CHAPTER 4: TEMPERATURE-MAINSTEM TMDL AND SUBBASIN SUMMARY

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SUMMARY OF TMDL DEVELOPMENT AND APPROACH

Table 4.1 Willamette Basin Mainstem Temperature TMDL Components

Waterbodies **OAR 340-042-0040(4)(a)**	Perennial and fish bearing intermittent streams (as identified by ODFW, USFW or NOAA Fisheries) within the Willamette Basin, HUC (Hydrologic Unit Code) 17090001,17090002,17090003,17090004,17090005,17090006,17090007,17090011,17090012
Pollutant Identification **OAR 340-042-0040(4)(b)**	*<u>Pollutants</u>:* Human caused temperature increases from (1) warm water discharge to surface waters (2) increased solar radiation loading, and (3) flow modification that affects natural thermal regimes including reservoir operations that influence the timing of maximum seasonal stream temperatures.
Beneficial Uses **OAR 340-042-0040(4)(c)** **OAR 340-41**	Salmonid fish spawning and rearing, anadromous fish passage, resident fish and aquatic life, and fishing.
Target Identification (Applicable Water Quality Standards) ***CWA §303(d)(1)*** **OAR 340-042-0040(4)(c)** **OAR 340-041-0028(4)(f)** **OAR 340-041-0028(4)(a)** **OAR 340-041-0028(4)(b)** **OAR 340-041-0028(4)(c)** **OAR 340-041-0028(4)(d)** **OAR 340-041-0028(8)** **OAR 340-041-0028(12)(b)(B)**	OAR 340, Division 41 provides numeric and narrative temperature criteria. Maps and tables provided in OAR 340-041-0101 to 0340 specify where and when the criteria apply. Biologically-based numeric criteria applicable to the Willamette Basin, as measured using the seven day average of the daily maximum stream temperature, include: 12.0°C during times and at locations of bull trout spawning and juvenile rearing. 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. 20.0°C during times and at locations of salmon and steelhead migration in identified migration corridors with sufficiently distributed coldwater refugia. Natural Conditions Criteria. Where ODEQ determines that the natural thermal potential temperature for all or a portion of a water body exceeds the biologically-based criteria the natural thermal potential temperatures supersede the biologically-based numeric criteria and are deemed the applicable criteria for that water body. 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)***	<u>Nonpoint sources</u> include excessive inputs of solar radiation because of the removal or reduction of streamside vegetation. Reservoir and dam operations are considered nonpoint sources that affect the quantity and timing of heat delivery to down stream river reaches. <u>Point sources</u> include municipal and industrial facilities that discharge warm water to receiving streams.
Seasonal Variation **OAR 340-042-0040(4)(j)** ***CWA §303(d)(1)***	Peak temperatures typically occur in mid-July through mid-August but anthropogenic heat loads are of concern and addressed from April through October.

Table 4.1 continued

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:* Oregon Administrative Rule 340-041-0028 (12)(b)(B) states that anthropogenic sources of heat may increase stream temperature no more than 0.3°C (0.5 °F) above the applicable biological criteria or the natural condition criteria. This is achieved when the cumulative heat input of all point and nonpoint sources results in no greater than a 0.3 °C increase in temperature above the criteria at the point of maximum impact. Loading capacity is the heat load that corresponds to the applicable numeric criteria plus an 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 is the excess heat load. Excess load in temperature TMDLs 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. *Load Allocations (Nonpoint Sources)*: System potential solar radiation is the targeted load allocation for nonpoint source activities in the Willamette Basin. A small portion of the human use allowance has been allocated to nonpoint source activities along the mainstem Willamette and its largest tributaries to address anthropogenic heat loads in excess of background rates. This human use allowance is for anthropogenic heat loads in landscapes that are not likely to achieve a natural condition characterized by native plant communities in streamside areas. The mainstem and subbasin load allocations for heat from such nonpoint source activities varies by location and may correspond to an increase in temperature of 0.05ºC. This allocation was not divided among specific sources as part of this TMDL. *Load Allocations (Reservoir Operations)*: Load Allocations for reservoirs and hydroelectric projects are based on no increase above natural thermal potential temperatures with the exception of PGE and EWEB Hydroelectric projects. Load allocations for the PGE Clackamas and PGE Willamette Falls projects are 0.15°C and 0.11°C of the human use allowance, respectively. The EWEB Leaburg and Walterville Project is allocated 0.10 °C of the human use allowance for the Lower McKenzie River downstream from the Walterville Project return flow and 0.30°C of the human use allowance upstream from the Walterville Project return flow. *Waste Load Allocations (NPDES Point Sources)*: Waste load allocations are based on allowing no greater than a 0.3°C increase in stream temperatures above the applicable temperature criteria at the point of maximum impact. Generally, waste load allocations in the mainstem and subbasin TMDLs limit the allowable increase in stream temperatures to no more than 0.20°C above natural thermal potential temperatures, although this allocation may be as large as 0.25°C as conditions warrant.
Surrogate Measures **OAR 340-042-0040(5)(b)** ***40 CFR 130.2(i)***	Surrogate measures are used throughout the temperature TMDL. Effective shade targets translate nonpoint source solar radiation loads into streamside vegetation objectives.
Margins of Safety **OAR 340-042-0040(4)(i)** ***CWA §303(d)(1)***	*Margins of Safety* are demonstrated in critical condition assumptions used for point source waste load allocations and are inherent to methodology for determination of nonpoint source loads.
Reserve Capacity **OAR 340-042-0040(4)(k)**	A portion of the human use allowance is allocated for future growth and new or expanded sources. This allowance varies by location.
Water Quality Management Plan **OAR 340-042-0040(4)(l)** ***CWA §303(d)(1)***	The Water Quality Management Plan (WQMP) provides the framework of management strategies to attain and maintain water quality standards. The framework is designed to work in conjunction with detailed plans and analyses provided in sector-specific or source-specific implementation plans.
Standards Attainment & Reasonable Assurance	Model simulations demonstrate that 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.
Heat load trading	Heat load trading is allowed between individual sources and sectors provided that all applicable water quality criteria are attained and sufficient legal or other mechanisms are put in place that ensure the trade will be implemented as designed. This is discussed further in the WQMP, Chapter 14.

WATER QUALITY SUMMARY

Stream temperatures are determined by the interactions of geomorphology, hydrology, vegetation, climate, elevation and watershed aspect (IMST 2004). Water temperature varies over time and space at multiple scales that are affected by each of these parameters. Salmon and trout life cycles are closely tied to the thermal regime of their habitats. Natural events or human activities that affect the input of thermal energy or the spatial and temporal distribution of that energy may be detrimental to these species. Persistent disturbances may threaten the viability of local populations.

The Oregon Department of Environmental Quality has identified the Willamette River as water quality limited because of elevated stream temperatures. This designation extends from the confluence of the Coast Fork Willamette and Middle Fork Willamette Rivers, which join to form the mainstem Willamette, downstream to the Columbia River. In addition, many stream segments tributary to the Willamette River have also been identified as impaired because of elevated temperatures. Approximately 1,200 miles of stream in the Willamette Basin are included on the 303(d) list of impaired waters because of temperature concerns.

The Willamette Basin TMDLs address elevated temperatures in the Willamette mainstem and nine Willamette subbasins identified in Table 4.2 and Map 4.1. This chapter presents TMDLs for the mainstem Willamette River and its major tributaries. Chapters 5 through 13 present TMDLs for the individual subbasins. A list of stream segments addressed in this TMDL and in each subbasin TMDL is located in Appendix 4.1. Three Willamette subbasins are not included in this analysis although temperature impaired streams are present in each. Temperature TMDLs were developed in the Tualatin River Subbasin in 2001 and implementation is underway. TMDLs for the Yamhill and Molalla-Pudding Subbasins are scheduled for completion by 2010.

Table 4.2 Willamette Subbasin names , USGS Hydrologic Unit Codes and Subbasin TMDL Chapters

Lower Willamette River	17090012	Chapter 5
Clackamas River	17090011	Chapter 6
Middle Willamette River	17090007	Chapter 7
North Santiam River	17090005	Chapter 8
South Santiam River	17090006	Chapter 9
Upper Willamette River	17090003	Chapter 10
McKenzie River	17090004	Chapter 11
Middle Fork Willamette River	17090001	Chapter 12
Coast Fork Willamette River	17090002	Chapter 13

Pollutant Identification

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

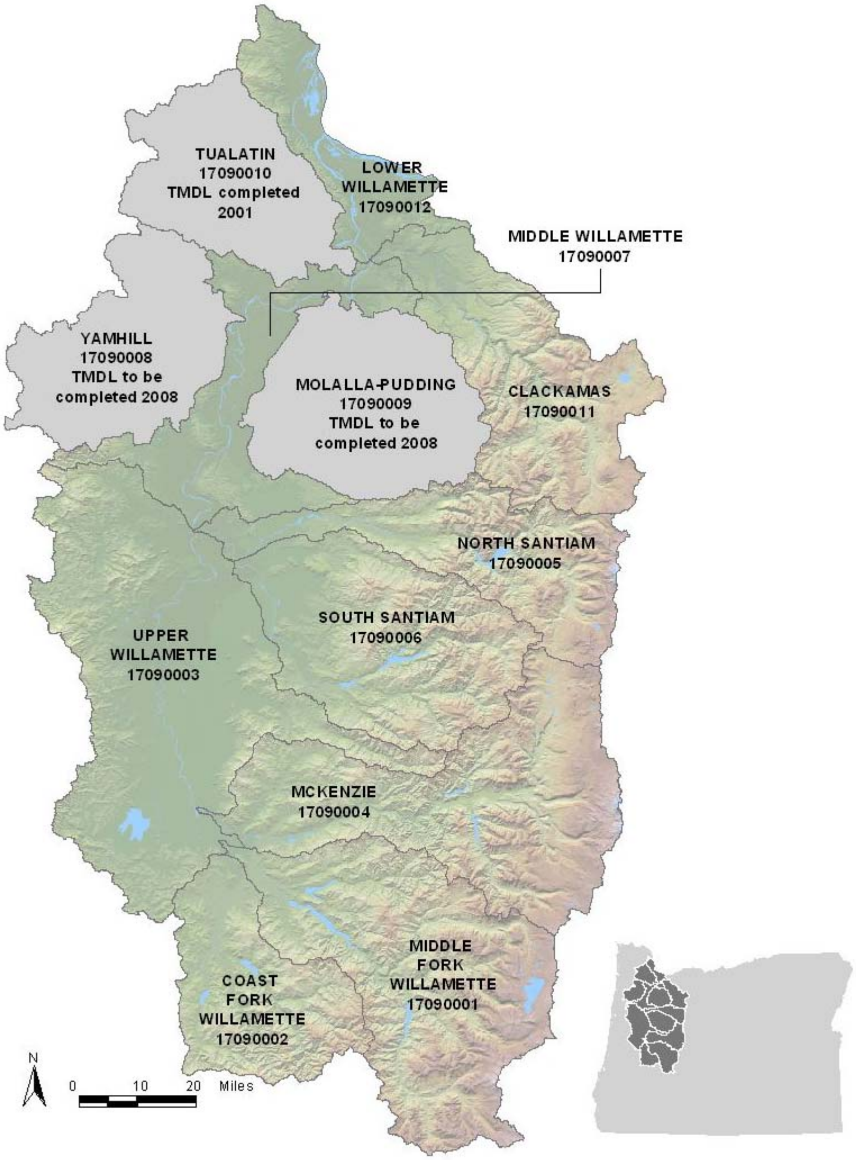
This element identifies the pollutant causing the impairment of water quality addressed in this TMDL.

Development of stream temperature TMDLs requires an understanding of the natural and human processes that contribute to stream warming. Temperature is the water quality parameter of concern, but heat, in particular heat from human activities or anthropogenic sources is the pollutant of concern in this TMDL. Specifically, water temperature change is an expression of heat energy flux to the waterbody:

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

Stream temperature is influenced by natural factors such as climate, geomorphology, hydrology, and vegetation. Human influenced or anthropogenic heat sources may include discharges of heated water to surface waters, the loss of streamside vegetation and reductions in stream shading, changes to stream channel form, and reductions in natural streamflows. The pollutant targeted in this TMDL is heat from the following sources: (1) heat from warm water discharges from various point sources (2) heat from human caused increases in solar radiation loading to the stream network, and (3) heat from reservoirs which, through their operations, increase water temperatures or otherwise modify natural thermal regimes in downstream river reaches.

Map 4.1 Temperature TMDLs are developed for 9 of 12 Willamette Subbasins



Beneficial Use Identification

OAR 340-042-0040(4) (c), OAR 340-41-442

This element identifies the beneficial uses in the basin and relevant water quality standards, including specific basin standards. The beneficial use that is most sensitive to impairment by the pollutant is specified.

Water quality standards include designation of beneficial uses of water, numeric and narrative criteria for individual parameters to protect those uses, and antidegradation policies to protect overall water quality. Beneficial uses and the associated water quality criteria are generally applicable throughout the basin. Some uses such as salmonid spawning require further delineation to ensure the appropriate application of numeric and narrative criteria. These criteria are intended to protect the beneficial uses within the Willamette Basin as designated by Oregon Administrative Rule (OAR 340-41-962, Table 19), Table 4.3.

The purpose of Oregon's temperature standard is to protect designated beneficial uses that are sensitive to temperature. Salmon, trout and other cold water species that inhabit most streams in the Willamette Basin are considered to be the beneficial uses most sensitive to stream temperature. Furthermore, each stage of the salmon or trout life cycle has separate water temperature preferences and tolerances. Biologically-based numeric criteria are specific to salmonid life stages such as spawning and rearing. There are also numeric criteria for critical habitat areas that serve as the core for salmonid protection and restoration efforts.

Table 4.3 Beneficial uses occurring in the Willamette Basin

Beneficial Uses	Clackamas River	Molalla River	Santiam River	McKenzie River	Tualatin River	All Other Streams & Tributaries	Mouth to Willamette Falls, Including Multnomah Channel	Willamette Falls to Newberg	Newberg to Salem	Salem to Coast Fork
Public Domestic Water Supply[1]	X	X	X	X	X	X	X	X	X	X
Private Domestic Water Supply[1]	X	X	X	X	X	X	X	X	X	X
Industrial Water Supply	X	X	X	X	X	X	X	X	X	X
Irrigation	X	X	X	X	X	X	X	X	X	X
Livestock Watering	X	X	X	X	X	X	X	X	X	X
Fish & Aquatic Life[2]	X	X	X	X	X	X	X	X	X	X
Wildlife & Hunting	X	X	X	X	X	X	X	X	X	X
Fishing	X	X	X	X	X	X	X	X	X	X
Boating	X	X	X	X	X	X	X	X	X	X
Water Contact Recreation	X	X	X	X	X	X	X	X[3]	X	X
Aesthetic Quality	X	X	X	X	X	X	X	X	X	X
Hydro Power	X	X	X	X	X	X	X	X		
Commercial Navigation & Transportation							X	X	X	

[1] With adequate pretreatment and natural quality that meets drinking water standards.

[2] See also Map 4.2 and 4.3 for fish use designations for this basin.

[3] Not to conflict with commercial activities in Portland Harbor.

Numeric stream temperature criteria are expressed as a seven-day moving average of daily maximum temperature. These numeric criteria may be considered action levels and indicators of water quality standards attainment. Table 4.4 shows the numeric temperature criteria that are applicable to specific salmonid life stages under Oregon's standard. All salmonid uses except Lahontan cutthroat and redband trout are found in the Willamette Basin.

Table 4.4 Biologically-based Numeric Temperature Criteria Applicable to Salmonid Uses

Use	Numeric Criteria (7-day statistic)
Salmon and Steelhead Spawning	13.0 °C / 55.4 °F
Core Cold Water Habitat	16.0 °C / 60.8 °F
Salmon and Trout Rearing and Migration	18.0 °C / 64.4 °F
Salmon and Steelhead Migration Corridors	20.0 °C / 68.0 °F
Lahontan Cutthroat or Redband Trout Use	20.0 °C / 68.0 °F
Bull Trout Spawning and Juvenile Rearing	12.0 °C / 53.6 °F

Oregon water quality standards also specify where and when the specific salmonid life stages occur and, therefore, where and when numeric criteria apply. Salmonid distribution and timing maps are provided in Map 4.2 and 4.3, below. Map 4.2 delineates where the rearing and migration use and numeric criteria apply, where core cold water habitats occur, and where bull trout uses are located. Map 4.3 designates where and when the numeric criteria applies to protect salmon and steelhead during periods of spawning through fry emergence. Where available, watershed-specific timing and use information is utilized to more precisely determine where and when the numeric temperature criteria apply.

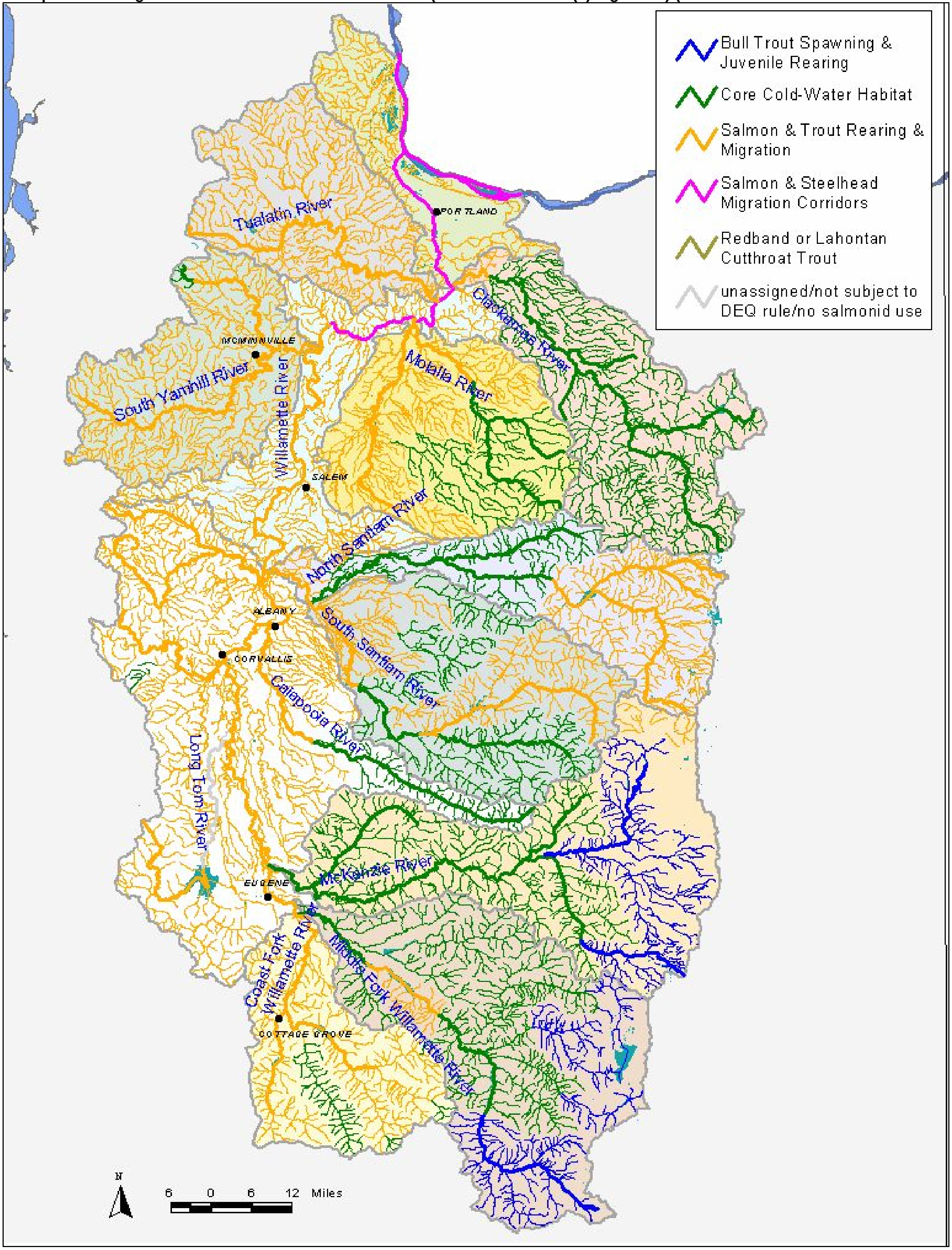
Migration Corridor Use and Cold Water Refugia

The mainstem Willamette River from its confluence with the Columbia River mouth upstream to approximately the City of Newberg (RM 0 to RM 50) has been designated as a salmon and steelhead migration corridor. The numeric temperature criteria for this use is 20°C (68°F) and applies throughout the year. In addition, narrative criteria for the migration use calls for cold water refugia that are sufficiently distributed so that salmon and steelhead migration can occur without significant adverse effects from higher water temperatures elsewhere in the river.

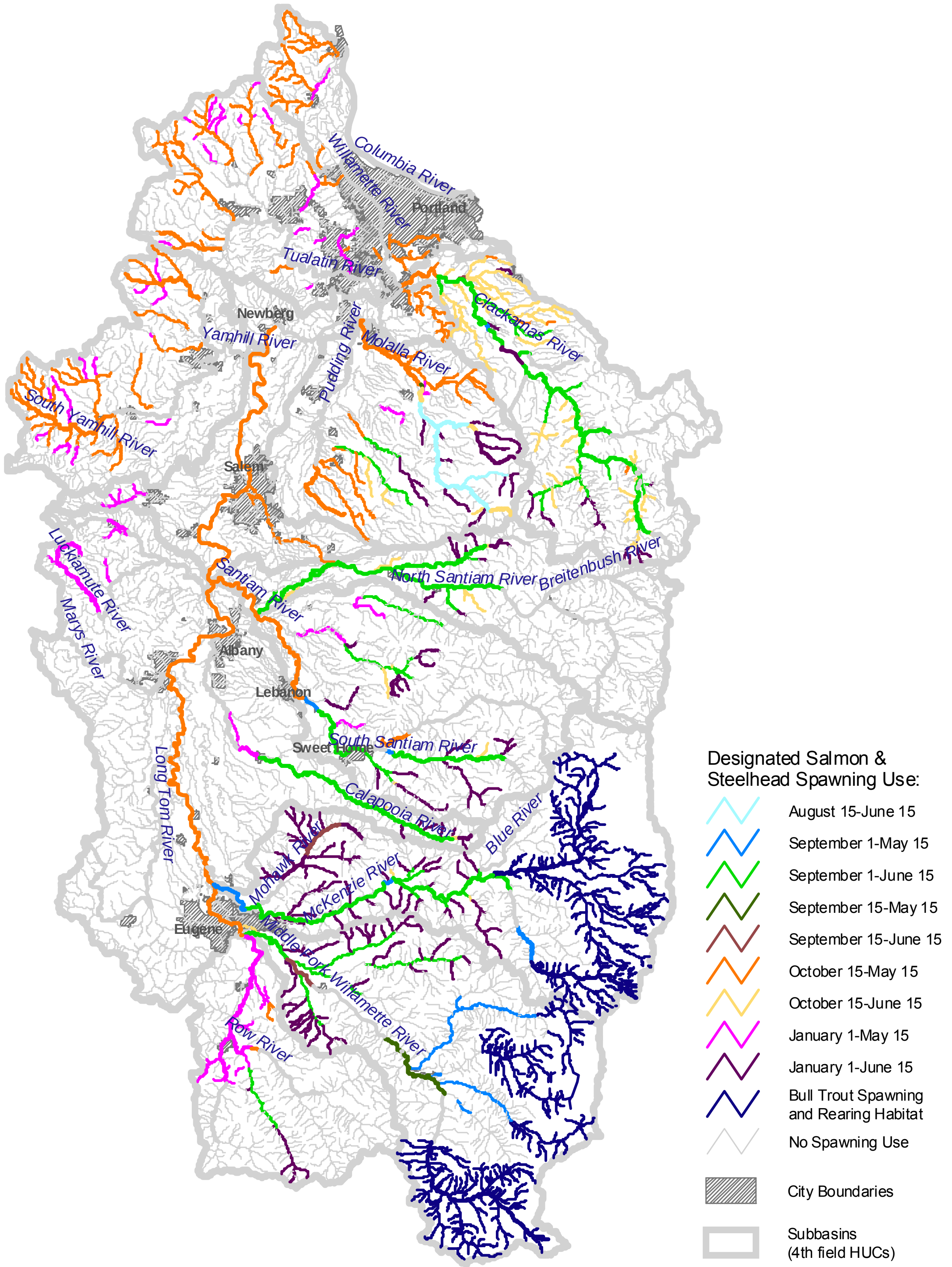
Cold water refugia are defined in OAR 340-041-0002(10) as "those portions of water body where, or times during the diel temperature cycle when, the water temperature is at least 2°C colder than the daily maximum temperature of the adjacent well mixed flow of the water body". Refugia include habitats and locations where temperature sensitive cold water species may find refuge when ambient stream temperatures are stressful.

Although not well documented, thermal refugia likely occur throughout the mainstem Willamette. Small, perennial tributaries are distributed throughout the migration corridor and some, such as Tryon Creek and Stephens Creek, are sources of cooler water during the peak summer period. Cool inflow from larger tributaries may be entrained along the bank of the river and create larger refugia. Hyporheic flow and groundwater inflows may also provide local thermal refugia. Protection of riparian areas and floodplains along tributaries and the mainstem river itself is necessary for the maintenance and restoration of thermal refugia and the processes that create them. This will be a key element for TMDL implementation not only in the lower 50 miles of the river, but also in other reaches where temperatures exceed the biologically-based numeric criteria.

Map 4.2 Designated fish use in the Willamette Basin (OAR 340-041-0028(4) Fig. 340A) (source: TMDL\transfer\dianne



Map 4.3 Designated Salmonid and Steelhead Spawning Use (OAR 340-041-0028(4) Fig. 340B)



Natural Conditions Criteria (OAR 340-041-0028(8))

Oregon water quality standards include provisions for periods and locations where biologically-based numeric criteria may not be achieved. If biologically-based numeric criteria are not achievable when waters are in their natural condition, stream temperatures achieved under such natural conditions shall be deemed to be the applicable temperature criteria for that water body. In other words, a stream that does not meet biologically-based numeric temperature criteria, but is free from anthropogenic influence, is considered to be at its natural thermal potential. In these situations the natural thermal potential temperatures supersede the biological numeric criteria and are considered the applicable numeric criteria. Unlike the biologically-based criteria such as the rearing criteria of 18ºC, which is constant for the entire beneficial use period, the natural thermal potential and natural condition criteria are site specific and vary over time.

Human Use Allowance (OAR 340-041-0028 (12)(b))

Oregon water quality standards also have provisions for human use when temperatures exceed applicable numeric criteria. The human use allowance limits cumulative anthropogenic heating of surface waters to no more than 0.3°C (0.5°F) above the applicable biological or natural conditions criteria at the point of maximum impact. Determination of the human use allowance is a key element of the Willamette Basin TMDLs because it often determines the heat loading capacity of receiving streams. The metric for compliance with the human use allowance is a seven day average of daily maximum temperatures.

Protecting Cold Water (OAR 340-041-0028(11))

Protection of cold water temperatures is further specified in OAR 340-041-0028 (11). Subsection (a) requires that streams with maximum summer temperatures less than applicable numeric criteria shall not be warmed by more than 0.3°C above ambient temperatures. This applies to all heat sources at the point of maximum impact in streams designated as critical habitat for threatened or endangered salmon, steelhead or bull trout.

Subsection (b) of the rule limits the warming of salmon and steelhead spawning waters from point source discharges to 0.5°C above the 60 day average maximum temperature when the rolling average is between 10 to 12.8°C. The allowable increase is 1°C when the 60 day rolling average maximum temperature is less than 10°C unless analysis demonstrates that a greater increase will not significantly impact the use.

Antidegradation (OAR 340-041-0004)

Among the antidegradation policies included in Oregon water quality standards are provisions to prevent the unnecessary degradation of high quality water and to ensure full protection of all existing beneficial uses. At a minimum, uses are considered attainable wherever feasible or wherever attained historically. Antidegradation policies generally apply when water temperatures are less than the numeric criteria and offer provisions that allow for some degradation in water quality provided that such degradation does not prevent attainment of standards.

Water quality standards for temperature including the antidegradation and mixing zone policies are included in available online at DEQ at http://www.deq.state.or.us/wq/wqrules/wqrules.htm. A much 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).

Waterbodies Listed for Temperature

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

This element describes the geographic area for which the TMDL is developed and applies to the following stream segments of the Willamette Basin

Over the last decade, temperature data were collected by local, state and federal agencies throughout the Willamette Basin. More recently, watershed councils have also been important sources of stream temperature data. Review of this information in 1998 indicated that 52 stream segments within the nine Willamette subbasins addressed by this plan exceeded numeric temperature criteria, which resulted in their inclusion on the 303(d) list of impaired waters. Another 43 stream segments were added to the list of water bodies that exceed temperature criteria with revisions to the 303(d) list in 2002. This TMDL addresses listed segments from both the 1998 and 2002 303(d) lists as shown in Table 4.5 and Map 4.4. All stream segments addressed in this TMDL and in each subbasin are shown in Appendix 4.1.

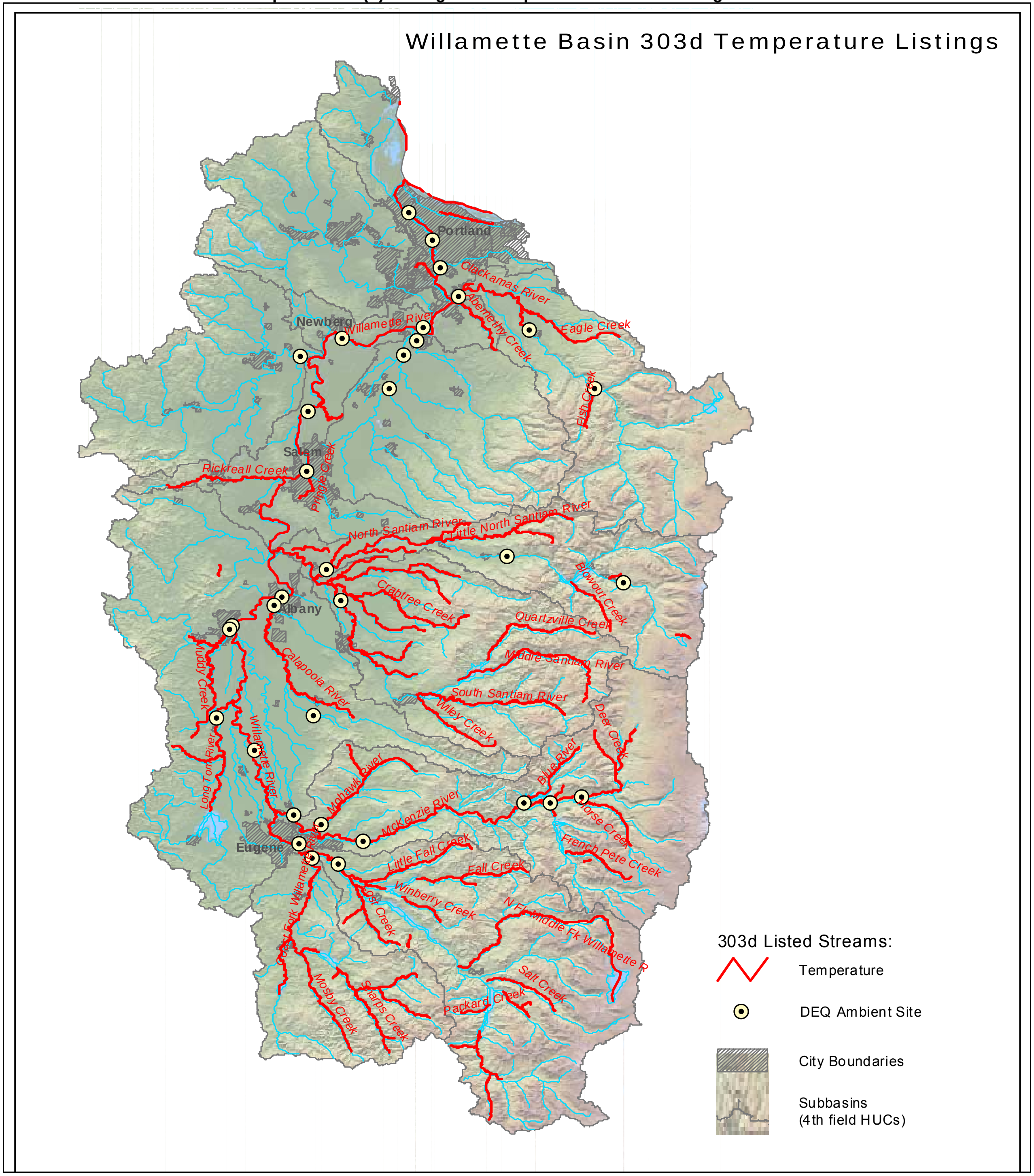
Exceedances of the salmon and trout rearing criteria were the most frequently documented cause for addition of a waterbody to the 303(d) list. Exceedances of rearing criteria and migration criteria accounted for 80 stream segment listings. Thirteen stream segments were included on the 303(d) lists because water temperatures were documented to exceed the salmon and steelhead trout spawning and egg incubation criteria. Three stream segments were listed because temperatures in the McKenzie Subbasin were measured to exceed bull trout numeric criteria.

Approximately 1,200 Willamette Basin stream miles covered by this plan were included in the 2002 303(d) list. This value is slightly different than the totals in Table 4.5 below which includes streams listed for salmonid rearing and spawning separately. For specific information regarding Oregon's 303(d) listing procedures, and to obtain more information regarding the Willamette Basin 303(d) listed streams, see the Department of Environmental Quality's web page at **http://www.ODEQ.state.or.us/**.

Table 4.5 Temperature Criteria Listed Segments covered in this document

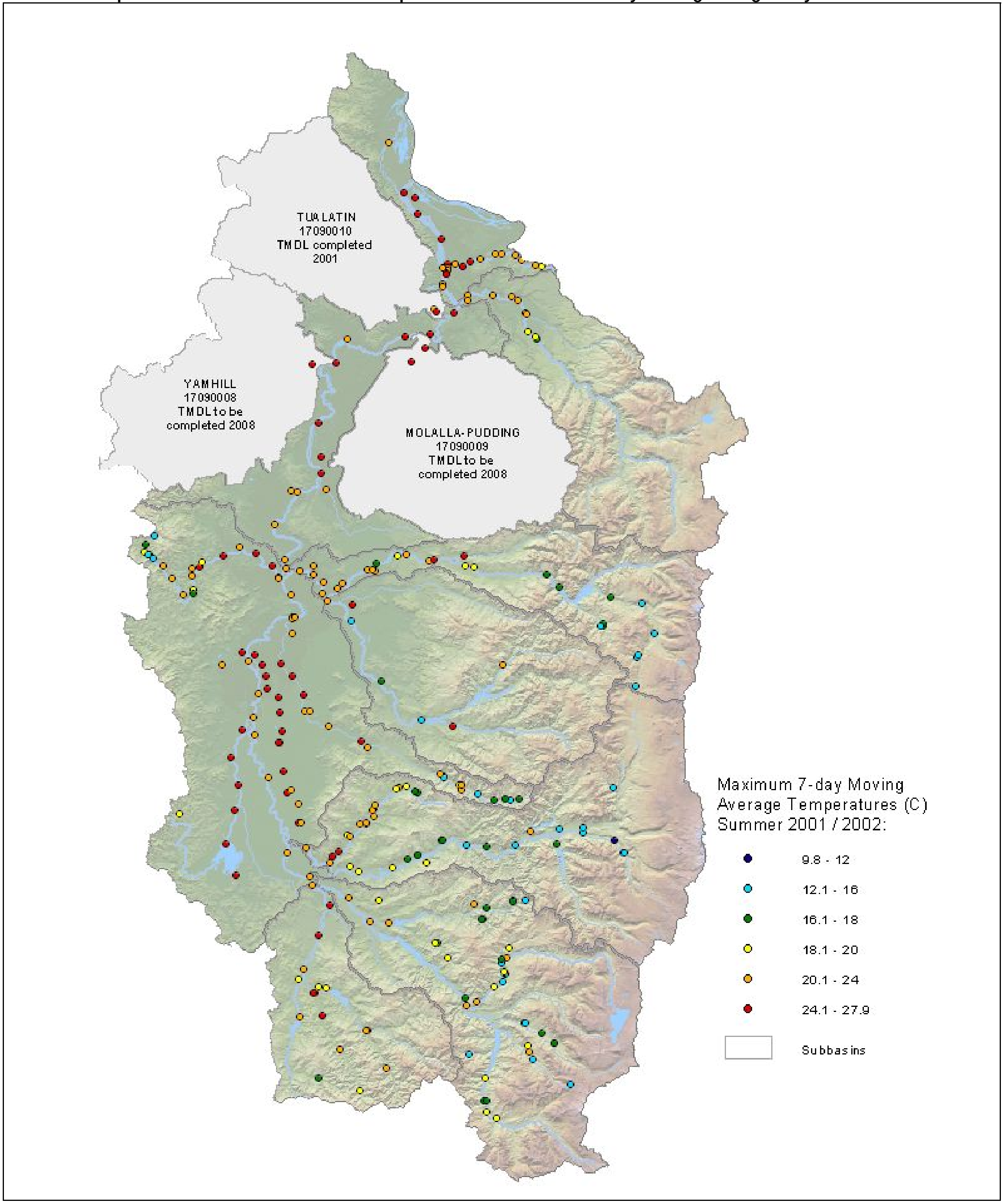
Subbasin	**303(d) List Date (segments)**		**Salmonid Rearing**		**Salmonid Spawning**		**Bull trout**	
	1998	2002	Segments	Miles	Segments	Miles	Segments	Miles
Coast Fork	6	3	9	106				
Middle Fork	13	10	17	137.3	6	76.2		
McKenzie	9	4	8	112.4	2	6.3	3	55.7
Upper Willamette	3	3	6	126				
South Santiam	5	10	13	237.4	2	53.6		
North Santiam	5	9	11	103.6	3	38.5		
Middle Willamette	2	1	3	38.3				
Lower Willamette	2		2	13.5				
Clackamas	1	3	4	52.3				
Mainstem Willamette	7		7	186.4				
Total	53	43	80	1,113.2	13	174.6	3	55.7

Map 4.4 303(d) Listings for Temperature and monitoring sites



Thermistor locations and seven day moving average of maximum temperatures for 2001 and 2002 are illustrated in Map 4.5. Generally, coldest maximum temperatures were recorded in high elevation streams whereas warmest values were recorded at low elevations. Streams draining the higher elevations of the Cascade Mountains were cooler than 16°C year round. Maximum temperatures in Coast Range streams and mid-elevation Cascade streams were warmer than 16°C, but not as warm as streams and river reaches on the valley floor where maximum temperatures were often well above 20°C.

Map 4.5 Willamette Basin Water Temperature: Maximum seven-day moving average daily maximums.



Time series plots of seven day average of daily maximum temperatures and biologically-based numeric criteria are shown in Figure 4.1 for four locations on the Willamette River. These locations were selected to represent the lower, middle and upper reaches of the mainstem river. Fluctuations in daily maximum temperatures are dampened by the use of seven day averages but changes in weekly and season maximum temperatures are readily apparent in the four plots.

As shown in the first plot in Figure 4.1, Oregon water quality standards designate only a single coldwater beneficial use for the lower Willamette. The biologically-based numeric criterion for salmon and steelhead migration (20°C) applies throughout the year to all mainstem locations below river mile 50. The remaining three plots in Figure 4.1 demonstrate that standards for middle and upper Willamette locations include two use periods and biologically-based numeric criteria. These are the salmon and steelhead rearing use and its 18°C numeric criterion, and the spawning use with its 13°C criterion. In these river reaches the spawning use and criterion apply from October 15 through May 15 and the rearing use and criterion apply from mid-May to mid-October.

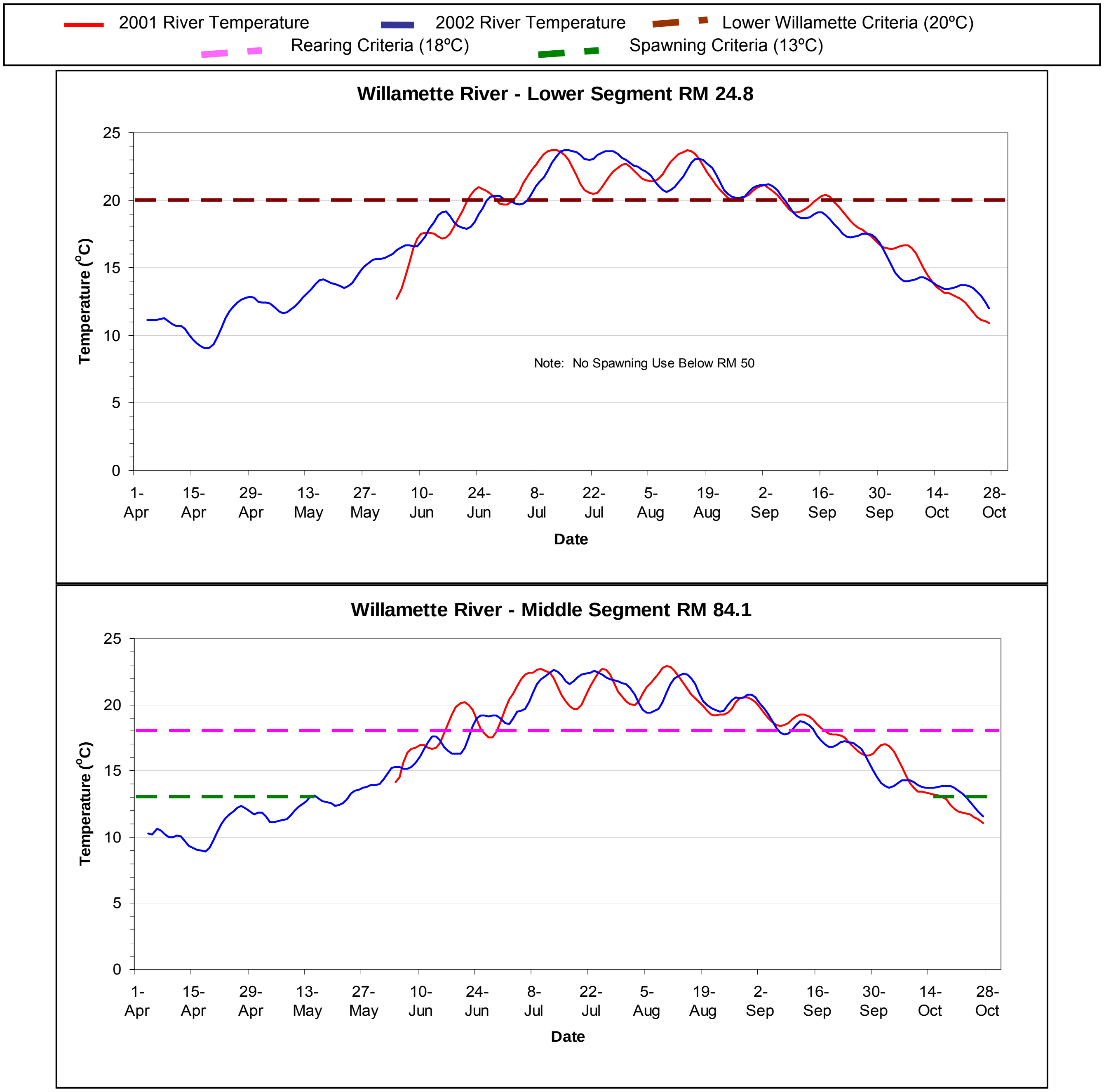
As shown in Figure 4.1, the Lower Willamette temperatures exceeded the migration corridor criterion throughout the summer period. The average of maximum daily temperatures at RM 24.8 exceeded the 20°C migration criterion from mid-June into September. Maximum seven day maximum temperatures at this location near Willamette Falls approach 24°C by mid-July.

The second, third and fourth plots in the figure illustrate temperature patterns in the Middle Willamette near Salem (RM 84.1) and two Upper Willamette Subbasin locations near Corvallis and Eugene (RM 132 and 187). Temperatures at these locations exceeded salmon and trout rearing criterion (18ºC) from mid-June into mid-September in 2001 and 2002. Spawning criterion of 13°C were also exceeded in the spring and early fall in the Middle and Upper Willamette Subbasins.

To restate the observations of Figure 4.1 for the Middle and Upper Willamette sites another way, stream temperatures exceeded the biologically-based numeric criterion for spawning near the end of that use period (May 15). Temperatures met the numeric criterion for salmon and trout rearing from mid-May until mid-June when temperatures began to exceed 18°C. Stream temperatures again met the numeric 18°C criterion by mid-September, but briefly exceeded the spawning criterion of 13°C again in the middle of October.

Data from the ODEQ ambient monitoring location in downtown Portland at the Hawthorne Bridge (**LASAR 10611** at RM 13.1) indicate that Willamette River temperatures warmer than 20°C are not uncommon in the period June through September. Seven of 27 June grab samples and six of 30 September observations exceeded the criterion. Upstream at Albany (LASAR 10350) grab temperature values equal to or greater than the 13°C spawning criterion were recorded in 17% of the April observations and 73% of observations made October 15 to October 31 were equal to or exceeded the spawning criterion. These data do not represent 7DADM values but substantiate the observations of 2001 and 2002.

Figure 4.1 Seven day average of daily maximum temperatures for 2001 and 2002 at four Willamette River locations. River mile 24.8 is in the lower river below Willamette Falls, RM 84.1 is near Salem; RM 132 at Corvallis, and RM 187 is near the confluence of the Coast Fork and Middle Fork Willamette River above Eugene.

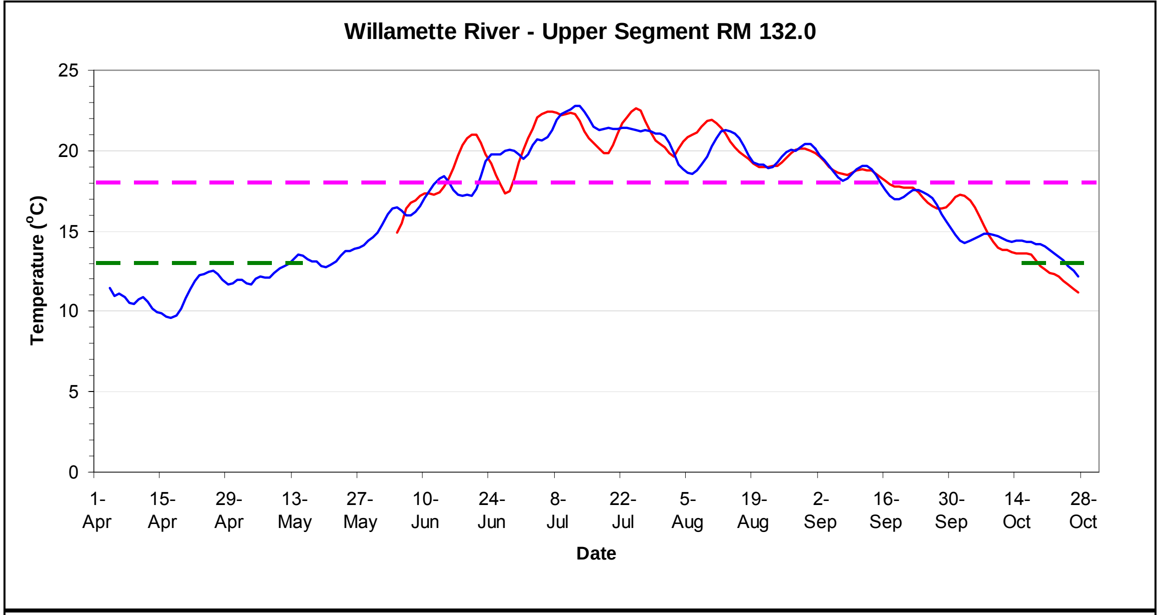


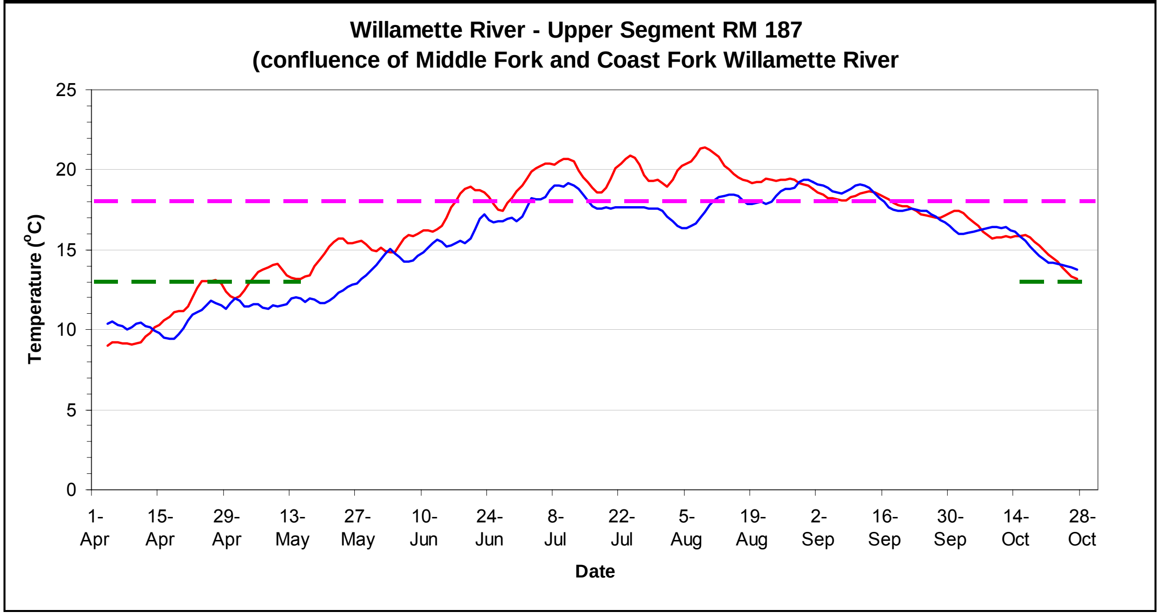
Willamette River - Lower Segment RM 24.8

Note: No Spawning Use Below RM 50

Willamette River - Middle Segment RM 84.1

Figure 4.1 cont'd





Stream temperatures observed for large Willamette River tributaries (Figure 4.2) frequently exceeded biologically-based criterion for salmon and trout rearing and spawning. Coast Fork Willamette temperatures exceeded the 18°C rearing criterion until early October. Temperatures in the McKenzie River near Springfield exceeded the core cold water criterion (16ºC) from mid-June to early September. Spawning criterion (13ºC) were also exceeded in late spring and early summer at this McKenzie River location. Santiam River temperatures at RM 11.7 upstream of Jefferson exceeded rearing temperatures from late June and into early September. Spawning criterion were also exceeded in mid-October. Figure 4.2 demonstrates that water temperatures in the Clackamas River near Estacada exceeded rearing criterion through the summer months and also exceeded spawning criterion in September. Note that the spawning criterion applies beginning September 1 in the Clackamas River but not until October 15 in the mainstem Santiam River.

Figure 4.2 **Seven day average of daily maximum temperatures for 2001 and 2002 in four Willamette River tributaries.**

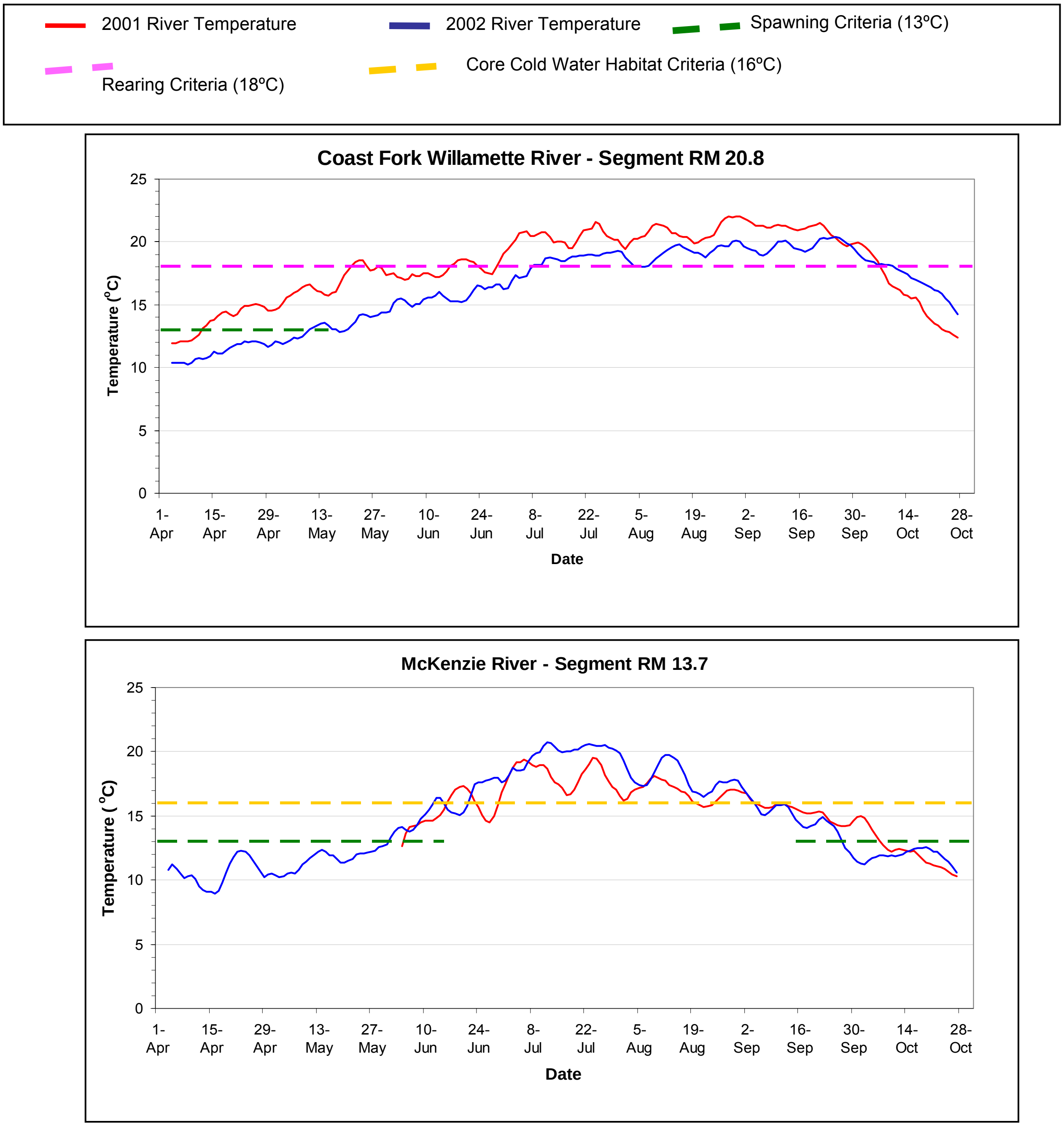
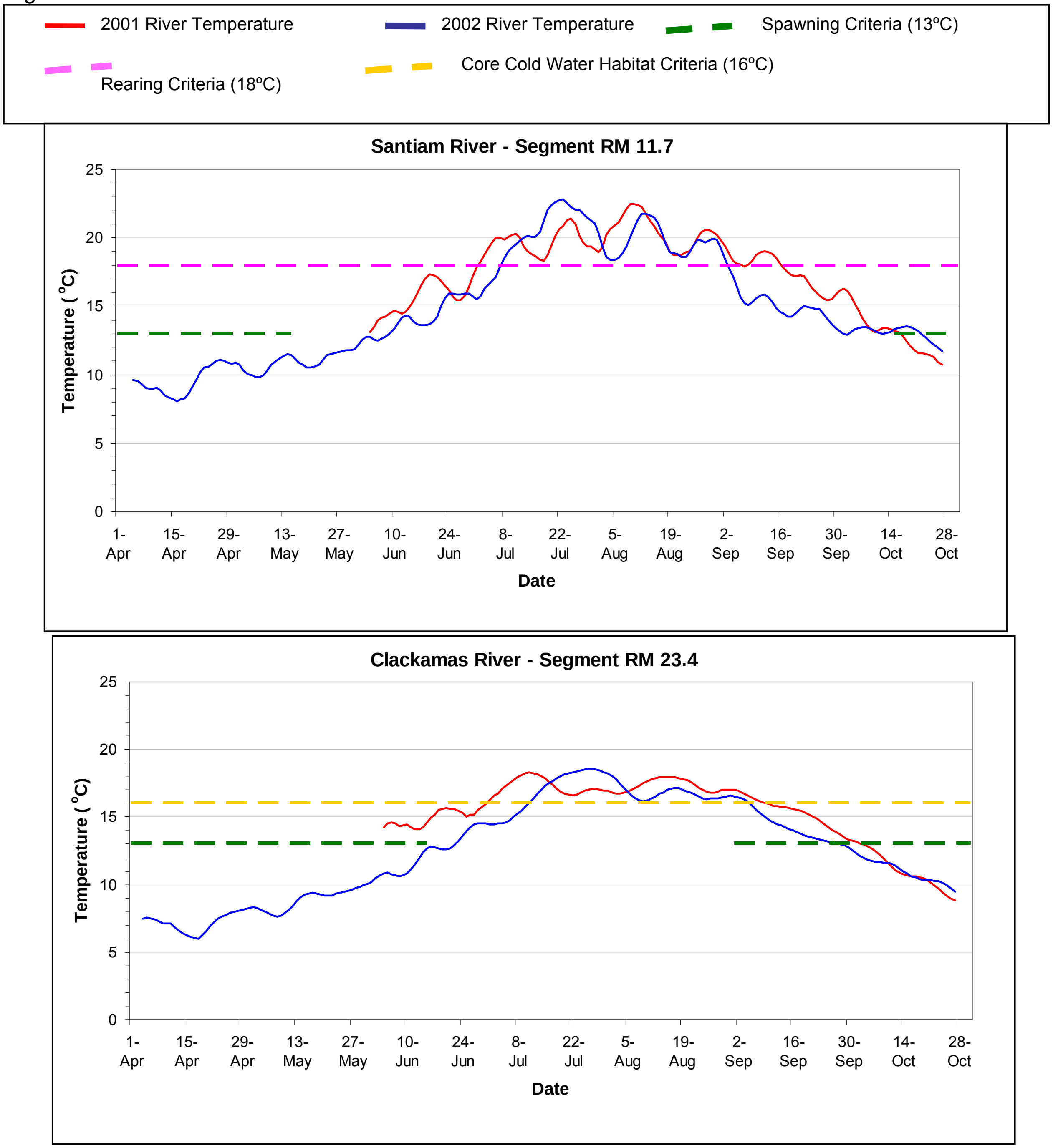
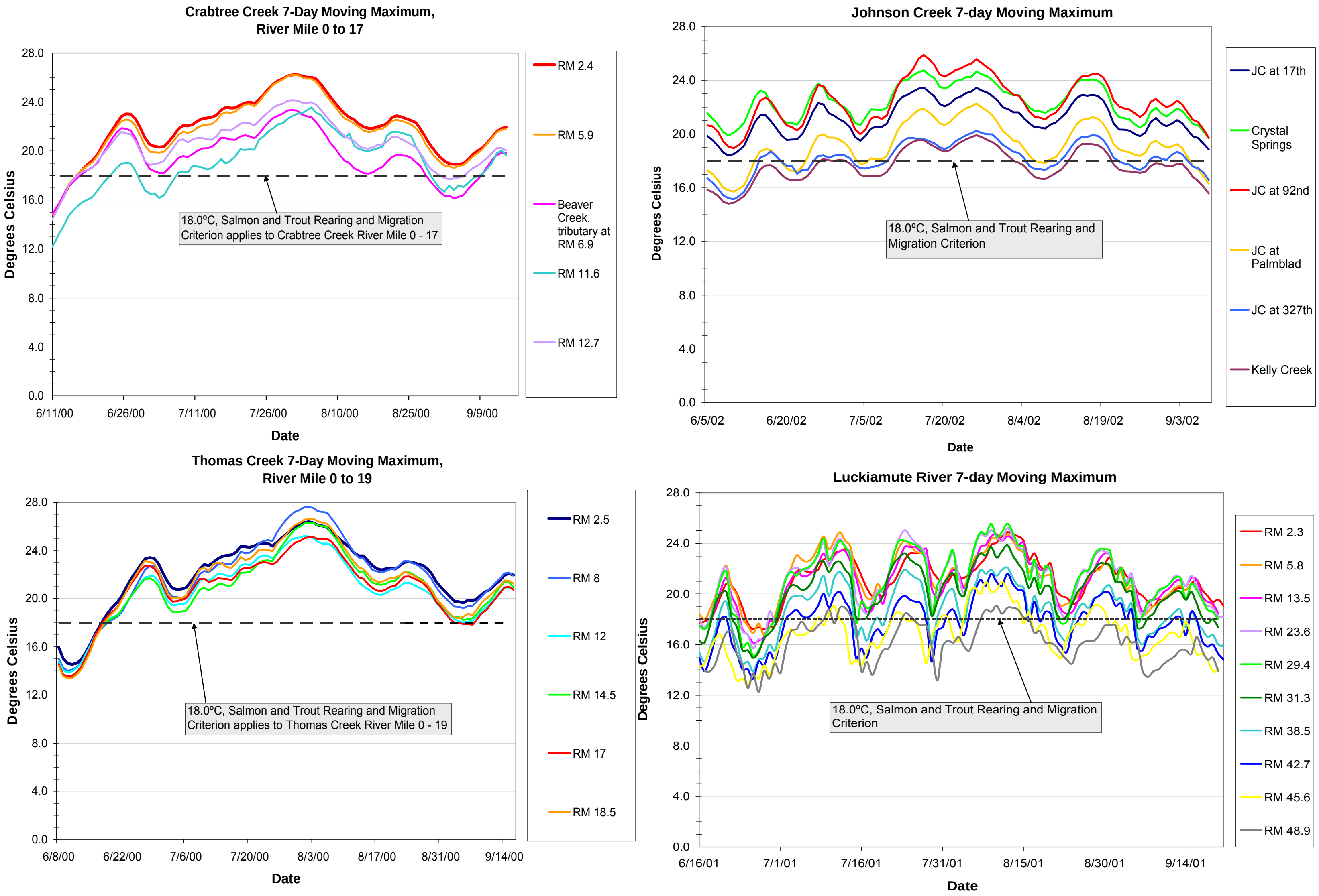


Figure 4.2 cont'd



Stream temperatures in smaller streams (Figure 4.3) follow a pattern similar to the larger streams. Exceedances of biologically-based criteria begin earlier in the season and are of greater duration and magnitude for low elevation tributaries than observed in stream segments at higher elevations. Four streams with multiple data sets illustrate this pattern. Crabtree and Thomas Creek originate in the Cascade foothills and drain forest and agricultural lands in the South Santiam Subbasin. Upper watershed locations (e.g. RM 12.7 and 18.5) are cooler than low elevation sites. The Luckiamute River, which drains the Coast Range southwest of Salem, and Johnson Creek, which drains agricultural and residential areas in the Portland area, have similar temperature patterns.

Figure 4.3 Seven day average of daily maximum temperatures in four small streams in the Willamette Basin. Temperature values are shown for multiple locations in each stream.



In summary, historical ODEQ temperature data and thermistor data collected for this TMDL demonstrate that Willamette River temperatures exceed biologically-based criteria during the April through October period. Total maximum daily load allocations and waste load allocations for heat generally apply during this critical period. However, exceedances of temperature are also observed in a few tributaries outside the April through October period. For example, exceedances of temperature criteria occur in river reaches below USACE reservoirs in November and, as discussed later in this chapter, heat load allocations necessary to attain water quality standards are assigned during this period.

Stream Temperature Analytical Methods Overview

Development of stream temperature TMDLs and load allocations requires identification of the natural thermal potential for each impaired waterbody. For many streams where both point and nonpoint sources of heat exist, detailed mathematical models were used to make these determinations. In other stream systems where nonpoint sources activities and the loss of riparian vegetation are the primary cause of stream warming, relationships between vegetation, channel width and solar radiation inputs were used to develop shade targets. These shade targets were applied as surrogate measures of loading capacity and load allocations.

Mathematical process models were used to assess current heat loads from natural and human sources in the mainstem Willamette River and key tributaries. These models were also used to predict *potential* stream temperatures in the absence of specified anthropogenic heat sources. These natural thermal potential temperatures vary with time and location. Anthropogenic sources of heat vary by subbasin, but generally include point sources that discharge heated water and nonpoint source activities associated with the loss of streamside shade. In addition, dams and reservoirs are also significant heat sources to the Willamette River system because of changes in the distribution of water and solar energy.

Heat loading capacities for individual tributary stream segments and the mainstem Willamette were calculated once the natural thermal potential temperatures of streams of interest were identified. Loading capacities identify the amount of heat that can enter a stream system while also meeting water quality standards. Individual contributions and cumulative effects of all defined anthropogenic sources of heat were identified and heat load allocation scenarios were developed for each TMDL.

Analytical approaches were selected based on the complexity of the analysis required to address the stream heating processes. The process model CE-QUAL-W2 (Cole and Wells, 2002) provided the framework for a dynamic basin scale model developed to evaluate current temperature patterns and predict natural thermal potential temperatures for the mainstem Willamette River and its largest tributaries. Watershed scale models based on CE-QUAL-W2 and Heat Source, another dynamic process model, were created to predict natural thermal potential temperatures and develop TMDLs on smaller tributary systems. Tributary temperature models were developed for the Upper McKenzie River above the South Fork McKenzie, Mohawk River, Mosby Creek, Crabtree Creek, Thomas Creek, Little North Santiam, Johnson Creek and Columbia Slough. Relationships between streamside vegetation, shade and solar heat loads were developed in these modeling efforts and served as the basis for vegetation and shade targets for other impaired waters. Models were developed and calibrated to existing streamflow, channel conditions and streamside vegetation with data collected during critical condition periods.

Methods developed to model effects of streamside vegetation and shade on solar radiation heat loads on the mainstem Willamette and its tributaries were also used to develop shade targets for streams that were not modeled. Streamside vegetation, channel characteristics and solar radiation inputs were used to derive shade targets and effective shade curves for these streams. Tree height, canopy density and other attributes were used to determine the amount of solar radiation expected to reach the stream if vegetation appropriate to the area is protected or restored. Effective shade curves represent general relationships between system potential vegetation, stream channel characteristics and effective shade, and are used as surrogate measures to implement the TMDL. Effective shade curves are applied to all 303(d) streams in the Willamette Basin not assessed using the model methods described above and also apply to all tributaries to temperature impaired streams.

Methods were not developed to assess the effects of channelization, bank armoring and other aspects of watershed development on stream temperature. Although difficult to quantify, these activities likely contribute to changes in tributary temperatures and the availability of thermal refugia. Implementation of the TMDL and attainment of narrative criteria in Oregon temperature standards will require the protection and restoration of diverse stream habitats and thermal regimes throughout the basin. This is especially true where temperatures exceed biologically-based criteria and refugia are necessary to sustain cold water species.

The TMDL for the mainstem Willamette River and its largest tributaries is discussed in detail in this chapter. Key elements of the mainstem TMDL such as current heat loads, load allocations, excess load and reserve capacity are presented separately. Details on data and model development are summarized in this chapter and discussed in greater detail in appendices. Current heat loads, load allocations, excess load and reserve capacity for Willamette subbasin TMDLs are summarized at the end of this chapter and are also described in greater detail in each subbasin chapter.

MAINSTEM WILLAMETTE RIVER TMDL

The mainstem Willamette River TMDL extends from its confluence with the Columbia River upstream to the confluence of the Middle Fork and Coast Fork Willamette Rivers near Eugene. It includes six tributaries with flows regulated by USACE reservoirs: the Long Tom, Coast Fork, Middle Fork, McKenzie, South Santiam and North Santiam Rivers. The Clackamas River is the seventh major tributary included in the mainstem TMDL and its flow regimes are influenced by the PGE hydroelectric project near Estacada. Specific 303(d) river segments included in the mainstem Willamette TMDL are shown below.

Table 4.6 303(d) Listed segments addressed in the Willamette mainstem

River Segment	River miles
Willamette River	0 to 24.8
Willamette River	24.8 to 54.8
Willamette River	54.8 to 108
Willamette River	108 to 119.7
Willamette River	119.7 to 148.8
Willamette River	148.8 to 174.5
Willamette River	174.5 to 186.4
Clackamas River	0 to 22.9
Santiam River	0 to 12
North Santiam River	0 to 10
North Santiam River	10 to 26.5
South Santiam River	0 to 25.9
McKenzie River	0 to 34.1
McKenzie River	34.1 to 54.5
South Fork McKenzie River	0 to 4.5
Blue River	0 to 1.8
Middle Fork Willamette River	0 to 15.6
Fall Creek	0 to 7
Coast Fork River	0 to 31.3
Row River	0 to 7.4
Long Tom River	0 to 24.2

Willamette Mainstem Model

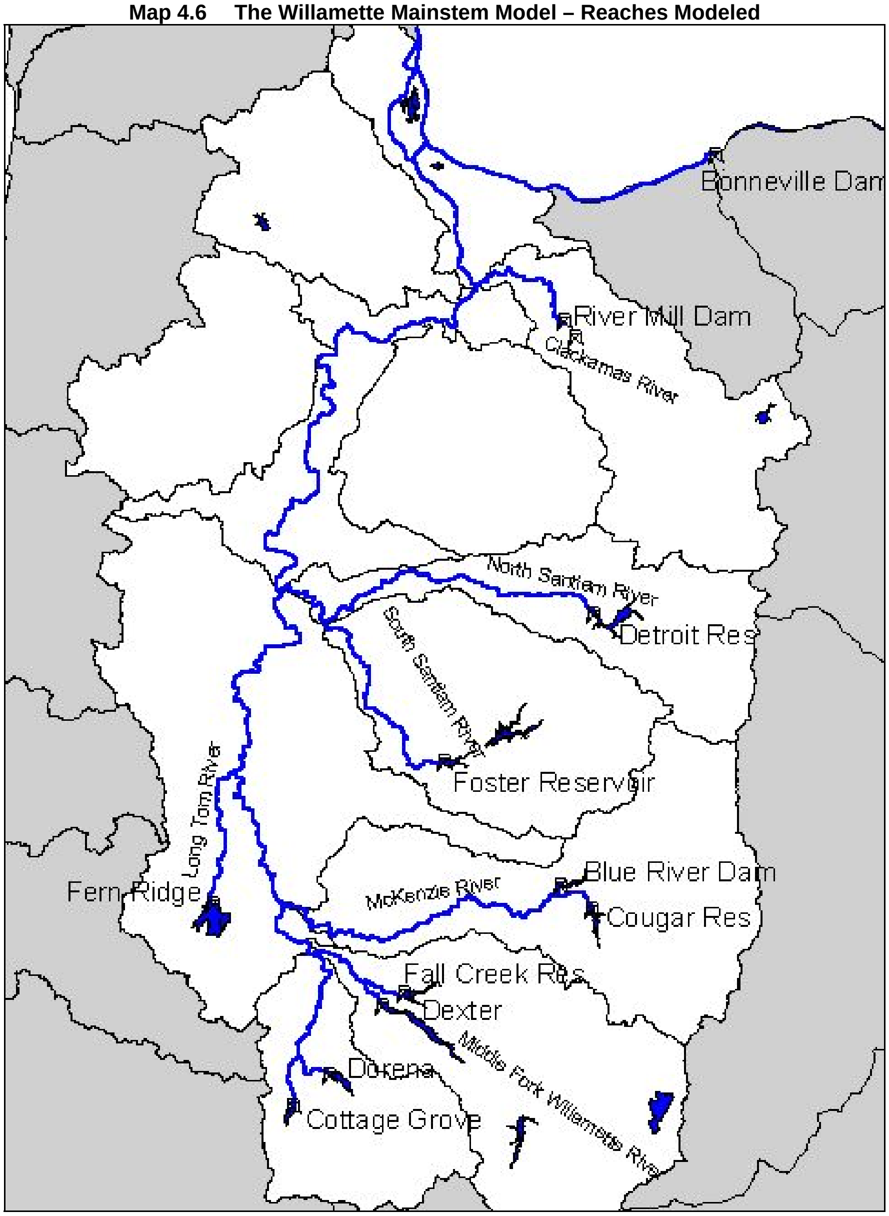
CE-QUAL-W2, a two dimensional, hydrodynamic and water quality modeling framework, was used to develop a set of models of the Willamette River and major tributaries in order to analyze river flow and water temperature patterns (Cole and Wells, 2002). This set of models is collectively referred to as the Willamette Mainstem model. The model includes the entire Willamette River, as well as the Clackamas, Santiam, McKenzie, Middle Fork, Coast Fork and Long Tom Rivers from the rivers' confluences with the Willamette to the first (lowest) mainstem reservoirs on each system (Map 4.6). The model also includes much of the lower Columbia River to capture tidal action and temperature effects on the Willamette River downstream of Willamette Falls. The model was used to analyze point source inputs, PGE and EWEB project operations, river flows and meteorological effects on mainstem flow and temperature. The model was also used to evaluate streamside vegetation and effective shade influences on river temperature. More information on CE-QUAL-W2 is available in the temperature Appendix C, as well as at the Portland State University webpage "Willamette River Temperature TMDL CE-QUAL-W2 Model": http://www.ce.pdx.edu/w2/index.html?projects_willamette_river.html

The mainstem model was developed and calibrated using streamflow and water temperature data, meteorological information and other environmental data collected in 2001 and 2002. Field information gathered to support model development included channel bathymetry, water elevation and wetted width data, time of travel data, and streamside vegetation data. Participants in these data collection efforts included the US Geological Survey, US Army Corps of Engineers, Association of Clean Water Agencies, Portland General Electric, Northwest Pulp and Paper Association and ODEQ. Field data were used to supplement and verify extensive topographic and vegetation data processed with geographic information system (GIS) tools. Municipal and industrial effluent data were gathered to support calculations of point source heat loads which were linked to environmental data to produce an energy budget model of the basin.

The mainstem model simulations were initially developed and calibrated using data collected June through October 2001 and April through October, 2002. These periods include the highest nonpoint source heat loads and the critical point source loads of late spring, summer and early fall. Simulated river flows were calibrated to existing USGS gages distributed throughout the Willamette Basin. Simulated water temperatures were calibrated using data recorded on an hourly or more frequent basis at 30 permanent USGS gages and approximately 95 seasonal thermistor stations. The USGS gages recorded flow and temperature year-round while seasonal thermistor stations recorded temperature from late spring to early fall. Overall, the model met the goal of a root mean square (RMS) error of +/- 1.0^{o}C. Models of tributaries which have steeper gradients, such as the McKenzie and North Santiam Rivers, were more difficult to calibrate and have somewhat higher errors associated with them. However, on average, model calculated temperatures were within +/-0.5ºC of observed temperatures (Berger et al, 2004).

In addition to the examination of stream temperature patterns and quantification of natural and anthropogenic heat loads under current conditions, the calibrated model was used to examine stream temperature response to changes in shade, flow, upstream boundary temperature, point sources inputs and hydroelectric project operations. Model calibration reports for the North Santiam and Santiam River were prepared by USGS (Sullivan and Rounds, 2004) http://water.usgs.gov/pubs/sir/2004/5001/pdf/sir20045001.pdf . Calibration reports for the Lower, Middle and Upper Willamette River, Coast and Middle Fork Willamette Rivers, McKenzie River, Long Tom River, and Clackamas River were prepared by PSU (Berger et al, 2004) http://www.ce.pdx.edu/w2/index.html

Map 4.6 The Willamette Mainstem Model – Reaches Modeled



Upper boundary locations for the mainstem Willamette River temperature model are immediately downstream of USACE reservoirs on each tributary and the PGE River Mill Dam at Estacada on the Clackamas River as shown in Map 4.6. Boundary condition flow rates and temperatures on the larger, reservoir-controlled tributaries were set to conditions observed in 2001 and 2002 downstream of each reservoir (Table 4.7). Flow rates and temperatures for smaller tributaries such as the Calapooia and the Luckiamute Rivers were also set to observed conditions for 2001 and 2002. Model sensitivity to boundary condition flow, boundary condition temperature, small tributaries inputs and other variables are reviewed in *Appendix 4.6 - Sensitivity of River Temperatures to Point and Nonpoint Source Influences*.

The PGE Willamette Falls project and EWEB Leaburg-Walterville project are located within the mainstem model and, therefore, do not affect boundary flow and water temperature conditions. For the model calibration scenarios these projects were modeled as operated in 2001 and 2002.

Natural Thermal Potential Temperatures

Determination of loading capacity and load allocations require identification of natural thermal potential temperatures. Oregon water quality standards direct that natural thermal potential temperature be calculated using the best method of analysis and best available information on site potential vegetation, stream geomorphology, streamflow and other measures to reflect natural conditions (OAR 340-041-0002(35)). In order to estimate natural thermal potential, the calibrated model was modified to remove point source effluent heat loads, and reflect system potential riparian vegetation. Therefore, anthropogenic solar radiation and point source heat loads are set to zero for these simulations. In addition, for these simulations PGE and Willamette hydroelectric project impacts were eliminated. Therefore, for the simulations no water is diverted into the McKenzie River EWEB hydroelectric projects and the concrete cap and flashboards present at Willamette Falls are eliminated, which results in the Newberg Pool being modeled at a natural water level. Boundary conditions and other variables for model calibration and natural thermal potential modeling simulations are shown in Table 4.7.

Table 4.7 Boundary Conditions and other variables for Willamette Mainstem modeling scenarios

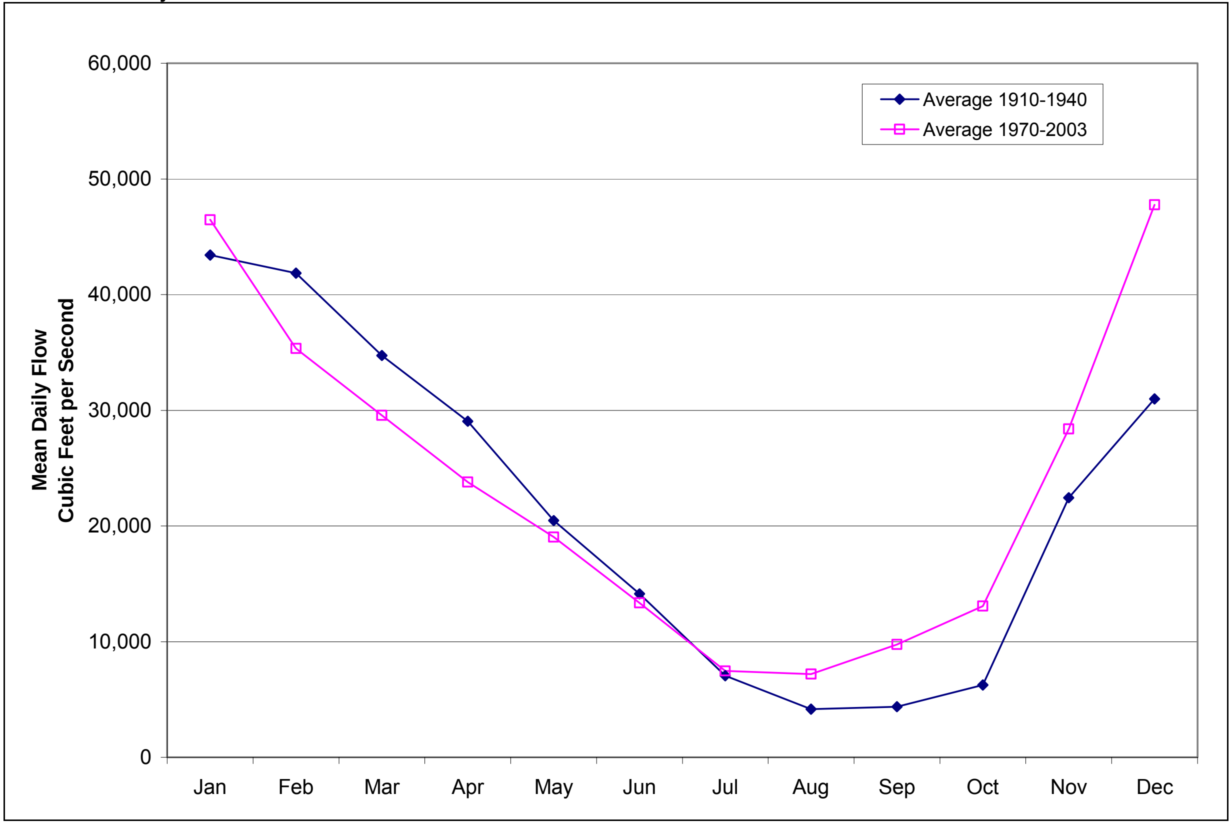
Model variable	Calibrated Model	Natural Thermal Potential Scenario
Boundary Condition Temperature at USACE Reservoirs	Current condition as observed in 2001 and 2002	Current condition as observed in 2001 and 2002
Boundary Condition Flows at USACE Reservoirs	Current condition as observed in 2001 and 2002	Current condition as observed in 2001 and 2002
Riparian Shade	Current condition as monitored and derived from other sources	Potential near stream land cover and corresponding effective shade
Point Sources	As reported	No point source loads
River Channel	Current channel	Current channel
Willamette Falls Hydroelectric Project	Current condition, concrete cap and flashboards in place	Concrete cap and flashboards removed
Eugene Water Electric Board (EWEB)	Current condition as operated in 2001 and 2002	No diversions through projects
Clackamas River Hydroelectric Project	Current condition as observed in 2001 and 2002	Current condition as observed in 2001 and 2002
Tributary Inflow Temperatures	Current condition as observed in 2001 and 2002	Current condition as observed in 2001 and 2002

Natural thermal potential temperatures are influenced by simulated levels of effective shade. System potential shade targets were based on assumed shade levels produced by riparian vegetation expected to occur in the absence of human disturbance. System potential vegetation and effective shade targets do not target mature vegetation throughout the basin. Simulations include an allowance for natural disturbance in model runs as lower tree heights and canopy densities. These disturbances were randomly distributed throughout the streamside area in model simulations and, to maintain model precision, were not changed once simulations began. The potential near-stream land cover in the Willamette Valley bottom is assigned a vegetation component defined by geomorphic unit or ecoregion. Each geomorphic unit or ecoregion unit is assigned unique vegetation characteristics such as height, density, and canopy overhang, (see Appendix C for detailed information). System potential simulations generally yielded higher levels of effective shade and lower levels of solar radiation input to the river than values used to calibrate the model to current conditions. In some locations, system potential simulated shade levels were lower than shade levels measured and included in the model calibration. These patches of elevated solar radiation loading are the natural disturbance contribution to stream warming.

For the natural thermal potential simulations, boundary condition flow rates and temperatures downstream from USACE reservoirs were not changed from calibration conditions observed in 2001 and 2002. Therefore, natural thermal potential temperatures utilized in the TMDL are based on model simulations with boundary conditions strongly influenced by current USACE reservoirs operations. USACE manages reservoir operations for the purposes of flood control and flow augmentation for other uses such river navigation, fisheries and dilution of pollutant loads. These reservoirs augment summer and early fall flows to the extent that base flows at Salem are double natural low-flow levels. While admittedly a poor representation of the natural condition, the regulated flow regime of the last 35 years is now the basis of pollution load calculations for point sources throughout the basin and pollutant load limits for parameters in current NPDES permits are based on these regulated flows.

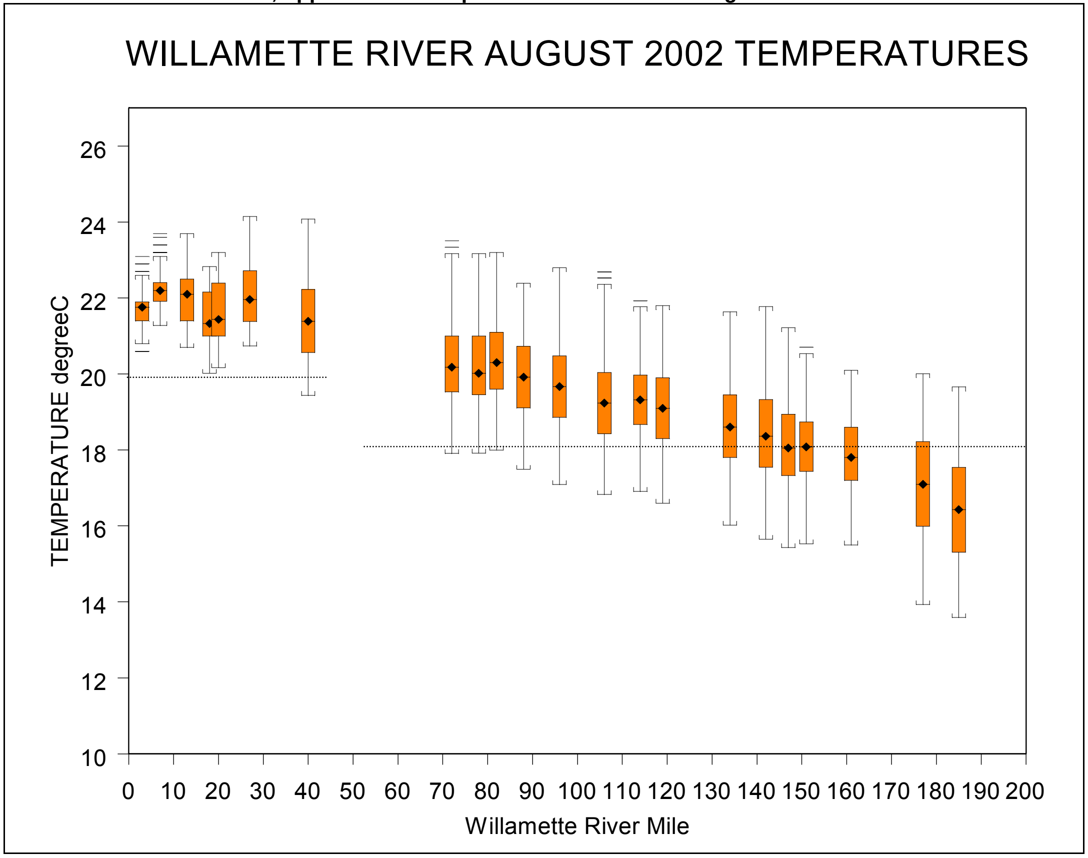
Figure 4.4 illustrates average daily flows at the USGS gage in Salem before and after the USACE Willamette Project began to augment summer flows. The influence of the USACE reservoirs is noticeable throughout the year and effects of augmentation on seasonal low flows are especially apparent in the second half of the year. Therefore, natural thermal potential temperatures as simulated in this TMDL do not reflect a natural flow regime or a natural stream channel, but the simulations used to derive these NTP temperatures reflect our understanding of the processes that affect temperature in the Willamette and its tributaries at this time. It is expected that this understanding will continue to improve as additional information is gathered and as the TMDL is implemented. This analysis identifies the effects of natural and specific anthropogenic processes on stream temperatures and meets the objectives necessary to establish the TMDL and implement the water quality standards for temperature.

Figure 4.4 **Average Willamette River flows at Salem (USGS gage 14191000) before and after construction of USACE Willamette Project reservoirs.**



USACE flow augmentation substantially modifies the temperature regime of the Willamette River in several ways. The reservoirs release large volumes of water that are often substantially cooler or warmer than natural water temperatures, an effect that can be detected in the mainstem river. Augmentation of natural flow also yields higher flow velocities, shorter travel time through mainstem river reaches and less exposure to meteorological heating and cooling processes. In addition, greater river volume means an increase in heat loading capacity over natural conditions; there is simply more water to heat before measurable change in temperatures occurs. In summer these factors contribute to cooler maximum daily temperatures in many mainstem locations. However, the greater summer river volume and heat loading capacity also suggests that the river does not dissipate heat as readily as a smaller stream. This trend is evident in mainstem temperature data collected in August 2002. As shown by Figure 4.5, minimum temperature values increase in a downstream direction and the range in temperature values decreases downstream from RM 50 (the upper end of Newburg Pool). As the river grows in size it retains heat for longer time periods and once warmed by either natural or anthropogenic sources the river maintains relatively warm temperatures throughout the day. During summer this corresponds to warmer minimum and median daily temperatures.

Figure 4.5 Box plot distribution of temperature values recorded in the Willamette River in August 2002. This demonstrates the median, upper and lower quartile values and the range of data observations.



Natural thermal potential in this TMDL is also based on a much simpler stream channel than a natural conditions channel. Improvements for navigation and flood control over 150 years have resulted in the loss of nearly one-third of the stream channel miles with the greatest losses in channel complexity upstream of Albany. River velocities in a simplified channel are also greater than flows in a complex channel with multiple threads and meanders and this also influences river temperatures.

Modeling a true natural thermal potential temperature for the Willamette system would require simulation of historic flow regimes and a complex channel configuration. Historic flow information is available for a number of long-term monitoring locations, but developing the model inputs for a complex channel requires substantially more resources than were available for this TMDL. Calibration of such a model would be challenging and the use of simulation outputs for regulatory purposes, problematic. Consequently, simulations with a well calibrated model and based on current USACE reservoir operations, boundary conditions, and system potential vegetation were used for the purposes of establishing the temperature TMDL in the mainstem Willamette River.

Additional simulations were performed to evaluate the impacts of the PGE Clackamas River hydroelectric project on the lower Clackamas River and Willamette River (see section Hydroelectric Project Heat Load Contributions as well as Appendix 4.6). Estimates of natural thermal potential temperatures at the River Mill Dam tailrace, which is the upper boundary of the Willamette Mainstem Model, were provided by PGE to ODEQ in order to support PGE's §401 certification application and FERC relicensing request. These values were calculated by PGE using a model of the Clackamas River system above and within the PGE hydroelectric project area. This information allowed ODEQ to evaluate PGE project impacts on temperature throughout the lower Clackamas River and into the Willamette River.

Additional simulations were also performed to evaluate the impacts of USACE projects on river temperatures (see section USACE Willamette Basin Project Reservoir Heat Load Contributions as well as Appendix 4.6). These included scenarios in which upper boundary temperatures were set to estimates of what temperatures would be in the absence of the projects. In addition, scenarios were performed to evaluate sensitivity of river temperatures to boundary condition flow rates.

Existing Heat Sources

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

This element identifies the pollutant sources and estimates, to the extent existing data allow, the amount of actual pollutant loading from these sources.

Natural Background Sources

Natural or background inputs of solar radiation are by far the largest heat source in the Willamette River system. Streams in Oregon are generally warmest in summer when solar radiation inputs are greatest and streamflows are low. The amount of solar energy that actually reaches the surface of a stream is determined by many factors including the position of the sun in the sky, cloud cover, local topography, stream aspect, stream width, and streamside vegetation. Streams generally warm in a downstream direction as they become wider and streamside vegetation is less effective at shading the surface of the water. Also, cooling influences of ground water inflow and smaller tributaries have less effect on the temperature of a stream as it becomes larger. Greater stream volume and mass are associated with a reduction in stream sensitivity to natural and human sources of heat.

In the absence of human disturbance, many low elevation streams were likely warmer at times than is optimal for salmon and trout. These cold water species may not have occupied these waters during the peak of the summer period or they persisted in cool water environments during stressful periods. Channel complexity, cool surface water and groundwater inflows, and hyporheic exchange are thought to provide local but important thermal refuges during the warmest months of the year.

Natural disturbance events can have significant effects on salmonid habitat. Flood, fire, windstorms and other natural disturbance processes contribute to the complexity of the stream environment. These disturbances affect streamside vegetation and the riparian tree canopy and often decrease stream shade. Following these events greater amounts of solar energy reach the stream for a period of time that may span decades. However, such disturbances are viewed as beneficial processes because with the structural components and ecological process in place, the riparian canopy and the values it provides will recover with time and salmon, trout and other species benefit from the large wood and habitat complexity these disturbance processes provide. Greater sunlight in these disturbed areas also allows for greater benthic algal production and contributes to overall stream productivity. For the purposes of this TMDL these disturbance processes are considered as natural background sources of heat to the river system.

Anthropogenic Sources

Human activities that increase water temperatures occur in addition to many natural disturbance processes and may contribute to the decline of salmon, trout and other cold water fish and aquatic life populations. There are several past or present human activities in the Willamette Basin that contribute to warming of rivers and streams. These activities include discharges of warm wastewater from municipal and industrial sources, nonpoint source activities that decrease riparian shade and increase the amount of solar radiation reaching a stream, and water management activities that impound or divert water from the stream channel. Impoundment and diversion either decrease the amount of water in the stream and thus its capacity to assimilate heat or modify the seasonal pattern of stream warming and cooling.

Figure 4.6 Temperature increases above the numeric criteria from anthropogenic sources in the Willamette River

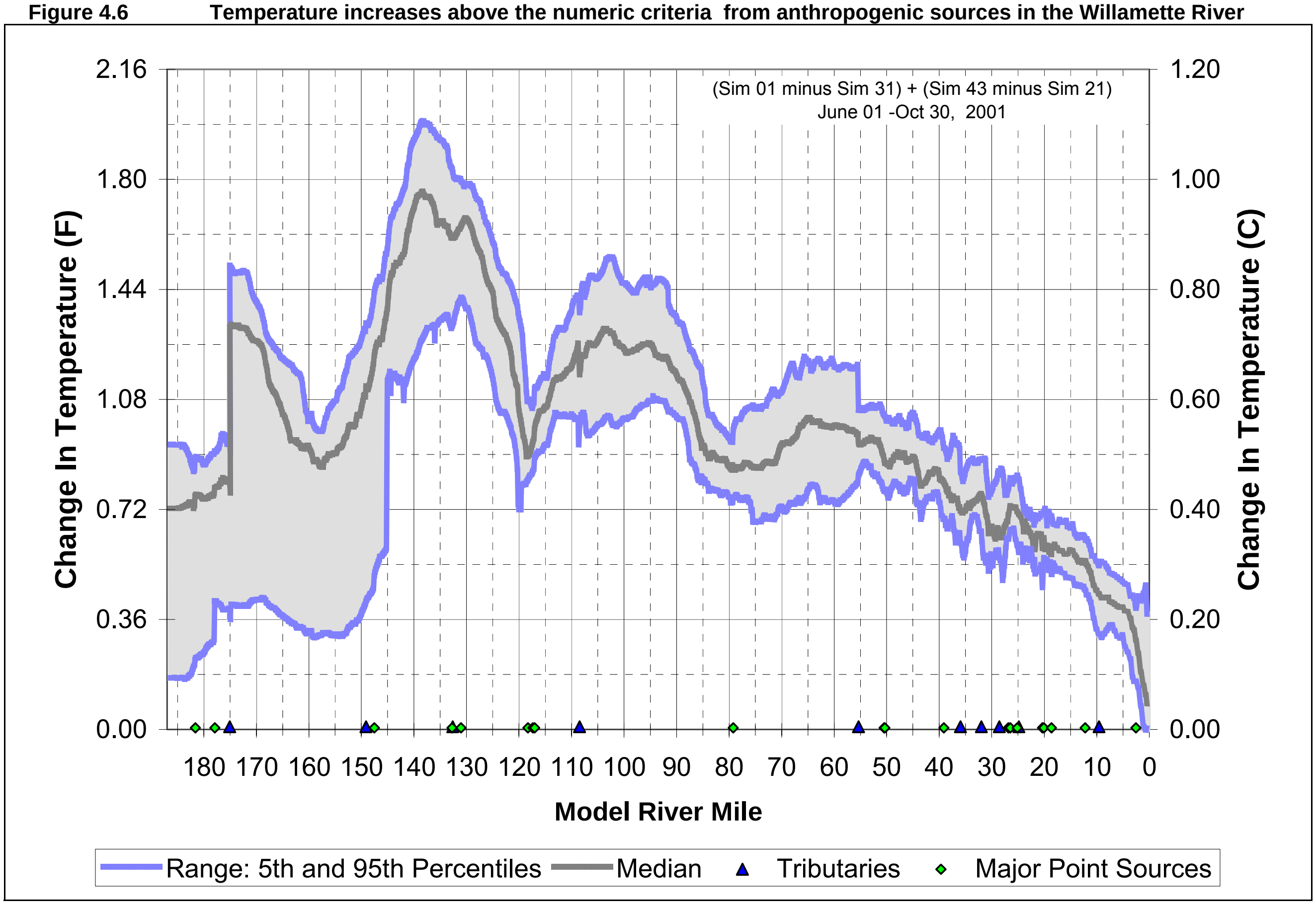


Figure 4.6 shows anthropogenic temperature increases above the numeric biological criteria in the Willamette River due to the loss of natural riparian vegetation and the impacts of point sources. The point of largest impact is seen near Corvallis at about river mile 138. As described in the excess load section, On average, approximately 86% of these increases are caused by the loss of natural riparian vegetation. The

other 14% are caused by point sources. The figure does not include impacts from dams, hydroelectric projects, or channel modifications. Discussion regarding these impacts is presented in Appendix 4.6.

Less obvious factors of stream warming include deliberate or coincidental changes in watershed processes and channel morphology. Watershed management activities that interrupt groundwater flows and hyporheic exchange with surface waters reduce summer base flows and the availability of cool water refugia that are necessary when mainstem temperatures exceed biological criteria. Channel modification activities such as deepening, bank armoring, dike construction, aggregate mining, wetlands and floodplain reclamation often contribute to the loss of channel complexity. Such activities may affect cool water refugia and simplify fish habitats. Although the impacts of such watershed and channel modifications on stream temperature are not quantified in this TMDL, protection of diverse temperature environments and refugia is an important element of Oregon’s temperature standards.

Point Sources

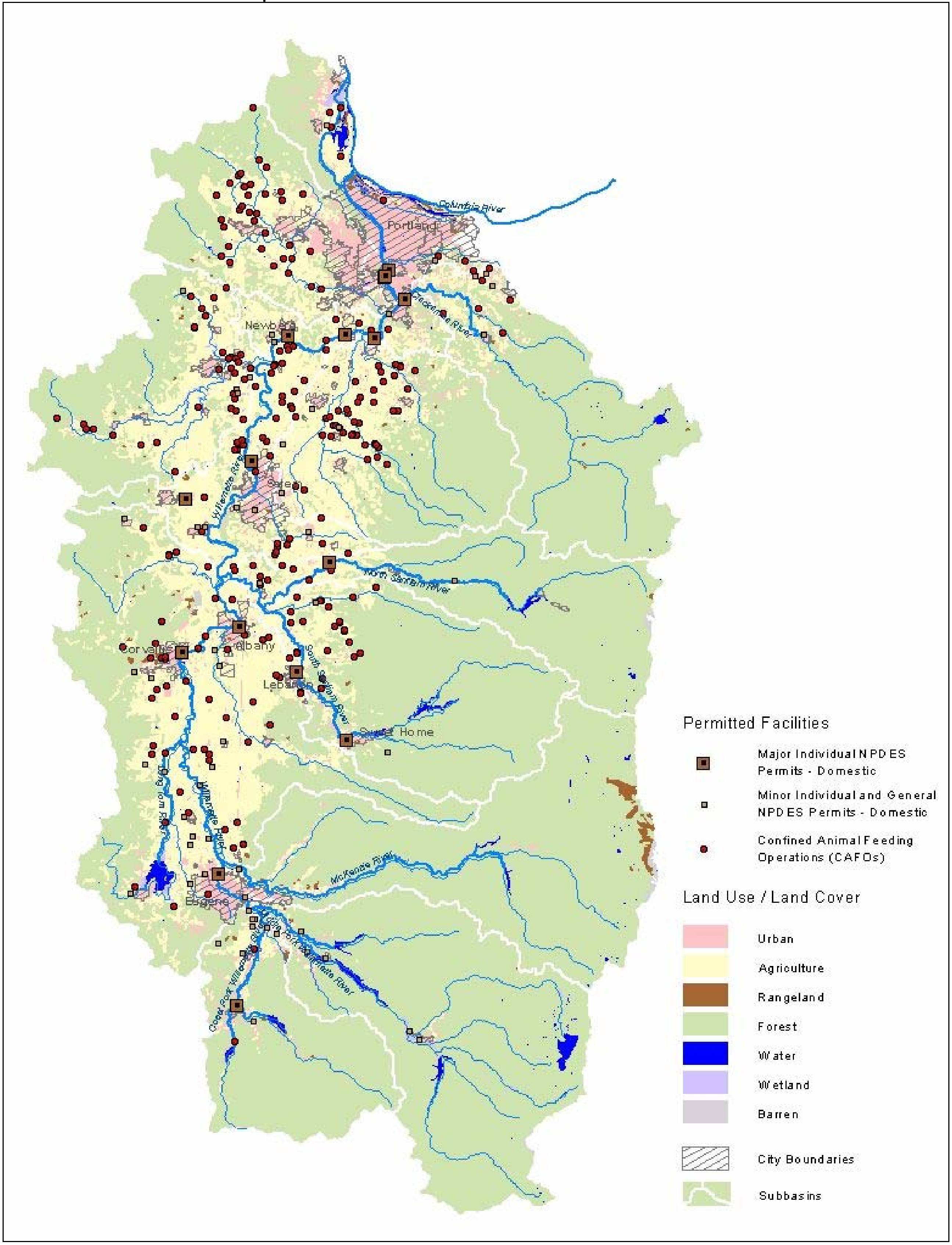
A water quality permit is required whenever there is a discharge of heated water or other pollutants to waters of the state. Permits are required for discharges of wastewater (sewage, processing water, etc.), wash water, and even for wastewater that may be relatively clean, such as cooling water. These discharges to surface water may occur directly through a pipe or ditch or indirectly through a storm sewer system. Certain industries and activities may also be required to obtain permits for storm water runoff from their properties. The National Pollution Discharge Elimination System (NPDES) permit is a requirement of the Federal Water Pollution Control Act (Clean Water Act) and Oregon law. ODEQ has been given authority from the U.S. Environmental Protection Agency (USEPA) to issue these permits.

Individual NPDES permits are site-specific and developed to address discharges from a specific sewage or industrial wastewater treatment facility. Individual permits are usually issued for a period of five years and often require frequent monitoring by the permittee to assure that permit limitations are being met. About 120 point sources are regulated by individual NPDES permits in the basin, Map 4.7. Permits for these municipal and industrial sources include language specifying the quantity and quality of wastewater that may be discharged to surface waters. These permits may also include thermal limits that regulate the amount of heat a permitted source can discharge into the river

General NPDES permits cover a category of similar discharges, rather than a specific site. ODEQ may issue a general permit when there are several minor sources or activities involved in similar operations that may be adequately regulated with a standard set of conditions. A general permit is issued once and expires within five years. ODEQ currently utilizes 29 different general permits and some of these such as boiler blowdown and non-contact cooling water permits regulate the discharge of heated water into natural waters.

There are over 1,200 point sources that are permitted to discharge wastewater or stormwater directly into surface waters of the Willamette Basin (ODEQ SIS database 4/15/03). Nearly half of these sources discharge stormwater into streams tributary to the Willamette River and are considered to have no reasonable potential to warm maximum daily water temperatures over a seven day period. There are also about 60 small sources in the basin that may discharge cooling water, or boiler blowdown to surface waters. These sources may affect stream temperatures and are usually regulated through general permits.

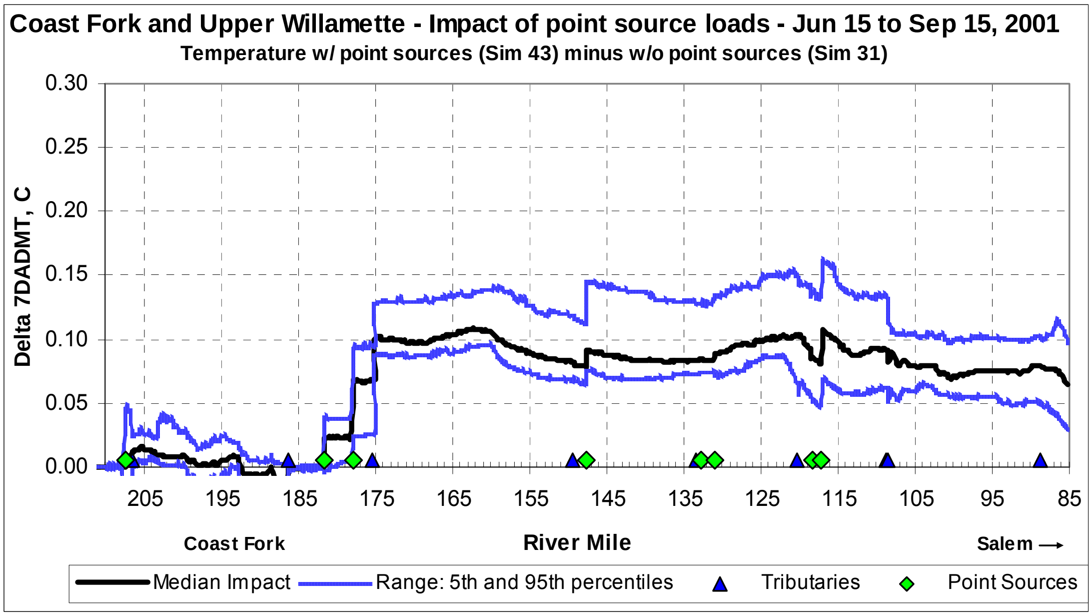
Map 4.7 Willamette Basin Point Sources and Land Use areas.



ODEQ gathered wastewater flow and temperature data to assess point source effects on stream temperature. ODEQ identified more than 20 point sources of interest to include in the assessment based on an estimated impact on receiving stream temperatures of 0.01°C or more. Heat loads from small point sources were not included in this analysis although the cumulative heat load from these sources is explicitly addressed through waste load allocations.

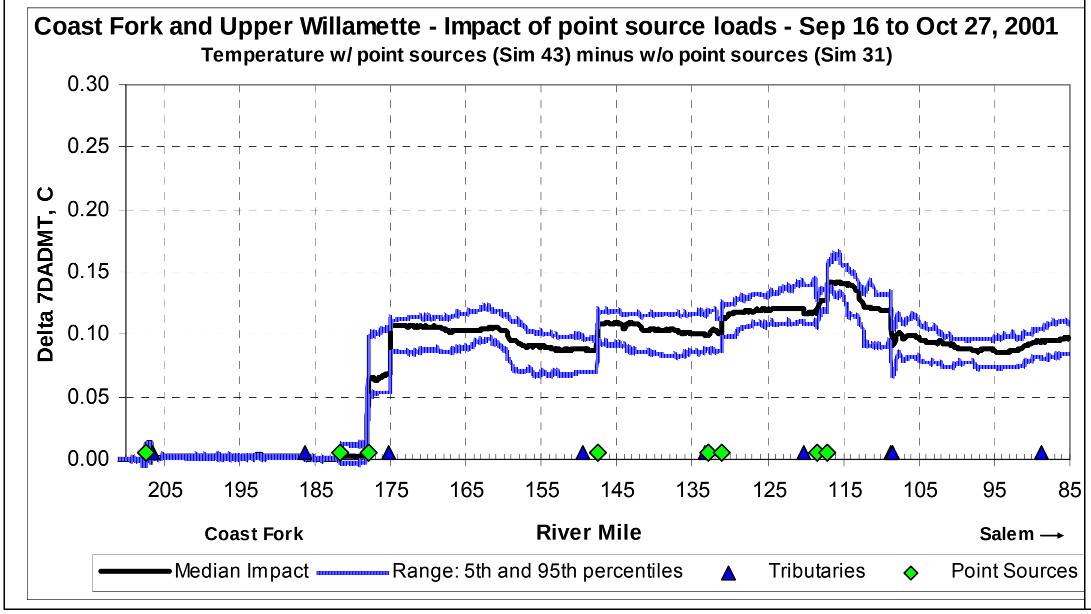
Today, the influence of point source effluent loads on river temperature is small. The figures below indicate that current point source heat loads warm the river by approximately 0.15° at the point of maximum impact. This occurs near Albany (approximately RM 115) where the upper 95th percentile of stream temperature changes exceeds 0.15°C (Figure 4.7). This means that for the 2001 period assessed, 95% of the calculated changes in ambient 7 DADM temperatures were equal to or less than the values shown shown. Median impacts in the Upper Willamette were closer to 0.1°C change in ambient 7DADM temperatures. Figure 4.8 indicates that temperature effects later in the season are similar to the summer period although median point source impacts on ambient temperatures are slightly greater than in the summer period. This may be because effluent temperatures remain warm, but receiving stream temperatures have started to cool as solar radiation inputs decrease over time.

Figure 4.7 **Current point source load effects on temperatures during late spring and summer 2001 period.**



RM	Point Sources
207.4	Cottage Grove POTW
181.6	Univ. of Oregon
177.9	Eugene WWTP
147.6	Georgia Pacific - Pope Talbot
132.8	Evanite
131.0	Corvallis WWTP
118.4	Albany WWTP
117.2	Weyco Albany

Figure 4.8 Current point source load effects on temperatures during late summer and early autumn, 2001.



RM	Point Sources
207.4	Cottage Grove POTW
181.6	Univ. of Oregon
177.9	Eugene WWTP
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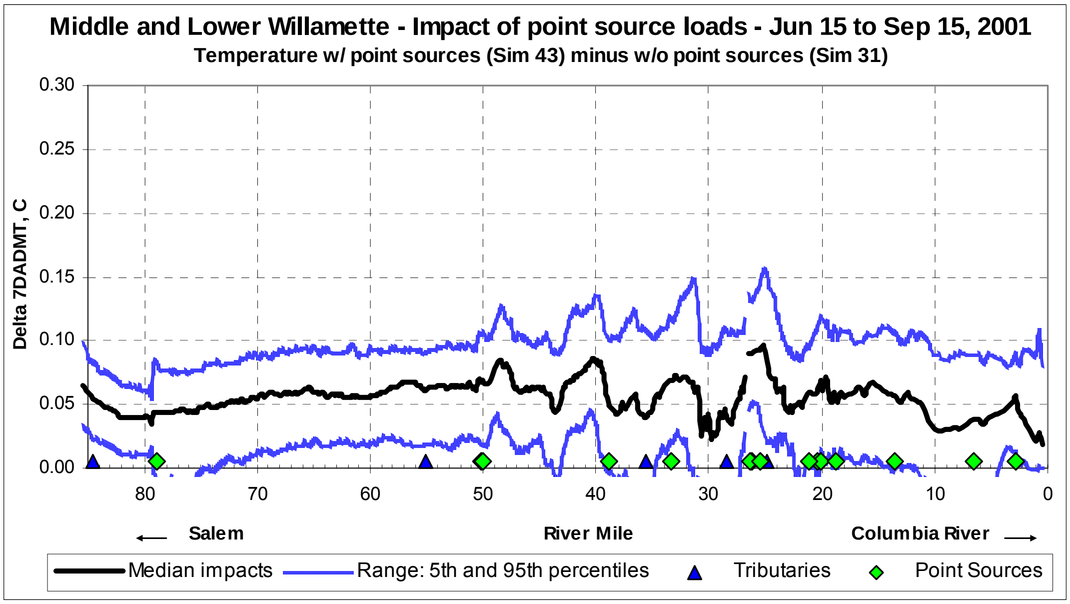
131.0	Corvallis WWTP
118.4	Albany WWTP
117.2	Weyco Albany

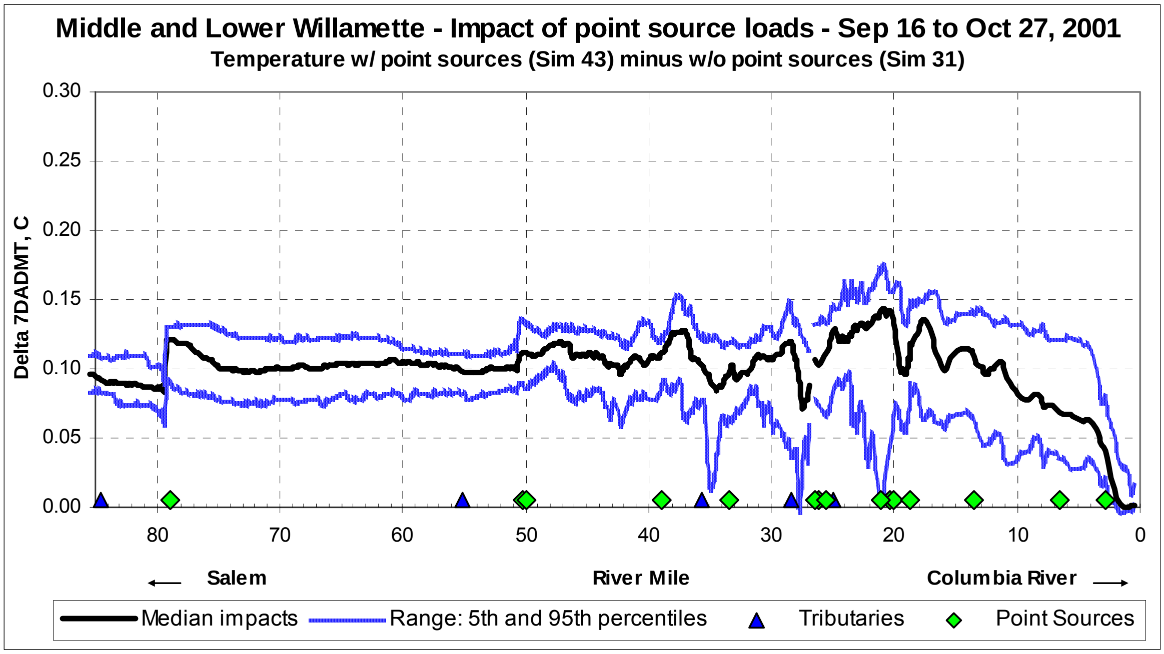
Figure 4.9 Current point source load effects on temperatures during late spring and summer 2001.



RM	Point Sources
78.9	Salem Willow Lake WWTP
50.2	SP Newsprint
50.0	Newberg WWTP
38.9	Wilsonville WWTP
33.4	Canby WWTP
26.2	West Linn Paper
26.4	Blue Heron Paper Mill
25.5	Tri-City WWTP
20.4	Tryon Creek WWTP
20.1	Oak Lodge WWTP
18.7	Kellogg Creek WWTP
13.5	OMSI
6.6	Wacker Siltronics
2.8	Oregon Steel

Current point source impacts in the middle and lower Willamette River also warm ambient 7DADM temperatures by 0.15°C or less (Figure 4.9), and slightly more in the early fall (Figure 4.10). This is due in part to the volume and larger loading capacity of the river below the Santiam River, but also reflects the warmer river temperatures. River and municipal effluent temperatures are similar during peak summer months. Also apparent are time of travel effects of effluent through the Newberg Pool (RM 53 to 26.5). Effluent loads add tens of millions of gallons per day of treated wastewater to the river and this volume slightly changes river velocity, which is demonstrated as peaks and troughs in temperature changes. These time of travel effects are addressed and corrected for the purposes of waste load allocation calculations.

Figure 4.10 **Current point source load effects on temperatures during late summer and early autumn, 2001.**



RM	Point Sources
78.9	Salem Willow Lake WWTP
50.2	SP Newsprint
50.0	Newberg WWTP
38.9	Wilsonville WWTP
33.4	Canby WWTP
26.2	West Linn Paper
26.4	Blue Heron Paper Mill
25.5	Tri-City WWTP
20.4	Tryon Creek WWTP
20.1	Oak Lodge WWTP
18.7	Kellogg Creek WWTP
13.5	OMSI
6.6	Wacker Siltronics
2.8	Oregon Steel

Nonpoint Source Heat Load Contributions

Nonpoint sources of pollution are diffuse or unconfined sources of pollution where wastes can either enter or be conveyed by the movement of water to public waters (OAR 340-41-0006 (17)). For the purposes of the Willamette Basin temperature TMDLs, nonpoint sources are past or present human activities that contribute to greater heat load to the stream network. Nonpoint source activities may include urban and rural development, agricultural practices, forest management, and associated developments such as transportation systems that cause or contribute to the removal of streamside vegetation or detrimental changes in stream channel form. Dam, reservoir, and hydroelectric project management operations are also identified as nonpoint sources because these activities have substantial impact on stream temperatures throughout the basin.

Vegetation Assessment and Development of System Potential Shade

The removal or disturbance of streamside vegetation can decrease the amount of vegetation effectively shading water. The loss of effective shade allows more solar radiation to reach the surface of the water and deliver more energy to the stream. Loss of shade has a greater effect on temperatures in smaller, narrow river systems than larger streams, but is of concern throughout the basin. Disturbances to vegetation may also result in loss of stream bank stability and accelerated bank erosion which in turn yields changes in channel characteristics such as width and depth. The combined loss of streamside vegetation and accelerated bank erosion that causes wider stream channels contributes further to reductions in effective shade and allows more solar radiation to reach surface waters. This source of anthropogenic heat input is most pronounced during summer months when the sun is high overhead for many hours and summer streamflows are often at or near their lowest levels of the year. During this period streams have little capacity for additional heat before temperatures are too warm for cold water species. Many streams included on the 303(d) list of temperature impaired streams are affected chiefly by nonpoint source activities.

Nonpoint source heat loads from land use activities were determined with model simulations of land cover at current shade levels and system potential shade levels. This required identification of current vegetation conditions and quantification of the amount of shade provided. System potential vegetation and shade levels were defined and were the basis for background rates of solar radiation inputs into the river system. Model simulations provided an estimation of the effects of changes in streamside vegetation on shading, solar radiation inputs, and river temperature responses. Heat loads in excess of background rates were attributed to anthropogenic sources as nonpoint source pollution.

Current streamside vegetation conditions throughout the basin were derived from aerial photographs. Relatively homogeneous areas of vegetation were aggregated in a GIS database and attributes for each streamside community, including the physical dimensions and canopy characteristics of the riparian corridor, were assigned. These attributes were based on information provided by the US Forest Service, Oregon Department of Fish and Wildlife, and the Pacific Northwest Ecosystem Research Consortium and verified with field measurements throughout the basin.

System potential riparian information for Coast Range and Cascade Mountain Range forest areas was derived from US Forest Service plant association data (Logan et al. 1987). System potential riparian cover in the valley was based on assessment of historic and current vegetation patterns, geology, soils, ecoregions, geomorphic surfaces, and other environmental factors. Vegetation characteristics were developed for vegetation cover types and included areas that support large coniferous trees, deciduous trees, mixed forest communities, or in the case of valley prairies, no trees at all (Table 4.8). In the Lower Willamette Subbasin, where surficial information was not available ecoregion vegetation characteristics were assigned. Map 4.8 illustrates where ecoregion and geomorphology classifications were used to determine system potential shade characteristics.

Table 4.8 Near stream vegetation characteristics used to determine system potential vegetation.

Vegetation Type	Tree Height (m)	Canopy Density %	Overhang (m)
Valley Forest			
Mature Conifer	48.8	75	4.9
Mature Mixed	27.4	75	3.3
Mature Hardwood	20.4	75	3.1
Savanna			
Mature Conifer	48.8	50	4.9
Mature Mixed	27.4	50	3.3
Mature Hardwood	20.4	50	3.1
Prairie Grassland	0.9	75	0
Upland Forests			
Disturbed: Semi closed Mixed	17.1	25	2.0
Undisturbed: Mature Coniferous	48.8	75	4.9

Current condition and system potential shade levels were calculated with tree height, canopy density and stream channel overhang values developed for each vegetation cover type. Effective shade levels for each cover type are also a function of channel width and channel aspect. As channel width increases system potential vegetation blocks less solar radiation and effective shade levels decrease. And because the sun tracks east to west, stream channel aspect or orientation also influences the effective shade value of existing vegetation. Wide stream reaches with an east-west aspect experience more solar radiation input over the course of a summer day than stream reaches with north-south aspects.

Potential near stream cover is intended to reflect effects of natural disturbance processes on effective shade. As discussed in *Appendix C – "Potential Near-Stream Land Cover in the Willamette Basin for TMDLs"*, natural disturbance is simulated through the geographic distribution of effective shade levels that vary from low to high levels of shade and represent the expected range of dominant species within each streamside community. While not truly representing the complexity and stochastic nature of riverine environments, this incorporation of a range of shade levels for each riparian community demonstrates that system potential vegetation is not a static condition represented exclusively by mature vegetation.

Map 4.8 Ecoregions and geomorphic units in the Willamette Basin

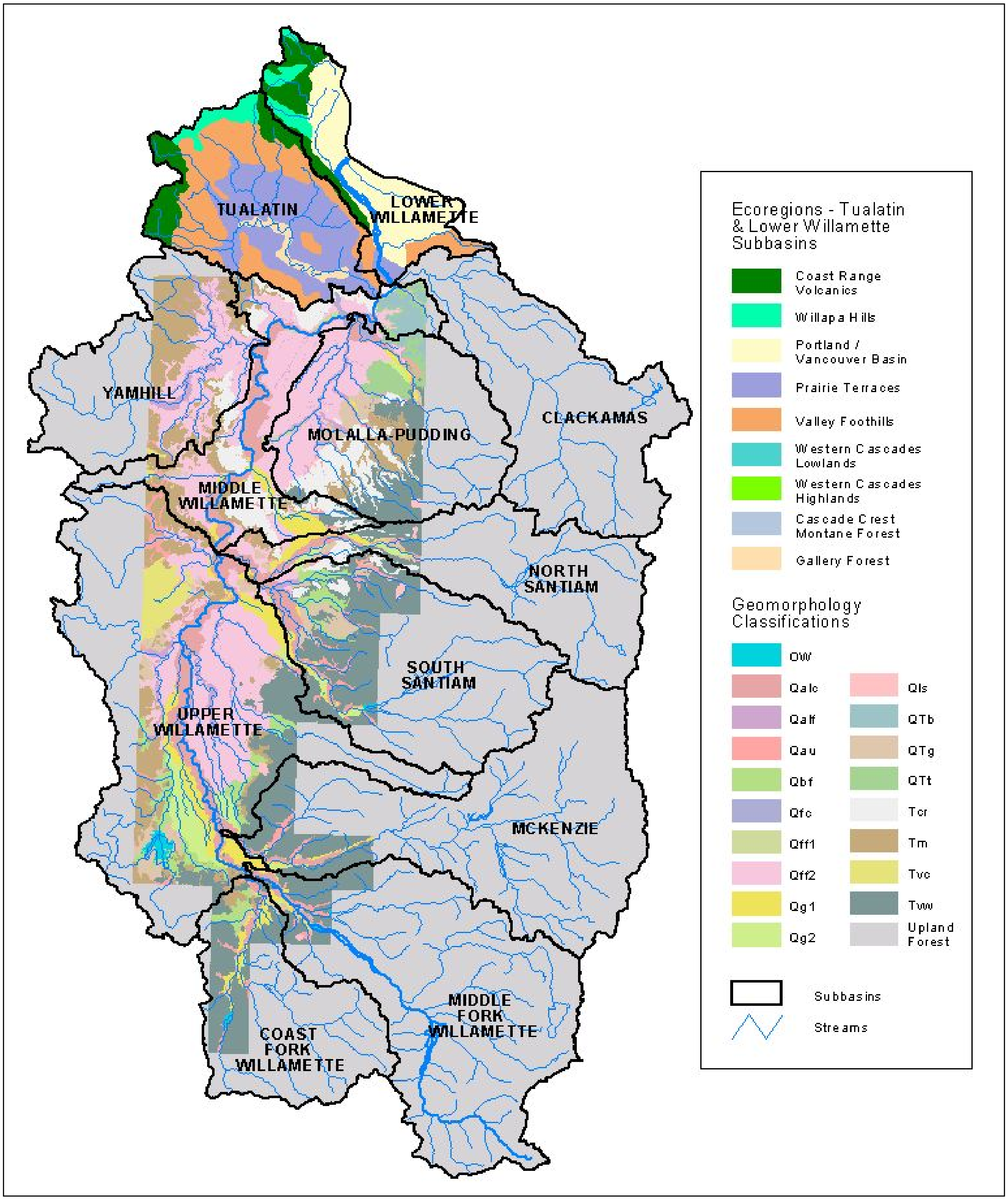
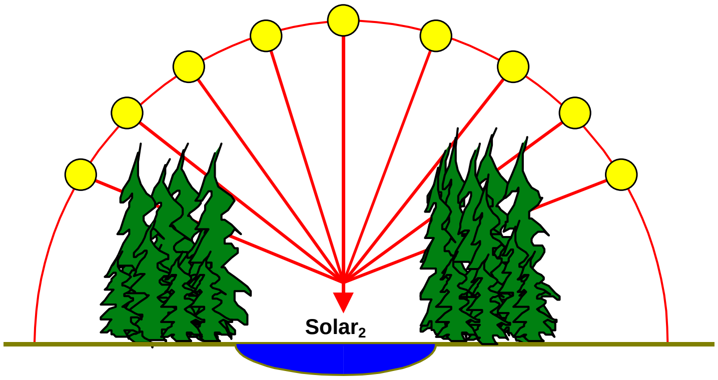


Figure 4.11 illustrates effective shade as applied in this TMDL. It is the percent of solar radiation that does not reach the stream surface because it is blocked by streamside vegetation. Any reduction in streamside effective shade will result in greater amounts of solar radiation reaching the stream.

Figure 4.11 **Diagram of effective shade**

Effective Shade Defined

Solar$_1$ – Potential daily direct beam solar radiation load adjusted for julian day, solar altitude, solar azimuth and site elevation.



$$\text{Effective Shade} = \frac{(\text{Solar}_1 - \text{Solar}_2)}{\text{Solar}_1}$$

Where,

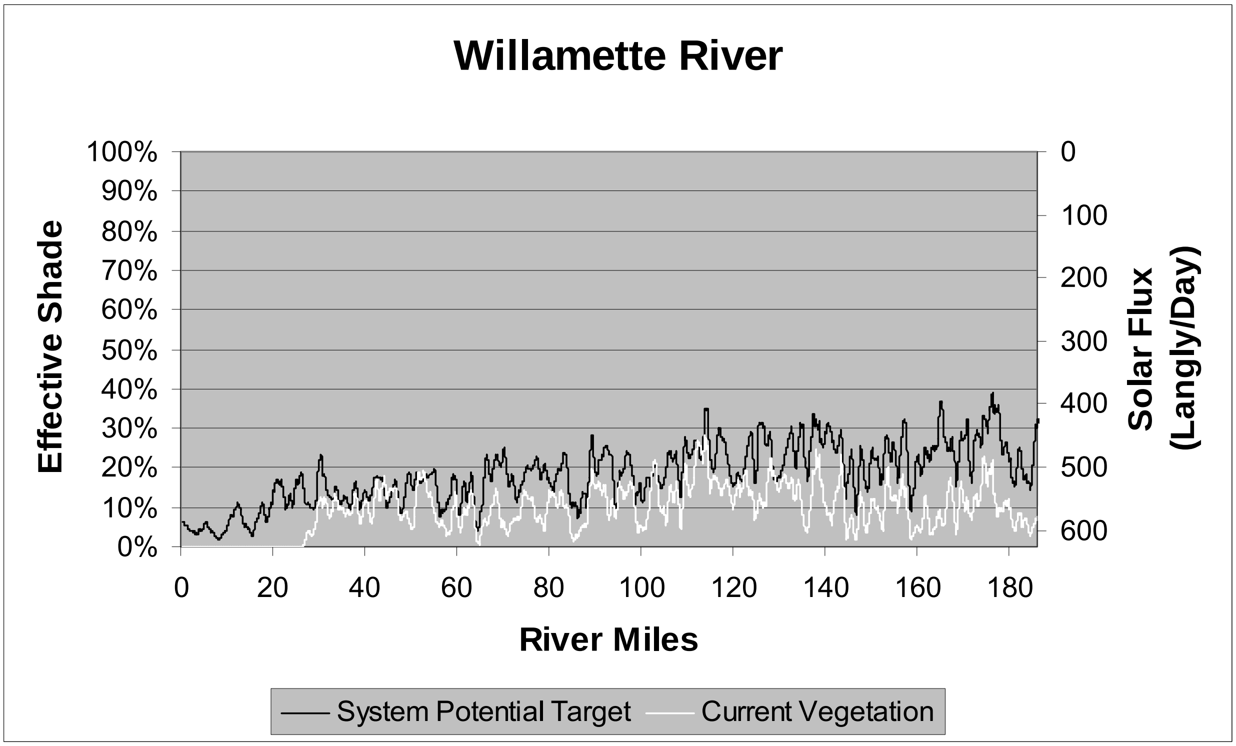
Solar$_1$: Potential Daily Direct Beam Solar Radiation Load
Solar$_2$: Daily Direct Beam Solar Radiation Load Received at the Stream Surface

Effective shade and daily heat loads were calculated by modeling site specific information and solar radiation information every 100 feet along the stream. Site specific information includes vegetative characteristics and topographic features as well as stream aspect and wetted widths. Solar inputs to the stream that are influenced by attributes such as solar altitude and azimuth, latitude/longitude, elevation, cloud cover and other meteorological data are accounted for in the modeling.

Application of Effective Shade in the TMDL

Figure 4.12 illustrates the difference between current effective shade levels and system potential shade levels for river mile 187 to river mile 26 at Willamette Falls. Current shade levels were not included in the calibrated model below Willamette Falls.

Figure 4.12 **Example of current and effective shade relationship for the Willamette River**



Nonpoint source heat loads were determined by quantifying the differences between solar radiation heat loads for current vegetation conditions and system potential vegetation conditions. Heat loads associated with potential near stream land cover and effective shade were considered the natural or background heat load for each stream system. Heat loads above this background level were attributed to anthropogenic disturbance of streamside vegetation and thus nonpoint source activities.

The relationships between total solar radiation heat load, natural or background heat load and anthropogenic heat loads are described in Table 4.9. For the Willamette and its largest tributaries, background heat load from solar radiation exceeds anthropogenic loads by an order of magnitude. Nevertheless, August average daily energy input from anthropogenic activities that diminish effective shade is estimated at 23 x10^9 kilocalories per day. Table 4.9 does not reflect an energy balance for each river reach or through time. Energy gains and losses are continuous through each reach and the table only reflects energy inputs through direct solar radiation. Furthermore heat loading capacity of the river increases in a downstream direction as a function of river volume and simple solar radiation inputs are not a predictor of maximum stream temperature.

Heat loads as reported in Table 4.9 are in kilocalories per day. These values were calculated by multiplying the wetted surface area of the river reach by the solar flux received by the stream. Solar flux is reported in Langley's per day (ly/day). Wetted surface area was calculated through interpolation of remote imagery, modeling, and by field measurements.

$$1 \text{ Langley} = 1\frac{\text{cal}}{\text{cm}^2} = .001\frac{\text{Kcal}}{\text{cm}^2}$$

$$\text{Solar Loading}\left(\frac{\text{Kcal}}{\text{day}}\right) = \left(\frac{\text{Langley}}{\text{day}}\right)\cdot\left(\frac{.001\text{Kcal}}{\text{cm}^2}\right)\cdot \text{wetted surface area}\left(\text{cm}^2\right)$$

Solar loading as displayed in Table 4.9 is largely a function of stream surface area. Longer river reaches have larger loads than shorter river reaches because of greater surface area. Emphasis should be placed on the difference between natural background loads and current loads. The decrease in solar radiation to reach system potential reflects the daily reduction in kilocalories necessary to realize background heat loads.

Current solar loading values for the lower Willamette River (RM 0 to 27) do not reflect actual vegetation conditions. No streamside vegetation was included in this portion of the model and the only shade provided in this reach is from topographic features. Vegetation has little impact on overall stream temperatures in the lower river because of the width of the river and the volume of water. System potential shade values are very low downstream of Willamette Falls and have negligible effect on mainstem model outputs.

Table 4.9 Heat load from solar radiation in August.

		August	August	August	August
	River Mile Reach	**Current Condition** Solar Loading	**Potential (Background)** Solar Loading	**Anthropogenic** Solar Loading	**Portion from Anthropogenic Non-Point Sources**
Subbasin		(Billion Kcal/day)	(Billion Kcal/day)	(Billion Kcal/day)	
Willamette River	**Willamette River (RM 0-187)**	287.93	265.01	22.92	8.0%
	187-171.8 (Upper Willamette)	13.52	11.37	2.15	15.9%
	171.8-161.2	9.11	7.59	1.52	16.7%
	161.2-149	11.25	9.81	1.44	12.8%
	149-132.1	14.52	12.41	2.11	14.5%
	132.1-119.4	12.04	11.07	0.98	8.1%
	119.4-109	10.45	9.60	0.84	8.1%
	109-84.1 (Middle Willamette)	32.99	30.48	2.51	7.6%
	84.1-54.9	40.35	36.96	3.39	8.4%
	54.9-35.7	30.68	29.61	1.06	3.5%
	35.7-24.8	23.93	22.22	1.71	7.2%
	24.8-13.1 (Lower Willamette)	30.40	27.88	2.51	8.3%
	13.1-3.4	43.56	41.50	2.05	4.7%
	3.4-0	15.14	14.50	0.64	4.2%
Clackamas Subbasin	**Clackamas**	11.99	8.89	3.09	25.8%
	23.4-5.1	9.53	7.14	2.40	25.1%
	5.1-0	2.45	1.76	0.70	28.3%
Coast Fork Willamette Subbasin	**Coast Fork**	5.78	4.31	1.47	25.4%
	29.4-20.8	0.64	0.39	0.25	39.4%
	20.8-0	5.14	3.92	1.22	23.7%
	Mosby River	0.32	0.28	0.04	12.1%
	Row River	1.78	1.12	0.66	37.4%
	7.5-0	1.78	1.12	0.66	37.4%
Lower Willamette Subbasin	**Columbia Slough**	3.54	2.66	0.89	25.0%
	Lower Slough	2.12	1.97	0.14	6.8%
	Middle Slough	1.07	0.42	0.65	60.7%
	Upper Slough	0.36	0.27	0.09	25.8%
	Johnson Creek	0.58	0.37	0.21	36.1%
Mckenzie Subbasin	**Blue River**	0.16	0.09	0.07	41.8%
	McKenzie	52.60	44.46	8.14	15.5%
	59.8-41.3	7.70	6.46	1.23	16.0%
	41.3-13.7	17.10	14.17	2.92	17.1%
	13.7-0	27.80	23.82	3.98	14.3%
	Mohawk River	0.77	0.61	0.16	20.7%
	South Fork Mckenzie	0.68	0.44	0.24	35.8%
	Upper McKenzie	1.78	0.96	0.81	45.8%
Middle Fork Willamette Subbasin	**Middle Fork**	9.98	8.85	1.13	11.3%
	11.2-16.8	2.84	2.44	0.39	13.8%
	11.2-0	7.15	6.41	0.74	10.3%
	Fall Creek	1.18	0.92	0.26	21.8%
	7.1-0	1.18	0.92	0.26	21.8%
North Santiam Subbasin	**Little North Santiam**	0.68	0.60	0.08	12.4%
	North Santiam	11.19	10.63	0.56	5.0%
	27-0	11.19	10.63	0.56	5.0%
	Santiam	9.19	8.44	0.75	8.2%
	11.7-0	9.19	8.44	0.75	8.2%
South Santiam Subbasin	**Crabtree**	1.58	1.32	0.26	16.7%
	South Santiam	21.51	18.33	3.18	14.8%
	37.7-0	21.51	18.33	3.18	14.8%
	Thomas Creek	1.01	1.01	0.00	0.3%
Upper Willamette Subbasin	**Calapooia River**	2.40	1.94	0.46	19.2%
	Coyote Creek	0.27	0.19	0.09	31.8%
	Lukiamute River	1.32	1.12	0.20	15.2%
	Long Tom	3.80	2.25	1.54	40.6%
	25.7-0	3.80	2.25	1.54	40.6%

Figure 4.13 illustrates by river mile solar loading from anthropogenic activities in kilocalories per 100 feet per day. This pattern of solar loading represents a 10 mile segment of the Willamette River near Eugene but is typical of much of the basin. Positive values reflect areas where solar loading is in excess of simulated background levels. Current inputs are generally more than a million kcal/day greater than system potential background loads. Negative values reflect areas where solar loading is currently less than loading at system potential conditions. In these areas existing vegetation provides more effective shade than provided with simulated system potential conditions. Values for current vegetation height or density may be greater than values assigned to streamside vegetation in these model segments. For example, valley bottom prairies rarely occur today but this vegetation cover type was included as an element of the system potential landscape. As shown previously in Table 4.8, valley prairie has essentially no effective shade value.

Figure 4.13

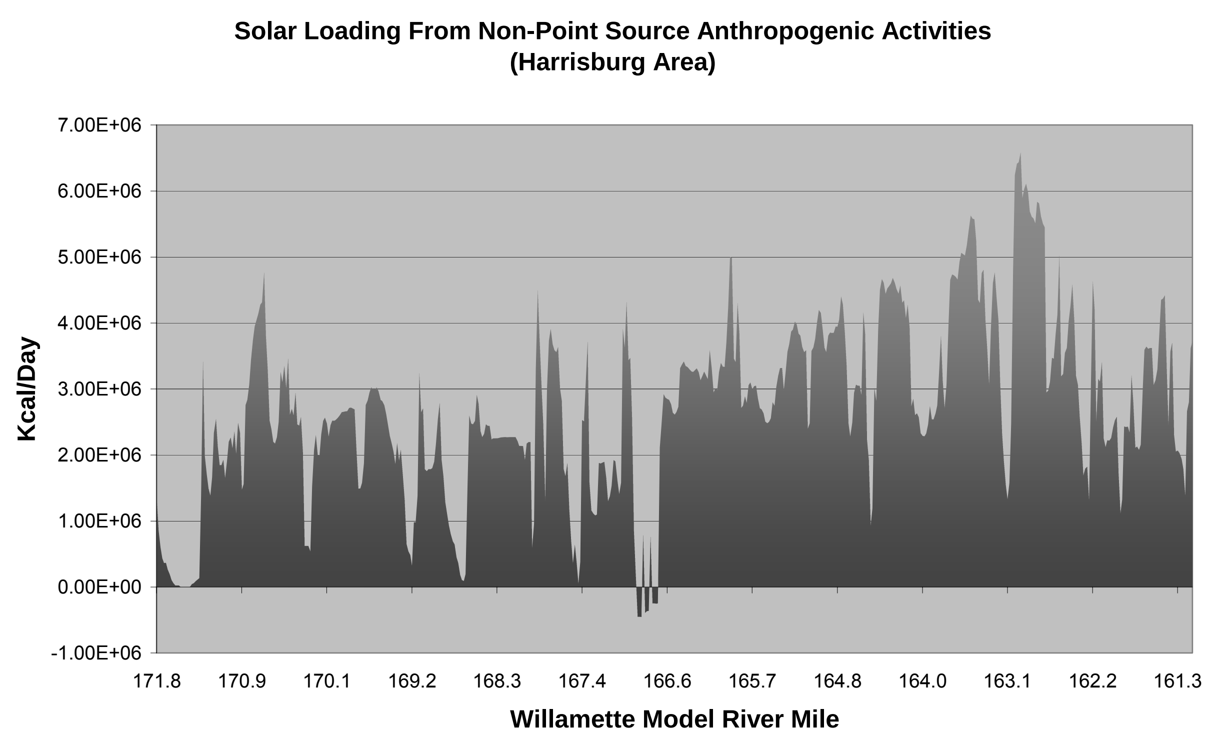
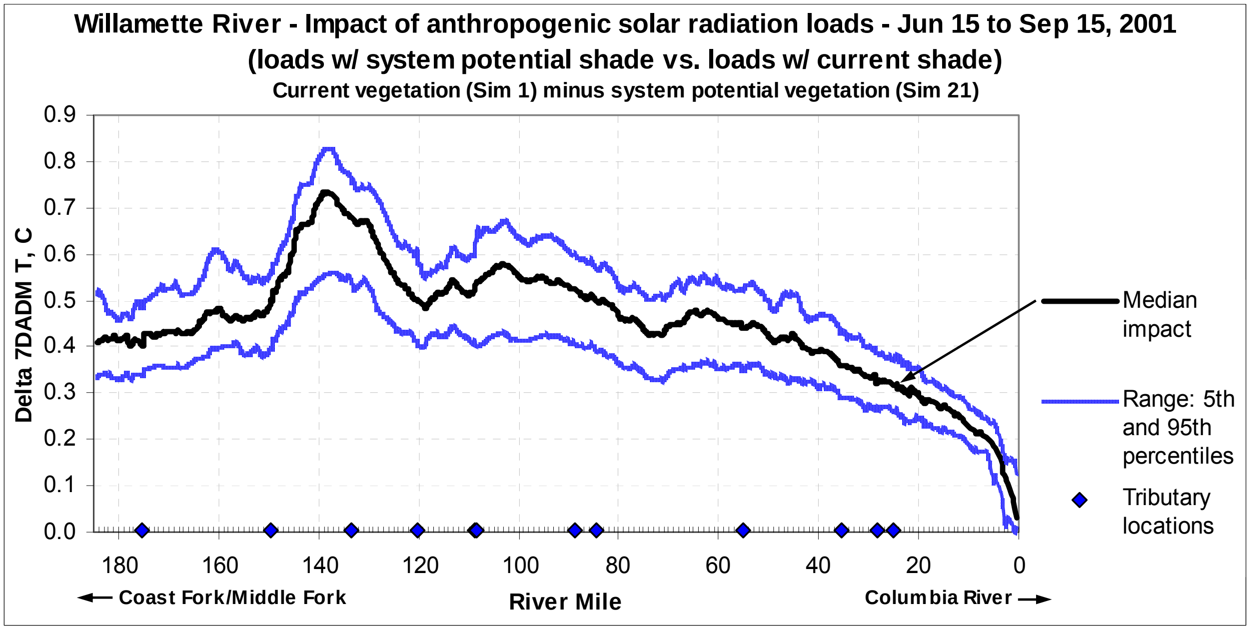


Figure 4.14 illustrates the effects of nonpoint source activities that influence shade along the river segments included in the mainstem model. The figure shows how much warmer the Willamette River is at current shade levels during the summer than it would be if shade were restored to system potential levels. The increase in seven day average of daily maximum (7DADM) stream temperatures is due to the increase in solar radiation load that results from shade being less than system potential levels. During the summer nonpoint source loads of solar radiation along the mainstem Willamette and its largest tributaries cause more than 0.75°C warming at river mile 140 near Corvallis, based on modeling for 2001. Effects diminish downstream as the river width and volume increases and current condition solar loads approach those of system potential. However, even at Willamette Falls (RM 26), nonpoint solar loads cause warming of river temperatures in excess of the 0.3°C allowed in Oregon temperature standards. The influence of shade on stream temperature is described in more detail in Appendix 4.6.

Figure 4.14 **Maximum difference in seven day average of the daily maximum temperatures between 2001 calibrated model and 2001 calibrated model with system potential vegetation.**



Reservoir and Dam Operations

Federal flood control reservoirs and public and private hydroelectric project reservoirs are located throughout the Willamette Basin (Map 4.9). These contribute to stream warming and the alteration of natural thermal regimes through a number of processes that affect the input and storage of solar energy. Storage reservoirs increase the surface area of water exposed to solar radiation and impoundment allows heat to accumulate in the reservoir pool. This heat energy dissipates to some extent but much of it is later released during drawdown periods. Reservoir operations also affect streamflow, which alters the heat loading capacity of the stream and seasonal temperature patterns.

Diversion dams affect stream temperature by dewatering downstream “bypass reaches.” Water is diverted from the river channel through canals and/or penstocks before the water passes through a powerhouse and is returned to the natural stream channel. Reduction in streamflow increases the time of travel through the bypass reach and increases the time that water in the bypass reach is exposed to solar radiation. Reductions in flow may also impact width to depth ratios and make it more difficult for streamside vegetation to shade the stream. Modeling presented below indicates that stream temperatures in bypass reaches can warm two or three degrees above natural stream temperatures.

USACE Willamette Basin Project Reservoir Heat Load Contributions

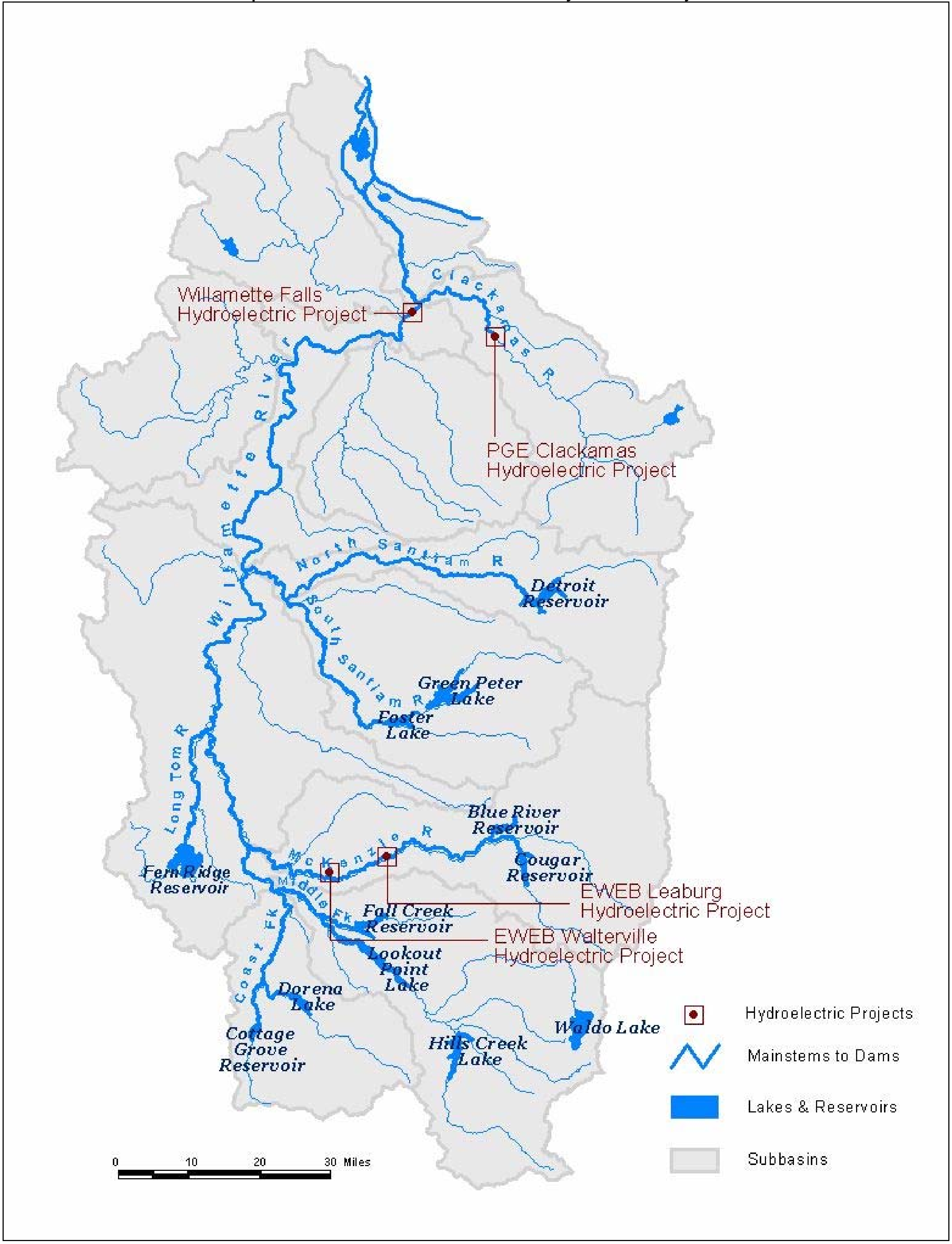
The most notable dams and reservoirs in the Willamette Basin and those with the largest influence on water quality are those of the US Army Corps of Engineers Willamette River Basin Project. The project includes a series of 13 dams and reservoirs in the basin constructed and operated by the USACE for purposes authorized by Congress over half a century ago. Most significant are the 11 relatively large reservoirs that provide seasonal flood control and multiple purpose conservation water storage. The remaining two projects are re-regulating reservoirs with little storage capacity that dampen the large daily fluctuations caused by hydropower peaking operations.

Flood control is the highest priority of the USACE Willamette Project. Project reservoirs attenuate flood flows and hold spring runoff from the Coast Range and Cascade Mountains. Stored water is released to augment streamflows during the dry months of summer and early fall. Beginning in September reservoir pools are drawn down to provide flood control capacity. Other authorized purposes include flow augmentation for navigation, irrigation, power production, fisheries and water quality. The project provides seasonal storage of nearly 1.6 million acre feet of water and a capacity to produce 2,100 megawatts of electric power.

USACE reservoirs modify natural temperature patterns in downstream river reaches. Except for Cougar Reservoir, for which recent construction of a temperature control tower allows water to be withdrawn from various depths, regulating outlets are well below the surface of each reservoir pool and cool waters are released from deep within the thermally stratified reservoirs during the summer months. Because of the design and operation of the reservoirs, summer river flows downstream of the reservoirs are higher and cooler than natural. Thermal stratification in the reservoirs breaks down in late summer at the same time as the reservoirs are drawn down to provide flood storage capacity. Reservoir temperatures remain warmer than temperatures in streams flowing into the reservoirs and flows in the mainstem Willamette are augmented with water much warmer than natural. This pattern generally occurs well into October or November, during the salmon and trout spawning period.

As a consequence of reservoir operations, fisheries biologists believe that summer water temperatures below some Willamette Project reservoirs are too cold for salmon to efficiently utilize available habitat. On the other hand, during the fall drawdown period fall water temperatures are too warm to fully support salmonid spawning and egg incubation. Warm temperatures result in accelerated fry development and premature emergence from the spawning gravels. These fry are exposed to more hazardous river conditions than would be experienced if egg development followed a slower, more natural pattern.

Map 4.9 Willamette Basin Reservoirs and Hydroelectric Projects



USACE has long recognized the adverse effects the Willamette Project can have on cold water fish use of river reaches below the dams. In late 2004 USACE completed modification of Cougar Reservoir on the South Fork McKenzie to allow for selective withdrawal of water from various depths in the reservoir. USACE can now better match outflow temperatures to natural temperatures and restore much of the natural seasonal temperature pattern of the South Fork McKenzie River. However, until selective withdrawal structures or their equivalent are in place at several other large Willamette reservoirs, project operations will continue to affect downstream water temperatures and fisheries.

Figure 4.15 Cougar Reservoir viewed from Terwillinger, May 15, 2002

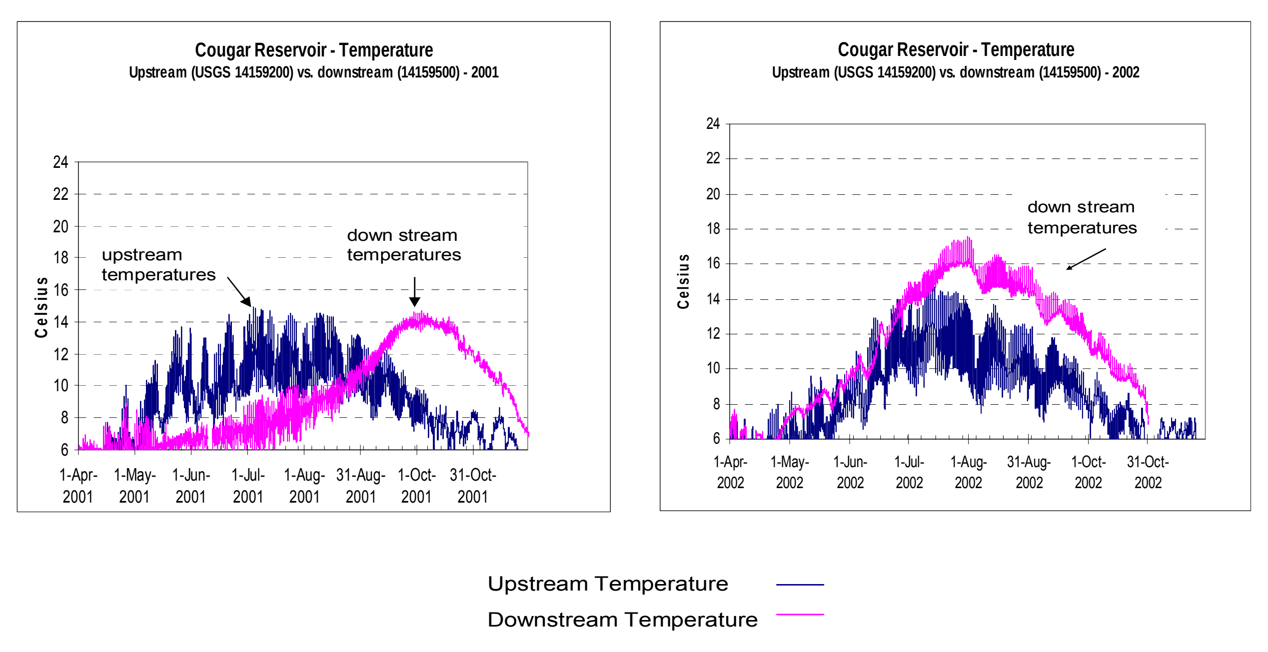
photo by Mark Wade, Oregon Department of Fish and Wildlife, used by permission
http://www.fsl.orst.edu/wpg/research/cougar/photos/

Figure 4.16 illustrates the effect that Cougar Reservoir had on South Fork McKenzie River temperatures in 2001 and 2002. The figures contrast water temperatures discharged from the reservoirs with flow-weighted composite temperatures of upstream tributaries. Upstream tributary temperatures are intended to serve as an indicator of natural stream temperature patterns including the timing, magnitude and duration of peak daily and seasonal maximum observations.

The left panel of Figure 4.16 presents 2001 data, which was the last year of normal operations before construction of the temperature control tower at Cougar Reservoir began. A shift or delay in the occurrence of maximum seasonal temperatures is readily apparent in this figure. The seasonal maximum temperatures downstream of Cougar occurred in October of 2001, rather than July or August. In addition to the maximum temperature shifts, short-term temporal (daily and weekly) fluctuations in temperature are also muted because of the long residence time of water in the reservoir and the withdrawal of water from the bottom of the reservoir. Reservoir temperatures were well below the 16°C cold water habitat criterion until late summer. However, once drawdown drained cold reservoir bottom waters and/or the lake “turned over,” i.e. surface waters cooled to less than bottom water temperatures, fish downstream of Cougar were exposed to water temperatures continuously above the 13°C numeric spawning criterion.

The right panel of Figure 4.16 presents temperature patterns observed in 2002 when there was no storage at Cougar and the pool was drawn down to minimum levels in order to construct the temperature control tower. Maximum downstream temperatures were warmer than flow-weighted composite tributary temperatures (in part because the water was flowing through a drawdown reservoir with no shade, see Figure 4.15), but there is much better alignment of seasonal maximum temperatures. Maximum temperatures are observed in mid summer above and below the reservoir and temporal variability in upstream tributary temperatures is also seen below the reservoir.

Figure 4.16 **Water temperatures for 2001 and 2002 collected upstream and downstream of Cougar Reservoir**



To assess current USACE reservoirs impacts on stream temperatures it was necessary to identify natural thermal potential temperatures below each reservoir. Because the temperature model did not extend upstream of USACE reservoirs model simulations were not available to identify natural thermal potential temperatures in the absence of the reservoirs. Instead, NTP temperatures were based on water temperature and flow data from streams that discharge to each reservoir. Recent tributary data were used to calculate flow-weighted seven-day rolling average temperatures and monthly median of these values are shown in (Table 4.10). These NTP estimates and assessment of project impacts are coarse and ODEQ anticipates they will be revised as more information becomes available. For example, USACE has demonstrated that ODEQ NTP estimates for South Fork McKenzie River are at or below the range of historical average monthly temperatures. ODEQ acknowledges this simple approach does not provide data of the quality generated elsewhere in this TMDL, but it does provide an estimate of natural seasonal temperature patterns and how these patterns differ from current thermal regimes.

Table 4.10 Monthly median seven-day rolling average temperatures downstream of USACE Willamette Project Reservoirs and monthly median seven-day rolling average of flow-weighted tributary temperatures upstream of each reservoir (^{o}C)

Subbasin:	Coast Fork Willamette				Middle Fork Willamette					
Reservoirs:	Cottage Grove		Dorena		Hills Creek		Dexter/ Lookout Pt.		Fall Creek	
	downstream	upstream	downstream	upstream	downstream	upstream	downstream	upstream	downstream	upstream
Apr	9.5		8.8	10.8		7.9	8.7		7.5	
May	10.4	11.4	10.2	16.5		11.0	9.5	13.2	11.3	
Jun	11.9	15.5	11.1	22.3	7.9	14.2	11.7	17.4	14.0	15.9
Jul	13.7	19.9	13.3	20.4	8.6	13.6	14.0	16.5	17.2	15.8
Aug	17.1	18.3	13.2	18.2	11.0	12.5	16.9	13.9	16.6	13.5
Sep	19.5	16.4	14.1		16.0		18.3	10.2	9.8	
Oct	15.5		16.2				15.9		12.9	
Nov	10.6		10.3				12.3		10.8	

Subbasin:	McKenzie				South Santiam		North Santiam		Upper Willamette	
Reservoirs:	Cougar		Blue		Foster/ Green Peter		Big Cliff/ Detroit		Fern Ridge	
	downstream	upstream	downstream	upstream	downstream	upstream	downstream	upstream	downstream	upstream
Apr	6.0	7.7	6.0	7.7	7.7	8.2	5.8	7.3	13.4	
May	7.3	10.0	6.7	9.9	8.9	12.4	6.7	9.7	15.5	14.6
Jun	9.2	11.7	7.4	11.2	10.1	18.5	8.8	12.9	19.8	16.7
Jul	11.6	10.9	8.0	10.6	11.7	18.0	10.0	12.8	22.9	16.0
Aug	12.3	9.5	13.0	9.5	11.9	15.5	11.2	10.9	21.8	14.1
Sep	12.9	7.2	14.4	7.2	12.2		12.6	7.7	20.0	8.0
Oct	11.7	6.1	14.6	6.1	12.2		13.6	5.5	14.8	
Nov	10.1		9.1		10.4		10.5			

Unlike point sources that discharge heat loads into a receiving water body, these large reservoirs control the temperature and flow of the entire stream. Effects of reservoirs on stream temperature are expressed as differences between calculated NTP temperatures and observed values. Among the causes for the differences between upstream, flow-weighted target temperatures and the observed downstream temperatures are natural warming, perhaps some anthropogenic warming related to land use activities, and USACE project effects. Additional monitoring and modeling is needed to refine the estimates of natural thermal potential that are the target temperatures for reservoir operations. Stream models are needed of currently impounded reaches to determine heating that would occur in these reaches in the absence of reservoirs. Models are also needed to determine the natural thermal potential of streams which flow into reservoirs. Reservoir models developed by USACE and others are needed to evaluate options for achieving target temperatures.

Hydroelectric Project Heat Load Contributions

Three major utility operated hydroelectric projects are located within the Willamette Basin TMDL planning area. Portland General Electric (PGE) owns and operates the Clackamas River Hydroelectric Project, a complex project on the Clackamas River which consists of multiple dams and reservoirs. PGE also owns and operates a facility on the Willamette River at the Willamette Falls. The Eugene Water and Electric Board (EWEB) owns and operates Leaburg-Walterville hydroelectric project on the lower McKenzie River

CWA Section 401 Certification

Section 401 of the federal Clean Water Act (CWA) authorizes state water quality programs to certify that federal actions involving the award of licenses or permits will not violate applicable state water quality requirements. In the case of hydroelectric projects, the Federal Energy Regulatory Commission (FERC) administers the licensing program, and ODEQ certifies the project application for licensing. The water quality certification typically includes operating conditions intended to provide reasonable assurance that project operation will not violate water quality standards.

ODEQ issued a §401 water quality certification for the PGE Willamette Falls project in November 2004. PGE also has been developing an application for § 401 certification for the Clackamas Project and is expected to submit it within a year. FERC issued an operating license to EWEB for the Leaburg-Walterville Project in 1993 without 401 certification.

Table 4.11 Hydroelectric Projects (>10 MW) in the Willamette Basin Temperature TMDL Analysis Area

Subbasin	Developments	MW	Ownership	401 Certification Date
Clackamas	North Fork, Faraday, River Mill	150	PGE	Application pending
Lower Willamette	Willamette Falls	17.5	PGE	November 2004
McKenzie	Leaburg, Walterville	55	EWEB	NA

PGE Clackamas Project

The PGE Clackamas River Hydroelectric Project on the Clackamas River includes the Oak Grove, North Fork, Faraday and River Mill developments. The Project is licensed as FERC Project No. 2195. The current license expires on August 31, 2006 (PGE, Aug. 2004).

Reaches within project boundaries include the Clackamas River from River Mill Dam at RM 23.4 to the confluence of Oak Grove Fork at RM 34.6 and Oak Grove Fork through Timothy Lake. River Mill Dam defines the upper boundary for the Willamette Mainstem model. Operations of the Clackamas Project influence boundary condition flows and temperatures for the Clackamas River portion of the mainstem Willamette TMDL.

PGE has conducted detailed water temperature studies in the Clackamas River. These studies provide information needed to support the ODEQ 401 water quality certification that will accompany a new Federal Energy Regulatory Commission operating license. Predictive models developed using the modeling framework CE-QUAL-W2 were used to understand processes that control water temperature in river reaches affected by the hydroelectric project. A no-project scenario was developed for the Clackamas River to assess effects of current reservoir operations on maximum stream temperatures. This no-project scenario simulated the system with all dams, diversions, artificial lakes or impoundments and their effects on temperature removed from the calibrated model. Simulation of the Clackamas River without the reservoirs required that effective shade be interpolated from adjacent river reaches and applied to the historical river reaches that pass through each reservoir. All other anthropogenic effects not associated with the project remained in place and upstream temperatures may be affected by other land use activities such as forest management and road systems.

Clackamas River hydroelectric project operations result in storage of water in reservoirs, diversion of water from natural stream channels, peaking power generation and the return of diverted flows to the river channel at various locations. Project effects include altered water depths, velocities and travel times through the river reach. In addition to flow regime modification, changes in diurnal water temperatures are seen within and below the project reach (PGE, Aug. 2004). Immediately below River Mill Dam average daily temperatures and minimum temperatures under current operating conditions are warmer than NTP, but for most periods current daily maximum temperatures are cooler than the simulated NTP temperatures. This is because impoundment of water behind River Mill Dam and elsewhere in the system dampens daily temperature fluctuations and suppresses peak daily temperatures.

Figures 4.17 and 4.18 show the effect that the hydroproject has on Clackamas River water temperatures at RM 23.4 (location of the River Mill Dam tailrace). Shown are model calculated temperatures for 2001, as provided to ODEQ by PGE in October, 2005. Water released from River Mill Dam with the project in place has minimal diurnal variation relative to the NTP scenario. For the NTP simulation River Mill Dam and the rest of the Clackamas River Project was removed. Figure 4.18, which shows the single month of August, demonstrates that daily maximum temperatures with current project operations are cooler than the no-project scenario temperatures, but daily minimum and average temperatures are warmer.

Figure 4.17 **Boundary Condition Temperatures with-project (current) and without project (natural thermal potential conditions)**

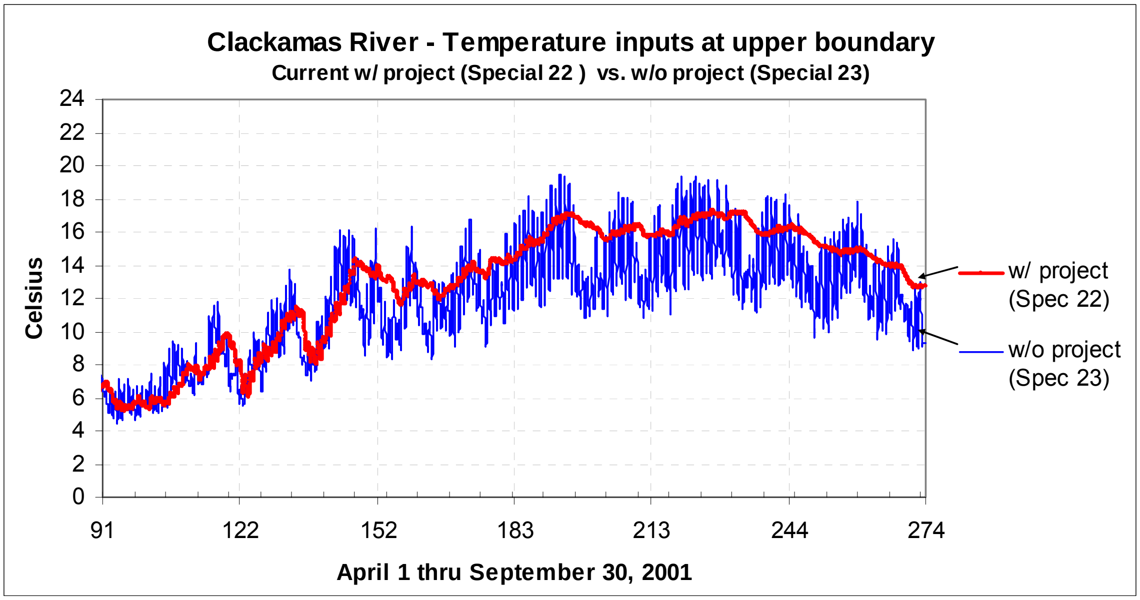
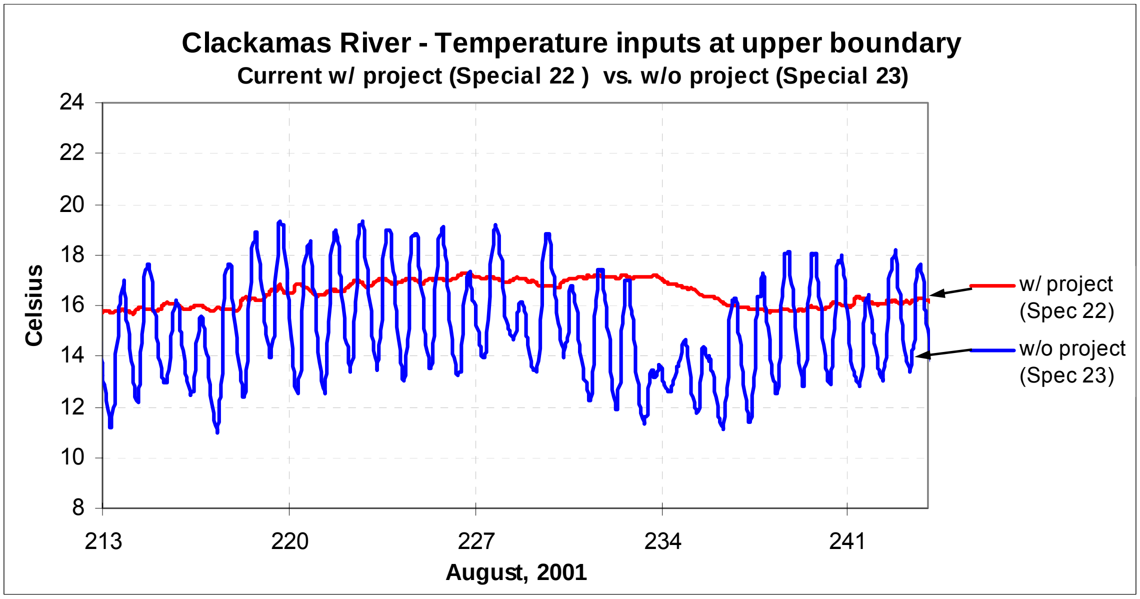
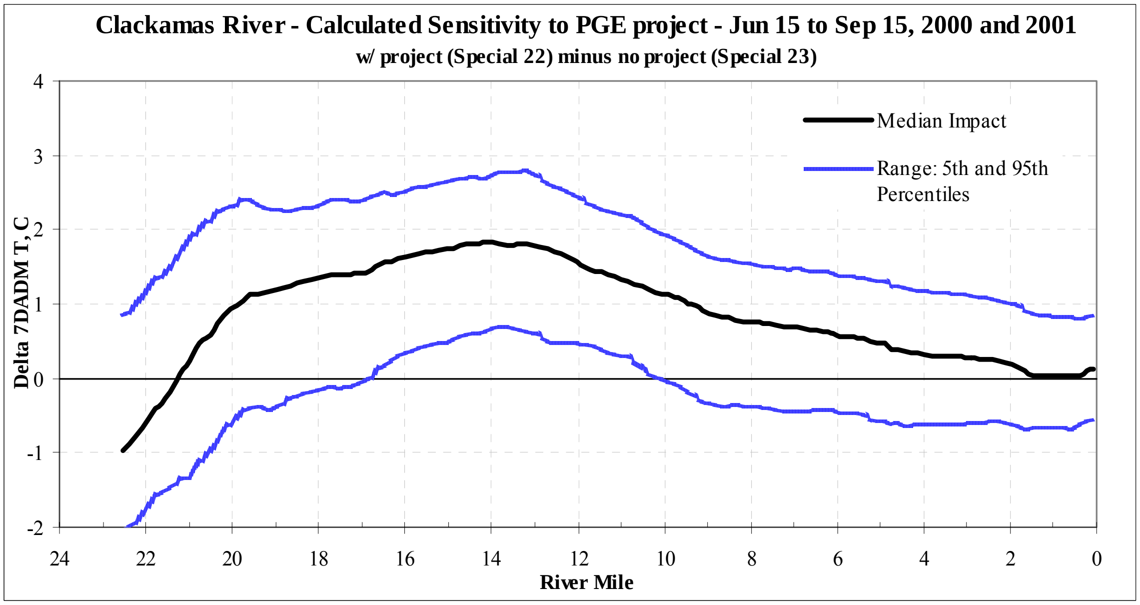


Figure 4.18 **Boundary Condition Temperatures with-project (current) and without project (natural thermal potential conditions)**



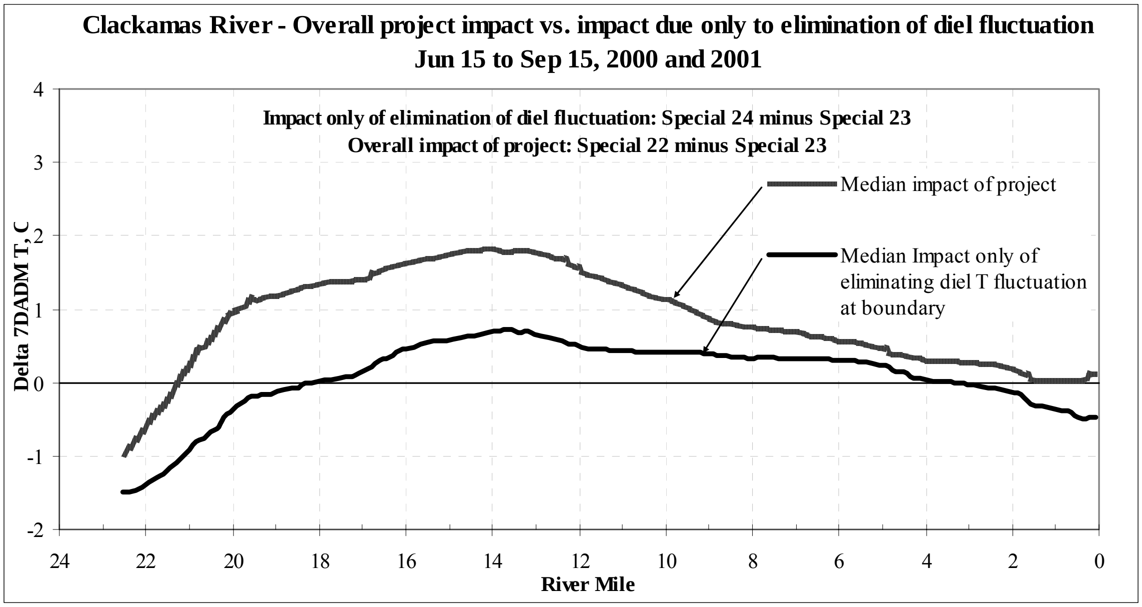
Project impacts on the lower Clackamas River were evaluated by the ODEQ modeling of the lower Clackamas River with and without the project. For the with-project scenario, flows and temperatures at the River Mill Dam tailrace were set to model calculated current reservoir operating conditions (Special Sim 22). For the without-project scenario, flows and temperatures were set to model calculated NTP conditions with the project removed (Special Sim 23). For both scenarios vegetation in the lower Clackamas below River Mill Dam was set to system potential levels so that temperature differences between the scenarios are limited to project impacts. As shown in Figure 4.19 simulations indicate that the hydroproject reduces daily maximum temperatures immediately downstream of River Mill Dam, but results in significantly warmer temperatures farther downstream. For the critical 2001 period, the median change in temperatures is negative upstream of river mile 21, but downstream of that location median impacts are positive. From river mile 17 downstream to river mile 10, simulated temperatures with the project are always warmer than without the project. Downstream of river mile 2, the project reduces daily maximum temperatures nearly as often as it increases them and median delta T values are nearly zero.

Figure 4.19 **Impact of the Clackamas R. Hydroelectric Project on lower Clackamas R. temperatures during the summer**



Project impacts are partially due to heating that occurs in reaches above River Mill Dam due to project and non-project impacts and partly due to suppression of the natural diel temperature fluctuation at the River Mill Dam tailrace location (RM 23.4). The impact of suppressing diel temperature fluctuations at the boundary is illustrated by Figure 4.20 (lower curve). This shows results of a model simulation in which hourly boundary condition NTP temperatures are replaced with daily averages of the NTP temperatures. For comparison purposes, also shown are the current project impacts (upper curve) which are partly due to suppression of diel temperature fluctuations, and partly due to heating which occurs in the system upstream from River Mill Dam. Only median impacts are shown on the plots. As shown by the lower curve, suppression of diel temperature fluctuations results in 7DADM temperatures during the summer that are warmer from RM 18 to RM 4. For example, eliminating diel fluctuation results in temperatures 0.7°C warmer than NTP at RM 14, on a median basis, whereas the overall impact of the project is 1.8°C at RM 14. This is probably because water released in the early morning is warmer than NTP for that time of day. As this water flows downstream it is exposed to normal meteorological conditions and warms to temperatures that exceed daily maximum NTP temperatures. This suppression of natural temperature fluctuations contributes to temperature standard exceedances because river temperatures are increased more than 0.3°C above NTP. Such exceedances probably occur downstream of many large reservoirs that suppress diel fluctuations.

Figure 4.20 Impacts on the Clackamas River of eliminating diel temperature fluctuations at River Mill Dam



While elimination of diel fluctuations results in warmer daily maximum temperatures from RM 18 to 4, below RM 4 the elimination results in cooler daily maximum temperatures, with the greatest cooling occurring at the river mouth. This may be because the time-of-travel from RM 23.4 to RM 0 is about a day, which would result in RM 23.4 reductions in daily maximum temperature also being expressed at RM 0. As shown by the figure, the impact has a sinusoidal shape, with a period equivalent to one day's time-of-travel. The sinusoidal shape probably extends into the Willamette River, albeit with an impact greatly reduced by Willamette River dilution. Therefore, elimination of diel fluctuations at Clackamas RM 23.4 may result in impacts on the lower Willamette River, in addition to the significantly warmer temperatures observed in the Clackamas. (More detail on the projects effects on NTP and the methods to assess these impacts are found in Appendix 4.6.)

PGE Willamette Falls Project

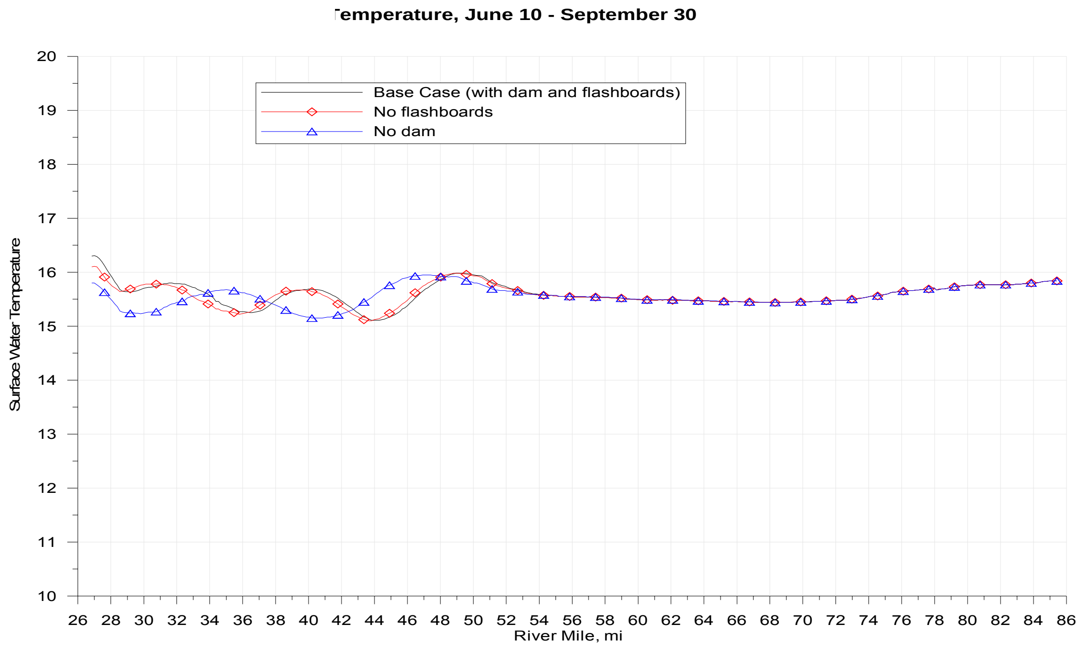
The Willamette Falls Project is a run of river project located at the Willamette Falls at RM 26.5. A low concrete cap or dam situated on the basalt formation that creates the natural falls is supplemented during summer low flow periods with flashboards which further increase the water surface elevation. Newberg Pool, the impounded area behind the Falls, has a volume of 33,700 acre-feet and extends to about RM 56. The dam and flashboards increase this storage by 16,300 acre-feet and extend the length of the pool upstream. The overall low flow travel time through the pool increases from about three days without the project to about four days with the dam and flash boards in place. It is this increase in pool volume and travel time that has the greatest impact on river temperatures.

PGE modeled the Middle Willamette River to examine project effects on river temperatures. The modeling showed that removal of the dam and flashboards (the “no-project” scenario) would result in lower water elevations and pool volume. This would allow temperatures to respond more quickly to daily heating and cooling processes and yield slightly higher temperatures during the day than the with-project simulations (PGE, Nov 2003, Vol 1, p.76). The modeling showed that the project does not have a significant deleterious impact on temperatures in Newberg Pool.

The PGE project does influence water travel time through the Newberg Pool and shifts temperature profiles. This is illustrated by Figure 4.21 (PGE, Nov 2003, vol. 2, p. 5), which shows average surface temperatures from RM 86 through the Newburg Pool to Willamette Falls at RM 26.5. Shown are average surface temperatures for the period modeled, June 10 through September 30, for three scenarios: (1) the current condition scenario with both dam and flashboards in place (the “base case”), (2) a scenario with the flashboards removed but the dam still in place (“no flashboards” scenario), and (3) a scenario with both flashboards and dam removed (“no dam” scenario). As shown, the project shifts the temperature profile, which results in warmer temperatures at some locations and cooler temperatures at others. The modeling indicates that reach average surface temperatures are slightly warmer with dam and flashboards in place than other project configurations, but the greater volume and heat loading capacity of the pool in this simulation yielded an overall reduction in flow-weighted and volume-weighted water temperatures (Berger et al. 2003).

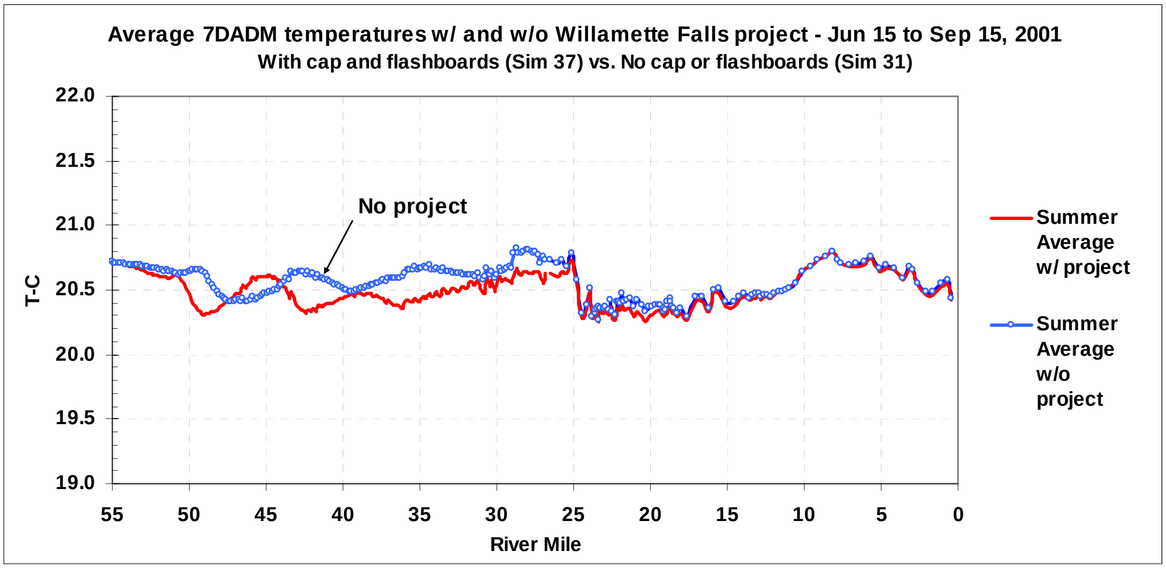
Figure 4.21 Model calculated average surface temperature in Newberg Pool for 3 scenarios

Average surface temperatures of the Willamette River from Salem at river mile 86 through the Newburg Pool river mile 50 to 26. Three scenarios are examined, the base case represents the current Willamette Falls hydroelectric project configuration with dam and flashboards in place, the project with no flashboards, and no dam and flashboard scenario. Note that maximum surface temperatures occur farther downstream in the no dam scenario than under the current base case configuration. From Berger et al. 2003



These conclusions are supported by similar simulations performed by ODEQ which compare the impact of the “with-project” scenario, with both dam and flashboards in place, to the “no-project” scenario, with both flashboards and dam removed (see Figure 4.22). Shown are summer average (June 15 to September 15, 2001) 7-day average daily maximum (7DADM) temperatures both above and below the falls. As shown, during the summer, average calculated temperatures in Newberg Pool are generally cooler with the project in place than without the project, while in the lower Willamette calculated average temperatures are similar for the two scenarios. Results for 2002 are similar (see Appendix 4.6 for additional information, including 2002 results).

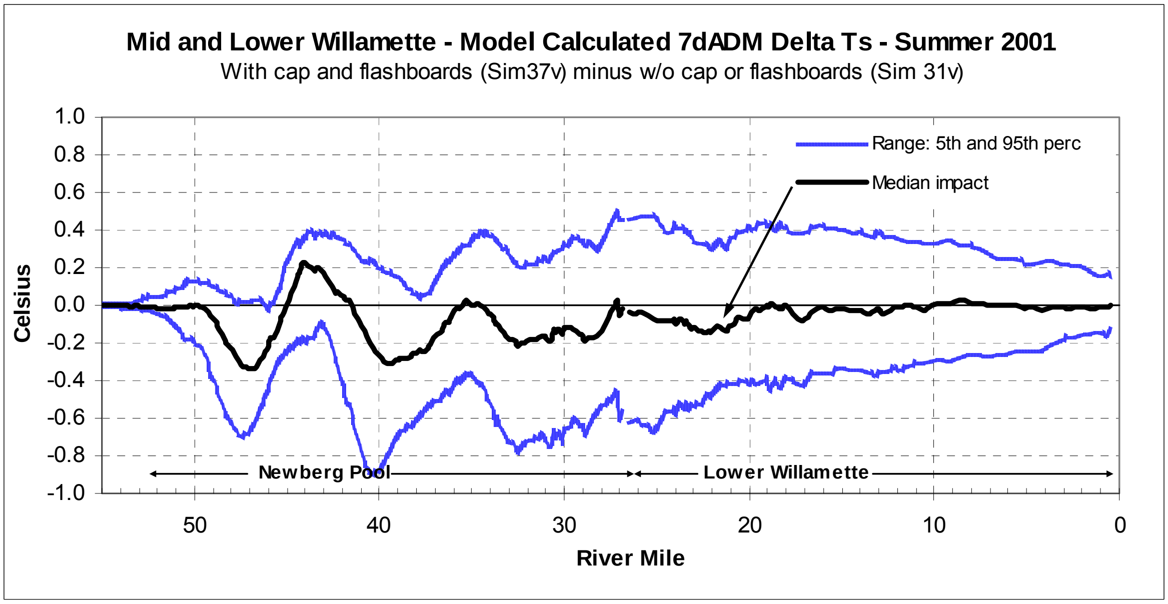
Figure 4.22 **Model calculated average 7DADM temperature with and without Willamette Falls project**



The 7DADM temperatures used for Figure 4.22, and most other ODEQ plots of Middle and Lower Willamette temperatures, are flow-weighted averages for each segment. Flow-weighted averages are calculated by averaging calculated temperatures for all vertical layers, with a weighting provided based on the relative flow of each layer. For example, if a segment consisted of 3 active vertical layers, and 50% of the flow was in the top layer, 30% was in the second layer, and 20% in the bottom layer, the flow-weighted average would be $T = (.5T_1 + .3T_2 + .2T_3)$.

Differences between calculated flow-weighted average 7DADM temperatures with the project vs. without the project are show in Figure 4.23. Shown is the median impact for the summer (June 15 to September 15), as well as well as the range of impacts (5^{th} and 95^{th} percentiles). As shown, at certain times and locations the project results in warmer temperatures, while at other times and locations the project results in cooler temperatures.

Figure 4.23 **Impacts of the Willamette Falls project on NTP Temperatures – June 15 to September 15, 2001**



Impacts of the project range from a 0.6°C 7DADM temperature increase (95^{th} percentile) to a 0.7°C 7DADM temperature reduction (5^{th} percentile). In the Newberg Pool, median temperature impacts range from -0.3 to

0.2°C, while in the lower Willamette median impacts range form -0.2 to 0°C. Overall, summer temperatures appear to be slightly cooler with the project in place than without the project.

The impact of the project over time is shown by Figure 4.24. This shows the impacts of the project on reach average Newberg Pool temperature for April through October, 2002. Simulation outputs for 2002 are shown instead of 2001 because a calibrated model is available for more of the critical stream temperature period in 2002 than 2001. In order to derive the values shown, differences ("delta Ts") between simulated flow-weighted average 7DADM temperatures with and without the project were calculated for all Newberg Pool model segments for all days simulated and then averaged for each day. Also shown on Figure 4.24 is a 30 day trend line.

As shown, the project generally has a neutral impact on Newberg Pool 7DADM temperatures in the spring, and a cooling influence in the summer. By early fall, the trend in Delta Ts turns positive, which suggests that the project may result in generally warmer temperatures in Newberg Pool in the fall.

Figure 4.24 **Seasonal trends in impacts of Willamette Falls Project on Newberg Pool temperatures**

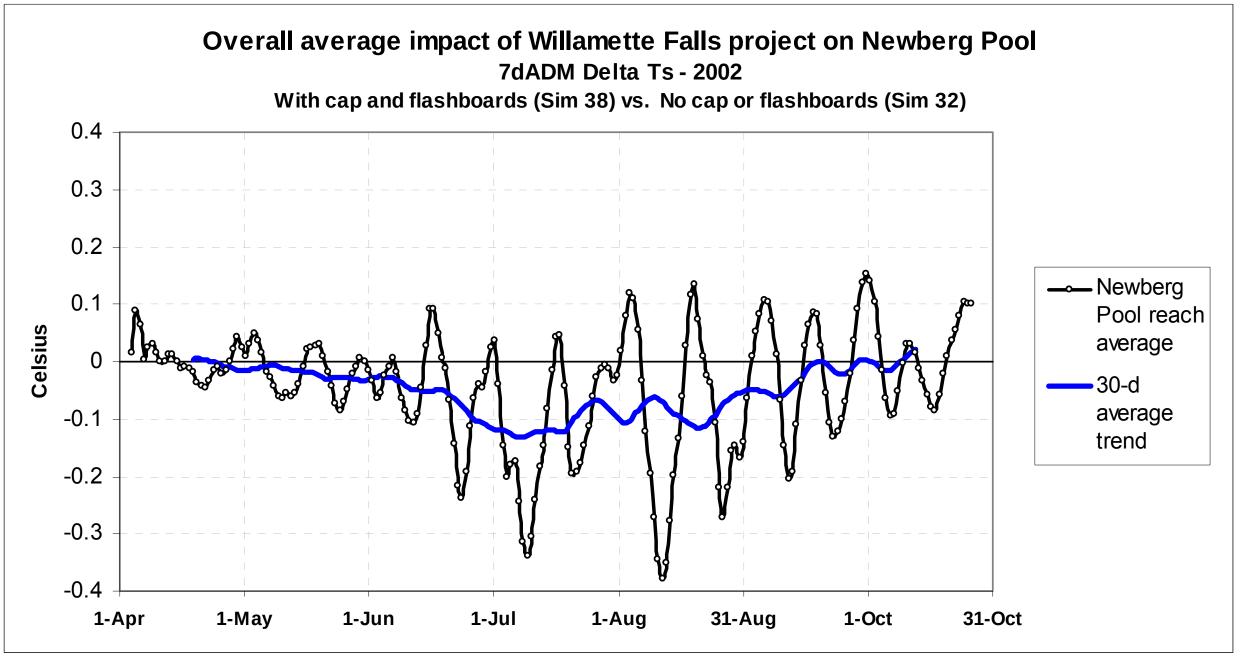
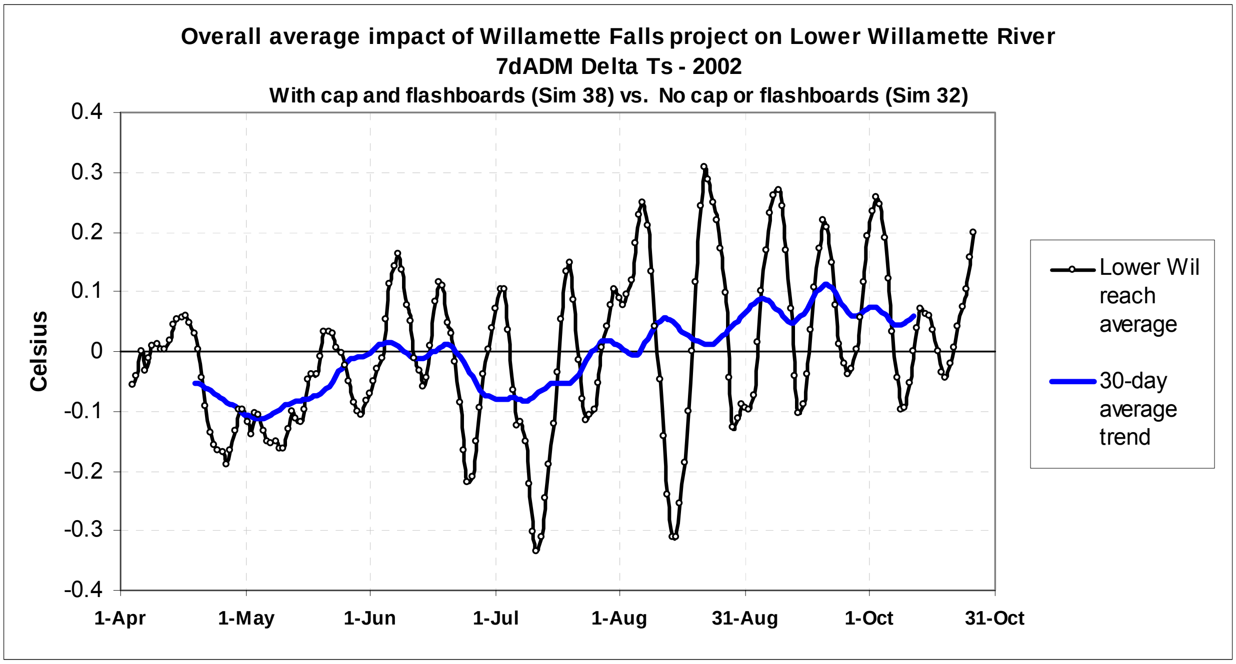


Figure 4.25 shows the impact over time of the project on reach average Lower Willamette River temperatures (Falls to Columbia River confluence, excluding Multnomah Channel). As shown, the project generally results in cooler temperatures in the spring and early summer, and generally warmer temperatures in late summer and fall. The warmer summer temperatures are of concern because the biologically-based numeric criterion of 20°C is frequently exceeded during this time.

Figure 4.25 **Seasonal trends in impacts of Willamette Falls Project on Lower Willamette temperatures**



To evaluate the overall impact of the project on river temperature, cumulative frequency distribution plots were generated of model calculated temperatures with and without the project for both Newberg Pool and the Lower Willamette (see Figures 4.26 and 4.27). For the Lower Willamette, calculated 7DADM temperatures (flow-weighted) in all Lower Willamette segments from the Willamette Falls to the river's confluence with the Columbia (excluding Multnomah Channel) were aggregated. For Newberg Pool, temperatures for all segments from RM 53 to the Falls were aggregated. Model results for 2001 and 2002 were combined and evaluated for the summer period (June 15 to Sept 15), when the 20°C biologically-based numeric criterion often is exceeded. No criterion exceedances were observed in these simulations outside of this period.

As shown, the PGE hydroproject has a slight cooling influence in the Newberg Pool during summer months. The frequency distribution of temperature data for the scenario with the project active deviates about -0.1°C from the distribution for the scenario without the project. This measurement indicates cooler water temperatures. For the Lower Willamette, the distribution of temperature data with the project deviates up to 0.1°C from the distribution without the project; however, when temperatures are above the 20°C criterion, the deviation is no greater than 0.08°C.

Figure 4.26 Cumulative frequency distribution of Newberg Pool temperature with and without project

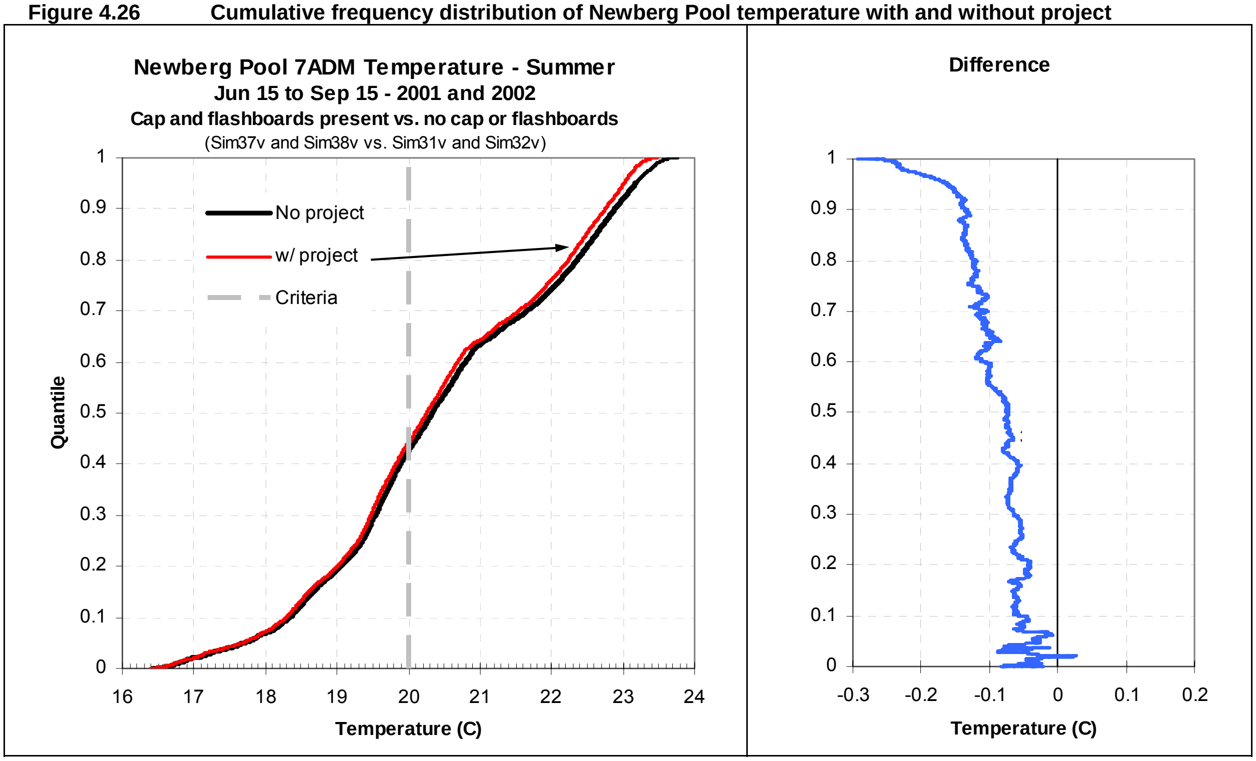
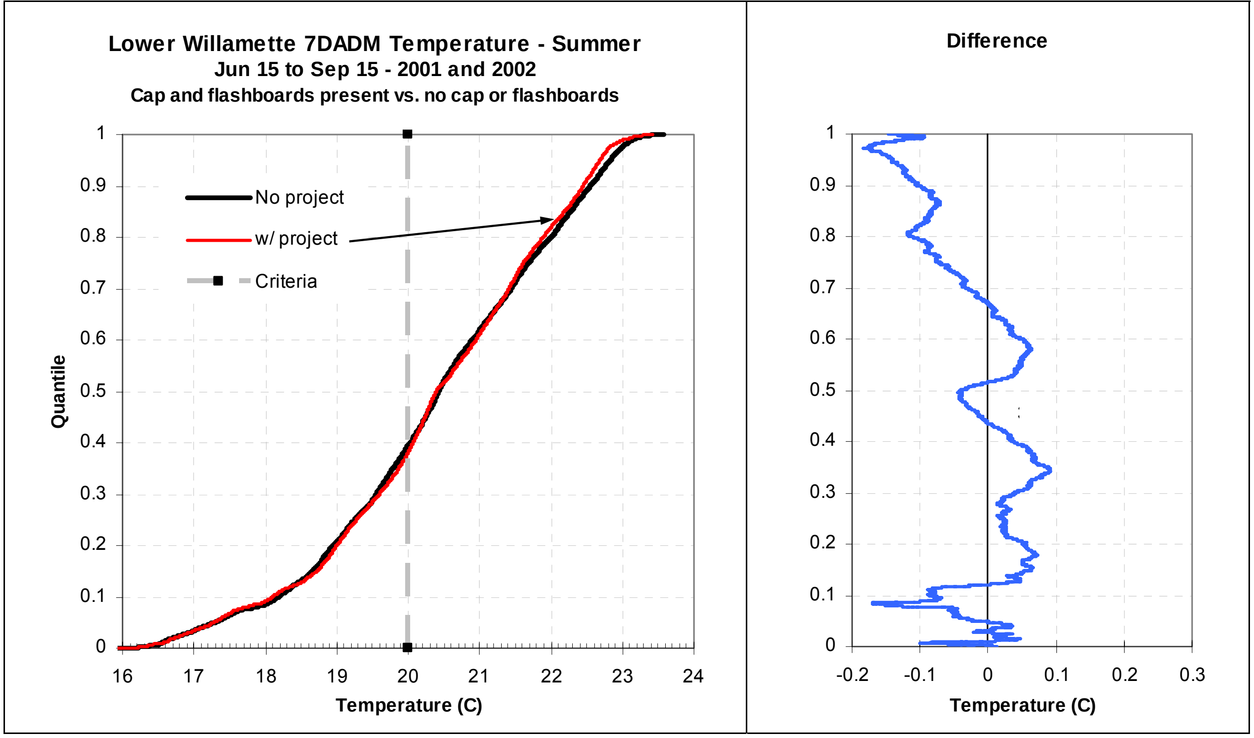


Figure 4.27 Cumulative frequency distribution of Lower Willamette temperature with and without project



In order to address the slightly warmer Lower Willamette summer temperatures, a load allocation has been provided for the project (see Load Allocation section below).

EWEB Leaburg Walterville Projects

The Eugene Water and Electric Board (EWEB) owns and operates the Leaburg and Walterville hydroelectric project on the lower McKenzie River. The Leaburg development diverts flow into a power canal near RM 35.7 and returns the flow to the river at RM 30. The Walterville development diverts flow near RM 25.6 and returns it at RM 17.4. (Note these distances are used in the CE-QUAL-W2 model; corresponding OWRD river mile are 38.9 to 33.2 and 28.3 to 21.0 for the for Leaburg and Walterville developments, respectively).

For the 2001 data collection and calibration period both canals were active while for 2002 the Waterville diversion was shut off for maintenance. Modeling simulations performed for 2001 and 2002 show that the diversions result in temperatures much warmer than NTP in the Leaburg and Walterville “bypass” reaches (natural channel reaches downstream from diversions). In the full-flow reach downstream of the Leaburg bypass reach, project impacts are small. However, in the full-flow reach downstream of the Walterville bypass reach, the project results in significantly warmer temperatures. This is illustrated by Figures 4.28 and 4.29, which show differences between model calculated seven day average daily maximum temperatures with and without-project operations.

Increased water temperatures in bypass reaches are due to reductions in flow in the bypass reaches, which result in reduced heat capacity, lower stream velocities and increased travel time. This allows for greater exposure to solar radiation heat loads and warmer bypass reach temperatures during summer months. On the other hand, water diverted through diversion canals and penstocks to generating facilities is exposed to less solar radiation because flow velocities are greater in diversion canals and penstocks and because penstocks and diversion canals are relatively deep and narrow. The model indicates that this reduction in heating of diverted water is sufficient to negate the heating that occurs in the Leaburg bypass reach and, therefore, temperatures return to normal in the downstream full flow reach.

Model results for the Walterville diversion indicate that cool return flow is not sufficient to negate the impact of the project diversion. Temperatures downstream of the powerhouse and bypass reach are warmer than natural and 0.8°C of heating persists in the McKenzie downstream from the Walterville bypass reach. The effects of this heating diminish downstream through normal loss processes and dilution and EWEB operations only slightly warm McKenzie River temperatures near the confluence with the Willamette.

As shown in Figure 4.28 and 4.29, the median impact of the project on daily maximum temperature exceeds 1°C in the Leaburg bypass reach and 2°C in the Walterville bypass reach. Maximum impacts in the Leaburg and Walterville bypass reaches, based on 95th percentiles, approach 1.5°C and 3.0°C, respectively. Immediately downstream from the Walterville bypass reach the median impact is 0.6°C. This impact gradually declines to less than 0.1°C at the confluence of the McKenzie and Willamette Rivers.

Figure 4.28 **Calculated impact of EWEB projects on McKenzie River for 2001**

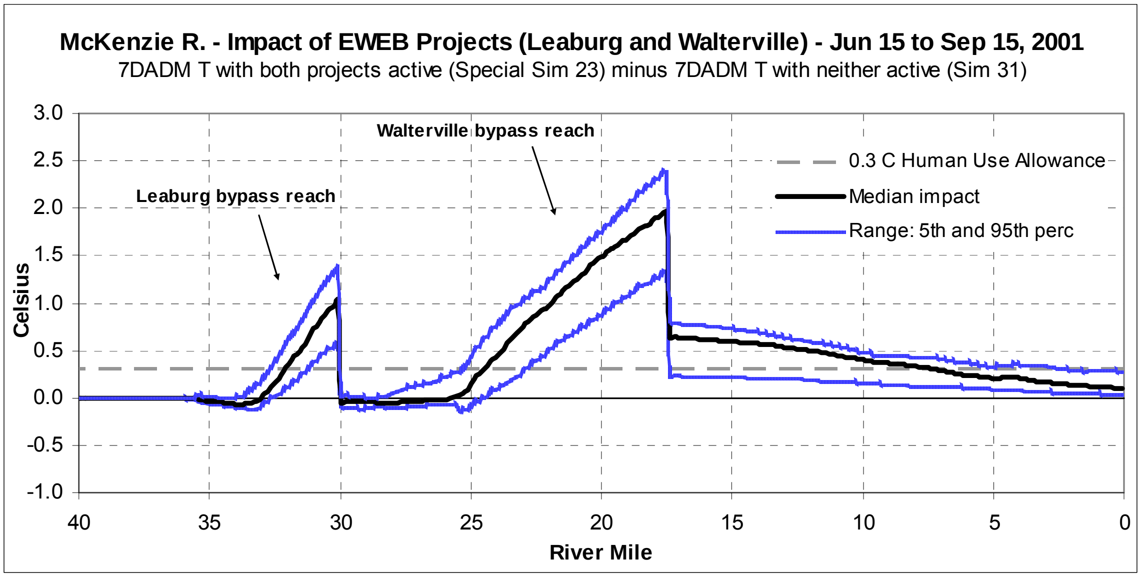
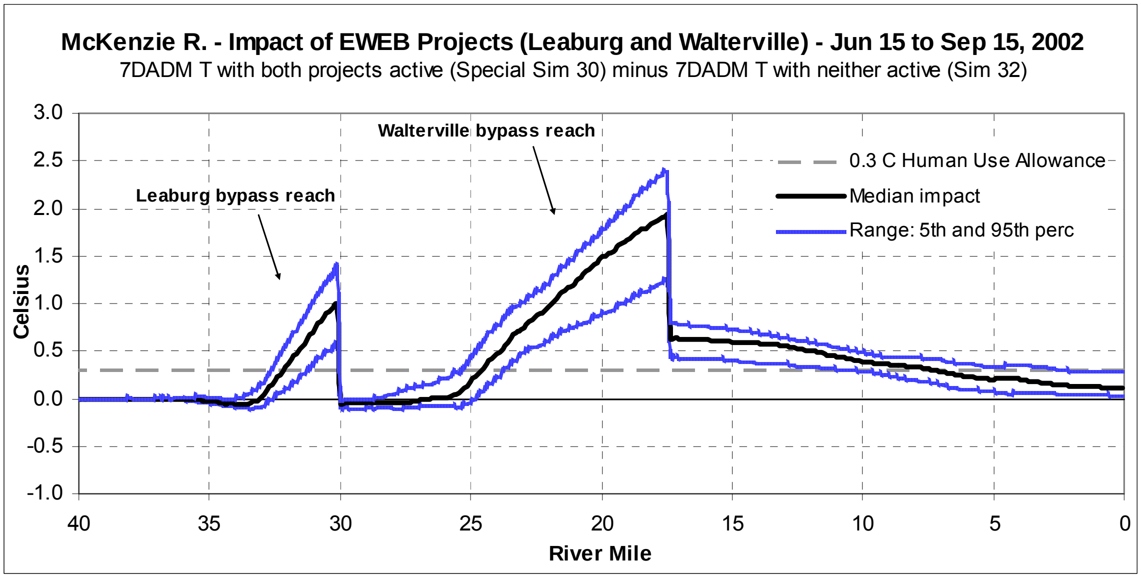


Figure 4.29 **Calculated impact of EWEB projects on McKenzie River for 2002**



Cumulative frequency distributions of calculated 7DADM temperatures in the reach between the Walterville return flow (RM 17.4) and the river mouth (RM 0.0) are presented below for scenarios with and without the two projects (Figures 4.30, 4.31 and 4.32. For the plots, calculated 7DADM temperatures for all segments in the reach of interest are grouped and ranked, with data from 2001 and 2002 simulations combined. Note that data for 2001 were not available prior to June 4. A quantile of 0.95 corresponds to a 7DADM temperature value that is greater than 95% of the observed 7DADM data. The 0.50 quantile is the median 7DADM temperature value.

As shown by Figure 4.30 the EWEB projects cause a positive frequency distribution shift of 0.20°C when temperatures exceed the 13° numeric criterion. Figure 4.31 demonstrates a greater shift of 0.46°C when temperatures exceed the core cold water criterion of 16°C. Figure 4.32 demonstrates impacts exceed 0.2°C when temperatures exceed 13°C during the fall spawning period.

Figure 4.30 Impact of EWEB projects – Cumulative frequency distributions – Spring 2002

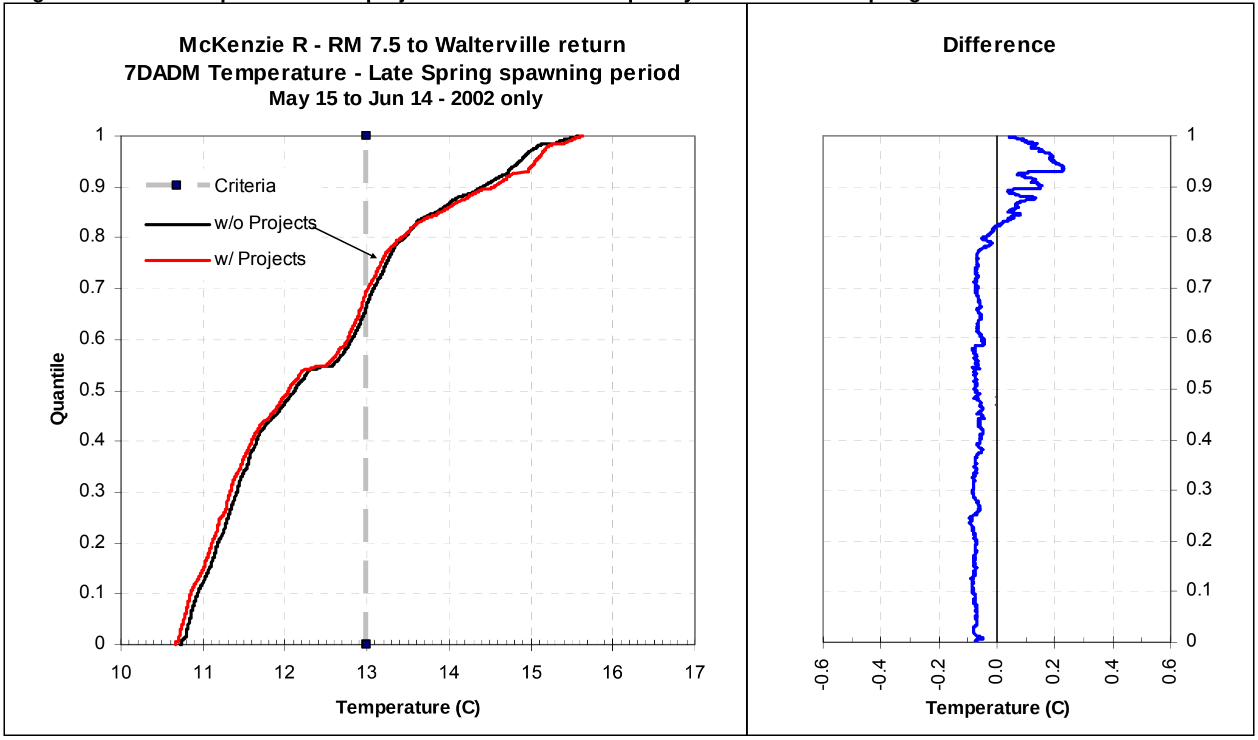
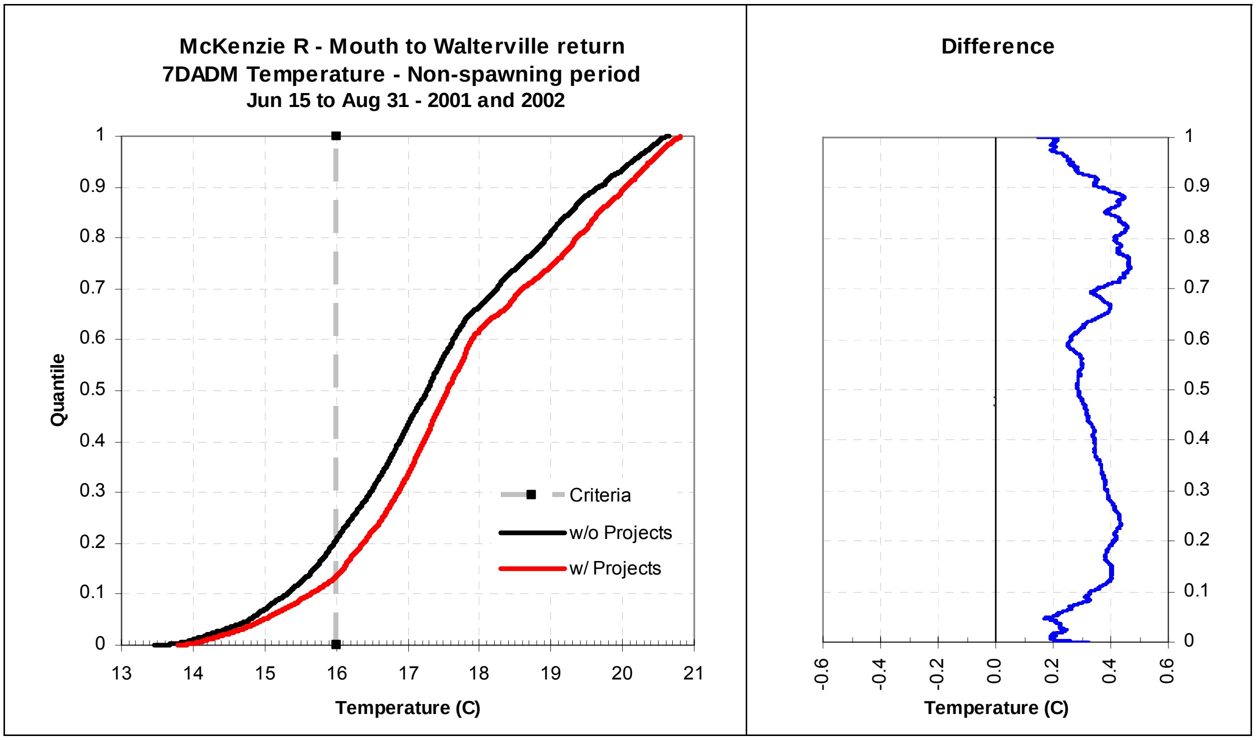


Figure 4.31 Impact of EWEB projects – Cumulative frequency distributions –Summer 2001 and 2002



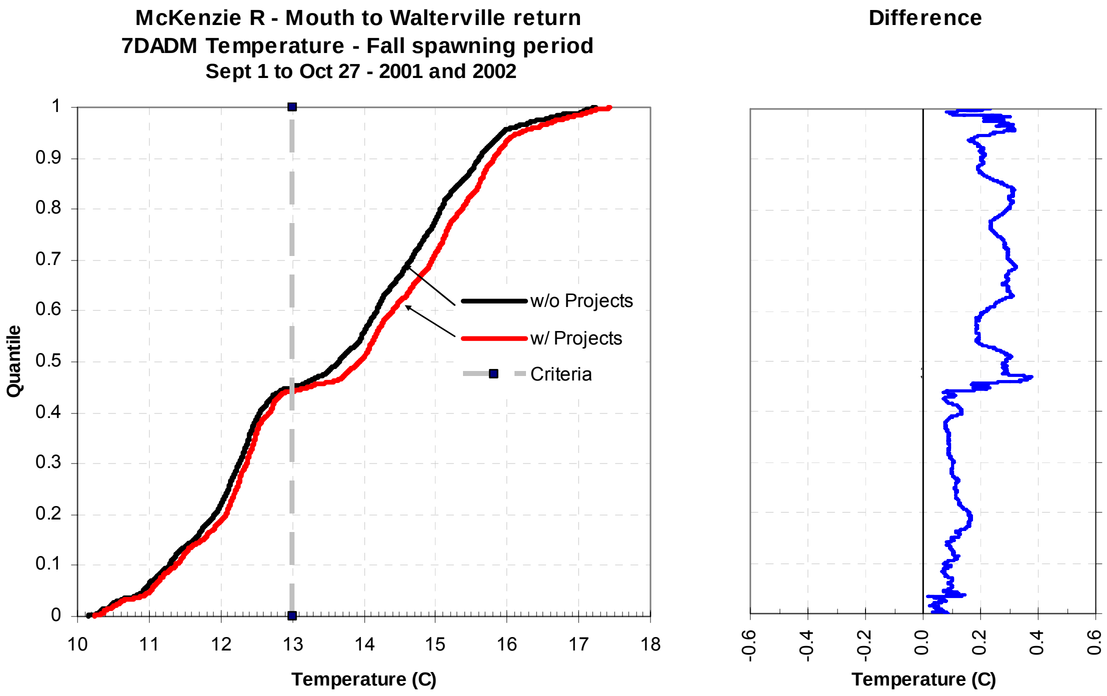


Figure 4.32 **Impact of EWEB projects – Cumulative frequency distributions – Fall 2001 and 2002**

For information on the load allocation for this and other projects, see the load allocation section. For additional information on project impacts, see Appendix 4.6.

Other Human Activities That Contribute to Stream Warming

As discussed in preceding pages, water withdrawals result in a reduction in heat loading capacity and stream velocity and greater exposure to solar radiation in unshaded or partially shaded stream reaches. Thus, as a result of substantial water withdrawals for hydropower, irrigation or municipal water supplies, otherwise acceptable rates of solar radiation may result in greater fluctuation in daily temperatures, higher daily maximum temperatures, and longer periods of temperature criteria exceedances in affected stream reaches.

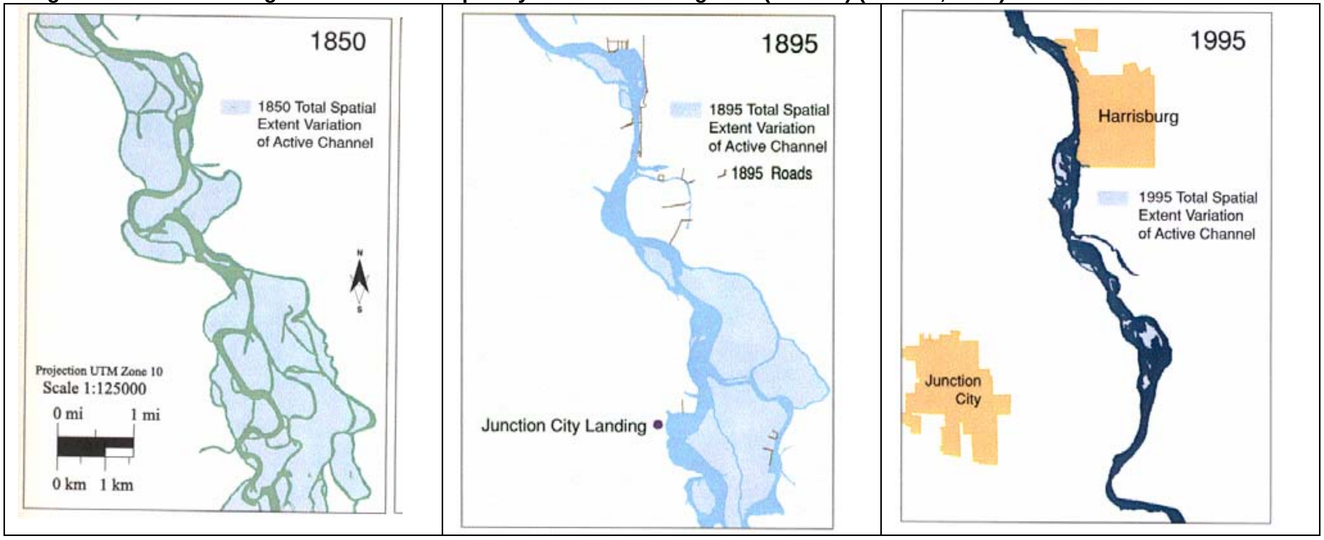
Stream channel simplification for flood control or navigation and watershed development also influences stream temperature. Historically, floodplains have not been treated as an integral part of the stream channel and this has lead to development in areas prone to channel migration and flooding (Kondolf and Keller, 1991). Channelization and bank armoring to protect these areas exacerbates erosion and flooding elsewhere in the basin unless much of the channel is armored (Sear 1994). Bank armoring and the loss of floodplain connectivity diminish over-bank flows that create and maintain channel complexity. Without access to floodplains high streamflows can cause channel down cutting and lower seasonal water tables. Riparian vegetation, off channel habitats and cold water refugia may all be negatively affected by such actions.

Upland and floodplain development also result in high levels of impervious areas in some areas of the basin. Increased impervious area within a watershed results in greater stormwater runoff and diminished groundwater recharge. Summer base flows are lower in small watersheds with substantial impervious area as a result of this loss of groundwater contribution during dry periods. This contributes to warmer stream temperatures and poorer water quality.

In the Willamette Basin, 150 years of river management for flood control and navigation has resulted in a loss of channel complexity, floodplain connectivity and other important stream processes. A consequence of channel simplification is the likely simplification of thermal regimes throughout the basin. Total stream channels in the river declined from 355 miles to 264 miles from the first surveys until 1995 (Gregory, et al, 2002, p.18). The greatest loss of channel complexity was reported in the Upper Willamette Subbasin from Albany to Eugene. Here, nearly half the stream network was lost through channelization and other navigation improvement work. The loss of side channels, alcoves and other off-channel habitats, along with flood plain connectivity and hyporheic exchange likely has diminished water quality in the alluvial reaches of the upper Willamette (Lee and Risley 2002), the availability of cool water refugia, and perhaps even affected mainstem temperatures in the river itself (Landers, et al, 2002, p.27).

An example of channel complexity loss for a reach near Harrisburg (RM 162) is shown in Figure 4.33. As shown, most of the sinuosity and channel complexity that the channel had in 1850 has been lost.

Figure 4.33 Changes in channel complexity in the Harrisburg area (RM 162) (PNERC, 1998)



Narrow side channels or multi-braided channels may be more effectively shaded by vegetation than a single channel and the loss of this channel complexity may contribute to high stream temperatures. In addition, complex channels with floodplain connectivity have significantly greater hyporheic flow than simple channels. Water that flows through gravel remains cool because it is isolated from heating by solar radiation and atmospheric influences. Historic hyporheic connectivity may have been five times as great as current values, which would have resulted in a significantly greater percentage of river water flowing through hyporheic zones than today (PNERC, 2002).

Little specific information is available on historic channel bathymetry and because it is difficult to accurately model hyporheic flow, no attempts have been made to model historic channel complexity using the Willamette models. However, the model utilized, CE-QUAL-W2, can model multiple channels and could be used to analyze the impact that potential side channel remediation projects might have on stream temperature.

Mainstem Willamette Loading Capacity

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

This element specifies the amount of a pollutant or pollutants that a water body can receive and still meet water quality standards. The TMDL will set a level to ensure that the loading capacity is not exceeded.

Loading capacity is the amount of heat a waterbody can receive and still meet water quality standards. Loading capacity can be quantified and allocated as the sum of natural background heat load and allowable heat loads from nonpoint source and point sources sectors. Portions of the loading capacity may also be reserved to accommodate future growth and as an explicit margin of safety. The established loading capacity must ensure that water quality standards are met regardless of seasonal variation and foreseeable increases in pollutant loads from point or nonpoint source activities. The loading capacity of a stream may be calculated as follows:

Loading Capacity = Background Nonpoint Source Load Allocation+ Anthropogenic Nonpoint Source Load Allocation+Point Source Waste Load Allocation+Reserve Capacity Allocation +Margin of Safety

Loading capacity in this TMDL is expressed as a heat load in kilocalories per day; however, in order for the TMDL to be more meaningful to the public and guide implementation efforts, allocations have also been expressed in terms of percent effective shade and/or change in seven day average of daily maximum stream temperature or ΔT (delta T). Thus allocations are expressed as follows:

1) Point source waste load allocations are expressed in kilocalories per day. A kilocalorie of energy increases the temperature of one liter of water by 1ºC.

2) Nonpoint source effective shade targets represent system potential vegetative conditions. These conditions were utilized in the modeling to quantify the level of natural heat loading and in defining the load allocations for the mainstem Willamette River and its tributaries. This is especially useful for nonpoint source activities that affect streamside vegetation and shade levels. Shade targets based on no anthropogenic disturbance identify TMDL objectives more clearly to land managers than change in stream temperature or energy units such as kilocalories.

3) Reservoir load allocations and point source waste load allocations may be expressed in terms of change in temperature or ΔT. This simple way to identify load allocations for most applications is commonly used in this document because it is the measure specified in the human use allowance of the temperature standards. This simply refers to the change in stream temperature associated with an anthropogenic heat source and can be quantified in kilocalories per day as follows:

$$\text{Heat Load} = \text{flow}\left(\frac{\text{m3}}{\text{sec}}\right) \cdot \frac{\text{1000kg}}{\text{m3}} \cdot \frac{\text{86400sec}}{\text{day}} \cdot \frac{\text{1Kcal}}{\text{kg}/1^{\circ}\text{C}} \cdot \Delta T(^{\circ}\text{C})$$

For the purposes of this TMDL and application of temperature criteria elements addressed by it, loading capacity available for human use is based on an allowable 0.3°C temperature increase at the point of maximum impact relative to the applicable seven day temperature criteria. The temperature criteria may either be the biologically-based numeric criteria or the natural conditions criteria based on natural thermal potential temperatures.

Model simulations demonstrate that natural thermal potential stream temperatures for some reaches of the Willamette River and its tributaries exceed biologically-based numeric criteria at times from April through October. When natural thermal potential temperatures exceed the biologically-based criteria the loading capacity of the river from that point and upstream is determined by the human use allowance provisions of the Oregon temperature standards. Thus, the loading capacity is the natural background load (natural thermal potential temperature) plus an anthropogenic heat load equivalent to a temperature increase of 0.30°C. When natural thermal potential temperatures are less than the applicable biologically-based criteria, anthropogenic heat load allocations are based on that numeric criteria. This allocation framework applies throughout the critical period, which for most segments of the Willamette River extends from April through October.

In this TMDL, the human use allowance has been divided up among the point source, nonpoint source and reserve capacity sectors following general principals of allocation developed with the Willamette TMDL council. This allocation framework generally allocated up to two-thirds of the human use allowance to NPDES sources. The remaining third of the HUA was divided equally between nonpoint source activities and reserve capacity. If necessary, the portion of the HUA allocated to point sources could be increased to accommodate existing operations at the expense of other sector allocations. No loading capacity was explicitly set aside as a margin of safety. The allocation framework and the loading capacity available for each sector is shown in Table 4.12.

Table 4.12 Distribution of the human use allowance in the Mainstem Willamette and Tributaries.

	Allowed Temperature Increase
Point Sources plus USACE Willamette Project dams and PGE and EWEB hydroelectric projects	Not greater then 0.20 ^{0}C (All locations except where noted)
	0.23^{0}C at the Willamette River point of maximum impact (Marys River-Santiam River)
	0.25^{0}C on Coast Fork Willamette River below Cottage Grove STP outfall
	0.30°C on the McKenzie River in the EWEB project bypass reaches.
	0.28^{0}C on McKenzie River below Weyerhaeuser Springfield outfall
	0.25^{0}C on the Clackamas River below PGE Clackamas Hydroelectric Project
	0.25^{0}C on the lower Willamette River below Willamette Falls
Nonpoint Source	Not greater then 0.05^{0}C. (All locations except where noted)
	0.035^{0}C at the Willamette River point of maximum impact (Marys River-Santiam River)
	0.025^{0}C on lower Coast Fork Willamette and lower McKenzie Rivers
	0.025^{0}C on the Clackamas River below PGE Clackamas Hydroelectric Project
	0. 025^{0} on the lower Willamette River below Willamette Falls
Margin of Safety	implicit based on conservative assumptions
Reserve Capacity	0.05^{0}C (All locations except where noted)
	0.01°C on McKenzie River below Weyerhaeuser Springfield outfall
	0.035^{0}C at the Willamette River point of maximum impact (Mary's River-Santiam River)
	0.025^{0}C on lower Coast Fork Willamette and lower McKenzie Rivers
	0.025^{0}C on the Clackamas River below PGE Clackamas Hydroelectric Project
	0.025 on the lower Willamette River below Willamette Falls

The Three Basin Rule (OAR 340-41-0350) places important limitations on the allocation of additional heat to new and existing point sources in the Clackamas, Santiam, and McKenzie Subbasins. In order to preserve or improve high quality water for municipal water supplies and other uses, new or increased waste discharges are prohibited in the Clackamas River, North Santiam River, and McKenzie River above Hayden Bridge (river mile 15). However, section six of the rule does provide some exceptions for point sources of warm water regulated by general permits. These include non-contact cooling water, filter backwash and boiler blowdown. Section six also enables ODEQ to issue 401 certifications with specific conditions identified in the certification.

Mainstem Willamette Excess Load

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

This element evaluates the difference between current pollutant load in a waterbody and the loading capacity of the waterbody.

Excess load refers to the point and nonpoint source heat load in excess of the load in compliance with temperature standard (see Table 4.13). Heat load may be calculated as follows:

$$\text{Heat Load (kcal/day)} = \Delta\text{T} \cdot \text{Q}_{\text{River}} \cdot C_F$$

$$\text{where:}$$

$$\Delta\text{T} = \text{river temperature increase, } {}^oC$$

$$\text{Q}_{\text{River}} = \text{River flow rate, } m^3/s$$

$$\text{C}_{\text{F}} = \text{Conversion factor, } 86.4x10^6 \ \frac{kcal \cdot s}{{}^oC \cdot m^3 \cdot day}$$

Heat loads during the summer in the Willamette River due to anthropogenic solar radiation loads can be calculated using Figure 4.14 (anthropogenic solar radiation loads are loads in excess of those which would occur if vegetation were at system potential levels). The figure shows differences between seven day average daily maximum (7DADM) temperatures for current conditions and 7DADM temperatures for conditions with riparian vegetation increased to system potential levels.

The current heat load during the summer in the Willamette River due to point source heat loads can be calculated using Figures 4.7 and 4.9. These figures show differences between 7DADM temperatures for current conditions and 7DADM temperatures for conditions with point source discharges eliminated.

Using the median impacts of anthropogenic solar radiation loads and point source heat loads for June 15 to September 15, 2001 and the median river flow rates for the period, excess heat load may be calculated for various locations in the river. Impacts on ΔT at several locations in the river due to anthropogenic solar radiation loads and point source loads are shown in Table 4.13.

Table 4.13 Excess load for the mainstem Willamette River

River Mile	Location	Median River Flow Rate Jun15 to Sep15	Anthropogenic Solar Radiation Delta T via Fig 4.14	Cumulative Point Source Delta T via Figs 4.7 and 4.9	Combined Heat Anthropogenic Delta T
(mile)		(m3/s)	(^{o}C)	(^{o}C)	(^{o}C)
178.0	Eugene	48.1	0.41	0.07	0.48
131.0	Corvallis	106.9	0.68	0.09	0.77
108.5	u/s Santiam R	115.5	0.55	0.095	0.645

These impacts in terms of excess heat loads are as follows:

River Mile	Anthropogenic Solar Radiation Heat Load	Cumulative Point Source Heat Load	Combined Anthropogenic Heat Load	Allowable Anthropogenic Heat Load	Excess Heat Load
(mile)	(billion kcal/day)	(billion kcal/day)	(billion kcal/day)	(billion kcal/day)	(billion kcal/day)
178.0	1.70	0.29	1.99	1.25	0.74
131.0	6.28	0.83	7.11	2.77	4.34
108.5	5.49	0.95	6.44	2.99	3.35

Since Oregon standards provide for a human use allowance of 0.3^{o}C, a portion of the heat load is allowable (column 5 above). The excess heat load is the difference between the current combined anthropogenic heat load and the allowable load based on 0.3^{o}C (column 6 above). As shown, current heat loads at these locations are from 1.6 to 2.6 times allowable loads.

The portions of the current anthropogenic heat load attributable to nonpoint sources (excess solar radiation) and point sources are shown in Table 4.13.

Table 4.14 Percent median excess load from nonpoint and point sources.

River Mile	Location	% Nonpoint	% Point
178.0	Eugene	85%	15%
131.0	Corvallis	88%	12%
108.5	u/s Santiam R	85%	15%
	Average:	86%	14%

As shown, via these three locations during the summer, about 86% of the heat load is due to nonpoint sources and 14% is due to point sources.

Note that this analysis ignores heat load impacts due to USACE reservoirs and PGE and EWEB hydroelectric projects. Impacts of USACE reservoirs are complicated. Not only do they influence boundary condition temperatures, but they also influence river flow rates. Limited data suggests that USACE reservoirs increase river temperatures in the Willamette River by a relatively small amount during the summer, with impacts possibly ameliorated by increased flow rates provided by the projects during the summer. Impacts of PGE and EWEB projects on the Willamette River also appear to be relatively small during the summer (although impacts on the Clackamas and McKenzie Rivers can be quite large).

During the fall, impacts of USACE reservoirs are much larger. It's quite possible that much of the excess heat load during the fall is due to USACE reservoirs, particularly in tributaries and upper Willamette River reaches.

Mainstem Willamette Waste Load Allocations

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

This element determines the portions of the receiving water's loading capacity that are allocated to existing point sources of pollution, including all point source discharges regulated under the federal Water Pollution Control Act Section 402 (33 USC Section 1342).

Current point source heat loads result in an increase of natural thermal potential river temperatures of slightly more than 0.15°C at the point of greatest cumulative impact near Albany at river mile 115 (Figure 4.7). As shown this increase represents the 95th percentile of all seven day average maximum observations during the critical period. Median effects of point source discharges on temperatures are approximately 0.1°C in the Upper Willamette. Also shown is that point source impacts have a smaller impact on summer river temperatures in the middle and lower reaches of the Willamette downstream of the Santiam River. The Santiam and other tributaries provide substantial flow and additional loading capacity to the mainstem Willamette. The 95th percentile of point source effects on water temperature below river mile 109 is about 0.10°C.

Although the increase in NTP temperatures resulting from current point source heat loads are well within the amount of warming allowed by the human use allowance, simulations demonstrated that if point source loads were allowed to discharge up to current permit design flows they would warm the river during critical periods and at some locations more than 0.3°C. This would consume all of the human use allowance and also result in temperature standards violations. Thus it is necessary to establish new limits for point source heat loads by assigning waste load allocations during the critical periods of the year when ambient or natural thermal potential temperatures exceed biologically-based criteria.

Upstream of river mile 50, waste load allocations apply during the critical period of April through October. Point sources in this part of the basin have been assigned waste load allocations that are specific to loading capacity available during each applicable fish use period, in other words separate allocations are provided for the salmonid rearing period when the biological criteria are 16°C or 18°C and the spawning period when the criterion is 13°C. This critical time period also generally applies to NPDES sources that discharge to tributaries of the Lower and Middle Willamette. Downstream of river mile 50, from about the Yamhill River and the City of Newberg downstream to the Columbia River, spawning and rearing are not designated uses and the less stringent 20°C numeric criterion applies. The critical period for this reach is from June through September when river temperatures are often warmer than the biologically-based numeric criterion for salmonid migration.

With guidance from the Willamette TMDL Council ODEQ decided that point source waste load allocations may, in general, create no more than a 0.2°C temperature increase above the applicable criteria. This allocation represents two-thirds of the of the human use allowance and applies at the point of discharge where an individual source has its maximum impact on river temperature as well as downstream where cumulative impacts of multiple sources are greatest. The council also recommended that an additional increment of the HUA – up to 0.23 – be allowed if necessary for existing discharges. In addition, the TMDL council recognized that demands on municipal sources would grow in step with population growth and recommended that, when possible, growth in point source loads be weighted in favor of municipal sources over industrial sources. As will be discussed, this weighting factor is evident in the wasteload allocations for the upper river sources.

Individual waste load allocations were quantified in this document for point sources that contribute significant heat loads to the Willamette River system. As an initial rule of thumb, sources that potentially warm the river 0.01°C or more at critical low flow conditions were included in this data set. Several other municipal and industrial sources that did not meet this criterion were also assigned waste load allocations because effluent data were available and these sources were originally included in the calibrated model.

Individual waste load allocations are flow-based heat load allocations. These allocations are based on attainment of the point source sector portion of the human use allowance (generally a change in river temperature of 0.2°C or less) at river flows equal to or greater than 7Q10.

Small point sources of heat were not included in TMDL modeling. However, to address concerns of the cumulative effects of these small sources and to ensure that they were accounted for within the HUA, a sector-specific or “bubble” waste load allocation was assigned to the three mainstem river reaches: the Willamette and its tributaries upstream of the Santiam (RM 109), the Willamette downstream of the Santiam River to river mile 50, and the lower 50 river miles. These small source bubble allocations are treated as a portion of the point source sector heat load and will be divided among all individual and general NPDES point sources that discharge heated wastewater into each respective river reach. The small source bubble allocation is described in more detail later in this chapter.

The lack of an explicit waste load allocation in this TMDL should not be interpreted as an allocation of no heat (0 kcal/day) to all other point sources in the basin. Facilities with a valid permit are included in this “bubble allocation”, and may continue to discharge their current heat load without affecting attainment of temperature standards. Upon issuance of the TMDL as an order, NPDES permit holders that are included in the bubble allocations may be notified of the requirement to gather data to support refinement of the allocation.

Waste load allocations were not assigned to storm water sources such as municipal separate storm sewer systems (MS4s) and combined sewer overflows because they have been determined not to be significant contributors to heat over a seven day period as specified in the temperature standard.

Weyerhaeuser Albany’s Outfall 002 is a permitted subsurface discharge of waste water near the Willamette River mainstem. ODEQ believes that the thermal impact from Outfall 002 is negligible in the context of the TMDL allocations. However if analysis by the department and the permittee during the NPDES permitting process indicates that the impact is not negligible, an allocation may be assigned to this outfall from the reserve capacity (refer to Temperature TMDL Implementation section of WQMP – Chapter 14). Any increase in thermal load through Outfall 002 must be approved by the department via modification to the facility’s NPDES permit coincident with a compensating decrease in thermal load from Outfall 001.

It is the intent of this TMDL that all Willamette Basin point sources are in full compliance with Oregon temperature criteria and that the cumulative heat loads of all point sources do not exceed the portion of the human use allowance allocated to them. NPDES permits for point sources need not only meet the TMDL wasteload allocations, but must also meet the temperature thermal plume limitations [340-041-00532(d)(A-D)]. These limitations prevent or minimize the adverse effects to salmonids inside the mixing zone, such as impairment to an active salmonid spawning area, acute impairment or instantaneous lethality, thermal shock, and migration blockage. Thermal plume limitations apply throughout the year, including critical periods addressed by the TMDL as well as the other months of the year when stream temperatures are generally well below biologically-based numeric criteria. When point sources cannot meet their waste load allocation at the time of NPDES permit renewal, a compliance schedule may be included within the permit. Compliance schedules developed under provisions of state and federal water quality standards require compliance as soon as reasonably possible, and generally within a 5-year permit cycle.

Individual Source Waste Load Allocations

Loading capacity of the Willamette River increases substantially below the confluence of the Santiam River and different waste load allocation strategies were developed to reflect this. Upstream of the Santiam River (RM 109), reductions in maximum observed effluent loads were necessary to ensure compliance with the human use allowance at 7Q10 low flow conditions. Downstream of the Santiam River, no reductions in maximum observed effluent loads were necessary. However, it was necessary to assign waste load allocations (WLAs) to limit future heat loads below river mile 109 because the cumulative effect of discharges at their current design flows would exceed the HUA. All individual WLAs are flow-based and allow for substantial growth in heat loads above low flow levels as receiving streamflow rates and heat loading capacities increase. WLAs presented in this chapter apply April through October except in the mainstem Willamette migration corridor which applies June through September. These time periods are based on when river temperatures are typically above the biological criteria. Development of WLAs is explained briefly in this section and in more detail in Appendix 4.5. WLAs for all other sources that discharge to Willamette Basin streams and that are not included in the mainstem TMDL are described in subbasin TMDLs (Chapters 5-13).

Point sources upstream of the Santiam River, including point sources on the McKenzie River and the Coast Fork Willamette River, were separated into municipal and industrial groups and separate WLA approaches were developed for each group. This development of separate WLAs for these groups followed recommendations of the Willamette TMDL Council allocating 70% load to municipal sources and 30% to industrial sources. Two WLAs were assigned to each point source: one applicable during the salmonid rearing and migration use period, and another for the spawning use period where applicable. Both WLAs demonstrate attainment of the human use allowance at 7Q10 low flows.

Individual WLAs upstream of the Santiam River are generally reduced relative to the maximum observed heat loads for a given facility. WLAs for these municipal wastewater treatment plants require reductions in maximum observed heat loads of six percent during the rearing and migration period, and 22 percent during the salmonid spawning period. WLAs for industrial sources upstream from the Santiam River require reductions in maximum observed heat loads of 15 percent during the salmonid rearing period and 51 percent during the salmonid spawning period.

Some sources received WLAs reflecting greater reductions relative to their maximum observed heat load. Current heat loads from the Weyerhaeuser Mill at Springfield and the Cottage Grove municipal wastewater treatment plan are constrained because of temperature impacts at their outfall locations. Allowances were made to the extent possible to accommodate existing loads following recommendations of the TMDL council, but limitations were necessary to address these impacts at the point of discharge. Heat load allocations for the MWMC facility in Eugene are also lower than allowed other municipal dischargers upstream of the Santiam because of the disproportionate impact this municipal treatment plant has on cumulative heat loads at the point of maximum impact near Albany. Without these additional reductions, all facilities downstream would have been severely limited by their WLAs.

Waste load allocations for sources downstream of the Santiam River (RM 109) and upstream of the Yamhill River (RM 50) ensure that point source heat loads meet the sector allocation of the human use allowance during low river flows. Throughout the critical period of April through October, WLAs limit heat loads to current maximum observed levels during 7Q10 flows. Higher heat loads are allowable when river flows are greater than 5630 cubic feet per second.

Downstream of river mile 50, WLAs limit heat loads to the current maximum observed levels. WLAs are necessary only during the June through September period because the salmon migration corridor use is the only fish use designation in this area (spawning is not a designated use). Water temperatures through the Newberg Pool and lower river currently meet the 20°C biologically-based numeric criterion for this use in all other months. The Clackamas River WLA found in the chapter are set to not to exceed an increase above 0.03°C

Waste load allocations for the municipal sources that discharge to the Santiam River are set at current design flow limits. Individual WLA developed in this TMDL for all sources other than those to the Santiam, which are already at maximum limits, allow sources to increase their heat load during periods when river flows are greater than 7Q10. These flow-based WLAs allow sources to utilize the greater loading capacity that accompanies an increase in river flow. Scaling factors were developed through a series of simulations to determine the rate of heat load increase up to the design flow for each municipal and industrial source with an individual WLA. Scaling factors were developed for municipal and industrial sources above and below the Santiam River and for each applicable salmonid use period (spawning, rearing, and migration). Scaling factors are described further in Appendix 4.5.

Table 4.15 Individual waste load allocations for low streamflow conditions.

Receiving Stream	River Mile	Point Source	Summer 7Q10 WLA (Million Kcal/day)	Spawning 7Q10 WLA (Million Kcal/day)
Clackamas River	22.6	ODFW Clackamas River Hatchery	51	49
Coast Fork Willamette River	21.5	Cottage Grove WWTP	11	21
McKenzie River	1.0	Weyerhaeuser Springfield	1071	744
North Santiam River	14.9	Stayton WWTP	57	89
Santiam River	9.3	Jefferson WWTP	7	12
South Santiam River	15.9	Lebanon WWTP	65	111
South Santiam River	31.5	Sweet Home WWTP	31	55
Willamette River	0 - 50	Small Point Sources	193	N/A
Willamette River	6.3	Siltronics	22	N/A
Willamette River	18.7	Kellogg Creek WWTP	105	N/A
Willamette River	20.1	Oak Lodge WWTP	42	N/A
Willamette River	20.2	Tryon Creek WWTP	52	N/A
Willamette River	25.5	Tri-City WWTP	156	N/A
Willamette River	27.5	Blue Heron Paper	485	N/A
Willamette River	27.7	West Linn Paper	197	N/A
Willamette River	39.0	Wilsonville WWTP	39	N/A
Willamette River	49.7	Newberg WWTP	44	N/A
Willamette River	49.8	SP Newsprint	546	N/A
Willamette River	50 - 108	Small Point Sources	95	216
Willamette River	78.1	Willow Lake (Salem) WWTP	714	1372
Willamette River	108 - 186	Small Point Sources	93	56
Willamette River	116.5	Teledyne Wah Chang	111	93
Willamette River	116.5	Weyerhaeuser Albany	332	271
Willamette River	119.0	Albany WWTP	111	173
Willamette River	130.8	Corvallis WWTP	127	213
Willamette River	132.2	Evanite	15	14
Willamette River	148.3	Pope & Talbot	395	337
Willamette River	148.4	Fort James Halsey	155	126
Willamette River	178.0	MWMC	398	428
Willamette River	181.7	University Of Oregon Heat Plant	200	210

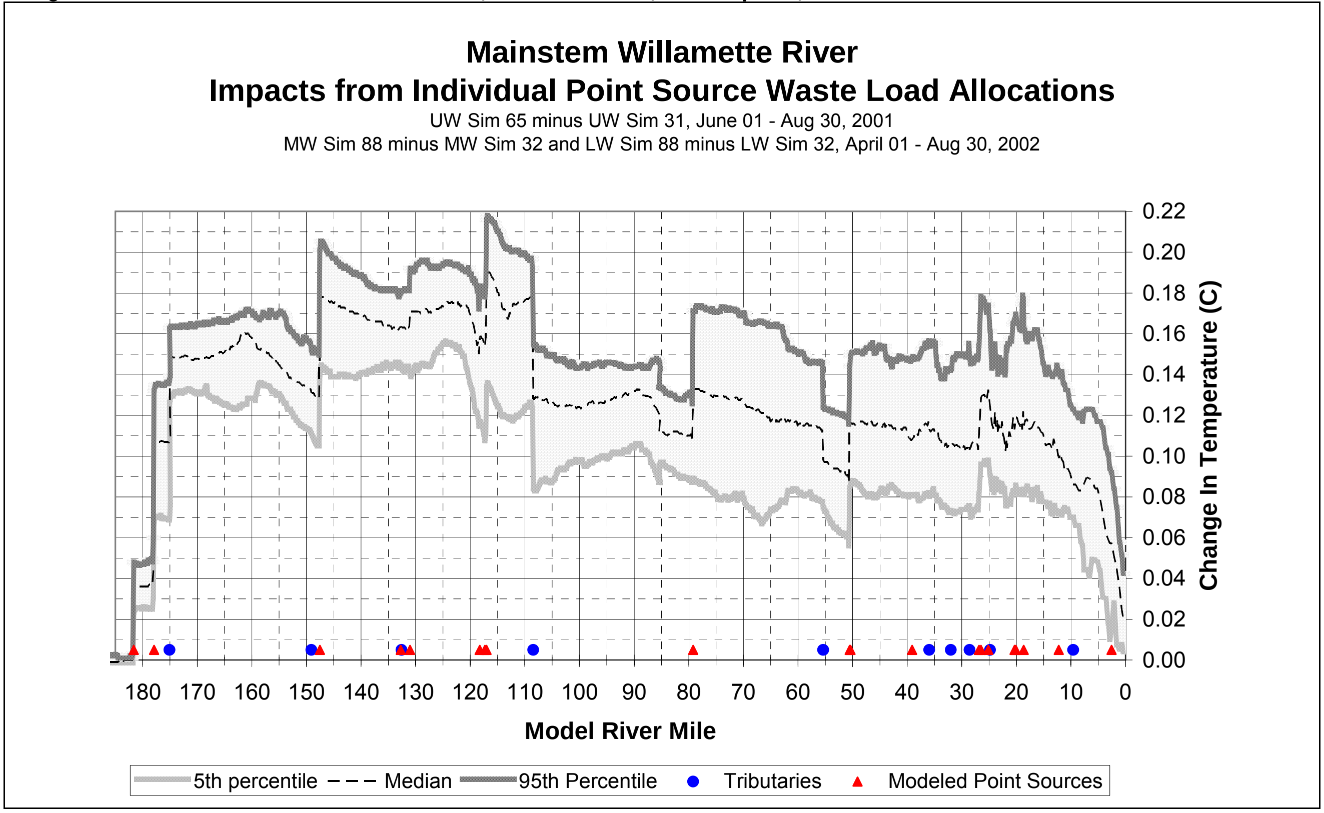
Flow-based allocations allow NPDES permitted sources the potential to utilize the greater loading capacity that is available during periods of higher flow. However, this approach requires that additional ambient flow and temperature data be collected and calculated using equations described in Appendix 4.5. Three alternative methods for implementing the WLA are available to sources. One option is to simply demonstrate compliance with a single 7Q10 allocation at all times during the critical period. Table 4.15 presents WLAs at 7Q10. The second option involves pre-calculated allocations based on river-flow benchmarks that will eliminate the need to gather ambient temperature data, but will require receiving streamflow data to demonstrate compliance. The existing USGS streamflow gauging network is sufficient to meet this need. The third option requires the collection of continuous ambient temperature data and receiving streamflow data to demonstrate compliance. This option allows the highest possible allocation.

Figure 4.34 below illustrates the effects that flow-based WLAs have on natural thermal potential temperatures in the mainstem Willamette River for the periods evaluated in 2001 and 2002, based on modeling using the CE-QUAL-W2 model. Values shown represent the upper 95th percentile, median, and lower 5th percentile temperature change (ΔT) for each model segment throughout the critical period and identifies where points of greatest stream temperature increase are located. Upper 95th percentile values rather than maximum temperature change are used in part to offset the series of conservative assumptions included in the cumulative effects analysis and so that allocations are not driven by extremely rare and unlikely occurrences. The 95th percentile values in the plots represent the upper range of change in natural thermal potential temperatures if all point sources above a point of interest discharge at maximum allocated heat loads.

The point of maximum cumulative WLA impact occurs near Albany (river mile 119), where median and 95th percentile impacts are 0.18°C and 0.22°C, respectively (Figure 4.34). A drop in cumulative impacts occurs at the confluence of the Santiam River (river mile 109).

Downstream of the Santiam River (RM 109), discrete increases in median and 95th percentile impacts are observed near Salem and Newberg area sources (RM 79 and RM 50). An increase in WLA effects is also observed immediately downstream of Willamette Falls (RM 26) near the outfall of two paper mills, but impacts decline rapidly in the lower river due to dilution by the intrusion of Columbia River water.

Figure 4.34 Mainstem Willamette River, final calibration, WLA impacts, 2001 and 2002



Impacts to other mainstem tributaries from individual point source waste load allocations can be found in Appendix 4.7.

Bubble Allocations for Small Point Sources

Many small point sources that discharge heat into the Willamette River system individually have an effect on the overall temperature of the river. The cumulative effects of these sources on mainstem temperature are also very small; but, because our knowledge of these sources is incomplete, small portions of the human use allowance are allocated as aggregate loads to small point sources. These WLAs represent a small portion of the total point source allocation at the point of maximum impact in each of the upper river, middle river, and lower river and together account for approximately 0.01°C of the 0.30°C HUA.

The small point source bubble allocations represent heat loads from a dynamic set of individual and general NPDES sources. The number of sources, their locations and heat load characteristics will change as new sources are permitted, old sources discontinue operations, or waste treatment processes change. It is the intent of this WLA to address all point sources that are operating or have applied to operate under a NPDES general permit. The small point source sector allocation was based on a conservative treatment of point source data. Impacts were estimated by using available data where possible, or by assuming an average flow of 0.5 MGD and effluent temperatures of 22°C. Effluent temperatures from a number of the non-contact cooling sources included in sector allocation are substantially warmer than 22°C, but their effluent flow rates are generally very low. Some sources do not discharge throughout the critical period but were tallied in these initial WLAs. Finally, WLAs apply at the point of maximum impact of all point source loads (for example river mile 115 near Albany) when in fact sources are distributed throughout each reach. Heat loss from river of these small source loads was not factored into the WLAs.

ODEQ will not assign individual effluent limits to each source within the small point source bubble allocation. Instead ODEQ will track the number of small sources within each river reach and estimate cumulative heat loads based on discharge monitoring reports or other effluent characterization approaches. To assist with this effort, some small sources, such as municipal treatment plants, may be required to collect additional effluent temperature data following issuance of the TMDL. However effluent monitoring is not required of most general permit sources and heat loads for each category such as non-contact cooling water, are assumed. Available reserve capacity will be drawn upon as the small source heat load approaches the bubble allocation limit. Table 4.16 details the location of each sector allocation, the number of permitted sources that discharge into the reach, and the allocation.

Table 4.16

Reach (Upstream RM)	Number of NPDES Sources	Rearing/Migration Period Sector Allocation (Million Kcals/Day)
Upper Willamette (RM 187-109)	18	93
Middle Willamette (RM 109-50)	10	95
Middle and Lower Willamette (RM 50- 0)	31	193

New Point Sources or Increased loads from Existing Sources
Additional point source heat loads may be allowed if there is adequate loading capacity in the river. New point sources and current point sources that seek to increase their waste load allocations will be required to follow policies and guidelines of Oregon antidegradation policies (OAR 340-41-0004). Key provisions are the growth policy (340-41-0004(2)), that requires growth and development be accommodated by increased efficiency and effectiveness rather than additional pollutant loads, and the non-degradation discharge policy for temperature (340-41-0004(3) (c)), that states insignificant temperature increases authorized under 340-41-0028(11) and (12) are not considered a reduction in water quality. Importantly, discharges that fall within the human use allowance are defined as insignificant (340-41-0028(12) (b)). New sources may be granted WLAs from reserve capacity as described in the Water Quality Management Plan for this TMDL (see Temperature TMDL Implementation section – WQMP). To the extent possible, ODEQ supports the use of water quality trading as a means to accommodate new or expanded sources.

Mainstem Willamette Load Allocations

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

This element determines the portion of the receiving water's loading capacity that is allocated to existing nonpoint sources of pollution or to background sources. Load allocations are best estimate of loading, and may range from reasonably accurate estimates to gross allotments depending on the availability of data and appropriate techniques for predicting loading. Whenever reasonably feasible, natural background and anthropogenic nonpoint source loads will be distinguished from each other.

Mainstem heat load allocations were developed with considerable input from the TMDL advisory council. The human use allowance language allows allocation to this sector and as a result, load allocations for anthropogenic nonpoint sources are provided in this TMDL. These allocations are much smaller than current heat loads and substantial reductions in nonpoint source loads are required.

Background Load Allocations

Background load allocation includes the amount of heat delivered to the stream system by solar radiation. This load was calculated with model simulations that included effective shade levels produced by system potential vegetation. Effective shade determines the amount of solar radiation that reaches the surface of the stream and higher levels of effective shade correspond to lower levels of solar energy inputs. Recall that system potential vegetation includes native plant communities which can grow and reproduce at a location given environmental constraints such as soil characteristics and local climate. Natural disturbances are reflected in the development of system potential shade targets and background heat loads, but resource management considerations such as the removal of trees and other human disturbances that may diminish effective shade levels are not.

Anthropogenic Nonpoint Source Load Allocations

Model simulations demonstrate that tributary and mainstem Willamette River NTP temperatures are at times well above the biologically-based numeric criteria for salmon and steelhead trout. Load allocations for nonpoint source heat must be within the provisions of the human use allowance during these periods. Model simulations show that improving shade from current conditions to system potential levels will result in cooler water temperatures in tributary reaches. Furthermore, modeling demonstrates the connectivity of the Willamette system and indicates that cooler temperatures in large tributaries such as the McKenzie and Santiam Rivers benefit downstream temperatures in the Willamette River itself. Thus restoration of system potential vegetation and effective shade along tributaries is necessary to restore mainstem Willamette River temperatures.

Per recommendation of the TMDL Council, the heat load allocation available to all anthropogenic nonpoint sources is one-sixth of the human use allowance and is equal to a 0.05ºC increase in stream temperatures above natural thermal potential temperatures. However, the heat allocation available to nonpoint source activities varies by location based on the point source sector allocation and is smallest where point sources consume most of the human use allowance. This is the case in the river segments above the Santiam River to the Marys River where at times point sources cumulatively consume 0.23°C of the 0.30°C human use allowance. Here, allocation of 0.035°C is available to the nonpoint source sector. The remaining 0.035^{o}C is allocated to reserve capacity.

Individual point sources also demand much of the human use allowance on the lower McKenzie and the lower Coast Fork Willamette and have a potential to warm these receiving streams by 0.25°C to 0.28°C during critical periods. The remaining loading capacity is allocated equally to nonpoint sources and reserve capacity.

The primary mechanism for achieving load allocations will be the protection and restoration of system potential vegetation and effective shade. The greatest opportunities for reducing heat loads through riparian restoration are on the smaller tributaries. On the mainstem river, there are reaches along the mainstem river where full restoration of riparian vegetation will accomplish little in the context of basin scale temperatures. However, it is the intent of this plan to eliminate, to the extent feasible, unnecessary degradation of water quality and warming of temperature-impaired streams from nonpoint sources. Furthermore, along the lower reaches of the Willamette, restoration and protection of natural vegetation is essential to the maintenance of riparian and floodplain processes that influence cold water refugia and provide other benefits to water quality and aquatic species. Such measures are necessary to attain water quality standards in the lower river. (OAR 340-41-0028(4)(d)).

ODEQ did not calculate allowable reductions in system potential effective shade that will meet the load allocations. In other words the department did not quantify the amount of solar radiation loading that would result in a temperature increase that is within the portion of the human use allowance allocated to anthropogenic nonpoint sources. Instead the TMDL targets system potential effective shade. Nonpoint source load allocations may address anthropogenic heat loads from roadways, ports and similar developments as well as agriculture, forestry, urban areas, or dam operations. As shown in Table 4.17, nonpoint source load allocations are based on a change in river temperature rather than solar loading values.

Table 4.17 Load allocations available to nonpoint sources.

	Rearing Upstream Santiam River (Billion Kcal/Day)	Spawning Upstream Santiam River (Billion Kcal/Day)	Rearing Upstream Yamhill River (Billion Kcal/Day)	Spawning Upstream Yamhill River (Billion Kcal/Day)	Migration Downstream Yamhill River (Billion Kcals/Day)
Background(1)	61.85	20.36	67.44	24.73	135.72
Allocation(2)	0.34	0.36	0.69	0.80	0.38

(1) Background is based on solar loading with complete restoration of riparian vegetation. River reaches where rearing and migration fish use apply is calculated in August. River reaches where spawning fish use apply is calculated in October.
(2) The portion of the HUA allocated to is based on an in-river temperature increase at 7Q10 river flow in the Albany area where spawning and rearing fish use apply, and in the Portland harbor where migration fish use apply.

Effective Shade Targets

The Willamette Basin Temperature TMDL incorporates measures other than "*daily loads*" to fulfill requirements of §303(d). Although load allocations for nonpoint source activities as shown in Table 4.17 are derived through model simulations, these values are of limited value in guiding management activities needed to address water quality problems. In addition to heat energy loads, this TMDL develops and allocates effective shade targets as surrogate indicators of heat load. Because factors that influence water temperature are interrelated, the surrogate measure (percent effective shade) relies on the restoration and protection of site potential riparian vegetation.

Summaries of the effective shade curve approach are discussed in greater detail in *Appendix C – Potential Near-Stream Land Cover for Temperature TMDLs.* Shade curves specific to each geomorphic unit (and eco-region in the Lower Willamette) are presented in *Appendix C – Shade Curves.*

USACE Willamette Project Reservoir Allocations

Monthly heat load allocations have been assigned to all USACE Willamette Project reservoirs. At times these reservoirs significantly heat downstream river reaches tributary to the Willamette River and also contribute to warming in the mainstem river itself. To meet temperature standards, load allocations assigned to the USACE reservoirs provide for no portion of the human use allowance and therefore no heating of river temperatures above background levels. Additional data collection and analysis are necessary to better understand the magnitude of individual and cumulative reservoir impacts and provide meaningful allocations of the human use allowance to USACE.

Historical data provide some indication of specific reservoir impacts on river temperatures. For example, data collected before Cougar Reservoir construction do exist for the South Fork McKenzie River, but the magnitude and duration of effects of all project reservoirs on downstream river reaches are unknown. What can be stated is that the Willamette Project reservoirs generally cool downstream water temperatures substantially during summer and delay the occurrence of maximum annual temperatures until autumn and this results in a significant shift in the seasonal temperature patterns under which salmonids evolved.

Although no portion of the human use allowance was allocated to the USACE reservoirs, it was necessary to identify target temperatures for each reservoir. These target temperatures were based on estimates of natural thermal potential temperatures; however, the CE-QUAL-W2 model did not extend upstream of USACE reservoirs. Consequently model simulations were not available to identify natural thermal potential temperatures and reservoir target temperatures. Instead, reservoir temperature targets were based on water temperature and flow data from streams tributary to each reservoir. Recent tributary data were used to calculate flow-weighted seven-day rolling average temperatures and individual reservoir targets were derived with the monthly median of these values (Table 4.18). This simple approach does not provide data of the quality generated elsewhere in this TMDL, but it does provide an estimate of natural seasonal temperature patterns and how these patterns differ from current thermal regimes. See Appendix C for a detailed description of how these values were calculated.

Implementation of load allocations and attainment of temperature targets will restore much of the natural seasonal thermal regime of downstream river reaches. However, complete restoration of the temporal and spatial thermal heterogeneity of a natural stream is unlikely in the river reaches downstream from each reservoir as reservoir operations will continue to dampen temporal temperature fluctuations and flow augmentation will continue to influence the temporal and spatial distribution of heat throughout the Willamette system.

Monthly reservoir target temperatures are preliminary and ODEQ anticipates that these target temperatures will be revised. For example, USACE has demonstrated that ODEQ temperature targets for South Fork McKenzie River are at or below the range of historical average monthly temperatures. Throughout the basin, USACE targets were based on thermistor data from locations often well above slack water of each reservoir. These targets do not account for heating that naturally occurs as waters flow downstream and may also include additional heat from nonpoint source activities throughout the upper watersheds.

Calculated Stream Temperature Targets

The load allocation for each Willamette Project reservoir is no increase in natural thermal potential temperatures when biologically-based numeric criteria are exceeded. Monthly stream temperature values presented in Table 4.18 are not the load allocations, but are ODEQ estimates of median seven day average values to meet the load allocations. Targets include summer temperatures warmer than those currently observed below some USACE reservoirs and cooler than current water temperatures in the late summer and early autumn.

Load allocations apply to all USACE reservoirs April through October when biologically-based numeric criteria are exceeded in downstream tributary reaches or the mainstem Willamette River. Load allocations are also necessary for the month of November for those reservoirs that release water with temperatures in excess of the biological criteria (usually the 13°C spawning criterion). Included on this list are the Middle Fork Willamette Projects, the McKenzie Projects, and the Santiam Projects. Insufficient data were available to calculate November temperature targets but it is anticipated that attainment of October targets will also result in attainment of November allocations. No load allocation limits apply during the months of December through March when tributary and mainstem temperatures meet all biologically-based numeric criteria.

Table 4.18 Monthly target temperatures (seven day average temperature) for USACE Willamette Basin Reservoirs (^{o}C)

Subbasin:	Coast Fork Willamette	Coast Fork Willamette	Middle Fork Willamette	Middle Fork Willamette	Middle Fork Willamette	McKenzie	McKenzie	South Santiam	North Santiam	Upper Willamette
Reservoirs:	**Cottage Grove**	**Dorena**	**Hills Creek**	**Dexter/ Lookout Pt.**	**Fall Creek**	**Cougar**	**Blue**	**Foster/ Green Peter**	**Big Cliff/ Detroit**	**Fern Ridge**
Jan	No Allocation Necessary									
Feb										
Mar										
Apr	9.4	8.8	5.8	6.5	6.5	5.5	5.5	6.1	5.4	9.0
May	11.4	10.8	7.8	8.6	8.6	7.7	7.6	8.2	7.3	10.8
Jun	15.5.0	16.5	11.0	13.2	12.2	10.0	9.9	12.4	9.7	14.6
Jul	19.9	22.3	14.2	17.4	15.9	11.7	11.2	18.4	12.8	16.7
Aug	18.3	20.4	13.6	16.5	15.8	10.9	10.6	18.0	12.8	16.0
Sep	16.4	18.2	12.5	13.9	13.5	9.5	9.5	15.5	10.9	14.0
Oct	13.5	15.3	9.6	10.2	10.6	7.2	7.2	12.6	7.7	8.0
Nov			9.6	10.2	10.6	7.2	7.2	12.6	7.7	
Dec	No Allocation Necessary									

Differences between NTP temperatures and current 7DADM temperatures are due to natural warming, perhaps some anthropogenic warming related to land use activities, and most significantly, USACE project effects on downstream temperatures. Unlike point sources that discharge heat loads into a receiving water body, these large reservoirs control the temperature and flow of the entire stream. Because heat load is a function of temperature and flow, reservoir effects on stream temperature are better expressed as water temperature targets than as a heat load expressed as units of energy such as calories.

Additional monitoring and modeling are needed to refine the estimates of natural thermal potential that are the target temperatures for reservoir operations. Stream models are needed of currently impounded reaches to determine heating that would occur in these reaches in the absence of reservoirs. Stream models of streams above the reservoirs are also needed to determine the natural thermal potential of streams where they flow into reservoirs. Reservoir models, currently being developed by USACE and others, are needed to optimize reservoir operations and evaluate potentials for achieving target temperatures. With these tools, cost-benefit analyses can be performed and load allocations greater than background may be provided. However, until better information is available, heat load allocations equivalent to natural background loads apply to all USACE Willamette Project reservoirs.

Public and Private Utility Hydroelectric Projects

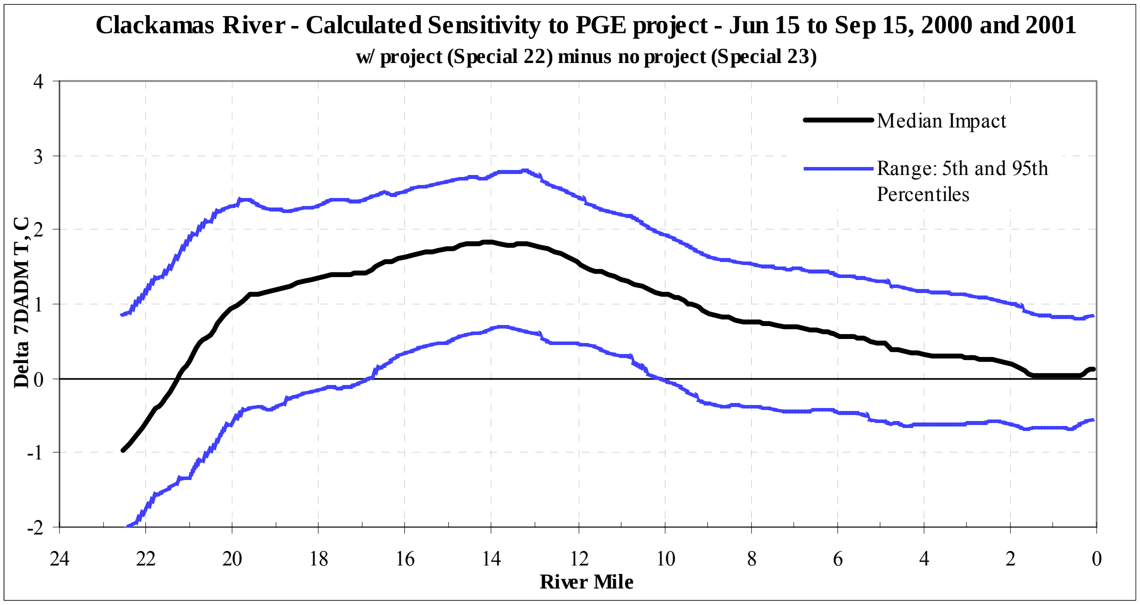
Heat load allocations for public and privately owned utility hydroelectric projects were developed to limit cumulative temperature impacts on each receiving stream. Load allocations are expressed as a portion of the human use allowance at each point of maximum impact for each project. The impact of the each project are described in detail in the discussion on existing heat sources and in Appendix 4.6.

PGE Clackamas River Hydroelectric Project:

The PGE Clackamas River Hydroelectric Project is allocated 0.15°C of the human use allowance for the Clackamas River. Modeling performed using the Clackamas River CE-QUAL-W2 model for 2000 and 2001 indicates that this allowance is frequently exceeded.

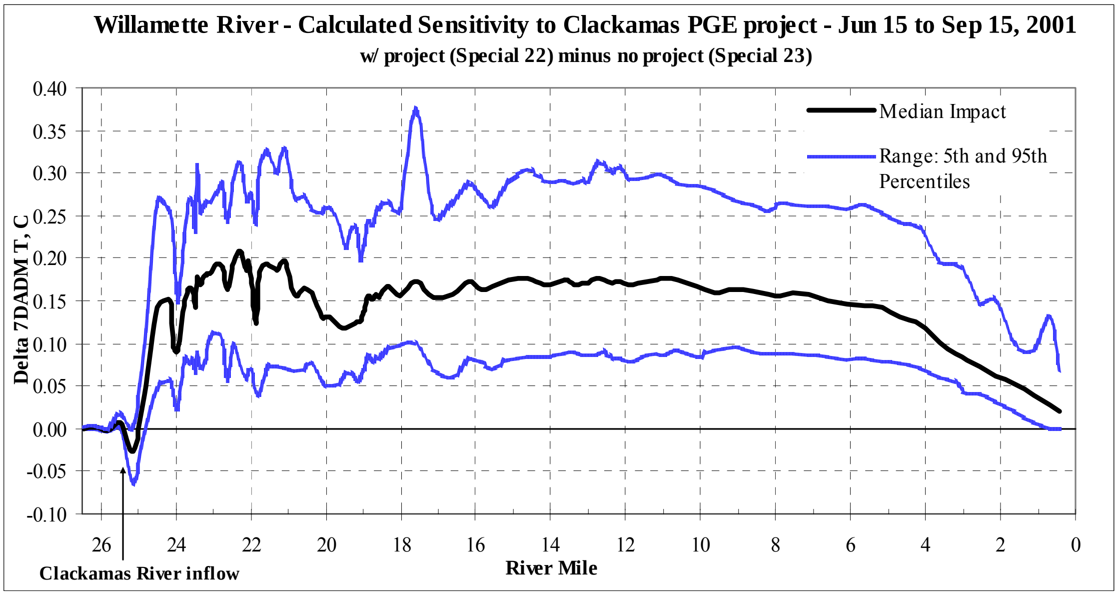
Figure 4.35, presented previously, shows that the median impact of the project on daily maximum temperature is negative immediately downstream of River Mill Dam because the project buffers diel temperature fluctuations. However, the impact rapidly turns positive and reaches a peak near RM 14, where the median impact approaches 2°C and the maximum (95th percentile) impact approaches 3.0°C. Below RM 14 the impact gradually declines and approaches zero near the mouth.

Figure 4.35 **Calculated impact of PGE Clackamas Project on the Clackamas River during the summer**



Because the PGE project is as likely to cool the lower few miles of the Clackamas River as it is to heat it, at least during the warmer days when the 18°C numeric criterion for this reach is exceeded, it would at first appear that the impact of the project on the Willamette River should be negligible. However, the minor impact on the project on lower reach temperatures appears to be time-of-travel related. The project reduces daily maximum temperatures in the River Mill Dam tailrace by buffering diel fluctuations. This results in cooler temperatures from RM 23 to 21, and impacts near zero from RM 2 to RM 0, which is about one day time-of-travel downstream from RM 23. The buffering of diel fluctuations at RM 23 results in warmer early morning temperatures, which results in warmer daily maximum temperatures as this water passes from RM 21 to RM 2. The transport of this warmer water into the Willamette may, at times, also result in slightly warmer temperatures in the Willamette River. This is supported by Figure 4.36, which indicates that the median impacts of the Clackamas Project on lower Willamette River 7-day average daily maximum temperatures generally exceed 0.15 °C during the summer.

Figure 4.36 **Calculated impact of PGE Clackamas Project on the Willamette River during summer, 2001.**



While current impacts of the Clackamas Project on the Willamette River appear to be significant, if the Clackamas Project is able to meet its load allocation, the impact on the Willamette should be virtually eliminated. Figure 4.36 indicates that summer impacts of the Project on the lower Willamette currently range from 0.05 to 0.3°C and median impacts range from 0.1 to 0.2°C, prior to dilution with Columbia River water near the mouth. In the Clackamas River, current overall Clackamas Project impacts are as much as 1.5°C in the reach from RM 23 to RM 8. If these are reduced to the allocated 0.15°C of impact, it is likely that the impact of the project on the Willamette River will be reduced a similar percentage amount. Therefore, it is reasonable to assume that maximum impacts on the lower Willamette will be reduced to less than 0.03°C and that median impacts will be reduced to no more than 0.02°C.

Conversion of the heat load allocation from an allowable temperature increase to a heat load allocation in terms of kilocalories per day is accomplished simply by multiplying river flow times the allowable 0.15°C increase and the specific heat of water, as follows:

$$Heat = river\ \ flow(\frac{m3}{\sec}) \cdot \frac{1000kg}{m3} \cdot \frac{86400\sec}{day} \cdot \frac{1Kcal}{kg/1°C} \cdot \Delta T(°C) = Kcal/day$$

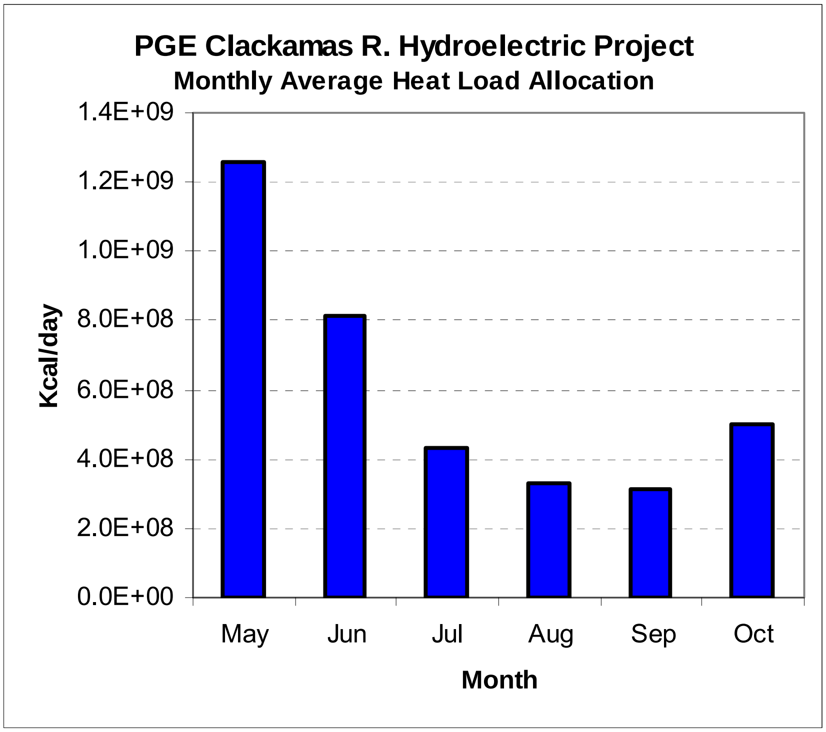
where ΔT = 0.15°C.

Using monthly average flow rates for the Clackamas River at Estacada (USGS gage 14210000), which is located downstream from River Mill Dam, the monthly average heat load allocations are as presented in Table 4.19 and Figure 4.37.

Table 4.19 PGE Clackamas River Hydroelectric Project heat load allocations

Month	Monthly Average Flow (cfs)	Monthly Average Flow (cms)	Allowable temperature increase	Heat Load Allocation (Kcal/day)
May	3434	97.3	0.15	1.260E+09
Jun	2221	62.9	0.15	8.152E+08
Jul	1172	33.2	0.15	4.302E+08
Aug	893	25.3	0.15	3.278E+08
Sep	956	27.1	0.15	3.509E+08
Oct	1368	38.7	0.15	5.021E+08

Figure 4.37 PGE Clackamas River Hydroelectric Project heat load allocation



Note that the load allocations shown in Table 4.19 and Figure 4.37 apply for monthly average flow conditions. If actual flow conditions are less than this, then load allocations on a Kcal/day basis are reduced accordingly. For example, if flow rates during a drought year approach 7Q10 conditions, then applicable load allocations are based on 7Q10 flow rates.

PGE Willamette Falls Hydroelectric Project:
The PGE Willamette Falls Hydroelectric Project is allocated 0.11^{o}C of the human use allowance. Modeling performed using the Willamette River CE-QUAL-W2 model for 2001 and 2002 indicates that the PGE Willamette Falls Project has little cumulative warming effects on river temperatures during the critical months covered by this TMDL. The Project does not warm water within the project (Newberg Pool), but does affect the distribution of heat throughout the Pool. The Willamette Falls hydroelectric project increases the size of the Newberg Pool and causes water to flow more slowly from river mile 50 to the falls at river mile 26. Thus warm parcels of water move more slowly through the pool with the concrete cap and flashboards in place than they would if these project features were removed. Longer travel times through the pool also affect the distribution of maximum daily temperatures downstream of the falls.

As discussed previously, the project does result in a positive shift in the temperature distribution in the lower Willamette. When temperatures exceed the biologically-based numeric criteria the shift is 0.06^{o}C for the 2001 model year and 0.11^{o}C for the 2002 model year (see Appendix 4.6).. In order to limit the impact of this project and insure that the human use allowance is not exceeded, a heat load allocation has been provided to limit heating due to the Project to 0.11°C.

Conversion of the heat load allocation from an allowable temperature increase to a heat load allocation in terms of kilocalories per day is accomplished simply by multiplying river flow times the allowable 0.11°C increase and the specific heat of water, as follows:

$$Heat = river\ flow\ (\frac{m3}{\sec}) \cdot \frac{1000\ kg}{m3} \cdot \frac{86400\ \sec}{day} \cdot \frac{1Kcal}{kg/1^\circ C} \cdot \Delta T\ (^\circ C) = Kcal/day$$

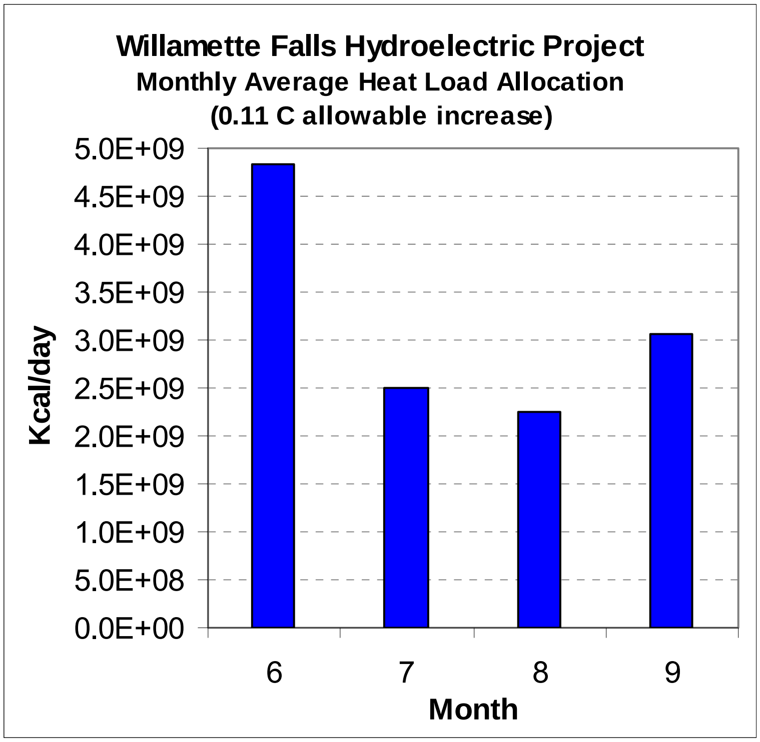
where $\Delta T = 0.11^\circ C$.

Using monthly average flow rates for the Willamette River at Portland (USGS gage #14211720), the monthly average heat load allocations are as presented in Table 4.20 and Figure 4.38.

Table 4.20 PGE Willamette Falls Hydroelectric Project heat load allocations

	Month	Monthly Average Flow (cfs)	Monthly Average Flow (cms)	Allowable temperature increase	Heat Load Allocation (Kcal/day)
6	Jun	17960	508.6	0.11	4.834E+09
7	Jul	9307	263.6	0.11	2.505E+09
8	Aug	8335	236.1	0.11	2.243E+09
9	Sep	11410	323.1	0.11	3.071E+09

Figure 4.38 PGE Willamette Falls Hydroelectric Project heat load allocation



Note that the load allocations shown in Table 4.20 and Figure 4.38 apply for monthly average flow conditions. If actual flow conditions are less than this, then load allocations on a Kcal/day basis are reduced accordingly. For example, if flow rates during a drought year approach 7Q10 conditions, then applicable load allocations are based on 7Q10 flow rates.

Eugene Water and Electric Board Hydroelectric Project

The EWEB Leaburg and Walterville Project is allocated 0.10 °C of the human use allowance for the Lower McKenzie River downstream from the Walterville Project return flow (at model RM 17.4) and 0.30°C of the human use allowance upstream from the Walterville Project return flow. Effects of the EWEB Leaburg and Walterville hydroelectric developments are most apparent within bypass reaches where modeling simulations demonstrate that bypass reach maximum temperatures are significantly warmer than natural thermal potential temperatures. Downstream of the projects, as defined by the location at RM 17.4 where water diverted by the Walterville project is returned to the river, stream temperature impacts are also significant.

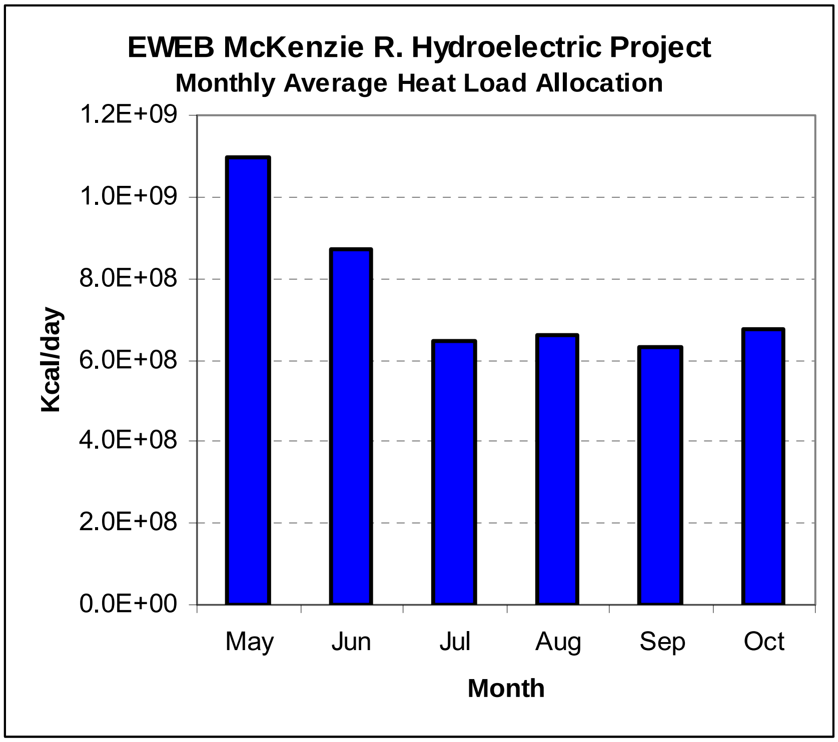
Attainment of the 0.3°C load allocation upstream of river mile 17.4 will require approximately a 90% reduction in simulated 2001 and 2002 peak heat loads. Load allocations downstream of RM 17.4 require similar reductions in peak heat loads and ensure there is adequate loading capacity remaining to accommodate the

Weyerhaeuser WLA at river mile 12.7. The load allocation will result in a peak EWEB heat load of about 0.03°C at the confluence with the Willamette River. Allocations are shown in Table 4.21 and Figure 4.39.

Table 4.21 EWEB McKenzie River Hydroelectric Project heat load allocations

	Month	Monthly Average Flow (cfs)	Monthly Average Flow (cms)	Allowable temperature increase	Heat Load Allocation (Kcal/day)
5	May	4489	127.1	0.10	1.098E+09
6	Jun	3562	100.9	0.10	8.716E+08
7	Jul	2636	74.6	0.10	6.450E+08
8	Aug	2703	76.5	0.10	6.614E+08
9	Sep	2583	73.2	0.10	6.321E+08
10	Oct	2759	78.1	0.10	6.751E+08

Figure 4.39



Mainstem Willamette Reserve Capacity

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

This element is an allocation for increases in pollutant loads for future growth and new and expanded sources. The TMDL may allocate no reserve capacity and explain that decision.

Explicit allocations for reserve capacity are provided for the mainstem Willamette River and its tributaries. In general, 0.05°C or 1/6th of the human use allowance is allocated to reserve capacity. Reserve capacity is reduced to less than 0.05°C where and when waste load allocations consume more than 0.2°C of the human use allowance. This occurs in the Willamette River reach between the Marys River (RM 132) and Santiam River (RM 109) where the portion of the human use allowance allocated to reserve capacity is set to 0.035°C, and between the Tualatin River (RM 28) and the Clackamas River (RM 25) where the reserve capacity is set to 0.015°C. No reserve capacity is reserved for the McKenzie River EWEB bypass reaches because the human use allowance is fully allocated to the EWEB hydroelectric project. At the confluence of the McKenzie River with the Willamette, 0.01°C of reserve capacity is available in the McKenzie River.

Reserve capacity is allocated to accommodate future growth as well as to provide allocations to existing sources that were not identified during the development of the TMDL. The reserve capacity, Table 4.22, will be available for use by either point sources or nonpoint sources. One-half of the reserve capacity will become available for use at the time the TMDL is issued by ODEQ. The second half of the reserve capacity will become available following analyses for the USACE dam and reservoirs and when it is demonstrated that significant steps to implement the TMDL have been taken. Reserve capacity will be available following a reasonable time (2 years) to allow ODEQ and sources to determine the impacts of wasteload and load allocations and to determine if any sources received inappropriate or insufficient allocations. Allocations of reserve capacity will be granted by the department first to sources that did not receive allocations but that have a demonstrated need to allow current operations. Secondly, reserve capacity may be granted to sources that have demonstrated a need for additional allocations, despite attempts to offset this need through technological improvements or trading options. This reallocation of reserve capacity will be at the discretion of the department, and will be considered following application by the permit writer for a given permit. See WQMP for additional information on reserve capacity and Trading options.

Table 4.22 Reserve capacity on the mainstem Willamette River based on location and designated use period.

	Upstream of Santiam River Salmonid Rearing (Billion Kcal/Day)	Upstream of Santiam River Salmonid Spawning (Billion Kcal/Day)	Upstream of Yamhill River Salmonid Rearing (Billion Kcal/Day)	Upstream of Yamhill River Salmonid Spawning (Billion Kcal/Day)	Downstream of Yamhill River Salmonid Migration (Billion Kcals/Day)
Reserve Capacity(1)	0.34	0.36	0.69	0.80	0.38

(1) The reserve capacity is based on a change in temperature at 7Q10 river flow at the point of maximum impact at Albany and Salem and Portland.

Mainstem Willamette Seasonal Variation and Critical Conditions

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

This element accounts for seasonal variation and critical conditions in streamflow, sensitive beneficial uses, pollutant loading and water quality parameters so that water quality standards will be attained and maintained during all seasons of the year.

Warmest water temperatures in the Willamette Basin typically occur during summer months when solar radiation levels are greatest. This also corresponds to the period when streamflows and heat loading capacity are low. Salmon migration and rearing and other beneficial uses including resident fish and aquatic life may be adversely affected or impaired when temperatures exceed the biologically-based numeric criteria for extended periods of time. This is the period of year when nonpoint source activities that decrease effective shade levels along the stream are of greatest concern.

Late summer and early autumn is another period when biologically-based numeric criteria are frequently exceeded. Ambient water temperatures begin to cool, but streamflow levels remain low and susceptible to point source heat loads. This is also at a time when salmon begin to spawn in many streams. Applicable numeric criteria during this time reflect this increase in beneficial use sensitivity and the target temperature for the seven-day average of the daily maximum is reduced from 16 or 18°C to 13°C. It is during this time that reservoir releases have their greatest effect on ambient stream temperatures.

Model simulations and historical data also demonstrate that water temperatures in the mainstem Willamette frequently exceed the spawning criterion in late April and early May. The spawning criterion applies throughout the mainstem Willamette River upstream of river mile 50, as well as most tributaries throughout the basin.

The mainstem Willamette temperature TMDL addresses the period spanning the months of April through October. Load allocations and monthly waste loads and were developed for the time period when stream temperatures exceed the biological criteria to ensure anthropogenic heat loads meet the human use allowance and other elements of Oregon temperature standards. Allocations apply June through September to the mainstem river heat sources downstream of river mile 50. Allocations apply April through October to sources upstream of river mile 50 as well as tributaries to the river. Load allocations are also necessary during November for select USACE reservoirs that release water warmer than ambient temperatures and biologically-based numeric criteria. Other criteria, including the protection of cold water requirement (OAR 340-41-0028(12)) and thermal plume limitations (OAR 340-41-0053(2)(d)) apply throughout the year.

Mainstem Willamette Margin of Safety

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

This element accounts for uncertainty related to the TMDL and, where feasible, quantifies uncertainties associated with estimating pollutant loads, modeling water quality and monitoring water quality.

A margin of safety is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and receiving 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).

Table 4.23 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.

No explicit margin of safety is provided in this TMDL. Specific heat load allocations are provided to point sources, nonpoint sources and reserve capacity, but no portion of the human use allowance is set aside as margin of safety. However, there are implicit margins of safety included in the TMDL through conservative assumptions during analysis, and interpretation and application of temperature criteria. For example, cumulative effects analyses were based on a set of circumstances unlikely to occur. Specifically, it was assumed for the purposes of identifying the point of maximum stream temperature impact that industrial and municipal facilities would discharge at maximum permitted levels simultaneously.

SUBBASIN TMDL TEMPERATURE ASSESSMENT

The remainder of this chapter provides an overview of subbasin temperature TMDLs. Many elements of these TMDLs are similar to those found in the discussion of the mainstem Willamette TMDL. However there are key differences with respect to heat load allocation processes. These differences are due in part to the level of information available and the analysis performed in these subbasin TMDLs. Details of each subbasin are found in Chapters 5 through 13.

Separate temperature models were developed for nine tributary streams located throughout the Willamette Basin (Table 4.24). Together these waterbodies represent the range of stream environments found in the basin including urban streams, stream draining areas of mixed land use, and streams flowing through forested watersheds. System potential vegetation was simulated and subsequent model results used to derive natural thermal potential temperatures and load allocations for each stream. Shade targets developed for these and the mainstem TMDL were applied to all 303(d) listed streams and their tributaries throughout the nine Willamette subbasins addressed in these TMDL.

Table 4.24 Analytical models used to develop watershed TMDLs arranged by subbasin.

Watershed TMDL	Model	Subbasin	Hydrologic Unit Code
Mosby Creek	Heat Source	Coast Fork Willamette River	17090002
McKenzie River above SF McKenzie	Heat Source	McKenzie River	17090004
Mohawk River	Heat Source		17090004
Coyote Creek	Heat Source	Upper Willamette River	17090003
Crabtree Creek	Heat Source	South Santiam River	17090006
Thomas Creek	Heat Source		
Little North Santiam	Heat Source	North Santiam River	17090005
Johnson Creek	Heat Source	Lower Willamette River	17090012
Columbia Slough	CE Qual W2		

Water temperature concerns in many Willamette Basin streams are driven primarily by the nonpoint source activities. The critical period of anthropogenic warming is summer and early fall when solar radiation inputs are high and streamflow levels are low. Two dynamic modeling tools were used to assess the impacts of land use activities on stream temperature, predict natural thermal potential temperatures, and develop loading capacity and load allocations. Effective shade curves based on relationships between vegetation and topographic characteristics, channel orientation, and position of the sun in the sky were used in to establish shade targets for all streams in the basin. The temperature models used in the subbasin TMDLs are described briefly below with additional information available in Chapters 5-13 and in *Appendix C - Subbasin Temperature Analysis.*

Heat Source is a heat transfer process model used to simulate stream thermodynamics and hydrology. Individual models were calibrated to temperature and flow during a single critical period, typically when high stream temperatures were observed. Natural thermal potential temperatures were identified for critical periods through model simulations that included system potential vegetation and corresponding effective shade levels. Solar radiation loads simulated with system potential vegetation (an absence of human disturbance) were identified as the natural background heat load. Current heat loads in excess of background loads were identified as anthropogenic heat loads or pollutant loads.

CE-QUAL-W2 is another model that simulates streamflow and heat energy exchange processes. It was used to assess stream temperature patterns in Columbia Slough (see Chapter 5) where flow manipulations and extensive aquatic plant growth affect streamflow and heat exchange processes. As with Heat Source simulations, streamside vegetation and effective shade estimates were used to identify natural or background heat loads from solar radiation and increases in heat load associated with nonpoint source activities.

Shade curves were developed for all nine subbasins and applied to all 303(d) streams and tributaries. Effective shade targets translate heat loads from energy units such as Langley's and kilocalories per day into more understandable streamside vegetation objectives. In many stream segments, especially those dominated by nonpoint source activities that affect streamside shade, detailed models were not necessary to identify loading capacity and nonpoint source load allocations. Shade curves were used as surrogate measures to represent both of these TMDL parameters. As discussed previously, shade curves were developed based on the relationship between potential vegetation cover type, stream channel width and channel orientation. These curves cannot be used to predict future water temperatures but can be used to determine effective shade targets and estimates of allocations necessary to eliminate nonpoint sources of heat.

As with the mainstem Willamette TMDL shade curves are applied to all streams in each subbasin. This approach is taken to ensure that streams tributary to those included on the 303(d) list do not contribute to water quality impairment. This comprehensive watershed approach is fundamental to broad scale restoration of stream temperatures in the basin.

Subbasin Existing Heat Sources

Most natural and anthropogenic heat sources that affect mainstem Willamette River temperatures also affect tributary stream temperatures. These include small point source discharges, land use activities that affect streamside vegetation, and water withdrawals and other flow modifications that change the heat loading capacity of the receiving stream. However, the overall impact of these anthropogenic sources of heat on small stream temperatures may be much greater than observed on the Willamette and its largest tributaries. Small streams have small loading capacities and are simply more sensitive to changes in heat input or reductions in flow. Whereas anthropogenic heat loads may increase mainstem Willamette River temperatures by about 1ºC, simulations suggest that increases of several degrees Celsius are likely in small streams throughout the basin.

Subbasin TMDL Loading Capacity

The heat loading capacity of a stream is dependent on its volume and whether stream temperatures exceed the applicable biologically-based numeric criteria. When stream temperatures are less than the biological criteria, the waterbody is meeting water quality standards and is not impaired. During this time the heat loading capacity corresponds to the biological criteria plus 0.3ºC. This applies to the lowest point in a stream system where the criteria apply as well as all tributary streams. As an example, when natural thermal potential stream temperatures are 17ºC and the biological criterion is 18ºC, the loading capacity corresponds to the temperature criterion plus the human use allowance, or 18.3ºC. However, it is not ODEQ's intent to allow human sources to warm all streams to the maximum extent possible as other criteria, including the protection of cold water requirement (OAR 340-41-0028(12)) and thermal plume limitations (OAR 340-41-0053(2)(d)) apply throughout the year.

When stream temperatures exceed the applicable biological criteria, the heat loading capacity is the amount of heat that corresponds to the natural thermal potential temperature plus the human use allowance of 0.3ºC. At this time, much of the loading capacity is consumed by background levels of solar radiation and the loading capacity available for anthropogenic sources is represented by the small increase in temperature allowed with the human use allowance. Thus if the natural thermal potential temperature is 19ºC and the biological criterion is 18ºC, the natural thermal potential temperature supersedes the biological criterion. The heat loading capacity corresponds to temperature target of 19.3ºC.

Subbasin TMDL Load Allocation Principles

Principles for heat load allocation in the subbasin TMDLs are similar to those used on the mainstem Willamette TMDL. The human use allowance was allocated among point source and nonpoint source sectors and some heat load allocation was set aside as reserve capacity for future growth. The load allocation strategy for subbasin TMDLs reflects the ability to monitor and quantify heat load effects from point sources with much greater confidence than individual nonpoint source activities. Thus wasteload allocations are assigned to individual point sources but load allocations are assigned to the entire nonpoint source sector in each subbasin. Furthermore, nonpoint source load allocations are commonly expressed as shade targets and management objectives for streamside vegetation.

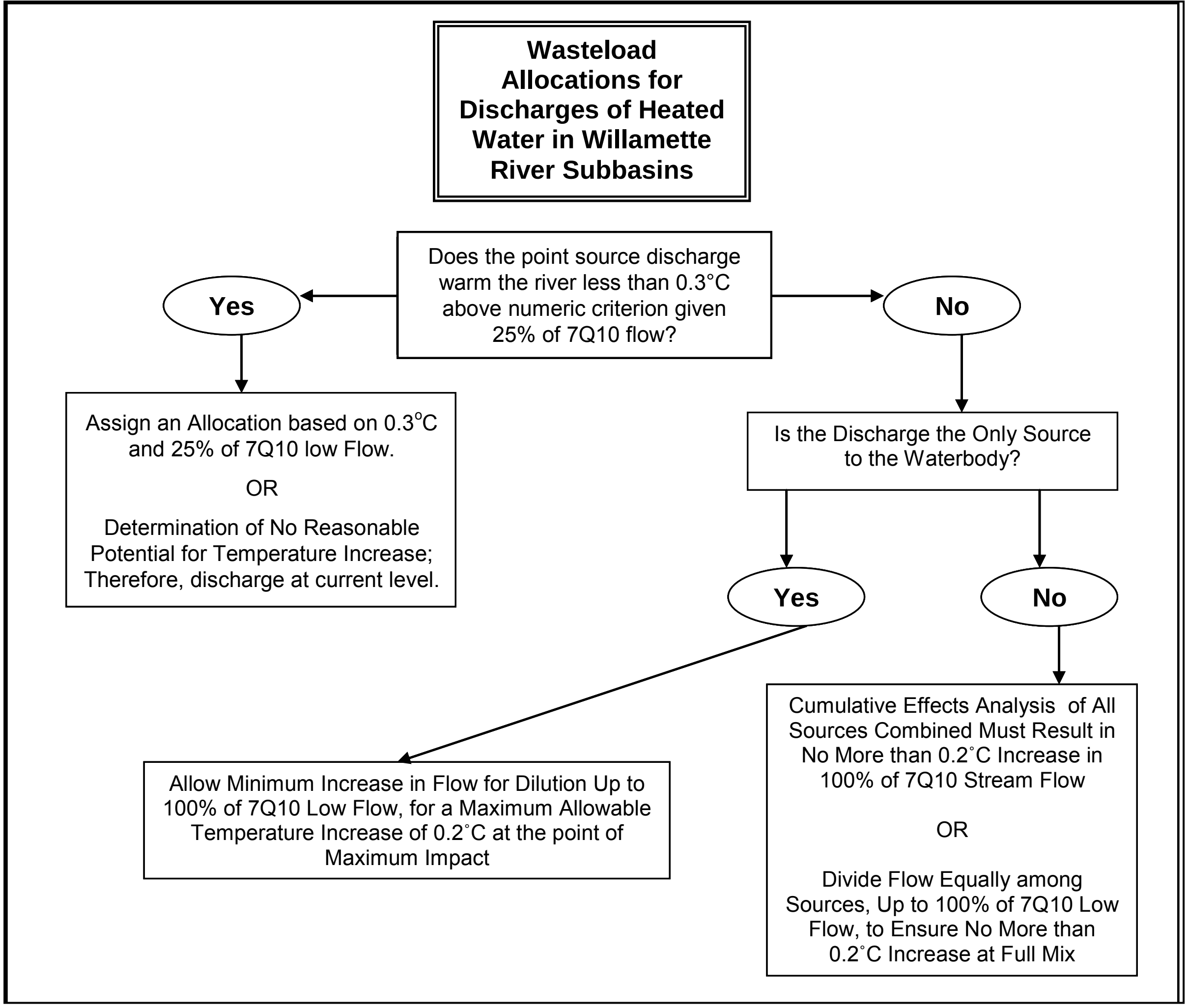
Subbasin TMDL Waste Load Allocations

Waste load allocations are assigned to individual point sources of treated industrial and municipal waste. Waste load allocations are necessary for all NPDES facilities that have reasonable potential to warm the receiving stream when the applicable criteria are exceeded. Sources that discharge effluent warmer than ambient temperatures and applicable biologically-based criteria are considered to have a reasonable potential to contribute to exceedances of numeric criteria.

Facilities found to have no reasonable potential to warm the receiving water do not require a wasteload allocation (WLA) and are allowed to discharge within their current permit. Sources that are unlikely to discharge significant volumes of warm water during critical periods, such as municipal separate storm sewer systems (MS4s) and other stormwater sources, are not expected to have a reasonable potential to affect attainment of the temperature standard.

Where information was available, discharge allocations were assessed by the process described in the following chart (see Figure 4.40). This allocation strategy assumes that the 25% of the human use allowance is allocated to an existing source as specified in OAR 340-41-0028(12)(b)(A) and the resultant temperature increase in fully mixed receiving water would be limited to 0.08˚C. However, if necessary two-thirds of the human use allowance is available to one or more point sources yielding up to a 0.2°C increase above applicable temperature criteria.

Figure 4.40



Efforts were made to develop waste load allocations for each significant source discharging to subbasin streams. However the lack of an explicit waste load allocation in subbasin TMDLs does not mean an allocation of no heat (0 kcal/day). In situations where insufficient information was available to develop WLAs, sources will be notified of their obligation to collect data and thermal effluent limits will be incorporated into NPDES permits as they are updated. When point sources cannot meet their waste load allocation at the time of NPDES permit renewal a compliance schedule may be included within the permit. Compliance schedules developed under provisions of state and federal water quality standards require compliance as soon as reasonably possible, and generally within a 5-year permit cycle.

NPDES permits require point sources to meet TMDL wasteload allocations and thermal plume limitations [340-041-00532(d)(A-D)]. These limitations prevent or minimize the adverse effects to salmonids inside the mixing zone, such as impairment to an active salmonid spawning area, acute impairment or instantaneous lethality, thermal shock, and migration blockage. Thermal plume limitations apply during the critical periods addressed by the TMDL as well as the other months of the year when stream temperatures are generally well below biologically-based numeric criteria.

Subbasin TMDL Load Allocations

Load allocations are the portion of loading capacity allocated to natural and anthropogenic sources of heat. Natural background heat loads consume most of the loading capacity when stream temperatures exceed the biological criteria, but reductions in these heat loads are not called for. Anthropogenic nonpoint sources of heat also contribute substantial heat loads and a small allocation has been assigned to this sector. The allocation allows a 0.05°C increase above the applicable numeric criteria and represents 1/6th of the human use allowance. However the load allocation is well below current anthropogenic loads and large reductions in this heat load are required.

Nonpoint source load allocations in the subbasin TMDLS are not assigned to individual sources. The nonpoint source sector allocations are available for all nonpoint source activities including reservoir impoundments and land use activities that influence effective shade level. In the meanwhile ODEQ will target system potential conditions and effective shade levels.

Attainment of effective shade levels associated with system potential vegetation will eliminate most anthropogenic nonpoint source heat loads, however additional measures are necessary to fully restore natural thermal regimes. These measures include stream bank stabilization and restoration of natural channel patterns to further improve effective shade and decrease anthropogenic heat loads. Streamflow restoration is necessary in some streams to further reduce anthropogenic effects.

Subbasin TMDL Excess Load

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

Excess load is the difference between the actual pollutant load and the loading capacity of a water body. Table 4.25 indicates the excess load or stream temperature impact for nine stream TMDLs at the point of maximum impact. This point of maximum impact is where the change in natural thermal potential temperatures caused by point and nonpoint sources of heat is greatest. Model outputs demonstrate that current anthropogenic heat loads warm streams as much as 8°C, but maximum stream temperature impacts for most streams are less than 4°C.

Table 4.25 also includes model outputs for stream temperatures at their mouths and demonstrates that TMDL allocations generally yield cooler temperatures here as well. However, the difference between current and system potential temperatures is less at the mouth than at upstream point of maximum impacts. This is due in part to influences of natural warming processes but also reflects assumptions about system potential vegetation and effective shade. For example, model outputs for the Thomas Creek simulation suggest that NTP with system potential effective shade is warmer than current conditions. This may be due to the distribution of natural disturbance and patches of low effective shade in the NTP simulation. This underscores the sensitivity of the temperature models used to effective shade variables and inputs of solar radiation.

Table 4.25 Point of maximum impact and magnitude of impact for each subbasin TMDL.

Subbasin	Stream	Point of Maximum Impact (River Mile)	Thermal Impact	Current Condition Stream Temperature at Mouth	System Potential Stream Temperature at Mouth
South Santiam	Thomas Creek	20.0	1.14ºC (2.1ºF)	25.0ºC (77.0ºF)	25.5ºC (77.9ºF)
South Santiam	Crabtree Creek	3.3	3.8ºC (6.8ºF)	25.8ºC (78.4ºF)	23.9ºC (75.0ºF)
North Santiam	Little North Santiam	8.0	1.7ºC (3.1ºF)	25.5ºC (77.ºF)	24.9ºC (76.8ºF)
Coast Fork Willamette	Mosby Creek	17.4	3.0ºC (5.4ºF)	26.4ºC (79.5ºF)	24.9ºC (76.8ºF)
Lower Willamette	Johnson Creek	11.8	8.5ºC (15.3ºF)	20.3ºC (68.5ºF)	16.5ºC (61.7ºF)
McKenzie	Mohawk River	18.5	3.1ºC (5.6ºF)	24.7ºC (76.5ºF)	22.8ºC (73.0ºF)
McKenzie	Upper McKenzie	62.5	0.4ºC (0.7ºF)	10.9ºC (51.6ºF)	10.5ºC (50.9ºF)
Upper Willamette	Coyote Creek	17.7	8.5ºC (15.3ºF)	27.5ºC (81.5ºF)	25.2ºC (77.4ºF)
Upper Willamette	Luckiamute River	26.5	3.6ºC (6.5ºF)	24.6ºC (76.3ºF)	24.3ºC (75.7ºF)

Excess loads were not calculated for streams where temperature models were not developed. Shade curves were used as surrogate measures of loading capacity and nonpoint source heat loads in these systems and excess load is simply the difference in system potential effective shade and current effective shade levels. Excess heat loading occurs when inadequate shade levels are widespread.

Subbasin TMDL Reserve Capacity

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

This element is an allocation for increases in pollutant loads for future growth and new and expanded sources. The TMDL may allocate no reserve capacity and explain that decision.

One sixth of the human use allowance was allocated to reserve capacity in the subbasin TMDLs. This is an allowable 0.05°C increase in temperature above numeric criteria. Reserve capacity was not explicitly quantified and allocated in stream systems where surrogate shade measures were used exclusively to develop TMDLs. Effective shade curves target background levels of solar radiation, but more detailed analysis may be required to evaluate individual source loads in these systems before reserve capacity is re-allocated to the other sectors.

Subbasin TMDL Seasonal Variation and Critical Conditions

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

This element accounts for seasonal variation and critical conditions in streamflow, sensitive beneficial uses, pollutant loading and water quality parameters so that water quality standards will be attained and maintained during all seasons of the year.

Summer months represent critical conditions in subbasin streams not affected by substantial point source discharges or reservoir operations. Data were gathered to specifically target the critical period of high solar radiation input and low streamflows. TMDLs for these streams focus on the middle summer period as the most critical time for water quality standards attainment, but improvements in effective shade and other measures will also benefit fisheries and other uses during other time periods. Anthropogenic load allocations allow no more than a 0.3°C increase in water temperature above numeric criteria throughout the period of concern. Waste load allocations are equal to or less than 0.2°C increase in seven day average of maximum temperatures. Allocations are applicable throughout the beneficial use period for which the waterbody was listed as temperature impaired. This period of impairment is usually the late spring, summer and early fall. The exact period for each designated use is specified in the subbasin TMDL. TMDL limitations do not apply when numeric criteria are attained but, all other aspects of temperature standards and thermal plume limitations do apply.

Subbasin TMDL Margin of Safety

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

This element accounts for uncertainty related to the TMDL and, where feasible, quantifies uncertainties associated with estimating pollutant loads, modeling water quality and monitoring water quality.

Many of the same conservative assumptions and implicit margins of safety were included in subbasin TMDL. Waste load allocations were based on critical source and receiving stream conditions unlikely to occur simultaneously. Maximum effluent flows and maximum effluent temperatures are unlikely to occur simultaneously, however, those values were used to screen point source loads for temperature impacts at the point of discharge. Furthermore, critical receiving stream values were also based on monthly low natural thermal potential temperatures or biologically-based criteria during low flow periods with a ten year return period. Low flow and low stream temperatures are not likely to occur in small, unregulated tributary streams at the same time.

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CHAPTER 4 TEMPERATURE APPENDIX

4.1: Temperature Criteria for 303(d) Listed Segments

4.2: 303(d) Listings and Data Summary

4.3: Temperature Rule (OAR 340-041-0058)

4.4: Model Simulations Summary

4.5: Point Source Waste Load Allocations and Methodology

4.6 Model Sensitivity Analyses

4.7 Impacts from Point Source Waste Load Allocations

Appendix 4.1 – Temperature Criteria for 303(d) Listed Segments by Subbasin

Table 4.26 Temperature criteria for 303(d) segments by subbasin

CLACKAMAS SUBBASIN

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	River mile	Season	Criteria/Text	TMDL
Clackamas River	0 to 22.9	Summer	Rearing: 17.8 C	Chapter 4
Cow Creek	0 to 2.6	Summer	Rearing: 17.8 C	Chapter 6
Eagle Creek	0 to 20	Summer	Rearing: 17.8 C	Chapter 6
Fish Creek	0 to 6.8	Summer	Rearing: 17.8 C	Chapter 6

COAST FORK SUBBASIN

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	River mile	Season	Criteria/Text	TMDL
Brice Creek	0 to 11.2	Summer	Rearing: 17.8 C	Chapter 13
Coast Fork Willamette River	0 to 31.3	Summer	Rearing: 17.8 C	Chapter 13
King Creek	0 to 1.6	Summer	Rearing: 17.8 C	Chapter 13
Laying Creek	0 to 7.7	Summer	Rearing: 17.8 C	Chapter 13
Martin Creek	0 to 3.4	Summer	Rearing: 17.8 C	Chapter 13
Mosby Creek	0 to 21.2	Summer	Rearing: 17.8 C	Chapter 13
Row River	0 to 7.4	Summer	Rearing: 17.8 C	Chapter 4
Row River	11.3 to 20.8	Summer	Rearing: 17.8 C	Chapter 13
Sharps Creek	0 to 12.5	Summer	Rearing: 17.8 C	Chapter 13

LOWER COLUMBIA SANDY/MAINSTEM WILLAMETTE

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	River mile	Season	Criteria/Text	TMDL
Willamette River	0 to 24.8	Summer	Rearing: 20 C	Chapter 4
Willamette River	24.8 to 54.8	Summer	Rearing: 20 C	Chapter 4
Willamette River	54.8 to 108	Summer	Rearing: 17.8 C	Chapter 4
Willamette River	108 to 119.7	Summer	Rearing: 17.8 C	Chapter 4
Willamette River	119.7 to 148.8	Summer	Rearing: 17.8 C	Chapter 4
Willamette River	148.8 to 174.5	Summer	Rearing: 17.8 C	Chapter 4
Willamette River	174.5 to 186.4	Summer	Rearing: 17.8 C	Chapter 4

LOWER WILLAMETTE SUBBASIN

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	River mile	Season	Criteria/Text	TMDL
Columbia Slough	0 to 8.5	Spring/Summer/Fall	Rearing: 17.8 C	Chapter 5
Tryon Creek	0 to 5	Summer	Rearing: 17.8 C	Chapter 5

MCKENZIE

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	River mile	Season	Criteria/Text	TMDL
Blue River	0 to 1.8	Spring/Summer/Fall	Spawning: 12.8 C	Chapter 4
Blue River	1.8 to 15.5	Summer	Rearing: 17.8 C	Chapter 11
Deer Creek	0 to 8.3	Summer	Rearing: 17.8 C	Chapter 11
French Pete Creek	0 to 12.9	Summer	Bull Trout: 10.0 C	Chapter 11
Horse Creek	0 to 14.2	Summer	Bull Trout: 10.0 C	Chapter 11

McKenzie River	34.1 to 54.5	Spring/Summer/Fall	Rearing: 17.8 C	Chapter 4
McKenzie River	0 to 34.1	Summer	Rearing: 17.8 C	Chapter 4
McKenzie River	54.4 to 83	Summer	Bull Trout: 10.0 C	Chapter 11
Mill Creek	0 to 2.7	Summer	Rearing: 17.8 C	Chapter 11
Mohawk River	0 to 25.4	Summer	Rearing: 17.8 C	Chapter 11
Shotgun Creek	0 to 6.6	Summer	Rearing: 17.8 C	Chapter 11
South Fork McKenzie River	0 to 4.5	Spring/Summer/Fall	Spawning: 12.8 C	Chapter 4
Unnamed Waterbody	0 to 1.2	Summer	Rearing: 17.8 C	Chapter 11

MIDDLE FORK WILLAMETTE SUBBASIN

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	**River mile**	**Season**	Criteria/Text	TMDL
Anthony Creek	0 to 4.3	Summer	Rearing: 17.8 C	Chapter 12
Bohemia Creek	0 to 4.4	September 15 - June 30	Spawning: 12.8 C	Chapter 12
Coal Creek	0 to 8.9	Summer	Rearing: 17.8 C	Chapter 12
Fall Creek	0 to 7	Summer	Rearing: 17.8 C	Chapter 4
Fall Creek	13 to 32.7	Summer	Rearing: 17.8 C	Chapter 12
Hills Creek	1.7 to 8.2	Summer	Rearing: 17.8 C	Chapter 12
Little Fall Creek	0 to 20.6	September 15 - June 30	Spawning: 12.8 C	Chapter 12
Lost Creek	0 to 8.2	September 15 - June 30	Spawning: 12.8 C	Chapter 12
Lost Creek	8.2 to 13.6	September 15 - June 30	Spawning: 12.8 C	Chapter 12
Lost Creek	0 to 8.2	Summer	Rearing: 17.8 C	Chapter 12
Lost Creek	13.6 to 14.7	Summer	Rearing: 17.8 C	Chapter 12
Middle Fork Willamette River	0 to 15.6	Summer	Rearing: 17.8 C	Chapter 4
Middle Fork Willamette River	52.5 to 64.1	Summer	Rearing: 17.8 C	Chapter 12
Mike Creek	0 to 2.2	Summer	Rearing: 17.8 C	Chapter 12
N Fk Middle Fk Willamette R	14.1 to 49.4	September 15 - June 30	Spawning: 12.8 C	Chapter 12
N Fk Middle Fk Willamette R	0 to 14.1	Summer	Rearing: 17.8 C	Chapter 12
Packard Creek	0 to 5.2	Summer	Rearing: 17.8 C	Chapter 12
Portland Creek	0 to 3	Summer	Rearing: 17.8 C	Chapter 12
Salt Creek	0 to 13.6	Summer	Rearing: 17.8 C	Chapter 12
South Fork Winberry Creek	0 to 3.1	Summer	Rearing: 17.8 C	Chapter 12
Unnamed Waterbody	0 to 2.3	September 15 - June 30	Spawning: 12.8 C	Chapter 12
Unnamed Waterbody	0 to 2.3	Summer	Rearing: 17.8 C	Chapter 12
Winberry Creek	2.9 to 8	Summer	Rearing: 17.8 C	Chapter 12

MIDDLE WILLAMETTE SUBBASIN

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	**River mile**	**Season**	Criteria/Text	TMDL
Patterson Creek	0 to 7.2	Summer	Rearing: 17.8 C	Chapter 7
Pringle Creek	0 to 6.2	Summer	Rearing: 17.8 C	Chapter 7
Rickreall Creek	0 to 24.9	Summer	Rearing: 17.8 C	Chapter 7

NORTH SANTIAM SUBBASIN

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	**River mile**	**Season**	Criteria/Text	TMDL
Bear Branch	0 to 9.8	Summer	Rearing: 17.8 C	Chapter 8
Blowout Creek	0 to 11.9	Summer	Rearing: 17.8 C	Chapter 8
Boulder Creek	0 to 2.4	Summer	Rearing: 17.8 C	Chapter 8
Chehulpum Creek	0 to 7.1	Summer	Rearing: 17.8 C	Chapter 8
Elkhorn Creek	0 to 7.4	Summer	Rearing: 17.8 C	Chapter 8

Little North Santiam River	0 to 25.1	Summer	Rearing: 17.8 C	Chapter 8
Marion Creek	0 to 6.2	Summer	Rearing: 17.8 C	Chapter 8
North Santiam River	0 to 10	September 1 - June 30	Spawning: 12.8 C	Chapter 4
North Santiam River	10 to 26.5	September 15 - June 30	Spawning: 12.8 C	Chapter 4
North Santiam River	0 to 10	Summer	Rearing: 17.8 C	Chapter 4
Santiam River	0 to 12	September 15 - June 30	Spawning: 12.8 C	Chapter 4
Santiam River	0 to 12	Summer	Rearing: 17.8 C	Chapter 4
Stout Creek	0 to 8.9	Summer	Rearing: 17.8 C	Chapter 8
Unnamed Waterbody	0 to 2.8	Summer	Rearing: 17.8 C	Chapter 8

SOUTH SANTIAM SUBBASIN

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	**River mile**	**Season**	Criteria/Text	TMDL
Beaver Creek	0 to 16	Summer	Rearing: 17.8 C	Chapter 9
Crabtree Creek	0 to 32.1	Summer	Rearing: 17.8 C	Chapter 9
Hamilton Creek	0 to 11.6	Summer	Rearing: 17.8 C	Chapter 9
McDowell Creek	0 to 5.7	Summer	Rearing: 17.8 C	Chapter 9
Middle Santiam River	5.3 to 37.1	Summer	Rearing: 17.8 C	Chapter 9
Neal Creek	0 to 10	Summer	Rearing: 17.8 C	Chapter 9
Quartzville Creek	3.3 to 26.8	Summer	Rearing: 17.8 C	Chapter 9
South Santiam River	35.7 to 63.4	September 1 - June 30	Spawning: 12.8 C	Chapter 9
South Santiam River	0 to 25.9	September 15 - June 30	Spawning: 12.8 C	Chapter 4
South Santiam River	0 to 25.9	Summer	Rearing: 17.8 C	Chapter 4
South Santiam River	35.7 to 63.4	Summer	Rearing: 17.8 C	Chapter 9
Sucker Slough	0 to 9.8	Summer	Rearing: 17.8 C	Chapter 9
Thomas Creek	0 to 16.2	Summer	Rearing: 17.8 C	Chapter 9
Thomas Creek	16.2 to 26.1	Summer	Rearing: 17.8 C	Chapter 9
Wiley Creek	0 to 17.2	Summer	Rearing: 17.8 C	Chapter 9

UPPER WILLAMETTE SUBBASIN

Stream Segments on the 1998 and 2002 303(d) List for Temperature

Stream Name	**River mile**	**Season**	Criteria/Text	TMDL
Calapooia River	0 to 42.8	Summer	Rearing: 17.8 C	Chapter 10
Ferguson Creek	0 to 10	Summer	Rearing: 17.8 C	Chapter 10
Long Tom River	0 to 24.2	Summer	Rearing: 17.8 C	Chapter 10
Marys River	0 to 13.9	Summer	Rearing: 17.8 C	Chapter 10
Muddy Creek	0 to 33	Summer	Rearing: 17.8 C	Chapter 10
South Fork Berry Creek	0 to 2.1	Summer	Rearing: 17.8 C	Chapter 10

Appendix 4.2 – 303(d) Listings and Data Summary for the Willamette Basin

Table 4.27 303(d) Listings for the Willamette Basin

Site Name	Site ID #	River Mile	Period of Exceedance Of Seven Day Moving Average of The Daily Maximum	Number of Exceedances During Season	Highest Value of the Seven Day Moving Average of The Daily Maximum
Middle Fork Willamette at Mouth	28724	0.1	06/16/2001 to 09/20/2001 07/07/2002 to 09/17/2002	92 49	21.7 19.6
Coast Fork Willamette at Goshen	14157500	5.4	Before 08/19/2001 to 10/04/2001 05/28/2202 to 09/23/2002	48+ 119	23.7++ 25.9
Willamette River at Springfield	10359	185	06/16/2001 to 09/21/2001 07/03/2002 to 09/16/2002	96 69	21.9 19.5
Willamette u/s of McKenzie	28723	177	Before 06/22/2001 to 09/19/2001 06/24/2002 to 09/16/2002	89+ 77	22.0* 19.6
TRIB – McKenzie near Coburg TRIB – McKenzie at Bellinger	10376 26757	(7) (15)	07/03/2002 to 08/17/2002 Before 07/09/01 to 08/14/2001 Between 07/04 and 07/28 to 08/02/2002	42 18+ 14+	20.3 19.5++ 19.7++
Willamette at Harrisburg	14166000	161	06/17/2001 to 09/18/2001 06/23/2002 to 09/14/2002	90 77	22.5 20.5
Willamette above Long Tom	26755	151	06/17/2001 to 09/18/2001 06/23/2002 to 09/14/2002	90 82	22.1 21.0
Willamette near River Mile 147	26753	147	06/17/2001 to 09/19/2001 06/23/2002 to 09/14/2002	91 84	22.1 21.4
TRIB – Long Tom near Mouth TRIB – Long Tom at Monroe	29644 14170000	(1) (6.7)	Before 06/04/2002 to After 09/28/2002 Before 08/16/2001 to 09/26/2001 05/23/2002 to 09/29/2002	117+ 47+ 133	27.2 24.0++ 24.7
Willamette below Long Tom	26772	141.7	06/16/2001 to 09/20/2001 Before 06/05/2002 to 09/16/2002	94 52+	22.4 21.2*
Willamette above Marys River	10353	134	06/16/2001 to 09/20/2001 06/22/2001 to 09/16/2002	96 87	22.8 21.6
TRIB – Marys at River Mile 0.5	26775	(0.5)	05/22/2001 to 09/24/2001 06/01/2002 to 09/25/2002	114 113	24.9 24.7
TRIB – Calapooia near Mouth	25450	(0.1)	Before 06/10/2001 to 09/13/2001 Before 06/10/2002 to 09/02/2002	86+ 85+	23.1* 23.2*
Willamette at Albany	14174000	119.3	Before 08/14/2001 to 09/21/2001 06/12/2002 to 09/16/2002	39+ 98	22.5++ 22.1
Willamette near River Mile 114	10349	113.5	Before 06/17/2001 to 09/19/2001 06/21/2001 to 09/16/2002	98+ 93	23.1* 22.4
TRIB – Santiam at Mouth	26756	(0.2)	06/19/2001 to 09/21/2001 07/05/2002 to 09/04/2002	87 62	23.3 22.1
TRIB – Luckiamute at RM 2.3	10658	(2.3)	06/17/2001 to After 09/21/2001 Before 06/17/2002 to After 07/14/2002	96+ 28+	24.9* 24.0++
Willamette at Buena Vista Ferry	10348	106	07/14/2002 to 09/05/2002	65	21.7

Site Name	Site ID #	River Mile	Period of Exceedance Of Seven Day Moving Average of The Daily Maximum	Number of Exceedances During Season	Highest Value of the Seven Day Moving Average of The Daily Maximum
Willamette at Independence	10347	96.1	Before 06/17/2001 to 09/24/2001 06/23/2002 to 09/16/2002	99+ 86	23.9* 22.3
Willamette above Rickreall Ck	28254	88.2	06/18/2001 to 09/23/2001 Before 07/13/2002 to 09/16/2002	96 67+	23.5 21.9++
TRIB – Rickreall Creek near Mouth	11102	(0.8)	05/22/2001 to 09/22/2001	114	23.7
TRIB – Mill Creek in Salem	26759	(2.2)	06/16/2001 to 09/22/2001 06/22/2002 to 09/03/2002	95 74	23.4 21.9
Willamette at Keizer/Salem	14192015	82.2	05/23/2001 to 09/24/2001 06/13/2002 to 09/16/2002	56+ 90	24.5++ 23.0
Willamette at Wheatland Ferry	10344	72	05/24/2001 to 09/25/2001 06/13/2002 to 09/17/2002	104 90	24.6 23.3
TRIB – Yamhill at Dayton	10363	(5)	Before 06/05/2001 to 09/29/2001 Before 06/17/2002 to 09/28/2002	117+ 103+	26.2* 25.0*
Willamette at Wilsonville	10340	38.5	Before 06/16/2001 to 09/29/2001 06/14/2002 to 09/27/2002	106+ 107	25.1* 24.4
TRIB – Molalla near Mouth	10637		Before 06/14/2002 to 09/26/2002	107+	26.2*
TRIB – Tualatin at West Linn	26773	1.8	Before 06/15/2001 to 09/30/2001 Before 06/08/2002 to 09/26/2002	108+ 102+	24.6* 25.3
Willamette above Willamette Falls	14207740	26.8	Before 08/12/2001 to 09/29/2001 06/13/2002 to 09/27/2002	49+ 107	24.5++ 23.8
TRIB – Clackamas near Oregon City	14211010	(1.6)	06/26/2002 to 09/06/2002	71	22.4
Willamette at Roehr Park	26745	20.57	Before 06/25/2001 to 09/29/2001 06/15/2002 to 09/27/2002	97+ 99	24.6* 24.0
Willamette near Deer Island	28506	18.76	Before 06/26/2001 to 10/01/2001 06/14/2002 to 09/28/2002	98+ 107	24.7* 24.4
Willamette above Johnson Creek	28507	17.76	Before 06/26/2001 to 09/30/2001	97+	24.3*
TRIB – Johnson Creek at Milwaukee	14211550	(0.7)	05/09/2001 to 09/24/2001	133	24.7* 23.6
Willamette below Johnson Creek	28508	17.56	Before 06/26/2001 to 10/01/2001	98+	24.7* 24.2
Willamette at Waverly Country Club	29747	17	06/15/2002 to 09/28/2002	104	24.0
Willamette at Portland gage	14211720	13	05/13/2002 to 09/28/2002	105	24.3
Willamette at St. John RR Bridge	28765	7	06/11/2002 to After 08/18/2002	69+	24.7*
Willamette above Oregon Steel Mills	29746		06/11/2002 to 10/01/2002	113	24.2
TRIB – Columbia Slough at	11201	(2.6)	Before 06/25/2001 to	102+	27.3*

Site Name	Site ID #	River Mile	Period of Exceedance Of Seven Day Moving Average of The Daily Maximum	Number of Exceedances During Season	Highest Value of the Seven Day Moving Average of The Daily Maximum
Landfill			10/04/2001 Before 05/17/2002 to 09/28/2002	135+	26.4*

"+" in the Number of Exceedances During Season column indicates that exceedances of seasonal criteria probably occurred prior to period of record.
"++" in the Highest Value of the Seven Day Moving Average of The Daily Maximum suggests that warmer maximum values may have occurred prior to the period of record.
"*"in the Highest Value of the Seven Day Moving Average of The Daily Maximum suggests that warmest maximum values likely were included in the period of record.

Appendix 4.3 – Temperature Rule

Temperature (OAR 340-041-0058)

(1) Background. Water temperatures affect the biological cycles of aquatic species and are a critical factor in maintaining and restoring healthy salmonid populations throughout the State. Water temperatures are influenced by solar radiation, stream shade, ambient air temperatures, channel morphology, groundwater inflows, and stream velocity, volume, and flow. Surface water temperatures may also be warmed by anthropogenic activities such as discharging heated water, changing stream width or depth, reducing stream shading, and water withdrawals.

(2) Policy. It is the policy of the Commission to protect aquatic ecosystems from adverse warming and cooling caused by anthropogenic activities. The Commission intends to minimize the risk to cold water aquatic ecosystems from anthropogenic warming, to encourage the restoration and protection of critical aquatic habitat, and to control extremes in temperature fluctuations due to anthropogenic activities. The Commission recognizes that some of the State's waters will, in their natural condition, not provide optimal thermal conditions at all places and at all times that salmonid use occurs. Therefore, it is especially important to minimize additional warming due to anthropogenic sources. In addition, the Commission acknowledges that control technologies, best management practices and other measures to reduce anthropogenic warming are evolving and that the implementation to meet these criteria will be an iterative process. Finally, the Commission notes that it will reconsider beneficial use designations in the event that man-made obstructions or barriers to anadromous fish passage are removed and may justify a change to the beneficial use for that water body.

(3) Purpose. The purpose of the temperature criteria in this rule is to protect designated temperature-sensitive, beneficial uses, including specific salmonid life cycle stages in waters of the State.

(4) Biologically-based Numeric Criteria. Unless superseded by the natural conditions criteria described in section (8) of this rule, or by subsequently adopted site-specific criteria approved by EPA, the temperature criteria for State waters supporting salmonid fishes are as follows:

(a) The seven-day-average maximum temperature of a stream identified as having salmon and steelhead spawning use on subbasin maps and tables set out in OAR 340-041-0101 to 340-041-0340: Tables 101B, and 121B, and Figures 130B, 151B, 160B, 170B, 220B, 230B, 271B, 286B, 300B, 310B, 320B, and 340B, may not exceed 13.0 degrees Celsius (55.4 degrees Fahrenheit) at the times indicated on these maps and tables;

(b) The seven-day-average maximum temperature of a stream identified as having core cold water habitat use on subbasin maps set out in OAR 340-041-101 to 340-041-340: Figures 130A, 151A, 160A, 170A, 220A, 230A, 271A, 286A, 300A, 310A, 320A, and 340A, may not exceed 16.0 degrees Celsius (60.8 degrees Fahrenheit);

(c) The seven-day-average maximum temperature of a stream identified as having salmon and trout rearing and migration use on subbasin maps set out at OAR 340-041-0101 to 340-041-0340: Figures 130A, 151A, 160A, 170A, 220A, 230A, 271A, 286A, 300A, 310A, 320A, and 340A, may not exceed 18.0 degrees Celsius (64.4 degrees Fahrenheit);

(d) The seven-day-average maximum temperature of a stream identified as having a migration corridor use on subbasin maps and tables OAR 340-041-0101 to 340-041-0340: Tables 101B, and 121B, and Figures 151A, 170A, and 340A, may not exceed 20.0 degrees Celsius (68.0 degrees Fahrenheit). In addition, these water bodies must have coldwater refugia that's sufficiently distributed so as to allow salmon and steelhead migration without significant adverse effects from higher water temperatures elsewhere in the water body. Finally, the seasonal thermal pattern in Columbia and Snake Rivers must reflect the natural seasonal thermal pattern;

(e) The seven-day-average maximum temperature of a stream identified as having Lahontan cutthroat trout or redband trout use on subbasin maps and tables set out in OAR 340-041-0101 to 340-041-0340: Tables 120B, 140B, 190B, and 250B, and Figures 180A, 201A, and 260A may not exceed 20.0 degrees Celsius (68.0 degrees Fahrenheit);

(f) The seven-day-average maximum temperature of a stream identified as having bull trout spawning and juvenile rearing use on subbasin maps set out at OAR 340-041-0101 to 340-041-0340: Figures 130B, 151B, 160B, 170B, 180A, 201A, 260A, 310B, and 340B, may not exceed 12.0 degrees Celsius (53.6 degrees Fahrenheit). From August 15 through May 15, in bull trout spawning waters below Clear Creek and Mehlhorn reservoirs on Upper Clear Creek (Pine Subbasin), below Laurance Lake on the Middle Fork Hood River, and below Carmen reservoir on the Upper McKenzie River, there may be no more than a 0.3 degrees Celsius (0.5 Fahrenheit) increase between the water temperature immediately upstream of the reservoir and the water temperature immediately downstream of the spillway when the ambient seven-day-average maximum stream temperature is 9.0 degrees Celsius (48 degrees Fahrenheit) or greater, and no more than a 1.0 degree Celsius (1.8 degrees Fahrenheit) increase when the seven-day-average stream temperature is less than 9 degrees Celsius.

(5) Unidentified Tributaries. For waters that are not identified on the fish use maps and tables referenced in section (4) of this rule, the applicable criteria for these waters are the same criteria as is applicable to the nearest downstream water body depicted on the applicable map.

(6) Natural Lakes. Natural lakes may not be warmed by more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) above the ambient condition unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life.

(7) Oceans and Bays. Except for the Columbia River above river mile 7, ocean and bay waters may not be warmed by more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) above the ambient condition unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life.

(8) Natural Conditions Criteria. Where the department determines that the natural thermal potential of all or a portion of a water body exceeds the biologically-based criteria in section (4) of this rule, the natural thermal potential temperatures supersede the biologically-based criteria, and are deemed to be the applicable temperature criteria for that water body.

(9) Cool Water Species. Waters that support cool water species may not be warmed by more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) above the ambient condition unless a greater increase would not reasonably be expected to adversely affect fish or other aquatic life. Cool waters of the State are described on subbasin tables set out in OAR 340-041-0101 to 340-041-0340: Tables 140B, 180B, 201B, and 250B.

(10) Borax Lake Chub. State waters in the Malheur Lake Basin supporting the borax lake chub may not be cooled more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) below the ambient condition.

(11) Protecting Cold Water.

(a) Except as described in subsection (c) of this rule, waters of the State that have summer seven-day-average maximum ambient temperatures that are colder than the biologically-based criteria in section (4) of this rule, may not be warmed by more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) above the colder water ambient temperature. This provision applies to all sources taken together at the point of maximum impact where salmon, steelhead or bull trout are present.

(b) A point source that discharges into or above salmon & steelhead spawning waters that are colder than the spawning criteria, may not cause the water temperature in the spawning reach where the physical habitat for spawning exists during the time spawning through emergence use occurs, to increase more than the following amounts after complete mixing of the effluent with the river:

(A) If the rolling 60 day average maximum ambient water temperature, between the dates of spawning use as designated under subsection (4)(a) of this rule, is 10 to 12.8 degrees Celsius, the allowable increase is 0.5 Celsius above the 60 day average; or

(B) If the rolling 60 day average maximum ambient water temperature, between the dates of spawning use as designated under subsection (4)(a) of this rule, is less than 10 degrees Celsius, the allowable increase is 1.0 Celsius above the 60 day average, unless the source provides analysis showing that a greater increase will not significantly impact the survival of salmon or steelhead eggs or the timing of salmon or steelhead fry emergence from the gravels in downstream spawning reach.

(c) The cold water protection narrative criteria in subsection (a) does not apply if:

(A) There are no threatened or endangered salmonids currently inhabiting the water body;

(B) The water body has not been designated as critical habitat; and

(C) The colder water is not necessary to ensure that downstream temperatures achieve and maintain compliance with the applicable temperature criteria.

(12) Implementation of the Temperature Criteria.

(a) Minimum Duties. There is no duty for anthropogenic sources to reduce heating of the waters of the State below their natural condition. Similarly, each anthropogenic point and nonpoint source is responsible only for controlling the thermal effects of its own discharge or activity in accordance with its overall heat contribution. In no case may a source cause more warming than that allowed by the human use allowance provided in subsection (b) of this rule.

(b) Human Use Allowance. Insignificant additions of heat are authorized in waters that exceed the applicable temperature criteria as follows:

(A) Prior to the completion of a temperature TMDL or other cumulative effects analysis, no single NPDES point source that discharges into a temperature water quality limited water may cause the temperature of the water body to increase more than 0.3 degrees Celsius (0.5 Fahrenheit) above the applicable criteria after mixing with either twenty five (25) percent of the streamflow, or the temperature mixing zone, whichever is more restrictive; or

(B) 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.

(C) Point sources must be in compliance with the additional mixing zone requirements set out in OAR 340-041-0053(2)(d).

(D) A point source in compliance with the temperature conditions of its NPDES permit is deemed in compliance with the applicable criteria.

(c) Air Temperature Exclusion. A water body that only exceeds the criteria set out in this rule when the exceedance is attributed to daily maximum air temperatures that exceed the 90th percentile value of annual maximum seven-day average maximum air temperatures calculated using at least 10 years of air temperature data, will not be listed on the section 303(d) list of impaired waters and sources will not be considered in violation of this rule.

(d) Low Flow Conditions. An exceedance of the biologically-based numeric criteria in section (4) of this rule, or an exceedance of the natural condition criteria in section (8) of this rule will not be considered a permit violation during streamflows that are less than the 7Q10 low flow condition for that water body.

(e) Forestry on State and Private Lands. For forest operations on State or private lands, water quality standards are intended to be attained and are implemented through best management practices and other control mechanisms established under the Forest Practices Act (ORS 527.610 to 527.992) and rules there under, administered by the Oregon Department of Forestry. Therefore, forest operations that are in compliance with the Forest Practices Act requirements are (except for the limits set out in ORS 527.770) deemed in compliance with this rule. ODEQ will work with the Oregon Department of Forestry to revise the Forest Practices program to attain water quality standards.

(f) Agriculture on State and Private Lands. For farming or ranching operations on State or private lands, water quality standards are intended to be attained and are implemented through the Agricultural Water Quality Management Act (ORS 568.900 to 568.933) and rules there under, administered by the Oregon Department of Agriculture. Therefore, farming and ranching operations that are in compliance with the Agricultural Water Quality Management Act requirements will not be subject to ODEQ enforcement under this rule. ODEQ will work with the Oregon Department of Agriculture to revise the Agricultural Water Quality Management program to attain water quality standards.

(g) Agriculture and Forestry on Federal Lands. Agriculture and forestry activities conducted on federal land must meet the requirements of this rule and are subject to the department's jurisdiction. Pursuant to Memoranda of Agreement with the U.S. Forest Service and the Bureau of Land Management, water quality standards are expected to be met through the development and implementation of water quality restoration plans, best management practices and aquatic conservation strategies. Where a Federal Agency is a Designated Management Agency by the Department, implementation of these plans, practices and strategies is deemed compliance with this rule.

(h) Other Nonpoint Sources. The department may, on a case-by-case basis, require nonpoint sources (other than forestry and agriculture), including private hydropower facilities regulated by a 401 water quality certification, that may contribute to warming of State waters beyond 0.3 degrees Celsius (0.5 degrees Fahrenheit), and are therefore designated as water-quality limited, to develop and implement a temperature management plan to achieve compliance with applicable temperature criteria or an applicable load allocation in a TMDL pursuant to OAR 340-042-0080.

(A) Each plan must ensure that the nonpoint source controls its heat load contribution to water temperatures such that the water body experiences no more than a 0.3 degrees Celsius (0.5 degree Fahrenheit) increase above the applicable criteria from all sources taken together at the maximum point of impact.

(B) Each plan must include a description of best management practices, measures, effluent trading, and control technologies (including eliminating the heat impact on the stream) that the nonpoint source intends to use to reduce its temperature effect, a monitoring plan, and a compliance schedule for undertaking each measure.

(C) The Department may periodically require a nonpoint source to revise its temperature management plan to ensure that all practical steps have been taken to mitigate or eliminate the temperature effect of the source on the water body.

(D) Once approved, a nonpoint source complying with its temperature management plan is deemed in compliance with this rule.

(i) Compliance Methods. Anthropogenic sources may engage in thermal water quality trading in whole or in part to offset its temperature discharge, so long as the trade results in at least a net thermal loading decrease in anthropogenic warming of the water body, and does not adversely affect a threatened or endangered species. Sources may also achieve compliance, in whole or in part, by flow augmentation, hyporheic exchange flows, outfall relocation, or other measures that reduce the temperature increase caused by the discharge.

(ii) Release of Stored Water. Stored cold water may be released from reservoirs to cool downstream waters in order to achieve compliance with the applicable numeric criteria. However, there can be no significant adverse impact to downstream designated beneficial uses as a result of the releases of this cold water, and the release may not contribute to violations of other water quality criteria. Where the Department determines that the release of cold water is resulting in a significant adverse impact, the Department may require the elimination or mitigation of the adverse impact.

(13) Site-Specific Criteria. The Department may establish, by separate rulemaking, alternative site-specific criteria for all or a portion of a water body that fully protects the designated use.

(a) These site-specific criteria may be set on a seasonal basis as appropriate.

(b) The Department may use, but is not limited by the following considerations when calculating site-specific criteria:

(A) Streamflow;

(B) Riparian vegetation potential;

(C) Channel morphology modifications;

(D) Cold water tributaries and groundwater;

(E) Natural physical features and geology influencing stream temperatures; and

(F) Other relevant technical data.

(c) ODEQ may consider the thermal benefit of increased flow when calculating the site-specific criteria.

(d) Once established and approved by EPA, the site-specific criteria will be the applicable criteria for the water bodies affected.

Stat. Auth.: ORS 468.020, 468B.030, 468B.035, 468B.048
Stats. Implemented: ORS 468B.030, 468B.035, 468B.048
Hist.: ODEQ 17-2003, f. & cert. ef. 12-9-03

Appendix 4.4 – Model Simulations Summary

Table 4.28 Model simulations

Sim No.	Current or System Potential	Year	Description
1	Current (Calibration)	2001	2001 calibration conditions
2	Current (Calibration)	2002	2002 calibration conditions
3	System potential 1	2001	No point sources
4	System potential 1	2001	Point sources, current
5	System potential 1	2001	Point sources, design
6	System potential 2	2001	No point sources
7	System potential 2	2001	Point sources, current
8	System potential 2	2001	Point sources, design
9	System potential 1	2002	No point sources
10	System potential 1	2002	Point sources, current
11	System potential 1	2002	Point sources, design
12	System potential 2	2002	No point sources
13	System potential 2	2002	Point sources, current
14	System potential 2	2002	Point sources, design
15	Current [1]	2001	with 20% boundary flow rate reduction
16	Current [1]	2001	with 20% boundary flow rate increase
17	Current [1]	2001	with upstream boundary flow rates set to NFMS biological opinion flow rates
18	Current [1]	2001	with 5°C boundary temperature reduction
19	Current [1]	2001	with 5°C boundary temperature increase
20	Current [1]	2001	with no vegetative shade
21	Current [1]	2001	with system potential vegetative shade
22	System potential 1	2002	Point sources, design flow, WLA based on 25% of river flow (Same as Sim 11 except for changes in effluent temperatures and flows and addition of U of O discharge)
23	System potential 1	2002	Point sources, design flow, WLA based on 100% of river flow (Same as Sim 22 except for changes in effluent temperatures and flows)
24	System potential 1	2002	Point sources, design flow, WLA based on 100% of river flow and temperature increase at the point of discharge of 0.25°C using monthly minimum river temperatures. (Same as Sim 23 except for changes in effluent temperatures and flow rates and the addition of flow diversion for most industrial facilities)

Sim No.	Current or System Potential	Year	Description
25	System potential 1	2002	Point sources, design flow, WLA based on 100% of river flow and temperature increase at the point of discharge of 0.25^{o}C using monthly 25th percentile river temperatures (Same as Sim 24 except for changes in effluent temperatures)
26	System potential 1	2002	Point sources, current (update of Sim 10 to reflect addition of flow diversion for most industrial facilities and U of O discharge)
27	System potential 1	2002	Point sources, design flow, WLA cumulative impact iteration (Same as Sim 25 except for changes in effluent temperatures and/or flows)
28	System potential 1	2002	Point sources, design flow, WLA cumulative impact iteration. (Same as Sim 27 except for changes in effluent temperatures and/or flows)
29	System potential 1	2002	Point sources, design flow, WLA cumulative impact iteration. (Same as Sim 28 except for changes in effluent temperatures and/or flow)
30	System potential 1	2002	Point sources, design flow, WLA cumulative impact iteration. Repeat of Sim 29 but with No Cap on Willamette Falls (same WLAs as Sim 29).
31	System Potential 3	2001	No point sources
32	System Potential 3	2002	No point sources
33	System Potential 3	2001	Simulations 33 and 34 are the same as Simulations 31 and 32, except that point source flow rates and temperatures are set to potential “flow based” wasteload allocations Wasteload allocations at all river flows are based on a single permitted delta T impact. This delta T impact is derived from the change in temperature calculated at 7Q10 low flow with the maximum monthly discharge multiplied by an explicit growth factor. An additional discharge, Teledyne Wah Chang, was found to be significant and, therefore, was added to the model.
34	System Potential 3	2002	
35	System Potential 3	2001	Simulations were performed to determine if calculated “delta Ts” due to point sources were sensitive to point source impacts on time of travel. Simulation 35 is identical to Simulation 33 (2001, SysPot 3, Flow based WLAs), except that flow rates equal to effluent flow rates were diverted for all point sources, not just for select industrial discharges. Since the results of Sim 35 for the Coast Fork and the Upper Willamette were very similar to Sim 33, it was determined that the calculated delta Ts are not sensitive to effluent time-of-travel impacts. Therefore, Sim 35 was not run for other reaches and Sim 36 was also not run.
36	System Potential 3	2002	
37	System Potential 3	2001	For these simulations, the Middle Willamette was modeled with the Willamette Falls project active (both flashboards and cap present) (for Simulations 31 to 36 neither flashboards nor cap were present). No point source discharges were included for these simulations, so they are the same as Sims 31 and 32, but with the Falls project active.
38	System Potential 3	2002	
39	System Potential 3	2001	Simulations 39 (year 2001) and 40 (year 2002) are the same as Simulations 33 and 34, except they are calculated using updated point source flow rates and temperatures to those obtained from the request for 1999-2004 effluent data sets.
40	System Potential 3	2002	
41	System Potential 3	2001	Same as Simulations 39 and 40 except U of O and MWMC pt. sources flow rates set to zero.
42	System Potential 3	2002	
43	System Potential 3	2001	Point sources set to latest estimate of 2001 and 2002 “current condition” effluent characteristics. These are the same as Sim 31

Sim No.	Current or System Potential	Year	Description
44	System Potential 3	2002	and 32 except that point sources are included at current conditions. Note that Sim 44 not run, but sim number is reserved.
45	System Potential 3	2001	Point source WLA iteration. Simulations 45 (year 2001) and 46 (year 2002). These are similar to Sim 39/40 except WLAs include ramped “delta Ts”, in which the permitted delta T impact is reduced exponentially as river flow is increased from that at 7Q10 low flow to an explicit delta T impact at 7Q5 high flow.
46	System Potential 3	2002	
47	System Potential 3	2001	Sims are revision of Sim 31 with boundary condition temperature changed to constant monthly NTP values. Sim 47A is reserved for a rerun of original NTP numbers (25th percentiles by JBloom to provide MOS). Sim 47B is the set of simulations using revised NTP numbers (medians by ESmith). Only Sim 47B run.
48	System Potential 3	2002	
49	System Potential 3	2001	Point source WLA iteration. Simulations 49 (year 2001) and 50 (year 2002). These WLAs included linear ramped “delta Ts”, in which the permitted delta T impact is adjusted based on a liner interpolation from explicit scaling factors at 7Q10 low flow and 7Q5 high river flow. WLAs are ramped “delta Ts”, in which the permitted delta T impact is derived from linearly increasing the scaling factor as river flow is increased from that at 7Q10 low flow to an explicit scaling factor at 7Q5 high flow. The calculation is slightly different from Sim 45/46 but the effect is similar on the permitted delta T impacts.
50	System Potential 3	2002	
51	System Potential 3	2001	Point source WLA iteration. Simulations 51 (year 2001) and 52 (year 2002) are the same as Simulations 49/50, except that another set of explicit scaling factors are tried.
52	System Potential 3	2002	
53	System Potential 3	2001	Point source WLA iteration. Simulations 53 (year 2001) and 54 (year 2002) are the same as Simulations 49/50, and 51/54 except that another set of explicit scaling factors are tried. Also, in this scenario an adjustment factor is applied to the flow based scaling factors to reduce permitted cumulative delta t impacts when there are excessive cooler nighttime river temperatures.
54	System Potential 3	2002	
55	System Potential 3	2001	Point source WLA iteration. Simulations 55 (year 2001) and 56 (year 2002). Wasteload allocations are monthly permitted delta T impacts derived from monthly 7Q10 low flows and effluent discharges set to the monthly maximum observed 1999-2004 effluent discharge data + 1.05 and 1.12 growth in effluent flow. This simulation is similar to simulation 29 and used as a comparison with the October 2004 draft wasteload allocations.
56	System Potential 3	2002	
57	System Potential 3	2001	Point source WLA iteration. Simulations 57 (year 2001) and 58 (year 2002) are the same as simulation 55/56 except the permitted delta T impacts are derived from effluent discharge set to the monthly maximum observed 1999-2004 effluent discharge data with no growth.. This simulation was used to determine if the maximum observed discharge can meet the cumulative human use allowance.
58	System Potential 3	2002	
59	System Potential 3	2001	UW/MCK/CF point source WLA iteration. Simulations 59 (year 2001) and 60 (year 2002) are the same as simulation 57/58 except Weyerhaeuser Springfield discharge is set to zero.
60	System Potential 3	2002	
61	System Potential 3	2001	UW/MCK/CF point source WLA iteration. Simulations 61 (year 2001) and 62 (year 2002) are the same as simulation 53/54 except another set of explicit scaling factors are tried and the adjustment factor equation is refined.
62	System Potential 3	2002	
63	System	2001	UW/MCK/CF point source WLA iteration. Simulations 63 (year 2001)

Sim No.	Current or System Potential	Year	Description
	Potential 3		and 64 (year 2002) are the same as simulation 61/62 except another set of explicit scaling factors are tried.
64	System Potential 3	2002	
65	System Potential 3	2001	UW/MCK/CF point source WLA iteration. Simulations 65 (year 2001) and 66 (year 2002) are the same as simulation 61/62 except another set of explicit scaling factors are tried. These are the UW/MCK/CF waste load allocations for the March 2006 draft TMDL. Point source WLA for the MW/LW are the same as simulation 33/34. Sim 65X/66X have MW/LW waste load allocations set to zero.
66	System Potential 3	2002	
67	System Potential 3	2001	MW/LW point source WLA iteration. Simulations 67 (year 2001) and 68 (year 2002) are the same as simulation 33/34 except the scaling factor is 0.667 from design flows. Effluent temperatures are the same as Sim 33/34.
68	System Potential 3	2002	
69	System Potential 3	2001	MW/LW point source WLA iteration. Simulations 69 (year 2001) and 70 (year 2002) have the same equations as simulation 65/66 except inputs are based on daily averages (24 equal inputs), Canby WWTP and OMSI are removed (moved to small point source bubble), and another set of explicit growth multipliers are tried for the remaining MW/LW point sources. The Clackamas Sim 70 point source has a non-flow based waste load allocation which is the waste load allocation for the March 2006 draft TMDL. 1999-2004 data sets have been incorporated into maximum effluent discharges.
70	System Potential 3	2002	
71	System Potential 3	2001	MW/LW point source WLA iteration. Simulations 71 (year 2001) and 72 (year 2002) are the same as simulation 69/70 except another set of explicit scaling factors are tried.
72	System Potential 3	2002	
73	System Potential 3	2001	Simulations 73 (year 2001) and 74 (year 2002) are the similar to simulation 37/38 with the Willamette Falls Project flashboards and cap present but the point sources waste load allocations on the UW/Mck/CF are the same as Sim 65/66 and the MW/LW are the same as Sim 71/72.
74	System Potential 3	2002	
75	System Potential 3	2001	MW/LW point source WLA iteration. Simulations 75 (year 2001) and 76 (year 2002) are the same as simulation 71/72 except sources in the MW upstream of the Newberg Pool have a different set of explicit scaling factors. There is also 75TOT/76TOT simulation which is exactly the same as Sim 75/76 but has time of travel effects removed.
76	System Potential 3	2002	
77	System Potential 3	2001	MW/LW point source WLA iteration. Simulations 77 (year 2001) and 78 (year 2002) are the same as simulation 71/72 except time of travel effects have been removed and there are a different set of explicit scaling factors.
78	System Potential 3	2002	
79	System Potential 3	2001	MW/LW point source WLA iteration. Simulations 79 (year 2001) and 80 (year 2002) are model runs with point source discharge at design flows and 1999-2004 maximum monthly effluent temperatures.
80	System Potential 3	2002	
81	System Potential 3	2001	Simulations 81 (year 2001) and 82 (year 2002) are the same as simulation 31/32 except updates to the model were made based on PSU model updates. Sims 81/82 are now redundant simulations because Simulation 31/32 were rerun with the new model revisions.
82	System Potential 3	2002	
83	System Potential 3	2001	MW/LW point source WLA iteration. Simulations 83 (year 2001) and 84 (year 2002) are the same as simulation 79/80 except the LW point sources use Sim 77/78 waste load allocations.
84	System Potential 3	2002	

Sim No.	Current or System Potential	Year	Description
85	System Potential 3	2001	MW/LW point source WLA iteration. Simulations 85 (year 2001) and 86 (year 2002) are the same as simulation 77/78 except MW/LW point source waste load allocations use a different set of explicit scaling factors.
86	System Potential 3	2002	
87	System Potential 3	2001	MW/LW point source WLA iteration. Simulations 87 (year 2001) and 88 (year 2002) are the same as simulation 77/78 except MW/LW point source waste load allocations use a different set of explicit scaling factors. These are the MW/LW waste load allocations for the March 2006 draft TMDL. There is also LW Sim 87CAP/88CAP which is the same as Sim 87/88 except the Willamette Falls Project flashboards and cap present.
88	System Potential 3	2002	
89	System Potential 3	2001	A McK/UW/MW/LW point source WLA iteration. Simulations 89 (year 2001) and 90 (year 2002) are the same as McK/UW simulation 65/66 and MW/LW 87/88 except the adjustment factor "a" has been eliminated.
90	System Potential 3	2002	
91	System Potential 3	2001	A McK/UW point source WLA iteration. All WLA discharges are set to Sims 65/66 maximum observed effluent discharge.
92	System Potential 3	2002	

[1] Current conditions except for deviation described in "Description" column

Table 4.29 Special model simulations

Special Sim No.	Current or System Potential	Year	Description
1	System potential 1	2002	McKenzie R only. Evaluates the impact of early morning effluent temperature (Weyco Springfield) on river temperature.
2	System potential 1	2002	McKenzie R only. Evaluates the impact of diverting an amount of flow upstream of the Weyco Springfield discharge equal to the effluent flow rate.
3	System potential 1	2002	McKenzie R only. Evaluates the combined impact of effluent temperature variation used in Spec Sim 1 and flow diversion used in Spec Sim 2.
4	Calibration	2001	McKenzie R EWEB project impact. Same as Sim 1 (as downloaded from PSU web page). Both canals operational
5	Calibration	2001	McKenzie R "no EWEB project" scenario. Same as Sim 4 except canals removed.
6	System potential 1 (see footnote)	2002	McKenzie R "no EWEB project" scenario (canals removed). Willamette Falls – no cap or flashboards. No point sources. Entire River modeled.
7	System potential 1	2002	McKenzie R EWEB project impact. Both canals active (in 2002 Walterville inactive, canal made operational for simulation). No point sources. Modeled thru Upper Willamette
8	System potential 1	2002	Both McKenzie R EWEB project canals active. Effluent WLAs at Sim 28 allocations (along with Sim 28 industrial diversions).
9	System potential 1	2002	Both McKenzie R EWEB project canals active. Willamette Falls – cap and sideboards active (as in normal System Potential 1 simulations). Effluent WLAs at Sim 29 allocations. Entire River modeled
10	System potential 1	2002	McKenzie R "no EWEB project" scenario (canals removed). Effluent WLAs at Sim 29 allocations.
11	Calibration	2001	Uses version of Clackamas River model provided by PGE

Special Sim No.	Current or System Potential	Year	Description
			(LC_Existing_051504) with Clackamas upper boundary at River Mill Dam at 2001 “current” conditions. (only run for Clackamas and Lower Willamette)
12	Calibration	2001	Uses version of Clackamas River model provided by PGE (LC_Existing_051504) with Clackamas upper boundary at River Mill Dam changed to 2001 “natural thermal potential” conditions (LC_NTP_031204). (only run for Clackamas and Lower Willamette)
13	Calibration	2001	Uses version of Clackamas River model provided by PGE (LC_Existing_051504) with Clackamas upper boundary at River Mill Dam temperature changed to 2001 “natural thermal potential” conditions (LC_NTP_031204) but flow kept at 2001 “current” conditions.
14	System potential 2	2000-2001	Uses version of Clackamas R model provided by PGE (LC_NTP_031204) w/ shade changed to system potential shade. Boundary temperature at natural thermal potential. No pt. sources.
15	System potential 2	2000-2001	Uses version of Clackamas R model provided by PGE (LC_NTP_031204) w/ shade changed to system potential shade. Boundary temperature at natural thermal potential. Pt. sources set to WLA.
16	System potential 2	2000-2001	Uses version of Clackamas R model provided by PGE (LC_NTP_031204) w/ shade changed to system potential shade. Boundary temperature at current calibration condition for 2000-2001. No pt. sources.
17	System potential 2	2000-2001	Uses version of Clackamas R model provided by PGE (LC_NTP_031204) w/ shade changed to system potential shade. Boundary temperature at current calibration condition for 2000-2001. Pt. sources set to WLA.
18	System potential 2	2000-2001	Uses version of Clackamas R model provided by PGE (LC_NTP_031204) w/ shade changed to system potential shade. Boundary temperature at potential boundary temperature target. Pt. sources set to WLA.
19	System potential 2	2000-2001	Uses version of Clackamas R model provided by PGE (LC_NTP_031204) w/ shade changed to system potential shade. Boundary temperature at 24hr average of natural thermal potential. No pt. sources.
22	System Potential 3	2001	Special Simulations 22A through 22H quantify individual point source Sim 39 WLA impacts. For example, Spec Sim 22A evaluates the impact of only Weyerhaeuser Springfield. 22B only U of O, 22C only MWMC, 22D only Pope Talbot, 22E only Weyerhaeuser Albany, 22F only Teledyne Wah Chang, 22G only Albany WWTP, and 22H only Corvallis WWTP.
23	System Potential 3	2001	Tests to evaluate sensitivity of Upper Willamette R temperature to changes in distributed tributary inflow temperatures. For Sim 23A distributed inflows two_399BrX.npt set equal to McKenzie R Sim 43 outflow T (which includes the heat load from Weyco Springfield), while for Sim 23B distributed inflows two_399BrX.npt set equal to McKenzie R Sim 31 outflow T (which does not include heat load from Weyco Springfield).
24	System Potential 3	2001	This is same as Sim 39 except that for Weyco Springfield. All point sources are set to Sim 39 WLAs except Weyco Springfield, which is set to 2001 “current condition” flow and temperature. This indicated that standards would likely be met for this scenario.

Special Sim No.	Current or System Potential	Year	Description
25	System Potential 3		Miscellaneous test run.
26	System Potential 3		Miscellaneous test run.
27	System Potential 3	2001	Special Simulation 27 for the McKenzie River and Upper Willamette to evaluate flow based WLA with test ramping (5 breaks 0.25-0.15).
30	System Potential 3		McKenzie R modeled for 2002 w/ 2 side channels (in 2002 only 1 channel active). This is same as Sim 32 except that 2 side channels active (whereas, for Sim 32, neither channel was active). As with Sim 32, updated May 2004 mainstem bathymetry was used, boundary condition flow rates were set to 2002 current conditions, shade set to system potential, and no pt. sources. Comparison of Special Sim 30 to Sim 32 shows the impacts of the PGE Leaburg and Walterville hydroelectric projects on temperature. The source of the 2 side channel model is Spec Sim 7, except that mainstem bathymetry updated to May 2004. Note that instabilities associated with running with 2 side channels at 2002 CC boundary conditions caused some problems which required minor time step revisions.
Special Simulations 6 thru 10 use System Potential 1 except for McKenzie EWEB project, as described above. Special Simulation 6 also deviates from System Potential 1 by removing cap and flashboards from Willamette Falls. Special Sims 1-5, 8 and 10 only modeled McKenzie. Others modeled part or all of Willamette, as shown.			

APPENDIX 4.5 - POINT SOURCE WASTE LOAD ALLOCATIONS AND METHODOLOGY

Willamette Basin Waste Load Allocation Tables

ALBANY WWTP
Willamette River Mile 119.0
NPDES WQ File Number 1098
USGS Flow Gage 14174000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	m	b
(cfs)	(Celsius)	(Celsius)	(cfs)		
3980	18.0	23.7	8.51	0.00007258	0.6511

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.0114	111	0.0097	95
4478	18.0	0.0106	116	0.0091	100
4838	18.0	0.0100	119	0.0086	102
5013	18.0	0.0098	120	0.0085	104
5388	18.0	0.0094	124	0.0081	107
6738	18.0	0.0082	135	0.0072	119
23734	18.0	0.0048	279	0.0046	267

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	m	b
(cfs)	(Celsius)	(Celsius)	(cfs)		
4160	13.0	23.7	8.51	0.00007653	0.4616

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.0170	173	0.0103	105
5338	13.0	0.0148	194	0.0096	126
5642	13.0	0.0144	199	0.0094	130
8855	13.0	0.0117	254	0.0085	184
9810	13.0	0.0112	269	0.0084	202
12999	13.0	0.0102	325	0.0080	255
46020	13.0	0.0079	890	0.0073	822

BLUE HERON PAPER
Willamette River Mile 27.5
NPDES WQ File Number 72634
USGS Flow Gage 14211720 - 14210000

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
5440	20.0	32.2	15.31	16.24

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal Load (Million Kcals/Day)
0	20.0	0.0363	485

No flow based WLA formula is provided. Facility design flow (Q_{DF}) is limiting. Waste Load Allocation is calculated using facility design flow.

ODFW CLACKAMAS RIVER HATCHERY
Clackamas River Mile 22.6
NPDES WQ File Number 4442
USGS Flow Gage 14210000

JUNE 16 - AUG 31 Core Cold-Water Habitat

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
693	16.0	19.6	see footnote	44.55

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal load (Million Kcals/Day)
0	16.0	0.0300	51

No data was available to determine Q_{PS}.

SEPT 1 - JUNE 15 Salmon & Steelhead Spawning Use

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
662	13.0	19.6	see footnote	44.55

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal load (Million Kcals/Day)
0	13.0	0.0300	49

CORVALLIS WWTP
Willamette River Mile 130.8
NPDES WQ File Number 20151
USGS Flow Gage 14166000 + 14170000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
3670	18.0	22.9	11.29	0.00007816	0.6532

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.0141	127	0.0120	108
3871	18.0	0.0136	129	0.0116	110
4074	18.0	0.0132	132	0.0113	113
4687	18.0	0.0120	138	0.0104	120
4918	18.0	0.0116	140	0.0101	122
5728	18.0	0.0106	149	0.0093	131
17141	18.0	0.0064	269	0.0060	252

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
3810	13.0	22.9	11.29	0.00009786	0.4072

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.0228	213	0.0138	129
5157	13.0	0.0197	249	0.0131	166
5388	13.0	0.0193	255	0.0130	172
8074	13.0	0.0165	327	0.0123	243
8841	13.0	0.0161	349	0.0122	264
11999	13.0	0.0147	432	0.0118	347
31500	13.0	0.0124	957	0.0113	872

COTTAGE GROVE WWTP
Coast Fork Willamette River Mile 21.5
NPDES WQ File Number 20306
USGS Flow Gage 14153500

MAY 16 - DEC 31 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
39	18.0	21.7	1.24	0.00086074	0.9064

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.1074	11	0.0919	9
47	18.0	0.0902	11	0.0772	9
48	18.0	0.0884	11	0.0758	9
53	18.0	0.0806	11	0.0691	9
69	18.0	0.0631	11	0.0542	9
145	18.0	0.0323	12	0.0280	10
3294	18.0	0.0052	42	0.0050	40

JAN 01 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
34	13.0	21.7	1.24	0.00245885	0.6964

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.2406	21	0.1473	13
71	13.0	0.1304	23	0.0847	15
72	13.0	0.1289	23	0.0839	15
74	13.0	0.1262	23	0.0824	15
74	13.0	0.1262	23	0.0824	15
78	13.0	0.1211	23	0.0795	15
1239	13.0	0.0325	99	0.0298	91

EVANITE
Willamette River Mile 132.2
NPDES WQ File Number 28476
USGS Flow Gage 14166000 + 14170000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
3670	18.0	25.7	0.93	0.00004130	0.6984

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.0017	15	0.0014	13
3871	18.0	0.0016	15	0.0013	12
4074	18.0	0.0015	15	0.0013	13
4687	18.0	0.0014	16	0.0012	14
4918	18.0	0.0013	16	0.0011	13
5728	18.0	0.0012	17	0.0010	14
667565	18.0	0.0003	490	0.0003	490

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
3810	13.0	25.7	0.93	0.00005022	0.2987

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.0015	14	0.0006	6
5157	13.0	0.0013	16	0.0006	8
5388	13.0	0.0012	16	0.0006	8
8074	13.0	0.0010	20	0.0006	12
8841	13.0	0.0010	22	0.0006	13
11999	13.0	0.0009	26	0.0006	18
556952	13.0	0.0006	818	0.0006	818

FORT JAMES HALSEY
Willamette River Mile 148.4
NPDES WQ File Number 105814
USGS Flow Gage 14166000 + 14170000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10 (cfs)	T_{RC} (Celsius)	T_{PS} (Celsius)	Q_{PS} (cfs)	*m*	*b*
3670	18.0	30.0	6.19	0.00004130	0.6984

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.0172	155	0.0144	129
3910	18.0	0.0163	156	0.0137	131
4270	18.0	0.0152	159	0.0128	134
4794	18.0	0.0139	163	0.0117	137
4969	18.0	0.0135	164	0.0114	139
5811	18.0	0.0120	171	0.0102	145
25335	18.0	0.0051	316	0.0047	291

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10 (cfs)	T_{RC} (Celsius)	T_{PS} (Celsius)	Q_{PS} (cfs)	*m*	*b*
3810	13.0	30.0	6.19	0.00005022	0.2987

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.0135	126	0.0050	47
5128	13.0	0.0114	143	0.0051	64
5417	13.0	0.0111	147	0.0051	68
7886	13.0	0.0093	180	0.0052	100
8516	13.0	0.0090	188	0.0052	108
11735	13.0	0.0080	230	0.0052	149
28794	13.0	0.0064	451	0.0052	366

JEFFERSON WWTP
Santiam River Mile 9.3
NPDES WQ File Number 43129
USGS Flow Gage 14189000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

7Q10 (cfs)	T_{RC} (Celsius)	T_{PS} (Celsius)	Q_{PS} (cfs)	Q_{DF} (cfs)
1010	18.0	23.0	0.31	0.93

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA Allowed Temperature Increase (Celsius)	WLA Excess Thermal load (Million Kcals/Day)
0	18.0	0.0030	7

No flow based WLA formula is provided. Facility design flow (Q_{DF}) is limiting. Waste Load Allocation is calculated using facility design flows multiplied by 1.5.

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

7Q10 (cfs)	T_{RC} (Celsius)	T_{PS} (Celsius)	Q_{PS} (cfs)	Q_{DF} (cfs)
1960	13.0	21.0	0.31	see footnote

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA Dry Weather Allowed Temperature Increase (Celsius)	WLA Dry Weather Excess Thermal load (Million Kcals/Day)	HUA Wet Weather Allowed Temperature Increase (Celsius)	WLA Wet Weather Excess Thermal load (Million Kcals/Day)
0	13.0	0.0024	12	0.0076	36

Q_{DF} during Dry Weather period is 0.93 cfs. Q_{DF} during Wet Weather Period is 1.86 cfs.

KELLOGG CREEK WWTP
Willamette River Mile 18.7
NPDES WQ File Number 16590
USGS Flow Gage 14211720

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

Equation WLA

7Q10 (cfs)	T_{RC} (Celsius)	T_{PS} (Celsius)	Q_{PS} (cfs)	*m*	*b*
6290	20.0	23.3	10.36	0.00004520	0.9657

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	20.0	0.0068	105	0.0062	96
8789	20.0	0.0053	114	0.0049	106
9955	20.0	0.0049	119	0.0045	110
11165	20.0	0.0045	123	0.0042	115
13049	20.0	0.0041	131	0.0038	121
18440	20.0	0.0033	149	0.0031	140
28179	20.0	0.0027	186	0.0026	179

LEBANON WWTP
South Santiam River Mile 15.9
NPDES WQ File Number 49764
USGS Flow Gage 14187500 - 14187600

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
510	18.0	21.8	3.71	6.96

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA Allowed Temperature Increase (Celsius)	WLA Excess Thermal load (Million Kcals/Day)
0	18.0	0.0512	65

No flow based WLA formula is provided. Facility design flow (Q_{DF}) is limiting. Waste Load Allocation is calculated using facility design flows multiplied by 1.5.

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
665	13.0	19.5	3.71	see footnote

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA Dry Weather Allowed Temperature Increase (Celsius)	WLA Dry Weather Excess Thermal load (Million Kcals/Day)	HUA Wet Weather Allowed Temperature Increase (Celsius)	WLA Wet Weather Excess Thermal load (Million Kcals/Day)
0	13.0	0.0673	111	0.0513	85

Q_{DF} during Dry Weather period is 6.96 cfs. Q_{DF} during Wet Weather Period is 13.92 cfs.

MWMC
Willamette River Mile 178.0
NPDES WQ File Number 55999
USGS Flow Gage 14157500 + 14152000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	m	b
(cfs)	(Celsius)	(Celsius)	(cfs)		
1310	18.0	22.7	36.82	0.00014033	0.7562

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.1210	398	0.1035	339
1673	18.0	0.1003	420	0.0865	361
1955	18.0	0.0895	436	0.0776	377
2244	18.0	0.0812	454	0.0708	395
2800	18.0	0.0700	487	0.0616	428
3107	18.0	0.0655	505	0.0579	446
16617	18.0	0.0319	1306	0.0305	1248

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	m	b
(cfs)	(Celsius)	(Celsius)	(cfs)		
1340	13.0	22.7	36.82	0.00021656	0.1998

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.1289	428	0.0483	159
2493	13.0	0.1048	646	0.0615	378
2702	13.0	0.1027	686	0.0626	417
2885	13.0	0.1010	721	0.0635	451
3116	13.0	0.0992	764	0.0645	495
3819	13.0	0.0951	898	0.0668	629
20899	13.0	0.0801	4130	0.0749	3860

NEWBERG WWTP
Willamette River Mile 49.7
NPDES WQ File Number 102894
USGS Flow Gage 14191000

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	m	b
(cfs)	(Celsius)	(Celsius)	(cfs)		
5460	20.0	24.9	2.94	0.00006878	0.8745

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	20.0	0.0033	44	0.0030	40
6100	20.0	0.0031	46	0.0028	42
6455	20.0	0.0029	46	0.0027	43
7144	20.0	0.0028	49	0.0026	45
8482	20.0	0.0025	52	0.0023	48
14226	20.0	0.0019	66	0.0018	63
33277	20.0	0.0014	114	0.0013	106

OAK LODGE WWTP
Willamette River Mile 20.1
NPDES WQ File Number 62795
USGS Flow Gage 14211720

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
6290	20.0	23.5	3.87	0.00004520	0.9657

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	20.0	0.0027	42	0.0025	39
8424	20.0	0.0022	45	0.0020	41
9438	20.0	0.0020	46	0.0019	44
10581	20.0	0.0018	47	0.0017	44
12479	20.0	0.0017	52	0.0016	49
18935	20.0	0.0013	60	0.0012	56
31801	20.0	0.0010	78	0.0010	78

POPE & TALBOT
Willamette River Mile 148.3
NPDES WQ File Number 36335
USGS Flow Gage 14166000 + 14170000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
3670	18.0	28.5	18.10	0.00004130	0.6984

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.0438	395	0.0367	331
3910	18.0	0.0416	400	0.0349	335
4270	18.0	0.0388	407	0.0326	342
4794	18.0	0.0354	417	0.0299	352
4969	18.0	0.0344	420	0.0292	356
5811	18.0	0.0306	436	0.0261	372
18259	18.0	0.0151	676	0.0137	613

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
3810	13.0	28.5	18.10	0.00005022	0.2987

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.0360	337	0.0134	126
5122	13.0	0.0304	382	0.0136	171
5413	13.0	0.0295	391	0.0136	180
7855	13.0	0.0247	476	0.0137	264
8487	13.0	0.0239	497	0.0138	287
11541	13.0	0.0213	602	0.0139	393
22975	13.0	0.0177	996	0.0140	788

SILTRONICS
Willamette River Mile 6.3
NPDES WQ File Number 93450
USGS Flow Gage 14211720

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
6290	20.0	24.7	1.55	0.00004520	0.9657

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	20.0	0.0014	22	0.0013	20
10988	20.0	0.0010	27	0.0009	24
14054	20.0	0.0008	28	0.0008	28
16383	20.0	0.0008	32	0.0007	28
18858	20.0	0.0007	32	0.0007	32
23389	20.0	0.0006	34	0.0006	34
38584	20.0	0.0005	47	0.0005	47

SP NEWSPRINT
Willamette River Mile 49.8
NPDES WQ File Number 72615
USGS Flow Gage 14191000

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
5460	20.0	28.5	21.04	0.00006878	0.8745

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	20.0	0.0407	546	0.0375	503
5780	20.0	0.0392	557	0.0361	513
5973	20.0	0.0383	562	0.0353	518
6070	20.0	0.0379	565	0.0350	522
6276	20.0	0.0371	572	0.0342	527
6353	20.0	0.0368	575	0.0340	531
6427	20.0	0.0365	577	0.0337	532

STAYTON WWTP
North Santiam River Mile 14.9
NPDES WQ File Number 84781
USGS Flow Gage 14183000

JUNE 16 - AUG 31 Core Cold-Water Habitat

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
863	16.0	21.3	1.55	4.41

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal load (Million Kcals/Day)
0	16.0	0.0269	57

No flow based WLA formula is provided. Facility design flow (Q_{DF}) is limiting. Waste Load Allocation is calculated using facility design flows multiplied by 1.5.

SEPT 1 - JUNE 15 Salmon & Steelhead Spawning Use

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
1090	13.0	see footnote	1.55	see footnote

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Dry Weather Allowed Temperature Increase (Celsius)	Dry Weather Excess Thermal load (Million Kcals/Day)	Wet Weather Allowed Temperature Increase (Celsius)	Wet Weather Excess Thermal load (Million Kcals/Day)
0	13.0	0.0334	89	0.0481	129

T_{PS} during Salmon & Steelhead Spawning Use for the Dry Weather period is 21.3 ^{0}C. T_{PS} during Salmon & Steelhead Spawning Use for the Dry Weather period is 19.0 ^{0}C

Q_{DF} during Dry Weather period is 4.41 cfs. Q_{DF} during Wet Weather Period is 8.82 cfs.

SWEET HOME WWTP
South Santiam River Mile 31.5
NPDES WQ File Number 86840
USGS Flow Gage 14187500

JUNE 16 - AUG 31 Core Cold-Water Habitat

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
523	16.0	20.0	1.86	3.2

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal load (Million Kcals/Day)
0	16.0	0.0243	31

No flow based WLA formula is provided. Facility design flow (Q_{DF}) is limiting. Waste Load Allocation is calculated using facility design flows multiplied by 1.5.

SEPT 1 - JUNE 15 Salmon & Steelhead Spawning Use

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
550	13.0	17.0	1.86	13.92

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Dry Weather Allowed Temperature Increase (Celsius)	Dry Weather Excess Thermal load (Million Kcals/Day)	Wet Weather Allowed Temperature Increase (Celsius)	Wet Weather Excess Thermal load (Million Kcals/Day)
0	13.0	0.0405	55	0.0987	136

Q_{DF} during Dry Weather period is 3.2 cfs. Q_{DF} during Wet Weather Period is 13.92 cfs.

TELEDYNE WAH CHANG
Willamette River Mile ~116.5
NPDES WQ File Number 87645
USGS Flow Gage 14174000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
3980	18.0	29.1	4.80	0.00003835	0.6974

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.0114	111	0.0095	93
4478	18.0	0.0103	113	0.0087	95
4838	18.0	0.0097	115	0.0082	97
5013	18.0	0.0094	115	0.0080	98
5388	18.0	0.0089	117	0.0076	100
6738	18.0	0.0076	125	0.0065	107
19842	18.0	0.0039	189	0.0035	170

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
4160	13.0	29.1	4.80	0.00003927	0.3266

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.0091	93	0.0034	35
5338	13.0	0.0078	102	0.0033	43
5641	13.0	0.0075	104	0.0033	46
8855	13.0	0.0059	128	0.0032	69
9799	13.0	0.0056	134	0.0032	77
13707	13.0	0.0049	164	0.0031	104
28819	13.0	0.0039	275	0.0031	219

TRI-CITY WWTP
Willamette River Mile 25.5
NPDES WQ File Number 89700
USGS Flow Gage 14211720 - 14210000

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
5440	20.0	24.8	10.67	0.00004872	0.9850

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	20.0	0.0117	156	0.0108	144
6429	20.0	0.0103	162	0.0095	150
6873	20.0	0.0098	165	0.0091	153
7362	20.0	0.0093	168	0.0086	155
8323	20.0	0.0085	173	0.0079	161
9962	20.0	0.0075	183	0.0070	171
17294	20.0	0.0054	229	0.0051	216

TRYON CREEK WWTP
Willamette River Mile 20.2
NPDES WQ File Number 70735
USGS Flow Gage 14211720

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
6290	20.0	21.8	9.59	0.00004520	0.9657

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	20.0	0.0034	52	0.0032	49
8322	20.0	0.0028	57	0.0026	53
9262	20.0	0.0026	59	0.0024	54
10232	20.0	0.0024	60	0.0022	55
11567	20.0	0.0022	62	0.0021	59
15189	20.0	0.0019	71	0.0018	67
23160	20.0	0.0015	85	0.0014	79

UNIVERSITY OF OREGON CENTRAL HEAT PLANT
Willamette River Mile 181.7
NPDES WQ File Number 104991
USGS Flow Gage 14157500 + 14152000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	m	b
(cfs)	(Celsius)	(Celsius)	(cfs)		
1310	18.0	24.1	15.78	0.00007770	0.7482

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.0618	200	0.0518	167
1656	18.0	0.0505	206	0.0426	174
2023	18.0	0.0428	213	0.0363	181
2242	18.0	0.0393	217	0.0335	185
2806	18.0	0.0330	228	0.0282	195
3117	18.0	0.0304	233	0.0262	201
6772	18.0	0.0181	301	0.0161	268

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	m	b
(cfs)	(Celsius)	(Celsius)	(cfs)		
1340	13.0	24.1	15.78	0.00010490	0.3494

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.0637	210	0.0237	78
2462	13.0	0.0431	261	0.0213	129
2694	13.0	0.0409	271	0.0210	139
2861	13.0	0.0396	278	0.0209	147
3042	13.0	0.0384	287	0.0207	154
3549	13.0	0.0355	309	0.0204	177
8818	13.0	0.0253	547	0.0192	415

WEST LINN PAPER
Willamette River Mile 27.7
NPDES WQ File Number 21489
USGS Flow Gage 14211720 - 14210000

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

7Q10	T_{RC}	T_{PS}	Q_{PS}	Q_{DF}
(cfs)	(Celsius)	(Celsius)	(cfs)	(cfs)
5440	20.0	28.7	8.20	9.28

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA Allowed Temperature Increase (Celsius)	WLA Excess Thermal load (Million Kcals/Day)
0	20.0	0.0148	197

No flow based WLA formula is provided. Facility design flow (Q_{DF}) is limiting. Waste Load Allocation is calculated using facility design flow.

WEYERHAEUSER ALBANY
Willamette River Mile 116.5
NPDES WQ File Number 97042
USGS Flow Gage 14174000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	m	b
(cfs)	(Celsius)	(Celsius)	(cfs)		
3980	18.0	30.0	13.30	0.00003835	0.6974

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.0340	332	0.0284	277
4478	18.0	0.0309	339	0.0260	286
4838	18.0	0.0291	345	0.0245	291
5013	18.0	0.0283	348	0.0239	294
5388	18.0	0.0267	353	0.0226	299
6738	18.0	0.0226	373	0.0193	319
27300	18.0	0.0102	682	0.0094	628

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	m	b
(cfs)	(Celsius)	(Celsius)	(cfs)		
4160	13.0	30.0	13.30	0.00003927	0.3266

Lookup Table WLA

Q_R River Flow greater than (cfs)	T_{RC} River Temperature Criteria (Celsius)	HUA a = 0 Allowed Temperature Increase (Celsius)	WLA a = 0 Excess Thermal load (Million Kcals/Day)	HUA a > 0 Allowed Temperature Increase (Celsius)	WLA a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.0266	271	0.0099	101
5338	13.0	0.0227	297	0.0097	127
5642	13.0	0.0219	303	0.0096	133
8855	13.0	0.0172	373	0.0093	202
9810	13.0	0.0164	394	0.0093	223
12999	13.0	0.0145	462	0.0092	293
36103	13.0	0.0109	964	0.0090	796

WEYERHAEUSER SPRINGFIELD
McKenzie River Mile 1.0
NPDES WQ File Number 96244
USGS Flow Gage 14162500

MAY 16 - AUG 31 Core Cold-Water Habitat

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
1950	16.0	30.6	35.27	0.00013241	0.5918

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	16.0	0.2211	1071	0.1810	875
2055	16.0	0.2133	1089	0.1753	892
2195	16.0	0.2041	1112	0.1685	916
2364	16.0	0.1945	1140	0.1613	943
2694	16.0	0.1791	1195	0.1499	998
3654	16.0	0.1500	1355	0.1285	1159
17072	16.0	0.0855	3593	0.0809	3398

SEPT 01 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
1580	13.0	30.6	35.27	0.00019371	0.1839

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.1904	744	0.0712	276
1920	13.0	0.1779	844	0.0798	377
2025	13.0	0.1749	875	0.0818	407
2119	13.0	0.1724	903	0.0835	435
2288	13.0	0.1685	953	0.0862	485
4989	13.0	0.1420	1748	0.1042	1280
13775	13.0	0.1276	4332	0.1139	3864

WILLOW LAKE (SALEM) WWTP
Willamette River Mile 78.1
NPDES WQ File Number 78140
USGS Flow Gage 14191000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
5630	18.0	23.0	46.72	0.00011052	0.6278

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	18.0	0.0513	714	0.0457	635
5960	18.0	0.0499	735	0.0446	656
6206	18.0	0.0490	751	0.0438	671
6383	18.0	0.0483	762	0.0433	682
6896	18.0	0.0466	794	0.0420	715
7707	18.0	0.0444	845	0.0403	766
10045	18.0	0.0401	994	0.0369	914

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
6540	13.0	23.0	46.72	0.00016846	0.0983

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	13.0	0.0850	1372	0.0633	1019
7070	13.0	0.0845	1474	0.0644	1121
7571	13.0	0.0841	1571	0.0653	1218
8107	13.0	0.0837	1674	0.0662	1322
8485	13.0	0.0834	1746	0.0667	1394
8640	13.0	0.0833	1776	0.0669	1424
9734	13.0	0.0827	1986	0.0682	1636

WILSONVILLE WWTP
Willamette River Mile 39
NPDES WQ File Number 97952
USGS Flow Gage 14191000

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

Equation WLA

7Q10	T_{RC}	T_{PS}	Q_{PS}	*m*	*b*
(cfs)	(Celsius)	(Celsius)	(cfs)		
5460	20.0	24.3	2.94	0.00006878	0.8745

Lookup Table WLA

Q_R	T_{RC}	HUA	WLA	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	a = 0 Allowed Temperature Increase (Celsius)	a = 0 Excess Thermal load (Million Kcals/Day)	a > 0 Allowed Temperature Increase (Celsius)	a > 0 Excess Thermal load (Million Kcals/Day)
0	20.0	0.0029	39	0.0027	36
6041	20.0	0.0027	40	0.0025	37
6367	20.0	0.0026	41	0.0024	37
6739	20.0	0.0025	41	0.0023	38
7415	20.0	0.0024	44	0.0022	40
8556	20.0	0.0022	46	0.0020	42
13001	20.0	0.0017	54	0.0016	51

SMALL POINT SOURCES
Willamette River Mile 108 - 186 (Santiam River - Confluence of The Coast Fork/Middle Fork Willamette)

USGS Flow Gage 14174000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

7Q10	T_{RC}	T_{PS}	Q_{PS}
(cfs)	(Celsius)	(Celsius)	(cfs)
3980	18.0	22.0	13.92

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal load (Million Kcals/Day)
0	18.0	0.0099	97

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

7Q10	T_{RC}	T_{PS}	Q_{PS}
(cfs)	(Celsius)	(Celsius)	(cfs)
3980	13.0	22.0	13.92

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal load (Million Kcals/Day)
0	13.0	0.0057	56

NPDES file numbers listed in Table 4.33.

SMALL POINT SOURCES
Willamette River Mile 50 - 108 (Yamhill River - Santiam River)

USGS Flow Gage 14191000

MAY 16 - OCT 14 Salmon & Trout Rearing & Migration

7Q10	T_{RC}	T_{PS}	Q_{PS}
(cfs)	(Celsius)	(Celsius)	(cfs)
5630	18.0	22.0	7.73

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal load (Million Kcals/Day)
0	18.0	0.0069	95

OCT 15 - MAY 15 Salmon & Steelhead Spawning Use

7Q10	T_{RC}	T_{PS}	Q_{PS}
(cfs)	(Celsius)	(Celsius)	(cfs)
6540	13.0	22.0	7.73

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal load (Million Kcals/Day)
0	13.0	0.0135	216

NPDES file numbers listed in Table 4.32.

SMALL POINT SOURCES
Willamette River Mile 0 - 50 (Mouth Willamette River - Yamhill River)

USGS Flow Gage 14211720

JAN 01 - DEC 31 Salmon & Steelhead Migration Corridor

7Q10	T_{RC}	T_{PS}	Q_{PS}
(cfs)	(Celsius)	(Celsius)	(cfs)
6290	20.0	22.4	26.31

Q_R	T_{RC}	HUA	WLA
River Flow greater than (cfs)	River Temperature Criteria (Celsius)	Allowed Temperature Increase (Celsius)	Excess Thermal load (Million Kcals/Day)
0	20.0	0.0125	193

NPDES file numbers listed in Table 4.31.

Table 4.30

SMALL POINT SOURCES
Willamette River Mile 0 - 50 (Mouth Willamette River - Yamhill River)

NPDES WQ File Number	Common Name	City	Category	Latitude	Longitude	Type	Stream	River Mile
104545	ALBERS MILL BUILDING PARTNERSHIP (ABN)	PORTLAND	IND	45.5292	-122.6730	GEN01	Willamette River	12.00
3690	ASH GROVE CEMENT - RIVERGATE LIME PLANT	PORTLAND	IND	45.6234	-122.7808	NPDES-IW-O	Willamette River	3.30
68471	ATOFINA CHEMICALS, INC.	PORTLAND	IND	45.5713	-122.7447	NPDES-IW-O	Willamette River	7.40
13691	CANBY STP	CANBY	DOM	45.2886	-122.6806	NPDES-DOM-C1a	Willamette River	33.00
70596	CASCADE GENERAL, INC.	PORTLAND	IND	45.5655	-122.7208	NPDES-IW-N	Willamette River	6.50
96010	CENTURY MEADOWS SANITARY SYSTEM (CMSS)	AURORA	DOM	45.2656	-122.8253	NPDES-DOM-Da	Willamette River	42.00
30554	FOREST PARK MOBILE VILLAGE	OREGON CITY	DOM	45.3382	-122.6410	NPDES-DOM-Da	Willamette River	28.20
101321	FREIGHTLINER TRUCK MANUFACTURING PLANT 2 (TMP2)	PORTLAND	IND	45.5622	-122.7037	GEN01	Willamette River	8.50
107178	FUJIMI CORPORATION	WILSONVILLE	IND	45.3353	-122.7764	NPDES-IW-N	Willamette River	37.60
8550	GS ROOFING PRODUCTS COMPANY, INC.	PORTLAND	IND	45.5722	-122.7488	GEN01	Willamette River	7.00
38192	HERCULES	PORTLAND	IND	45.5463	-122.7097	GEN01	Willamette River	12.00
100415	J. R. SIMPLOT COMPANY - RIVERGATE TERMINAL	PORTLAND	IND	45.6268	-122.7803	GEN01	Willamette River	3.00
47430	KOPPERS	PORTLAND	IND	45.5755	-122.7598	NPDES-IW-N	Willamette River	6.40
48480	LAKE OSWEGO WTP	WEST LINN	IND	45.3859	-122.6325	GEN02	Willamette River	23.83
108460	LINNTON SAND DISTRIBUTION FACILITY	PORTLAND	IND	45.5989	-122.7829	NPDES-IW-N	Willamette River	4.80
54175	MCCALL MARINE TERMINAL	PORTLAND	IND	45.5635	-122.7363	GEN05	Willamette River	7.84
62231	NORTHWEST NATURAL GAS COMPANY (LNG PLANT)	PORTLAND	IND	45.5788	-122.7583	GEN01	Willamette River	6.40
6739	NORTHWEST PIPE COMPANY	PORTLAND	IND	45.6074	-122.7662	GEN01	Willamette River	4.00
106060	OMSI	PORTLAND	IND	45.5082	-122.6647	NPDES-IW-O	Willamette River	13.50
110322	OREGON TRANSFER CO.	PORTLAND	IND	45.5690	-122.7106	GEN01	Willamette River	9.00
65589	OWENS CORNING (CORP.)	PORTLAND	IND	45.6061	-122.7891	GEN01	Willamette River	4.01
65589	OWENS CORNING (CORP.)	PORTLAND	IND	45.6061	-122.7891	GEN05	Willamette River	4.01
100025	PORTLAND BULK TERMINAL 4	PORTLAND	IND	45.6091	-122.7680	NPDES-IW-O	Willamette River	4.60
64905	PORTLAND STEELWORKS - RIVERGATE (SEE FILE 108565)	PORTLAND	IND	45.6256	-122.7794	NPDES-IW-G	Willamette River	2.70
44571	RIVER ST. CEMENT TERMINAL	PORTLAND	IND	45.5375	-122.6769	GEN01	Willamette River	11.10
74995	SLLI	PORTLAND	IND	45.5690	-122.7500	NPDES-IW-N	Willamette River	7.00
102334	SULZER PUMPS	PORTLAND	IND	45.5433	-122.6982	GEN01	Willamette River	10.50
110220	UNION STATION HOUSING PROJECT	PORTLAND	IND	45.5174	-122.6726	NPDES-IW-N	Willamette River	11.90
100517	UNIVAR USA INC	PORTLAND	IND	45.5530	-122.7270	NPDES-IW-N	Willamette River	9.00
109444	WILLAMETTE OAKS BUILDING	PORTLAND	IND	45.4755	-122.6713	NPDES-IW-O	Willamette River	15.80
87640	XEROX	WILSONVILLE	IND	45.3249	-122.7625	GEN01	Willamette River	39.00

Table 4.31

SMALL POINT SOURCES
Willamette River Mile 50 - 108 (Yamhill River - Santiam River)

NPDES WQ File Number	Common Name	City	Category	Latitude	Longitude	Type	Stream	River Mile
959	BASSETT ST PROPERTY	SALEM	IND	44.9449	-123.0534	NPDES-IW-O	Willamette River	84.00
100077	BROOKS SEWAGE TREATMENT PLANT	BROOKS	DOM	45.0492	-122.9634	NPDES-DOM-Db	Willamette River	71.70
89638	COVANTA MARION, INC	BROOKS	IND	45.0492	-122.9634	NPDES-IW-O	Willamette River	71.70
25567	DUNDEE STP	DUNDEE	DOM	45.2700	-122.9989	NPDES-DOM-Db	Willamette River	51.70
41513	INDEPENDENCE STP	INDEPENDENC	DOM	44.8583	-123.1958	NPDES-DOM-Db	Willamette River	95.50
57871	MONMOUTH STP	MONMOUTH	DOM	44.8583	-123.2167	NPDES-DOM-Db	Willamette River	95.50
60598	NEWBERG WTP	NEWBERG	IND	45.2857	-122.9665	GEN02	Willamette River	50.00
64192	OREGON FRUIT PRODUCTS CO.	SALEM	IND	44.9427	-123.0541	GEN01	Willamette River	84.60
962	RAINSWEET INC.	SALEM	IND	44.9562	-123.0128	GEN01	Willamette River	83.00
108451	RAINSWEET, INC.	SALEM	IND	44.9452	-123.0533	GEN01	Willamette River	78.20

Table 4.32

SMALL POINT SOURCES
Willamette River Mile 108 - 186 (Santiam River - Confluence of The Coast Fork/Middle Fork Willamette)

NPDES WQ File Number	Common Name	City	Category	Latitude	Longitude	Type	Stream	River Mile
500	ADAIR VILLAGE STP	CORVALLIS	DOM	44.3299	-123.1500	NPDES-DOM-Da	Willamette River	122.00
107559	ADAIR VILLAGE WATER TREATMENT PLANT	ALBANY	IND	44.6333	-123.1667	GEN02	Willamette River	122.55
10125	BORDEN CHEMICAL, INC. - SPRINGFIELD	SPRINGFIELD	IND	44.0428	-123.0243	GEN01	Willamette River	184.90
107972	CARPENTER TRUCKING, INC.	EUGENE	IND	44.0583	-123.1167	GEN17A	Willamette River	180.00
20165	CORVALLIS TAYLOR WTP	CORVALLIS	IND	44.5320	-123.2500	GEN02	Willamette River	134.00
101760	DUNHAM OLDS.-CADILLAC, INC.	EUGENE	IND	44.0699	-123.1080	GEN17A	Willamette River	179.52
106870	FARWEST STEEL CORPORATION	EUGENE	IND	44.0376	-123.0387	GEN17A	Willamette River	186.00
105415	HARRISBURG LAGOON TREATMENT PLANT	HARRISBURG	DOM	44.2902	-123.1828	NPDES-DOM-Db	Willamette River	158.40
38385	HEWLETT-PACKARD - CORVALLIS	CORVALLIS	IND	44.5855	-123.2434	GEN01	Willamette River	131.00
38385	HEWLETT-PACKARD - CORVALLIS	CORVALLIS	IND	44.5855	-123.2434	GEN02	Willamette River	131.00
109706	JENOVA LAND COMPANY	EUGENE	IND	44.0546	-123.0893	NPDES-IW-O	Willamette River	181.00
32910	MCKENZIE FOREST PRODUCTS	SPRINGFIELD	IND	44.0410	-122.9952	NPDES-IW-N	Willamette River	185.50
112467	ODEQ-MCAYEALS WARDROBE CLEANERS AIR STRIPPER	EUGENE	IND	44.0482	-123.0948	NPDES-IW-N	Willamette River	180.00
107264	OREGON FREEZE DRY, INC.	ALBANY	IND	44.6167	-123.1058	GEN01	Willamette River	116.00
103919	OSU - MICROBIOLOGY, SALMON DISEASE LABORATORY	CORVALLIS	IND	44.5676	-123.2452	NPDES-IW-O	Willamette River	130.00
102789	PACIFIC CAST TECHNOLOGIES, INC.	ALBANY	IND	44.6232	-123.1024	GEN01	Willamette River	119.00
107138	PANOLAM INDUSTRIES, INC.	ALBANY	IND	44.6131	-123.1057	GEN01	Willamette River	116.00
82095	SKYLINE PRODUCTS	HARRISBURG	IND	44.2738	-123.1674	GEN01	Willamette River	161.10

Point Source Waste Load Allocations Methodology

This section outlines the methodology and equations used to determine the mainstem Willamette waste load allocations presented above.

General Description

Waste load allocations are expressed as excess thermal loads. They describe the acceptable amount of thermal load a point source can discharge and not cause a cumulative exceedance of the allocated human use allowance for the river. Allocations are designed to allow for increased thermal loads as the loading capacity of the river increases with river flow. This type of waste load allocation is referred to as a “flow based” waste load allocation. Waste load allocations presented in this chapter apply April through October except in the mainstem Willamette migration corridor which applies June through September. These time periods are based on when river temperatures are typically above the biological criteria.

Flow based waste load allocations are expressed in two ways: as an increase in temperature, and as an energy unit in million kilocalories per day. The text throughout this section frequently references equations used to calculate flow based waste load allocations. These equations, Equations 5 through 12, are located at the end of this section.

Maximum Observed Effluent Discharge

Calculating flow based waste load allocations is complicated by the variability of river loading capacities and effluent flow rates and temperatures. To make flow based waste load allocations less complex, constant base effluent flow rates and temperatures are used by computing the maximum observed effluent discharge. The maximum observed effluent discharge is defined as the summer period pair of effluent flow rate and temperature which results in the largest calculated river temperature increase for river conditions of summer period 7Q10 low river flow rate and summer period biological-based numeric criteria. The summer period is defined as the same time period as the summer fish use designation. Typically in the Willamette River this is May 15 to October 15 for the salmon and trout rearing use, except in the Lower Willamette migration corridor where the use is year round.

The change in river temperature, ΔT, is calculated by Equation 1:

$$\Delta \mathrm{T} = \left[\frac{\left(Q_{Effluent} T_{Effluent}\right) + \left(Q_{R,7Q10} T_{R,BioCriteria}\right)}{Q_{Effluent} + Q_{R,7Q10}}\right] - T_{R,BioCriteria} \qquad \textbf{(Eq. 1)}$$

In Equation 1, Q_{Effluent} is the effluent flow rate, T_{Effluent} is the effluent temperature, $Q_{\mathrm{R,7Q10}}$ is the 7Q10 low river flow rate (annual minimum 7-day average flow rate with a recurrence interval of 10 years), and $T_{\mathrm{R,BioCriteria}}$ is the applicable biologically-based numeric criteria for the river.

For individual sources, the effluent temperature metric used in the equation is the rolling seven-day average maximum temperature for each day, unless daily maximum temperatures are unavailable. When daily maximum temperatures were unavailable, ODEQ treated the available data without averaging as an approximate seven-day average maximum value. The effluent flow metric used in the equation is the seven-day average effluent flow rate.

Tables 4.33 and 4.34 describe years in which effluent data were available to ODEQ to calculate the maximum observed effluent discharge and what effluent temperature and flow metric was used for each source.

Table 4.33 Time period of available data and effluent temperature metric.

Point Source	Time Period/Effluent Temperature Metric
Albany WWTP	Maximum of either the 1999-2002 maximum monthly grab sample, or the 2003-2004 seven-day average maximums
Blue Heron Paper	2001 seven-day average maximums
Corvallis WWTP	2001-2003 seven-day average maximums
Cottage Grove WWTP	2001 seven-day average maximums
Evanite	2004 seven-day average maximums
Fort James Halsey	1999-2004 grab sample (daily grab)
Jefferson WWTP	2001 grab sample (2 grabs per week)
Kellogg Creek WWTP	2001-2004 seven-day average maximums
Lebanon WWTP	2000-2001 grab sample (2 grabs per week)
MWMC	1999-2004 seven-day average maximums
Newberg WWTP	2002 seven-day average maximums
Oak Lodge WWTP	1999-2004 grab sample (daily grab)
ODFW Clackamas River Hatchery	Maximum observed Temperature from DMR (very limited data)
Pope & Talbot	2001-2004 seven-day average maximums
Siltronics	2002-2004 seven-day average maximums
Small Point Sources	Effluent flow weighted average maximum grab temperatures of all sources. When effluent temperature was unknown a value of 22 ^{o}C was assumed.
SP Newsprint	2002 Maximum monthly value (no specific sampling frequency was provided)
Stayton WWTP	2001 grab sample (2 grabs per week)
Sweet Home WWTP	1999-2004 grab sample (4-5 grabs per week)
Teledyne Wah Chang	2000-2004 seven-day average maximums
Tri-City WWTP	2001-2004 seven-day average maximums
Tryon Creek WWTP	2001-2004 grab sample (daily grab)
University Of Oregon Heat Plant	2002 seven-day average maximums
West Linn Paper	2001-2002 seven-day average maximums
Weyerhaeuser Albany	1999-2004 grab sample (daily grab)
Weyerhaeuser Springfield	1999-2004 grab sample (daily grab)
Willow Lake (Salem) WWTP	2001-2002 seven-day average maximums
Wilsonville WWTP	2001-2002 seven-day average maximums

Table 4.34 Time period of available data and effluent flow metric.

Point Source	Time Period/Effluent Flow Metric
Albany WWTP	1999-2004 seven-day average total flows
Blue Heron Paper	2001-2002 seven-day average total flows
Corvallis WWTP	2001-2003 seven-day average total flows
Cottage Grove WWTP	2001-2002 seven-day average total flows
Evanite	1999-2004 seven-day average total flows
Fort James Halsey	1999-2004 seven-day average total flows
Jefferson WWTP	Average dry/wet weather design flows x 1.5
Kellogg Creek WWTP	2001-2004 seven-day average total flows
Lebanon WWTP	Average dry/wet weather design flows x 1.5
MWMC	1999-2004 seven-day average total flows
Newberg WWTP	2002 seven-day average total flows
Oak Lodge WWTP	1999-2004 seven-day average total flows
ODFW Clackamas River Hatchery	No data available, calculated based on WLA
Pope & Talbot	2000-2004 seven-day average total flows
Siltronics	2002-2004 seven-day average total flows
Small Point Sources	Average grab sample effluent flow. When effluent flow was unknown 0.5 MGD was assumed.
SP Newsprint	2001-2002 seven-day average total flows
Stayton WWTP	Average dry/wet weather design flows x 1.5
Sweet Home WWTP	Average dry/wet weather design flows x 1.5
Teledyne Wah Chang	2000-2004 seven-day average total flows
Tri-City WWTP	2001-2004 seven-day average total flows
Tryon Creek WWTP	1999-2004 seven-day average total flows
University Of Oregon Heat Plant	2002 seven-day average total flows
West Linn Paper	2001-2002 seven-day average total flows
Weyerhaeuser Albany	1999-2004 seven-day average total flows outfall 001
Weyerhaeuser Springfield	1999-2004 seven-day average total flows from outfall 001+002
Willow Lake (Salem) WWTP	2001-2002 seven-day average total flows
Wilsonville WWTP	2001-2002 seven-day average total flows

Scaling Factor, "d"

The scaling factor, "d," is a dimensionless value that is used in the waste load allocation equation to increase or decrease permissible point source loads based on loading capacity. The available loading capacity differs by location throughout the basin and is influenced by factors, such as varying river flow rates, different water quality temperature criteria, and the cumulative downstream impacts of combined discharges. Five geographic groupings of point sources (described in Table 4.35) were developed to respond to these differences.

Table 4.35 Geographic point source groupings

Group 1	All sources (including small point sources) on the Willamette River upstream of the Santiam River, major sources on the McKenzie River and the Coast Fork Willamette River.
Group 2	Major sources on the Santiam, South Santiam and North Santiam Rivers.
Group 3	All Willamette River sources (including small point sources) downstream of the Santiam River and upstream of the Yamhill River.
Group 4	All Willamette River sources (including small point sources) downstream of the Yamhill River.
Group 5	Major sources on the Clackamas River.

Groups 1, 3, and 4 utilize scaling factors while groups 2 and 5 do not.

Waste load allocations for group 2 are not limited by the loading capacity of the river so they are calculated using dry or wet weather design flows x 1.5.

For the groups 1, 3 and 4 the loading capacity of the river may be limiting to point source loads at low river flow rates, but not at high river flow rates. Scaling factors were introduced to adjust loads accordingly.

The source in group 5 is limited by the loading capacity of the river during all river flow regimes and the maximum waste load allocation is defined as a change in river temperature no greater than 0.03 ^{o}C

If a source has an existing thermal permit limit or design flow load that is less than allowed under the flow based waste load allocation, then the allocation is considered limited and no scaling is provided beyond this point. The maximum waste load allocation is calculated using the limiting factor such as design flow or the existing thermal permit limit

The primary forcing function used to scale loads is river flow. The scaling factor is calculated using a linear function, such as Equation 2 below.

Linear Function: $d = m(Q_R) + b$ **(Eq. 2)**

In Equation 2, d is the scaling factor, Q_R is the river flow rate, m is the slope and b is the y-axis intercept. Both m and b are constants. ODEQ experimented with other functions but found the simplest and most effective was a linear equation.

To derive a linear function for scaling, the value of “d” must be known for two different river flows. ODEQ choose to find appropriate values for d at 7Q10 low river flow rates and at 7Q5 high river flow rates in each respective grouping. Figure 4.41 illustrates how the scaling function works. Information on 7Q10 and 7Q5 is discussed in the following section. Finding appropriate “d” values at these flows were derived through Willamette Mainstem CE-QUAL-W2 wasteload allocation model iterations. Willamette CE-QUAL-W2 model simulations are described in Appendix 4.4.

Table 4.36 Scaling factors for geographic groupings.

Geographic Grouping	Fish Use Designation Period	Point Source Sector	Scaling factor "d" at 7Q10 Low River Flow	Scaling factor "d" 7Q5 High River Flow
Group 1	Rearing	Domestics	0.94	2.17
	Rearing	Industrials	0.85	1.50
	Spawning	Domestics	0.78*	5.71
	Spawning	Industrials	0.49	3.02
Group 3	Rearing	All Sectors	1.25	4.50
	Spawning	All Sectors	1.20	20.00
Group 4	Migration	All Sectors	1.25	9.00

* MWMC's scaling factor is 0.49.

To calculate "m" and "b", Equations 3 and 4 were used with the scaling factors in Table 4.36.

Slope of the scaling function "d"	Y-axis intercept
$m = \frac{(d_2 - d_1)}{(x_2 - x_1)}$ **(Eq. 3)**	$b = d_1 - (m \cdot x_1)$ **(Eq. 4)**

where,

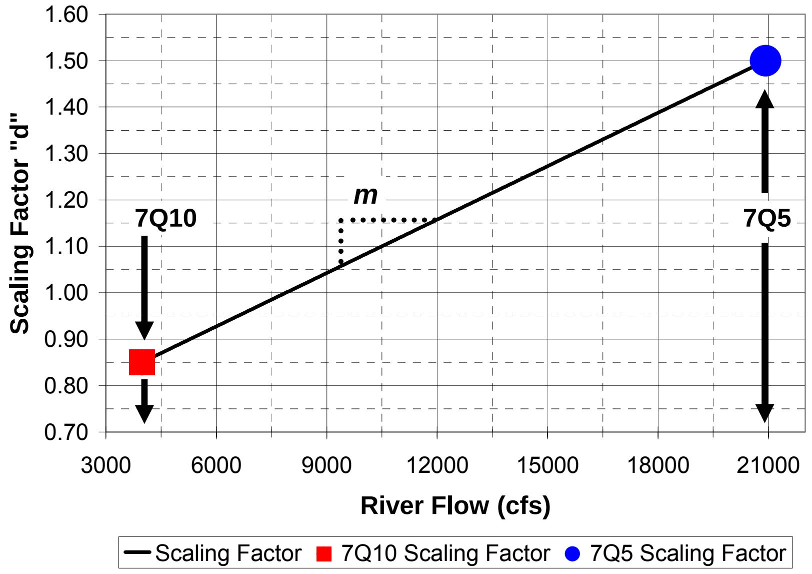
$d_1 =$ d value at 7Q10 Low River Flow

$d_2 =$ d value at 7Q5 High River Flow

$x_1 =$ 7Q10 Low River Flow

$x_2 =$ 7Q5 High River Flow

Figure 4.41 Scaling function

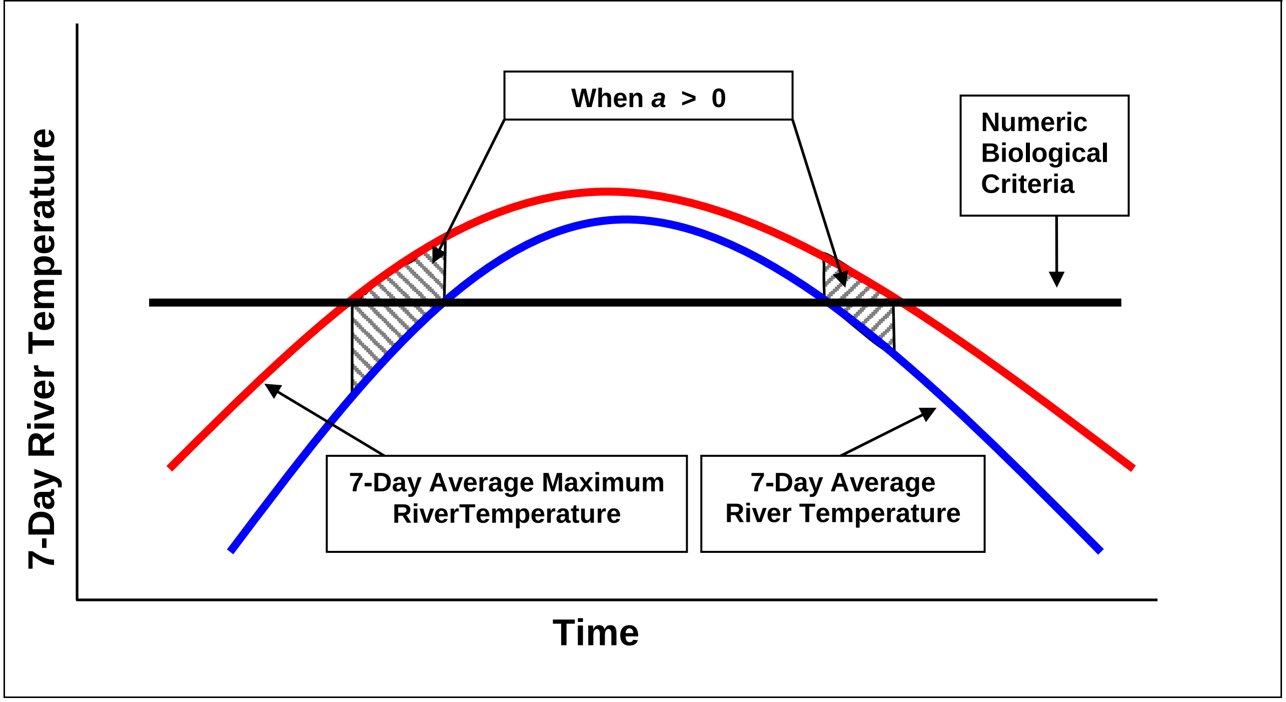


Individual point sources that have flow based waste load allocations may calculate a continuous waste load allocation using Equations 6 and 7. This requires the collection of ambient river flow and temperature data. Alternatively, individual point sources may use allocations based on pre-calculated river flow benchmarks instead of calculating a continuous allocation. Examples of allocations based on river flow bench marks are presented in the waste load allocations tables. Using benchmarks still requires the collection of ambient river flow data but may not be as complex or laborsome as determining a continuous allocation. Sources may monitor river flow data at gages described in the waste load allocation or at a location or multiple locations approved by ODEQ. If a source does not collect ambient river flow data, the waste load allocation is calculated using 7Q10 low flow rates. 7Q10 low river flow rates are represented as zero flow in the waste load allocation tables.

Adjustment Factor, "a"

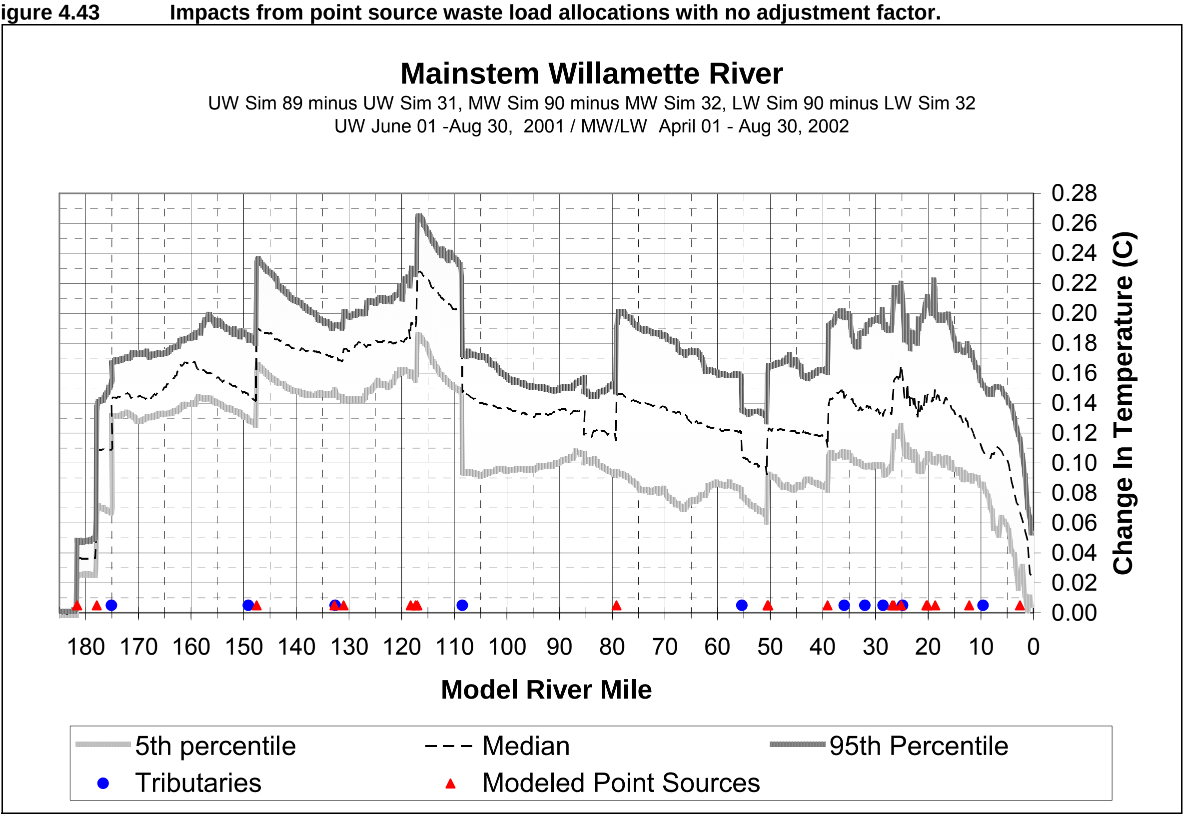
There are river conditions when the scaling factor alone will not ensure compliance with allowable cumulative temperature increases at points of maximum impact. During such conditions an adjustment factor, "a", as defined below, reduces the scaling factor, and thus the allowable point source load, when the seven-day average maximum river temperature is greater than the biological-based numeric criteria and the seven-day average river temperature is less than the biological criteria. Figure 4.42 illustrates such a river condition.

Figure 4.42 River conditions when "a" reduces the scaling factor.



If there were no adjustment factor during these conditions, the scaling factors would allow greater discharges and thus greater thermal loads, on average, than scaling factors were calibrated to. This is because, with a constant effluent discharge, the temperature increase for a cooler river temperature is larger than one for a warmer river temperature. If there were no adjustment factor, modeling (shown in Figure 4.43) demonstrates that this larger (on average) thermal load does not dissipate fast enough, which results in greater daily maximum temperatures at the point of maximum impact which result in human use allowance exceedances.

Figure 4.43 **Impacts from point source waste load allocations with no adjustment factor.**



Conditions when “a” applies occur most frequently during low flow periods, particularly in the McKenzie River and the Upper Willamette River (see Figure 4.44 and 4.45). It occurs less frequently in the Middle or Lower Willamette (see Figure 4.46). Because the frequency when “a” applies in the McKenzie and Upper Willamette is greater than in other river reaches, the adjustment factor is calibrated to be most sensitive in the McKenzie and Upper Willamette.

The adjustment factor equation requires that the natural thermal potential be known on a continuous basis. While it is not possible to run models on a continuous basis using future data, it is possible to analyze data from 2001 and 2002 to make predictions of the behavior of natural thermal potential based on current conditions. Linear regressions presented in Tables 4.39 and 4.40 are good estimates (plus or minus ~0.20^{o}C) of modeled natural thermal potential values in any given time period. Figures 4.47 through 4.53 at the end of this section illustrate these regression relationships and error statistics. Note that ODEQ assumes these linear relationships will change when significant operational changes are made at the USACE dams and other significant improvements from nonpoint sources occur.

The waste load allocations presented in the main body of Chapter 4 allocate loads for river conditions when a > 0. These loads are based on adjustment factor calculations with conservative estimates of seven-day average natural thermal potential temperatures (presented in Table 4.37). ODEQ acknowledges that in the Middle and Lower Willamette River the frequency of “a” river conditions is small and, furthermore, that values in Table 4.37 may be conservative compared to values calculated with monitored river temperatures. However, in the absence of continuously monitored river temperature values, values in Table 4.37 will be used as the seven day average NTP river temperature for T_{RA_N} and used to calculate “a” in Equation 7.

Table 4.37

Fish Use Designations	**WLA Seven-Day Average NTP River Temperatures During Adjustment Factor Period**
Core Cold Water	13.5 °C
Salmon and Trout Rearing & Migration	15.5 °C
Salmon & Steelhead Migration Corridors	18.0 °C
Spawning	9.0 °C

Figure 4.44 2001-2002 adjustment factor "a" values at Springfield in the McKenzie River

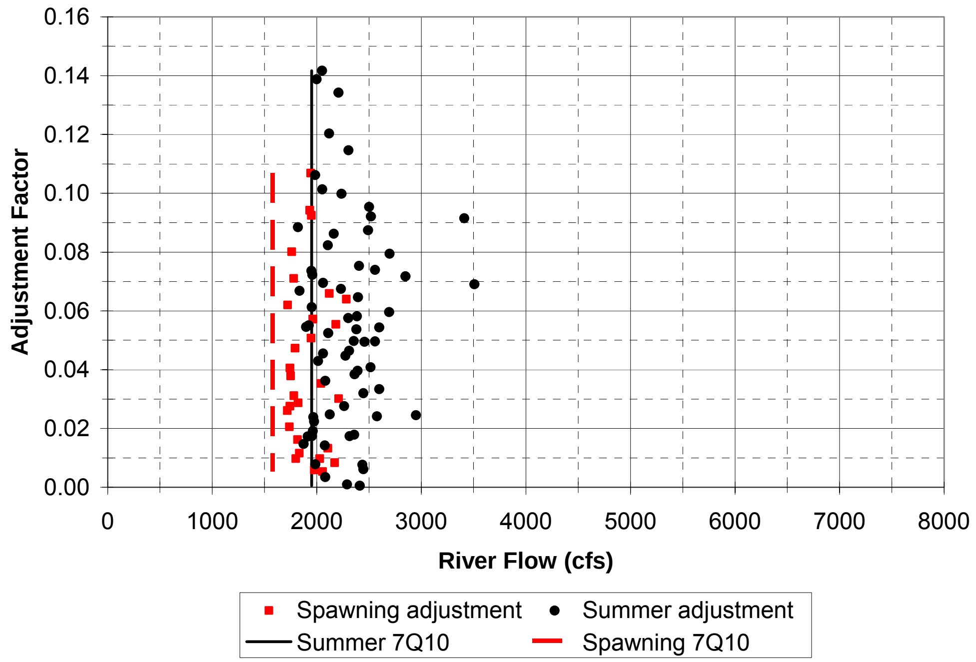


Figure 4.45 **2001-2002 adjustment factor "a" near the Long Time River in the Upper Willamette River**

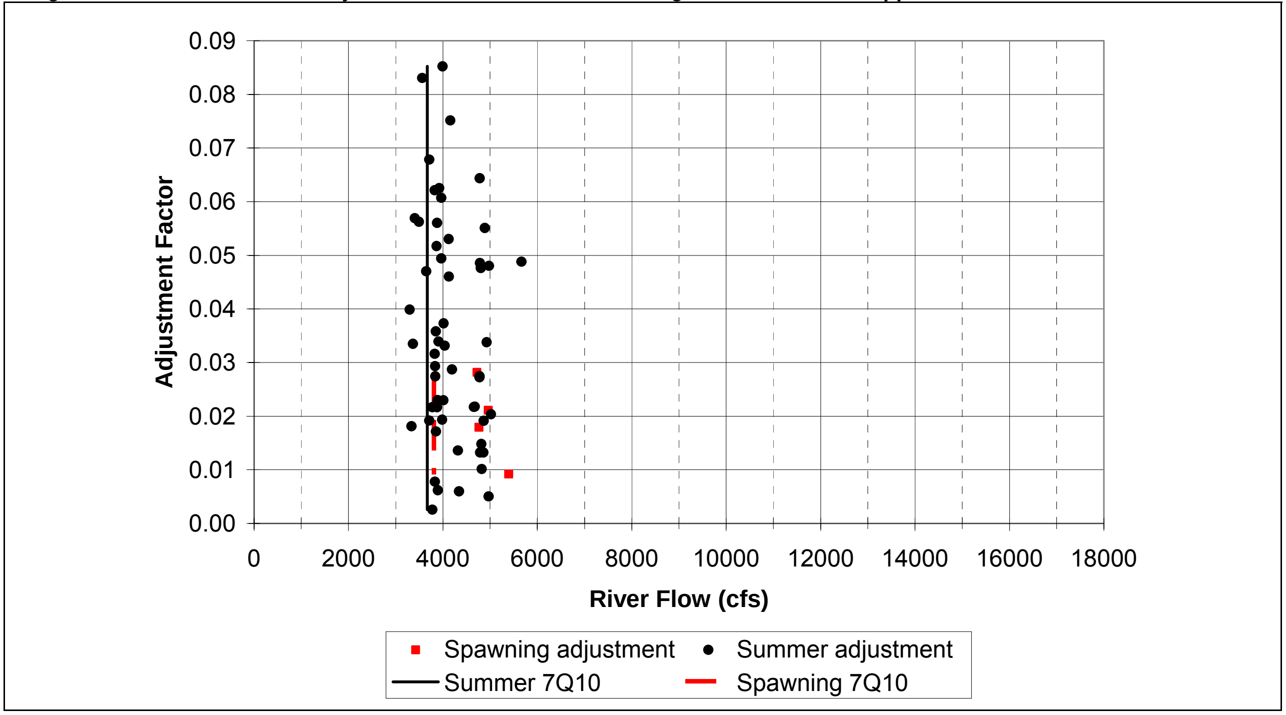
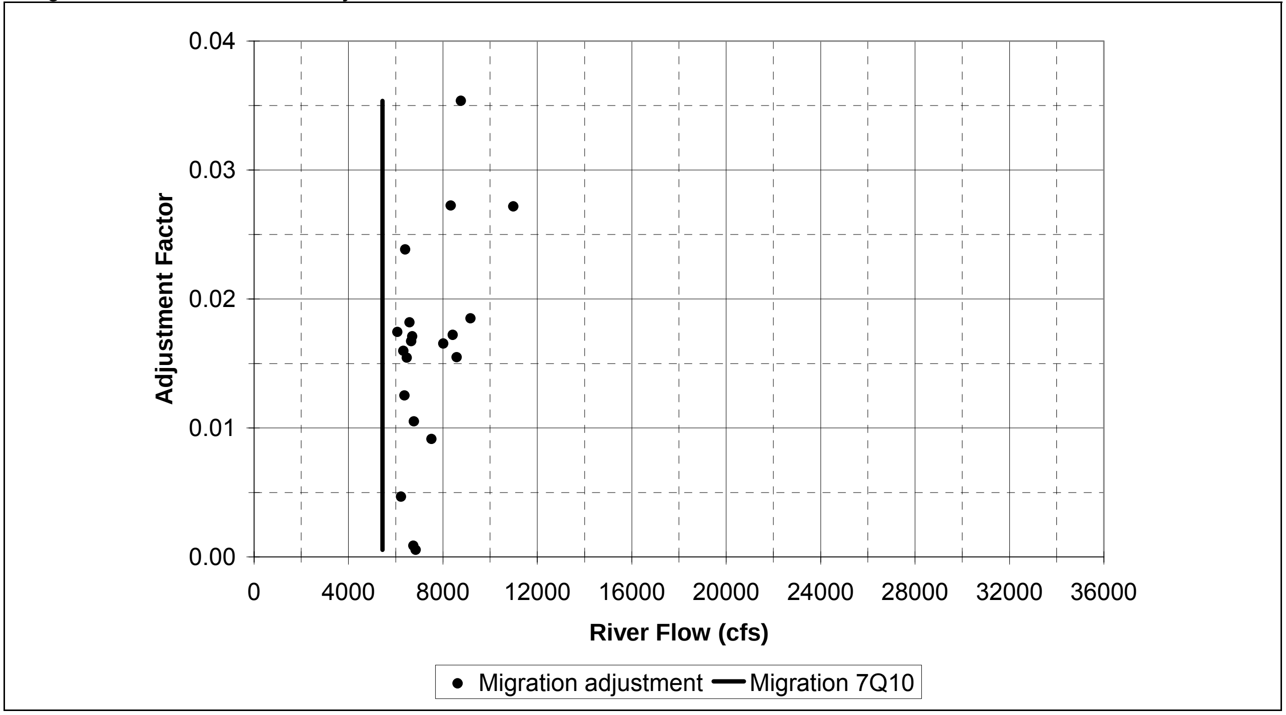


Figure 4.46 **2001-2002 adjustment factor "a" near West Linn in the Lower Willamette River**



7Q10 Low Flow and 7Q5 High Flow

The 7Q10 low flow is the annual minimum seven-day average river flow with a recurrence interval of ten years in a particular fish use designation period. The 7Q5 high flow is the annual maximum seven-day average river flow with a recurrence of five years in a particular fish use designation period. The fish use designation period is defined by the fish and spawning use designation maps in Oregon's Division 41 temperature rules. They may be downloaded on ODEQ's website at: http://www.ODEQ.state.or.us/wq/standards/WQStdsTemp.htm.

7Q10 low flows were calculated using a freeware EPA flow analysis tool called DFLOW 3.0. For more information on DFLOW visit this website: http://epa.gov/waterscience/dflow/index.htm. 7Q5 high flows were calculated by ODEQ. Both values are derived using the Log Pearson Type III distribution technique.

Historic river flow data sufficient to calculate 7Q10 low flow and 7Q5 high flow statistics were downloaded from the USGS gage closest to the source. Only post-dam data (typically after 1970) was included in these calculations. When sufficient data were available, two or more gages were utilized to calculate a daily flow at locations where no historical USGS flow gage currently exists. It should be noted that daily flow was calculated before the 7Q10 or 7Q5 values were calculated. Table 4.38 presents the 7Q10 and 7Q5 values at different locations in the basin.

Table 4.38

River Mile	USGS Gage/s	Period	Fish Use Period	7Q10 Low Flow (cfs)	7Q5 High Flow (cfs)
CF 29	14153500 Coast Fork Willamette R Blw Cottage Grove Dam	1970-2004	Rearing	39	1468
			Spawning	34	2039
CLK 23	14210000 Clackamas R. At Estacada	1970-2004	Core Cold	693	N/A
			Spawning	662	N/A
MCK 48	14162500 Mckenzie R. Near Vida	1970-2004	Core Cold	1950	6859
			Spawning	1580	14641
NS 27	4183000 North Santiam R. At Mehama	1970-2004	Core Cold	863	N/A*
			Spawning	1090	N/A*
SAN 09	14189000 Santiam River At Jefferson	1970-2004	Rearing	1010	N/A*
			Spawning	1960	N/A*
SS 20	14187500 South Santiam R. At Waterloo - 14187600 Lebanon Santiam Canal Near Lebanon	1993-2004	Rearing	510	N/A*
			Spawning	665	N/A*
SS 23	14187500 South Santiam R. At Waterloo	1970-2004	Rearing	523	N/A*
			Spawning	550	N/A*
WR 012	14211720 Willamette R. At Portland	1973-2004	Migration	6290	177737
WR 025	14211720 Willamette R. At Portland - 14210000 Clackamas R. At Estacada	1973-2004	Migration	5440	164512
WR 084	14191000 Willamette R. At Salem	1970-2004	Rearing	5630	35036
			Spawning	6540	118140
WR 119	14174000 Willamette R. At Albany	1970-2004	Rearing	3980	20927
			Spawning	4160	68582
WR 148	14166000 Willamette R. At Harrisburg + 14170000 Long Tom R. At Monroe	1970-2004	Rearing	3670	19407
			Spawning	3810	54186
WR 186	14157500 Coast Fork Willamette R. Near Goshen + 14152000 Middle Fork Willamette R. At Jasper	1970-2004	Rearing	1310	10075
			Spawning	1340	25444

* 7Q5 high river flow not required for determination of waste load allocation.

Equations

Equations 5, 6, 7, 8 and 9 describe how to calculate a waste load allocation. Equation 10 describes how to calculate an actual load being discharged to determine compliance with the waste load allocation. Equations 11 and 12 describe how to calculate maximum effluent flow or temperature to maintain compliance with the waste load allocations.

If an existing thermal permit limit or design flow load is less than allowed under equations 5 and 6, then the maximum waste load allocation allowed is the existing thermal permit limit or one calculated with the effluent design flow and maximum observed effluent temperature with no scaling factor.

1. WLA Equation

A. The waste load allocation expressed as a change in temperature. This is a point source's portion of the human use allowance. (°C)

$$HUA = \left(\frac{d \cdot Q_{PS}}{\left(d \cdot Q_{PS}\right) + Q_R}\right) \cdot \left(T_{PS} - T_{RC}\right) \qquad \textbf{(Eq. 5)}$$

B. The waste load allocation expressed as an excess thermal load. (million kilocalories per day). This equation should be used to develop permit limits and determine compliance.

$$WLA = d \cdot Q_{PS} \cdot k \cdot \left(T_{PS} - T_{RC}\right) \qquad \textbf{(Eq. 6)}$$

where,

$d =$	Scaling factor between maximum observed effluent flow and the effluent flow at the river's loading capacity (see Scaling Factor Equation 7)
$T_{PS} =$	The effluent temperature (°C) that is defined as the maximum observed effluent discharge. This value is a constant.
$T_{RC} =$	The fish use designation period numeric biological temperature criteria (°C).
$Q_R =$	The rolling seven-day average ambient river flow (cfs).
$Q_{PS} =$	The effluent flow (cfs) that is defined as the maximum observed effluent discharge. This value is a constant.
$k =$	Million kilocalories conversion factor: (2.447 million kcals/day °C) $\frac{1\,\text{ft}^3}{1\,\text{sec}} \cdot \frac{1\,\text{m}^3}{35.31\,\text{ft}^3} \cdot \frac{1000\,\text{kg}}{1\,\text{m}^3} \cdot \frac{86400\,\text{seconds}}{1\,\text{day}} \cdot \frac{1\,\text{kcal}}{1\,\text{kg} \cdot 1\ {}^\circ\text{C}} \cdot \frac{1\,\text{Million kcals}}{1000000\,\text{kcals}} = 2.447$

2. Scaling Factor Equation	
$d = ((m \cdot Q_R) + b) - a$ **(Eq. 7)**	
where,	
$m =$	A dimensionless value that is precise to 1.0 x 10^{-8} and is the slope of a linear equation intersecting the 7Q10 low river flow effluent loading capacity scaling factor and the 7Q5 high river flow effluent loading capacity scaling factor for each fish use designation period.
$b =$	A dimensionless value that has four significant digits and is defined as the $Q_R = 0$ y-intercept of a linear equation intersecting the 7Q10 low river flow effluent loading capacity scaling factor and the 7Q5 high river flow effluent loading capacity scaling factor for each fish use designation period
$Q_R =$	The rolling seven-day average ambient river flow (cfs).
$a =$	A value that adjusts the scaling factor if the seven-day average maximum natural thermal potential river temperature is warmer than the fish use designation period numeric biological temperature criteria “and” the seven-day average of the daily average natural thermal potential river temperature is cooler than the fish use designation period numeric biological temperature criteria. • If T_{RM_N} < = T_{RC}, then $a = 0$ • If T_{RM_N} > T_{RC} and T_{RA_N} >= T_{RC}, then $a = 0$ • If T_{RM_N} > T_{RC} and T_{RA_N} < T_{RC}, then $a = 1 - \left(\frac{T_{RA\_N}}{T_{RC}}\right)$
$T_{RM\_N} =$	The rolling seven-day average maximum natural thermal potential river temperature (^{o}C). Use equations in table 4.60 to estimate a “daily maximum” natural thermal potential.
$T_{RA\_N} =$	The rolling seven-day average natural thermal potential river temperature (^{o}C). Use equations in Table 4.40 to estimate a “daily average” natural thermal potential.

Table 4.39 Equations to estimate a daily maximum natural thermal potential river temperature (C).

Location	**NTP Daily Maximum**
McKenzie River at Springfield	$= \left(0.8878 \cdot T_{RM\_A}\right) + 1.39$
Willamette River at Eugene	$= \left(0.9957 \cdot T_{RM\_A}\right) - 0.29$
Willamette River at Corvallis	$= \left(1.0804 \cdot T_{RM\_A}\right) - 2.25$
Willamette River at Albany	$= \left(0.9792 \cdot T_{RM\_A}\right) - 0.87$
Willamette River at Salem	$= \left(1.0140 \cdot T_{RM\_A}\right) - 1.25$
Willamette River at Newberg	$= \left(0.9982 \cdot T_{RM\_A}\right) - 0.53$
Willamette River at Portland	$= \left(0.9981 \cdot T_{RM\_A}\right) - 0.34$
where,	
$T_{RM\_A} =$	The daily maximum ambient river temperature (^{o}C).

Table 4.40 Equations to estimate a daily average natural thermal potential river temperature (C).

Location	**NTP Daily Average**
McKenzie River at Springfield	$= \left(0.8689 \cdot T_{RA\_A}\right) + 1.35$
Willamette River at Eugene	$= \left(1.0547 \cdot T_{RA\_A}\right) - 1.28$
Willamette River at Corvallis	$= \left(1.0543 \cdot T_{RA\_A}\right) - 2.07$
Willamette River at Albany	$= \left(0.9967 \cdot T_{RA\_A}\right) - 1.19$
Willamette River at Salem	$= \left(1.0447 \cdot T_{RA\_A}\right) - 1.71$
Willamette River at Newberg	$= \left(0.9402 \cdot T_{RA\_A}\right) + 0.21$
Willamette River at Portland	$= \left(0.9768 \cdot T_{RA\_A}\right) - 0.47$
where,	
$T_{RA\_A} =$	The-daily average ambient river temperature (^{o}C).

3. Combined WLA Equation

Equation 8 substitutes equation 7 into equation 5.

A. Waste load allocation as a portion of the human use allowance and expressed as a change in temperature. (^{o}C)

$$HUA = \left(\frac{\left(\left(\left(m \cdot Q_R\right) + b\right) - a\right) \cdot Q_{PS}}{\left(\left(\left(\left(m \cdot Q_R\right) + b\right) - a\right) \cdot Q_{PS}\right) + Q_R} \right) \cdot \left(T_{PS} - T_{RC}\right) \qquad \textbf{(Eq. 8)}$$

B. Waste load allocation expressed as an excess thermal load (million kilocalories per day). This equation should be used to develop permit limits and determine compliance.

$$WLA = \left(\left(\left(m \cdot Q_R\right) + b\right) - a\right) \cdot Q_{PS} \cdot k \cdot \left(T_{PS} - T_{RC}\right) \qquad \textbf{(Eq. 9)}$$

4. Actual ETL Equation

The excess thermal load a source is actually discharging (million kilocalories per day). This equation is used to determine compliance with the waste load allocation (WLA) in equation 9.

$$\text{Actual Load} = Q_{PSC} \cdot k \cdot (T_{PSC} - T_{RC}) \quad \textbf{(Eq. 10)}$$

where,

$T_{RC} =$	The fish use designation period numeric biological temperature criteria (^{o}C).
$Q_{PSC} =$	The rolling seven-day average effluent flow (cfs).
$T_{PSC} =$	The rolling seven-day average maximum effluent temperatures (^{o}C).
$k =$	Million kilocalories conversion factor: (2.447 million kcals/day ^{o}C) $\frac{1\,\text{ft}^3}{1\,\text{sec}} \cdot \frac{1\,\text{m}^3}{35.31\,\text{ft}^3} \cdot \frac{1000\,\text{kg}}{1\,\text{m}^3} \cdot \frac{86400\,\text{seconds}}{1\,\text{day}} \cdot \frac{1\,\text{kcal}}{1\,\text{kg} \cdot 1\ {}^\circ\text{C}} \cdot \frac{1\,\text{Million kcals}}{1000000\,\text{kcals}} = 2.447$

5. Calculating Acceptable Effluent Flow

The maximum rolling seven-day average effluent flow (cfs) acceptable under the waste load allocation (WLA) equation 9 given a known effluent temperature (Tps).

$$Q_{PS\_WLA} = \frac{WLA}{(T_{PSC} - T_{RC}) \cdot k} \quad \textbf{(Eq. 11)}$$

where,

$WLA =$	Waste load allocation (Million kilocalories per day).
$T_{RC} =$	The fish use designation period numeric biological temperature criteria (^{o}C).
$T_{PSC} =$	The rolling seven-day average maximum effluent temperatures (^{o}C).
$k =$	Million kilocalories conversion factor: (2.447 million kcals/day ^{o}C) $\frac{1\,\text{ft}^3}{1\,\text{sec}} \cdot \frac{1\,\text{m}^3}{35.31\,\text{ft}^3} \cdot \frac{1000\,\text{kg}}{1\,\text{m}^3} \cdot \frac{86400\,\text{seconds}}{1\,\text{day}} \cdot \frac{1\,\text{kcal}}{1\,\text{kg} \cdot 1\ {}^\circ\text{C}} \cdot \frac{1\,\text{Million kcals}}{1000000\,\text{kcals}} = 2.447$

6. Calculating Acceptable Effluent Temperature

The maximum rolling seven-day average maximum effluent temperatures (^{o}C) acceptable under the waste load allocation (WLA) equation 9 given a known effluent flow (Qps).

$$T_{PS\_WLA} = \left(\frac{WLA}{Q_{PSC} \cdot k} \right) + T_{RC} \quad \textbf{(Eq. 12)}$$

where,

$WLA =$	Waste load allocation (Million kilocalories per day).
$T_{RC} =$	The fish use designation period numeric biological temperature criteria (^{o}C).
$Q_{PSC} =$	The rolling seven-day average effluent flow (cfs).
$k =$	Million kilocalories conversion factor: (2.447 million kcals/day ^{o}C) $\frac{1\,\text{ft}^3}{1\,\text{sec}} \cdot \frac{1\,\text{m}^3}{35.31\,\text{ft}^3} \cdot \frac{1000\,\text{kg}}{1\,\text{m}^3} \cdot \frac{86400\,\text{seconds}}{1\,\text{day}} \cdot \frac{1\,\text{kcal}}{1\,\text{kg} \cdot 1\ {}^\circ\text{C}} \cdot \frac{1\,\text{Million kcals}}{1000000\,\text{kcals}} = 2.447$

Figures 4.47 through 4.53 present statistical errors in estimating daily natural thermal potential using equations found in Table 4.39 and 4.40. These statistics should not be confused with those found in the W2 model calibration summary in Technical Appendix C which compares current condition values with modeled current condition values.

Root Mean Square Error (RMS) – A root mean square error of zero indicates a perfect fit. Root mean square error is a measure of the magnitude of the difference between predicted data and known data.

$$RMS = \sqrt{\frac{\sum (y-x)^2}{n}} \quad \textbf{(Eq. 13)}$$

R Squared – An r squared of one indicates a perfect fit. R squared measures how well a regression line fits observed data.

$$R^2 = \frac{n\left(\sum xy\right) - \left(\sum x\right)\left(\sum y\right)}{\sqrt{\left[n\sum x^2 - \left(\sum x\right)^2\right]\left[n\sum y^2 - \left(\sum y\right)^2\right]}} \quad \textbf{(Eq, 14)}$$

y = The predicted daily natural thermal potential river temperature using current condition data and equations found in Table 4.39 and 4.40.
x = The daily natural thermal potential river temperature determined through modeling
n = Total number of data points or observations

Figure 4.47 McKenzie River NTP temperatures compared to observed temperatures at Springfield

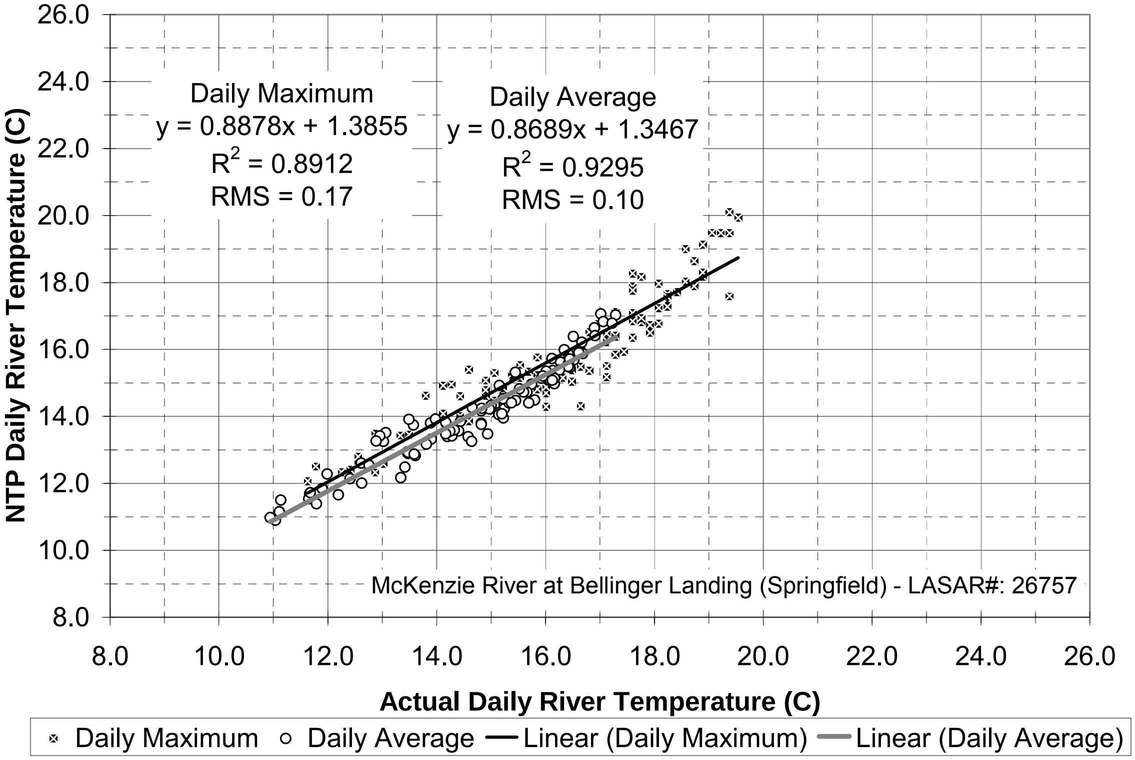


Figure 4.48 **Willamette River NTP temperatures compared to observed temperatures at Eugene**

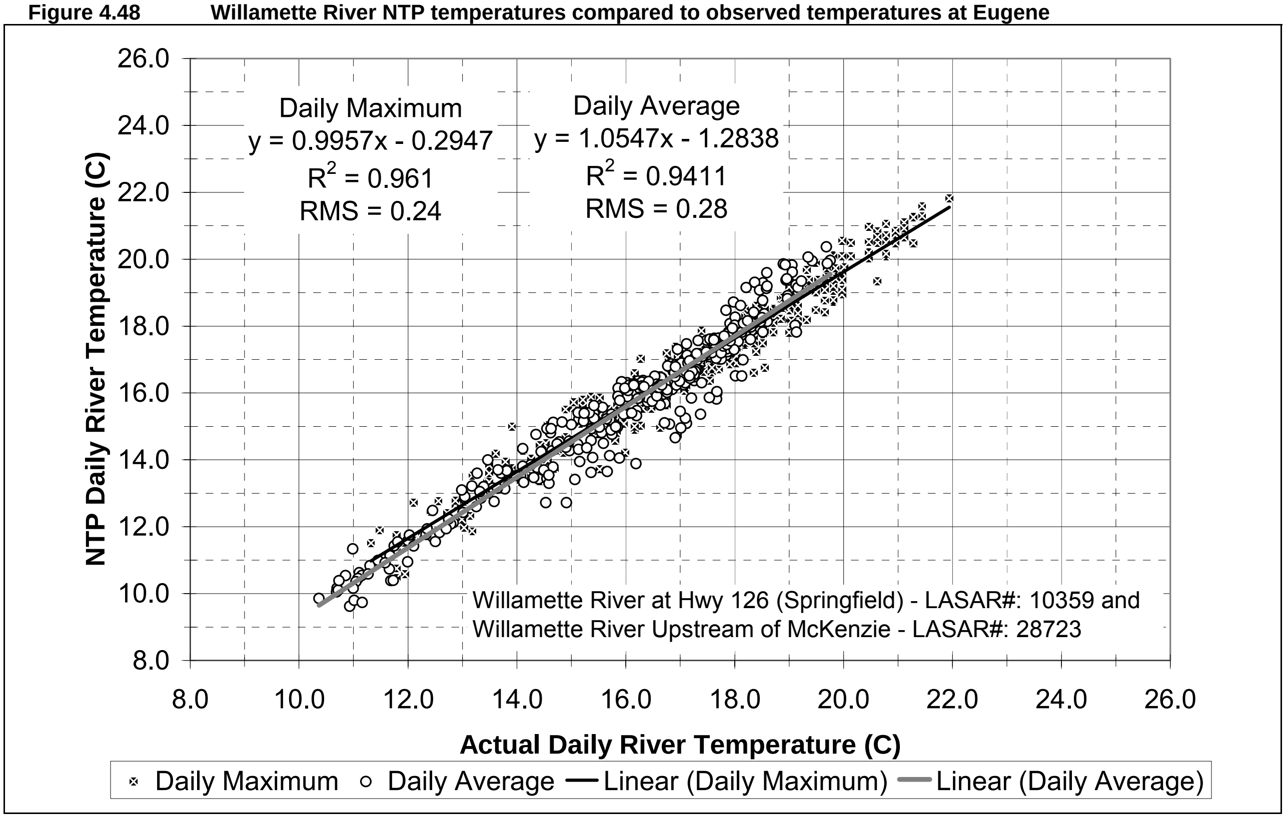


Figure 4.49 **Willamette River NTP temperatures compared to observed temperatures at Corvallis**

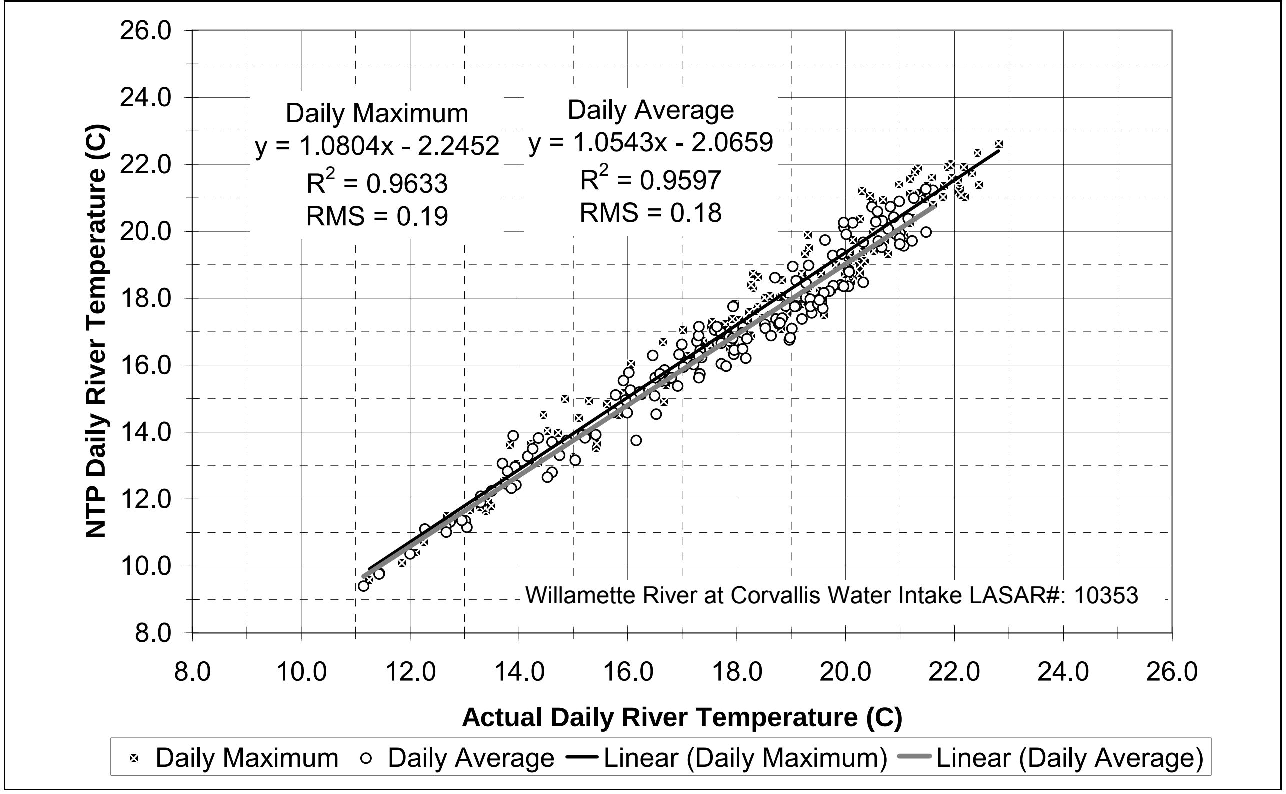


Figure 4.50 **Willamette River NTP temperatures compared to observed temperatures at Albany**

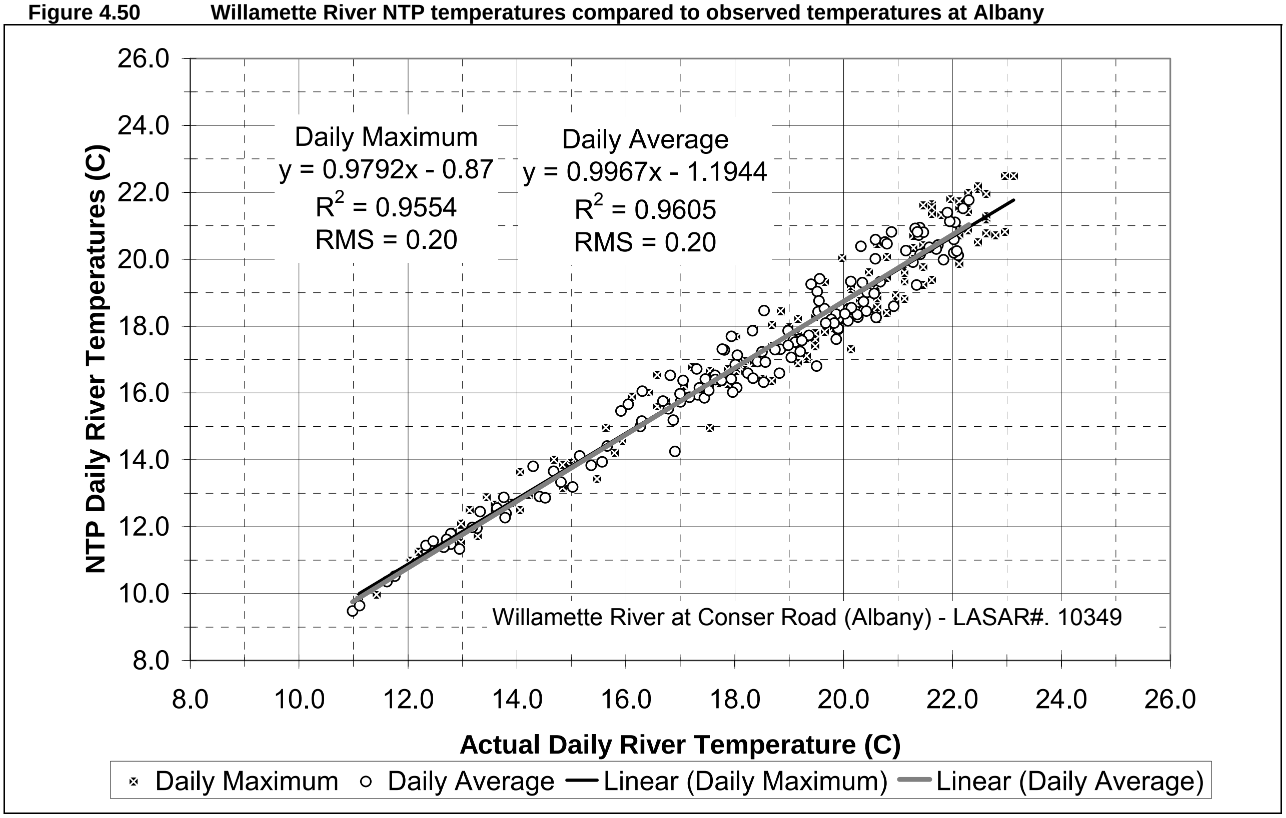


Figure 4.51 **Willamette River NTP temperatures compared to observed temperatures at Salem**

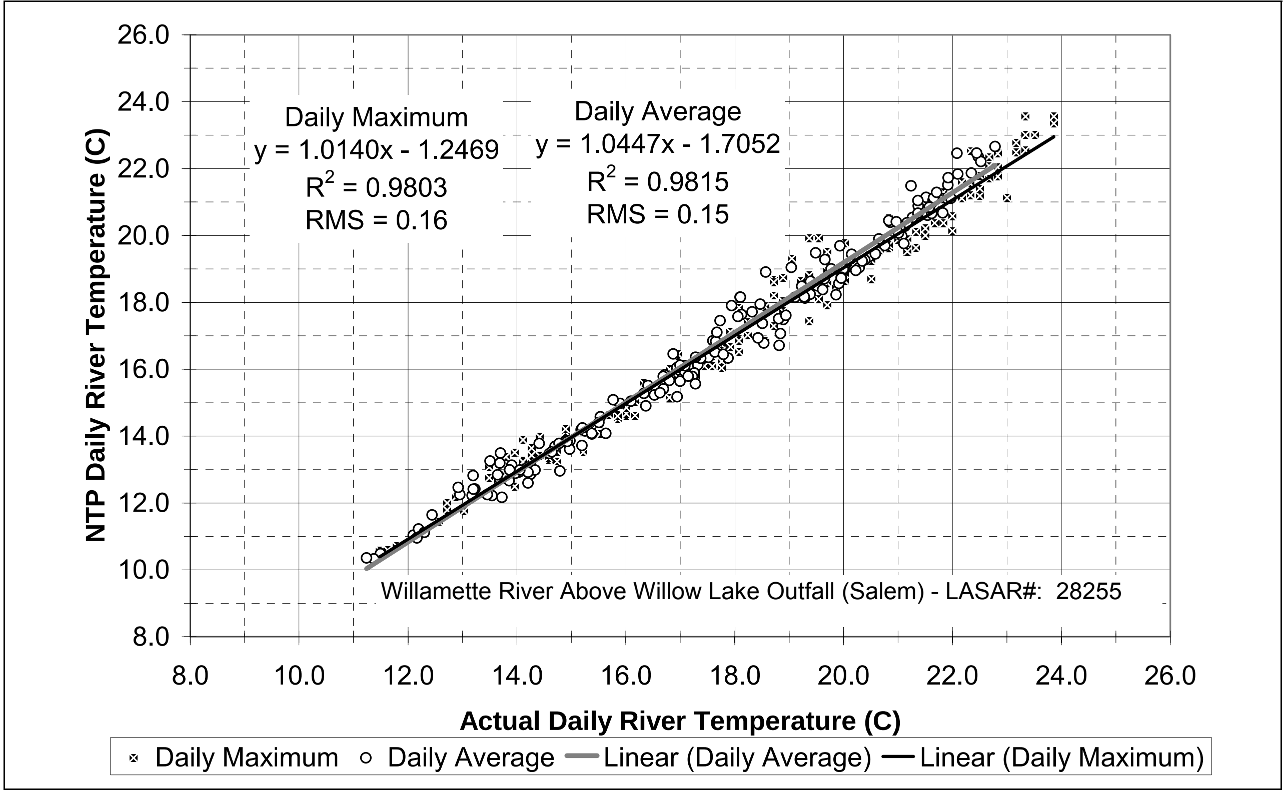


Figure 4.52 Willamette River NTP temperatures compared to observed temperatures at Newberg

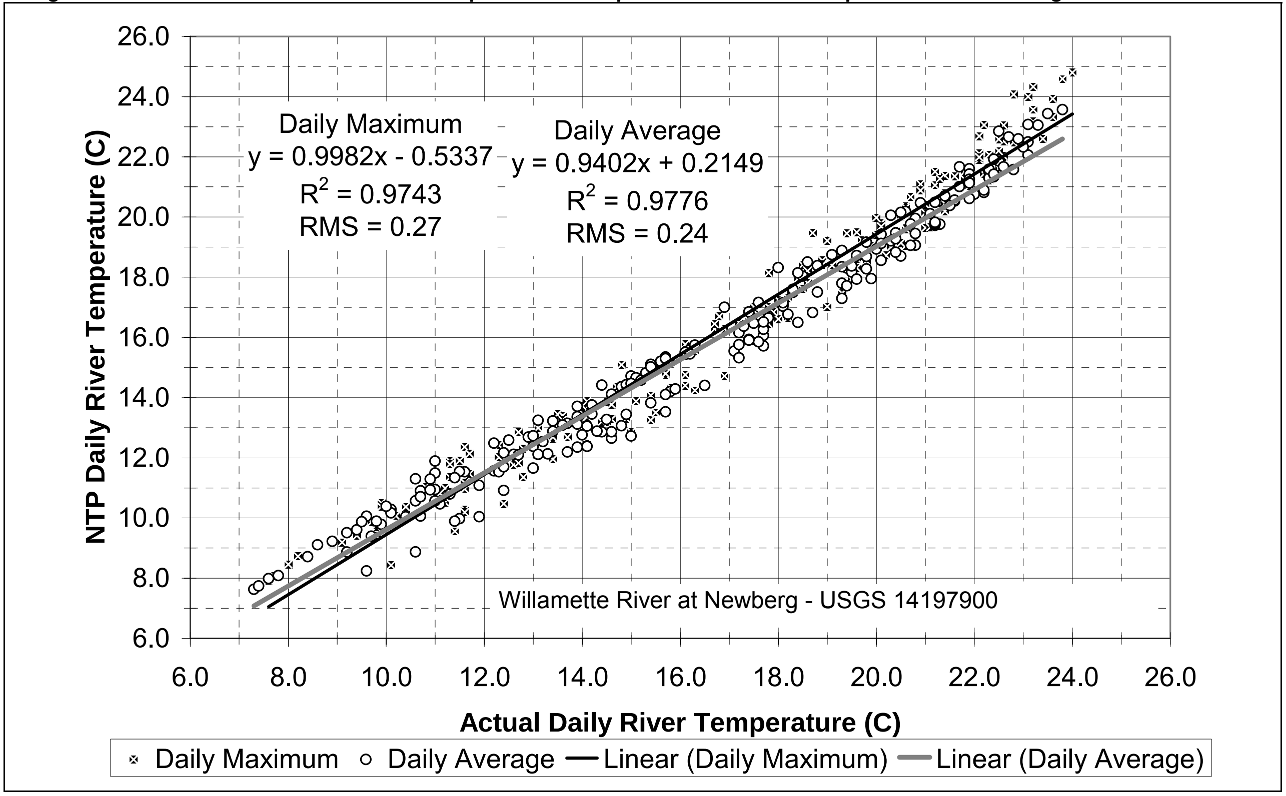
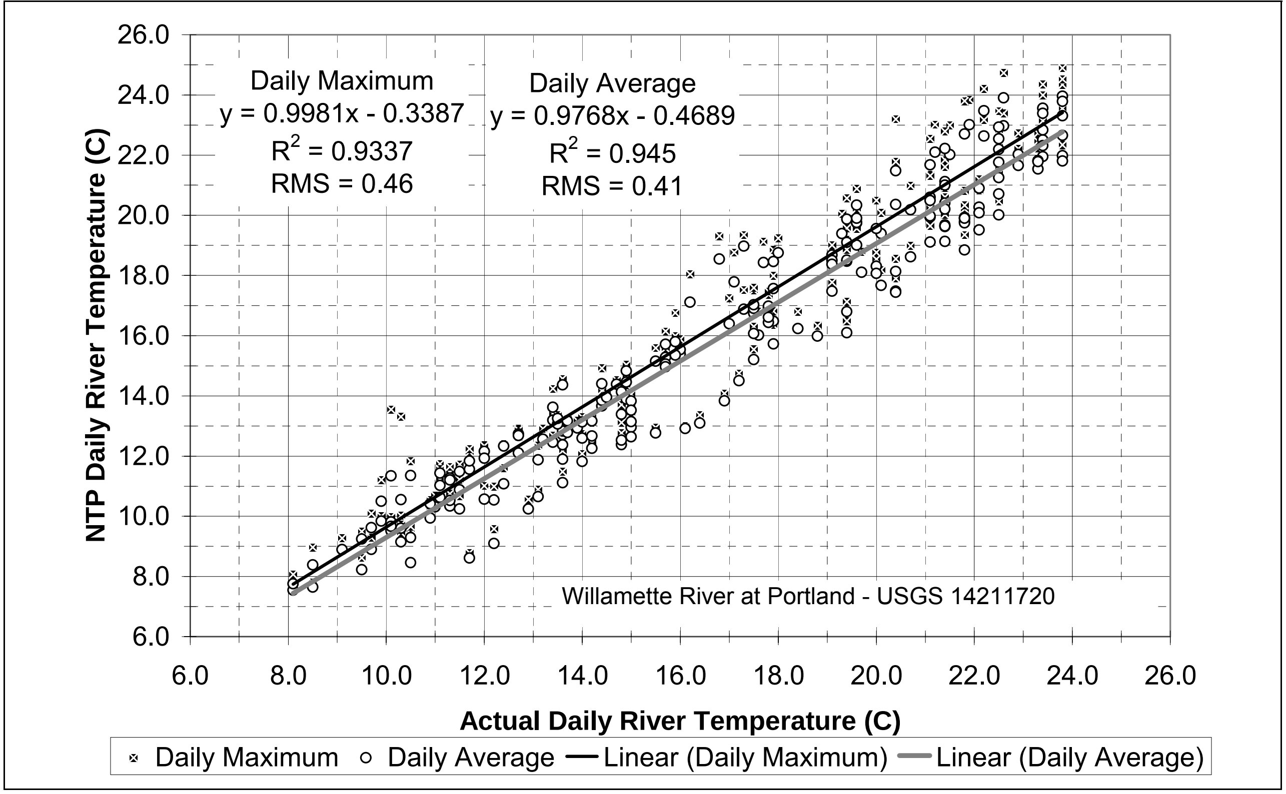


Figure 4.53 Willamette River NTP temperatures compared to observed temperatures at Portland



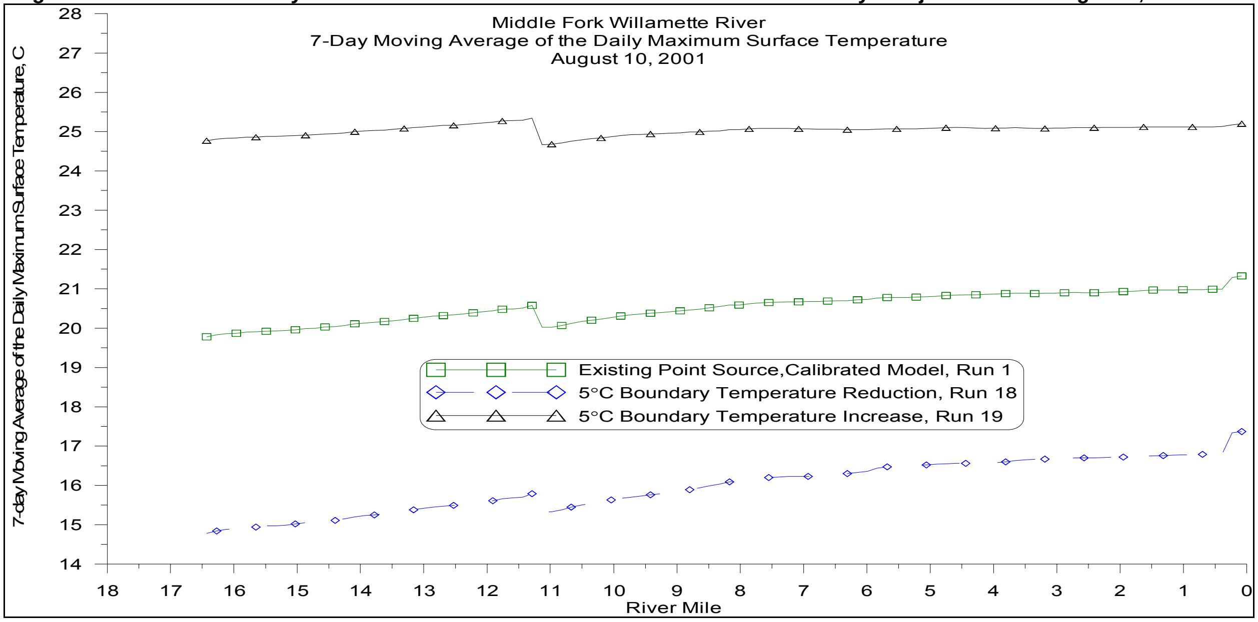
Appendix 4.6 - Sensitivity of River Temperatures to Point and Nonpoint Source Influences

This section describes the results of modeling analyses performed to evaluate the sensitivity of river temperature to various influences including upper boundary flow rate and temperature, vegetative shade, existing effluent heat loads, and hydroelectric project operations. In addition, the section analyzes the impact several system potential condition scenarios and the impact of small tributaries.

Influence of Boundary Condition Temperature

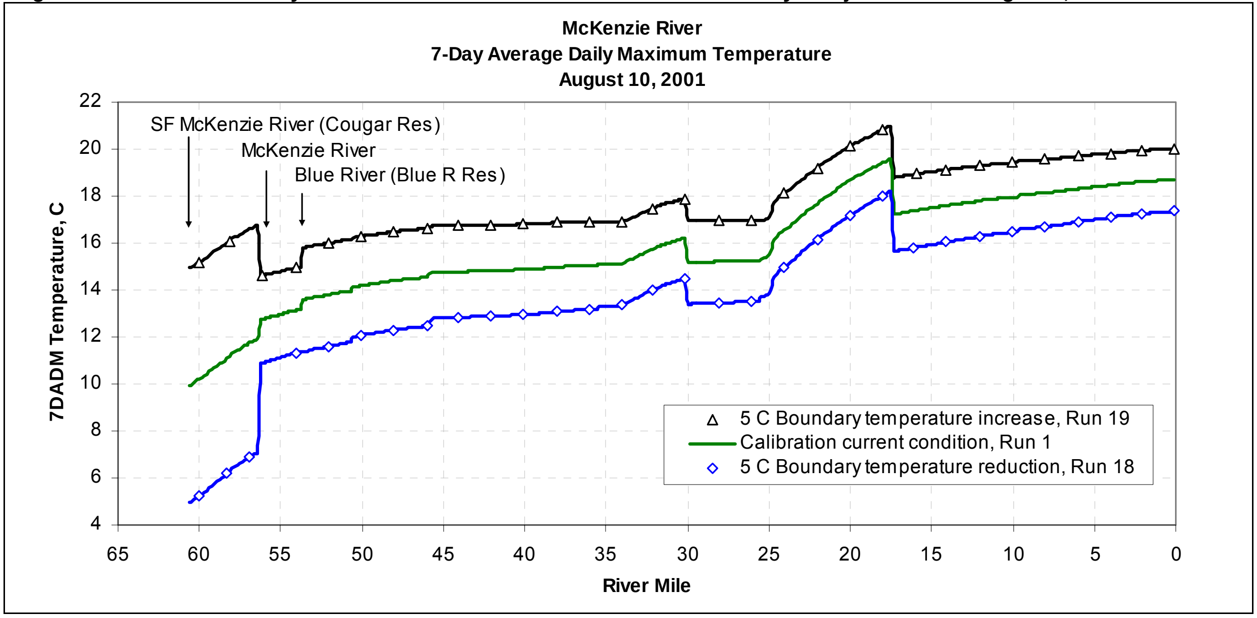
Upper boundary temperatures influence temperature all the way to the Willamette River's confluence with the Columbia River. In order to evaluate the degree of influence, modeling simulations were performed with +/- 5°C dam tailrace temperature adjustments made at all dams. The simulations were performed for actual 2001 flow conditions (not BiOp flows). Calculated 7-day average daily maximum (7DADM) temperatures for an example week centered on August 10, 2001 (the seven day average of daily maximums for August 7-13) are presented for two major tributaries, the Middle Fork Willamette River and the McKenzie River (Figures 4.54 and 4.55).

Figure 4.54 **Sensitivity of Middle Fork Willamette 7DADM T to +/- 5°C boundary T adjustment for Aug 7-13, 2001**



Because of its high flow and short (16.5 mile) distance from the dam to mouth, the Middle Fork Willamette is quite sensitive to boundary temperature (Figure 4.54). About 7.5°C of the 10°C boundary temperature difference remains at the river's mouth where the river combines with the Coast Fork Willamette to form the Willamette River. This equates to a 0.75°C increase for every 1.0°C increase in boundary temperature. For the McKenzie River, for which the distance from dam to mouth is much greater, the temperature at the mouth is less sensitive to upper boundary temperature (Figure 4.55). About 2.6°C of the 10°C boundary temperature difference remains at the McKenzie River mouth.

Figure 4.55 **Sensitivity of McKenzie River 7DADM T to +/- 5°C boundary T adjustment for Aug 7-13, 2001**



As the water moves downstream through the Willamette River, the influence of upper boundary temperature gradually diminishes (Figure 4.56). By the City of Salem at RM 84, 2.3°C of the 10°C boundary temperature difference remains. By the Willamette Falls at RM 26.5, 1.0°C of the 10°C boundary temperature difference remains (Figure 4.57).

Figure 4.56 **Sensitivity of Upper Willamette 7DADM T +/- 5°C boundary T adjustment for Aug 7-13, 2001**

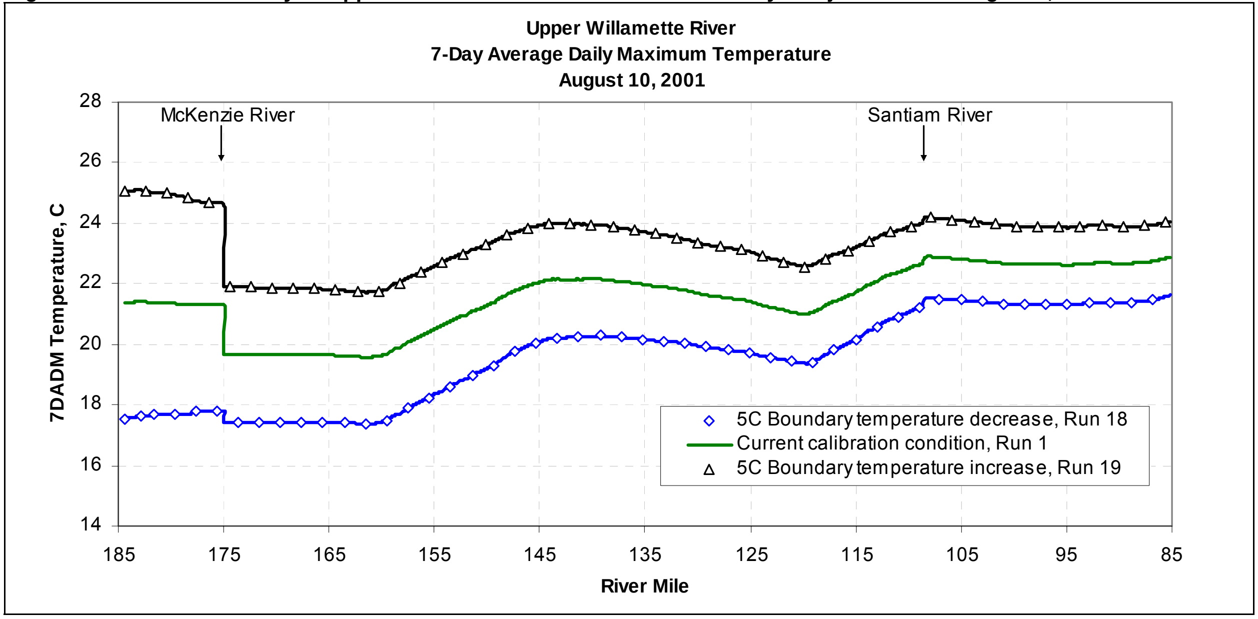
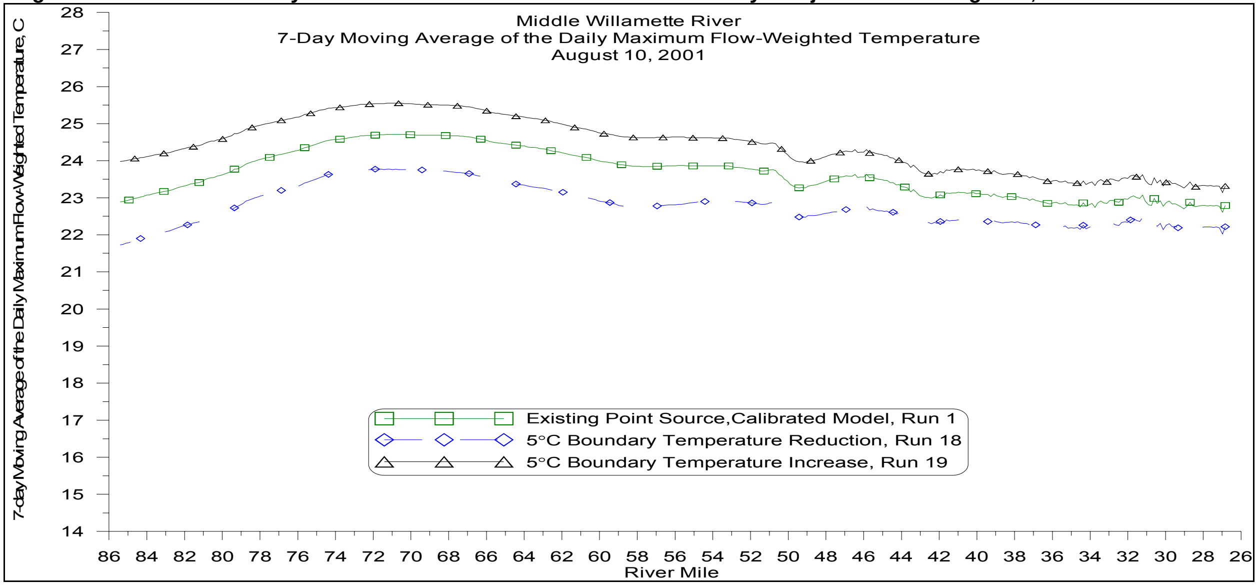


Figure 4.57 Sensitivity of Mid-Willamette 7DADM T +/- 5°C boundary T adjustment for Aug 7-13, 2001



Unit Delta T, based on the calculated difference between +5°C and -5°C model runs divided by 10°C, is presented in Figure 4.58 and Figure 4.59 for the summer (June 15 through September 15, 2001). As shown, the model indicates that a 1.0°C increase in temperature at upper boundaries results in median temperature increases of 0.75°C near the confluence of the Coast Fork and Middle Fork Willamette, 0.25°C near Salem (RM 85), and a little over 0.10°C upstream at the Willamette Falls (RM 26.5).

The median condition is the value for which half the values are greater than and half the values are less than. For a normally distributed dataset, it is equal to the average. One of the advantages of using the median over the average is that it is not influenced by extreme outliers which may affect the average.

5th and 95th percentile percentiles are also used in some of the plots. The 5th percentile is a low value for which only 5% of values are less than, while the 95th percentile is a high value which 95% of the values are less than. These values are generally better to uses than minimums and maximums because, like the median, they are less likely to be influenced by outliers.

In the lower Willamette below the Falls, the influence increases to about 0.15°C per degree of boundary condition temperature increase, presumably due to the influence of the Clackamas River (the upper boundary for the Clackamas River is only 23.4 miles above the Willamette). At the Willamette River mouth the influence diminishes to zero due to the influence of the Columbia River.

Figure 4.58 Impact of 1.0°C increase in upper boundary temperature on Upper Willamette

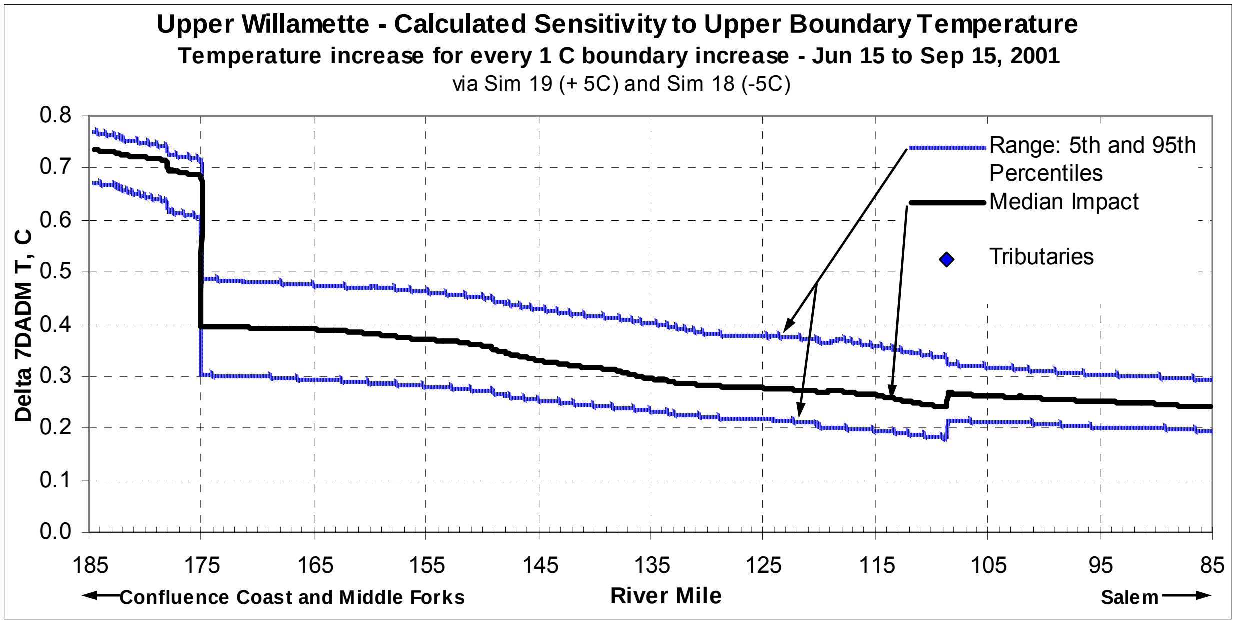
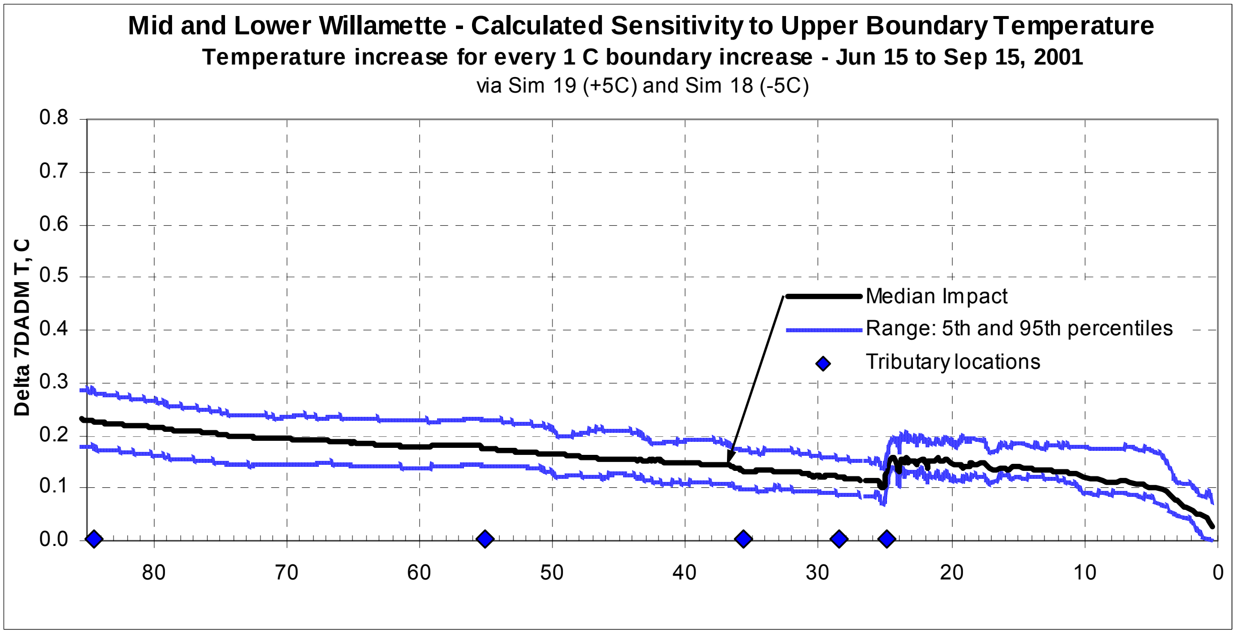


Figure 4.59 Impact of 1.0°C increase in upper boundary temperature on Mid and Lower Willamette - Summer



During the fall, the impact is of upper boundary temperature is slightly greater (see Figure 4.60 and 4.61).

Figure 4.60 Impact of 1.0°C increase in upper boundary temperature on Upper Willamette - Fall

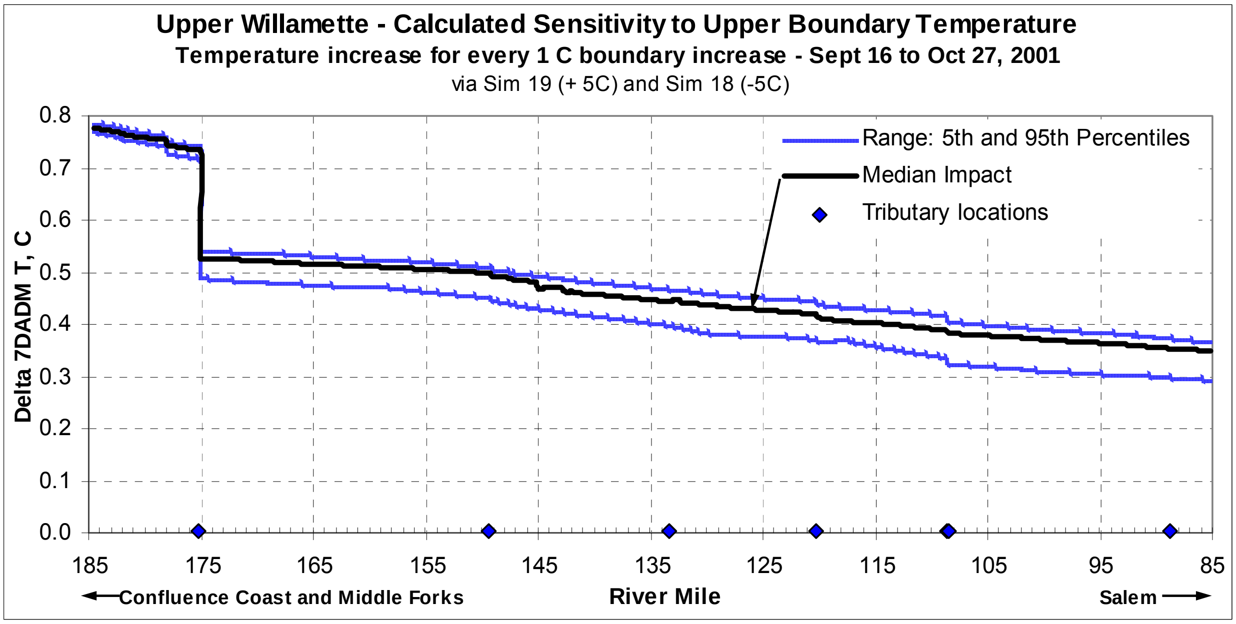
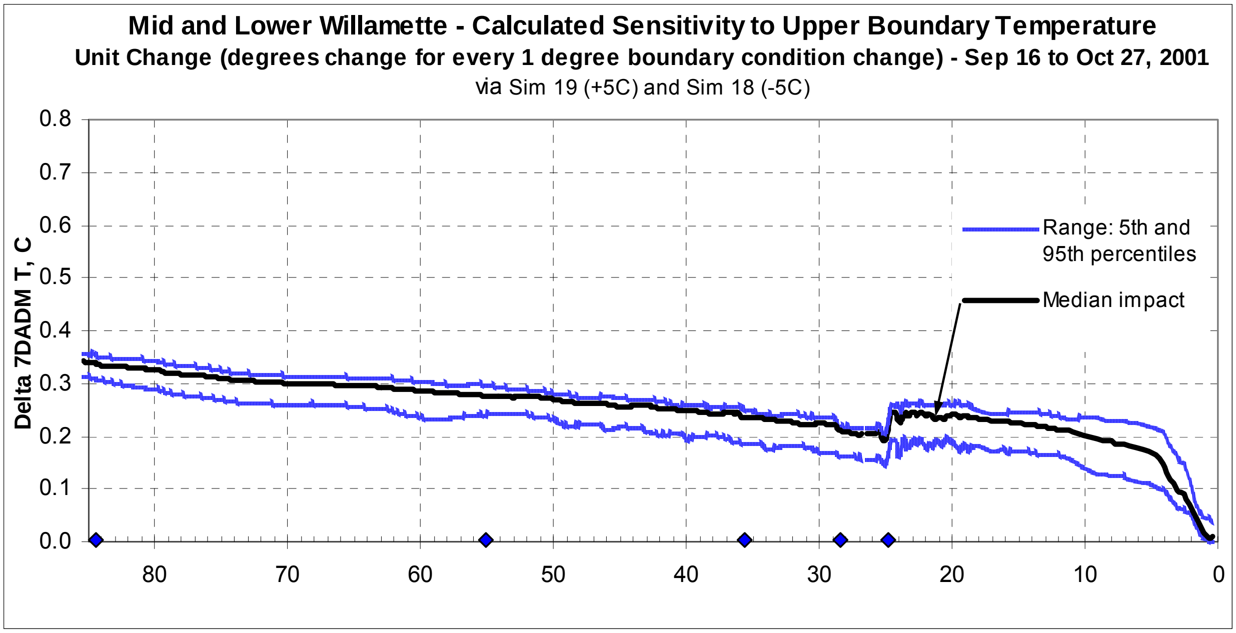
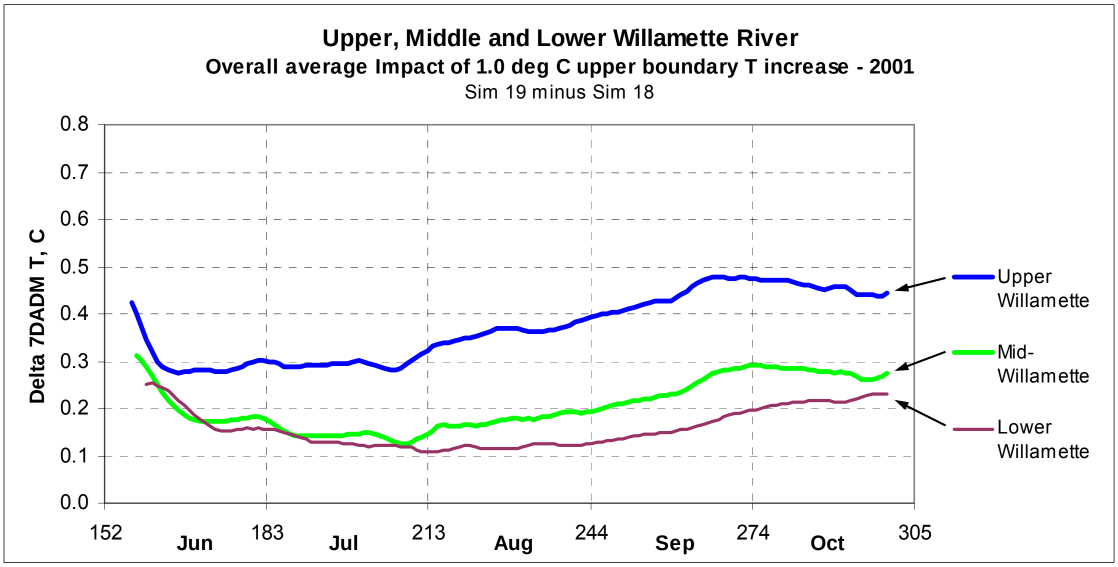


Figure 4.61 Impact of 1.0°C increase in upper boundary temperature on Mid and Lower Willamette - Fall



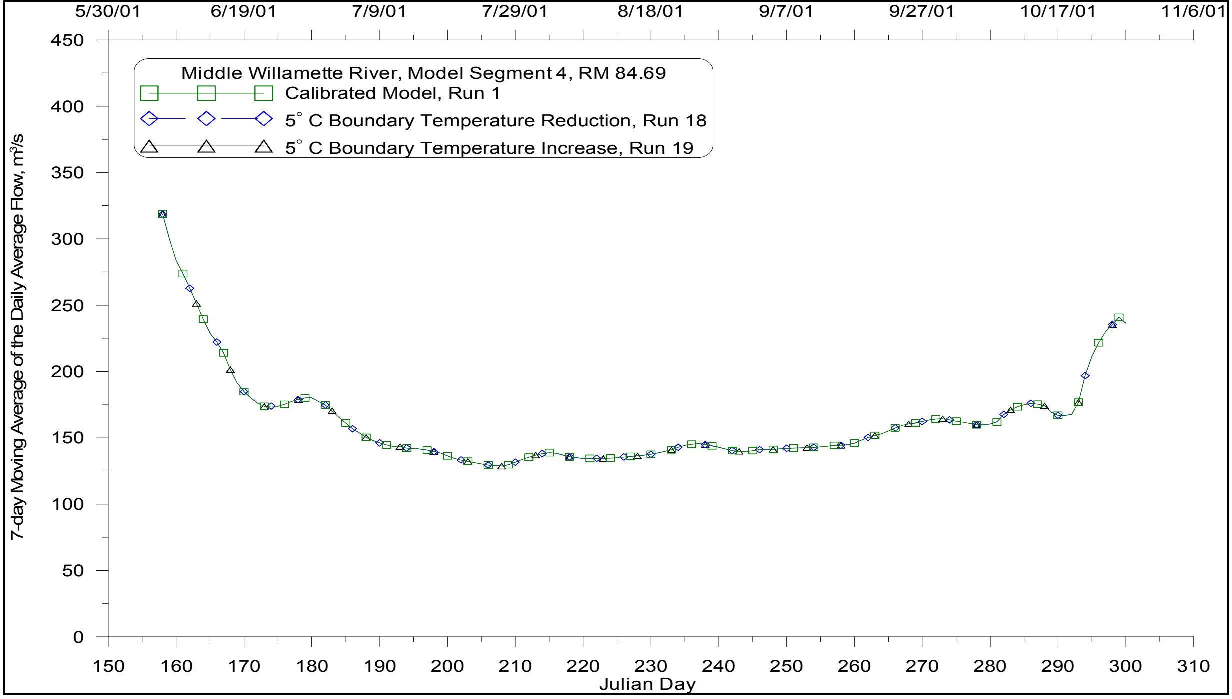
The seasonal influence of boundary temperature is shown in Figure 4.62, which shows overall average unit impacts for the upper, mid, and lower Willamette. This is calculated by averaging, for each day modeled, the difference between calculated 7DADM temperatures for Simulations 18 and 19 for all model segments for each reach. As shown, the influence of boundary temperature is least in the early summer and greatest in the early fall.

Figure 4.62 **Overall average impact of boundary condition temperature impact on river temperature**



The degree of boundary condition impact may be partly a function of river flow rate. As river flow rate increases, time-of-travel decreases and the impact of upper boundary conditions are carried downstream more quickly. As shown by Figure 4.63, flow rate was greatest in early June, when the impact of boundary condition temperature was relatively large, and least in late June, when the boundary condition temperature impact was least. However, the gradual increase in unit impact from late July to mid September seems to be only partly due to flow, since flow rates were relatively constant during this period.

Figure 4.63 **Model calculated flow near Salem (2001 calibration)**



Influence of Flow

River temperature is also sensitive to river flow rate, with flow increases generally resulting in river temperature reductions. To evaluate the degree of influence, modeling simulations were performed with upper boundary dam release flow rates adjusted 20% upwards and downwards from actual 2001 flow rates (not BiOp flow rates). Calculated 7DADM temperatures for August 10, 2001 (average of daily maximums for August 7-13) are presented for two major tributaries, the Middle Fork Willamette River (Figure 4.64) and the McKenzie River (Figure 4.65). As expected, there is an inverse relationship between flow and temperature, with flow reductions resulting in temperature increases. A 20% flow reduction produces river mouth temperatures that are 0.5°C warmer in the Middle Fork and 0.3°C warmer in the McKenzie.

Figure 4.64 **Sensitivity of Middle Fork 7DADM T to +/- 20% boundary flow adjustments for Aug 7-13, 2001**

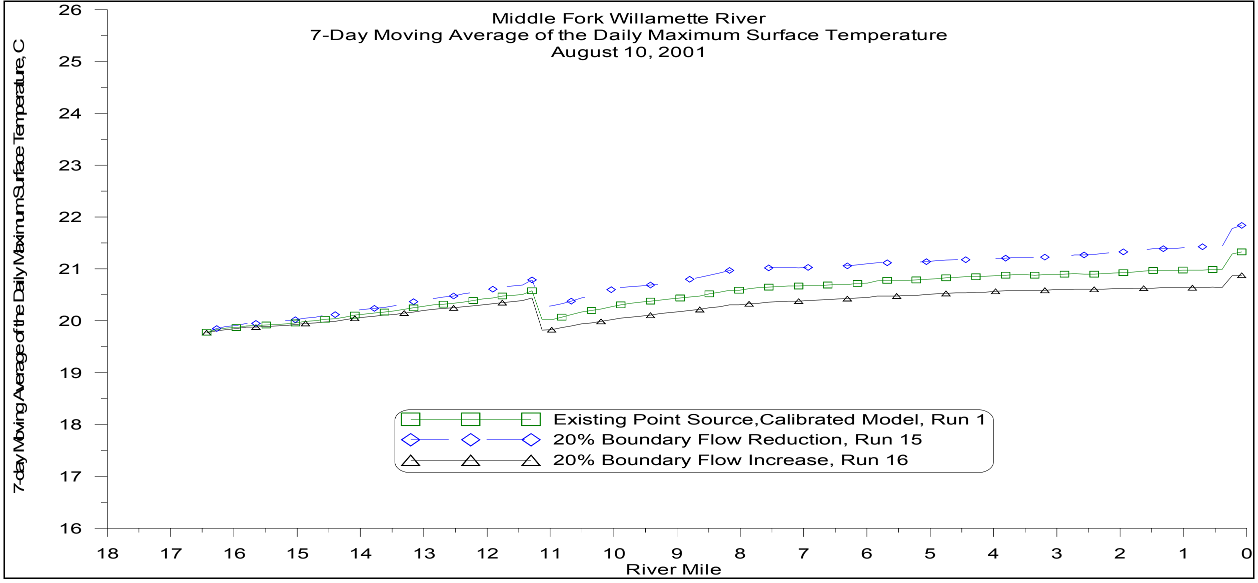
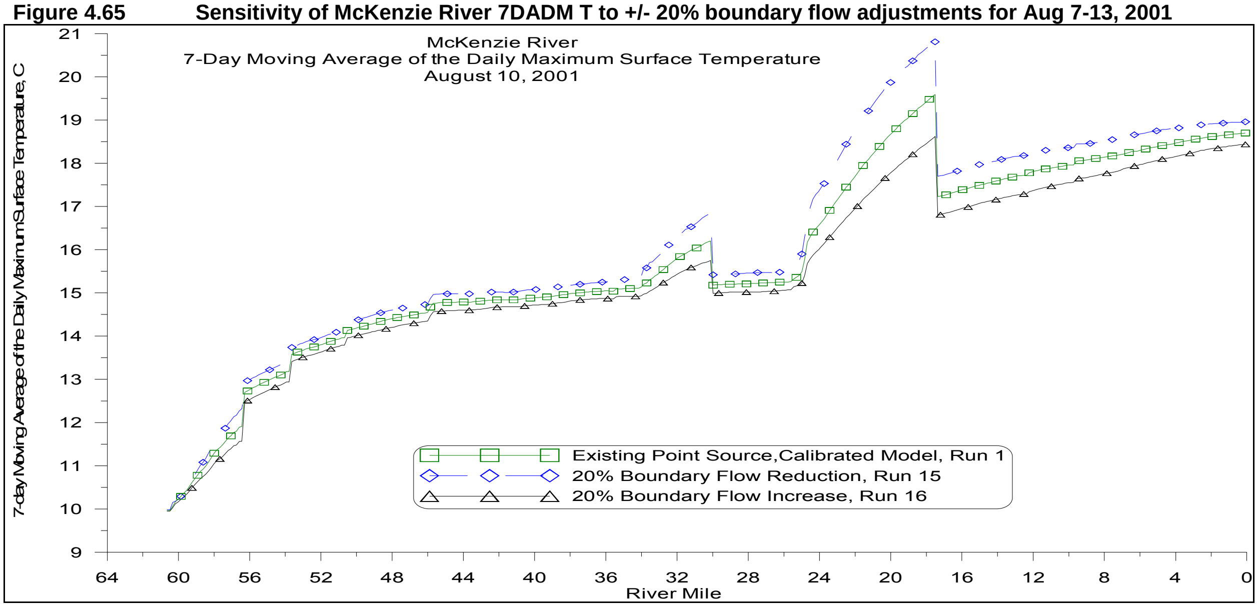
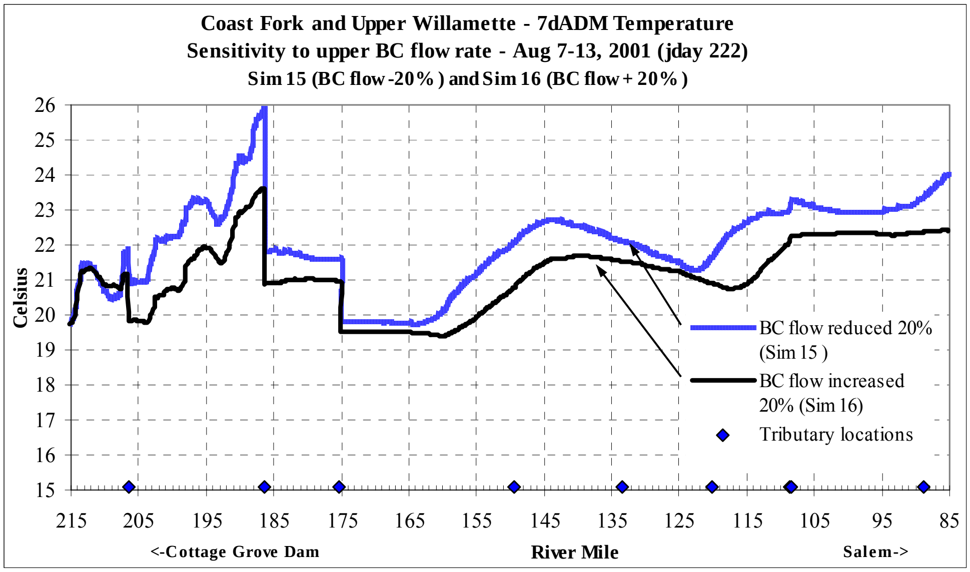


Figure 4.65 **Sensitivity of McKenzie River 7DADM T to +/- 20% boundary flow adjustments for Aug 7-13, 2001**



Unlike the influence of upper boundary temperature, changes in upper boundary flow generally result in temperature changes that become more pronounced as the water moves downstream, at least in the Upper Willamette. In the Upper Willamette, a 20% flow reduction results in a 0.6°C increase in temperature at RM 145 and a 0.9°C increase at RM 115 (Figure 4.66).

Figure 4.66 **Sensitivity of Willamette temperature to +/-20% boundary flow adjustment for Aug 7-13, 2001**

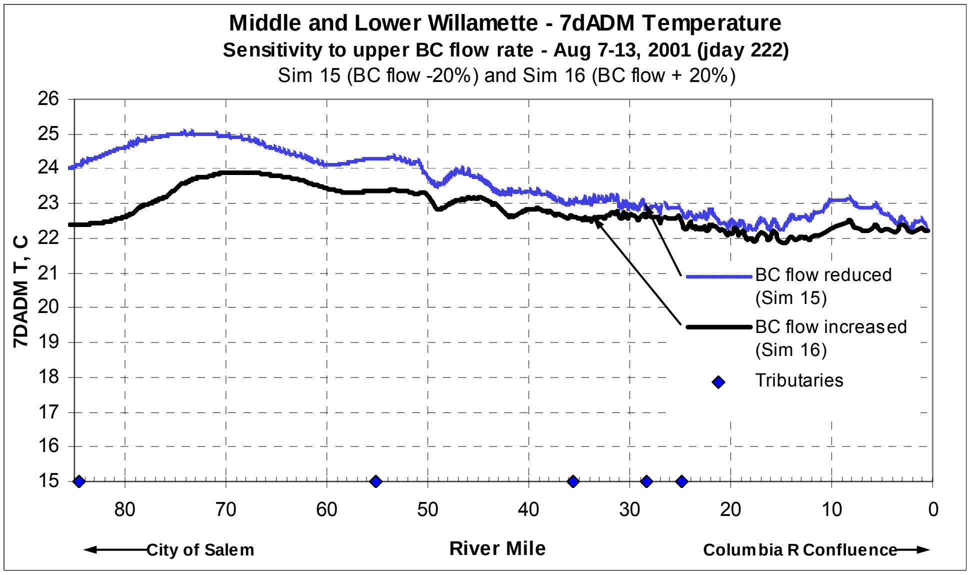


RM	*Tributaries*
206.52	***Row River***
186.32	***CF/MF Confluence***
175.3	***McKenzie R***
149.4	***Long Tom R***
133.4	***Marys R***
120.2	***Calapooia R***
108.7	***Luckiamute R***
108.5	***Santiam R***
88.8	***Rickreal Cr***

Some of this increase is due to time-of-travel related shifts in locations of maximum and minimum temperatures. This is illustrated by temperatures in the Upper Willamette at RM 126, where the difference between the temperatures for the model runs is negligible, versus RM 115, where it is quite large.

The greatest impact of flow on temperature for August 10 is at RM 82, where a 10% reduction in flow results in a 1.0°C increase in temperature (Figure 4.67). Below RM 52 in the Newberg Pool, the impact of flow on temperature gradually diminishes.

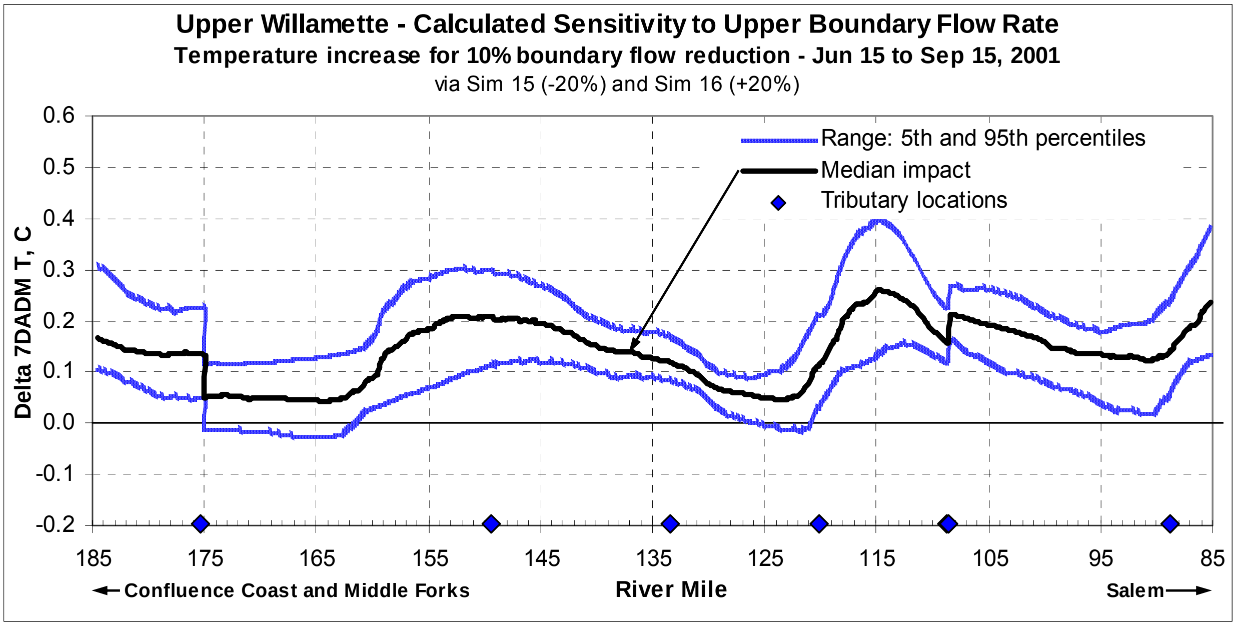
Figure 4.67 **Sensitivity of Willamette temperature to +/-20% boundary flow adjustment for Aug 7-13, 2001**



RM	*Tributaries*
84.5	***Mill Creek***
55.1	***Yamhill R***
35.6	***Molalla R***
28.4	***Tualatin R***
24.85	***Clackamas R***

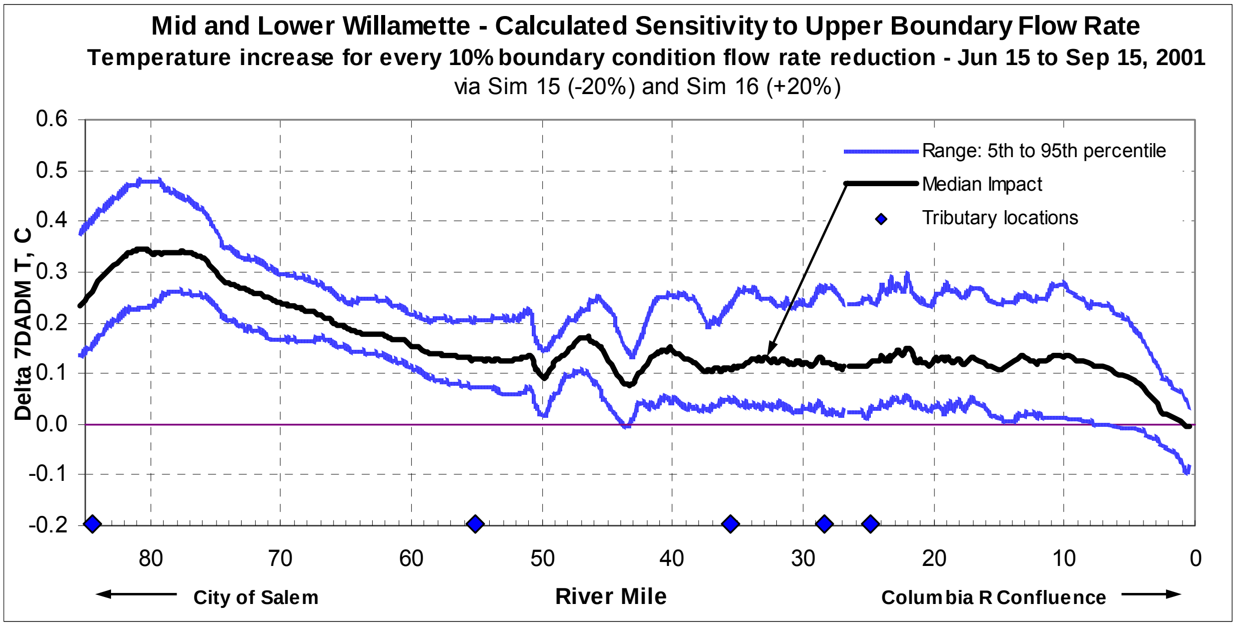
Median temperature increases for a 10% boundary condition flow reduction (based on Sim 15 calculated 7DADM temperature minus Sim 16 7DADM T, divided by 4) is presented in Figure 4.68 and Figure 4.69 for the summer (June 15 through September 15, 2001). Values were divided by 4 to convert from the impact of a +/- 20% flow change to the impact of a 10% flow reduction. Shown are medians for every river mile for the summer (June 15 to September, 2001), along with 5th and 95th percentiles.

Figure 4.68 **Sensitivity of Upper Willamette temperature to a 10% boundary flow reduction - Summer**



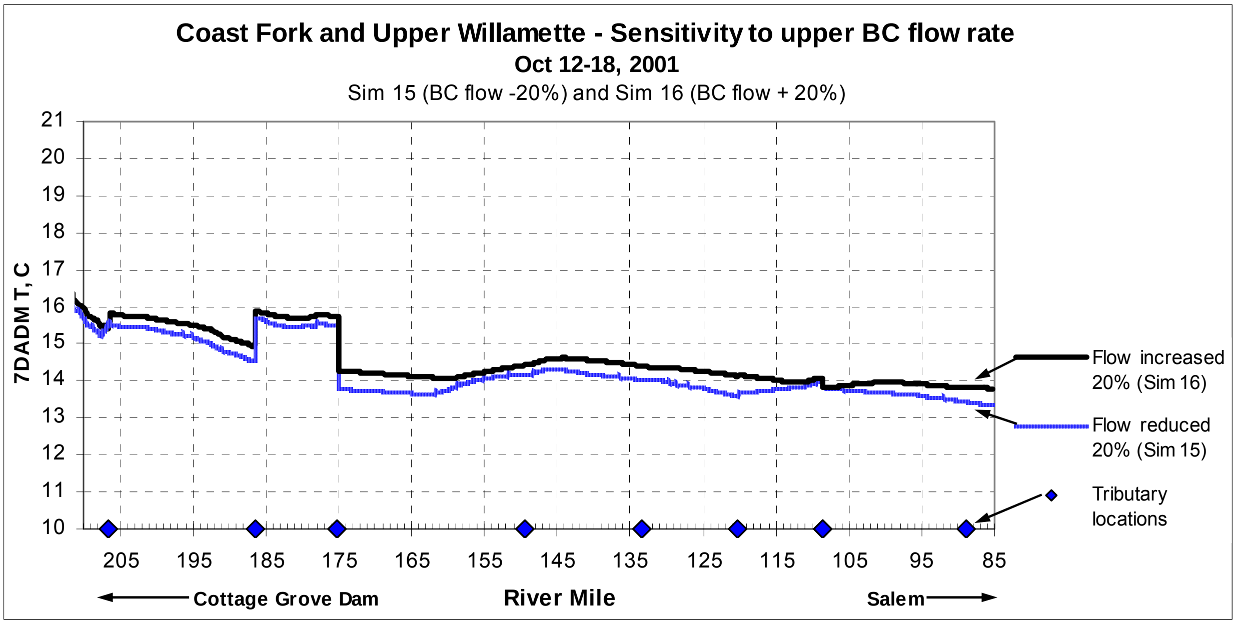
The model indicates that a 10% decrease in flow at all upper boundaries will result in median increases in temperature of 0.05 to 0.35°C (Figure 4.83). The maximum sensitivity is near RM 115 and near RM 80, where a 10% reduction in flow produces 0.35°C increases in temperature (Figures 4.68 and Figure 4.69).

Figure 4.69 **Sensitivity of Mid and Lower Willamette temperature to a 10% boundary flow reduction - Summer**



Unlike during the summer, the relationship during the fall between river flow rate and river temperature is less clear. Oftentimes the relationship is reversed and increases in flow result in river temperatures that are warmer, rather than cooler. This is illustrated for an example fall 7-day period by Figure 4.70 The positive relationship between flow and temperature is probably because tailrace temperatures were warmer than equilibrium temperatures on these dates due to storage of heat in the reservoirs. This resulted in the water cooling as it flowed downstream. Reducing the flow increases travel time and allows more time for the water to cool.

Figure 4.70 **Sensitivity of Willamette temperature to +/-20% boundary flow adjustment for Oct 15, 2001**



Impacts during the fall period modeled (September 16 to October 27, 2001) are shown in Figures 4.71 and 4.72. As shown, reductions in flow during this period sometimes results in warmer temperatures, and sometimes cooler temperatures. In the Lower Willamette, reductions in flow rates, like in the summer months, generally result in warmer temperatures (Figure 4.72).

Figure 4.71 **Sensitivity of Mid and Lower Willamette temperature to a 10% boundary flow reduction - Fall**

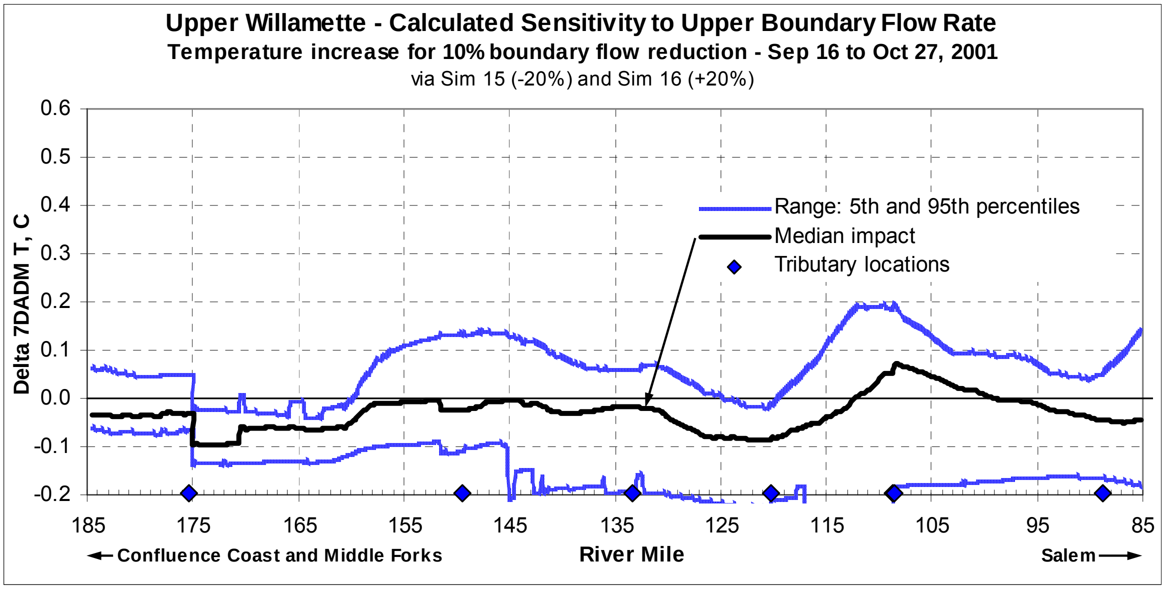
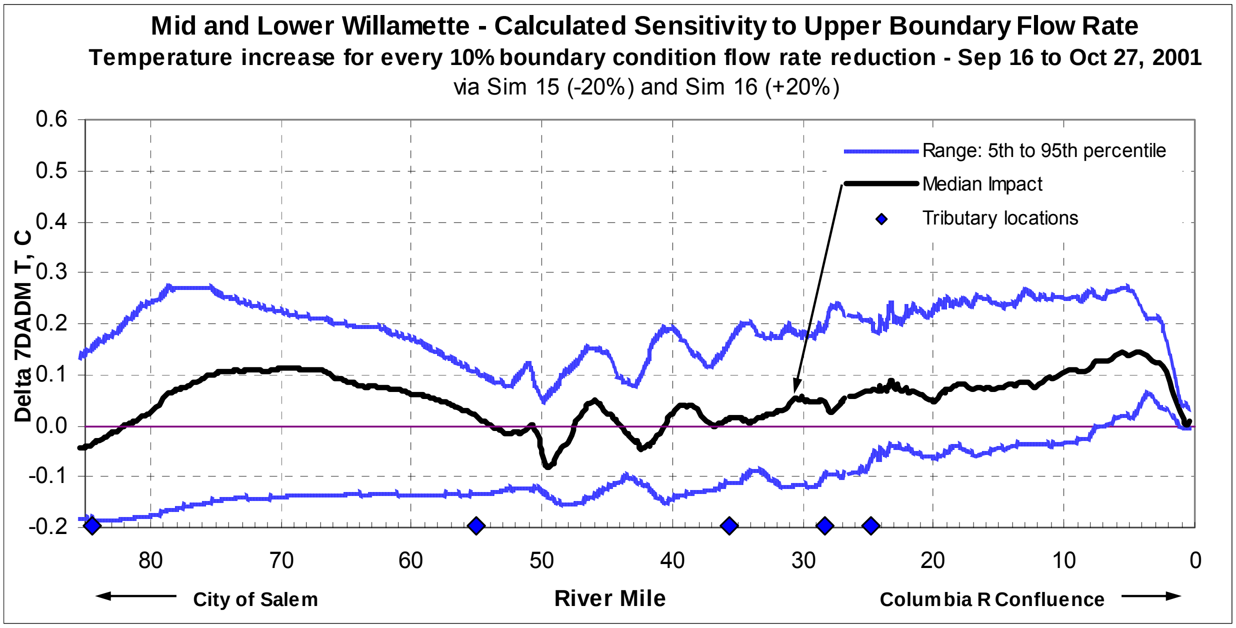
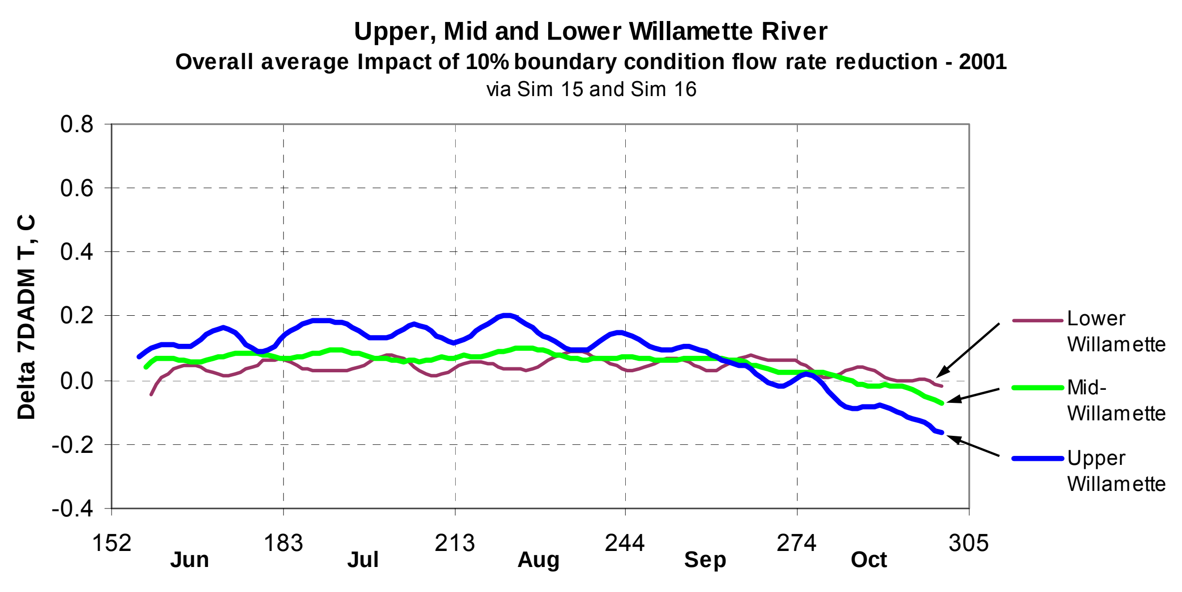


Figure 4.72 **Sensitivity of Mid and Lower Willamette temperature to a 10% boundary flow reduction - Fall**



The seasonal influence of boundary flow is also illustrated by Figure 4.73, which shows overall average unit impacts for the upper, middle, and lower Willamette. This is calculated by averaging, for each day modeled, the differences between calculated 7DADM temperatures for Simulations 15 and 16 for all model segments. As shown, as discussed above, river temperature is inversely related to flow during the summer, but frequently directly related to flow during the fall. The figure also shows that the impacts of flow are generally greatest in the Upper Willamette.

Figure 4.73 **Overall average impact of boundary condition flow on river temperature**



Influence of Shade

The entire system, except for the lower most reaches of the Willamette River and the Columbia River, is significantly influenced by shade provided by riparian vegetation. The influence is greatest on narrow reaches which are more easily shaded. On wide reaches, such as Newberg Pool and lower Willamette below Willamette Falls, the influence is less significant.

To evaluate the influence, simulations were performed with shade at current conditions (Sim 1), system potential conditions (Sim 21), and also a hypothetical condition with no vegetative shade (Sim 20). All simulations were performed for 2001 calibration current conditions, with shade the only deviation from calibration current conditions (CCC). Results for a typical summer day are presented in figures below.

A reach with a large sensitivity to shade is the Coast Fork Willamette (Figure 4.74). The model indicates that restoring shade to system potential levels could reduce temperatures 2^{o}C at the rivers confluence with the Middle Fork Willamette. The Coast Fork is more sensitive to shade than the Middle Fork Willamette, which has a corresponding sensitivity of 1^{o}C at the mouth (Figure 4.75), partly because it has significantly less flow than the Middle Fork which results in greater time of travel and time of solar radiation exposure.

Figure 4.74 Influence of shade on Coast Fork Willamette - August 10, 2001

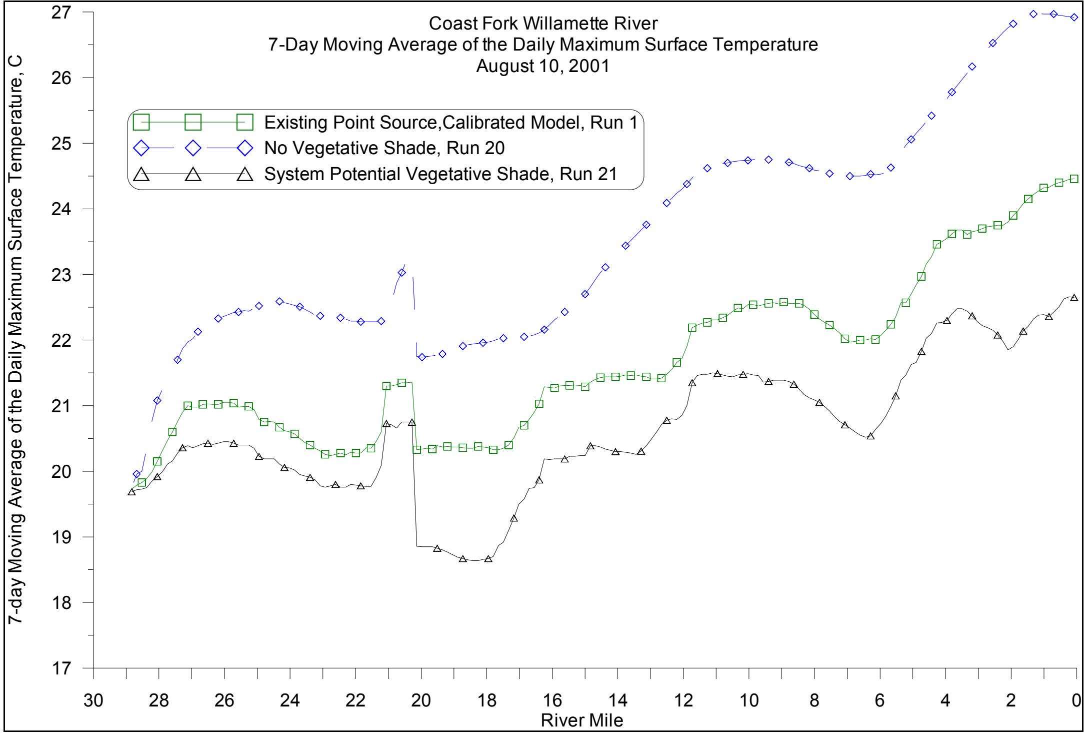
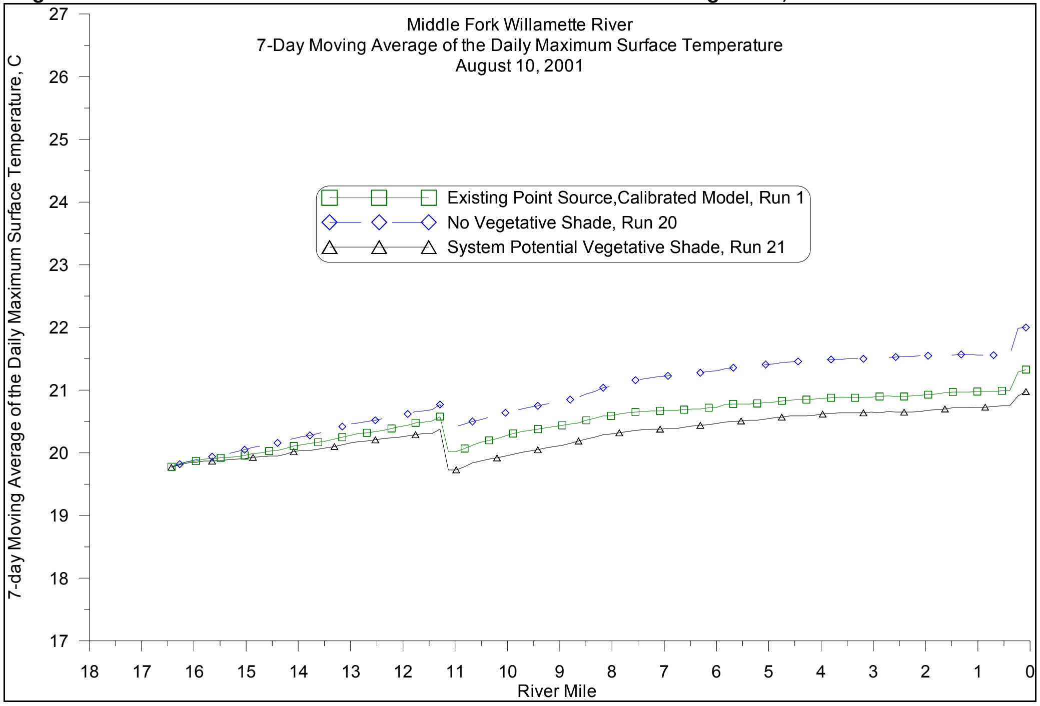
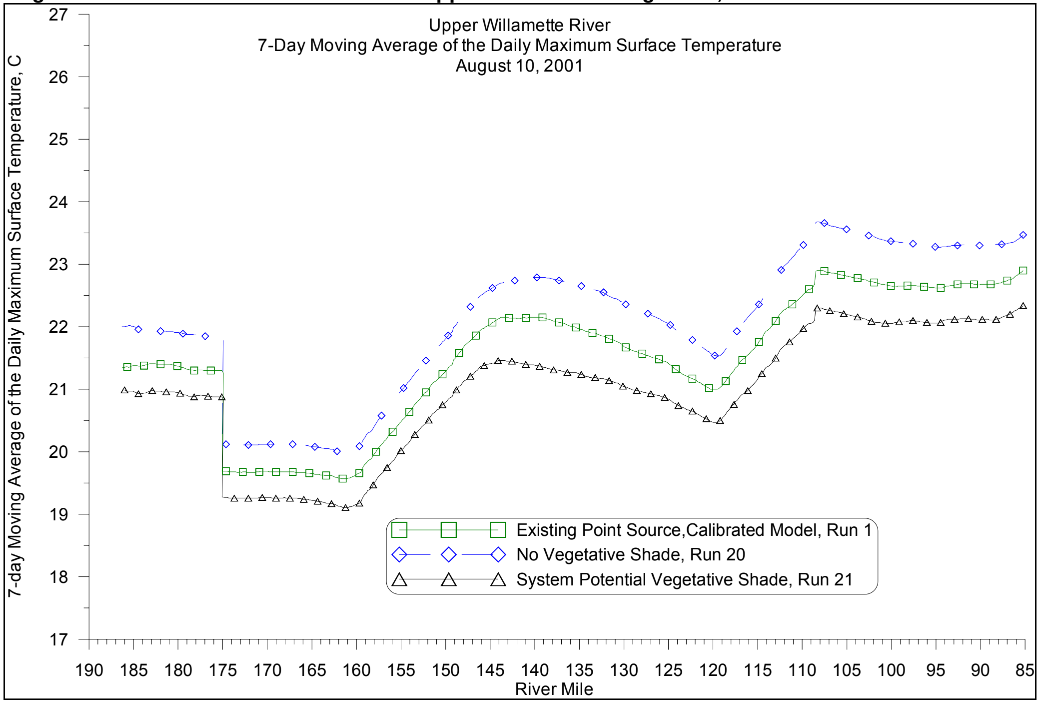


Figure 4.75 **Influence of shade on Middle Fork Willamette - August 10, 2001**



The influence of shade carries through upper Willamette River reaches (Figure 4.76). The influence is relatively constant throughout the upper Willamette, which indicates that the influence is not simply due to the Coast and Middle Fork influence carrying through the reach, but rather, temperature is influenced by local shade. The model indicates that restoring shade to system potential levels would result in about a 0.5 ^{o}C reduction in temperature for this day.

Figure 4.76 **Influence of shade on Upper Willamette - August 10, 2001**



The influence of shade gradually diminishes as the water moves through Middle and Lower Willamette River reaches (Figure 4.77 and Figure 4.78). However, the influence is clearly visible all the way to the Columbia River.

Figure 4.77 Influence of shade on Mid-Willamette - August 10, 2001

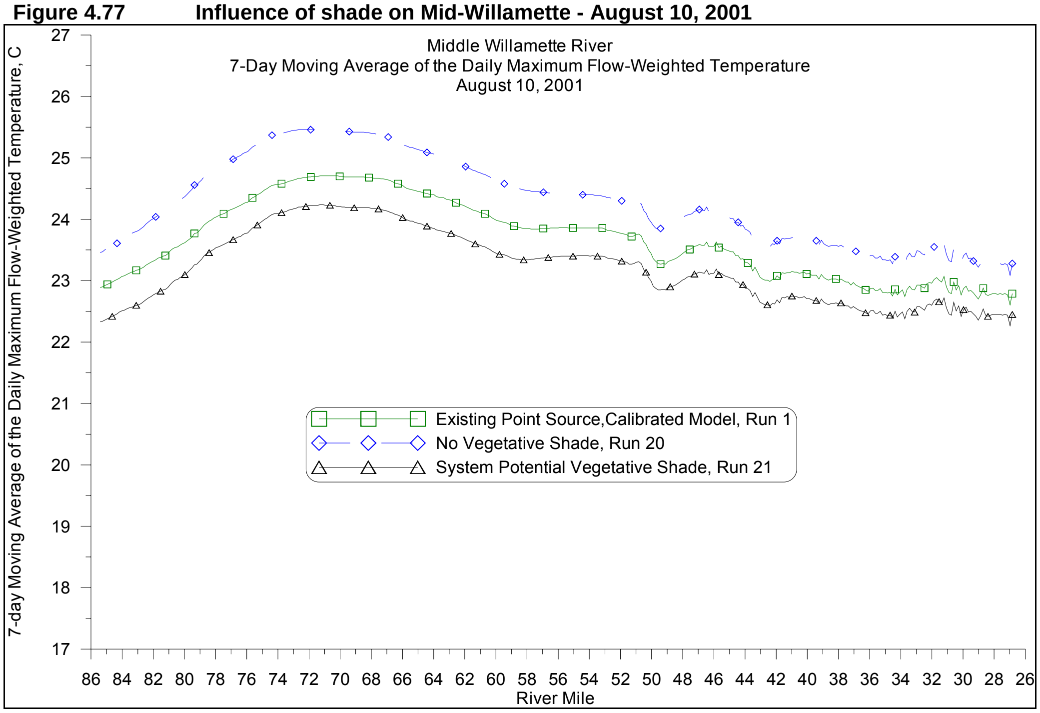
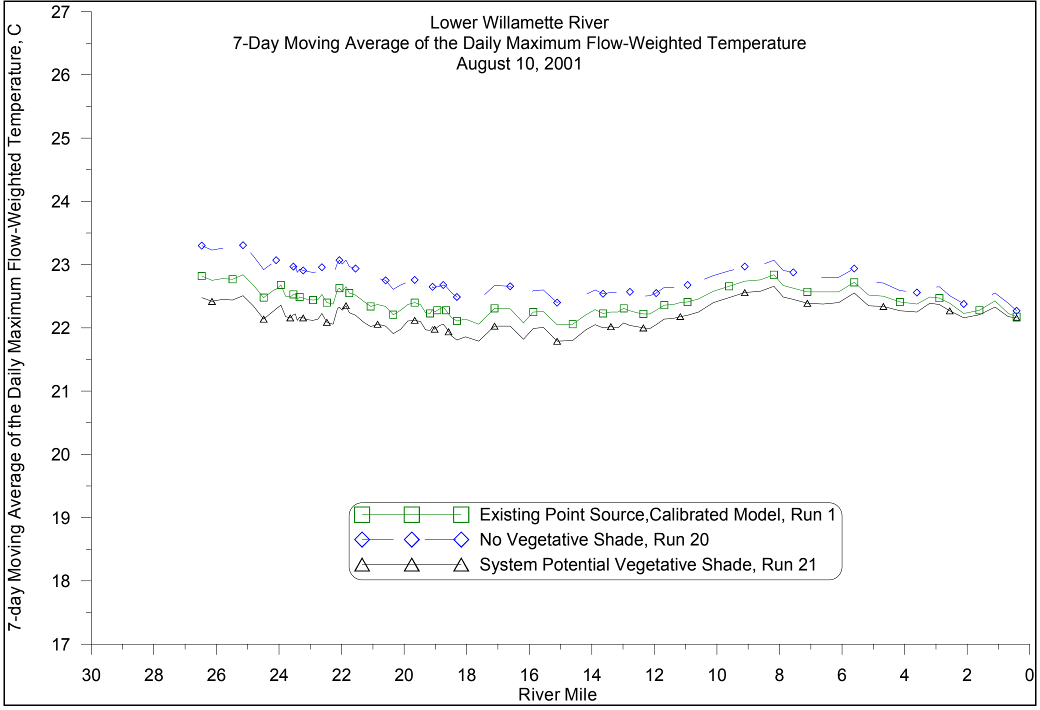


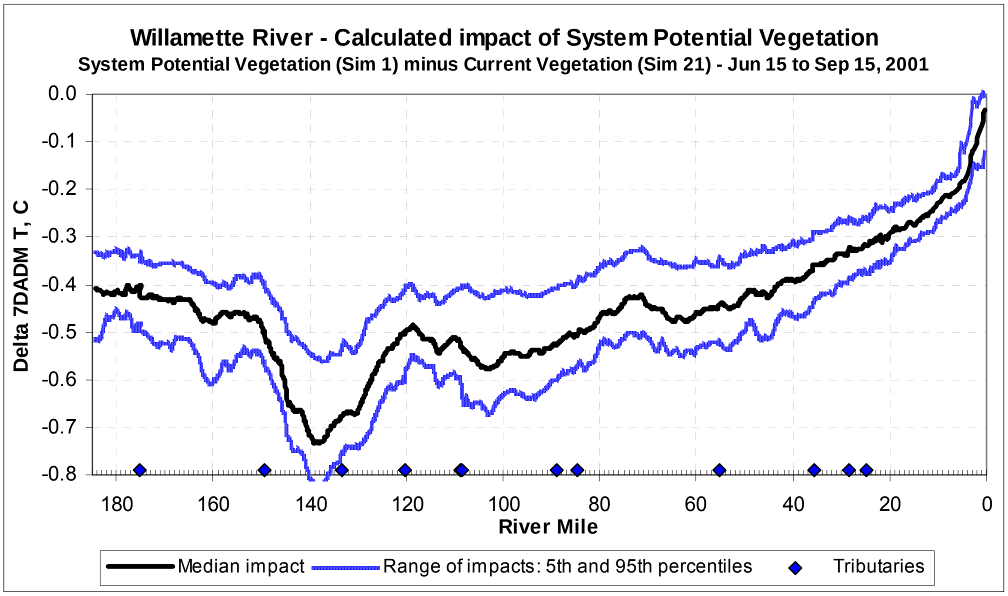
Figure 4.78 Influence of shade on Lower Willamette - August 10, 2001



The median impact of restoring shade to system potential levels is presented in Figure 4.79. This shows the median summer impact, as well as the minimum and maximum impacts as represented by 5th and 95th percentiles. As shown, the point of maximum impact is downstream of the Long Tom River at RM 140, where the median impact exceeds 0.7°C. Below this location the impact declines, but still exceeds 0.3°C all the way to the Willamette Falls at RM 26.5.

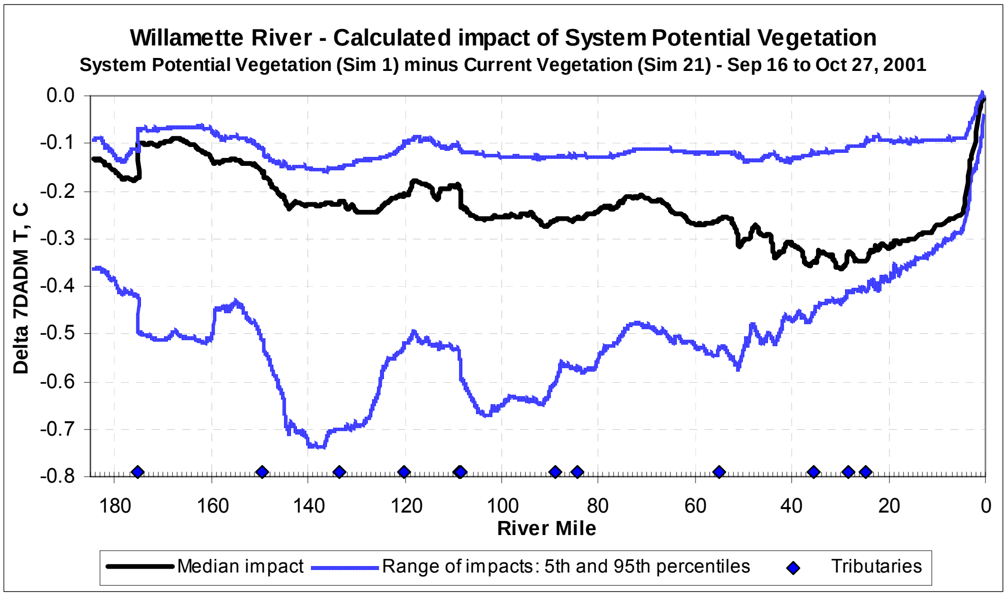
During the fall, the impact of shade is less (see Figure 4.80). This is presumably because the impact of solar radiation on water temperature is less during this period.

Figure 4.79 Impact of restoring shade to system potential levels – Summer, 2001



RM	*Tributaries*
186.3	***CF/MF Confluence***
175.3	***McKenzie R***
149.4	***Long Tom R***
133.4	***Marys R***
120.2	***Calapooia R***
108.7	***Luckiamute R***
108.5	***Santiam R***
88.8	***Rickreall Cr***
84.5	***Mill Creek***
55.1	***Yamhill R***
35.6	***Molalla R***
28.4	***Tualatin R***
24.9	***Clackamas R***

Figure 4.80 Impact of restoring shade to system potential levels – Fall, 2001

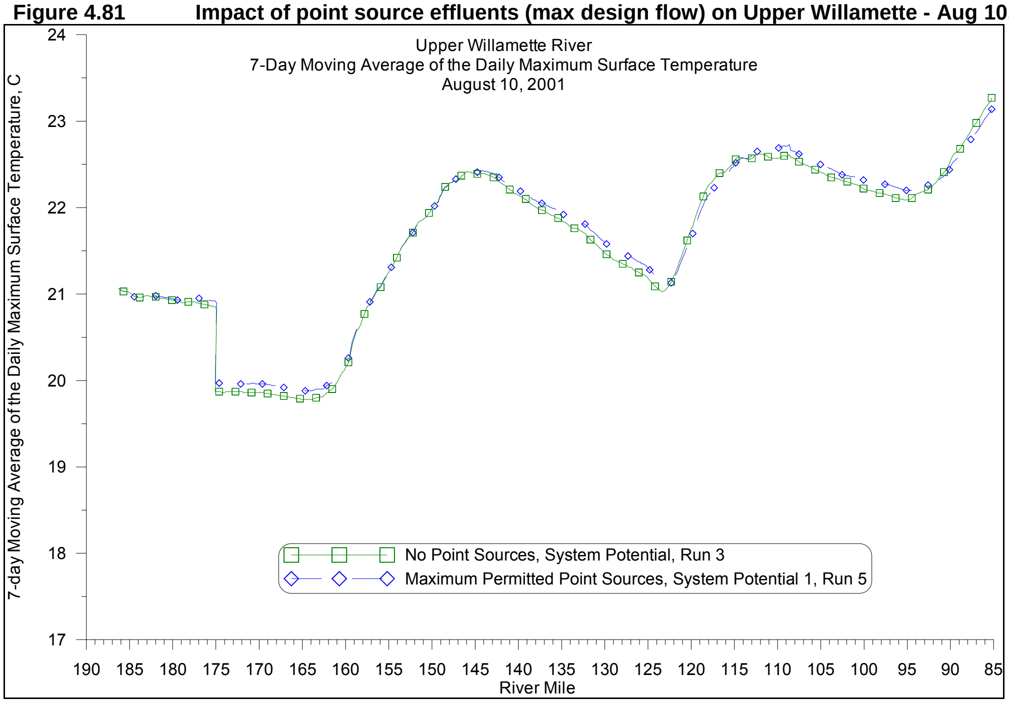


RM	*Tributaries*
186.3	***CF/MF Confluence***
175.3	***McKenzie R***
149.4	***Long Tom R***
133.4	***Marys R***
120.2	***Calapooia R***
108.7	***Luckiamute R***
108.5	***Santiam R***
88.8	***Rickreall Cr***
84.5	***Mill Creek***
55.1	***Yamhill R***
35.6	***Molalla R***
28.4	***Tualatin R***
24.9	***Clackamas R***

Influence of Point Sources of Effluent

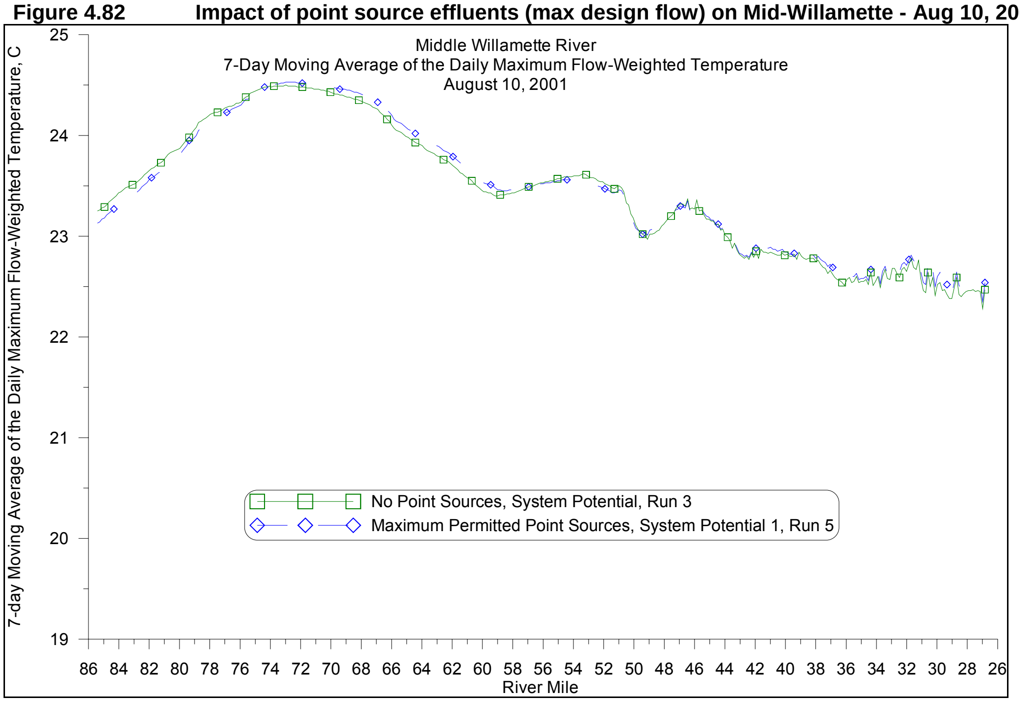
The influence of point source effluent loads on river temperature is generally less than 0.15^{o}C. To evaluate the sensitivity, calculated temperatures for simulations with effluent loads present were compared to calculated temperatures with effluent loads removed. . The impacts of effluents at design flow rates on the Upper and Mid Willamette for a typical August 2001 day are shown in Figure 4.81 and Figure 4.82. For these simulations river flow rates were set to "System Potential 2" BiOp flow rates rather than 2001 current condition flow rates.

Figure 4.81 Impact of point source effluents (max design flow) on Upper Willamette - Aug 10, 2001



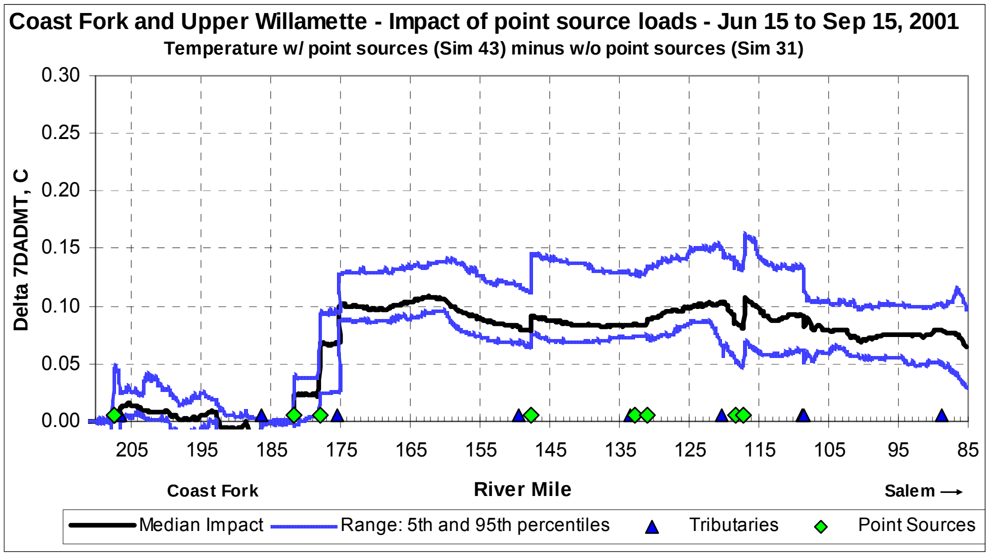
As shown, the difference between calculated temperatures with and without point sources is relatively minor, with a maximum impact of about 0.1^{o}C.

Figure 4.82 Impact of point source effluents (max design flow) on Mid-Willamette - Aug 10, 2001



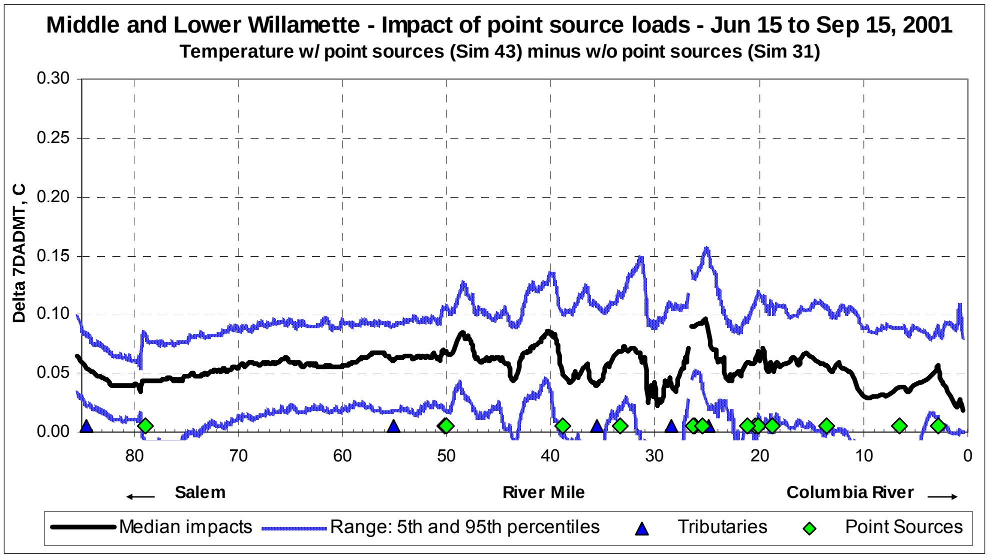
Median impacts of “current” (vs. design) 2001 effluent flow rates for summer 2001 are shown in Figures 4.83 and 4.84. For these simulations, river flow rates were set to 2001 current condition flow rates (rather than BiOp flow rates). Note that these simulations were performed later than the simulations presented above and include several model improvements including the addition of two point sources (University of Oregon heat plant and Wah Chang), a few minor revisions in effluent loads, and the addition of process water diversions for several industrial plants. Shown also are minimum and maximum impacts, as represented by 5th and 95th percentiles. As shown, median point source impacts are generally less than 0.10°C, while maximum impacts rarely exceed 0.15°C.

Figure 4.83 Impacts of “current” effluent loads on Coast Fork and Upper Willamette for Summer 2001



RM	*Point Sources*
207.4	***Cottage Grove POTW***
181.6	***Univ. of Oregon***
177.9	***Eugene WWTP***
147.6	***Georgia Pacific - Pope Talbot***
132.8	***Evanite***
131.0	***Corvallis WWTP***
118.4	***Albany WWTP***
117.2	***Weyco Albany***

Figure 4.84 Impacts of “current” effluent loads on Middle and Lower Willamette for Summer 2001



RM	*Point Sources*
78.9	***Salem Willow Lake WWTP***
50.2	***SP Newsprint***
50.0	***Newberg WWTP***
38.9	***Wilsonville WWTP***
33.4	***Canby WWTP***
26.2	***West Linn Paper***
26.4	***Blue Heron Paper Mill***
25.5	***Tri-City WWTP***
20.4	***Tryon Creek WWTP***
20.1	***Oak Lodge WWTP***
18.7	***Kellogg Creek WWTP***
13.5	***OMSI***
6.6	***Wacker Siltronics***
2.8	***Oregon Steel***

During the fall period of September 16 to October 27, 2001 the impacts of point sources is greater in the Willamette than during the summer, particularly in the Lower Willamette , Figures 4.85 and 4.86. This is somewhat surprising, considering that river flow rates are greater during this period. The greater impact is probably because the difference in temperatures between effluents and receiving waters is greater during this period because river temperatures are cooler.

Figure 4.85 **Impacts of "current" effluent loads on Coast Fork and Upper Willamette for Fall 2001**

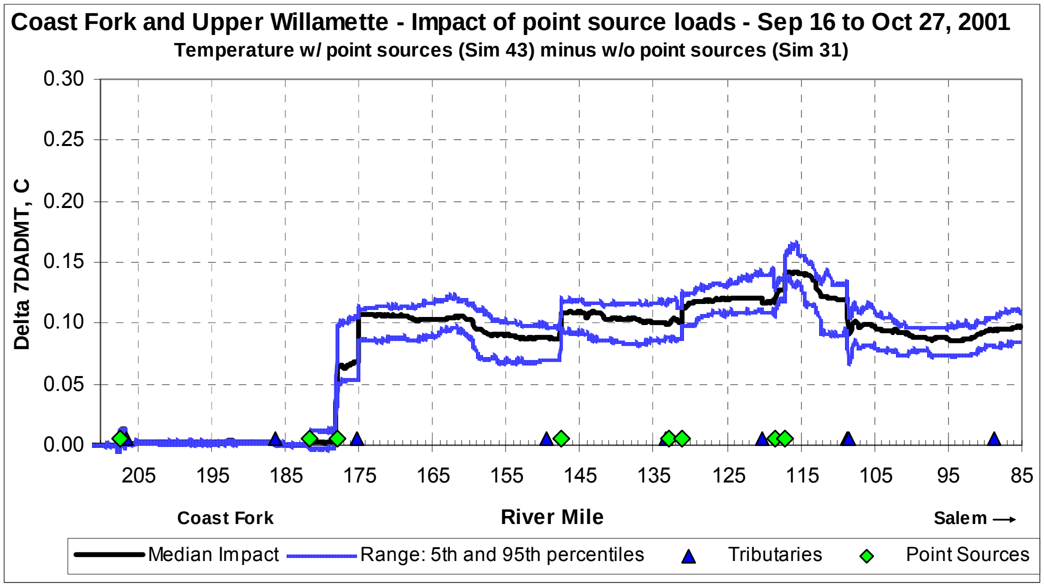
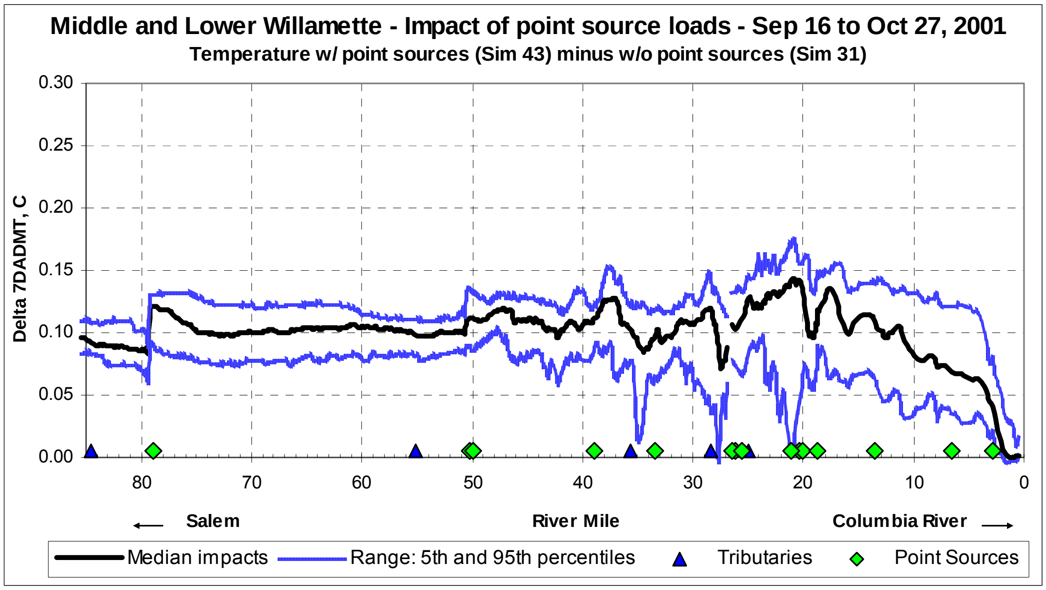


Figure 4.86 **Impacts of "current" effluent loads on Middle and Lower Willamette for Fall 2001**



Influence of System Potential (without changing boundary conditions)

The impact of achieving system potential conditions without changing upper boundary flow rates or temperatures is presented in Figures 4.87 and 4.88. These compare model calculated temperatures for 2002 system potential conditions to model calculated temperatures for 2002 current conditions. Results are presented for 2002 rather than 2001 because the model could be run for a larger portion of the year than for 2001. The scenario modeled is referred to as "System Potential 3". For this, observed 2002 river flow rates are used, rather than the "Biological Opinion (BiOp)" flow rates used for the System Potential 1 scenarios presented in the draft TMDL. The use of BiOp flow rates for simulations was abandoned following release of the draft due to concerns raised during the public comment period regarding the accuracy of the BiOp flow rates.

Figure 4.87 **Modeled calculated Willamette River temperatures for 2002 system potential (SysPot3, Sim 32) and current conditions (Sim 2)**

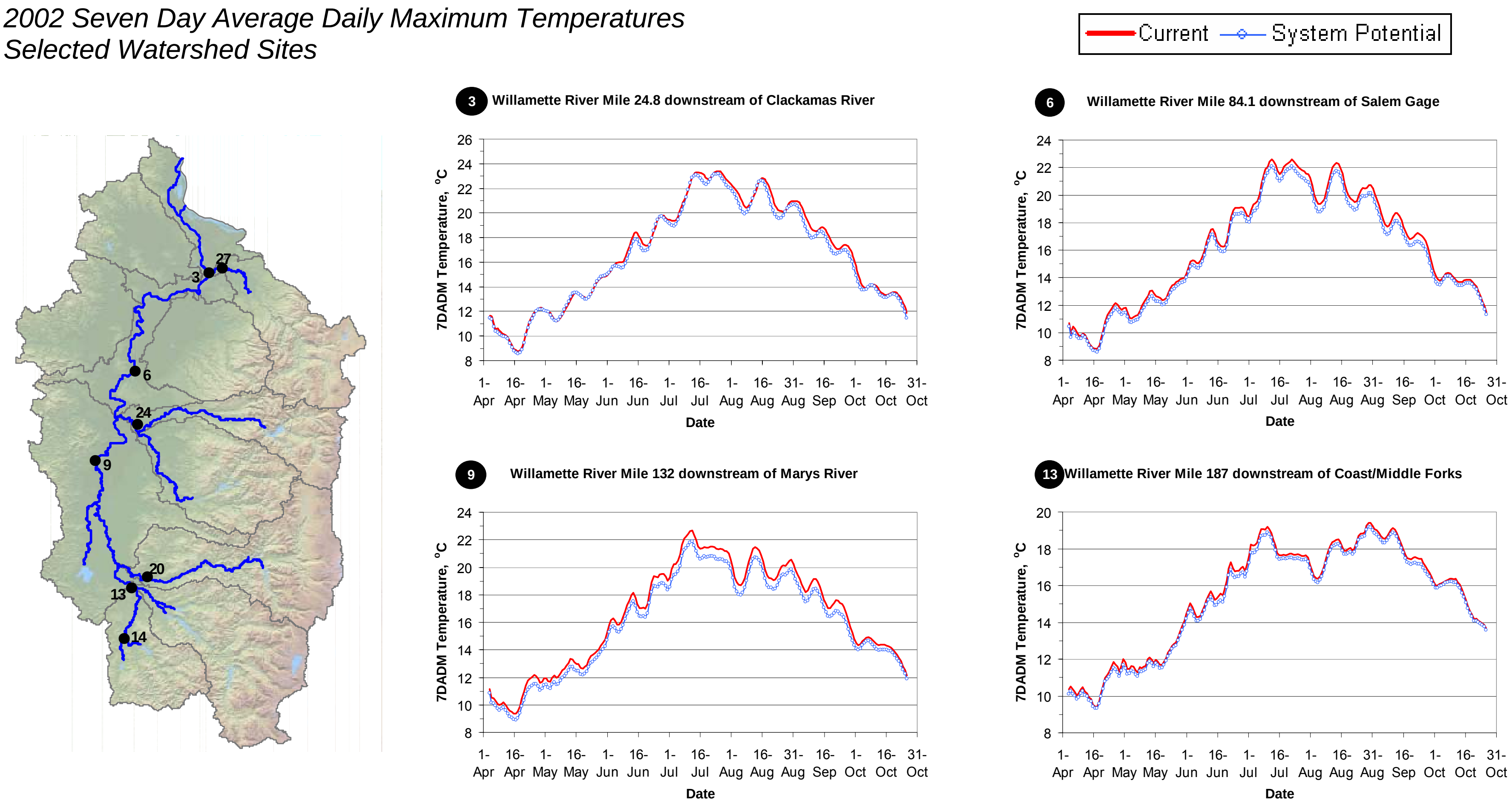
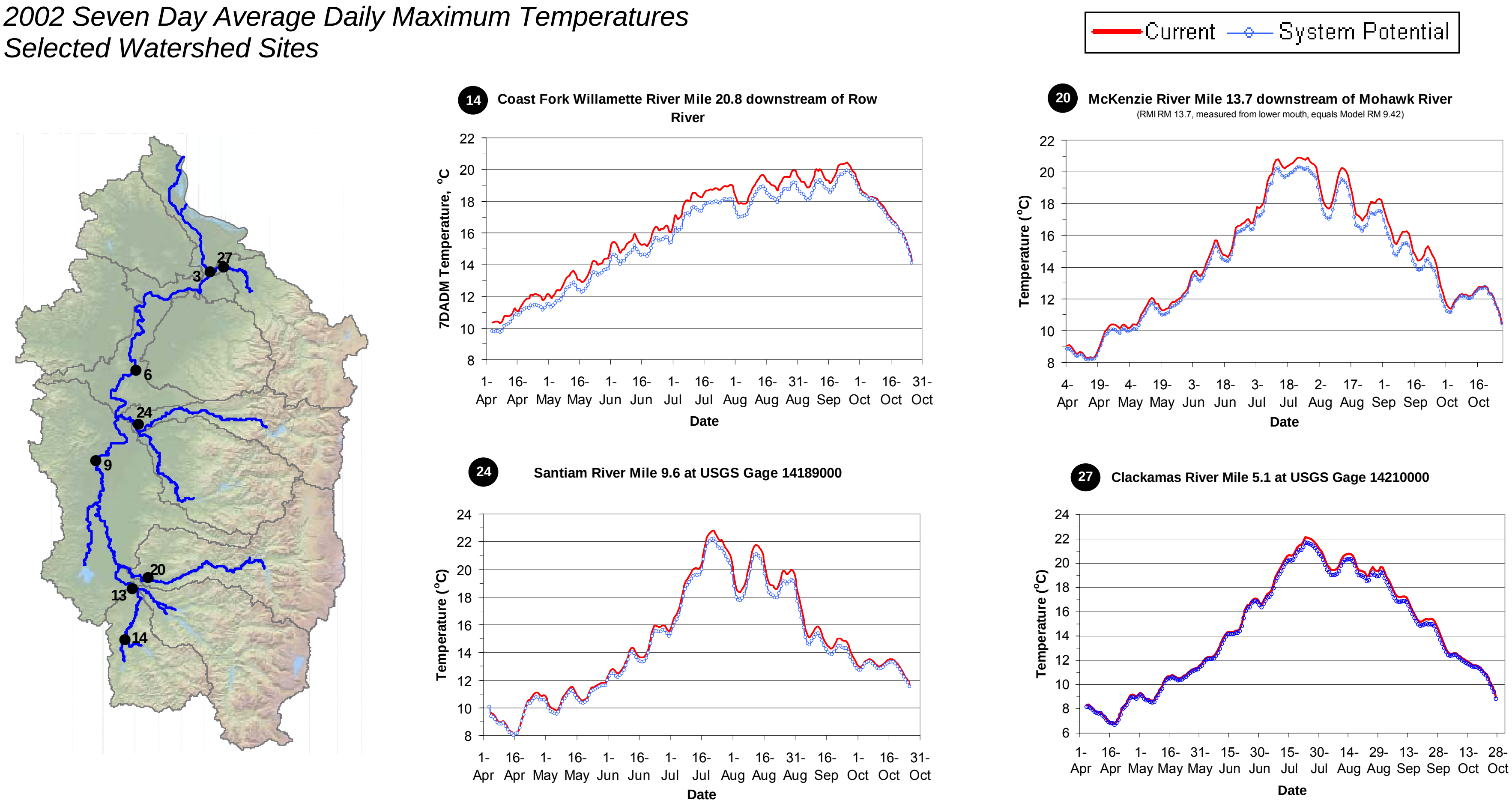


Figure 4.88 Modeled calculated Willamette tributary temperatures for 2002 system potential (SysPot3, Sim 32) and current condition (Sim 2) conditions



The major differences between the system potential conditions evaluated (System Potential 3) and current conditions are: (1) shade is set to system potential vegetation shade, (2) point source effluent loads are removed and (3) EWEB McKenzie River and PGE Willamette Falls projects are eliminated. No changes were made to boundary condition flow rates or temperatures for this scenario. As expected, temperatures under system potential conditions would be cooler at virtually all locations and times than current conditions.

For the Willamette River, median impacts during the summer of achieving system potential conditions are shown for 2001 in Figure 4.89, and 2002 in Figure 4.90. These are based on calculated 7DADM temperatures for System Potential 3 conditions (Simulations 31 and 32) minus calculated current condition 7DADM temperatures (Simulations 1 and 2). As shown, median improvements for the summer range from 0.4 to to 1.1 °C in the upper and middle Willamette and 0.0 to 0.4°C in the lower Willamette.

Note that in the Newberg Pool area the impact is quite variable. This variability is due to the Willamette Falls Hydroelectric Project, which causes temperatures to be warmer in some areas and cooler in others.

Figure 4.89 Impact of moving to system potential conditions for Summer 2001

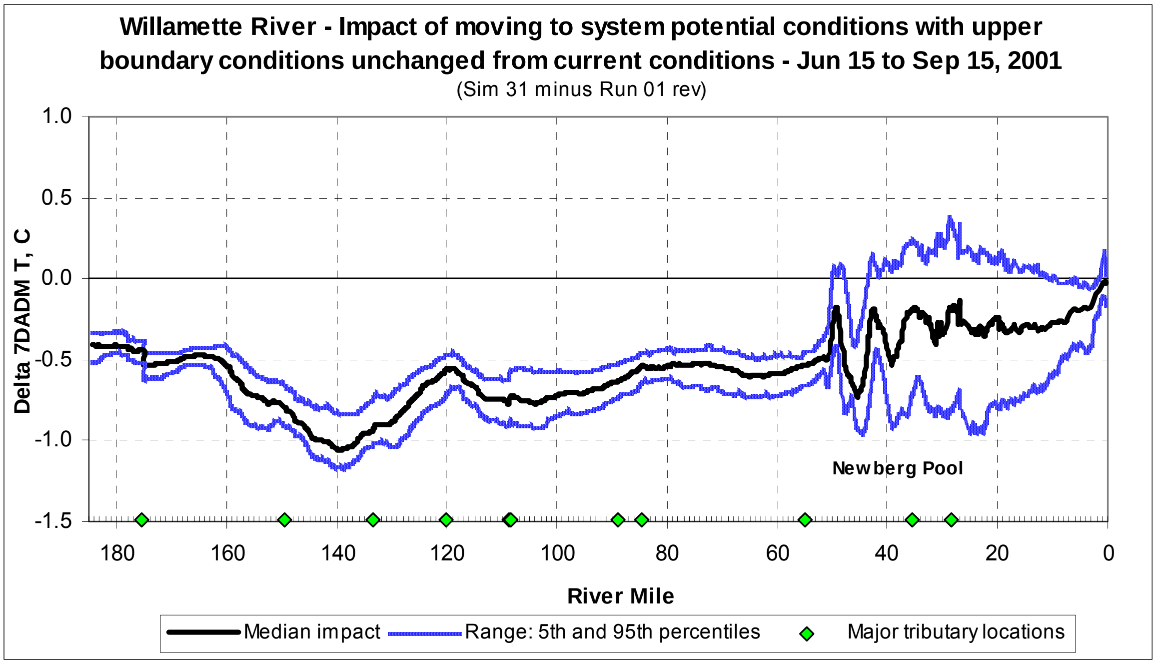
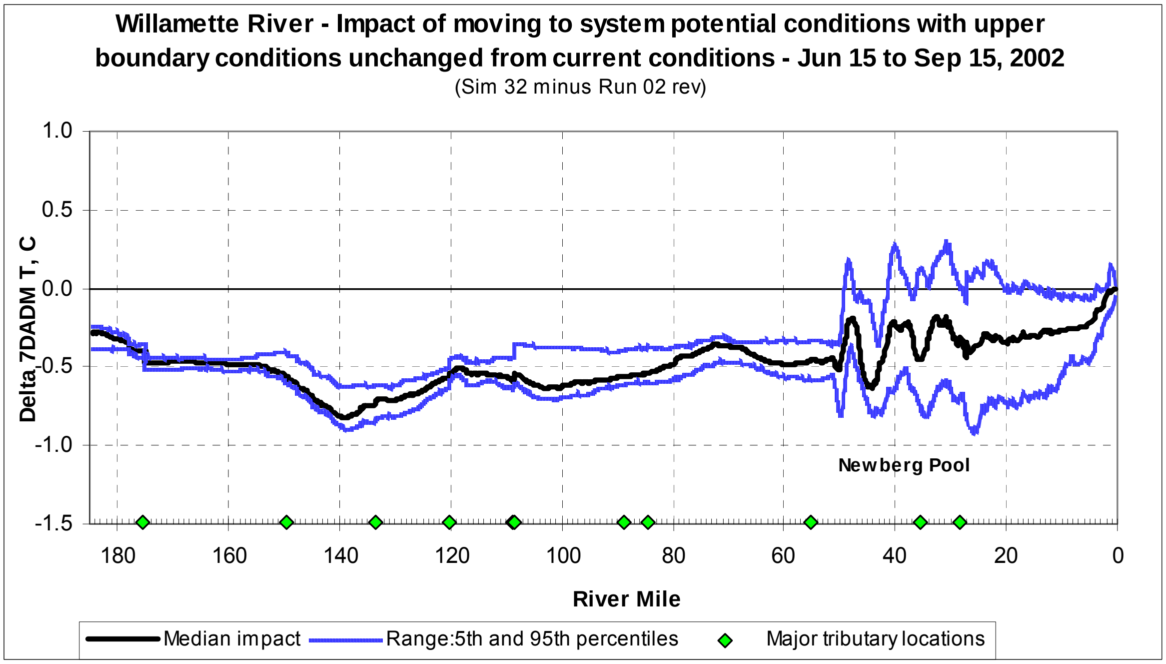
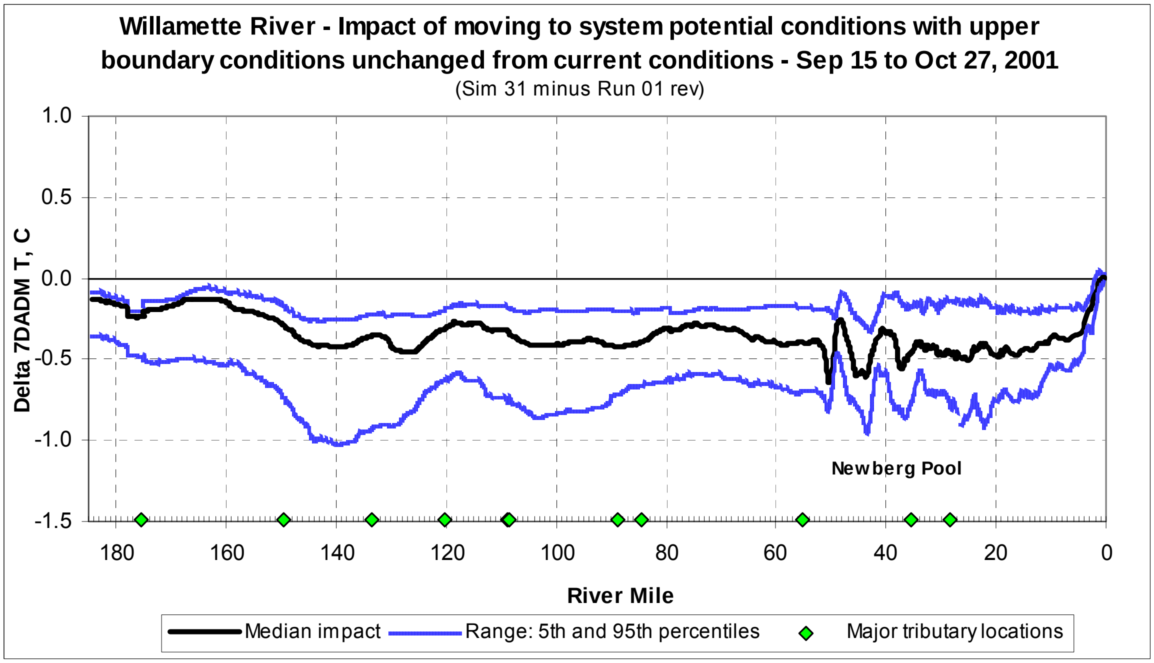


Figure 4.90 Impact of moving to system potential conditions for Summer 2002



Impacts for the fall for 2001 are shown in Figure 4.91. As shown, the impacts are less in the fall than in the summer.

Figure 4.91 Impact of moving to system potential conditions for Fall, 2001



Seasonal impacts are further illustrated by Figures 4.92 and 4.93. These show, for 2001 and 2002, the overall average impact on temperature over time for each of the modeled reaches presented: the Upper Willamette (confluence of Coast and Middle Forks to Salem), Middle Willamette (including Newberg Pool), and Lower Willamette (below Willamette Falls). As shown, the impact of moving to system potential is generally greatest in the Upper Willamette, where the river is more sensitive to shade. The figures also show that the impact of moving to system potential is greatest during the summer months, presumably because the influence of solar radiation and, hence, shade is greatest during the summer.

Figure 4.92 **Change in reach average temperature due to moving from current to system potential conditions - 2001**

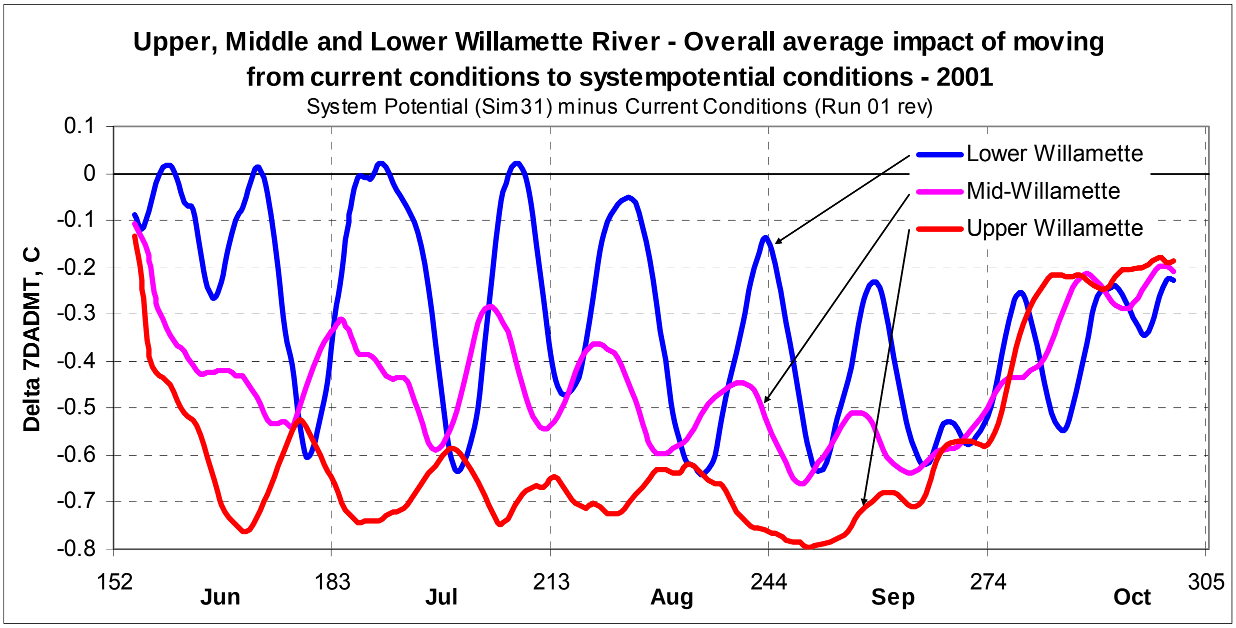
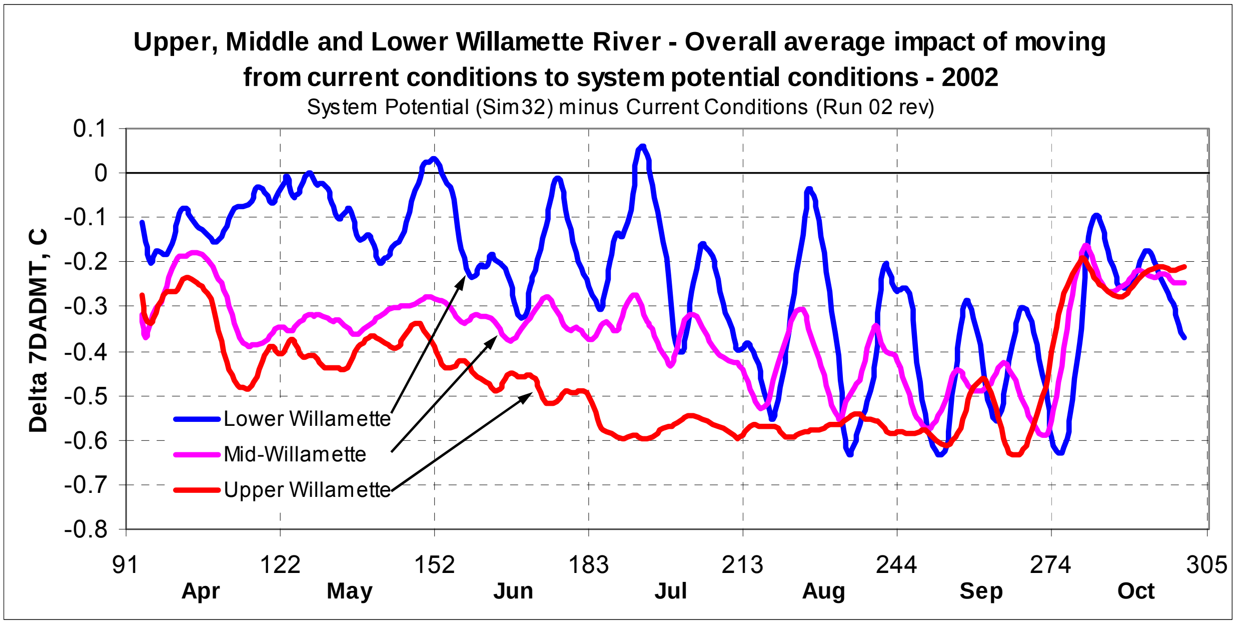


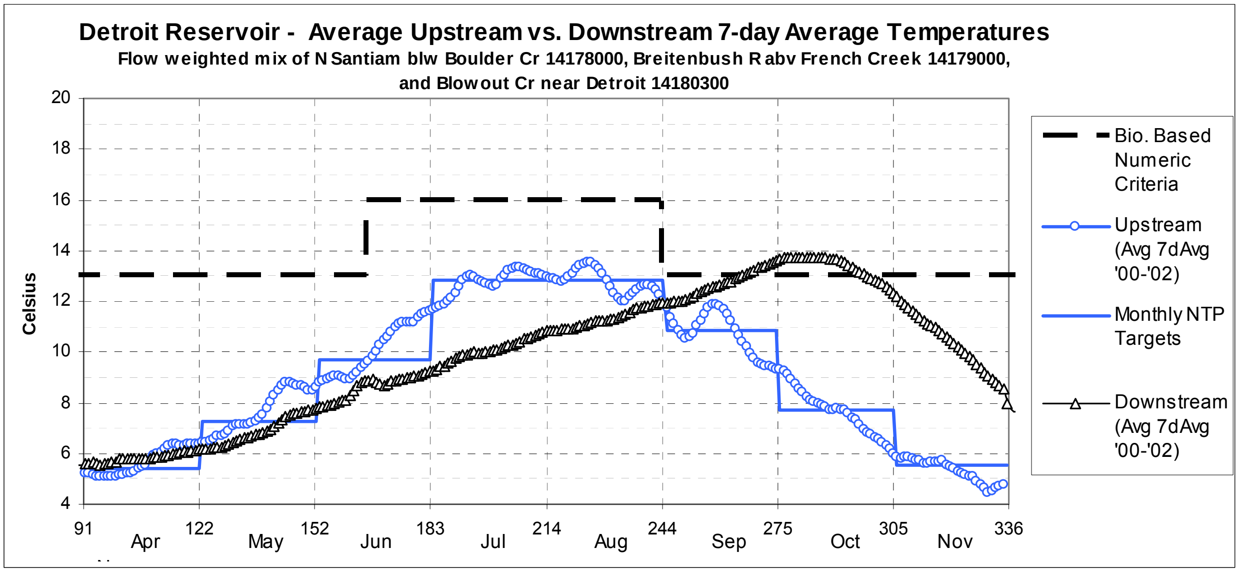
Figure 4.93 **Change in reach average temperature due to moving from current to system potential conditions - 2002**



Influence of System Potential (with upper boundary temperatures changed to NTP)

The large USACE operated reservoir projects at the upstream boundaries of modeled reaches significantly influence temperatures downstream. These projects generally cause downstream daily maximum temperatures to be cooler than natural thermal potential during the summer and warmer during the fall. This is illustrated by Figure 4.94, which shows estimated natural thermal potential (NTP) temperatures based on the observed flow rates and temperatures of the three major tributaries which feed the reservoir. While this is a rough estimate and excludes things such as potential heating in currently inundated reaches and current land use impacts on vegetative shade in reaches above the reservoir, it does suggest that, in the absence of the reservoir, temperatures in the North Santiam would be several degrees ^{o}C warmer during the summer and 5 to 6 ^{o}C cooler in the fall. The fall impacts are of particular concern due to impacts on spawning.

Figure 4.94 **Estimates of tailrace NTP temperatures for Detroit Reservoir vs. current conditions**



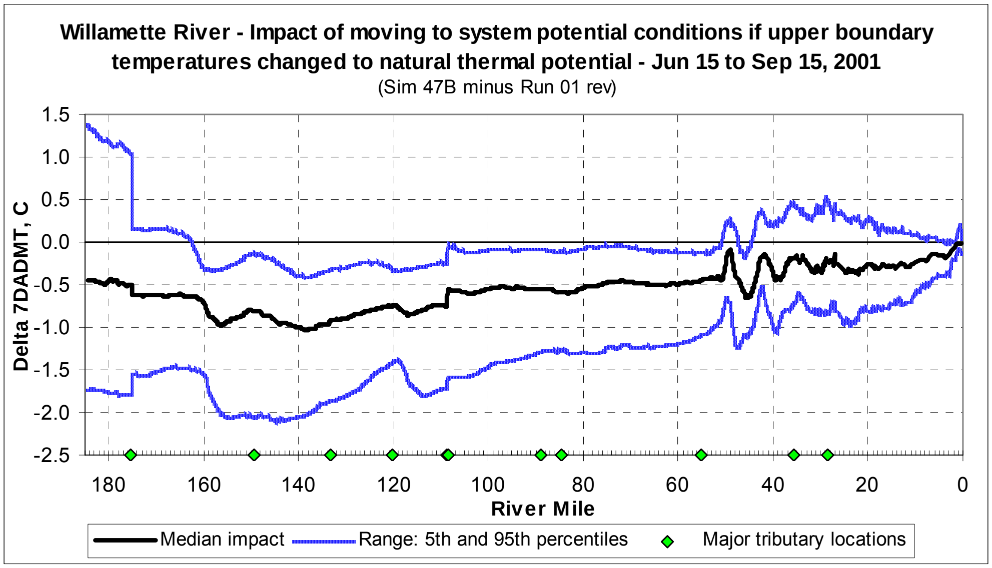
In order to estimate the impact of achieving a system potential condition in which temperatures below the reservoirs meet NTP temperature targets, an additional set of simulations was performed. This scenario is referred to as “System Potential 4”. As with the System Potential 3 simulations discussed above, shade for these simulations is set to system potential vegetation shade, point source effluent loads are removed, and EWEB McKenzie River and PGE Willamette Falls projects are eliminated. In addition, upstream boundary temperatures are set to monthly average estimates of NTP.

Note that in the draft TMDL, system potential scenarios referred to as System Potential 1 and 2 were discussed. These are essentially the same as System Potential 3 and 4, except that for System Potential 1 and 2, upper boundary flow rates were set to estimated Biological Opinion (BiOp) flow rates, whereas for System Potential 3 and 4 boundary flow rates were left at the actual flow rates observed in 2001 and 2002. Leaving flow rates at current conditions allows the impact of achieving system potential conditions to be more readily observed.

As described previously, System Potential 4 simulations have not been used to establish effluent wasteload allocations, since additional modeling is needed to define NTP temperatures and since the expensive dam retrofits needed to meet the targets have not been mandated for most reservoirs. The System Potential 4 simulations, however, do provide useful insight into the effects of moving to NTP targets at the boundaries and will be considered during future analyses and revisions to the TMDL. Also, because they represent the best available data for estimated NTP at the dams, these values will be utilized in developing load allocations for the USACE dams.

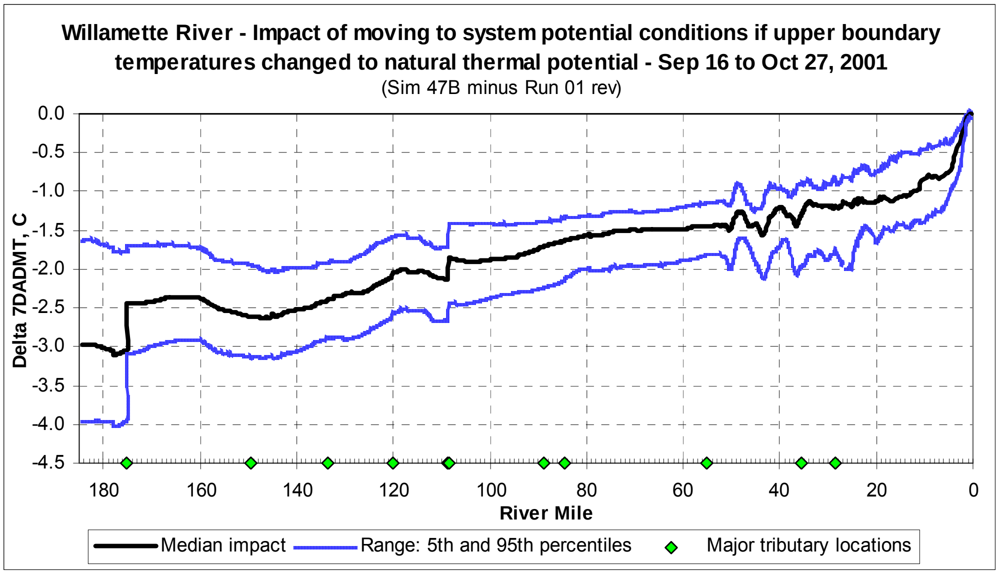
In order to evaluate the impact of achieving NTP temperature targets at upstream boundaries, calculated temperatures for 2001 System Potential 4 conditions (Sim 47B) are compared to 2001 calculated current conditions (Sim 1) in Figure 4.95. As described previously, the NTP targets are preliminary estimates of natural thermal potential (NTP) temperature and additional modeling and analyses are necessary to more accurately define them. As shown on the figure, median reductions in temperature approach 1.0°C. However, the reduction in temperature during the summer is not as great as for System Potential 3, since estimated NTP temperatures downstream from reservoirs are often greater than current condition temperatures during the summer.

Figure 4.95 **Impact of moving to system potential conditions with upper boundary set to NTP – Summer, 2001**



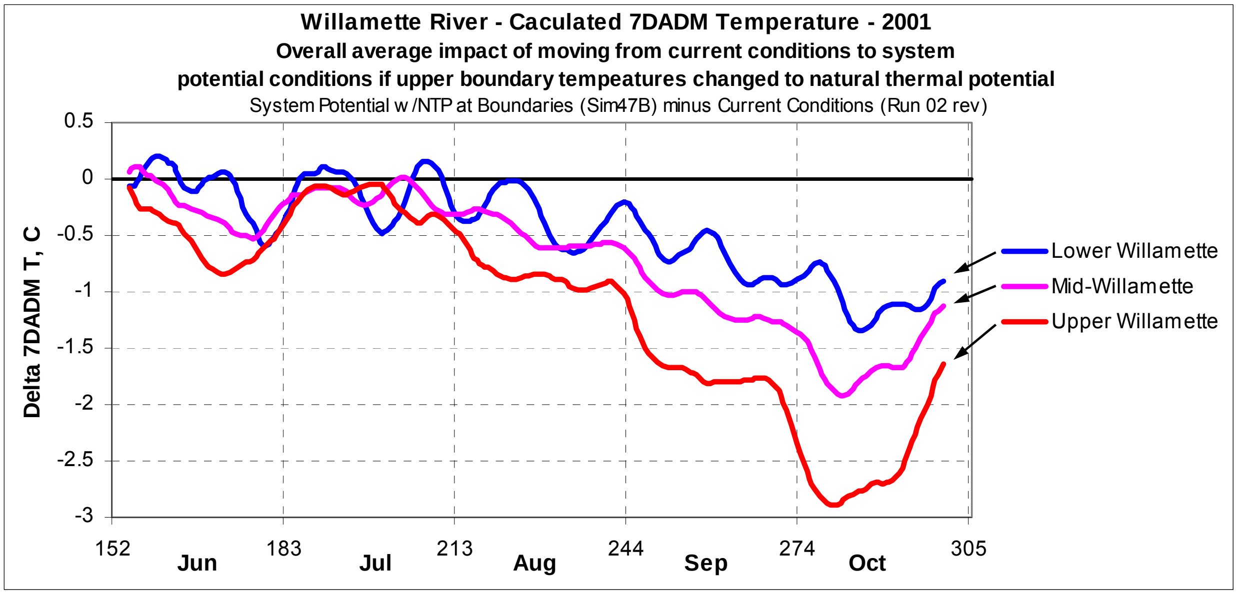
The greatest impact of achieving NTP temperature targets would occur during the fall spawning period. During the fall, temperature improvements are much greater for the scenario in which boundary temperatures are changed to NTP (System Potential 4) than for scenario in which boundary temperatures are left at current conditions (System Potential 3). As shown by Figure 4.96, in the reaches above RM 50, for which spawning is a designated beneficial use, improvements range from 1.5 to 3.0°C. Comparison of this to Figure 4.91 above shows that achieving NTP at upper boundaries would provide significant temperature improvements in spawning reaches.

Figure 4.96 **Impact of moving to system potential conditions with upper boundary set to NTP – Fall, 2001**



The seasonal influence is further illustrated by Figure 4.97, which shows the calculated changes in reach average 7DADM temperatures over time of moving from current to System Potential 4 conditions. For the figure, calculated 7DADM temperatures are averaged for the upper Willamette, middle Willamette, and lower Willamette and plotted for the 2001 period modeled. As shown, improvements in temperature are relatively modest in the three reaches during the summer. However, during the fall, impacts are quite large (up to 3 ^{o}C) in the upper Willamette. This is not particularly surprising since, during the fall, the reservoirs currently increase water temperatures quite a bit over natural conditions.

Figure 4.97 **Temporal reach average 7DADM temperature changes expected for System Potential 4**



The impact of upper boundary temperatures is further illustrated by Figures 4.98 and 4.99. These compare calculated system potential temperatures at two Willamette River locations for the scenario in which boundary temperatures are changed to NTP (System Potential 4: Sim 47B) to the scenario in which boundary temperatures are left at current conditions (System Potential 3: Sim 31). As shown, during the summer, the impact of achieving NTP targets at the boundaries is rather small. However, in September and October the impact is quite large. At the Upper Willamette site, which is influenced by Coast Fork, Middle Fork and McKenzie River river temperatures, the simulations indicate that temperatures would be up to 3 ^{o}C cooler if upper boundary temperatures achieved NTP. This is because USACE reservoir operations currently delay occurrence of maximum downstream temperatures until September.

Figure 4.98 Simulated 7DADM temperatures in the Willamette R at RM 161 for two system potential scenarios

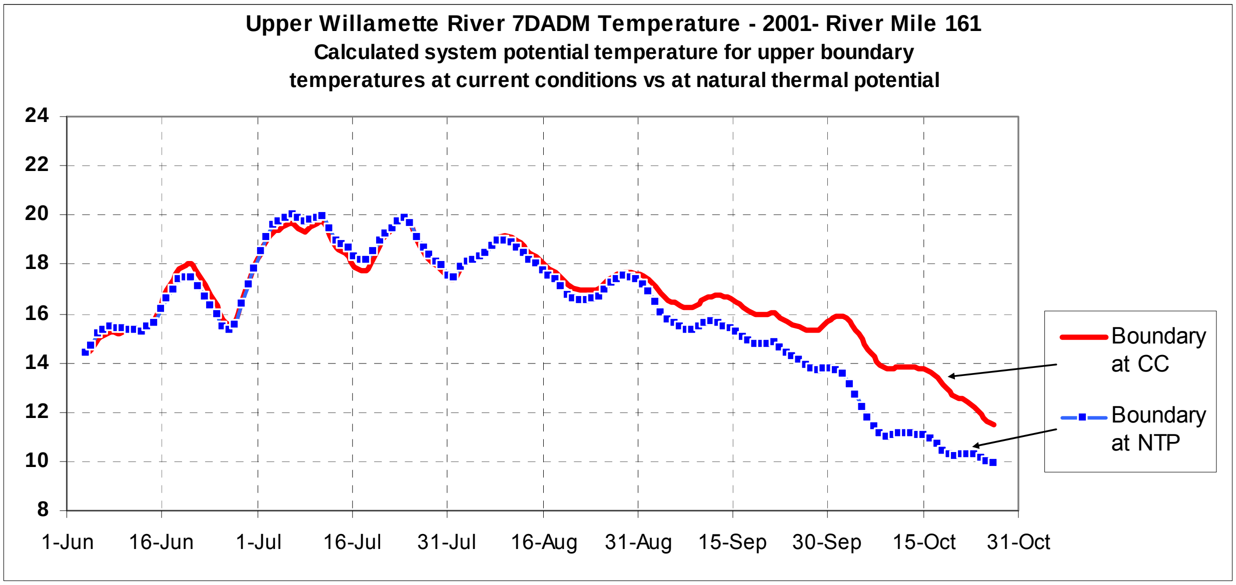


Figure 4.99 Simulated 7DADM temperatures in the Willamette R at RM 55 for two system potential scenarios

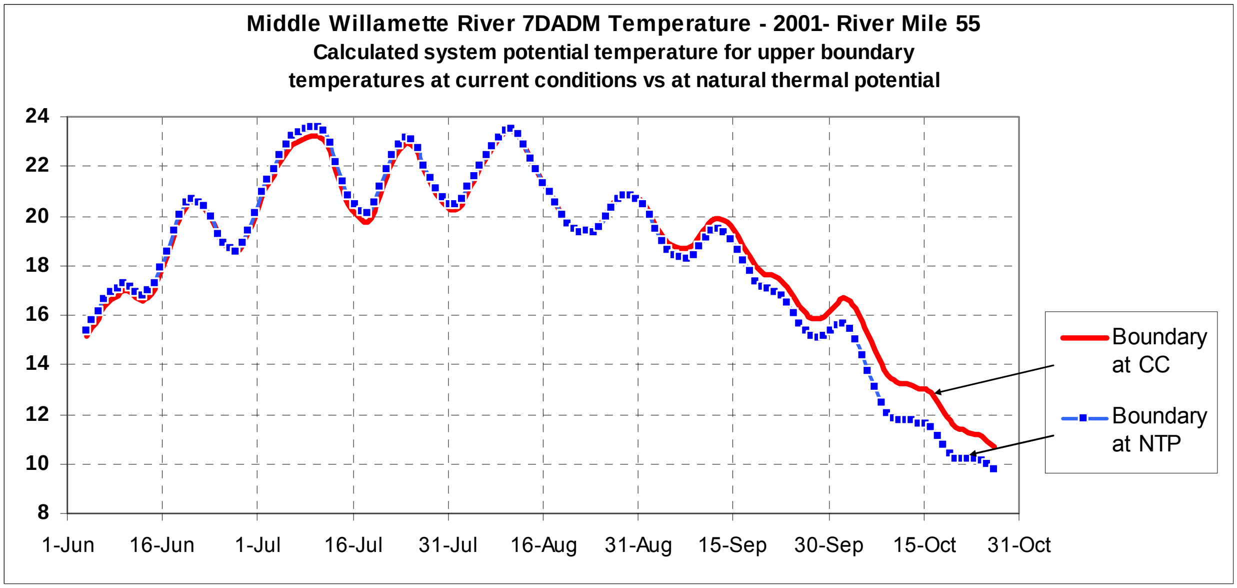


Figure 4.99 shows the effects at RM 55, which is just above the upper extent of the Newburg pool. Boundary condition impacts shown at river mile 161 continue to be seen at this mid basin location, even though the location is well downstream of USACE reservoirs.

Influence of PGE Clackamas River Hydroelectric Project

Four major hydroprojects potentially influence water quality in the Willamette Mainstem. These are the two Eugene Water and Electric Board (EWEB) projects on the McKenzie River (Leaburg and Walterville); the Willamette Falls PGE project; and the PGE Clackamas River Hydroelectric Project.

The PGE Clackamas River Hydroelectric Project influences temperature in the Clackamas River and lower Willamette River. In order to quantify the influence, modeling of the lower Clackamas River (River Mill Dam at RM 23.4 to the mouth) and the Lower Willamette River was performed for two scenarios: a “with project” scenario with flows and temperatures at the River Mill Dam tailrace set to model calculated conditions with the hydroelectric project as it currently operates (Special Simulation 22), and a “no project” natural thermal potential (NTP) scenario with flows and temperatures set to model calculated NTP conditions with the project removed (Special Simulation 23). For both the project and no project scenarios vegetation in the lower Clackamas below River Mill Dam was set to site potential conditions. Therefore, differences between Special Simulations 22 and 23 are strictly due to boundary condition differences.

Boundary condition temperatures and flow rates at the River Mill Dam location for both scenarios were model calculated values provided by PGE. These were calculated by PGE consultant Tarang Khangaonkar and his team at Battelle Seattle Service Center and provided to DEQ in October, 2005, along with bathymetry and other lower Clackamas model inputs. The values were calculated by Battelle using an updated version of a Clackamas River model originally developed by Scott Wells and his team at Portland State University. This model covers all reaches of the Clackamas River potentially influenced by the hydroelectric project, including Oak Grove Fork up to Timothy Lake. For the with project scenario, the project was modeled as it currently operates. Therefore, calculated River Mill Dam tailrace flow rates and temperatures should be similar to current conditions. For the no project scenario the system was simulated with all dams, diversions, artificial lakes or impoundments and their effects on temperature removed from the calibrated model. Simulation of the Clackamas River without the reservoirs required that effective shade be interpolated from adjacent river reaches and applied to the historical river reaches that pass through each reservoir. All other anthropogenic effects not associated with the project remained in place and upstream temperatures may be affected by other land use activities such as forest management and road systems. While model calculated temperatures for the no project scenario may not be true natural thermal potential temperatures, they represent the best estimate of NTP currently available.

Special Simulation 22 is equivalent to a “System Potential 3” scenario, while Special Simulation 23 is similar to a “System Potential 4” scenario. An important deviation from the other Willamette Mainstem reaches modeled is that, since a model is available of the Clackamas for NTP conditions above River Mill Dam, the NTP estimates for the Clackamas are much more accurate and include flow for NTP conditions in addition to temperature. Therefore, both flow and temperature are set to NTP estimates for the Clackamas System Potential 4 scenario.

Year 2001 RM 23.4 temperatures for the two scenarios are presented below (see Figure 4.100 for April through September and Figure 4.101 for August only). As shown, temperature fluctuations for the upper boundary of the lower Clackamas River model would be much greater without the project (Special Simulation 23) than currently occur with the project in place (Special Simulation 22). In general, daily maximum temperatures without the project would be greater than current temperatures, but daily average and minimum temperatures would be less.

Figure 4.100 Clackamas River upper boundary condition temperatures – 2001

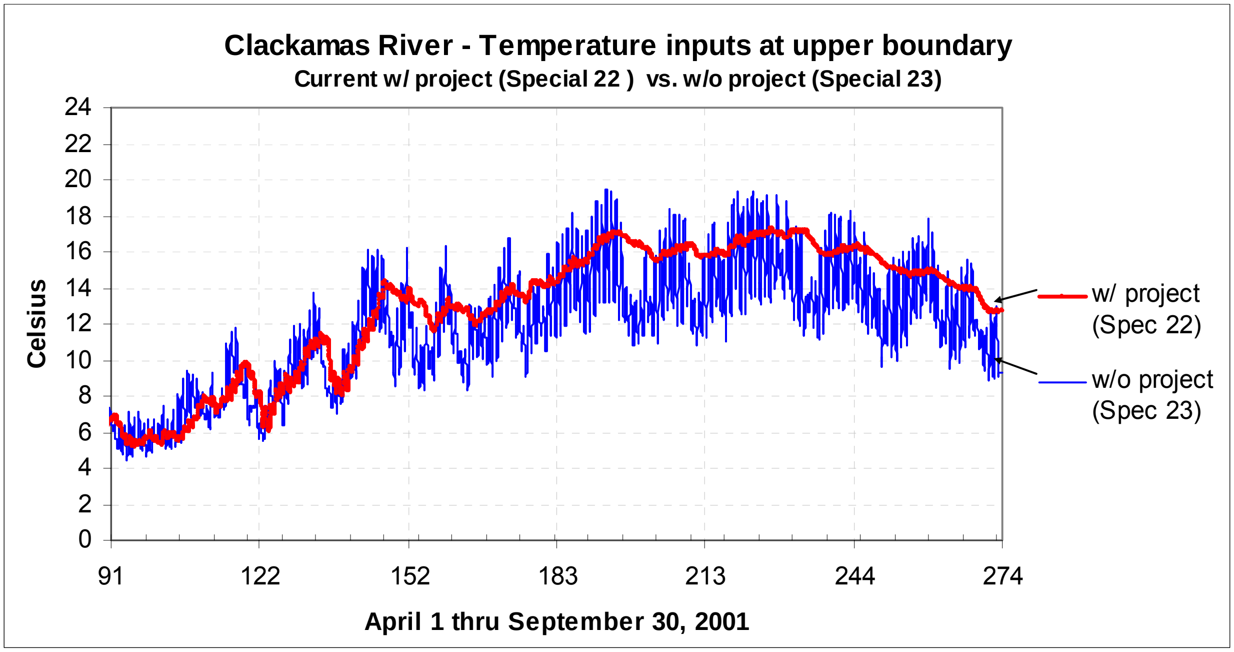
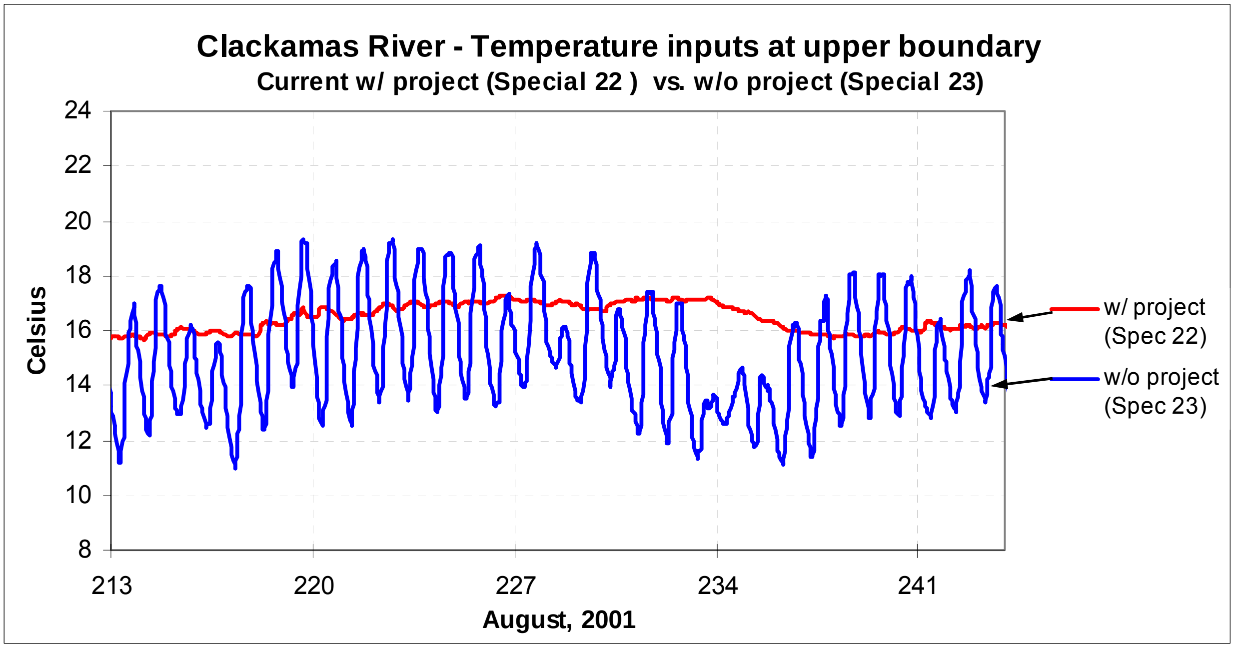


Figure 4.101 Clackamas River upper boundary condition temperatures – August



The model indicates that the project reduces daily maximum temperatures immediately downstream of River Mill dam, but increases daily maximum temperatures further downstream. The reason daily maximum temperatures are increased downstream is that water leaving the dam during most times of the day is warmer with the project in place than without the project and, therefore, the water warms to higher temperatures. However, model calculated daily maximum temperatures at the river's confluence with the Willamette tend to be similar for the two scenarios (see Figure 4.102 and Figure 4.103).

Figure 4.102 Calculated impact of PGE project on Clackamas River temperature at mouth - 2001

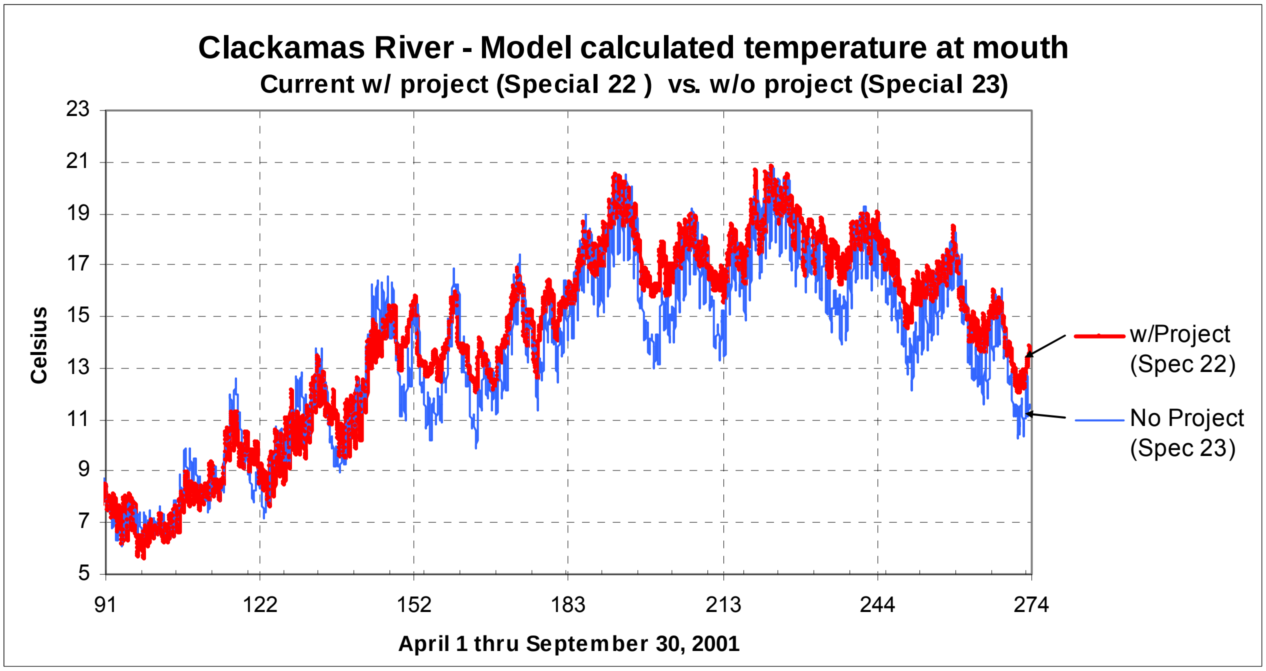
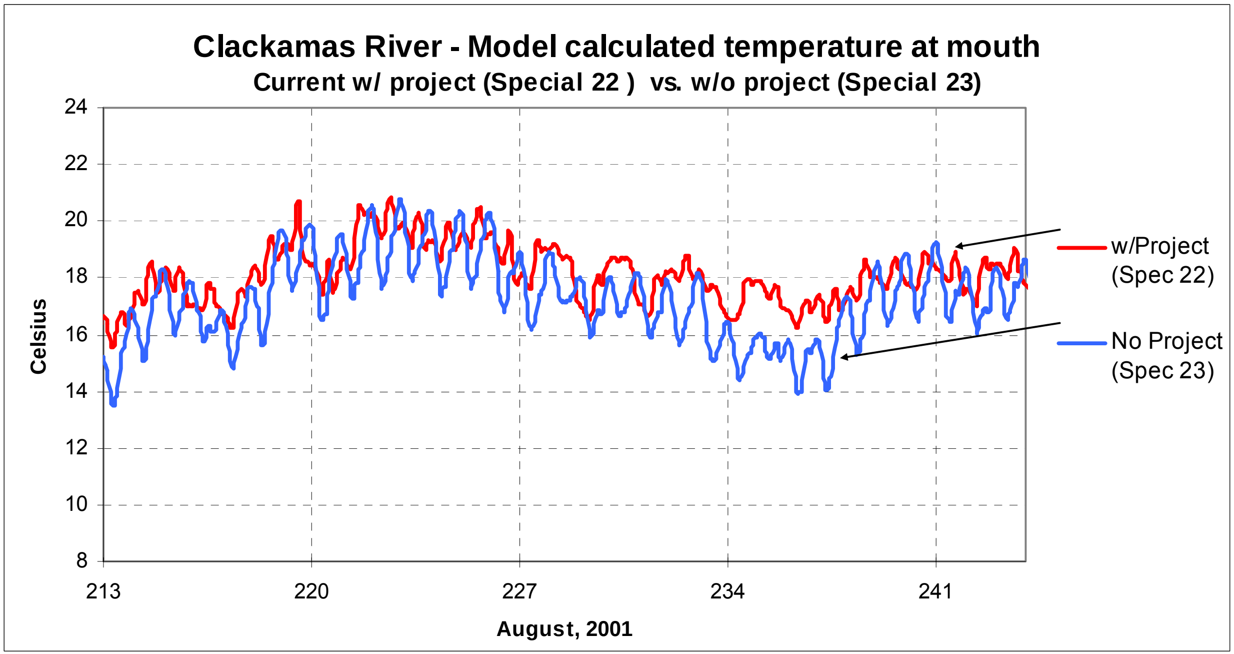
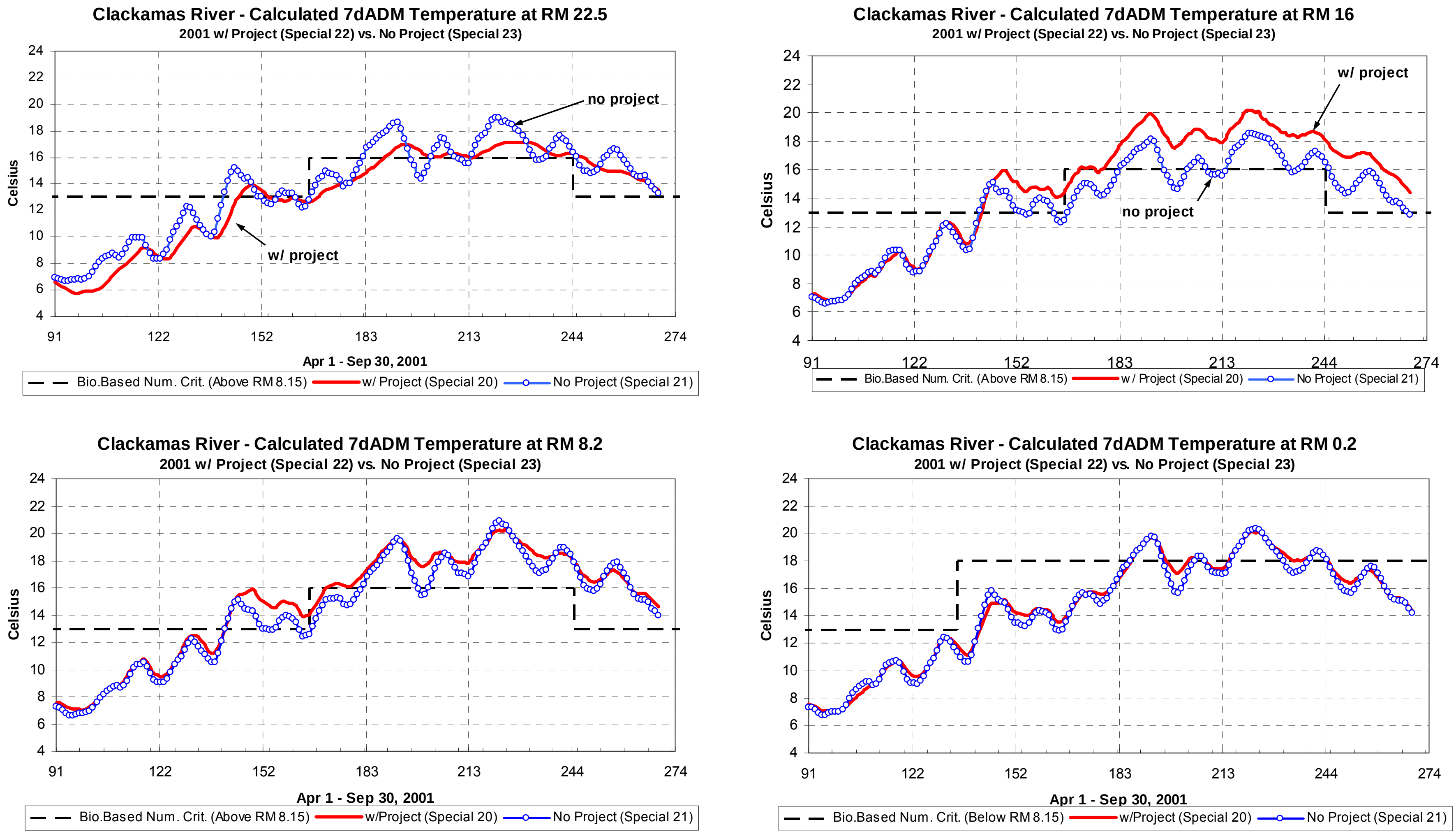


Figure 4.103 Calculated impact of PGE project on Clackamas River temperature at mouth - August



Calculated temperatures in terms of 7-d average maximum (7DADM) for four locations are presented in Figure 4.104. As shown, just downstream of River Mill dam at RM 22.5, temperatures with the project (Special Sim 22) are cooler than if the project was not present (Special 23). However, just 6.5 miles downstream at RM 16, the river is several degrees warmer with the project than without it.

Figure 4.104 7DADM with and without project for 4 locations



Clackamas River - Calculated 7dADM Temperature at RM 22.5

2001 w/ Project (Special 22) vs. No Project (Special 23)

Clackamas River - Calculated 7dADM Temperature at RM 16

2001 w/ Project (Special 22) vs. No Project (Special 23)

Clackamas River - Calculated 7dADM Temperature at RM 8.2

2001 w/ Project (Special 22) vs. No Project (Special 23)

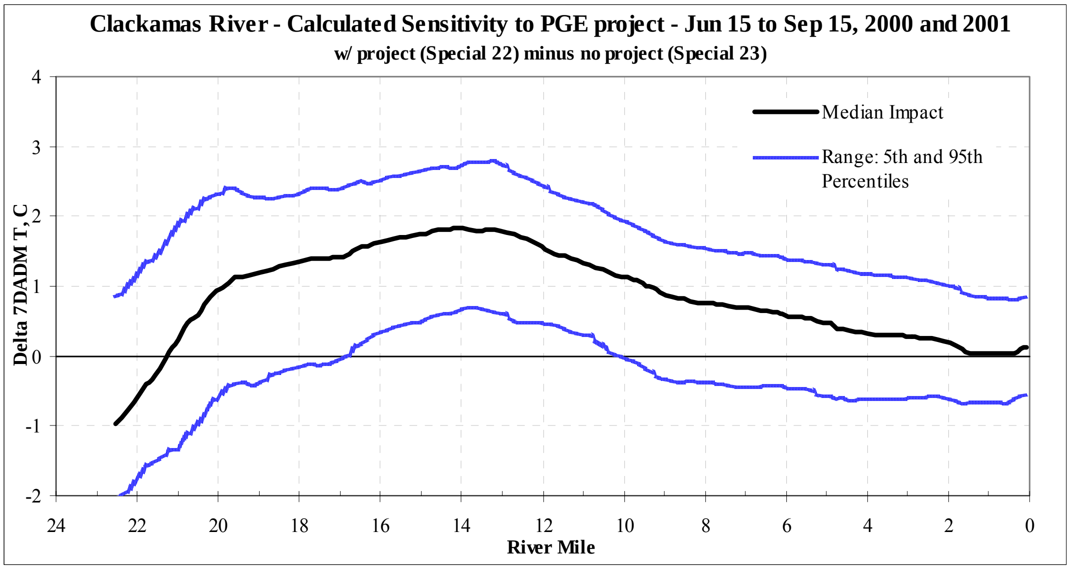
Clackamas River - Calculated 7dADM Temperature at RM 0.2

2001 w/ Project (Special 22) vs. No Project (Special 23)

RM 16 is in the area of maximum impact of the project (Figure 4.104 above). At locations further downstream, such as RM 8.2 and RM 0.2 (mouth), 7DADM temperatures are increased less by the project, particularly on the warmest days when the project has very little if any impact.

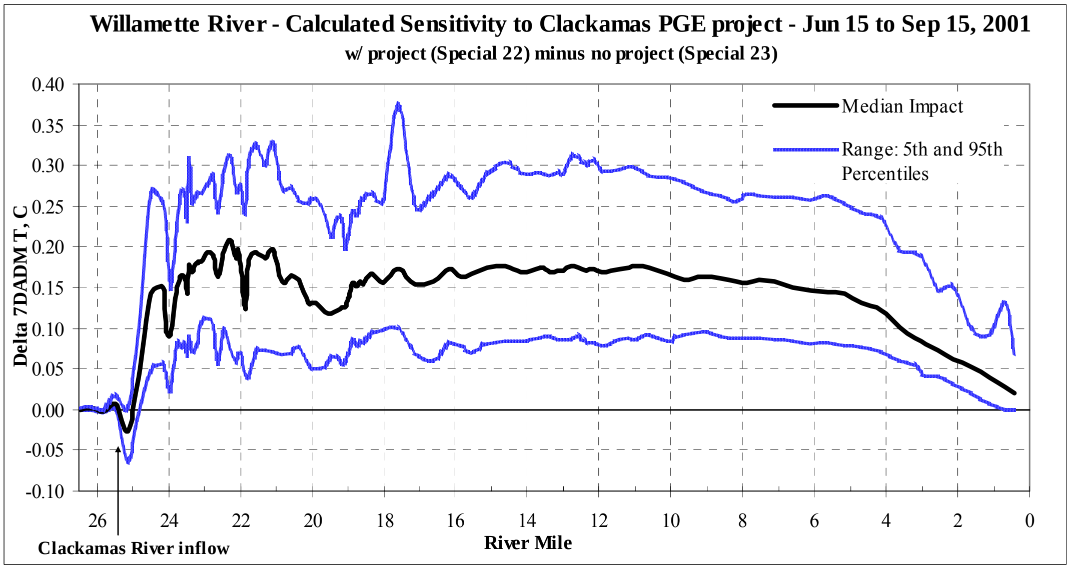
The model indicates that temperature is increased more than 1°C by the project in the reach between river mile 10 and 20. This is illustrated by Figure 4.105, which shows median, 5th and 95th percentile temperature differences (delta T) between Special Sim 22 (conditions with current project operations) and Special Sim 22 (NTP without project). As shown, the area of greatest impact is RM 12 to 16, where median impacts approach 2°C. In the last 10 miles of the river the impact diminishes, and median delta Ts decline to near zero near the mouth.

Figure 4.105 **Calculated impact of PGE Clackamas Project on the Clackamas River during the summer**



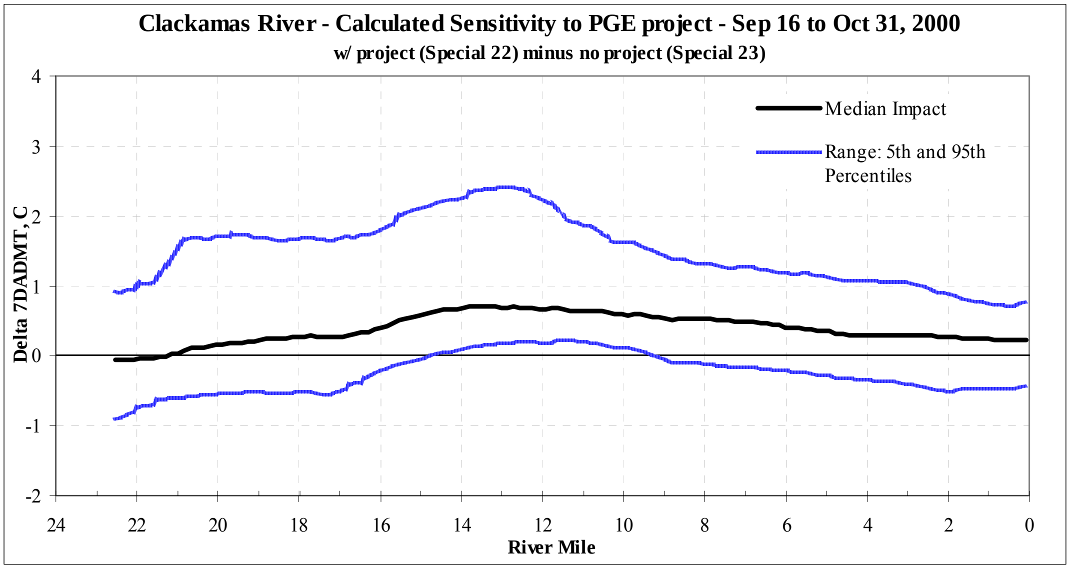
Impacts continue into the Lower Willamette, although dilution results in impacts that are much less than in the Clackamas (see Figure 4.106); note that only output for 2001 presented, since a calibrated model is not available for the lower Willamette for 2000). However, the impacts are still potentially significant, with median summer impacts in excess of 0.15°C in much of the river.

Figure 4.106 **Calculated impact of PGE Clackamas Project on the Willamette River during the summer**



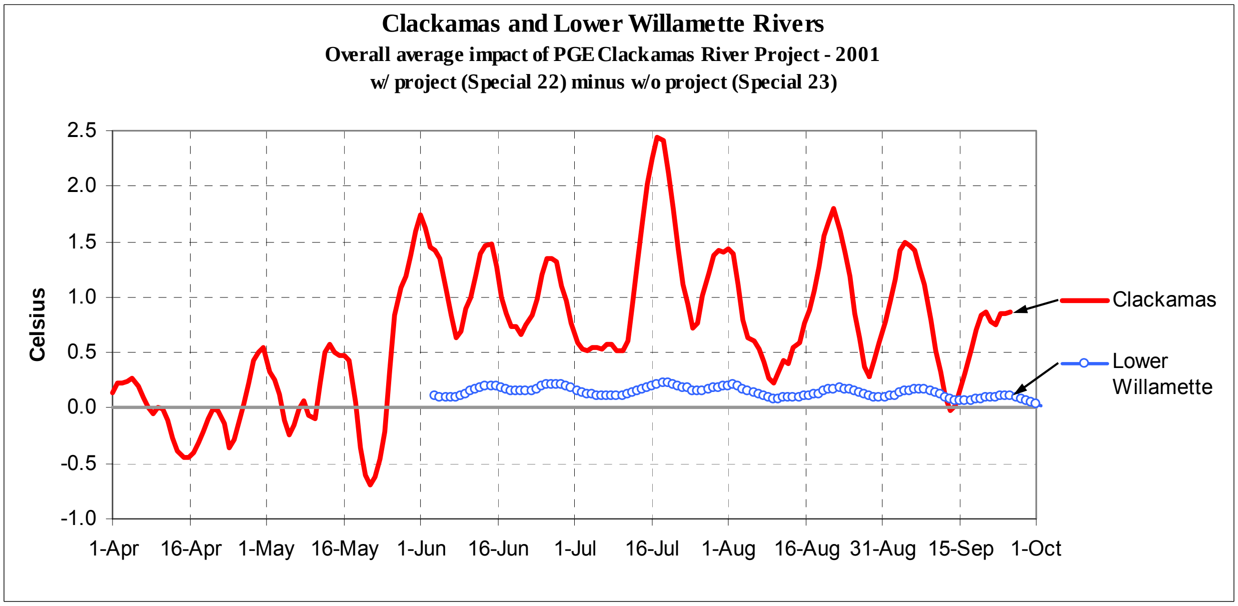
In early fall (September 16 to October 31), the impact of the Project on the Clackamas is more uniform than during the summer (see Figure 4.107); only year 2000 output presented since no model output is available for October 2001). This is partly because flow rates are greater during the fall, which results in quicker passage of water through reach. But it is also because, unlike during the summer, daily maximum temperatures immediately below River Mill Dam during the fall are often not less with current operations than they would be without the project.

Figure 4.107 Calculated impact of PGE Clackamas Project on the Clackamas River during the fall



The overall average impact of the project on the Clackamas and Lower Willamette on a seasonal basis for 2001 is presented in Figure 4.108. This was calculated by averaging for each simulation day the delta Ts for all model segments. As shown, the overall impact on the Clackamas is greater in the summer than in the spring. While on some days in the spring the project results in cooler overall average impacts, in general the project results in warmer temperatures. In the Willamette, the project also results in warmer temperatures, although the impact is much less than in the Clackamas (output for the Willamette not plotted for the spring since modeled only from June through September for 2001).

Figure 4.108 Seasonal variation in impact of PGE project on Clackamas and Willamette



In order to evaluate the overall impact of the project for time periods of concern, cumulative frequency distribution plots have been developed of calculated 7DADM temperatures with and without the project. The time periods of concern are those for which biologically based numeric criteria are potential exceeded. Since criteria for the reach from RM 0 to 8 (mouth to Clear Creek) are less stringent than RM 8 to 23 (River Mill Dam), separate plots are presented for the two reaches.

Applicable criteria and time periods of potential exceedance (based on 2000 and 2001 modeling) are presented in Table 4.41. For RM 0 to 8, model calculated temperatures only exceed applicable criteria from July 1 to September 15. Model calculated temperatures in this reach do not exceed spawning criteria in 2001 or 2002 during time periods for which the spawning period applies, either with or without the Project. Therefore, for the lower reach a cumulative frequency distribution plot is only provided for the non-spawning period from July 1 to Sept 15 (Figure 4.109). Calculated 7DADM temperatures for all segments for both 2000 and 2001 were aggregated for the plot. Therefore, there was no explicit spatial or temporal averaging.

Table 4.41 Biologically based numeric criteria and time periods for plots

	Biologically based numeric criteria		**Time periods for which plots generated (periods experience criteria exceedances and model output is available for 2 yrs)**	
	RM 0 to 8	**RM 8 to 23**	**RM 0 to 8**	**RM 8 to 23**
Jan 1 to May 15	13	13	no exceedances	no exceedances
May 16 to Jun 15	18	13	no exceedances	May 16 to Jun 15
Jun 16 to Aug 31	18	16	Jul 1 to Sep 15	Jun 16 to Aug 31
Sep 1 to Oct 14	18	13		Sep 1 to Sep 30
Oct 14 to Dec 31	13	13	no exceedances	no exceedances

The reach from RM 8 to 23 has more stringent criteria than the lower reach and criteria exceedances occur for a greater period of the year. Criteria exceedances occur during a spring spawning period from May 16 to June 15, the summer non-spawning period from June 16 to August 31, and a fall spawning period from September 1 to October 14. Cumulative frequency distribution plots are provided for all three periods (Figure 4.109 - 4.111, with 2000 and 2001 output combined for all three plots. Since no model output is available for October 2001, the time period for the fall spawning period plot is limited to only September (Figure 4.112)

As shown in Figure 4.109, in the lower reach from RM 8 to 0 project impacts are relatively modest. In this reach the project contributes to criteria exceedances only when temperatures are less than 19.4^{o}C. When temperatures are warmer, the project reduces daily maximum temperatures. However, in the upper reach, project impacts are much more significant (see Figures 4.110 to 4.112). In this reach the project results in a shift in the cumulative frequency distribution by up to 1.5^{o}C.

Figure 4.109 RM 0 to 8, Non-spawning period, Jul 1 to Sep 15, 2000 and 2001

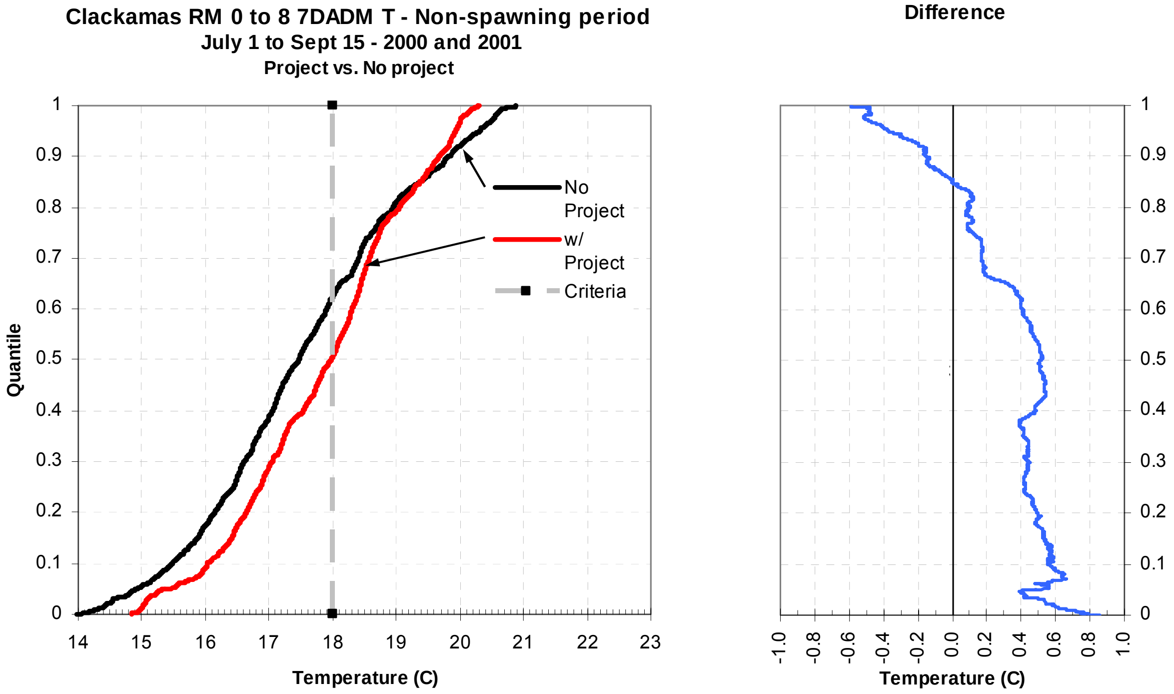


Figure 4.110 RM 8 to 23, Spring spawning period, May 16 to Jun 15, 2000 and 2001

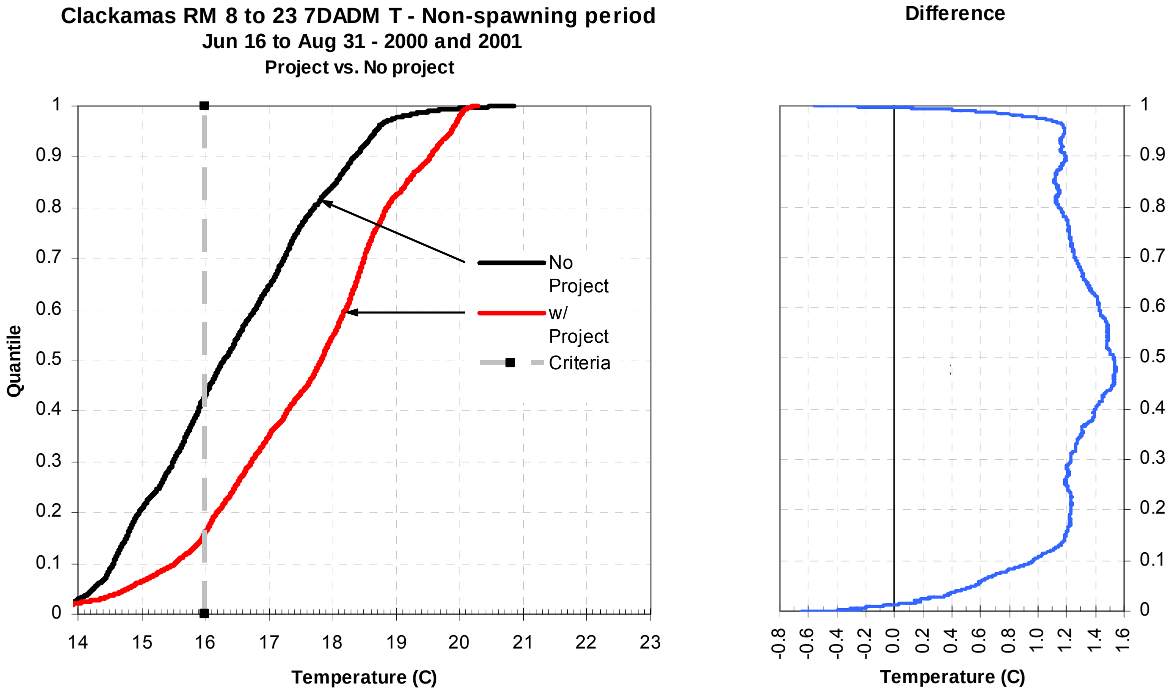


Figure 4.111 RM 8 to 23, Non-spawning period, Jun 16 to Aug 31, 2000 and 2001

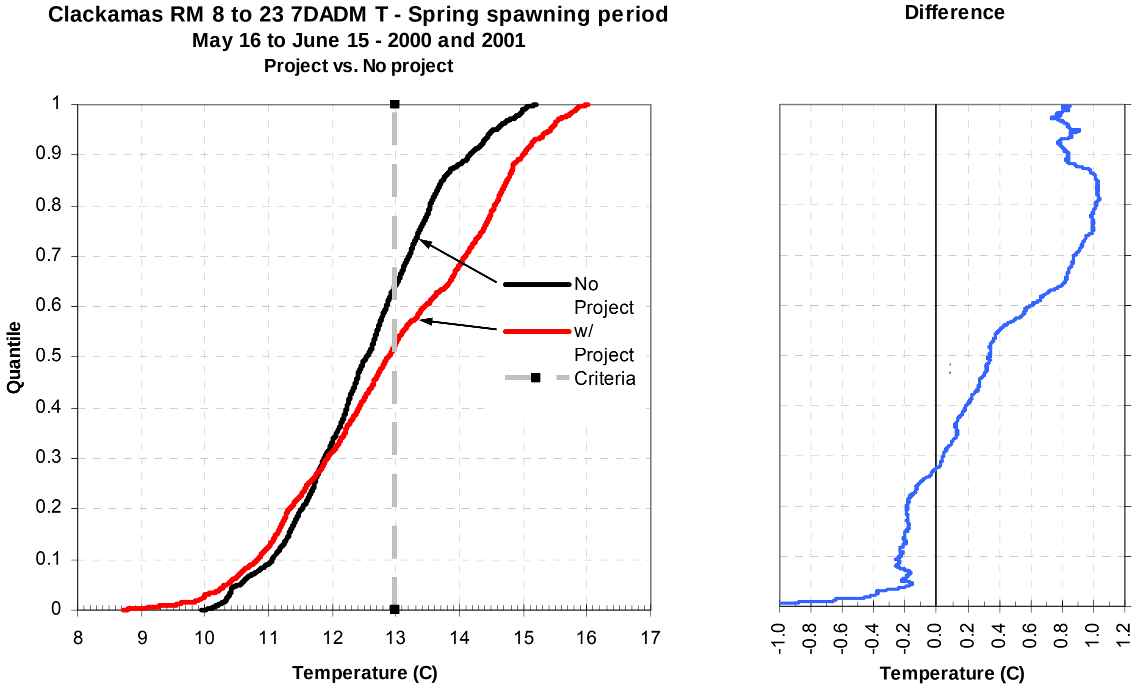
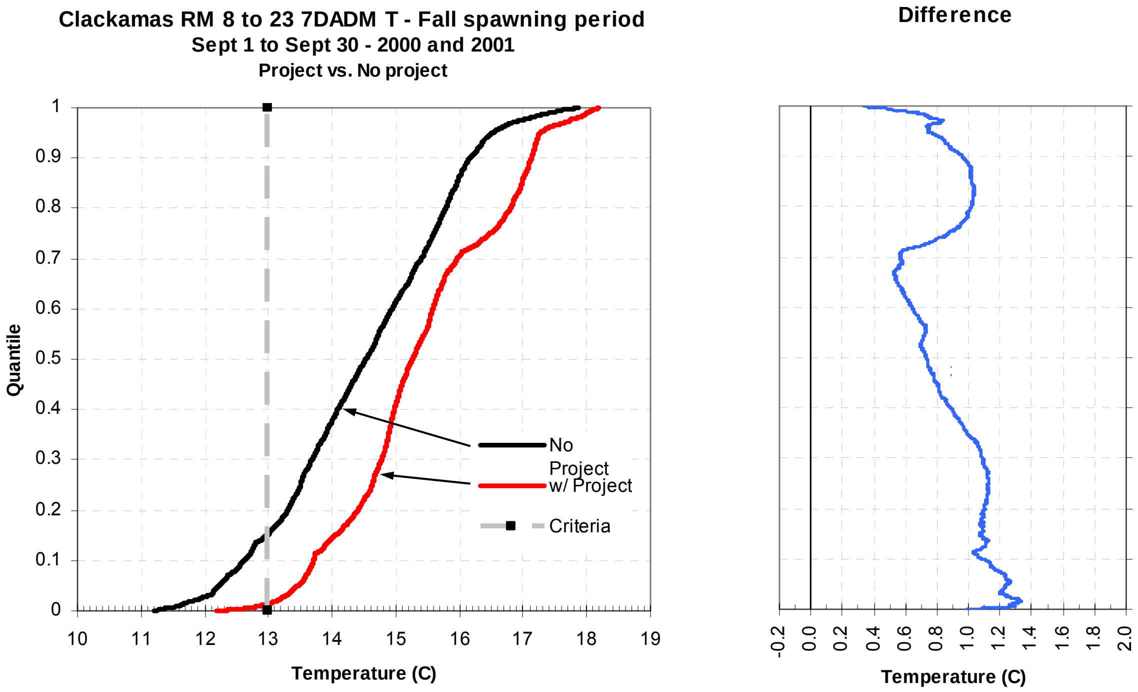


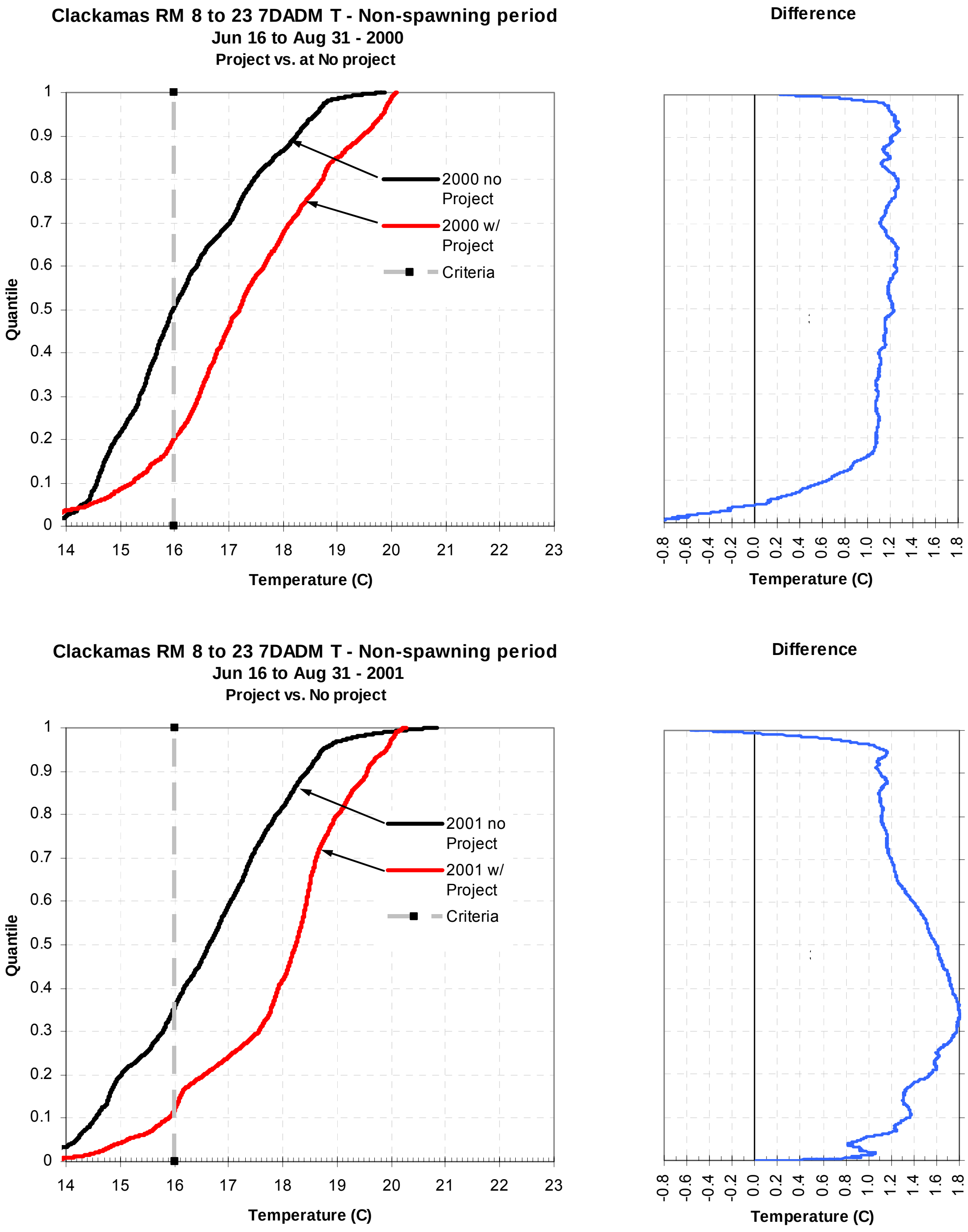
Figure 4.112 RM 8 to 23, Fall spawning period, Sep 1 to Sep 30, 2000 and 2001



In order to see if 2000 and 2001 differ significantly, cumulative frequency distribution plots are also provided for the upper reach from RM 8 to 23 for the June 16 to August 31 non-spawning period with the two years treated separately (Figure 4.113 and Figure 4.114). As shown, the project contributes significantly to criteria exceedances in the reach in both 2000 and 2001.

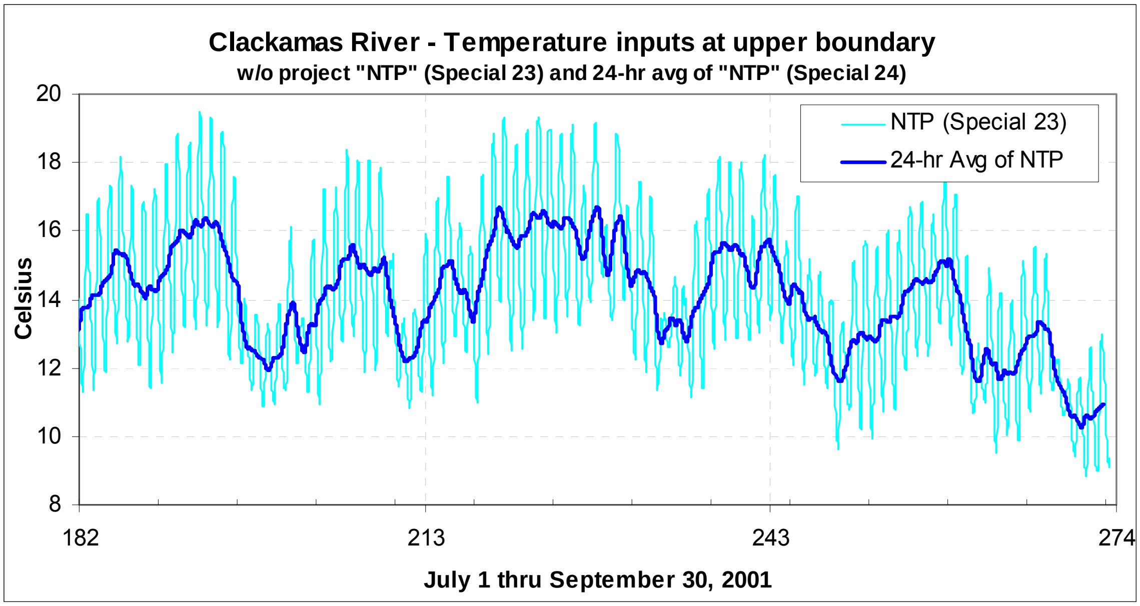
The figures show the impact of 2001 drought conditions on river temperature. For year 2000, the model calculated median “non-project” temperature for the period is equal to the biologically based numeric criteria of 16.0°C and the 90th percentile temperature is 18.3°C (Figure 4.113). For the drought year of 2001, when river flow rates were unusually low, the model calculated median “non-project” temperature is 16.7°C and the 90th percentile temperature is 18.5°C (Figure 4.113, below).

Figure 4.113 **RM 8 to 23, Non-spawning period, Jun 16 to Aug 31, 2000 (above) and RM 8 to 23, Non-spawning period, Jun 16 to Aug 31, 2001 (below)**



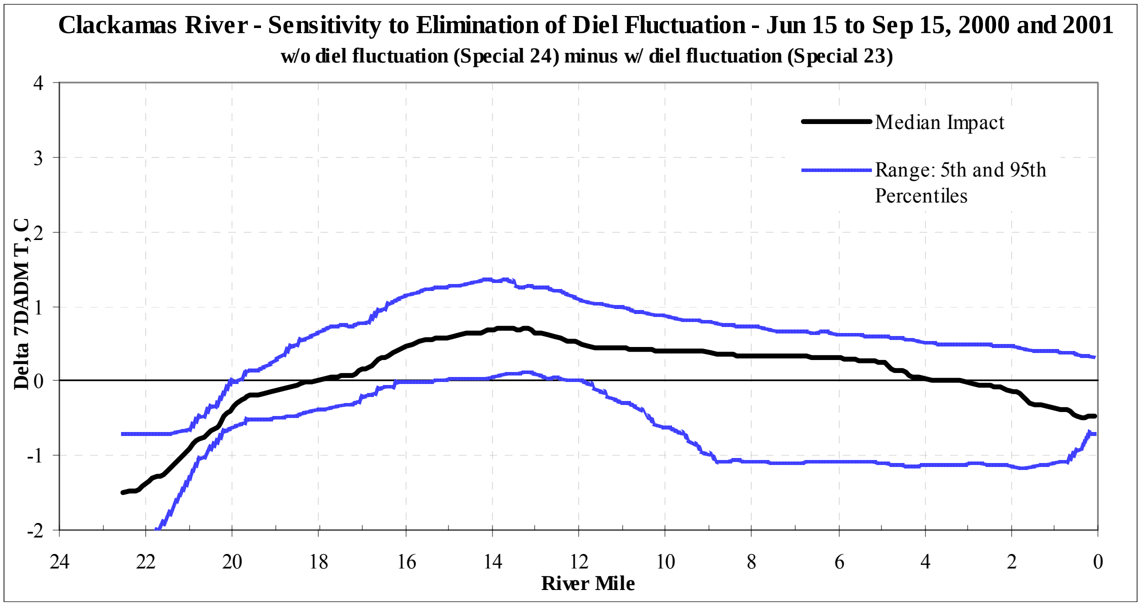
Much of the impact of the Clackamas Project is due to reduction of natural diel temperatures by the reservoirs. The impacts of the elimination of diel temperature fluctuation at the River Mill Dam tailrace were evaluated by performing a simulation (Special Sim 24) in which the boundary temperature was set to a 24 hour average of the Special Sim 23 natural thermal potential (Figure 4.114).

Figure 4.114 24 Hour Average of boundary NTP condition used for input to Special Sim 24



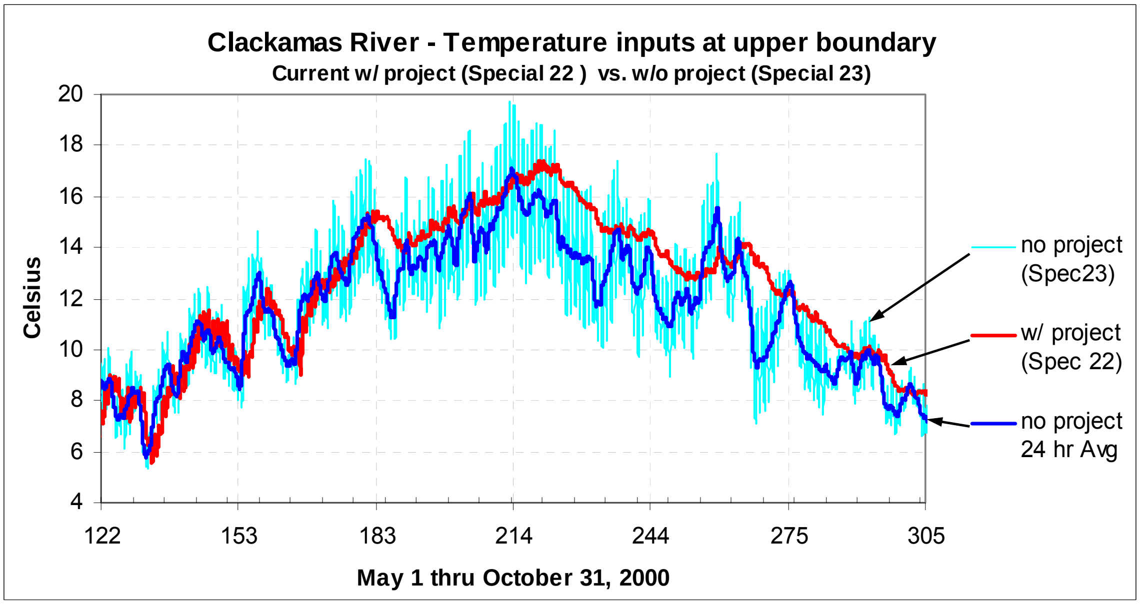
The simulations indicate that elimination of natural temperature fluctuations results in daily maximum temperatures that are warmer than natural thermal potential in certain reaches, and cooler in others. This is illustrated by Figure 4.115, which shows that suppression of diel temperature fluctuations results in 7DADM temperatures during the summer that are warmer from RM 18 to RM 4. This probably is because water released in the early morning is warmer than natural thermal potential for that time of day. As this water flows downstream it heats to temperatures that exceed daily maximum natural thermal potential temperatures. Therefore, suppression of natural temperature fluctuations contributes to temperature standard exceedances because river temperatures are increased more than 0.3^{o}C above natural thermal potential. Such exceedances probably occur downstream of many large reservoirs that suppress diel fluctuations. While elimination of diel fluctuations results in warmer daily maximum temperatures from RM 18 to 4, below RM 4 the elimination results in cooler daily maximum temperatures, with the greatest cooling occurring at the river mouth (Figure 4.115). This may be because the time-of-travel from RM 23.4 to RM 0 is about a day, which would result in RM 23.4 reductions in daily maximum temperature also being felt at RM 0. As shown by the figure, the impact has a sinusoidal shape, with a period equivalent to one day's time-of-travel. The sinusoidal shape probably extends into the Willamette River, albeit with an impact greatly reduced by Willamette River dilution. Therefore, elimination of diel fluctuations at Clackamas RM 23.4 may result in impacts on the lower Willamette River, in addition to the significantly warmer temperatures observed in the Clackamas.

Figure 4.115 Impact of elimination of diel temperature fluctuation on river temperature



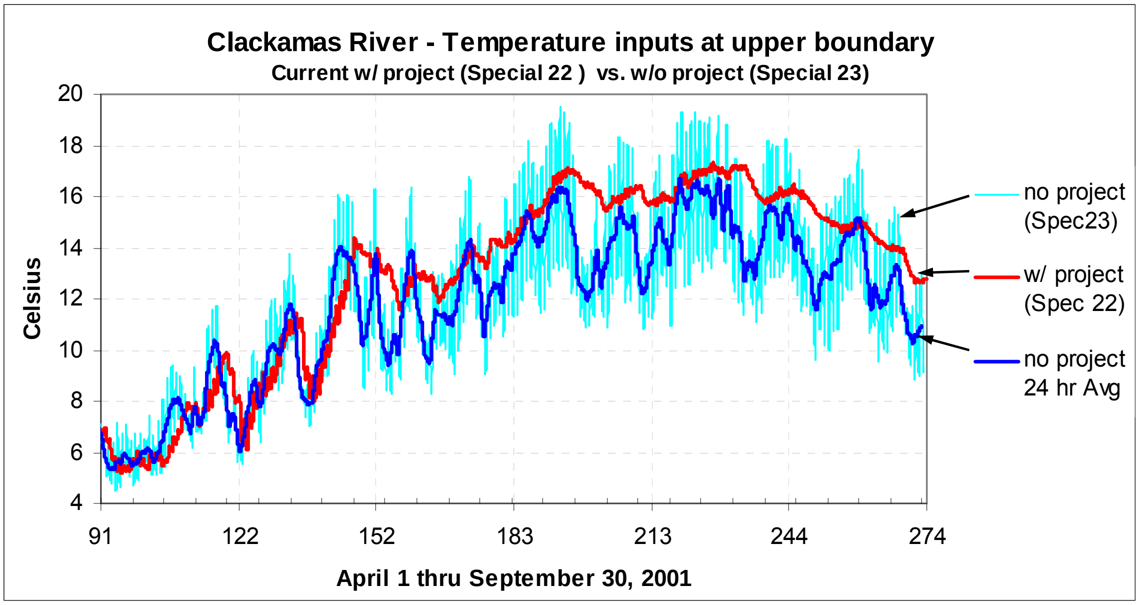
While part of the impact of the Clackamas Hydroelectric Project on Clackamas River temperature is due to the elimination of diel temperature fluctuations, this is not the only cause. Some of the impact appears to be due to overall heating beyond natural potential in reaches above River Mill Dam. This is illustrated by Figures 4.116. and 4.117, which show model calculated hourly temperatures at the River Mill Dam tailrace for years 2000 and 2001 for the with project (Special Sim 22) and no project (Special Sim 23) scenarios. Also shown is a 24 hour moving average of the no project temperatures.

Figure 4.116 Temperature at RM 23.4 with project vs. without project – 2000



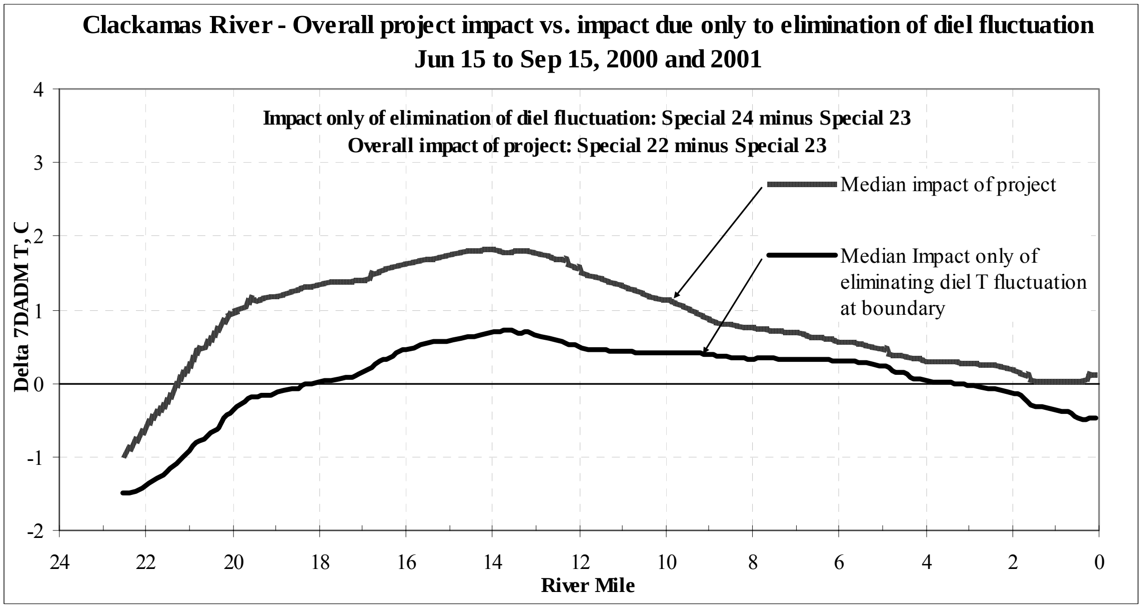
The difference between project and 24 hour average no project temperatures provides an indication of the overall heating or cooling provided by the project. As shown, daily average temperatures are often significantly warmer with the project than without the project. This indicates that the project not only increases daily maximum temperatures by suppressing diel temperature fluctuations, but that it also increases temperatures by providing a heat load to the river that is roughly equal to the difference between the temperatures at the River Mill Dam tailrace location with and without the project.

Figure 4.117 Temperature at RM 23.4 with project vs. without project - 2001



The overall impact of project relative to the impact of only eliminating diel temperature fluctuations is shown by Figure 4.118. Eliminating diel fluctuations results in temperatures 0.7°C warmer than NTP at RM 14, whereas the overall impact of the project is 1.8°C at RM 14.

Figure 4.118 Overall impact of project vs. impact only of elimination of diel fluctuation



To summarize, the impact of the Clackamas Hydroelectric Project on the Clackamas River significantly exceeds the human use allowance in the reach from RM 8 to 23. In addition, the project consumes a portion of the human use allowance in the Willamette River. While at certain times and locations the project results in cooler river temperatures, overall, the project causes temperatures in the Clackamas River to be significantly warmer than natural thermal potential.

Influence of McKenzie River EWEB Hydroelectric Projects

The Eugene Water and Electric Board (EWEB) owns and operates two hydroelectric projects on the lower McKenzie River. The Leaburg project diverts flow into a power canal near RM 35.7 and returns the flow to the river at RM 30.1, based on distances above the uppermost confluence with the Willamette River (corresponding Oregon Water Resources Board river miles, which are from 1967 and based on the lowermost confluence with the Willamette, are RM 38.9 and 33.2). The Walterville project diverts flow near RM 25.6 and returns it at RM 17.4 (Oregon Water Resources Board RM 28.3 and 21.0). For the 2001 calibration period both canals were active, while for 2002 the Waterville diversion was shut off for maintenance.

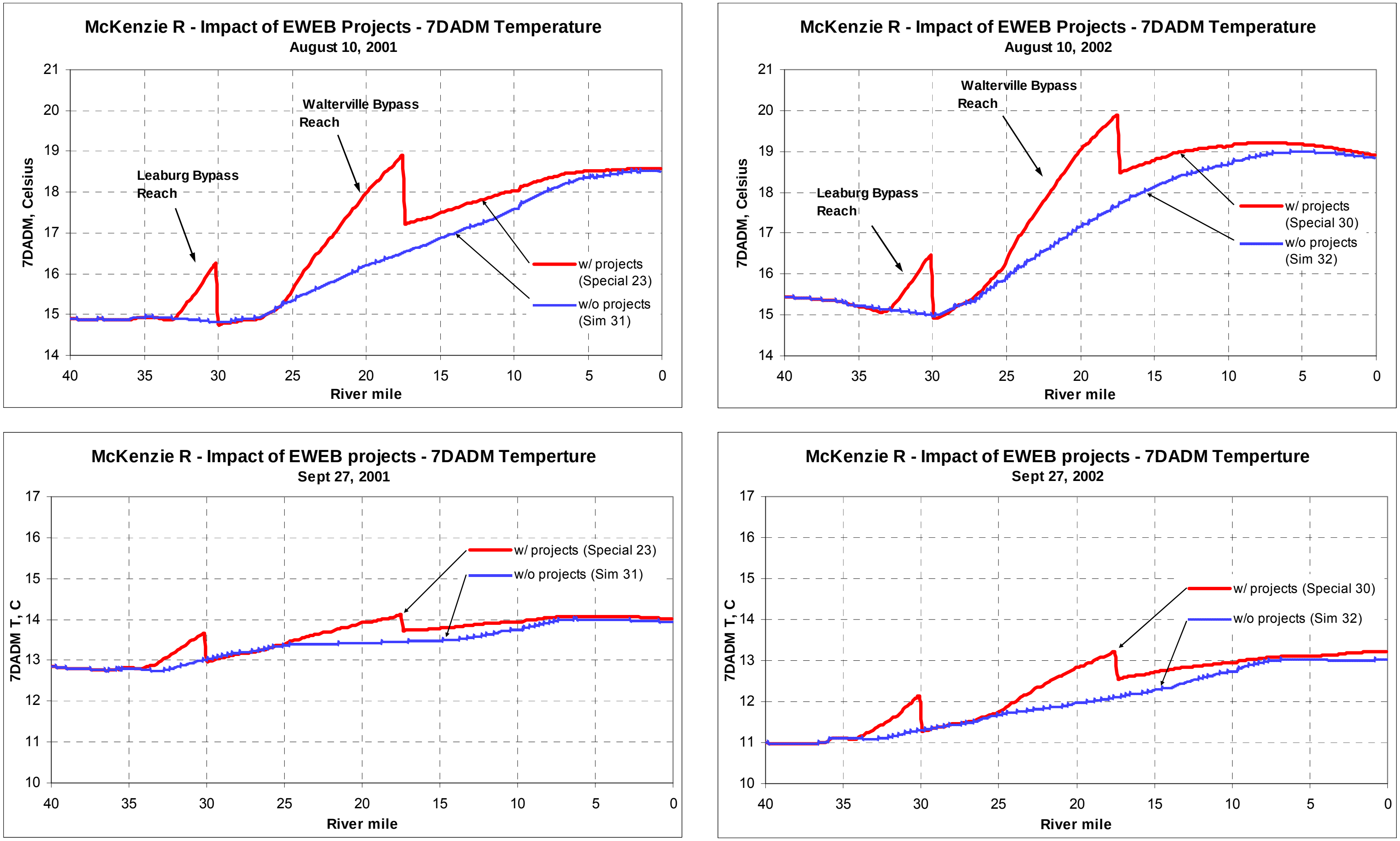
In order to evaluate the impact of the projects, simulations were performed with and without the projects active for 2001 and 2002. Special Simulations 23 and 30 are 2001 and 2002 simulations with both canals active. For these, flow is diverted through the canals, which results in significantly reduced flow in the Leaburg and Walterville “bypass” reaches (natural river channels in which flow is reduced by hydroelectric project diversions). Simulations 31 and 32 are “natural thermal potential” simulations with both canals inactive and full flow in the bypass reaches. For all four simulations shade is set to system potential, point source wastewater effluent discharges are eliminated, and upper boundary flow rates and temperatures are set to observed 2001 and 2002 conditions.

The river bathymetry used for the four simulations is May 2004 bathymetry provided to DEQ in April 2005 by Portland State University. This more recent bathymetry differs from bathymetry used for McKenzie River simulations presented in the October 2004 draft TMDL. This change results in model calculated project impacts that, in general, are greater than those presented in the draft.

Model calculated seven day average daily maximum (7DADM) temperatures for select summer and fall seven day periods are shown in Figure 4.119. As shown, the model indicates that diversions result in considerably warmer temperatures in both the Leaburg and Walterville bypass reaches. Downstream from the Leaburg bypass reach, project impacts are minimal. However, in the reach downstream from the Walterville bypass reach, the project results in significantly warmer temperatures.

The increased temperatures in the bypass reaches are due to reductions in flow in the bypass reaches, which result in reduced heat capacity, lower stream velocities and increased times of travel which allow for greater times of exposure to solar radiation heat loads. On the other hand, water diverted from the river and transported through hydroelectric facilities via penstocks and relatively narrow diversion canals is exposed to less solar radiation loads than water which remains in the river. Therefore, when the diverted water is returned to the river downstream from the bypass reaches, much of the heating that occurs in the bypass reaches is negated. Downstream from the Leaburg bypass reach, the return of diverted water results in temperatures that are similar to natural thermal potential. However, downstream from the longer Walterville bypass reach, the return of diverted water is insufficient to negate the heating which occurs in the bypass reach. Therefore, downstream temperatures are still warmer than natural thermal potential. This temperature impact persists all the way to the Willamette River.

Figure 4.119 Impact of McKenzie River EWEB projects on daily maximum temperature for example 7-day periods in August and September



Differences between calculated temperatures with and without the project (Delta T's) are shown by Figures 4.120 and 4.121. Shown are median Delta T's for all days for the non-spawning period from May 15 to September 1 during which the biologically based numeric criteria is 16°C, as well as the range of impacts (based on 5th and 95th percentiles delta Ts). As shown, median temperatures are increased about 1°C in the Leaburg bypass reach by the project and about 2°C in the Walterville bypass reach. Downstream of where the diverted water returns to the river below the Walterville bypass reach, the median temperature increase is 0.6 to 0.7°C. This impact declines to about 0.1°C by the river mouth.

Figure 4.120 **Calculated impact of EWEB projects on McKenzie River for Summer, 2001**

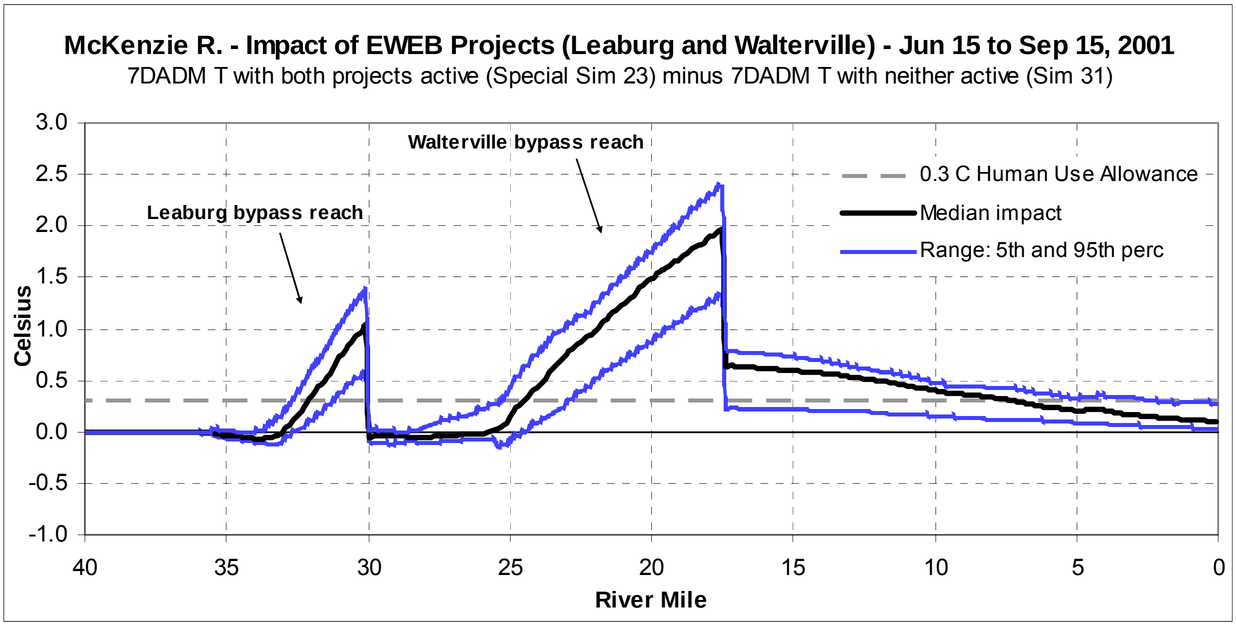
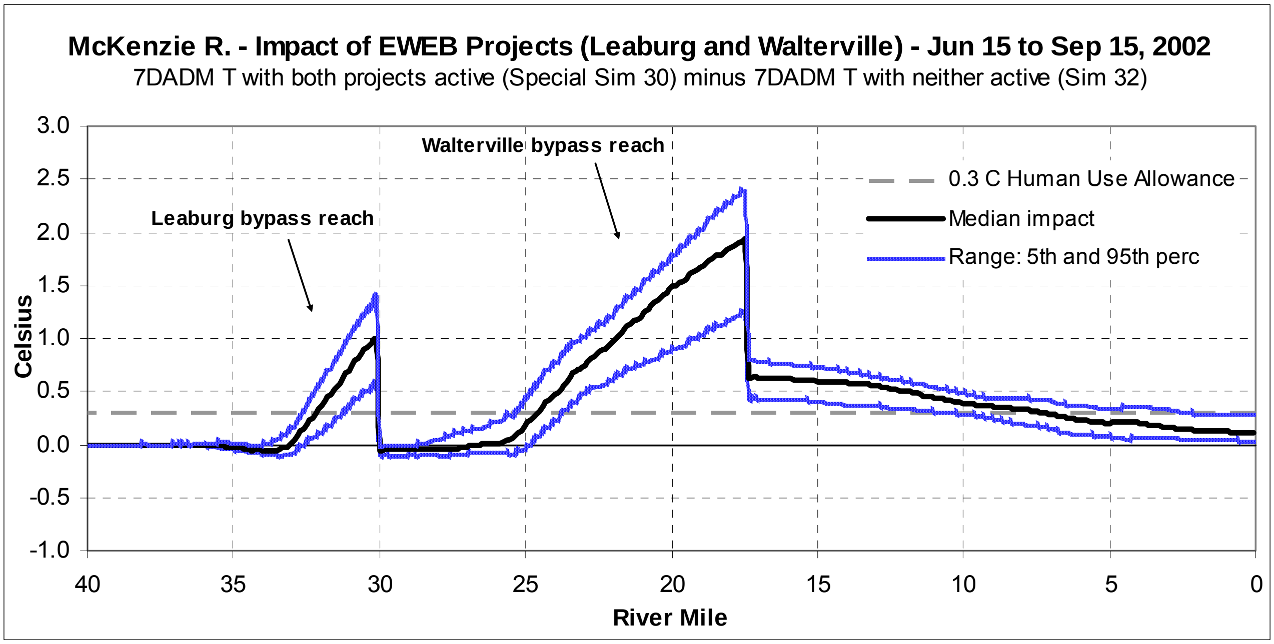


Figure 4.121 **Calculated impact of EWEB projects on McKenzie River for Summer, 2002**



Cumulative frequency distributions of calculated 7DADM temperatures in the reach between the Walterville return flow (RM 17.4) and the river mouth (RM 0.0) are presented below for scenarios with and without the two projects (Figures 4.122 to 4.124). For the plots, calculated 7DADM temperatures for all segments in the reach of interest are grouped and ranked, with data form 2001 and 2002 simulations combined. A quantile of 0.9 corresponds to a temperature for which calculated temperatures are less than 90% of the time and a quantile of 0.5 corresponds to the median calculated temperature.

Data for the cumulative frequency distribution plots is grouped based on applicable criteria. The applicable biologically-based numeric criterion for the McKenzie River during non-spawning periods is 16.0^{o}C (core cold water habitat use). Upstream from RM 7.5 the non-spawning period is June 15 to September 1, while downstream the period is May 15 to September 1. During the rest of the year the spawning criterion of 13^{o}C applies. Project and point source locations are shown in Table 4.42.

Table 4.42 Locations of some sources of stream heating and cooling

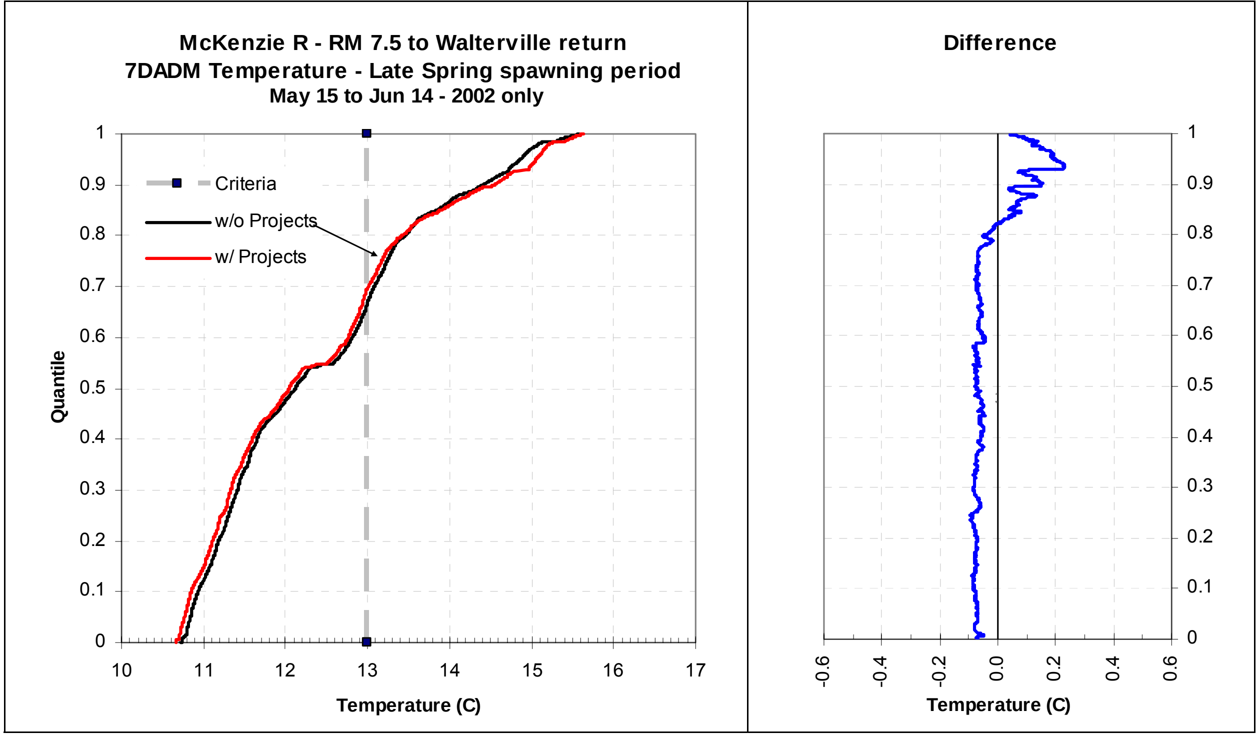
Landmark	Model RM	Model Segment
Leaburg project diversion	35.7	164
Leaburg project return flow	30.1	204
Walterville project diversion	25.6	233
Walterville project return flow	17.4	288
Weyerhaeuser Springfield discharge	12.2	321
Mohawk River confluence	9.6	338
Location of change in period of spawning	7.5	351

Prior to May 15, the 13C spawning criterion applies for all reaches. For natural thermal potential modeling scenarios, this criterion is never exceeded in the lower river for this time period. Since the criterion is never exceeded, no plot is presented.

For May 15 to Jun 15, the 16C criterion applies below RM 7.5. Based on NTP modeling, this criterion is rarely exceeded during this time period in this reach. The criterion is only exceeded during this time period on June 12 and June 13, 2002, and then only below RM 4. For 2001, the criterion is always met for this time period. Based on the modeling, the frequency of criterion exceedance is 0% above RM 4, 1.6% from RM 3 to 4, and 3.2% below RM 3. Since the criterion is rarely exceeded in this reach during the May 15 to June 15 time period, no plot is provided below RM 7.5 for this period.

The criterion of concern for May 15 to Jun 15 is the spawning criteria from RM 17.4 to RM 7.4. This criterion is exceeded about 30% of the time during this time period in this reach, based on modeling for 2002. Since the criterion is exceeded, cumulative frequency distribution curves are presented for the "with project" and "no project" scenarios (see Figure 4.122). (This is based only on the 2002 simulation, since 2001 output is not available for much of the time period since the model run did not start until June). To generate the curves, 7DADM stream temperatures for 2002 for McKenzie river model segments from RM 17.4 to RM 7.4 were aggregated. As shown, the project results in warmer temperatures during some of this time.

Figure 4.122 **Cumulative frequency distributions of model calculated 7DADM temperatures w/ and w/o EWEB projects for the May 15 to Jun 14 spawning period.**

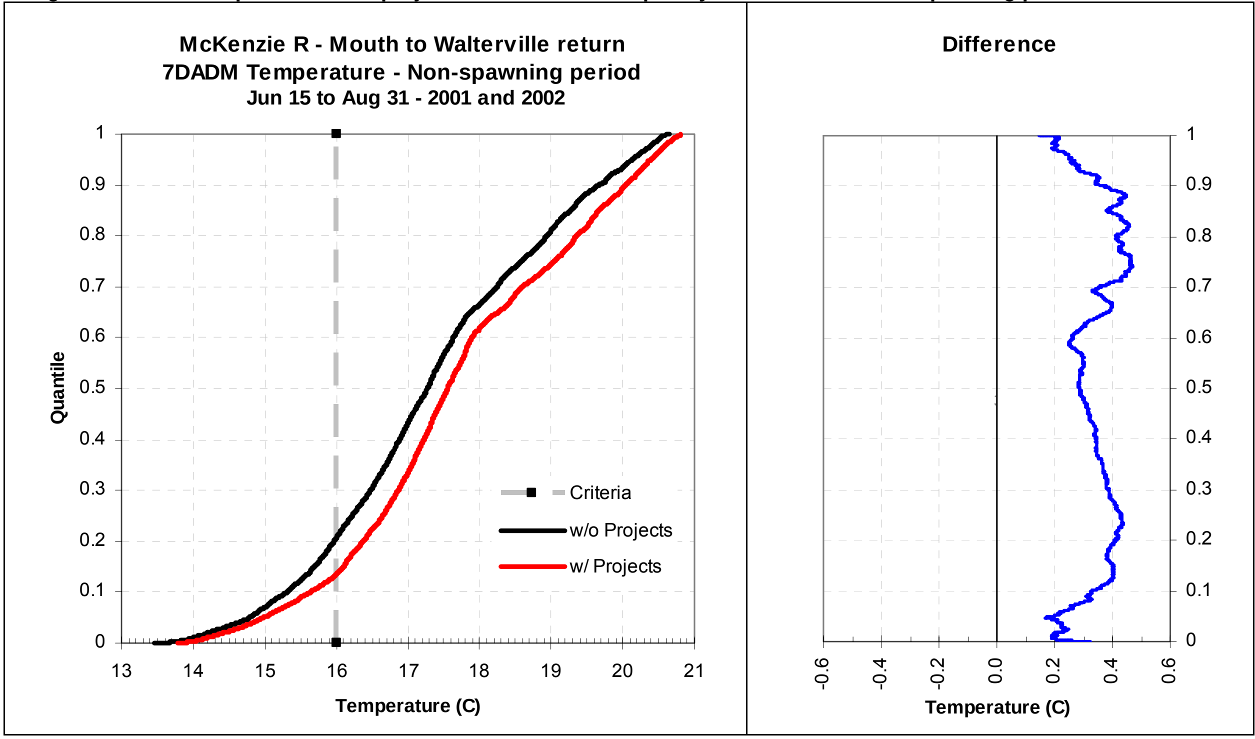


McKenzie R - RM 7.5 to Walterville return
7DADM Temperature - Late Spring spawning period
May 15 to Jun 14 - 2002 only

Difference

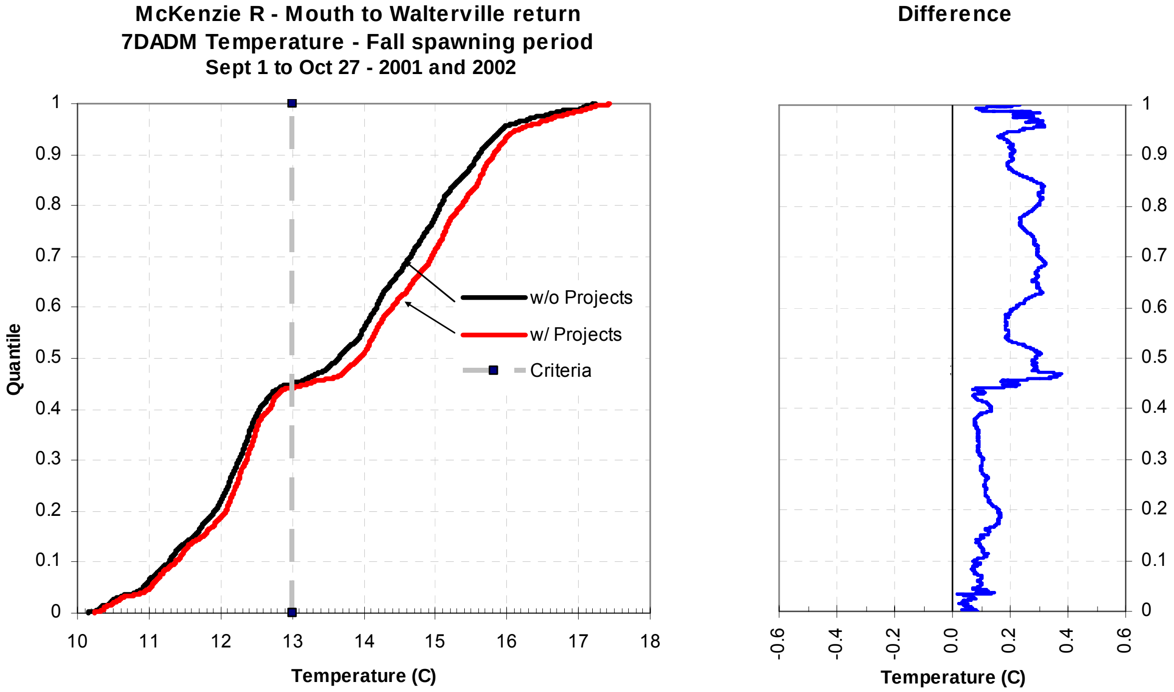
Model calculated 7DADM temperature output for the June 15 to August 31 non-spawning period is presented in Figure 4.123. To generate the plots, 7DADM stream temperatures for 2001 and 2002 for all McKenzie river model segments downstream from the RM 17 location where the Walterville diversion is returned to the main channel were aggregated. As shown, the project results in a general shift in the cumulative frequency distribution of about 0.4°C. This indicates that the projects warm the river beyond natural thermal potential temperatures during this period.

Figure 4.123 Impact of EWEB projects – Cumulative frequency distributions – Non-spawning period



During the fall spawning period, the projects result in a positive frequency distribution shift of 0.17 to 0.36°C when temperatures exceed the 13°C spawning criterion (Figure 4.124).

Figure 4.124 Impact of EWEB projects – Cumulative frequency distributions – Fall spawning period



Influence of Willamette Falls PGE Project

The PGE Willamette Falls Project is a run-of-the-river project located at the Willamette Falls at RM 26.5. A concrete cap on the basalt formation that creates the Willamette Falls is supplemented in summer low flow periods with flashboards. The increased water level provided by the project increases the volume of water in the Newberg Pool, the impounded reach behind the Falls which extends to about RM 56, and increases the time-of-travel through the reach.

Modeling simulations were performed to evaluate the impact of the project on temperatures in the Newberg Pool and in the lower Willamette downstream of the Falls. Four simulations are compared:

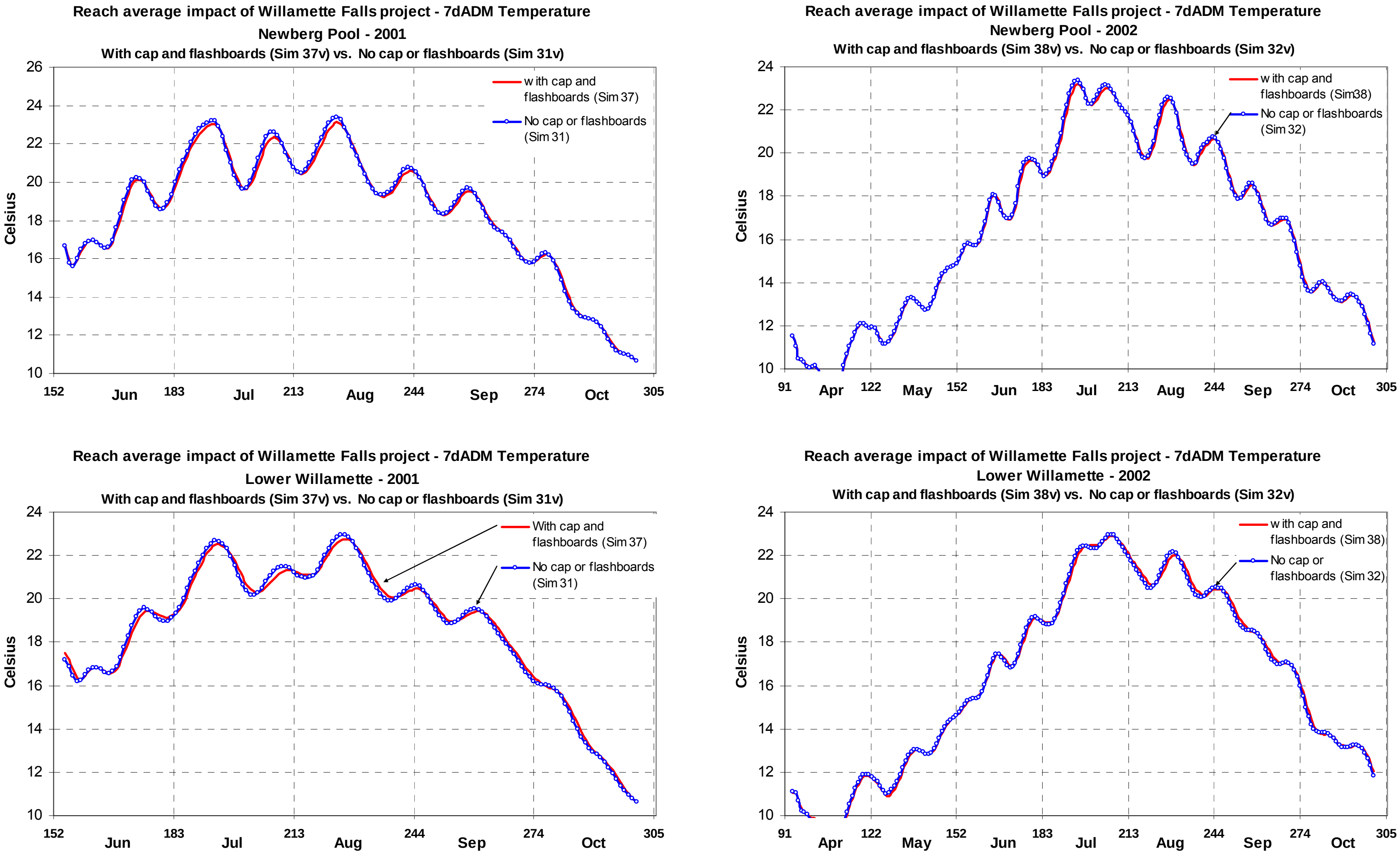
1. Sim 31 – 2001 conditions, no cap or flashboards (no project)
2. Sim 32 – 2002 conditions, no cap or flashboards (no project)
3. Sim 37 – 2001 conditions, with cap and flashboards (with project)
4. Sim 38 – 2002 conditoins, with cap and flashboards (with project)

For all scenarios upper boundary conditions are set to current conditions (2001 or 2002), vegetation is set system potential, and point source wastewater discharges are eliminated.

Model calculated temperatures with and without the project are shown in Figure 4.125. Shown are reach average 7DADM (7-day average daily maximum) temperatures in Newberg Pool and the Lower Willamette for 2001 and 2002. As shown, at certain times and locations the project results in warmer temperatures, while at other times and locations the project results in cooler temperatures.

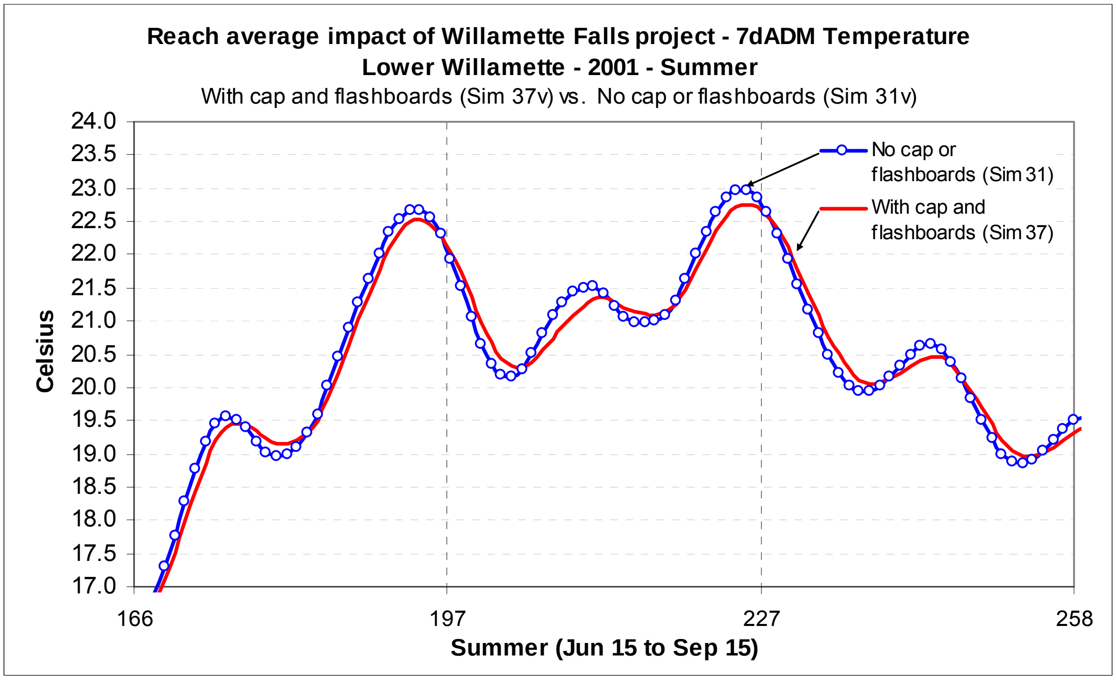
The 7DADM temperatures used for Figures 4.125, and most other ODEQ plots of Middle and Lower Willamette temperatures, are flow-weighted averages for each segment. Flow-weighted averages are calculated by averaging calculated temperatures for all vertical layers, with a weighting provided based on the relative flow of each layer. For example, if a segment consisted of 3 active vertical layers, and 50% of the flow was in the top layer, 30% was in the second layer, and 20% in the bottom layer, the flow-weighted average would be $T = (.5T_1 + .3T_2 +.2T_3)$.

Figure 4.125 Model calculated reach average temperatures with and without the project for 2001 and 2002



One positive impact of the project is that during the warmest days of the summer, reach average temperatures in both Newberg Pool and the Lower Willamette are reduced by the project (see Figure 4.126).

Figure 4.126 Model calculated reach average temperatures with and without the project for Summer 2001



The overall impact of the project is also shown by Figure 4.127 and 4.128. In these, summer average (June 15 to September 15) flow-weighted 7DADM temperatures for 2001 and 2002 with and without the project are compared above and below the falls. The data plotted in these figures differ from the above figures in that no reach averaging is performed. Instead, for each model segment calculated 7DADM temperatures for all summer days are averaged and plotted. This allows areas heated and cooled by the project to be identified. As shown, during the summer, average calculated temperatures in Newberg Pool are generally cooler with the project in place than without the project, while in the lower Willamette average temperatures are similar for the two scenarios.

Figure 4.127 Model calculated average 7DADM temperatures in the summer w/ and w/o Falls project - 2001

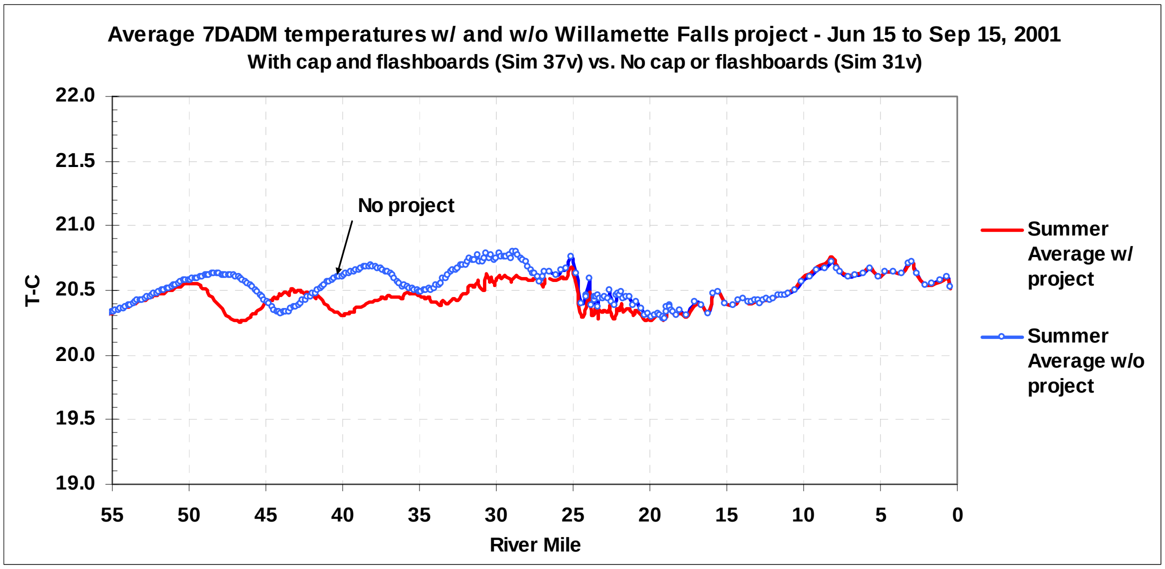
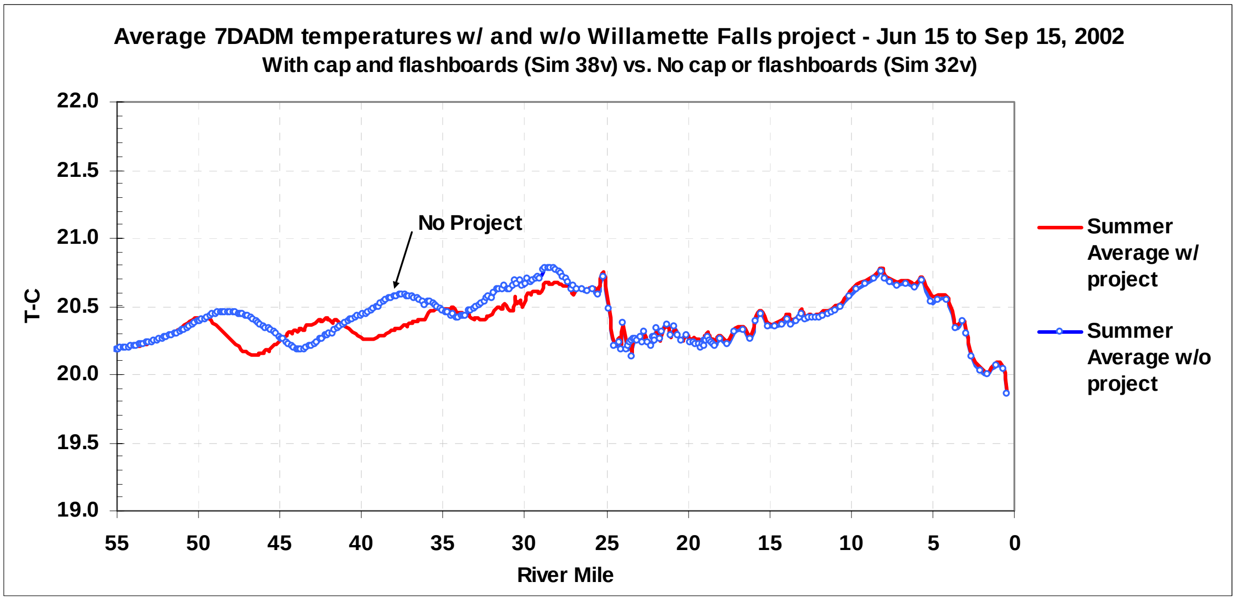


Figure 4.128 **Model calculated average 7DADM temperatures in the summer w/ and w/o Falls project - 2002**



Similar plots are also presented for fall periods (see Figure 4.129 and 4.130). As shown, modeling indicates that fall temperatures in the lower Willamette are warmer with the project in place than they would be without the project. Note also the influence of warmer Columbia River water near the river mouth (RM 0).

Figure 4.129 **Model calculated average 7DADM temperature in the fall w/ and w/o the Falls project - 2001**

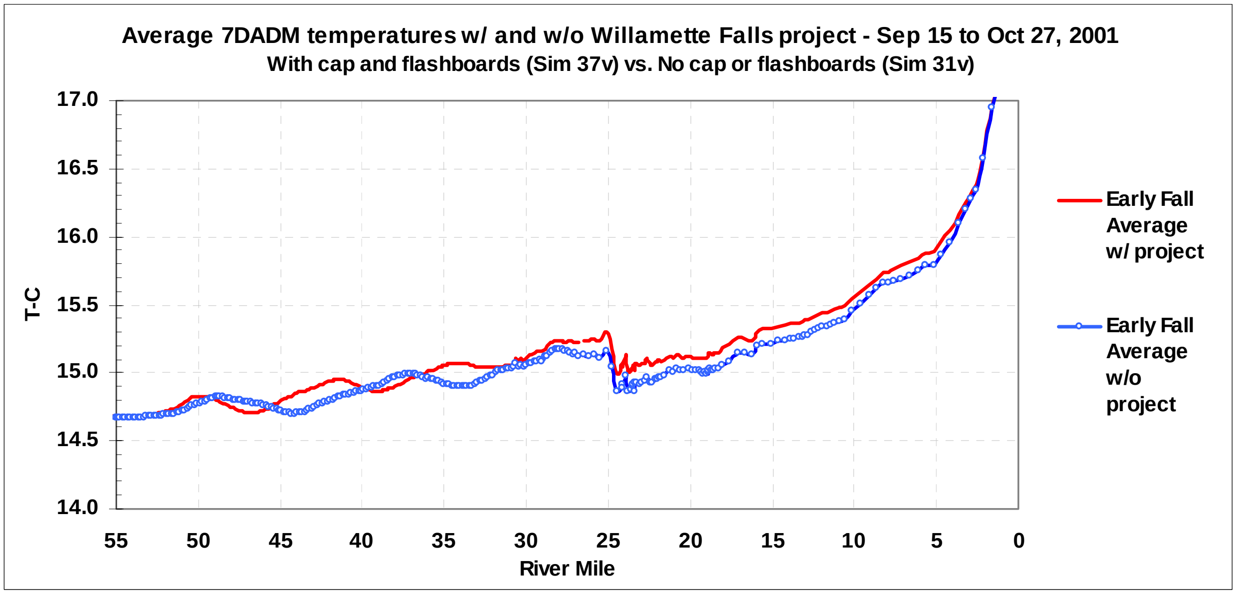
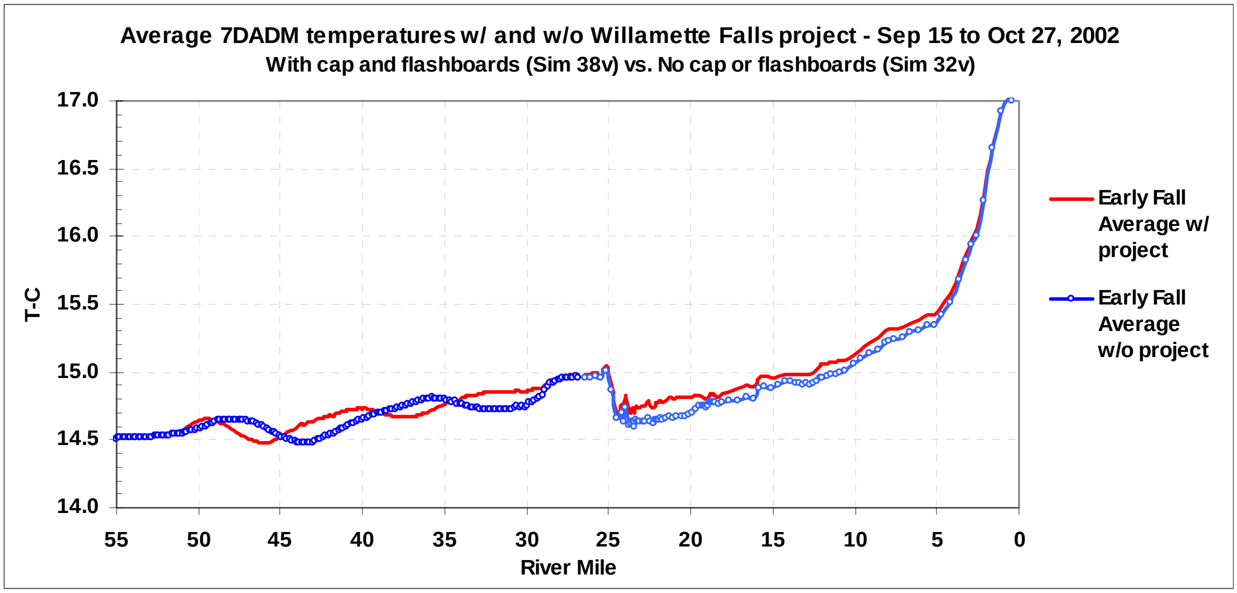


Figure 4.130 Model calculated average 7DADM temperature in the fall w/ and w/o the Falls project - 2002



Another way to look at project impacts is to compare differences between calculated temperatures with the project vs. calculated temperatures without the project at each segment. Such differences, referred to as "Delta Ts," are shown for the summer months of 2001 and 2002 in Figure 4.131and 4.132 Shown are median Delta Ts for the June 15 to September 15 period, as well as the range of impacts (5th and 95th percentiles). As shown, at certain times and locations the project results in warmer temperatures, while at other times and locations the project results in cooler temperatures. Note that all 7DADM temperatures are flow-weighted.

Figure 4.131 Impacts of the Willamette Falls project for June 15 to September 15, 2001

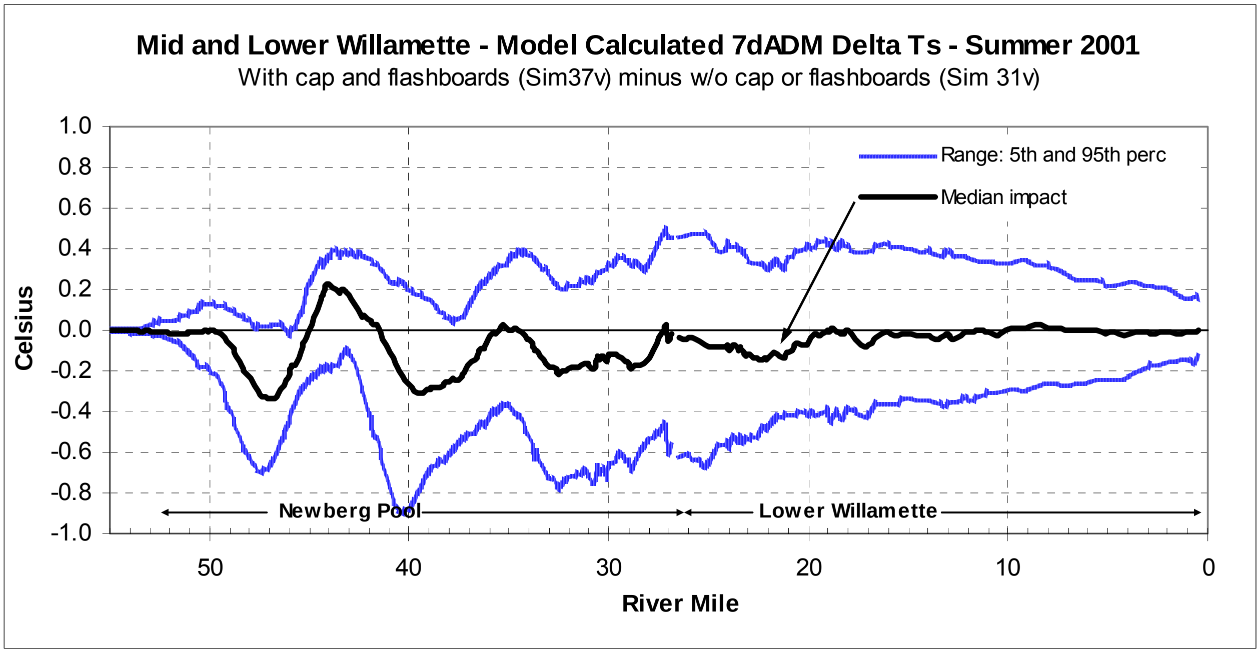
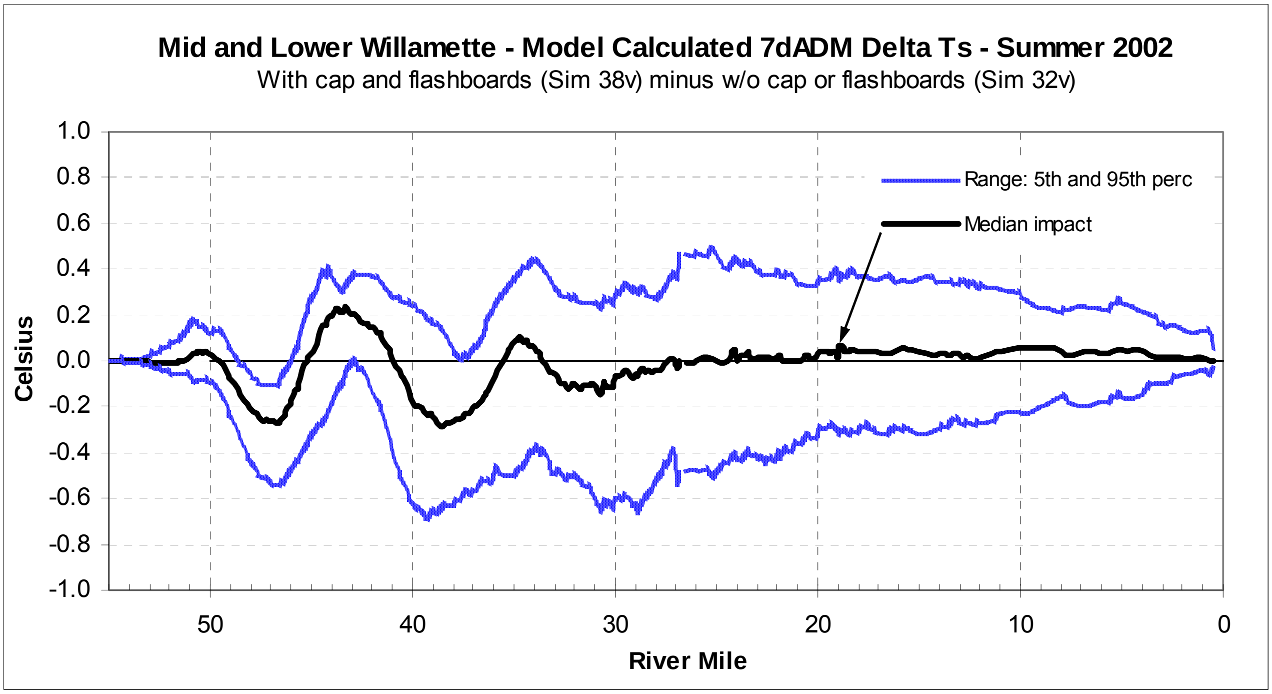


Figure 4.132 Impacts of the Willamette Falls project for June 15 to September 15, 2002



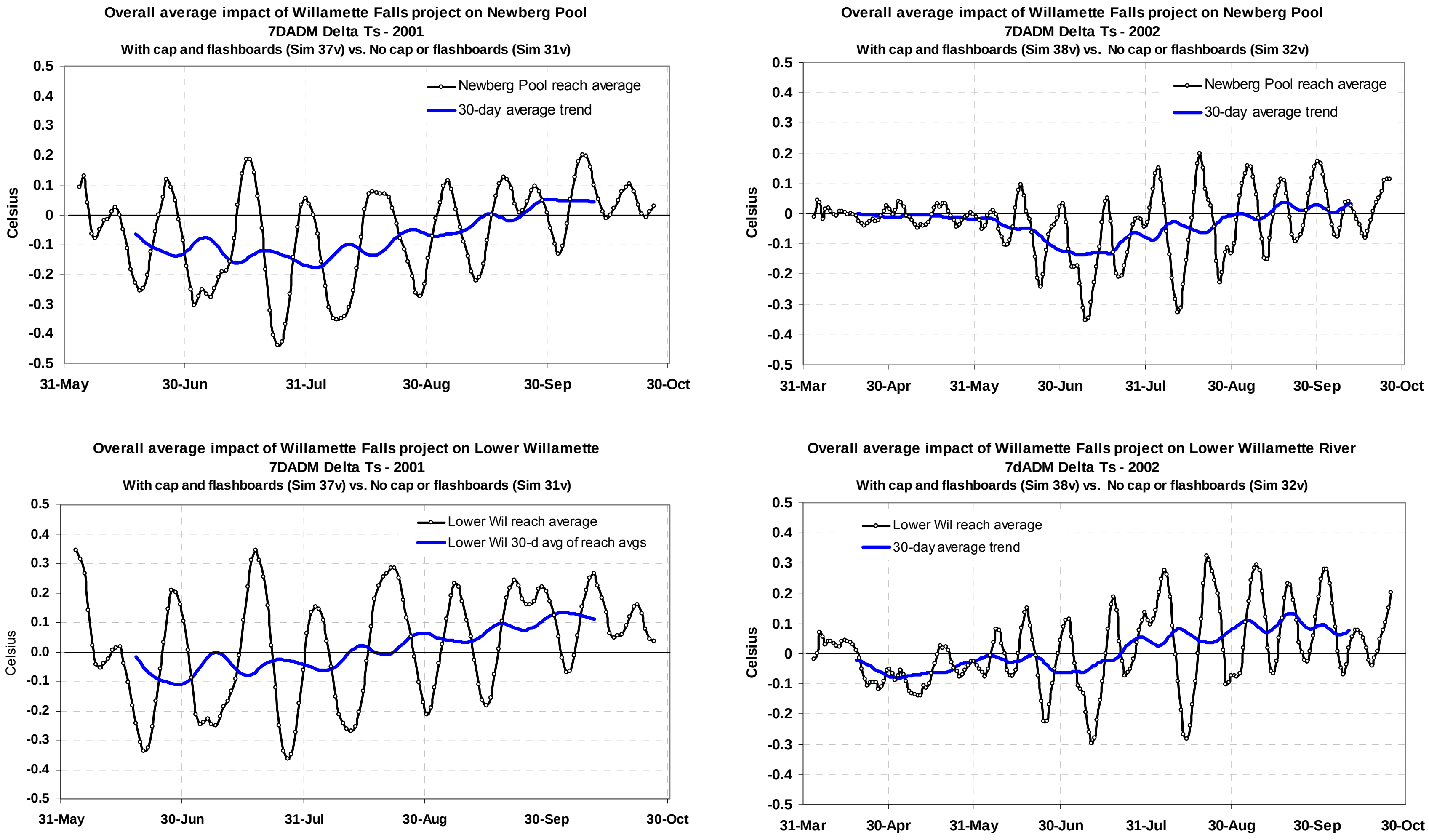
The patterns of heating and cooling are similar for the two summers modeled. Overall, the project appears to result in slightly cooler summer 7DADM temperatures in Newberg Pool, and slightly warmer summer temperatures in the lower Willamette in 2002. In Newberg Pool, median temperature impacts range from -0.3 to 0.2 ^{o}C, while in the lower Willamette median impacts do not exceed 0.05^{o}C.

Seasonal trends in project impacts are shown by Figure 4.133. The plots show the impact of the project on reach average Newberg Pool and Lower Willamette temperatures for the two time periods modeled (June 1 to October 31, 2001 and April 1 to October 31, 2002). To derive the values plotted, Delta Ts between simulated 7DADM temperatures with and without the project were calculated for all Newberg Pool and Lower Willamette segments for all days simulated. For each day the Delta Ts for all Newberg segments were averaged and the Delta Ts for all Lower Willamette segments were averaged. As before, all 7DADM temperatures are flow-weighted averages. Also shown on the plots are 30 day trend lines.

As shown, for Newberg Pool the project generally has a neutral impact on 7DADM temperatures in the spring. In the summer, the project usually results in somewhat cooler temperatures. By early fall, the trend in Delta Ts turns positive, which suggests that the project may result in generally warmer temperatures in Newberg Pool in the fall.

For the Lower Willamette River (Falls to Columbia River confluence, excluding Multnomah Channel), the project generally results in cooler temperatures in the spring and early summer, and generally warmer temperatures in late summer and fall. The warmer summer temperatures are of concern because the biologically based numeric criteria of 20^{o}C is frequently exceeded during the summer.

Figure 4.133 Seasonal trends in impacts of Willamette Falls Project on Newberg Pool and Lower Willamette



In order to evaluate overall project impacts, cumulative frequency distributions of calculated 7DADM temperatures in Newberg Pool and the lower Willamette River are presented below for scenarios with and without the project (Figures X10 to X13). As for the plots presented above, for the "with project" scenario the river is modeled with both concrete cap and temporary flashboards present and for the "without project" scenario both flashboards and cap are removed and Newberg Pool water levels restored to natural levels. To derive cumulative frequency distributions, calculated 7DADM temperatures (flow-weighted) for all segments in the reach of interest are grouped and ranked. A quantile of 0.9 corresponds to a temperature for which calculated temperatures are less than 90% of the time and a quantile of 0.5 corresponds to the median calculated temperature. Since no spawning criteria apply for Newberg Pool or the Lower Willamette River, the analysis was limited to the summer period (June 15 to Sept 15) during which the 20°C biologically based numeric criteria is frequently exceeded. Outside of this summer period no criteria exceedances occur.

Figure 4.134 shows combined summer data for 2001 and 2002 for Newberg Pool. As shown, the project results in a negative shift in the cumulative frequency distribution. This indicates that the project results in slightly cooler overall summer temperatures in Newberg Pool.

Figure 4.134 Impact of Falls Project on Newberg Pool – Frequency distributions – Summer 2001 and 2002

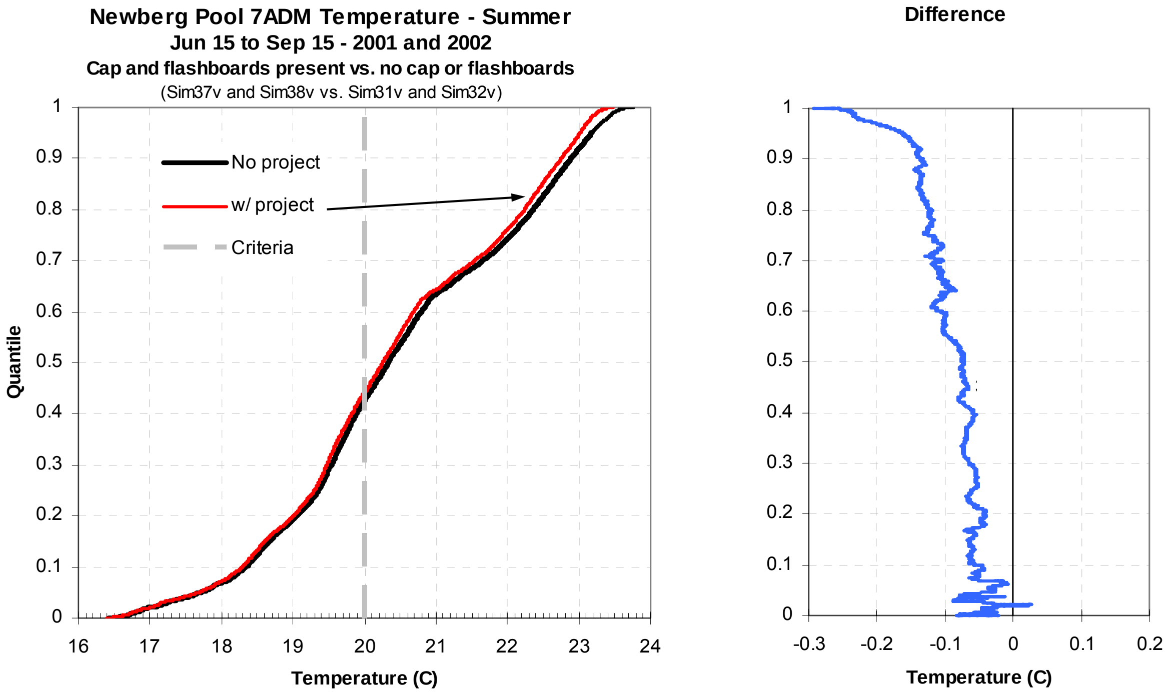


Figure 4.135 shows combined summer data for 2001 and 2002 for the Lower Willamette. As shown, the project at times results in a positive shift in the cumulative frequency distribution and at times a negative shift. This indicates that at times the project results in warmer overall summer temperatures in the Lower Willamette. Note, however, that when temperatures exceed the 20^{o}C biological based numeric criteria, the shift does not exceed 0.08^{o}C. For individual years, the model indicates that the impact of the project was greater in 2002 than in 2001 (Figures 4.136 and 4.137). For 2001, the maximum shift is 0.06^{o}C (Figure 4.136), while for 2002 the maximum shift is 0.11^{o}C (Figure 4.137).

Figure 4.135 Impact of Falls Project on Lower Willamette – Frequency distributions – Summer 2001 and 2002

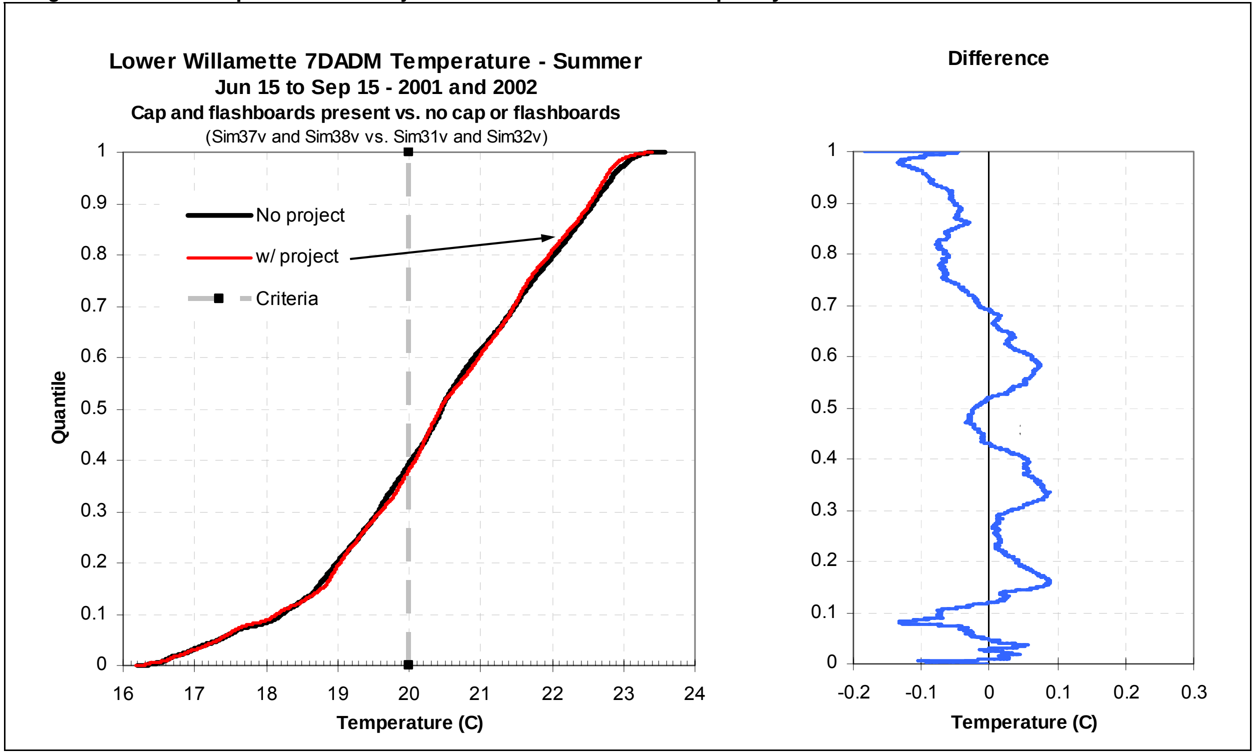


Figure 4.136 Impact of Falls Project on Lower Willamette – Frequency distributions – Summer 2001

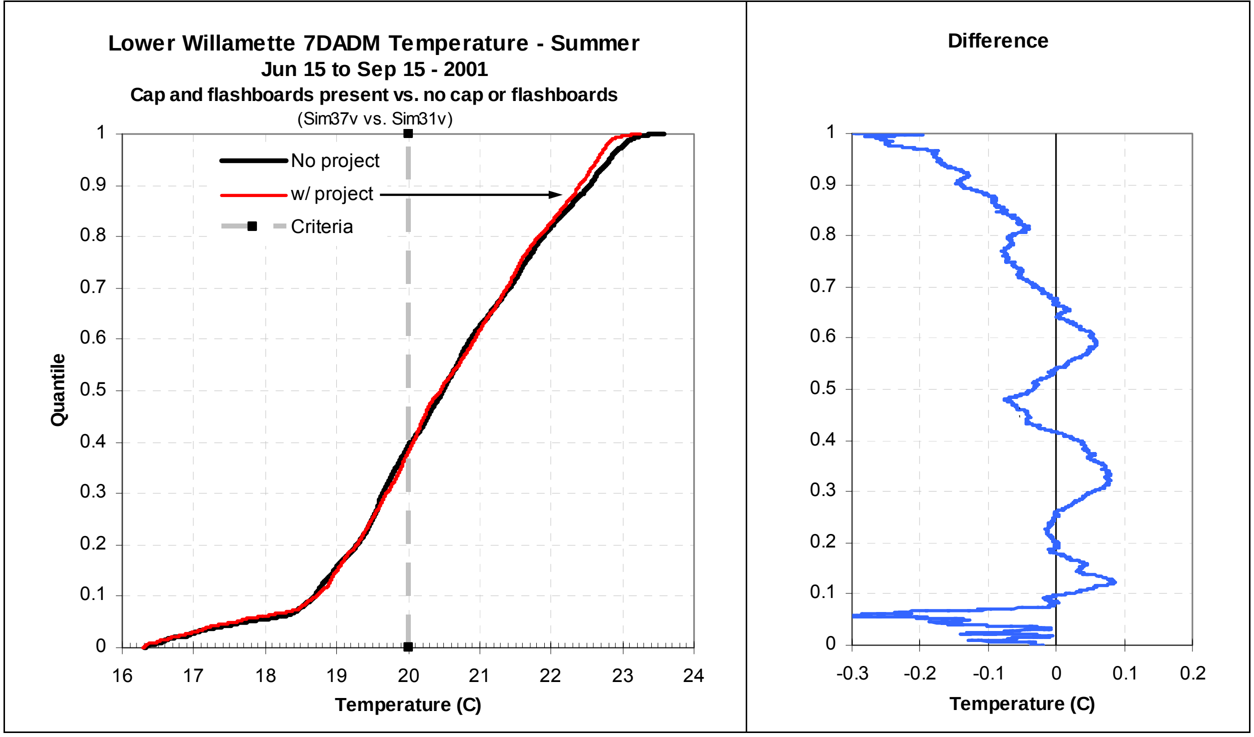
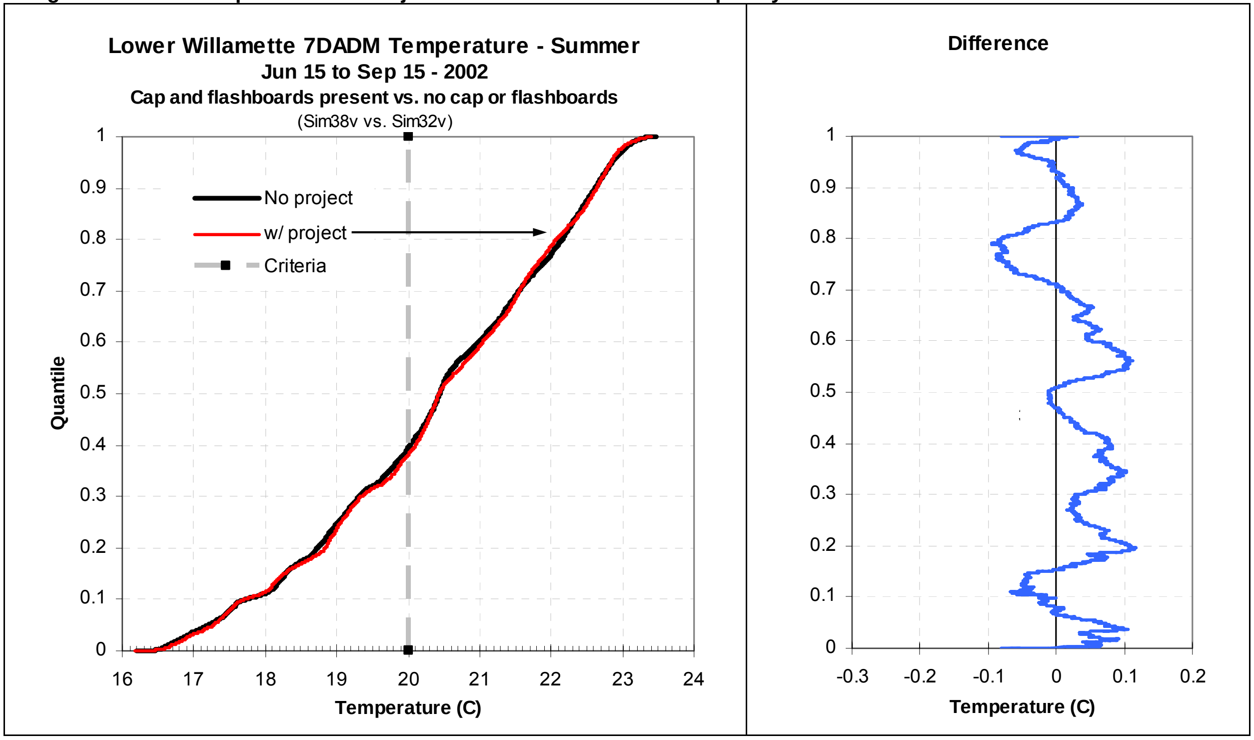


Figure 4.137 Impact of Falls Project on Lower Willamette – Frequency distributions – Summer 2002

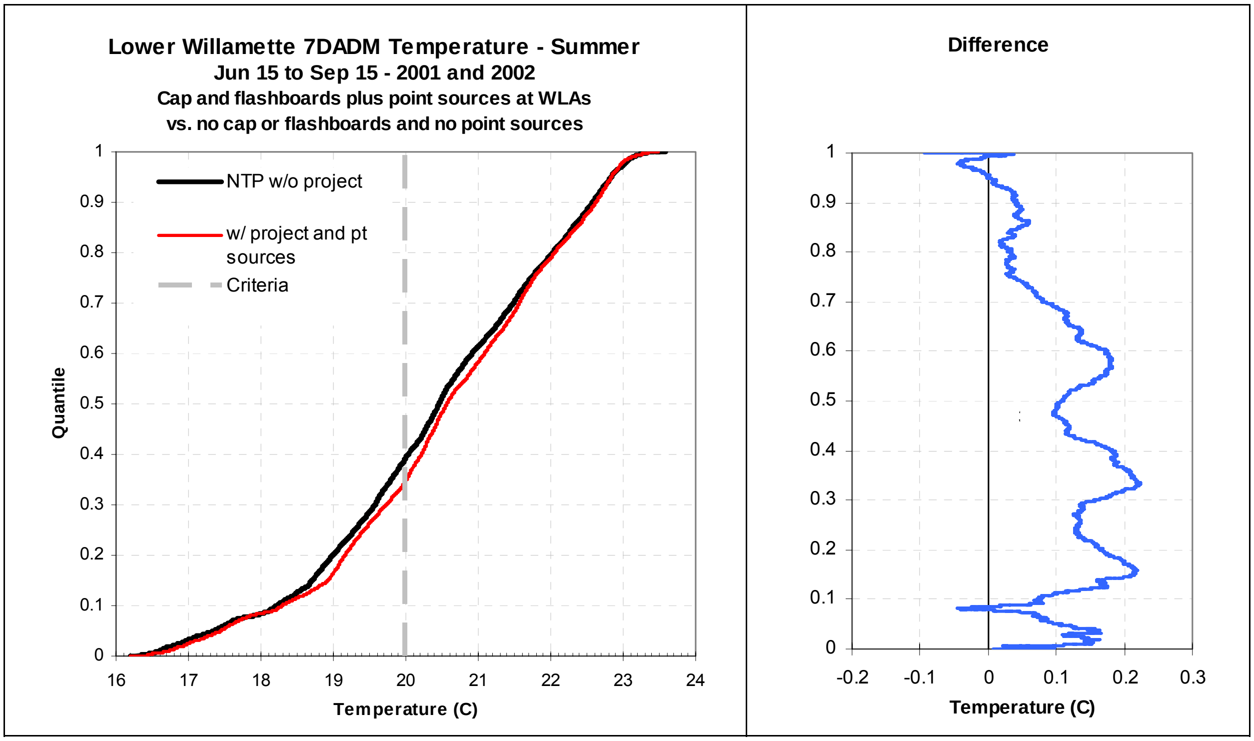


Influence of Willamette Falls PGE Project plus Point Sources at Wasteload Allocations

The overall combined impact of the PGE Willamette Falls Project and proposed point source wasteload allocations on river temperature is presented in figures below. The figures show cumulative frequency distribution plots of model calculated 7-day average daily maximum (7DADM) temperatures for both Newberg Pool and the Lower Willamette River. For Newberg Pool, 7DADM temperatures (flow-weighted) for all segments from RM 53 to the Falls were aggregated. For the Lower Willamette, calculated 7DADM temperatures (flow-weighted) in all Lower Willamette segments from the Willamette Falls to the river's confluence with the Columbia (excluding Multnomah Channel) were aggregated. Model results are only presented for summer months, since the 20^{o}C biologically based numeric criterion is only exceeded in Newberg Pool and the Lower Willamette River during the summer.

The model calculated combined impact of the Willamette Falls Project plus the point source wasteload allocations (Simulations 87 and 88) on 7DADM temperature for the summer for model years 2001 and 2002 combined is shown in Figure 4.138 (Simulation 87/88 wasteloads use Sim 65/66 wasteload allocations for Coast Fork/Middle Fork Willamette, McKenzie, and Upper Willamette; and Sim 87/88 wasteload allocations for Middle and Lower Willamette). As shown, when temperatures exceed the applicable biological based numeric criterion of 20^{o}C, the project and point sources wasteload allocations result in a maximum shift in the cumulative frequency distribution of 0.19^{o}C.

Figure 4.138 Impact of Willamette Falls Project plus Pt. Source Wasteload Allocations on Lower Willamette - 2001 and 2002



Impacts are greater for the 2002 model year than for 2001. For 2001, when temperatures exceed the applicable biological based numeric criterion of 20°C, the project and point source wasteload allocations result in a maximum shift in the cumulative frequency distribution of 0.19°C for 2001 (Figure 4.138) and 0.23°C for 2002 (Figure 4.140).

Figure 4.139 Impact of Willamette Falls Project plus Pt. Source Wasteload Allocations on Lower Willamette - 2001

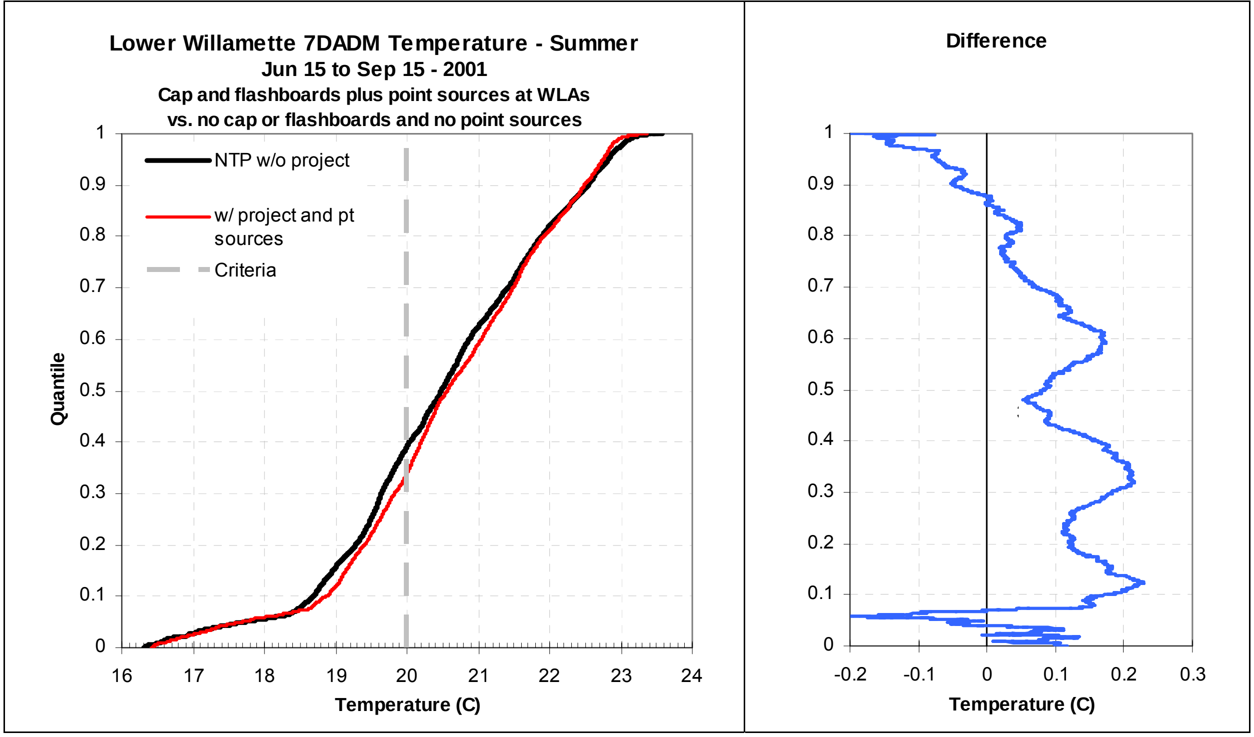
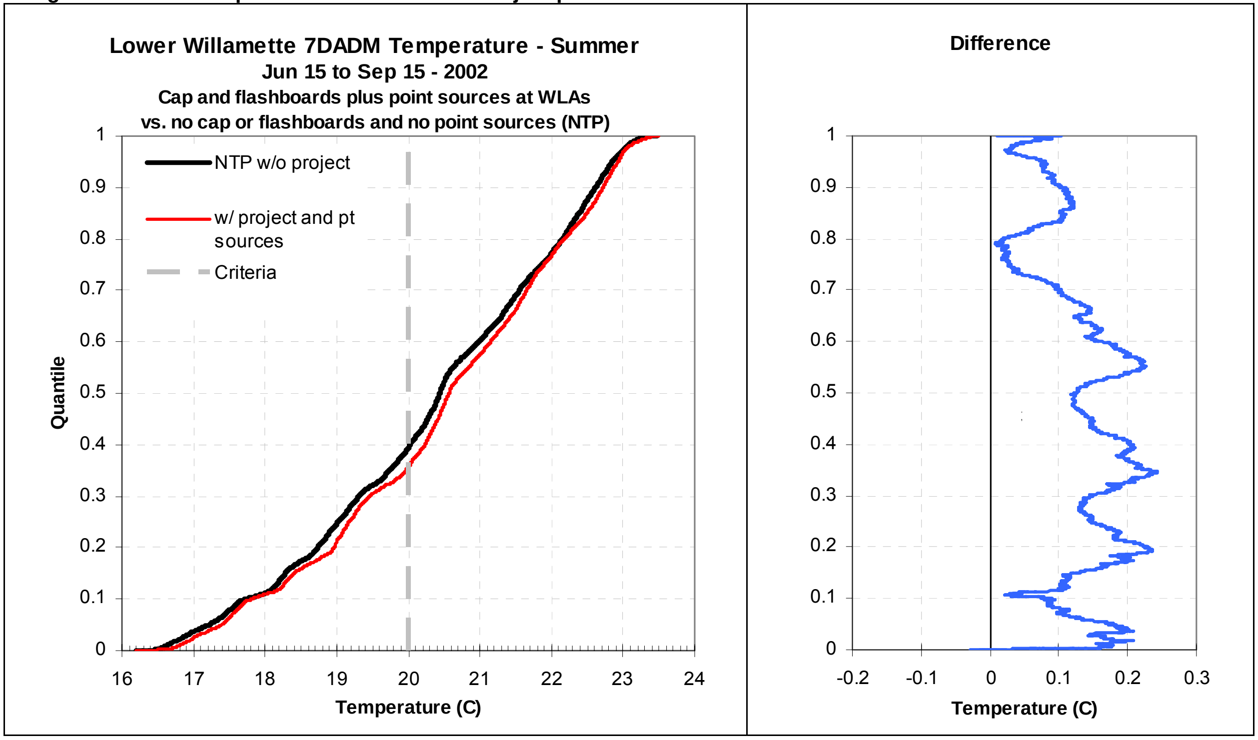


Figure 4.140 Impact of Willamette Falls Project plus Pt. Source Wasteload Allocations on Lower Willamette - 2002



While at times the Project warms the river and at other times cools the river, point sources consistently heat the river. The amount of this temperature increase is about 0.10°C, as shown by Figure 4.141 and Figure 4.142 below. These show the Willamette Falls Project impact "difference" plots presented above, combined with the Willamette Falls Project plus wasteload allocations "difference" plots, also presented above. The average shift due to point sources is 0.11°C for 2001, 0.10°C for 2002, and 0.11°C for the two years combined. If the Project meets the proposed wasteload allocation of 0.11°C, the overall combined impact should not exceed 0.22°C.

Figure 4.141 Cumulative Frequency Distribution "Difference" plots - Project and Project + WLAs impacts

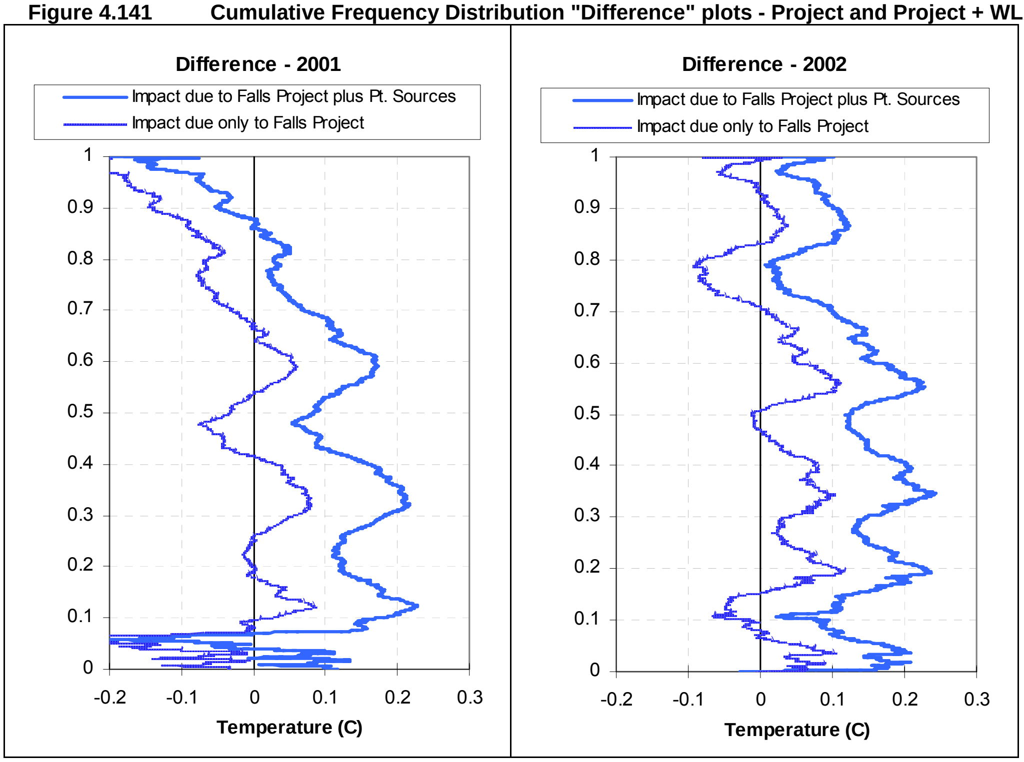
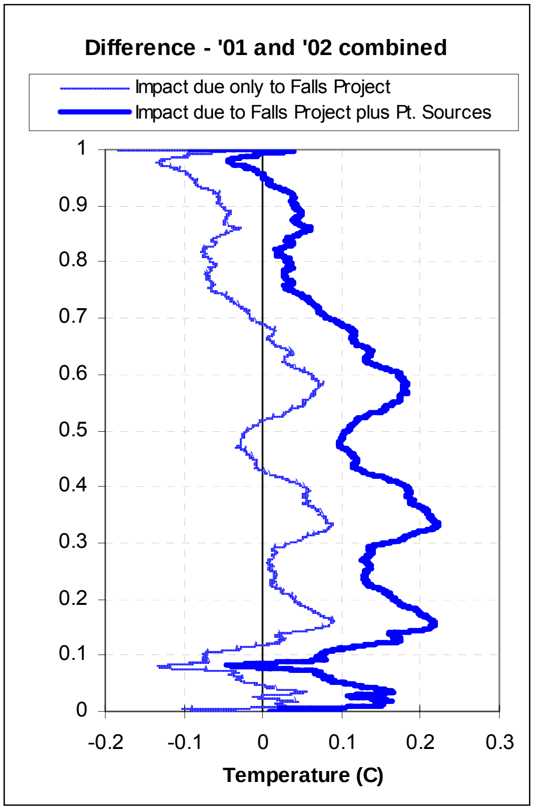


Figure 4.142 **Cumulative Frequency Distribution "Difference" plots - Project and Project + WLAs impacts**



In addition to retaining sufficient capacity to assimilate Willamette Falls Project and Willamette River point source impacts, sufficient assimilative capacity must be retained in the lower Willamette to accommodate Clackamas River Hydroelectric Project temperature impacts. Clackamas River modeling indicates that summer impacts of the Clackamas Project on Lower Willamette River temperatures currently range from 0.05 to 0.3°C and median impacts range from 0.1 to 0.2°C, prior to dilution with Columbia River water near the mouth. In the Clackamas River, current overall Clackamas Project impacts are as much as 1.5°C in the reach from RM 23 to RM 8. If these are reduced to meet the proposed allocation of 0.15 °C of impact, it is likely that the impact of the project on the Willamette River will be reduced a similar percentage amount. Therefore, it is reasonable to assume that maximum impacts on the lower Willamette will be reduced to less than 0.03 °C and that median impacts will be reduced to no more than 0.02 °C. Therefore, Willamette River and tributary major point sources impacts, when combined with Willamette Falls Hydroelectric Project current operation impacts plus Clackamas River Hydroelectric Project load allocation impacts, should be less than 0.25°C.

Influence of Small Tributaries on Willamette River Temperatures

A number of relatively small tributaries which are still large enough to potentially influence Mainstem river temperatures enter modeled Willamette Mainstem reaches. These include Rickreall Creek, Mill Creek, Calapooia River, Luckiamute River, Marys River, Little North Santiam River, Mosby Creek, and Little Fall Creek.

Heat load allocations may be given to the tributaries which receive point source discharges that could increase the temperatures of these smaller tributaries as much as 0.3°C above natural thermal potential (note that all tributaries have been given system potential shade allocations, so such temperatures should still be less than current levels). In order to determine if such allocations above natural thermal potential could adversely impact Willamette Mainstem reaches, dilution analyses were performed (Table 4.43).

As shown, six dilution factors were calculated for each tributary using gaged flow rates in the tributary relative to gaged flow rates in the receiving water. Dilutions factors (DF) were calculated using median and lower 10th percentile flows for the entire year, spring and fall (May, June and October), and summer (July, August and September). Analyses are presented only for potentially significant tributaries that receive NPDES permitted effluent discharges. Little North Santiam River and Little Fall Creek are excluded because they do not receive NPDES permitted effluent discharges.

Median and 10th percentile flow rates were selected over 7Q10 flow rates to calculate dilution. Willamette River flow is regulated by reservoir releases; however, tributary flow rates are not. This results in flow rates in tributaries declining more during drought conditions than flow rates in the Willamette. Therefore, dilution calculated using 7Q10 flow rates would be greater than dilution calculated using median and 10th percentile flow rates. The use of median and 10th percentile flow rates provides more conservative estimates of potential impacts than the use of 7Q10 flow rates.

As shown in Table 4.43, potential mainstem temperature increases that could result from 0.3°C tributary temperature increases are generally quite small. The largest potential increase is due to Mosby Creek, which has dilution factors which range from 6 to 16. A 0.3°C increase in Mosby Creek temperature could cause a temperature increase in the Row River of 0.02 to 0.05 °C. Note, however, that 3.8 miles downstream of the Mosby Creek confluence the Row River enters the Coast Fork Willamette River, at which point the impact would be significantly less.

The tributary with the next most significant impact is the Calapooia River, which enters the Willamette River near Albany. Dilution Factors for the Calapooia range from 17 to 171. A 0.3°C increase in Calapooia Creek temperature could cause a temperature increase in the Willamette River of 0.002 to 0.017 °C. This is a small fraction of the human use allowance for the Willamette.

The potential impacts of the other small tributaries are even less and the cumulative impacts of all tributaries will be negligible. Even if all the tributaries entered the Willamette at the same location, the total impact would be less than 0.02°C, or less than 6% of the human use allowance, based on the combined median summer flows of the tributaries relative to the Willamette River flow at Salem. Since some dissipation of heat will occur over the time of travel through the Willamette, the cumulative impact of all tributaries will be considerably less than 0.02°C.

Table 4.43 Influences of small tributary human use allowance temperature increases on the Willamette mainstem

			Median			**Lower 10th Percentile**		
Station Name	**Gage Stations**	**Dates, dilution and potential impact**	**Annual**	**May-Jun, Oct**	**Jul-Aug-Sep**	**Annual**	**May-Jun, Oct**	**Jul-Aug-Sep**
Middle Willamette								
Rickreall Creek Nr Dallas	14190700	*01/01/1967-09/30/1978*	47	24	6	5	7	2
Willamette River At Salem	*14191000*	*01/01/1988-09/30/1999*	15100	13000	7430	6800	8013	6020
		% Flow	0.31	0.18	0.08	0.07	0.09	0.03
		DF	322	543	1239	1361	1146	3011
	Impact of 0.3C Trib T incr:		**0.001**	**0.001**	**0.000**	**0.000**	**0.000**	**0.000**
Mill Creek At Salem	14192000	*01/01/1967-09/30/1978*	87	72	51	41	46	27
Willamette River At Salem	*14191000*	*01/01/1988-09/30/1999*	15100	13000	7430	6800	8013	6020
		% Flow	0.58	0.55	0.69	0.60	0.57	0.45
		DF	175	182	147	167	175	224
	Impact of 0.3C Trib T incr:		**0.002**	**0.002**	**0.002**	**0.002**	**0.002**	**0.001**
Upper Willamette								
Calapooia River At Albany	14173500	*01/01/1970-12/10/1981*	320	340	352	30	30	30
Willamette River At Albany	*14174000*	*01/01/1988-09/30/1999*	8970	8320	5690	5110	4900	4690
		% Flow	3.6	4.1	6.2	0.6	0.6	0.6
		DF	29	25	17	171	164	157
	Impact of 0.3C Trib T incr:		**0.010**	**0.012**	**0.017**	**0.002**	**0.002**	**0.002**
Luckiamute River nr Suver	14190500	*01/01/1988-09/30/1999*	380	222	46	35	38	24
Willamette River At Albany	*14174000*	*01/01/1988-09/30/1999*	8970	8320	5690	5110	4900	4690
		% Flow	4.2	2.7	0.8	0.7	0.8	0.5
		DF	25	38	125	147	130	196
	Impact of 0.3C Trib T incr:		**0.012**	**0.008**	**0.002**	**0.002**	**0.002**	**0.002**

Marys River nr Philomath	14171000	*01/01/1974-09/30/1985*	159	95	24	19	20	13
Willamette River At Albany	*14174000*	*01/01/1988-09/30/1999*	8970	8320	5690	5110	4900	4690
		% Flow	1.8	1.1	0.4	0.4	0.4	0.3
		DF	57	89	238	270	246	362
	Impact of 0.3C Trib T incr:		**0.005**	**0.003**	**0.001**	**0.001**	**0.001**	**0.001**
Coast Fork Willamette								
Mosby Cr At Mouth	14156500	*01/01/1970-10/13/1981*	93	57	12	9	14	6
Row River nr Cottage Grove	*14155500*	*01/01/1988-09/30/1999*	447	470	109	98	105	89
		% Flow	20.8	12.1	11.0	9.2	13.3	6.7
		DF	6	9	10	12	9	16
	Impact of 0.3C Trib T incr:		**0.052**	**0.032**	**0.030**	**0.025**	**0.035**	**0.019**

This analysis demonstrates that small tributaries have a relatively minor influence on mainstem temperatures and, thus, they have a minimal impact on the cumulative effect analysis. Therefore, tributary human use allowance loading does not need to be further considered in allocations of the human use allowance for the mainstem.

Conclusions

Modeling using the CE-QUAL-W2 Willamette Mainstem model shows that Willamette River and tributary temperatures are influenced by boundary temperatures, flow, riparian vegetative shade, point source loads, and hydroelectric projects. Modeling shows that the temperature of water released from reservoirs not only influences the temperature of reaches immediately downstream, but can influence the temperature of the entire Willamette River. Based on modeling for 2001, a 1^{o}C increase in temperature at the boundaries results in a median temperature increase during the summer that exceeds 0.3^{o}C from headwaters to RM 135, 0.2^{o}C from RM 135 to RM 70, and 0.1^{o}C in the rest of the river. During the fall, impacts are greater, with median impacts exceeding 0.3^{o}C from headwaters to RM 70 and 0.2^{o}C to RM 10. In the Upper Willamette, the overall average impact of a 1^{o}C boundary temperature increase approaches 0.5^{0}C in early fall. Therefore, changes in the temperature of water released from reservoirs can significantly influence temperatures throughout the Willamette system.

The temperature of water released from USACE reservoirs has its greatest impact on reaches immediately downstream from the dams. Not only are downstream temperatures impacted by maximum tailrace temperatures that occur in the late afternoon, but they are also influenced by early morning tailrace temperatures. If early morning temperatures are increased beyond natural temperatures by the reservoir, then temperatures in reaches a few hours in travel time downstream will also be increased.

Flow also influences river temperature. The impacts of boundary flow rates are minor near the boundaries, but increase in a downstream direction until they reach a maximum at RM 80 near Salem. Near Salem, a 10% reduction in flow results in a 0.35^{o}C median increase in temperature during the summer based on modeling for 2001. The lower reaches are less sensitive to flow, with a 10% flow rate reduction resulting in a median temperature increase slightly greater than 0.1^{o}C in the lower Willamette.

The system is also sensitive to riparian shade levels. Modeling for 2001 shows that improving shade to allocated system potential shade levels will reduce median temperatures during the summer up to 0.7^{o}C in upper reaches, 0.3^{o}C at the Willamette Falls, and 0.2^{o}C at Portland. During the fall impacts do not exceed 0.35^{o}C.

The influence of point source effluent heat loads on the river is currently relatively minor. Modeling for 2001 indicates that the median impact of effluent loads is about 0.1^{o}C in the upper Willamette, with a maximum impact, based on the 95th percentile, of about 0.15^{o}C. Impacts during the early fall are slightly larger, presumably because river flow rates did not increase enough in fall, 2001, to counter cooler river temperatures. Therefore the impacts of effluents, which haven't cooled by the fall as much as the river, are greater. Since effluent heat loads currently consume up to 50% of the 0.3°C human use allowance and since population and economic growth are likely to result greater effluent loads in the future, wasteload allocations have been provided which limit the growth of point source heat loads and insure that future loads will continue to not be significant.

Four utility hydroelectric projects influence temperature in the McKenzie, Clackamas, and Willamette Rivers, in addition to USACE Willamette River Basin Project reservoirs. These include the PGE Clackamas River Hydroelectric Project, the EWEB McKenzie River Leaburg and Walterville hydroelectric projects, and the PGE Willamette Falls Hydroelectric Project.

The Clackamas River Hydroelectric Project results in significantly increased temperatures in certain reaches of the Clackamas River, and reduced temperatures in other reaches. Based on modeling for 2000 and 2001, in about 6 miles of the river from RM 18 to RM 12 the project results in median temperature impacts in excess of 1.0°C. However, in the reach immediate downstream from River Mill Dam from RM 23.4 to RM 21, and in the last 5 miles of the river before its confluence with the Willamette River, the project results in daily maximum temperatures that are cooler than they would be without the project. The Willamette River is also heated by the project a small amount. Median impacts on the Willamette during the summer can exceed 0.15°C.

The McKenzie River Leaburg and Walterville hydroelectric projects result in significantly increased temperatures in bypass reaches, as well as increased temperatures in the reach of the McKenzie River downstream of the bypass reaches. Based on modeling for 2001 and 2002, the projects result in median summer temperature increases in the Leaburg bypass reach of more than 1.0°C, in the Walterville bypass reach of up to 2.0°C, and in the reach downstream from the Walterville bypass reach of over 0.6°C.

The Willamette Falls Hydroelectric Project at certain times and locations heats the river slightly and at other times and locations cools the river slightly. Overall, the project results in slightly cooler summer temperatures in Newberg Pool (reach above Willamette Falls at Oregon City) and slightly warmer summer temperatures in the Lower Willamette (below Willamette Falls). Overall summer temperatures impacts in the Lower Willamette are less than 0.1°C.

The USACE Willamette River Basin Project reservoirs represent perhaps the greatest impact on stream temperature in the Willamette Basin because they influence both boundary temperature and flow. At times, such as in the fall, the reservoirs increase Willamette River temperatures. At other times, such as during the summer, they reduce river temperatures. However, as discussed previously, it is not appropriate at present to use the System Potential 4 scenario, in which upper boundary temperatures are set to natural thermal potential (NTP) temperatures, to develop point source wasteload allocations for the Willamette because accurate estimates of upper boundary NTP temperatures are not currently available. After detailed modeling and analyses have been completed for USACE reservoirs and for streams upstream of the reservoirs, accurate estimates of upper boundary NTP temperatures and the ability of reservoirs to meet such temperatures will be available. These temperatures will be used in the next Willamette TMDL iteration to recalculate Willamette River and tributary NTP temperatures and recalculate and revise load and wasteload allocations.

Appendix 4.7 – Impacts from Point Source Waste Load Allocations

The below figures represent the change in temperature resulting from individual point source waste load allocations described in Appendix 4.5. For this analysis the impacts do not include heating or cooling from nonpoint sources (including dams) as well as time of travel impacts. Time of travel impacts are those resulting from minor changes to river velocity as a result of additional flow from point sources. Time of travel impacts can give the appearance of both cooling and heating depending on location and time. Time of travel impacts are eliminated to understand the actual in-river heating as a result of point source discharges. Impacts are calculated by subtracting 7-day average daily maximum system potential 3 model temperatures (with point sources removed) from 7-day average daily maximum temperature model runs with point sources discharging at waste load allocation levels.

Figure 4.143 Clackamas River

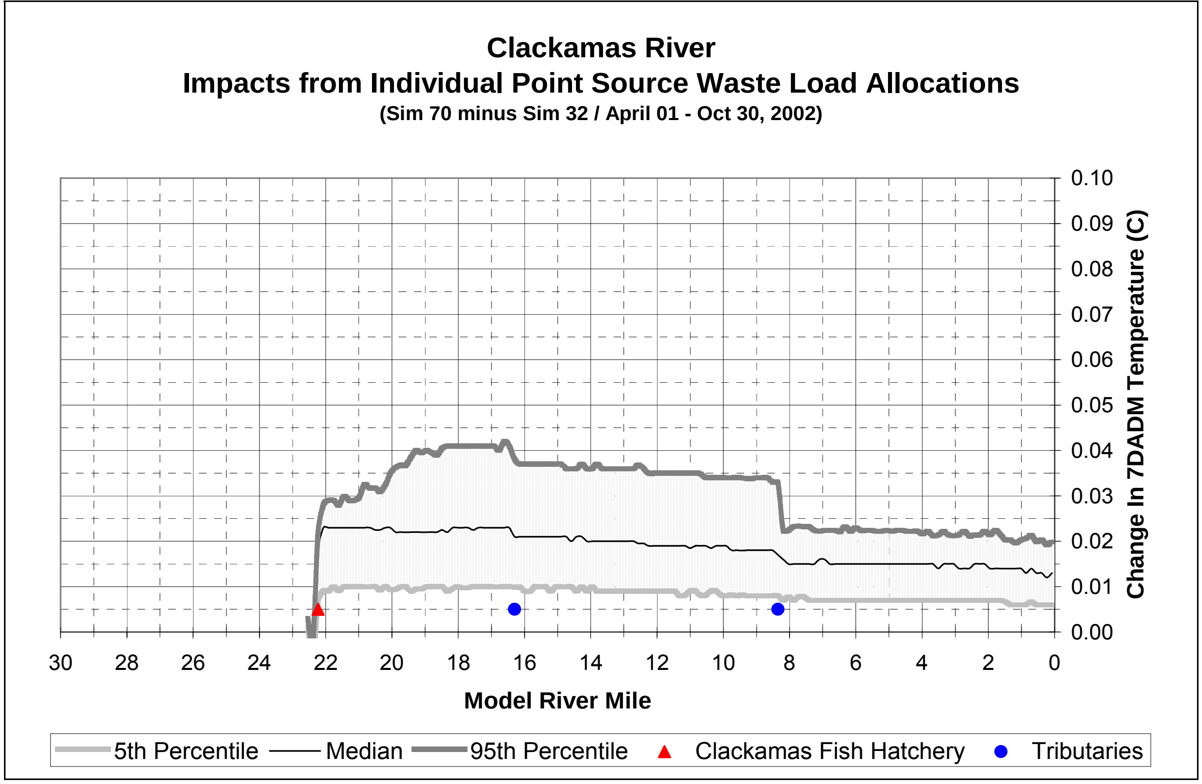


Figure 4.144 **Coast Fork Willamette River**

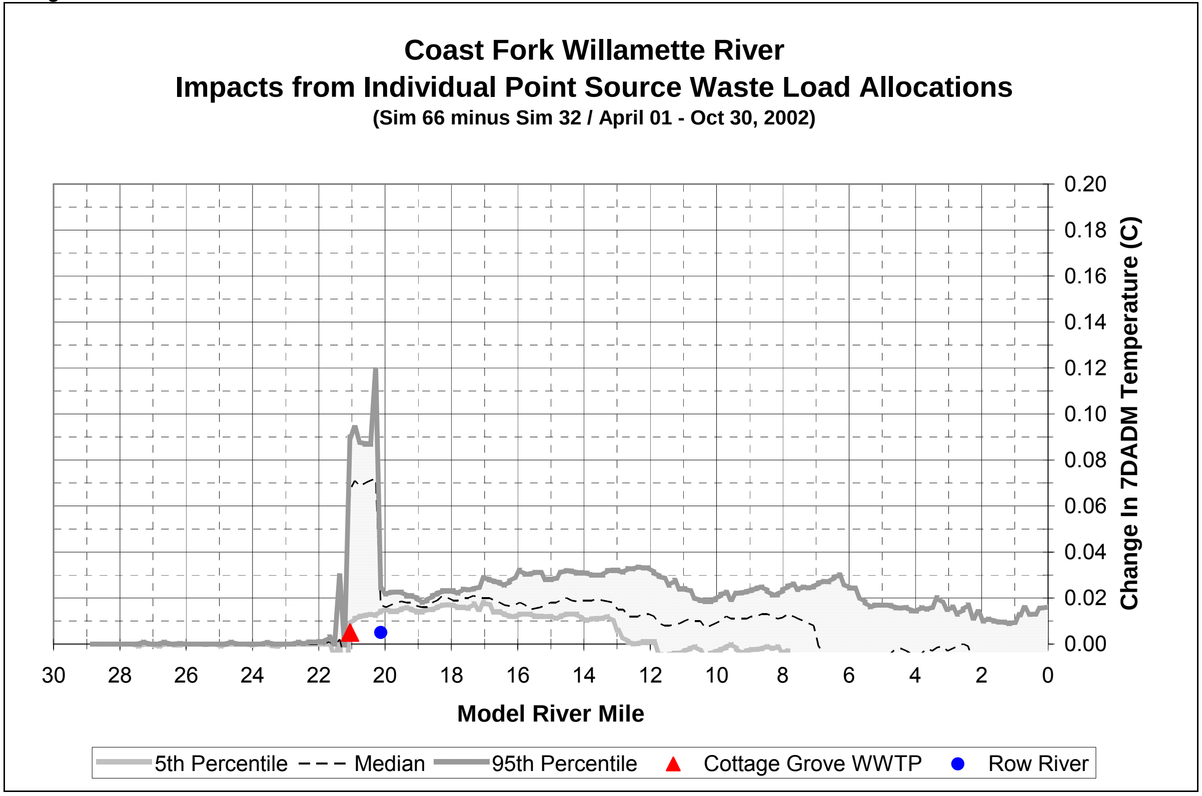


Figure 4.145 **McKenzie River**

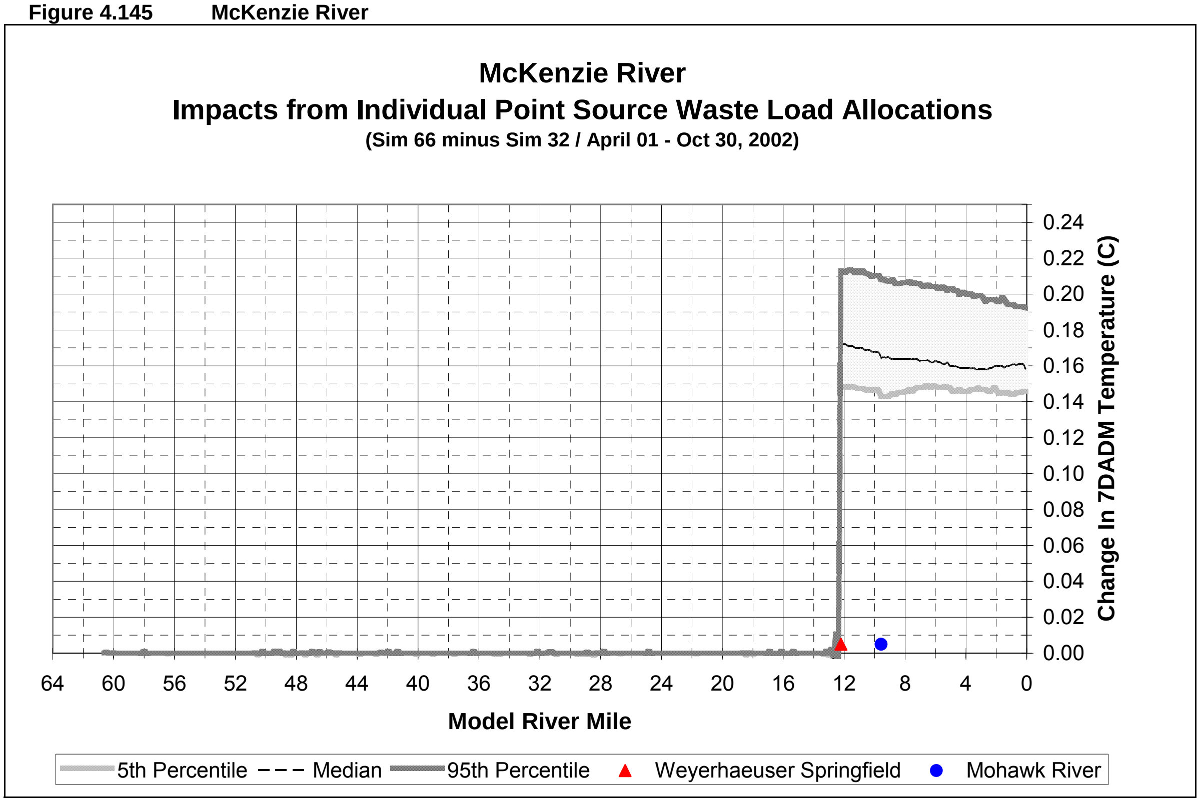
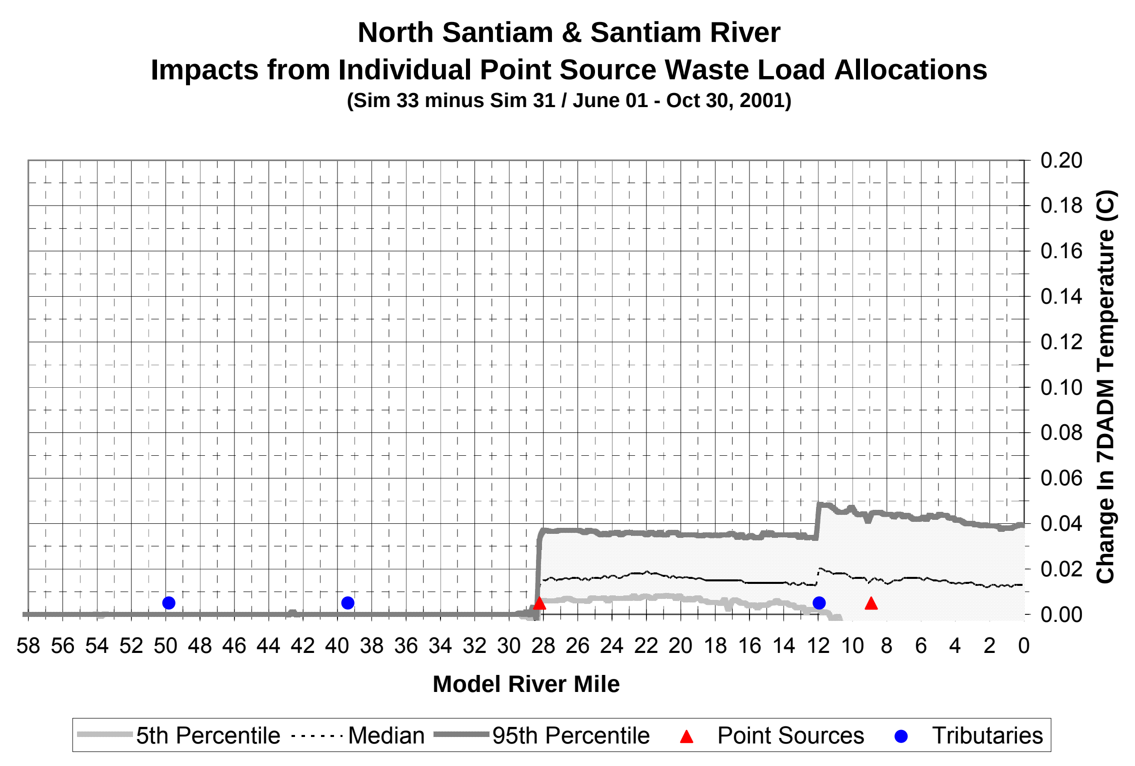
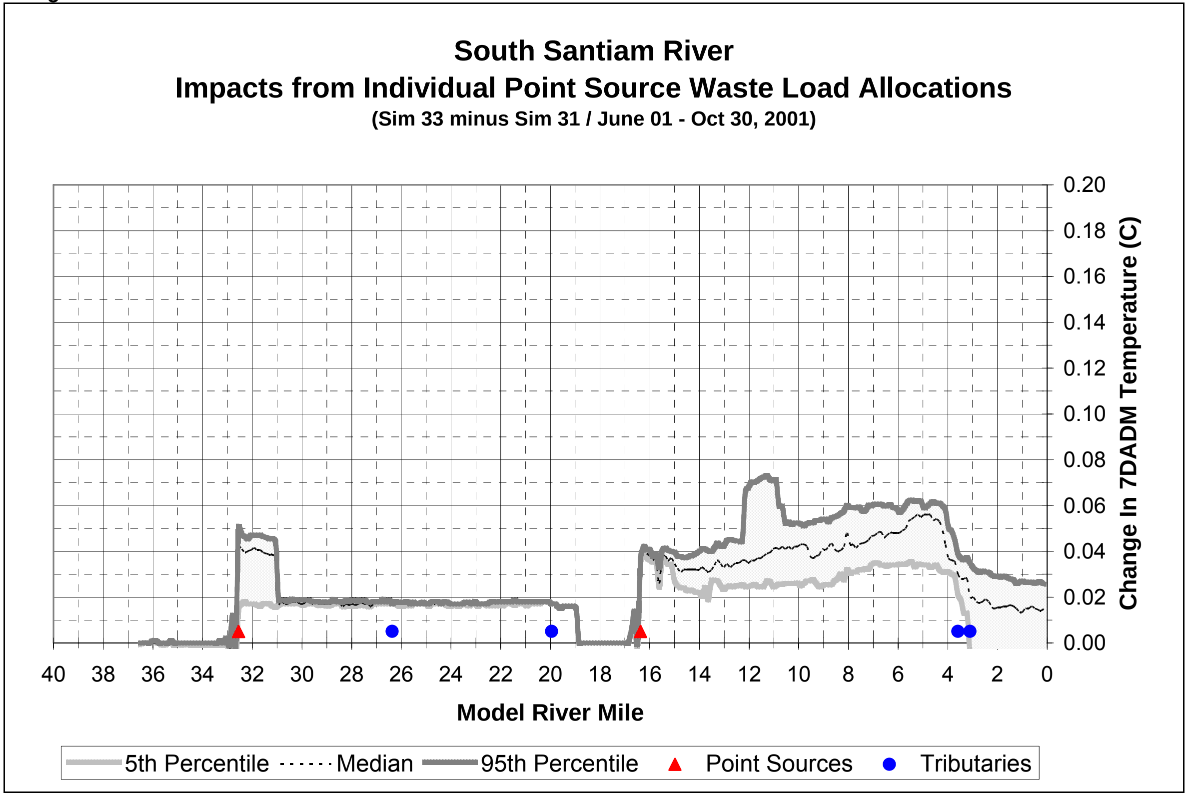


Figure 4.146 **North Santiam and Santiam Rivers**



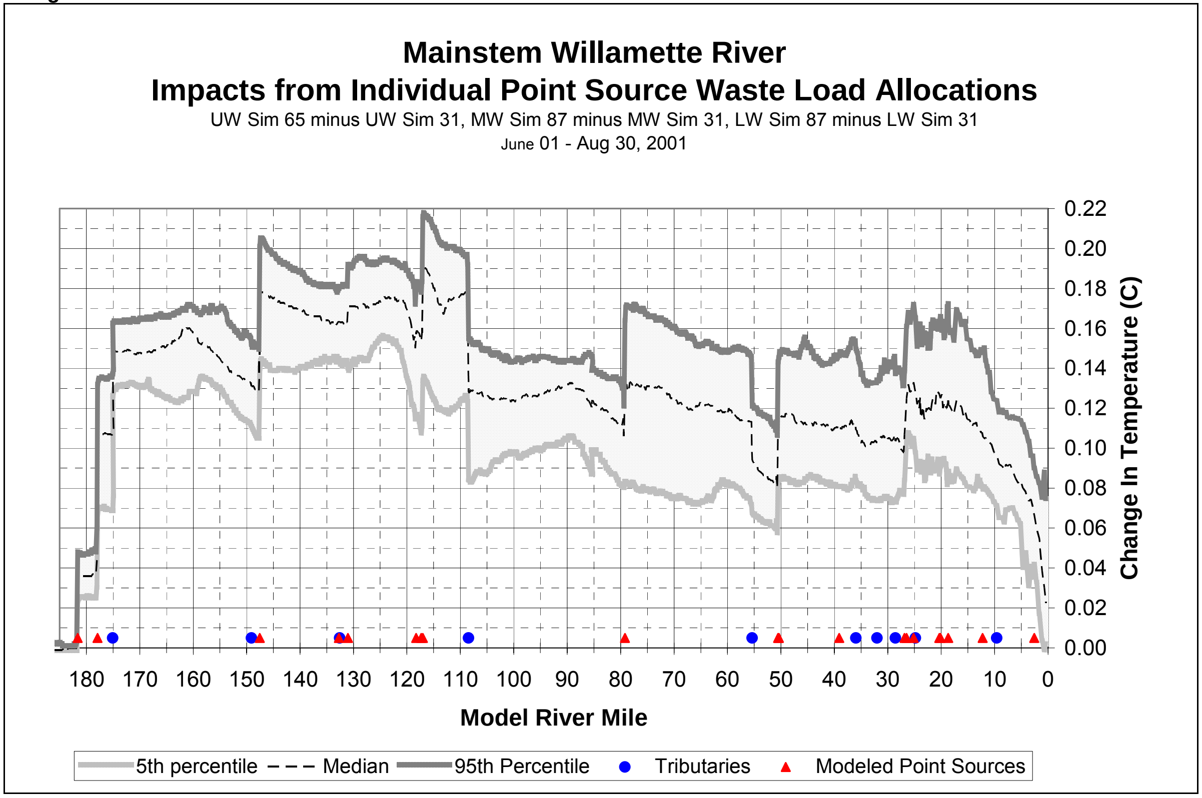
Model River Mile	North Santiam / Santiam Point Source / Tributary
49.8	Rock Creek
39.4	Little North Santiam
28.2	Stayton WWTP
11.9	South Santiam / Santiam River
8.9	Jefferson WWTP

Figure 4.147 **South Santiam River**



Model River Mile	**South Santiam Point Source / Tributary**
32.5	Sweet Home WWTP
26.4	McDowell Creek
19.9	Hamilton Creek
16.4	Lebanon WWTP
3.6	Crabtree Creek
3.1	Thomas Creek

Figure 4.148 **Willamette River mainstem**



Model River Mile	Willamette River Point Source / Tributary
182	U of O
178	MWMC
175	McKenzie River
149	Long Tom River
148	Georgia Pacific/Pope and Talbot
133	Evanite
133	Marys River
131	Corvallis WWTP
118	Albany WWTP
117	Wah Chang
117	Weyerhaeuser Albany
108	Santiam River
79	Willow Lake WWTP
55	Yamhill River
51	SP Newsprint
50	Newberg WWTP
39	Wilsonville WWTP
36	Molalla-Pudding River
29	Tualatin River
27	West Linn Paper
26	Blue Heron Paper
25	Tri-City WPCP
25	Clackamas River
20	Tryon Creek WWTP
20	Oak Lodge WWTP
19	Kellogg Creek WWTP
3	Siltronics