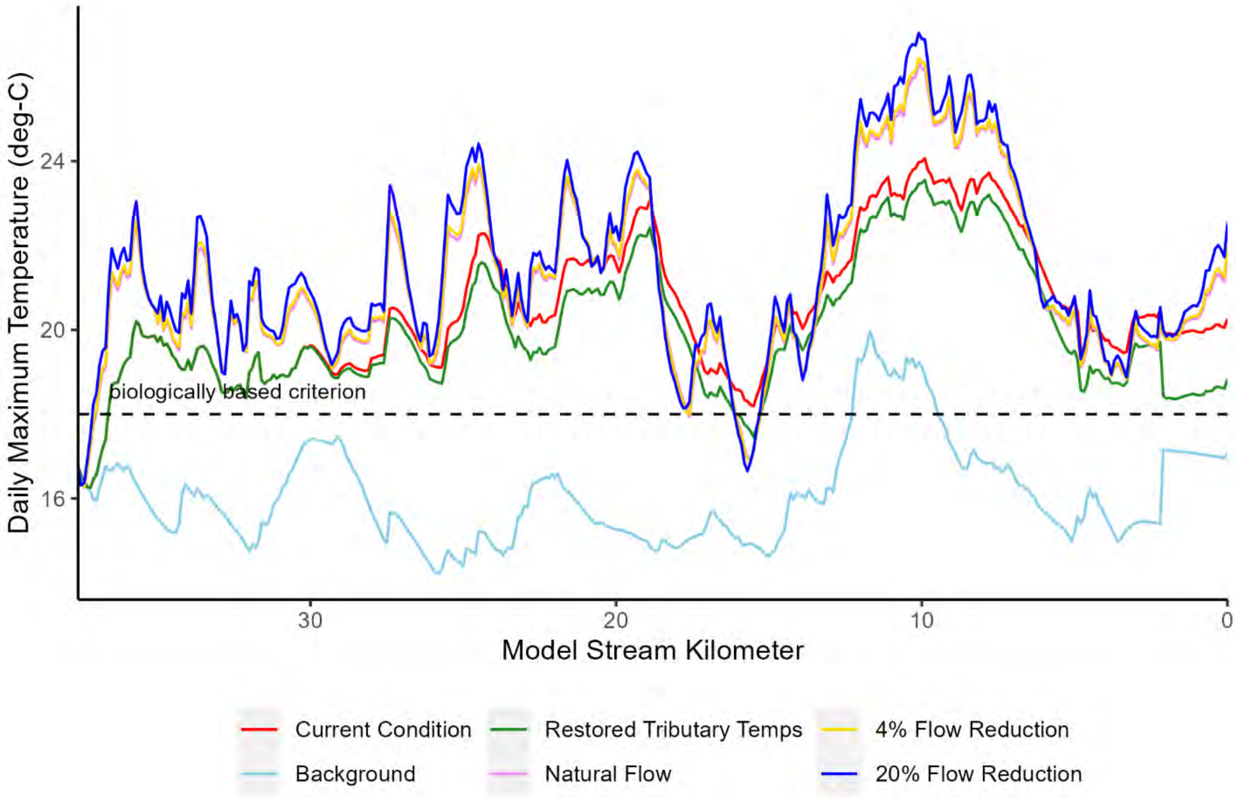


Figure 4.1. Predictions of Johnson Creek scenarios based on daily maximum temperatures for July 31, 2002.

Background vs. Current Conditions

Johnson Creek current conditions stream temperature is warmer than background stream temperature at every point along the mainstem. The median temperature change between these two scenarios was greatest at model kilometer 18.9, where the current conditions stream temperature was 8.18 °C warmer than the background stream temperature (Figure A#).

Johnson Creek current conditions effective shade is lower than background effective shade at almost every model location (Figure A#).

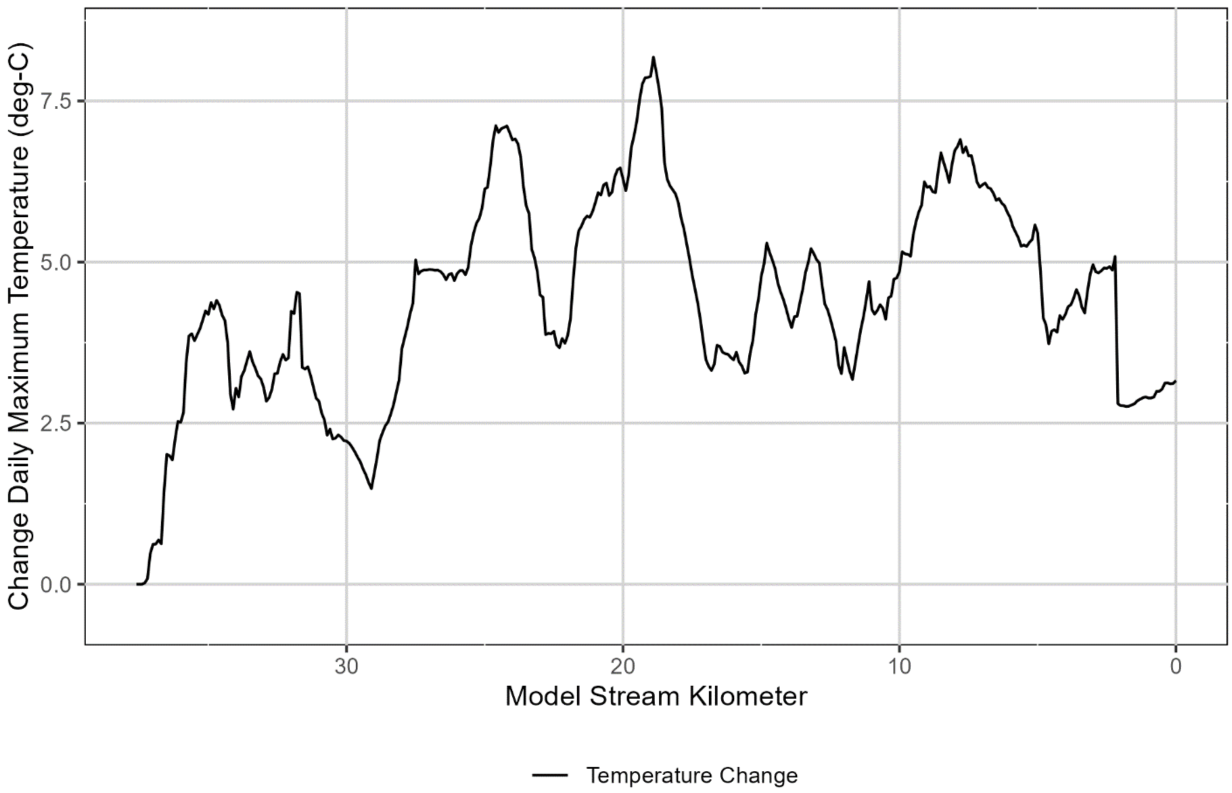


Figure A4.2. Predicted change in daily maximum water temperature in Johnson Creek between Background and Current Conditions scenarios.

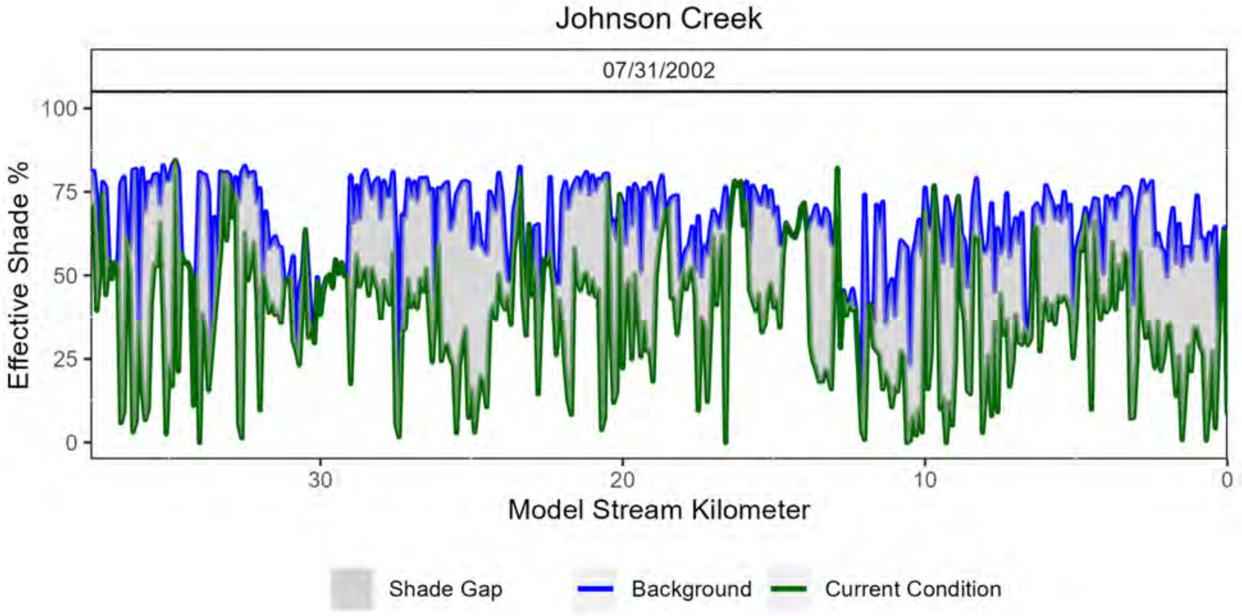


Figure 4.3. Comparison of Current Conditions and Background scenarios effective shade in Johnson Creek.

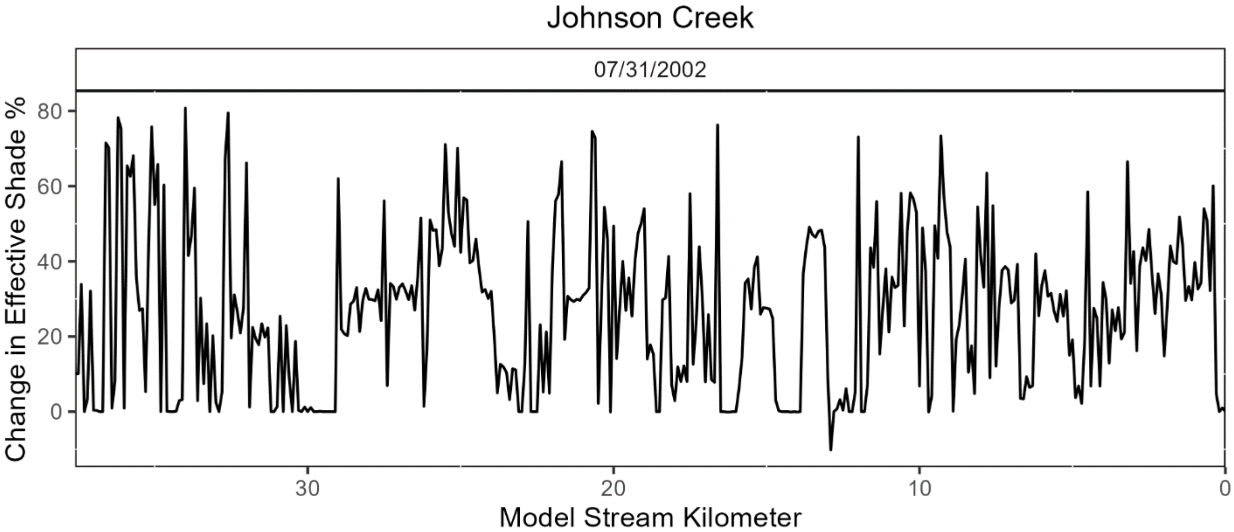


Figure 4.4. Predicted change in effective shade between Tributary Temperatures and Current Conditions scenarios in Johnson Creek.

Tributary Temperatures vs. Current Conditions

The restored tributary temperatures scenario was cooler than the current conditions scenario at almost every point along the mainstem. The median temperature change between the current conditions and the restored tributary temperatures scenarios was greatest at model kilometer 2, where the temperature change was 1.54°C.

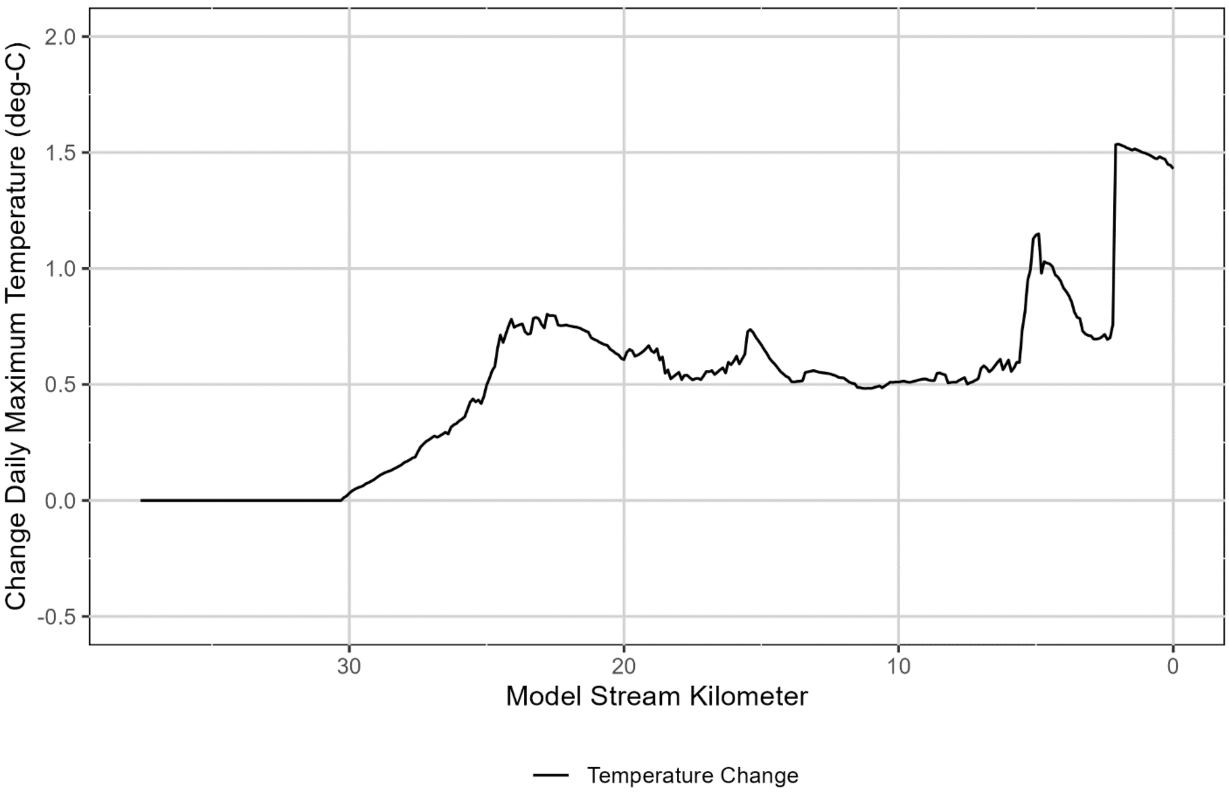


Figure 4.5. Predicted change in daily maximum water temperature between Tributary Temperatures and Current Conditions scenarios in Johnson Creek.

Restored Stream Flow vs. HUA Attaining Stream Flow Reduction

The portion of the HUA that is allocated to water withdrawals (0.05 °C) is attained at the flow reference site on Johnson Creek when the August median flow is reduced by 4%. The flow reference site is located at USGS gage 14211550 Johnson Creek at Milwaukie, OR. The temperature change between the August median flow and the 4% reduced flow scenarios was greatest at model kilometer 25.5, where the temperature change was 0.16°C (Figure A#).

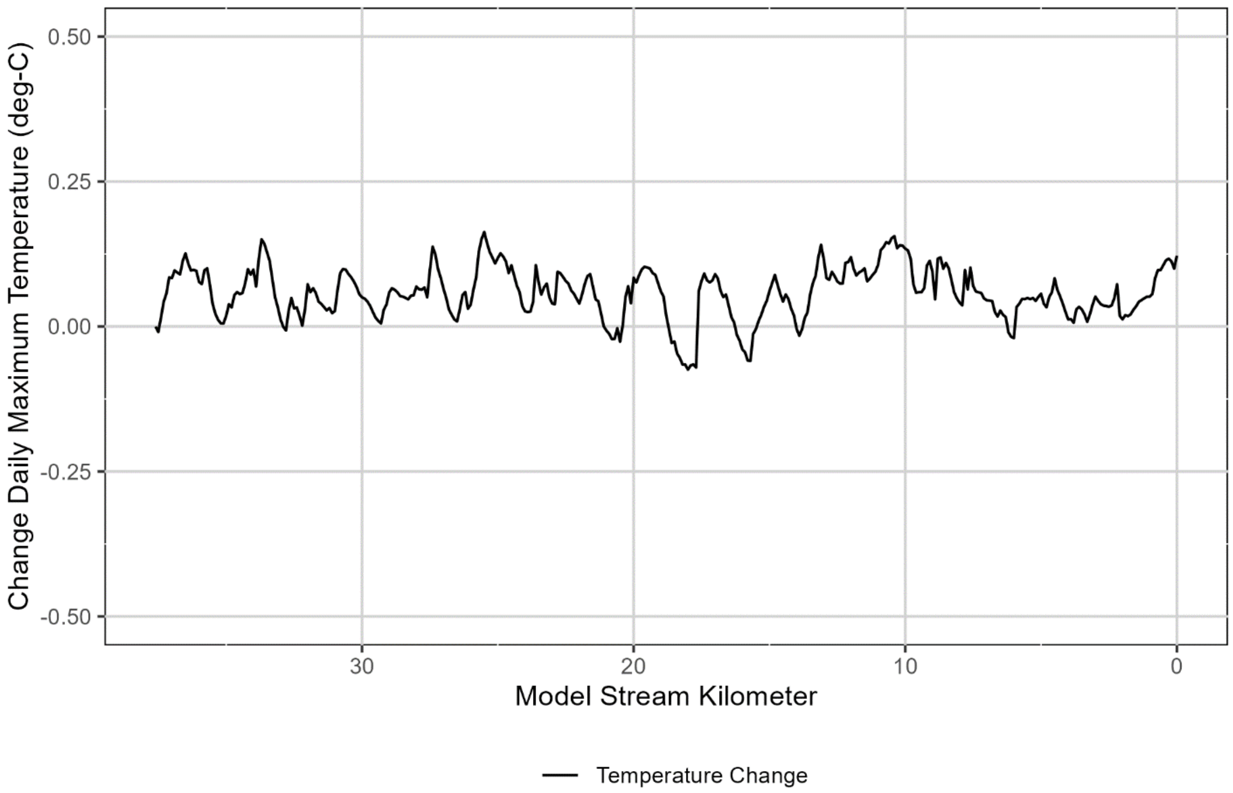


Figure 4.6. Predicted change in daily maximum water temperature between Restored Flow and HUA Attaining Flow scenarios in Johnson Creek.

Restored Stream Flow vs. 20% Stream Flow Reduction

The 20% reduced flow stream temperature is warmer than restored flow stream temperature at almost every point along the mainstem. The median temperature change between the restored flow and the 20% reduced flow scenarios was greatest at model kilometer 25.5, where the temperature change was 0.9°C (Figure A#).

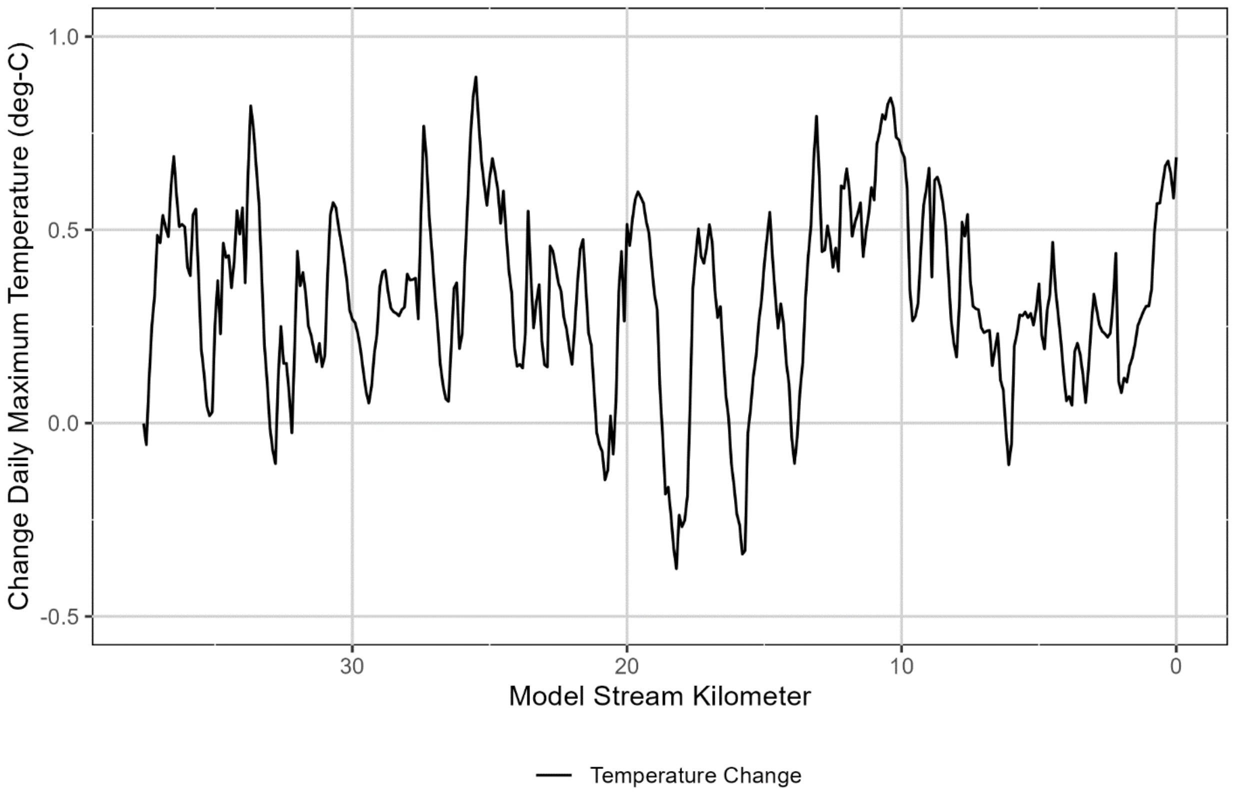


Figure 4.7. Predicted change in daily maximum water temperature between Restored Flow and 20% Reduction Flow scenarios in Johnson Creek.

4.2 Molalla River

Table 4.2 describes the different simulation scenarios for the Molalla River.

Table 4.2 Molalla River model scenario descriptions.

Scenario Name	Description
Current Condition	
No Point Sources	
Wasteload Allocations	
Background	

4.3 Pudding River

Table 4.3 describes the different simulation scenarios for the Pudding River.

Figure # displays the longitudinal water temperature profiles of the different simulation scenarios for the Pudding River.

Table 4.3. Pudding River model scenario descriptions.

Scenario Name	Description
Current Condition	The Pudding River Current Condition Scenario model has the following updates from the current condition calibrated model created to support the original 2008 Molalla Pudding TMDL. 1. Point source discharges were added to the flow data sheet for Gervais STP, Aurora STP and Mt. Angel STP. Flow inputs at these facilities were set at zero since they are not permitted to discharge during the model period. 2. The NPDES permit for JLR authorizes discharge to the Pudding River but based on a review of the DMRs from 2018 - 2020 there were no discharges to the Pudding River during the model period. All discharge was land applied via outfall 004 and therefore flow inputs to the model were set at zero. 3. Flow and temperature inputs for Woodburn WWTP were updated to reflect discharge conditions in August 2020 as reported on the DMRs.
No Point Sources	This scenario evaluates the stream temperature response from removing point source heat load. Water temperature and flow inputs from individually permitted point source discharges within the model extent were removed.
Wasteload Allocations	This scenario evaluates the stream temperature response from the TMDL wasteload allocations. Water temperature and flow inputs from individually permitted point source discharges within the model extent Aurora STP, Gervais STP, and Mt Angel STP were set to zero. Woodburn WWTP effluent temperature was updated to reflect their wasteload allocation. JLR does not discharge to river during the summer so the discharge from outfall 004 (land application) reported on the August 2022 DMR was used as the effluent flow for the WLA scenario. JLR's effluent temperature was calculated to reflect their wasteload allocation.
Background	

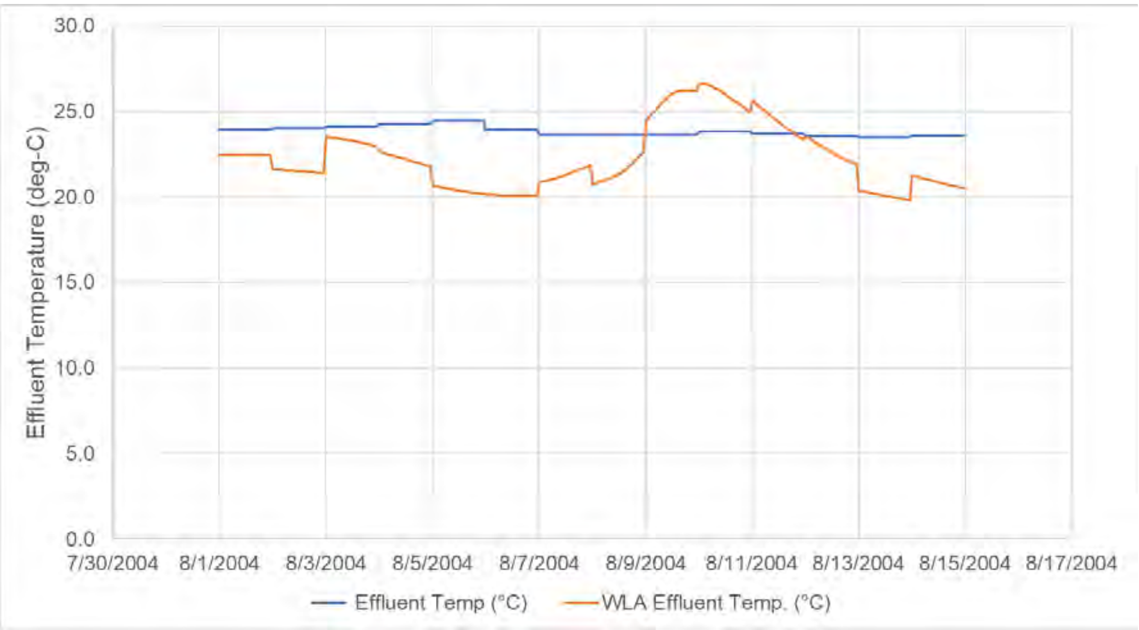


Figure 4.8. Woodburn WWTP August 2020 effluent temperatures and wasteload allocaton model scenario effluent temperature (deg-C).

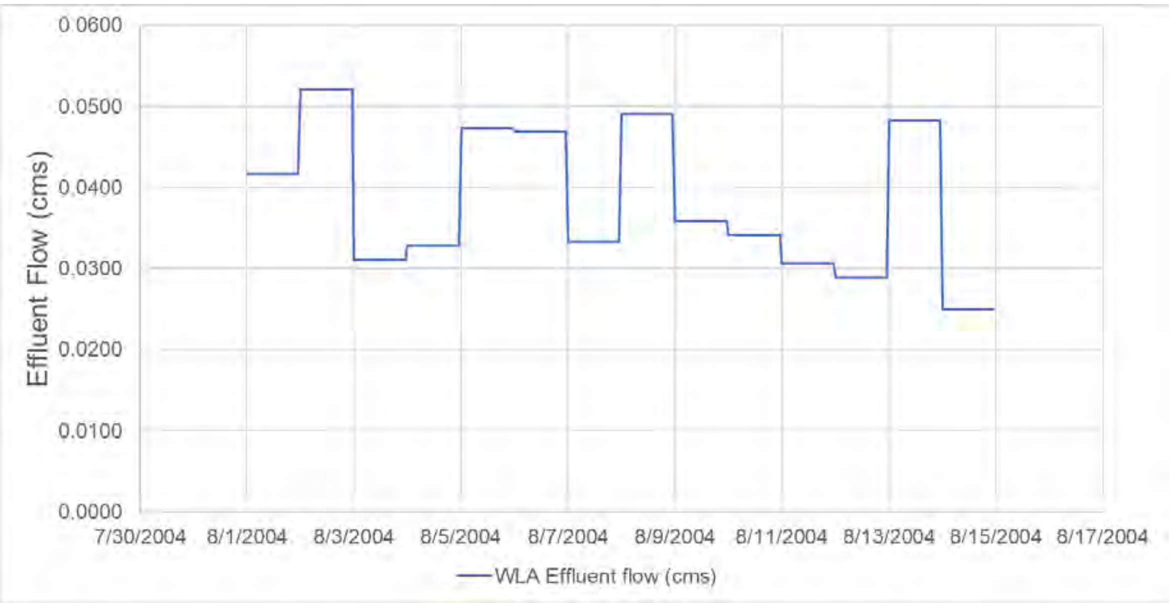


Figure 4.9. Woodburn WWTP wasteload allocation model scenario effluent flow (cms) based upon August 2020 effluent flow reported on DMRs.

Figure 4.10. JLR current condition effluent temperatures at outfall 004 and wasteload allocaton model scenario effluent temperature (deg-C).

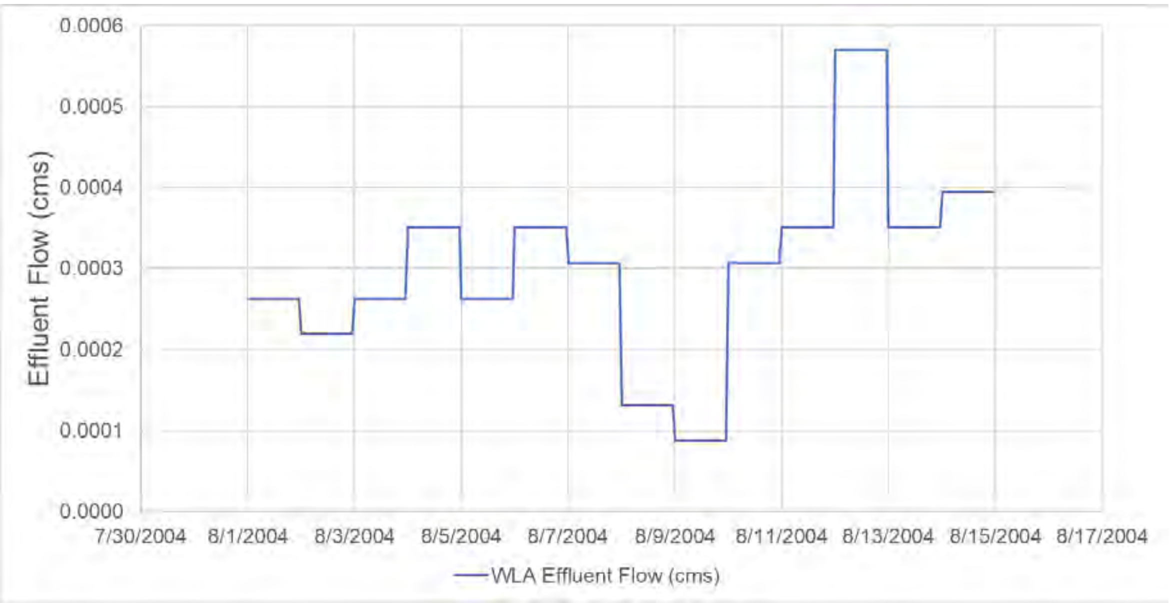


Figure 4.11. JLR wasteload allocaton model scenario effluent flow (cms) based upon August 2020 effluent flow at outfall 004.

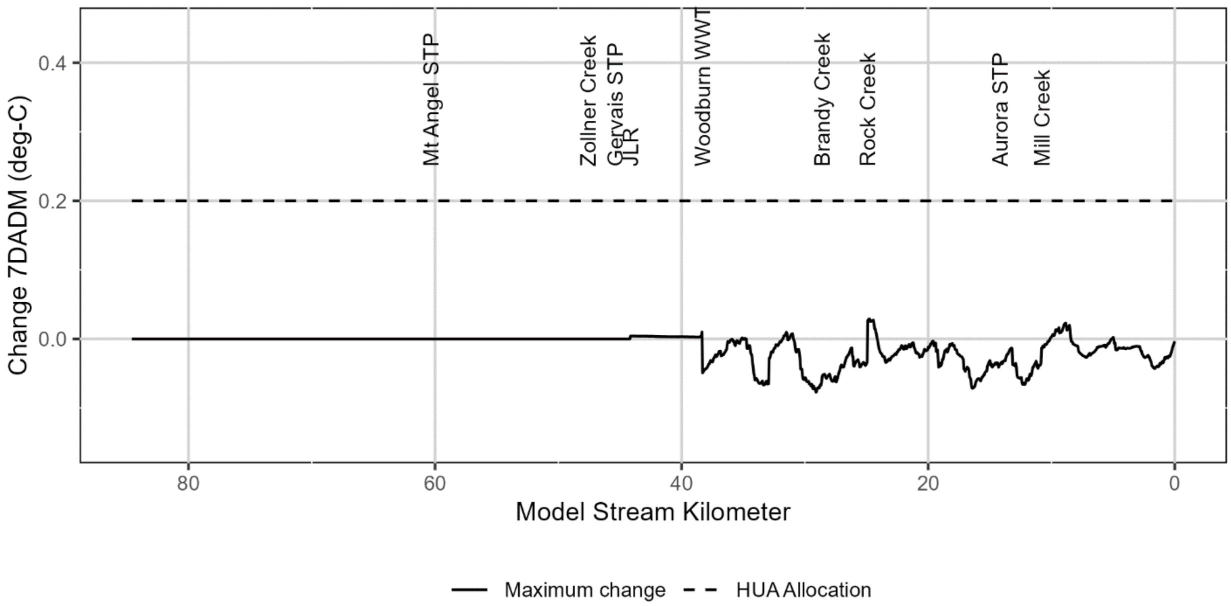


Figure 4.12. Predicted change in 7DADM water temperature between the wasteload allocation scenario and No Point Sources scenarios in the Pudding River.

4.4 Little North Santiam River

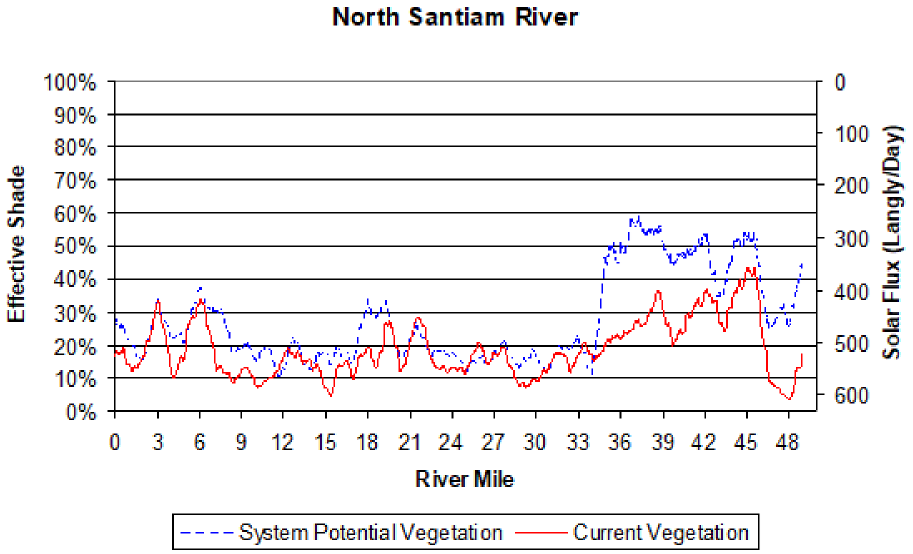


Figure 4.13 One mile averaged effective shade and solar flux for the North Santiam River, North Santiam Subbasin.

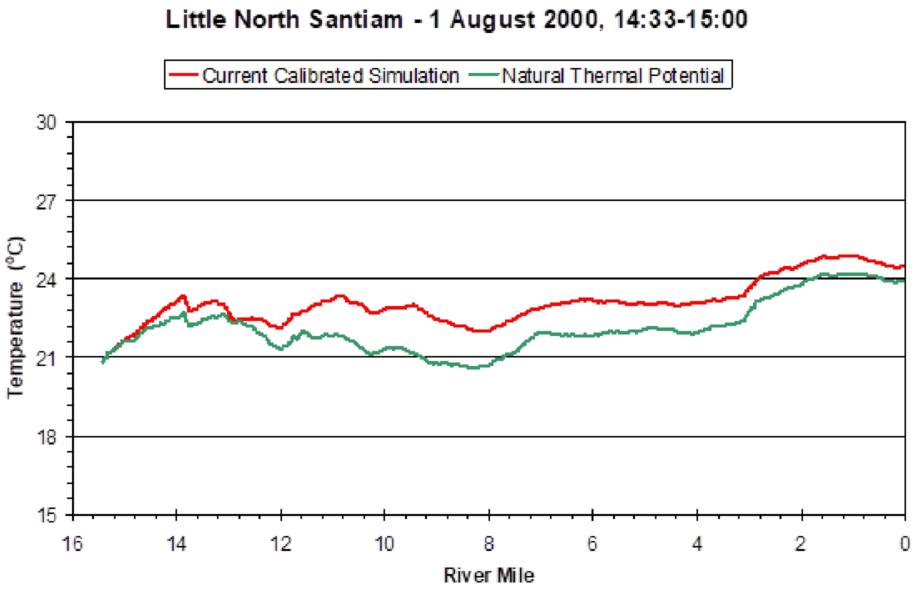


Figure 4.14 Simulation scenario results, Little North Santiam River, North Santiam Subbasin.

4.5 Thomas Creek

Table 4.4. Thomas Creek model scenario descriptions.

Scenario Name	Description
Natural Thermal Potential	Potential Near Stream Land Cover (Vegetation) Conditions
Natural Thermal Potential /No PODS (Thomas Creek Only)	Potential Near Stream Land Cover (Vegetation) Conditions No Water Withdrawals
Natural Thermal Potential /Tribs (Thomas Creek Only)	Potential Near Stream Land Cover (Vegetation) Conditions Tributaries set at Maximum Biological Criteria (16/18°C)
Natural Thermal Potential /No PODs /Tribs (Thomas Creek Only)	Potential Near Stream Land Cover (Vegetation) Conditions Tributaries Maximum Biological Criteria (16/18°C) No Water Withdrawals

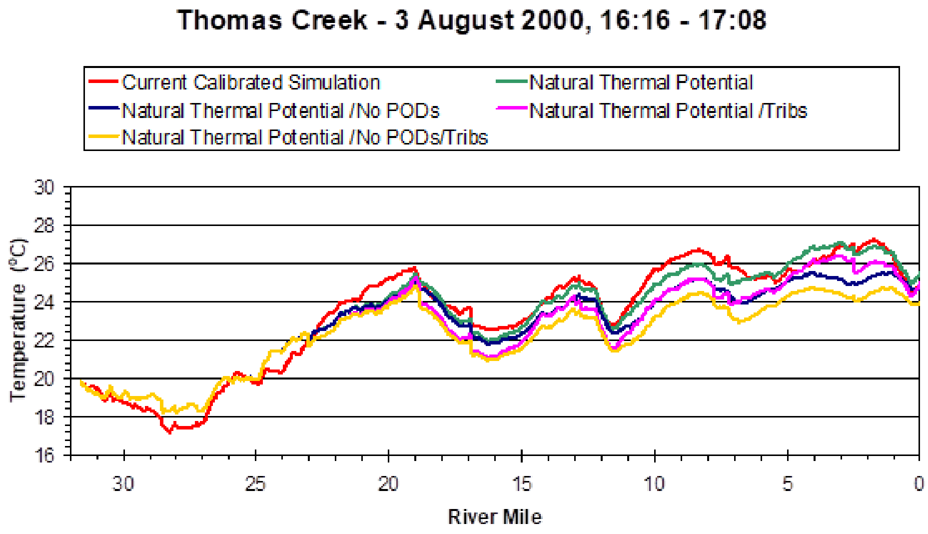


Figure 4.15 Simulation scenario results, Thomas Creek, South Santiam Subbasin.

4.6 Crabtree Creek

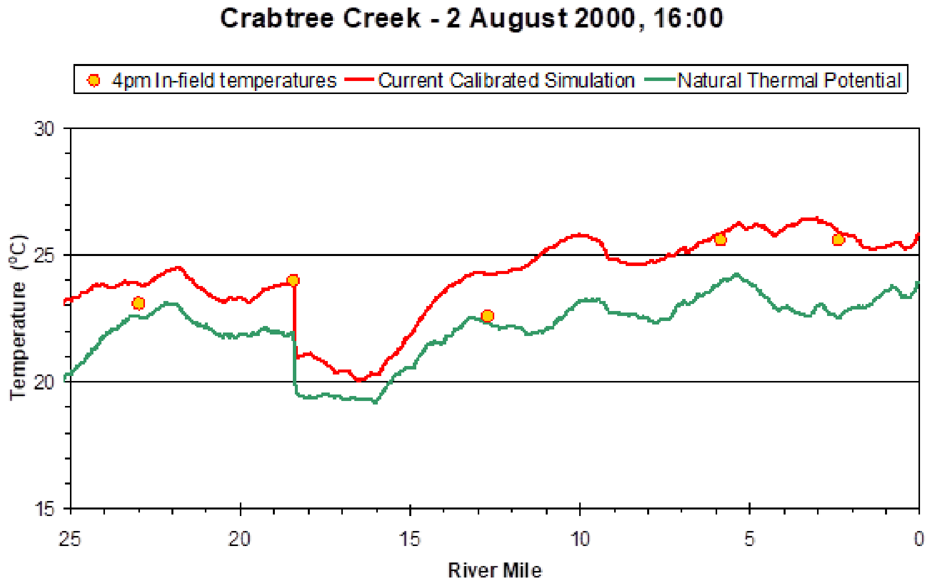


Figure 4.16 Simulation scenario results, Crabtree Creek, South Santiam Subbasin

4.7 Luckiamute River

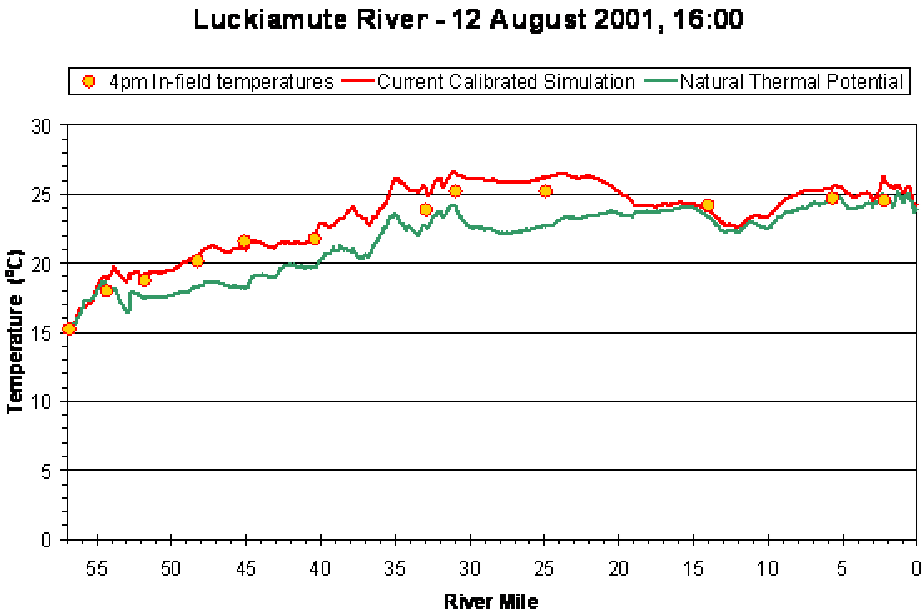


Figure 4.17 Simulation scenario results, Luckiamute River, Upper Willamette Subbasin.

4.8 Mohawk River

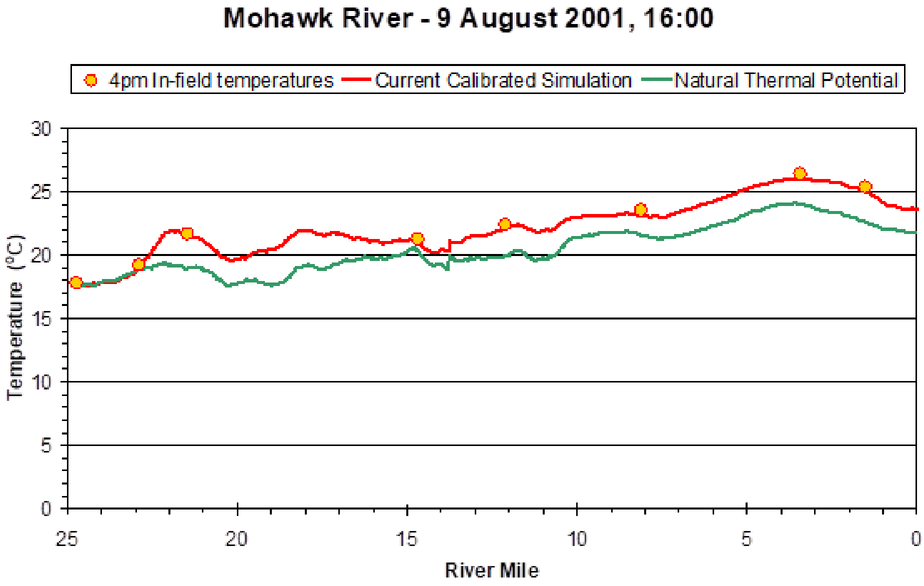


Figure 4.18 Simulation scenario results, Mohawk River, McKenzie Subbasin.

4.9 McKenzie River: Upper

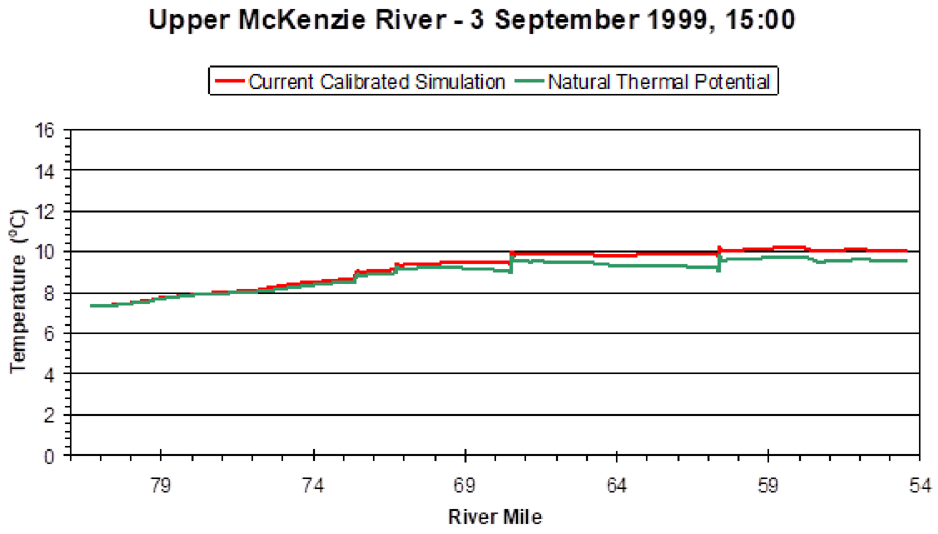


Figure 4.19 Simulation scenario results, McKenzie River (upper), McKenzie Subbasin.

4.10 Coyote Creek

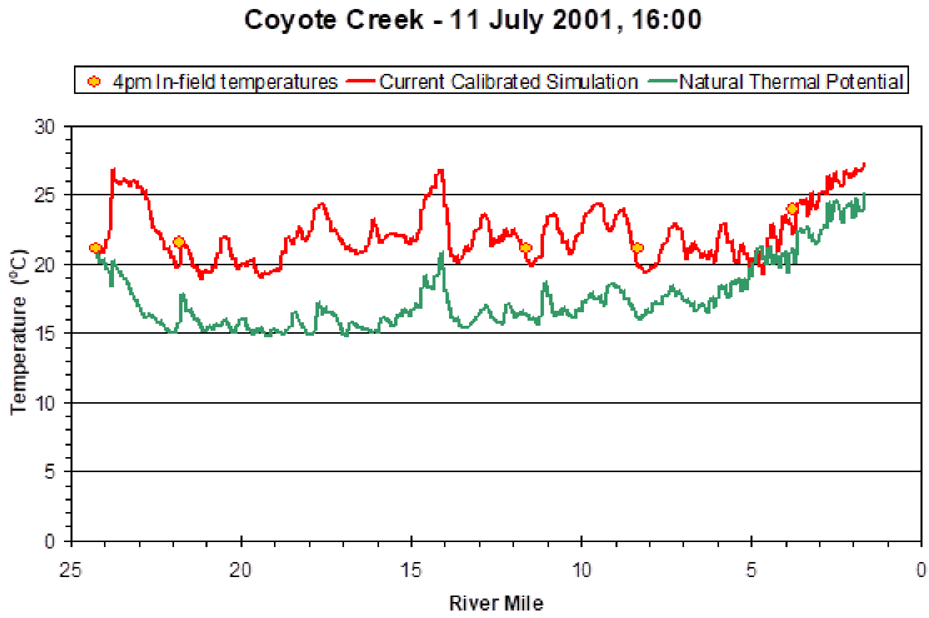


Figure 4.20 Simulation scenario results, Coyote Creek, Upper Willamette Subbasin.

4.11 Mosby Creek

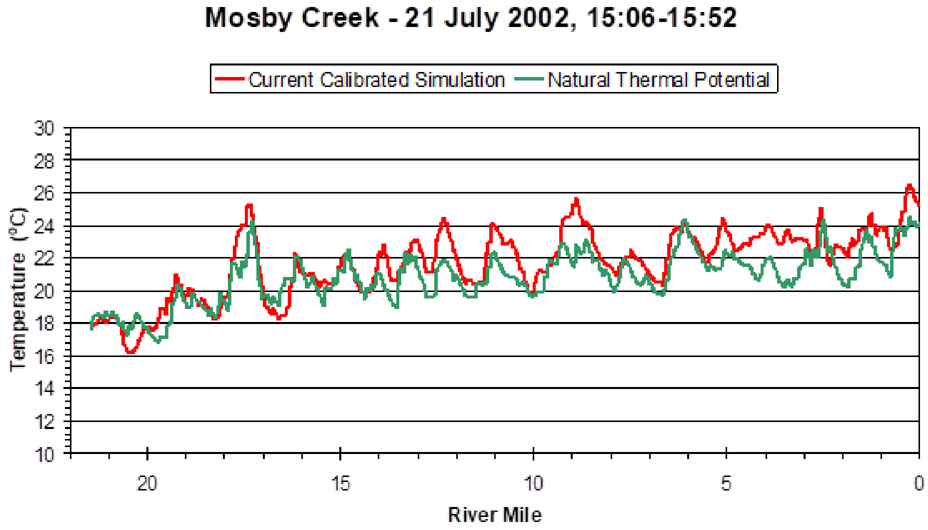


Figure 4.21 Simulation scenario results, Mosby Creek, Coast Fork Willamette Subbasin.

4.12 Southern Willamette shade

A restored vegetation scenario was run using the Southern Willamette effective shade model. The restored vegetation scenario represents the effective shade under site potential vegetation conditions and is the primary basis for the TMDL solar load allocation and effective shade surrogate measure target. The site potential vegetation described in the technical support document Appendix C is the type and mix of vegetation that is assumed to be restored in any given location and is the basis for the TMDL effective shade targets. The type, height, and density of site potential vegetation at any given location is primarily based upon on the Quaternary geologic mapping unit and the relative mix of forest, savanna, and prairie within that mapping unit.

In order to model the site potential effective shade targets across the project area, the appropriate type of site potential vegetation needed to be spatially mapped. To complete this task, python scripts were developed to process a raster layer of the Quaternary geologic geomorphic units and distribute forest, savanna, and prairie landcover types across the landscape following the process laid out in the technical support document Appendix C. Two modifications to the approach needed to be made for the Southern Willamette project. Both modifications relate to the two land cover classes for water: open water and general water.

General water are areas which include natural river channels, lakes, ponds, or wetland areas. Under the site potential vegetation scenario these features continued to stay as water. The 2006 effort mapped these areas using aerial photos and digitized them into a landcover feature class only for the streams that were modeled. The landcover class code used for general water was 3011. For this project general water features needed to be mapped across the entire study area. The National Wetland Inventory (USFWS, 2004) and the National Hydrography Dataset high resolution v2.2 databases contain extensive inventories of water features. These features were incorporated into the geomorphic raster. The assumption is that these spatial data features accurately capture most large river channels, lakes, ponds, or wetland areas that would be classified as “general water”.

The National Wetland Inventory’s classification system (FGDC, 2013) allowed the removal of most anthropogenic related water areas such as impounded reservoirs and gravel mining ponds. Waters classified as Lacustrine (L), Palustrine (P), Marine (M), or Estuarine (E) that are not forested (FO), scrub/shrub (SS), diked/impounded (h), a spoil (s), or excavated (x) were coded as general water. Forested and scrub/shrub classes were removed because they have emergent or overhanging vegetation. The NHD channel areas were used to map the riverine reaches because in some areas it was a little more accurate than NWI where the channel has migrated in recent years, mostly in portions of the Willamette River.

Open water (code 2000) are areas representing the ACOE reservoirs within the boundaries of the original geomorphic feature class and other anthropogenic related water areas that did not meet the criteria for general water. Under the classification rules for site potential vegetation these areas were treated as prairie or savanna vegetation types. In the upland forest zone impounded reservoirs were not mapped. They were classified as upland forest (code 1900). The intent was that these site potential vegetation types would be present along the natural unimpounded channel (rather than present in the river channel). The reservoirs areas were not modeled so no effort was made to map the location of the where the water channel would be located in a natural (unimpounded) scenario.

Mapping the natural channel within impoundments requires additional analysis and attention and is beyond the scope of this project. Therefore, impounded lakes and reservoirs and areas classified as open waters in the geomorphic layer will be treated the same as general water (no change). Just as was done in other scenarios, stream nodes in these areas will be removed from the analysis and excluded when calculating watershed effective shade.

Once the mapping of site potential vegetation was completed the vegetation classification raster was resampled with TTools and input into the model. The effective shade results reflect the TMDL effective shade target for that location. Models results on streams outside of the Willamette Subbasins project area were removed and not included in the results summary.

Results were summarized as the effective shade gap. The effective shade gap is the percentage point difference between the TMDL restored vegetation effective shade (TMDL surrogate measure target) and the current condition shade assessed from the LiDAR. Larger numbers mean greater lack of shade.

Table 4.5 Southern Willamette effective shade results summarized as a mean over the entire model extent.

Mean Assessed Current Condition Effective Shade (%)	Mean Restored Vegetation Effective Shade (%)	Mean Shade Gap (%)	Total Stream Kilometers Assessed	Stream Kilometers with 0%-15% Shade Gap	Stream Kilometers with 16%-25% Shade Gap	Stream Kilometers with 26%-50% Shade Gap	Stream Kilometers with 51%-100% Shade Gap
67	93	26	21281.3	11734.8	1412.8	2481.4	5652.2

The mean shade gap over the entire study area is summarized in Table 4.5. The mean shade gap for each HUC12 subwatershed is presented in Figure 4.18. Results were also stratified by HUC8 subbasins, HUC10 watersheds, designated management agency, DEQ assessment unit ID, and by Oregon Department of Agriculture’s water quality management areas.

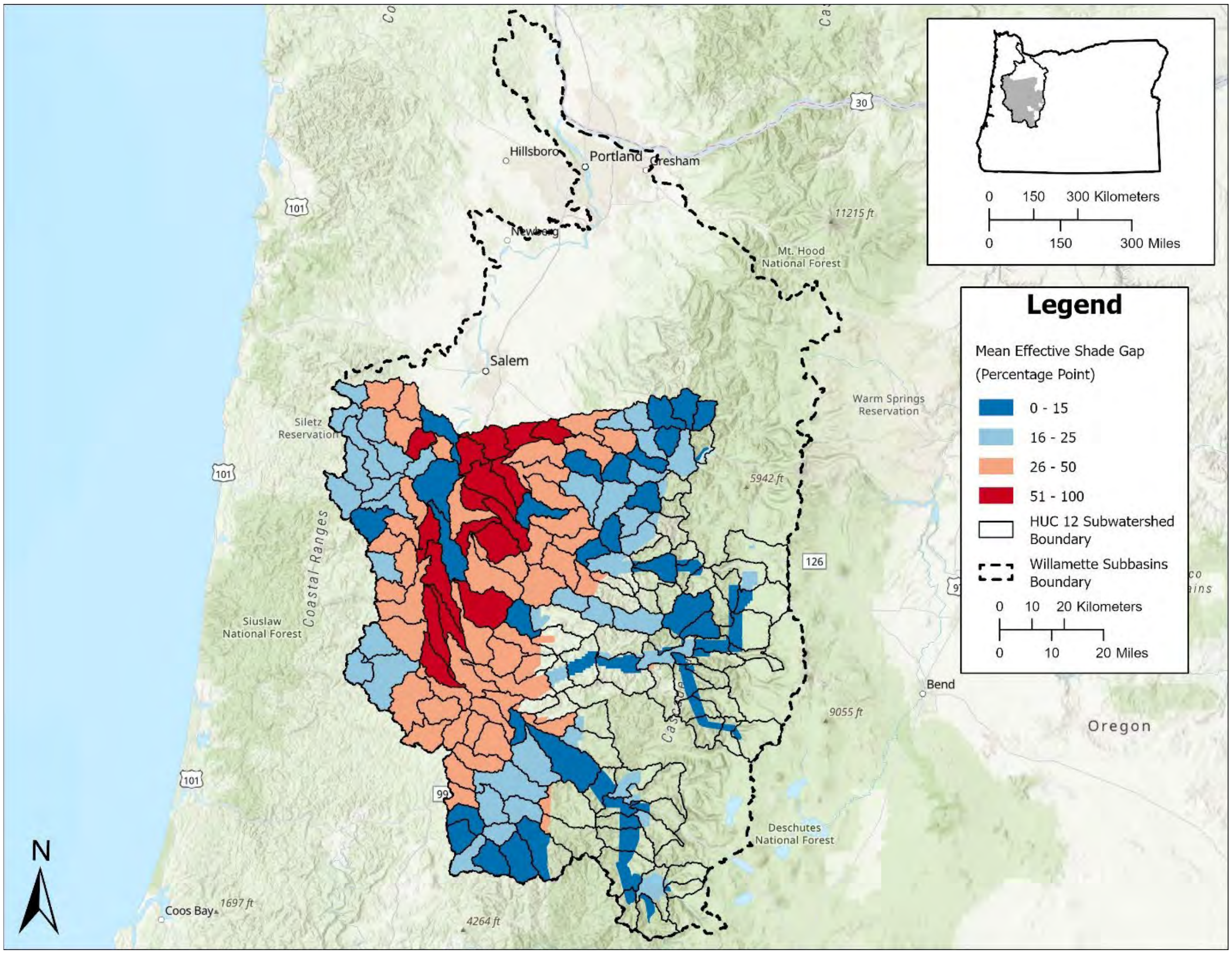


Figure 4.22 Mean effective shade gap for each HUC12 subwatershed within the Southern Willamette Shade model extent.

The results of the modeling indicate that agricultural areas regulated by the Oregon Department of Agriculture have the largest number of assessed stream nodes (2784.8 kilometers out of 4790.6 total assessed kilometers) with mean shade gaps more than 50 percentage. Private non-federal forestlands regulated by the Oregon Department of Forestry has the second largest number of assessed streams nodes with shade gaps more than 50 percentage points (1,898.2 kilometers out of 8,597.7 total assessed kilometers). The Oregon Department of Agriculture and Oregon Department of Forestry also have the largest number of stream kilometers with large shade gaps relative to other DMAs. Most cities have fewer stream miles in their jurisdiction but have much higher proportion of shade gaps that exceed 50 percentage points. For example, all the stream nodes assessed in the cities of Halsey and Harrisburg (1.6 and 0.8 stream kilometers respectively) have shade gaps greater than 50 percentage points. On the opposite end of the spectrum, the federal forestlands managed by the Bureau of Land Management only have 2 percent of the assessed steam nodes (62.4 kilometers out of 2569.5 total assessed kilometers) with shade gaps greater than 50 percentage points. BLM had the fourth highest number of assessed stream nodes. Most of the federal forestlands managed by the USFS were not evaluated because of the lack of LiDAR.

The Muddy Creek-Willamette River Watershed (1709000306) had the largest number of assessed stream nodes (816.4 kilometers out of 1397.9 total assessed kilometers), with effective shade gaps greater than 50 percentage.

5. References

Brown, L.C. and Barnwell, T.O. 1987. The enhanced stream water quality models QUAL2E and QUAL2E-UNCAS: Documentation and user manual. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, Georgia.

DEQ (Oregon Department of Environmental Quality). 2013. “Data validation criteria for water quality parameters measured in the field. DEQ04-LAB-0003-QAG Version 5.0.”

DEQ (Oregon Department of Environmental Quality). 2021. “Quality Assurance Project Plan, Monitoring and assessment for Total Maximum Daily Loads”. DEQ21-LAB-0013-QAPP Version 1.0.

O’Connor, J.E., Sarna-Wojcick, A., Woznikak, K.C., Polette, D.J., Fleck, R.J., 2001. Origin, extent, and thickness of Quaternary geologic units in the Willamette Valley, Oregon; U.S. Geological Survey, Professional Paper 1620.

ODFW (Oregon Department of Fish and Wildlife). 1998. “Willamette Valley land use / land cover map informational report”. https://digital.osl.state.or.us/islandora/object/osl:18785.

PNWERC/ISE (Pacific Northwest Ecosystem Research Consortium Institute for a Sustainable Environment). 1999. “Landuse and Landcover ca. 1990”. Version 121599. http://www.fsl.orst.edu/pnwerc/wrb/access.html.

USFWS (U.S. Fish & Wildlife Service). 2004. National Wetlands Inventory. https://data.nal.usda.gov/dataset/national-wetlands-inventory.

Watershed Sciences. 2008. LiDAR remote sensing data collection: HJ Andrews & Willamette National Forest.

Watershed Sciences. 2009. LiDAR remote sensing data collection. Department of Geology and Mineral Industries. Willamette Valley Phase 1. Oregon.

Watershed Sciences. 2010. LiDAR remote sensing data collection. Department of Geology and Mineral Industries. Yambo study area.

Watershed Sciences. 2012a. LiDAR remote Sensing. Blue River, Oregon. Prepared for USDA Forest Service and the U.S. EPA Western Ecology Division. January 1, 2012.

Watershed Sciences. 2012b. LiDAR remote sensing data collection. Department of Geology and Mineral Industries. Fall Creek. March 28, 2012.

WSI. 2012a. LiDAR remote sensing data collection. Department of Geology and Mineral Industries. Central coast study area. July 31, 2012.

WSI. 2012b. OLC Green Peter LiDAR Report. December 20, 2012

WSI. 2013. OLC Clackamol LiDAR Report.

WSI. 2015. OLC Lane County: Delivery 7 LiDAR Report.

CITY OF PORTLAND
ENVIRONMENTAL SERVICES
1120 SW Fifth Avenue, Suite 613, Portland, Oregon 97204 ▪ Mingus Mapps, Commissioner ▪ Michael Jordan, Director

APPENDIX B
CITY OF PORTLAND MODEL REPORT

TECHNICAL MEMORANDUM

April 14, 2022

TO: TMDL Implementation Program File

FROM: Julia Bond

CC: Kaitlin Lovell, Loren Shelley, Barb Adkins

RE: Riparian Shade Assessment

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1 Introduction

A healthy riparian canopy provides multiple benefits to a stream, including the shading of the stream channel. In the Portland area, the shade provided by riparian vegetation is of particular importance to streams in the summer when water temperatures frequently exceed the conditions needed by salmon and trout to survive. Riparian shade reduces the amount of incoming solar radiation from reaching the stream, which in turn helps prevent the water from warming.

To address excess stream temperatures, Oregon's Department of Environmental Quality (DEQ) developed a total maximum daily load (TMDL) for temperature for the Lower Willamette basin. The temperature TMDL includes load allocations for all perennial streams, including the Columbia Slough, Johnson Creek, and Tryon Creek (DEQ, 2006). The Tualatin River subbasin temperature TMDL applies to the perennial or fish-bearing streams located in the Fanno Creek and Rock Creek basins. The TMDLs use percent effective shade as a surrogate for measuring temperature nonpoint source pollutant loading. Effective shade is the proportion of solar radiation that is attenuated or scattered before reaching the stream. DEQ defines system potential shade as the maximum effective shade possible for a stream reach. System potential shade is achieved when the riparian plant community has reached its mature, undisturbed condition in which vegetation heights are at or near their expected potential, resulting in the maximum effective shade for the stream.

Anthropogenic activities in the Portland area have degraded riparian conditions, resulting in a loss of riparian vegetation and an increase in solar loading. Based on modeling for the 2006 TMDL, the loss of stream shade has resulted in a 25% increase in solar loading to the Columbia Slough mainstem. The increase in solar loading due to the loss of riparian shade, or excess thermal load, to the Johnson Creek mainstem was found to be 51% above system potential shade conditions. The TMDL identifies restoration and protection of riparian vegetation as the primary methods for increasing stream shading and bases the nonpoint source load allocations on achieving system potential shade conditions.

The City and its watershed partners have engaged in riparian restoration activities for several decades. These activities include tree plantings and efforts to revegetate streambanks, as well as maintaining natural areas to promote mature riparian conditions. Monitoring of these projects has demonstrated an increase in streamside vegetation and improved riparian canopy across the Portland area, but these monitoring efforts are not able to assess riparian conditions in a single citywide effort.

The City committed to conducting an effective shade assessment in the City's 2019 TMDL Implementation Plan (Goal ID TIP-01; City of Portland, 2019). This report documents the findings of the effectives shade assessment. Assessing the current level of effective shade along the streams in the Portland area provides insight into the City's progress toward meeting the TMDL nonpoint source load allocation of system potential shade. The results of this assessment are compared to the TMDL goal of system potential shade and can be used to inform the prioritization of areas that would benefit from future riparian restoration.

2 Methods

The effective shade values presented in this memo were calculated using the shade module of Heat Source version 26 (Michie et al., 2021), a computer model used and maintained by DEQ to simulate stream thermodynamics and hydrology (Boyd & Kasper, 2003). The model can be used to calculate the effective shade at any point (or points) along a stream channel for a specified time of the year. The key model parameters used in this assessment are presented in Table 1.

Table 1. Heat Source model parameter values used to calculate effective shade along streams in the Portland area.

Model Parameter	Parameter Value
Model start date	July 1
Model end date	August 31
Model time step	15 minutes
Longitudinal stream sample distance	25 meters
Number of transects per stream node	8
Number of samples per transect	25
Distance between transect samples	3 meters
Cloud cover	0%
Topographic shade angles	East, South, West
Topographic angle sampling distance	Maximum of 10 km

To calculate effective shade, the model relies on GIS inputs that characterize the surrounding topography and land use (including vegetation) that affect the amount of solar radiation that can reach the surface of the modeled stream. For this effort, these GIS inputs were gathered using TTools version

9.0 (Michie, 2021). The GIS inputs used to characterize surrounding land use and topography are listed in Table 2.

Table 2. GIS datasets used to characterize land use surrounding the modeled streams. See the References section for links to complete GIS metadata.

GIS Dataset	Purpose	Source
Stream center lines	Linear feature used to locate the modeling nodes	City of Portland (2010)*
Impervious areas	To construct land cover code for current and future conditions	City of Portland (2017)*
Canopy classification	To construct land cover code for current and future conditions, including specifying canopy density values and future feature heights	Oregon Metro (2016)
Waterbodies	To identify right and left stream bank lines and to construct land cover codes for current and future conditions	City of Portland (2005)*
Wetlands	To construct land cover codes for current and future conditions, including where future canopy growth may occur	City of Portland (2005)*
Management areas	To support modeling scenarios of future conditions with changes limited to areas with environmental protections	City of Portland (1996)*
2007 LiDAR	To characterize the surrounding topography and the heights of the surrounding land use in 2007	City of Portland (2013)
2014 LiDAR	To characterize the surrounding topography and the heights of the surrounding land use in 2014	City of Portland (2015)
2019 LiDAR	To characterize the surrounding topography and the heights of the surrounding land use in 2019	City of Portland (2021)

* Regularly updated GIS layers

The GIS layers in Table 2 were all (where needed) converted to raster datasets. These raster layers were then combined to create unique land cover codes that represent both the features on the landscape (e.g., canopy type, impervious areas, open water, wetlands, etc.) as well as the height above the ground surface of any features (e.g., trees or buildings) at that location. The land cover codes also include whether the area falls within a management area with environmental restrictions that limit riparian disturbances. Separate land cover layers were created for each of the three evaluated time periods (2007, 2014, and 2019). The raster layers representing land cover codes had a pixel resolution of 3 feet.

Stream channel widths were characterized based on field measurements from stream surveys conducted by the Oregon Department of Fish and Wildlife (ODFW). ODFW staff conducted stream habitat surveys during the summers of 2019 and 2020 throughout the Portland area (ODFW 2019, 2020). For this shade modeling effort, the stream channel widths measured by ODFW were used to generate a variable buffer around the stream center line to represent the right and left banks of the channel.

As noted above, TTools was used to sample the area surrounding each modeling node (Figure 1). The TTools sampling provided information on the adjacent topography, land cover, and feature heights above the ground surface within 75 meters of the center of the stream with a sample spacing of 3 meters.

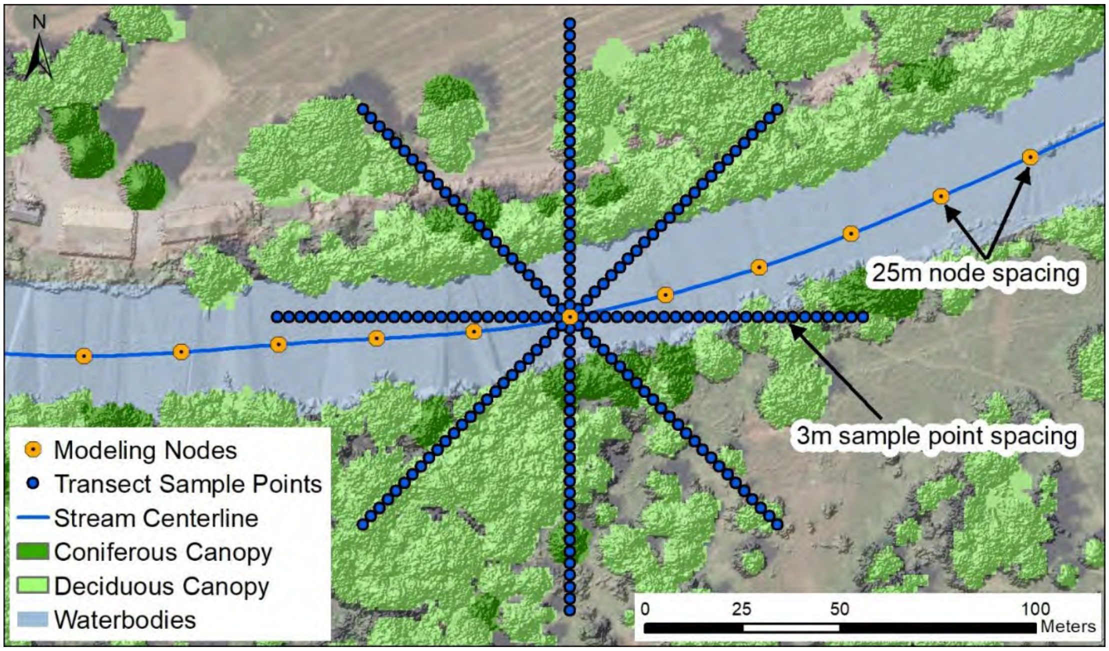

Figure 1. Example of the GIS sampling approach used to calculate effective shade. Effective shade values are calculated for each of the orange modeling nodes (25 meter spacing between nodes). The blue transect sample points (3 meter spacing between points) are used to characterize the surrounding land use and serve as inputs to the model.

2.1 *Modeling Scenarios*

Six modeling scenarios were evaluated as part of the assessment. The scenarios aim to represent the conditions on the landscape during different years, as well as estimate future conditions based on changes in vegetation.

Three of the modeling scenarios were designed to represent riparian canopy conditions based on available LiDAR collected in 2007, 2014, and 2019. These three scenarios represent observed canopy conditions. Three other modeling scenarios were developed to represent possible future riparian canopy conditions. The scenarios are described more fully in Table 3.

Table 3. Shade modeling scenarios.

Model Scenario	Description
Topography Only	Topographic conditions with no vegetation. Represents existing topographic conditions in 2019.
2007 Canopy	Riparian vegetation conditions characterized by 2007 LiDAR tree heights. Represents existing conditions in 2007.
2014 Canopy	Riparian vegetation conditions characterized by 2014 LiDAR tree heights. Represents existing conditions in 2014.
2019 Canopy	Riparian vegetation conditions characterized by 2019 LiDAR tree heights. Represents existing conditions, in 2019.
Maximum System Potential	A hypothetical future condition representing the maximum projected riparian shade. All existing vegetation from 2019 is assumed to have reached mature

Model Scenario	Description
	heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy.
System Potential within Management Areas	A hypothetical future condition representing the maximum projected riparian shade within only areas protected by existing policies or regulations. All current vegetation within management areas is assumed to have reached mature heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy in these management areas. No change to the 2019 conditions outside of the management areas.
System Potential within Management Areas + Canopy Loss in Unprotected Areas	A hypothetical future condition representing the maximum projected riparian shade within only areas protected by existing policies or regulations and complete loss of tree canopy outside of these protected areas. All current vegetation within management areas is assumed to have reached mature heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy in these management areas. Outside of the management areas, tree heights are set to zero.
System Potential within Portland's p-zone + 2019 canopy in c-zone	A hypothetical future condition representing the maximum projected riparian shade within only areas in Portland covered by Portland's Environmental Protection overlay zones (p-zone) and management areas outside of Portland. All current vegetation within p-zones is assumed to have reached mature heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy in these management areas. Management areas covered by Portland's Environmental Conservation overlay zones (c-zone) are characterized by 2019 canopy conditions. No change to the 2019 conditions outside of the management areas.
System Potential within Portland's p-zone + no canopy in c-zone	A hypothetical future condition representing the maximum projected riparian shade within only areas in Portland covered by Portland's Environmental Protection overlay zones (p-zone) and management areas outside of Portland. All current vegetation within p-zones is assumed to have reached mature heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy in these management areas. In the management areas covered by Portland's Environmental Conservation overlay zones (c-zone), tree heights are set to zero. No change to the 2019 conditions outside of the management areas.

As noted above, system potential shade is achieved when the riparian plant community has reached its mature, undisturbed condition. The modeling scenarios that represent system potential include the following important assumptions:

- System potential tree heights
    - Deciduous canopy is assumed to have a mature height of 100 feet
    - Coniferous canopy is assumed to have a mature height of 150 feet
    - Unidentified tree canopy (or no current tree canopy) is assumed to be deciduous and will have a mature height of 100 feet
- Open water remains unchanged in terms of feature heights (vegetation overhanging the stream channel is assumed to grow as above)
- Vegetation heights within emergent wetlands are represented with 2019 LiDAR heights, no future growth is assumed

- Buildings are unchanged in terms of feature heights (vegetation overhanging a building is assumed to grow as above)
- Streets are unchanged in terms of feature heights (vegetation overhanging a street is assumed to grow as above)
- Tree planting possible on parking lots and the scenarios assume future mature tree heights as above
- Areas with no identified land use (no canopy, impervious area, waterbody, or wetland) are assumed to have a future condition of mature deciduous trees

2.2 *Model Extent*

The focus of this modeling effort was limited to the perennial streams within Portland and the immediate area. To streamline the modeling, the area was divided into two model runs, representing: (1) streams east of the Willamette River, and (2) streams west of the Willamette River. A map of the modeled stream reaches and a list of modeling nodes is included in the Appendix.

2.3 *Model Calibration*

A key parameter in the shade calculation is the canopy density value. Streamside vegetation does not attenuate 100% of the light that passes through it, only a portion of it. The canopy density parameter in the model represents the proportion of incoming solar radiation that is blocked by a section of riparian vegetation. The canopy density values used in the initial model runs were based on the vegetation characteristics described in the Lower Willamette temperature TMDL (DEQ, 2006) and included a 75% density value for deciduous vegetation and an 80% density value for coniferous vegetation.

The canopy density value plays an important role in the effective shade calculation, as such it was important to evaluate how well the density value reflected conditions on the ground. The data available for calibration was limited to canopy cover measurements collected from the center of the stream channel using a densiometer (ideally, canopy cover measurement from within the riparian area itself would be used for calibration, however, these data were not available). Densiometer values were recorded as part of the City's watershed monitoring program (Portland Area Watershed Monitoring and Assessment Program) and the bureau's Restoration Monitoring Program. Densiometer readings were collected and converted canopy cover using the methods of Lemmon (1957). A complete list of canopy cover values used in the model calibration are included in the Appendix.

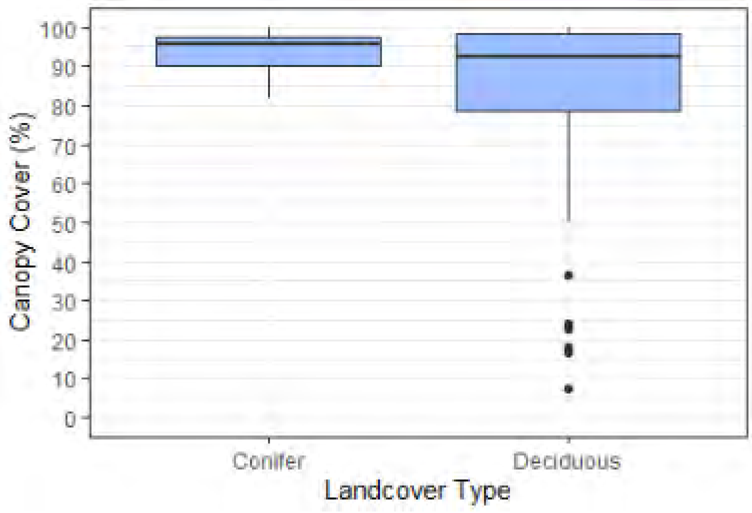

Figure 2. Distribution of canopy cover values measured in the field at the center of the stream for the two major canopy types.

The measured canopy cover values were typically substantially higher than the initial density values, particularly in riparian areas dominated by conifers (Figure 2). For the purposes of this assessment, the 25th percentile canopy cover values were used as the canopy density value in the model to better reflect measured field conditions. As such, both density values were increased, with the density value for deciduous canopy increased to 78% and the density for coniferous canopy increased to 90%.

3 Results

Effective shade was modeled for all streams from July 1 to August 31 at a 15-minute timestep (Table 1). These results have been summarized as the July–August mean at each modeling node. This summer time period represents the period where stream temperatures in Portland tend to be highest. The following sections summarize the effective shade results for the different streams in the Portland area for all six modeling scenarios.

3.1 Johnson Creek

Effective shade varied along the modeled streams in the Johnson Creek watershed. The conditions along the smaller tributaries located west of the Kelley Creek confluence (e.g. Deardorff, Mitchell, and Wahoo creeks) produced high amounts of effective shade, with most reaches achieving approximately 90% of system potential shade in 2019 (Table 4). The highly urbanized Crystal Springs Creek differed from these other tributaries, with conditions in 2019 achieving approximately 70% of system potential.

Table 4. Mean effective shade results for the six model scenarios for the mainstem of Johnson Creek and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	**Total Length (km)**	**Mean Width (m)**	**Mean Effective Shade (%)**					
			2007	**2014**	**2019**	**Max System Potential**	**System Potential in Management Areas**	**System Potential in Management Areas + Loss**
Mainstem								
Johnson Creek 0-10 km	10.0	7.6	53.0	63.3	61.9	80.9	77.8	77.0
Johnson Creek 10-20 km	10.0	7.4	59.7	64.7	66.7	82.4	80.3	79.5
Johnson Creek 20-30 km	10.0	9.2	59.6	65.5	65.6	85.0	84.9	84.9
Johnson Creek 30-43 km	12.6	4.5	59.8	64.8	66.9	85.0	84.0	83.7
Tributaries								
Badger Creek	3.9	1.9	75.4	77.2	76.6	89.0	87.2	86.1
Butler Creek	2.7	1.3	74.9	79.3	78.2	85.9	84.7	84.3
Clatsop Creek	2.3	0.9	84.8	87.8	86.6	90.7	89.9	88.4
Crystal Springs	3.9	9.1	39.2	47.3	51.1	71.4	68.1	67.6
Deardorff Creek	1.7	1.5	83.0	85.9	85.3	89.7	88.5	87.7
Errol Creek	0.6	1.3	61.6	68.7	50.4	82.8	75.7	59.8
Frog Creek	1.5	0.7	74.7	79.8	78.7	88.3	82.4	79.4
Indian Creek	1.5	0.7	69.2	79.7	81.0	88.2	85.2	83.2
Jenne Creek	2.0	0.6	69.9	73.2	72.7	88.7	86.3	82.9
Kelley Creek	7.2	2.2	70.2	77.8	76.5	89.6	88.4	87.0
Mitchell Creek	3.1	1.2	76.2	78.2	75.0	90.2	88.9	87.7
Sunshine Creek	6.7	1.9	55.6	58.4	59.1	87.1	84.5	84.0
Veterans Creek	2.1	1.3	70.3	75.6	75.4	87.6	86.0	84.2
Wahoo Creek	1.1	1.3	89.3	91.0	90.6	92.8	92.7	92.6

Conditions along the mainstem of Johnson Creek were variable in 2019 (Figure 3), with few reaches achieving close to system potential shade. Along the mainstem, 2019 conditions were within approximately 78% of system potential.

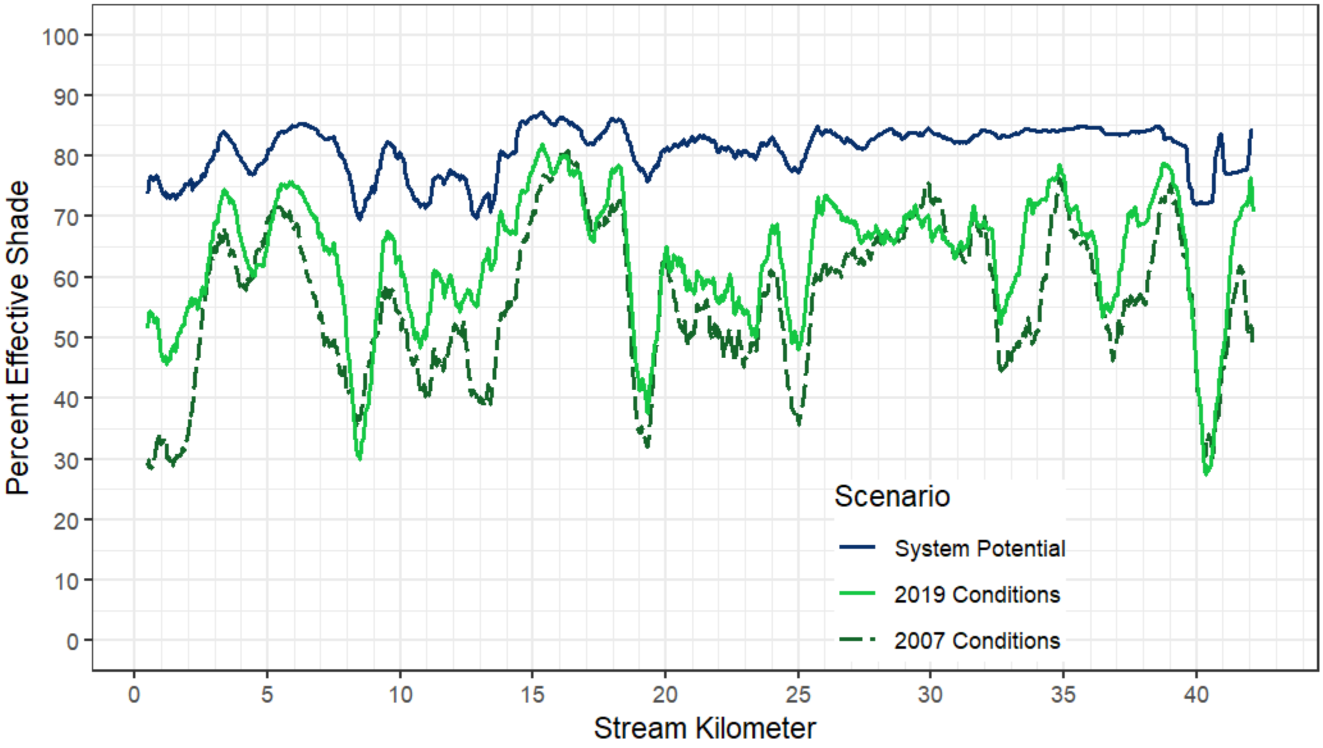

Figure 3. Johnson Creek effective shade scenarios for 2007, 2019, and system potential. Results are presented as 1000 meter rolling averages centered on the reporting node.

3.2 *Columbia Slough*

The wide reaches of the Lower Columbia Slough generally had the lowest values of effective shade in the watershed, 13.3% in 2019, while many of the narrower reaches had substantially more effective shade (Table 5). The results from the system potential scenarios highlight what is possible along these different reaches, emphasizing how the wide channels of Buffalo and the Lower Slough are more difficult to shade. Even with their low effective shade values, both reaches are currently achieving approximating 60% of the shade that is possible along that reach.

Table 5. Mean effective shade results for the six model scenarios for the mainstem of the Columbia Slough and its tributaries and side channels. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	**Total Length (km)**	**Mean Width (m)**	**Mean Effective Shade (%)**					
			2007	**2014**	**2019**	**Max System Potential**	**System Potential in Management Areas**	**System Potential in Management Areas + Loss**
Lower Slough	13.9	51.2	6.4	13.2	13.3	21.0	20.7	20.4
North Slough	1.4	23.4	22.7	35.9	36.4	57.1	57.1	57.1
Blind Slough	0.5	37.8	16.4	26.1	27.3	37.4	37.4	37.4
Wapato Wetland	1.7	34.5	5.0	25.1	25.0	38.6	35.8	33.9
Middle Slough	11.3	15.7	19.2	46.3	44.4	67.3	67.1	67.1

Stream	**Total Length (km)**	**Mean Width (m)**	**Mean Effective Shade (%)**					
			2007	**2014**	**2019**	**Max System Potential**	**System Potential in Management Areas**	**System Potential in Management Areas + Loss**
Buffalo Slough	1.5	47.8	19.3	11.7	13.4	24.1	23.9	23.9
Whitaker Slough	5.5	5.5	14.3	37.2	39.5	54.3	53.3	53.1
Upper Slough	4.6	17.7	10.2	20.4	17.6	45.0	44.7	44.6
Warren Slough	1.1	8.9	23.8	76.6	75.6	83.9	83.7	83.6
Wilkes Creek	1.6	0.9	17.8	61.4	53.8	84.0	76.3	72.7

Conditions along the Upper Slough in 2019 were furthest from system potential conditions (Figure 4). Despite having a mean channel width simliar to that of the Middle Slough, the effective shade in 2019 represented less than 40% of what is possible for that reach. Generally, the amount of shade along the waterways in the Columbia Slough watershed has increased since 2007. With the exception of the Upper Slough, all of the waterways achieved over half of system potential shade in 2019.

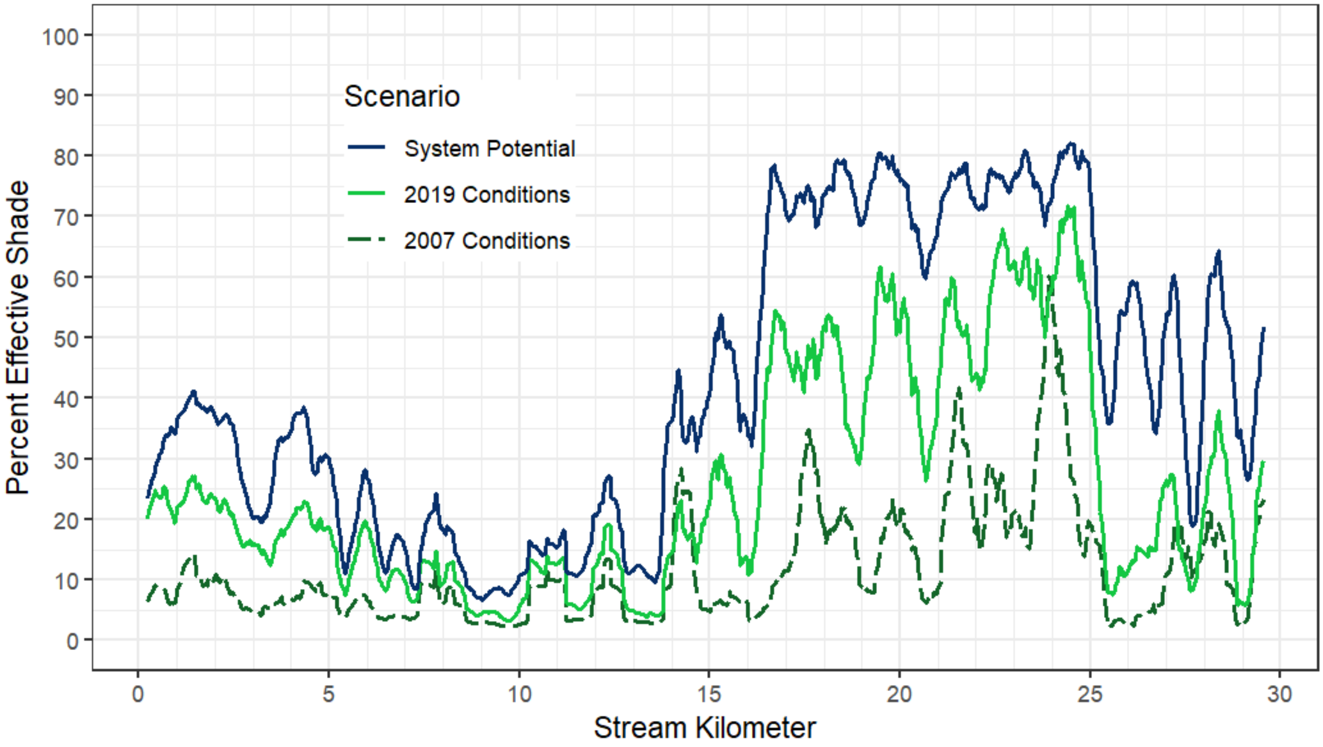

Figure 4. Columbia Slough effective shade scenarios for 2007, 2019, and modeled system potential. Results are presented as 500 meter rolling averages centered on the reporting node.

3.3 *Tryon Creek*

The streams within the Tryon Creek watershed are well shaded. In 2019, the modeled effective shade along all of the reaches was at least 90% of system potential, with some reaches in the Tryon Creek Natural Area achieving more than 97% of system potential in 2019.

Table 6. Mean effective shade results for the five model scenarios for the mainstem of Tryon Creek and its tributaries. Effective shade results from 2007 are not included due to concerns related to the accuracy of the available LiDAR used to characterize canopy conditions in 2007. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	**Total Length (km)**	**Mean Width (m)**	**Mean Effective Shade (%)**				
			2014	**2019**	**Max System Potential**	**System Potential in Management Areas**	**System Potential in Management Areas + Loss**
Arnold Creek	3.3	1.5	90.8	90.5	92.3	92.1	92.1
Falling Creek	2.4	1.2	78.8	80.4	86.8	82.2	77.8
Nettle Creek	2.6	1.9	82.0	81.1	90.2	86.3	83.1
Park Creek	1.2	1.4	89.9	88.8	90.8	90.7	90.7
TCNA Tributaries	4.9	0.9	89.8	88.4	91.4	91.3	91.1
Tryon Creek Tributaries	1.3	1.1	83.2	84.9	88.9	84.3	76.5
Tryon Creek	7.5	3.9	82.2	80.1	89.0	86.8	84.1

* TCNA: Tryon Creek Natural Area

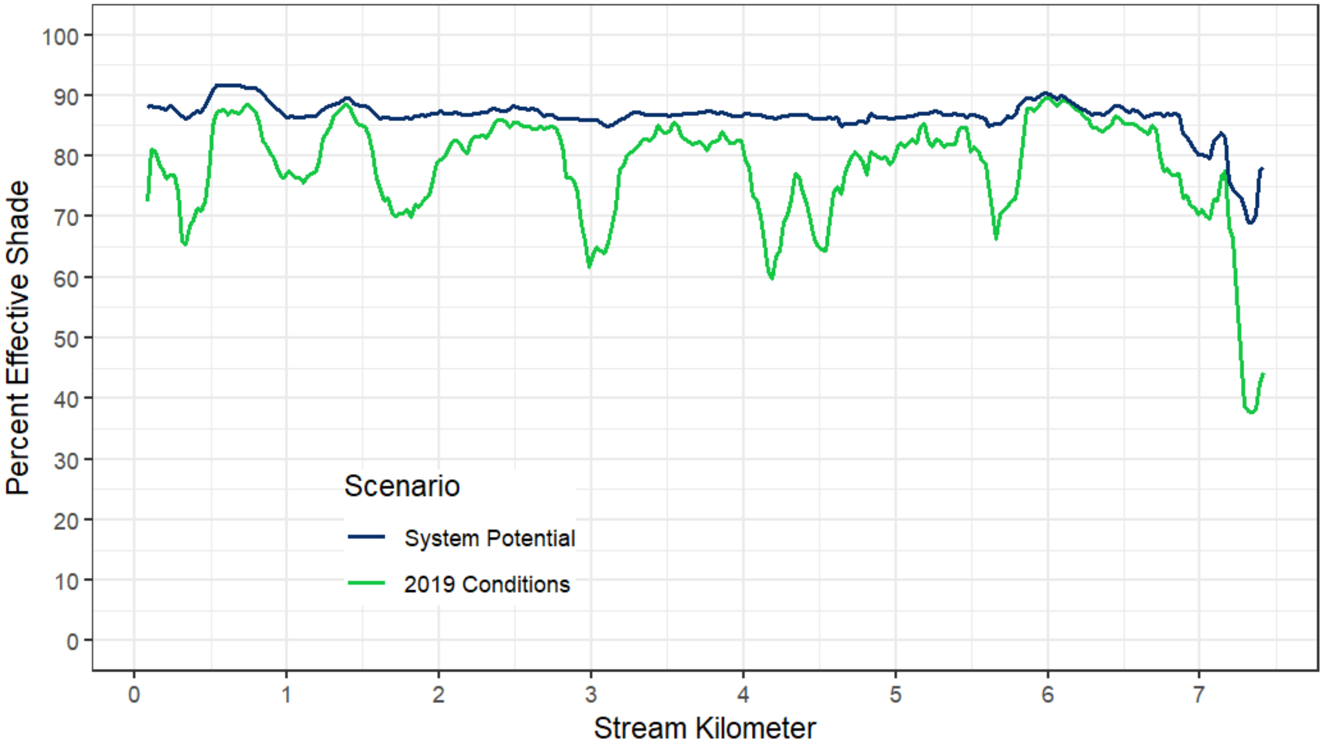

Figure 5. Mainstem Tryon Creek effective shade scenarios for 2019 and system potential. Results are presented as 200 meter rolling averages centered on the reporting node. The 2007 scenario is not included here due to concerns related to the accuracy of the available LiDAR used to characterize canopy conditions in 2007.

3.4 *Fanno Creek*

Fanno Creek and its tributaries in Portland are well shaded. Conditions in 2019 achieved over 85% of system potential along all of the modeled reaches, with conditions along some of the small tributaries, such as Columbia and Lowell creeks, achieving over 97% of system potential.

Table 7. Mean effective shade results for the six model scenarios for the mainstem of Fanno Creek in Portland and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	**Total Length (km)**	**Mean Width (m)**	**Mean Effective Shade (%)**					
			2007	**2014**	**2019**	**Max System Potential**	**System Potential in Management Areas**	**System Potential in Management Areas + Loss**
Fanno Creek	5.8	2.7	49.5	77.2	77.7	86.8	81.5	77.5
Ash Creek	6.6	1.6	54.9	72.5	72.8	84.2	79.3	77.0
Ash Creek South Fork	3.3	1.2	71.4	80.3	80.1	88.7	84.2	77.5
Columbia Creek	1.9	1.2	55.7	85.5	84.3	90.6	86.6	82.2
Ivey Creek	1.9	0.6	52.2	83.1	82.6	89.2	85.5	81.2
Lowell Creek	2.2	0.6	51.7	87.2	87.4	91.1	88.6	86.6
Pendleton Creek	1.8	0.7	46.4	78.0	77.3	86.8	82.7	79.9
Restoration Creek	0.6	0.7	51.3	76.0	74.5	88.3	73.6	67.4
Sylvan Creek	4.5	1.2	37.8	76.5	75.9	88.5	84.4	74.9
Vermont Creek	3.4	3.1	43.1	76.5	77.1	87.0	83.0	80.3
Woods Creek	4.7	4.3	50.4	80.9	80.5	88.8	85.9	77.3

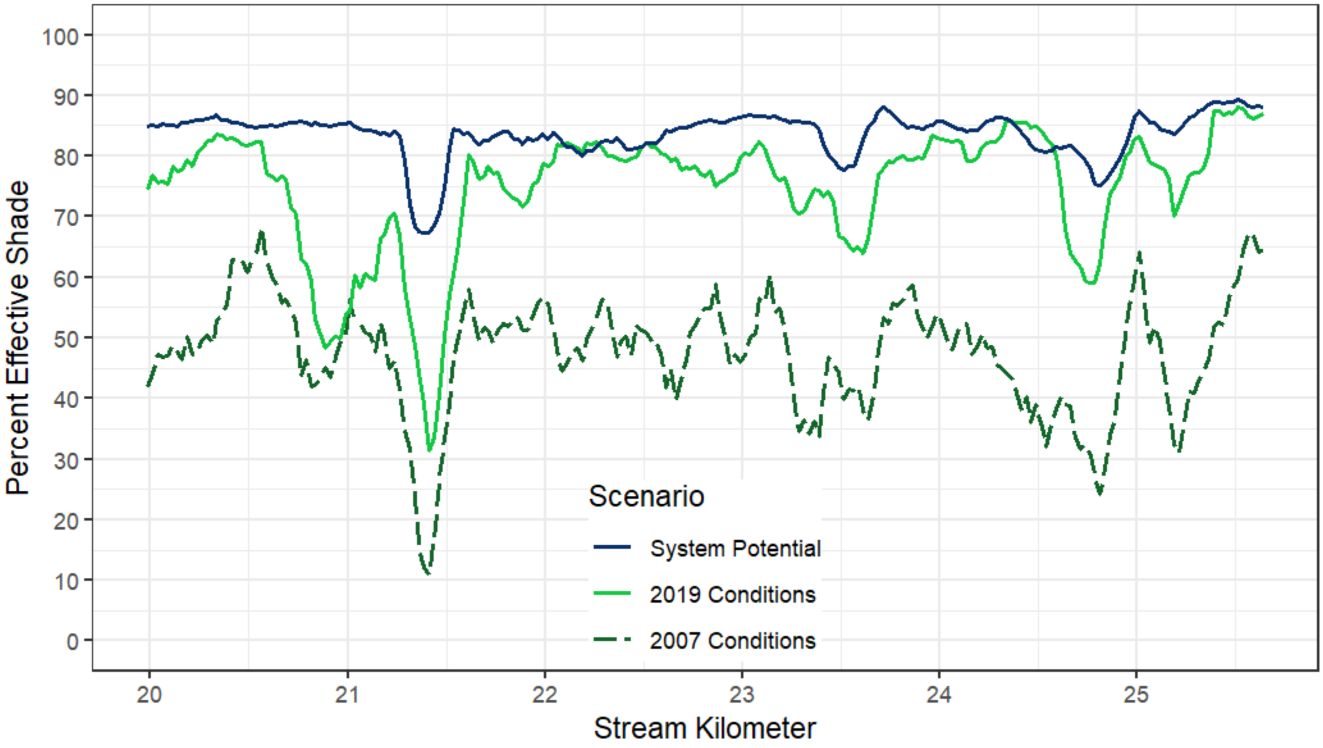

Figure 6. Fanno Creek effective shade scenarios for 2007, 2019, and system potential. Results are presented as 200 meter rolling averages centered on the reporting node. Results are presented for the mainstem of Fanno Creek from the confluence of Vermont Creek to SW 25th Ave.

3.5 *Westside Willamette Streams*

Many of the small streams draining to the Willamette River on the westside (the area referred to as the Tualatin Mountains in the Lower Willamette temperature TMDL) are located in the well-forested Forest Park. Conditions in 2019 for most of the streams produced effective shade values that are very close to system potential.

Table 8. Mean effective shade results for the five model scenarios for the streams and their tributaries on the westside that flow directly to the Willamette River. Effective shade results from 2007 are not included due to concerns related to the accuracy of the available LiDAR used to characterize canopy conditions in 2007. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	Total Length (km)	Mean Width (m)	Mean Effective Shade (%)				
			2014	2019	Max System Potential	System Potential in Management Areas	System Potential in Management Areas + Loss
Balch Creek	4.9	1.8	90.7	89.9	92.9	92.9	92.8
Doane Creek	3.9	1.1	77.1	76.9	90.6	79.4	74.1
Doane Creek Tribs	3.9	0.7	92.9	92.4	93.6	93.6	93.6
Linnton Creek NF	0.9	1.0	93.2	92.3	95.1	95.1	95.1
Linnton Creek SF	1.9	1.4	94.9	94.6	95.8	95.8	95.8

Stream	Total Length (km)	Mean Width (m)	Mean Effective Shade (%)				
			2014	2019	Max System Potential	System Potential in Management Areas	System Potential in Management Areas + Loss
Miller Creek	3.1	1.1	90.2	89.5	93.5	92.7	90.3
Miller Creek Trib	1.6	1.1	93.5	93.7	95.1	95.0	93.2
Munger Creek	1.4	0.7	94.4	93.4	95.2	95.2	94.7
Munger Creek Trib	0.6	1.1	94.2	93.6	94.7	94.7	94.7
Newton Creek	2.1	1.36	93.1	92.5	95.0	94.9	94.7
River View Streams	2.8	0.8	86.9	86.8	89.8	88.5	82.0
Rocking Chair Creek	2.1	1.2	92.9	92.2	93.8	93.5	83.1
Rocking Chair Creek NF	0.7	0.9	95.4	94.8	96.0	96.0	96.0
Saltzman Creek	2.7	1.0	73.6	74.4	90.4	76.3	70.6
Stephens Creek	3.3	1.5	72.6	73.2	85.7	78.6	71.8
Stephens Creek Trib	1.0	0.7	85.8	85.7	90.5	87.3	83.4

4 Portland's Environmental Overlay Zones

The management areas in Portland are composed of environmental overlay zones that limit activities in riparian areas. Two environmental overlay zones apply to the modeled streams in Portland: Environmental Protection (p-zone) and Environmental Conservation (c-zone) zones (Portland City Code 33.430). The two environmental overlay zones help protect natural resources in the city. The p-zone overlay is applied to areas where the natural resources are critical and development activities are not permitted except under special circumstances. The c-zone overlay is applied to areas with important natural resources, but where some environmentally sensitive development may be permitted.

Two modeling scenarios were evaluated to understand the relative contribution to system potential shade of Portland's two environmental overlay zones. As described in Table 3, both scenarios assume mature vegetation (system potential) within the p-zone. The first of the environmental overlay scenarios includes the 2019 canopy conditions in the c-zone, while the second scenario assumes no canopy is present in the c-zone. The results of these two scenarios are presented in the following sections.

It is important to note that results presented in the following sections represent modeled conditions based on the mapping of the environmental overlays zones at the time of this report. Portland's Bureau of Planning and Sustainability is currently working on an effort to update and refine the environmental overlay zones.[1] The purpose of the Environmental Overlay Zone Map Correction Project is to align the mapped location of the overlay zones with the most current information identifying the locations of

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[1] For more information see: https://www.portland.gov/bps/ezones.

existing natural resources. The project will not alter the protections placed on the City's natural resources through the environmental overlay zones, but the location and extent of current environmental overlay zones may change as a result of this effort.

4.1 Johnson Creek

Current and future riparian vegetation in the two environmental overlays zones plays an important role in achieving system potential shade along Johnson Creek and its tributaries. In many places existing vegetation is approaching mature conditions and providing abundant shade. The results of the modeling indicate that much of this shade is provided by the riparian canopy currently with p-zone overlays; however, vegetation within areas covered by c-zone also contributes to system potential. Along certain tributaries, such as Crystal Springs and Indian creeks, vegetation within the c-zone provides a greater proportion of both the current and potential riparian shade. Along Crystal Springs Creek, the loss of riparian canopy from areas covered by c-zones would reduce the potential stream shading by close to 25%, while along Indian Creek a simliar canopy loss would reduce the shading potential by over 40% (Table 9).

Table 9. Mean effective shade results for the environmental overlay zone model scenarios for the mainstem of Johnson Creek and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions. Streams that are entirely outside of the Portland city limits are not included in the table.

Stream	**Mean Effective Shade (%)**				**Shade Reduction (%)**	
	2019	**System Potential in Management Areas**	**System Potential in P-Zones + 2019 Canopy in C-Zones**	**System Potential in P-Zones + No Canopy in C-Zones**	**2019 Canopy in C-Zones**	**No Canopy in C-Zones**
Mainstem						
Johnson Creek 0-10 km	61.9	77.8	76.4	75.2	-1.9	-3.5
Johnson Creek 10-20 km	66.7	80.3	75.0	68.7	-7.4	-14.7
Tributaries						
Clatsop Creek	86.6	89.9	89.7	82.2	-0.2	-9.1
Crystal Springs	51.1	68.1	61.6	51.7	-10.1	-23.5
Deardorff Creek	85.3	88.5	87.7	86.5	-0.9	-2.3
Errol Creek	50.4	75.6	67.6	59.0	-10.0	-20.4
Frog Creek	78.7	82.4	82.2	75.3	-0.3	-8.3
Indian Creek	81.0	85.3	81.2	50.4	-5.2	-41.8
Jenne Creek	72.7	86.7	86.6	86.6	-0.4	-0.4
Kelley Creek	76.5	88.9	88.7	87.5	-0.2	-1.8
Mitchell Creek	75.0	88.9	88.9	88.9	-0.0	-0.0
Veterans Creek	75.4	86.0	84.6	78.8	-1.8	-8.7
Wahoo Creek	90.6	92.7	92.3	91.6	-0.5	-1.3

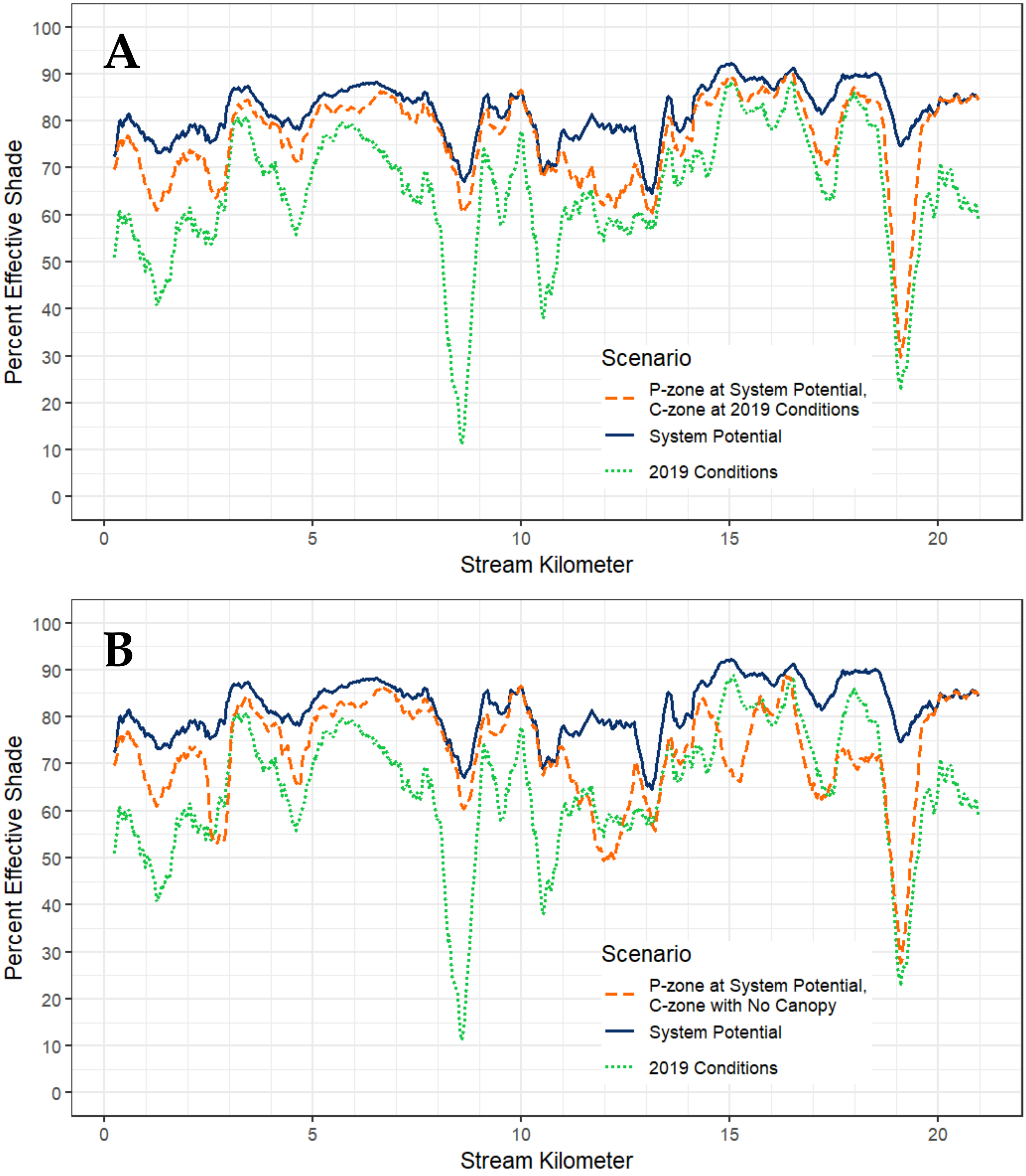

Figure 7. Johnson Creek mainstem effective shade scenarios for 2019, system potential, and the environmental overlay scenarios with p-zone at system potential and (A) c-zone with 2019 canopy conditions and (B) c-zone with no canopy. Results are presented as 1000 meter rolling averages centered on the reporting node. See Table 3 for scenario definitions.

4.2 *Columbia Slough*

The riparian vegetation within the two environmental overlays zones plays an important role in achieving system potential shade. Along the Columbia Slough the majority of the riparian shade is being produced by the vegetation within the c-zone (Table 10). Particularly along the Lower Slough, close to all of the existing riparian shade is being produced by vegetation within the c-zone. Along some reaches of the Lower Slough, the complete loss of riparian canopy from areas covered by c-zones would result in more than an 80% reduction in riparian shade compared to system potential. The modeling results emphasize the importance of vegetation within Portland's c-zone in achieving riparian shade in the Columbia Slough.

Table 10. Mean effective shade results for the environmental overlay zone model scenarios for the mainstem of the Columbia Slough and its tributaries and side channels. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	Mean Effective Shade (%)				Shade Reduction (%)	
	2019	System Potential in Management Areas	System Potential in P-Zones + 2019 Canopy in C-Zones	System Potential in P-Zones + No Canopy in C-Zones	2019 Canopy in C-Zones	No Canopy in C-Zones
Lower Slough	13.3	20.8	13.9	5.1	-35.3	-70.6
North Slough	36.4	57.1	56.4	55.4	-2.1	-4.6
Blind Slough	27.3	37.4	27.7	4.0	-23.7	-82.7
Wapato Wetland	25.0	35.7	33.9	25.7	-6.4	-26.1
Middle Slough	44.4	67.1	56.7	44.0	-19.2	-39.1
Buffalo Slough	13.4	23.9	15.5	8.1	-28.7	-54.9
Whitaker Slough	39.5	53.4	43.4	30.7	-25.2	-50.2
Upper Slough	17.6	44.7	44.7	44.7	0.0	0.0
Warren Slough	75.6	83.7	83.7	83.7	0.0	0.0
Wilkes Creek	53.8	76.3	54.4	14.2	-30.3	-81.3

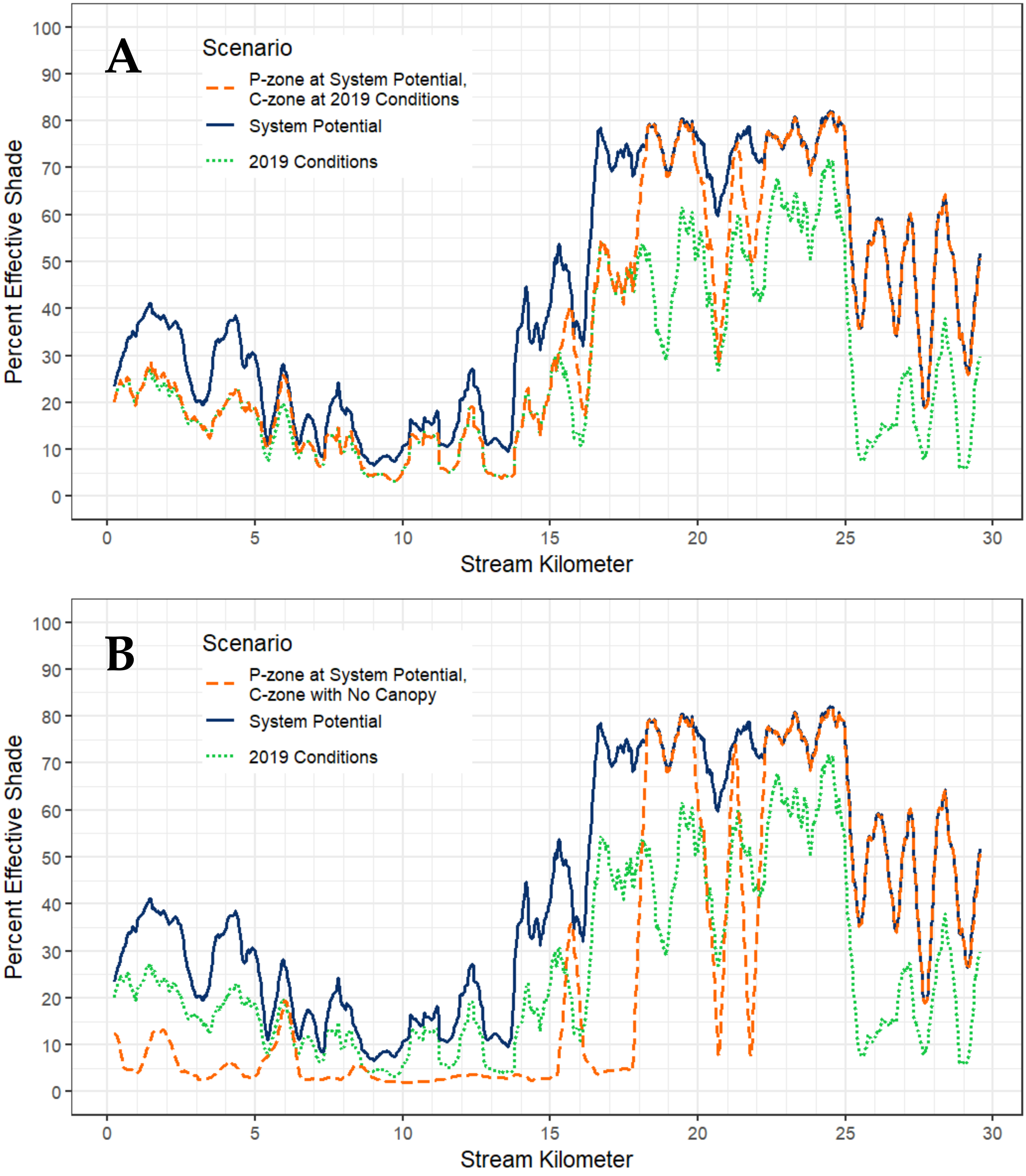

Figure 8. Mainstem Columbia Slough effective shade scenarios for 2019, system potential, and the environmental overlay scenarios with p-zone at system potential and (A) c-zone with 2019 canopy conditions and (B) c-zone with no canopy. Results are presented as 500 meter rolling averages centered on the reporting node. See Table 3 for scenario definitions.

4.3 *Tryon Creek*

The riparian vegetation within the two environmental overlays zones plays an important role in achieving system potential shade in the Tryon Creek watershed; however, the modeling results highlight that much of the shade is provided by vegetation covered by p-zones. Throughout the watershed, much of the riparian areas are covered by p-zones, with the exception of Falling Creek and the private land along many of the tributaries. A greater portion of these riparian areas are covered by c-zone overlays.

Table 11. Mean effective shade results for the environmental overlay zone model scenarios for the mainstem of Tryon Creek and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions. Streams that are entirely outside of the Portland city limits are not included in the table.

Stream	**Mean Effective Shade (%)**				**Shade Reduction (%)**	
	2019	**System Potential in Management Areas**	**System Potential in P-Zones + 2019 Canopy in C-Zones**	**System Potential in P-Zones + No Canopy in C-Zones**	**2019 Canopy in C-Zones**	**No Canopy in C-Zones**
Arnold Creek	90.5	92.2	90.8	86.7	-1.5	-6.1
Falling Creek	80.4	82.2	78.3	48.5	-5.0	-41.5
Park Creek	88.8	90.7	90.7	88.9	-0.1	-2.0
TCNA Tributaries	88.4	91.3	91.2	90.1	-0.1	-1.3
Tryon Creek Tributaries	84.9	84.3	83.5	65.1	-1.0	-23.0
Tryon Creek	80.1	86.8	86.5	84.1	-0.3	-3.2

* TCNA: Tryon Creek Natural Area

4.4 *Fanno Creek*

The environmental overlays around the mainstem of Fanno Creek are currently primarily composed of c-zones. These riparian areas currently provide a substantial proportion of the effective shade to the mainstem. The loss of existing riparian canopy would reduce the mainstem shade by over 40% (Table 12). Other smaller streams in the watershed, such as Pendleton and Restoration creeks, are also largely covered by c-zones, showing a simliar result to the Fanno mainstem.

Table 12. Mean effective shade results for the environmental overlay zone model scenarios for the mainstem of Fanno Creek and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	**Mean Effective Shade (%)**				**Shade Reduction (%)**	
	2019	**System Potential in Management Areas**	**System Potential in P-Zones + 2019 Canopy in C-Zones**	**System Potential in P-Zones + No Canopy in C-Zones**	**2019 Canopy in C-Zones**	**No Canopy in C-Zones**
Fanno Creek	77.7	81.7	80.5	45.1	-1.3	-44.2
Ash Creek	72.8	79.3	78.9	72.5	-0.6	-8.3
Ash Creek SF	80.1	84.3	84.0	80.3	-0.3	-4.9
Columbia Creek	84.3	86.5	84.8	68.0	-2.1	-22.4
Ivey Creek	82.6	85.5	84.5	61.6	-1.4	-27.5
Lowell Creek	87.4	88.6	87.7	76.7	-1.2	-14.3
Pendleton Creek	77.3	82.8	80.4	49.3	-2.9	-41.8
Restoration Creek	74.5	73.7	73.6	33.7	-0.3	-47.3
Sylvan Creek	75.9	84.5	84.4	84.0	-0.1	-0.6
Vermont Creek	77.1	83.1	82.1	76.4	-1.2	-7.5
Woods Creek	80.5	86.0	85.4	81.4	-0.6	-5.2

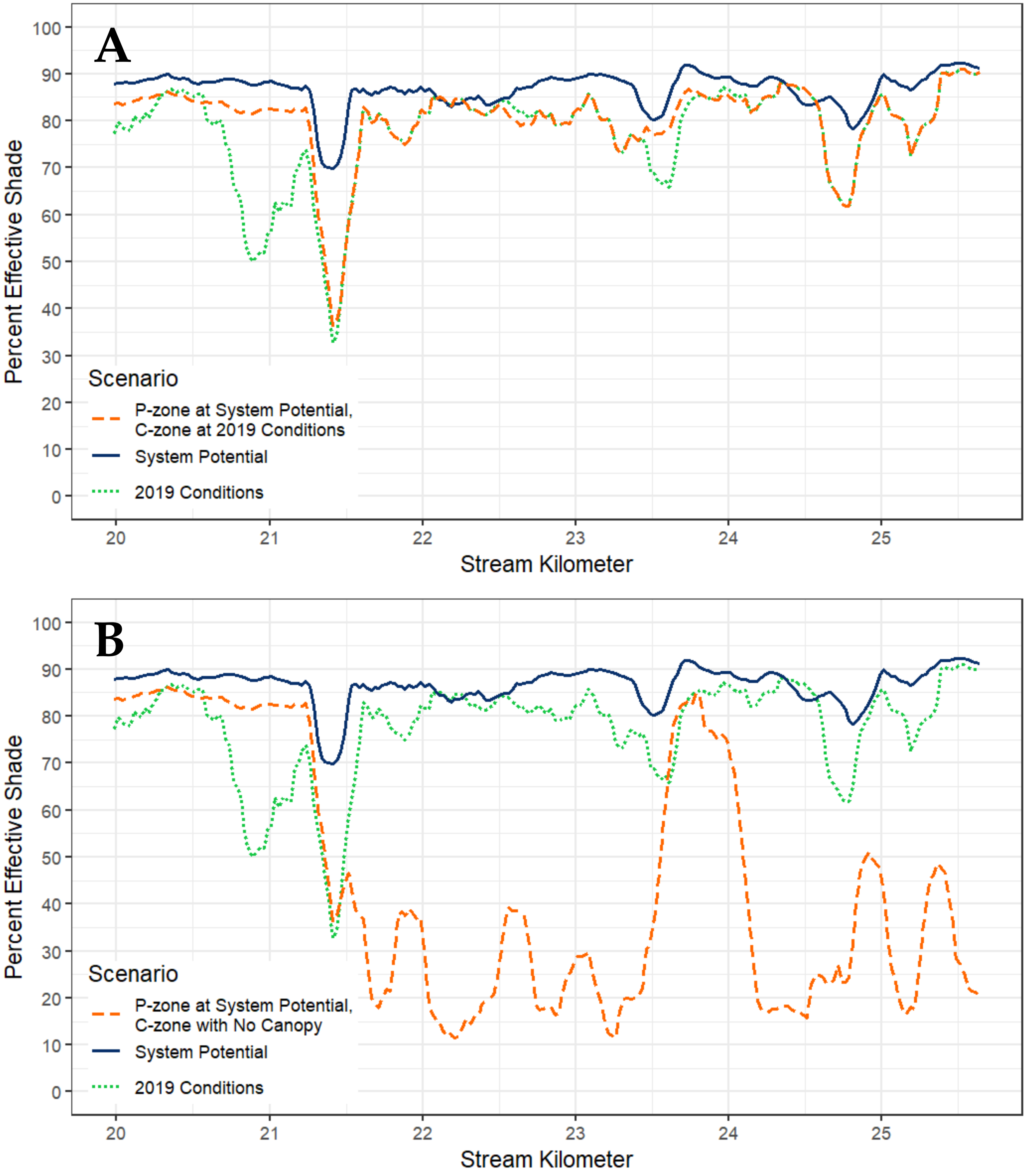

Figure 9. Mainstem Fanno Creek effective shade scenarios for 2019, system potential, and the environmental overlay scenarios with p-zone at system potential and (A) c-zone with 2019 canopy conditions and (B) c-zone with no canopy. Results are presented as 200 meter rolling averages centered on the reporting node. Results are presented for the mainstem of Fanno Creek from the confluence of Vermont Creek to SW 25th Ave. See Table 3 for scenario definitions.

4.5 *Westside Willamette Streams*

The majority of the small westside streams are located in Forest Park. As such, the environmental overlays covering these riparian areas are almost exclusively p-zones. Outside of Forest Park, the c-zones cover a greater proportion of the riparian areas of streams like Stephens Creek. In the case of Stephens Creek, the riparian vegetation within the existing c-zones contributes to approximately 15% of the system potential shade along the stream.

Table 13. Mean effective shade results for the environmental overlay zone model scenarios for the streams and their tributaries on the westside that flow directly to the Willamette River. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	**Mean Effective Shade (%)**				**Shade Reduction (%)**	
	2019	**System Potential in Management Areas**	**System Potential in P-Zones + 2019 Canopy in C-Zones**	**System Potential in P-Zones + No Canopy in C-Zones**	**2019 Canopy in C-Zones**	**No Canopy in C-Zones**
Balch Creek	89.9	92.9	92.9	92.9	0.0	0.0
Doane Creek	92.4	93.6	93.5	92.9	0.0	-0.7
Doane Creek Tribs	76.9	79.4	77.8	70.7	-2.3	-10.6
Linnton Creek NF	92.3	95.1	95.1	95.1	0.0	0.0
Linnton Creek SF	94.6	95.8	95.8	95.8	0.0	0.0
Miller Creek	89.5	92.7	92.4	92.4	-0.3	-0.4
Miller Creek Trib	93.7	95.1	95.1	95.1	0.0	0.0
Munger Creek	93.4	95.2	95.2	95.2	0.0	0.0
Munger Creek Trib	93.6	94.7	94.6	94.1	-0.1	-0.6
Newton Creek	82.8	84.9	84.9	83.9	-0.1	-1.2
River View Streams	86.8	88.5	88.1	82.7	-0.5	-6.4
Rocking Chair Creek	92.2	93.8	93.8	93.8	0.0	0.0
Rocking Chair Creek NF	94.8	96.0	96.0	96.0	0.0	0.0
Saltzman Creek	74.4	76.3	76.2	75.6	-0.1	-0.7
Stephens Creek	73.2	78.6	75.1	65.6	-4.2	-15.4
Stephens Creek Trib	85.7	87.3	85.9	81.0	-2.3	-7.8

5 Summary

The streams west of the Willamette River were found to have higher amount of modeled effective shade than those east of the Willamette. The size of the waterbodies plays a role in this difference—the Columbia Slough and Johnson Creek are wider waterways which limits the extent to which riparian vegetation can shade the stream channel. System potential on these wider channels is lower—across both watersheds the mean effective shade under the maximum system potential scenario is approximately 70% compared to 90% for streams on the westside.

While the wider stream channels do limit the possible shade, it is not the only explanation of the difference in effective shade between the two areas. Generally, there is more riparian canopy present along the streams west of the Willamette River. This is evident when comparing how far the results from the 2019 effective shade scenario are from system potential. West of the Willamette, the 2019 riparian canopy is achieving over 90% of system potential. In comparison, for streams east of the Willamette, the 2019 conditions are achieving only 73% of system potential.

Across all of the modeled streams, the results from the scenarios looking at canopy conditions in 2007, 2014, and 2019 indicate that the streams in the Portland area are gaining riparian shade—no substantial reach-wide losses in effective shade were identified. Small reductions in effective shade were noted in certain locations. For example, within the Luther Road project area (located along Johnson Creek near SE 73rd Ave and Luther Road), riparian vegetation was removed as part of the restoration work conducted in 2014 and 2019. The project represents a short-term loss in riparian canopy while the newly planted vegetation takes time to mature.

The Kelley Creek confluence project (located at the confluence of Kelley and Johnson creeks) provides a good example of how quickly riparian shade can be restored along a smaller stream. The restoration project was completed in 2005 and included re-meandering the stream channel to a historic location. All vegetation along the new channel was newly installed after construction was completed. Conditions in 2007 reflect the minimal riparian canopy present at the site with the newly planted vegetation producing only 16% effective shade in 2007. By 2014, the vegetation had grown enough such that the site's mean effective shade had increased to 83%, and to 85% effective shade in 2019, which is within a few percent of system potential at the site.

The changes in the Columbia Slough watershed highlight the importance and effectiveness of the City's revegetation work along the Slough. The bureau's Revegetation Program began in 1995 in the Columbia Slough Watershed planting streamside trees throughout the watershed. Aerial imagery from the late-1990s shows minimal riparian vegetation present along many of the channels in the Slough. The beneficial impact of the bureau and its partners continued planting and stewardship of riparian vegetation can be seen in the steady improvements in effective shade throughout the watershed.

The observed improvements in riparian shade emphasize the importance of retaining riparian vegetation and allowing it to grow to maturity. Environmental zoning and restrictions on riparian disturbances appear to have limited the loss of riparian canopy since 2007 across the study area. The benefit to the stream in term of effective shade can be seen when comparing the results from the different system potential scenarios. Under the scenarios representing system potential within management areas (where canopy conditions within management areas are assumed to reach maturity, but assumed to remain the same as 2019 conditions outside of these areas), the modeled potential effective shade was found to be slightly lower, but still within a few percent of the maximum system potential scenario (mature canopy conditions everywhere). That is, if the riparian canopy within these management areas is maintained and allowed to mature, the future riparian canopy will provide close to the greatest possible effective shade to the stream. The modeling also results emphasize that in Portland, the riparian vegetation protected by both environmental overlay zones contributes substantially to shading the streams.

6 References

Boyd, M., & Kasper, B. (2003). *Analytical Methods for Dynamic Open Channel Heat and Mass Transfer: Methodology for the Heat Source Model Version 7.0*. Oregon DEQ; Portland, OR. Retrieved from https://www.oregon.gov/deq/FilterDocs/heatsourcemanual.pdf

City of Portland. (2019). *TMDL Implementation Plan for the Willamette River and Tributaries*. Portland, OR. Retrieved from https://www.portlandoregon.gov/bes/article/509613

Lemmon, Paul E. (1957). *A New Instrument for Measuring Forest Overstory Density*. Journal of Forestry 55(9) 667-668.

Michie, R. (2021). TTools. Version 9.0. Portland, OR: Oregon Department of Environmental Quality. Retrieved from https://github.com/DEQrmichie/TTools

Michie, R., Boyd, M., Kasper, B., Metta, J., & Turner, D. (2021). Heat Source 9. Version 26. Portland, OR: Oregon Department of Environmental Quality. Retrieved from https://github.com/DEQrmichie/heatsource-9

Oregon Department of Environmental Quality. (2006). *Willamette Basin Total Maximum Daily Load, Chapter 5: Lower Willamette Subbasin TMDL*. Portland, OR. Retrieved from https://www.oregon.gov/deq/FilterDocs/chpt5lowerwill.pdf

7 GIS References

City of Portland (1996). *Zoning*. Data accessed: November 2021.
https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=52098

City of Portland (2005). *Regional Waterbodies*. Date accessed: March 2020.
https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=52070

City of Portland (2005). *Wetlands*. Date accessed: March 2020.
https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=52608

City of Portland (2010). *Stream Centerlines*. Date accessed: March 2020.
https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=53227

City of Portland (2013). *LiDAR Bare Earth Digital Elevation Model (2007)*. Date accessed: March 2020.
https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=53834

City of Portland (2015). *LiDAR Bare Earth Digital Elevation Model (2014)*. Date accessed: March 2020.
https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=54308

City of Portland (2017). *Impervious Areas*. Date accessed: March 2020.
https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=52649

City of Portland (2021). *LiDAR Bare Earth Digital Elevation Model* (2019). Date accessed: August 2021.

Oregon Department of Fish and Wildlife (2019). *Stream Habitat Surveys (2019)*. Date accessed: November 2021.
https://odfw.forestry.oregonstate.edu/freshwater/inventory/basin_portland_reports.html

Oregon Department of Fish and Wildlife (2020). *Stream Habitat Surveys (2020)*. Date accessed: November 2021.
https://odfw.forestry.oregonstate.edu/freshwater/inventory/basin_portland_reports.html

Oregon Metro (2016). *2014 Canopy Classification*. Date accessed: March 2020.
https://www.portlandmaps.com/metadata/index.cfm?&action=DisplayLayer&LayerID=54362

Appendix A: Canopy Cover Measurements

Project	Sample Point	Sample Date	Canopy Cover (%)	Coordinates
Brunkow	Cc1_2020	10/1/2020	83.5	45.481581, -122.493047
Brunkow	Cc2_2020	10/1/2020	36.5	45.481970, -122.492489
Brunkow	CC3_2020	10/1/2020	82.0	45.482316, -122.491921
Luther Rd. Repair	CC2	8/27/2020	0.0	45.458372, -122.587833
Luther Rd. Repair	CC4	9/3/2020	0.0	45.458803, -122.585433
Oxbow Phase II	Bypass cc3	8/4/2020	88.0	45.462471, -122.618211
Oxbow Phase II	cc_sub	7/30/2020	27.0	45.463254, -122.617920
Oxbow Phase II	Cc4_2020	7/30/2020	56.0	45.464086, -122.618086
PAWMAP	P0012	8/16/2018	92.5	45.468831, -122.679336
PAWMAP	P0016	6/24/2019	98.5	45.466684, -122.481781
PAWMAP	P0058	8/21/2018	97.0	45.461908, -122.725529
PAWMAP	P0060	9/27/2018	98.5	45.464306, -122.559901
PAWMAP	P0078	7/3/2018	92.5	45.541688, -122.750016
PAWMAP	P0124	9/19/2018	65.0	45.475543, -122.515614
PAWMAP	P0129	7/31/2018	12.0	45.557441, -122.508147
PAWMAP	P0137	9/4/2018	95.5	45.550354, -122.756821
PAWMAP	P0144	7/24/2018	98.5	45.429271, -122.676874
PAWMAP	P0153	8/20/2019	97.0	45.568189, -122.768583
PAWMAP	P0185	8/13/2019	95.5	45.591922, -122.792416
PAWMAP	P0208	7/10/2018	82.0	45.444613, -122.683359
PAWMAP	P0250	7/23/2018	98.5	45.532319, -122.716678
PAWMAP	P0272	9/5/2018	24.0	45.486646, -122.481899
PAWMAP	P0297	7/29/2019	100.0	45.587175, -122.797750
PAWMAP	P0298	8/28/2018	98.5	45.535867, -122.783413
PAWMAP	P0313	7/1/2020	95.5	45.604061, -122.811966
PAWMAP	P0314	9/10/2018	98.5	45.483097, -122.712615
PAWMAP	P0337	9/30/2020	0.0	45.586373, -122.670805
PAWMAP	P0352	9/11/2018	50.0	45.455848, -122.603152
PAWMAP	P0380	7/23/2019	100.0	45.470614, -122.529716
PAWMAP	P0444	8/1/2019	16.5	45.488193, -122.463728
PAWMAP	P0464	9/16/2019	89.5	45.461733, -122.689420
PAWMAP	P0498	8/29/2019	98.5	45.448503, -122.730792
PAWMAP	P0513	10/2/2019	65.5	45.563579, -122.537784
PAWMAP	P0524	7/17/2018	80.5	45.468823, -122.670229
PAWMAP	P0526	7/9/2019	100.0	45.537531, -122.739525
PAWMAP	P0544	8/7/2019	30.5	45.458222, -122.642001
PAWMAP	P0554	8/27/2019	95.5	45.536832, -122.777025

Project	Sample Point	Sample Date	Canopy Cover (%)	Coordinates
PAWMAP	P0592	10/1/2019	100.0	45.436542, -122.675387
PAWMAP	P0633	8/14/2019	82.0	45.607094, -122.796643
PAWMAP	P0705	9/19/2019	29.0	45.578852, -122.617189
PAWMAP	P0720	7/18/2019	95.5	45.453423, -122.668508
PAWMAP	P0746	9/24/2019	95.5	45.489287, -122.719557
PAWMAP	P0754	9/4/2019	97.0	45.456470, -122.708394
PAWMAP	P0762	7/17/2019	86.5	45.527765, -122.725957
PAWMAP	P0800	7/21/2020	95.5	45.453442, -122.662653
PAWMAP	P0828	10/7/2019	89.5	45.471003, -122.525190
PAWMAP	P0892	7/30/2019	18.0	45.474182, -122.559758
PAWMAP	P0940	7/15/2020	100.0	45.463090, -122.528831
PAWMAP	P1010	7/31/2020	100.0	45.444324, -122.713304
PAWMAP	P1020	8/6/2019	97.0	45.477216, -122.499041
PAWMAP	P1102	7/28/2020	91.0	45.538187, -122.762109
PAWMAP	P1130	7/9/2020	92.5	45.538561, -122.782940
PAWMAP	P1148	8/23/2021	94.0	45.467592, -122.530931
PAWMAP	P1184	8/18/2020	76.0	45.462983, -122.636416
PAWMAP	P1194	9/30/2021	97.0	45.497063, -122.738882
PAWMAP	P1473	10/1/2020	24.0	45.577503, -122.620142
PAWMAP	P1593	8/13/2020	98.5	45.612211, -122.812364
PAWMAP	P1612	8/19/2021	22.5	45.463385, -122.617889
PAWMAP	P1616	9/15/2021	95.5	45.439227, -122.671563
PAWMAP	P1744	9/2/2021	100.0	45.459530, -122.671366
PAWMAP	P1769	7/27/2021	100.0	45.616890, -122.808750
PAWMAP	P1770	9/29/2020	94.0	45.492050, -122.718789
PAWMAP	P1778	10/12/2021	98.5	45.455481, -122.721983
PAWMAP	P1834	7/8/2021	100.0	45.540177, -122.777702
PAWMAP	P1872	7/7/2020	91.0	45.429589, -122.674861
PAWMAP	P1916	8/4/2020	88.0	45.465717, -122.562163
PAWMAP	P1936	8/26/2021	83.5	45.448595, -122.686744
PAWMAP	P2185	7/20/2021	98.5	45.556943, -122.751266
PAWMAP	P2208	8/5/2021	82.0	45.458937, -122.612571
PAWMAP	P2290	10/7/2021	92.5	45.448437, -122.742861
PAWMAP	P2320	7/22/2021	76.0	45.482536, -122.491601
PAWMAP	P2362	8/26/2020	100.0	45.473566, -122.726399
PAWMAP	P2384	9/3/2020	100.0	45.434906, -122.680302
PAWMAP	P2512	9/22/2020	92.5	45.455235, -122.693936
PAWMAP	P2524	8/10/2021	98.5	45.459051, -122.499942
SW 45th Culvert Replacement	Cc1_2020	10/12/2020	98.5	45.486768, -122.722873
SW 45th Culvert Replacement	Cc4_2020	10/12/2020	70.0	45.487013, -122.723386

Project	Sample Point	Sample Date	Canopy Cover (%)	Coordinates
SW Boones Ferry Rd. Culvert Replacement	Cc4	10/21/2020	76.0	45.447322, -122.687389
SW Boones Ferry Rd. Culvert Replacement	TC CC 1	10/21/2020	79.0	45.446758, -122.686517
West Lents	Wl_cc2_2020	8/6/2020	24.0	45.464041, -122.578341
West Lents	WL_cc3_2020	8/6/2020	62.0	45.464639, -122.577851
West Lents	WL_cc4_2020	8/6/2020	7.5	45.465123, -122.577232
West Lents	WL_cc5_2020	8/6/2020	98.5	45.465386, -122.576296
West Lents	Wl_cc6_2020	8/6/2020	77.5	45.465561, -122.575307
West Lents	Wl_cc7_2020	8/6/2020	88.0	45.465788, -122.574399

Appendix B: Model Nodes

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
East	Johnson Creek	Badger Creek_1	3.9	0–156
		Butler Creek_1	2.65	157–263
		Clatsop Creek_1	2.275	264–355
		CrystalSpringsCreek_1	0.45	3101–3119
		CrystalSpringsCreek_2	1.55	3120–3182
		CrystalSpringsCreek_3	1.175	3183–3230
		CrystalSpringsCreek_4	0.6	356–380
		DeardorffCreek_1	1.225	381–430
		DeardorffCreek_2	0.45	5369–5387
		Errol Creek_1	0.575	431–454
		Frog Creek_1	1.475	455–514
		Indian Creek_1	1.525	515–576
		Jenne Creek_1	1.95	577–655
		JohnsonCreek_01	1.125	2192–2237
		JohnsonCreek_02	0.85	2238–2272
		JohnsonCreek_03	0.4	2273–2289
		JohnsonCreek_04	0.625	2290–2315
		JohnsonCreek_05	0.875	2316–2351
		JohnsonCreek_06	0.575	2352–2375
		JohnsonCreek_07	0.35	2376–2390
		JohnsonCreek_07a	0.125	4515–4520
		JohnsonCreek_08	1.1	2391–2435
		JohnsonCreek_09	0.95	2436–2474
		JohnsonCreek_10	0.55	2475–2497
		JohnsonCreek_11	1.15	2498–2544
		JohnsonCreek_12	0.5	2545–2565
		JohnsonCreek_13	0.775	2566–2597
		JohnsonCreek_14	0.55	2598–2620
		JohnsonCreek_15	0.675	2621–2648
		JohnsonCreek_16	1.675	2649–2716
		JohnsonCreek_17	1.6	2717–2781
		JohnsonCreek_18	1.075	2782–2825
		JohnsonCreek_19	1.2	2826–2874
		JohnsonCreek_20	1.275	2875–2926
		JohnsonCreek_21	1.075	2927–2970
		JohnsonCreek_22	0.825	4481–4514
		JohnsonCreek_23	0.325	5355–5368
		Johnson Creek_24	21.8	656–1528

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
		KelleyCreek_1	0.375	2971–2986
		KelleyCreek_2	1.1	2987–3031
		KelleyCreek_3	5.675	1529–1756
		MitchellCreek_1	1.025	3032–3073
		MitchellCreek_2	0.65	3074–3100
		MitchellCreek_3	0.625	4455–4480
		MitchellCreek_4	0.675	1757–1784
		Sunshine Creek_1	6.7	1785–2053
		VeteransCreek_1	2.125	2054–2139
		WahooCreek_1	0.075	5452–5455
		WahooCreek_2	0.35	5437–5451
		WahooCreek_3	0.575	5413–5436
		WahooCreekTrib1_1	0.6	5388–5412
		WahooCreekTrib2_1	1.275	2140–2191
	Columbia Slough	BlindSlough_1	0.5	3231–3251
		Buffalo Slough_1	1.525	3252–3313
		LowerSlough_1a	2.75	4521–4631
		LowerSlough_1b	2.45	4682–4780
		LowerSlough_1e	2.675	4781–4888
		LowerSlough_1f	2.125	4889–4974
		LowerSlough_1g	3.775	3364–3515
		LowerSloughSideChannel_1e	1.075	3516–3559
		MiddleSlough_3a	2.45	4356–4454
		MiddleSlough_3b	1.65	5288–5354
		MiddleSlough_4a	2.025	5179–5260
		MiddleSlough_4b	4.4	3560–3736
		MiddleSlough_4c	0.65	5261–5287
		NorthSlough_1	0.975	3759–3798
		NorthSlough_2	0.425	4632–4649
		UpperSlough_6a	2.3	5060–5152
		UpperSlough_6b	2.25	3956–4046
		WapatoWetland_1	0.775	4650–4681
		WapatoWetland_2	0.925	4047–4084
		Warren Slough_1	1.1	4085–4129
		WhitakerSlough_1	1.975	4975–5054
		WhitakerSlough_2	3.525	4130–4271
		Wilkes Creek Trib_1	0.475	4336–4355
		Wilkes Creek_1	1.575	4272–4335
West	Tryon Creek	ArnoldCreek_1	0.7	4364–4392
		ArnoldCreek_2	1.725	3451–3520
		ArnoldCreek_3	0.85	4393–4427

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
		FallingCreek_1	0.725	4290–4319
		FallingCreek_2	0.65	4320–4346
		FallingCreek_4	0.575	3521–3544
		Nettle Creek_1	2.625	3545–3650
		ParkCreek_1	1.15	3651–3697
		TryonCreek_1	0.45	3989–4007
		TryonCreek_2	1.375	4008–4063
		TryonCreek_3	1.275	4064–4115
		TryonCreek_4	1.55	4116–4178
		TryonCreek_5	1.375	4179–4234
		TryonCreek_6	0.775	4235–4266
		TryonCreek_7	0.55	4267–4289
		TryonCreekTrib1_1	0.35	3729–3743
		TryonCreekTrib2_1	0.275	4804–4815
		TryonCreekTrib2_2	0.6	3744–3768
		TryonCreekTrib4_1	0.65	3814–3840
		TryonCreekTrib5_1	0.7	3841–3869
		TryonCreekTrib5_2	0.3	4784–4796
		TryonCreekTrib5TribA_1	0.175	3870–3877
		TryonCreekTrib5TribA_2	0.075	4800–4803
		TryonCreekTrib6_1	0.4	3878–3894
		TryonCreekTrib6_2	0.05	4797–4799
		TryonCreekTrib7_1	1.05	3895–3937
		TryonCreekTrib8_1	0.575	3938–3961
		TryonCreekTrib8TribA_1	0.35	3962–3976
		TryonCreekTrib8TribB_1	0.275	3977–3988
	Fanno Creek	AshCreek-SouthFork_1	2.025	99–180
		AshCreek-SouthFork_2	0.475	1941–1960
		AshCreek-SouthFork_3	0.75	1741–1771
		AshCreek_0	2.45	0–98
		AshCreek_1	1.75	4485–4555
		AshCreek_2	1.225	1891–1940
		AshCreek_3	1.05	1772–1814
		Columbia Creek Trib A_1	1	325–365
		Columbia Creek Trib_1	1.625	259–324
		Columbia Creek_1	1.925	181–258
		FannoCreek_1	1.4	4428–4484
		FannoCreek_2	1.025	2180–2221
		FannoCreek_3	1.175	2132–2179
		FannoCreek_4	0.55	2109–2131
		FannoCreek_5	0.975	2069–2108

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
		FannoCreek_6	0.575	2045–2068
		Ivey Creek Trib_1	0.6	1277–1301
		Ivey Creek_1	1.925	1199–1276
		Lowell Creek_1	2.225	1302–1391
		Pendleton Creek_1	1.775	1392–1463
		Restoration Creek_1	0.625	1464–1489
		Sylvan Creek Trib_1	0.425	1671–1688
		Sylvan Creek_1	4.5	1490–1670
		VermontCreek_1	0.7	2016–2044
		VermontCreek_2	1.275	1689–1740
		VermontCreek_3	1.35	1961–2015
		WoodsCreek_0	1.125	1845–1890
		WoodsCreek_1	0.975	4629–4668
		WoodsCreek_2	1.8	4556–4628
		WoodsCreek_3	0.725	1815–1844
	Westside Willamette Streams	BalchCanyon_1	2.1	3187–3271
		BalchCanyon_2	1.225	3272–3321
		BalchCanyon_3	1.55	2222–2284
		DoaneCreek_0	1.2	5069–5117
		DoaneCreek_1	1	4856–4896
		DoaneCreek_2	0.525	4897–4918
		DoaneCreek_3	1.075	2366–2409
		DoaneCreekTrib1_1	0.55	2343–2365
		DoaneCreekTrib1_2	0.3	4919–4931
		DoaneCreekTrib2_1	0.5	4932–4952
		DoaneCreekTrib2_2	1.075	2299–2342
		DoaneCreekTrib3_1	1.35	2410–2464
		LinntonCreek_0	0.3	5026–5038
		LinntonCreekNF_1	0.9	2531–2567
		LinntonCreekSF_1	0.15	4849–4855
		LinntonCreekSF_2	1.75	2568–2638
		MillerCreek_0	0.325	5055–5068
		MillerCreek_1	1.45	2639–2697
		MillerCreek_2	1.275	3322–3373
		MillerCreekTrib_1	1.575	2698–2761
		MungerCreek_1	0.975	2762–2801
		MungerCreek_2	0.35	4967–4981
		MungerCreekTrib_1	0.6	2802–2826
		NewtonCreek_0	0.375	5039–5054
		NewtonCreek_1	0.8	4816–4848
		NewtonCreek_2	1.25	2827–2877

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
		RiverViewStream2_1	0.35	4769–4783
		RiverViewStream2_2	0.625	2878–2903
		RiverViewStream6_1	1	2904–2944
		RiverViewStream7_1	0.25	4749–4759
		RiverViewStream7_2	0.25	2945–2955
		RiverViewStream7_3	0.2	4760–4768
		RockingChairCreek_1	0.325	4982–4995
		RockingChairCreek_2	0.75	2998–3028
		RockingChairCreek_3	0.525	3044–3065
		RockingChairCreek_4	0.4	4996–5012
		RockingChairCreekNF_1	0.3	5013–5025
		RockingChairCreekNF_2	0.35	3029–3043
		SaltzmanCreek_0	0.825	5118–5151
		SaltzmanCreek_1	0.325	4953–4966
		SaltzmanCreek_2	1.5	3066–3126
		Stephens Creek I5 Trib_1	0.075	3183–3186
		StephensCreek_1	0.175	3408–3415
		StephensCreek_2	0.2	3399–3407
		StephensCreek_3	0.6	3374–3398
		StephensCreek_4	1.375	3127–3182
		StephensCreek_5	0.475	3416–3435
		StephensCreek_6	0.35	3436–3450
		StephensCreekTrib1_1	1.025	2956–2997

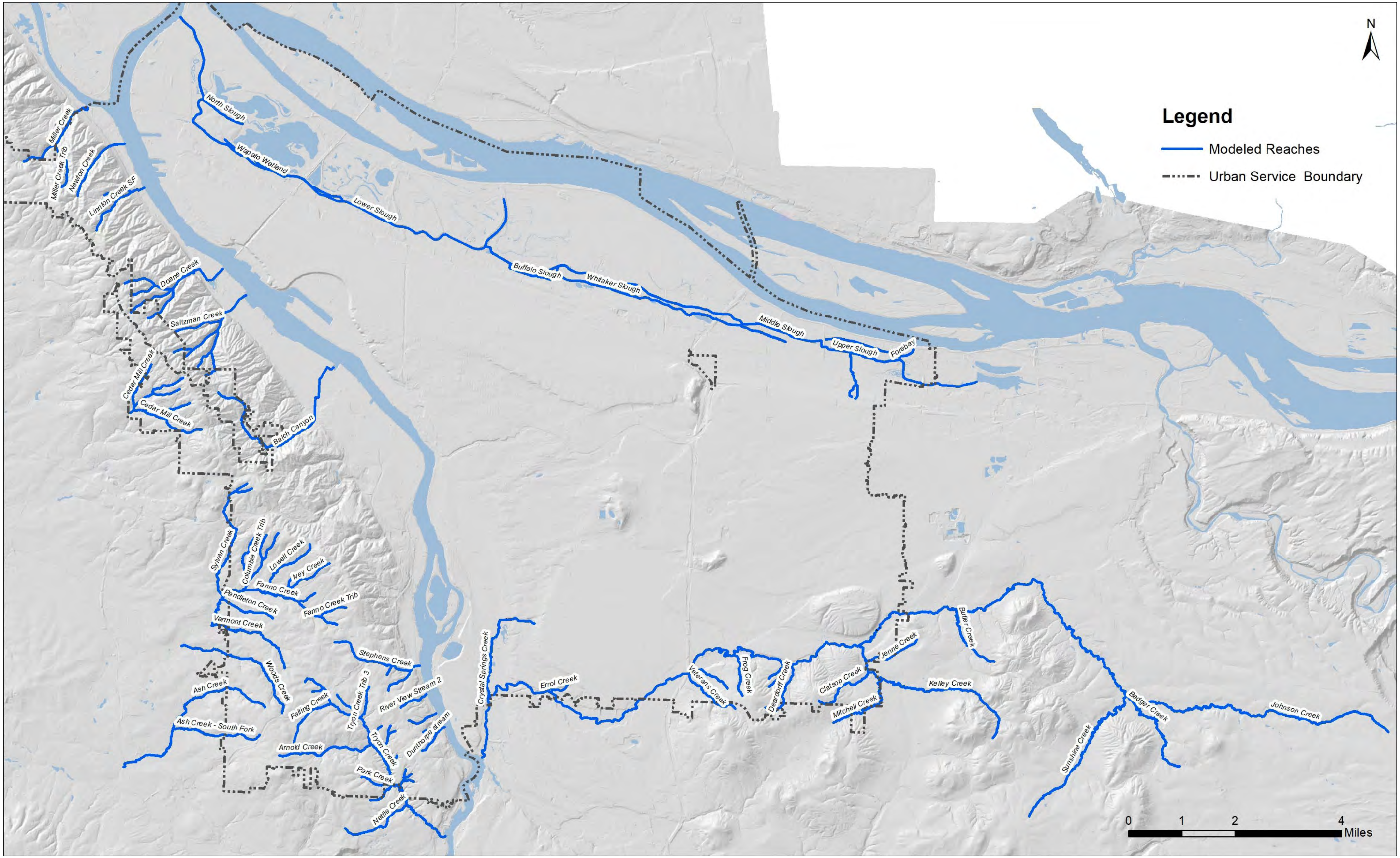

Figure 10. Stream reaches in the Portland area modeled for effective shade.

Appendix C

Potential Near-Stream Land Cover in the Willamette Basin for Temperature Total Maximum Daily Loads (TMDLs)

Water Quality Division
Oregon Department of Environmental Quality

(January 2004)

Preface

This document is one component of work by the Oregon Department of Environmental Quality to support development of water quality improvement plans in the Willamette Basin. Specifically, this document supports the development of surrogate measures used in temperature Total Maximum Daily Loads in the Willamette Basin, as required under 40 CFR 130 Federal Clean Water Act.

Pamela Wright, a riparian ecologist, was the primary author of this document.

For more information about this document or other aspects of determining Total Maximum Daily Loads for waters of the Willamette Basin, please contact:

Portland:
Dennis Ades
(503) 229-6351 or (800) 452-4011
Water Quality Division
811 S.W. 6th Avenue
Portland, OR 97204-1390

Eugene:
Jared Rubin
(541) 686-7838, ext. 261 or (800) 844-8467
Water Quality Division
1102 Lincoln St., # 210
Eugene, OR 97401

Also please refer to ODEQ’s Willamette Basin TMDL webpage:
http://www.deq.state.or.us/wq/willamette/WRBHome.htm .

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1 Introduction

Potential near-stream land cover is an aspect of stream temperature that is critical to determining temperature Total Maximum Daily Loads (TMDLs) for surface waters in the Willamette Basin. Potential near-stream land cover is commonly referred to as system potential vegetation. In this document the Oregon Department of Environmental Quality (ODEQ) explains the methodology and analysis results for predicting potential near-stream land cover in the basin. The work presented in this document reflects the analysis conducted by ODEQ and knowledge from local experts from outside the agency that reviewed and gave comments regarding the analysis and assumptions made from the analysis. A list of experts who participated in this process is available in Appendix 1. ODEQ also provides documentation of possible model scenarios to predict vegetation distribution given a range of potential near-stream land cover for various riparian environments in the Willamette Basin. The potential near-stream land cover approach described in this document applies to ten of the twelve subbasins in the Basin: Clackamas, Middle Willamette, Upper Willamette, North Santiam, South Santiam, McKenzie, Middle Fork Willamette, Coast Fork Willamette, Yamhill, and Molalla-Pudding. The Tualatin and Lower Willamette subbasin potential near-stream land cover approach is described in the 2001 Tualatin Subbasin TMDL, Appendix A: Temperature Technical Analysis, Tualatin River Subbasin Vegetation Conditions section starting on page A-6, http://www.deq.state.or.us/wq/TMDLs/Tualatin/AppendixA.pdf .

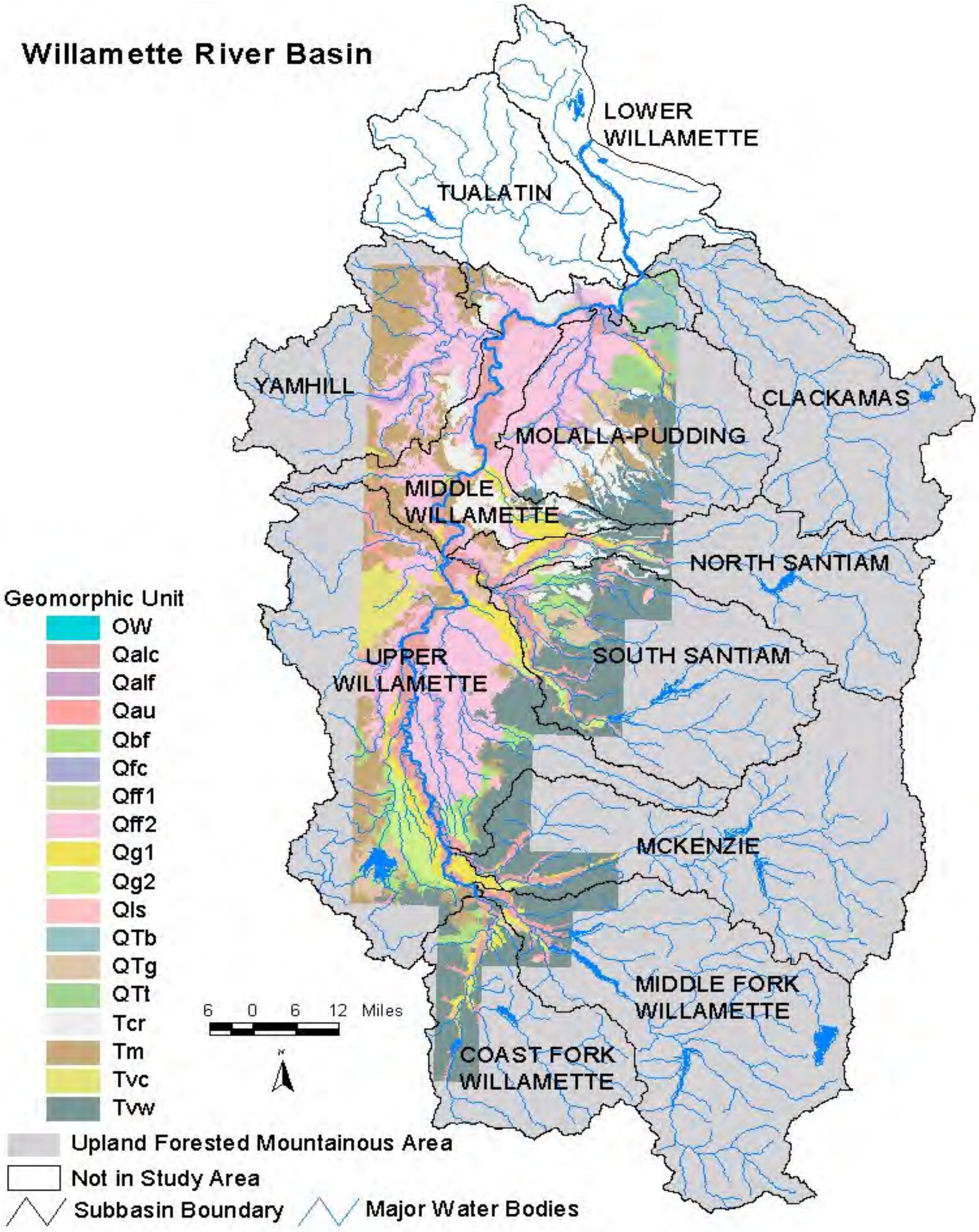
Temperature in many Willamette Basin streams currently exceeds the temperature criteria in Oregon's temperature standard. Riparian vegetation is known to be one of the primary factors controlling stream temperature (Boyd and Sturdevant, 1997) http://www.deq.state.or.us/wq/standards/WQStdsTempStdSciBasis.pdf . ODEQ needs to determine potential near-stream land cover, or system potential vegetation, and use this information to predict stream temperatures in the absence of anthropogenic heat. The potential near-stream land cover is the basis of the load allocation for nonpoint source sectors of heat. This methodology is therefore the basis for preparing system potential vegetation and shade targets for the temperature TMDLs. The shade targets developed take into account a natural disturbance regime that is reflected in the diversity of species composition derived for each geomorphic unit and upland forest.

The Willamette Valley is bounded on the east by the Cascade Range, and by the Coast Range on the west. To predict potential near-stream land cover in the upland forested mountainous areas, ODEQ is using the plant associations developed by the US Forest Service for the Willamette Basin (Logan, et.al. 1987).

Currently, there are no plant association data sets available for the Willamette Valley bottom, similar to what the US Forest Service has compiled for the upland forest mountainous area. For the valley, ODEQ is using landscape level environmental data (geomorphology, ecoregions, geology, soils, ODFW 1998 Willamette Vegetation, in-field current conditions) and a historic 1850's vegetation layer developed from notes of General Land surveys to predict potential near-stream land cover. ODEQ's objective is not to model a particular point in history, but to use historic data to understand the relationship between the relatively undisturbed vegetation of the mid-1800s and the corresponding environments that currently exist along the various streams in the Willamette Valley. ODEQ is using that understanding, information about plant physiology and silviculture, and environmental data to predict future potential near-stream land cover.

The Willamette Valley bottom potential near-stream land cover is assigned a vegetation component defined by the geomorphic unit; Figure 1 below illustrates the extent of the upland forest coverage provided by the US Forest Service and the geomorphic unit coverage for the valley bottom.

Figure 1 **Willamette Basin potential near-stream land cover area for stream temperature modeling of the upland forest mountainous area and Willamette Valley, Oregon.**



In addition to describing ODEQ's objectives, methodology, and results of the technical analysis, this document includes general "rules" and principles that other entities can use for implementing potential near-stream land cover to improve water quality.

2 Background and Objectives

The process of developing data on potential near-stream land cover is specific to the context in which the data are used in ODEQ's TMDL methodology. In this context, potential near-stream land cover is defined as that which can grow and reproduce on a site given plant biology, site elevation, soil characteristics, and local climate. Potential near-stream land cover does not include considerations for resource management, human use, or other human disturbance, however natural disturbance regimes (i.e. fire, disease, wind-throw, etc.) are accounted for in this definition. The ODEQ assumes that potential near-stream land cover types (as defined) survive and recover from natural disturbance events.

Oregon water temperature criteria's limit anthropogenic warming to a small amount of no more than 0.3ºC when specific numeric criteria are exceeded. This condition is one in which stream warming related to human activities is minimized. Because near-stream land cover is a controlling factor in stream temperature regimes, the condition and health of land cover is a primary parameter considered in determining the temperature TMDL. Reversing or removing human disturbance from near-stream land cover is a pathway for compliance with Oregon's water temperature standard even when the numeric temperature criteria are not met.

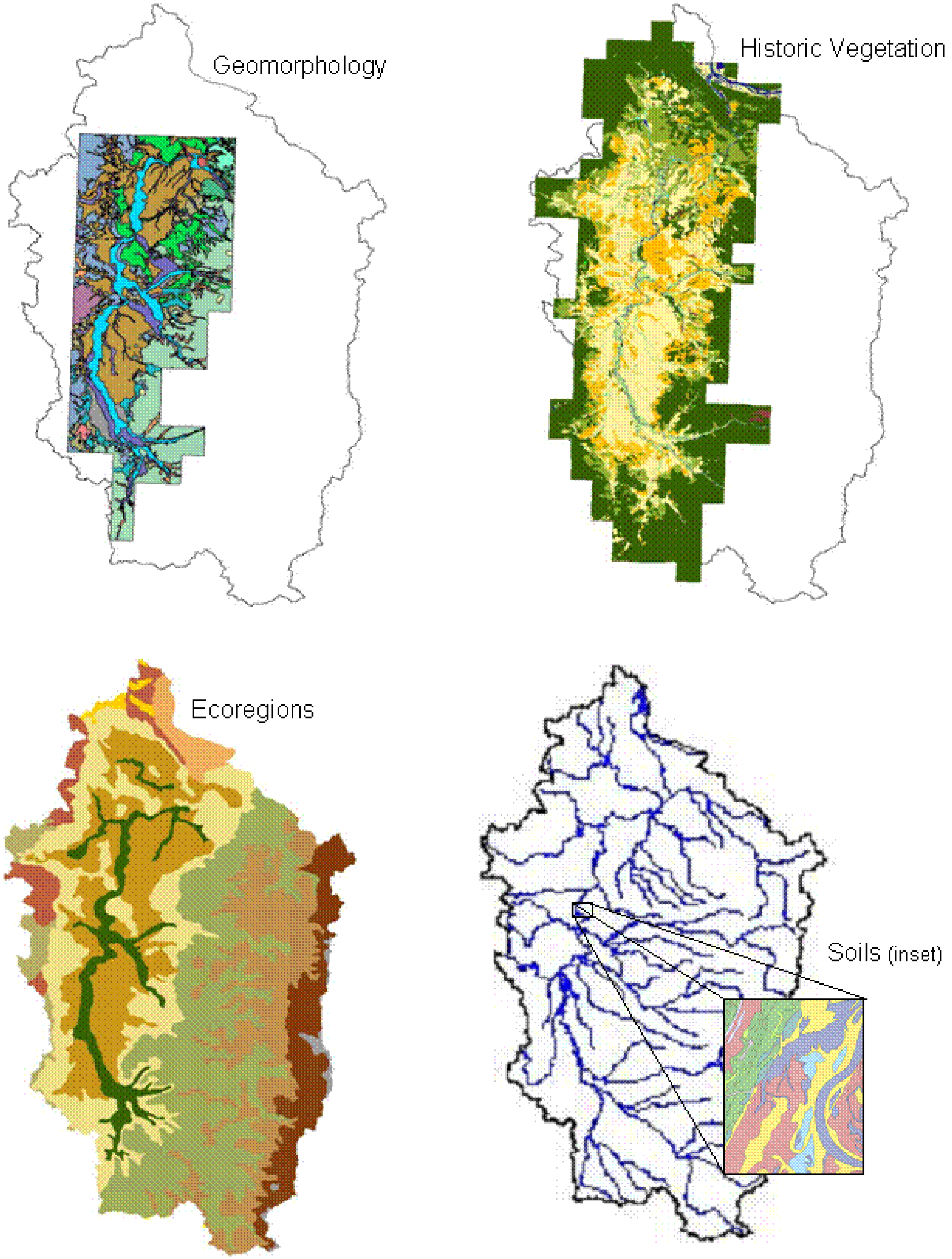
Developing potential near-stream land cover can often be complex because natural systems are highly variable. ODEQ has developed simple rules to determine potential near-stream land cover data sets based on physical characteristics and clearly stated assumptions. ODEQ acknowledges that determining the potential near-stream land cover type and distribution for some areas is not easily done. This is particularly true for the Willamette Valley bottom, where vegetation has been removed near low gradient streams altering channels by constructing dikes and revetments. Literature on the land cover potential and local knowledge in the universities and federal and state agencies is limited. Consequently, for areas where land cover potential is not documented in the literature or evident in ground level studies and data, ODEQ is using a range of land cover types and attributes in the TMDL.

3 Methodology

3.3 The Analysis

Step 1. Geomorphic units, geology, soils, ODFW 1998 Willamette Vegetation, ecoregions, and historic 1850's vegetation maps, were examined to assess the availability of data and to understand the variability in the Basin, Figure 2.

Figure 2 Data sets used in the analysis, from clockwise upper left: geomorphology, historic vegetation, ecoregions, and soils (inset near Willamette River)



Step 2. Using the existing data sets, together with ground level riparian data collected by ODEQ in 2000 and 2001, ODEQ selected a set of 30 streams that represent the various conditions that exist within the Willamette Valley. The frequency of occurrence of factors that would influence vegetation height and canopy density for each type of stream throughout the Willamette Valley was quantified by geomorphic unit. The water bodies selected for this analysis are representative of the Willamette Valley and include the Willamette River, it's major tributaries, and streams of large and small watersheds (4th, 5th and 6th level hydrologic units). These waterbodies represent a range of geomorphic surfaces and other environmental conditions, and streams that are highly- to relatively little-altered from historic conditions. The sampled water bodies include the McKenzie, South Santiam, Pudding, Yamhill, Long Tom, Row, Mohawk, Mary's, Calapooia, and Luckiamute Rivers; Thomas, Crabtree, Mosby, Rickreall, Muddy, West Muddy, Oak, Mill, Flat, Lake, Patterson, Howell Prairie, Palmer, Ash, N. Fork Ash, Berry, and Beaver Creeks; and Walton and Sucker Sloughs. Each water body was sampled to 300 feet upland from the left bank and right bank. A Geographic Information System (GIS) was used to clip, intersect, and manage environmental data.

Step 3. Analysis of geomorphology, ecoregions, geology, soils, ODFW 1998 Willamette Vegetation, and 1850s vegetation data sets examined the near-stream land cover along water bodies of different environments and characteristics. The goal was to assess the relationship between tree stands and other environmental factors along 1850s Willamette Valley water bodies. Based on this assessment, ODEQ estimated which environments supported large coniferous trees, versus smaller deciduous trees, and environments that supported dense tree stands (forest) compared to sparse trees (savannas) or no trees (prairie). This approach does not attempt a return to historic conditions, but rather to establish what tree species are suitable to specific environments and determine the size of trees that may grow in a given area.

Step 4. ODEQ invited experts from outside the agency to review the analysis and assumptions made from the analysis at this stage. Reviewers, listed in Appendix A, provided suggestions that were incorporated into the final analysis to quantify the acreage for the historic vegetation of each type of geomorphic surface and soil drainage, as indicated in Table 1.

Table 1. Proportions of forest, savanna and prairie to be used in temperature models to quantify potential near-stream land cover by geomorphic unit

Geomorphic unit^1	Sampled streams dominated by geomorphic unit (surface)	Vegetation structure	Acres	Model Scenario: Tree Distribution
Qff1	Lower Mainstem Willamette	Forest	154	0.81
		Savanna	97	0.19
		Prairie	0	0.00
		Total	**251**	**1.00**
Qfc	Lower Mainstem Willamette	Forest	20	0.56
		Savanna	148	0.44
		Prairie	0	0.00
		Total	**168**	**1.00**
Qalc	Lower Willamette	Forest	7973	0.80
		Savanna	1132	0.17
		Prairie	1393	0.03
		Total	**10498**	**1.00**
Qg1	Mill Cr.	Forest	260	0.41
		Savanna	1196	0.44
		Prairie	646	0.15
		Total	**2102**	**1.00**

Geomorphic unit[1]	Sampled streams dominated by geomorphic unit (surface)	Vegetation structure	Acres	Model Scenario: Tree Distribution
Qau	Mohawk, upper Luckiamute, upper Oak Cr., middle Thomas	Forest	1337	0.60
		Savanna	288	0.23
		Prairie	811	0.17
		Total	**2436**	**1.00**
Qalf	Pudding, Muddy Cr, Marys, Yamhill, SF Yamhill, Calapooia	Forest	3112	0.52
		Savanna	1150	0.28
		Prairie	2806	0.20
		Total	**7068**	**1.00**
Qff2	Berry Cr., Ash & NF Ash Cr. , upper Muddy (east), upper Lake Cr.	Forest	2729	0.43
		Savanna	2261	0.35
		Prairie	4049	0.22
		Total	**9039**	**1.00**
Qbf	Long Tom, upper Amazon, upper Crabtree Cr.	Forest	1170	0.47
		Savanna	479	0.30
		Prairie	1381	0.23
		Total	**3030**	**1.00**
Qg2	Amazon Cr., Flat Cr.	Forest	40	0.08
		Savanna	0	0.46
		Prairie	446	0.46
		Total	**486**	**1.00**
Tvc	Headwaters Rickreall Cr.	Forest	29	0.60
		Savanna	104	0.39
		Prairie	4	0.01
		Total	**137**	**1.00**
QTg	Small portions of upper Rickreall, Marys, Beaver Cr.	Forest	387	0.77
		Savanna	42	0.14
		Prairie	102	0.09
		Total	**531**	**1.00**
Tvw	Upper Thomas, upper Crabtree, Headwaters Muddy Cr (east)	Forest	510	0.57
		Savanna	390	0.39
		Prairie	220	0.04
		Total	**1120**	**1.00**
Tcr	Upper Mill Cr.	Forest	121	0.63
		Savanna	972	0.27
		Prairie	302	0.10
		Total	**1395**	**1.00**
Tm	Upper Ash & NF Ash Cr,	Forest	175	0.56

Geomorphic unit[1]	Sampled streams dominated by geomorphic unit (surface)	Vegetation structure	Acres	Model Scenario: Tree Distribution
	upper Berry Cr.	Savanna	511	0.39
		Prairie	85	0.05
		Total	**771**	**1.00**
QTt	Small sample size (10 ac)	Forest	2	
		Savanna	8	
		Prairie	0	
		Total	**10**	

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[1] Geomorphic units are described in Appendix 4.

Step 5. A data matrix was examined to identify the frequency of occurrence among environmental factors such as soil type, geomorphic unit, and the 1850s vegetation types. This information is found in Appendix 3.

Step 6. ODEQ developed tables identifying the dominant paths of near-stream land cover, specifically mixed conifer-hardwood forest, hardwood forest, savanna, and prairie. ODEQ and other agencies ground-verified existing vegetation during TMDL fieldwork in 2000 and 2001, and also verified it with the US Fish and Wildlife Service wetlands inventory and current vegetation maps (ODFW's 1998 Willamette Vegetation coverage). The successional path of the various 1850s vegetation types was projected and combined to produce a range of potential near-stream land cover types to be modeled for each geomorphic surface. The shade produced by the potential near-stream land cover is a surrogate target for the TMDL. Also, a healthy near-stream land cover will support important ecological processes associated with riparian vegetation.

Step 7. The final step in the analysis was to develop a set of "rules" for predicting potential near-stream land cover based on environmental conditions. These rules are intended to guide the TMDL temperature model simulations for potential land cover. Species composition for the various ecoregions in the Willamette Valley will be based on ecological knowledge of plant communities and historic vegetation. The corresponding tree heights will be estimated from current forest inventory plots for the Willamette Basin. Tree heights are listed Appendix 2.

3.4 Data Sources and Scale

ODEQ analyzed sources of data that have been peer-reviewed and published, in addition to field observations conducted by ODEQ. Data sources are available in an electronic format that can be used with Arcview GIS software by ESRI. Each GIS data source was clipped to 300 feet of the right and left bank.

A map of ecoregions by USGS-EPA provided the broadest scale environmental data. Ecoregions are vegetation classifications derived from physical data such as elevation, rainfall, temperature, and geology (Pater, et al. 1998). Ecoregions were used to estimate site productivity for forested areas. These are associated with the Forest Service derived Plant Associations, which are the basis of potential vegetation for Coast and Cascade Mountain Range forests.

The Quaternary geology map and report (USGS, 2001) provided information on the dominant geomorphic features and floodplain development for the Willamette Valley. It delineates areas of the Willamette Valley floodplain, older terraces, Missoula Flood Deposits, and other geomorphic surfaces that influence vegetation.

Soils maps were used from County Soil Surveys developed by the USDA Soil Conservation Service (SCS). Soil drainage was available from the SCS database.

The source of the historic, 1850s vegetation is a map and species list compiled by the Natural Heritage Program and Nature Conservancy from records of the General Land Office Surveyors, 1851 to 1865. Notes of their surveys along transects of section lines provide descriptions of streams and vegetation including tree species and size identification at each section corner.

Ecoregions were mapped at the coarsest scale, while soils were mapped at the finest scale. Geomorphology was mapped at relatively coarse scales, and historic vegetation was mapped at an intermediate scale.

3.5 Range and Assumptions for Modeling Natural Variability

An analysis that seeks to describe the relationship between plants and their physical environment must account for known natural spatial and temporal variability, and also for uncertainty. ODEQ used a level of uncertainty and expected variability to determine the range of potential land cover for use in modeling stream temperatures. To achieve this, ODEQ randomly distributed the range of potential vegetation types over each geomorphic surface.

Various researchers on historic fire disturbance in the Willamette Valley have drawn conclusions on the frequency, extent, and ignition sources of fires prior to Euro-American settlement. The 1850s vegetation reported in General Land Office (GLO) Survey Notes reflects recent disturbance, including fires that may have resulted from Native American or Euro-American activity, and from lightning strikes. To consider relatively undisturbed vegetation for the purpose of modeling stream temperatures, ODEQ estimated a range of potential vegetation cover given a level of disturbance. The level of disturbance is based on the belief that there are more trees today than in the 1850s due to a reduction in fire disturbance.

Savannas and prairies of the 1850s were maintained primarily by fire. Now these areas have soil and water levels capable of supporting more trees than existed at the time of the GLO surveys. Areas that were forests in the 1850s, have the potential to be forest again. Considering current knowledge about succession, ODEQ estimates that today the potential vegetation of areas that were savanna in the 1850s is half forest and half savanna. For areas that were prairies in the 1850s, ODEQ estimate the potential vegetation to be half savanna and half prairie.

Tree heights for hardwood and conifer species are estimated from the published literature for high quality site conditions, Appendix 2. For modeling purposes, ODEQ will assign a percent density canopy cover to each of the vegetation structures. For forested areas ODEQ has assigned a tree density canopy cover of 85 percent, 50 percent for savanna, and 0 percent for prairie. Density is defined as the canopy closure. ODEQ assumes that stands designated as coniferous in the 1850s GLO survey data, Appendix C, were mixed conifer-hardwoods in the riparian areas, because pure conifer riparian stands are rare or nonexistent in the Willamette Valley riparian area.

For Willamette TMDL development, ODEQ modeled an expected range of variability in the coniferous upland riparian areas to account for the patchy nature of riparian vegetation. To calculate the expected range, ODEQ determined the potential vegetation from US Forest Service Plant Association Guides. Based on literature values for natural disturbance in forest stands (Teensma, 1990), ODEQ assumes that at any given time about 25% of the near-stream vegetation would be disturbed.

4 Results of GIS Analysis and Planned Model Scenarios

The results of the analysis, summarized in Figure 3 and in Appendix 3, suggest that three geomorphic surfaces dominate the fluvial and riparian environments of the Willamette Valley bottom, the Willamette River floodplain deposits (Willamette River and major tributaries), alluvium of smaller streams, and the main body of the Missoula Flood deposits (medium and small streams).

Figure 3 **1850s General Land Survey Office Vegetation (forest, savanna, or prairie) by geomorphic surface**

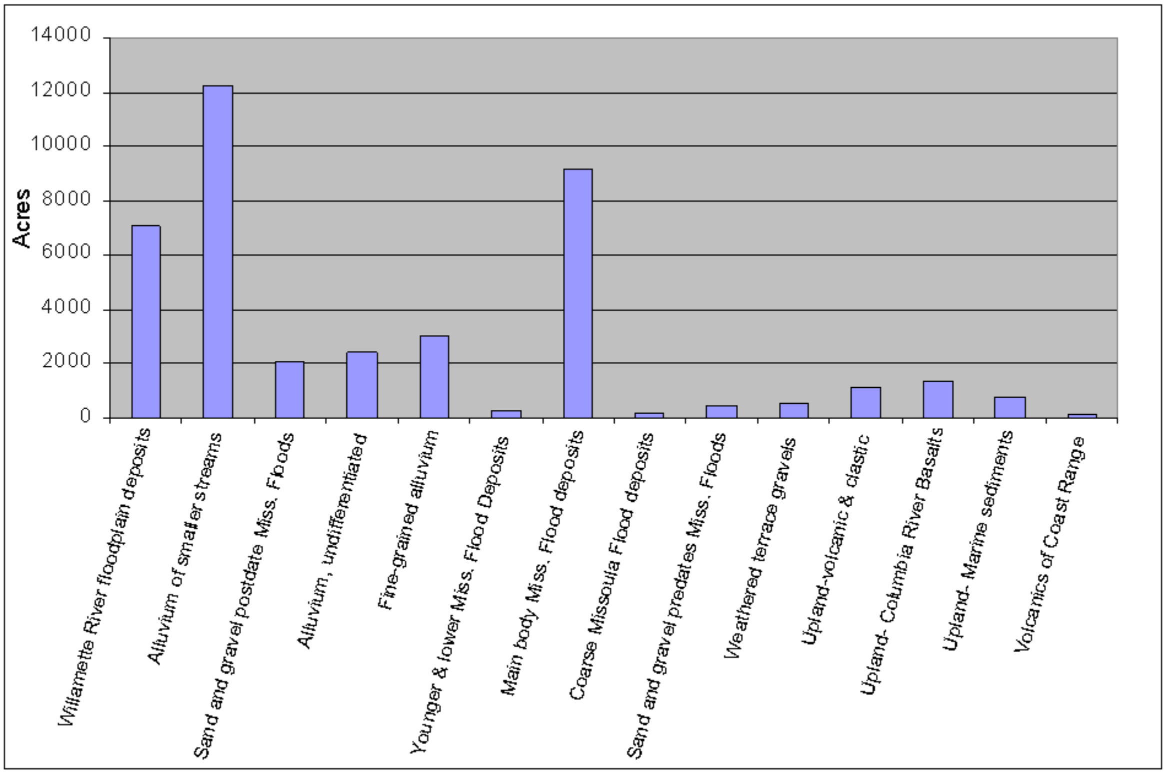
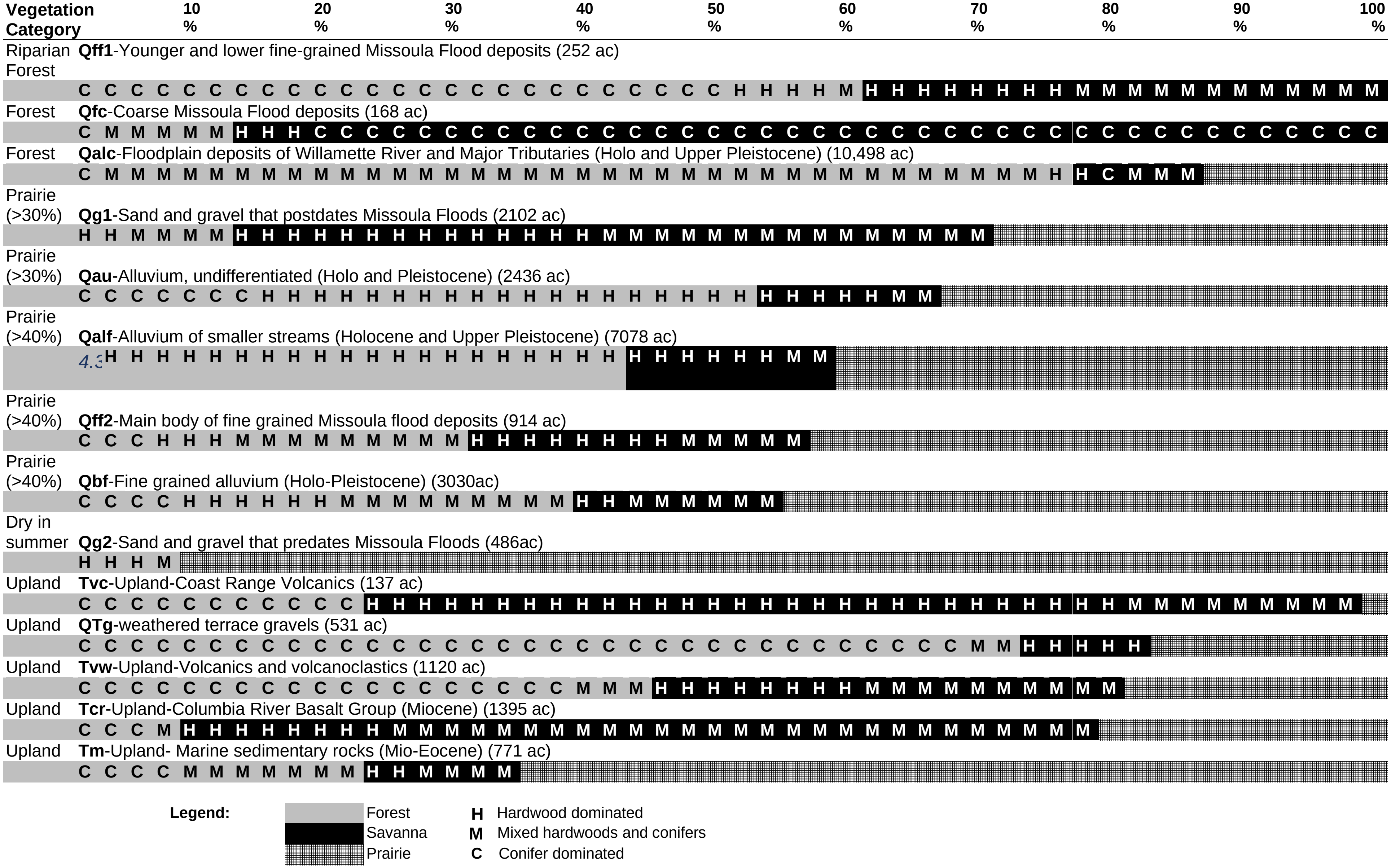


Figure 4 Geomorphic surfaces ordered by relative proportion of 1850s forest, savanna, and prairie vegetation



The historic vegetation for all geomorphic surfaces within the Willamette Valley, summarized in Figure 4, indicates that although there is a continuum of relationships between vegetation structure (forest, savanna, and prairie), and that the geomorphic surfaces can be grouped into four broad categories. The first category is geomorphic surfaces dominated by forest (Qff1, Qfc, Qalc). The second is geomorphic surfaces that were dominated by forest or savanna, and had considerable non-forest (prairie) vegetation (Qg1, Qau, Qalf, Qff2, and Qbf). The third category is a geomorphic surface that had 90% prairie, and dry streams in summer (Qg2). The fourth category is geomorphic surfaces in the upland areas (Tvc, QTg, Tvw, Tcr, and Tm). As already noted, for upland surfaces US Forest Service Plant Associations will be used where available, rather than the 1850 vegetation mapped upland surfaces. The Willamette Valley geomorphic surfaces in Figure 4 are ordered from those with the greatest proportion of forest and savanna (tree covered) when surveyed in the 1850s to those with the greatest proportion of prairie (non tree covered) (Qg2). Figure 4 also indicates the proportion of hardwoods (H) versus mixed conifer-hardwood stands (M) for forest and savanna vegetation types. Average tree heights for conifer stands are greater than for mixed conifer-hardwood stands, which are greater than for hardwood stands.

Analysis indicates that forest dominated three geomorphic surfaces in the 1850s: Qalc, Qff1, and Qfc. The vast majority of the 7498 acres of these geomorphic types occur within or adjacent to the active floodplain of the Willamette River and major tributaries. Qalc are the recent floodplain deposits of the Willamette River and its major tributaries. Qff1 are fine-grained Missoula Flood deposits, and Qfc are coarse Missoula Flood deposits. Qff1 and Qfc occur adjacent to Qalc along the lower Willamette River. Additional information about geomorphic types is provided in Appendix 4.

Forest and savanna dominated five geomorphic surfaces, historically, though four surfaces had a considerable proportion (30 to 46 percent) of prairie vegetation, Qalf, Qff2, Qbf, and Qfb. Qalf is alluvium of relatively small streams, Qff2 is the main body of Missoula Flood deposits, and Qbf is made of fine-grained alluvium deposits. The data indicates that 42 to 46 percent of the Qalf, Qff2, and Qfb units were prairie at the time of the GLO surveys. Together Qalf, Qff2, and Qbf made up the largest area (14,442 acres) of our sampled streams, reflecting the historic vegetation of the small and medium sized valley bottom streams, Figure 3.

Prairie units account for 30-34 percent of the landscape, and native prairie openings are considered an important part of the Willamette Valley ecosystem. The best function of these areas is to remain as native prairie rather than be planted with trees. According to mapping by Christy, et al, 1997, the geomorphic surface Qg2, sand and gravel, that pre-dates the Missoula Floods, had 90% prairie vegetation in the 1850s. The two streams sampled on this surface, Amazon Cr. and Flat Cr., historically ran dry in the summer with water flowing subsurface.

The surfaces of the Cascade foothills and Coast Ranges were primarily forested in the 1850s. Where data are available, the USFS plant associations will be used to determine potential land cover for these upland coniferous forest landforms. For purposes of modeling, the upland coniferous forest vegetation types presented in Appendix 2 will be used.

5 Rules for Developing Potential Near-Stream Land Cover for Modeling Stream Temperature

The rules that follow document the logic for specific riparian vegetation inputs for modeling to predict stream temperature correlated with potential near-stream land cover for the Willamette Basin, except for the Tualatin and Lower Willamette Subbasins. The proportion of vegetation types listed in Table 1 were distributed over each appropriate geomorphic unit and inserted into the temperature model. The temperature model potential near-stream land cover was defined for each 50 foot by 100 foot sampled polygon. The potential near-stream land cover lookup table used in the temperature model to define each polygon is provided in Appendix 5.

Shade targets defining the effective shade for each geomorphic unit have been developed and apply to all streams within the Willamette Basin TMDL analysis area. The shade targets are presented in the form of a shade-curve for each geomorphic unit and the upland forest mountainous area, they are based on the water bodies measured bankful width and aspect, Appendix 6. Shade-curves follow the rules presented for developing potential near-stream land cover, below. Shade-curves may be used to determine the appropriate potential effective shade for unmodeled streams, based on the extent of the specific geomorphic units for the water body.

1. In upland coniferous forests, large conifers are the potential near-stream land cover. The upland coniferous forest is defined as the area within the Willamette Basin outside of the geomorphic unit GIS coverage. Species composition and tree heights used are from the forested plant associations developed by the U. S. Forest Service (Logan, et. al. 1987).

2. Where native Willamette Valley wet and dry prairies remain well-established, native prairie ecosystems should be preserved and/or maintained.

3. Willamette Valley geomorphic units for which plant associations have not been developed; the vegetation types should be managed according to the following rules and ranges, after examining the results of temperature modeling. The proportion of hardwood stands and mixed conifer-hardwood stands have been derived from the 1850s GLO Survey vegetation database, Appendix 3. The proportions of forest, savanna, and prairie composition for each geomorphic unit are listed in Table 1.

A. For Qalc, Qff1, and Qfc, which were historically forested geomorphic surfaces, the potential near-stream land cover is primarily mixed conifer hardwood forest.

- For Qalc (Lower Willamette), ODEQ will model forest cover at 80%, savanna 17%, and prairie 3%. For forestland cover, the portion of conifer is 4%, the portion of mixed hardwood-conifer is 93% and the portion of hardwoods is 3%. For savanna land cover, the portion of mixed hardwood-conifer is 80%, and the portion of hardwoods is 20% (Appendix B).

- For Qff1 (Lower Mainstem Willamette), ODEQ will model forest cover at 81%, savanna 19% and no prairie. For forestland cover, the portion of conifer is 84%, the portion of mixed hardwood-conifer is 3%, and the portion of hardwoods is 13%. For savanna land cover, the portion of mixed hardwood-conifer is 60%, and the portion of hardwoods is 40%.

- For Qfc (Lower Mainstem Willamette), ODEQ will model forest at 56%, savanna 44% and no prairie. For forestland cover, the portion of conifer is 15%, and the portion of mixed hardwood-conifer is 85%. For savanna land cover, the portion of conifer is 93%, and the portion of hardwoods is 7%.

B. The Qg1, Qau, Qalf, Qff2, Qbf, and Qg2 geomorphic units historically had primarily forest and savanna vegetation, but also had considerable prairie. For these units, ODEQ will model forest, savanna and prairie similar to historic conditions and an increased tree cover based on knowledge of current vegetation and soil conditions.

- For Qg1 (Mill Creek), ODEQ will model forest cover at 41%, 44% savanna, and 15% prairie. For forestland cover, the portion of conifer is 8%, the portion of mixed hardwood-conifer is 59% and the portion of hardwoods is 33%. For savanna land cover, the portion of mixed hardwood-conifer is 50%, and the portion of hardwoods is 50%.

- For Qau (Mohawk, upper Luckiamute, upper Oak, middle Thomas Creeks), ODEQ will model forest cover at 60%, 23% savanna, and 17% prairie. For forestland cover, the portion of conifer is 29% and the portion of hardwoods is 71%. For savanna land cover, the portion of conifer is 5%, the portion of mixed hardwood-conifer is 17%, and the portion of hardwoods is 78%.

- For Qalf (Pudding, Muddy Cr, Marys, Yamhill, South Fork Yamhill, Calapooia Rivers), ODEQ will model forest at 52%, 28% savanna, and 20% prairie. For forestland cover, the portion of conifer is 4% and the portion of hardwoods is 96%. For savanna land cover, the portion of mixed hardwood-conifer is 22%, and the portion of hardwoods is 78%.

- For Qff2 (Berry, Ash and North Fork Ash Creeks, upper Muddy (east), upper Lake Creek), ODEQ will model forest at 43%, 35% savanna, and 22% prairie. For forestland cover, the portion of conifer is 19%, the portion of mixed hardwood-conifer is 59% and the portion of hardwoods is 22%. For savanna land cover, the portion of conifer is 5%, the portion of mixed hardwood-conifer is 34%, and the portion of hardwoods is 61%.

- For Qbf (Long Tom, upper Amazon, upper Crabtree Cr.), ODEQ will model forest cover at 47%, 30% savanna, and 23% prairie. For forestland cover, the portion of conifer is 21%, the portion of mixed hardwood-conifer is 48% and the portion of hardwoods is 31%. For savanna land cover, the portion of mixed hardwood-conifer is 81%, and the portion of hardwoods is 19%.

C. For Qg2 (Amazon and Flat Creeks), which had 90% prairie vegetation along streams that historically became subsurface in the summer and for which water is currently artificially diverted to maintain summer flows, historic vegetation is probably not a good guideline for modeling potential present day stream temperature. Instead, ODEQ will use nearest adjacent land potential land cover (see Upper Klamath TMDL for example).

D. For the upland geomorphic surfaces, Tvc, QTg, Tvw, Tcr, and Tm, ODEQ will model using U.S. Forest Service plant associations and the Plant Association Group Model, and incorporate a range of land cover using disturbance suggested by the GIS analysis.

  - Where plant associations are not available, for Tvc (Rickreall Creek headwaters), ODEQ will model forest at 60%, 39% savanna, and 1% prairie. For forestland cover, the portion of conifer is 21%, the portion of mixed hardwood-conifer is 79%. For savanna land cover, the portion of mixed hardwood-conifer is 26%, and the portion of hardwoods is 74%.

  - For QTg (Small portions of upper Rickreall, Marys, Beaver Creek), ODEQ will model forest cover at 77%, 14% savanna, and 9% prairie. For forestland cover, the portion of conifer is 95%, the portion of mixed hardwood-conifer is 4% and the portion of hardwoods is 1%. For savanna land cover, the portion of mixed hardwood-conifer is 90%, and the portion of hardwoods is 10%.

  - For Tvw (Upper Thomas, upper Crabtree, and east headwaters Muddy Creeks), ODEQ will model forest cover at 57%, 39% savanna, and 4% prairie. For forestland cover, the portion of conifer is 84%, the portion of mixed hardwood-conifer is 16%. For savanna land cover, the portion of mixed hardwood-conifer is 45%, and the portion of hardwoods is 55%.

  - For Tcr (Upper Mill Creek), ODEQ will model forest cover at 63%, 27% savanna, and 10% prairie. For forestland cover, the portion of conifer is 93 %, the portion of mixed hardwood-conifer is 7%. For savanna land cover, the portion of mixed hardwood-conifer is 77%, and the portion of hardwoods is 23%.

- For Tm (Upper Ash, North Fork Ash, and upper Berry Creeks), ODEQ will model forest cover at 56%,39% savanna, and 5% prairie. For forestland cover, the portion of conifer is 40%, and the portion of mixed hardwood-conifer is 60%. For savanna land cover, the portion of mixed hardwood-conifer is 59%, and the portion of hardwoods is 41%.

6 Principles for Implementing Willamette Valley Potential Near-Stream Land Cover

The implementation of the modeling and analysis of potential land cover types, to meet temperature TMDL requirements, will be based on three principles. This analysis in not intended to provide a blanket prescription for near-stream vegetation, but rather to recommend appropriate management direction for the areas pertinent to each recommendation.

The first principle is to plant trees in places that previously had tree cover, as indicated by the analysis. Areas that were historically forested and are currently not forested are the highest priority for reforestation.

The second principle is that areas that were historically savanna or prairie, but are currently forested, do not offer further opportunities for increasing stream shade. Existing trees should be retained on these areas.

The third principle is that areas that historically had prairie vegetation, due to fire or to soil and moisture conditions, are the lowest priority for establishing of tree cover. The analysis indicates that landscape diversity in the Willamette Valley is important. Maintaining some open areas can be ecologically important; however, other public goals may lead to establishing trees in these open areas.

In general, areas where the greatest difference is observed between historic/potential land cover and current land cover are the areas that provide the greatest opportunity for establishing near-stream vegetation. These areas are ODEQ’s highest priority for improving stream temperature for aquatic life.

7 References

Alverson, Edward. 1992. Wetland Type Map for West Eugene. Unpublished document prepared for Lane Council of Governments. Nature Conservancy.

Balster, C.A. and R.B. Parsons. 1968. Geomorphology and Soils Willamette Valley, Oregon. Special Report 265. Agricultural Experiment Station Oregon State University, Corvallis and Soil Conservation Service, United States Department of Agriculture

Boyd, Matthew, and Debra Sturdevant. 1997. The Scientific basis for Oregon's Stream Temperature Standard: Common Questions and Straight Answers. Oregon Department of Environmental Quality, Portland OR. 29 pp.

Brenner, P.A., and J.R. Sedell. 1997. Upper Willamette River landscape: a historical perspective. Pages 23-47, in A. Laenen and D.A. Dunnette (eds.), River quality: dynamics and restoration. CRC Press, Boca Raton, Florida.

Christy, J., E. Alverson, M. Dougherty, S. Kolar, L. Ashkenas, and P. Minear. 1998. Presettlement Vegetation for the Willamette Valley, Oregon, (map and species list compiled from records of the General Land Office Surveyors circa 1980). Oregon Natural Heritage Program, Portland, OR.

Christy, John, Edward R. Alverson, Molly P. Dougherty and Susan C. Kolar. 1997. Provisional Classification of "Presettlement" Vegetation in Oregon, As Recorded by General Land Office Surveyors. Oregon Natural Heritage Program, the Nature Conservancy of Oregon.

Cowardin L.M., V. Carter, F.C. Golet and E.T. La Rue. 1979. Classification of Wetlands and Deepwater Habitats of the United States FWS/OBS-79/31. US Fish and Wildlife Service.

Dykaar, B.B. and P.J. Wigington, Jr. 2000. Floodplain Formation and Cottonwood Colonization Patterns on the Willamette River, Oregon, USA. In. Environmental Management Vol. 25 (1): 87-104.

Fowells, H.A. Silvics of Forest Trees of the United States. 1965. USDA Forest Service. Agriculture Handbook No. 271. Washington, D.C.

Frenkel, R.E., S. N. Wickramaratne, and E.F. Heinitz. 1984. Vegetation and land cover change in the Willamette River greenway in Benton and Linn counties, Oregon: 1972-1981. Association of Pacific Coast Geographers 1984 Yearbook 46:63-77.

Gutowsky, S. and J.A. Jones. 2000. Riparian Cover Changes Along the Upper Willamette River, 1939 to 1996. In: Wigington, P.J. and Beschta, R.L. (editors) International Conference on Riparian Ecology and Management in Multi-land Use Watersheds. American Water Resources Association.

Gregory, Stanley, K., S. Kaufman, J.B., Hall, J., Dwire, K.A., Baxter, C. Brookshire, J. 2000. Scientists as citizens: Integrating ecological considerations with riverfront development. In : Wigington, P.J. and Beschta, R.L. (editors) International Conference on Riparian Ecology and Management in Multi-land Use Watersheds. American Water Resources Association.

Heritage Research Associates 1982. Historic use of six reservoir areas in the Upper Willamette Valley, Lane County, Oregon. Report prepared by US Army Corps of Engineers.

Hoerauf, E.A. 1970. Willamette River: riverlands and river boundaries. Water Resources Research Institute, Oregon State University, Corvallis, Oregon. Report number WRRI-1.

Johanessen, C.I., WA Davenport, Millet, McWilliams. 1971. The vegetation of the Willamette Valley. Association of American Geographers. 61:286-302.

Klock, C., S. Smith, T. O'Neil, R. Goggans, C., Barrett. 1998. Willamette Valley Land Use/ Land Cover Map Information Report and Map. Oregon Department Fish and Wildlife.

Knox, Margaret Ann. 2000. Ecological Change in the Willamette Valley at the time of Euro-American contact ca. 1800-1850. M.A. Thesis. University of Oregon.

Landers, D.H. P.K. Haggerty, S. Cline, W. Carson, and F. Faure. . 1999. The role of regionalization in large river restoration. Verh. International. Verein. Limnology, 27:1-8.

Logan, Sheila E., Hemstrom, Miles A., and Pavlat, Warren. 1987 Plant Association and Management Guide Willamette and Siuslaw National Forests. USDA Forest Service, Pacific NorthWest Region.

McAllister, L.S., Dwire, K.A., Griffith, S.M 2000. In: Wigington, P.J. and Beschta, R.L. (editors) International Conference on Riparian Ecology and Management in Multi-land Use Watersheds. American Water Resources Association.

O'Connor, Jim E., Sarna-Wojcicki, Andre, Wozniak, Karl C., Polette, Danial J. Fleck, Robert J. 2001. Origin , Extent, and Thickness of Quaternary Geologic Units in the Willamette Valley, Oregon. U.S. Geological Survey Professional Paper 1620. Denver, Co.

Pater, D.E., S. A. Bryce, T.D. Thorson, J.S. Kagan, C. Chappell, J.M. Omernik, S.H. Azevedo, and A.J. Woods. 1998. Ecoregions of Western Washington and Oregon. USGS/USEPA, Denver, Co

Taylor, Trevor. 1999. Long term vegetation response to fireof the Willamette Valley Wet prairie species. M.A. Thesis. University of Oregon

USDA Soil Conservation Service. 1975. Soils Survey of Benton County, Oregon

USDA Soil Conservation Service. 1987. Soils Survey of Lane County, Oregon

USDA Soil Conservation Service. 1977. Soils Survey of Linn County, Oregon

USDA Soil Conservation Service. 1987. Soils Survey of Yamhill Area, Oregon

USDA Soil Conservation Service. 1974. Soils Survey of Polk County

USGS. Oregon State Geology map

Appendix 1. Scientists Who Participated in Peer Review

Ed Alverson, Nature Conservancy
Mack Barington, Oregon Department of Agriculture
Pat Brenner, Oregon State University
Stan Gregory, Oregon State University, Department of Fisheries and Wildlife
Steve Cline, Environmental Protection Agency Research Laboratory
Dave Hibbs, Oregon State University, Department of Forestry
Sherry Johnson, USDA Pacific Northwest Research Station
Lynn McAllister, Environmental Protection Agency Research Laboratory
Cindy McCain, Willamette and Siuslaw National Forests
Pat McDowell, University of Oregon, Geography Department
Maryanne Reiter, Weyerhauser Corporation
Mindy Taylor, Oregon State University, Department of Fisheries and Wildlife
James Wigington, Environmental Protection Agency Research Laboratory

Appendix 2. Tree heights used for modeling coniferous forest, mixed forest (hardwood and conifer), hardwood forest, and prairie.

System Potential Vegetation for Willamette Valley Ecoregion. Savanna tree heights are the same as forest, except the density of the canopy cover is reduced.

Vegetation type	Height (ft)	Density (%)	Overhang (m)	Height (m)
Forest--Mature Coniferous	160	75%	4.9	48.8
Forest--Mature Mixed Conifer-Hardwood	90	75%	3.3	27.4
Forets--Mature Hardwood	67	75%	3.1	20.4
Savanna--Mature Coniferous	160	50%	4.9	48.8
Savanna--Mature Mixed Conifer-Hardwood	90	50%	3.3	27.4
Savanna--Mature Hardwood	67	50%	3.1	20.4
Prairie--Grassland	3	75%	0.0	0.9

System Potential Vegetation for upland forest mountainous area with USFS Plant Associations available (Logan, et. al. 1987). Range for forests with and without disturbance.

Vegetation type		Height (ft)	Density (%)	Overhang (m)	Height (m)
Disturbed	Forest Semi-closed mixed--25% probability	56	25%	2.0	17.1
No Disturbance	Forest--Mature Coniferous-75% probability	160	75%	4.9	48.8

Appendix 3. Geomorphic surface, 1850s vegetation type, and soil drainage acres

Vegetation Type	General Land Survey Vegetation Type	Geomorphic surface		Acres					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
Forest	Ash swamp and ash swale, sometimes with alder	Qalc	H			4	8	*12*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Qalc	H				10	*10*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Qalc	H				5	*5*	
Forest	Black cottonwood forest, sometimes with willow	Qalc	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Qalc	H	10	109	13	31	*163*	
Forest	White oak forest, oak brush, or oak and hazel brush	Qalc	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Qalc	H					*0*	
Forest	Swamp, composition unknown	Qalc	H		5		5	*10*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Qalc	H		7		27	*34*	234
Forest	Conifer-dominated woodland; various combinations of Douglas	Qalc	C		3	16		*19*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Qalc	C		90	5	88	*183*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Qalc	C	3	44	4	10	*61*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Qalc	C		6			*6*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Qalc	C		72	4	3	*79*	348
Forest	Red alder-mixed conifer riparian forest; combinations of red	Qalc	M	9	453	62	164	*688*	
Forest	White oak-Douglas fir-ponderosa pine forest	Qalc	M			3		*3*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Qalc	M	392	4835	534	939	*6700*	7391
	Total Qalc Forest			**414**	**5624**	**645**	**1290**	***7973***	**7973**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Qalc	H					*0*	
Savanna	White oak savanna	Qalc	H		123	53	52	*228*	
Savanna	White oak-ash savanna	Qalc	H					*0*	
Savanna	White oak-black oak savanna	Qalc	H					*0*	228
Savanna	Douglas fir savanna	Qalc	C		26	9		*35*	
Savanna	Douglas fir-ponderosa pine savanna	Qalc	C			17	6	*23*	
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Qalc	C	5	35	25		*65*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Savanna	Ponderosa pine savanna.	Qalc	C	29	19			*48*	
Savanna	FF, but burned, often with scattered trees surviving fire	Qalc	C		10	3		*13*	184
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Qalc	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Qalc	M		64	22	60	*146*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Qalc	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Qalc	M	20				*20*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Qalc	M		8	16	4	*28*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Qalc	M		353	25	45	*423*	
Savanna	White oak-ponderosa pine savanna	Qalc	M	5	83	5		*93*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Qalc	M		10			*10*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Qalc	M					*0*	720
	Total Qalc Savanna			**59**	**731**	**175**	**167**	***1132***	**1132**
Prairie	Seasonally Wet prairie	Qalc	O				56	*56*	
Prairie	Upland prairie, xeric	Qalc	O	109	1043	128	5	*1285*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Qalc	O	149	1023	53	489	*0*	
Prairie	Gravel bar	Qalc	O	4	42			*46*	
Prairie	Sand bar and sandy barrens	Qalc	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Qalc	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Qalc	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	Qalc	O				6	*6*	
	Total Qalc Prairie			**262**	**2108**	**181**	**556**	***1393***	**10498**
Forest	Ash swamp and ash swale, sometimes with alder	Qalf	H				19	*19*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Qalf	H			5	156	*161*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Qalf	H	14		1492	715	*2221*	
Forest	Black cottonwood forest, sometimes with willow	Qalf	H			18	26	*44*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Qalf	H			260	265	*525*	
Forest	White oak forest, oak brush, or oak and hazel brush	Qalf	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Qalf	H					*0*	

Vegetation Type	**General Land Survey Vegetation Type**	**Geomorphic surface**		**Acres**					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
Forest	Swamp, composition unknown	Qalf	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Qalf	H			7	19	*26*	2996
Forest	Conifer-dominated woodland; various combinations of Douglas	Qalf	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Qalf	C		22	80	9	*111*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Qalf	C					*0*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Qalf	C					*0*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Qalf	C					*0*	111
Forest	Red alder-mixed conifer riparian forest; combinations of red	Qalf	M				5	*5*	
Forest	White oak-Douglas fir-ponderosa pine forest	Qalf	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Qalf	M					*0*	5
	Total Qalf Forest			**14**	**22**	**1862**	**1214**	***3112***	**3112**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Qalf	H		3	19	5	*27*	
Savanna	White oak savanna	Qalf	H		115	227	264	*606*	
Savanna	White oak-ash savanna	Qalf	H		53	94	113	*260*	
Savanna	White oak-black oak savanna	Qalf	H					*0*	893
Savanna	Douglas fir savanna	Qalf	C			6		*6*	
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Qalf	C				4	*4*	
Savanna	Douglas fir-ponderosa pine savanna	Qalf	C					*0*	
Savanna	Ponderosa pine savanna.	Qalf	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Qalf	C					*0*	10
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Qalf	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Qalf	M		19	66	12	*97*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Qalf	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Qalf	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Qalf	M					*0*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Qalf	M					*0*	
Savanna	White oak-ponderosa pine savanna	Qalf	M		68	45	37	*150*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Qalf	M					*0*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
Savanna	FFHC, but burned, often with scattered trees surviving fire	Qalf	M					*0*	247
	Total Qalf Savanna			**0**	**258**	**457**	**435**	***1150***	**1150**
Prairie	Seasonally Wet prairie	Qalf	O				1099	*1099*	
Prairie	Upland prairie, xeric	Qalf	O		484	1134	65	*1683*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Qalf	O		5	5		*10*	
Prairie	Gravel bar	Qalf	O					*0*	
Prairie	Sand bar and sandy barrens	Qalf	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Qalf	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Qalf	O		6	4	14	*24*	
Prairie	Fern openings, fern hills, or open fern land	Qalf	O					*0*	
	Total Qalf Prairie			**0**	**495**	**1143**	**1178**	***2816***	**7078**
Forest	Ash swamp and ash swale, sometimes with alder	Qau	H				13	*13*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Qau	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Qau	H	48	448	210	40	*746*	
Forest	Black cottonwood forest, sometimes with willow	Qau	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Qau	H					*0*	
Forest	White oak forest, oak brush, or oak and hazel brush	Qau	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Qau	H					*0*	
Forest	Swamp, composition unknown	Qau	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Qau	H				188	*188*	947
Forest	Conifer-dominated woodland; various combinations of Douglas	Qau	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Qau	C	7	105	140	65	*317*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Qau	C		9			*9*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Qau	C		3			*3*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Qau	C		52	4		*56*	385
Forest	Red alder-mixed conifer riparian forest; combinations of red	Qau	M		5			*5*	
Forest	White oak-Douglas fir-ponderosa pine forest	Qau	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Qau	M					*0*	5

Vegetation Type	**General Land Survey Vegetation Type**	**Geomor-phic surface**		**Acres**					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
	Total Qau Forest			**55**	**622**	**354**	**306**	***1337***	**1337**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Qau	H					*0*	
Savanna	White oak savanna	Qau	H	4	89	114	19	*226*	
Savanna	White oak-ash savanna	Qau	H					*0*	
Savanna	White oak-black oak savanna	Qau	H					*0*	226
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Qau	C					*0*	
Savanna	Douglas fir savanna	Qau	C					*0*	
Savanna	Douglas fir-ponderosa pine savanna	Qau	C			13		*13*	
Savanna	Ponderosa pine savanna.	Qau	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Qau	C					*0*	13
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Qau	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Qau	M					*0*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Qau	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Qau	M	8				*8*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Qau	M		13	8		*21*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Qau	M				14	*14*	
Savanna	White oak-ponderosa pine savanna	Qau	M		6			*6*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Qau	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Qau	M					*0*	49
	Total Qau Savanna			**12**	**108**	**135**	**33**	***288***	**288**
Prairie	Seasonally Wet prairie	Qau	O				238	*238*	
Prairie	Upland prairie, xeric	Qau	O	17	213	239	90	*559*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Qau	O					*0*	
Prairie	Gravel bar	Qau	O					*0*	
Prairie	Sand bar and sandy barrens	Qau	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Qau	O				10	*10*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Qau	O		4			*4*	
Prairie	Fern openings, fern hills, or open fern land	Qau	O					*0*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
	Total Qau Prairie			**17**	**217**	**239**	**338**	***811***	**2436**
Forest	Ash swamp and ash swale, sometimes with alder	Qbf	H			7	33	*40*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Qbf	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Qbf	H					*0*	
Forest	Black cottonwood forest, sometimes with willow	Qbf	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Qbf	H	2	14	115	193	*324*	
Forest	White oak forest, oak brush, or oak and hazel brush	Qbf	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Qbf	H					*0*	
Forest	Swamp, composition unknown	Qbf	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Qbf	H					*0*	364
Forest	Conifer-dominated woodland; various combinations of Douglas	Qbf	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Qbf	C		221	14		*235*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Qbf	C			15		*15*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Qbf	C					*0*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Qbf	C					*0*	250
Forest	Red alder-mixed conifer riparian forest; combinations of red	Qbf	M					*0*	
Forest	White oak-Douglas fir-ponderosa pine forest	Qbf	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Qbf	M	8	297	157	94	*556*	556
	Total Qbf Forest			**10**	**532**	**308**	**320**	***1170***	**1170**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Qbf	H			4		*4*	
Savanna	White oak savanna	Qbf	H		24	45	16	*85*	
Savanna	White oak-ash savanna	Qbf	H					*0*	
Savanna	White oak-black oak savanna	Qbf	H					*0*	89
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Qbf	C					*0*	
Savanna	Douglas fir savanna	Qbf	C					*0*	
Savanna	Douglas fir-ponderosa pine savanna	Qbf	C					*0*	
Savanna	Ponderosa pine savanna.	Qbf	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Qbf	C					*0*	0

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Qbf	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Qbf	M					*0*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Qbf	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Qbf	M			29		*29*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Qbf	M		161	49	43	*253*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Qbf	M				18	*18*	
Savanna	White oak-ponderosa pine savanna	Qbf	M	4	59	27		*90*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Qbf	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Qbf	M					*0*	390
	Total Qbf Savanna			**4**	**244**	**154**	**77**	***479***	**479**
Prairie	Seasonally Wet prairie	Qbf	O				826	*826*	
Prairie	Upland prairie, xeric	Qbf	O	5	103	357	90	*555*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Qbf	O					*0*	
Prairie	Gravel bar	Qbf	O					*0*	
Prairie	Sand bar and sandy barrens	Qbf	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Qbf	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Qbf	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	Qbf	O					*0*	
	Total Qbf Prairie			**5**	**103**	**357**	**916**	***1381***	**3030**
Forest	Ash swamp and ash swale, sometimes with alder	Qfc	H					*0*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Qfc	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Qfc	H					*0*	
Forest	Black cottonwood forest, sometimes with willow	Qfc	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Qfc	H					*0*	
Forest	White oak forest, oak brush, or oak and hazel brush	Qfc	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Qfc	H					*0*	
Forest	Swamp, composition unknown	Qfc	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Qfc	H					*0*	0

Vegetation Type	General Land Survey Vegetation Type	Geomorphic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Forest	Conifer-dominated woodland; various combinations of Douglas	Qfc	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Qfc	C					*0*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Qfc	C					*0*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Qfc	C					*0*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Qfc	C		3			*3*	3
Forest	Red alder-mixed conifer riparian forest; combinations of red	Qfc	M		3	14		*17*	
Forest	White oak-Douglas fir-ponderosa pine forest	Qfc	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Qfc	M					*0*	17
	Total Qfc Forest			**0**	**6**	**14**	**0**	***20***	**20**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Qfc	H		11			*11*	
Savanna	White oak savanna	Qfc	H					*0*	
Savanna	White oak-ash savanna	Qfc	H					*0*	
Savanna	White oak-black oak savanna	Qfc	H					*0*	11
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Qfc	C		39			*39*	
Savanna	Douglas fir savanna	Qfc	C			98		*98*	
Savanna	Douglas fir-ponderosa pine savanna	Qfc	C					*0*	
Savanna	Ponderosa pine savanna.	Qfc	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Qfc	C					*0*	137
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Qfc	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Qfc	M					*0*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Qfc	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Qfc	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Qfc	M					*0*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Qfc	M					*0*	
Savanna	White oak-ponderosa pine savanna	Qfc	M					*0*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Qfc	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Qfc	M					*0*	0
	Total Qfc Savanna			**0**	**50**	**98**	**0**	***148***	**148**

Vegetation Type	**General Land Survey Vegetation Type**	**Geomor-phic surface**		**Acres**					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
Prairie	Seasonally Wet prairie	Qfc	O					*0*	
Prairie	Upland prairie, xeric	Qfc	O					*0*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Qfc	O					*0*	
Prairie	Gravel bar	Qfc	O					*0*	
Prairie	Sand bar and sandy barrens	Qfc	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Qfc	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Qfc	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	Qfc	O					*0*	
	Total Qfc Prairie			**0**	**0**	**0**	**0**	***0***	**168**
Forest	Ash swamp and ash swale, sometimes with alder	Qff1	H					*0*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Qff1	H			6	7	*13*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Qff1	H					*0*	
Forest	Black cottonwood forest, sometimes with willow	Qff1	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Qff1	H					*0*	
Forest	White oak forest, oak brush, or oak and hazel brush	Qff1	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Qff1	H					*0*	
Forest	Swamp, composition unknown	Qff1	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Qff1	H			8		*8*	21
Forest	Conifer-dominated woodland; various combinations of Douglas	Qff1	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Qff1	C		16	49	7	*72*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Qff1	C		36	16	5	*57*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Qff1	C					*0*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Qff1	C					*0*	129
Forest	Red alder-mixed conifer riparian forest; combinations of red	Qff1	M			4		*4*	
Forest	White oak-Douglas fir-ponderosa pine forest	Qff1	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Qff1	M					*0*	4
	Total Qff1 Forest			**0**	**52**	**83**	**19**	***154***	**154**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Qff1	H			25	14	*39*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Savanna	White oak savanna	Qff1	H					*0*	
Savanna	White oak-ash savanna	Qff1	H					*0*	
Savanna	White oak-black oak savanna	Qff1	H					*0*	39
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Qff1	C					*0*	
Savanna	Douglas fir savanna	Qff1	C					*0*	
Savanna	Douglas fir-ponderosa pine savanna	Qff1	C					*0*	
Savanna	Ponderosa pine savanna.	Qff1	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Qff1	C					*0*	0
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Qff1	M		7			*7*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Qff1	M					*0*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Qff1	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Qff1	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Qff1	M			51		*51*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Qff1	M					*0*	
Savanna	White oak-ponderosa pine savanna	Qff1	M					*0*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Qff1	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Qff1	M					*0*	58
	Total Qff1 Savanna			**0**	**7**	**76**	**14**	***97***	**97**
Prairie	Seasonally Wet prairie	Qff1	O					*0*	
Prairie	Upland prairie, xeric	Qff1	O					*0*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Qff1	O					*0*	
Prairie	Gravel bar	Qff1	O					*0*	
Prairie	Sand bar and sandy barrens	Qff1	O					*0*	
Prairie	Marsh, composition unknown; includes "wet meadow"	Qff1	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Qff1	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	Qff1	O					*0*	
	Total Qff1 Prairie			**0**	**0**	**0**	**0**	***0***	**251**
Forest	Ash swamp and ash swale, sometimes with alder	Qff2	H			25	175	*200*	

Vegetation Type	General Land Survey Vegetation Type	Geomorphic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Qff2	H				3	*3*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Qff2	H			26	33	*59*	
Forest	Black cottonwood forest, sometimes with willow	Qff2	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Qff2	H		26	118	159	*303*	
Forest	White oak forest, oak brush, or oak and hazel brush	Qff2	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Qff2	H					*0*	
Forest	Swamp, composition unknown	Qff2	H		6			*6*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Qff2	H		8	26		*34*	605
Forest	Conifer-dominated woodland; various combinations of Douglas	Qff2	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Qff2	C		50	390	72	*512*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Qff2	C					*0*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Qff2	C					*0*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Qff2	C					*0*	512
Forest	Red alder-mixed conifer riparian forest; combinations of red	Qff2	M			6		*6*	
Forest	White oak-Douglas fir-ponderosa pine forest	Qff2	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Qff2	M	3	419	780	404	*1606*	1612
	Total Qff2 Forest			**3**	**509**	**1371**	**846**	***2729***	**2729**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Qff2	H		17	5	9	*31*	
Savanna	White oak savanna	Qff2	H		99	430	720	*1249*	
Savanna	White oak-ash savanna	Qff2	H		7	32	63	*102*	
Savanna	White oak-black oak savanna	Qff2	H					*0*	1382
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Qff2	C		5	88	8	*101*	
Savanna	Douglas fir savanna	Qff2	C		8	84		*92*	
Savanna	Douglas fir-ponderosa pine savanna	Qff2	C			26		*26*	
Savanna	Ponderosa pine savanna.	Qff2	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Qff2	C					*0*	118
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Qff2	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Qff2	M			543	121	*664*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Qff2	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Qff2	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Qff2	M	7	7	32	13	*59*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Qff2	M					*0*	
Savanna	White oak-ponderosa pine savanna	Qff2	M		6	16	16	*38*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Qff2	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Qff2	M					*0*	761
	Total Qff2 Savanna			**7**	**149**	**1256**	**950**	***2362***	**2261**
Prairie	Seasonally Wet prairie	Qff2	O		4		1391	*1395*	
Prairie	Upland prairie, xeric	Qff2	O		396	1544	625	*2565*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Qff2	O		4	9	4	*17*	
Prairie	Gravel bar	Qff2	O					*0*	
Prairie	Sand bar and sandy barrens	Qff2	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Qff2	O				41	*41*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Qff2	O			18	13	*31*	
Prairie	Fern openings, fern hills, or open fern land	Qff2	O					*0*	
	Total Qff2 Prairie			**0**	**404**	**1571**	**2074**	***4049***	**9140**
Forest	Ash swamp and ash swale, sometimes with alder	Qg1	H				3	*3*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Qg1	H			3	9	*12*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Qg1	H				36	*36*	
Forest	Black cottonwood forest, sometimes with willow	Qg1	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Qg1	H			8	6	*14*	
Forest	White oak forest, oak brush, or oak and hazel brush	Qg1	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Qg1	H					*0*	
Forest	Swamp, composition unknown	Qg1	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Qg1	H				22	*22*	87
Forest	Conifer-dominated woodland; various combinations of Douglas	Qg1	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Qg1	C		11			*11*	

Vegetation Type	**General Land Survey Vegetation Type**	**Geomorphic surface**		**Acres**					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
Forest	Douglas fir-white oak (bigleaf maple) forest,	Qg1	C					*0*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Qg1	C		10			*10*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Qg1	C					*0*	21
Forest	Red alder-mixed conifer riparian forest; combinations of red	Qg1	M		47		5	*52*	
Forest	White oak-Douglas fir-ponderosa pine forest	Qg1	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Qg1	M	5	51	36	8	*100*	152
	Total Qg1 Forest			**5**	**119**	**47**	**89**	***260***	**260**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Qg1	H					*0*	
Savanna	White oak savanna	Qg1	H		105	43	97	*245*	
Savanna	White oak-ash savanna	Qg1	H		39	15	298	*352*	
Savanna	White oak-black oak savanna	Qg1	H					*0*	597
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Qg1	C					*0*	
Savanna	Douglas fir savanna	Qg1	C			10		*10*	
Savanna	Douglas fir-ponderosa pine savanna	Qg1	C					*0*	
Savanna	Ponderosa pine savanna.	Qg1	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Qg1	C					*0*	10
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Qg1	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Qg1	M		111		48	*159*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Qg1	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Qg1	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Qg1	M		63	109	253	*425*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Qg1	M			5		*5*	
Savanna	White oak-ponderosa pine savanna	Qg1	M					*0*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Qg1	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Qg1	M					*0*	589
	Total Qg1 Savanna			**0**	**318**	**182**	**696**	***1196***	**1196**
Prairie	Seasonally Wet prairie	Qg1	O				131	*131*	
Prairie	Upland prairie, xeric	Qg1	O		161	240	89	*490*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Qg1	O		25			*25*	
Prairie	Gravel bar	Qg1	O					*0*	
Prairie	Sand bar and sandy barrens	Qg1	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Qg1	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Qg1	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	Qg1	O					*0*	
	Total Qg1 Prairie			**0**	**186**	**240**	**220**	***646***	**2102**
Forest	Ash swamp and ash swale, sometimes with alder	Qg2	H					*0*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Qg2	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Qg2	H					*0*	
Forest	Black cottonwood forest, sometimes with willow	Qg2	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Qg2	H			14	11	*25*	
Forest	White oak forest, oak brush, or oak and hazel brush	Qg2	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Qg2	H					*0*	
Forest	Swamp, composition unknown	Qg2	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Qg2	H					*0*	25
Forest	Conifer-dominated woodland; various combinations of Douglas	Qg2	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Qg2	C					*0*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Qg2	C					*0*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Qg2	C					*0*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Qg2	C					*0*	0
Forest	Red alder-mixed conifer riparian forest; combinations of red	Qg2	M					*0*	
Forest	White oak-Douglas fir-ponderosa pine forest	Qg2	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Qg2	M		6	6	3	*15*	15
	Total Qg2 Forest			**0**	**6**	**20**	**14**	***40***	**40**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Qg2	H					*0*	
Savanna	White oak savanna	Qg2	H					*0*	
Savanna	White oak-ash savanna	Qg2	H					*0*	

Vegetation Type	General Land Survey Vegetation Type	Geomorphic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Savanna	White oak-black oak savanna	Qg2	H					*0*	0
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Qg2	C					*0*	
Savanna	Douglas fir savanna	Qg2	C					*0*	
Savanna	Douglas fir-ponderosa pine savanna	Qg2	C					*0*	
Savanna	Ponderosa pine savanna.	Qg2	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Qg2	C					*0*	0
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Qg2	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Qg2	M					*0*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Qg2	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Qg2	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Qg2	M					*0*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Qg2	M					*0*	
Savanna	White oak-ponderosa pine savanna	Qg2	M					*0*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Qg2	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Qg2	M					*0*	0
	Total Qg2 Savanna			**0**	**0**	**0**	**0**	***0***	**0**
Prairie	Seasonally Wet prairie	Qg2	O				238	*238*	
Prairie	Upland prairie, xeric	Qg2	O		20	103	85	*208*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Qg2	O					*0*	
Prairie	Gravel bar	Qg2	O					*0*	
Prairie	Sand bar and sandy barrens	Qg2	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Qg2	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Qg2	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	Qg2	O					*0*	
	Total Qg2 Prairie			**0**	**20**	**103**	**323**	***446***	**486**
Forest	Ash swamp and ash swale, sometimes with alder	QTg	H				4	*4*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	QTg	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	QTg	H					*0*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Forest	Black cottonwood forest, sometimes with willow	QTg	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	QTg	H					*0*	
Forest	White oak forest, oak brush, or oak and hazel brush	QTg	H					*0*	
Forest	ODEQ Wetland, composition unknown; includes "slough" & "swale" in	QTg	H					*0*	
Forest	Swamp, composition unknown	QTg	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	QTg	H					*0*	4
Forest	Conifer-dominated woodland; various combinations of Douglas	QTg	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	QTg	C		106	206	31	*343*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	QTg	C					*0*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	QTg	C		4			*4*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	QTg	C		19			*19*	366
Forest	Red alder-mixed conifer riparian forest; combinations of red	QTg	M					*0*	
Forest	White oak-Douglas fir-ponderosa pine forest	QTg	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	QTg	M			17		*17*	17
	Total QTg Forest			**0**	**129**	**223**	**35**	***387***	**387**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	QTg	H					*0*	
Savanna	White oak savanna	QTg	H		27	6	5	*38*	
Savanna	White oak-ash savanna	QTg	H					*0*	
Savanna	White oak-black oak savanna	QTg	H					*0*	38
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	QTg	C					*0*	
Savanna	Douglas fir savanna	QTg	C					*0*	
Savanna	Douglas fir-ponderosa pine savanna	QTg	C					*0*	
Savanna	Ponderosa pine savanna.	QTg	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	QTg	C					*0*	0
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	QTg	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	QTg	M					*0*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	QTg	M					*0*	

Vegetation Type	**General Land Survey Vegetation Type**	**Geomor-phic surface**		**Acres**					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
Savanna	White oak-black oak-ponderosa pine savanna	QTg	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	QTg	M		4			*4*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	QTg	M					*0*	
Savanna	White oak-ponderosa pine savanna	QTg	M					*0*	
Savanna	FFA, but burned, often with scattered trees surviving fire	QTg	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	QTg	M					*0*	4
	Total QTg Savanna			**0**	**31**	**6**	**5**	***42***	**42**
Prairie	Seasonally Wet prairie	QTg	O				34	*34*	
Prairie	Upland prairie, xeric	QTg	O		17	20	24	*61*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	QTg	O	3	4			*7*	
Prairie	Gravel bar	QTg	O					*0*	
Prairie	Sand bar and sandy barrens	QTg	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	QTg	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	QTg	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	QTg	O					*0*	
	Total QTg Prairie			**3**	**21**	**20**	**58**	***102***	**531**
Forest	Ash swamp and ash swale, sometimes with alder	QTt	H					*0*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	QTt	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	QTt	H					*0*	
Forest	Black cottonwood forest, sometimes with willow	QTt	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	QTt	H					*0*	
Forest	White oak forest, oak brush, or oak and hazel brush	QTt	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	QTt	H					*0*	
Forest	Swamp, composition unknown	QTt	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	QTt	H					*0*	0
Forest	Conifer-dominated woodland; various combinations of Douglas	QTt	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	QTt	C					*0*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	QTt	C					*0*	

Vegetation Type	General Land Survey Vegetation Type	Geomorphic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	QTt	C					*0*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	QTt	C					*0*	0
Forest	Red alder-mixed conifer riparian forest; combinations of red	QTt	M					*0*	
Forest	White oak-Douglas fir-ponderosa pine forest	QTt	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	QTt	M		2			*2*	2
	Total QTt Forest			**0**	**2**	**0**	**0**	***2***	**2**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	QTt	H					*0*	
Savanna	White oak savanna	QTt	H					*0*	
Savanna	White oak-ash savanna	QTt	H					*0*	
Savanna	White oak-black oak savanna	QTt	H					*0*	0
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	QTt	C		5	3		*8*	
Savanna	Douglas fir savanna	QTt	C					*0*	
Savanna	Douglas fir-ponderosa pine savanna	QTt	C					*0*	
Savanna	Ponderosa pine savanna.	QTt	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	QTt	C					*0*	0
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	QTt	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	QTt	M					*0*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	QTt	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	QTt	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	QTt	M					*0*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	QTt	M					*0*	
Savanna	White oak-ponderosa pine savanna	QTt	M					*0*	
Savanna	FFA, but burned, often with scattered trees surviving fire	QTt	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	QTt	M					*0*	0
	Total QTt Savanna			**0**	**5**	**3**	**0**	***8***	**0**
Prairie	Seasonally Wet prairie	QTt	O					*0*	
Prairie	Upland prairie, xeric	QTt	O					*0*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	QTt	O					*0*	

Vegetation Type	**General Land Survey Vegetation Type**	**Geomor-phic surface**		**Acres**					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
Prairie	Gravel bar	QTt	O					*0*	
Prairie	Sand bar and sandy barrens	QTt	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	QTt	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	QTt	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	QTt	O					*0*	
	Total QTt Prairie			**0**	**0**	**0**	**0**	***0***	**10**
Forest	Ash swamp and ash swale, sometimes with alder	Tcr	H					*0*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Tcr	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Tcr	H					*0*	
Forest	Black cottonwood forest, sometimes with willow	Tcr	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Tcr	H					*0*	
Forest	White oak forest, oak brush, or oak and hazel brush	Tcr	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Tcr	H					*0*	
Forest	Swamp, composition unknown	Tcr	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Tcr	H					*0*	0
Forest	Conifer-dominated woodland; various combinations of Douglas	Tcr	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Tcr	C		47	41	24	*112*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Tcr	C					*0*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Tcr	C					*0*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Tcr	C					*0*	112
Forest	Red alder-mixed conifer riparian forest; combinations of red	Tcr	M					*0*	
Forest	White oak-Douglas fir-ponderosa pine forest	Tcr	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Tcr	M			9		*9*	9
	Total Tcr Forest			**0**	**47**	**50**	**24**	***121***	**121**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Tcr	H					*0*	
Savanna	White oak savanna	Tcr	H		120	81	25	*226*	
Savanna	White oak-ash savanna	Tcr	H					*0*	
Savanna	White oak-black oak savanna	Tcr	H					*0*	226

Vegetation Type	**General Land Survey Vegetation Type**	**Geomor-phic surface**		**Acres**					
				Excessively drained	**Well-drained**	**Mod.-Well drained**	**Poorly drained**	**Total Veg.**	**Hdwd, Con, Mix**
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Tcr	C		46	61	31	*138*	
Savanna	Douglas fir savanna	Tcr	C					*0*	
Savanna	Douglas fir-ponderosa pine savanna	Tcr	C					*0*	
Savanna	Ponderosa pine savanna.	Tcr	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Tcr	C					*0*	0
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Tcr	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Tcr	M		46	17	33	*96*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Tcr	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Tcr	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Tcr	M		322	185	5	*512*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Tcr	M					*0*	
Savanna	White oak-ponderosa pine savanna	Tcr	M					*0*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Tcr	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Tcr	M					*0*	746
	Total Tcr Savanna			**0**	**534**	**344**	**94**	***972***	**972**
Prairie	Seasonally Wet prairie	Tcr	O				19	*19*	
Prairie	Upland prairie, xeric	Tcr	O		193	42	23	*258*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Tcr	O				22	*22*	
Prairie	Gravel bar	Tcr	O					*0*	
Prairie	Sand bar and sandy barrens	Tcr	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Tcr	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Tcr	O			3		*3*	
Prairie	Fern openings, fern hills, or open fern land	Tcr	O					*0*	
	Total Tcr Prairie			**0**	**193**	**45**	**45**	***302***	**1395**
Forest	Ash swamp and ash swale, sometimes with alder	Tm	H					*0*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Tm	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Tm	H					*0*	
Forest	Black cottonwood forest, sometimes with willow	Tm	H					*0*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Tm	H					*0*	
Forest	White oak forest, oak brush, or oak and hazel brush	Tm	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Tm	H					*0*	
Forest	Swamp, composition unknown	Tm	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Tm	H					*0*	0
Forest	Conifer-dominated woodland; various combinations of Douglas	Tm	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Tm	C					*0*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Tm	C		40			*40*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Tm	C			30		*30*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Tm	C					*0*	70
Forest	Red alder-mixed conifer riparian forest; combinations of red	Tm	M					*0*	
Forest	White oak-Douglas fir-ponderosa pine forest	Tm	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Tm	M		20	26	59	*105*	105
	Total Tm Forest			**0**	**60**	**56**	**59**	***175***	**175**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Tm	H					*0*	
Savanna	White oak savanna	Tm	H		27	120	60	*207*	
Savanna	White oak-ash savanna	Tm	H					*0*	
Savanna	White oak-black oak savanna	Tm	H					*0*	207
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Tm	C					*0*	
Savanna	Douglas fir savanna	Tm	C					*0*	
Savanna	Douglas fir-ponderosa pine savanna	Tm	C					*0*	
Savanna	Ponderosa pine savanna.	Tm	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Tm	C					*0*	0
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Tm	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Tm	M		151	118	28	*297*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Tm	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Tm	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Tm	M		7			*7*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Savanna	White oak-Douglas fir-ponderosa pine savanna	Tm	M					*0*	
Savanna	White oak-ponderosa pine savanna	Tm	M					*0*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Tm	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Tm	M					*0*	304
	Total Tm Savanna			**0**	**185**	**238**	**88**	***511***	**511**
Prairie	Seasonally Wet prairie	Tm	O				9	*9*	
Prairie	Upland prairie, xeric	Tm	O		13	48	15	*76*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Tm	O					*0*	
Prairie	Gravel bar	Tm	O					*0*	
Prairie	Sand bar and sandy barrens	Tm	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Tm	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Tm	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	Tm	O					*0*	
	Total Tm Prairie			**0**	**13**	**48**	**24**	***85***	**771**
Forest	Ash swamp and ash swale, sometimes with alder	Tvc	H					*0*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Tvc	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Tvc	H					*0*	
Forest	Black cottonwood forest, sometimes with willow	Tvc	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Tvc	H					*0*	
Forest	White oak forest, oak brush, or oak and hazel brush	Tvc	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Tvc	H					*0*	
Forest	Swamp, composition unknown	Tvc	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Tvc	H					*0*	0
Forest	Conifer-dominated woodland; various combinations of Douglas	Tvc	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Tvc	C					*0*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Tvc	C		6			*6*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Tvc	C					*0*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Tvc	C					*0*	6

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Forest	Red alder-mixed conifer riparian forest; combinations of red	Tvc	M					*0*	
Forest	White oak-Douglas fir-ponderosa pine forest	Tvc	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Tvc	M		20	3		*23*	23
	Total Tvc Forest			**0**	**26**	**3**	**0**	***29***	**29**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Tvc	H					*0*	
Savanna	White oak savanna	Tvc	H	5	27	35	10	*77*	
Savanna	White oak-ash savanna	Tvc	H					*0*	
Savanna	White oak-black oak savanna	Tvc	H					*0*	77
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Tvc	C					*0*	
Savanna	Douglas fir savanna	Tvc	C					*0*	
Savanna	Douglas fir-ponderosa pine savanna	Tvc	C					*0*	
Savanna	Ponderosa pine savanna.	Tvc	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Tvc	C					*0*	0
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Tvc	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Tvc	M		18	7	2	*27*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Tvc	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Tvc	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Tvc	M					*0*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Tvc	M					*0*	
Savanna	White oak-ponderosa pine savanna	Tvc	M					*0*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Tvc	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Tvc	M					*0*	27
	Total Tvc Savanna			**5**	**45**	**42**	**12**	***104***	**104**
Prairie	Seasonally Wet prairie	Tvc	O					*0*	
Prairie	Upland prairie, xeric	Tvc	O		4			*4*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Tvc	O					*0*	
Prairie	Gravel bar	Tvc	O					*0*	
Prairie	Sand bar and sandy barrens	Tvc	O					*0*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Prairie	Marsh, composition unknown; includes "Wet meadow"	Tvc	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Tvc	O					*0*	
Prairie	Fern openings, fern hills, or open fern land	Tvc	O					*0*	
	Total Tvc Prairie			**0**	**4**	**0**	**0**	***4***	**137**
Forest	Ash swamp and ash swale, sometimes with alder	Tvw	H					*0*	
Forest	Ash-alder-willow swamp, sometimes with bigleaf maple	Tvw	H					*0*	
Forest	Ash-willow swamp, sometimes w/ ninebark & briars; "very thick"	Tvw	H					*0*	
Forest	Black cottonwood forest, sometimes with willow	Tvw	H					*0*	
Forest	White oak-ash riparian forest, sometimes with ponderosa pine,	Tvw	H					*0*	
Forest	White oak forest, oak brush, or oak and hazel brush	Tvw	H					*0*	
Forest	Wetland, composition unknown; includes "slough" & "swale" in	Tvw	H					*0*	
Forest	Swamp, composition unknown	Tvw	H					*0*	
Forest	Willow swamp, sometimes with ninebark, including riparian	Tvw	H					*0*	0
Forest	Conifer-dominated woodland; various combinations of Douglas	Tvw	C					*0*	
Forest	Douglas fir forest, often with bigleaf maple, grand fir,	Tvw	C	3	76	139	16	*234*	
Forest	Douglas fir-white oak (bigleaf maple) forest,	Tvw	C		20	4		*24*	
Forest	Low-elevation mix of (1) xeric Douglas fir-chinquapin-madrone	Tvw	C		11			*11*	
Forest	Mesic mixed conifer forest with mostly deciduous understory	Tvw	C		104	57		*161*	430
Forest	Red alder-mixed conifer riparian forest; combinations of red	Tvw	M		14	4		*18*	
Forest	White oak-Douglas fir-ponderosa pine forest	Tvw	M					*0*	
Forest	Ash-mixed deciduous riparian forest with combinations of red	Tvw	M	5	30	15	12	*62*	80
	Total Tvw Forest			**8**	**255**	**219**	**28**	***510***	**510**
Savanna	"Scattering" or "thinly timbered" white oak woodland, brushy	Tvw	H					*0*	
Savanna	White oak savanna	Tvw	H		31	96	87	*214*	
Savanna	White oak-ash savanna	Tvw	H					*0*	
Savanna	White oak-black oak savanna	Tvw	H					*0*	214
Savanna	Douglas fir woodland or "timber" often with bigleaf maple, alder	Tvw	C			3		*3*	
Savanna	Douglas fir savanna	Tvw	C					*0*	

Vegetation Type	General Land Survey Vegetation Type	Geomor-phic surface		Acres					
				Excessively drained	Well-drained	Mod.-Well drained	Poorly drained	Total Veg.	Hdwd, Con, Mix
Savanna	Douglas fir-ponderosa pine savanna	Tvw	C					*0*	
Savanna	Ponderosa pine savanna.	Tvw	C					*0*	
Savanna	FF, but burned, often with scattered trees surviving fire	Tvw	C					*0*	3
Savanna	"Scattering" or "thinly timbered" Douglas fir-white oak-ponderosa	Tvw	M					*0*	
Savanna	Scattering or thinly timbered Douglas fir-white oak woodland	Tvw	M					*0*	
Savanna	White oak-black oak-Douglas fir-ponderosa pine savanna	Tvw	M					*0*	
Savanna	White oak-black oak-ponderosa pine savanna	Tvw	M					*0*	
Savanna	White oak-Douglas fir savanna, mostly herbaceous undergrowth	Tvw	M		91	51		*142*	
Savanna	White oak-Douglas fir-ponderosa pine savanna	Tvw	M				26	*26*	
Savanna	White oak-ponderosa pine savanna	Tvw	M			5		*5*	
Savanna	FFA, but burned, often with scattered trees surviving fire	Tvw	M					*0*	
Savanna	FFHC, but burned, often with scattered trees surviving fire	Tvw	M					*0*	173
	Total Tvw Savanna			**0**	**122**	**155**	**113**	***390***	**390**
Prairie	Seasonally Wet prairie	Tvw	O				33	*33*	
Prairie	Upland prairie, xeric	Tvw	O		86	75	13	*174*	
Prairie	Water bodies 1 or more chains across, including rivers, sloughs,	Tvw	O		7			*7*	
Prairie	Gravel bar	Tvw	O					*0*	
Prairie	Sand bar and sandy barrens	Tvw	O					*0*	
Prairie	Marsh, composition unknown; includes "Wet meadow"	Tvw	O					*0*	
Prairie	Brush, unknown; includes "thickets" if no species or other	Tvw	O		6			*6*	
Prairie	Fern openings, fern hills, or open fern land	Tvw	O					*0*	
	Total Tvw Prairie			**0**	**99**	**75**	**46**	***220***	**1120**

Appendix 4. Geomorphic Surfaces identified in Origin, Extent, and Thickness of Quaternary Geologic Units in the Willamette Valley, Oregon. (O'Connor et al, 2001)

Qalc—Floodplain deposits of the Willamette River and major tributaries (Holocene and upper Pleistocene)--Unconsolidated silt, sand, and gravel of the Willamette River and major Cascade Range tributaries. Includes active channel and modern floodplain surfaces. Meander-scroll topography with surfaces as high as 15 meters above summer water stage. Drillers' logs and exposures indicate that unit thickness ranges up to 15 meters. Isotopic dating, tephrochronology, and stratigraphic relations within the Willamette Valley indicate that these deposits are mostly younger than 12 ka.

Qalf—Alluvium of smaller streams (Holocene and upper Pleistocene)—Unconsolidated clay, silt, sand, and minor gravel deposited in floodplains and active channels of smaller streams and rivers. Variable surface morphology. Thickness not defined, but probably less than 10 meters. Differentiated from units Qbf and Qau where clearly younger than Missoula Flood deposits. Mostly younger than 12 ka.

Qg1—Sand and Gravel that postdates Missoula Floods (upper Pleistocene)— Alluvial sand and gravel deposited in broad braidplains within Willamette Valley and traced upstream as alluvial fills in major Cascade Range tributary valleys. Forms surfaces of large fans where major Cascade Range tributaries enter the Willamette Valley. Deposits now preserved as planar to slightly undulating terraces 0 to 15 meters above the modern floodplain. Drillers' logs and stratigraphic exposures indicate that unit is up to 30 meters thick. Stratigraphic relations and isotopic dating indicate that deposits primarily date from about 12 ka, although some areas mapped as Qg1 in the Eugene-Springfield area within the Cascade Range foothills may be substantially older.

Missoula Flood deposits (upper Pleistocene)—Unconsolidated clay, silt, sand, and gravel deposited by floods originating in glacial Lake Missoula that flowed down the Columbia River and backflooded into the Willamette Valley (Glenn, 1965; Allison, 1978). Largest flows reached stages of about 120 meters above sea level in the map area. Maximum thickness of deposits about 35 meters in northern Willamette Valley, thins to less than 1 meter at elevations above about 100 meters. Radiocarbon dating, tephrochronology, and straigraphic relations from within and outside the map area indicate that most units date from about 15 to 12.7 ka. Divided into the following three types:

> **Qff1—Younger and lower fine-grained Missoula Flood deposits**—Clay, silt, sand, and minor gravel forming benches along Labish channel and Pudding River, and locally flanking Willamette River in northern Willamette Valley. Planar to undulating surface almost everywhere 40-50 meters above sea level. Set into main-body fine facies (Qff2). Probably mostly deposited by latest Pleistocene Missoula Floods between 13.5 and 12.7 ka, but possibly includes late Pleistocene and early Holocene deposits of units Qalf and Qalc.
>
> **Qff2—Main body of fine-grained Missoula Flood deposits—**Stratified silt and clay with minor sand. Underlies much of Willamette Valley lowland floor. Many sections show rhythmic bedding, with up to 40 individual beds between 0.1 and 1.0 meter thick. Encloses sparse pebbles to boulders of types exotic to Willamette Basin. Forms undulating to planar topography in lowlands; mantles foothills below altitudes of 120 meters. Mapped where thickness is sufficient to obscure previous topography. Commonly capped by up to two meters of late Pleistocene and Holocene alluvium, colluvium, and loess.
>
> **Qfc—Coarse Missoula Flood deposits**—Bouldery, cobbly, sandy gravel fans deposited by Missoula Floods as they spilled into northern Willamette Valley through the Oregon City and Rock Creek gaps. Crudely stratified commonly with south-dipping foresets. Commonly capped by several meters of sandy silt, especially south of Willamette River. Drillers' logs indicate that thickness locally exceeds 30 meters.

Qg2—Sand and gravel that predates Missoula Floods (Pleistocene)—Unconsolidated to semiconsolidated sand and gravel deposited in broad braidplains and meandering floodplain environments within Willamette

Valley and upstream as alluvial fills along major Cascade Range tributaries. Locally contains lahar deposits. Forms planar to slightly undulating terrace surfaces 0 to 20 meters above the modern floodplain and generally at slightly higher elevations than adjacent surfaces of unit Qg1. Thickness not systematically determined but locally exceeds 100 meters in braod fans formed where major Cascade Range tributaries enter the Willamette lowlands. Isotopic dating and tephrochronology indicate these deposits range from greater than 0.41 Ma to about 22ka.

Qau—Alluvium, Undifferentiated (Holocene and Pleistocene)—Sand, silt, clay, and minor gravel deposited by smaller streams and rivers that enter the Willamette Valley, and by larger streams and rivers outside the area of detailed mapping. Age and thickness not determined.

Qbf—Fine-grained alluvium (Holocene and Pleistocene)—Clay, silt, sand, and minor gravel deposited in small basins flanking the Willamette Valley. Planar surfaces. Age and thickness not determined. Distinction with unit Qau locally arbitrary.

Qls—Landslide deposits and colluvium (Holocene and Pleistocene)—Unconsolidated and heterogeneous mixtures of rock fragments and soil. Some landslide deposits have hummocky surfaces. Colluvium mapped on steep debris-mantled slopes where underlying bedrock is not known. Only larger deposits mapped, mostly after Walker and McLeod (1991). Age and thickness not defined.

QTg—Weathered terrace gravel (Pleistocene and Pliocene?)—Alluvial sand and gravel preserved as terraces flanking Willamette Valley and tributary valleys. Terrace surfaces planar to undulating, with thick, strongly-developed soils, and severely weathered clasts. Terrace surfaces up to 100 meters above modern floodplains. Drillers' logs and stratigraphic exposures indicate sand and gravel 0 to 60 meters thick. May be in part equivalent to Troutdale Formation (QTt) as mapped near Molalla. Probably mostly deposited between 2.5 and 0.5 Ma.

UPLAND UNITS (primarily compiled from previous sources.)

QTb—Boring Lava (Pleistocene and Pliocene)—Gray to light-gray, open-textured olivine basalt lava flows. Only mapped in the northern part of map area after Hampton (1973). Up to 60 meters thick. Ten radiometric ages on separate flows near Oregon City span 0.427+/-0.026 Ma to 3.15 +/-0.062 Ma (Madin, 1994).

QTt—Troutdale Formation (Pleistocene? And Pliocene)—Sand, gravel, sandstone, conglomerate, siltstone, and mudstone. Only mapped in northern part of map area after Trimble (1963) and Hampton (1972) where it is up to 150 meters thick. May be locally equivalent to the weathered terrace gravel (QTg) near Molalla. Overlain by Boring Lava near Oregon City.

Tvw—Volcanic and volcaniclastic rocks in the Western Cascade Range, undivided (upper Eocene to Pliocene)—Lava flows, tuff, breccia, and volcaniclastic sediment of variable composition. Locally interfingers with marine sedimentary rocks (Tm) in the southern portion of map area. Includes the Fisher Formation, "volcanic rocks of the Western Cascade Range", and Sardine Formation as compiled by Gannett and Caldwell (1998). Youngest rocks are ridge-capping basalt flows in Santiam River drainage with reported ages as young as 2.8 +/- 0.3 Ma (Verplanck, 1985, cited in Walker and Duncan, 1989).

Tcr--Columbia River Basalt Group (Miocene)—Lava flows of dark gray to black, locally porphyritic basalt. Locally deeply weathered. Mostly between 16 and 15 Main northern Willamette Valley (M.H. Beeson, Portland State University, written communication, 1998). Also includes small areas of alluvium, colluvium, loess, and landslide debris. Distribution after Gannett and Caldwell (1998).

Tm—Marine sedimentary rocks (lower Miocene to Eocene)—Marine sandstone, siltstone, shale, and claystone,with lesser conglomerate; locally tuffaceous. Also includes numerous small mafic intrusions, and small areas of alluvium, colluvium, loess, and landslide debris. Distribution after Gannett and Caldwell (1998).

Tvc—Volcanic rocks of the Coast Range (Eocene)—Basaltic pillow lava, tuff breccia, subaerial basalt lava flows, and sills, with interbeds of basaltic sandstone, siltstone, and conglomerate. Includes small areas of alluvium, colluvium, loess, and landslide debris. Distribution after Gannett and Caldwell (1998).

Note: “Am” refers to millions of years before present, and in this report is used to indicate radiometric and fission track ages on volcanic rocks. “ka” refers to kiloannum, indicating thousands of radiocarbon years before present.

Appendix 5. Geomorphic Unit Potential Near-Stream Land Cover Quantitative Look-up Table for the Temperature Model Input

Code	Source	Description	Height (m)	Density (%)	OH (m)
3011	DEQ	Water	0.0	0%	0.0
101	DEQ	Qff1 Forest	44.5	75%	5.3
102	DEQ	Qff1 Savanna	24.6	50%	3.0
103	DEQ	Qff1 Prairie	0.9	75%	0.0
111	DEQ	Qff1 Forest	44.5	75%	5.3
112	DEQ	Qff1 Savanna	24.6	50%	3.0
113	DEQ	Qff1 Prairie	0.9	75%	0.0
201	DEQ	Qfc Forest	30.6	75%	3.7
202	DEQ	Qfc Savanna	46.8	50%	5.6
203	DEQ	Qfc Prairie	0.9	75%	0.0
211	DEQ	Qfc Forest	30.6	75%	3.7
212	DEQ	Qfc Savanna	46.8	50%	5.6
213	DEQ	Qfc Prairie	0.9	75%	0.0
301	DEQ	Qalc Forest	28.0	75%	3.4
302	DEQ	Qalc Savanna	26.0	50%	3.1
303	DEQ	Qalc Prairie	0.9	75%	0.0
311	DEQ	Qalc Forest	28.0	75%	3.4
312	DEQ	Qalc Savanna	26.0	50%	3.1
313	DEQ	Qalc Prairie	0.9	75%	0.0
401	DEQ	Qg1 Forest	26.8	75%	3.2
402	DEQ	Qg1 Savanna	23.9	50%	2.9
403	DEQ	Qg1 Prairie	0.9	75%	0.0
411	DEQ	Qg1 Forest	26.8	75%	3.2
412	DEQ	Qg1 Savanna	23.9	50%	2.9
413	DEQ	Qg1 Prairie	0.9	75%	0.0
501	DEQ	Qau Forest	28.6	75%	3.4
502	DEQ	Qau Savanna	23.0	50%	2.8
503	DEQ	Qau Prairie	0.9	75%	0.0
511	DEQ	Qau Forest	28.6	75%	3.4
512	DEQ	Qau Savanna	23.0	50%	2.8
513	DEQ	Qau Prairie	0.9	75%	0.0
601	DEQ	Qalf Forest	21.5	75%	2.6
602	DEQ	Qalf Savanna	21.9	50%	2.6
603	DEQ	Qalf Prairie	0.9	75%	0.0
611	DEQ	Qalf Forest	21.5	75%	2.6
612	DEQ	Qalf Savanna	21.9	50%	2.6
613	DEQ	Qalf Prairie	0.9	75%	0.0
701	DEQ	Qff2 Forest	29.9	75%	3.6
702	DEQ	Qff2 Savanna	24.2	50%	2.9
703	DEQ	Qff2 Prairie	0.9	75%	0.0
711	DEQ	Qff2 Forest	29.9	75%	3.6
712	DEQ	Qff2 Savanna	24.2	50%	2.9
713	DEQ	Qff2 Prairie	0.9	75%	0.0
801	DEQ	Qbf Forest	29.7	75%	3.6
802	DEQ	Qbf Savanna	26.1	50%	3.1
803	DEQ	Qbf Prairie	0.9	75%	0.0
811	DEQ	Qbf Forest	29.7	75%	3.6
812	DEQ	Qbf Savanna	26.1	50%	3.1
813	DEQ	Qbf Prairie	0.9	75%	0.0

Code	Source	Description	Height (m)	Density (%)	OH (m)
1001	DEQ	Tvc Forest	31.9	75%	3.8
1002	DEQ	Tvc Savanna	22.2	50%	2.7
1003	DEQ	Tvc Prairie	0.9	75%	0.0
1011	DEQ	Tvc Forest	31.9	75%	3.8
1012	DEQ	Tvc Savanna	22.2	50%	2.7
1013	DEQ	Tvc Prairie	0.9	75%	0.0
1101	DEQ	Qtg Forest	47.7	75%	5.7
1102	DEQ	Qtg Savanna	26.7	50%	3.2
1103	DEQ	Qtg Prairie	0.9	75%	0.0
1111	DEQ	Qtg Forest	47.7	75%	5.7
1112	DEQ	Qtg Savanna	26.7	50%	3.2
1113	DEQ	Qtg Prairie	0.9	75%	0.0
1201	DEQ	Tvw Forest	45.4	75%	5.4
1202	DEQ	Tvw Savanna	23.6	50%	2.8
1203	DEQ	Tvw Prairie	0.9	75%	0.0
1211	DEQ	Tvw Forest	45.4	75%	5.4
1212	DEQ	Tvw Savanna	23.6	50%	2.8
1213	DEQ	Tvw Prairie	0.9	75%	0.0
1301	DEQ	Tcr Forest	47.3	75%	5.7
1302	DEQ	Tcr Savanna	25.8	50%	3.1
1303	DEQ	Tcr Prairie	0.9	75%	0.0
1311	DEQ	Tcr Forest	47.3	75%	5.7
1312	DEQ	Tcr Savanna	25.8	50%	3.1
1313	DEQ	Tcr Prairie	0.9	75%	0.0
1401	DEQ	Tm Forest	36.0	75%	4.3
1402	DEQ	Tm Savanna	24.5	50%	2.9
1403	DEQ	Tm Prairie	0.9	75%	0.0
1411	DEQ	Tm Forest	36.0	75%	4.3
1412	DEQ	Tm Savanna	24.5	50%	2.9
1413	DEQ	Tm Prairie	0.9	75%	0.0
1925	DEQ / USFS	Disturbed: Forest Mature Conifer	17.1	25%	1.7
1950	DEQ / USFS	Not Disturbed: Forest Mature Conife	48.8	75%	4.9
1511	DEQ	Qtt Forest	36.0	75%	4.3
1512	DEQ	Qtt Savanna	27.4	50%	2.9
1513	DEQ	Qtt Prairie	0.9	75%	0.0
2011	DEQ	Ow Forest	0.0	75%	4.3
2012	DEQ	Ow Savanna	20.4	50%	2.9
2013	DEQ	Ow Prairie	0.9	75%	0.0
2111	DEQ	Qtb Forest	40.2	75%	4.3
2112	DEQ	Qtb Savanna	33.3	50%	2.9
2113	DEQ	Qtb Prairie	0.9	75%	0.0
2211	DEQ	Qls Forest	48.8	75%	4.3
2212	DEQ	Qls Savanna	37.0	50%	2.9
2213	DEQ	Qls Prairie	0.9	75%	0.0

State of Oregon Department of Environmental Quality

Appendix D

Temperature Total Maximum Daily Load Replacements
Willamette Subbasins
April 6, 2023

Assessment Units addressed by Temperature TMDLs for the Willamette Subbasins

This table lists all the assessment units included in the Willamette Subbasins Temperature TMDls

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000101_02_100676	Timpanogas Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Waterbodies
OR_LK_1709000101_02_107260	Alameda Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Waterbodies
OR_LK_1709000103_02_100677	Gold Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Waterbodies
OR_LK_1709000103_02_100678	Upper Marilyn Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Waterbodies
OR_LK_1709000103_02_100679		Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Waterbodies
OR_LK_1709000103_02_100680		Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Waterbodies
OR_LK_1709000104_02_100681	Gander Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000104	Salmon Creek	Waterbodies

Translation or other formats

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State of Oregon
DEQ Department of Environmental Quality

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000104_02_100682		Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000104	Salmon Creek	Waterbodies
OR_LK_1709000104_02_100683	Blair Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000104	Salmon Creek	Waterbodies
OR_LK_1709000105_02_100684	Packard Creek	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Waterbodies
OR_LK_1709000105_02_100685	Hills Creek Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Waterbodies
OR_LK_1709000105_02_100686	Larison Creek	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100687	Waldo Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100688	Middle Erma Bell Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100689	Upper Eddeeleo Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100690	Long Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100691	Round Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100692	Lower Erma Bell Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000106_02_100693	Lower Eddeeleo Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100694		Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100695		Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100696		Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_100697		Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_107252	Unnamed Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_107263	Devils Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000106_02_107265	Lower Quinn Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Waterbodies
OR_LK_1709000107_02_100698	Goodman Creek	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Waterbodies
OR_LK_1709000107_02_100699	Dexter Reservoir	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Waterbodies
OR_LK_1709000107_02_100700	Lookout Point Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
								Willamette River	
OR_LK_1709000109_02_100701	Fall Creek Lake	Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Waterbodies
OR_LK_1709000110_02_100702		Lake or Reservoir Unit	170900	Willamette	17090001	Middle Fork Willamette	1709000110	Pudding Creek-Middle Fork Willamette River	Waterbodies
OR_SR_1709000101_02_103712	Swift Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000101_02_103713	Middle Fork Willamette River	Swift Creek to Simpson Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000101_02_103714	Middle Fork Willamette River		170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000102_02_103715	Hills Creek	Pinto Creek to Hills Creek Lake	170900	Willamette	17090001	Middle Fork Willamette	1709000102	Hills Creek	Rivers_CoastLine
OR_SR_1709000103_02_103716	Salt Creek	South Fork Salt Creek to confluence with Middle Fork Willamette River	170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Rivers_CoastLine
OR_SR_1709000103_02_103717	Salt Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Rivers_CoastLine
OR_SR_1709000103_02_103718	South Fork Salt Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Rivers_CoastLine
OR_SR_1709000104_02_103719	Salmon Creek	Black Creek to confluence with Middle Fork Willamette River	170900	Willamette	17090001	Middle Fork Willamette	1709000104	Salmon Creek	Rivers_CoastLine
OR_SR_1709000105_02_103720	Middle Fork Willamette River	Salt Creek to North Fork Middle Fork	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		Willamette River						Willamette River	
OR_SR_1709000105_02_104578	Packard Creek	Headwaters WA Unit to Packard Creek backwater	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000105_02_104579	Middle Fork Willamette River	Simpson Creek to Snow Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000105_02_104580	Middle Fork Willamette River	Hills Creek Dam to Salt Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000106_02_103721	North Fork Middle Fork Willamette River	Christy Creek to confluence with Middle Fork Willamette River	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000106_02_103722	Christy Creek	Lowell Creek to confluence with North Fork Middle Fork Willamette River	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000106_02_103723	North Fork Middle Fork Willamette River	Headwaters WA Unit to Christy Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000107_02_103724	Tire Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000107_02_103725	Middle Fork Willamette River	North Fork Middle Fork Willamette River to Sweeney Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000107_02_103726	Deception Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000107_02_103727	Lost Creek	Headwaters WA unit to Gosage Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000107_02_103728	Lost Creek	Gosage Creek to confluence with Middle Fork Willamette River	170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000107_02_104568	Gosage Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000107_02_104582	Goodman Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Rivers_CoastLine
OR_SR_1709000108_02_103729	Norton Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000108	Little Fall Creek	Rivers_CoastLine
OR_SR_1709000108_02_103730	Little Fall Creek	Headwaters WA unit to Sturdy Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000108	Little Fall Creek	Rivers_CoastLine
OR_SR_1709000108_02_103731	Sturdy Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000108	Little Fall Creek	Rivers_CoastLine
OR_SR_1709000108_02_103732	Little Fall Creek	Sturdy Creek to confluence with Fall Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000108	Little Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103733	Alder Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103734	Hehe Creek	Pernot Creek to confluence with Fall Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000109_02_103736	Fall Creek	Saturn Creek to Delp Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103737	Fall Creek	Portland Creek to Murphy Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103738	North Fork Winberry Creek	Traverse Creek to Brush Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103739	Delp Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103740	Gold Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103741	Portland Creek	Logan Creek to confluence with Fall Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103742	Logan Creek	PK Creek to confluence with Portland Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103743	Fall Creek	Delp Creek to Portland Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103744	Portland Creek	Nevergo Creek to Logan Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103745	South Fork Winberry Creek	Cabin Creek to confluence with Winberry Creek	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103746	Nelson Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103747	Winberry Creek	confluence of North Fork Winberry Creek and South Fork Winberry Creek to Fall Creek Lake	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000109_02_103748	Brush Creek		170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Rivers_CoastLine
OR_SR_1709000110_02_103749	Hills Creek	Wallace Creek to confluence	170900	Willamette	17090001	Middle Fork Willamette	1709000110	Pudding Creek-Middle Fork	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		with Middle Fork Willamette River						Willamette River	
OR_WS_170900010101_02_104185	HUC12 Name: Paddys Valley-Middle Fork Willamette *	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Watersheds
OR_WS_170900010102_02_104186	HUC12 Name: Tumblebug Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Watersheds
OR_WS_170900010103_02_104187	HUC12 Name: Pioneer Gulch-Middle Fork Willamette *	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Watersheds
OR_WS_170900010104_02_104188	HUC12 Name: Swift Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Watersheds
OR_WS_170900010105_02_104189	HUC12 Name: Staley Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Watersheds
OR_WS_170900010106_02_104190	HUC12 Name: Echo Creek-Middle Fork Willamette Riv*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000101	Headwaters Middle Fork Willamette River	Watersheds
OR_WS_170900010201_02_104191	HUC12 Name: Upper Hills Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000102	Hills Creek	Watersheds
OR_WS_170900010202_02_104192	HUC12 Name: Lower Hills Creek	Watershed Unit (1st through 4th	170900	Willamette	17090001	Middle Fork Willamette	1709000102	Hills Creek	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		order streams)							
OR_WS_170900010301_02_104193	HUC12 Name: Upper Salt Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Watersheds
OR_WS_170900010302_02_104194	HUC12 Name: Middle Salt Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Watersheds
OR_WS_170900010303_02_104195	HUC12 Name: Lower Salt Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000103	Salt Creek	Watersheds
OR_WS_170900010401_02_104196	HUC12 Name: Black Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000104	Salmon Creek	Watersheds
OR_WS_170900010402_02_104197	HUC12 Name: Upper Salmon Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000104	Salmon Creek	Watersheds
OR_WS_170900010403_02_104198	HUC12 Name: Lower Salmon Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000104	Salmon Creek	Watersheds
OR_WS_170900010501_02_104199	HUC12 Name: Coal Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Watersheds
OR_WS_170900010502_02_104200	HUC12 Name: Buck Creek-Middle Fork Willamette Riv*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Watersheds
OR_WS_170900010503_02_104201	HUC12 Name: Packard	Watershed Unit (1st through 4th	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Creek-Middle Fork Willamette *	order streams)						Willamette River	
OR_WS_170900010504_02_104581	HUC12 Name: Larison Creek-Middle Fork Willamette *	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Watersheds
OR_WS_170900010505_02_104202	HUC12 Name: Gray Creek-Middle Fork Willamette Riv*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000105	Hills Creek Reservoir-Middle Fork Willamette River	Watersheds
OR_WS_170900010601_02_104203	HUC12 Name: Waldo Lake-North Fork Middle Fork Wil*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Watersheds
OR_WS_170900010602_02_104204	HUC12 Name: Skookum Creek-North Fork Middle Fork *	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Watersheds
OR_WS_170900010603_02_104205	HUC12 Name: Fisher Creek-North Fork Middle Fork W*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Watersheds
OR_WS_170900010604_02_104206	HUC12 Name: Devils Canyon-North Fork Middle Fork *	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Watersheds
OR_WS_170900010605_02_104207	HUC12 Name: Upper Christy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900010606_02_104208	HUC12 Name: Lower Christy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Watersheds
OR_WS_170900010607_02_104209	HUC12 Name: Eighth Creek-North Fork Middle Fork W*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Watersheds
OR_WS_170900010608_02_104210	HUC12 Name: Dartmouth Creek-North Fork Middle For*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000106	North Fork Middle Fork Willamette River	Watersheds
OR_WS_170900010701_02_104211	HUC12 Name: Deception Creek-Middle Fork Willamett*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Watersheds
OR_WS_170900010702_02_104212	HUC12 Name: Lost Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Watersheds
OR_WS_170900010703_02_104213	HUC12 Name: Dexter Reservoir-Middle Fork Willamet*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000107	Lookout Point Reservoir-Middle Fork Willamette River	Watersheds
OR_WS_170900010801_02_104214	HUC12 Name: Upper Little Fall Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000108	Little Fall Creek	Watersheds
OR_WS_170900010802_02_104215	HUC12 Name: Lower Little Fall Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000108	Little Fall Creek	Watersheds
OR_WS_170900010901_02_104216	HUC12 Name: Delp	Watershed Unit (1st	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Creek-Fall Creek	through 4th order streams)							
OR_WS_170900010902_02_104217	HUC12 Name: Portland Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Watersheds
OR_WS_170900010903_02_104218	HUC12 Name: Hehe Creek-Fall Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Watersheds
OR_WS_170900010904_02_104219	HUC12 Name: Andy Creek-Fall Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Watersheds
OR_WS_170900010905_02_104220	HUC12 Name: Winberry Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Watersheds
OR_WS_170900010906_02_104221	HUC12 Name: Fall Creek Lake-Fall Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000109	Fall Creek	Watersheds
OR_WS_170900011001_02_104222	HUC12 Name: Hills Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000110	Pudding Creek-Middle Fork Willamette River	Watersheds
OR_WS_170900011002_02_104601	HUC12 Name: Rattlesnake Creek-Middle Fork Willame*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000110	Pudding Creek-Middle Fork Willamette River	Watersheds
OR_WS_170900011003_02_104223	HUC12 Name: Mill Race-Middle Fork Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090001	Middle Fork Willamette	1709000110	Pudding Creek-Middle Fork Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000202_02_100705	Dorena Lake	Lake or Reservoir Unit	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Waterbodies
OR_LK_1709000203_02_100706	Cottage Grove Lake	Lake or Reservoir Unit	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Waterbodies
OR_SR_1709000201_02_103751	Smith Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000201	Mosby Creek	Rivers_CoastLine
OR_SR_1709000201_02_103752	Mosby Creek	Middle Fork Mosby Creek to confluence with Row River	170900	Willamette	17090002	Coast Fork Willamette	1709000201	Mosby Creek	Rivers_CoastLine
OR_SR_1709000201_02_103753	Middle Fork Mosby Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000201	Mosby Creek	Rivers_CoastLine
OR_SR_1709000201_02_103754	East Fork Mosby Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000201	Mosby Creek	Rivers_CoastLine
OR_SR_1709000202_02_103755	Sharps Creek	Martin Creek to confluence with Row River	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103756	Martin Creek	Clark Creek to confluence with Sharps Creek	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103757	Dinner Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103758	Smith Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103759	Smith Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103760	Rat Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103761	Row River	confluence of Laying Creek and Brice Creek to Sharps Creek	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103762	Alex Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103763	Junetta Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000202_02_103764	Teeter Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103765	Layng Creek	Alex Creek to confluence with Row River	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103766	Row River	Sharps Creek to Vaughn Creek	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103767	Martin Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103768	Culp Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103769	Alder Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103770	Layng Creek	Headwaters WA unit to Alex Creek	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103771	Brice Creek	Grass Creek to confluence with Row River	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103772	Clark Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103773	Brice Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103774	Champion Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103775	Sharps Creek	Fairview Creek to Martin Creek	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103776	Sharps Creek	Confluence of Puddin Creek and Bohemia Creek to Fairview Creek	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103777	Wyatt Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103778	Fairview Creek	Cinge Creek to confluence with Sharps Creek	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine
OR_SR_1709000202_02_103780	Grass Creek	Headwaters WA unit to confluence	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		with Brice Creek							
OR_SR_1709000203_02_103781	Little River	confluence of Garoutte Creek and Trail Creek to Big River	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Rivers_CoastLine
OR_SR_1709000203_02_103782	Silk Creek	Muslin Creek to confluence with Coast Fork Willamette River	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Rivers_CoastLine
OR_SR_1709000203_02_103783	Wilson Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Rivers_CoastLine
OR_SR_1709000203_02_103784	Big River		170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Rivers_CoastLine
OR_SR_1709000203_02_103785	Bar Creek		170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Rivers_CoastLine
OR_SR_1709000203_02_104586	Coast Fork Willamette River	Big River to Cottage Grove Lake	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Rivers_CoastLine
OR_SR_1709000204_02_103786	Camas Swale Creek	Skunk Creek to confluence with Coast Fork Willamette River	170900	Willamette	17090002	Coast Fork Willamette	1709000204	Lower Coast Fork Willamette River	Rivers_CoastLine
OR_WS_170900020101_02_104224	HUC12 Name: Upper Mosby Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000201	Mosby Creek	Watersheds
OR_WS_170900020102_02_104225	HUC12 Name: Middle Mosby Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000201	Mosby Creek	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900020103_02_104226	HUC12 Name: Lower Mosby Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000201	Mosby Creek	Watersheds
OR_WS_170900020201_02_104227	HUC12 Name: Layng Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Watersheds
OR_WS_170900020202_02_104228	HUC12 Name: Brice Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Watersheds
OR_WS_170900020203_02_104229	HUC12 Name: Sharps Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Watersheds
OR_WS_170900020204_02_104230	HUC12 Name: King Creek-Row River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Watersheds
OR_WS_170900020205_02_104231	HUC12 Name: Dorena Lake-Row River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000202	Row River	Watersheds
OR_WS_170900020301_02_104232	HUC12 Name: Upper Big River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Watersheds
OR_WS_170900020302_02_104233	HUC12 Name: Lower Big River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Watersheds
OR_WS_170900020303_02_104234	HUC12 Name: Combs Creek-Coast Fork	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Willamette Riv*								
OR_WS_170900020304_02_104235	HUC12 Name: Cottage Grove Lake-Coast Fork Willame*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Watersheds
OR_WS_170900020305_02_104236	HUC12 Name: Martin Creek-Coast Fork Willamette Ri*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Watersheds
OR_WS_170900020306_02_104237	HUC12 Name: Silk Creek-Coast Fork Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000203	Upper Coast Fork Willamette River	Watersheds
OR_WS_170900020401_02_104238	HUC12 Name: Hill Creek-Coast Fork Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000204	Lower Coast Fork Willamette River	Watersheds
OR_WS_170900020402_02_104239	HUC12 Name: Upper Camas Swale Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000204	Lower Coast Fork Willamette River	Watersheds
OR_WS_170900020403_02_104240	HUC12 Name: Lower Camas Swale Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000204	Lower Coast Fork Willamette River	Watersheds
OR_WS_170900020404_02_104241	HUC12 Name: Bear Creek-Coast Fork Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000204	Lower Coast Fork Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900020405_02_104242	HUC12 Name: Papenfus Creek-Coast Fork Willamette *	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090002	Coast Fork Willamette	1709000204	Lower Coast Fork Willamette River	Watersheds
OR_LK_1709000301_02_100707	Noti Creek	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Waterbodies
OR_LK_1709000301_02_100708	Fern Ridge Lake	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Waterbodies
OR_LK_1709000301_02_100709		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Waterbodies
OR_LK_1709000301_02_100710		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Waterbodies
OR_LK_1709000302_02_100711	Clemens Log Pond	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Waterbodies
OR_LK_1709000302_02_100712	Larson Log Pond	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Waterbodies
OR_LK_1709000302_02_100713	Thompson Lake	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Waterbodies
OR_LK_1709000304_02_100714	Oak Creek	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000304	Lower Calapooia River	Waterbodies
OR_LK_1709000305_02_100715	McTimmonds Creek	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Waterbodies
OR_LK_1709000306_02_100716	McBee Lake	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100717	Harkens Lake	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100718	Second Lake	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000306_02_100719	Winkle Lake	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100720	Colorado Lake	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100721		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100722		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100723		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100724		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100725		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100726		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100727		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100728		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100729		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000306_02_100730		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100731		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100732		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100733		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100734		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_100735		Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_107234	First Lake	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_107246	Unnamed Pond	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_LK_1709000306_02_107266	Diannas Kelly Pond	Lake or Reservoir Unit	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Waterbodies
OR_SR_1709000301_02_103788	Bear Creek	Owens Creek to confluence with Long Tom River	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103789	Long Tom River	Poodle Creek to Fern Ridge Lake	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103790	Ferguson Creek	Davidson Creek to confluence	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		with Long Tom River							
OR_SR_1709000301_02_103792	Long Tom River	Jones Creek to Poodle Creek	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103793	Jones Creek		170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103794	Poodle Creek	Elk Creek to confluence with Long Tom River	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103795	Battle Creek	West Fork Battle Creek to Coyote Creek	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103796	Coyote Creek	Battle Creek to Warren Slough	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103797	Long Tom River		170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103798	Poodle Creek		170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103799	Coyote Creek	Doak Creek to Battle Creek	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103800	Elk Creek		170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103801	Spencer Creek	Headwaters WA unit to confluence with Coyote Creek	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103802	Noti Creek		170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000301_02_103803	Amazon Creek		170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Rivers_CoastLine
OR_SR_1709000302_02_103804	Marys River	Lasky Creek to Greasy Creek	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000302_02_103805	Reese Creek		170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000302_02_103806	Muddy Creek	Miller Creek to confluence with Marys River	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000302_02_103807	Oliver Creek		170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000302_02_103808	Hammer Creek	confluence of Nye Creek and Gardner Creek to confluence with Muddy Creek	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000302_02_103809	Beaver Creek	Duffy Creek to confluence with Muddy Creek	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000302_02_103810	Greasy Creek		170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000302_02_103811	Miller Creek		170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000302_02_103812	Marys River	Muddy Creek to confluence with Willamette River	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000302_02_103813	Marys River	Greasy Creek to Muddy Creek	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000302_02_103814	Millrace		170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Rivers_CoastLine
OR_SR_1709000303_02_103815	Calapooia River	United States Creek to Brush Creek	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Rivers_CoastLine
OR_SR_1709000303_02_103816	Calapooia River	Bickmore Creek to Shedd Slough	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Rivers_CoastLine
OR_SR_1709000303_02_103817	West Brush Creek		170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Rivers_CoastLine
OR_SR_1709000303_02_103818	Bickmore Creek		170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Rivers_CoastLine
OR_SR_1709000303_02_103819	Courtney Creek	Headwaters WA unit to confluence with Calapooia River	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000303_02_103820	Brush Creek		170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Rivers_CoastLine
OR_SR_1709000304_02_103821	Calapooia River	Shedd Slough to confluence with Willamette River	170900	Willamette	17090003	Upper Willamette	1709000304	Lower Calapooia River	Rivers_CoastLine
OR_SR_1709000305_02_103822	Little Luckiamute River	Headwaters WA unit to confluence with Luckiamute River	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103823	Little Luckiamute River		170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103824	Teal Creek	confluence of North Fork Teal Creek and South Fork Teal Creek to confluence with Little Luckiamute River	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103825	Miller Creek	Headwaters WA unit to confluence with Luckiamute River	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103826	Boulder Creek		170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103827	Black Rock Creek		170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103828	North Fork Pedee Creek	Headwaters WA unit to confluence with Luckiamute River	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103829	Luckiamute River	Miller Creek to confluence	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		with Willamette River							
OR_SR_1709000305_02_103830	Luckiamute River		170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103831	Luckiamute River		170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103832	Soap Creek	Writsman Brook to Luckiamute River	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103833	Ritner Creek	Sheythe Creek to Luckiamute River	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103834	tributary to Little Luckiamute River		170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103835	tributary to Miller Creek		170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000305_02_103836	Miller Creek		170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Rivers_CoastLine
OR_SR_1709000306_02_103837	Dead River		170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000306_02_103838	Muddy Creek	Headwaters WA unit to confluence with Willamette River	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Rivers_CoastLine
OR_WS_170900030101_02_104243	HUC12 Name: Upper Coyote Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds
OR_WS_170900030102_02_104244	HUC12 Name: Spencer Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds
OR_WS_170900030103_02_104245	HUC12 Name: Lower	Watershed Unit (1st through 4th	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Coyote Creek	order streams)							
OR_WS_170900030104_02_104246	HUC12 Name: Headwaters Long Tom River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds
OR_WS_170900030105_02_104247	HUC12 Name: Elk Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds
OR_WS_170900030106_02_104248	HUC12 Name: Amazon Diversion Canal-Amazon Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds
OR_WS_170900030107_02_104249	HUC12 Name: Fern Ridge Lake-Long Tom River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds
OR_WS_170900030108_02_104250	HUC12 Name: Amazon Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds
OR_WS_170900030109_02_104251	HUC12 Name: Bear Creek-Long Tom River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds
OR_WS_170900030110_02_104252	HUC12 Name: Ferguson Creek-Long Tom River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000301	Long Tom River	Watersheds
OR_WS_170900030201_02_104253	HUC12 Name: Headwaters Marys River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds
OR_WS_170900030202_02_104254	HUC12 Name:	Watershed Unit (1st	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Tumtum River	through 4th order streams)							
OR_WS_170900030203_02_104255	HUC12 Name: Upper Marys River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds
OR_WS_170900030204_02_104256	HUC12 Name: Greasy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds
OR_WS_170900030205_02_104257	HUC12 Name: Middle Marys River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds
OR_WS_170900030206_02_104258	HUC12 Name: Upper Muddy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds
OR_WS_170900030207_02_104259	HUC12 Name: Oliver Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds
OR_WS_170900030208_02_104260	HUC12 Name: Middle Muddy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds
OR_WS_170900030209_02_104261	HUC12 Name: Beaver Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds
OR_WS_170900030210_02_104262	HUC12 Name: Lower Muddy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds
OR_WS_170900030211_02_104263	HUC12 Name:	Watershed Unit (1st through 4th	170900	Willamette	17090003	Upper Willamette	1709000302	Marys River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Lower Marys River	order streams)							
OR_WS_170900030301_02_104264	HUC12 Name: Hands Creek-Calapooia River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Watersheds
OR_WS_170900030302_02_104265	HUC12 Name: Bigs Creek-Calapooia River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Watersheds
OR_WS_170900030303_02_104266	HUC12 Name: Pugh Creek-Calapooia River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Watersheds
OR_WS_170900030304_02_104267	HUC12 Name: Brush Creek-Calapooia River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Watersheds
OR_WS_170900030305_02_104268	HUC12 Name: Sodom Ditch-Calapooia River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Watersheds
OR_WS_170900030306_02_104269	HUC12 Name: Butte Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Watersheds
OR_WS_170900030307_02_104270	HUC12 Name: Courtney Creek-Calapooia River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Watersheds
OR_WS_170900030308_02_104271	HUC12 Name: Shedd Slough-	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000303	Upper Calapooia River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Calapooia River								
OR_WS_170900030401_02_104272	HUC12 Name: Upper Oak Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000304	Lower Calapooia River	Watersheds
OR_WS_170900030402_02_104273	HUC12 Name: Lower Oak Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000304	Lower Calapooia River	Watersheds
OR_WS_170900030403_02_104274	HUC12 Name: Calapooia River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000304	Lower Calapooia River	Watersheds
OR_WS_170900030501_02_104275	HUC12 Name: Headwaters Luckiamute River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030502_02_104276	HUC12 Name: Vincent Creek-Luckiamute River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030503_02_104277	HUC12 Name: Maxfield Creek-Luckiamute River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030504_02_104278	HUC12 Name: Pedee Creek-Luckiamute River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030505_02_104279	HUC12 Name: Jont Creek-Luckiamute River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900030506_02_104280	HUC12 Name: Upper Little Luckiamute River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030507_02_104281	HUC12 Name: Middle Little Luckiamute River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030508_02_104282	HUC12 Name: Lower Little Luckiamute River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030509_02_104283	HUC12 Name: Upper Soap Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030510_02_104284	HUC12 Name: Berry Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030511_02_104285	HUC12 Name: Lower Soap Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030512_02_104286	HUC12 Name: Nisly Reservoir-Luckiamute River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000305	Luckiamute River	Watersheds
OR_WS_170900030601_02_104287	HUC12 Name: Sring Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_WS_170900030602_02_104288	HUC12 Name: Curtis Slough-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900030602_05_104289	HUC12 Name: Curtis Slough-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_WS_170900030603_02_104290	HUC12 Name: Flat Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_WS_170900030604_02_104291	HUC12 Name: Lake Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_WS_170900030605_02_104292	HUC12 Name: Booneville Channel-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_WS_170900030606_02_104294	HUC12 Name: Dry Muddy Creek-Muddy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_WS_170900030607_02_104295	HUC12 Name: Little Muddy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_WS_170900030608_02_104296	HUC12 Name: Fischer Island-Muddy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_WS_170900030609_02_104297	HUC12 Name: Frazier Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900030610_02_104298	HUC12 Name: Truax Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_WS_170900030611_02_104299	HUC12 Name: McCarthy Slough-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090003	Upper Willamette	1709000306	Muddy Creek-Willamette River	Watersheds
OR_LK_1709000401_02_100736	Horse Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Waterbodies
OR_LK_1709000401_02_100737	Nash Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Waterbodies
OR_LK_1709000401_02_107259	Sunset Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Waterbodies
OR_LK_1709000402_02_100738	Fish Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100739	Carmen Reservoir	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100740	Big Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100741	Clear Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100742	Trail Bridge Reservoir	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100743	Lava Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100744	Scott Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100745	Smith Reservoir	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000402_02_100746	Lost Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100747	Hand Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100748		Lake or Reservoir Unit	170900	Willamette	17090004	Mckenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_100749		Lake or Reservoir Unit	170900	Willamette	17090004	Mckenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000402_02_107253	Tenas Lakes	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Waterbodies
OR_LK_1709000403_02_100750	Hidden Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Waterbodies
OR_LK_1709000403_02_100751	Mink Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Waterbodies
OR_LK_1709000403_02_100752	Porky Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Waterbodies
OR_LK_1709000403_02_100753	Cougar Reservoir	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Waterbodies
OR_LK_1709000403_02_100754	Cliff Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Waterbodies
OR_LK_1709000403_02_100755	McFarland Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Waterbodies
OR_LK_1709000403_02_100756	Mac Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Waterbodies
OR_LK_1709000403_02_100757		Lake or Reservoir Unit	170900	Willamette	17090004	Mckenzie	1709000403	South Fork McKenzie River	Waterbodies
OR_LK_1709000404_02_100758	Blue River Lake	Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000404	Blue River	Waterbodies
OR_LK_1709000407_02_100759		Lake or Reservoir Unit	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000401_02_103855	Horse Creek	Separation Creek to confluence with McKenzie River	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Rivers_CoastLine
OR_SR_1709000401_02_103856	Horse Creek	Headwaters WA unit to Separation Creek	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Rivers_CoastLine
OR_SR_1709000401_02_103857	Separation Creek	Mesa Creek to confluence with Horse Creek	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Rivers_CoastLine
OR_SR_1709000402_02_103858	McKenzie River		170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Rivers_CoastLine
OR_SR_1709000402_02_104587	McKenzie River	Kink Creek to Trail Bridge Reservoir	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Rivers_CoastLine
OR_SR_1709000402_02_104588	McKenzie River	Trail Bridge Dam to Horse Creek	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Rivers_CoastLine
OR_SR_1709000403_02_103859	Elk Creek		170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Rivers_CoastLine
OR_SR_1709000403_02_103860	tributary to Elk Creek		170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Rivers_CoastLine
OR_SR_1709000403_02_103861	Rebel Creek	Headwaters WA unit to confluence with South Fork McKenzie River	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Rivers_CoastLine
OR_SR_1709000403_02_103862	French Pete Creek	Headwaters WA unit to confluence with South Fork McKenzie River	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Rivers_CoastLine
OR_SR_1709000403_02_103863	East Fork South Fork	Headwaters WA unit to	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	McKenzie River	Cougar Reservoir							
OR_SR_1709000403_02_103864	Roaring River	Headwaters WA unit to confluence with South Fork McKenzie River	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Rivers_CoastLine
OR_SR_1709000403_02_103865	Augusta Creek	Headwaters WA unit to confluence with South Fork McKenzie River	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Rivers_CoastLine
OR_SR_1709000403_02_104589	South Fork McKenzie River	Elk Creek to Ridge Creek	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Rivers_CoastLine
OR_SR_1709000404_02_104570	Lookout Creek		170900	Willamette	17090004	McKenzie	1709000404	Blue River	Rivers_CoastLine
OR_SR_1709000404_02_104571	Lookout Creek	McRae Creek to Upper Blue River	170900	Willamette	17090004	McKenzie	1709000404	Blue River	Rivers_CoastLine
OR_SR_1709000404_02_104572	Tidbits Creek		170900	Willamette	17090004	McKenzie	1709000404	Blue River	Rivers_CoastLine
OR_SR_1709000404_02_104573	McRae Creek		170900	Willamette	17090004	McKenzie	1709000404	Blue River	Rivers_CoastLine
OR_SR_1709000404_02_104574	Upper Blue River	Quentin Creek to Mona Creek	170900	Willamette	17090004	McKenzie	1709000404	Blue River	Rivers_CoastLine
OR_SR_1709000404_02_104575	Cook Creek	Headwaters WA unit to confluence with Upper Blue River	170900	Willamette	17090004	McKenzie	1709000404	Blue River	Rivers_CoastLine
OR_SR_1709000404_02_104576	Quentin Creek	Headwaters WA unit to confluence with Upper Blue River	170900	Willamette	17090004	McKenzie	1709000404	Blue River	Rivers_CoastLine
OR_SR_1709000404_02_104577	Upper Blue River	Mann Creek to Quentin Creek	170900	Willamette	17090004	McKenzie	1709000404	Blue River	Rivers_CoastLine
OR_SR_1709000405_02_103867	Quartz Creek		170900	Willamette	17090004	McKenzie	1709000405	Quartz Creek-	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
								McKenzie River	
OR_SR_1709000405_02_103868	McKenzie River	West Fork Horse Creek to South Fork McKenzie River	170900	Willamette	17090004	McKenzie	1709000405	Quartz Creek-McKenzie River	Rivers_CoastLine
OR_SR_1709000406_02_103870	Mohawk River	Shotgun Creek to Mill Creek	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine
OR_SR_1709000406_02_103871	Mohawk River	Mill Creek to confluence with McKenzie River	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine
OR_SR_1709000406_02_103872	Shotgun Creek	Owl Creek to confluence with McKenzie River	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine
OR_SR_1709000406_02_103873	Mill Creek	Headwaters WA unit to Deer Creek	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine
OR_SR_1709000406_02_103874	Mill Creek	Deer Creek to confluence with Mohawk River	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine
OR_SR_1709000406_02_103875	Cartwright Creek	Headwaters WA unit to confluence with Mohawk River	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine
OR_SR_1709000406_02_103876	Parsons Creek		170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine
OR_SR_1709000406_02_103877	Mohawk River	confluence of North Fork Mohawk River and South Fork Mohawk River to Shotgun Creek	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine
OR_SR_1709000406_02_103878	Deer Creek		170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000406_02_103879	McGowan Creek	Headwaters WA unit to confluence with Mohawk River	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Rivers_CoastLine
OR_SR_1709000407_02_103880	South Fork Gate Creek		170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103881	North Fork Gate Creek		170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103882	Deer Creek	confluence of East Fork Deer Creek and West Fork Deer Creek to confluence with McKenzie River	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103883	Marten Creek		170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103885	Bear Creek		170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103886	East Fork Deer Creek		170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103887	North Fork North Fork Gate Creek		170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103888	North Fork Gate Creek	North Fork North Fork Gate Creek to confluence with McKenzie River	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103889	Camp Creek	Cougar Creek to confluence with McKenzie River	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103890	West Fork Deer Creek		170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine
OR_SR_1709000407_02_103891	Cedar Creek	Cougar Creek to confluence with	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		McKenzie River							
OR_WS_170900040101_02_104300	HUC12 Name: Upper Separation Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Watersheds
OR_WS_170900040102_02_104301	HUC12 Name: Lower Separation Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Watersheds
OR_WS_170900040103_02_104302	HUC12 Name: Upper Horse Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Watersheds
OR_WS_170900040104_02_104303	HUC12 Name: Middle Horse Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Watersheds
OR_WS_170900040105_02_104304	HUC12 Name: Lower Horse Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000401	Horse Creek	Watersheds
OR_WS_170900040201_02_104305	HUC12 Name: Parks Creek-Lost Lake	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Watersheds
OR_WS_170900040202_02_104306	HUC12 Name: Hackleman Creek-McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Watersheds
OR_WS_170900040203_02_104307	HUC12 Name: Smith River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Watersheds
OR_WS_170900040204_02_104308	HUC12 Name: Kink Creek-	Watershed Unit (1st through 4th	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	McKenzie River	order streams)							
OR_WS_170900040205_02_104309	HUC12 Name: Deer Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Watersheds
OR_WS_170900040206_02_104310	HUC12 Name: Boulder Creek-McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Watersheds
OR_WS_170900040207_02_104311	HUC12 Name: White Branch	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Watersheds
OR_WS_170900040208_02_104312	HUC12 Name: Lost Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Watersheds
OR_WS_170900040209_02_104313	HUC12 Name: Florence Creek-McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000402	Headwaters McKenzie River	Watersheds
OR_WS_170900040301_02_104314	HUC12 Name: Elk Creek-South Fork McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Watersheds
OR_WS_170900040302_02_104315	HUC12 Name: Roaring River-South Fork McKenzie Riv*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Watersheds
OR_WS_170900040303_02_104316	HUC12 Name: Augusta Creek-	Watershed Unit (1st through 4th	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	South Fork McKenzie Riv*	order streams)							
OR_WS_170900040304_02_104317	HUC12 Name: Rebel Creek-South Fork McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Watersheds
OR_WS_170900040305_02_104318	HUC12 Name: French Pete Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Watersheds
OR_WS_170900040306_02_104319	HUC12 Name: East Fork South Fork McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Watersheds
OR_WS_170900040307_02_104320	HUC12 Name: Cougar Reservoir-South Fork McKenzie *	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Watersheds
OR_WS_170900040308_02_104321	HUC12 Name: Cougar Creek-South Fork McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000403	South Fork McKenzie River	Watersheds
OR_WS_170900040401_02_104322	HUC12 Name: Lookout Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000404	Blue River	Watersheds
OR_WS_170900040402_02_104323	HUC12 Name: Upper Blue River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000404	Blue River	Watersheds
OR_WS_170900040403_02_104324	HUC12 Name:	Watershed Unit (1st	170900	Willamette	17090004	McKenzie	1709000404	Blue River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Lower Blue River	through 4th order streams)							
OR_WS_170900040501_02_104325	HUC12 Name: Quartz Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000405	Quartz Creek-McKenzie River	Watersheds
OR_WS_170900040502_02_104326	HUC12 Name: Elk Creek-McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000405	Quartz Creek-McKenzie River	Watersheds
OR_WS_170900040601_02_104327	HUC12 Name: Headwaters Mohawk River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Watersheds
OR_WS_170900040602_02_104328	HUC12 Name: Shotgun Creek-Mohawk River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Watersheds
OR_WS_170900040603_02_104329	HUC12 Name: Mill Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Watersheds
OR_WS_170900040604_02_104330	HUC12 Name: Parsons Creek-Mohawk River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Watersheds
OR_WS_170900040605_02_104331	HUC12 Name: McGowan Creek-Mohawk River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000406	Mohawk River	Watersheds
OR_WS_170900040701_02_104332	HUC12 Name: Gate Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900040702_02_104333	HUC12 Name: East Fork Deer Creek-McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Watersheds
OR_WS_170900040703_02_104334	HUC12 Name: Ritchie Creek-McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Watersheds
OR_WS_170900040704_02_104335	HUC12 Name: Holden Creek-McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Watersheds
OR_WS_170900040705_02_104336	HUC12 Name: Camp Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Watersheds
OR_WS_170900040706_02_104337	HUC12 Name: Walterville Canal-McKenzie River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090004	McKenzie	1709000407	McKenzie River	Watersheds
OR_LK_1709000502_02_100761	Nan-Scott Lake	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Waterbodies
OR_LK_1709000502_02_100762	Pamelia Lake	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Waterbodies
OR_LK_1709000502_02_100763	Mowich Lake	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Waterbodies
OR_LK_1709000502_02_100764	Jorn Lake	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000502_02_100765	Duffy Lake	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Waterbodies
OR_LK_1709000502_02_100766	Lake Ann	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Waterbodies
OR_LK_1709000502_02_100767	Marion Lake	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Waterbodies
OR_LK_1709000503_02_100768	Detroit Lake	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Waterbodies
OR_LK_1709000503_02_100769	Tumble Lake	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Waterbodies
OR_LK_1709000503_02_100770	Big Cliff Reservoir	Lake or Reservoir Unit	170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Waterbodies
OR_SR_1709000501_02_103892	Breitenbush River	Confluence of North Fork Breitenbush River and South Fork Breitenbush River to Detroit Lake	170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Rivers_CoastLine
OR_SR_1709000501_02_103893	East Humbug Creek	Headwaters WA unit to confluence with Breitenbush River	170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Rivers_CoastLine
OR_SR_1709000501_02_103894	South Fork Breitenbush River	Headwaters WA Unit to confluence with Breitenbush River	170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Rivers_CoastLine
OR_SR_1709000501_02_103895	North Fork Breitenbush River		170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000501_02_103896	Devils Creek		170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Rivers_CoastLine
OR_SR_1709000502_02_103897	Marion Creek		170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Rivers_CoastLine
OR_SR_1709000502_02_103898	Whitewater Creek		170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Rivers_CoastLine
OR_SR_1709000502_02_103899	North Santiam River	Marion Creek to Dry Creek	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Rivers_CoastLine
OR_SR_1709000502_02_103900	Pamelia Creek		170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Rivers_CoastLine
OR_SR_1709000502_02_103901	North Santiam River		170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Rivers_CoastLine
OR_SR_1709000502_02_103902	Boulder Creek	Headwaters WA unit to confluence with North Santiam River	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Rivers_CoastLine
OR_SR_1709000503_02_103903	French Creek		170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Rivers_CoastLine
OR_SR_1709000503_02_103904	Ivy Creek		170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Rivers_CoastLine
OR_SR_1709000503_02_103905	Cliff Creek		170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Rivers_CoastLine
OR_SR_1709000503_02_103907	Blowout Creek	Ivy Creek to Detroit Lake	170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Rivers_CoastLine
OR_SR_1709000503_02_103908	Kinney Creek		170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Rivers_CoastLine
OR_SR_1709000503_02_103909	Blowout Creek	Lost Creek to Ivy Creek	170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000503_02_103910	Box Canyon Creek		170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Rivers_CoastLine
OR_SR_1709000504_02_103911	Mad Creek		170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Rivers_CoastLine
OR_SR_1709000504_02_103912	tributary to North Santiam River		170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Rivers_CoastLine
OR_SR_1709000504_02_103913	tributary to North Santiam River		170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Rivers_CoastLine
OR_SR_1709000504_02_103914	Turnridge Creek		170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Rivers_CoastLine
OR_SR_1709000504_02_103915	Rock Creek		170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Rivers_CoastLine
OR_SR_1709000504_02_103916	Snake Creek		170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Rivers_CoastLine
OR_SR_1709000504_02_103917	East Rock Creek		170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Rivers_CoastLine
OR_SR_1709000504_02_103918	Rock Creek	East Rock Creek to confluence with North Santiam River	170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Rivers_CoastLine
OR_SR_1709000505_02_103919	Opal Creek		170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Rivers_CoastLine
OR_SR_1709000505_02_103920	Cedar Creek		170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Rivers_CoastLine
OR_SR_1709000505_02_103921	Evans Creek		170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Rivers_CoastLine
OR_SR_1709000505_02_103922	Battle Ax Creek		170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000505_02_103923	Elkhorn Creek	Big Twelve Creek to confluence with Little North Santiam River	170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Rivers_CoastLine
OR_SR_1709000505_02_103924	Gold Creek		170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Rivers_CoastLine
OR_SR_1709000505_02_104564	Little North Santiam River	Battle Ax Creek to confluence with North Santiam River	170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Rivers_CoastLine
OR_SR_1709000506_02_103926	Chehulpum Creek	Sidney Ditch to confluence with Santiam River	170900	Willamette	17090005	North Santiam	1709000506	Lower North Santiam River	Rivers_CoastLine
OR_SR_1709000506_02_103928	Bear Branch	Headwaters WA unit to confluence with North Santiam River	170900	Willamette	17090005	North Santiam	1709000506	Lower North Santiam River	Rivers_CoastLine
OR_SR_1709000506_02_103929	Stout Creek	Shellburg Creek to confluence with North Santiam River	170900	Willamette	17090005	North Santiam	1709000506	Lower North Santiam River	Rivers_CoastLine
OR_SR_1709000506_02_103931			170900	Willamette	17090005	North Santiam	1709000506	Lower North Santiam River	Rivers_CoastLine
OR_WS_170900050101_02_104338	HUC12 Name: South Fork Breitenbush River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Watersheds
OR_WS_170900050102_02_104339	HUC12 Name: North Fork Breitenbush River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900050103_02_104340	HUC12 Name: Humbug Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Watersheds
OR_WS_170900050104_02_104341	HUC12 Name: Upper Breitenbush River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Watersheds
OR_WS_170900050105_02_104342	HUC12 Name: Lower Breitenbush River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000501	Breitenbush River	Watersheds
OR_WS_170900050201_02_104343	HUC12 Name: Swede Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Watersheds
OR_WS_170900050202_02_104344	HUC12 Name: Straight Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Watersheds
OR_WS_170900050203_02_104345	HUC12 Name: Marion Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Watersheds
OR_WS_170900050204_02_104346	HUC12 Name: Pamelia Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Watersheds
OR_WS_170900050205_02_104347	HUC12 Name: Minto Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Watersheds
OR_WS_170900050206_02_104348	HUC12 Name:	Watershed Unit (1st through 4th	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Whitewater Creek	order streams)						Santiam River	
OR_WS_170900050207_02_104349	HUC12 Name: Boulder Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Watersheds
OR_WS_170900050208_02_104350	HUC12 Name: Sauers Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000502	Headwaters North Santiam River	Watersheds
OR_WS_170900050301_02_104351	HUC12 Name: Upper Blowout Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Watersheds
OR_WS_170900050302_02_104352	HUC12 Name: Lower Blowout Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Watersheds
OR_WS_170900050303_02_104353	HUC12 Name: French Creek-Detroit Lake	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Watersheds
OR_WS_170900050304_02_104354	HUC12 Name: Kinney Creek-Detroit Reservoir	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000503	Upper North Santiam River	Watersheds
OR_WS_170900050401_02_104355	HUC12 Name: Sevenmile Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Watersheds
OR_WS_170900050402_02_104356	HUC12 Name: Rock Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900050403_02_104357	HUC12 Name: Mad Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Watersheds
OR_WS_170900050404_02_104358	HUC12 Name: Walker Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000504	Middle North Santiam River	Watersheds
OR_WS_170900050501_02_104565	HUC12 Name: Opal Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Watersheds
OR_WS_170900050502_02_104566	HUC12 Name: Headwaters Little North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Watersheds
OR_WS_170900050503_02_104567	HUC12 Name: Upper Little North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Watersheds
OR_WS_170900050504_02_104563	HUC12 Name: Middle Little North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Watersheds
OR_WS_170900050505_02_104562	HUC12 Name: Lower Little North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000505	Little North Santiam River	Watersheds
OR_WS_170900050601_02_104359	HUC12 Name: Stout Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000506	Lower North Santiam River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900050602_02_104360	HUC12 Name: Bear Branch-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000506	Lower North Santiam River	Watersheds
OR_WS_170900050603_02_104361	HUC12 Name: Marion Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000506	Lower North Santiam River	Watersheds
OR_WS_170900050604_02_104362	HUC12 Name: Morgan Creek-North Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090005	North Santiam	1709000506	Lower North Santiam River	Watersheds
OR_LK_1709000601_02_107235	Daly Lake	Lake or Reservoir Unit	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Waterbodies
OR_LK_1709000603_02_100771	Green Peter Lake	Lake or Reservoir Unit	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Waterbodies
OR_LK_1709000604_02_100772	Foster Lake	Lake or Reservoir Unit	170900	Willamette	17090006	South Santiam	1709000604	South Santiam River-Foster Reservoir	Waterbodies
OR_LK_1709000605_02_100773	Willamette Log Pond	Lake or Reservoir Unit	170900	Willamette	17090006	South Santiam	1709000605	Wiley Creek	Waterbodies
OR_LK_1709000608_02_100774	Western Log Pond	Lake or Reservoir Unit	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Waterbodies
OR_LK_1709000608_02_100775	Snow Peak Log Pond	Lake or Reservoir Unit	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Waterbodies
OR_LK_1709000608_02_100776		Lake or Reservoir Unit	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000608_02_100777		Lake or Reservoir Unit	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Waterbodies
OR_SR_1709000601_02_103932	Bear Creek		170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Rivers_CoastLine
OR_SR_1709000601_02_103933	Swamp Creek	Headwaters WA unit to confluence with Middle Santiam River	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Rivers_CoastLine
OR_SR_1709000601_02_103934	Middle Santiam River	Pyramid Creek to Bear Creek	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Rivers_CoastLine
OR_SR_1709000601_02_103935	Pyramid Creek	Single Creek to confluence with Middle Santiam River	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Rivers_CoastLine
OR_SR_1709000601_02_103936	Middle Santiam River	Headwaters WA unit to Pyramid Creek	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Rivers_CoastLine
OR_SR_1709000601_02_103937	Jude Creek		170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Rivers_CoastLine
OR_SR_1709000601_02_103938	Middle Santiam River	Bear Creek to Elk Creek	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Rivers_CoastLine
OR_SR_1709000601_02_103939	Bear Creek		170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Rivers_CoastLine
OR_SR_1709000601_02_103940	tributary to Bear Creek		170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103941	Owl Creek	Boundary Creek to confluence	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		with Canyon Creek							
OR_SR_1709000602_02_103942	Trout Creek	Headwaters WA unit to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103943	South Santiam River		170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103944	tributary to Sevenmile Creek		170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103945	Canyon Creek		170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103946	Keith Creek		170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103947	Soda Fork	Headwaters WA unit to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103948	Two Girls Creek	Headwaters WA unit to confluence with Canyon Creek	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103949	Canyon Creek	Two Girls Creek to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103950	South Santiam River	Headwaters WA unit to Canyon Creek	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103951	Sevenmile Creek		170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000602_02_103952	Snow Creek		170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103953	Sheep Creek	Headwaters WA unit to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103954	Moose Creek	Headwaters WA unit to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000602_02_103955	Latiwi Creek	Headwaters WA unit to Sevenmile Creek	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Rivers_CoastLine
OR_SR_1709000603_02_103956	Moose Creek		170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000603_02_103957	Quartzville Creek	No Man Creek to Canal Creek	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000603_02_103958	Whitcomb Creek		170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000603_02_103959	Elk Creek		170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000603_02_103960	Quartzville Creek	Elk Creek to Green Peter Lake	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000603_02_103961	Canal Creek		170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000603_02_103962	Packers Gulch		170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000603_02_103963	Yellowstone Creek		170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000603_02_103964	Tally Creek		170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000603_02_103965	Middle Santiam River	Elk Creek to Green Peter Lake	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000603_02_103966	Rumbaugh Creek		170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Rivers_CoastLine
OR_SR_1709000604_02_103967	Shot Pouch Creek		170900	Willamette	17090006	South Santiam	1709000604	South Santiam River-Foster Reservoir	Rivers_CoastLine
OR_SR_1709000604_02_103968	South Santiam River	Canyon Creek to Foster Lake	170900	Willamette	17090006	South Santiam	1709000604	South Santiam River-Foster Reservoir	Rivers_CoastLine
OR_SR_1709000604_02_103969	Middle Santiam River	Green Peter Dam to Foster Lake	170900	Willamette	17090006	South Santiam	1709000604	South Santiam River-Foster Reservoir	Rivers_CoastLine
OR_SR_1709000605_02_103970	Little Wiley Creek		170900	Willamette	17090006	South Santiam	1709000605	Wiley Creek	Rivers_CoastLine
OR_SR_1709000605_02_103971	Wiley Creek	Little Wiley Creek to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000605	Wiley Creek	Rivers_CoastLine
OR_SR_1709000605_02_103972	Wiley Creek	Headwaters WA unit to Little Wiley Creek	170900	Willamette	17090006	South Santiam	1709000605	Wiley Creek	Rivers_CoastLine
OR_SR_1709000606_02_103973	Beaver Creek	South Fork Beaver Creek to confluence with Crabtree Creek	170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Rivers_CoastLine
OR_SR_1709000606_02_103974	Roaring River	South Roaring River to confluence with Crabtree Creek	170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Rivers_CoastLine
OR_SR_1709000606_02_103975	Crabtree Creek		170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Rivers_CoastLine
OR_SR_1709000606_02_103976	White Rock Creek		170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Rivers_CoastLine
OR_SR_1709000606_02_103977	Bald Peter Creek		170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000606_02_103978	Crabtree Creek	White Rock Creek to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Rivers_CoastLine
OR_SR_1709000606_02_103979	Rock Creek		170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Rivers_CoastLine
OR_SR_1709000606_02_103980	tributary to Crabtree Creek		170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Rivers_CoastLine
OR_SR_1709000607_02_103981	Thomas Creek		170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103982	Hall Creek		170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103983	Devils Den		170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103984	Ella Creek		170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103985	South Fork Neal Creek	Headwaters WA unit to Bilyeu Creek	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103986	Bilyeu Creek	South Fork Neal Creek to confluence with Thomas Creek	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103987	Jordan Creek		170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103988	Thomas Creek	Bilyeu Creek to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103989	Bilyeu Creek	Headwaters WA Unit to South Fork Neal Creek	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103990	tributary to Thomas Creek		170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000607_02_103991	Thomas Creek	Headwaters WA unit to Bilyeu Creek	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000607_02_103992	tributary to Thomas Creek		170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Rivers_CoastLine
OR_SR_1709000608_02_103993	Hamilton Creek	Headwaters WA unit to Scott Creek	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Rivers_CoastLine
OR_SR_1709000608_02_103994	McDowell Creek	confluence of Morgan Creek and Johnson Creek to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Rivers_CoastLine
OR_SR_1709000608_02_103995	Spring Branch		170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Rivers_CoastLine
OR_SR_1709000608_02_103996	Hamilton Creek	Scott Creek to confluence with South Santiam River	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Rivers_CoastLine
OR_SR_1709000608_02_103997	Scott Creek	South Fork Scott Creek to confluence with Hamilton Creek	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Rivers_CoastLine
OR_SR_1709000608_02_103998	Noble Creek		170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Rivers_CoastLine
OR_WS_170900060101_02_104363	HUC12 Name: Pyramid Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Watersheds
OR_WS_170900060102_02_104364	HUC12 Name: Cougar Creek-Middle Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900060103_02_104365	HUC12 Name: Donaca Creek-Middle Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Watersheds
OR_WS_170900060104_02_104366	HUC12 Name: Bear Creek-Middle Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000601	Headwaters Middle Santiam River	Watersheds
OR_WS_170900060201_02_104367	HUC12 Name: Sevenmile Creek-South Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Watersheds
OR_WS_170900060202_02_104368	HUC12 Name: Sheep Creek-South Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Watersheds
OR_WS_170900060203_02_104369	HUC12 Name: Soda Fork	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Watersheds
OR_WS_170900060204_02_104370	HUC12 Name: Upper Canyon Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Watersheds
OR_WS_170900060205_02_104371	HUC12 Name: Owl Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Watersheds
OR_WS_170900060206_02_104372	HUC12 Name: Moose Creek	Watershed Unit (1st through 4th	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		order streams)							
OR_WS_170900060207_02_104373	HUC12 Name: Lower Canyon Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Watersheds
OR_WS_170900060208_02_104374	HUC12 Name: Trout Creek-South Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000602	South Santiam River	Watersheds
OR_WS_170900060301_02_104375	HUC12 Name: Headwaters Quartzville Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Watersheds
OR_WS_170900060302_02_104376	HUC12 Name: Upper Quartzville Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Watersheds
OR_WS_170900060303_02_104377	HUC12 Name: Canal Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Watersheds
OR_WS_170900060304_02_104378	HUC12 Name: Middle Quartzville Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Watersheds
OR_WS_170900060305_02_104379	HUC12 Name: Lower Quartzville Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Watersheds
OR_WS_170900060306_02_104380	HUC12 Name: Upper Green Peter Lake	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Watersheds
OR_WS_170900060307_02_104381	HUC12 Name: Lower	Watershed Unit (1st through 4th	170900	Willamette	17090006	South Santiam	1709000603	Quartzville Creek-Green Peter Lake	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Green Peter Lake	order streams)							
OR_WS_170900060401_02_104382	HUC12 Name: Shot Pouch Creek-South Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000604	South Santiam River-Foster Reservoir	Watersheds
OR_WS_170900060402_02_104383	HUC12 Name: Middle Santiam River-Foster Lake	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000604	South Santiam River-Foster Reservoir	Watersheds
OR_WS_170900060501_02_104384	HUC12 Name: Little Wiley Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000605	Wiley Creek	Watersheds
OR_WS_170900060502_02_104385	HUC12 Name: Jackson Creek-Wiley Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000605	Wiley Creek	Watersheds
OR_WS_170900060601_02_104386	HUC12 Name: Upper Crabtree Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Watersheds
OR_WS_170900060602_02_104387	HUC12 Name: Middle Crabtree Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Watersheds
OR_WS_170900060603_02_104388	HUC12 Name: Beaver Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Watersheds
OR_WS_170900060604_02_104389	HUC12 Name: Lower Crabtree Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000606	Crabtree Creek	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900060701_02_104390	HUC12 Name: Headwaters Thomas Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Watersheds
OR_WS_170900060702_02_104391	HUC12 Name: Upper Thomas Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Watersheds
OR_WS_170900060703_02_104392	HUC12 Name: Middle Thomas Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Watersheds
OR_WS_170900060704_02_104393	HUC12 Name: South Fork Neal Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Watersheds
OR_WS_170900060705_02_104394	HUC12 Name: Lower Thomas Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000607	Thomas Creek	Watersheds
OR_WS_170900060801_02_104395	HUC12 Name: Ames Creek-South Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Watersheds
OR_WS_170900060802_02_104396	HUC12 Name: McDowell Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Watersheds
OR_WS_170900060803_02_104397	HUC12 Name: Vail Creek-South Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Watersheds
OR_WS_170900060804_02_104398	HUC12 Name:	Watershed Unit (1st through 4th	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Hamilton Creek	order streams)						Santiam River	
OR_WS_170900060805_02_104399	HUC12 Name: Onehorse Slough Creek-South Santiam R*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Watersheds
OR_WS_170900060806_02_104400	HUC12 Name: Mill Creek-South Santiam River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090006	South Santiam	1709000608	Hamilton Creek-South Santiam River	Watersheds
OR_LK_1709000701_02_100778	Aaron Mercer Reservoir	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Waterbodies
OR_LK_1709000701_02_100779	Morgan Lake	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Waterbodies
OR_LK_1709000701_02_100780	Humbug Lake	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Waterbodies
OR_LK_1709000701_02_100781	South Slough Pond	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Waterbodies
OR_LK_1709000701_02_100782		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Waterbodies
OR_LK_1709000701_02_100783		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Waterbodies
OR_LK_1709000701_02_100784		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Waterbodies
OR_LK_1709000702_02_100785		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000702_02_100786		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Waterbodies
OR_LK_1709000702_02_100787		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Waterbodies
OR_LK_1709000702_02_100788		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Waterbodies
OR_LK_1709000702_02_100789		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Waterbodies
OR_LK_1709000702_02_100790		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Waterbodies
OR_LK_1709000702_02_107244	Wirth Lake	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Waterbodies
OR_LK_1709000703_02_100791	Hubbard Lake	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100793	Horseshoe Lake	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100796	Mission Creek Reservoir	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100797	Clear Lake	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100798	Spada Reservoir	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100799	Skookum Lakes	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100800	McKay Reservoir	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000703_02_100801		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100802		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100803		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100804		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100805		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100806		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100807		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100808		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100809		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100810		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100811		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000703_02_100812		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100813		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000703_02_100814		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Waterbodies
OR_LK_1709000704_02_100815	Coffee Lake Creek	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Waterbodies
OR_LK_1709000704_02_100816	Mompano Reservoir	Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Waterbodies
OR_LK_1709000704_02_100817		Lake or Reservoir Unit	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Waterbodies
OR_SR_1709000701_02_103999	Bashaw Creek	Chehulpum Creek to confluence with Willamette River	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000701_02_104000	Rickreall Creek		170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000701_02_104001	Baskett Slough	Headwaters WA unit to confluence with Rickreall Creek	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000701_02_104002	tributary to Rickreall Creek		170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000701_02_104003	Rockhouse Creek		170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
								Willamette River	
OR_SR_1709000701_02_104004	Ash Creek	Headwaters WA Unit to confluence with Willamette River	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000701_02_104591	Rickreall Creek	Mercer Dam to confluence with Willamette River	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000701_02_104592	Rickreall Creek	tributary to Rickreall Creek to Aaron Mercer Reservoir	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000702_02_104006			170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Rivers_CoastLine
OR_SR_1709000703_02_104007	Mill Creek	McKinney Creek to confluence with Willamette River	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Rivers_CoastLine
OR_SR_1709000703_02_104008	Shelton Ditch	Mill Creek to confluence with Pringle Creek	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000703_02_104009	Chehalem Creek	Headwaters WA unit to confluence with Willamette River	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000703_02_104011	Willamette Slough		170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000703_02_104012	Pringle Creek	Mill Creek to confluence with Willamette River	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000704_02_104016	Holcomb Creek		170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000704_02_104017	Abernethy Creek	Holcomb Creek to confluence with Willamette River	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000704_02_104593	Abernethy Creek		170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Rivers_CoastLine
OR_SR_1709000704_02_104594	Abernethy Creek	Mompano Dam to Holcomb Creek	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Rivers_CoastLine
OR_WS_170900070101_02_104401	HUC12 Name: Bashaw Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Watersheds
OR_WS_170900070101_05_104402	HUC12 Name: Bashaw Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Watersheds
OR_WS_170900070102_02_104403	HUC12 Name: Ash Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Watersheds
OR_WS_170900070103_02_104404	HUC12 Name: Upper Rickreall Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Watersheds
OR_WS_170900070104_02_104405	HUC12 Name: Baskett Slough	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900070105_02_104406	HUC12 Name: Hayden Slough Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Watersheds
OR_WS_170900070106_02_104407	HUC12 Name: Lower Rickreall Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Watersheds
OR_WS_170900070107_02_104408	HUC12 Name: Wilkerson Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000701	Rickreall Creek-Willamette River	Watersheds
OR_WS_170900070201_02_104409	HUC12 Name: Upper Mill Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Watersheds
OR_WS_170900070202_02_104410	HUC12 Name: Beaver Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Watersheds
OR_WS_170900070203_02_104411	HUC12 Name: McKinney Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Watersheds
OR_WS_170900070204_02_104412	HUC12 Name: Lower Mill Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000702	Mill Creek	Watersheds
OR_WS_170900070301_02_104413	HUC12 Name: Croisan Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Watersheds
OR_WS_170900070302_02_104414	HUC12 Name: Spring	Watershed Unit (1st through 4th	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Valley Creek	order streams)							
OR_WS_170900070303_02_104415	HUC12 Name: Glenn Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Watersheds
OR_WS_170900070304_02_104599	HUC12 Name: Lambert Slough-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Watersheds
OR_WS_170900070305_02_104416	HUC12 Name: Champoeg Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Watersheds
OR_WS_170900070306_02_104417	HUC12 Name: Chehalem Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Watersheds
OR_WS_170900070307_02_104602	HUC12 Name: Hess Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000703	Chehalem Creek-Willamette River	Watersheds
OR_WS_170900070401_02_104418	HUC12 Name: Corral Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Watersheds
OR_WS_170900070402_02_104419	HUC12 Name: Coffee Lake Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Watersheds
OR_WS_170900070403_02_104420	HUC12 Name: Parrott Creek-	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Beaver Creek								
OR_WS_170900070404_02_104421	HUC12 Name: Abernethy Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Watersheds
OR_WS_170900070405_02_104422	HUC12 Name: Tanner Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090007	Middle Willamette	1709000704	Abernethy Creek-Willamette River	Watersheds
OR_LK_1709000901_02_100826	Silver Creek Reservoir	Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Waterbodies
OR_LK_1709000901_02_100827	Fitzpatrick Creek	Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Waterbodies
OR_LK_1709000901_02_100828		Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Waterbodies
OR_LK_1709000901_02_100829		Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Waterbodies
OR_LK_1709000902_02_100830	Zollner Creek	Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Waterbodies
OR_LK_1709000902_02_100831	Deardorff Reservoir	Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Waterbodies
OR_LK_1709000903_02_100832	Rose Reservoir	Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000903	Rock Creek	Waterbodies
OR_LK_1709000903_02_100833		Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000903	Rock Creek	Waterbodies
OR_LK_1709000904_02_107249	Cougar Lake	Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709000906_02_100834	Molalla River Oxbow	Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Waterbodies
OR_LK_1709000906_02_100835		Lake or Reservoir Unit	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Waterbodies
OR_SR_1709000901_02_104062	Abiqua Creek	Headwaters WA Unit to confluence with Pudding River	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000901_02_104063	North Fork Silver Creek		170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000901_02_104064	Pudding River	Silver Creek to Little Pudding River	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000901_02_104065	Pudding River		170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000901_02_104066	South Fork Silver Creek	Smith Creek to North Fork Silver Creek	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000901_02_104067	Pudding River	Drift Creek to Silver Creek	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000901_02_104068	Little Pudding River	Fruitland Creek to confluence with Pudding River	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000901_02_104069	Drift Creek	Lorence Reservoir to confluence with Pudding River	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000901_02_104595	Silver Creek	Silver Creek Reservoir to confluence with Pudding River	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000901_02_104596	Silver Creek	Confluence of North Fork Silver Creek and South Fork Silver Creek to Silver Creek Reservoir	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000902_02_104070	Butte Creek	Fall Creek to Coak Creek	170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000902_02_104071	Coal Creek		170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000902_02_104072	Butte Creek	Coal Creek to confluence with Pudding River	170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000902_02_104073	Pudding River	Little Pudding River to Rock Creek	170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000903_02_104074	Rock Creek	Marquam Creek to confluence with Pudding River	170900	Willamette	17090009	Molalla-Pudding	1709000903	Rock Creek	Rivers_CoastLine
OR_SR_1709000903_02_104075	Rock Creek	Teasel Creek to Marquam Creek	170900	Willamette	17090009	Molalla-Pudding	1709000903	Rock Creek	Rivers_CoastLine
OR_SR_1709000903_02_104076	Garret Creek		170900	Willamette	17090009	Molalla-Pudding	1709000903	Rock Creek	Rivers_CoastLine
OR_SR_1709000904_02_104077	Molalla River		170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000904_02_104078	Molalla River		170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000904_02_104079	Gawley Creek		170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000904_02_104080	Henry Creek		170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000904_02_104081	Dead Horse Canyon Creek		170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000904_02_104082	Lukens Creek		170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709000904_02_104083	North Fork Molalla River		170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000904_02_104084	North Fork Molalla River		170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000904_02_104085	Copper Creek		170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000904_02_104086	Molalla River	Henry Creek to North Fork Molalla River	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000904_02_104087	Table Rock Fork	Lost Creek to confluence with Molalla River	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Rivers_CoastLine
OR_SR_1709000905_02_104088	Pudding River	Rock Creek to confluence with Molalla River	170900	Willamette	17090009	Molalla-Pudding	1709000905	Senecal Creek-Pudding River	Rivers_CoastLine
OR_SR_1709000906_02_104089	Buckner Creek		170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Rivers_CoastLine
OR_SR_1709000906_02_104090	Milk Creek		170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Rivers_CoastLine
OR_SR_1709000906_02_104091	Milk Creek	Canyon Creek to confluence with Molalla River	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Rivers_CoastLine
OR_SR_1709000906_02_104092	Cedar Creek		170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Rivers_CoastLine
OR_SR_1709000906_02_104093	Molalla River	Dickey Creek to confluence with Pudding River	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Rivers_CoastLine
OR_SR_1709000906_02_104094	Molalla River		170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Rivers_CoastLine
OR_SR_1709000906_02_104095	Canyon Creek		170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Rivers_CoastLine
OR_WS_170900090101_02_104454	HUC12 Name: Headwaters Pudding River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Watersheds
OR_WS_170900090102_02_104455	HUC12 Name: Drift Creek	Watershed Unit (1st through 4th	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		order streams)						Pudding River	
OR_WS_170900090103_02_104456	HUC12 Name: North Fork Silver Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Watersheds
OR_WS_170900090104_02_104457	HUC12 Name: Silver Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Watersheds
OR_WS_170900090105_02_104458	HUC12 Name: Upper Abiqua Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Watersheds
OR_WS_170900090106_02_104459	HUC12 Name: Middle Abiqua Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Watersheds
OR_WS_170900090107_02_104460	HUC12 Name: Lower Abiqua Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Watersheds
OR_WS_170900090108_02_104461	HUC12 Name: Upper Little Pudding River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Watersheds
OR_WS_170900090109_02_104462	HUC12 Name: Lower Little Pudding River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Watersheds
OR_WS_170900090110_02_104463	HUC12 Name: Howell Prairie Creek-Pudding River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000901	Abiqua Creek-Pudding River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900090201_02_104464	HUC12 Name: Upper Butte Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Watersheds
OR_WS_170900090202_02_104465	HUC12 Name: Middle Butte Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Watersheds
OR_WS_170900090203_02_104466	HUC12 Name: Lower Butte Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Watersheds
OR_WS_170900090204_02_104467	HUC12 Name: Brandy Creek-Pudding River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000902	Butte Creek-Pudding River	Watersheds
OR_WS_170900090301_02_104468	HUC12 Name: Garret Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000903	Rock Creek	Watersheds
OR_WS_170900090302_02_104469	HUC12 Name: Upper Rock Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000903	Rock Creek	Watersheds
OR_WS_170900090303_02_104470	HUC12 Name: Bear Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000903	Rock Creek	Watersheds
OR_WS_170900090304_02_104471	HUC12 Name: Lower Rock Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000903	Rock Creek	Watersheds
OR_WS_170900090401_02_104472	HUC12 Name: Table Rock Fork	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900090402_02_104473	HUC12 Name: Headwaters Molalla River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Watersheds
OR_WS_170900090403_02_104474	HUC12 Name: Pine Creek-Molalla River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Watersheds
OR_WS_170900090404_02_104475	HUC12 Name: Trout Creek-Molalla River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Watersheds
OR_WS_170900090405_02_104476	HUC12 Name: Dead Horse Canyon Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Watersheds
OR_WS_170900090406_02_104477	HUC12 Name: Upper North Fork Molalla River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Watersheds
OR_WS_170900090407_02_104478	HUC12 Name: Lower North Fork Molalla River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Watersheds
OR_WS_170900090408_02_104479	HUC12 Name: Cedar Creek-Molalla River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000904	Upper Molalla River	Watersheds
OR_WS_170900090501_02_104480	HUC12 Name: Senecal Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000905	Senecal Creek-Pudding River	Watersheds
OR_WS_170900090502_02_104481	HUC12 Name: Mill Creek-Pudding River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000905	Senecal Creek-Pudding River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900090601_02_104482	HUC12 Name: Canyon Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Watersheds
OR_WS_170900090602_02_104483	HUC12 Name: Headwaters Milk Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Watersheds
OR_WS_170900090603_02_104484	HUC12 Name: Upper Milk Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Watersheds
OR_WS_170900090604_02_104485	HUC12 Name: Woodcock Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Watersheds
OR_WS_170900090605_02_104486	HUC12 Name: Middle Milk Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Watersheds
OR_WS_170900090606_02_104487	HUC12 Name: Lower Milk Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Watersheds
OR_WS_170900090607_02_104488	HUC12 Name: Molalla River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090009	Molalla-Pudding	1709000906	Lower Molalla River	Watersheds
OR_LK_1709001101_02_100845	Elk Lake	Lake or Reservoir Unit	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Waterbodies
OR_LK_1709001103_02_100846	Timothy Lake	Lake or Reservoir Unit	170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Waterbodies
OR_LK_1709001104_02_100847	North Fork Reservoir	Lake or Reservoir Unit	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709001104_02_100848	Serene Lake	Lake or Reservoir Unit	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Waterbodies
OR_LK_1709001106_02_100849	Faraday Lake	Lake or Reservoir Unit	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Waterbodies
OR_LK_1709001106_02_100850	Estacada Lake	Lake or Reservoir Unit	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Waterbodies
OR_LK_1709001106_02_100851	North Fork Reservoir	Lake or Reservoir Unit	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Waterbodies
OR_SR_1709001101_02_104142	Collawash River	Nohorn Creek to confluence with Clackamas River	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Rivers_CoastLine
OR_SR_1709001101_02_104143	Hot Springs Fork	Whetstone Creek to Nohorn Creek	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Rivers_CoastLine
OR_SR_1709001101_02_104144	Collawash River	East Fork Collawash River to Hot Springs Fork	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Rivers_CoastLine
OR_SR_1709001101_02_104145	Nohorn Creek	Headwater WA Unit to confluence with Hot Springs Fork	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Rivers_CoastLine
OR_SR_1709001102_02_104146	Cub Creek		170900	Willamette	17090011	Clackamas	1709001102	Upper Clackamas River	Rivers_CoastLine
OR_SR_1709001102_02_104147	Clackamas River	Cub Creek to Collawash River	170900	Willamette	17090011	Clackamas	1709001102	Upper Clackamas River	Rivers_CoastLine
OR_SR_1709001102_02_104148	Clackamas River	Squirrel Creek to Cub Creek	170900	Willamette	17090011	Clackamas	1709001102	Upper Clackamas River	Rivers_CoastLine
OR_SR_1709001103_02_104149	Oak Grove Fork Clackamas River		170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Rivers_CoastLine
OR_SR_1709001103_02_104150	Oak Grove Fork Clackamas River	Shellrock Creek to confluence with	170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		Clackamas River							
OR_SR_1709001103_02_104151	Shellrock Creek		170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104152	North Fork Clackamas River	Boyer Creek to confluence with North Fork Reservoir	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104153	Big Creek		170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104154	Clackamas River	Collowash River to Oak Grove Fork Clackamas River	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104155	Clackamas River	Oak Grove Fork Clackamas River to North Fork Reservoir	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104156	Fish Creek	Tweed Creek to Wash Creek	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104157	Trout Creek		170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104158	Wash Creek		170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104159	South Fork Clackamas River		170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104160	Roaring River		170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine
OR_SR_1709001104_02_104161	Fish Creek	Wash Creek to confluence with Clackamas River	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709001105_02_104162	Eagle Creek		170900	Willamette	17090011	Clackamas	1709001105	Eagle Creek	Rivers_CoastLine
OR_SR_1709001105_02_104163	Eagle Creek	Delph Creek to confluence with Clackamas River	170900	Willamette	17090011	Clackamas	1709001105	Eagle Creek	Rivers_CoastLine
OR_SR_1709001105_02_104164	Delph Creek		170900	Willamette	17090011	Clackamas	1709001105	Eagle Creek	Rivers_CoastLine
OR_SR_1709001105_02_104165	North Fork Eagle Creek	Confluence of Trout Creek and Grabenheim Creek to confluence with Eagle Creek	170900	Willamette	17090011	Clackamas	1709001105	Eagle Creek	Rivers_CoastLine
OR_SR_1709001106_02_104166	Deep Creek	Headwaters WA Unit to confluence with Clackamas River	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Rivers_CoastLine
OR_SR_1709001106_02_104167	Clear Creek	Headwaters WA Unit to Little Clear Creek	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Rivers_CoastLine
OR_SR_1709001106_02_104168	Little Clear Creek		170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Rivers_CoastLine
OR_SR_1709001106_02_104169	Clear Creek	Little Clear Creek to confluence with Clackamas River	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Rivers_CoastLine
OR_SR_1709001106_02_104598	Clackamas River		170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Rivers_CoastLine
OR_WS_170900110101_02_104516	HUC12 Name: Upper Hot Springs Fork	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Watersheds
OR_WS_170900110102_02_104517	HUC12 Name:	Watershed Unit (1st	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Nohorn Creek	through 4th order streams)							
OR_WS_170900110103_02_104518	HUC12 Name: Lower Hot Springs Fork	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Watersheds
OR_WS_170900110104_02_104519	HUC12 Name: Elk Lake Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Watersheds
OR_WS_170900110105_02_104520	HUC12 Name: East Fork Collawash River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Watersheds
OR_WS_170900110106_02_104521	HUC12 Name: Happy Creek-Collawash River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Watersheds
OR_WS_170900110107_02_104522	HUC12 Name: Farm Creek-Collawash River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001101	Collawash River	Watersheds
OR_WS_170900110201_02_104523	HUC12 Name: Cub Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001102	Upper Clackamas River	Watersheds
OR_WS_170900110202_02_104524	HUC12 Name: Headwaters Clackamas River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001102	Upper Clackamas River	Watersheds
OR_WS_170900110203_02_104525	HUC12 Name: Lowe Creek-Clackamas River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001102	Upper Clackamas River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900110204_02_104526	HUC12 Name: Last Creek-Pinhead Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001102	Upper Clackamas River	Watersheds
OR_WS_170900110205_02_104527	HUC12 Name: Pot Creek-Clackamas River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001102	Upper Clackamas River	Watersheds
OR_WS_170900110301_02_104528	HUC12 Name: Headwaters Oak Grove Fork Clackamas R*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Watersheds
OR_WS_170900110302_02_104529	HUC12 Name: Timothy Lake-Oak Grove Fork Clackamas*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Watersheds
OR_WS_170900110303_02_104530	HUC12 Name: Stone Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Watersheds
OR_WS_170900110304_02_104531	HUC12 Name: Shellrock Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Watersheds
OR_WS_170900110305_02_104532	HUC12 Name: Anvil Creek-Oak Grove Fork Clackamas *	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Watersheds
OR_WS_170900110306_02_104533	HUC12 Name: Cot Creek-Oat Grove Fork Clackamas Ri*	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001103	Oak Grove Fork Clackamas River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_WS_170900110401_02_104534	HUC12 Name: Three Lynx Creek-Clackamas River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Watersheds
OR_WS_170900110402_02_104535	HUC12 Name: Roaring River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Watersheds
OR_WS_170900110403_02_104536	HUC12 Name: Fish Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Watersheds
OR_WS_170900110404_02_104537	HUC12 Name: South Fork Clackamas River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Watersheds
OR_WS_170900110405_02_104538	HUC12 Name: North Fork Clackamas River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Watersheds
OR_WS_170900110406_02_104539	HUC12 Name: Helion Creek-Clackamas River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001104	Middle Clackamas River	Watersheds
OR_WS_170900110501_02_104540	HUC12 Name: Upper Eagle Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001105	Eagle Creek	Watersheds
OR_WS_170900110502_02_104541	HUC12 Name: North Fork Eagle Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001105	Eagle Creek	Watersheds
OR_WS_170900110503_02_104542	HUC12 Name: Lower Eagle Creek	Watershed Unit (1st through 4th	170900	Willamette	17090011	Clackamas	1709001105	Eagle Creek	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		order streams)							
OR_WS_170900110601_02_104543	HUC12 Name: Upper Clear Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Watersheds
OR_WS_170900110602_02_104544	HUC12 Name: Middle Clear Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Watersheds
OR_WS_170900110603_02_104545	HUC12 Name: Dubois Creek-Clackamas River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Watersheds
OR_WS_170900110604_02_104546	HUC12 Name: Tickle Creek-Deep Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Watersheds
OR_WS_170900110605_02_104547	HUC12 Name: North Fork Deep Creek-Deep Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Watersheds
OR_WS_170900110606_02_104548	HUC12 Name: Lower Clear Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Watersheds
OR_WS_170900110607_02_104549	HUC12 Name: Rock Creek-Clackamas River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090011	Clackamas	1709001106	Lower Clackamas River	Watersheds
OR_LK_1709001201_02_100853	Lake Oswego	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001201	Johnson Creek-Willamette River	Waterbodies
OR_LK_1709001202_02_100854	Blue Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
								Willamette River	
OR_LK_1709001202_02_100855	Bybee Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Waterbodies
OR_LK_1709001202_02_100856	Smith Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Waterbodies
OR_LK_1709001202_02_100857	Buffalo Slough	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Waterbodies
OR_LK_1709001202_02_100858	Fairview Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Waterbodies
OR_LK_1709001202_02_100859		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Waterbodies
OR_LK_1709001202_02_100860		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Waterbodies
OR_LK_1709001202_02_100861		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Waterbodies
OR_LK_1709001202_02_107245	Laurelhurst Pond	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Waterbodies
OR_LK_1709001203_02_100862		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100863		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100864	Guiles Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100865	Petes Slough Reservoir	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709001203_02_100866	McNary Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100867		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100868	Rest Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100869	Scappoose Bay	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100870	Honeyman Creek	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100871	Seal Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100872	Steelman Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100873	Crane Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100874	Millionaire Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100875	Sturgeon Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100876	Frogmore Slough	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100877	Aarons Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100878	Teal Creek	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100879		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100880		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_LK_1709001203_02_100881	Racetrack Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100882	Henrici Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100883	Cunningham Lake	Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100884		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100885		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100886		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100887		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100888		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100889		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100890		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100891		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_100892		Lake or Reservoir Unit	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_LK_1709001203_02_107247	Haldeman Pond		170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Waterbodies
OR_SR_1709001201_02_104170	Johnson Creek	North Fork Johnson Creek to confluence with Willamette River	170900	Willamette	17090012	Lower Willamette	1709001201	Johnson Creek-Willamette River	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
OR_SR_1709001201_02_104171	Mount Scott Creek	Phillips Creek to confluence with Willamette River	170900	Willamette	17090012	Lower Willamette	1709001201	Johnson Creek-Willamette River	Rivers_CoastLine
OR_SR_1709001201_02_104172	Tryon Creek	Palatine Hill Creek to confluence with Willamette River	170900	Willamette	17090012	Lower Willamette	1709001201	Johnson Creek-Willamette River	Rivers_CoastLine
OR_SR_1709001202_02_104173	Saltzman Creek	Headwaters WA Unit to confluence with Willamette River	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Rivers_CoastLine
OR_SR_1709001202_02_104174	Tanner Creek	Confluence at NW Flanders St and NW 17th Ave to confluence with Willamette River	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Rivers_CoastLine
OR_SR_1709001203_02_104176	Milton Creek	Headwaters WA Unit to confluence with Lower Scappoose Bay	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Rivers_CoastLine
OR_SR_1709001203_02_104177	Scappoose Creek	Confluence of South Scappoose Creek and North Scappoose Creek to confluence with Lower Scappoose Bay	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Rivers_CoastLine
OR_SR_1709001203_02_104178	tributary to Multnomah Channel	Burlington Bottoms to confluence with	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Rivers_CoastLine

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
		Multnomah Channel							
OR_SR_1709001203_02_104179	North Scappoose Creek	Lizzie Creek to confluence with Scappoose Creek	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Rivers_CoastLine
OR_SR_1709001203_02_104180	South Scappoose Creek	Lazy Creek to confluence with Scappoose Creek	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Rivers_CoastLine
OR_SR_1709001203_02_104181	Lower Scappoose Bay	Milton Creek to confluence with Multnomah Channel	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Rivers_CoastLine
OR_SR_1709001203_02_104182	Crabapple Creek		170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Rivers_CoastLine
OR_SR_1709001203_02_104183	McCarthy Creek		170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Rivers_CoastLine
OR_WS_170900120101_02_104550	HUC12 Name: Upper Johnson Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001201	Johnson Creek-Willamette River	Watersheds
OR_WS_170900120102_02_104551	HUC12 Name: Kellogg Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001201	Johnson Creek-Willamette River	Watersheds
OR_WS_170900120103_02_104552	HUC12 Name: Lower Johnson Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001201	Johnson Creek-Willamette River	Watersheds
OR_WS_170900120104_02_104553	HUC12 Name: Oswego Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001201	Johnson Creek-Willamette River	Watersheds
OR_WS_170900120201_02_104554.1	HUC12 Name: Columbia	Watershed Unit (1st through 4th	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Watersheds

AU_ID	AU Name	AU Description	HUC_6	HU_6 NAME	HUC_8	HU_8 NAME	HUC_10	HU_10 NAME	GIS_source
	Slough (Lower)	order streams)							
OR_WS_170900120201_02_104554.2	HUC12 Name: Columbia Slough (Upper)	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Watersheds
OR_WS_170900120202_02_104555	HUC12 Name: Balch Creek-Willamette River	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001202	Columbia Slough-Willamette River	Watersheds
OR_WS_170900120301_02_104557	HUC12 Name: South Scappoose Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Watersheds
OR_WS_170900120302_02_104558	HUC12 Name: North Scappoose Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Watersheds
OR_WS_170900120303_02_104559	HUC12 Name: Milton Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Watersheds
OR_WS_170900120304_02_104560	HUC12 Name: Scappoose Creek	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Watersheds
OR_WS_170900120305_02_104561	HUC12 Name: Multnomah Channel	Watershed Unit (1st through 4th order streams)	170900	Willamette	17090012	Lower Willamette	1709001203	Multnomah Channel	Watersheds

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