CHAPTER 8: NORTH SANTIAM SUBBASIN TMDL

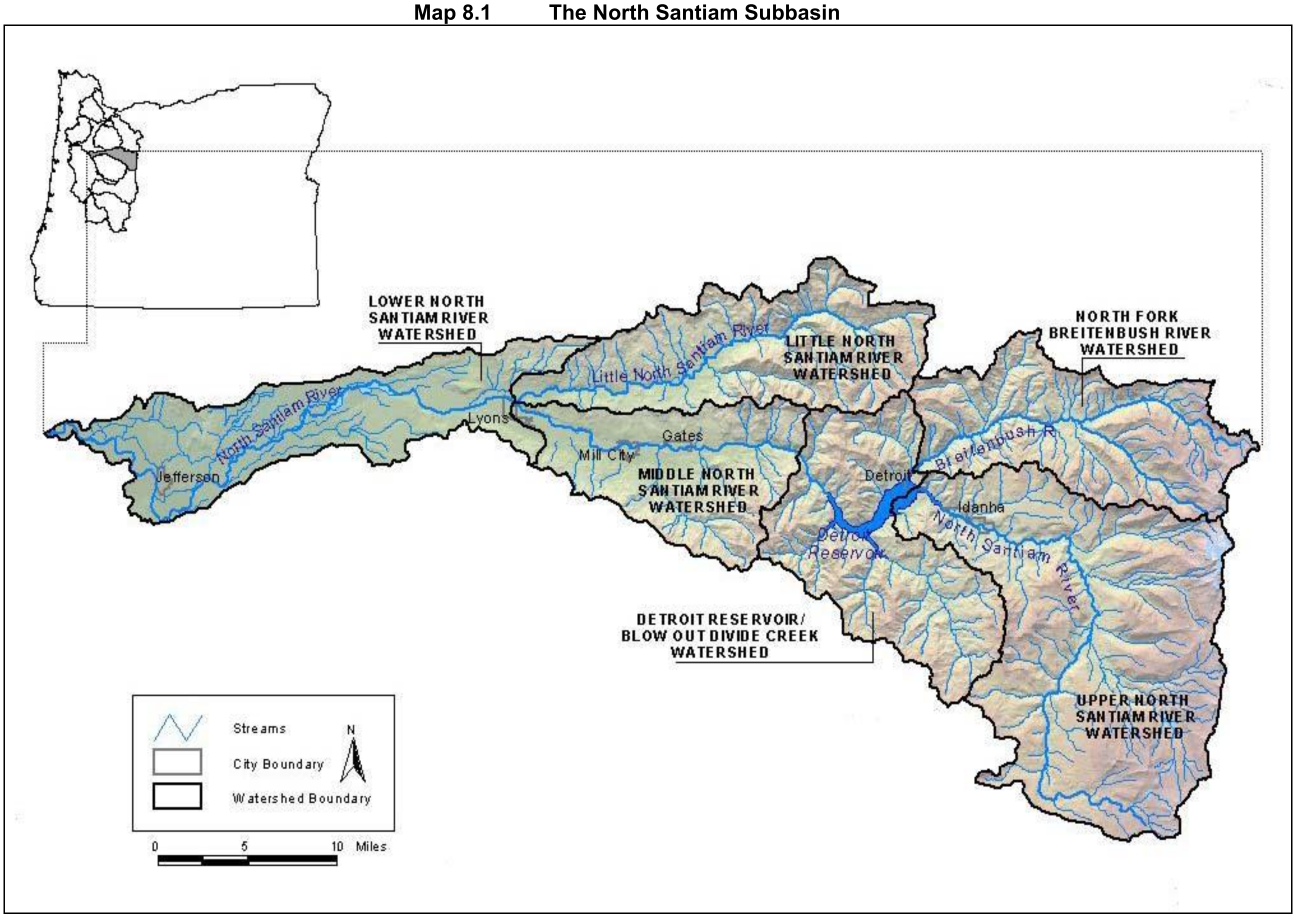
TABLE OF CONTENTS

WATER QUALITY SUMMARY

Reason for action

The North Santiam Subbasin (Map 8.1) has stream segments listed under section 303(d)[1] of the federal Clean Water Act (CWA) that are exceeding water quality criteria for temperature and dissolved oxygen. Total Maximum Daily Loads (TMDLs) for temperature are developed based on information for this parameter. Wasteload allocations are developed for individual facilities (point sources) that discharge during the critical period. Load allocations for nonpoint sources are developed for each geomorphic unit and apply to all sectors in the subbasin.

Map 8.1 The North Santiam Subbasin



This chapter only includes TMDLs for rivers and streams in the North Santiam Subbasin. These subbasin rivers and streams are tributary to the North Santiam and Santiam Rivers. For the North Santiam River from the mouth to Detroit Reservoir (River Mile 49) and the Santiam River, the temperature analysis is included in the mainstem Willamette River TMDLs, see Chapter 4. All other subbasin TMDLs are included in Chapters 5 – 13.

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[1] The 303(d) list is a list of stream segments that do not meet water quality criteria.

Water Quality 303(d) Listed Waterbodies
OAR 340-042-0040(4)(a)

All current 303(d) listings for the North Santiam Subbasin are presented in Table 8.1.

Table 8.1 Name and location of listed North Santiam Subbasin waterbodies.

Waterbody Name	River Mile	Parameter	Season	TMDL
Bear Branch	0 to 9.8	Temperature	Summer	Chapter 8
Blowout Creek	0 to 11.9	Temperature	Summer	Chapter 8
Boulder Creek	0 to 2.4	Temperature	Summer	Chapter 8
Chehulpum Creek	0 to 7.1	Temperature	Summer	Chapter 8
Elkhorn Creek	0 to 7.4	Temperature	Summer	Chapter 8
Little North Santiam River	0 to 25.1	Temperature	Summer	Chapter 8
Marion Creek	0 to 6.2	Temperature	Summer	Chapter 8
North Santiam	0 to 10	Temperature	Summer	Chapter 4
North Santiam	0 to 10	Temperature	Sept 1 – June 30	Chapter 4
Santiam River	0 to 12	Dissolved Oxygen	Sept 15 – June 30	No
Santiam River	10 to 26.5	Temperature	Summer	Chapter 4
Santiam River	0 to 12	Temperature	Summer	Chapter 4
Santiam River	0 to 12	Temperature	Sept 15 – June 30	Chapter 4
Stout Creek	0 to 8.9	Temperature	Summer	Chapter 8
Unnamed tributary to Marion Creek	0 to 2.8	Temperature	Summer	Chapter 8

Water Quality Parameters Addressed

- In this North Santiam Subbasin chapter, temperature is the only parameter addressed with allocations.

- Bacteria has been addressed through a basin wide assessment of TMDLs developed for subbasins with streams listed as water quality limited for bacteria, specifically the Upper Willamette Subbasin, Middle Willamette Subbasin, and Lower Willamette Subbasin. Planning targets have been identified for urban and agricultural land in the North Santiam Subbasin where no streams have been listed. The appropriate use of planning targets is in water quality management planning. The ubiquitous nature of fecal bacteria suggests that water quality would benefit from implementation of these targeted reductions in the absence of documented violations. In general, targeted reductions for agricultural areas range from 66% to 83%, and reductions for urban areas range from 80% to 94%; relative to current concentrations. The details of this assessment and the planning targets are contained in the Allocation Section of Chapter 2, Willamette Basin Bacteria TMDL.

- Mercury is a parameter of concern throughout the Willamette Basin. A 27% reduction in mercury pollution is needed in the mainstem Willamette to remove fish consumption advisories. Pollutant load allocations are set for each sector but no effluent limits are specified at this time. Sources of mercury in the subbasin will be required to develop mercury reduction plans. Details of the mercury TMDL are included in Chapter 3, the Willamette Basin Mercury TMDL.

Water Quality Parameters Not Addressed

The Willamette Basin TMDL project began in early 2000 and was designed to address the 1998 303(d) listed waterbodies for parameters that exceeded water quality criteria. In 2002, the 303(d) list was updated. Where data were readily available, new parameter listings were addressed in this TMDL document. However, there was not sufficient time to collect the additional data and complete the analysis for the newly listed parameter for this TMDL study. This parameter will be addressed in subsequent TMDL efforts. The parameter that is specifically excluded from this TMDL is:

- Dissolved Oxygen

The dissolved oxygen (DO) listing is for the Santiam River, and will not be addressed in this TMDL. This listing applies to river mile (RM) zero to 12. The Santiam River was listed in 2002 because 2 out of 11 samples had less than 11 mg/L DO concentrations at a 95% saturation at river mile 11.2, LASAR # 25817; and 4 out of 10 samples at river mile 9.3 had less than 11 mg/L DO concentrations at a 95% saturation level. Both sites violated the spawning criteria of 11 mg/ L or 95% saturation. The listing is for the period of September 15th to June 30th. Management efforts to restore riparian vegetation will also benefit dissolved oxygen issues that are driven by elevated periphyton productivity.

Who helped us

Many organizations assisted ODEQ in the development of this TMDL and data from many different sources were considered. ODEQ would like to acknowledge the assistance of the following organizations and agencies:

- North Santiam Watershed Council
- Oregon Department of Fish and Wildlife
- Oregon Water Resources Department
- U.S. Bureau of Land Management (BLM)
- U.S. Geological Survey (USGS)
- U.S. Forest Service (USFS)

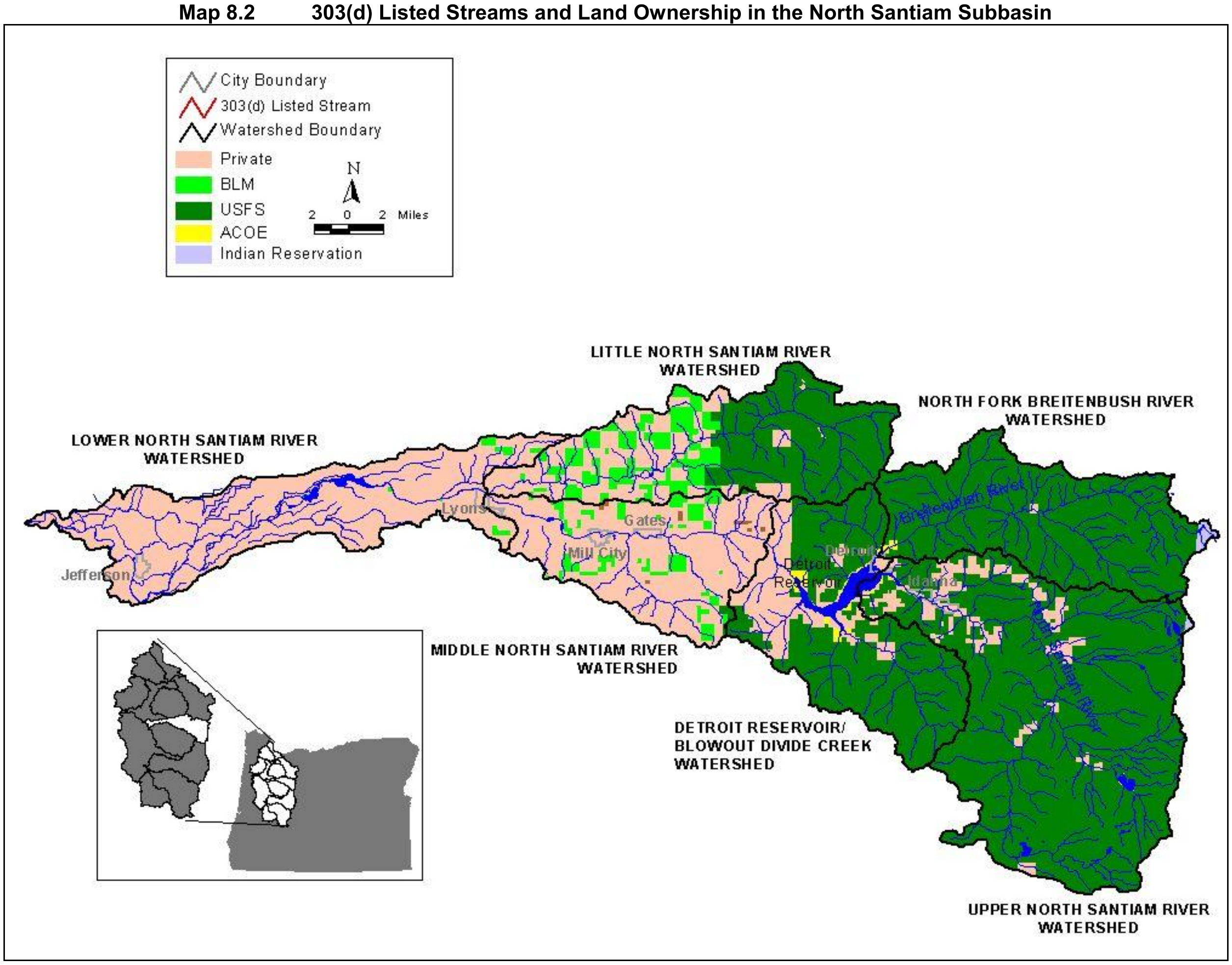
SUBBASIN OVERVIEW

The North Santiam Subbasin (Hydrologic Unit Code 17090005) is located in the eastern portion of the Willamette Basin and drains the Cascade Range. The North Santiam River flows into the Santiam River just upstream of the city of Jefferson. The Santiam River drains into the Willamette River at RM 109. The Subbasin's 764 square miles (488,958 acres) includes the following six watersheds:

- Detroit Reservoir / Blowout Divide Creek Watershed
- Little North Santiam River Watershed
- Lower North Santiam River Watershed
- Middle North Santiam River Watershed
- North Fork Breitenbush River Watershed
- Upper North Santiam River Watershed

The subbasin's political jurisdiction is within Linn and Marion County, and includes the Cities of Jefferson, Marion, Stayton, Sublimity, Lyons, Mehama, Mill City, Gates, Detroit, and Idanaha, Map 8.2. A small portion of the upper subbasin is within Warm Springs Tribal land, this TMDL is not applicable to these tribal lands. Land ownership in the subbasin is almost equally shared by both private and public landowners. The United States Forest Service (USFS) dominates public ownership, but there are also scattered parcels of lands managed by the Bureau of Land Management and the U.S. Army Corps of Engineers (USACE) throughout the subbasin. The subbasin is primarily forest land, with agricultural land use mainly occurring downstream of the Little North Santiam River Watershed.

Map 8.2 303(d) Listed Streams and Land Ownership in the North Santiam Subbasin



Watershed Descriptions

Detroit Reservoir / Blowout Divide Creek Watershed

The Detroit Reservoir / Blowout Divide Creek Watershed drains a 112 square mile (71,679 acres) area of the west slope of the Cascade Range and includes the city of Detroit and Detroit Reservoir. The watershed is split between Linn County, south of the North Santiam River, and Marion County, north of the North Santiam River. Forestry is the dominant land use in this area. Over 50% of the watershed is in public ownership and is administered primarily by the Willamette National Forest.

There are no CAFOs in the watershed as reported by the Oregon Department of Agriculture (ODA) in March 2003. There are no NPDES permits in the watershed.

Detroit Reservoir is a major recreational waterbody located in the Blowout Divide Creek Watershed. There are six major tributaries that flow into the reservoir, Breitenbush River, North Santiam River, Box Canyon Creek, Blowout Creek, Kinney Creek and French Creek. The watershed is habitat for winter steelhead and resident fisheries in the North Santiam River. There are two USGS real-time flow gages in the watershed, Blowout Creek near Detroit (gage # 14180300) and French Creek near Detroit (gage # 14179100).

Little North Santiam River Watershed

The Little North Santiam River Watershed drains a 113 square mile (72,319 acres) area of the west slope of the Cascade Range. The watershed is located within the southeastern most portion of Marion County. Forestry accounts for all of the land use area. The watershed is dominated by Willamette National Forest lands (50%) and by BLM lands (18%) with the remaining 32% in private ownership

There are no CAFOs in the watershed as reported by ODA in March 2003. There are no NPDES permits in the watershed.

The watershed has five major tributaries that flow into the Little North Santiam River: Elkhorn Creek, Cedar Creek, Big Creek, Battle Ax Creek, and Opal Creek. The Little North Santiam River is a tributary to the North Santiam River. The watershed provides habitat for spring Chinook, summer steelhead and winter steelhead. There is one USGS real-time flow gage in the Little North Santiam River Watershed, Little North Santiam River near Mehama, USGS # 14182500.

Lower North Santiam River Watershed

The Lower North Santiam River Watershed drains a 113 square mile (72,319 acres) area of the west slope of the Cascade Range. The City of Jefferson and a large portion of the City of Lyons are located within the watershed. The watershed is split by the Santiam River, which also creates the boundary between Marion County to the north and Linn County to the south. The City of Lyons is located in Linn County, and Jefferson is located in Marion County. This is the most heavily populated watershed in the subbasin. Geren Island is located in this watershed and is the drinking water facility for the City of Salem providing drinking water from the North Santiam River. Ownership is mostly private with agricultural land use accounting for 67% of the watershed. Forest land occupies 25% of the area, and urban areas are only 4% of the watershed.

There are seven CAFOs, one mink farm, one veal farm and five dairy operations, as reported by ODA in March 2003. There are three individual NPDES permits in the watershed, one major domestic permit for the City of Stayton STP, one minor domestic for the City of Jefferson STP, and one minor industrial to Norpac Foods. The City of Jefferson STP discharges to the Santiam River, and the City of Stayton STP and Norpac Foods discharge to the North Santiam River. There are also 13 general NPDES permits in the subbasin.

The North Santiam River flows into the Santiam River just upstream of Jefferson, right at the confluence of the South Santiam River. The watershed provides habitat for spring Chinook, fall Chinook, coho, summer steelhead, and winter steelhead. There are two USGS real-time flow gages in the watershed, one in the Santiam River at Jefferson (gage #14189000) and the other in the North Santiam River at Mehama (gage #14183000).

Middle North Santiam River Watershed

The Middle North Santiam River Watershed drains an 86 square mile (55,039 acres) area of the Cascade Range. Mill City, Gates, Stayton, Sublimity, Marion, Mehama and a portion of the City of Lyons are located within the watershed boundary. Forestry dominates the land use area. The watershed is dominated by private ownership, however, 11% of the watershed is owned by BLM.

There are no CAFOs as reported by ODA in March 2003. There is one minor individual NPDES permit in the watershed that discharges to the North Santiam River, Frank Lumber. There are seven general NPDES permits issued in the watershed.

The flow in the North Santiam River is supplemented from Rock Creek. It is the largest tributary in this watershed. The watershed provides habitat to spring Chinook, summer steelhead, winter steelhead, resident cutthroat, rainbow trout, Oregon chub, and bull trout. There is one USGS real-time flow gages in the upper Middle North Santiam River Watershed at Niagara (gage # 14181500).

North Fork Breitenbush River Watershed

The North Fork Breitenbush River Watershed is 108 square miles (69,119 acres). This area drains the headwaters of the Cascade Range. This watershed is known to have several hot springs including Breitenbush hot springs. The watershed is located in eastern Marion County. Forest lands dominate the watershed which is mostly publicly owned and managed by the Forest Service.

There are no CAFOs as reported by ODA in March 2003. There are no NPDES point sources in this watershed.

Breitenbush River flows into Detroit Reservoir. The South Fork and North Fork Breitenbush River, are the major tributaries, draining the upper Cascade Mountains, as well as Humbug and Devils creeks. The watershed provides habitat to winter steelhead. There is one real-time USGS flow gage in the North Fork Breitenbush River Watershed located on Breitenbush River above French Creek (gage # 14179000).

Upper North Santiam River Watershed

The Upper North Santiam River Watershed is 229 square miles (146,559 acres) flowing from the upper Cascade Mountains. Both Linn and Marion counties have jurisdiction in this watershed. The watershed is dominated by Forest Service ownership, however 8% of the watershed is privately owned.

There are no CAFOs in the watershed as reported by ODA in March 2003. There is one individual NPDES point source in the watershed, ODFW Marion Forks Fish Hatchery a minor NPDES permitted facility that discharges to Horn Creek.

The North Santiam River flows into Detroit Reservoir in this watershed and is supplemented by the Marion Creek drainage, the largest tributary in the watershed. The watershed provides habitat to resident fisheries. There is one USGS real-time flow gage in the watershed, USGS flow gage #14178000, North Santiam River below Boulder Creek near Detroit.

NORTH SANTIAM SUBBASIN TEMPERATURE TMDL

The temperature TMDL for the North Santiam Subbasin includes tributaries to the North Santiam River and the Santiam River within HUC 17090005. As per Oregon Administrative Rule (OAR) 340-042-0040 required components of a TMDL are listed in Table 8.2.

Table 8.2 North Santiam Subbasin Temperature TMDL Components.

Waterbodies **OAR 340-042-0040(4)(a)**	Perennial and/or fish bearing, as identified in OAR 340-041- 0340; Figures 340A & 340B, streams in the North Santiam Subbasin, HUCs 170900501, 170900502, 170900503, 170900504, 170900505, and 170900506.
Pollutant Identification **OAR 340-042-0040(4)(b)**	*Pollutants:* Human caused temperature increases from (1) solar radiation loading and (2) warm water discharge to surface waters
Beneficial Uses **OAR 340-042-0040(4)(c)**	Salmonid fish spawning and rearing, anadromous fish passage, resident fish and aquatic life are the most sensitive beneficial uses in the North Santiam Subbasin.
Target Criteria Identification **OAR 340-042-0040(4)(c)** ***CWA §303(d)(1)*** **OAR 340-041-0028(4)(a)** **OAR 340-041-0028(4)(b)** **OAR 340-041-0028(4)(c)** ***OAR* 340-041-0028(8)** **OAR 340-041-0028(12)(b)(B)**	OAR 340-041-0028 provides numeric and narrative temperature criteria. Maps and tables provided in OAR 340-041-0101 to 0340 specify where and when the criteria apply. 13.0°C during times and at locations of salmon and steelhead spawning. 16.0°C during times and at locations of core cold water habitat identification. 18.0°C during times and at locations of salmon and trout rearing and migration. Natural Conditions Criteria: Where the department determines that the natural thermal potential temperature of all or a portion of a water body exceeds the biologically-based criteria in section 4 the natural thermal potential temperatures supersede the biologically-based criteria and are deemed the applicable criteria for that water body. Maps and tables provided in OAR 340-041-0101 to 0340 specify where and when the criteria apply. Following a temperature TMDL or other cumulative effects analysis, waste load and load allocations will restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.3 degrees Celsius (0.5Fahrenheit) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact.
Existing Sources **OAR 340-042-0040(4)(f)** ***CWA §303(d)(1)***	Nonpoint source solar loading due to a lack of riparian vegetation from forestry, agriculture, rural residential, and urban activities. Point source discharge of warm water to surface water.
Seasonal Variation **OAR 340-042-0040(4)(j)** ***CWA §303(d)(1)***	Peak temperatures typically occur in mid-July through mid-August and often exceed the salmon and trout rearing and migration criterion. Temperatures are much cooler late summer through late spring but occasionally exceed the spawning criterion.
TMDL **Loading Capacity and Allocations** **OAR 340-042-0040(4)(d)** **OAR 340-042-0040(4)(e)** **OAR 340-042-0040(4)(g)** **OAR 340-042-0040(4)(h)** ***40 CFR 130.2(f)*** ***40 CFR 130.2(g)*** ***40 CFR 130.2(h)***	*Loading Capacity:* OAR 340-041-0028 (12)(b)(B) states that no more than a 0.3°C increase in stream temperature above the applicable biological criteria or the natural condition criteria as a result of human activities is allowable. This condition is achieved when the cumulative effect of all point and nonpoint sources results in no greater than a 0.3 °C (0.5 °F) increase at the point of maximum impact. Loading capacity is the heat load that corresponds to the applicable numeric criteria plus the small increase in temperature of 0.3°C provided with the human use allowance. *Excess Load*: The difference between the actual pollutant load and the loading capacity of the waterbody. In these temperature TMDLs excess load is the difference between heat loads that meet applicable temperature criteria plus the human use allowance and current heat loads from background, nonpoint source and point source loads. *Wasteload Allocations (NPDES Point Sources)*: Allowable heat load based on achieving no greater than a 0.3°C temperature increase at the point of maximum impact. This is achieved by limiting stream temperature increases from individual point sources to 0.075ºC. This may also be expressed as a limitation of 0.3ºC increase in 25% of the 7Q10 stream flow. Where multiple point sources discharge to a single receiving stream the accumulated heat increase for point sources is limited to 0.2˚C. *Load Allocations (Nonpoint Sources)*: Background solar radiation loading based on system potential vegetation near the stream. An additional heat load equal to 0.05°C temperature increase at the point of maximum impact is available but is not explicitly allocated to individual sources. • Little North Santiam River background solar radiation loading based on system potential vegetation is 5.97×10^8 kcal/day.
Surrogate Measures **OAR 340-042-0040(5)(b)** ***40 CFR 130.2(i)***	*Translates Nonpoint Source Load Allocations* Effective shade targets translate riparian vegetation objectives into the nonpoint source solar radiation loading capacity. These targets are based on vegetation communities appropriate for each geomorphic unit in the subbasin.

Margins of Safety OAR 340-042-0040(4)(i) *CWA §303(d)(1)*	*Margins of Safety* are demonstrated in critical condition assumptions for point source load calculations and are inherent in the methodology for determining nonpoint source loads.
Reserve Capacity OAR 340-042-0040(4)(k)	Allocation for increases in pollutant loads for future growth from new or expanded sources. Reserve Capacity will be a percentage of the 0.3˚C Human use allowance (HUA). The HUA will be divided among various sources. When point sources are present reserve capacity will be 0.05˚C, 17% of the HUA. Where there are no point sources in a subbasin, or less than the allowed 0.2˚C is used by point source discharges, the remainder is allocated to Reserve Capacity.
Water Quality Management Plan OAR 340-042-0040(4)(l)	The Water Quality Management Plan (WQMP) provides the framework of management strategies to attain and maintain water quality standards. The WQMP is designed to complement the detailed plans and analyses provided in specific implementation plans. See Chapter 14.
Standards Attainment & Reasonable Assurance OAR 340-042-0040(4)(l)(e) & (j)	Implementation of pollutant load reductions and limitations in the point source and non point source sectors will result in water quality standards attainment. Standards Attainment and Reasonable Assurance are addressed in the WQMP, Chapter 14.

Waterbodies Listed for Temperature

OAR 340-042-0040(4)(a)

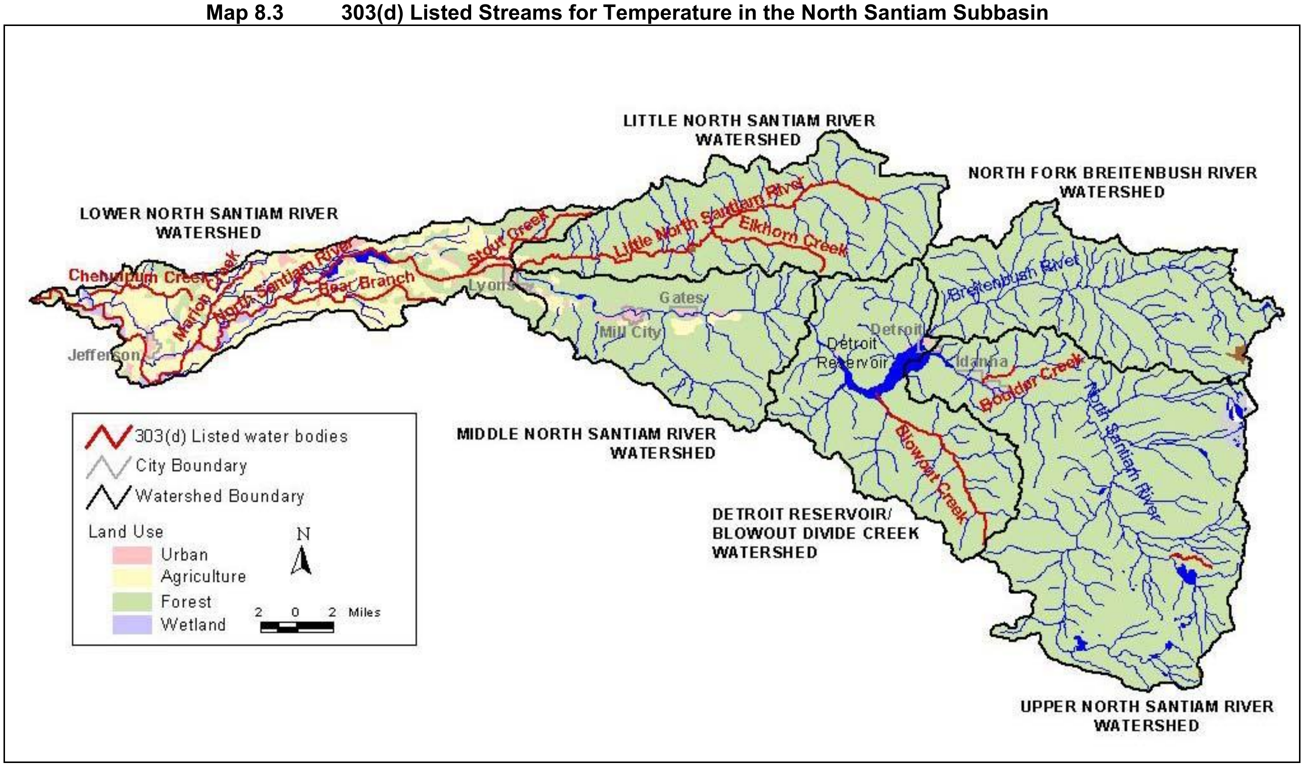
The North Santiam Subbasin has nine stream segments on the 303(d) list for exceeding the summer time rearing water temperature criterion: Bear Branch, Blowout Creek, Boulder Creek, Chehulpum Creek, Elkhorn Creek, Little North Santiam River, Marion Creek, Stout Creek, and an unnamed tributary to Marion Creek upstream of Detroit Reservoir, Table 8.3 and Map 8.3. The Santiam River and the North Santiam River from its mouth to Detroit Reservoir are addressed in Chapter 4.

Stream segments were listed under the previous temperature standard because they exceeded the temperature criterion of 17.8^{o}C (64^{o}F) for salmonid migration and rearing, Table 8.3. However, new temperature standards were adopted by the Environmental Quality Commission in December 2003 and approved by USEPA in March 2004. The new temperature criterion for salmon and trout rearing and migration is 18.0°C (64.4°F). Temperature data for the streams listed in Table 8.3 indicate that these streams exceed the recently adopted numeric criterion as well.

Table 8.3 North Santiam Subbasin 303(d) Temperature Listed Stream Segments

Waterbody Name	Listed River Mile	Parameter	Criteria	Season
Bear Branch	0 to 9.8	Temperature	Rearing: 17.8 C	Summer
Blowout Creek	0 to 11.9	Temperature	Rearing: 17.8 C	Summer
Boulder Creek	0 to 2.4	Temperature	Rearing: 17.8 C	Summer
Chehulpum Creek	0 to 7.1	Temperature	Rearing: 17.8 C	Summer
Elkhorn Creek	0 to 7.4	Temperature	Rearing: 17.8 C	Summer
Little North Santiam River	0 to 25.1	Temperature	Rearing: 17.8 C	Summer
Marion Creek	0 to 6.2	Temperature	Rearing: 17.8 C	Summer
Stout Creek	0 to 8.9	Temperature	Rearing: 17.8 C	Summer
Unnamed Tributary to Marion Creek	0 to 2.8	Temperature	Rearing: 17.8 C	Summer

Map 8.3 303(d) Listed Streams for Temperature in the North Santiam Subbasin



Pollutant Identification

OAR 340-042-0040(4)(b)

ODEQ must establish a TMDL for any waterbody designated on the 303(d) list as exceeding water quality criteria. Although temperature criteria are designed to protect beneficial uses from excessive water temperature, the pollutant of concern is heat energy. Water temperature change is an expression of heat energy exchange per unit of volume:

$$\Delta Temperature \propto \frac{\Delta Heat\ Energy}{Volume}$$

Stream temperatures are affected by natural and human caused sources of heating. Disturbance processes such as wildfire, flood, and insect infestation influence the presence, height and density of riparian vegetation which in turn determines the amount of solar radiation reaching the stream. Such processes are recognized and incorporated as a natural condition in the TMDL. This temperature TMDL does address stream heating caused by human activities that affect characteristics of riparian vegetation in addition to point sources that discharge heat directly into surface waters in the North Santiam Subbasin.

Beneficial Use Identification

OAR 340-042-0040(4)(c)

Numeric and narrative water quality criteria are applied to protect the most sensitive beneficial uses. The most sensitive beneficial uses to temperature in the North Santiam Subbasin are:

- Resident fish and aquatic life
- Salmonid spawning, rearing and migration
- Anadromous fish passage

At a minimum, beneficial uses are considered attainable wherever feasible or wherever attained historically.

Salmonid Stream Temperature Requirements

This temperature TMDL is focused on the protection of cold water salmonids, specifically steelhead and salmon. In general, there are three levels of thermally induced fish mortality. If stream temperatures become greater than 32 °C (>90°F), fish die almost instantly due to denaturing of critical enzyme systems in their bodies (Hogan, 1970). This level is termed *instantaneous lethal limit.* The second level is termed *incipient lethal limit* and can cause fish mortality in hours to days when temperatures are in the 21°C to 25°C (70°F to 77°F) range. The time period to death depends on the acclimation and life-stage of the fish. The cause of death is from the breakdown of physiological regulation, such as respiration and circulation, which are vital to fish health (Heath and Hughes, 1973). The third level is the most common and widespread cause of thermally induced fish mortality, termed *indirect or sub-lethal limit* and can occur weeks to months after the onset of elevated stream temperatures of 17.8°C to 23°C (64°F to 74°F). The cause of death is from interactive effects such as: decreased or lack of metabolic energy for feeding, growth, and reproductive behavior; increased exposure to pathogens (viruses, bacteria and fungus); decreased food supply because the macroinvertebrate populations are also impaired by high stream temperature; and increased competition from warm water tolerant species. Table 8.4 summarizes the modes of cold water fish mortality.

Table 8.4 Thermally Induced Cold Water Fish Mortality Modes (Brett, 1952; Bell, 1986, Hokanson et al., 1977)

Modes of Thermally Induced Fish Mortality	Temperature Range	Time to Death
Instantaneous Lethal Limit – Denaturing of bodily enzyme systems	> 32°C (> 90°F)	Instantaneous
Incipient Lethal Limit – Breakdown of physiological regulation of vital bodily processes, namely: respiration and circulation	21°C - 25°C (70°F - 77°F)	Hours to Days
Sub-Lethal Limit – Conditions that cause decreased or lack of metabolic energy for feeding, growth or reproductive behavior, encourage increased exposure to pathogens, decreased food supply and increased competition from warm water tolerant species	17.8°C - 23°C (64°F - 74°F)	Weeks to Months

Target Criteria Identification

OAR 340-041-0028(4)(c), OAR 340-041-0028(4)(d),OAR 340-041-0028(9) CWA 303(d)(1)

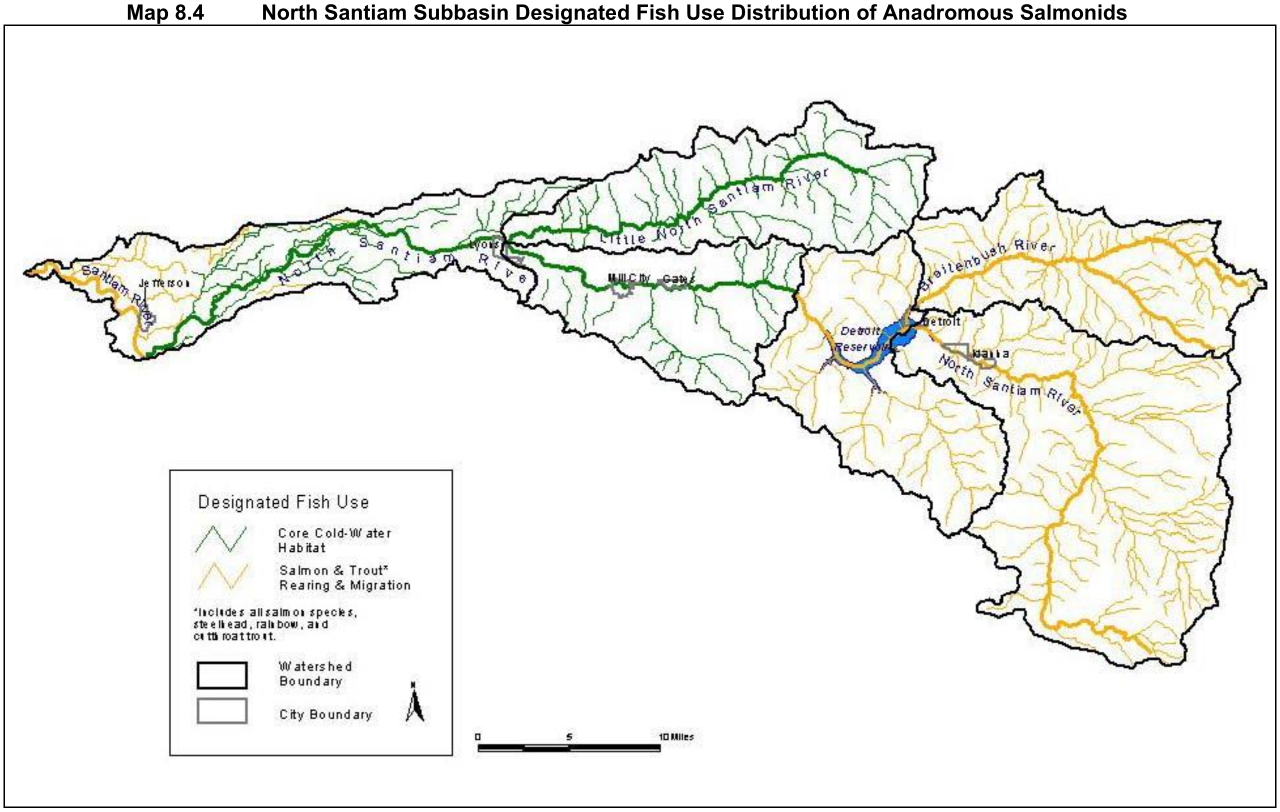
Oregon's water quality criteria for temperature are designed to protect beneficial uses, such as cold-water salmon and trout species, based on specific salmonid life stages. The temperature criteria include both narrative and numeric criteria. Table 8.5 lists the temperature criteria that are applicable to the North Santiam Subbasin. Maps 8.4 and 8.5 illustrate designated subbasin fish use and salmonid spawning use. The maps indicate where salmonid spawning through fry emergence criterion, core cold water habitat criterion, and salmonid rearing and migration criterion apply. For subbasin waters where fisheries uses are not identified the applicable criteria are the same as the nearest downstream waterbody that is identified in fish use maps. Willamette Basin fish use and spawning use maps are available for electronic download on ODEQs website at:
http://www.deq.state.or.us/wq/standards/FishUseMapsFinal/FFigure340A_Willamette.pdf and
http://www.deq.state.or.us/wq/standards/FishUseMapsFinal/FFigure340B_Willamette.pdf

Table 8.5 Oregon's Biologically Based Temperature Criteria.

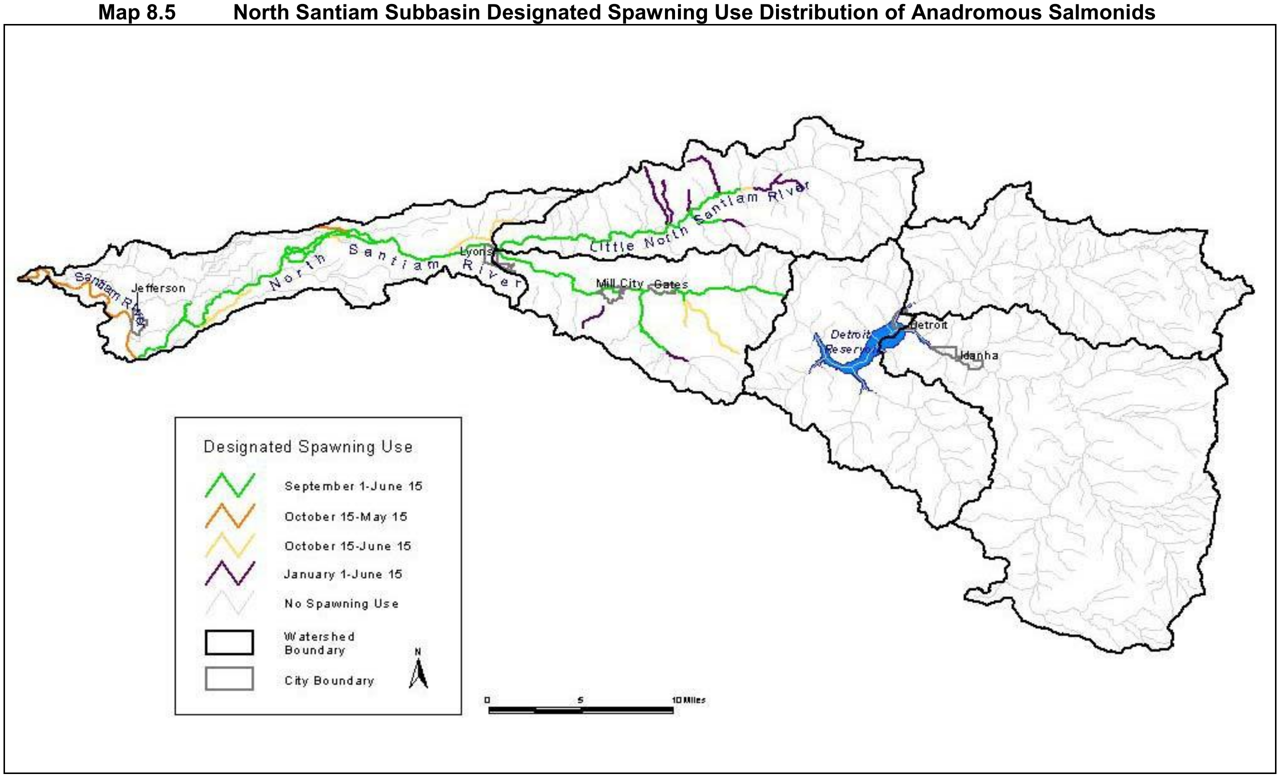
Beneficial Use	**Temperature Criteria**
Salmon and Steelhead Spawning	∗13.0°C (55.4°F)
Core Cold Water Habitat Identification	*16.0°C (60.8°F)
Salmon and Trout Rearing and Migration	∗18.0°C (64.4°F)

∗ Stream temperature is calculated using the average of seven consecutive daily maximum temperatures on a rolling basis (7-day calculation).

Map 8.4 North Santiam Subbasin Designated Fish Use Distribution of Anadromous Salmonids



Map 8.5 North Santiam Subbasin Designated Spawning Use Distribution of Anadromous Salmonids



The narrative criteria that apply to the North Santiam Subbasin describe the conditions under which biological numeric criteria may be superseded. The criteria acknowledge that in some instances the biologically based numeric criteria may not be achieved because the natural thermal potential of the stream temperature is warmer than the biologically based numeric criteria. A stream that is free from anthropogenic influence is considered to be at natural thermal potential. When it exceeds the appropriate biologically based criterion, the natural thermal potential becomes the natural condition numeric temperature criterion for that specific stream or stream segment. This often occurs in low elevation streams in the basin during summer months.

Following a temperature TMDL or other cumulative effects analysis, waste load and load allocations will restrict all NPDES point sources and nonpoint sources to a cumulative increase of no greater than 0.3 degrees Celsius (0.5 Fahrenheit) above the applicable criteria after complete mixing in the water body, and at the point of maximum impact.

A more extensive analysis of water temperature related to aquatic life and supporting documentation for the temperature standard can be found in the *1992-1994 Water Quality Standards Review Final Issue Papers* (ODEQ, 1995) and in *EPA Region 10 Guidance for Pacific Northwest State and Tribal Temperature Water Quality Standards* (USEPA, 2003).

Existing Heat Sources

OAR 340-042-0040(4)(f), CWA §303(d)(1)

Sources of heat pollution include nonpoint sources and point sources. Nonpoint sources are generally more diffuse in nature and cannot be traced back to a particular location. These sources are defined below in terms of land use. Dams and reservoir operations are also included as nonpoint sources of pollution although their effects on water quality are generally more identifiable than dispersed land use activities. Point sources are individual facilities that discharge a pollutant from a defined conveyance (e.g. an outfall pipe) and are regulated by permit.

Nonpoint Sources of Heat

Land use activities. Riparian vegetation, stream morphology, hydrology (including groundwater interactions), climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, riparian condition, channel morphology and hydrology are affected by land use activities. Disturbance or removal of vegetation near a stream reduces stream surface shading because of decreased vegetation height, width and density. This results in greater amount of solar radiation reaching the stream surface.

Riparian vegetation also influences channel morphology. Vegetation supports stream banks during erosive, high flow events and slows floodwaters and promotes sediment deposition when floodwaters overtop the banks. Loss or disturbance of riparian vegetation may precede lateral stream bank erosion and channel widening. This decreases the effectiveness of remaining vegetation to shade the stream and increases the stream surface area exposed to heat exchange processes, particularly solar radiation.

Dam and Reservoir operations. Dams and reservoir operations affect stream temperature through the modification of flow regimes and through the delivery of heat stored within the system. Flow augmentation during the low flow periods of the year may be beneficial to stream segments below the dam as higher flows increase stream volume and therefore the loading capacity of the segment. Also, higher volumes correspond to greater stream velocities and shorter travel times through stream reaches exposed to solar radiation. However, operations that divert flows from natural channels during low flow periods may substantially diminish the loading capacity of the stream while also increasing solar loading to the stream because of lower velocities and greater travel times through exposed reaches.

The release of water from reservoirs may also increase downstream temperatures as the heat held by the impounded water is also released. The timing, duration and magnitude of such impacts are dependent upon reservoir characteristics such as surface area, depth, and whether water is released from the bottom of the reservoir or may be selectively withdrawn at various depths.

Detroit Dam and Big Cliff Dam are part of a large storage and re-regulating reservoir complex located in the upper subbasin. These dams affect water quantity, water quality, and beneficial uses in the mainstem North Santiam River and Santiam River. A discussion of the impacts of this reservoir complex is discussed in Chapter 4.

Point Sources of Heat

Point source discharges play a role in stream heating in the streams of the North Santiam Subbasin. There are five individual NPDES permitted sources in the North Santiam Subbasin, Map 8.6, three of these permitted sources discharge directly into the North Santiam River and one discharges to the Santiam River. Point sources that discharge into the Santiam River or the North Santiam River downstream of Big Cliff Dam are considered in the analysis for the mainstem Willamette temperature TMDL presented in Chapter 4. The remaining individual NPDES point source is ODFW's Marion Forks Fish Hatchery, which discharges to Horn Creek, a tributary to Marion River upstream of Detroit Reservoir, Table 8.6. Horn Creek is not listed on the 303(d) list. In addition to the individual NPDES point sources identified above, there are also 21 general NPDES permits within the North Santiam Subbasin.

Map 8.6 North Santiam Subbasin NPDES Permit Locations. April, 2003.

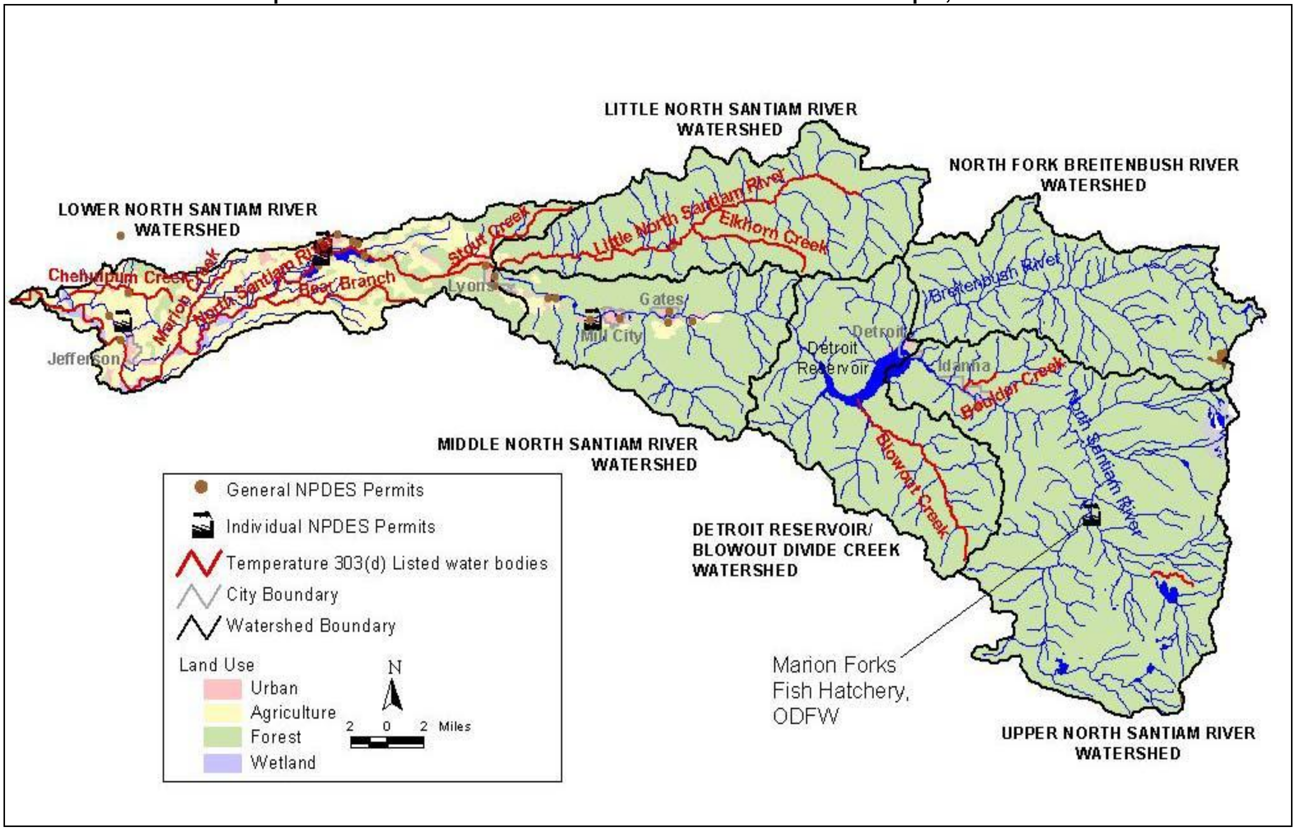


Table 8.6 Individual NPDES facility in the North Santiam Subbasin, which does not discharge to the mainstem North Santiam River or Santiam River. April, 2003.

Facility Name	Permit Type	Permit Description	Receiving Stream	River Mile	Type of Discharge	Season of Discharge
ODFW - MARION FORKS HATCHERY	NPDES-IW-O	Industrial Wastewater; NPDES non-process wastewater NEC	Horn Creek	0.1	Process Water	Year Round

NEC = Not Elsewhere Classified

Temperature TMDL Approach Summary

North Santiam Subbasin stream temperature TMDLs were developed at the watershed scale. These TMDLs include all surface waters that affect the temperatures of 303(d) listed water bodies because stream temperature is affected by heat loads from upstream as well as local sources. Point and nonpoint sources of heat may not cause an increase in temperature of more than the human use allowance (0.3˚C) when fully mixed with a stream and at the point of maximum impact. For the purposes of Willamette Basin TMDLs, the human use allowance has been divided among various sources using a framework established by DEQ with input from the Willamette TMDL Council. The framework allocates to point sources heat loads that yield a cumulative increase in stream temperature of no more than 0.2˚C. The framework allocates nonpoint sources an increase in temperatures of 0.05˚C and a heat load equivalent to 0.05˚C is held as reserve capacity. Where less than the 0.2˚C cumulative increase in temperature is actually used by point source discharges, the remainder is allocated to reserve capacity. The actual allocation of heat within the human use allowance is not specified in the water quality standards and this framework is used simply as guidance for implementation of the TMDL.

Point Source Approach. Allocations or permit limits are developed for individual point source discharges that ensure the combined increase in temperature for all discharges does not exceed 0.2˚C at the point of maximum impact. Wasteload allocations for individual point sources are generally based on a quarter of the human use allowance and yield less than a 0.08ºC increase in temperature at the point of maximum impact. Individual waste load allocations may be greater than 0.08ºC based on an analysis of site specific needs provided the overall point source allocation is within the established human use allowance framework. The specific methods and equations used to develop wasteload allocations are contained in the Allocation section of this chapter, below.

Nonpoint Source Approach. Removal or disturbance of riparian vegetation is the primary nonpoint source activity that affects stream temperatures in the subbasin. The temperature model Heat Source was used to calculate load allocations. Surrogate measures are used to represent nonpoint source heat loads. While heat from solar radiation in excess of natural background rates is considered the pollutant, the surrogate measure is effective shade. Effective shade targets, through the use of shade curves can be translated into site-specific load allocations such as Langleys per day. Both shade curves and system potential vegetation objectives were developed for the geomorphic units and upland forest areas in the North Santiam Subbasin.

Temperature TMDL Analytical Methods Overview

Load capacity is the assimilative capacity of each stream when anthropogenic sources of heat warm the stream no more than 0.3ºC above its natural thermal potential. Natural thermal potential is realized when point sources discharges of heat are eliminated and vegetation near the stream is undisturbed by management activities. Small additional heat load allocations can be made once these conditions are identified. Wasteload allocations for individual point sources are based on a change in river temperature at the point of maximum impact. These allocations are expressed in energy units such as kilocalories per day. Load allocations for nonpoint sources for the Little North Santiam River are based on kilocalories per day, and the surrogate measure of percent effective shade.

Development of stream temperature TMDLs requires the identification of load capacity for each impaired stream. This often demands extensive data collection to support the development of detailed and complex models that are in turn used to simulate system responses to changes in pollutant loads. However, in many stream systems in the North Santiam Subbasin the primary sources of anthropogenic heat are land use activities that affect riparian and near-stream vegetation. Identification of load capacity in these systems first requires determination of stream shade conditions when these disturbances of vegetation are eliminated. This drives the need to determine system potential vegetation and its shade producing characteristics.

System potential vegetation is vegetation that can grow and reproduce at a near-stream site given climate, elevation, soil properties, plant community requirements and hydrologic processes. System potential vegetation is an estimate of the riparian condition where land use activities that cause stream warming are minimized. It is not intended to be an estimate of pre-settlement conditions, but is an important element in the determination of the natural thermal potential of a stream. In the absence of significant point sources of heat or stream flow modification, system potential vegetation is the basis for identification of natural thermal potential temperatures. These natural thermal potential temperatures serve as the natural conditions temperature criterion in many low elevation streams throughout the Willamette Basin.

The Oregon Administrative Rule for temperature has defined both natural conditions and natural thermal potential.

- OAR 340-041-0002(38) states:
  “Natural conditions” means conditions or circumstances affecting the physical, chemical, or biological integrity of a water of the State that are not influenced by past or present anthropogenic activities. Disturbances from wildfire, floods, earthquakes, volcanic or geothermal activity, wind, insect infestation, diseased vegetation are considered natural conditions.

- OAR 340-041-0002(39) states:
  “*Natural Thermal Potential” means the determination of the thermal profile of a water body using best available methods of analysis and the best available information on the site potential riparian vegetation, stream geomorphology, stream flows and other measures to reflect natural conditions.*

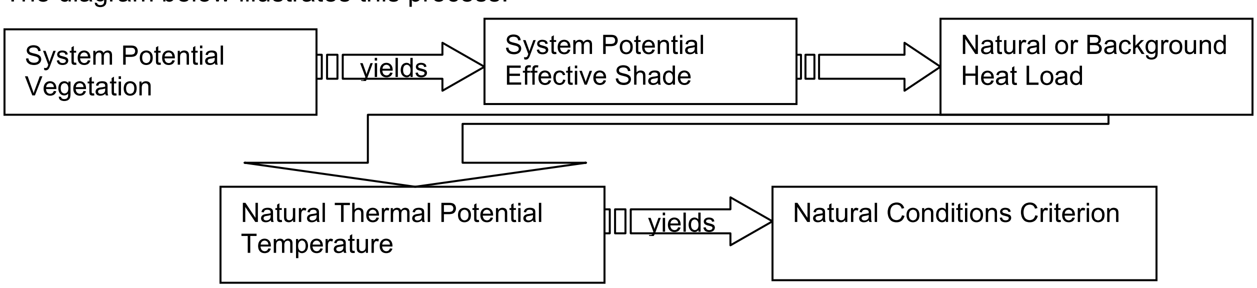
North Santiam Subbasin temperature TMDLs are based on the identification of system potential vegetation for each impaired waterbody and the calculation of the amount of shade provided by that vegetation to the stream. System potential vegetation in this analysis does allow for some level of natural disturbance such as fire and this is reflected as smaller tree heights and lower canopy densities in the calculation of shade levels. Put another way, mature vegetation was not used to simulate target conditions throughout the subbasin.

Effective shade is the percent of daily solar radiation that is blocked by vegetation and topography. System potential vegetation characteristics are used to estimate effective shade for each riparian community. These estimated effective shade values are often referred to as system potential effective shade when in the absence of human disturbance.

Solar radiation is a function of regional and local characteristics and is a factor in determining water temperature in the absence of significant point source influences. Regional factors such as latitude and topography determine potential solar radiation loading whereas local factors such as stream aspect, stream width and streamside vegetation characteristics determine actual solar radiation loading to the stream. Streamside vegetation characteristics that determine effective shade include vegetation height, canopy density, overhang, setback or distance from the edge of the stream, and the width of the riparian buffer. Mature, well-stocked riparian stands generally provide more effective shade to a stream than sparsely stocked riparian stands or stands of early successional plant communities. For more information on system potential vegetation refer to Appendix C, “Potential Near-Stream Land Cover for Willamette Basin”.

Effective shade is a surrogate measure used for development of temperature load allocations. The use of effective shade targets alone will not support calculation of natural thermal potential stream temperatures. Extensive modeling is required to describe heat and water movement through the stream system and support the estimation of stream temperatures. Stream temperature estimation at system potential vegetation is calculated using the Heat Source Model for Little North Santiam River. The Heat Source Model version 6.5 was used to calculate stream temperatures and effective shade at system potential vegetation. A description of the Heat Source model, model calibration statistics, and overview of the analytical analysis are described in Appendix C. An overview of Heat Source is also found on-line: http://www.heatsource.info/ Effective shade targets will allow for the calculation of the amount of solar loading reaching the stream and perhaps most importantly shade targets translate non-point source load allocations into site specific vegetation targets for land owners and managers.

The diagram below illustrates this process:

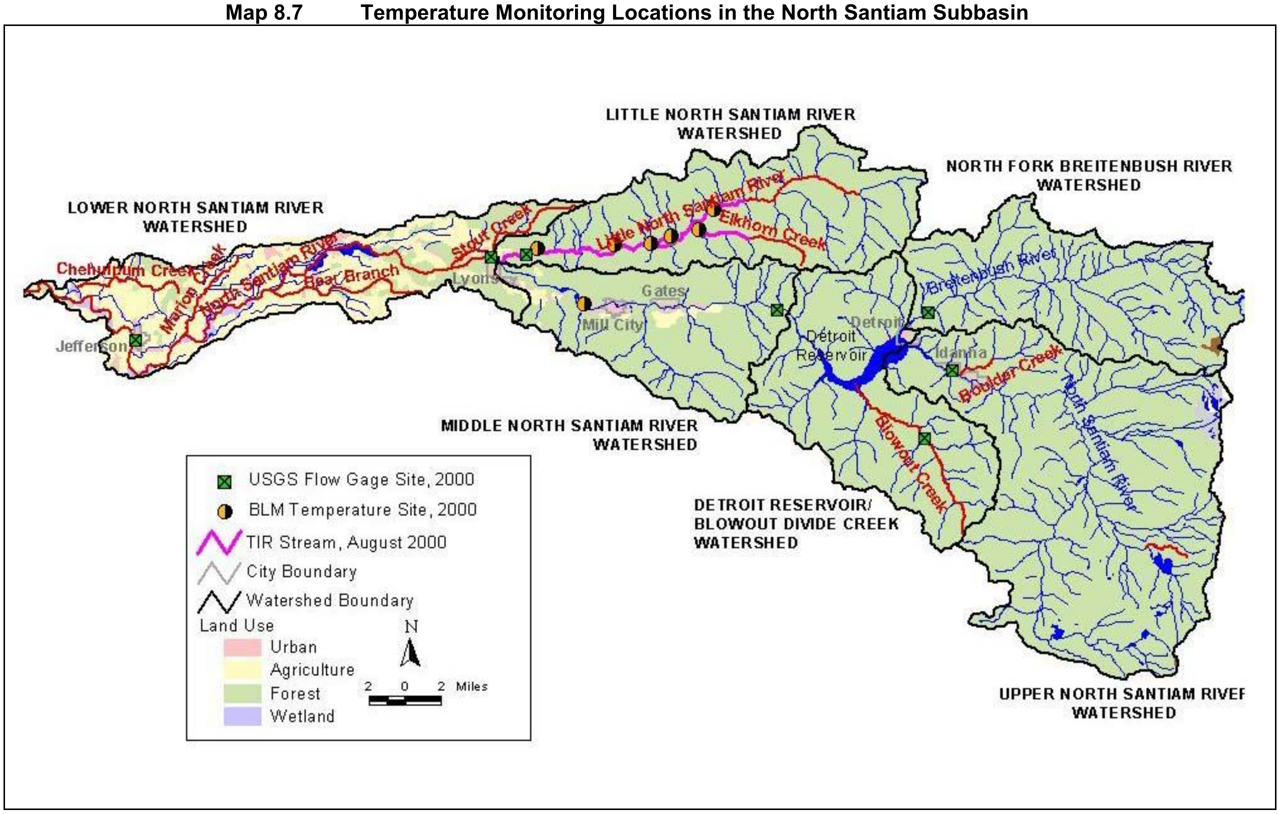


Stream temperature analysis discussed in this chapter is limited to stream systems in the North Santiam Subbasin. The water quality restoration strategies identified are applicable to all streams in the subbasin. Application of these strategies contributes to the basin-scale effort to restore and protect cooler water temperatures in other Willamette River tributaries. This broad scale application to all tributaries is an important element in the protection of coldwater aquatic life in the Willamette Basin. Although these streams are not likely to individually affect temperatures in the Willamette River, collectively they provide important localized sources of cool water and temporary thermal refugia for resident or migrating coldwater fish.

Seasonal Variation
OAR 340-042-0040(4)(j), CWA 303(d)(1)

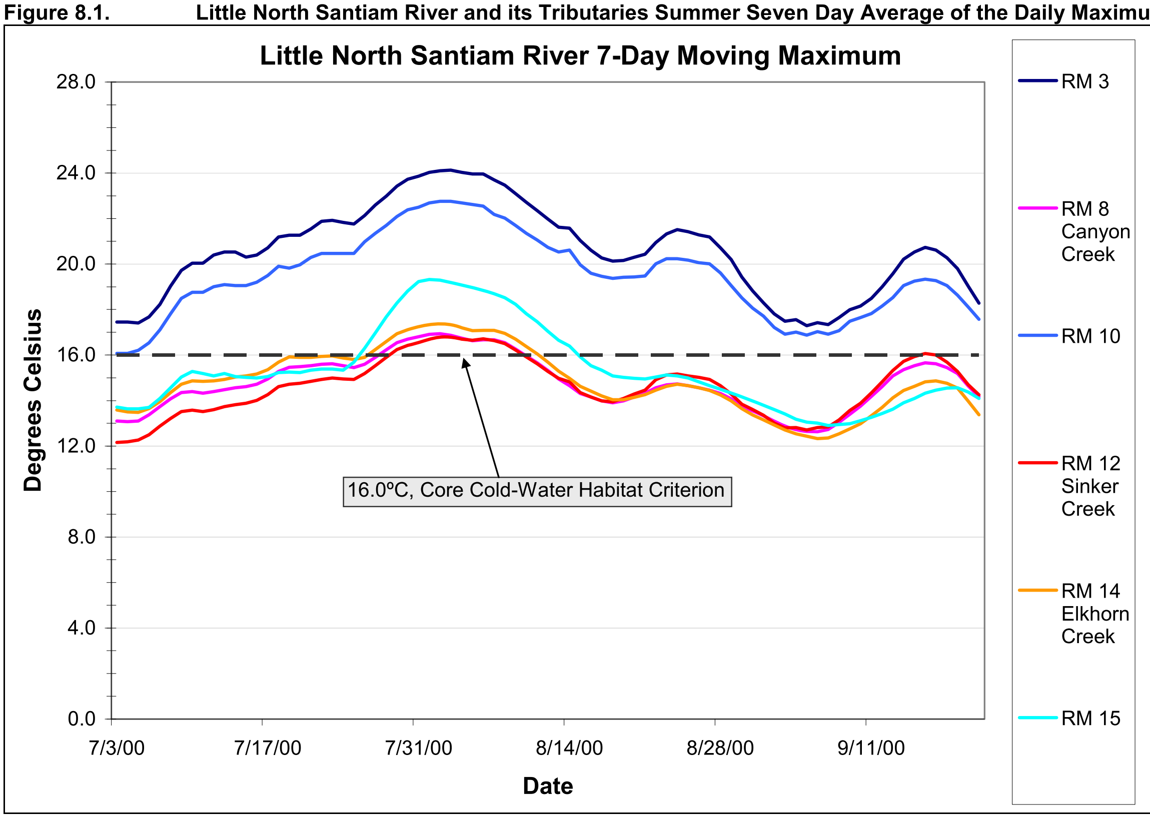
During the Fall of 2000, ODEQ coordinated and led a temperature data collection field exercise for the Bureau of Land Management (BLM) Salem Division. The purpose of this field exercise was to train BLM field staff in temperature TMDL field collection methods such as in-stream temperature thermometer placement, riparian vegetation characterization, channel characterization, and flow monitoring. In early June 2000, BLM placed eight temperature thermisters in-stream at various locations in the North Santiam Subbasin, Map 8.7. These thermisters were removed from the stream before stream flow conditions became hazardous, in September 2000. During the last week of July, 2000, BLM staff conducted field sampling exercises to record instantaneous flow, characterize the stream channel, take an audit of in-stream temperatures, and to characterize the riparian vegetation. Digital photos and a Geographical Positioning System (GPS) were used to record the latitude and longitude of each temperature monitoring location. USGS real-time flow gage information was also recorded when available, specifically for Heat Source hydrology development. Thermal Infra-Red (TIR) radiometry and visible video imagery for Little North Santiam and Elkhorn River were also collected.

Map 8.7 Temperature Monitoring Locations in the North Santiam Subbasin



Streams in the North Santiam Subbasin exceed biologically based rearing criteria starting in late spring and through late summer. Maximum temperatures typically occurred in late July and early August, Figure 8.1. Figure 8.1 shows the longitudinal profile of Little North Santiam River temperatures and its tributaries such as Canyon Creek, Sinker Creek, and Elkhorn Creek. In-stream temperatures increase by 2.0ºC (3.6ºF) between river mile 15 and 10, and continue increasing downstream to river mile 3. Long-term temperature recorders deployed by ODEQ, BLM, and USGS indicate that summer stream temperatures exceed the 18.0ºC (64.4ºF) migration and rearing, 16.0ºC (60.8ºF) core cold water habitat, and 13.0ºC (55.4ºF) salmon and steelhead spawning criteria. Temperatures in Little North Santiam River were commonly in the 19.0°-24.0°C (66.2°-75.2°F) range during summer. Streams exceeding the temperature standard include Bear Branch, Blowout Creek, Boulder Creek, Chehulpum Creek, Elkhorn Creek, Little North Santiam River, Marion Creek, Stout Creek, and an unnamed tributary to Marion Creek upstream of Detroit Reservoir.

Figure 8.1. **Little North Santiam River and its Tributaries Summer Seven Day Average of the Daily Maximum**



During August 1st, 2000, ODEQ contracted Watershed Sciences, to collect and analyze TIR and visible video imagery for Little North Santiam River and Elkhorn River, Figure 8.2 through 8.4. TIR data identified hyporheic flow in the Little North Santiam River at RM 10.6, Figure 8.3, and a spring-brook cool water refugia at RM 11.6, Figure 8.4. Data collection was timed to capture daily maximum stream temperatures, which typically occur between 14:00 and 18:00 hours. Before calibrating the Heat Source Model for the Little North Santiam, ODEQ staff performed a site visit of the Little North Santiam River during the summer of 2001 to become familiar with the hydrology and riparian vegetation community in the area.

Figure 8.2. **TIR/Day TV image mosaic (frames: Inf0510 to Inf0517) showing the Little North Santiam River at RM 10.66. The river splits into two branches at RM 10.46 and the FLIR survey covered both branches. This image mosaic is from the smaller, left branch (looking upstream) and shows numerous cool water seeps. These seeps are most likely due to hyporheic flow through the channel substrate. August 1, 2000.**

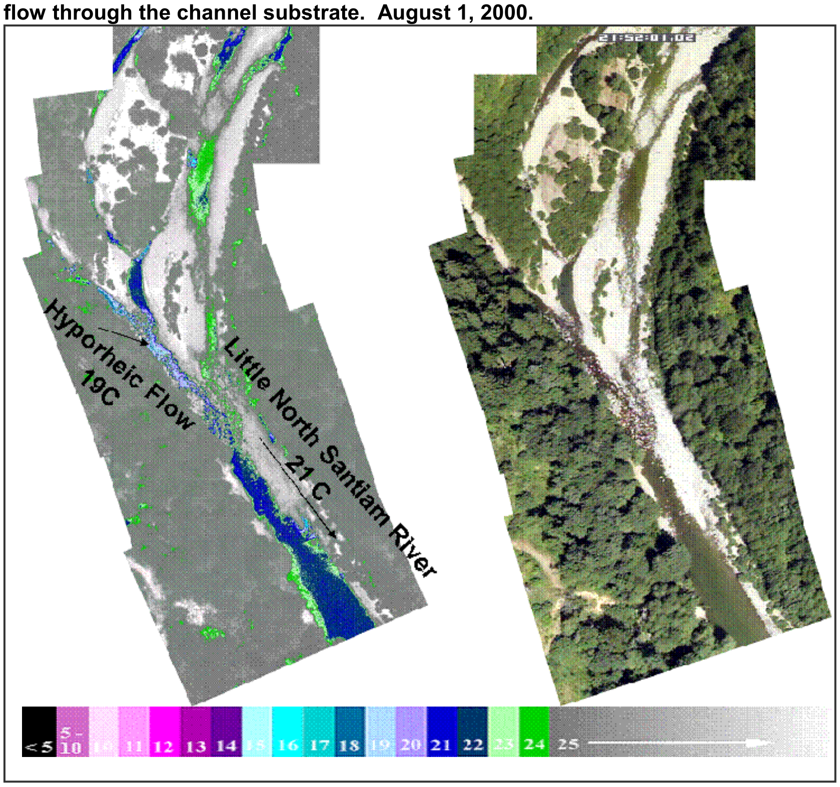


Figure 8.3. **TIR/Day TV image mosaic (frames: Inf0611 to Inf0614) showing the confluence of the Little North Santiam River (23.3 deg C) and Elkhorn Creek (20.6 deg C). August 1, 2000.**

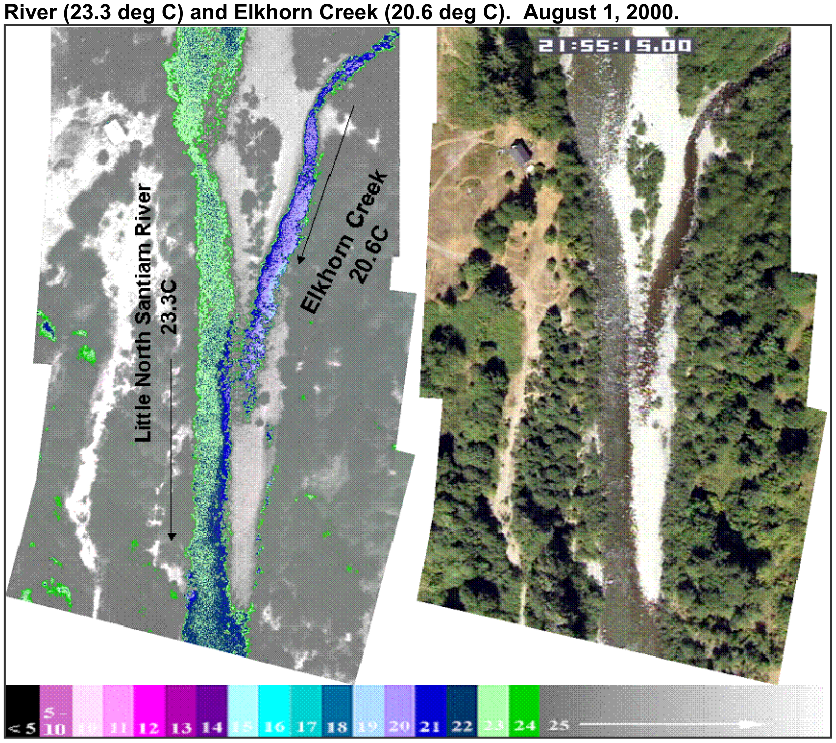
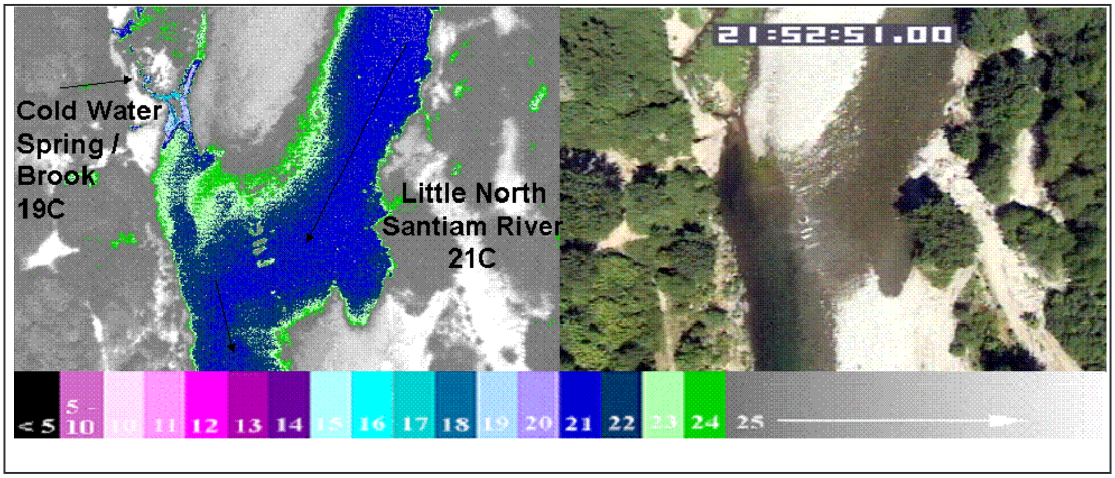


Figure 8.4. **TIR/Day TV image pair (frame: Inf0542) showing an apparent spring brook at RM 11.58. August 1, 2000.**



Loading Capacity

OAR 340-042-0040(4)(d), 40 CFR 130.2 (f)

The loading capacity is the total amount of a pollutant that a water body can assimilate without exceeding a water quality criterion or impairing a beneficial use. This is the pollutant load that may be divided among all point and nonpoint sources as allocations.

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with water quality standards. USEPA's current regulation defines loading capacity as "*the greatest amount of loading that a water can receive without violating water quality standards*" (40 CFR § 130.2(f)). Oregon's temperature criteria states that a surface water temperature increase of no more than 0.3°C (0.54ºF) above the applicable criterion is allowed from all anthropogenic sources at the point of maximum impact.

The loading capacity is dependent on the available assimilative capacity of the receiving water. For water bodies whose natural thermal potential temperatures are at or above the temperature criterion for a given period, there is no available assimilative capacity beyond the 0.3°C (0.54ºF) human use allocation. The loading capacity is essentially consumed by non-anthropogenic sources. When natural thermal potential temperatures are less than biological based numeric criteria, the load capacity may be somewhat greater than the human use allowance provided additional heat loads do not prevent attainment of water quality standards in downstream waters.

Critical Condition

The critical condition for stream temperature and heat loading is the seasonal period of maximum stream temperatures and lowest stream flows. Maximum stream temperatures are often a function of the combined effects of atmospheric inputs (solar radiation) and low stream flows that usually occur during the summer period. For many point sources the most critical condition for complying with the human use allowance occurs during the period of low stream flow and when there is large difference between effluent and river temperatures, usually in late summer to early fall.

Allocations

40 CFR 130.2(g), 40 CFR 130.2(h)

Loading capacity is allocated among point sources as wasteload allocations and to nonpoint sources as load allocations. Load allocations to anthropogenic sources are only available where surface water temperatures throughout a given stream meet the applicable water quality criteria plus the human use allowance. The general principle for allocation in the North Santiam Subbasin is to target natural background heat inputs from nonpoint sources and to limit point source loads to small allocations within the human use allowance.

Wasteload Allocations

OAR 340-042-0040(4)(g)

A wasteload allocation (WLA) is the amount of pollutant that a point source can contribute to the stream without violating water quality criteria. Waste load allocations for temperature are expressed as heat load limits assigned to individual point sources of treated industrial and domestic waste. Waste load allocations are provided for all NPDES facilities that have reasonable potential to warm the receiving stream when the applicable criteria are exceeded. Major and minor sources indentified in this TMDL do not discharge during the critical summer period to 303(d) listed streams, thus no WLAs have been provided for these point sources. If necessary, a wasteload allocations and permit limits will be developed by the methods following in this section. Facilities found not to be a significant contributor of heat to subbasin streams and found not to have a reasonable potential to contribute to the temperature impairment in the subbasin and therefore require no numeric limits in their NPDES permit may continue to discharge at their current heat load. Again, point sources that discharge directly to the North Santiam River downstream of Detroit Reservoir have been considered as part of the mainstem Willamette TMDL detailed Chapter 4.

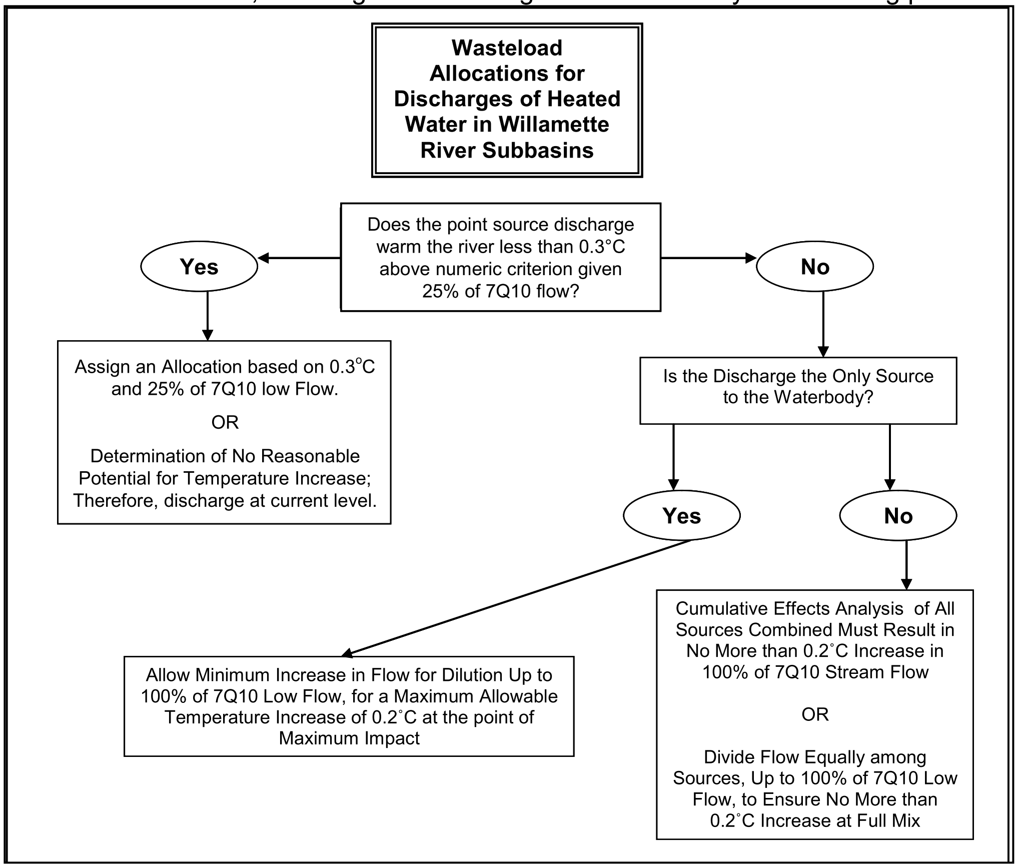
Waste Load Allocations in Small Streams

Discharges were screened to determine which would likely receive a wasteload allocation based on the type of discharge, and the volume and temperature of effluent. General permits that are unlikely to discharge significant volumes of warm water during critical periods (e.g., stormwater permits) are not expected to have a reasonable potential to increase instream temperatures. General permits that discharge heated effluent (e.g., boiler blowdown, log ponds) were considered as potential sources. For discharges with insufficient information (absence of stream flow data) to screen for effects or develop a wasteload allocation (WLA), a WLA will be calculated at the time of permit renewal by the method described below.

Oregon's temperature standard [OAR 340-041-0028(12)] allows an insignificant increase in temperature from all point source and nonpoint sources combined as a Human Use Allowance (HUA = 0.3˚C). Prior to development of a TMDL, the standard allows the assumption that a 0.3˚C increase in ¼ of the receiving stream flow or the volume of the temperature mixing zone (whichever is more restrictive) will not cause an impairment.

The waste load allocation scheme below assumes an allowable change in temperature above criteria of 0.3˚C within 25% of the 7Q10 low flow (a calculation of the seven-day, consecutive low flow with a ten year return frequency). This is the initial step in the development of a waste load allocation on smaller streams or when information is insufficient to allow a greater proportion of receiving water flow for mixing. The resultant temperature increase in fully mixed receiving water would be limited to 0.08˚C. More than the minimum flow allowance (25% of 7Q10 low flow) may be allocated to an individual source when analysis demonstrates standards attainment. The resulting temperature increase in this scenario depends on the proportion of low flow allocated, but should not exceed the point source sector allocation of 0.2°C over the entire waterbody. Moreover, each discharge is also required to ensure the local effects of discharge will not cause impairment to health of fish by meeting thermal plume requirements adopted under OAR 340-41-0053(2)(d).

Where information was available, discharge heat loading was assessed by the following process:



The pre-TMDL limits in the flow chart above refer to currently permitted discharge limits for existing point sources. Wasteload allocations are expressed in terms of heat load (kilocalories per day). These heat loads are calculated from estimates of river flow, effluent flow, effluent temperature, and either the appropriate biologically based criterion or the natural thermal potential at the point of discharge. Heat load is calculated with **Equation 1** (below). Where in-stream and effluent flow information is sufficient, allocations, and effluent limits may be developed based on flow rates for time periods other than monthly or an entire season (e.g., daily loads). The Q_{ZOD} term may vary depending upon the situation for the discharger as explained in the decision tree above, but will usually be ¼ of the 7Q10 low flow on either a monthly or a yearly basis dependent on data availability.

Equation 1:

$$H_{PS} = (Q_{ZOD} + Q_{PS}) \frac{1 \cdot ft^3}{1 \cdot sec} \cdot \frac{1 \cdot m^3}{35.31 \cdot ft^3} \cdot \frac{1000 \cdot kg}{1 \cdot m^3} \cdot \frac{86400 \cdot sec}{1 \cdot day} \cdot \Delta T_{ZOD} \cdot c = \frac{Kcal}{day}$$

where:

H_{PS}:	Heat from point source effluent received by river (kcal/day)
Q_{ZOD}:	River flow volume allowed for mixing- ¼ of 7Q10 low flow statistic (cfs)
Q_{PS}:	Point source effluent discharge (cfs)
ΔT_{ZOD}:	Change in river temperature at point of discharge - 0.3°C allowable (°C)
c:	Specific heat of water (1 Kcal / 1kg 1ºC)

Estimates of effluent temperature were calculated using mass loading equations (**Equation 2**) taking into account river flow and temperature, and effluent flow and temperature. Allocations are usually calculated to ensure an increase in temperature of no more than 0.3°C (0.54°F) in one-quarter of the volume of the receiving stream. When this volume is fully mixed with the receiving stream, this increase in temperature would be limited to 0.08°C. Where more than the minimal flow volume is allocated, either to allow more heat load to an individual discharger on a stream, or to calculate the cumulative effects of multiple discharges, the allocation is no more than 0.2°C (0.36°F) increase given the entire flow of the river receiving the cumulative discharges. If new or more comprehensive information (e.g. flow data, temperature data, mixing zone characteristics) is available at the time permits are renewed, permit limits will reflect revised wasteload allocations as calculated using **Equation 1** above and the best information available.

Equation 2:

$$T_{WLA} = \frac{[(Q_{PS} + Q_{ZOD}) \cdot (T_R + \Delta T_{ZOD})] - (Q_{ZOD} \cdot T_R)}{Q_{PS}}$$

where:

T_R:	Temperature Criterion or Upstream potential river temperature (^{o}C)
T_{WLA}:	Maximum allowable point source effluent temperature (^{o} C)
ΔT_{ZOD}:	Change in river temperature at point of discharge - 0.3^{o}C allowable (^{o}C)
Q_{ZOD}:	River flow volume allowed for mixing- ¼ of 7Q10 low flow statistic (cfs)
Q_{PS}:	Point source effluent discharge flow volume (cfs)

No waste load allocations were developed in this TMDL as they are unnecessary to demonstrate attainment of water quality standards in impaired streams because they were found to not discharge during the critical period. However, waste load allocations will be developed for all permitted sources that discharge heated waste water to subbasin waters using Equations 1 and 2 (above). Waste load allocations for existing and future thermal point sources will ensure that the sum of waste load and load allocations result in an increase in stream temperature of no greater than 0.3°C above the applicable criteria after complete mixing and at the point of maximum impact. Pollutant trading opportunities may be available to new or existing point sources in order to offset temperature impacts.

Load Allocations

OAR 340-042-0040(4)(h)

Load Allocations are portions of the loading capacity divided among natural, current anthropogenic, and future anthropogenic nonpoint pollutant sources. Load allocations (i.e. distributions of the loading capacity) are provided in Table 8.7 for the Little North Santiam River.

In this TMDL, load allocations are allowed 0.05˚C of the human use allowance (0.3˚C). This heat allowance is in addition to the load that streams would receive when they are at system potential and would allow activities that might increase the loading (such as riparian management activities) or for human disturbance that may not easily be addressed (e.g. presence of a road near a stream that would limit shading). The 0.05°C increase in temperature above criteria (1/6th of the HUA) is dedicated to nonpoint sources but is not allocated to individual sources at this time.

The current loading from nonpoint sources is much greater than that which would exist under natural thermal potential. This requires nonpoint sources to reduce thermal inputs to reach natural thermal potential conditions through allocation of a surrogate measure, effective shade. The principal means of achieving this condition is through protection and restoration of riparian vegetation. Additional measures may also be taken to improve summer temperatures. For example, water conservation measures that improve summer stream flows will benefit stream temperatures through an increase in load capacity. Stream restoration efforts that result in narrower stream channel widths will improve the effectiveness of existing vegetation to shade the stream surface.

Nonpoint source allocations were assigned natural background loads and are implemented as shade curves for upland forests and each geomorphic unit. This allocation also applies to tributaries of temperature listed waterbodies. Shade curves illustrate the relationship between each potential vegetation cover type, channel width and the resulting effective shade level.

The total nonpoint source solar radiation heat load was derived for Little North Santiam River. Current solar radiation loading was calculated by simulating current stream and vegetation conditions using the Heat Source Temperature Model version 6.5. Background loading was calculated by simulating the solar radiation heat loading that resulted with system potential vegetation. This background condition reflects an estimate of nonpoint source heat load that would occur while meeting the temperature criterion.

The relationships below were used to determine solar radiation heat loads for the current condition, anthropogenic contributions, and loading capacity derivations based on system potential, see diagram below:

Solar Radiation Heat Load Calculation Diagram

Total Solar Radiation Heat Load from All Nonpoint Sources,

$$H_{Total\ NPS} = H_{SP\ NPS} + H_{Anthro\ NPS} = \Phi_{Total\ Solar} \cdot A$$

Solar Radiation Heat Load from Background Nonpoint Sources (*System Potential*),

$$H_{SP\ NPS} = \Phi_{SP\ Solar} \cdot A$$

Solar Radiation Heat Load from Anthropogenic Nonpoint Sources,

$$H_{Anthro\ NPS} = H_{Total\ NPS} - H_{SP\ NPS}$$

Note: All solar radiation loads are the clear sky received loads that account for Julian time, elevation, atmospheric attenuation and scattering, stream aspect, topographic shading, near-stream vegetation stream surface reflection, water column absorption and stream bed absorption.

where,

$H_{Total\ NPS}$:	Total Nonpoint Source Heat Load (kcal/day)
$H_{SP\ NPS}$:	Background Nonpoint Source Heat Load based on *System Potential* (kcal/day)
$H_{Anthro\ NPS}$:	Anthropogenic Nonpoint Source Heat Load (kcal/day)
$\Phi_{Total\ Solar}$:	Total Daily Solar Radiation Load (ly/day)
$\Phi_{SP\ Solar}$:	Background Daily Solar Radiation Load based on *System Potential* (ly/day)
$\Phi_{Anthro\ Solar}$:	Anthropogenic Daily Solar Radiation Load (ly/day)
A:	Stream Surface Area - calculated at each 100 foot stream segment node (cm^2)

System Potential vegetation characteristics were developed to include the effects of natural disturbance on riparian vegetation distribution and attributes within each geomorphic unit. The term "geomorphic unit" refers to quaternary geologic units shown as polygons that were differentiated on the basis of stratigraphic, topographic, pedogenic, and hydrogeologic properties (O'Connor et al, 2001). In other words, surface deposits of unconsolidated material above bed rock shaped by processes of erosion, sediment transport and deposition.

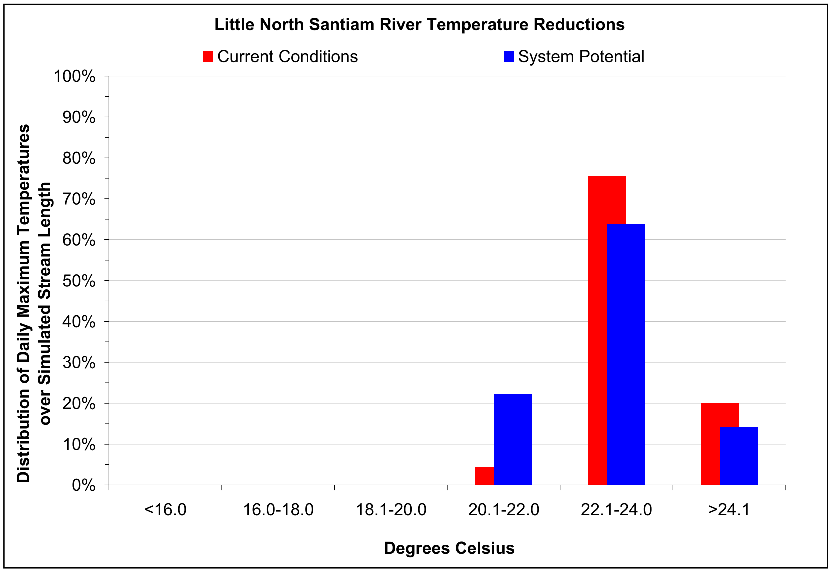
Natural disturbance includes among other processes:

- Flood
- Wind Throw
- Fire
- Insect Infestation

System potential vegetation includes the random distribution of conifer, mix conifer-hardwood, and hardwood species in each geomorphic unit. This random distribution of attributes within each geomorphic unit is intended to include the effects of natural disturbance in the system potential riparian vegetation condition. Some geomorphic units may also incorporate prairie. The proportions of forest, savanna and prairie to be used in of each geomorphic unit were developed following rules detailed in Table 1 and on page 14 of the Potential Near-Stream Land Cover document included in Appendix C. As an example, in the quaternary alluvium unit (Qalc) which is unconsolidated silt, sand, and gravel of the Willamette River and major Cascade Range tributaries the vegetation distribution includes 80% forest, 17% savanna and 3% prairie. Forest land includes a mix of conifer (4%), hardwood (3%) and mixed (93%) forests, which determine the shade characteristics of the near-stream plant community.

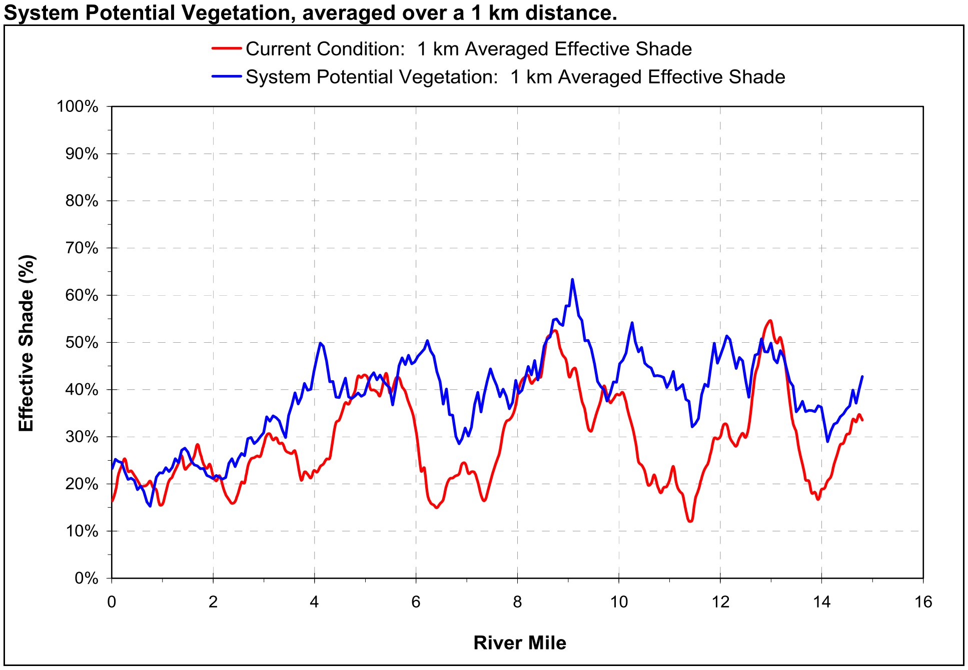
A total of 15 river miles in the North Santiam Subbasin, Little North Santiam River from its mouth to Salmon Falls, were analyzed and simulated during the critical period, August 1st, 2000. The stream temperatures that result from system potential riparian conditions are presented in Figure 8.5. This graph represents the maximum daily stream temperatures observed longitudinally downstream. A decrease in the maximum observed daily maximum stream temperatures are predicted for the river when system potential riparian vegetation is applied. The stream temperatures that result from system potential riparian vegetation are the allocated condition.

Figure 8.5. Little North Santiam River distribution of maximum daily stream temperatures at current conditions and system potential vegetation.



The percent effective shade calculated for current conditions versus system potential vegetation conditions in the Little North Santiam River averaged over a 1 km (0.6 miles) distance is shown in Figure 8.6. Typically system potential vegetation provides greater percent effective shade values to the stream, however for the Little North Santiam River under the currently simulated system potential vegetation conditions the river has lower percent effective shade calculated values than at current conditions in specific reaches of the stream. This decrease in effective shade under system potential conditions is due in part to random distribution of natural disturbance included in the system potential vegetation scenario. For example, the system potential condition at RM 13 of the river may have accounted for a disturbance in the riparian community when in fact under current conditions the riparian community at RM 13 may not be disturbed.

Figure 8.6. Little North Santiam River Longitudinal Percent Effective Shade Profile of Current Conditions versus System Potential Vegetation, averaged over a 1 km distance.



It is expected that effective shade values would increase if stream channel widths decreased and riparian vegetation increased. Decreasing channel widths would increase the effectiveness of the system potential vegetation to shade the stream and in effect decrease in-stream temperatures, and also decrease the width-to-depth ratio of the stream. On a stream system average there is about a 10% increase in effective shade in the Little North Santiam River under system potential vegetation conditions.

A summary of the solar radiation loads for the Little North Santiam River at current and system potential is shown in Table 8.7. The difference between current and system potential conditions is the calculated anthropogenic load for non-point sources. This table does not represent all listed waterbodies in the subbasin but only the one where resources and priority allowed for load calculation. Little North Santiam river was calibrated for August 1, 2000, utilizing TIR and in-stream thermometers. Modeling of the river with system potential riparian vegetation indicates that 5.97x10^8 kcal/day heat load is attributed to system potential condition and 0.84x10^8 kcal/day is due to anthropogenic sources.

Table 8.7 Little North Santiam River Solar Radiation Load Summary

Stream	**Current Condition** (10^8 kcal/d) $H_{Total\ NPS}$	**System Potential Condition (Background)** (10^8 kcal/d) $H_{SP\ NPS}$	**Anthropogenic** $H_{Anthro\ NPS}$ (10^8 kcal/d)
Little North Santiam River	6.82	5.97	0.84

The point of maximum impact for anthropogenic sources of heat is defined as the point in the stream where the maximum difference in temperature between natural thermal potential temperature and current temperatures are observed. In the Little North Santiam River this is where the differences between system potential vegetation and current vegetation conditions most affect stream temperatures. The point of maximum impact occurs at RM 8.0, downstream of Canyon Creek. The change between current condition stream temperatures and system potential vegetation temperatures at the point of maximum impact is 1.7°C (3.1°F). At the mouth of the river current condition temperature is 25.5°C (77.9°F), but simulations suggest this temperature would decrease under system potential vegetation to 24.9°C (76.8°F).

In addition to system potential vegetation other restoration efforts may decrease stream temperatures. These include:

- Restoring stream channel morphology
- Increasing stream channel complexity
- Restoring floodplain processes
- Restoring natural stream flow
- Decreasing tributary stream temperatures

Excess Load

OAR 340-042-0040(4)(e)

The excess load is the difference between the actual pollutant load and the loading capacity of a water body. Load allocations for nonpoint sources are based on system potential vegetation. Riparian information collected by the ODEQ and BLM, and analyzed by ODEQ indicates that there is inadequate shade throughout the North Santiam Subbasin. ODEQ data also suggest shade levels are less than system potential in the Little North Santiam River. Excess heat loading occurs wherever inadequate shade levels are widespread.

Surrogate Measures

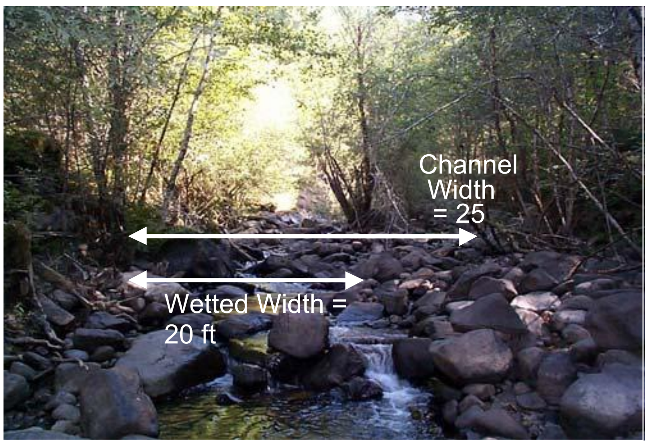
OAR 340-042-0040(5)(b,) 40 CFR 130.2(i)

The North Santiam Subbasin Temperature TMDL incorporates measures other than “daily loads” in allocating heat to nonpoint sources. These measures are termed surrogate measures. The applied surrogate measure in this temperature TMDL is percent effective shade expressed as a shade curve. Shade curves have been developed for each geomorphic unit in the Willamette Valley and upland forest area of the Cascade and Coast Ranges in the Willamette Basin. Shade curves determine the nonpoint source load allocation. They were developed using trigonometric equations estimating the shade underneath tree canopies.

Percent effective shade is perhaps the most straightforward stream parameter to monitor and calculate. It is easily translated into quantifiable water quality management and recovery objectives. Percent effective shade is defined as the percentage of direct beam solar radiation attenuated and scattered before reaching the ground or stream surface, commonly measured with a Solar Pathfinder.

Shade curves represent general relationships between the percent effective shade reaching the stream surface, solar radiation loading of the stream, system potential vegetation, stream aspect from north, and the width of the channel. The channel width, Figure 8.7, is the distance from the edge of right bank vegetation to the edge of left bank vegetation.

Figure 8.7. The Channel width and wetted width.



System potential vegetation has been developed for each geomorphic unit in the Willamette Basin. System potential vegetation is defined as the riparian vegetation which can grow and reproduce on a site given the plant biology, site elevation, soil characteristics, and local climate. However, it does not include considerations for resource management, human use, and other human disturbances. A natural disturbance regime has been incorporated into the riparian composition for each geomorphic region that includes provisions for fire, disease, wind-throw, and other natural occurrences. Each shade curve translates the amount of percent effective shade that each geomorphic unit tree composition provides to the stream based on the streams channel width and stream aspect from north. Each geomorphic unit is composed of a percentage of forest, savannah, and prairie and reflects the tree species composition that will grow and reproduce in each geomorphic unit. For a detailed description of the system potential vegetation development and of the riparian tree species composition for each geomorphic unit please see "Potential Near-Stream Land Cover for Willamette Basin TMDL Determination" in Appendix C. A shade curve has been developed for each geomorphic and upland forest unit in the North Santiam Subbasin, Map 8.8 to 8.11 and Figure 8.8. Watershed geomorphic maps that represent more than one geomorphic unit are shown for the Lower North Santiam River, Little North Santiam River, and Middle North Santiam River watersheds; the following watersheds are to apply the upland forest geomorphic unit to all streams: North Fork Breitenbush River, Detroit Reservoir / Blowout Divide Creek, and Upper North Santiam River watersheds.

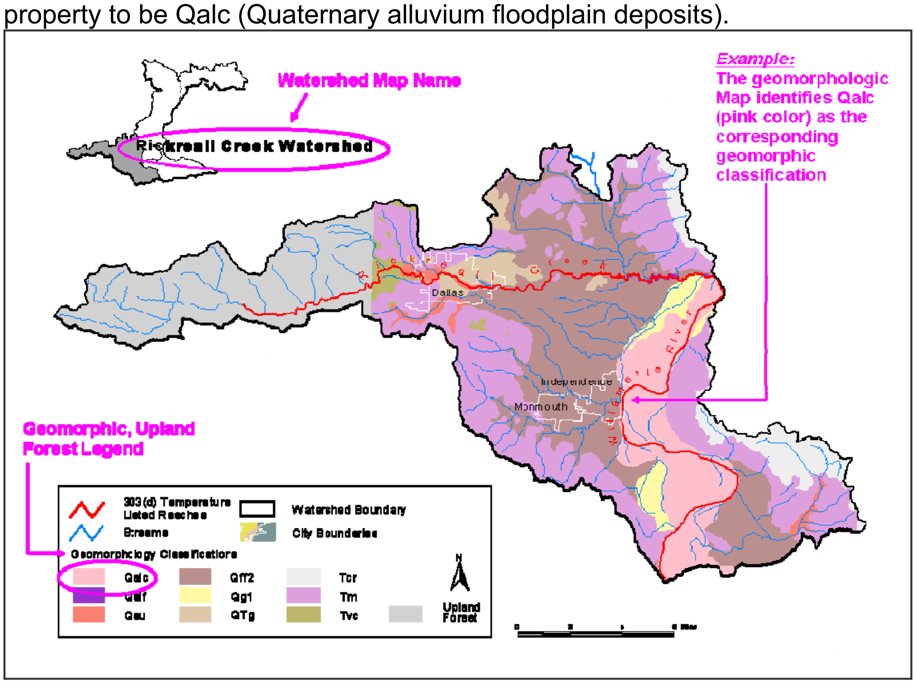
The relative areas of the geomorphic classifications of the North Santiam Subbasin are presented in Table 8.8. Despite the relatively fine scale of the geomorphic classifications, the differences among the various shade curves are subtle in some cases.

Table 8.8 Area of Geomorphic Units in North Santiam Subbasin. Values are Ranked in Order of Increasing Area.

Geomorphic Class	Acres	Square Miles	Relative Area (%)
Quaternary alluvium floodplain deposits (Qalc)	18,965	30	3.9
Undifferentiated Quaternary Alluvium (Qau)	1,567	2	0.3
Quaternary fine-grained Flood deposits (Qff2)	7,345	11	1.5
Post Flood Quaternary sand/gravel (Qg1)	9,885	15	2.0
Pre-Flood Quaternary sand/gravel (Qg2)	5,291	8	1.1
Quaternary Landslide deposits (Qls)	733	1	0.1
Quaternary terrace gravels (QTg)	7,698	12	1.6
Tertiary Columbia River Basalt (Tcr)	12,494	20	2.6
Tertiary Marine sedimentary rock (Tm)	3,943	6	0.8
Western Cascades tertiary volcanics (Tvw)	23,458	37	4.8
Upland Forests (Uf)	397,623	621	81.3
Total	**489,002**	**764**	**100**

How to Use a Shade Curve:

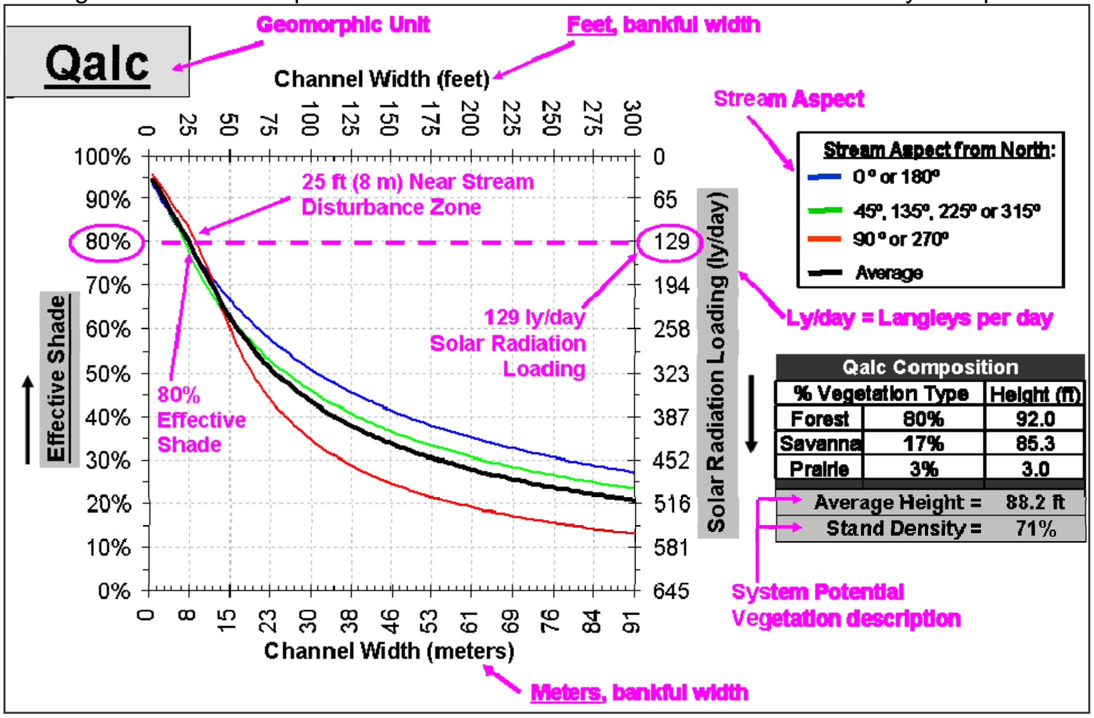
Determine the applicable geomorphic or upland forest unit that applies to the stream reach you are applying a Shade Curve to.
Example: You are located in the Rickreall Creek watershed, in the city of Independence along the west bank of the Willamette River. By using the appropriate map, below, you identify the geomorphic unit on your property to be Qalc (Quaternary alluvium floodplain deposits).



Determine the stream aspect from north.
Example: Based on your location on a tributary to the west bank of the Willamette River in Independence, standing in-stream mid-channel, facing north you determine the river's aspect as 0º or 180º from north (this means the river reach runs south to north).

Determine the channel width of the stream reach.
Example: At your location you measure the channel width using a tape measure or lasar range finder, you determine the stream width is 25 feet.

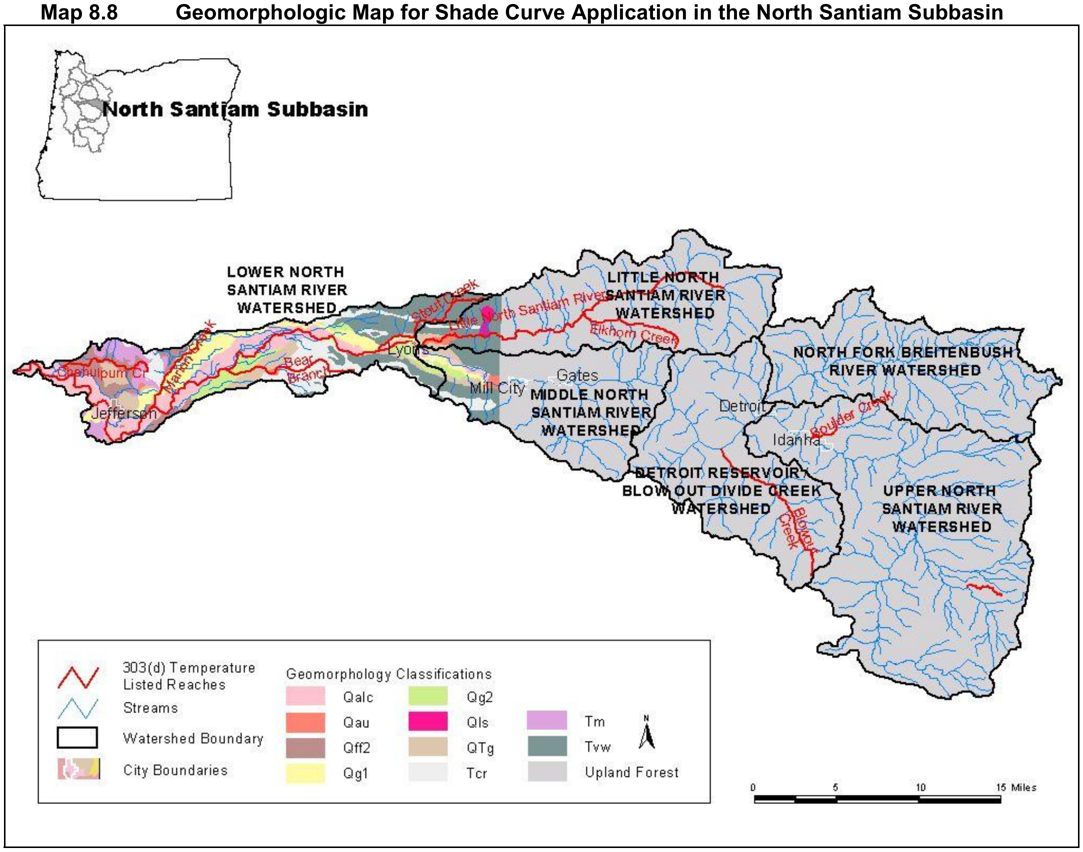
Using the appropriate geomorphic or upland forest Shade Curve, using the appropriate stream aspect line and channel width (x-axis), read the y-axis to determine the percent effective shade and solar radiation loading. This is the non-point source load allocation of the stream reach at system potential vegetation.



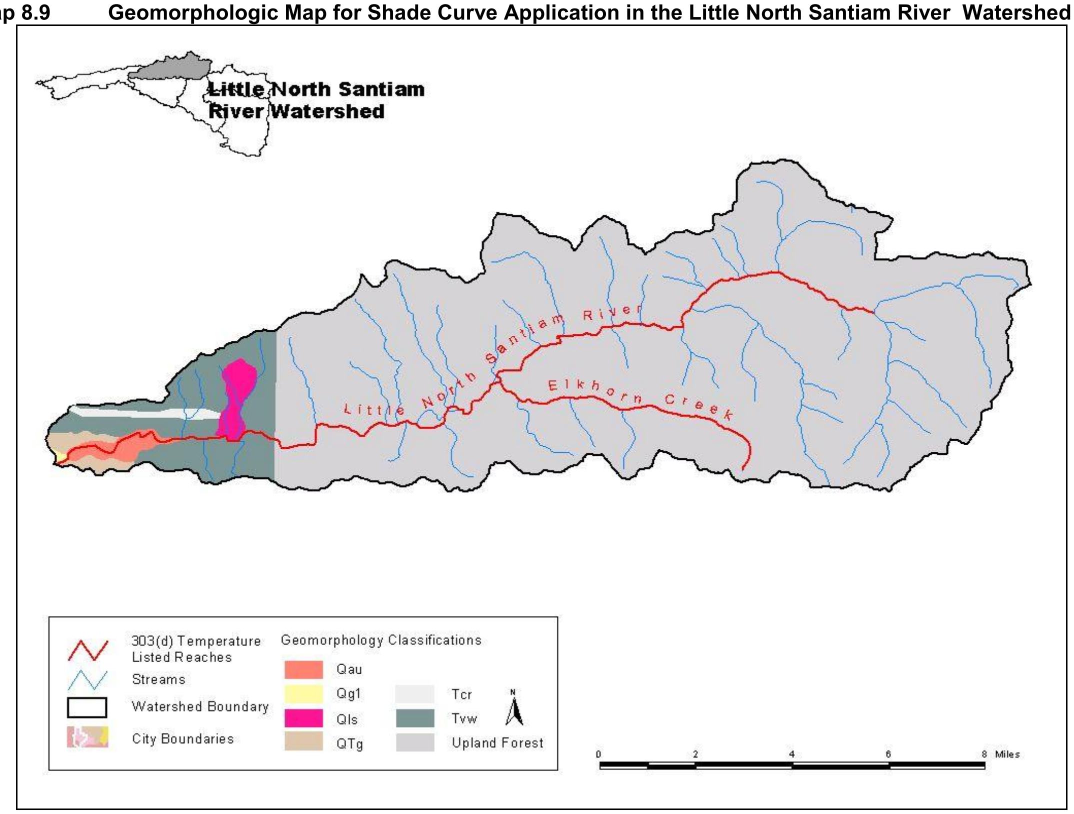
Example: A tributary to the Willamette River on the west bank near Independence with a stream aspect from north of 0º or 180º (blue line) and a channel width of 25 feet: using the blue line to determine the loading capacity from the x-axis identify the 25 feet (8 m) mark and read the y-axis, the solar radiation loading would be 129 Langleys/day with 80% effective shade when system potential vegetation is applied to the left and right bank of the stream reach. System potential vegetation identifies the riparian average height, 88.2 feet (26.9 m), and stand density (tree canopy density), 71 %, that would be established in the riparian area. If it is difficult to determine the streams aspect from north, the average stream aspect from north, black line, can be used to determine the solar radiation loading and effective shade.

Conclusion: A land owner or manager living on the west side of the Willamette River near the city of Independence, measures the channel width of the tributary stream as 25 feet (8 m), with a stream aspect from north of 0º or 180º. By using the geomorphic map for shade curve development that is specific to the areas watershed, provided by ODEQ, in this case Rickreall Creek Watershed geomorphic map. The land owner identifies their location and the corresponding geomorphic unit as Qalc in this example. The land owner then uses the Qalc shade curve to identify what the effective shade and solar radiation loading reaching the stream would be when the land owner establishes a riparian area corresponding to the system potential vegetation description. This is considered the non-point source load allocation.

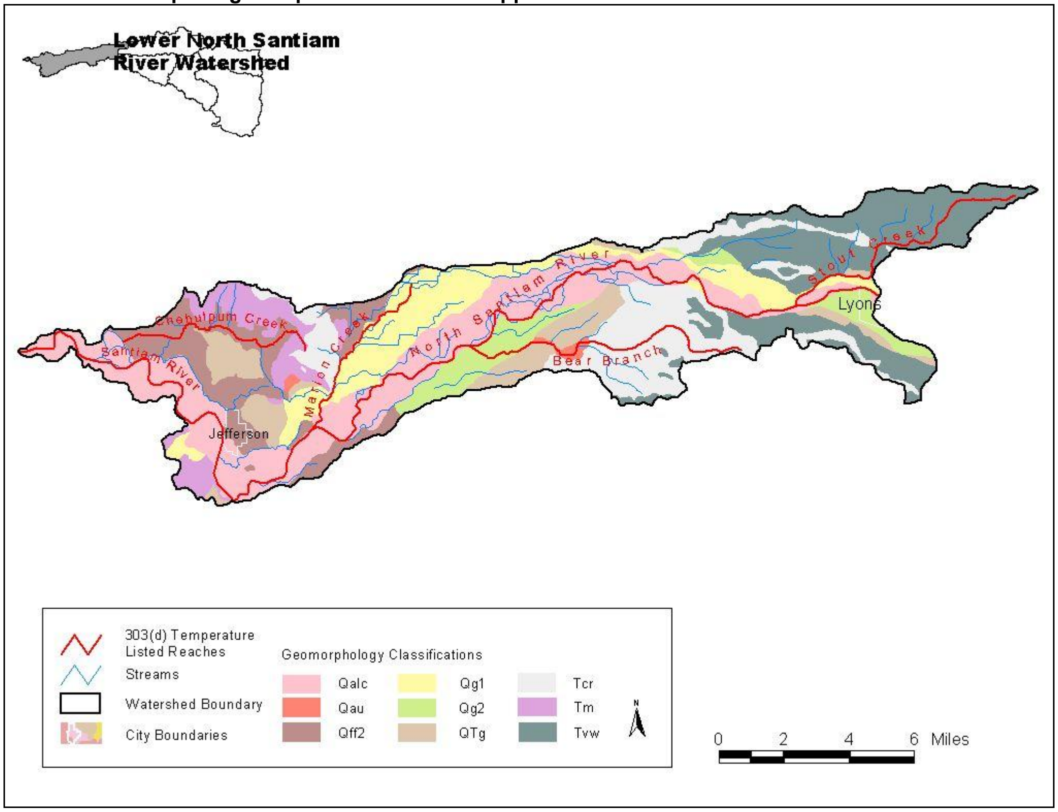
Map 8.8 Geomorphologic Map for Shade Curve Application in the North Santiam Subbasin



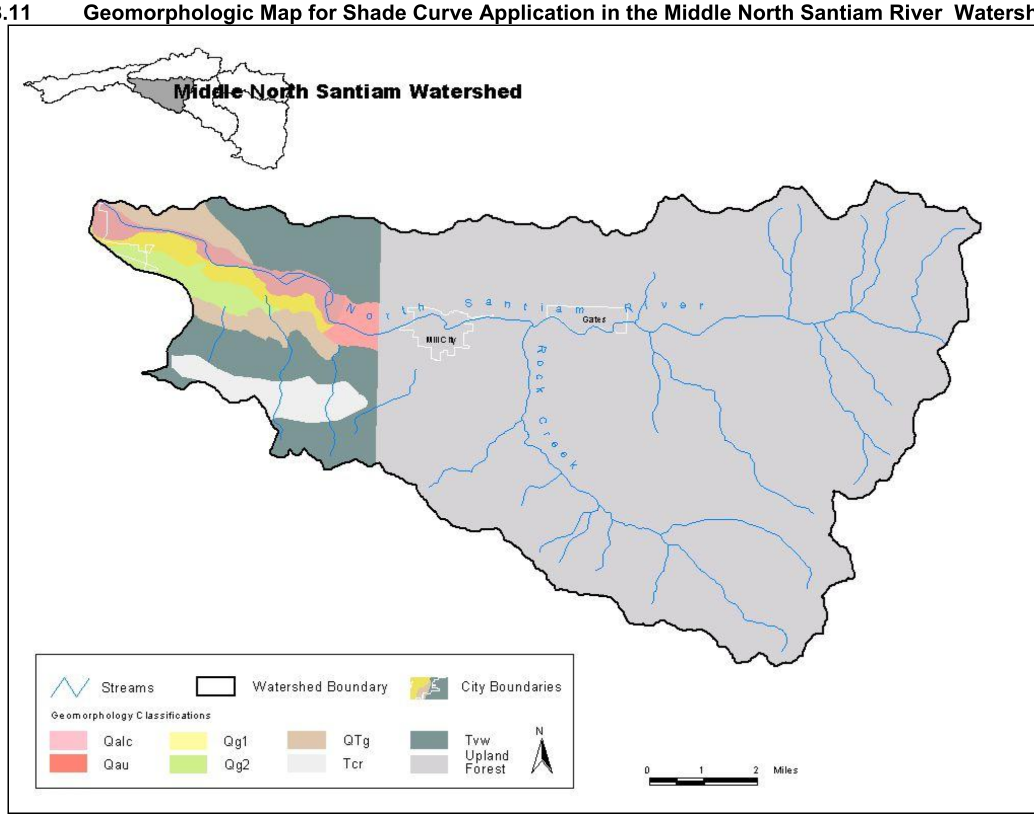
Map 8.9 Geomorphologic Map for Shade Curve Application in the Little North Santiam River Watershed



Map 8.10 Geomorphologic Map for Shade Curve Application in the Lower North Santiam River Watershed



Map 8.11 Geomorphologic Map for Shade Curve Application in the Middle North Santiam River Watershed



The shade curve method provides no information on existing shade conditions or the expected system potential stream temperature. It does provide quick and accurate estimates of the allocations necessary to eliminate temperature increases resulting from anthropogenic impacts on stream shading. The shade curves presented in Figure 8.8 apply to all water bodies in the North Santiam Subbasin based on the geomorphic and upland forest unit of the reach. The shade curves represented in each figure have been calculated based on the average height for each unit as defined by system potential vegetation. Interpretation and implementation of the shade curves requires the identification of the geomorphic or upland forest unit that applies to the stream reach (Map 8.8 to 8.11), measuring the streams channel width and then depending on the streams aspect from north reading the shade curves graph to determine the percent effective shade and solar radiation loading that the system potential vegetation composition will provide. For a list of geomorphic class abbreviations for each shade curve please see the Table 8.8 titled "Area of Geomorphic Units in the North Santiam Subbasin", above.

Geomorphic unit code Pre Flood Quaternary Sand/Gravel (Qg2) is represented in the North Santiam Subbasin. The shade curve for Qg2 has not been developed. Historically the geomorphic unit code Qg2 had 90% prairie vegetation along streams that historically became subsurface in the summer and for which water is currently artificially diverted to maintain summer flows, historic vegetation is probably not a good guideline for modeling potential present day stream temperature. Instead, ODEQ will use nearest adjacent geomorphic code as determined by the geomorphologic maps, Map 8.8 to 8.11.

Figure 8.8. Shade Curves that apply to the North Santiam Subbasin, based on geomorphology.

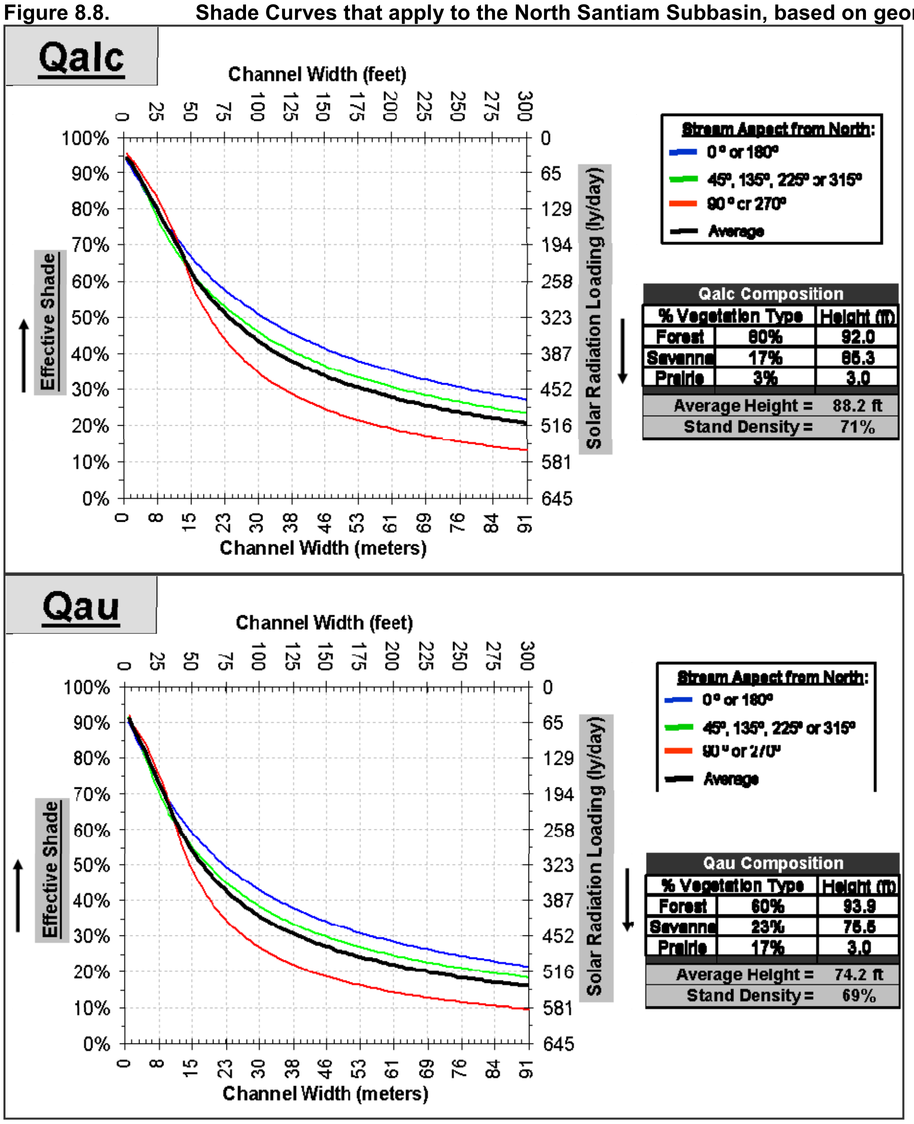
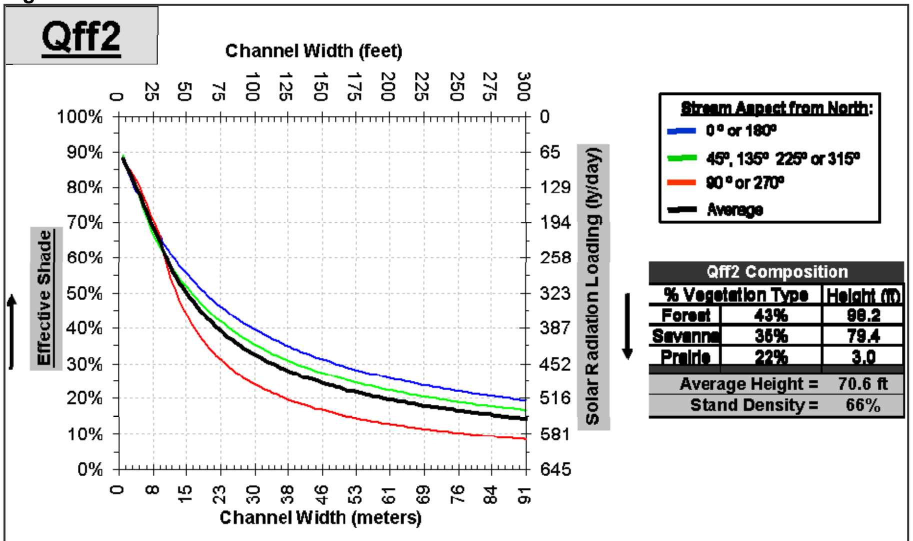
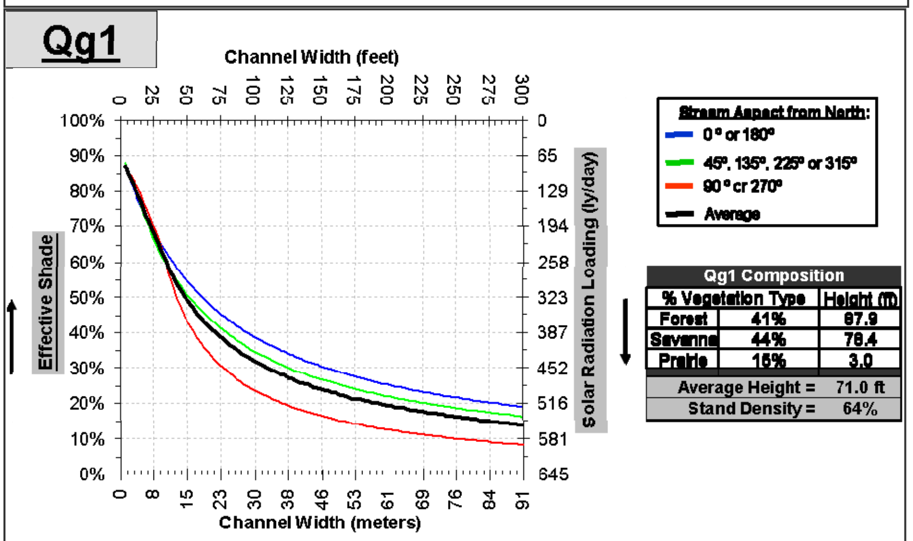


Figure 8.8 continued



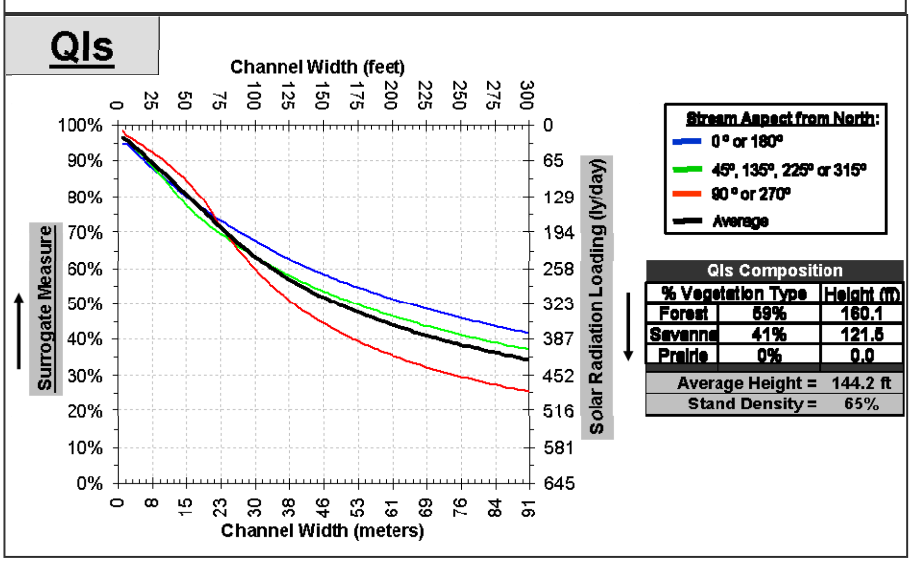
Qff2 Composition	
% Vegetation Type	Height (ft)

Forest	43%	98.2
Savanna	35%	79.4
Prairie	22%	3.0
Average Height =	70.6 ft	
Stand Density =	66%	



Qg1 Composition	
% Vegetation Type	Height (ft)

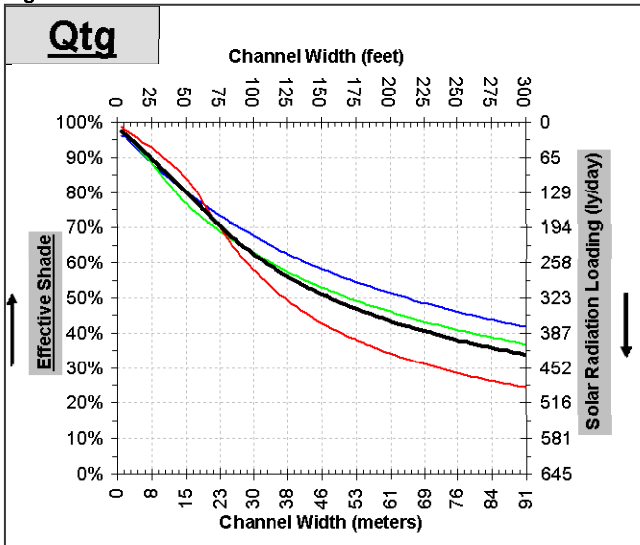
Forest	41%	97.9
Savanna	44%	78.4
Prairie	15%	3.0
Average Height =	71.0 ft	
Stand Density =	64%	



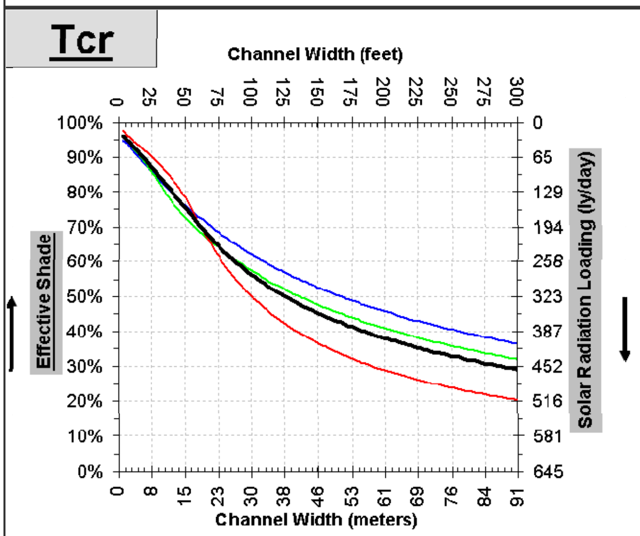
Qls Composition	
% Vegetation Type	Height (ft)

Forest	59%	160.1
Savanna	41%	121.5
Prairie	0%	0.0
Average Height =	144.2 ft	
Stand Density =	65%	

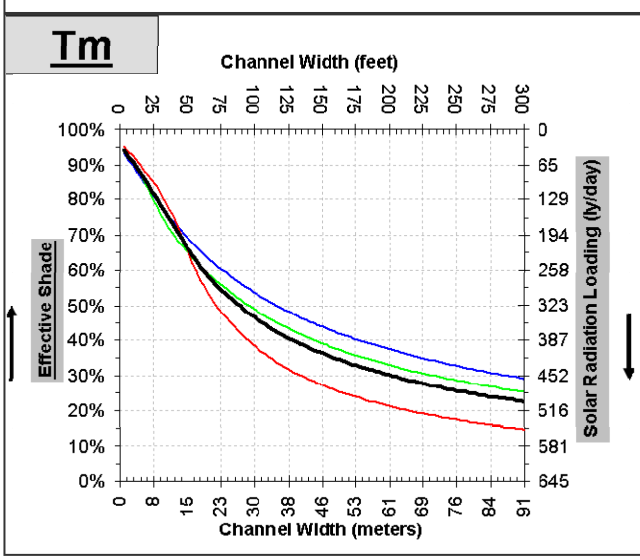
Figure 8.8 continued



Qtg Composition		
% Vegetation Type		Height (ft)
Forest	77%	156.3
Savanna	14%	87.6
Prairie	9%	3.0
Average Height =		132.9 ft
Stand Density =		72%

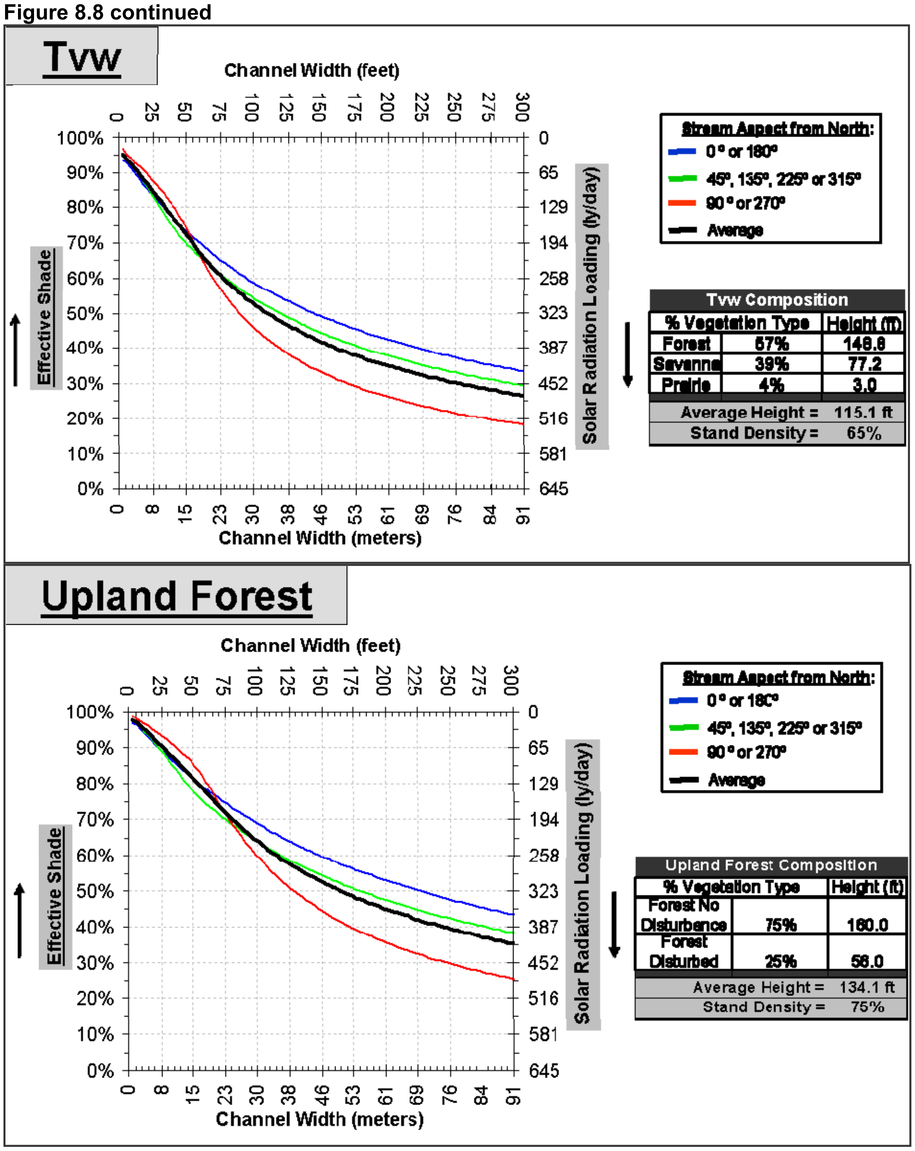


Tcr Composition		
% Vegetation Type		Height (ft)
Forest	63%	155.2
Savanna	27%	84.6
Prairie	10%	3.0
Average Height =		120.9 ft
Stand Density =		68%



Tm Composition		
% Vegetation Type		Height (ft)
Forest	56%	117.9
Savanna	39%	80.5
Prairie	5%	3.0
Average Height =		97.6 ft
Stand Density =		65%

Figure 8.8 continued



Margin of Safety

OAR 340-042-0040(4)(i), CWA 303(d)(1)

A margin of safety is intended to account for uncertainty in available data or in the effect controls will have on loading reductions and water quality. A margin of safety is expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions).

The margin of safety may be implicit, as in conservative assumptions used in calculating the Loading Capacity, Wasteload Allocations, and Load Allocations. It may also be explicitly stated as an added, separate quantity in the TMDL calculation. In any case, assumptions should be stated and the basis behind the margin of safety documented. The margin of safety is not meant to compensate for a failure to consider known sources. Table 8.9 presents six approaches for incorporating a margin of safety into TMDLs.

The following factors may be considered in evaluating and deriving an appropriate MOS:

- The analysis and techniques used in evaluating the components of the TMDL process and deriving an allocation scheme.
- Characterization and estimates of source loading (e.g., confidence regarding data limitation, analysis limitation or assumptions).
- Analysis of relationships between the source loading and instream impact.
- Prediction of response of receiving waters under various allocation scenarios (e.g., the predictive capability of the analysis, simplifications in the selected techniques).
- The implications of the MOS on the overall load reductions identified in terms of reduction feasibility and implementation time frames.

A TMDL and associated margin of safety, which results in an overall allocation, represent the best estimate of how standards can be achieved. The selection of the margin of safety should clarify the implications for monitoring and implementation planning in refining the estimate if necessary (adaptive management). The TMDL process accommodates the ability to track and ultimately refine assumptions within the TMDL implementation-planning component.

Table 8.9 Approaches for Incorporating a Margin of Safety into a TMDL

Type of Margin of Safety	Available Approaches
Explicit	1. Set numeric targets at more conservative levels than analytical results indicate. 2. Add a safety factor to pollutant loading estimates. 3. Do not allocate a portion of available loading capacity; reserve for margin of safety.
Implicit	1. Conservative assumptions in derivation of numeric targets. 2. Conservative assumptions when developing numeric model applications. 3. Conservative assumptions when analyzing prospective feasibility of practices and restoration activities.

A margin of safety has been incorporated into the temperature assessment methodology. Wasteload allocations are based on critical conditions that are unlikely to occur simultaneously. For example, it is unlikely that maximum effluent flows and maximum effluent temperatures are likely to occur simultaneously however those values were used to calculate point source heat loads. Furthermore, receiving stream values were also based on attainment of biological based criteria during low flow periods defined as the low flow of a ten year cycle.

Calculating a numeric margin of safety for nonpoint source loads is not easily performed with the methodology presented in this document. In fact, the basis for the loading capacities and load allocations is system potential conditions and it is not the purpose of this plan to promote riparian conditions and shade levels that exceed natural conditions.

Reserve Capacity
OAR 340-042-0040(4)(k)

Reserve capacity has been allocated for temperature through much of the Willamette Basin. Explicit allocations have generally only been made in conjunction with point source wasteload allocations. Where there are multiple point sources in a waterbody, point sources in combination have been allocated 0.2˚C of the Human Use Allowance. Another 0.05˚C is allocated to nonpoint sources of heat. These latter sources have generally been limited to natural solar radiation levels determined by shade curves for a given area. The final 0.05˚C is allocated to reserve capacity and will be available for use by point sources or nonpoint sources by application to ODEQ. In total, these allocations may not increase temperature in a water quality limited waterbody by more than 0.3°C (0.54°F) at the point of maximum impact.

In those situations where the point source allocation is less than 0.2˚C or if there are no point sources, the remaining portion of the Human Use Allowance will be set aside as reserve capacity. The nonpoint source allocation will remain at 0.05˚C unless special circumstances exist that require a larger or smaller allocation. More information regarding the use of reserve capacity may be found in Chapter 14, Water Quality Management Plan, Part 2, under Temperature Implementation.

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