



Draft Total Maximum Daily Loads for the Lower Columbia-Sandy Subbasin

Temperature

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Table of Contents

1	Introduction	1
1.1	Previous TMDLs.....	1
1.2	TMDL administrative process and public participation.....	1
2	TMDL name and location	2
3	Pollutant identification	5
4	Water quality standards and beneficial uses.....	6
5	Seasonal variation and critical period for temperature	9
6	Temperature water quality data evaluation overview	10
7	Pollutant sources or source categories	11
7.1	Point sources.....	11
7.2	Nonpoint sources	13
7.3	Background sources	13
8	Loading capacity and excess loads	14
9	Allocations, reserve capacity, and margin of safety	17
9.1	Thermal allocations	17
9.1.1	Human Use Allowance allocations	17
9.1.2	Thermal wasteload allocations for point sources	20
9.1.3	Thermal load allocations for nonpoint sources.....	21
9.1.4	Surrogate measures	23
9.1.5	Reserve capacity.....	31
9.2	Margin of safety.....	32
10	Water quality management plan	33
11	Reasonable assurance	33
12	Protection plan	34
12.1	Identification of specific waters to be protected and risks to their condition.....	34
12.2	Quantification of loads and activities expected to resist degradation.....	34
12.3	Timeframes for protection.....	35
12.4	Measures of success.....	35
13	References.....	35
14	Appendix of effective shade curve tables.....	36

List of Figures

- Figure 2-1: Lower Columbia-Sandy Subbasin temperature TMDLs project area overview. 3
- Figure 2-2: Lower Columbia-Sandy Subbasin Category 5 temperature impairments on the 2022 Integrated Report. 5
- Figure 4-1: Fish use designations in the Lower Columbia-Sandy Subbasin temperature TMDL project area. 8
- Figure 4-2: Salmon and steelhead spawning use designations in the Lower Columbia-Sandy Subbasin temperature TMDL project area. 9
- Figure 6-1: Lower Columbia-Sandy River Subbasin temperature analysis overview. 11
- Figure 9-1: Effective shade targets for high density mixed conifer and hardwood stream sites. 27
- Figure 9-2: Effective shade targets for medium density mixed conifer and hardwood stream sites. 28
- Figure 9-3: Effective shade targets for high density hardwood dominated stream sites. 28
- Figure 9-4: Effective shade targets for high density conifer dominated stream sites. 29
- Figure 9-5: Effective shade targets for low density conifer dominated stream sites. 29
- Figure 9-6: Effective shade targets for high density shrub sites. 30
- Figure 9-7: Effective shade targets for low density shrub sites. 30
- Figure 9-8: Effective shade targets for grass or wetland stream sites. 31

List of Tables

- Table 1-1: Summary of previous TMDLs developed for the Lower Columbia-Sandy Subbasin. ... 1
- Table 2-1: Watersheds within the Lower Columbia-Sandy Subbasin. 2
- Table 2-2: Lower Columbia-Sandy Subbasin Category 5 temperature impairments on the 2022 Integrated Report. 3
- Table 4-1: Designated beneficial uses in the Lower Columbia-Sandy Subbasin as identified in OAR 340-041-0286 Table 286A. 6
- Table 4-2: Applicable water quality standards and most sensitive beneficial uses. 7
- 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 exceedances to the temperature standard. 12
- Table 7-2: General NPDES permit registrants that contribute thermal loads to Lower Columbia-Sandy Subbasin streams at a frequency and magnitude to cause exceedances to the temperature standard. 12
- Table 8-1: Thermal loading capacity (LC) for select assessment units by applicable fish use period at 7Q10 flow. 14
- Table 8-2: Excess temperature and percent load reduction for various assessment units in the Lower Columbia-Sandy Subbasin. 15
- Table 9-1: Human use allowance allocations on the Sandy River from City of Troutdale WPCF outfall to the mouth. 17
- Table 9-2: Human use allowance allocations on the Sandy River from Bull Run River to upstream of the Troutdale WPCF outfall. 18
- Table 9-3: Human use allowance allocations on the Sandy River from the headwaters to the Bull Run River. 18
- Table 9-3: Human use allowance allocations on the Bull Run River. 19
- Table 9-4: Human use allowance allocations on Cedar Creek. 19
- Table 9-5: Human use allowance allocations on Camp Creek. 19

Table 9-6: Human Use Allowance allocations for all other waters in the Lower Columbia-Sandy Subbasin.....	19
Table 9-7: Thermal wasteload allocations for point sources.....	21
Table 9-8: Thermal load allocations for background sources.....	22
Table 9-12: Shade surrogate measure targets to meet nonpoint source load allocations on model stream extents.....	26
Table 9-13: Vegetation height, density, overhang, and horizontal distance buffer widths used to derive generalized effective shade curve targets.....	27
Table 9-14: Target percent consumptive use flow rate at USGS 14142500 relative to the monthly median natural flow rate at USGS 14142500.....	31
Table 1414-1: Effective shade targets for high density mixed conifer and hardwood dominated stream sites (code 348).....	36
Table 1414-2: Effective shade targets for medium density mixed conifer and hardwood dominated stream sites (code 550).....	38
Table 1414-3: Effective shade targets for high density hardwood dominated stream sites (code 600).....	41
Table 1414-4: Effective shade targets for high density conifer dominated stream sites (code 700).....	43
Table 14-5: Effective shade targets for low density conifer dominated stream sites (code 750).....	46
Table 1414-6: Effective shade targets for high density shrub dominated stream sites (code 800).....	48
Table 1414-7: Effective shade targets for low density shrub dominated stream sites (code 850).....	51
Table 1414-8: Effective shade targets for grass and wetland dominated stream sites (code 950).....	54

List of Equations

Equation 8-1	14
Equation 9-1	20
Equation 9-2.....	22
Equation 9-3.....	23
Equation 9-3	25
Equation 9-4	25

1 Introduction

This TMDL project is applicable within the Lower Columbia-Sandy Subbasin and will be adopted by reference in Oregon Administrative Rules 340-42-0090.

OAR 340-42-0040(3) requires DEQ or the 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 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 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 Oregon Department of Environmental Quality’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 will be proposed for adoption by Oregon’s Environmental Quality Commission, 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, Technical Support Document, 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. DEQ has submitted the drafts for public comment to fulfill the public participation requirements. DEQ considered all input received during these public participation opportunities and used input to guide the

analyses and preparation of documents. DEQ will provide response to comments that will be available online.

2 TMDL name and location

Per Oregon Administrative Rule 340-042-0040(4)(a), this element describes the geographic area for which the TMDL is developed.

Temperature TMDLs for the Lower Columbia-Sandy are developed to address all Category 5 listed assessment units impaired for temperature (Table 2-2) and to serve as a protection plan for all other assessment categories, including unimpaired and unassessed. The loading capacity and allocations, including surrogate measures, and implementation framework apply to all waters of the state as defined under ORS 468B.005(10), including all perennial and intermittent streams, 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 TMDL Water Quality Management Plan 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, below.

The map in Figure 2-1 provides an overview of where the temperature TMDLs are applicable. Appendix H of the Lower Columbia-Sandy Technical Support Document provides a list of all assessment units addressed by this TMDL.

In Oregon, the Lower Columbia-Sandy Subbasin is comprised of seven smaller 10-digit watersheds as listed in Table 2-1.

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

HU10 code	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

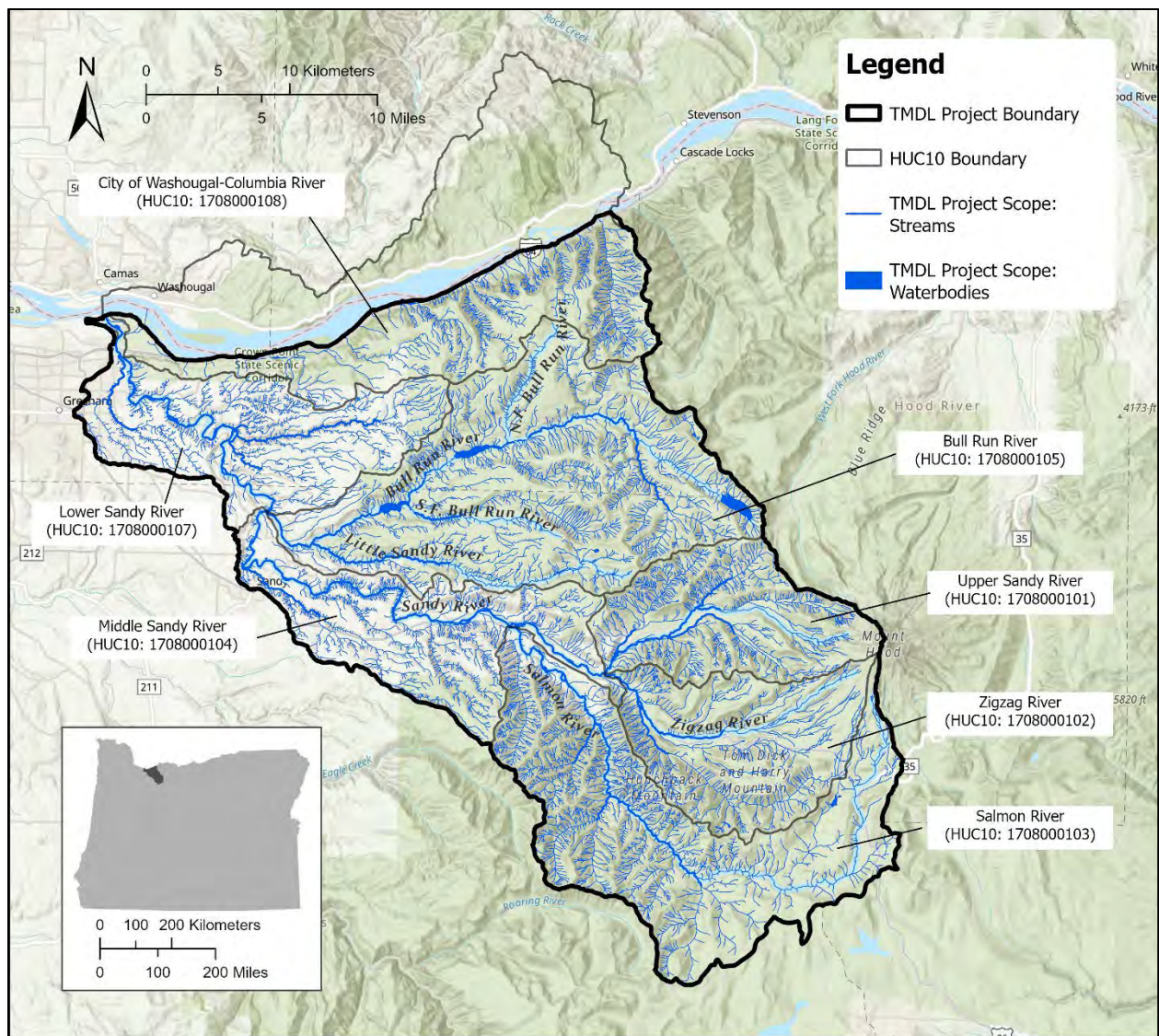


Figure 2-1: Lower Columbia-Sandy Subbasin temperature TMDLs project area overview.

Table 2-2 presents stream assessment units 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 Environmental Protection Agency on September 1, 2022. Status category designations are prescribed by Sections 305(b) and 303(d) of the Clean Water Act. Assessment units listed in Category 5 (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 on 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

Assessment Unit Name	Assessment Unit	Use Period
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

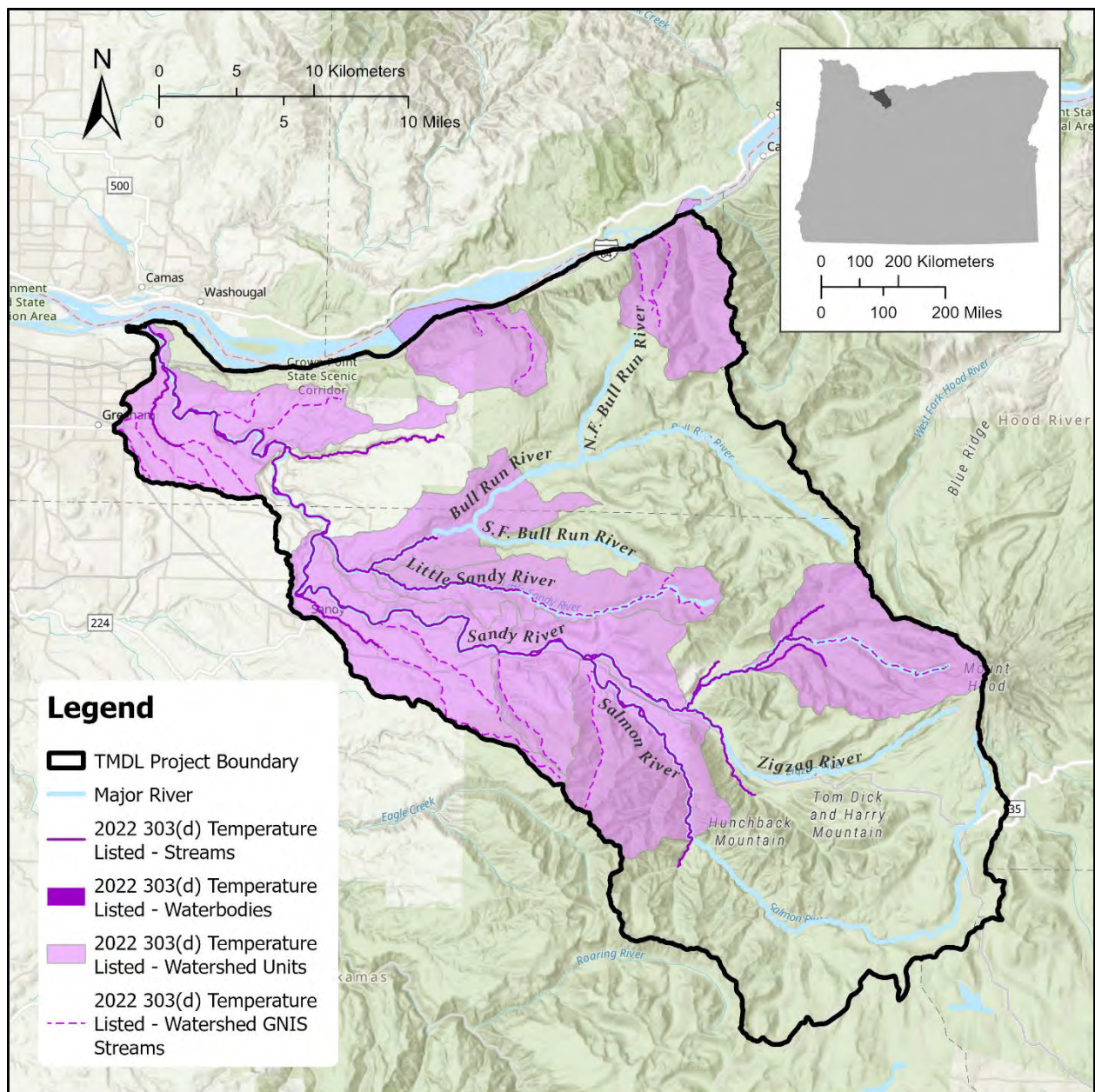


Figure 2-2: Lower Columbia-Sandy Subbasin Category 5 temperature impairments on the 2022 Integrated Report.

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 are 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 a surrogate measure 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 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 water, 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 are designed with the understanding that meeting water quality standards for the most sensitive beneficial uses will be 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 so as to maintain dissolved oxygen and overall water quality at the highest possible levels and <u>water temperatures</u> , 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°C - 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

Parameter	Rule Citation	Summary of applicable standards	Waters where standards apply	Most sensitive beneficial use
	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.		

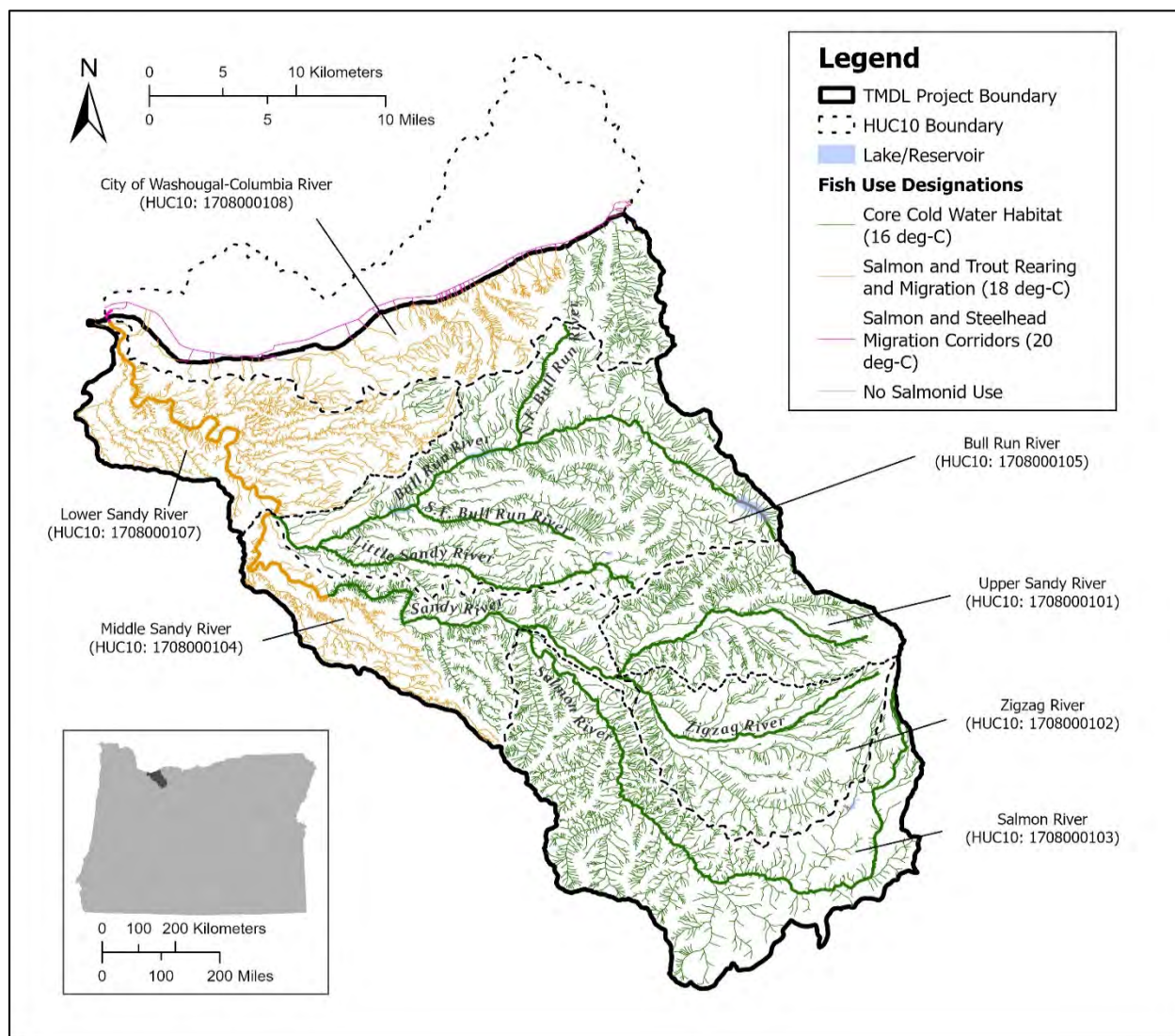


Figure 4-1: Fish use designations in the Lower Columbia-Sandy Subbasin temperature TMDL project area.

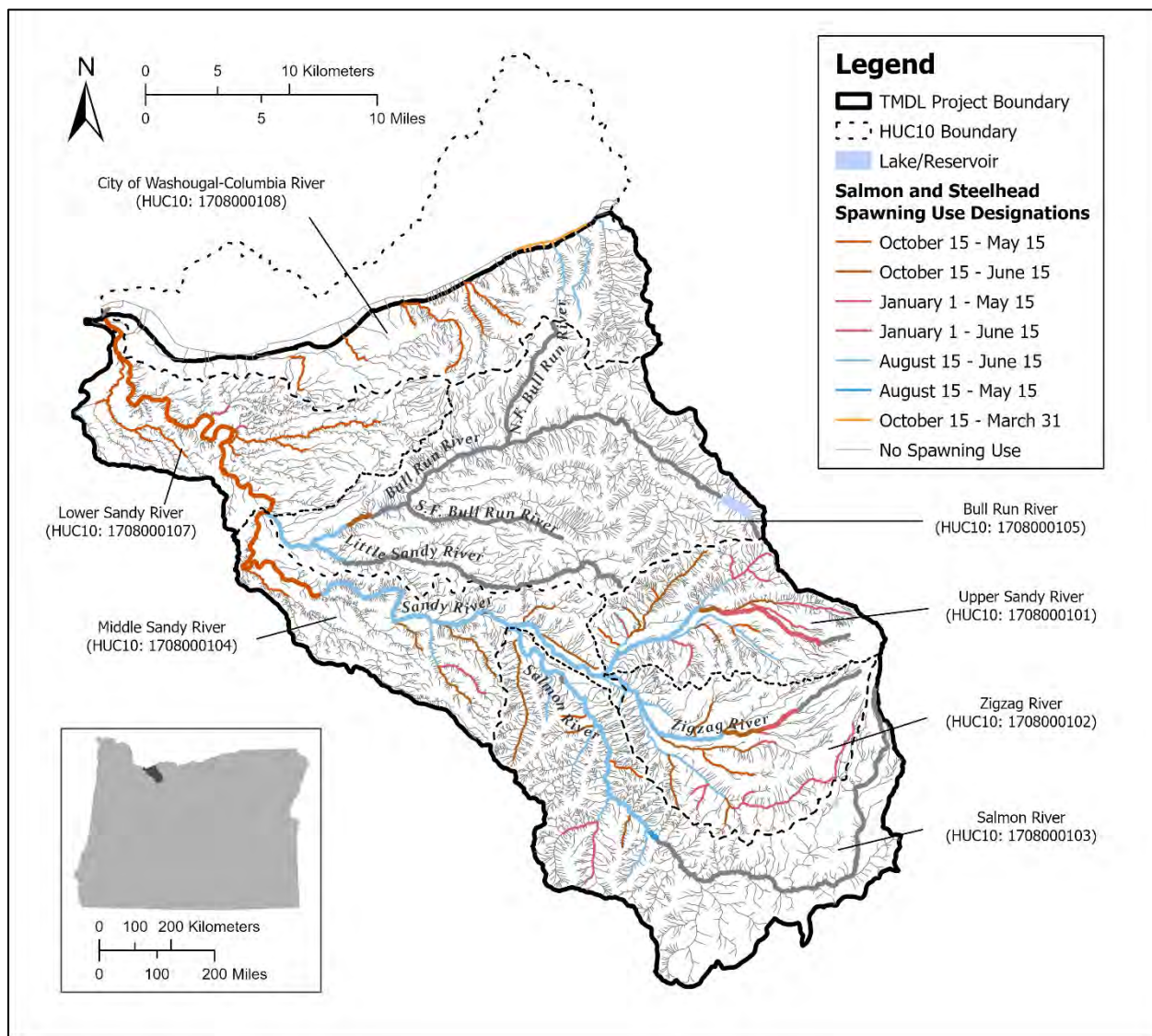


Figure 4-2: Salmon and steelhead spawning use designations in the Lower Columbia-Sandy Subbasin temperature TMDL project area.

5 Seasonal variation and critical period for temperature

Per OAR 340-042-0040(4)(j) and 40 Code of Federal Regulation 130.7(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 is 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 is determined based on when seven-day average daily maximum stream temperatures (7DADM) exceed the applicable temperature criteria. DEQ uses 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 have longer exceedance periods relative to upstream waters, the longer period is 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.

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 Technical Support Document summarizes the critical period approach and presents plots of 7DADM temperature data used to determine seasonal variation and the critical period.

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 loading capacity, 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 Technical Support Document model appendices.

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

1. Stream temperatures spanning months at $\leq 500\text{m}$ longitudinal resolution.
2. Solar radiation fluxes and daily effective shade at $\leq 100\text{m}$ 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.

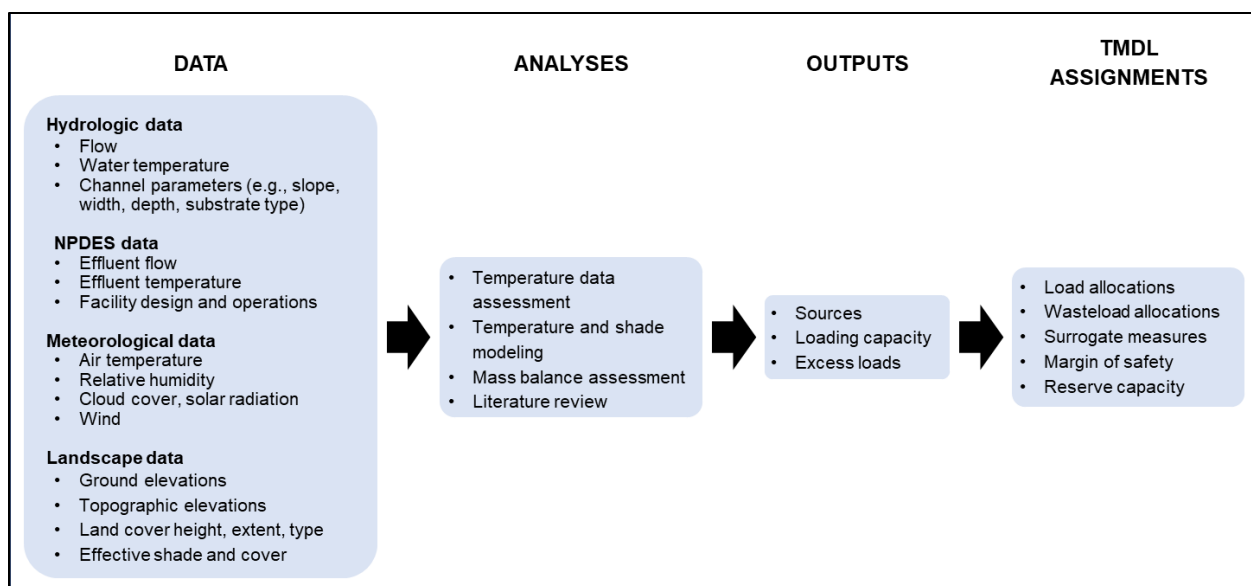


Figure 6-1: Lower Columbia-Sandy River Subbasin temperature analysis overview.

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 exceedances to the temperature standard.

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	1.3	2.15
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 0.36°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 exceedances to the temperature standard.

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 found that there is insufficient evidence to demonstrate that stormwater discharges authorized under this latter set of general permits (MS4 Phase II, Construction (1200-C), and Industrial (1200-A and 1200-Z)) contribute to temperature standard exceedances in the Lower Columbia-Sandy. This determination was based on a review of published literature and other studies related to stormwater runoff and stream temperature in Oregon.

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 a number of 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 impacts related to the surrogate measures. 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 were identified

as 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**.

$$LC = (T_C + HUA) \cdot Q_R \cdot C_F \quad \text{Equation 8-1}$$

where,

LC = Loading Capacity (kilocalories/day).

T_C = The applicable river temperature criterion ($^{\circ}\text{C}$).

HUA = The 0.3°C human use allowance allocated to point sources, nonpoint sources, margin of safety, or reserve capacity.
The daily mean river flow rate (cfs).

Q_R = When river flow is $\leq 7\text{Q}10$, $Q_R = 7\text{Q}10$. When river flow $> 7\text{Q}10$, 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

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

Equation 8-1 shall be used to calculate the thermal loading capacity for any surface water location in the Lower Columbia-Sandy Subbasin. Table 8-1 presents the loading capacities for select temperature-impaired Category 5 assessment units that have a current NPDES discharge within the assessment unit extent or that were modeled for the TMDL analysis. The loading capacities in Table 8-1 were calculated based on the 7Q10 low-flow. **Equation 8-1** may be used to calculate loading capacity when river flow is greater than 7Q10. **Equation 8-1** may also be used to calculate the loading capacity 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 ($^{\circ}\text{C}$)	Spawning Criterion + HUA ($^{\circ}\text{C}$)	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	20.4	16.3	13.3	813.57E+6	663.83E+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

Little Sandy River - Bow Creek to confluence with Bull Run River OR_SR_1708000105_11_103609	10.5	16.3	13.3	418.75E+6	341.68E+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	278.4	18.3	13.3	12,465.07E+6	9,059.32E+6
Sandy River - Clear Fork to Zigzag River OR_SR_1708000101_02_103599	50.3	18.3	13.3	2,252.13E+6	1,636.79E+6
Sandy River - Zigzag River to Bull Run River OR_SR_1708000104_02_103608	215.9	16.3	13.3	8,610.23E+6	7,025.53E+6
Zigzag River - Still Creek to confluence with Sandy River OR_SR_1708000102_02_103600	48.2	16.3	13.3	1,922.25E+6	1,568.46E+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 loading capacity 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 assessment unit 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 human use allowance. 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
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 allocations

The human use allowance discussion 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 9-11 present the assigned portion of the human use allowance to anthropogenic source categories across different streams and stream extents in the Lower Columbia-Sandy Subbasin. The assigned portion of the human use allowance represents the maximum cumulative warming anywhere in the waterbody and at the point of maximum impact 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 9-6. DEQ will implement the TMDL in a manner consistent with the human use allowance rule by requiring all nonpoint sources to implement management strategies and reduce their warming impact such that the assigned human use allowance is attained.

Table 9-1: Human use allowance allocations on the Sandy River from City of Troutdale WPCF outfall to the mouth.

Portion of Human Use Allowance (°C)	Source or source category
0.09*	NPDES point sources
0.09	Warming from tributaries
0.00	City of Portland Bull Run dam and reservoir operations

0.05	Water management activities and water withdrawals
0.04	Solar loading from existing transportation corridors, existing buildings, and existing utility infrastructure
0.00	Solar loading from other NPS sectors
0.03	Reserve capacity
0.30	Total
<p>Note: * NPDES permitted point sources are allowed up to 0.09°C cumulatively at the point of maximum impact on the Sandy River from the City of Troutdale WPCF outfall to the mouth. The portion of the human use allowance allocated to each point source at the point of discharge is identified in Table 9-7.</p>	

Table 9-2: Human use allowance allocations on the Sandy River from Bull Run River to upstream of the Troutdale WPCF outfall.

Portion of Human Use Allowance (°C)	Source or source category
0.05*	NPDES point sources
0.00	Warming from tributaries
0.01	City of Portland Bull Run dam and reservoir operations
0.05	Water management activities and water withdrawals
0.00	Solar loading from existing transportation corridors, existing buildings, and existing utility infrastructure
0.00	Solar loading from other NPS sectors
0.19	Reserve capacity
0.30	Total
<p>Note: * NPDES permitted point sources are allowed up to 0.05°C cumulatively at the point of maximum impact on the Sandy River from Bull Run River to just upstream of the City of Troutdale WPCF outfall. The portion of the human use allowance allocated to each point source at the point of discharge is identified in Table 9-7.</p>	

Table 9-3: Human use allowance allocations on the Sandy River from the headwaters to the Bull Run River.

Portion of Human Use Allowance (°C)	Source or source category
0.08*	NPDES point sources
0.21	Warming from tributaries
0.01	Water management activities and water withdrawals
0.00	Solar loading from existing transportation corridors, existing buildings, and existing utility infrastructure
0.00	Solar loading from other NPS sectors
0.00	Reserve capacity
0.30	Total
<p>Note: * NPDES permitted point sources are allowed up to 0.08°C cumulatively at the point of maximum impact on the Sandy River from the headwaters to the Bull Run River. The portion of the human use allowance allocated to each point source at the point of discharge is identified in Table 9-7.</p>	

Table 9-4: Human use allowance allocations on the Bull Run River.

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	Other anthropogenic nonpoint sources
0.00	Reserve capacity
0.30	Total

Table 9-5: Human use allowance allocations on Cedar Creek.

Portion of Human Use Allowance (°C)	Source or source category
0.30	ODFW Sandy River Fish Hatchery
0.00	Anthropogenic Nonpoint sources
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 human use allowance on Cedar Creek will be identical to those in Table 9-6.

Table 9-6: Human use allowance allocations on Camp Creek.

Portion of Human Use Allowance (°C)	Source or source category
0.20	Government Camp STP
0.05	Water management activities and water withdrawals
0.02	Solar loading from existing transportation corridors, existing buildings, and existing utility infrastructure
0.00	Other anthropogenic nonpoint source sectors
0.03	Reserve capacity
0.30	Total

Table 9-7: Human Use Allowance allocations 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
0.00	Dam and reservoir operations
0.05	Water management activities and water withdrawals
0.02	Solar loading from existing transportation corridors, existing buildings, and existing utility infrastructure
0.00	Solar loading from other nonpoint sectors
0.23	Reserve capacity
0.30	Total

9.1.2 Thermal wasteload allocations for point sources

Wasteload allocations are assigned to NPDES permitted point sources listed in Table 9-7. The wasteload allocation for registrants under the general stormwater permits (MS4, 1200-A, 1200-C and 1200-Z) and general permit registrants not identified in Table 9-7 is equal to any existing thermal load authorized under the current permit. For all general wastewater and stormwater NPDES permits, more precise wasteload allocations may be considered if subsequent data analysis indicates a need and capacity is available.

Wasteload allocations for the NPDES permitted point sources listed in Table 9-7 were calculated using **Equation 9-1**.

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

- (1) Incorporate the 7Q10-based wasteload allocation in Table 9-7 as a static numeric limit. Permit writers may recalculate the limit using **Equation 9-1** with different values for 7Q10 (Q_R), and effluent flow (Q_E), if better estimates are available
- (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 human use allowance (ΔT) is static and based on the value in Table 9-7.

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

Equation 9-1

where,

WLA = Wasteload allocation (kilocalories/day).

ΔT = The allocated portion of the human use allowance from Table 9-7. It is the maximum temperature increase ($^{\circ}\text{C}$) above the applicable river temperature criterion, using 100% of river flow, not to be exceeded by each individual source from all outfalls combined.

Q_E = The daily mean effluent flow rate (cfs).

When effluent flow is in million gallons per day (MGD) convert to cfs: 1.5472

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

Q_R = The daily mean river flow rate (cfs), upstream (of the NPDES discharge).

When river flow is \leq 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

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

NPDES permitted point sources discharging to the Sandy River are allowed up to 0.09 $^{\circ}\text{C}$ cumulatively at the point of maximum impact. Based on DEQ modeling, the point of maximum impact is located at the City of Troutdale WPCF's outfall (river km 2.15). Modeling described in the Technical Support Document, Appendix C, Section 5 shows that these allocations attain the cumulative allocation. Note that the maximum cumulative impact of all point sources at the point of maximum impact 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 wasteload allocation 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 instead relocated to another Sandy River reach, modeling will be required to ensure the wasteload allocation in Table 9-7 attains the 0.09°C point source cumulative human use allowance at the point of maximum impact, as presented in Table 9-1 and Table 9-2.

Table 9-7 provides two wasteload allocation 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 wasteload allocation option.

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

NPDES Permittee WQ File# : EPA Number	Allocated Human Use Allowance (°C)	WLA period start	WLA period end	Annual 7Q10 River flow (cfs)	Effluent discharge (cfs)	7Q10 WLA ¹ (kcal/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	0.06	5/1	10/31	278.4	4.6	41.54E+6
City of Sandy WWTP 78615 : OR0026573	0.05	5/1	10/31	215.9	1.9	26.64E+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	215.9	3.2	42.89E+6
¹ Listed WLAs were calculated based on the 7Q10 flow. Notes: Applicable criterion = Biologically-based numeric criteria WLA = wasteload allocation; kcal/day = kilocalories/day * When the minimum duties provision at OAR 340-041-0028(12)(a) applies, ODFW Sandy River Fish Hatchery ΔT = 0.0 and the WLA = 0 kilocalories/day. Minimum duties provision does not apply under WLA Option B.						

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. Load allocations apply May 1 through October 31 on all waters except the Bull Run River and in the Beaver Creek-Sandy Subwatershed (HUC 170800010703). On the Bull Run River, load allocations apply May 1 through November 15. Load allocations apply March 15 through November 15 in the Beaver Creek-Sandy Subwatershed.

Load allocations for background sources are calculated using Equation 9-2.

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

where,

- LA_{BG} = Load allocation to background sources (kilocalories/day).
 The applicable temperature criteria, not including the human use allowance.
- T_C = 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).
 Conversion factor using flow in cubic feet per second (cfs): 2,446,665
- C_F = $\left(\frac{1 \text{ m}}{3.2808 \text{ ft}}\right)^3 \cdot \frac{1000 \text{ kg}}{1 \text{ m}^3} \cdot \frac{86400 \text{ sec}}{1 \text{ day}} \cdot \frac{1 \text{ kcal}}{1 \text{ kg} \cdot 1^\circ\text{C}} = 2,446,665$

Table 9-8 presents the 7Q10-based load allocations for background sources on temperature-impaired Category 5 assessment units that (a) have current NPDES discharge(s) within the assessment unit extent, and/or (b) were modeled for the TMDL analysis. The load allocations are based on the 7Q10 low river flows and the minimum year-round applicable criterion when two year-round applicable temperature criteria apply to the same assessment unit. Equation 9-2 shall be used to calculate the load allocations assigned to background sources on all other assessment units or stream location in the Lower Columbia-Sandy Subbasin not identified in Table 9-8, or for assessment units identified in Table 9-8 when river flows are greater than 7Q10.

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

Table 9-9: 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	20.4	16.0	13.0	5/1	11/15	798.59E+6	648.86E+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	10.5	16.0	13.0	5/1	10/31	411.04E+6	333.97E+6
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	278.4	18.0	13.0	5/1	10/31	12,260.73E+6	8,854.97E+6
Sandy River - Clear Fork to Zigzag River OR_SR_1708000101_02_103599	50.3	18.0	13.0	5/1	10/31	2,215.21E+6	1,599.87E+6
Sandy River - Zigzag River to Bull Run River OR_SR_1708000104_02_103608	215.9	16.0	13.0	5/1	10/31	8,451.76E+6	6,867.05E+6
Zigzag River - Bow Creek to confluence with Bull Run River OR_SR_1708000102_02_103600	48.2	16.0	13.0	5/1	10/31	1,886.87E+6	1,533.08E+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.

Load allocations assigned to anthropogenic nonpoint sources on any assessment unit or stream location in the Lower Columbia-Sandy Subbasin are calculated using **Equation 9-3**. The portions of the human use allowance (ΔT) assigned to nonpoint source categories are presented in Table 9-1 through Table 9-6.

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

where,

LA_{NPS} = Load allocation to anthropogenic nonpoint sources (kilocalories/day).
The portion of the human use allowance assigned to each nonpoint source category representing the maximum cumulative temperature increase ($^{\circ}\text{C}$) from all source activity in the nonpoint source category. When the minimum duties provision at OAR 340-041-0028(12)(a) applies, $\Delta T = 0.0$.

ΔT =

Q_R = The daily average river flow rate (cfs).
Conversion factor using flow in cubic feet per second (cfs): 2,446,665

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

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 load allocations.

9.1.4.1 Dam and reservoir operations

Dam and reservoir operations in the Lower Columbia-Sandy have been allocated a portion of the human use allowance as presented in Table 9-1 through Table 9-7 and the equivalent load allocation as calculated using Equation 9-2. Monitoring stream temperature, rather than a thermal load, is easier and a more meaningful approach for 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 load allocation for dam and reservoir operations. The minimum duties provision in rule at OAR 340-042-0028(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 dam and reservoir operations, the minimum duties provision is implemented when 7DADM temperatures upstream of the reservoirs exceed the applicable temperature criteria, the dam and reservoir operations must not contribute any additional warming above and beyond those upstream temperatures entering the reservoir. DEQ has developed the following surrogate measure temperature approach to implement the load allocation. 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. With DEQ approval, the estimated free flowing (no dam) temperatures may also be calculated using a model to account for any warming or cooling that would occur through the

reservoir reaches absent the dam and reservoir operations and applied as the temperature surrogate measure.

- b) On days the surrogate measure calculated or measured under item a) is cooler than the most restrictive applicable temperature criteria anywhere in the assessment unit immediately downstream of the dam, the surrogate 7DADM temperature may be no warmer than the applicable criteria when all of the following are true:
 - I. The protecting cold water criterion at OAR 340-041-0028(11) does not apply;
 - II. DEQ approves a cumulative effects analysis demonstrating release temperatures warmer than the cooler ambient temperatures will not increase downstream 7DADM temperatures more than the portion of the HUA allocated to the dam and reservoir above the applicable criteria.

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 isn't 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 0.3 °C of the human use allowance (Table 9-4) and the equivalent load allocation on the Bull Run River as calculated using Equation 9-2. In the Sandy River, warming from the dam and reservoirs has been assigned 0.01°C of the human use allowance (Table 9-2), and zero downstream of Troutdale WPCF outfall (Table 9-1).

A temperature data analysis and model based cumulative effects analysis were completed for the TMDL analysis. DEQ used the model to estimate the free flow dam temperatures and assess the surrogate measure temperature target. Based on this analysis, DEQ has determined that release temperatures below the most restrictive applicable criteria but warmer than ambient temperatures will not increase downstream 7DADM temperatures more than the portion of human use allowance assigned to the Bull Run project. This assumes free flowing conditions and attainment of the surrogate measure temperature target.

The transition to the 13°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 Reservoir #2 is:

- a) The estimated free flowing (no dam) 7DADM temperatures at the lamprey barrier as calculated using **Equation 9-3**; 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 June 16 - August 14
 - II. 13.3°C May 1 - June 15 and August 15 - 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 9-3**) 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 Technical Support Document. With DEQ approval, an alternative approach may be used to calculate the free flowing no dam temperatures.

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

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 listed in Table 9-11, the effective shade surrogate measure values (current and target) are the means across all model nodes assigned to that designated management agency (**Equation 9-4**). **Equation 9-4** may be used to recalculate the mean effective shade values if designated management agency boundaries change or need correction. **Equation 9-4** 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 Water Quality Management Plan 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, human use allowance, or the load allocations. They remain the same as presented in this TMDL.

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

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 9-12: Shade surrogate measure targets to meet nonpoint source load allocations on model stream extents.

Designated Management Agency	Stream Name	Current Shade (%)	TMDL Target (%)	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	24	37	13
Oregon Department of Forestry - Private	Salmon River	26	40	14
U.S. Bureau of Land Management	Salmon River	26	35	9
U.S. Forest Service	Salmon River	49	59	10
City of Portland	Sandy River	10	13	3
City of Sandy	Sandy River	24	25	1
City of Troutdale	Sandy River	15	20	5
Clackamas County	Sandy River	18	28	10
Multnomah County	Sandy River	16	19	3
Oregon Department of Agriculture	Sandy River	24	29	5
Oregon Department of Fish and Wildlife	Sandy River	22	26	4
Oregon Department of Forestry - Private	Sandy River	19	24	5
Oregon Parks and Recreation Department	Sandy River	6	8	2
Port of Portland	Sandy River	3	9	6
State of Oregon	Sandy River	13	18	5
U.S. Bureau of Land Management	Sandy River	25	29	4
U.S. Forest Service	Sandy River	3	7	4
U.S. Government	Sandy River	16	17	1

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 9.1.2.1.2). Effective shade curves represent the maximum possible effective shade for a given vegetation type. The values presented in Figure 9-1 to Figure 9-8 and Table 14-1 to Table 14-8 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 Technical Support Document, Appendix B for the methodology used to calculate shade curves.

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 9-13: 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)
348	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
600	Hardwood - High Density	20.1	65.9	75	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 <td 30	3.5	36.8	
800	Shrubs – High Density	1.8	5.9	75	0.0	36.8
850	Shrubs – Low Density	1.8	5.9	25	0.0	36.8
950	Grasses/Shrubs - Wetlands	1.6	5.3	75	0.8	36.8

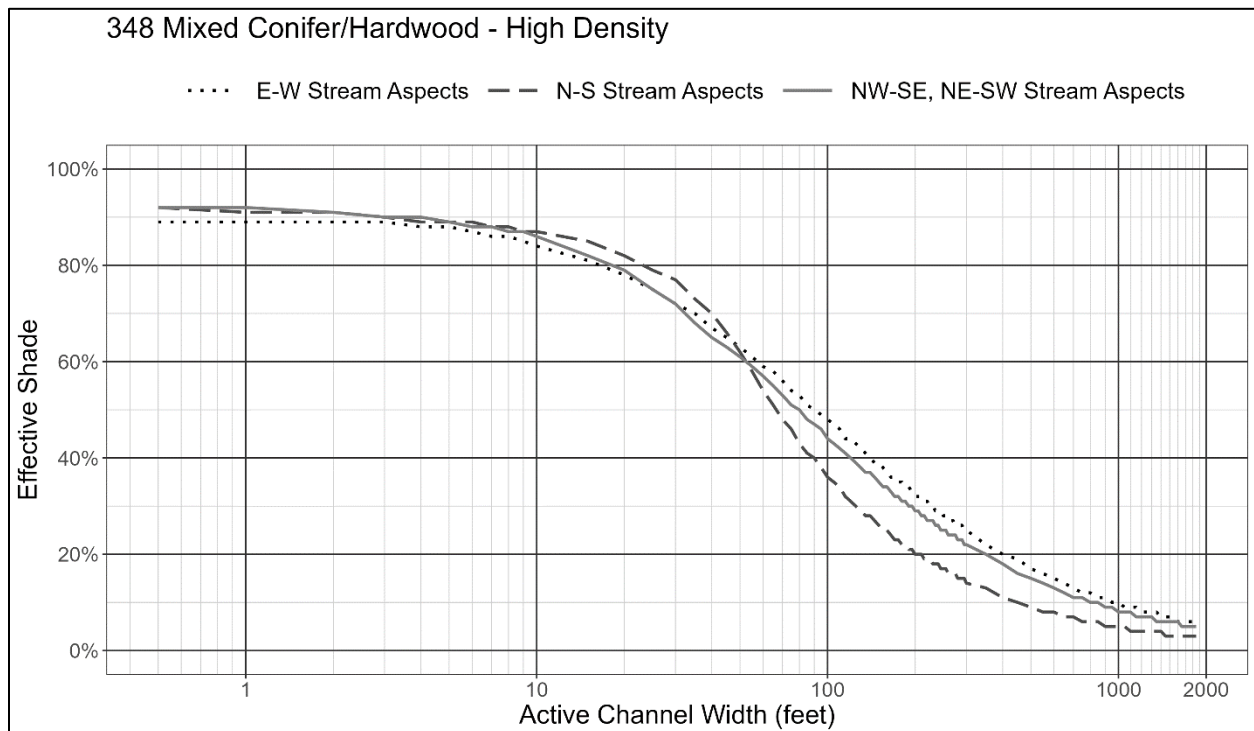


Figure 9-1: Effective shade targets for high density mixed conifer and hardwood stream sites.

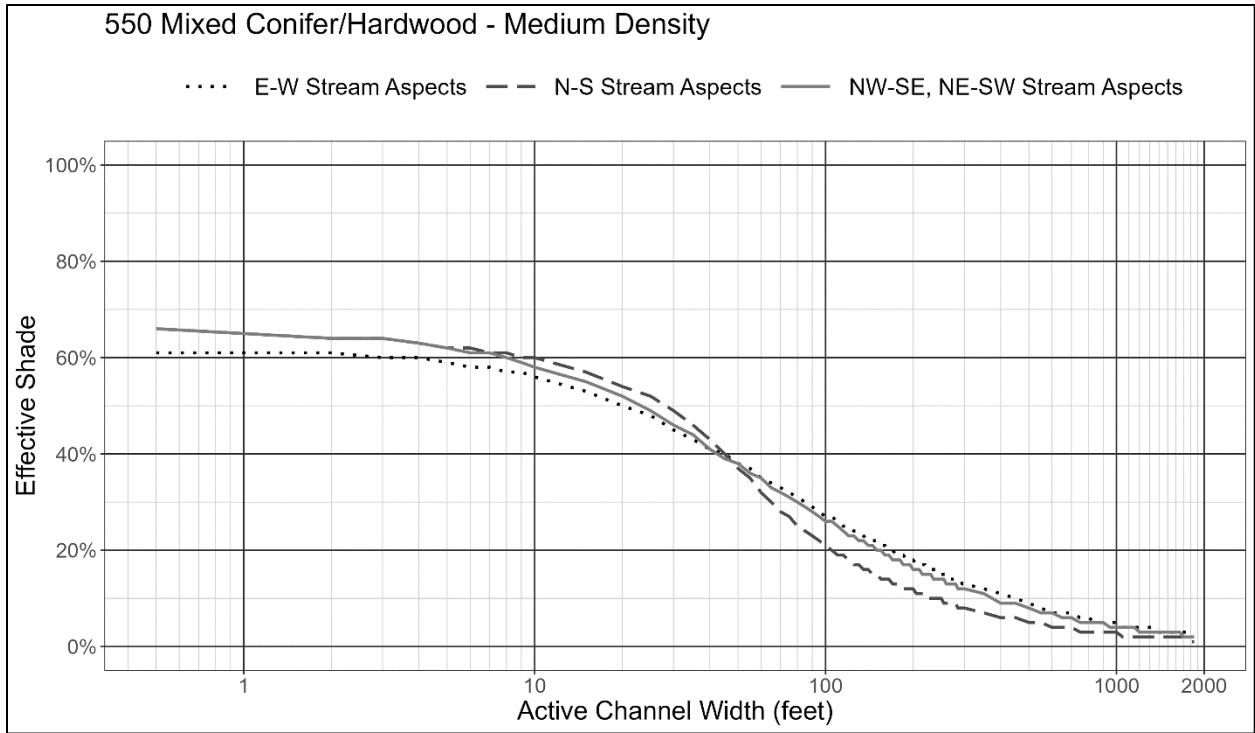


Figure 9-2: Effective shade targets for medium density mixed conifer and hardwood stream sites.

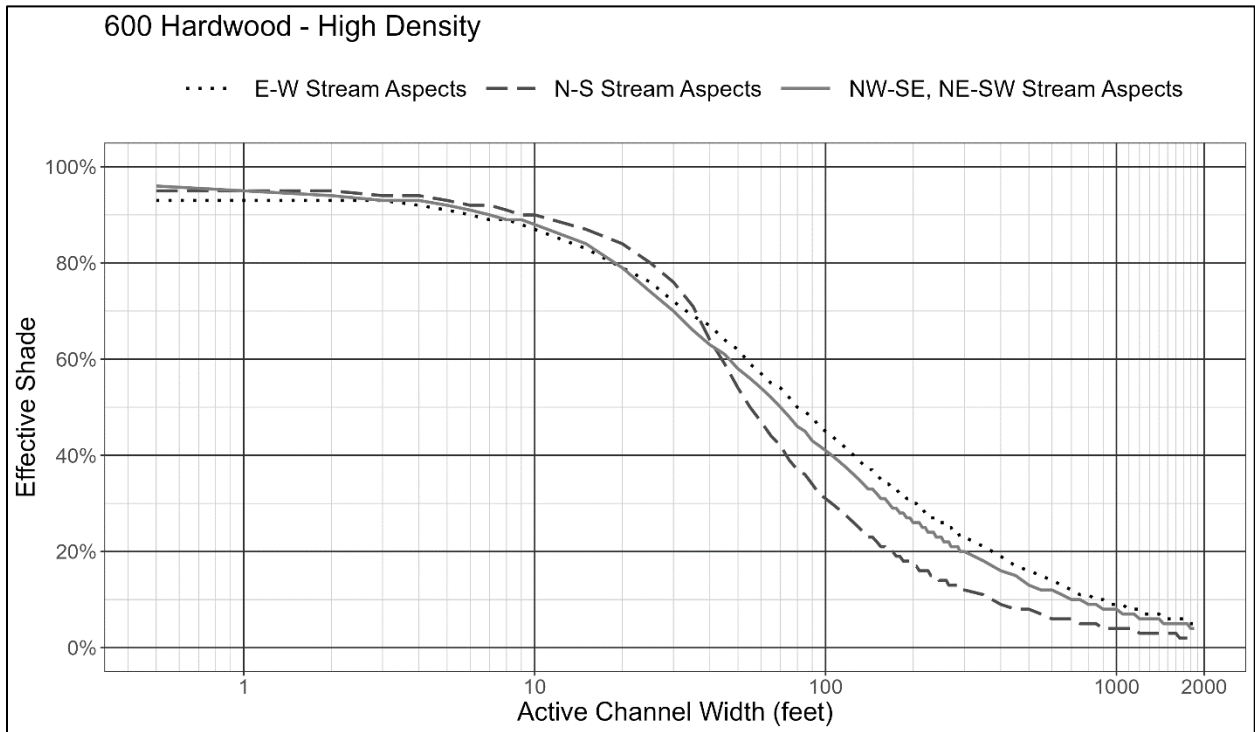


Figure 9-3: Effective shade targets for high density hardwood dominated stream sites.

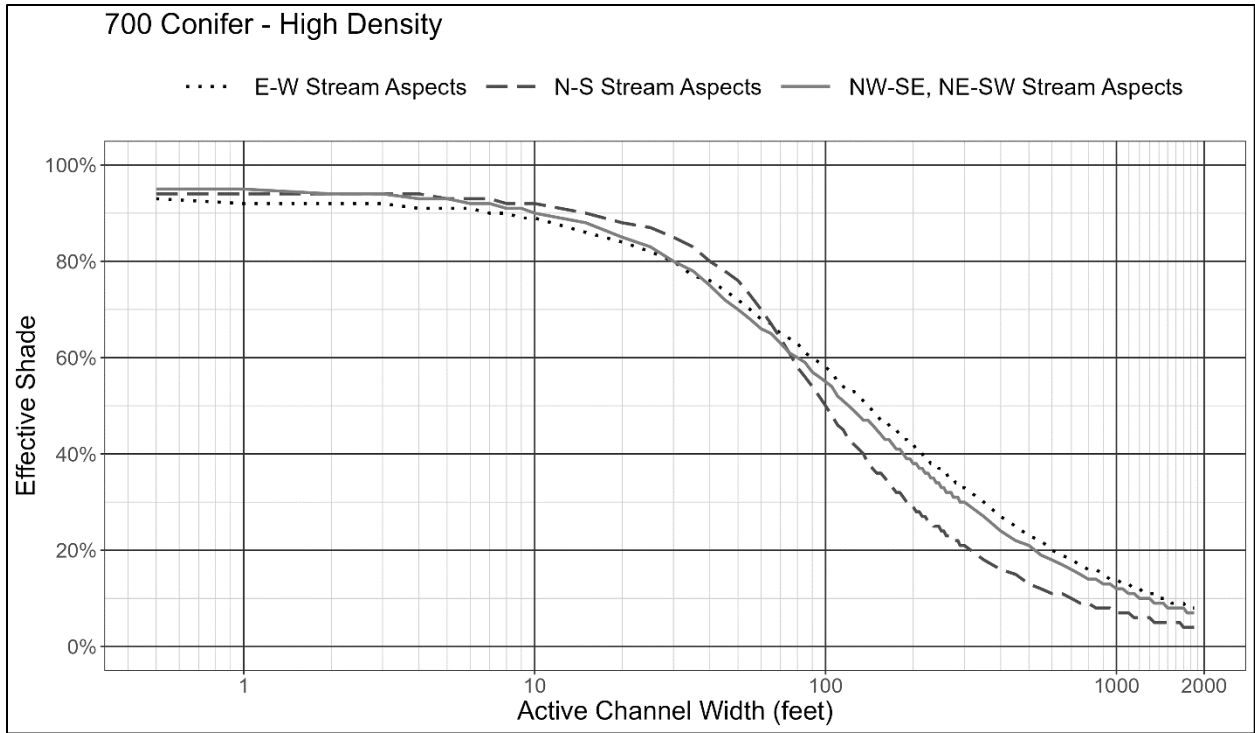


Figure 9-4: Effective shade targets for high density conifer dominated stream sites.

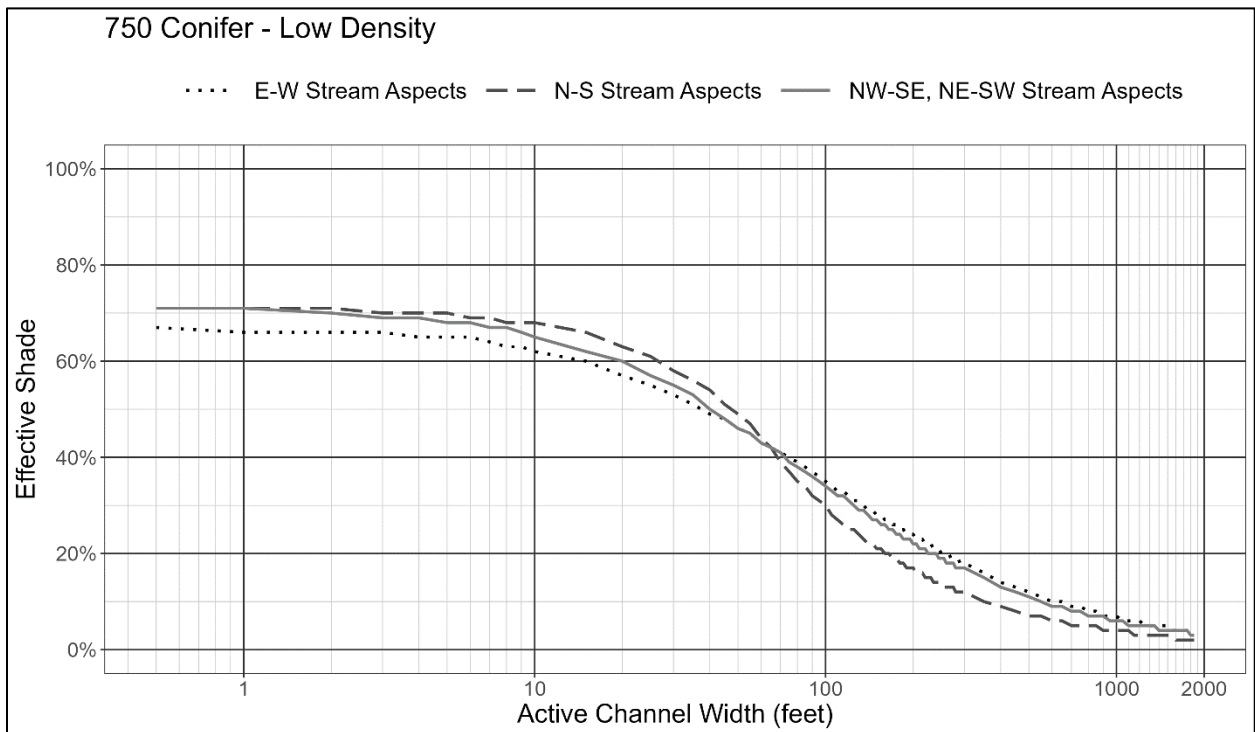


Figure 9-5: Effective shade targets for low density conifer dominated stream sites.

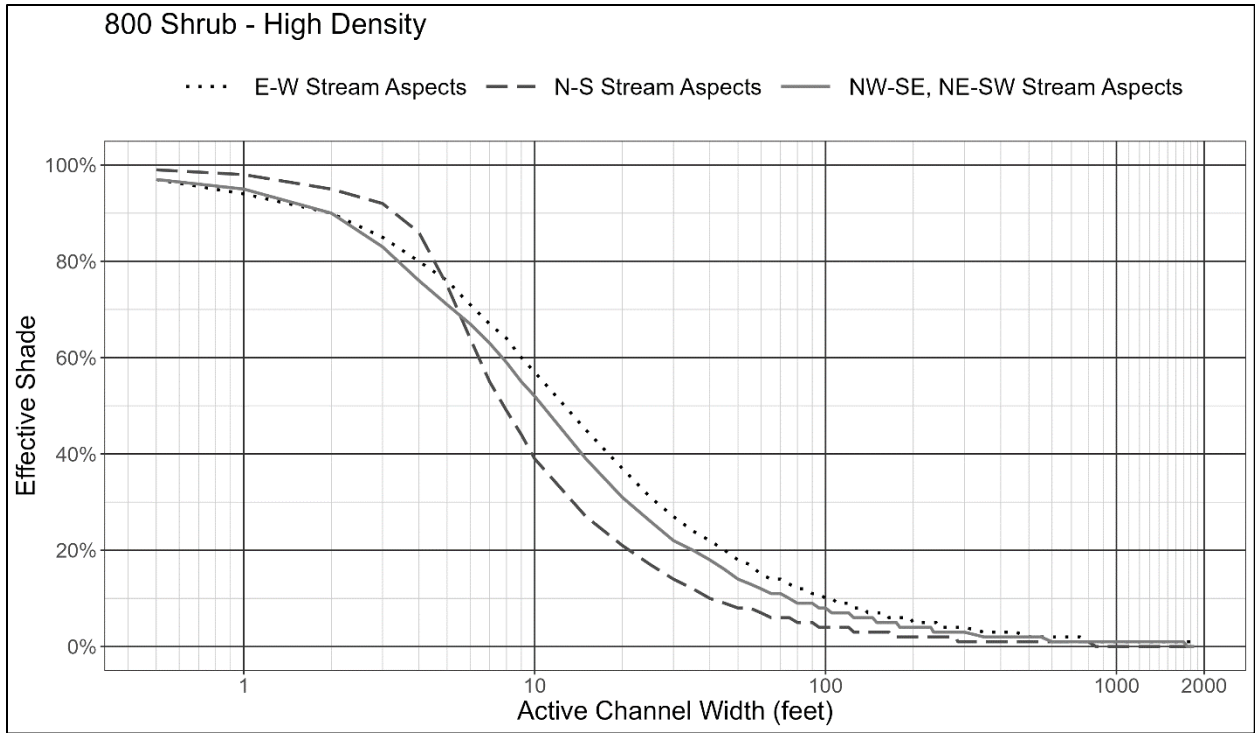


Figure 9-6: Effective shade targets for high density shrub sites.

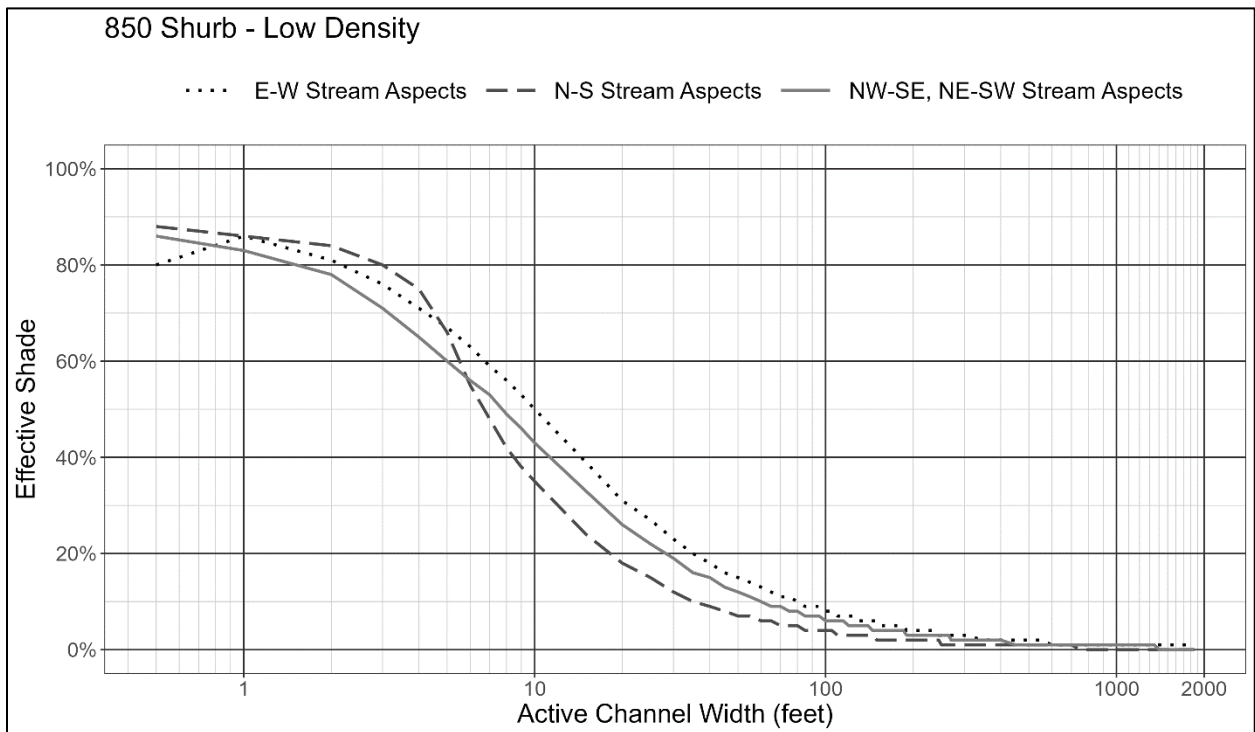


Figure 9-7: Effective shade targets for low density shrub sites.

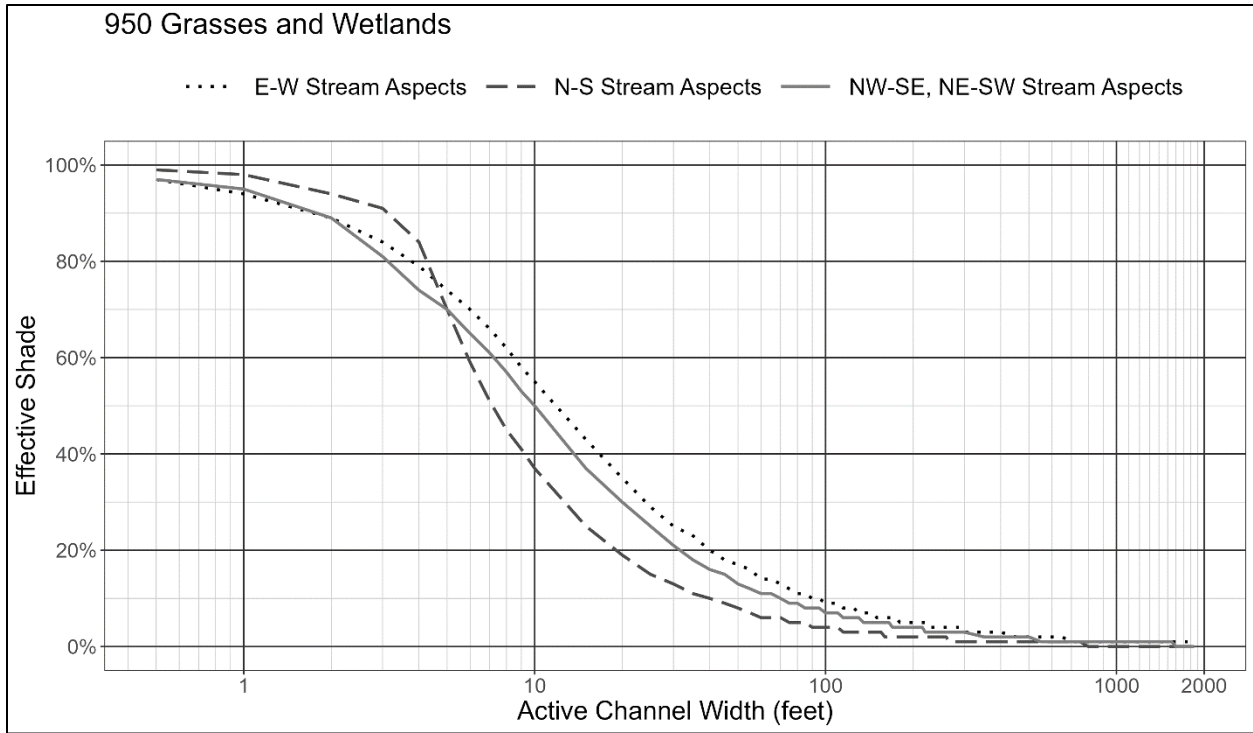


Figure 9-8: Effective shade targets for grass or wetland stream sites.

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 human use allowance as presented in Table 9-1 through Table 9-5 and the equivalent load allocation as calculated using Equation 9-2. For most streams, the portion of the human use allowance allocated is 0.05°C. DEQ completed modeling to estimate the percent consumptive uses 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 was based on the monthly median natural flow.

Table 9-14: Target percent consumptive use flow rate 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 reserve capacity for providing 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 human use allowance associated with the reserve capacity is described in Table 9-1 through Table 9-7. The thermal load associated with allocations of reserve capacity is calculated using Equation 9-1 for point sources and Equation 9-2 for nonpoint sources. Allocations from reserve capacity apply May 1 through October 31 on all waterbodies except the Bull Run River and in the Beaver Creek-Sandy Subwatershed (HUC 170800010703). On the Bull Run River, allocations from reserve capacity apply May 1 through November 15. Allocations from reserve capacity apply March 15 through November 15 in the Beaver Creek-Sandy Subwatershed (HUC 170800010703).

DEQ will consider requests for allocation of reserve capacity submitted in writing on a case-by-case basis. Except when DEQ is correcting an error or omission, requesters must demonstrate that there are no reasonable alternatives to an increased load and may be required to prepare a modeling or similar analysis to ensure that loading capacity is available at the discharge location(s). 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 reserve capacity over time and will not approve requests once reserve capacity is depleted. Allocations of reserve capacity 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 a margin of safety. The margin of safety 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 the actual effect controls will have on loading reductions and the receiving stream. The margin of safety is intended to account for such uncertainties in a manner that is conservative and will result in water quality protection. A margin of safety 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 a margin of safety.

In the Lower Columbia-Sandy, an implicit margin of safety was used in derivation of the allocations. The primary conservative assumptions include:

- Setting effluent flow rates at average dry weather design flow or a maximum flow obtained from discharge monitoring reports for the model scenario assessing the wasteload allocations. It is rare that actual discharges from point sources will reach design flows and sustain that discharge for long periods of time all at the same time.
- Setting effluent temperatures as high as 32°C for the model scenario assessing the wasteload allocations. On days when the current thermal load was less than the wasteload allocation, the maximum effluent temperatures were increased above the actual temperatures up to either 32°C or the effluent temperature that would fully utilize the wasteload allocation. Actual maximum effluent temperatures are unlikely to be this warm or be sustained over multiple days or weeks.
- The cumulative effects analysis used the maximum increase as the basis for assigning and determining attainment of allocations. The maximum increase occurs less than 5% of the time and the median increase is less. The maximum increase is geographically limited and focused to distinct locations. This means that a portion of the loading capacity reserved for

human use over the majority of the waters of the Lower Columbia-Sandy Subbasin will go unutilized most of the time.

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 Designated Management Agencies, 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 designated management agencies, responsible for TMDL implementation and other interested public and prepared the Lower Columbia-Sandy Subbasin WQMP as a stand-alone document. DEQ intends to propose the draft WQMP as an element of Temperature TMDLs for the Lower Columbia-Sandy Subbasin for adoption as rule by the Oregon Environmental Quality Commission.

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 (USEPA 1991). Comprehensive explanations of reasonable assurances of implementation are provide in Section 7 of the Lower Columbia-Sandy Subbasin Water Quality Management Plan.

12 Protection plan

The scope of these temperature TMDLs includes all 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, whether those waters are assessed or unassessed. 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 is 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 and 2023b), are fulfilled by the statements and references to specific sections of the TMDLs, WQMP and TMDL Technical Support Document in the subsections that follow.

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

Table 3.1 lists all the assessments units within the watershed with 2022 Integrated Report assessment status of Category 5. Those assessment units with the status of Category 2, Category 3 or unassessed 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 Technical Support Document provides a list of all assessment units 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 TMDLs 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 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 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

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14 Appendix of effective shade curve tables

Table 1414-1: Effective shade targets for high density mixed conifer and hardwood dominated stream sites (code 348).

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S 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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
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
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
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
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 1414-2: 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 E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S 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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
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
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
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
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
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
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 1414-3: Effective shade targets for high density hardwood dominated stream sites (code 600).

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S 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
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
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
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
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
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 1414-4: Effective shade targets for high density conifer dominated stream sites (code 700).

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S 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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
1.2	4	91	93	94
1.5	5	91	93	93
1.8	6	91	92	93
2.1	7	90	92	93
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
57.9	190	43	39	30
59.4	195	42	39	30
61	200	42	38	29
62.5	205	41	38	28
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
396.2	1300	11	10	6
411.5	1350	11	9	5
426.7	1400	10	9	5
442	1450	10	9	5
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 14-5: Effective shade targets for low density conifer dominated stream sites (code 750).

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S 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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
24.4	80	39	38	35
25.9	85	38	37	34
27.4	90	37	36	32
29	95	36	35	31
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
88.4	290	18	17	12
89.9	295	18	17	12
91.4	300	18	17	12
106.7	350	16	15	10
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 1414-6: Effective shade targets for high density shrub dominated stream sites (code 800).

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
0.2	0.5	97	97	99
0.3	1	94	95	98

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
0.6	2	90	90	95
0.9	3	85	83	92
1.2	4	80	76	86
1.5	5	76	71	75
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
54.9	180	6	4	2
56.4	185	6	4	2
57.9	190	6	4	2
59.4	195	6	4	2
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

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
365.8	1200	1	1	0
381	1250	1	1	0
396.2	1300	1	1	0
411.5	1350	1	1	0
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 1414-7: Effective shade targets for low density shrub dominated stream sites (code 850).

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
0.2	0.5	80	86	88
0.3	1	86	83	86
0.6	2	81	78	84
0.9	3	76	71	80
1.2	4	71	65	75
1.5	5	67	60	66
1.8	6	63	56	55
2.1	7	59	53	48
2.4	8	56	49	42
2.7	9	53	46	38
3	10	50	43	35
4.6	15	39	33	24
6.1	20	31	26	18
7.6	25	27	22	15
9.1	30	23	19	12
10.7	35	20	16	10
12.2	40	18	15	9
13.7	45	16	13	8
15.2	50	15	12	7
16.8	55	14	11	7
18.3	60	13	10	6
19.8	65	12	9	6

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
21.3	70	11	9	5
22.9	75	11	8	5
24.4	80	10	8	5
25.9	85	9	7	4
27.4	90	9	7	4
29	95	9	7	4
30.5	100	8	6	4
32	105	8	6	4
33.5	110	7	6	3
35.1	115	7	6	3
36.6	120	7	5	3
38.1	125	7	5	3
39.6	130	6	5	3
41.1	135	6	5	3
42.7	140	6	5	3
44.2	145	6	4	3
45.7	150	6	4	2
47.2	155	5	4	2
48.8	160	5	4	2
50.3	165	5	4	2
51.8	170	5	4	2
53.3	175	5	4	2
54.9	180	5	4	2
56.4	185	5	4	2
57.9	190	4	3	2
59.4	195	4	3	2
61	200	4	3	2
62.5	205	4	3	2
64	210	4	3	2
65.5	215	4	3	2
67.1	220	4	3	2
68.6	225	4	3	2
70.1	230	4	3	2
71.6	235	4	3	2
73.2	240	4	3	2
74.7	245	3	3	2
76.2	250	3	3	1
77.7	255	3	3	1
79.2	260	3	3	1
80.8	265	3	3	1
82.3	270	3	2	1
83.8	275	3	2	1

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
85.3	280	3	2	1
86.9	285	3	2	1
88.4	290	3	2	1
89.9	295	3	2	1
91.4	300	3	2	1
106.7	350	2	2	1
121.9	400	2	2	1
137.2	450	2	1	1
152.4	500	2	1	1
167.6	550	2	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	1	0
381	1250	1	1	0
396.2	1300	1	1	0
411.5	1350	1	1	0
426.7	1400	1	0	0
442	1450	1	0	0
457.2	1500	1	0	0
472.4	1550	1	0	0
487.7	1600	1	0	0
502.9	1650	1	0	0
518.2	1700	1	0	0
533.4	1750	1	0	0
548.6	1800	0	0	0
563.9	1850	0	0	0

Table 1414-8: Effective shade targets for grass and wetland dominated stream sites (code 950).

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
0.2	0.5	97	97	99
0.3	1	94	95	98
0.6	2	89	89	94
0.9	3	84	81	91
1.2	4	79	74	84
1.5	5	74	70	70
1.8	6	70	65	59
2.1	7	66	61	51
2.4	8	62	57	45
2.7	9	58	53	41
3	10	55	50	37
4.6	15	43	37	25
6.1	20	35	30	19
7.6	25	29	25	15
9.1	30	25	21	13
10.7	35	23	18	11
12.2	40	20	16	10
13.7	45	18	15	9
15.2	50	17	13	8
16.8	55	16	12	7
18.3	60	14	11	6
19.8	65	14	11	6
21.3	70	13	10	6
22.9	75	12	9	5
24.4	80	11	9	5
25.9	85	11	8	5
27.4	90	10	8	4
29	95	10	8	4
30.5	100	9	7	4
32	105	9	7	4
33.5	110	9	7	4
35.1	115	8	6	3
36.6	120	8	6	3
38.1	125	8	6	3
39.6	130	7	6	3
41.1	135	7	5	3
42.7	140	7	5	3
44.2	145	7	5	3
45.7	150	6	5	3
47.2	155	6	5	3

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
48.8	160	6	5	2
50.3	165	6	5	2
51.8	170	6	4	2
53.3	175	6	4	2
54.9	180	5	4	2
56.4	185	5	4	2
57.9	190	5	4	2
59.4	195	5	4	2
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	3	2
68.6	225	4	3	2
70.1	230	4	3	2
71.6	235	4	3	2
73.2	240	4	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	1
82.3	270	4	3	1
83.8	275	4	3	1
85.3	280	4	3	1
86.9	285	4	3	1
88.4	290	4	3	1
89.9	295	3	3	1
91.4	300	3	3	1
106.7	350	3	2	1
121.9	400	3	2	1
137.2	450	2	2	1
152.4	500	2	2	1
167.6	550	2	1	1
182.9	600	2	1	1
198.1	650	2	1	1
213.4	700	1	1	1
228.6	750	1	1	1
243.8	800	1	1	0
259.1	850	1	1	0
274.3	900	1	1	0
289.6	950	1	1	0

Active Channel Width (m)	Active Channel Width (feet)	Effective Shade Target for E-W Stream Aspects (%)	Effective Shade Target for NW-SE, NE-SW Stream Aspects (%)	Effective Shade Target for N-S Stream Aspects (%)
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
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	0	0
502.9	1650	1	0	0
518.2	1700	1	0	0
533.4	1750	1	0	0
548.6	1800	1	0	0
563.9	1850	1	0	0