Total Maximum Daily Loads for the Lower Columbia-Sandy Subbasin

Temperature

August 2024

State of Oregon
DEQ Department of Environmental Quality

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Acknowledgments

The Lower Columbia-Sandy Subbasin Temperature TMDLs and Water Quality Management Plan would not be possible without the support, contributions, and review of the following:

Benjamin Beal	City of Portland Water Bureau
Liane Davis	City of Portland Water Bureau
Steve Kucas	City of Portland Water Bureau
Dan Brown	Oregon Department of Environmental Quality
Rob Burkhart	Oregon Department of Environmental Quality
Gene Foster	Oregon Department of Environmental Quality
Michele Martin	Oregon Department of Environmental Quality
James McConaghie	Oregon Department of Environmental Quality
Jordan Palmeri	Oregon Department of Environmental Quality
Josh Seeds	Oregon Department of Environmental Quality
Debra Sturdevant	Oregon Department of Environmental Quality
Jennifer Wigal	Oregon Department of Environmental Quality
Sen Bai	Tetra Tech
Mustafa Faizullabhoy	Tetra Tech
Aileen Molloy	Tetra Tech
Joel Achenbach	U.S. Environmental Protection Agency, Region 10
Ben Cope	U.S. Environmental Protection Agency, Region 10
Gunnar Johnson	U.S. Environmental Protection Agency, Region 10
Lisa Kusnierz	U.S. Environmental Protection Agency, Region 10
Peter Leinenbach	U.S. Environmental Protection Agency, Region 10
Jayshika Ramrakha	U.S. Environmental Protection Agency, Region 10
Rebecca Veiga-Nascimento	U.S. Environmental Protection Agency, Region 10
Jenny Wu	U.S. Environmental Protection Agency, Region 10

In addition, we would like to thank the TMDL Rule Advisory Committee Members, Tribal Nations, and all the individuals or organizations who provided data or took time to review and provide comments to DEQ.

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Acronyms

7DADM	7-Day Average Daily Maximum
7Q10	7-Day, 10-Year Low Flow
AU	Assessment Unit
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
DEQ	Oregon Department of Environmental Quality
DMA	Designated Management Agency
DMR	Discharge Monitoring Report
EPA	Environmental Protection Agency
EQC	Oregon Environmental Quality Commission
HUA	Human Use Allowance
HUC	Hydrologic Unit Code
LA	Load Allocation
LC	Loading Capacity
MGD	Millions of Gallons per Day
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
OAR	Oregon Administrative Rules
ODFW	Oregon Department of Fish & Wildlife
ORS	Oregon Revised Statutes
POMI	Point of Maximum Impact
RC	Reserve Capacity
STP	Sewage Treatment Plant
TMDL	Total Maximum Daily Load
TSD	Technical Support Document
USGS	United States Geological Survey
WLA	Wasteload Allocation
WQMP	Water Quality Management Plan
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

1 Introduction

This Total Maximum Daily Load (TMDL) project is applicable within the Lower Columbia-Sandy Subbasin and was adopted by reference into Oregon Administrative Rules OAR 340-42-0090.

OAR 340-42-0040(3) requires the Oregon Department of Environmental Quality (DEQ) or Oregon's Environmental Quality Commission (EQC) to prioritize and schedule TMDLs for completion considering various factors outlined in the rule. Temperature TMDLs for the Lower Columbia-Sandy Subbasin were identified as a high priority due to court order to Oregon and the Environmental Protection Agency (EPA) to establish TMDLs to replace the temperature TMDLs developed as part of the 2005 Sandy River Basin (action ID 11395) (**Table 1-1**).

1.1 Previous TMDLs

DEQ has issued one previous TMDL action in 2005 that addressed listings for temperature and bacteria (DEQ, 2005). Once approved by EPA, the Lower Columbia-Sandy Subbasin TMDLs for temperature will replace the temperature TMDLs approved by EPA in 2005. The bacteria TMDLs approved by the EPA in 2005 are still effective.

Table 1-1: Summary of previous TMDLs developed for the Lower Columbia-Sandy Subbasin.

TMDL action ID	TMDL name	EPA approval date	Water quality impairments addressed
11395	Sandy River Basin Total Maximum Daily Load (TMDL)	4/14/2005	Bacteria (water contact recreation), Temperature

1.2 TMDL administrative process and public participation

Following completion of DEQ's drafting process, including engagement of a rule advisory committee on the fiscal impact statement and aspects of the rule, this revised temperature TMDL for the Lower Columbia-Sandy Subbasin was adopted by the EQC, by reference, into rule section OAR 340-042-0090. Any subsequently amended or renumbered rules cited in this document are intended to apply.

DEQ convened a rule advisory committee to provide input on drafts of the TMDL, Water Quality Management Plan (WQMP), Technical Support Document (TSD), fiscal and economic impacts, and Environmental Justice and Racial Equity. The committee met on February 22, 2023, and April 5, 2023. The agency held two informational webinars about this TMDL. A public comment period was held from January 10 through February 26, 2024. DEQ held a public hearing on February 16, 2024. DEQ considered all input received during these public participation opportunities and used input to guide the analyses and preparation of documents. DEQ developed a response to comments that is available online.

2 TMDL name and location

Per OAR 340-042-0040(4)(a), this element describes the geographic area for which the TMDL was developed.

Temperature TMDLs for the Lower Columbia-Sandy were developed to address all Category 5 listed assessment units (AUs) impaired for temperature (**Table 2-2**) and, as applicable, any AUs identified as temperature-impaired in the future. Likewise, this TMDL includes a protection plan for all other assessment categories including AUs identified as a potential concern, attaining, or unassessed.

The loading capacity (LC) and allocations, including surrogate measures, and implementation framework apply to all waters determined to be waters of the state as defined under ORS 468B.005(10), including all perennial and intermittent streams that have surface flow or residual pools during the TMDL allocation period, located in the Lower Columbia-Sandy Subbasin (17080001). The temperature TMDLs do not include the section of the Columbia River that flows through the Lower Columbia-Sandy Subbasin (17080001). However, this TMDL implements EPA's Columbia and Lower Snake Rivers temperature TMDL (EPA, 2021) allocation to anthropogenic sources in Columbia River tributaries, including the Sandy River.

The TMDL implementation framework is presented in the Lower Columbia-Sandy Subbasin WQMP and includes implementation activities and timeframes to improve water quality, as well as measures of success. These and other protection plan elements are further explained in Section 12.

The map in **Figure 2-1** provides an overview of where the temperature TMDLs are applicable. Appendix H of the Lower Columbia-Sandy TSD provides a list of all AUs addressed by this TMDL.

In Oregon, the Lower Columbia-Sandy Subbasin is comprised of seven smaller 10-digit hydrologic unit code (HUC) watersheds as listed in **Table 2-1**.

Table 2-1: Watersheds within the Lower Columbia-Sandy Subbasin.

HUC	Watershed name
1708000101	Upper Sandy River
1708000102	Zigzag River
1708000103	Salmon River
1708000104	Middle Sandy River
1708000105	Bull Run River
1708000107	Lower Sandy River
1708000108	City of Washougal-Columbia River

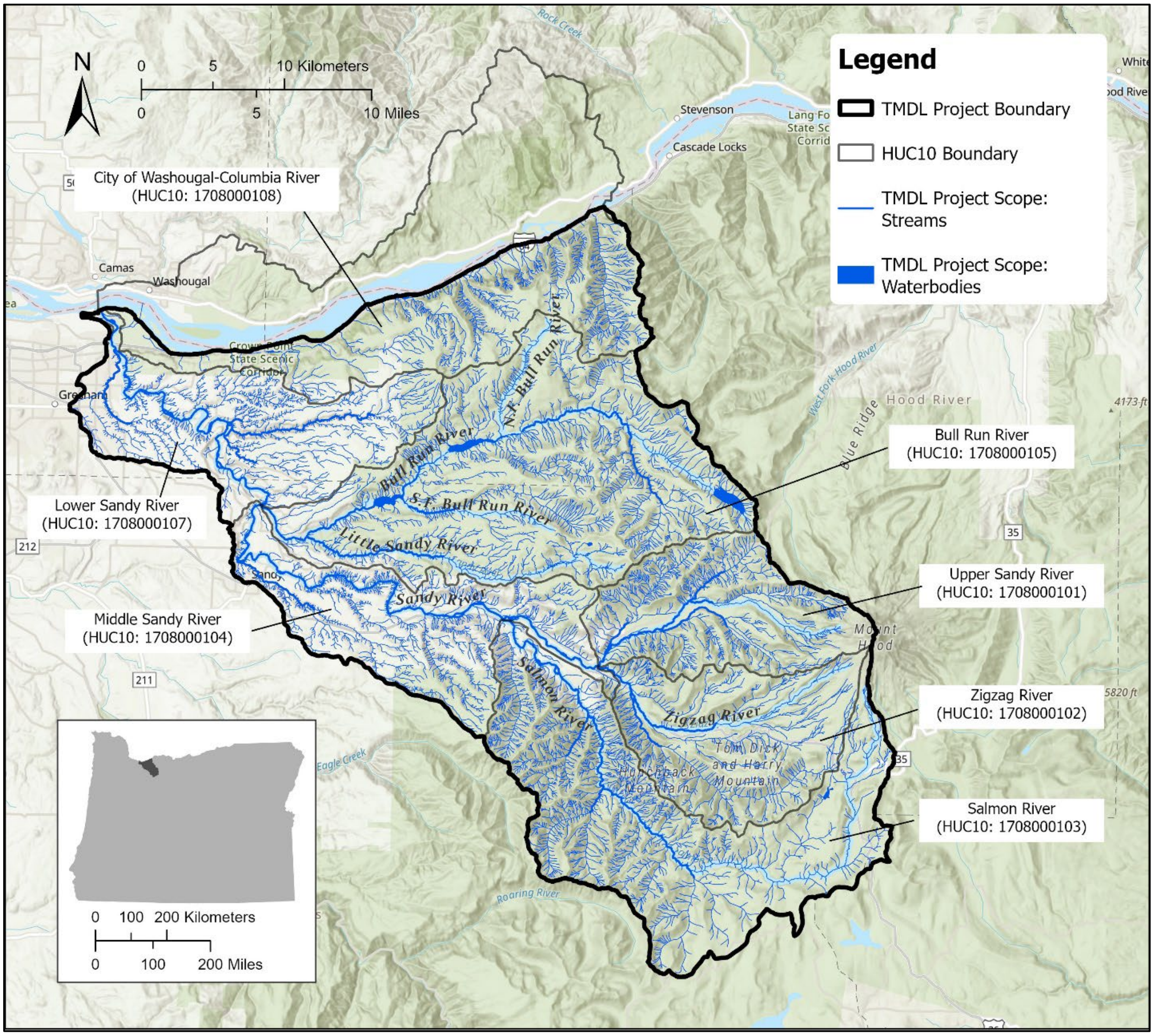

Figure 2-1: Lower Columbia-Sandy Subbasin temperature TMDLs project area overview.

Table 2-2 presents stream AUs within the Lower Columbia-Sandy Subbasin that were listed as impaired for temperature on DEQ's 2022 Clean Water Act Section 303(d) List (as part of Oregon's Integrated Report), which was approved by the EPA on September 1, 2022. Status category designations are prescribed by Sections 305(b) and 303(d) of the Clean Water Act. AUs listed in Category 5 (i.e., designated use is not supported or a water quality standard is not attained) require development of a TMDL. Locations of these listed segments are depicted in **Figure 2-2**.

Table 2-2: Lower Columbia-Sandy Subbasin Category 5 temperature impairments on the 2022 Integrated Report.

Assessment unit name	Assessment unit	Use period
Beaver Creek	OR_SR_1708000107_02_103612	Year round
Beaver Creek	OR_SR_1708000107_02_103612	Spawning
Benson Lake	OR_LK_1708000108_15_100639	Year round
Bull Run River	OR_SR_1708000105_11_103611	Year round
Bull Run River	OR_SR_1708000105_11_103611	Spawning
Cedar Creek	OR_SR_1708000104_02_103607	Year round
Clear Creek	OR_SR_1708000101_02_103597	Year round
Clear Creek	OR_SR_1708000101_02_103597	Spawning
Clear Fork	OR_SR_1708000101_02_103596	Spawning
Gordon Creek	OR_SR_1708000107_02_103615	Spawning
Gordon Creek	OR_SR_1708000107_02_103617	Spawning
HUC12 Name: Beaver Creek-Sandy River	OR_WS_170800010703_02_103703	Spawning
HUC12 Name: Beaver Creek-Sandy River	OR_WS_170800010703_02_103703	Year round
HUC12 Name: Bridal Veil Creek-Columbia River	OR_WS_170800010803_15_103654	Year round
HUC12 Name: Cedar Creek-Sandy River	OR_WS_170800010402_02_103644	Year round
HUC12 Name: Headwaters Sandy River	OR_WS_170800010101_02_103635	Year round
HUC12 Name: Little Sandy River	OR_WS_170800010505_11_103669	Year round
HUC12 Name: Lower Bull Run River	OR_WS_170800010506_11_103650	Year round
HUC12 Name: Lower Salmon River	OR_WS_170800010304_02_103642	Year round
HUC12 Name: Tanner Creek-Columbia River	OR_WS_170800010801_15_103707	Spawning
HUC12 Name: Tanner Creek-Columbia River	OR_WS_170800010801_15_103707	Year round
HUC12 Name: Wildcat Creek-Sandy River	OR_WS_170800010401_02_103643	Spawning
Little Sandy River	OR_SR_1708000105_11_103609	Year round
Little Sandy River	OR_SR_1708000105_11_103609	Spawning
Lost Creek	OR_SR_1708000101_02_103598	Spawning
Salmon River	OR_SR_1708000103_02_103606	Year round
Salmon River	OR_SR_1708000103_02_103606	Spawning
Sandy River	OR_SR_1708000101_02_103595	Year round
Sandy River	OR_SR_1708000101_02_103599	Year round
Sandy River	OR_SR_1708000101_02_103599	Spawning
Sandy River	OR_SR_1708000104_02_103608	Year round
Sandy River	OR_SR_1708000104_02_103608	Spawning
Sandy River	OR_SR_1708000107_02_103616	Year round
South Fork Salmon River	OR_SR_1708000103_02_103604	Spawning
Still Creek	OR_SR_1708000102_02_103601	Spawning
Zigzag River	OR_SR_1708000102_02_103600	Spawning

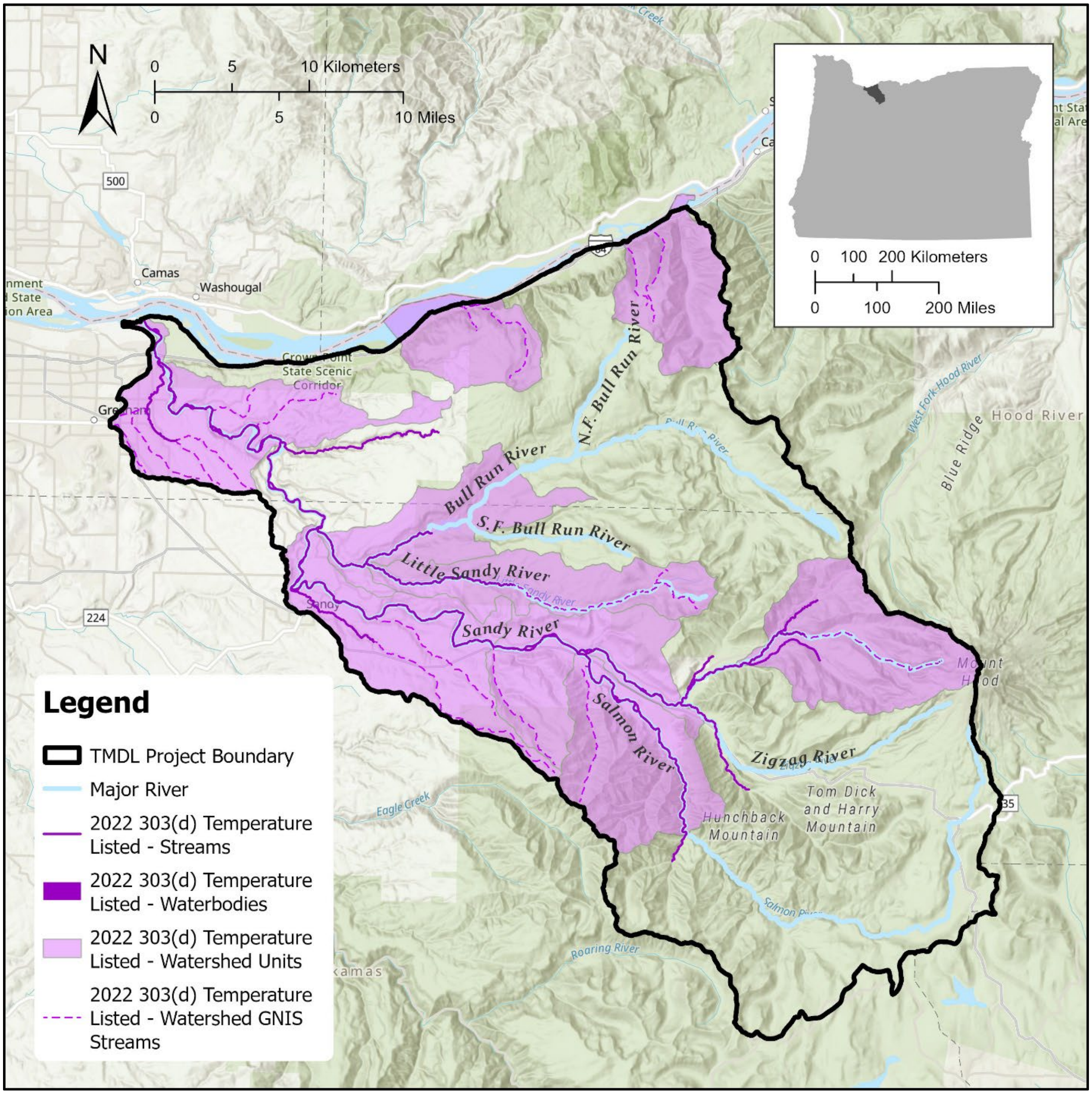

Figure 2-2: Lower Columbia-Sandy Subbasin Category 5 temperature impairments on the 2022 Integrated Report.

3 Pollutant identification

As stated in OAR 340-042-0040(4)(b), this element identifies the pollutants causing impairment of water quality that are addressed by these TMDLs. The associated water quality standards and beneficial uses are identified in Section 4.

Temperature is the water quality parameter of concern, but heat or thermal loading is the pollutant of concern causing impairment. Heat caused by human activities is of particular concern.

EPA regulations (40 CFR 130.2(i)) and OAR 340-042-0040(O)(5)(b) allow for TMDLs to utilize other appropriate measures (or surrogate measures). Surrogate measures are defined in OAR 340-042-0030(14) as “substitute methods or parameters used in a TMDL to represent pollutants.” In accordance with OAR 340-042-0040(5)(b), DEQ used effective shade and a percent consumptive use target as surrogate measures for thermal loading caused by solar radiation and other fluxes that introduce heat. Implementation of the surrogate measures ensures achievement of necessary pollutant reductions and the nonpoint load allocations (LAs) for these temperature TMDLs.

4 Water quality standards and beneficial uses

As stated in OAR 340-042-0040(4)(c), this element identifies the beneficial uses in the basin, specifying the most sensitive beneficial use, and the relevant water quality standards established in OAR 340-041-0202 through 340-041-0975.

Table 4-1 and **Table 4-2** specify the designated beneficial uses in the Lower Columbia-Sandy Subbasin surface waters, the applicable numeric and narrative water quality standards and antidegradation rule and policy addressed by these TMDLs, and the most sensitive beneficial uses pertinent to each standard. These TMDLs were designed with the understanding that meeting water quality standards for the most sensitive beneficial uses is protective of all other uses for that parameter. **Figure 4-1** shows various designated fish uses and applicable criteria, while **Figure 4-2** shows salmon and steelhead spawning use designations.

Table 4-1: Designated beneficial uses in the Lower Columbia-Sandy Subbasin as identified in OAR 340-041-0286 Table 286A.

Beneficial uses	Streams forming waterfalls near Columbia River highway	Sandy River	Bull Run River and all tributaries	All other tributaries to Sandy River
Public Domestic Water Supply		X	X	X
Private Domestic Water Supply		X		X
Industrial Water Supply		X		X
Irrigation		X		X
Livestock Watering		X		X
Fish and Aquatic Life	X	X	X	X
Wildlife and Hunting	X	X		X
Fishing	X	X		X
Boating		X		X
Water Contact Recreation	X	X		X
Aesthetic Quality	X	X	X	X
Hydro Power		X	X	X
Commercial Navigation & Transportation				

Table 4-2: Applicable water quality standards and most sensitive beneficial uses.

Parameter	Rule citation	Summary of applicable standards	Waters where standards apply	Most sensitive beneficial use
Statewide Narrative Criteria	OAR 340-041-0007(1)	The highest and best practicable treatment and/or control of wastes, activities, and flows must in every case be provided to maintain dissolved oxygen and overall water quality at the highest possible levels and water temperatures, coliform bacteria concentrations, dissolved chemical substances, toxic materials, radioactivity, turbidities, color, odor and other deleterious factors at the lowest possible levels.	All waters of the state	Fish and aquatic life
Temperature	OAR 340-041-0028(4) OAR 340-041-0286 Figures 286A and 286B	(a) The 7-day average maximum temperature may not exceed 13.0°C (55°F) at the times indicated on maps and tables (salmon and steelhead spawning) (b) The 7-day average maximum temperature may not exceed 16.0°C (60.8°F) (core cold water habitat) (c) The 7-day average maximum temperature may not exceed 18.0°C (64.4°F) (salmon and trout rearing and migration)	See OAR Figures 286A and 286B (**Figure 4-1** and **Figure 4-2** in this document)	Salmonid and steelhead spawning
	OAR 340-041-0028(6)	Natural lakes may not be warmed by more than 0.3°C (0.5°F) above the natural condition unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life.	Natural Lakes	Fish and aquatic life
	OAR 340-041-0028(11)	(a) Waters that have 7-day average maximum colder than the biologically based criteria may not be warmed by more than 0.3°C (0.5°F) above the colder water ambient temperature, by all sources taken together at the point of maximum impact. (b) A point source that discharges into or above salmon & steelhead spawning waters that are colder than the spawning criterion may not cause the water temperature in the spawning reach to (A) increase 0.5°C above the 60-day average when the 60-day average is 10-12.8°C; or (B) increase 1.0°C above the 60-day average when the 60-day average is less than 10°C.	Cold water	Salmon, steelhead or bull trout presence
	OAR 340-041-0028(12)(b)	(B) Human use allowance. Following a temperature TMDL or other cumulative effects analysis, wasteload and load allocations will restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.3°C (0.5°F) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact.	All waters of the state	Salmonid and steelhead spawning
	Antidegradation OAR 340-041-0004 and 40 CFR 131.12(a)(2)	(3)(c) Insignificant temperature increases authorized under OAR 340-041-0028(11) and (12) are not considered a reduction in water quality.		
		(5)(a) Riparian Restoration Activities Exemption: When DEQ determines that activities to restore geomorphology or riparian vegetation have a net ecological benefit, antidegradation review is not needed.		

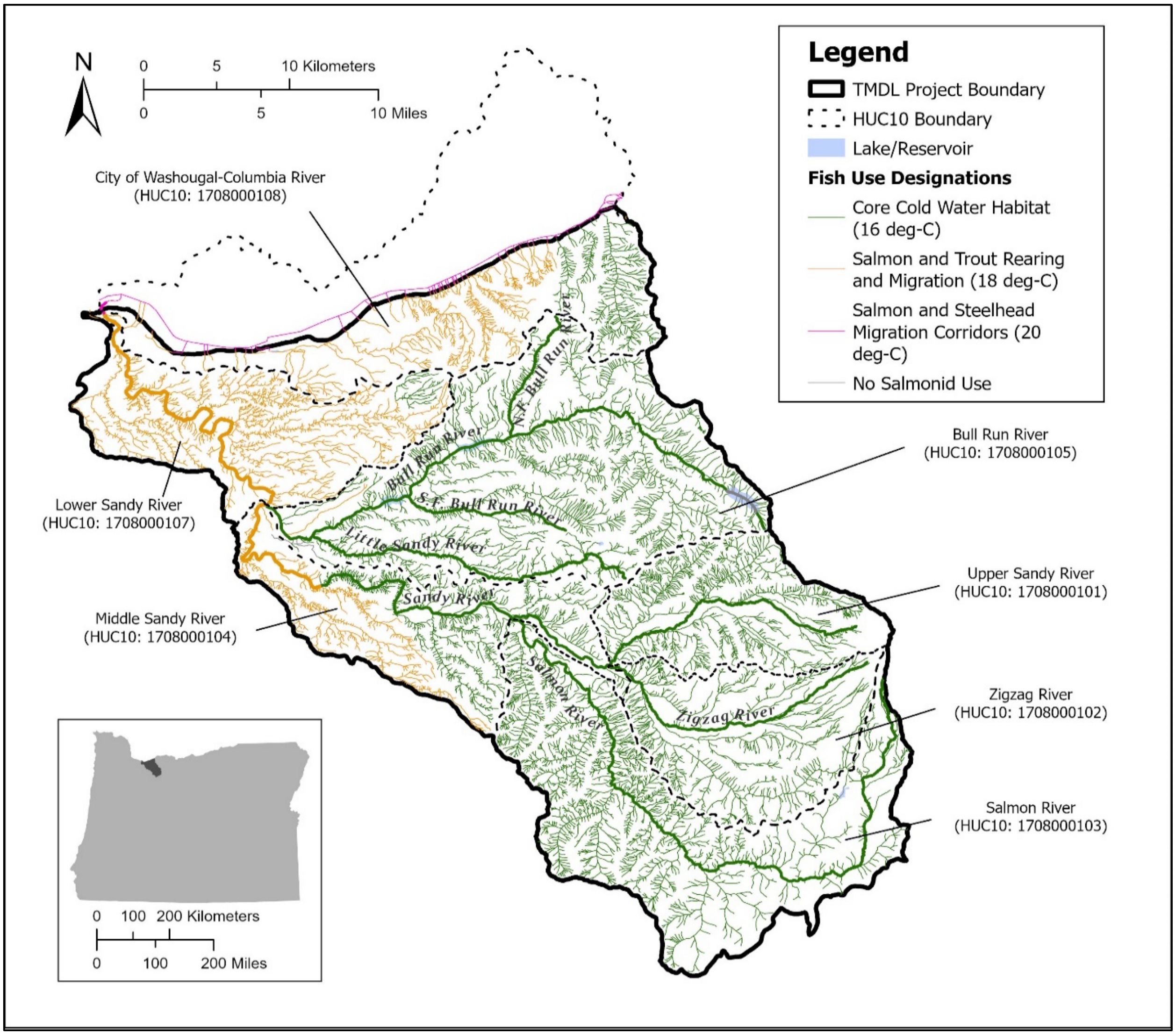

Figure 4-1: Fish use designations in the Lower Columbia-Sandy Subbasin temperature TMDL project area.

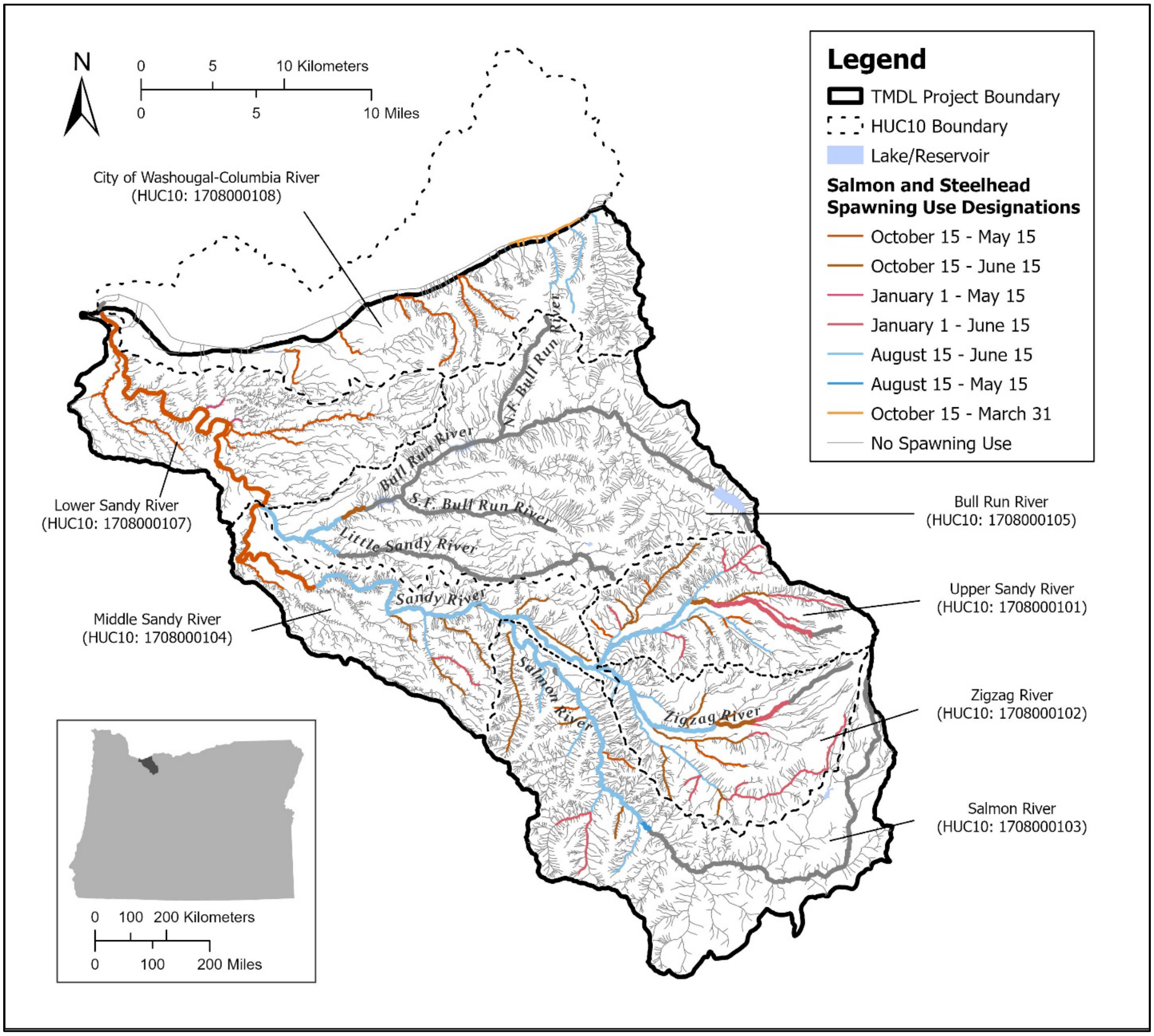

Figure 4-2: Salmon and steelhead spawning use designations in the Lower Columbia-Sandy Subbasin temperature TMDL project area.

5 Seasonal variation and critical period for temperature

Per OAR 340-042-0040(4)(j) and 40 Code of Federal Regulation130.7(c)(1), TMDLs must also identify any seasonal variation and the critical condition or period of each pollutant, if applicable.

Maximum stream temperatures typically occur in July or August when stream flows are low, solar radiation fluxes are high, and ambient air temperature conditions are warmest. This TMDL was designed to meet applicable criteria for river flows down to the “7Q10” flow, which is a summary statistic equal to the lowest seven-day average flow that occurs once every ten years (on average) (see Section 8).

The critical period was determined based on when seven-day average daily maximum stream temperatures (7DADM) exceeded the applicable temperature criteria. DEQ used the critical period to determine when allocations apply. In setting this period, DEQ relied upon monitoring sites with the longest period of exceedance. When downstream monitoring sites had longer exceedance periods relative to upstream waters, the longer period was used as the critical period for upstream waterbodies. This is a margin of safety to ensure warming of upstream waters does not contribute to downstream exceedances.

The critical periods for waterbodies in the Lower Columbia-Sandy Subbasin are presented in **Table 5-1**. Based on available temperature data, the critical period is May 1 through October 31 on all waterbodies in the Lower Columbia-Sandy Subbasin except those within the Bull Run River Watershed (HUC 1708000105) and Beaver Creek-Sandy Subwatershed (HUC 170800010703). For waterbodies in the Bull Run River Watershed, the critical period is May 1 through November 15. The critical period is March 15 through November 15 for waterbodies located in the Beaver Creek-Sandy Subwatershed.

Section 5 of the TSD summarizes the critical period approach and presents plots of 7DADM temperature data used to determine seasonal variation and the critical period.

Table 5-1: Designated critical periods for Lower Columbia-Sandy Subbasin waterbodies.

HUC	Watershed name	Critical period
17090001	Lower Columbia-Sandy Subbasin except Bull Run River Watershed and Beaver Creek-Sandy Subwatershed	May 1 – October 31
1708000105	Bull Run River Watershed	May 1 – November 15
170800010703	Beaver Creek-Sandy Subwatershed	March 15 – November 15

6 Temperature water quality data evaluation overview

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 LC, identify pollutant sources, and assess various management scenarios that 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 and CE-QUAL-W2 models were used in this effort and are described in TSD Appendices A through D.

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

1. Stream temperatures spanning months at ≤500 m longitudinal resolution.
2. Solar radiation fluxes and daily effective shade at ≤100 m 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, and
    d. Effluent temperature and flow discharge from NPDES-permitted facilities.

Figure 6-1 provides an overview of the types of data and analyses completed for this TMDL.

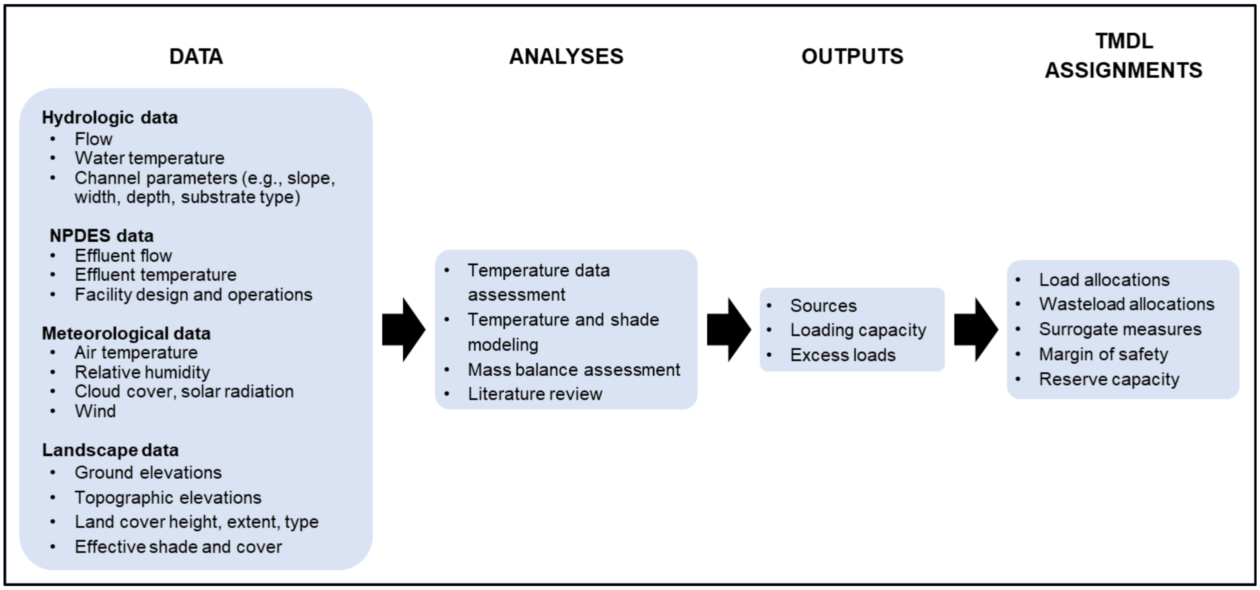

Figure 6-1: Lower Columbia-Sandy River Subbasin temperature analysis overview.

7 Pollutant sources or source categories

As noted in OAR 340-042-0040(4)(f) and OAR 340-042-030(12), a source is any process, practice, activity or resulting condition that causes or may cause pollution or the introduction of pollutants to a waterbody. This section identifies the various pollutant sources and estimates, to the extent existing data allow, the significance of pollutant loading from existing sources.

Both point and nonpoint sources contribute thermal pollution to surface waters in the Lower Columbia-Sandy Subbasin. Within the nonpoint source category, both background and anthropogenic nonpoint sources contribute thermal pollution. Each source's thermal loading varies in frequency and magnitude based on discharge rate and temperature, the prevalence of associated activities, the land area extent on which activities occur, the proximity of activities to surface water, and thermal transport mechanisms.

7.1 Point sources

OAR 340-045-001(17) defines a point source as “any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged.” Under the NPDES program, points sources are regulated under either “individual” or “general” permits.

Three individual NPDES permittees (**Table 7-1, Table 2-1**) and a 300-J general permit registrant (**Table 7-2**) were identified as sources of thermal loading to streams in the Lower Columbia-Sandy Subbasin. A fourth individual NPDES permittee, City of Sandy WWTP, was identified as a potential source.

The City of Sandy WWTP currently holds an individual NPDES permit for discharge to Tickle Creek in the Clackamas Subbasin but is under an EPA consent decree to upgrade and add treatment capacity. The city submitted an NPDES permit application to DEQ for the upgrade and construction of a new outfall to the Sandy River. If implemented, this discharge to the Sandy River is estimated to be a source of thermal loading.

Table 7-1: Individual NPDES permit registrants that contribute thermal loads or are proposed to contribute to thermal loads to Lower Columbia-Sandy Subbasin streams at a frequency and magnitude to cause temperature standard exceedances.

Permittee	Permit type	DEQ WQ file number	EPA number	Receiving water name	River mile	River km
Government Camp STP	NPDES-DOM-Da	34136	OR0027791	Camp Creek	6.5	10.2
WES Hoodland STP	NPDES-DOM-Da	39750	OR0031020	Sandy River	41	67.4
City of Troutdale Water Pollution Control Facility	NPDES-DOM-C2a	89941	OR0020524	Sandy River	2.3	3.70
City of Sandy WWTP	NPDES-DOM-Da	78615	OR0026573	Sandy River	24[1]	38.50[1]

[1] Potential future discharge location. Current location is outside of TMDL watershed boundary.

There are multiple types of general NPDES permits with registrants in the Lower Columbia-Sandy, including:

- 300-J Industrial Wastewater, NPDES fish hatcheries
- 1200-A Stormwater: NPDES sand & gravel mining
- 1200-C Stormwater: NPDES construction
- 1200-Z Stormwater: NPDES specific Standard Industrial Classification codes
- MS4 – Phase II: Stormwater, NPDES: Municipal Separate Storm Sewer System

There is one 300-J permit registrant (**Table 7-2)** found to be a thermal loading source, with a temperature impact on Cedar Creek as high as 0.38°C.

Table 7-2: General NPDES permit registrants that contribute thermal loads to Lower Columbia-Sandy Subbasin streams at a frequency and magnitude to cause temperature standard exceedances.

Permittee	Permit type	DEQ WQ file number	EPA number	Receiving water name	River mile	River km
ODFW Sandy River Hatchery	300-J	64550	ORG130009	Cedar Creek	0.7	1.1

Additionally, there is one registrant to the general MS4 Phase II permit (City of Troutdale), and approximately 26 total registrants to the 1200-A, 1200-C, and 1200-Z permits. DEQ completed a review of published literature and other studies related to stormwater runoff and stream temperature in Oregon and concluded that stormwater discharges authorized under the current municipal (MS4), construction (1200-C) and industrial (1200-A and 1200-Z) general stormwater permits are unlikely to contribute to exceedances of the temperature standard. Therefore, no additional TMDL requirements are needed for stormwater sources to control temperature, other than those included in the current permits.

7.2 Nonpoint sources

OAR 340-41-0002 (42) defines nonpoint sources as “diffuse or unconfined sources of pollution where wastes can either enter, or be conveyed by the movement of water, into waters of the state.” Generally, nonpoint thermal sources in the Lower Columbia-Sandy Subbasin include activities associated with agriculture, forestry, dam and reservoir management, and development. Sources and/or activities that contribute nonpoint thermal loads that increase stream temperature include:

- Human-caused increases in solar radiation loading to streams from stream-side vegetation disturbance or removal,
- Channel modification and widening,
- Dam and reservoir operation,
- Activities that modify flow rate or volume, and
- Background sources, including natural sources and anthropogenic sources of warming through climate change and other factors.

Anthropogenically influenced thermal loads are targeted for reduction to attain the applicable temperature water quality criteria. The following actions are needed to attain the TMDL allocations:

- Restoration of stream-side vegetation to reduce thermal loading from exposure to solar radiation,
- Management and operation of dams and reservoirs to minimize temperature warming, and
- Maintenance of minimum instream flows.

7.3 Background sources

By definition (OAR 340-042-0030(1)), background sources include all sources of pollution or pollutants not originating from human activities. Background sources may also include anthropogenic sources of a pollutant that DEQ or another Oregon state agency does not have authority to regulate, such as pollutants emanating from another state, tribal lands, or sources otherwise beyond the jurisdiction of the state.

The background thermal loading a stream receives is influenced by landscape and meteorological characteristics, such as: substrate and channel morphology conditions, streambank and channel elevations, near-stream vegetation, groundwater, hyporheic flow, tributary inflows, precipitation, cloudiness, air temperature, relative humidity, and others. Many of these factors, however, are influenced by anthropogenic factors. As such, it was not possible to develop a model in which all human influences were controlled or accounted for. As a best estimate, background thermal sources were quantified for the modeled rivers with delineable anthropogenic influences (i.e., dams and reservoirs, vegetation alterations, point source discharges) accounted for, thus isolating the remaining background sources. In each river modeled, thermal loading from background sources contributed to exceedances of the applicable temperature criteria and therefore was identified as a significant source of thermal loading. Reductions from background sources will be required to attain the applicable temperature criteria.

8 Loading capacity and excess loads

Summarizing OAR 340-042-0040(4)(d) and 40 CFR 130.2(f), loading capacity is the amount of a pollutant or pollutants that a waterbody can receive and still meet water quality standards.

For temperature, thermal loading capacity is calculated using **Equation 8-1**.

$$LC = (T_C + \mathrm{HUA}) \cdot Q_R \cdot C_F \qquad \textbf{Equation 8-1}$$

where,

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

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

$\mathrm{HUA} =$ The 0.30°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

$$\left(\frac{1\ \mathrm{m}}{3.2808\ \mathrm{ft}}\right)^3 \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1°\mathrm{C}} = 2{,}446{,}665$$

Equation 8-1 shall be used to calculate the thermal LC for any surface water location in the Lower Columbia-Sandy Subbasin. **Table 8-1** presents the LCs for select temperature-impaired Category 5 AUs that have a current NPDES discharge within the AU extent or that were modeled for the TMDL analysis. The LCs in **Table 8-1** were calculated based on the 7Q10 low-flow. **Equation 8-1** may be used to calculate LC when river flow is greater than 7Q10. **Equation 8-1** may also be used to calculate the LC if in the future the applicable temperature criteria are updated and approved by EPA.

Table 8-1: Thermal loading capacity (LC) for select assessment units by applicable fish use period at 7Q10 flow.

Assessment unit name, ID, and extent	Annual 7Q10 (cfs)	Year-round criterion + HUA (°C)	Spawning criterion + HUA (°C)	7Q10 LC, year-round[1] (kilocalories/day)	7Q10 LC, spawning[1] (kilocalories/day)
Bull Run River - Bull Run Reservoir Number Two to confluence with Sandy River OR_SR_1708000105_11_103611	20	16.3	13.3	797.61E+6	650.81E+6
Cedar Creek - Beaver Creek to confluence with Sandy River OR_SR_1708000104_02_103607	4.9	18.3	13.3	219.39E+6	159.45E+6

Assessment unit name, ID, and extent	Annual 7Q10 (cfs)	Year-round criterion + HUA (°C)	Spawning criterion + HUA (°C)	7Q10 LC, year-round[1] (kilocalories/day)	7Q10 LC, spawning[1] (kilocalories/day)
Little Sandy River - Bow Creek to confluence with Bull Run River OR_SR_1708000105_11_103609	11	16.3	13.3	438.69E+6	357.95E+6
Salmon River - South Fork Salmon River to confluence with Sandy River OR_SR_1708000103_02_103606	174	16.3	13.3	6,939.23E+6	5,662.07E+6
Sandy River - Bull Run River to confluence with Columbia River OR_SR_1708000107_02_103616	278	18.3	13.3	12,447.16E+6	9,046.30E+6
Sandy River - Clear Fork to Zigzag River OR_SR_1708000101_02_103599	50	18.3	13.3	2,238.70E+6	1,627.03E+6
Sandy River - Zigzag River to Bull Run River OR_SR_1708000104_02_103608	217	16.3	13.3	8,654.10E+6	7,061.32E+6
Zigzag River - Still Creek to confluence with Sandy River OR_SR_1708000102_02_103600	48	16.3	13.3	1,914.27E+6	1,561.95E+6
[1] Listed LCs were calculated based on the 7Q10 flow.					

In accordance with OAR 340-042-0040(4)(e), the excess load calculation evaluates, to the extent existing data allow, the difference between the actual pollutant load in a waterbody and the LC of that waterbody.

Because flow monitoring data were not available at most temperature monitoring locations, it was not possible to calculate the excess load. Instead, the excess temperature and percent load reduction were calculated for each AU where temperature data were available (**Table 8-2**). The excess temperature is the maximum positive difference between the monitored 7DADM river temperature and sum of the applicable numeric criterion plus the HUA. The percent load reduction represents the portion of the actual thermal loading that must be reduced to attain the TMDL loading capacity. The percent load reduction required to attain the TMDL loading capacity is calculated from the maximum observed excess temperature. If the maximum calculated observed excess temperature is negative, the excess temperature and required percent load reduction are zero.

Table 8-2: Excess temperature and percent load reduction for various assessment units in the Lower Columbia-Sandy Subbasin.

Assessment unit name	Assessment unit ID	Maximum 7DADM river temperature (°C)	Applicable criterion + HUA (°C)	Excess temperature (°C)	Percent load reduction
Clear Fork	OR_SR_1708000101_02_103596	14.7	13.3	1.4	9.2
Clear Fork	OR_SR_1708000101_02_103596	14.9	16.3	0.0	0.0
Clear Creek	OR_SR_1708000101_02_103597	17.4	13.3	4.1	23.5
Clear Creek	OR_SR_1708000101_02_103597	17.8	16.3	1.5	8.2
Lost Creek	OR_SR_1708000101_02_103598	13.6	13.3	0.3	2.1
Lost Creek	OR_SR_1708000101_02_103598	15.2	16.3	0.0	0.0
Sandy River	OR_SR_1708000101_02_103599	19.4	13.3	6.1	31.5
Sandy River	OR_SR_1708000101_02_103599	20.1	16.3	3.8	19.0
Zigzag River	OR_SR_1708000102_02_103600	13.9	13.3	0.6	4.3
Zigzag River	OR_SR_1708000102_02_103600	15.7	16.3	0.0	0.0
Still Creek	OR_SR_1708000102_02_103601	16.0	13.3	2.7	16.8

Assessment unit name	Assessment unit ID	Maximum 7DADM river temperature (°C)	Applicable criterion + HUA (°C)	Excess temperature (°C)	Percent load reduction
Still Creek	OR_SR_1708000102_02_103601	16.3	16.3	0.0	0.2
Zigzag River	OR_SR_1708000102_02_103602	12.1	13.3	0.0	0.0
Zigzag River	OR_SR_1708000102_02_103602	12.5	16.3	0.0	0.0
Salmon River	OR_SR_1708000103_02_103605	11.4	16.3	0.0	0.0
Salmon River	OR_SR_1708000103_02_103606	19.7	13.3	6.4	32.6
Salmon River	OR_SR_1708000103_02_103606	21.0	16.3	4.7	22.3
Cedar Creek	OR_SR_1708000104_02_103607	19.7	18.3	1.4	6.9
Sandy River	OR_SR_1708000104_02_103608	19.3	13.3	6.0	31.2
Sandy River	OR_SR_1708000104_02_103608	19.5	16.3	3.2	16.3
Little Sandy River	OR_SR_1708000105_11_103609	19.1	13.3	5.8	30.3
Little Sandy River	OR_SR_1708000105_11_103609	22.2	16.3	5.9	26.6
South Fork Bull Run River	OR_SR_1708000105_11_103610	18.3	16.3	2.0	10.9
Bull Run River	OR_SR_1708000105_11_103611	20.6	13.3	7.3	35.4
Bull Run River	OR_SR_1708000105_11_103611	21.1	16.3	4.8	22.6
Bull Run River	OR_SR_1708000105_11_103688	17.8	16.3	1.5	8.4
Beaver Creek	OR_SR_1708000107_02_103612	20.1	13.3	6.8	33.8
Beaver Creek	OR_SR_1708000107_02_103612	27.8	18.3	9.5	34.2
Gordon Creek	OR_SR_1708000107_02_103615	13.3	13.3	0.0	0.0
Gordon Creek	OR_SR_1708000107_02_103615	19.2	18.3	0.9	4.5
Sandy River	OR_SR_1708000107_02_103616	14.5	13.3	1.2	8.2
Sandy River	OR_SR_1708000107_02_103616	23.2	18.3	4.9	21.2
HUC12 Name: Upper Salmon River	OR_WS_170800010302_02_103640	15.7	16.3	0.0	0.0
HUC12 Name: Wildcat Creek-Sandy River	OR_WS_170800010401_02_103643	16.5	13.3	3.2	19.3
HUC12 Name: Wildcat Creek-Sandy River	OR_WS_170800010401_02_103643	15.5	16.3	0.0	0.0
HUC12 Name: Upper Bull Run River	OR_WS_170800010502_11_103647	7.0	16.3	0.0	0.0
HUC12 Name: Middle Bull Run River	OR_WS_170800010503_11_103648	16.9	16.3	0.6	3.6
HUC12 Name: Little Sandy River	OR_WS_170800010505_11_103669	24.2	16.3	7.9	32.5
HUC12 Name: Lower Bull Run River	OR_WS_170800010506_11_103650	17.6	16.3	1.3	7.5
HUC12 Name: Gordon Creek	OR_WS_170800010701_02_103651	13.0	16.3	0.0	0.0
HUC12 Name: Beaver Creek-Sandy River	OR_WS_170800010703_02_103703	21.4	13.3	8.1	37.8
HUC12 Name: Beaver Creek-Sandy River	OR_WS_170800010703_02_103703	26.2	18.3	7.9	30.0
HUC12 Name: Tanner Creek-Columbia River	OR_WS_170800010801_15_103707	18.1	13.3	4.8	26.3
HUC12 Name: Tanner Creek-Columbia River	OR_WS_170800010801_15_103707	18.9	16.3	2.6	13.9
HUC12 Name: Woodard Creek-Columbia River	OR_WS_170800010802_15_103653	17.5	18.3	0.0	0.0
HUC12 Name: Bridal Veil Creek-Columbia River	OR_WS_170800010803_15_103654	19.9	18.3	1.6	8.1

9 Allocations, reserve capacity, and margin of safety

OAR 340-042-0040(4)(g),(h),(i) and (k) [and 40 CFR 130.2(h) and (g) and 130.7(c) (1) and (2)] respectively define the required TMDL elements of apportionment of the allowable pollutant load: point source wasteload allocations; nonpoint source load allocations (including background); margin of safety; and reserve capacity. Collectively, these elements add up to the maximum pollutant load that still allows a waterbody to meet water quality standards. OAR 304-042-0040(5) and (6) describe potential factors to consider when determining and distributing these allocations of the pollutant loading capacities. Water quality data analysis must be conducted to determine allocations, potentially including statistical analysis and mathematical modeling. Factors to consider in allocation distribution may include: source contributions, costs to implement management measures, ease of implementation, timelines to attain water quality standards, environmental impacts of allocations, unintended consequences, reasonable assurance of implementation, and any other relevant factor.

TMDL allocations have been determined in conjunction with requirements established in this TMDL to demonstrate achievement of all Oregon temperature criteria.

9.1 Thermal allocations

9.1.1 Human use allowance assignments

The HUA at OAR 340-041-0028(12)(b)(B) identifies the allowed temperature increase reserved for human uses. The rule requires that wasteload and load allocations restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.30°C (0.5°F) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact (POMI). **Table 9-1** through **Table 9-7** present the portions of the HUA assigned to anthropogenic source categories across different AUs in the Lower Columbia-Sandy Subbasin.

The dam and reservoir operations source category accounts for nonpoint source temperature impacts associated with the dam impoundment and release of the impounded water back into the natural channel.

The water management activities and water withdrawals source category accounts for nonpoint source temperature impacts associated with the withdrawal of water that is intended for consumptive uses (e.g., irrigation) and the warming that may occur as withdrawn water moves through a canal or ditch before being returned to the source river (i.e., non-consumptive uses).

The assigned HUA for NPDES point sources is the maximum cumulative warming anywhere in the AU and at the POMI from all NPDES individual permittees and registrants to general NPDES permits.

The assigned portion of the HUA for nonpoint source categories represents the maximum cumulative warming anywhere in the AU and at the POMI from all nonpoint source activities within each source category. Therefore, DEQ expects the amount of warming for each unique nonpoint source activity to be less than the values shown in **Table 9-1** through **Table 9-7**. DEQ will implement the TMDL in a manner consistent with the HUA rule by requiring all nonpoint sources to implement management strategies and reduce their warming impact such that the assigned HUA is attained.

Table 9-1: HUA assignments on the Sandy River, model km 69.90-29.55 (Assessment Unit OR_SR_1708000104_02_103608) and on the Zigzag River (Assessment Units OR_SR_1708000102_02_103600 and OR_SR_1708000102_02_103602).

Portion of human use allowance (°C)	Source or source category
0.09	NPDES point sources
0.00	Dam and reservoir operations
0.05	Water management activities and water withdrawals
0.03	Solar loading from existing transportation, buildings, and utility easements and infrastructure
0.00	Solar loading from other NPS sectors
0.13	Reserve capacity
0.30	**Total**

Table 9-2: HUA assignments on the Sandy River, model km 29.50-0.00 (Assessment Unit OR_SR_1708000107_02_103616).

Portion of human use allowance (°C)	Source or source category
0.12*	NPDES point sources
0.02	City of Portland Bull Run dam and reservoir operations
0.05	Water management activities and water withdrawals
0.05	Solar loading from existing transportation, buildings, and utility easements and infrastructure
0.00	Solar loading from other NPS sectors
0.06	Reserve capacity
0.30	**Total**
Note: * NPDES permitted point sources are allowed up to 0.12°C cumulatively at the POMI on the Sandy River. The portion of the HUA allocated to each point source at the point of discharge is identified in **Table 9-8**.	

Table 9-3: HUA assignments on the Bull Run River (Assessment Unit OR_SR_1708000105_11_103611).

Portion of human use allowance (°C)	Source or source category
0.00	NPDES point sources
0.30	City of Portland Bull Run dam and reservoir operations*
0.00	Solar loading from other NPS sectors
0.00	Reserve capacity
0.30	**Total**
Note: * The HUA assigned to City of Portland includes discharges of any cooling water or sump pump wastewater associated with the dam or powerhouses.	

Table 9-4: HUA assignments on the Salmon River (Assessment Unit OR_SR_1708000103_02_103606).

Portion of human use allowance (°C)	Source or source category
0.00	NPDES point sources
0.05	Water management activities and water withdrawals
0.06	Solar loading from existing transportation, buildings, and utility easements and infrastructure
0.00	Solar loading from other NPS sectors
0.19	Reserve capacity
0.30	**Total**

Table 9-5: HUA assignments on Cedar Creek (Assessment Unit OR_SR_1708000104_02_103607).

Portion of human use allowance (°C)	Source or source category
0.30	NPDES point sources: ODFW Sandy River Fish Hatchery
0.00	Solar loading from other NPS sectors
0.00	Reserve capacity
0.30	**Total**
Note: If DEQ approves ODFW's Sandy River Fish Hatchery discharge to the Sandy River (WLA option B), the distribution of the HUA on Cedar Creek will be identical to those in **Table 9-7**.	

Table 9-6: HUA assignments on Camp Creek (Assessment Unit OR_WS_170800010202_02_103638).

Portion of human use allowance (°C)	Source or source category
0.20	NPDES point sources: Government Camp STP
0.05	Water management activities and water withdrawals
0.02	Solar loading from existing transportation, buildings, and utility easements and infrastructure
0.00	Solar loading from other NPS sectors
0.03	Reserve capacity
0.30	**Total**

Table 9-7: HUA assignments for all other waters in the Lower Columbia-Sandy Subbasin.

Portion of human use allowance (°C)	Source or source category
0.00	NPDES point sources
0.05	Water management activities and water withdrawals
0.02	Solar loading from existing transportation, buildings, and utility easements and infrastructure
0.00	Solar loading from other NPS sectors
0.23	Reserve capacity
0.30	**Total**

9.1.2 Thermal wasteload allocations for point sources

Equation 9-1 was used to calculate 7Q10-based WLAs for NPDES-permitted point sources (**Table 9-8**). The effluent flows for all permitted point sources (**Table 9-8**) were based on average (mean) dry-weather facility design flow, except for the ODFW Sandy River Fish Hatchery, where the effluent flow value was the maximum effluent discharge characterized from discharge data provided by ODFW. The WLA for registrants under the general stormwater permits (MS4 phase II, 1200-A, 1200-C, and 1200-Z) and general permit registrants not identified in **Table 9-8** is equal to any existing thermal load authorized under the current permit. This means that registrants must follow their permit conditions to meet the narrative WLA. Beyond current permit limits, no additional TMDL requirements are needed for stormwater sources to control temperature. For all general wastewater and stormwater NPDES permits, more precise WLAs may be considered if subsequent data analysis indicates a need and capacity is available.

WLAs may be implemented in NPDES permits in any of the following ways:

(1) Incorporate the 7Q10-based WLA in **Table 9-8** as a static numeric limit. Permit writers may recalculate the static limit using different values for 7Q10 (Q_R) and effluent discharge (Q_E), if better estimates are available (including the use of seasonal values, as appropriate).
(2) Incorporate **Equation 9-1** directly into the permit with effluent flow (Q_E), river flow (Q_R), and the wasteload allocation (WLA) being dynamic and calculated on a daily basis. The

assigned portion of the HUA (ΔT) is static and based on the value in **Table 9-8**. Permit writers may recalculate the 7Q10 using seasonal or annual values, as appropriate, if better estimates are available.

$$WLA = (\Delta T) \cdot (Q_E + Q_R) \cdot C_F \qquad \textbf{Equation 9-1}$$

where,

$WLA =$ Wasteload allocation (kilocalories/day), expressed as a rolling seven-day average.

$\Delta T =$ The assigned portion of the human use allowance from **Table 9-8**. It is the maximum temperature increase (°C) 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. See **Table 9-9** for list of NPDES permittees where minimum duties provision may apply.

$Q_E =$ The daily mean effluent flow rate (cfs).
When effluent flow is in million gallons per day (MGD) convert to cfs: 1.5472

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

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

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

$$\left(\frac{1\ \text{m}}{3.2808\ \text{ft}}\right)^3 \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1℃} = 2{,}446{,}665$$

NPDES-permitted point sources discharging to the Sandy River are allowed up to 0.12°C cumulatively at the POMI. Based on DEQ modeling, the POMI is located at the City of Troutdale WPCF’s outfall (river km 3.70). Modeling described in the TSD Appendix C, Section 5 shows that these allocations attain the cumulative allocation. Note that the maximum cumulative impact of all point sources at the POMI is less than the sum of individual point source impacts at their respective points of discharge due to heat dissipation between point source discharges.

The City of Sandy WWTP currently holds an NPDES permit for discharge to Tickle Creek (Clackamas Subbasin) but is under an EPA consent decree to upgrade and add treatment capacity. At the time of writing, the city has provided DEQ with an NPDES permit application to upgrade and construct a new outfall to the Sandy River. DEQ evaluated this potential discharge and provided a WLA based on the discharge location proposed in the NPDES application. The proposed outfall (outfall 004) is in the Sandy River reach between Cedar Creek and Badger Creek just downstream of Revenue Bridge (Ten Eyck Road). If the outfall is constructed in another Sandy River reach, modeling will be required to ensure the WLA in **Table 9-8** attains the 0.12°C point source cumulative HUA at the POMI, as presented in **Table 9-2**.

Table 9-8 provides two WLA options to ODFW’s Sandy River Fish Hatchery (option A and option B). Option A is for discharge to Cedar Creek, i.e., the current discharge location. Option B is for the potential Sandy River discharge location described in the previous paragraph. Option B was developed in case ODFW relocates the discharge point from Cedar Creek to the Sandy River. ODFW may only select one WLA option.

Table 9-8: Thermal wasteload allocations for point sources.

NPDES permittee WQ file number : EPA number	Assigned human use allowance ΔT (°C)	WLA period start	WLA period end	Annual 7Q10 river flow (cfs)	Effluent discharge (cfs)	7Q10 WLA[1] (kcals/day)
Government Camp STP 34136 : OR0027791	0.20	5/1	10/31	5.7	0.4	2.98E+6
Hoodland STP (WES) 39750 : OR0031020	0.06	5/1	10/31	158	1.4	23.40E+6
City of Troutdale WPCF 89941 : OR0020524	0.09	5/1	10/31	278	4.6	62.23E+6
City of Sandy WWTP 78615 : OR0026573	0.05	5/1	10/31	217	1.9	26.78E+6
ODFW Sandy River Fish Hatchery 64550 : ORG130009 Option A – Discharge to Cedar Creek	0.30*	5/1	10/31	4.9	3.2	5.95E+6*
ODFW Sandy River Fish Hatchery 64550 : ORG130009 Option B – Discharge to Sandy River	0.08	5/1	10/31	217	3.2	43.10E+6

[1] Listed WLAs were calculated based on the 7Q10 flow.
Notes:
WLA = wasteload allocation; kcals/day = kilocalories/day
* When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ODFW Sandy River Fish Hatchery ∆T = 0.0 and the WLA = 0 kilocalories/day. Minimum duties provision does not apply under WLA Option B.

The minimum duties provision at OAR 340-041-0028(12)(a) states that anthropogenic sources are only responsible for controlling the thermal effects of their own discharge or activity in accordance with its overall heat contribution.

For point sources, DEQ is implementing the minimum duties provision if a facility operation meets acceptable operation and design requirements. The facility must be operated as a “flow through” facility where intake water moves through the facility and is not processed as part of an industrial or wastewater treatment operation. If a facility mixes the intake water with other wastewater or as a method to cool equipment DEQ considers the thermal effects of this operation to be part of the facility’s own activity and the minimum duties provision does not apply. The intake water must also be returned to the same stream where the intake is located. If the water is not returned to the same stream the thermal effects do not originate from the receiving stream and therefore are considered as part of the facilities own discharge.

When the minimum duties provision applies, the facility cannot add any additional thermal loading to the intake temperatures when the intake temperatures are warmer than the maximum effluent discharge temperatures allowed by the WLA. The purpose is to ensure the facility controls for thermal effects resulting from passing the water through and not from upstream sources. The specific equations to implement this approach in NPDES permits are included in the TSD Section 9.1. DEQ determined the minimum duties provision is applicable to the facilities listed in **Table 9-9**.

Table 9-9: NPDES permittees where the minimum duties provision may be implemented as part of the TMDL wasteload allocation.

NPDES permittee	WQ file number : EPA number	Intake and receiving stream	Assessment unit
ODFW Sandy River Fish Hatchery	64550 : ORG130009	Cedar Creek	OR_SR_1708000104_02_103607

9.1.3 Thermal load allocations for nonpoint sources

Load allocations are assigned to background sources and anthropogenic nonpoint sources on all waters in the Lower Columbia-Sandy Subbasin. LAs apply during the critical periods identified in **Table 4-1**. LAs for background sources are calculated using **Equation 9-2**.

$$LA_{BG} = (T_C) \cdot (Q_R) \cdot C_F \qquad \textbf{Equation 9-2}$$

where,

$LA_{BG} =$ Load allocation to background sources (kilocalories/day), expressed as a rolling seven-day average.

$T_C =$ The minimum applicable temperature criteria, not including the human use allowance. When there are two year-round applicable temperature criteria that apply to the same assessment unit, the more stringent criterion shall be used.

$Q_R =$ The daily average river flow rate (cfs).

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

$$\left(\frac{1\ \mathrm{m}}{3.2808\ \mathrm{ft}}\right)^3 \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1°\mathrm{C}} = 2{,}446{,}665$$

Table 9-10 presents the 7Q10-based LAs for background sources on temperature-impaired Category 5 AUs that (a) have current NPDES discharge(s) within the AU extent, and/or (b) were modeled for the TMDL analysis. The LAs were calculated with **Equation 9-2** based on the applicable year-round criterion and the spawning criterion in the respective AU, along with the 7Q10 low river flows. In cases when more than one year-round criterion applied in the AU, the minimum criterion was used. **Equation 9-2** shall be used to calculate the LAs assigned to background sources on all other AUs or stream locations in the Lower Columbia-Sandy Subbasin not identified in **Table 9-10**, or for AUs identified in **Table 9-10** when river flows are greater than 7Q10.

If the applicable temperature criteria are updated and approved by EPA, the background LAs assigned to any AU or stream location where the temperature criterion changed shall be recalculated using the updated criteria and **Equation 9-2**.

Table 9-10: Thermal load allocations for background sources.

Assessment unit	Annual 7Q10 flow (cfs)	Year-round criterion (°C)	Spawning criterion (°C)	LA period start	LA period end	7Q10 LA[1] – year-round (kcal/day)	7Q10 LA[1] – spawning (kcal/day)
Bull Run River - Bull Run Reservoir Number Two to confluence with Sandy River ; OR_SR_1708000105_11_103611	20	16.0	13.0	5/1	11/15	782.93E+6	636.13E+6
Cedar Creek - Beaver Creek to confluence with Sandy River ; OR_SR_1708000104_02_103607	4.9	18.0	13.0	5/1	10/31	215.80E+6	155.85E+6
Little Sandy River - Bow Creek to confluence with Bull Run River ; OR_SR_1708000105_11_103609	11	16.0	13.0	5/1	10/31	430.61E+6	349.87E+6

Assessment unit	Annual 7Q10 flow (cfs)	Year-round criterion (°C)	Spawning criterion (°C)	LA period start	LA period end	7Q10 LA[1] – year-round (kcal/day)	7Q10 LA[1] – spawning (kcal/day)
Salmon River - South Fork Salmon River to confluence with Sandy River ; OR_SR_1708000103_02_103606	174	16.0	13.0	5/1	10/31	6,811.52E+6	5,534.36E+6
Sandy River - Bull Run River to confluence with Columbia River ; OR_SR_1708000107_02_103616	278	18.0	13.0	5/1	10/31	12,243.11E+6	8,842.25E+6
Sandy River - Clear Fork to Zigzag River ; OR_SR_1708000101_02_103599	50	18.0	13.0	5/1	10/31	2,202.00E+6	1,590.33E+6
Sandy River - Zigzag River to Bull Run River ; OR_SR_1708000104_02_103608	217	16.0	13.0	5/1	10/31	8,494.82E+6	6,902.04E+6
Zigzag River - Bow Creek to confluence with Bull Run River ; OR_SR_1708000102_02_103600	48	16.0	13.0	5/1	10/31	1,879.04E+6	1,526.72E+6

[1] Listed LAs were calculated based on the 7Q10 river flow.
Notes: Applicable criterion = Biologically-based numeric criteria (to protect cold water fish); LA = load allocation; kcals/day = kilocalories/day.

LAs assigned to anthropogenic nonpoint sources on any AU or stream location in the Lower Columbia-Sandy Subbasin are calculated using **Equation 9-3**. The portions of the HUA (ΔT) assigned to nonpoint source categories are presented in **Table 9-1** through **Table 9-7**.

$$LA_{NPS} = (\Delta T) \cdot (Q_R) \cdot C_F \qquad \textbf{Equation 9-3}$$

where,

$LA_{NPS} =$ Load allocation to anthropogenic nonpoint sources (kilocalories/day), expressed as a rolling seven-day average.

$\Delta T =$ The portion of the human use allowance assigned to each nonpoint source category representing the maximum cumulative temperature increase (°C) from all source activity in the nonpoint source category. When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ΔT = 0.0.

$Q_R =$ The daily average river flow rate (cfs).

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

$$\left(\frac{1\text{ m}}{3.2808\text{ ft}}\right)^3 \cdot \frac{1\ m^3}{35.31\ ft^3} \cdot \frac{1000\ kg}{1\ m^3} \cdot \frac{86400\ sec}{1\ day} \cdot \frac{1\ kcal}{1\ kg\ \cdot 1°\text{C}} = 2{,}446{,}665$$

9.1.4 Surrogate measures

EPA regulations (40 CFR 130.2(i)) and OAR 340-042-0040(O)(5)(b) allow for TMDLs to utilize other appropriate measures (or surrogate measures). This section presents surrogate measures that implement the LAs.

9.1.4.1 Dam and reservoir operations

Dam and reservoir operations in the Lower Columbia-Sandy have been allocated a portion of the HUA as presented in **Table 9-1** through **Table 9-7** and the equivalent LA as calculated using **Equation 9-2**. Monitoring stream temperatures, rather than thermal loads, is an easier and more meaningful approach to reservoir management. Temperature is mathematically related to excess thermal loading and directly linked to the temperature water quality standard. For these reasons, DEQ is using a surrogate measure to implement the LA for dam and reservoir operations.

DEQ has developed the following surrogate measure temperature approach to implement the LA. The surrogate measure compliance point is located just downstream of the dam or just downstream of where impounded water is returned to the free-flowing stream. The surrogate measure is:

a) The 7DADM temperatures immediately upstream of the reservoirs. If multiple streams flow into the reservoir, 7DADM temperatures upstream of the reservoirs may be calculated as a flow-weighted mean of temperatures from each inflowing tributary. The estimated free-flowing (no dam) temperatures may be calculated using a mechanistic or empirical model to account for any warming or cooling that would occur through the reservoir reaches absent the dam and reservoir operations. The results may be applied as the temperature surrogate measure or to adjust the 7DADM temperatures monitored immediately upstream of the reservoirs. Use of the model approach for the surrogate measure must be approved by DEQ.

b) Additional adjustments to the surrogate temperature target calculated or measured under item a) may be allowed when all the following are true:

    I. Monitoring data show 7DADM temperatures do not exceed the applicable temperature criteria in the AU downstream of the dam;
    II. The PCW criterion at OAR 340-041-0028(11) does not apply. DEQ completed an initial screen (summarized in TSD Section 9.3.1.1) and determined the PCW criterion likely does not apply to dams in the Lower Columbia-Sandy;
    III. A cumulative effects analysis, approved by DEQ, demonstrates that dam release water temperatures warmer than the surrogate measure calculated or measured under item a) will result in attainment of the dam and reservoir assigned HUA above the applicable criteria in downstream waters.

For implementation of the low-flow conditions provision at OAR 340-041-0028(12)(d), the 7Q10 shall be calculated at a gage upstream of the reservoir or at nearby monitoring gage that is not influenced by the dam’s operations.

9.1.4.2 City of Portland Bull Run drinking water and hydroelectric project

The City of Portland Bull Run drinking water and hydroelectric project has been assigned 0.30°C of the HUA (**Table 9-3**) and the equivalent LA on the Bull Run River as calculated using **Equation 9-2**. In the Sandy River below the Bull Run River confluence, warming from the dam and reservoirs has been assigned 0.02**°**C of the HUA (**Table 9-2**).

For the TMDL analysis, a temperature data analysis and model-based cumulative effects analysis were completed to estimate the free-flow dam temperatures and evaluate the sufficiency of the surrogate measure temperature target to attain the assigned HUA on the Bull Run River. Based on these analyses, DEQ determined that dam release temperatures that are below the most restrictive applicable criteria but above ambient temperatures will not increase downstream 7DADM temperatures above the 0.30°C HUA assigned to the Bull Run project. The model assumed free-flowing conditions and surrogate measure temperature target attainment.

The transition to the 13.0°C spawning use varies spatially and temporally in the Bull Run River. To be protective of these downstream spawning uses, DEQ used the most restrictive temporal period to determine when to apply the spawning criterion for the surrogate measure target.

Based on these results, the surrogate measure temperature target at the lamprey barrier just downstream of Reservoir #2 is:

a) The estimated free-flowing (no dam) 7DADM temperatures at the lamprey barrier as calculated using **Equation 9-4**; or

b) On days the surrogate measure calculated under item a) is cooler than the values in I and II, the surrogate 7DADM temperature may be no warmer than values in I and II.

   I. 16.3°C from June 16 to August 14
   II. 13.3°C from May 1 to June 15 and August 15 to November 15.

If the most restrictive applicable temperature criteria on the Bull Run River between Reservoir #2 and the confluence of the Bull Run River and Sandy River are updated and approved by EPA, the updated criteria and period when they apply shall be used instead.

The low-flow conditions provision at OAR 340-041-0028(12)(d) may apply when the daily mean flow at USGS gage 14138850 is less than the 7Q10 of 33 cfs.

DEQ developed a regression equation (**Equation 9-4**) to predict the free-flowing (no dam) daily maximum temperatures at the lamprey barrier. The methodology and data for development of the regression is documented in the Lower Columbia-Sandy TSD. With DEQ approval, an alternative approach may be used to calculate the free-flowing no dam temperatures.

$$T_{Max} = 0.1405173 + 1.1572642\overline{T_{LS}} + -0.3588068\log\overline{Q_{LS}} + \left(\frac{3.7557135 + 1.1668769T_{dLS} + -0.5969993\log\overline{Q_{LS}}}{2}\right)$$ **Equation 9-4**

Where,

$T_{Max} =$	The no dam daily maximum stream temperature at the lamprey barrier downstream of Reservoir #2.
$\overline{T_{LS}} =$	The daily mean temperature (°C) at USGS Gage 14141500 Little Sandy River Near Bull Run.
$\overline{Q_{LS}} =$	The mean daily discharge (cfs) at USGS Gage 14141500 Little Sandy River Near Bull Run.
$T_{dLS} =$	The daily temperature range (°C) calculated as the daily maximum minus the daily minimum at USGS Gage 14141500 Little Sandy River Near Bull Run.

9.1.4.3 Site-specific effective shade surrogate measure

For each Designated Management Agency (DMA) listed in **Table 9-11**, the effective shade surrogate measure values (current and target) are the means across all model nodes assigned to that DMA (**Equation 9-5**). **Equation 9-5** may be used to recalculate the mean effective shade values if DMA boundaries change or need correction. **Equation 9-5** may also be used to recalculate the mean effective shade targets based on an updated shade gap assessment following the process and methods outlined in the WQMP Section 5.3.1.

Changes in the target effective shade may result in redistribution of the sector or source responsible for excess load reduction. If the shade target increases, the equivalent portion of the excess load is reassigned from background sources to nonpoint sources. If the shade target decreases, the portion of the excess load is reassigned from nonpoint sources to background sources. The exact portion reassigned can only be determined in locations where temperature models have been developed. In locations without temperature models, the reassignment remains unquantified. Changes to the target effective shade do not impact the loading capacity, HUA, or the load allocations. They remain the same as presented in this TMDL.

$$\overline{ES} = \frac{\sum ES_{n_i}}{n_i}$$ **Equation 9-5**

Where,

$\overline{ES} =$	The mean effective shade for designated management agency *i.*
$\sum ES_{n_i} =$	The sum of effective shade from all model nodes or measurement points assigned to designated management agency *i.*
$n_i =$	Total number of model nodes or measurement points assigned to designated management agency *i.*

Table 9-11: Shade surrogate measure targets to meet nonpoint source load allocations for DMAs on modeled stream extents in the TMDL.

Designated management agency	Stream name	Current shade (%)	TMDL target[1] (%)	Shade gap
Oregon Department of Forestry - Private	Little Sandy River	74	74	0
U.S. Bureau of Land Management	Little Sandy River	54	66	12
U.S. Forest Service	Little Sandy River	69	71	2
Clackamas County	Zigzag River	32	52	20
Oregon Department of Forestry - Private	Zigzag River	22	37	15
U.S. Forest Service	Zigzag River	50	62	12
Clackamas County	Salmon River	25	37	12
Oregon Department of Forestry - Private	Salmon River	27	43	16
U.S. Bureau of Land Management	Salmon River	27	36	9
U.S. Forest Service	Salmon River	41	56	15
City of Portland	Sandy River	9	13	4
City of Sandy	Sandy River	21	23	2
City of Troutdale	Sandy River	15	19	4
Clackamas County	Sandy River	17	26	9
Multnomah County	Sandy River	16	18	2
Oregon Department of Agriculture	Sandy River	23	28	5
Oregon Department of Fish and Wildlife	Sandy River	22	26	4
Oregon Department of Forestry - Private	Sandy River	19	23	4
Oregon Parks and Recreation Department	Sandy River	6	7	1
Port of Portland	Sandy River	3	9	6
State of Oregon	Sandy River	13	17	4
U.S. Bureau of Land Management	Sandy River	24	27	3
U.S. Forest Service	Sandy River	3	6	3

[1] TMDL shade targets for the Sandy River and Salmon River are based on Restored Vegetation “B” shade values.

9.1.4.4 General effective shade curve surrogate measure

Effective shade curves are applicable to any stream that does not have site-specific shade targets (Section 9.1.4.3). Effective shade curves represent the maximum possible effective shade for a given vegetation type. The values presented in **Figure 9-1** to **Figure 9-10** and **Table 14-1** to **Table 14-10** represent the mean effective shade target for different composite vegetation types, stream aspects, and active channel widths. The vegetation height, density, overhang, and buffer width used for each vegetation type are summarized in **Table 9-12**. See the TSD Appendix A for the shade curve calculation methodology. Note that the vegetation type “555 - Mixed Conifer/Hardwood - Low Density” and “650 - Hardwood - Low Density” shade curves are associated with the vegetation assumptions applicable to infrastructure land uses (e.g., existing buildings, transportation, and utility corridors), and are intended for use only in such areas. Likewise, the “975 - Grasses or wetlands” shade curve is intended for use only in naturally open meadows and wetlands.

Effective shade may be prevented from reaching effective shade targets by natural factors including local geology, geography, soils, climate, natural disturbance rates, and other natural phenomena. DEQ will not take enforcement actions for effective shade reductions caused by such natural factors.

Table 9-12: Vegetation height, density, overhang, and horizontal distance buffer widths used to derive generalized effective shade curve targets.

Landcover code	Vegetation type	Height (m)	Height (feet)	Density (%)	Overhang (m)	Buffer width (m)
500	Mixed Conifer/Hardwood - High Density	26.7	87.6	60	3.3	36.8
550	Mixed Conifer/Hardwood - Medium Density	26.7	87.6	30	3.3	36.8
555	Mixed Conifer/Hardwood - Low Density	26.7	87.6	10	3.3	36.8
600	Hardwood - High Density	20.1	65.9	75	3.0	36.8
650	Hardwood - Low Density	20.1	65.9	30	3.0	36.8
700	Conifer - High Density	35.1	115.2	60	3.5	36.8
750	Conifer - Low Density	35.1	115.2	30	3.5	36.8
800	Shrub – High Density	1.8	5.9	75	0.0	36.8
850	Shrub – Low Density	1.8	5.9	25	0.0	36.8
975	Grasses or Wetlands	0.9	2.0	90	0.0	36.8

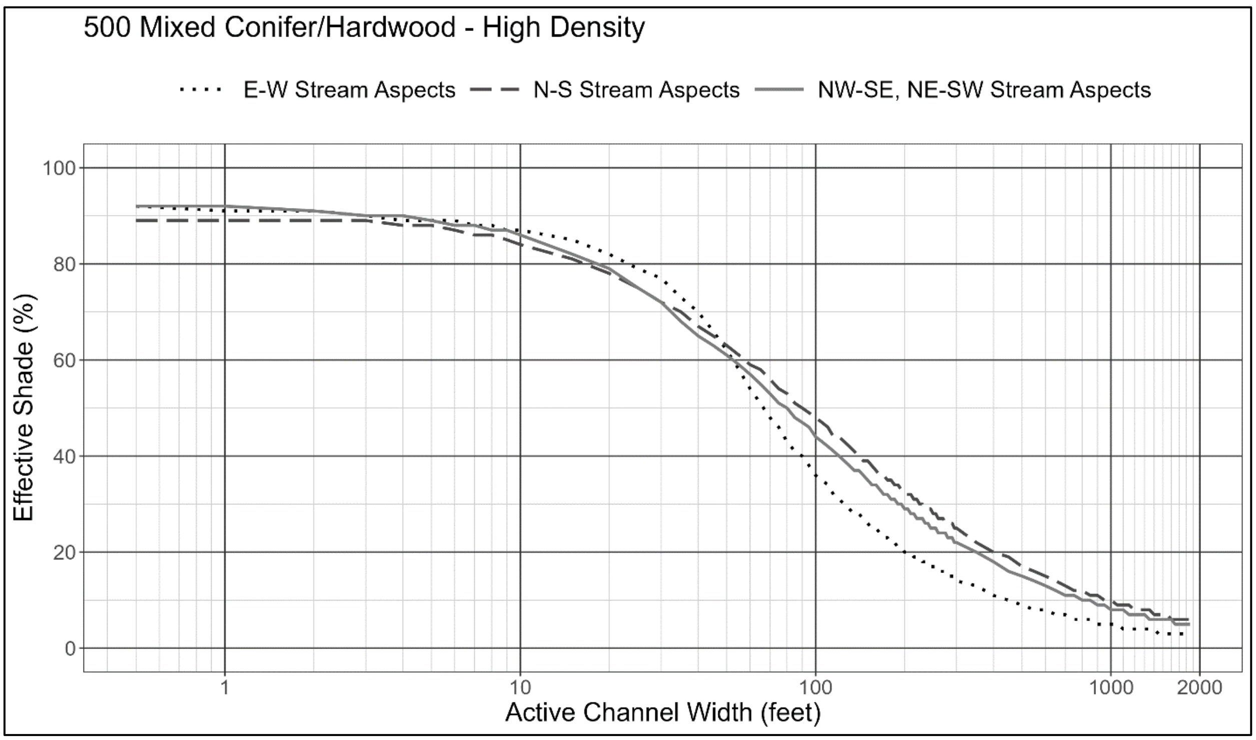

Figure 9-1: Effective shade targets for high density mixed conifer and hardwood stream sites.

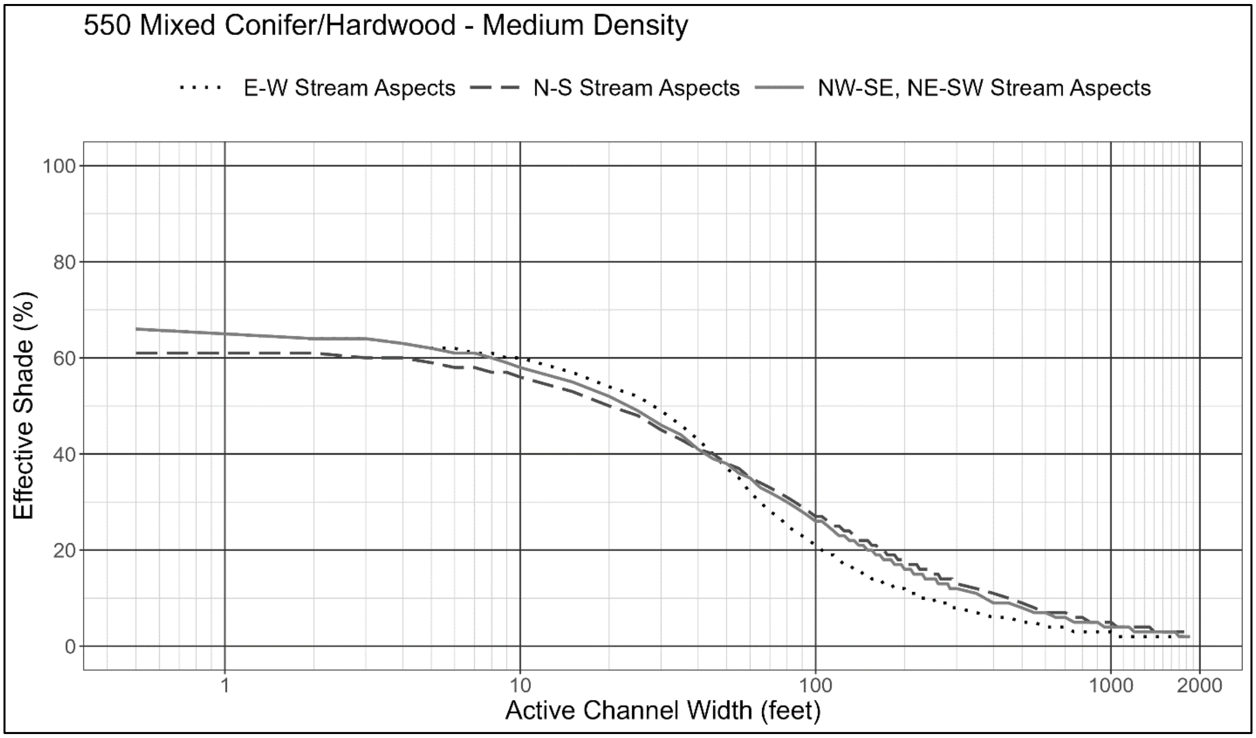

Figure 9-2: Effective shade targets for medium density mixed conifer and hardwood stream sites.

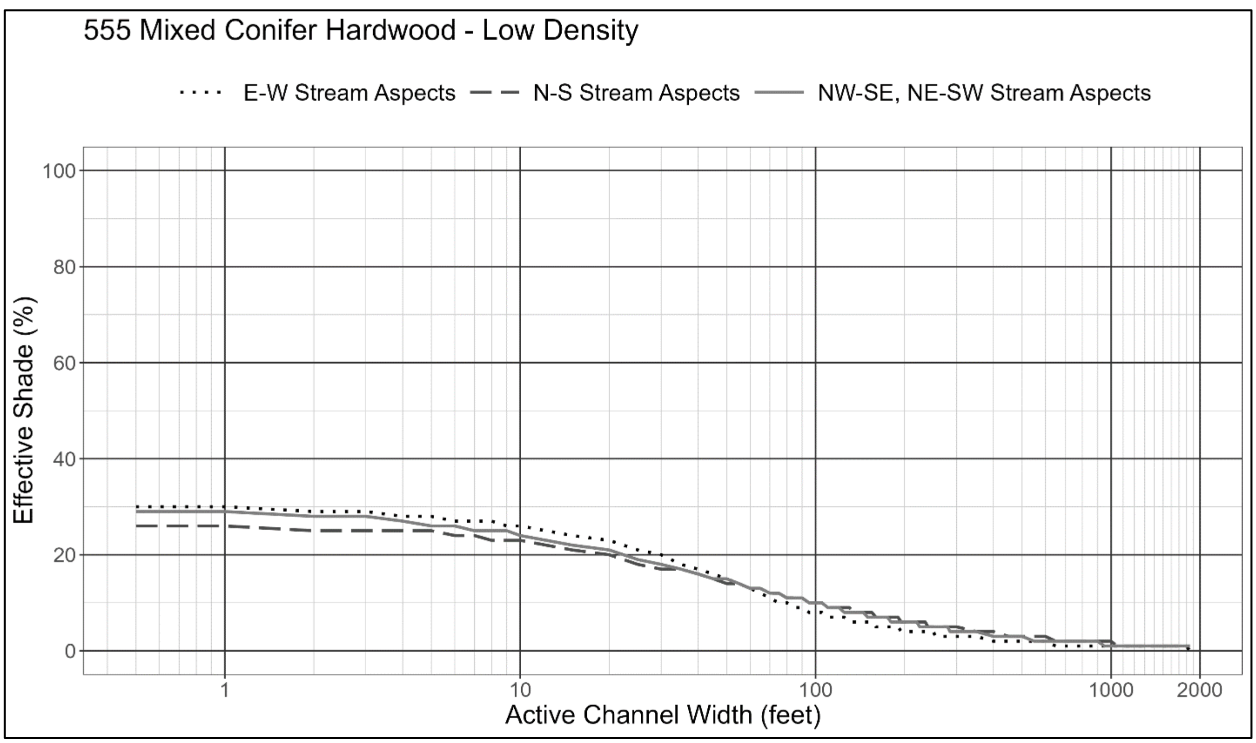

Figure 9-3: Effective shade targets for low density mixed conifer and hardwood stream sites.

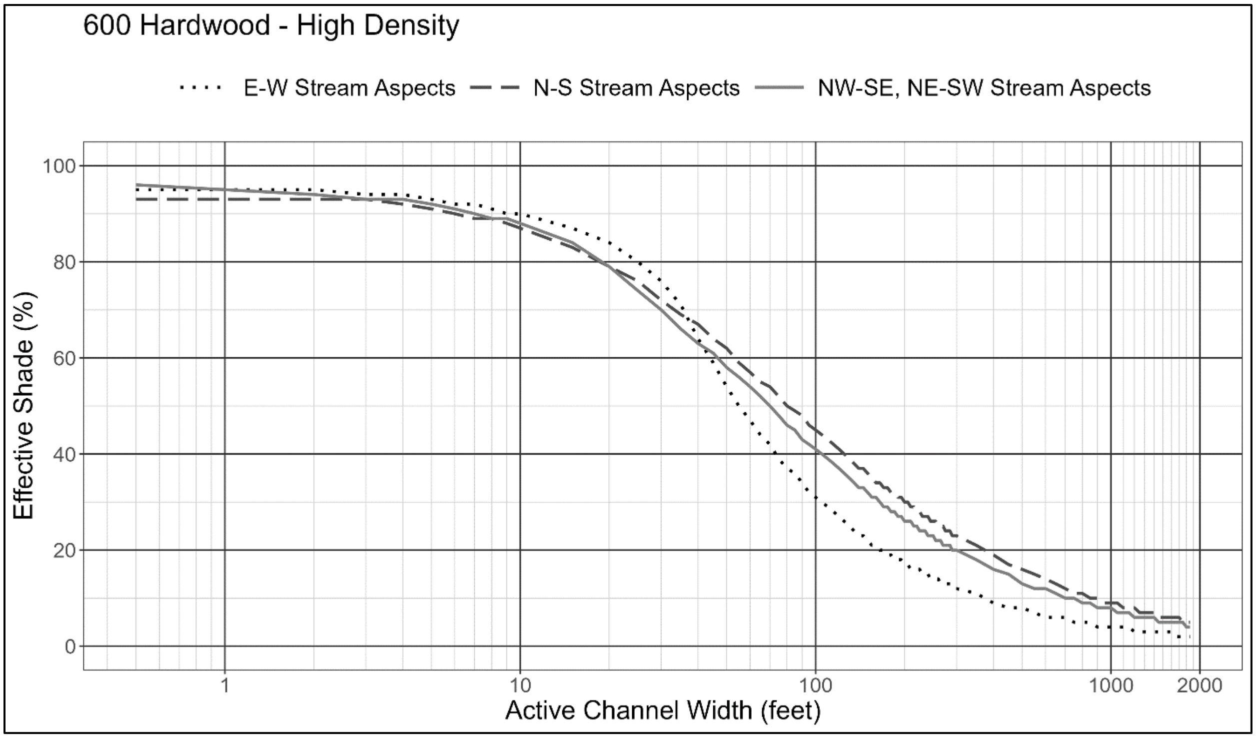

Figure 9-4: Effective shade targets for high density hardwood dominated stream sites.

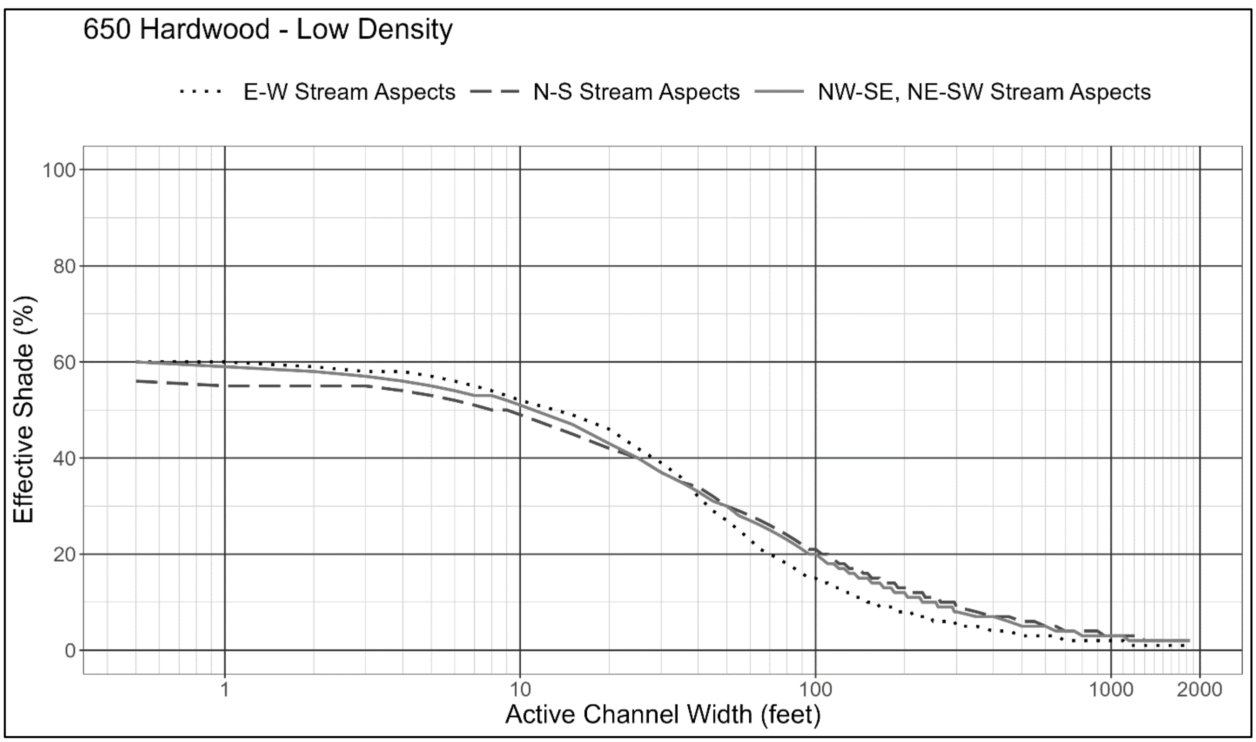

Figure 9-5: Effective shade targets for low density hardwood dominated stream sites.

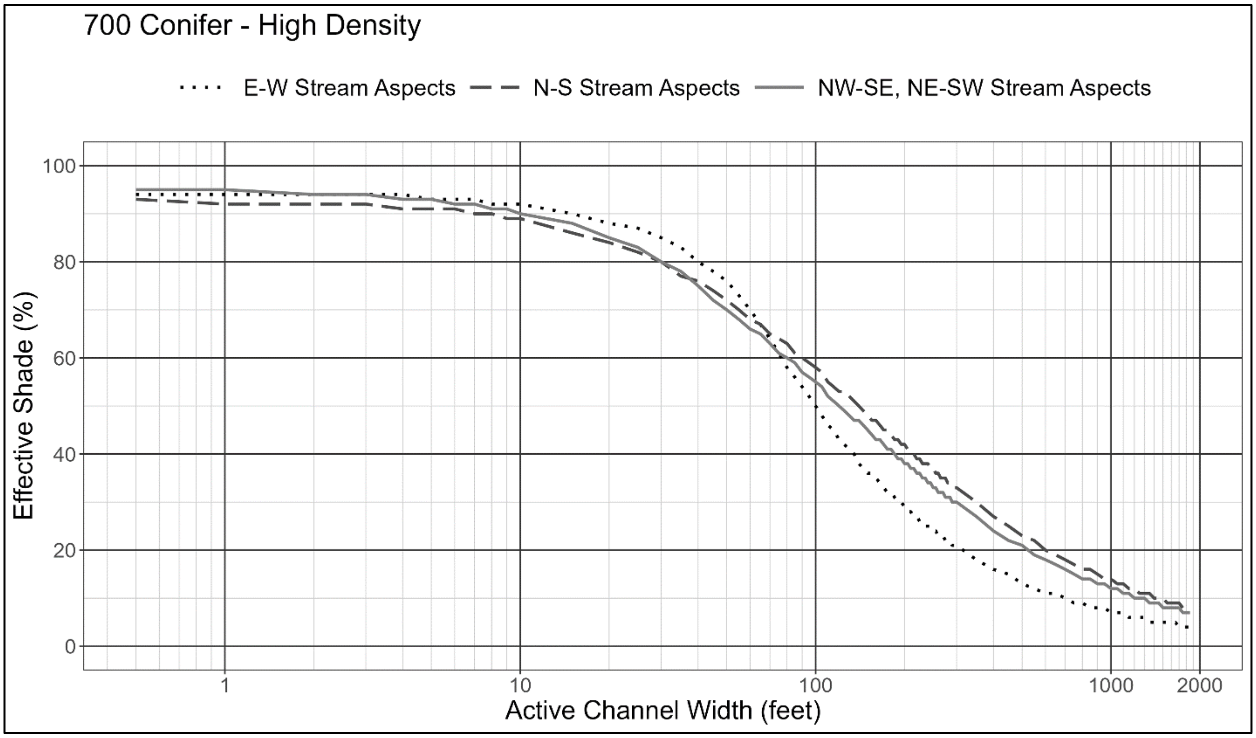

Figure 9-6: Effective shade targets for high density conifer dominated stream sites.

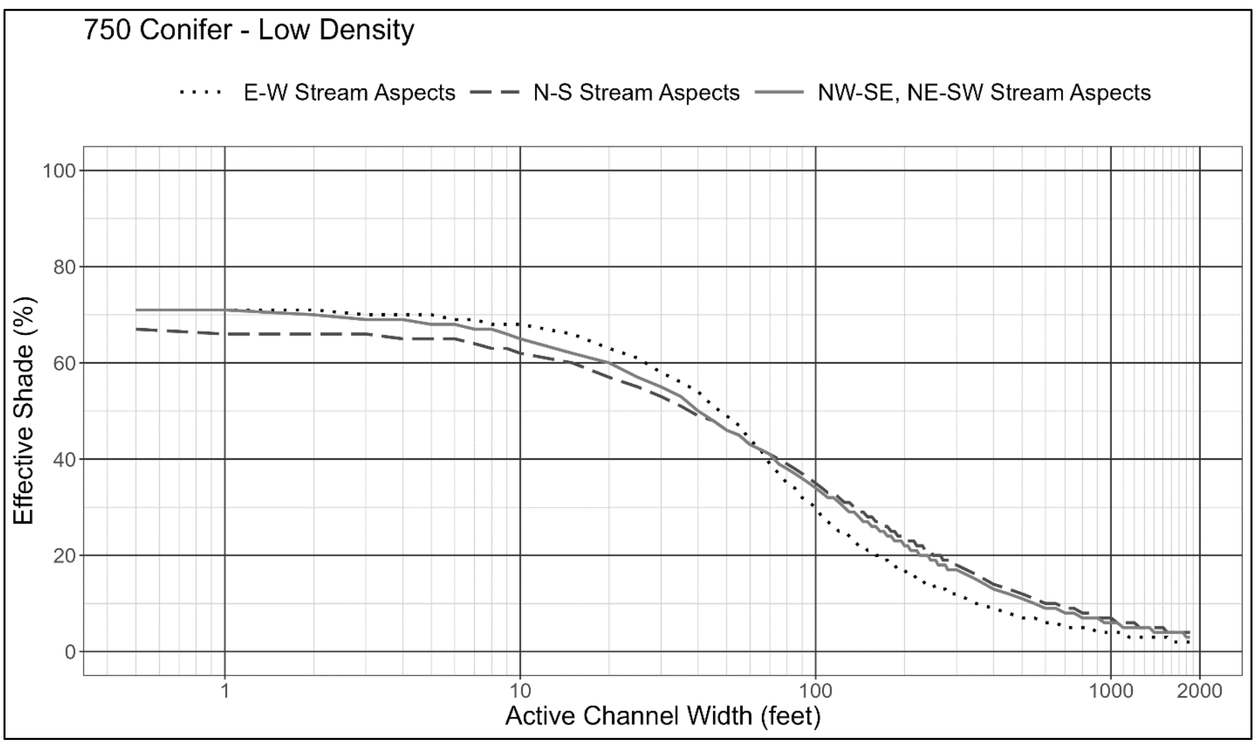

Figure 9-7: Effective shade targets for low density conifer dominated stream sites.

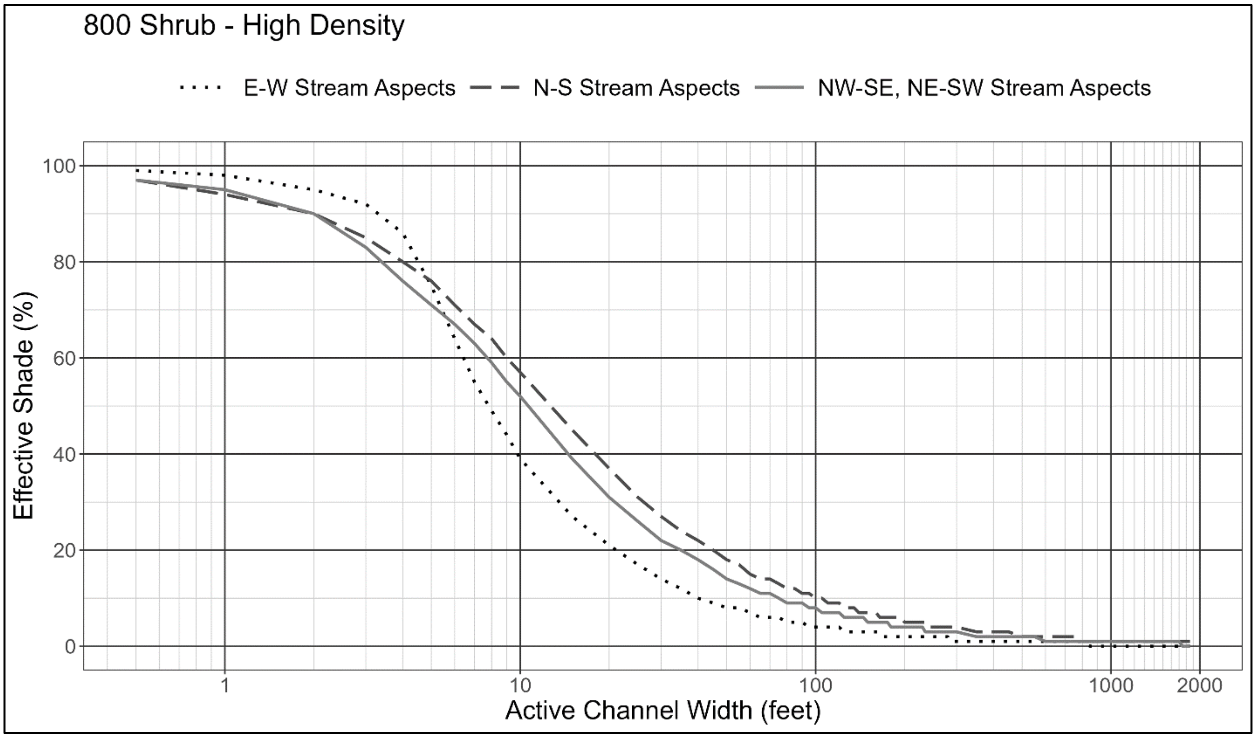

Figure 9-8: Effective shade targets for high density shrub sites.

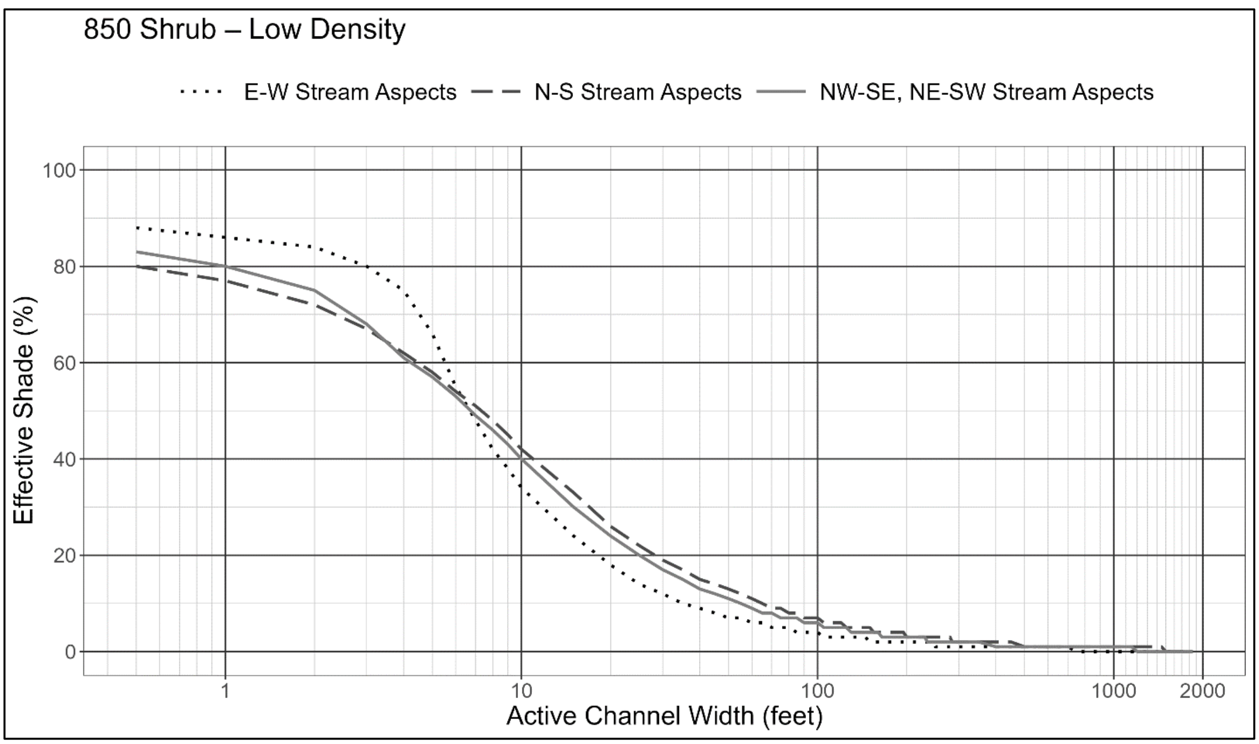

Figure 9-9: Effective shade targets for low density shrub sites.

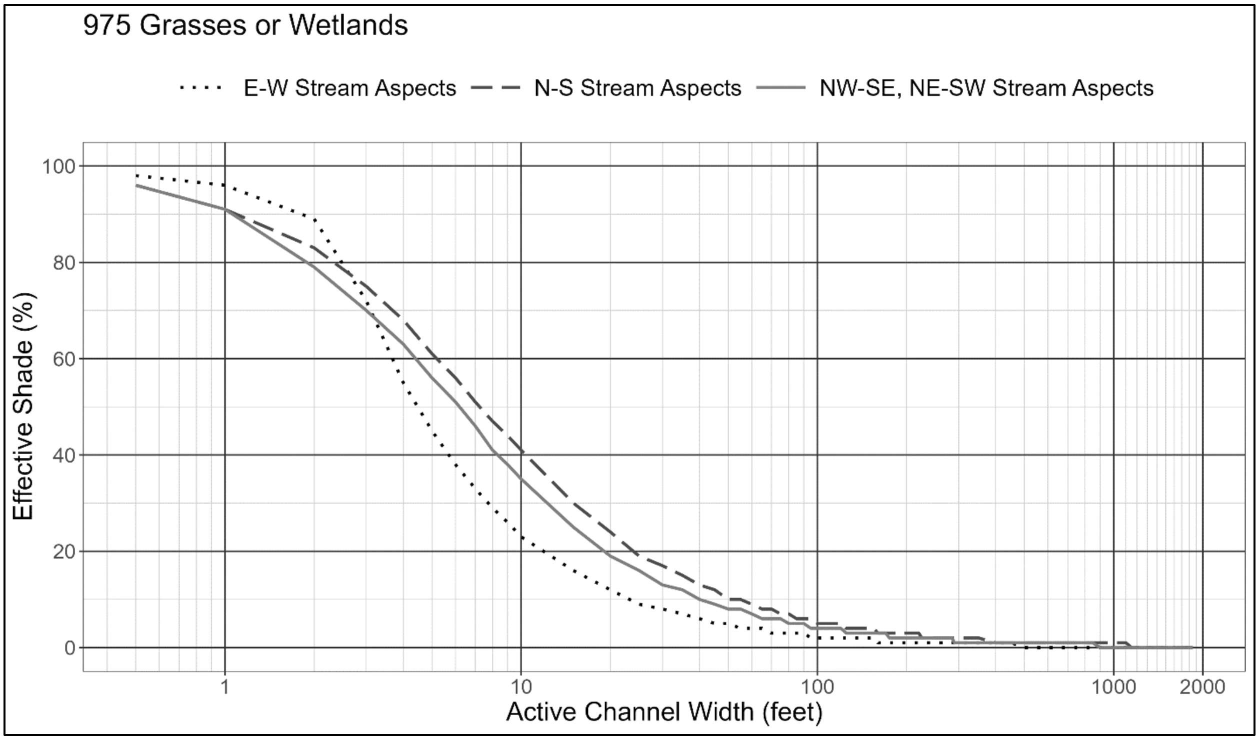

Figure 9-10: Effective shade targets for grass or wetland stream sites.

9.1.4.5 Percent consumptive use surrogate measure

Water management activities and water withdrawal activities in the Lower Columbia-Sandy have been assigned a portion of the HUA as presented in **Table 9-1** through **Table 9-7** and the equivalent LA as calculated using **Equation 9-2**. For most streams, the portion of the HUA allocated is 0.05°C. DEQ completed modeling to estimate the percent consumptive use that will attain this allocation (see TSD Appendix C, Section 9.0). The percent consumptive use is the percent of the natural surface flow that does not return to surface water after it has been withdrawn for a water use activity. Modeling indicates that a consumptive use flow rate reduction of 1.90 percent at USGS gage 14142500 (Sandy River below Bull Run) will maintain warming from water withdrawal activities at or less than 0.05°C. The natural flow rate is based on the monthly median natural flow.

Table 9-13: Target percent consumptive use flow rate reduction at USGS 14142500 relative to the monthly median natural flow rate at USGS 14142500.

Maximum percent consumptive use	Reference flow monitoring site
1.90	USGS 14142500 – Sandy River below Bull Run

9.1.5 Reserve capacity

DEQ set aside explicit allocations for RC to provide either point or nonpoint source allocation(s) to new or increased thermal loads, or to assign corrected allocations to any existing source(s) that were assigned an erroneous allocation or may not have been identified during the development of this TMDL. The portion of the HUA associated with the RC is described in **Table 9-1** through **Table 9-7**. The thermal load associated with RC allocations is calculated using

Equation 9-1 for point sources and **Equation 9-2** for nonpoint sources. Allocations from RC apply during the critical period.

If DEQ determines the cumulative warming from all NPDES point sources is less than the assigned portion of the HUA, the remainder may be considered as RC for point sources.

DEQ will consider requests for RC allocation submitted in writing on a case-by-case basis. Except when DEQ is correcting an error or omission, DEQ may require requesters to demonstrate that there are no reasonable alternatives to an increased load and may require preparation of a modeling or similar analysis to ensure that LC is available at the discharge location(s) or in downstream waters. The HUA assigned to RC may not be available for allocation due to cumulative warming and points of maximum impact downstream. DEQ will use its discretion in making determinations on requests, based on the information available and priorities appropriate at the time of the request. DEQ will track allocation of RC over time and will not approve requests once RC is depleted. Allocations of RC must be approved by DEQ's director or designee.

9.2 Margin of safety

CFR 130.7(c)(1) and OAR 340-042-0040(4)(i) require that a TMDL include an MOS. The MOS accounts for lack of knowledge or uncertainty. This may result from limited data, an incomplete understanding of the exact magnitude or quantity of thermal loading from various sources, or incomplete understanding of the actual effects controls will have on loading reductions and the receiving stream. The MOS is intended to account for such uncertainties in a manner that is conservative and will result in water quality protection. An MOS can be achieved through two approaches: (1) implicitly using conservative analytical assumptions to develop allocations, or (2) explicitly specifying a portion of the TMDL loading capacity as an MOS.

In the Lower Columbia-Sandy, an implicit MOS was used to derive the allocations. The primary associated conservative assumptions included:

- For model scenarios that assessed point sources' WLAs:
    - Effluent flow rates were set to average dry weather design flow or the maximum flow obtained from DMRs.
    - Effluent temperatures were set up to 32°C. On days when actual thermal loads were below the WLA(s), maximum effluent temperatures (model inputs) were raised above actual temperatures to either 32°C or the effluent temperature that would fully utilize the WLA.
    - Actual flow and temperature discharges from all point sources rarely reached these maximum values simultaneously, much less sustained them over extended periods. Thus, modeled wasteloads were generally greater than actual wasteloads, and resulting instream temperatures would be lower than modeled results.
- Groundwater inflows were assumed to be zero. Because groundwater directly cools stream temperatures via mixing, this means that actual instream temperatures would be lower than modeled temperatures anywhere that groundwater influences exist.
- DEQ used the critical period to determine when allocations apply. In this determination, DEQ relied on monitoring sites with the longest periods of exceedance. When downstream monitoring sites' exceedance periods were longer than in upstream waters, the longer period was used as the critical period for upstream waterbodies. This MOS ensures warming of upstream waters does not contribute to downstream exceedances.

- The sum of individual HUAs was used to assess cumulative attainment across the entirety of a given AU. This method does not account for longitudinal instream heat dissipation downstream from each thermal source. Thus, the total thermal load and corresponding temperature increase is likely to result in a maximum temperature increase less than the 0.30°C HUA.
- The cumulative effects analysis applied the maximum assigned HUA to each source category to assess cumulative allocation attainment. The modeling shows the maximum allowed temperature increase is limited to one or two days and generally less than 5% of the time. Moreover, the maximum increase is geographically limited and focused to distinct locations. Thus, the portion of the LC reserved for human uses will be unutilized most of the time over most Lower Columbia-Sandy Subbasin waters.
- In addition, the cumulative effects for the Sandy River attainment model scenario applied the maximum allowed temperature increase from tributary allocations at the mouth of each tributary, thus maximizing the potential warming downstream from that tributary. The POMI is unlikely to occur at the mouth of every tributary resulting in an overestimate of the cumulative warming contributed from point or nonpoint sources in the tributaries to the Sandy River.

Together, these model assumptions simulated greater thermal loading and transport than would be calculated with measured data. As a result, less solar radiation loading is allowed in the river system, which translates to greater required reductions and an implicit MOS.

10 Water quality management plan

As described in OAR 340-042-0040(4)(l)(A)-(O), an associated WQMP is a required element of a TMDL and must include the following components: (A) Condition assessment and problem description; (B) Goals and objectives; (C) Proposed management strategies design to meet the TMDL allocations; (D) Timeline for implementing management strategies; (E) Explanation of how TMDL implementation will attain water quality standards; (F) Timeline for attaining water quality standards; (G) Identification of persons, including DMAs, responsible for TMDL implementation; (H) Identification of existing implementation plans; (I) Schedule for submittal of implementation plans and revision triggers; (J) Description of reasonable assurance of TMDL implementation; (K) Plan to monitor and evaluate progress toward achieving TMDL allocations and water quality standards; (L) Plan for public involvement in TMDL implementation; (M) Description of planned efforts to maintain management strategies over time; (N) General discussion of costs and funding for TMDL implementation; and (O) Citation of legal authorities relating to TMDL implementation.

DEQ sought and considered input from various persons, including DMAs, responsible for TMDL implementation and other interested public and prepared the Lower Columbia-Sandy Subbasin WQMP as a stand-alone document. DEQ proposed, and the EQC adopted by rule, this WQMP as an element of the Lower Columbia-Sandy Subbasin Temperature TMDLs.

11 Reasonable assurance

OAR 340-042-0030(9) defines Reasonable Assurance as “a demonstration that a TMDL will be implemented by federal, state or local governments or individuals through regulatory or voluntary actions including management strategies or other controls.” EPA’s TMDL guidance describes that when a TMDL is developed for waters impaired by both point and nonpoint sources and WLAs are based on an assumption that NPS load reductions will occur, the TMDL must provide “reasonable assurances” that NPS control measures will achieve expected load reductions (EPA, 1991). Comprehensive explanations of reasonable assurances of implementation are provided in Section 7 of the Lower Columbia-Sandy Subbasin WQMP.

12 Protection plan

The scope of these temperature TMDLs includes all waters of the state, including freshwater perennial and intermittent streams in the Lower Columbia-Sandy Subbasin. As such, these TMDLs also serve as a “protection plan” to prevent impairment in waters currently attaining the applicable water quality standards, or for unassessed waters. The protection of these unimpaired waters has watershed-wide benefits such as:

- Clarity and consistency for implementation of management strategies throughout the watershed,
- Proactively applying management strategies and protections to waters where data are not available for establishing listing status,
- Improving TMDL outcomes by maintaining or improving water quality in streams that are tributary to listed streams,
- Creating efficiencies between TMDL and protection plan implementation (including monitoring, evaluating progress, adaptive management, enforcement, and leveraging partner entities’ efforts), and
- Assisting with funding opportunities for implementation when grants require projects to be part of a larger watershed plan.

Protection plan core elements, as described in materials available on EPA’s webpage (EPA, 2023a, 2023b), are fulfilled by the statements and references to specific sections of the TMDLs, WQMP, and TSD in the subsections that follow.

12.1 Identification of specific waters to be protected and risks to their condition

Table 2-2 lists all the AUs within the watershed with 2022 Integrated Report assessment status of Category 5. Those AUs with the status of Category 2 or Category 3 are included in the protection plan, along with other unassessed waters that may be found to be unimpaired for temperature in the future. The map in **Figure 2-1** provides an overview of where the temperature TMDLs and protection plan are applicable. Appendix H of the Lower Columbia-Sandy TSD provides a list of all AUs addressed by this TMDL and the current 2022 Integrated Report assessment status. The same sources and processes described in Section 7 that have caused temperature impairments to some reaches in the watershed also pose a risk to unimpaired waters.

12.2 Quantification of loads and activities expected to resist degradation

Multiple temperature monitoring stations provided data used in the TMDL analyses. The specific stations and analysis are presented in Appendices A, B and D of the TSD. These data, along with 7Q10 flow estimates, were used to calculate thermal loading capacities presented in Section 8, above, and are supported by TSD Section 6.1.

Instructions for calculating loading capacities for any unimpaired or unassessed stream reaches are provided in Section 8, above. Instructions for calculating allocations are provided in Section 9, above.

The implementation of management practices specified in Sections 2 and 5 of the WQMP also protect against risks to unimpaired waters.

12.3 Timeframes for protection

Timelines for watershed-wide implementation of the TMDLs are described in Section 5 of the WQMP and estimated timelines for attainment of water quality standards in the impaired stream reaches are provided in Section 4 of the WQMP. DEQ’s watershed-wide approach ensures that the TMDLs and the protection plan will be implemented in a prioritized manner over the same timeframe that will be required to demonstrate effectiveness of management strategies in reducing excess pollutant loads.

12.4 Measures of success

The WQMP describes in detail DEQ’s approach to quantitative and qualitative measures of progress in attaining and maintaining water quality standards, which is applied watershed-wide. Section 6 of the WQMP discusses quantitative and qualitative evaluation of implementation of management strategies, development of a plan for periodic monitoring, and an approach to adaptive management. Section 7 of the WQMP details the interconnected framework for accountability of implementation, including: engaging with sources; setting measurable objectives; evaluating progress; conducting enforcement; and tracking status and trends.

13 References

DEQ (Oregon Department of Environmental Quality). 2005. “Sandy River Basin Total Maximum Daily Load (TMDL).”

DEQ (Oregon Department of Environmental Quality). 2023a. “Draft Lower Columbia-Sandy River Subbasin TMDL Technical Support Document.”

DEQ (Oregon Department of Environmental Quality). 2023b. “Draft Lower Columbia-Sandy River Subbasin TMDL Water Quality Management Plan.”

EPA. 1991. Guidance for Water Quality-based Decisions: The TMDL Process. EPA/440/4-91-001. Washington, D.C.

EPA (United State Environmental Protection Agency). 2021. Columbia and Lower Snake Rivers temperature Total Maximum Daily Load

EPA (United State Environmental Protection Agency). 2023a. Impaired Waters and TMDLs – Protection Approaches webpage. https://www.epa.gov/tmdl/protection-approaches. Accessed July 20, 2023.

EPA (United State Environmental Protection Agency). 2023b. Draft Protection Frequently Asked Questions. https://www.epa.gov/sites/default/files/2021-06/documents/protection_faqs.pdf. Accessed July 20, 2023.

14 Appendix of effective shade curve tables

Table 14-1: Effective shade targets for high density mixed conifer and hardwood dominated stream sites (code 500).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	89	92	92
0.3	1	89	92	91
0.6	2	89	91	91
0.9	3	89	90	90
1.2	4	88	90	89
1.5	5	88	89	89
1.8	6	87	88	89
2.1	7	86	88	88
2.4	8	86	87	88
2.7	9	85	87	87
3	10	84	86	87
4.6	15	81	82	85
6.1	20	78	79	82
7.6	25	75	75	79
9.1	30	72	72	77
10.7	35	70	68	73
12.2	40	67	65	70
13.7	45	65	63	66
15.2	50	63	61	62
16.8	55	61	59	58
18.3	60	59	57	54
19.8	65	58	55	51
21.3	70	56	53	48
22.9	75	54	51	46
24.4	80	53	50	43
25.9	85	51	48	41
27.4	90	50	47	40
29	95	49	46	38
30.5	100	48	44	36
32	105	47	43	35
33.5	110	46	42	34
35.1	115	44	41	32
36.6	120	44	40	31
38.1	125	43	39	30

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
39.6	130	42	38	29
41.1	135	41	37	28
42.7	140	40	37	28
44.2	145	39	36	27
45.7	150	39	35	26
47.2	155	38	34	25
48.8	160	37	34	25
50.3	165	36	33	24
51.8	170	36	32	23
53.3	175	35	32	23
54.9	180	35	31	22
56.4	185	34	31	22
57.9	190	34	30	21
59.4	195	33	30	21
61	200	32	29	20
62.5	205	32	29	20
64	210	32	28	20
65.5	215	31	28	19
67.1	220	31	27	19
68.6	225	30	27	19
70.1	230	30	27	18
71.6	235	29	26	18
73.2	240	29	26	18
74.7	245	29	25	17
76.2	250	28	25	17
77.7	255	28	25	17
79.2	260	27	24	16
80.8	265	27	24	16
82.3	270	27	24	16
83.8	275	26	24	16
85.3	280	26	23	15
86.9	285	26	23	15
88.4	290	26	23	15
89.9	295	25	22	15
91.4	300	25	22	14
106.7	350	22	20	13
121.9	400	20	18	11
137.2	450	19	16	10
152.4	500	17	15	9
167.6	550	16	14	8
182.9	600	15	13	8
198.1	650	14	12	7

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
213.4	700	13	11	7
228.6	750	12	11	6
243.8	800	12	10	6
259.1	850	11	10	6
274.3	900	11	9	5
289.6	950	10	9	5
304.8	1000	10	8	5
320	1050	9	8	5
335.3	1100	9	8	4
350.5	1150	9	7	4
365.8	1200	8	7	4
381	1250	8	7	4
396.2	1300	8	7	4
411.5	1350	8	6	4
426.7	1400	7	6	4
442	1450	7	6	3
457.2	1500	7	6	3
472.4	1550	7	6	3
487.7	1600	6	6	3
502.9	1650	6	5	3
518.2	1700	6	5	3
533.4	1750	6	5	3
548.6	1800	6	5	3
563.9	1850	6	5	3

Table 14-2: Effective shade targets for medium density mixed conifer and hardwood dominated stream sites (code 550).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	61	66	66
0.3	1	61	65	65
0.6	2	61	64	64
0.9	3	60	64	64
1.2	4	60	63	63
1.5	5	59	62	62
1.8	6	58	61	62
2.1	7	58	61	61
2.4	8	57	60	61
2.7	9	57	59	60
3	10	56	58	60
4.6	15	53	55	57

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
6.1	20	50	52	54
7.6	25	48	49	52
9.1	30	45	46	49
10.7	35	43	44	46
12.2	40	41	41	43
13.7	45	40	39	40
15.2	50	38	38	37
16.8	55	37	36	35
18.3	60	35	35	32
19.8	65	34	33	30
21.3	70	33	32	28
22.9	75	32	31	27
24.4	80	31	30	25
25.9	85	30	29	24
27.4	90	29	28	23
29	95	28	27	22
30.5	100	27	26	21
32	105	27	26	20
33.5	110	26	25	19
35.1	115	25	24	19
36.6	120	25	23	18
38.1	125	24	23	17
39.6	130	24	22	17
41.1	135	23	22	16
42.7	140	22	21	16
44.2	145	22	21	15
45.7	150	22	20	15
47.2	155	21	20	14
48.8	160	21	19	14
50.3	165	20	19	14
51.8	170	20	18	13
53.3	175	19	18	13
54.9	180	19	18	13
56.4	185	19	17	12
57.9	190	18	17	12
59.4	195	18	17	12
61	200	18	16	12
62.5	205	17	16	11
64	210	17	16	11
65.5	215	17	15	11
67.1	220	17	15	11
68.6	225	16	15	10

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
70.1	230	16	15	10
71.6	235	16	14	10
73.2	240	16	14	10
74.7	245	15	14	10
76.2	250	15	14	10
77.7	255	15	14	9
79.2	260	15	13	9
80.8	265	14	13	9
82.3	270	14	13	9
83.8	275	14	13	9
85.3	280	14	13	9
86.9	285	14	12	8
88.4	290	14	12	8
89.9	295	13	12	8
91.4	300	13	12	8
106.7	350	12	11	7
121.9	400	11	9	6
137.2	450	10	9	6
152.4	500	9	8	5
167.6	550	8	7	5
182.9	600	7	7	4
198.1	650	7	6	4
213.4	700	7	6	4
228.6	750	6	5	3
243.8	800	6	5	3
259.1	850	5	5	3
274.3	900	5	5	3
289.6	950	5	4	3
304.8	1000	5	4	3
320	1050	4	4	2
335.3	1100	4	4	2
350.5	1150	4	4	2
365.8	1200	4	3	2
381	1250	4	3	2
396.2	1300	4	3	2
411.5	1350	4	3	2
426.7	1400	3	3	2
442	1450	3	3	2
457.2	1500	3	3	2
472.4	1550	3	3	2
487.7	1600	3	3	2
502.9	1650	3	3	2

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
518.2	1700	3	2	2
533.4	1750	3	2	2
548.6	1800	3	2	1
563.9	1850	3	2	1

Table 14-3: Effective shade targets for low density mixed conifer and hardwood dominated stream sites (code 555).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	26	29	30
0.3	1	26	29	30
0.6	2	25	28	29
0.9	3	25	28	29
1.2	4	25	27	28
1.5	5	25	26	28
1.8	6	24	26	27
2.1	7	24	25	27
2.4	8	23	25	27
2.7	9	23	25	26
3	10	23	24	26
4.6	15	21	22	24
6.1	20	20	21	23
7.6	25	18	19	21
9.1	30	17	18	20
10.7	35	17	17	18
12.2	40	16	16	17
13.7	45	15	15	16
15.2	50	14	15	15
16.8	55	14	14	14
18.3	60	13	13	13
19.8	65	13	13	12
21.3	70	12	12	11
22.9	75	12	12	10
24.4	80	11	11	10
25.9	85	11	11	9
27.4	90	11	11	9
29	95	10	10	8
30.5	100	10	10	8
32	105	10	10	8
33.5	110	9	9	7
35.1	115	9	9	7

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
36.6	120	9	9	7
38.1	125	9	8	7
39.6	130	9	8	6
41.1	135	8	8	6
42.7	140	8	8	6
44.2	145	8	8	6
45.7	150	8	7	6
47.2	155	8	7	6
48.8	160	7	7	5
50.3	165	7	7	5
51.8	170	7	7	5
53.3	175	7	7	5
54.9	180	7	6	5
56.4	185	7	6	5
57.9	190	7	6	5
59.4	195	6	6	4
61	200	6	6	4
62.5	205	6	6	4
64	210	6	6	4
65.5	215	6	6	4
67.1	220	6	6	4
68.6	225	6	5	4
70.1	230	6	5	4
71.6	235	6	5	4
73.2	240	5	5	4
74.7	245	5	5	4
76.2	250	5	5	4
77.7	255	5	5	3
79.2	260	5	5	3
80.8	265	5	5	3
82.3	270	5	5	3
83.8	275	5	5	3
85.3	280	5	5	3
86.9	285	5	4	3
88.4	290	5	4	3
89.9	295	5	4	3
91.4	300	5	4	3
106.7	350	4	4	3
121.9	400	4	3	2
137.2	450	3	3	2
152.4	500	3	3	2
167.6	550	3	2	2

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
182.9	600	3	2	2
198.1	650	2	2	1
213.4	700	2	2	1
228.6	750	2	2	1
243.8	800	2	2	1
259.1	850	2	2	1
274.3	900	2	2	1
289.6	950	2	1	1
304.8	1000	2	1	1
320	1050	1	1	1
335.3	1100	1	1	1
350.5	1150	1	1	1
365.8	1200	1	1	1
381	1250	1	1	1
396.2	1300	1	1	1
411.5	1350	1	1	1
426.7	1400	1	1	1
442	1450	1	1	1
457.2	1500	1	1	1
472.4	1550	1	1	1
487.7	1600	1	1	1
502.9	1650	1	1	1
518.2	1700	1	1	1
533.4	1750	1	1	1
548.6	1800	1	1	1
563.9	1850	1	1	0

Table 14-4: Effective shade targets for high density hardwood dominated stream sites (code 600).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	93	96	95
0.3	1	93	95	95
0.6	2	93	94	95
0.9	3	93	93	94
1.2	4	92	93	94
1.5	5	91	92	93
1.8	6	90	91	92
2.1	7	89	90	92
2.4	8	89	89	91
2.7	9	88	89	90

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
3	10	87	88	90
4.6	15	83	84	87
6.1	20	79	79	84
7.6	25	76	74	80
9.1	30	72	70	76
10.7	35	69	66	71
12.2	40	67	63	64
13.7	45	64	61	59
15.2	50	62	58	54
16.8	55	59	56	50
18.3	60	57	54	47
19.8	65	55	52	44
21.3	70	54	50	42
22.9	75	52	48	39
24.4	80	50	46	37
25.9	85	49	45	36
27.4	90	48	43	34
29	95	46	42	32
30.5	100	45	41	31
32	105	44	40	30
33.5	110	43	39	29
35.1	115	42	38	28
36.6	120	41	37	27
38.1	125	40	36	26
39.6	130	39	35	25
41.1	135	38	34	24
42.7	140	37	33	23
44.2	145	37	33	23
45.7	150	36	32	22
47.2	155	35	31	21
48.8	160	34	31	21
50.3	165	34	30	20
51.8	170	33	29	20
53.3	175	33	29	19
54.9	180	32	28	19
56.4	185	32	28	18
57.9	190	31	27	18
59.4	195	31	27	18
61	200	30	26	17
62.5	205	30	26	17
64	210	29	26	16
65.5	215	29	25	16

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
67.1	220	28	25	16
68.6	225	28	24	16
70.1	230	27	24	15
71.6	235	27	24	15
73.2	240	27	23	15
74.7	245	26	23	14
76.2	250	26	23	14
77.7	255	26	22	14
79.2	260	25	22	14
80.8	265	25	22	13
82.3	270	25	21	13
83.8	275	24	21	13
85.3	280	24	21	13
86.9	285	24	21	13
88.4	290	23	20	12
89.9	295	23	20	12
91.4	300	23	20	12
106.7	350	21	18	11
121.9	400	19	16	9
137.2	450	17	15	8
152.4	500	16	13	8
167.6	550	15	12	7
182.9	600	14	12	6
198.1	650	13	11	6
213.4	700	12	10	6
228.6	750	11	10	5
243.8	800	11	9	5
259.1	850	10	9	5
274.3	900	10	8	4
289.6	950	9	8	4
304.8	1000	9	8	4
320	1050	9	7	4
335.3	1100	8	7	4
350.5	1150	8	7	4
365.8	1200	8	6	3
381	1250	7	6	3
396.2	1300	7	6	3
411.5	1350	7	6	3
426.7	1400	7	6	3
442	1450	6	5	3
457.2	1500	6	5	3
472.4	1550	6	5	3

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
487.7	1600	6	5	3
502.9	1650	6	5	2
518.2	1700	6	5	2
533.4	1750	5	5	2
548.6	1800	5	4	2
563.9	1850	5	4	2

Table 14-5: Effective shade targets for low density hardwood dominated stream sites (code 650).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	56	60	60
0.3	1	55	59	60
0.6	2	55	58	59
0.9	3	55	57	58
1.2	4	54	56	58
1.5	5	53	55	57
1.8	6	52	54	56
2.1	7	51	53	55
2.4	8	50	53	54
2.7	9	50	52	53
3	10	49	51	52
4.6	15	45	47	49
6.1	20	42	43	46
7.6	25	40	40	42
9.1	30	37	37	39
10.7	35	35	35	36
12.2	40	34	33	32
13.7	45	32	31	29
15.2	50	30	30	27
16.8	55	29	28	25
18.3	60	28	27	23
19.8	65	27	26	21
21.3	70	26	25	20
22.9	75	25	24	19
24.4	80	24	23	18
25.9	85	23	22	17
27.4	90	22	21	16
29	95	21	20	15
30.5	100	21	20	15
32	105	20	19	14

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
33.5	110	20	18	14
35.1	115	19	18	13
36.6	120	18	17	13
38.1	125	18	17	12
39.6	130	17	16	12
41.1	135	17	16	11
42.7	140	17	15	11
44.2	145	16	15	11
45.7	150	16	15	10
47.2	155	15	14	10
48.8	160	15	14	10
50.3	165	15	14	9
51.8	170	14	13	9
53.3	175	14	13	9
54.9	180	14	13	9
56.4	185	14	12	9
57.9	190	13	12	8
59.4	195	13	12	8
61	200	13	12	8
62.5	205	13	11	8
64	210	12	11	8
65.5	215	12	11	7
67.1	220	12	11	7
68.6	225	12	11	7
70.1	230	12	10	7
71.6	235	11	10	7
73.2	240	11	10	7
74.7	245	11	10	7
76.2	250	11	10	6
77.7	255	11	10	6
79.2	260	11	9	6
80.8	265	10	9	6
82.3	270	10	9	6
83.8	275	10	9	6
85.3	280	10	9	6
86.9	285	10	9	6
88.4	290	10	9	6
89.9	295	10	8	6
91.4	300	9	8	5
106.7	350	8	7	5
121.9	400	7	7	4
137.2	450	7	6	4

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
152.4	500	6	5	3
167.6	550	6	5	3
182.9	600	5	5	3
198.1	650	5	4	3
213.4	700	4	4	2
228.6	750	4	4	2
243.8	800	4	3	2
259.1	850	4	3	2
274.3	900	4	3	2
289.6	950	3	3	2
304.8	1000	3	3	2
320	1050	3	3	2
335.3	1100	3	3	2
350.5	1150	3	2	1
365.8	1200	3	2	1
381	1250	3	2	1
396.2	1300	2	2	1
411.5	1350	2	2	1
426.7	1400	2	2	1
442	1450	2	2	1
457.2	1500	2	2	1
472.4	1550	2	2	1
487.7	1600	2	2	1
502.9	1650	2	2	1
518.2	1700	2	2	1
533.4	1750	2	2	1
548.6	1800	2	2	1
563.9	1850	2	2	1

Table 14-6: Effective shade targets for high density conifer dominated stream sites (code 700).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	93	95	94
0.3	1	92	95	94
0.6	2	92	94	94
0.9	3	92	94	94
1.2	4	91	93	94
1.5	5	91	93	93
1.8	6	91	92	93
2.1	7	90	92	93

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
2.4	8	90	91	92
2.7	9	89	91	92
3	10	89	90	92
4.6	15	86	88	90
6.1	20	84	85	88
7.6	25	82	83	87
9.1	30	80	80	85
10.7	35	77	78	83
12.2	40	76	75	80
13.7	45	74	72	78
15.2	50	72	70	76
16.8	55	70	68	73
18.3	60	68	66	70
19.8	65	67	65	67
21.3	70	65	63	64
22.9	75	64	61	61
24.4	80	63	60	58
25.9	85	61	59	56
27.4	90	60	57	54
29	95	59	56	52
30.5	100	58	55	50
32	105	57	54	48
33.5	110	55	52	46
35.1	115	54	51	45
36.6	120	53	50	43
38.1	125	53	49	42
39.6	130	52	48	41
41.1	135	51	47	40
42.7	140	50	47	38
44.2	145	49	46	37
45.7	150	48	45	36
47.2	155	47	44	36
48.8	160	47	43	35
50.3	165	46	43	34
51.8	170	45	42	33
53.3	175	45	41	32
54.9	180	44	41	32
56.4	185	43	40	31
57.9	190	43	39	30
59.4	195	42	39	30
61	200	42	38	29
62.5	205	41	38	28

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
64	210	41	37	28
65.5	215	40	37	27
67.1	220	39	36	27
68.6	225	39	36	26
70.1	230	38	35	26
71.6	235	38	35	25
73.2	240	38	34	25
74.7	245	37	34	25
76.2	250	37	33	24
77.7	255	36	33	24
79.2	260	36	32	23
80.8	265	35	32	23
82.3	270	35	32	23
83.8	275	35	31	22
85.3	280	34	31	22
86.9	285	34	31	22
88.4	290	34	30	21
89.9	295	33	30	21
91.4	300	33	30	21
106.7	350	30	27	18
121.9	400	27	24	16
137.2	450	25	22	15
152.4	500	23	21	13
167.6	550	22	19	12
182.9	600	20	18	11
198.1	650	19	17	11
213.4	700	18	16	10
228.6	750	17	15	9
243.8	800	16	14	9
259.1	850	16	14	8
274.3	900	15	13	8
289.6	950	14	13	8
304.8	1000	14	12	7
320	1050	13	12	7
335.3	1100	13	11	7
350.5	1150	12	11	6
365.8	1200	12	10	6
381	1250	11	10	6
396.2	1300	11	10	6
411.5	1350	11	9	5
426.7	1400	10	9	5
442	1450	10	9	5

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
457.2	1500	10	8	5
472.4	1550	9	8	5
487.7	1600	9	8	5
502.9	1650	9	8	5
518.2	1700	9	8	4
533.4	1750	8	7	4
548.6	1800	8	7	4
563.9	1850	8	7	4

Table 14-7: Effective shade targets for low density conifer dominated stream sites (code 750).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	67	71	71
0.3	1	66	71	71
0.6	2	66	70	71
0.9	3	66	69	70
1.2	4	65	69	70
1.5	5	65	68	70
1.8	6	65	68	69
2.1	7	64	67	69
2.4	8	63	67	68
2.7	9	63	66	68
3	10	62	65	68
4.6	15	60	62	66
6.1	20	57	60	63
7.6	25	55	57	61
9.1	30	53	55	58
10.7	35	51	53	56
12.2	40	49	50	54
13.7	45	48	48	51
15.2	50	46	46	49
16.8	55	45	45	47
18.3	60	43	43	44
19.8	65	42	42	42
21.3	70	41	41	39
22.9	75	40	39	37
24.4	80	39	38	35
25.9	85	38	37	34
27.4	90	37	36	32
29	95	36	35	31

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
30.5	100	35	34	30
32	105	34	33	28
33.5	110	33	32	27
35.1	115	33	32	26
36.6	120	32	31	25
38.1	125	31	30	25
39.6	130	31	29	24
41.1	135	30	29	23
42.7	140	29	28	22
44.2	145	29	27	22
45.7	150	28	27	21
47.2	155	28	26	21
48.8	160	27	26	20
50.3	165	27	25	20
51.8	170	26	25	19
53.3	175	26	24	19
54.9	180	25	24	18
56.4	185	25	23	18
57.9	190	24	23	17
59.4	195	24	23	17
61	200	24	22	17
62.5	205	23	22	16
64	210	23	21	16
65.5	215	23	21	16
67.1	220	22	21	15
68.6	225	22	20	15
70.1	230	22	20	15
71.6	235	21	20	14
73.2	240	21	20	14
74.7	245	21	19	14
76.2	250	20	19	14
77.7	255	20	19	13
79.2	260	20	18	13
80.8	265	20	18	13
82.3	270	19	18	13
83.8	275	19	18	13
85.3	280	19	17	12
86.9	285	19	17	12
88.4	290	18	17	12
89.9	295	18	17	12
91.4	300	18	17	12
106.7	350	16	15	10

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
121.9	400	14	13	9
137.2	450	13	12	8
152.4	500	12	11	7
167.6	550	11	10	7
182.9	600	10	9	6
198.1	650	10	9	6
213.4	700	9	8	5
228.6	750	9	8	5
243.8	800	8	7	5
259.1	850	8	7	5
274.3	900	7	7	4
289.6	950	7	6	4
304.8	1000	7	6	4
320	1050	6	6	4
335.3	1100	6	5	4
350.5	1150	6	5	3
365.8	1200	6	5	3
381	1250	5	5	3
396.2	1300	5	5	3
411.5	1350	5	5	3
426.7	1400	5	4	3
442	1450	5	4	3
457.2	1500	5	4	3
472.4	1550	4	4	3
487.7	1600	4	4	2
502.9	1650	4	4	2
518.2	1700	4	4	2
533.4	1750	4	4	2
548.6	1800	4	3	2
563.9	1850	4	3	2

Table 14-8: Effective shade targets for high density shrub dominated stream sites (code 800).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	97	97	99
0.3	1	94	95	98
0.6	2	90	90	95
0.9	3	85	83	92
1.2	4	80	76	86
1.5	5	76	71	75

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
1.8	6	71	67	64
2.1	7	67	63	55
2.4	8	64	59	49
2.7	9	60	55	44
3	10	57	52	39
4.6	15	45	39	27
6.1	20	37	31	21
7.6	25	31	26	17
9.1	30	27	22	14
10.7	35	24	20	12
12.2	40	22	18	10
13.7	45	20	16	9
15.2	50	18	14	8
16.8	55	17	13	8
18.3	60	15	12	7
19.8	65	14	11	6
21.3	70	14	11	6
22.9	75	13	10	6
24.4	80	12	9	5
25.9	85	12	9	5
27.4	90	11	9	5
29	95	11	8	4
30.5	100	10	8	4
32	105	10	7	4
33.5	110	9	7	4
35.1	115	9	7	4
36.6	120	9	7	4
38.1	125	8	6	3
39.6	130	8	6	3
41.1	135	8	6	3
42.7	140	7	6	3
44.2	145	7	6	3
45.7	150	7	5	3
47.2	155	7	5	3
48.8	160	7	5	3
50.3	165	6	5	3
51.8	170	6	5	2
53.3	175	6	5	2
54.9	180	6	4	2
56.4	185	6	4	2
57.9	190	6	4	2
59.4	195	6	4	2

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
61	200	5	4	2
62.5	205	5	4	2
64	210	5	4	2
65.5	215	5	4	2
67.1	220	5	4	2
68.6	225	5	4	2
70.1	230	5	4	2
71.6	235	5	3	2
73.2	240	5	3	2
74.7	245	4	3	2
76.2	250	4	3	2
77.7	255	4	3	2
79.2	260	4	3	2
80.8	265	4	3	2
82.3	270	4	3	2
83.8	275	4	3	2
85.3	280	4	3	2
86.9	285	4	3	1
88.4	290	4	3	1
89.9	295	4	3	1
91.4	300	4	3	1
106.7	350	3	2	1
121.9	400	3	2	1
137.2	450	3	2	1
152.4	500	2	2	1
167.6	550	2	2	1
182.9	600	2	1	1
198.1	650	2	1	1
213.4	700	2	1	1
228.6	750	2	1	1
243.8	800	1	1	1
259.1	850	1	1	0
274.3	900	1	1	0
289.6	950	1	1	0
304.8	1000	1	1	0
320	1050	1	1	0
335.3	1100	1	1	0
350.5	1150	1	1	0
365.8	1200	1	1	0
381	1250	1	1	0
396.2	1300	1	1	0
411.5	1350	1	1	0

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
426.7	1400	1	1	0
442	1450	1	1	0
457.2	1500	1	1	0
472.4	1550	1	1	0
487.7	1600	1	1	0
502.9	1650	1	1	0
518.2	1700	1	1	0
533.4	1750	1	0	0
548.6	1800	1	0	0
563.9	1850	1	0	0

Table 14-9: Effective shade targets for low density shrub dominated stream sites (code 850).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	80	83	88
0.3	1	77	80	86
0.6	2	72	75	84
0.9	3	67	68	80
1.2	4	62	61	75
1.5	5	58	57	66
1.8	6	54	53	55
2.1	7	51	49	48
2.4	8	48	46	42
2.7	9	45	43	38
3	10	42	40	34
4.6	15	33	30	24
6.1	20	26	24	18
7.6	25	22	20	14
9.1	30	19	17	12
10.7	35	17	15	10
12.2	40	15	13	9
13.7	45	14	12	8
15.2	50	13	11	7
16.8	55	12	10	7
18.3	60	11	9	6
19.8	65	10	8	6
21.3	70	9	8	5
22.9	75	9	7	5
24.4	80	8	7	5
25.9	85	8	7	4

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
27.4	90	7	6	4
29	95	7	6	4
30.5	100	7	6	4
32	105	6	5	3
33.5	110	6	5	3
35.1	115	6	5	3
36.6	120	6	5	3
38.1	125	5	5	3
39.6	130	5	4	3
41.1	135	5	4	3
42.7	140	5	4	3
44.2	145	5	4	3
45.7	150	5	4	2
47.2	155	4	4	2
48.8	160	4	4	2
50.3	165	4	3	2
51.8	170	4	3	2
53.3	175	4	3	2
54.9	180	4	3	2
56.4	185	4	3	2
57.9	190	4	3	2
59.4	195	4	3	2
61	200	3	3	2
62.5	205	3	3	2
64	210	3	3	2
65.5	215	3	3	2
67.1	220	3	3	2
68.6	225	3	3	2
70.1	230	3	3	2
71.6	235	3	2	2
73.2	240	3	2	2
74.7	245	3	2	2
76.2	250	3	2	1
77.7	255	3	2	1
79.2	260	3	2	1
80.8	265	3	2	1
82.3	270	3	2	1
83.8	275	3	2	1
85.3	280	3	2	1
86.9	285	2	2	1
88.4	290	2	2	1
89.9	295	2	2	1

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
91.4	300	2	2	1
106.7	350	2	2	1
121.9	400	2	1	1
137.2	450	2	1	1
152.4	500	1	1	1
167.6	550	1	1	1
182.9	600	1	1	1
198.1	650	1	1	1
213.4	700	1	1	1
228.6	750	1	1	0
243.8	800	1	1	0
259.1	850	1	1	0
274.3	900	1	1	0
289.6	950	1	1	0
304.8	1000	1	1	0
320	1050	1	1	0
335.3	1100	1	1	0
350.5	1150	1	1	0
365.8	1200	1	0	0
381	1250	1	0	0
396.2	1300	1	0	0
411.5	1350	1	0	0
426.7	1400	1	0	0
442	1450	1	0	0
457.2	1500	0	0	0
472.4	1550	0	0	0
487.7	1600	0	0	0
502.9	1650	0	0	0
518.2	1700	0	0	0
533.4	1750	0	0	0
548.6	1800	0	0	0
563.9	1850	0	0	0

Table 14-10: Effective shade targets for grass or wetland dominated stream sites (code 975).

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
0.2	0.5	96	96	98
0.3	1	91	91	96
0.6	2	83	79	89
0.9	3	75	70	72

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
1.2	4	68	63	55
1.5	5	61	56	45
1.8	6	56	51	38
2.1	7	51	46	33
2.4	8	47	41	29
2.7	9	44	38	26
3	10	41	35	23
4.6	15	30	25	16
6.1	20	24	19	12
7.6	25	19	16	9
9.1	30	17	13	8
10.7	35	15	12	7
12.2	40	13	10	6
13.7	45	12	9	5
15.2	50	10	8	5
16.8	55	10	8	4
18.3	60	9	7	4
19.8	65	8	6	4
21.3	70	8	6	3
22.9	75	7	6	3
24.4	80	7	5	3
25.9	85	6	5	3
27.4	90	6	5	3
29	95	6	4	2
30.5	100	5	4	2
32	105	5	4	2
33.5	110	5	4	2
35.1	115	5	4	2
36.6	120	5	4	2
38.1	125	4	3	2
39.6	130	4	3	2
41.1	135	4	3	2
42.7	140	4	3	2
44.2	145	4	3	2
45.7	150	4	3	2
47.2	155	4	3	2
48.8	160	3	3	1
50.3	165	3	3	1
51.8	170	3	3	1
53.3	175	3	2	1
54.9	180	3	2	1
56.4	185	3	2	1

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
57.9	190	3	2	1
59.4	195	3	2	1
61	200	3	2	1
62.5	205	3	2	1
64	210	3	2	1
65.5	215	3	2	1
67.1	220	3	2	1
68.6	225	2	2	1
70.1	230	2	2	1
71.6	235	2	2	1
73.2	240	2	2	1
74.7	245	2	2	1
76.2	250	2	2	1
77.7	255	2	2	1
79.2	260	2	2	1
80.8	265	2	2	1
82.3	270	2	2	1
83.8	275	2	2	1
85.3	280	2	2	1
86.9	285	2	2	1
88.4	290	2	1	1
89.9	295	2	1	1
91.4	300	2	1	1
106.7	350	2	1	1
121.9	400	1	1	1
137.2	450	1	1	1
152.4	500	1	1	0
167.6	550	1	1	0
182.9	600	1	1	0
198.1	650	1	1	0
213.4	700	1	1	0
228.6	750	1	1	0
243.8	800	1	1	0
259.1	850	1	1	0
274.3	900	1	0	0
289.6	950	1	0	0
304.8	1000	1	0	0
320	1050	1	0	0
335.3	1100	1	0	0
350.5	1150	0	0	0
365.8	1200	0	0	0
381	1250	0	0	0

Active channel width (m)	Active channel width (feet)	Effective shade target for N-S stream aspects (%)	Effective shade target for NW-SE, NE-SW stream aspects (%)	Effective shade target for E-W stream aspects (%)
396.2	1300	0	0	0
411.5	1350	0	0	0
426.7	1400	0	0	0
442	1450	0	0	0
457.2	1500	0	0	0
472.4	1550	0	0	0
487.7	1600	0	0	0
502.9	1650	0	0	0
518.2	1700	0	0	0
533.4	1750	0	0	0
548.6	1800	0	0	0
563.9	1850	0	0	0