CHAPTER 5: LOWER WILLAMETTE SUBBASIN TMDL

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WATER QUALITY SUMMARY

Reason for action

Section 303(d) of the Federal Clean Water Act (CWA) requires that a list be developed of all impaired or threatened waters within each state. The Oregon Department of Environmental Quality (ODEQ) is responsible for assessing data, compiling the 303(d) list and submitting the 303(d) list to the Environmental Protection Agency (USEPA) for federal approval. Section 303(d) also requires that the state establish a Total Maximum Daily Load (TMDL) for any waterbody designated as water quality limited (with a few exceptions, such as in cases where violations are due to natural causes or pollutants cannot be defined). TMDLs are written plans with analyses that establish how waterbodies will attain and maintain water quality levels specified in State water quality standards. The Lower Willamette Subbasin (not including the mainstem Willamette River) has stream segments listed on the 2002 Oregon 303(d)[1] List for temperature, bacteria, pH, aquatic weeds or algae, iron, manganese, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs) and the pesticides DDT and dieldrin.

303(d) Listed Parameters Addressed by this TMDL

The Lower Willamette Subbasin (not including the mainstem Willamette River) has stream segments listed on the 2002 Oregon 303(d) List for temperature, bacteria, pH, aquatic weeds or algae, iron, manganese, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs) and the pesticides DDT and dieldrin. This document only addresses parameters listed on the 1998 303(d) list. ODEQ published an updated 303(d) list in 2002 but is not proposing TMDLs at this time for parameters added to the 303(d) list in 2002. In most cases a TMDL is being proposed to address specific pollutants and/or surrogate measures necessary to achieve water quality standards (**Table 5.1**).

303(d) listings fall within four watersheds: Johnson Creek, Columbia Slough, Tryon Creek and Springbrook Creek (**Figure 5.1**). However, this chapter is largely organized according by parameter rather than watershed and analytical techniques sometimes differ between basins (such as the modeling techniques used for Columbia Slough vs. Johnson Creek). Every effort has been made to incorporate individual watershed TMDLs into the Lower Willamette Subbasin TMDL document in a way that both recognizes the need for a subbasin-scale document while maintaining a level of detail and organizational structure that adequately addresses individual watersheds.

303(d) Listed Parameters Not Addressed by this TMDL

As noted above, ODEQ is not establishing TMDLs at this time for parameters added to the 303(d) list in 2002. These include listings for iron, manganese, pH, PAHs and PCBs.

ODEQ does not propose to address the following 1998 303(d) listings through TMDL development and detailed discussions are provided at the end of this chapter:

Low pH: Fairview Creek is on the 303(d) list for low pH (less than 6.5 SU). Upon closer examination of the data used to list Fairview Creek for pH, it appears that the data are questionable and that a TMDL should not be established for pH. It appears likely that improper calibration and/or maintenance of field pH meters resulted in erroneously low pH values.

Aquatic Weeds or Algae: Smith and Bybee Lakes are on the 303(d) list for pH, and aquatic weeds violations. The lakes are impaired due to the altered hydrology caused by a dam that was installed in 1982. Metro is planning on removing the dam and restoring natural hydrology to the lakes. ODEQ is confident that water quality and habitat conditions in Smith and Bybee Lakes will improve after Metro implements their management plan and the dam is removed. ODEQ also believes that phosphorus controls established in the 1998 Columbia Slough TMDLs will address water quality problems in the lakes when a more natural hydrology is restored.

Table 5.1 303(d) Listed Waterbodies in the Lower Willamette Subbasin (not including the mainstem Willamette River)

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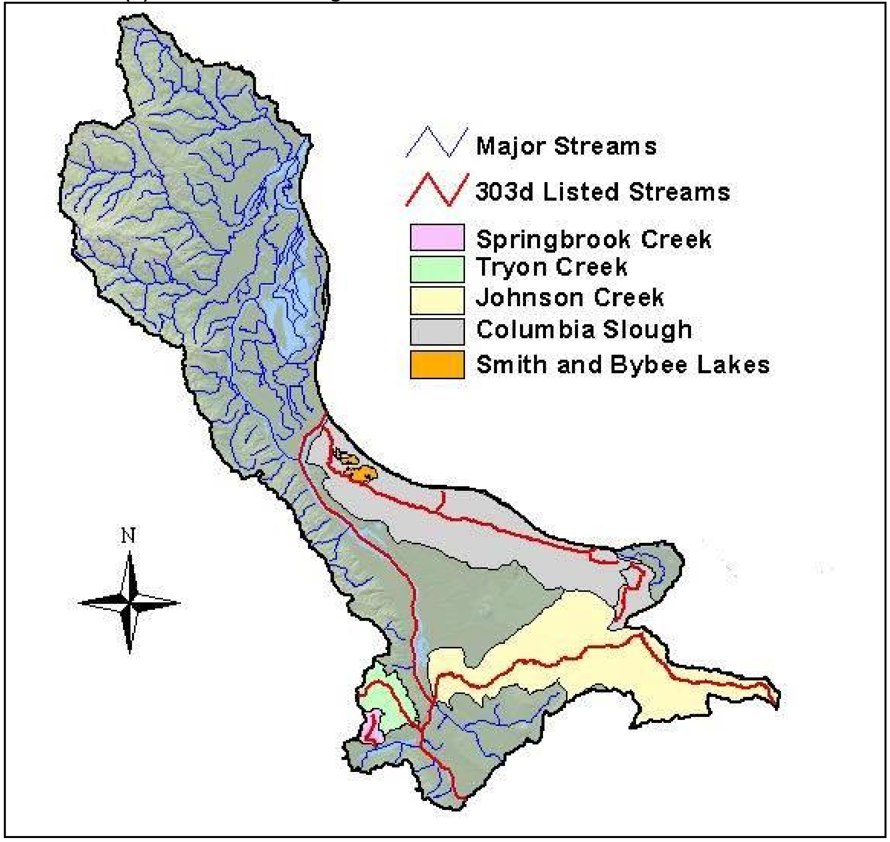
[1] The 303(d) list is a list of stream segments that do not meet water quality standards

Waterbody / Watershed	Listed Reaches	Parameter	TMDL?
Columbia Slough	Mouth to Fairview Lake	Temperature*	YES
Columbia Slough	Mouth to Fairview Lake	Iron[†]	NO
Columbia Slough	Mouth to Fairview Lake	Manganese[†]	NO
Fairview Creek	Mouth to Headwaters	Bacteria	YES
Fairview Creek	Mouth to Headwaters	pH	NO
Smith and Bybee Lakes	Lakes	Aquatic Weeds/Algae	NO
Smith and Bybee Lakes	Lakes	pH	NO
Fairview Lake / Osburn Cr.	Lake and Creek	pH[†]	NO
Springbrook Creek	Mouth to Headwaters	Bacteria	YES
Johnson Creek	Mouth to Headwaters	Temperature	YES
Johnson Creek	Mouth to Headwaters	Bacteria	YES
Johnson Creek	Mouth to Headwaters	Pesticides (DDT and Dieldrin)	YES
Johnson Creek	Mouth to Headwaters	PCBs [†]	NO
Johnson Creek	Mouth to Headwaters	PAHs [†]	NO
Tryon Creek	Mouth to Headwaters	Temperature	YES

*** Columbia Slough temperature TMDL also includes the Fairview Creek Watershed**

[†] Added to the 303(d) list in 2002

Figure 5.1. 303(d) Listed Stream Segments and Watersheds in the Lower Willamette Subbasin



Who helped us

Lower Willamette Subbasin TMDL development often relied on historical water quality monitoring data, particularly that collected by the Cities of Portland and Gresham, Clackamas County Water Environment Services, ODEQ and the U.S. Geological Survey (USGS). Current and historical stream flow data from USGS and Oregon Water Resources Department monitoring stations were also crucial to TMDL development. Meteorological data collected by the Oregon Climatological Service and the City of Portland HYDRA network contributed greatly to the development of these TMDLs.

Completion of the Johnson Creek TMDL document was made possible through the cooperation and financial support of the various organizations that serve as leaders in protecting the water quality of Johnson Creek. Members of the Johnson Creek Inter-jurisdictional Committee (IJC), especially Clackamas County Water Environment Services, the cities of Portland, Gresham and Milwaukie and Multnomah County provided financial and technical assistance in a cooperative study with the U.S. Geological Survey. This study provided data and analyses to support development of the Johnson Creek TMDLs. The Johnson Creek TMDLs were developed with continual input from the IJC members and greatly benefited from their combined expertise. Karl Lee and Dwight Tanner of the USGS provided technical assistance throughout the project.

Chris Berger at Portland State University Department of Civil Engineering performed CE-QUAL-W2 water temperature modeling on the Columbia Slough.

Bruce Cleland of America’s Clean Water Foundation kindly provided information and training on the use of load duration curves for TMDL development.

TMDL Summaries

Temperature

ODEQ is establishing a stream temperature TMDL for all perennial streams in the Lower Willamette Subbasin except for the mainstem Willamette River, which is discussed in Chapter 4 of this document.

Percent effective shade is used as a surrogate measure for nonpoint source pollutant loading since it is easily translated into quantifiable water management objectives. This TMDL established site-specific shade targets for the mainstem of Johnson Creek and the Columbia Slough and subbasin-wide “shade curves” that can be used to establish shade targets for all streams in the Lower Willamette Subbasin. Modeling results included in this chapter indicate that improved stream shading through the establishment of mature riparian vegetation will result in a significant reduction of Johnson Creek water temperatures and that a combination of improved shading and hydrologic improvements will result in significantly cooler water temperatures within the Columbia Slough.

Oregon’s temperature standard contains provisions that effectively limit the cumulative anthropogenic (point and nonpoint source) heating of surface waters to no more than 0.3 degrees Celsius at the point of maximum impact. In theory, once the system potential condition with respect to nonpoint source pollution is known, ODEQ could then calculate the amount of additional nonpoint source loading that a waterbody can assimilate without resulting in more than a 0.3°C increase in water temperature. ODEQ did not attempt to calculate this additional allowable nonpoint source heat load or incorporate the information into nonpoint source load allocations. Rather, ODEQ considers the conservative methodology that bases nonpoint source load allocations on achieving system potential shade conditions to be part of the explicit margin of safety. The means of achieving these conditions is through restoration and protection of riparian vegetation, increasing instream flows, and, where appropriate, narrowing of stream channel widths. Implementation plans submitted by each designated management agency (DMA) will address the lands and activities that impact stream segments in the watershed within their boundaries to the extent of the DMA’s authority.

Existing and future thermal point sources in the subbasin may be permitted to discharge under the following conditions:

1) They do not cause more than a 0.3°C increase in stream temperature above the applicable criteria after mixing with 25 percent of the stream flow or at the edge of a defined mixing zone, whichever is more restrictive.

2) The sum of waste load and load allocations result in an increase in stream temperature of no greater than 0.3°C above the applicable criteria after complete mixing and at the point of maximum impact.

Pollutant trading opportunities may be available to new or existing point sources in order to offset temperature impacts. Point source dischargers are present in the Johnson Creek and Columbia Slough watersheds and are assigned waste load allocations designed to meet Oregon's temperature standard.

Bacteria

Violations of bacteria water quality standards were routine in the three streams evaluated for this TMDL effort.

ODEQ chose to use the load duration curve approach to develop the bacteria TMDLs for Johnson, Fairview and Springbrook Creeks within the Lower Willamette Subbasin. Load duration curves are a method of determining a flow based loading capacity, assessing current conditions, and calculating the necessary reductions to comply with water quality standards. Wasteload and load allocations are expressed in terms of the percent reduction necessary to achieve the numeric criteria in order to translate the acceptable loads into more applicable measures of performance.

Numeric waste load allocations were assigned to the three (3) Confined Animal Feeding Operations (CAFOs) in the Johnson Creek Watershed. They are consistent with existing NPDES permit limitations.

Analysis of the load duration curves developed for the watersheds within the subbasin reveals no clearly dominant source of bacteria. That is, similar reductions are necessary under low flow and high flow conditions and the percent reduction necessary from all sources and/or land use categories appears to be similar. Specifically, data from Johnson Creek, the only watershed evaluated in the subbasin that has significant amount of rural acreage, showed that urban and rural land uses contribute similar bacteria loads to the stream. The percent reduction was determined conservatively by calculating a reduction based upon some confidence interval of the mean of the measured samples that ensures compliance with the geometric mean criterion of 126 cfu/100ml and also addresses the 406 cfu/100ml criterion. Required reductions are **66%** for the Fairview Creek Watershed, **78%** for the Johnson Creek Watershed and **80%** for the Springbrook Creek Watershed. Except for CAFOs in the Johnson Creek Watershed, both wasteload and load allocations will be expressed as a percent reduction from current levels. ODEQ believes that this approach will aid in implementation of the TMDL because it sets a tangible and common goal for both point and nonpoint source management practices and programs.

Toxics

ODEQ is establishing a TMDL for organochlorine pesticides for the Johnson Creek Watershed. Dieldrin and DDT (dichlorodiphenyltrichloroethane) are toxic organochlorine pesticides that were widely used throughout the Johnson Creek Watershed before their use was restricted and/or banned in the 1970's. Analysis of historic and current data shows that DDT levels in Johnson Creek have decreased approximately 74% since the early 1990's, yet they persist at concentrations that cause violations of State water quality standards.

DDT water column loads were highest at the upstream-most sampling site that drains primarily agricultural land uses. Historic sediment and biotic (crayfish) studies also showed that the upstream-most sampling sites had much higher concentrations of DDT than downstream sites.

ODEQ chose to base this TMDL analysis (and allocations) on the attainment of the State of Oregon fresh water chronic criteria for DDT and dieldrin and also provided an estimated date for attainment of human health criteria based upon natural attenuation. For this phase of the TMDL process it will be assumed that if the chronic criteria for the protection of aquatic life are not violated, then fish tissue concentrations will also be below levels necessary to demonstrate impairment of beneficial uses.

ODEQ chose to provide an alternate allocation expressed as a percent reduction of DDT for urban stormwater and as either a percent reduction or Total Suspended Solids (TSS) concentration for nonpoint sources. The percent reduction in DDT concentration is **77%** for urban stormwater and **94%** for nonpoint sources. For nonpoint sources, a surrogate measure of **15 mg/l** TSS may also be used to express compliance with instream DDT concentrations. ODEQ expects Johnson Creek DMAs to collect additional data in an effort to establish a surrogate measure of Total Suspended Solids and/or Turbidity for urban stormwater. ODEQ may revise the instream TSS reductions and/or allocations for urban stormwater when sufficient monitoring data have been collected and submitted for review.

Mercury

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

Designated Management Agencies

The purpose of this section is to identify the designated management agencies (DMAs) responsible for implementation of the TMDL (see Chapter 14). However, because achieving water quality standards will likely be a community-wide effort, a complete listing would have to include every business, every industry, every farm, and ultimately every citizen living or working within the subbasin. In addition to activities and programs implemented by the DMAs, many other important activities are occurring throughout the Lower Willamette Subbasin that will help attain water quality standards. Entities such as watershed councils have no regulatory authority and are therefore not considered DMAs. However, the activities and programs implemented by these non-regulatory organizations hold tremendous promise to help improve water quality conditions. Detailed information is available in Chapter 14 (Water Quality Management Plan).

An excellent example of a non-regulatory cooperative effort that will improve water quality conditions is currently underway in the Columbia Slough:

MCDD1, City of Portland and US Army Corps of Engineers Project

In many ways the Multnomah County Drainage District #1 (MCDD1) controls the day-to-day hydrology of the Columbia Slough through the operation of pumps and maintenance of channels. Over the last several years MCDD1 has cooperated with a number of agencies in efforts to manage Slough hydrology in a way that will be most beneficial to water quality. Most recently, MCDD1 partnered with the City of Portland and received funding through the US Army Corps of Engineers (USACE) “1135 Grant Program” to complete an ambitious restoration project in the Columbia Slough. Under Section 1135 of the Water Resources Development Act of 1986, the USACE may undertake restoration of habitats degraded by previous USACE actions. Recent (1995) USACE guidance for ecosystem restoration identifies water quality as an important part of the ecosystem. The multi-year project will create channel meanders, emergent wetland benches and restore aquatic and riparian habitat along nearly 7.5 miles of the middle and upper Slough from the MCDD pump station #1 near NE 13th Avenue upstream to 158th Avenue. A meandering low-water channel will be created and native riparian vegetation will be established in many areas. These modifications were incorporated into the temperature modeling scenarios presented in the Columbia Slough Temperature TMDL, resulting in significantly improved water temperatures. Other water quality benefits are also expected. The City of Portland provided 25% of the funding for this project and the USACE provided 75%.

Johnson Creek, Columbia Slough and Fairview Creek Watershed Councils

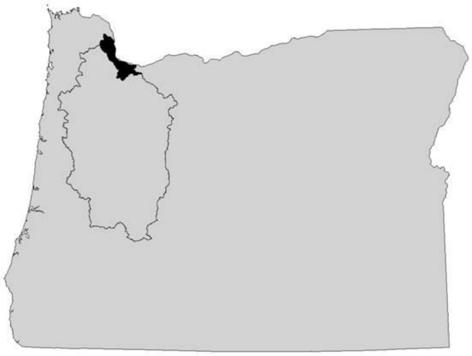
The Johnson Creek, Columbia Slough and Fairview Creek Watershed Councils are officially recognized and supported by the Oregon Watershed Enhancement Board (OWEB). They have completed Watershed Assessments and Action Plans according to OWEB protocols that detail restoration priorities for the watershed. The Councils are engaged in virtually every aspect of watershed management, and will be crucial in building support for water quality and riparian enhancement projects that directly addresses the needs outlined in this TMDL. It is expected that many future restoration efforts, especially those on private lands within the basin, will be led by the councils.

Table 5.2 shows streams in the Lower Willamette Subbasin where TMDLs are applicable, along with the responsible DMAs.

Table 5.2 Designated Management Agencies in the Lower Willamette Subbasin

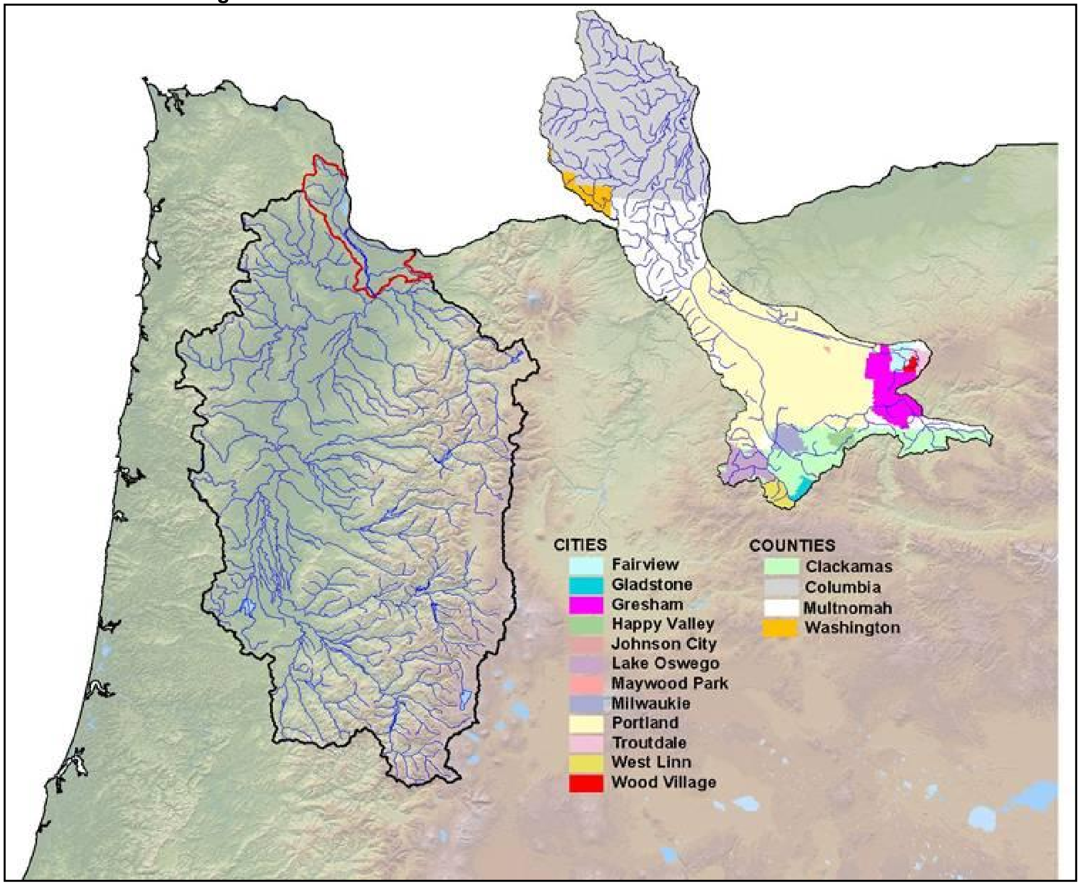
Designated Management Agency	Stream(s)	Parameter(s)
City of Portland	Columbia Slough, Springbrook Creek, Johnson Creek, Tryon Creek	Temperature, Bacteria, Toxics
City of Gresham	Columbia Slough, Fairview Creek, Johnson Creek	Temperature, Bacteria, Toxics
City of Lake Oswego	Springbrook Creek, Tryon Creek	Temperature, Bacteria
City of Milwaukie	Johnson Creek	Temperature, Bacteria, Toxics
City of Happy Valley	Johnson Creek	Temperature, Bacteria, Toxics
City of Wood Village	Fairview Creek	Temperature, Bacteria
City of Fairview	Fairview Creek	Temperature, Bacteria
Multnomah County	Johnson Creek, Tryon Creek, Springbrook Creek	Temperature, Bacteria, Toxics
Clackamas County	Johnson Creek, Tryon Creek, Springbrook Creek	Temperature, Bacteria, Toxics
Port of Portland	Columbia Slough	Temperature
Oregon Department of Environmental Quality	All Streams	All Parameters
Oregon Department of Agriculture	All streams in the basin with agricultural land use	All Parameters
Oregon Department of Transportation	All streams impacted by State roadways	Appropriate Parameters
Metro (Portland area Metropolitan Government)	All streams impacted by Metro-owned facilities	Appropriate Parameters

SUBBASIN OVERVIEWS



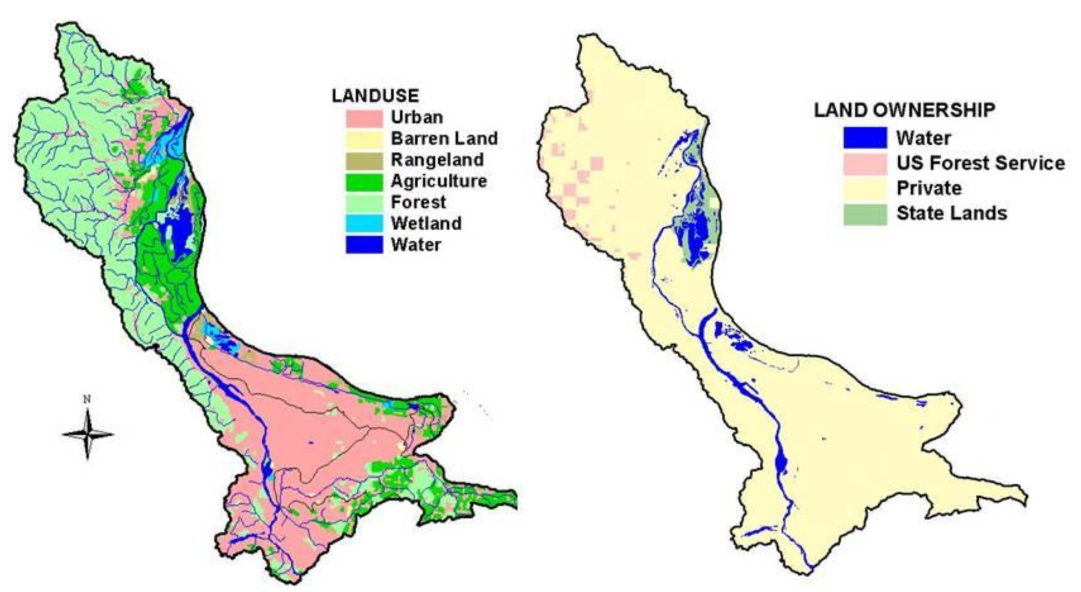
The Lower Willamette Subbasin (Hydrologic Unit Code 17090012) is located in the northern most portion of the Willamette Basin and is drained by the Willamette River, Multnomah Channel and tributaries. The subbasin's 408 square miles extend from the divides shared with the Sandy and Clackamas subbasins in Cascade foothills on the east, across the Willamette River to the Tualatin divide on the west, north to the town of St. Helens and south to Willamette Falls at river mile 26.6. The southeastern portion of the subbasin drains directly to the Willamette River and contains the majority of the Portland metropolitan area, while the northwestern portion generally drains rural and agricultural lands through tributaries that discharge to the Multnomah Channel. Major tributaries include Johnson Creek, Tryon Creek, Kellogg Creek and the Columbia Slough in the Portland metropolitan area and Milton Creek, Scappoose Creek and McNulty Creek in the northwest. Political jurisdictions include all or portions of the cities of Portland, Gresham, Fairview, Wood Village, Troutdale, Johnson City, Happy Valley, Gladstone, Lake Oswego, Maywood Park, Milwaukie, West Linn, Scappoose, and St. Helens as well as portions of Multnomah, Clackamas, Washington and Columbia Counties (**Figure 5.2**).

Figure 5.2. Political Jurisdictions in the Lower Willamette Subbasin



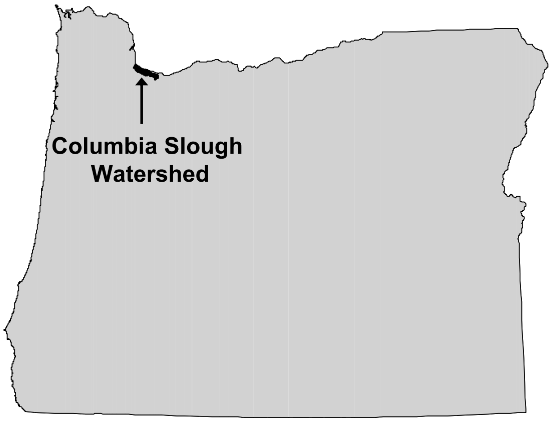
The subbasin is almost entirely in private ownership, with scattered parcels in the northwest portion owned by the US Forest Service and State wildlife refuge lands in the lowlands surrounding Sturgeon Lake. Land use is primarily urban, forestry and agriculture (**Figure 5.3**).

Figure 5.3. Land Use and Ownership in the Lower Willamette Subbasin



Columbia Slough Watershed

Introduction



The Columbia Slough is a 19-mile (31km) long complex of channels located in Northwest Oregon on the floodplain of the Columbia River between Fairview Lake on the east and the Willamette River at Kelley Point Park on the west. The Slough watershed drains approximately 51 square miles (82 sq km) of land. Fairview Creek, which drains to Fairview Lake, also lies within the geographic boundary of the Columbia Slough Watershed.

Over the years the Slough system has been extensively dredged, diked, filled and channelized, principally by the U.S. Army Corps of Engineers, the City of Portland and the Port of Portland. Originally a series of wetlands and marshes created by annual flooding of the Columbia and Willamette Rivers, the Slough is now a highly managed water system with dikes and pumps to provide watershed drainage and flood control for the lowlands surrounding it. The Multnomah County Drainage District No. 1 (MCDD1) is a special purpose district whose primary responsibility is to provide flood control for most of the Slough watershed. The jurisdictional boundaries of the district are roughly from (east to west) NE 223rd westward to NE 13th, and from (north to south) the Columbia River levee to the natural embankment that follows the contour of Columbia and Sandy Boulevards (MCDD 2001). Due to the extensive modifications noted above, the area within MCDD's boundaries no longer drains naturally, but relies on two primary pump stations that lift water over the levee, and into the Columbia River and/or lower Columbia Slough which drains to the Willamette River. The hydraulic management of the Slough can have a significant impact on the water quality and uses supported by the Slough.

The Columbia Slough is water quality limited for chlorophyll *a*, pH and phosphorus from spring through fall due to excessive algal growth. This algal growth affects the aesthetic quality of the Slough and may affect such beneficial uses as fishing and boating.

The dissolved oxygen criteria for cool water aquatic life are violated throughout the year. These dissolved oxygen criteria violations may prevent the Columbia Slough from supporting salmonid fish rearing as well as resident fish and aquatic life. Diurnal swings in dissolved oxygen during the summer months are most likely the result of algal growth, while winter violations are likely due to storm water runoff. Historic winter violations were tied to aircraft de-icing activities at Portland International Airport. ODEQ has since developed an NPDES permit for this discharge and control mechanisms are now in place.

The Slough is water quality limited for dieldrin, DDE, DDT, PCBs and dioxin due to elevated levels found in fish tissue, impairing the use of the Slough for fishing. The State of Oregon Health Division and the City of Portland have issued recommendations against eating fish from the Slough due to PCBs, DDE and DDT (http://www.ohd.hr.state.or.us/esc/docs/lowcolum.htm).

Elevated bacteria and lead concentrations have also been documented in the Slough.

To address these water quality problems, ODEQ developed ten TMDLs that specify pollutant loading limits and require pollution reduction programs for pollutant sources. In December 1998, the U.S. Environmental Protection Agency approved the TMDLs for the Columbia Slough. The 1998 TMDL established for the Columbia Slough remains in effect.

The Columbia Slough has been divided into several reaches (**Figure 5.4**), based primarily on hydraulic characteristics. The reaches of the Columbia Slough are generally shallow and slow moving with channel widths ranging from 20 feet or less in the upper to 200 feet or more in the lower portions.

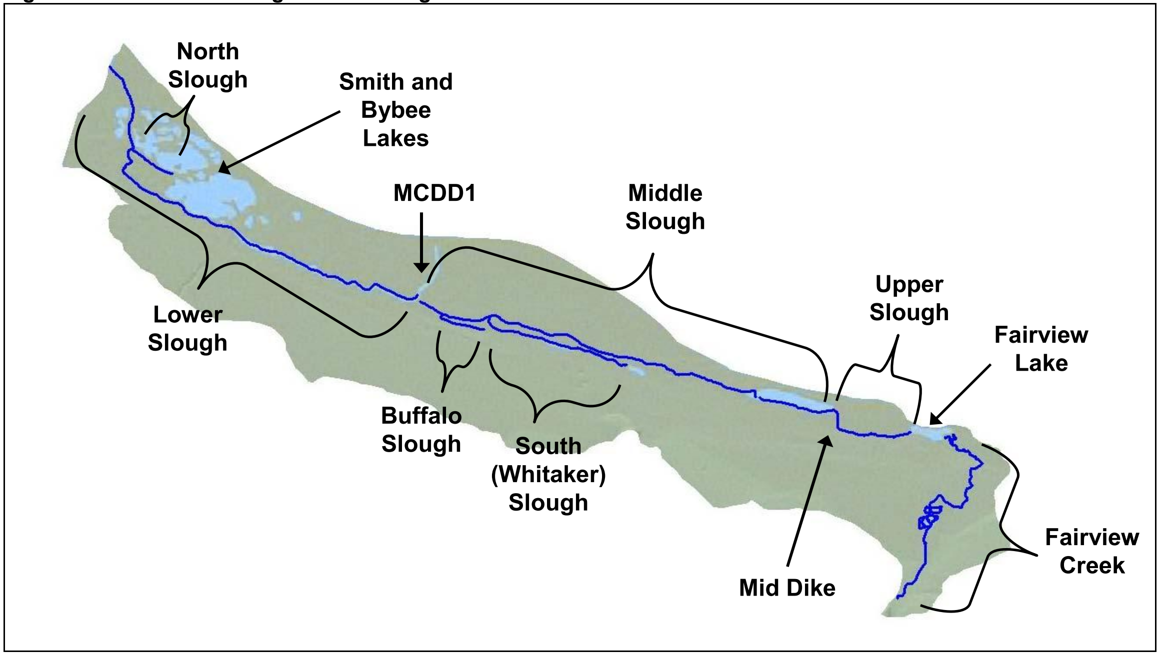
The Lower Slough extends from the Willamette River to the Multnomah County Drainage District Pump Station No.1 at NE 13th Avenue (MCDD1). The North Slough enters the Lower Slough near river mile (RM) 1.7 and extends upstream to Smith and Bybee Lakes, skirting the north side of the former St. Johns Landfill. The Lower and North Sloughs are tidally influenced, so the water quality is heavily influenced by that in the Willamette River. At MCDD1 there is a dike that physically separates the Lower and Middle Sloughs.

The Middle Slough extends from the pumping station at MCDD1 to a cross levee (a.k.a. mid-dike) between NE 138th and 148th Avenues. The mid-dike has slide gates that can hydraulically isolate flows between the Middle and Upper Sloughs. Groundwater contributes approximately one-half of the annual flow in the Middle Slough. The Buffalo Slough and Whitaker Slough (also known as the South Slough) run parallel to the Middle Slough and enter from the south. Their flows are also heavily influenced by groundwater.

The Upper Slough extends from the mid-dike to the outlet of Fairview Lake. The Upper Slough receives considerably less groundwater than the Middle Slough. West of “Four Corners”, which is in the area of NE 162nd Avenue, the Slough is subject to reversal of flows due to the operations of the MCDD Pump Station No.4 located on Marine Drive. MCDD4 can take water from the Upper Slough and discharge it directly to the Columbia River. The arm of the Slough to MCDD4 often has little or no flow exchange with other portions of the reach.

Fairview Lake is very shallow and turbid with a surface area of 103 acres (42 ha). During the summer months, flow from Fairview Lake to the Upper Slough is negligible relative to the flow from groundwater. An earthen dam and control structure at the west end of the lake regulates lake level and discharge to the Upper Slough. The control structure is generally closed from May 15 through October 15 and the water elevation in the lake is raised for recreational purposes (CH2MHill 1995). The flow from the Fairview Creek drainage basin, which is composed of Fairview, Osborn, and No Name Creeks, enters Fairview Lake from the south.

Figure 5.4. Columbia Slough Reach Designations



History

In times before European settlement, spring floods in the Columbia River would spread over the bottomlands in the area now known as the Columbia Slough. Yearly flood events cut side channels and sloughs, creating meandering off-channel areas with marshy areas, seasonal shallow lakes, and flat lowland areas. Beginning in the 1840's European settlers began clearing trees and farming these rich bottomlands. Levees were constructed to the east that cut off the spring freshets that formed the bottomlands and in 1917 the State of Oregon empowered drainage districts to begin diking, pumping and filling the wetlands, lakes and side channels (Portland 1989). By the 1940's the Slough was completely surrounded by dikes and levees and only the lower section was influenced by tidal fluctuations.

Subsequent development in the Columbia Slough occurred rapidly and dramatically. In 1919 the City of Portland dug the Peninsula Drainage Canal from the lower Slough out to the Columbia River near present-day NE 21st Avenue. The purpose of the canal was to flush water through the lower portion of the Slough, which was reported to run "red" with the discharge from meat packing plants. Industrial, agricultural and municipal sewage wastes were routinely discharged to the Slough, creating abysmal water quality conditions. The wood products industry left the area after workers refused to handle logs floated through the stagnant water (Portland 1989).

Water quality in the Slough is generally thought to have begun improving in the late 1940's after the catastrophic Vanport Flood. Today the water quality of the Slough is much improved over the conditions that existed in the 1940's, but still fails to meet state water quality standards and is ranked near the bottom of a statewide list of waterbodies monitored by ODEQ (see Oregon Water Quality Index at http://www.deq.state.or.us/lab/wqm/wqimain.htm). Efforts to improve water quality in the Slough, especially the permitting of point source discharges and the removal of combined sewer overflows, has resulted in a significant improvement in water quality over the last 10 years.

Hydrology and Water Rights

The hydrology of the Columbia Slough has a significant effect upon water quality. The Slough is a shallow, slow-moving water body subject to a variety of physical and meteorological conditions that affect both flow and water quality (CH2MHill 1995). The Slough receives water from groundwater, stormwater runoff, point sources and rainfall. Point sources account for a fraction of a percent of the overall stream flow. The lower portion of the Slough is tidally influenced and the level fluctuates between 1 and 3 feet daily depending upon the tidal cycle. High flow periods in the Willamette River has the potential to stop the outflow in the lower reach and at times create a net inflow to the Slough for several days (CH2MHill

1995). Water movement through the middle and upper sections of the Slough is effected by the presence of under-sized culverts at several road crossings. These culverts do not allow free movement in certain areas of the Slough, resulting in higher surface water elevations and stagnation. Flows in the lower Slough, measured at USGS gauging station #14211820 near the Lombard Street Bridge (**Figure 5.5**), average approximately 60 cubic feet per second (cfs) during the summer and 150 cfs during the winter months. All water leaving the middle and upper Slough must pass through pumps or through gravity-fed conduits to the lower Slough. Operation of these pumps has the ability to rapidly change the flow regime in the Slough, but attempts have been made to moderate these effects.

The hydrology of Fairview Creek, the uppermost portion of the Slough watershed, is typical of a small urban stream. Stream flow in Fairview Creek is measured at USGS gauging station #14211814 at Glisan Street in Fairview (**Figure 5.5**). Summertime low flows of less than 1 cfs typically occur in August and wintertime high flows occur in January and February, with average flows of approximately 10 cfs and occasional storm-related flows approaching 50 cfs.

According to the State of Oregon Water Resources Department (WRD), there are 29 active surface water withdrawal rights in the Columbia Slough Watershed. **Table 5.3** shows the total amount appropriated through these water rights and **Figure 5.5** shows their approximate location in the watershed. It should be noted that the total amount appropriated in both Fairview and Osburn Creeks exceeds their typical summertime stream flow and that all water rights shown in **Table 5.3** are granted year-around. These water rights generally date back several decades and may or may not be currently exercised. A water right must be exercised at least once every five years to remain valid. If it is not, it is forfeited. The Oregon Water Resources Department is required to begin forfeiture proceedings when they discover abandoned water rights (Bastasch 1998).

Figure 5.5. Location of Surface Water Points of Diversion and USGS Stream Flow Gages

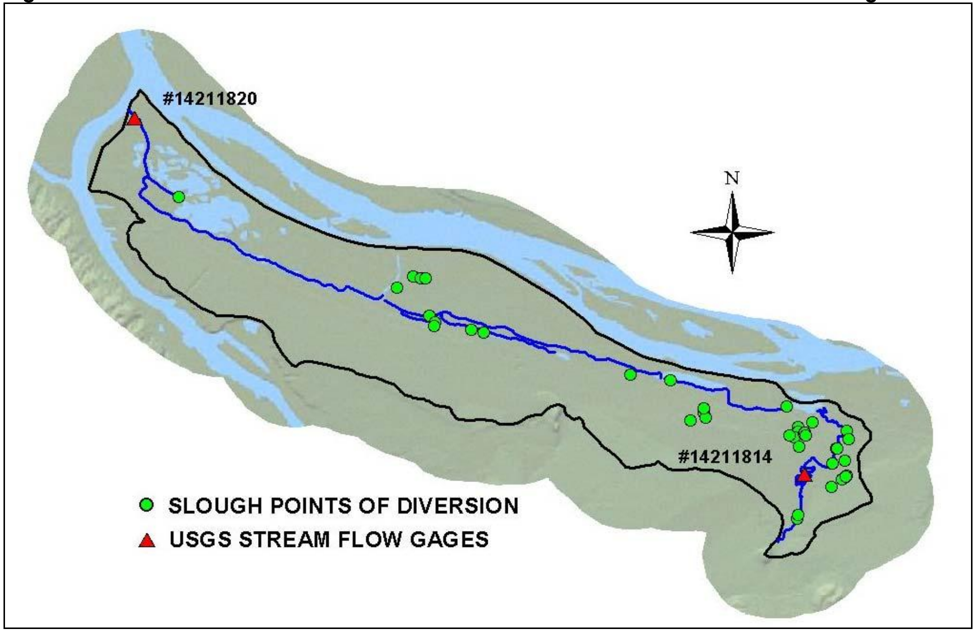


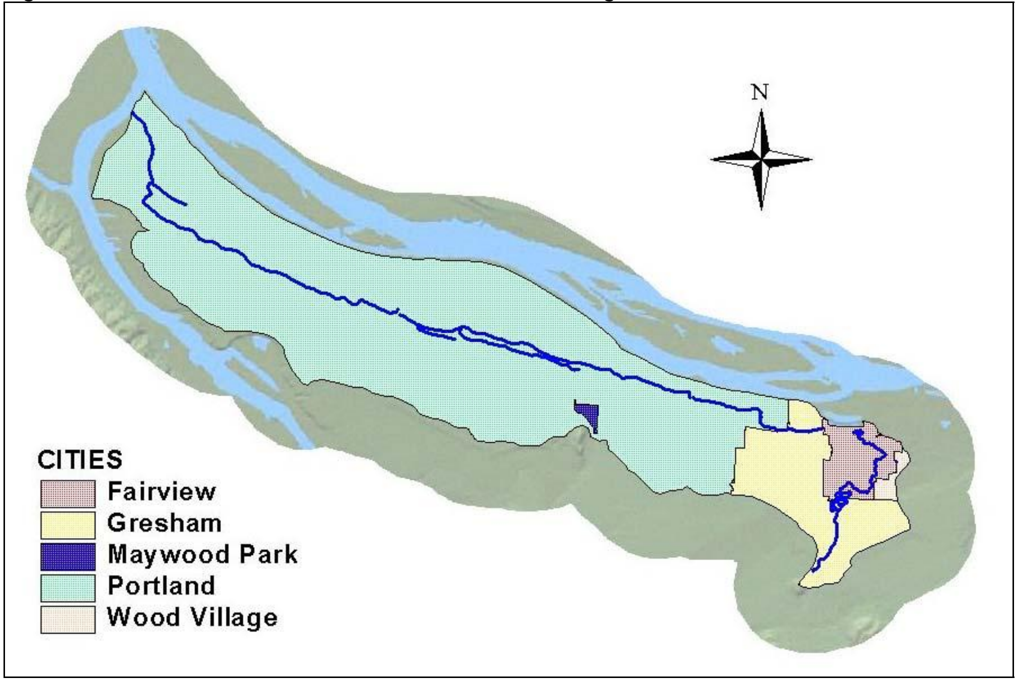
Table 5.3. Columbia Slough Watershed Surface Water Withdrawals

Source	Permit Number	Use	Priority Date	Rate of Diversion (cfs)
COLUMBIA SLOUGH				
SPRING	6761	Domestic	1925	.02
COLUMBIA SL.	14393	Irrigation	1939	11.2
COLUMBIA SL.	38868	Irrigation	1973	0.01
SPRING	50240	Manufacturing	1987	0.09
UNNAMED TRIB.	13541	Irrigation+ Domestic+ Livestock	1939	0.11
SPRING	15341	Irrigation + Domestic + Fish	1942	0.5
UNNAMED TRIB.	17343	Irrigation	1946	0.022
UNNAMED TRIB.	32993	Irrigation + Domestic	1967	0.015
UNNAMED TRIB.	36295	Irrigation	1971	0.02
COLUMBIA SL.	50872	Irrigation	1994	0.11
UNNAMED TRIB.	17343	Irrigation	1946	0.02
			SUBTOTAL:	**12.2**
FAIRVIEW CREEK				
FAIRVIEW CR.	7494	Irrigation	1925	0.14
FAIRVIEW CR.	9031	Irrigation + Domestic	1929	1.0
SPRING	11987	Irrigation + Domestic	1935	0.09
FAIRVIEW CR.	12788	Irrigation	1937	0.05
FAIRVIEW CR.	13987	Irrigation + Recreation	1939	0.04
FAIRVIEW CR.	14814, 906	Irrigation	1941	0.52
UNNAMED TRIB.	6666	Irrigation	1925	2.1
			SUBTOTAL:	**3.9**
OSBURN CREEK				
OSBURN CR.	900	Irrigation + Domestic	1911	0.2
OSBURN CR.	5202	Domestic + Fish Culture	1921	2.0
OSBURN CR.	7239	Fish Culture	1926	0.1
OSBURN CR.	11351	Irrigation + Domestic + Fish	1934	1.0
OSBURN CR.	13937	Irrigation + Domestic	1939	0.24
OSBURN CR.	15536	Irrigation	1943	0.01
UNNAMED TRIB.	20579	Irrigation	1951	0.1
OSBURN CR.	21728	Domestic + Lawn	1952	0.27
OSBURN CR.	27120	Irrigation	1960	0.31
OSBURN CR.	36510	Irrigation	1971	0.01
			SUBTOTAL:	**4.2**
			GRAND TOTAL:	**20.3 cfs**

Land Use

Many kinds of land use are found within the watershed including heavy and light industries, residential areas, vegetable farming and the Portland International Airport (PDX), which occupies approximately 3200 acres near the center of the watershed. PDX, the 34th busiest airport in the country, is owned and operated by the Port of Portland. The Columbia Slough also serves as one of the City of Portland's largest open space and wildlife habitat areas. Political jurisdictions include portions of the cities of Portland, Gresham, Fairview and Wood Village (**Figure 5.6**). Multnomah County maintains some jurisdictional responsibility in the Interlachen area between Blue and Fairview lakes and for a number of roadways in the watershed. The City of Maywood Park is also located in the watershed but does not discharge to the Slough directly.

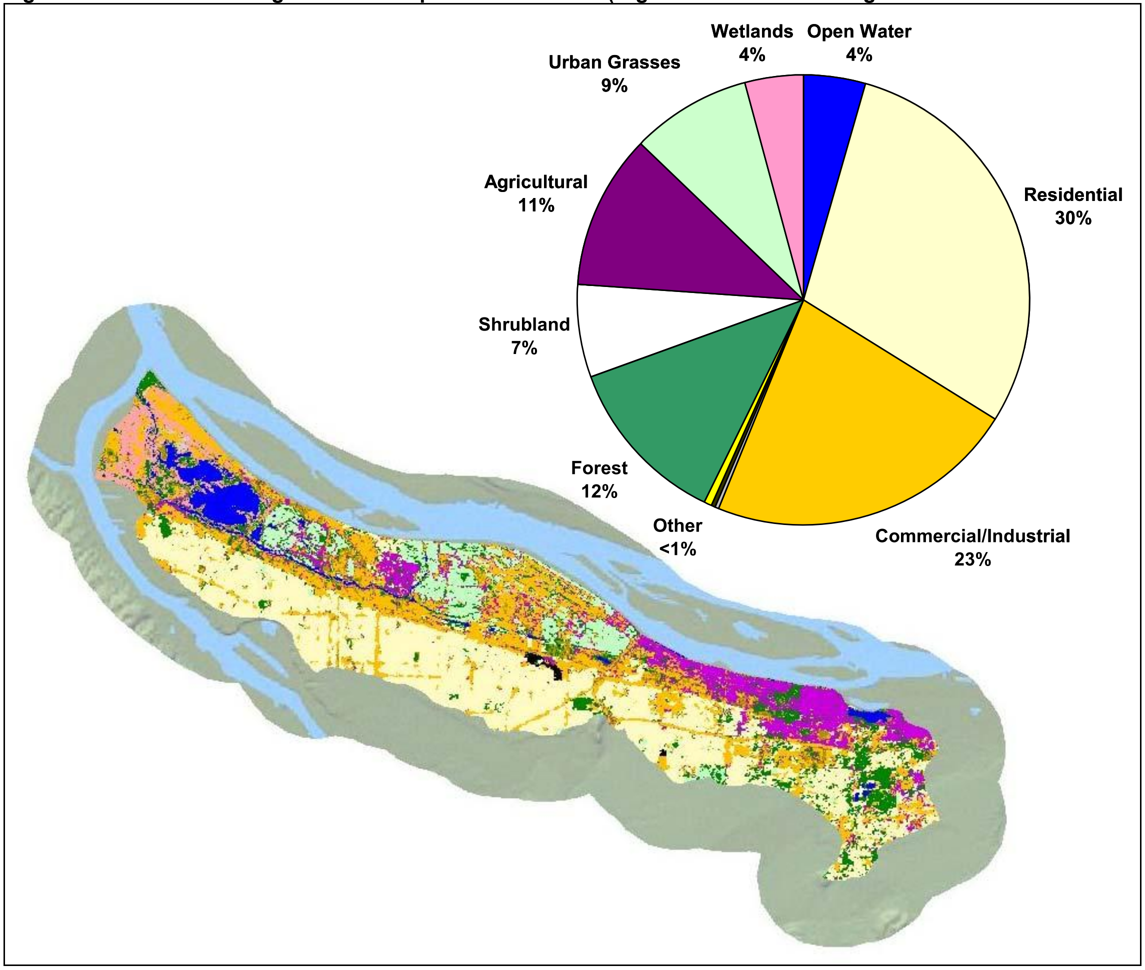
Figure 5.6. Political Jurisdictions within the Columbia Slough Watershed



The Columbia Slough Watershed is home to over 150,000 Oregonians and encompasses an industrial area with over 88,000 jobs and 4,200 companies. It is also home to Port of Portland facilities, six golf courses and more than 40 schools (CSWC 2002).

Spatial distribution of land use is shown in **Figure 5.7**. Approximately 23% of the basin is currently being used for commercial and industrial purposes. Commercial and industrial uses are primarily located north of Columbia Boulevard and in the western portion of the basin. Residential use occupies approximately 30% of the basin, mainly south of Columbia Boulevard. Agriculture land uses still occupy approximately 11% of the watershed. Agricultural lands in the Columbia Slough are mainly confined to the eastern portion of the watershed and are rapidly being developed into commercial areas (CSWC 2002).

Figure 5.7. Columbia Slough Land Use Spatial Distribution (Digital data from the Oregon State Service Center for GIS)

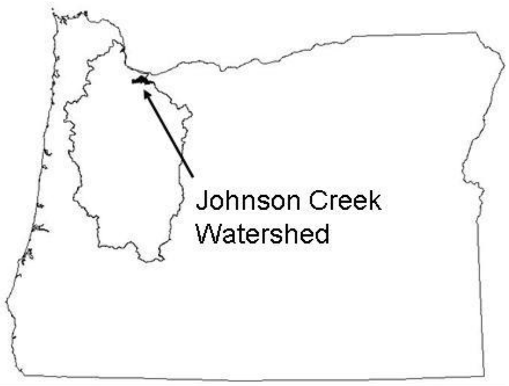


Outdoor recreation in the Columbia Slough Watershed has expanded in recent years. During the summer months the Columbia Slough is increasingly utilized by kayakers and canoeists. Seven canoe launching sites are located along the slough, with upgrades and additional launching points in the planning phase. Kelly Point Park, at the confluence of the Columbia Slough, Willamette River and Columbia River is heavily utilized by recreational swimmers, fishers and picnickers. The 40-mile loop trail, which has many sections along the Slough, provides walking, bicycling and bird watching opportunities (CSWC 2002).

Johnson Creek Watershed

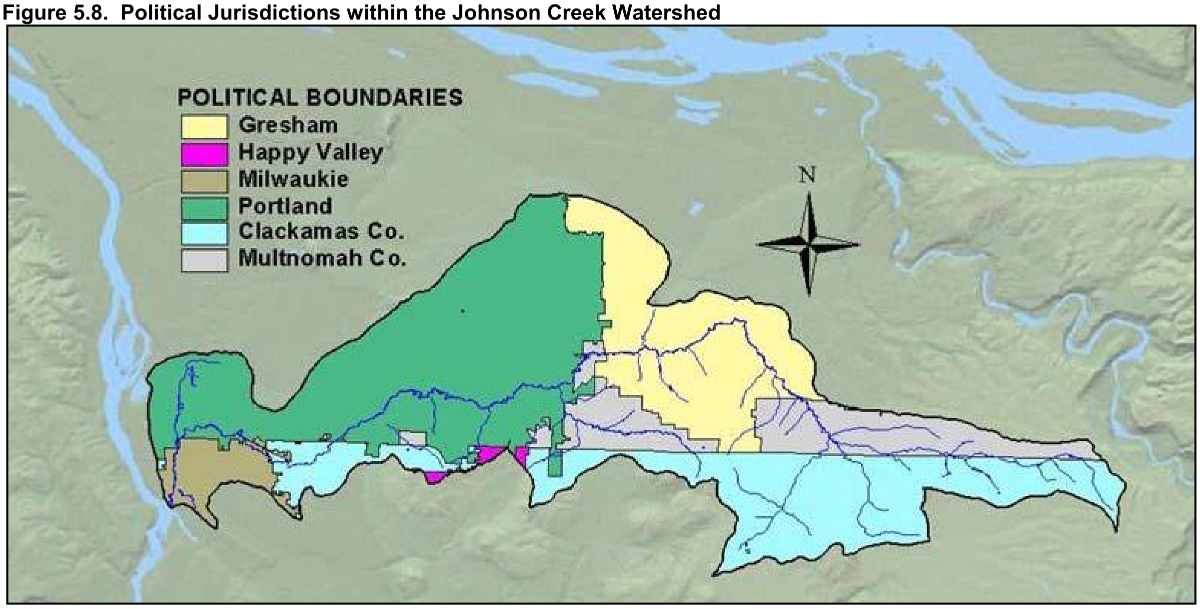
Introduction

Johnson Creek flows 25 miles from its headwaters in the Cascade foothills to its confluence with the Willamette River near the City of Milwaukie. The watershed drains approximately 54 square miles and includes portions of the cities of Gresham, Happy Valley, Portland and Milwaukie as well as portions of Clackamas and Multnomah counties (**Figure 5.8**). Significant tributaries to Johnson Creek include Crystal Springs, Kelley, Butler, Hogan Sunshine and Badger Creeks. Crystal Springs Creek enters Johnson Creek approximately 2 miles upstream from the confluence with the Willamette River.



Crystal Springs Creek has been cited as contributing cool, clear water to Johnson Creek. In many ways this is a misconception. Crystal Springs Creek provides a substantial constant flow to the lower portion of Johnson Creek and maintains much greater flows than Johnson Creek during the summer months. However, monitoring data shows that, while the source of Crystal Springs Creek are cool spring-fed waters, impoundments along the stream cause the creek to heat well beyond optimal temperatures for salmonids and that bacteria levels are well above water quality standards. In fact, Crystal Springs Creek is slightly warmer than Johnson Creek during the summer months and both waterbodies show similar bacteria concentrations.

Figure 5.8. Political Jurisdictions within the Johnson Creek Watershed



The Johnson Creek Watershed has been the subject of a number of water quality investigations over the last decade. The U.S. Geological Survey has been quite active in the basin and has published a number of excellent reports on the hydrology and water quality of Johnson Creek. Many can be found on their website at http://oregon.usgs.gov. In addition to the USGS investigations, the Johnson Creek Watershed has been the subject of numerous studies and reports that provide detailed information on various aspects of the watershed, including history, fisheries, water quality, hydrology, habitat and restoration opportunities. They include, but are not limited to: Johnson Creek Resource Management Plan (Woodward-Clyde 1995); Salmon Restoration in an Urban Watershed (Meross 2000); Johnson Creek Watershed Council Action Plan and Watershed Assessment (Adolfson 2003); and the Johnson Creek Restoration Plan (Portland 2001).

The following sections provide some detail on the physical and biological attributes of the Johnson Creek Watershed that may be pertinent to current and future water quality conditions and the attainment of beneficial uses.

General Water Quality - OWQI

The ODEQ Laboratory monitors Johnson Creek near the mouth (RM 0.2) as part of the statewide ambient water quality monitoring program. Routine monitoring has been conducted at this location since 1990. In June 1998 the monitoring frequency increased to bimonthly. The Oregon Water Quality Index (OWQI) analyzes a defined set of water quality parameters and produces a score describing general water quality. The water quality parameters included in the OWQI are temperature, dissolved oxygen (percent saturation and concentration), biochemical oxygen demand, pH, total solids, ammonia and nitrate nitrogen, total phosphorous, and fecal coliform. OWQI scores range from 10 (worst case) to 100 (ideal water quality). Scores are further broken down as follows: 0-59 = “very poor”, 60-79 = “poor”, 80-84 = “fair”, 85-89 = “good”, and 90-100 = “excellent”.

Average OWQI scores for Johnson Creek are very poor throughout the year, with an average summer score of 26 and an average winter score of 31. Johnson Creek is impacted by consistently very high concentrations of nitrate nitrogen and high concentrations of total phosphorus, fecal coliform, total solids and biochemical oxygen demand. These conditions occur throughout the year. This indicates the introduction of inorganic and organic materials and untreated human or animal waste. OWQI scores were greater than 30 only fourteen percent of the time. With one exception (score of 61, “poor”, on 1/29/96), all results were in the “very poor” range of OWQI scores. Of all of the ODEQ-monitored sites in the Willamette Basin, only the Columbia Slough scores worse than Johnson Creek in terms of minimum seasonal averages. Results from the Seasonal-Kendall trend analysis show no significant change in water quality over the past eight years. This means that although water quality in Johnson Creek has not significantly deteriorated since 1990, neither has it improved.

The OWQI index is used to assess general water quality conditions and should not be confused with the 303(d) listing process that leads to TMDL development. Information on the OWQI is included in this chapter for informational purposes only and does not suggest the need for additional TMDLs at this time. However, evaluation of Johnson Creek water quality data collected as part of the statewide ambient monitoring program may lead to future 303(d) listings for parameters beyond those addressed by this TMDL.

Hydrology and Water Rights

The hydrology of Johnson Creek can be generally characterized as “flashy” in that it responds very quickly to precipitation events in the watershed, a common characteristic of many urban streams with a high proportion of impervious surfaces. Johnson Creek has a long history of serious flooding and also a long history of public works projects designed to reduce the property damage associated with flooding. The hydrology of Johnson Creek has a significant impact on water quality, both during low- and high-flow periods of the year.

The Johnson Creek Restoration Plan (Portland 2001) provides an excellent overview of how the current hydrology of Johnson Creek came to be and how it has impacted the watershed:

> *“Today the quality of Johnson Creek and the condition of its channels represent the integrated history of how nature and man have influenced it. Geological, hydrological and other natural processes are the primary factors that define the watershed. In addition, residents have altered the watershed and used the natural resources found throughout for their respective needs and benefits. The combination of these factors has reduced the natural stability of the watershed and its ability to support fish and wildlife. Until natural conditions (physical, chemical and biological) and a natural flow regime can be restored to Johnson Creek, it will be impossible to achieve restoration objectives.*
>
> *Alteration of the natural flood plain has eliminated many of the areas that once absorbed and conveyed floods through the watershed. The most significant alteration was performed in the 1930s by the Works Progress Administration (WPA), when Johnson Creek was subjected to extensive rock-*

> *lining, channel deepening, and straightening to control flooding. These activities caused adverse impacts to the natural resources and ecological integrity of the creek, yet flood damage continued. Continued development has further changed the creek's hydrological capacity to rapidly move large volumes of water through the watershed to the detriment of residents, fish and wildlife, and water quality."*

Johnson Creek and its tributaries have experienced development-related impacts to its natural hydrology that may influence stream temperatures. Of these, altered channel morphology, water withdrawals and reduction of summertime base flows due to increases in impervious surface area probably have the most impact on stream temperatures. Bacteria and toxics water quality problems are also exacerbated by the current hydrology of the basin. In the case of bacteria, the paths and time in which it takes bacteria to go from "source" to "stream" are often greatly altered by modern stormwater conveyance systems and land use practices. For example, fecal waste deposited several hundred feet away from a stream could be transported to the stream in minutes via an urban storm system – a path that may take several days under natural overland flow conditions. Since die-off rates for bacteria are typically in the order of days, the bacteria from the fecal waste would likely contribute to stream standards violations when transported quickly via the storm system, but would be much less likely to survive natural overland transport – as evidenced by the low bacteria numbers seen in forested watersheds with natural hydrology and abundant wildlife. Lastly, the current water quality standards violations for the "legacy" pesticides DDT and dieldrin may also be exacerbated by human-related factors that impact hydrology. DDT and dieldrin were used extensively throughout the watershed and typically find their way to Johnson Creek attached to sediment particles transported during rainfall events. Human activities have a large influence on the magnitude and duration of the erosional processes that move these toxic-laden sediments from land to the stream. Sediment laden runoff from agricultural areas carries with it DDT and dieldrin, as does the runoff from construction sites, landscaping and other land disturbing activities occurring in the urban areas of the watershed. Practices typical of both landscapes contribute to the "flashy" nature of the Johnson Creek hydrograph and result in an increase in overall pollutant loads to the system.

Four U.S. Geological Survey (USGS) flow gaging stations are located in the watershed. They are operated in cooperation with local jurisdictions, including the cities of Portland, Gresham, Milwaukie, and Clackamas and Multnomah counties. Three sites are located on the mainstem of Johnson Creek and one site is located near the mouth of Kelley Creek. The Oregon Water Resources Department (WRD) operates a flow station near the mouth of Crystal Springs Creek. **Figure 5.9** shows their geographic location in the watershed and **Table 5.4** provides additional information on the gaging stations. Johnson Creek stream flow characteristics are discussed in more detail in the bacteria TMDL section of this chapter. During the summer the flow of Crystal Springs Creek is approximately 10 cfs, whereas the mainstem of Johnson Creek may be as low as 1 cfs.

Figure 5.9. Location of Johnson Creek Surface Water Points of Diversion, Reservoirs, OWRD and USGS Monitoring Sites

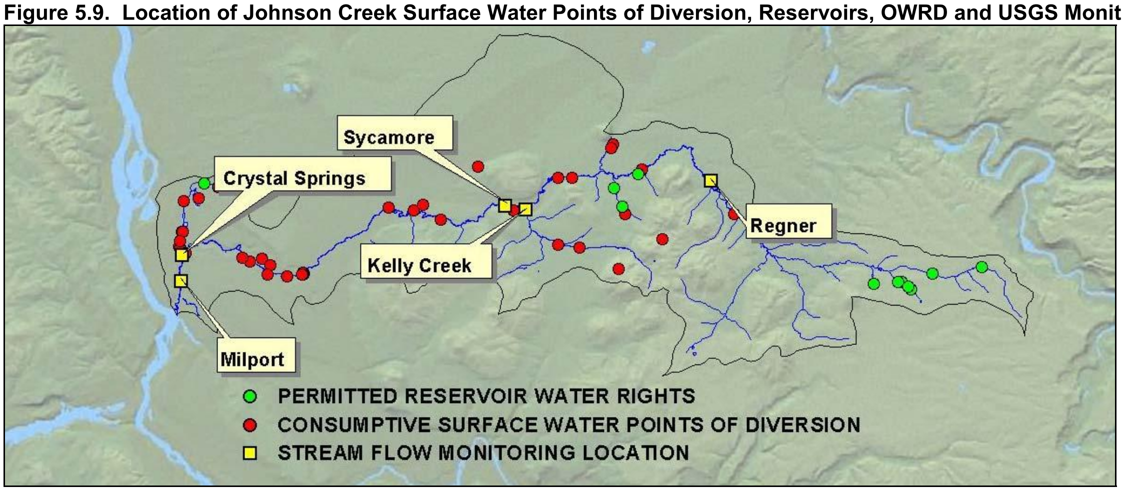


Table 5.4. Description of Johnson Creek Watershed USGS and OWRD Flow Gaging Stations

Station Number	Station Name	River Mile	Period of Record	Agency
14211400	Johnson Creek at Regner Road at Gresham	16.3	1998-present	USGS
14211500	Johnson Creek at Sycamore	10.2	1940-present	USGS
14211550	Johnson Creek at Milwaukie (Milport Gage)	0.7	1989-present	USGS
14211499	Kelley Creek at 159th at Portland	0.0	2000-present	USGS
14211546	Crystal Springs Creek at Mouth at Portland	0.0	Periodic	OWRD

Flow duration curves for the appropriate USGS gage sites in the watershed were developed and are presented in **Figures 5.10** through **5.12**. The flow duration curve is a plot of the frequency of which a flow is exceeded. The flows are ranked from maximum to minimum for the period of record at a particular site and the exceedance probability (EP) for each flow was computed. The exceedance probability (EP) for each flow was computed by:

$$EP = \frac{rank}{n+1}$$

where n is the number of daily mean flow values.

The “flow exceedance probability” is the exceedance probability multiplied by 100. The data are plotted with the flow exceedance probability on the x-axis and the flow in cubic feet per second on the y-axis (log scale). A value of 5% on the x-axis indicates extremely high flows, while a value of 95% indicates drought conditions. For example, **Figure 5.10** illustrates that, for the period of record at the Milport USGS gage, 90% of the measured flows exceeded 16 cubic feet per second. Flow and load duration curves and their use by ODEQ in bacteria TMDL development, are discussed further in the bacteria TMDL section of this chapter.

Figure 5.10. **Flow Duration Curve for Milport USGS gage #14211550**

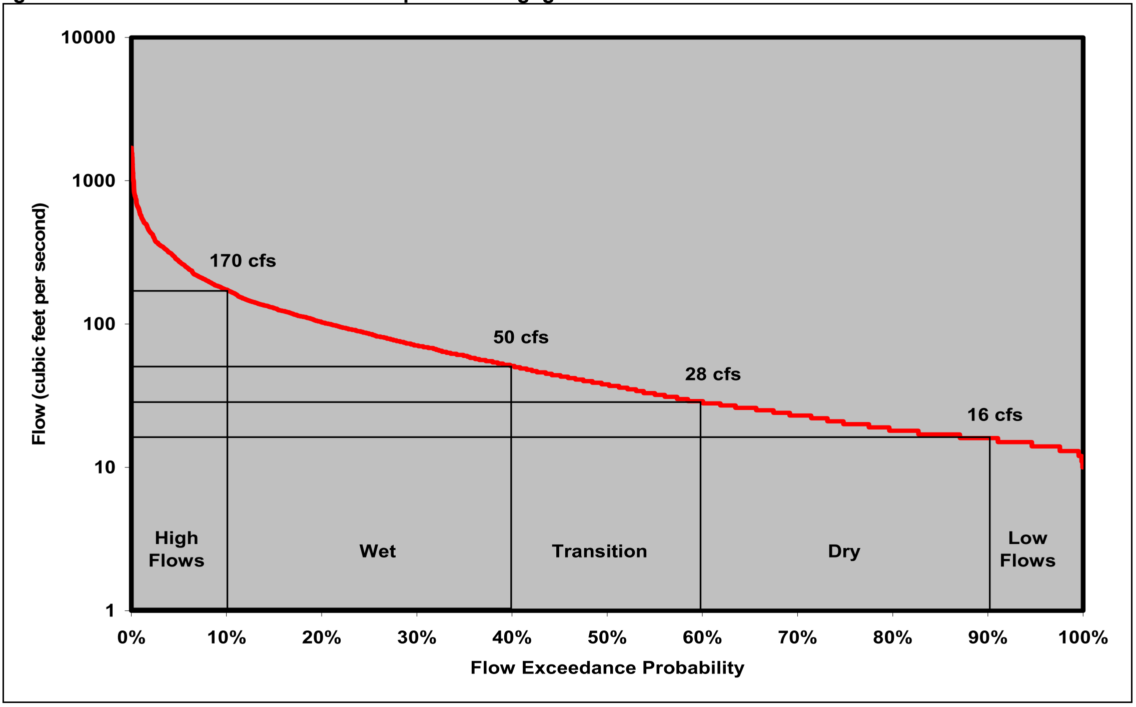


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Figure 5.11. Flow Duration Curve for Sycamore USGS gage #14211500

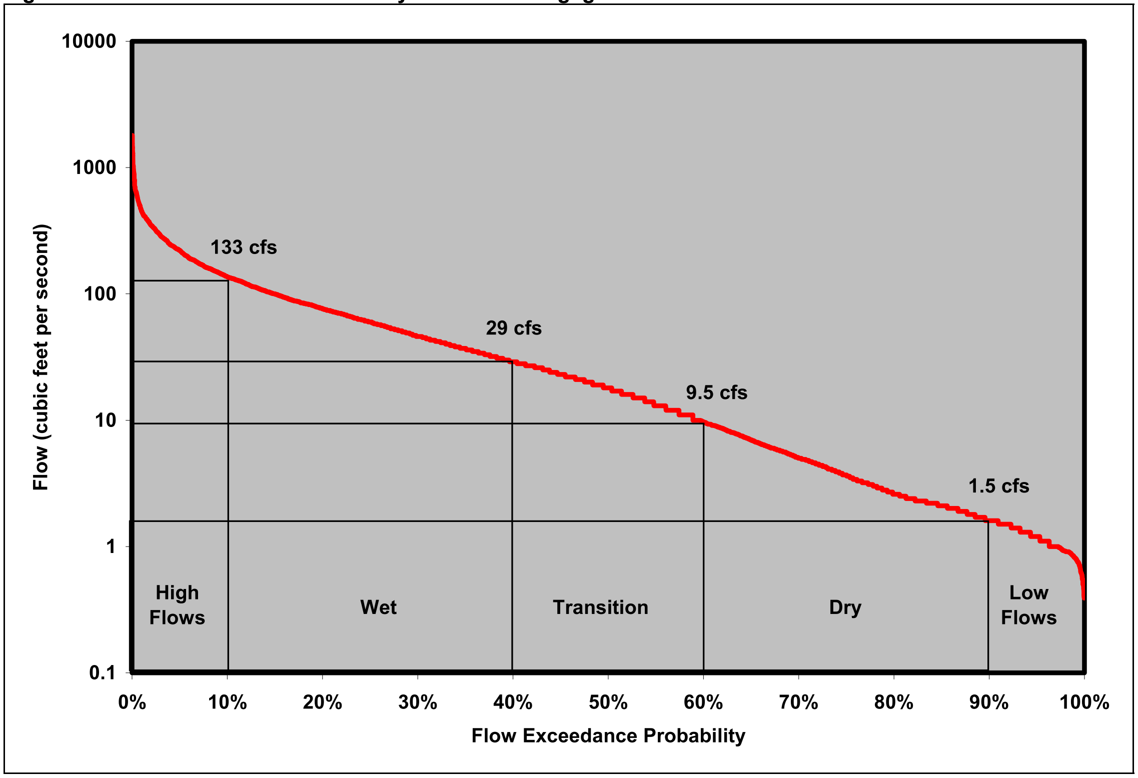
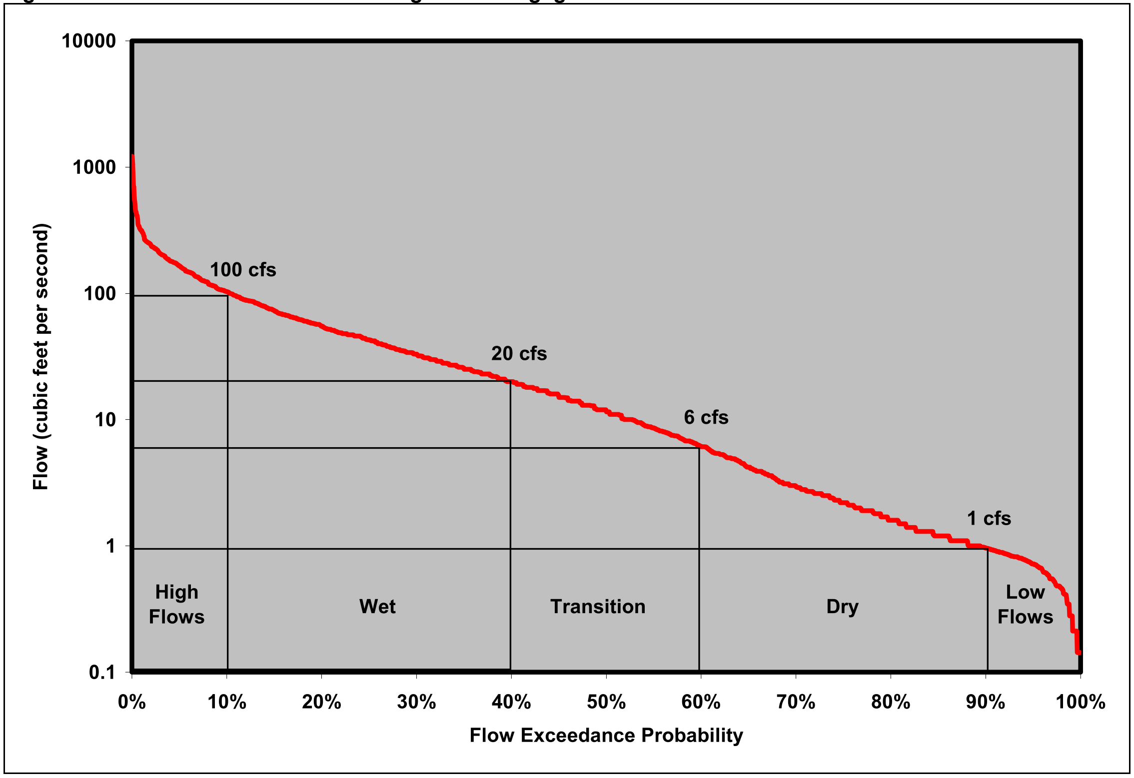


Figure 5.12. Flow Duration Curve for Regner USGS gage #14211400



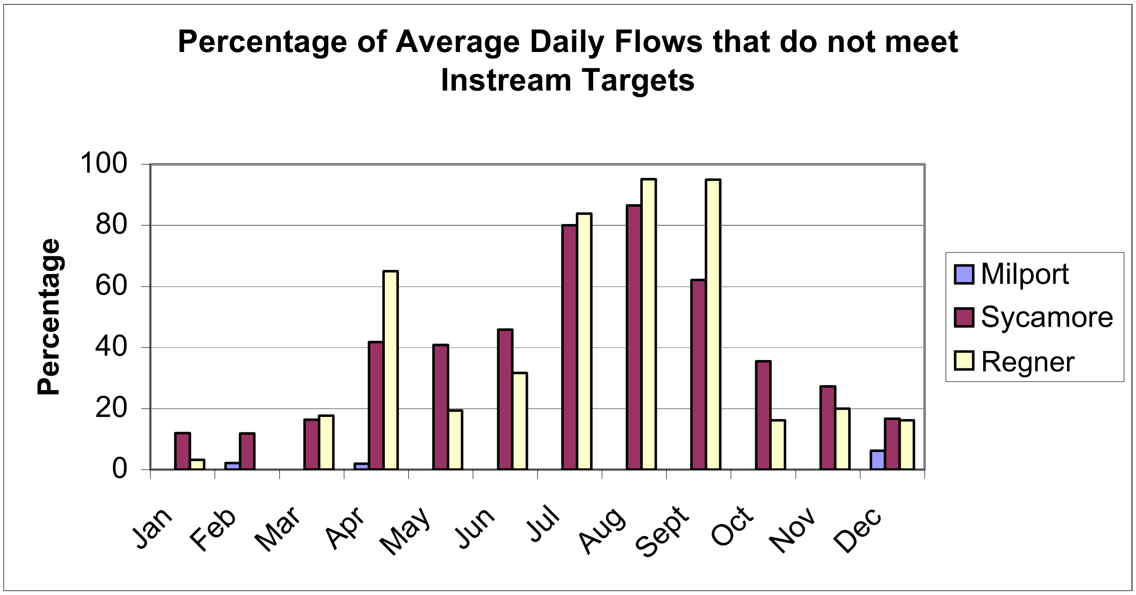
According to the State of Oregon Water Resources Department (WRD), there are 41 active surface water withdrawal rights in the Johnson Creek watershed. **Table 5.5** shows the total amount appropriated through these water rights and **Figure 5.9** (above) shows their approximate location in the watershed. It should be noted that the total amount appropriated in Johnson Creek exceeds the typical summertime stream flow and that all water rights shown in **Table 5.5** are granted year-around. ODEQ only considered consumptive year-around surface water rights in this analysis. Reservoir rights and non-consumptive or seasonally restricted rights were not considered. However, **Figure 5.9** does include the location of reservoir water rights because in-stream reservoirs in the upper watershed have the potential to contribute to the overall heat load. These water rights generally date back several decades and may or may not be currently exercised. For example, a water right for 2.19 cubic feet per second was granted in 1938 that allowed the holder to divert the effluent from the City of Gresham's municipal sewage treatment plant for irrigation. The water right is still listed as "non-cancelled" although the City of Gresham abandoned the plant in the 1950s (this withdrawal is not included in **Table 5.5**). A water right must be exercised at least once every five years to remain valid. If it is not, it is forfeited. The Oregon Water Resources Department is required to begin forfeiture proceedings when they discover abandoned water rights (Bastasch 1998).

The State of Oregon Departments of Fish and Wildlife (ODFW), Environmental Quality and Parks and Recreation have the ability to apply for instream water rights to support aquatic life, minimize pollution and maintain recreational values. The priority dates of instream water rights are assigned according to the date of the application. ODFW obtained "in stream" water rights for Crystal Springs and Johnson Creeks in an effort to protect summer stream flows for the benefit of salmonids. The priority date on the ODFW water rights is April 30, 1991. The amount of stream flow that was requested varies by month, but ranges from 10 to 15 cubic feet per second for Crystal Springs Creek and 2 to 25 cubic feet per second for Johnson Creek. **Figure 5.13** shows how often the ODFW-requested flows are NOT met at various USGS flow monitoring stations along Johnson Creek (Adolfson 2003). **Figure 5.9** shows where these flow monitoring stations are located in the watershed.

Table 5.5. Johnson Creek Watershed Surface Water Withdrawals

Source	Permit Number	Use	Priority Date	Rate of Diversion (cubic feet per second)
JOHNSON CREEK				
Spring	994	Irrigation + Domestic	1911	0.33
Spring	6929	Domestic + Lawn	1925	0.01
Spring	7056	Irrigation	1925	0.01
Spring	7857	Domestic	1927	0.1
Spring	12317	Irrigation	1935	0.18
Spring	21740	Irrigation	1952	0.14
Unnamed Stream	36170	Irrigation	1972	0.01
Johnson Creek	640	Manufacturing	1911	0.5
Johnson Creek	4524	Manufacturing	1920	1.0
Johnson Creek	5540	Irrigation	1922	0.016
Johnson Creek	6343, 70	Irrigation	1924	0.03
Johnson Creek	6573	Irrigation	1924	0.1
Johnson Creek	6620	Irrigation	1925	0.05
Johnson Creek	6833	Irrigation	1925	0.06
Johnson Creek	7215	Irrigation	1926	0.05
Johnson Creek	7269	Irrigation	1926	0.06
Johnson Creek	7743	Irrigation + Domestic	1927	0.23
Johnson Creek	8133	Irrigation	1927	0.01
Johnson Creek	9636	Manufacturing	1930	0.1
Johnson Creek	10845	Irrigation	1932	0.1
Johnson Creek	10605	Irrigation	1932	0.05
Johnson Creek	11670	Irrigation	1935	0.25
			SUBTOTAL:	**3.4**
CRYSTAL SPRINGS CREEK				
Spring	26577	Irrigation	1960	0.01
Spring	27144	Domestic	1961	0.005
Crystal Springs Cr.	9496	Domestic + Fish Culture	1930	3.0
Crystal Springs Cr.	11148	Irrigation	1934	1.0
Crystal Springs Cr.	30822,29,46,99	Irrigation	1965	2.04
Crystal Springs Cr.	31807	Irrigation	1966	0.005
Crystal Springs Cr.	32907	Air Conditioning / Heating	1967	0.16
Crystal Springs Cr.	33292	Irrigation	1968	0.01
Crystal Springs Cr.	38629	Irrigation	1975	0.03
Crystal Springs Cr.	50185	Irrigation	1987	0.01
			SUBTOTAL:	**6.3**
OTHER TRIBUTARIES				
Butler Cr	23074, 569	Irrigation	1954	0.32
Heiney Spring	8389	Domestic + Lawn	1927	0.1
Hieny Creek	24173	Irrigation	1956	0.96
Kelley Creek	6891	Domestic + Lawn	1925	0.02
Mitchell Creek	11315	Domestic	1934	0.02
Unnamed Stream	51488	Irrigation	1991	1.63
Unnamed Stream	5166	Irrigation + Domestic	1921	0.11
Unnamed Stream	5480	Irrigation	1922	0.2
Veterans Creek	5844	Irrigation	1923	0.06
			SUBTOTAL:	**3.4**
			GRAND TOTAL:	**13.1**

Figure 5.13. Percent of Days Average Flows failed to meet ODFW Instream Water Right Applications at Various locations along Johnson Creek. (Adolfson 2003)



Land Use

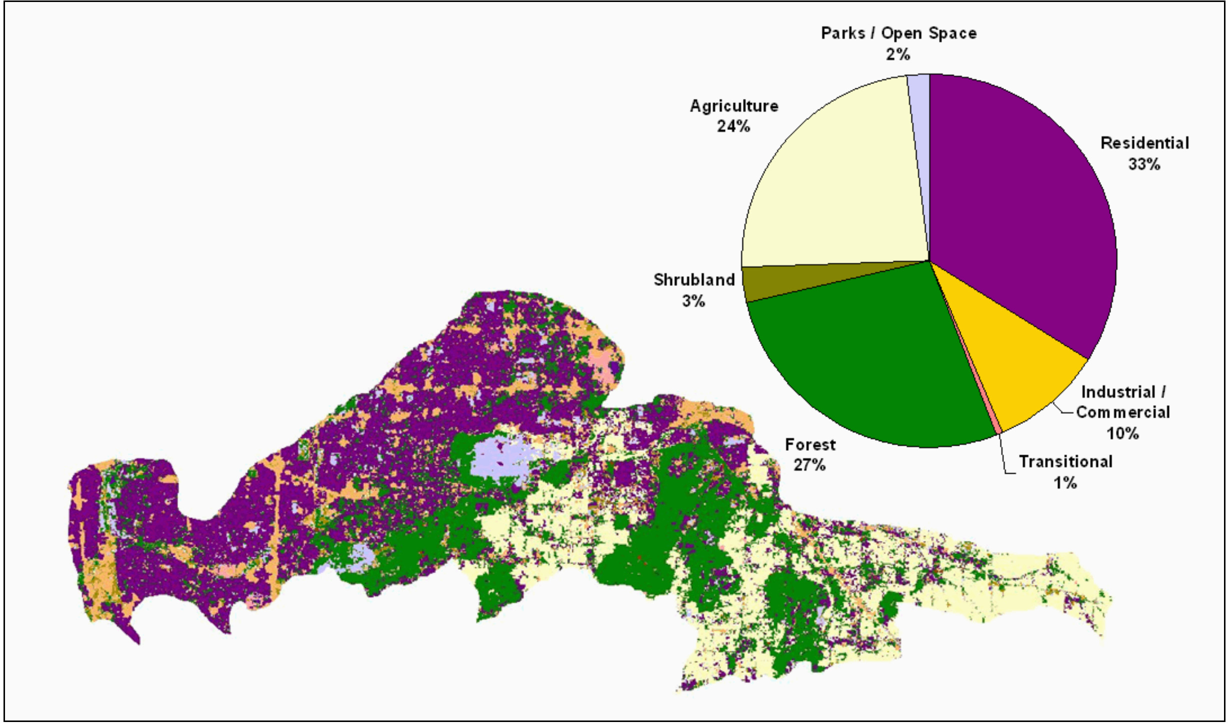
Human population in the Johnson Creek Watershed has grown rapidly, increasing from 96,000 in 1980 to an estimated 164,000 as of 1998. Seventy-two percent of the watershed is within the urban growth boundary (Meross 2000).

Many kinds of land use are found within the watershed including commercial and industrial areas, residential areas and various agricultural uses. Many agricultural areas in the upper watershed are dominated by container and in-ground plant nursery operations. Spatial distribution of land use is shown in **Figure 5.14**. Agriculture land uses occupy approximately 24% of the watershed, mostly in the upper portions of Johnson Creek and in the Kelley Creek watersheds. Approximately 10% of the basin is currently being used for commercial and industrial purposes. Commercial and industrial uses are primarily located north of Johnson Creek and in the western (urban) portion of the watershed. Residential use occupies approximately 33% of the basin, with higher density development in the urban areas and a mix of low density residential and “hobby farms” between the urban and commercial agricultural areas in the upper watershed.

If land uses within the watershed develop according to city and county comprehensive land use plans, the proportion of residential land use will increase and the proportion of agricultural and open space land will decrease. According to the Johnson Creek Resource Management Plan, *“future land use is expected to be 63 percent low-density residential, 22 percent farmland and open space, 9 percent commercial and industrial, and 6 percent high-density residential”* (Woodward-Clyde 1995).

Johnson Creek’s water quality, riparian areas, stream channel characteristics, and hydrology have been significantly altered by past development and will continue to benefit or suffer as a result the future development choices made by jurisdictions in the watershed.

Figure 5.14. Johnson Creek Land Use Spatial Distribution (Digital data from the Oregon State Service Center for GIS)



Tryon Creek Watershed

Introduction

Tryon Creek is a seven mile, perennially flowing stream located in southwest Multnomah County and northwest Clackamas County, within the city boundaries of Portland and Lake Oswego. It originates in the West Hills of Portland and flows in a southeasterly direction from Multnomah Village, through the Tryon Creek State Park, to its confluence with the Willamette River in Lake Oswego. The Creek is one of the major remaining free flowing tributaries that descend Portland's West Hills. Major tributaries to Tryon Creek include Falling and Arnold Creeks. Tryon Creek is primarily an open stream system, with the exceptions being culverts at road crossings (PSU, 2003). Tryon Creek has large seasonal fluctuations in water volume. It also carries large amounts of stormwater run-off during the winter and carries water from underground aquifers that surface through springs and seeps during the summer months.

Tryon Creek Canyon was logged in the 1880s by the Oregon Iron Co. to provide fuel for an iron smelter in Lake Oswego. The forest has naturally regrown into a mixed stand of red alder, douglas fir, bigleaf maple and western red cedar (PSU, 2003).

Tryon Creek State Park is a 641-acre natural day-use area located within the city limits of Portland. The park has 8 miles of hiking trails, 3.5 miles of horse trails and 3 miles of bicycle trails.

Jurisdictions and Land Use

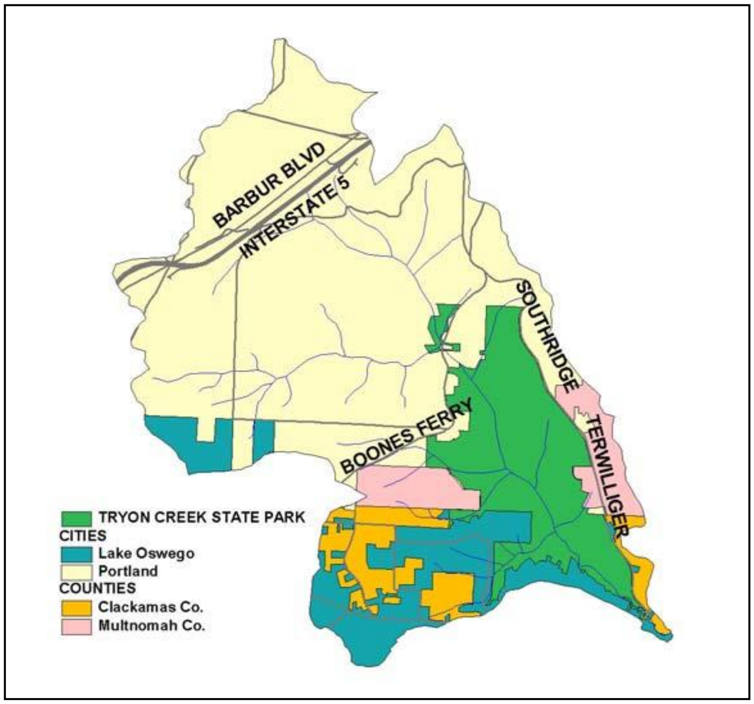
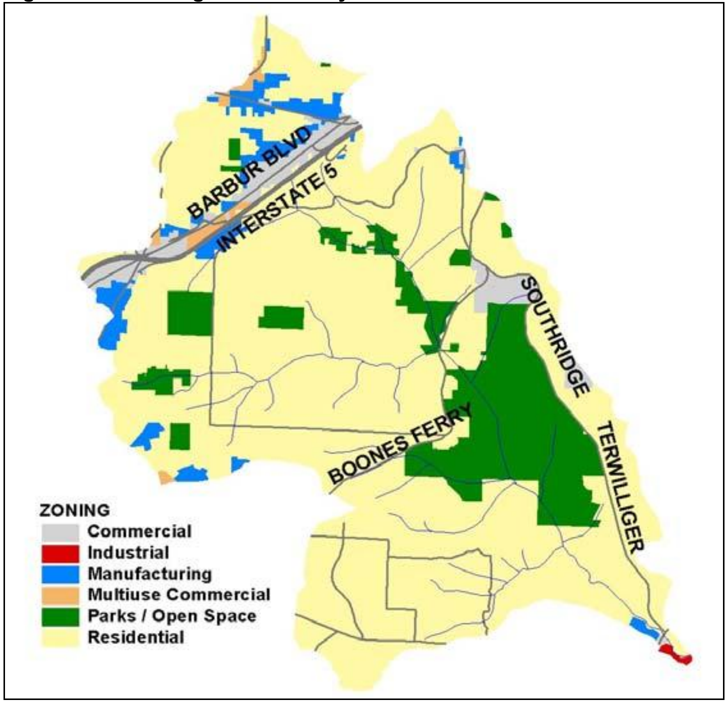


Figure 5.15. Jurisdictions within the Tryon Creek Watershed

Political jurisdictions include the Cities of Portland and Lake Oswego, portions of unincorporated Multnomah and Clackamas counties and Tryon Creek State Park (**Figure 5.15**). Zoning in the watershed is almost exclusive residential, with a relatively large proportion of parks and open space zoning due to the presence of Tryon Creek State Park (**Figure 5.16**). Pacific Habitat Services (1997) notes that "urban development of the upper watershed outside the Park combined with past logging within the Park appear to have substantially modified hydrologic conditions and vegetation characteristics". The City of Portland (1997) analyzed current and future zoning scenarios in the upper watershed and concluded that future zoning will result in increases in commercial (from 3.7% to 17.5%) and open spaces (from 14.4% to 24.2%) zoning and decreases in residential (from 77.5% to 56.3%) zoning in the watershed. Increases in the open spaces zoning reflects an effort to protect stream buffers. However, overall impervious area was calculated at 26% currently and 28% under future zoning conditions.

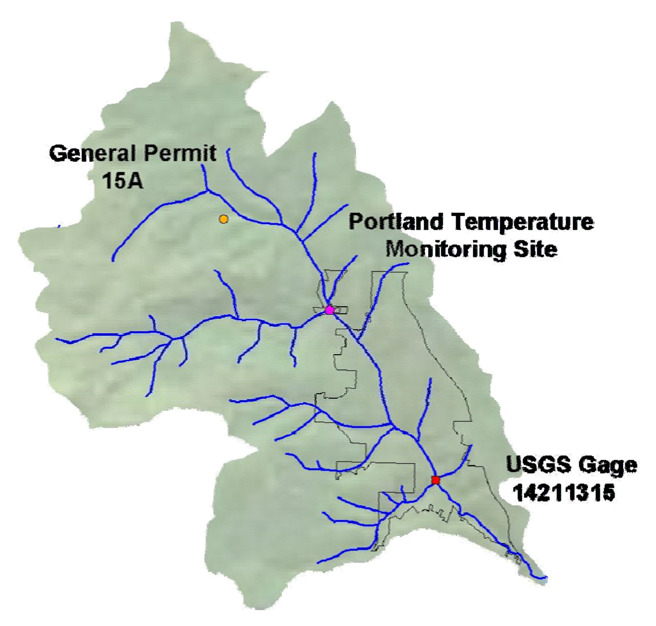
Figure 5.16. Zoning within the Tryon Creek Watershed



Hydrology and Water Rights

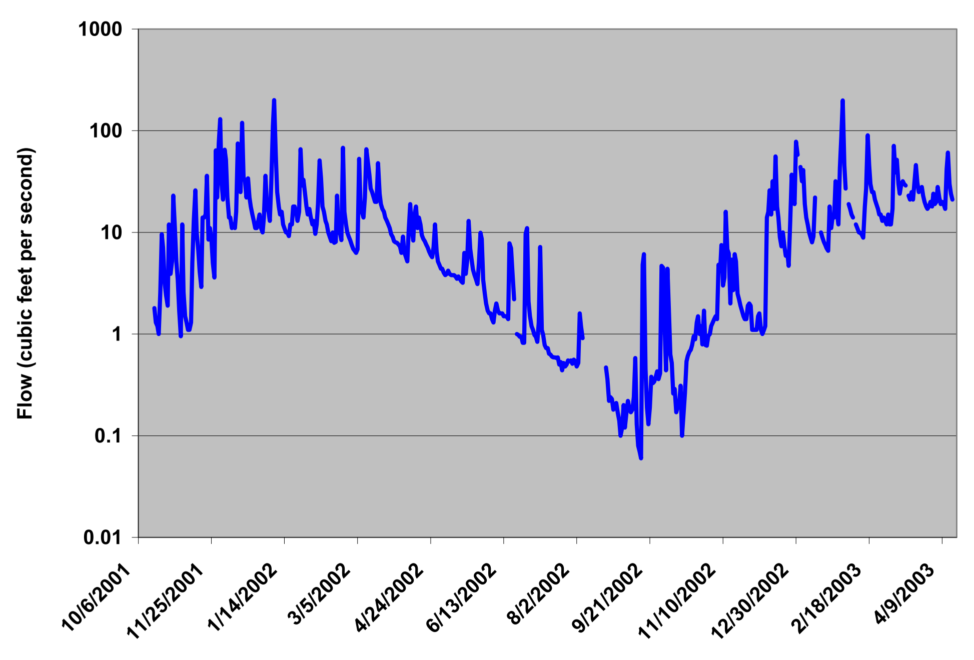
The Tryon Creek Watershed has experienced development-related impacts to its natural hydrology that may influence stream temperatures. Of these, altered channel morphology and reduction of summertime base flows due to increases in impervious surfaces in the watershed probably have the most impact on stream temperatures (PHS 1997). A U.S. Geological Survey (USGS) flow gauging station, operated in cooperation with the City of Portland, is located in the lower watershed within the boundaries of Tryon Creek State Park (**Figure 5.17**).

Figure 5.17. Location of Tryon Creek USGS gauging station #14211315 and NPDES General Permit 15A



The gauging station has been operational since October, 2001. High flows of approximately 200 cfs occurred in January of 2002 and 2003. Low flow conditions, generally between 0.1 and 0.5 cfs, occurred in September and October of 2002. Given the short period of record available for this monitoring location, long term statistical analysis of flow conditions is not yet possible. However, the abrupt peaks in the hydrograph suggest a "flashy" stream condition brought on by large amounts of impervious surfaces in the watershed (**Figure 5.18**).

Figure 5.18. Tryon Creek Flow Conditions as measured at USGS gage 14211315



According to WRD, there are 17 active surface water withdrawal rights in the Tryon Creek Watershed. **Table 5.6** shows the total amount appropriated through these water rights and **Figure 5.19** shows their location in the watershed. It should be noted that the total amount appropriated (0.41 cfs) exceeds the total stream flow measurements that were made during the summer of 2002. These water rights generally date back several decades and may or may not be currently exercised. A water right must be exercised at least once every five years to remain valid. If it is not, it is forfeited. WRD is required to begin forfeiture proceedings when they discover abandoned water rights (Bastasch 1998).

Figure 5.19. Location of Tryon Creek Surface Water Points of Diversion

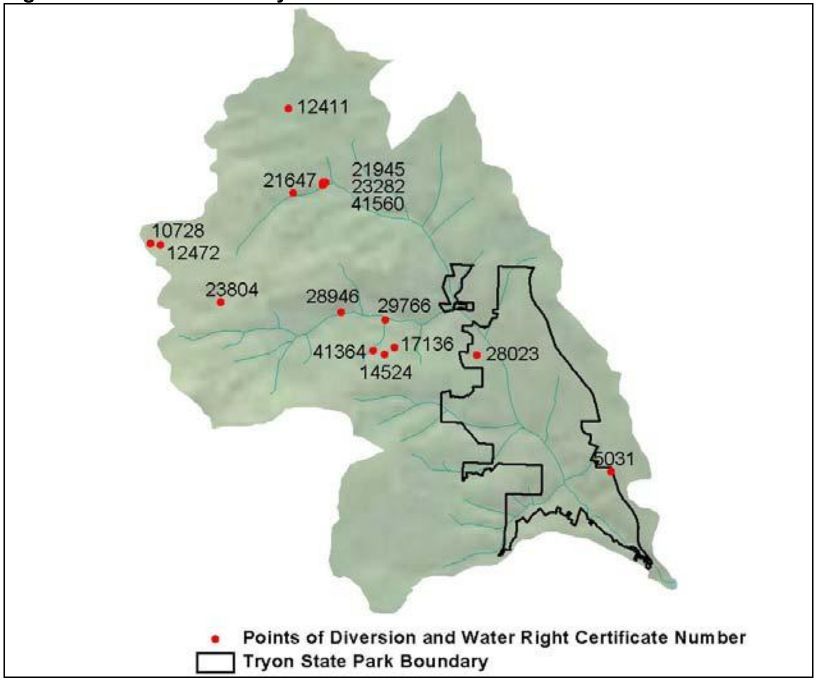
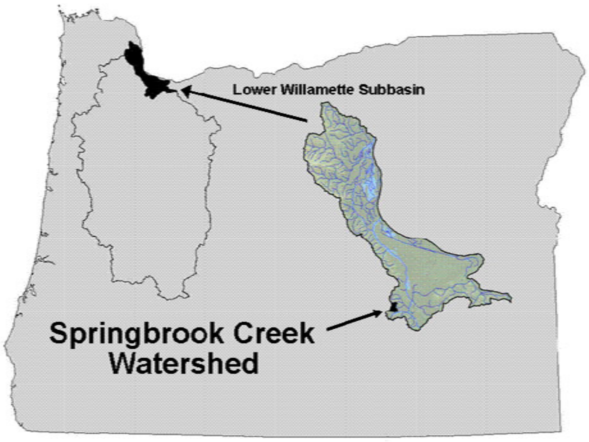


Table 5.6. Tryon Creek Watershed Surface Water Withdrawals

Source	Certificate #	Use	Priority Date	Rate of Diversion (cfs)
FALLING CR.	12472	Irrigation	1938	.01
FALLING CR.	21647	Irrigation	1946	.01
FALLING CR.	23282	Irrigation	1955	.005
SPRING	28023	Irrigation	1938	.01
SPRING	14524	Domestic + Lawn	1941	.02
SPRING	5031	Irrigation + Domestic	1922	.18
SPRING	10728	Domestic + Lawn	1929	.05
TRYON CR.	21945	Irrigation	1951	.004
TRYON CR.	29766	Irrigation	1959	.01
TRYON CR.	41560	Irrigation	1962	.01
UNNAMED CR.	17136	Manufacturing	1941	.0175
UNNAMED CR.	17136	Irrigation	1941	.0125
UNNAMED CR.	28946	Irrigation	1953	.03
UNNAMED CR.	41364	Irrigation	1967	.01
UNNAMED CR.	41364	Domestic	1967	.01
UNNAMED CR.	23804	Irrigation	1952	.01
UNNAMED CR.	12411	Irrigation	1937	.01
			TOTAL	**0.41 cfs**

Springbrook Creek Watershed

Introduction



The Springbrook Creek Watershed drains 1219 acres (1.95 square miles) within the city limits of Lake Oswego, Oregon. The stream drains an area from west of the Oswego Country Club northwest as far as Mountain Park and eventually flows into Oswego Lake at the lake's northern shore. The terrain is mostly rolling with localized areas of steep banks and flatter terrain surrounding Springbrook Creek. Elevation ranges from 974 feet at the top of Mt. Sylvania to 98.6 feet where the creek enters Oswego Lake.

Land Use and Ownership

Political jurisdictions in the watershed include portions of the Cities of Lake Oswego and Portland as well as very small portions of unincorporated areas in Multnomah and Clackamas Counties. The City of Lake Oswego is the dominant jurisdiction in the watershed, followed by the City of Portland, Clackamas County and Multnomah County.

Land use along Springbrook Creek is mainly residential with some commercial development along Kruse Way, Lower Boones Ferry Road, along McNary Parkway, and in the Mountain Park area. Relatively high density residential and associated large impervious areas exist within all of the upper reaches and headwater areas of Springbrook Creek and its tributaries (Wolfe 1998). **Figures 5.20** and **5.21** show the political boundaries, geographic distribution of zoning and land use in the Springbrook Creek watershed. It should be noted that the City of Lake Oswego requires the preservation of trees over 5 inches in diameter where possible on new building lots as well as one for one replanting for trees that are removed. Over the years, this has resulted in many residential lots with significant canopy coverage and likely inflates the “forest” land use designation.

Figure 5.20. Zoning and Political Jurisdictions in the Springbrook Creek Watershed

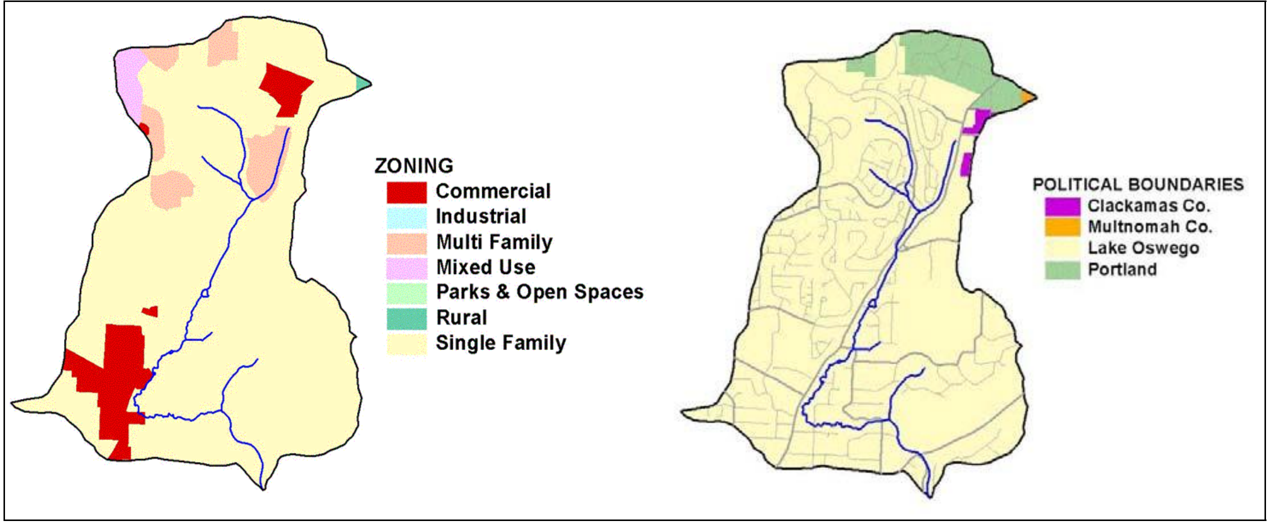
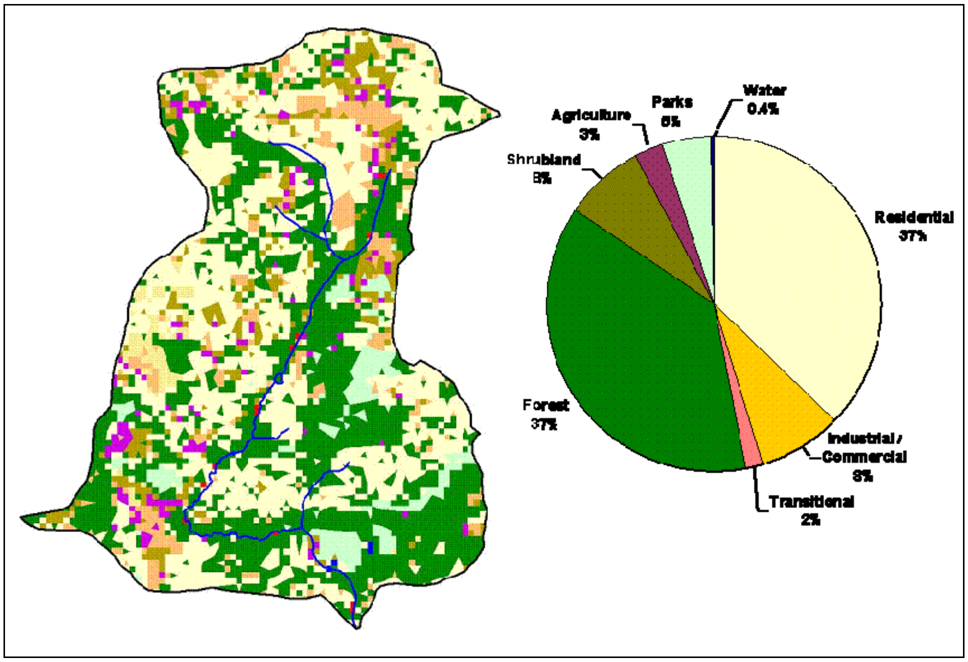


Figure 5.21. Spatial Distribution of Major Land Use Types in the Springbrook Creek Watershed


Water
0.4%
Parks
6%
Agriculture
3%
Shrubland
8%
Residential
37%
Forest
37%
Industrial/
Commercial
8%
Transitional
2%

TEMPERATURE TMDLS

TMDL Components

The TMDL components applicable to the entire Lower Willamette Subbasin are described below and are followed by sections containing watershed-specific TMDL components. ODEQ organized the chapter in this manner because there is considerable stakeholder interest in each of the individual watersheds and because a variety of analytical techniques were employed according to the characteristics of the individual watersheds. Lastly, the shade curves used to determine compliance with nonpoint source load allocations are provided at the end of this chapter and are applicable to the entire subbasin.

For all temperature 303(d) listed waterbodies in the Lower Willamette Subbasin, Oregon's temperature standard specifies that sources of anthropogenic heating may result in no more than a 0.3 ^{o}C increase in stream temperature. Since stream temperature results from cumulative interactions between upstream and local sources, the TMDL considers all surface waters that affect the temperatures of 303(d) listed waterbodies. For example, only the mainstem of Johnson Creek is 303(d) listed for temperature, but to address this listing the TMDL will assign allocations for all surface tributaries in the watershed. This concept applies throughout the subbasin. More information is provided in Appendix C, "Subbasin Temperature Analysis Summary".

Table 5.7 provides a summary of the Lower Willamette subbasin temperature TMDL components.

Table 5.7. Lower Willamette Subbasin Temperature TMDL Components

Waterbodies	Perennial and/or fish bearing (as identified by ODFW, USFW or NFMS) streams within the HUC (Hydrologic Unit Code) 17090012 – Lower Willamette.
Pollutant Identification	***Pollutants:*** Human caused temperature increases from (1) solar radiation loading and (2) warm water discharge to surface waters.
Target Identification (Applicable Water Quality Standards) ***CWA §303(d)(1)***	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 lower Willamette subbasin, as measured using the seven day average of the daily maximum stream temperature are 13.0°C during times and at locations of salmonid and steelhead spawning, 18.0°C during times and at locations utilized by salmon and trout for rearing and migration, and 20.0°C during times and at locations when the mainstem Willamette River is utilized as a migration corridor. Natural Conditions Criteria: Where the department determines that the natural thermal potential temperature of all or a portion of a water body exceeds the biologically-based criteria in section 4 the natural thermal potential temperatures supersede the biologically-based criteria and are deemed the applicable criteria for that water body. 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.
Seasonal Variation ***CWA §303(d)(1)***	Peak temperatures typically occur in mid-July through mid-August and often exceed the salmon and trout rearing and migration criterion. Temperatures are cooler late summer through late spring but occasionally exceed the spawning criterion.
Existing Sources ***CWA §303(d)(1)***	Nonpoint source solar loading due to a lack of riparian vegetation and point source discharges of warm water.
TMDL Loading Capacity and Allocations ***40 CFR 130.2(f)*** ***40 CFR 130.2(g)*** ***40 CFR 130.2(h)***	***Loading Capacity:*** OAR 340-041-0028 (12)(b)(B) states that no more than a 0.3°C increase in stream temperature above the applicable biological criteria or the natural condition criteria as a result of human activities is allowable. This condition is achieved when the cumulative effect of all point and nonpoint sources results in no greater than a 0.3 °C (0.5 °F) increase at the point of maximum impact. Loading capacity is the heat load that corresponds to the applicable numeric criteria plus the small increase in temperature of 0.3°C provided with the human use allowance. ***Load Allocations (Nonpoint Sources)*****:** Background solar radiation loading based on system potential vegetation near the stream. An additional heat load equal to 0.05°C temperature increase at the point of maximum impact is available but is not explicitly allocated to individual sources. ***Waste Load Allocations (NPDES Point Sources)*****:** Allowable heat load based on achieving no greater than a 0.3°C temperature increase at the point of maximum impact. This is achieved by limiting stream temperature increases from individual point sources to 0.075ºC. This may also be expressed as a limitation of 0.3ºC increase in 25% of the 7Q10 stream flow. Where multiple point sources discharge to a single receiving stream the accumulated heat increase for point sources is limited to 0.2˚C. ***Excess Load*****:** The difference between the actual pollutant load and the loading capacity of the waterbody. In these temperature TMDLs excess load is the difference between heat loads that meet applicable temperature criteria plus the human use allowance and current heat loads from background, nonpoint source and point source loads. Background solar radiation loading based on system potential vegetation near the stream. An additional heat load equal to 0.05°C temperature increase at the point of maximum impact is available but is not explicitly allocated to individual sources.
Surrogate Measures ***40 CFR 130.2(i)***	Translates Nonpoint Source Load Allocations Site specific and ecoregionally based effective shade targets translate the nonpoint source solar radiation loading capacity.
Margins of Safety ***CWA §303(d)(1)***	Implicit Margins of Safety are demonstrated in critical condition assumptions and are inherent to methodology for determination of nonpoint source loads.
Reserve Capacity	Allocation for increases in pollutant loads for future growth from new or expanded sources. Reserve capacity will be a percentage of the 0.3˚C human use allowance (HUA). The HUA will be divided among various sources. When point sources are present reserve capacity will be 0.05˚C, 17% of the HUA. Where there are no point sources in a subbasin, or less than the allowed 0.2˚C is used by point source discharges, the remainder is allocated to reserve capacity.
Water Quality Standard Attainment Analysis ***CWA §303(d)(1)***	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.

Pollutant Identification

With a few exceptions, such as in cases where violations are due to natural causes, ODEQ must establish a TMDL for any waterbody designated on the 303(d) list as violating water quality standards. A TMDL is the total amount of a pollutant (from all sources) that can enter a specific waterbody without violating water quality standards.

Water temperature change is an expression of heat energy exchange per unit volume:

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

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

Beneficial Use Identification

Oregon Administrative Rules (OAR 340 – 41 – 340, Table 340A) lists the beneficial uses occurring within the Willamette River Basin tributaries and are applicable to streams within the Lower Willamette Subbasin. Numeric and narrative water quality standards are designed to protect the most sensitive beneficial uses. Resident fish and aquatic life and salmonid spawning, rearing and migration are the most sensitive temperature-related beneficial uses occurring in the watershed.

The distribution of fish in the subbasin varies through the year and temperature impairment is in part a function of fish habitat requirements and usage. .

Salmonid Stream Temperature Requirements

Water temperature significantly affects the distribution, health and survival of salmonids in Oregon. Since salmon are ectothermic (cold-blooded), their survival is dependent on external water temperatures and they will experience adverse health effects when exposed to temperatures outside their optimal range. Salmonids have evolved and thrived under the water temperature patterns that historically existed in Oregon's rivers and streams. Although historical stream temperatures likely exceeded optimal conditions for salmonids at times during the summer months on some rivers, the temperature diversity in unaltered river systems provided enough cold water habitat during the summer months to allow salmonid populations as a whole to thrive.

If stream temperatures become too hot, fish die almost instantaneously due to denaturing of critical enzyme systems in their bodies (Hogan, 1970). The ultimate *instantaneous lethal limit* occurs in high temperature ranges (upper-90°F).

These temperatures cause death of cold-water fish species during exposure times lasting a few hours to one day. The exact temperature at which a cold water fish succumbs to such a thermal stress depends on the temperature that the fish is acclimated to and on particular development life-stages. This cause of mortality, termed the *incipient lethal limit*, results from breakdown of physiological regulation of vital processes such as respiration and circulation (Heath and Hughes, 1973).

The most common and widespread cause of thermally induced fish mortality is attributed to interactive effects of decreased or lack of metabolic energy for feeding, growth or reproductive behavior, increased exposure to pathogens (viruses, bacteria and fungus), decreased food supply (impaired macroinvertebrate populations) and increased competition from warm water tolerant species. This mode of thermally induced mortality, termed indirect or *sub-lethal*, is more delayed, and occurs weeks to months after the onset of elevated temperatures (mid-60°F to low-70°F). **Table 5.9** summarizes the modes of cold water fish mortality.

Table 5.9. Modes of Thermally Induced Cold Water Fish Mortality (Brett, 1952; Bell, 1986, Hokanson et al., 1977)

Modes of Thermally Induced Fish Mortality	Range	Time to Death
Instantaneous Lethal Limit – Denaturing of bodily enzyme systems	> 90°F > 32°C	Instantaneous
Incipient Lethal Limit – Breakdown of physiological regulation of vital bodily processes, namely: respiration and circulation	70°F - 77°F 21°C - 25°C	Hours to Days
Sub-Lethal Limit – Conditions that cause decreased or lack of metabolic energy for feeding, growth or reproductive behavior, encourage increased exposure to pathogens, decreased food supply and increased competition from warm water tolerant species	64°F - 74°F 18°C - 23°C	Weeks to Months

Target Criteria Identification

The purpose of Oregon's stream temperature standard is to protect designated temperature-sensitive beneficial uses in waters of the State, including specific salmonid life stages. Several numeric criteria that are specific to these life stages are used to gage whether surface waters are "water quality limited" with respect to temperature. A seven-day moving average of daily maximum temperature (7-day statistic) was adopted as the measure of the stream temperature standard. Absolute numeric criteria may be considered action levels and indicators of water quality standard compliance. **Table 5.8** shows the numeric temperature criteria that are applicable to specific salmonid life stages under Oregon's standard. Oregon's standard also specifies where and when the specific salmonid life stages occur and, therefore, where and when the numeric criteria apply. A subbasin-wide distribution and timing map is provided in **Figures 5.22** and **5.23**. **Figure 5.22** delineates where the numeric rearing and migration standards of 18°C and 20°C apply. The 16°C and 18°C criteria apply at all times of year except during designated spawning through fry emergence periods, during which a more stringent criterion is applied. **Figure 5.23** delineates where and when the numeric spawning through fry emergence standard of 13°C applies. Fish use maps and tables to follow show salmonid distribution and timing and are consistent with those delineated in OAR 340, Division 41, with some tables providing more detailed timing and use information. ODEQ primarily relied on the ODFW for information on fish distribution and life stage timing. This information can be viewed on the internet at http://osu.orst.edu/dept/nrimp/information/fishdistdata.htm. The database is the product of a multi-year effort by ODFW to develop consistent and comprehensive fish distribution data for a number of salmonid species. ODFW compiled and reviewed fish distribution and timing information from a number of sources, including state and federal agencies, federal land management agencies, tribal entities, watershed councils and other interested public or private organizations. ODEQ believes the ODFW database is scientifically sound and represents the best information readily available.

Table 5.8. 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

Figure 5.22. Fish Use Designations and Associated Numeric Temperature Criteria for the Lower Willamette Subbasin.

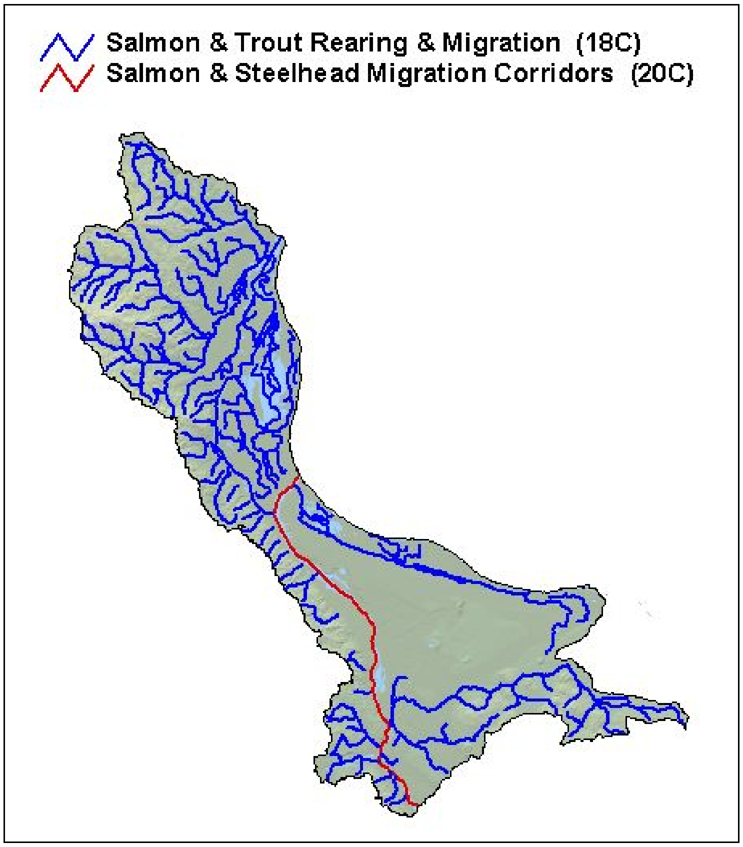
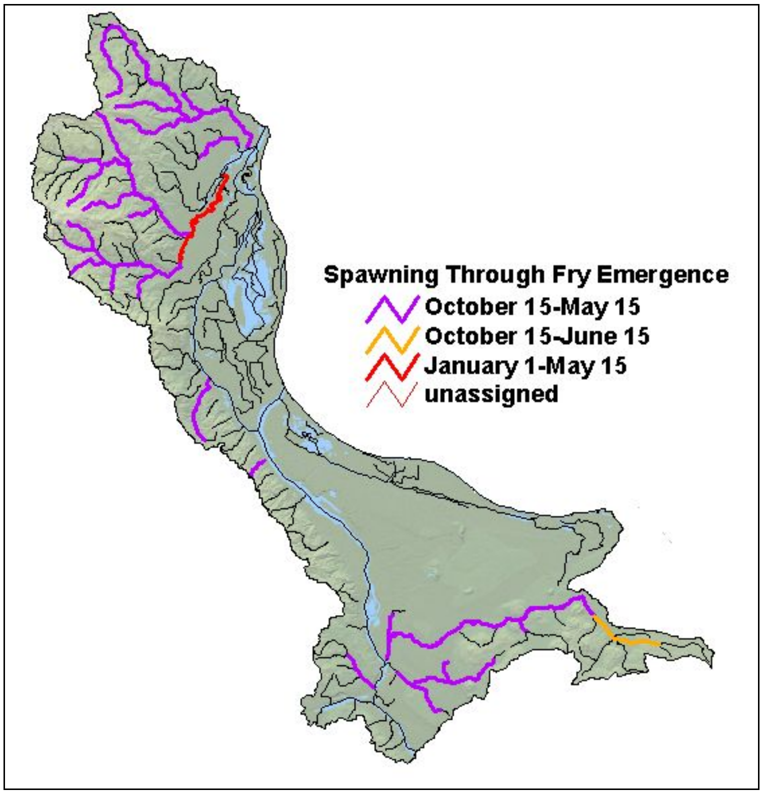


Figure 5.23. Salmon and Steelhead Spawning Through Fry Emergence Use Designations for the Lower Willamette Subbasin.



The temperature standard contains a narrative portion describing conditions under which the numeric criteria may be superseded. Language in the standard acknowledges that in some instances the biologically-based numeric criteria may not be achieved even when waters are in their natural condition and specifies that stream temperatures achieved under natural conditions shall be deemed to be the applicable temperature criteria for that water body. In other words, a stream that does not meet one or more of the numeric temperature criteria, but is free from anthropogenic influence, is considered to be at the natural thermal potential and therefore in compliance with the temperature standard.

Lastly, Oregon's temperature standard contains provisions that limit the cumulative anthropogenic heating of surface waters to no more than 0.3 degrees Celsius (0.5 degrees Fahrenheit) in almost all instances. Oregon chose to include a 0.3°C human use allowance for insignificant additions of heat in waters that exceed applicable numeric criteria. This last portion of the standards is the one which most directly impacts the loading capacity and allocations established in these TMDLs. 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).

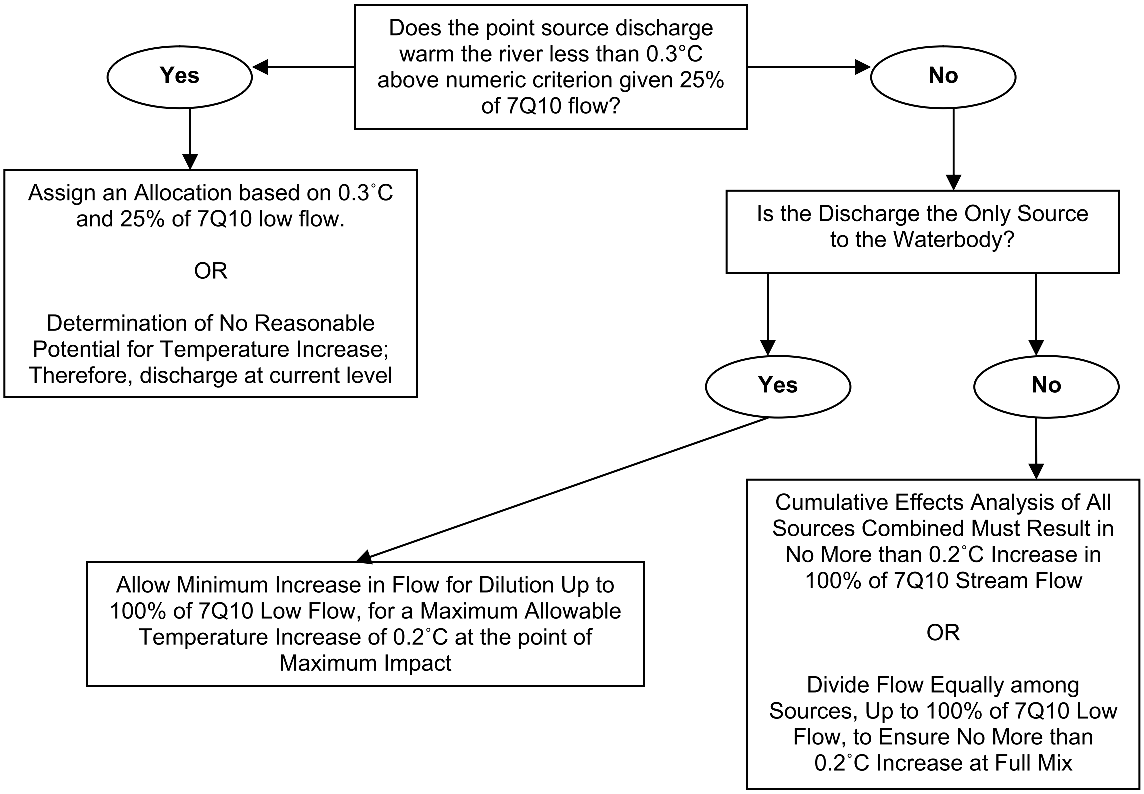
Point Source Methodology

Waste load allocations are heat load limits assigned to individual point sources of treated industrial and domestic waste. Waste load allocations are provided for all NPDES facilities that have reasonable potential to warm the receiving stream when the applicable criteria are exceeded. Point source facilities in the Lower Willamette Subbasin that are allocated heat load limits in this TMDL are shown in **Table 5.19**.

Discharges were screened to determine which would likely receive a waste load allocation based on the type of discharge, and the volume and temperature of effluent. General permits that are unlikely to discharge significant volumes of warm water during critical periods (e.g., stormwater permits) are not expected to have a reasonable potential to increase instream temperatures. General permits that discharge heated effluent (e.g., non-contact cooling water) were considered as potential sources.

The waste load allocation flow chart on the next page assumes an allowable change in temperature above criteria of 0.3˚C within 25% of the 7Q10 low flow (a calculation of the seven-day, consecutive low flow with a ten year return frequency). This is the initial step in the development of a waste load allocation on smaller streams or when information is insufficient to allow a greater proportion of receiving water flow for mixing.

Waste load Allocation Decision Tree for Discharges of Heated Water



The resultant temperature increase in fully mixed receiving water would be limited to 0.08˚C. More than the minimum flow allowance (25% of 7Q10 low flow) may be allocated to an individual source when analysis demonstrates standards attainment. The resulting temperature increase in this scenario depends on the proportion of low flow allocated, but should not exceed the point source sector allocation of 0.2°C over the entire waterbody. Moreover, each discharge is also required to ensure the local effects of discharge will not cause impairment to health of fish by meeting thermal plume requirements adopted under OAR 340-41-0053(2)(d).

During development of a TMDL, when more than the minimum flow allowance (25% of 7Q10 low flow) is allocated, a portion of the HUA is allocated to non-point sources of heat (0.05˚C) and a portion is allocated to Reserve Capacity (0.05˚C) for future uses, leaving 0.2˚C for allocation to point sources. The resulting temperature increase in this scenario depends on the proportion of flow allocated, but will not exceed 0.2˚C in any case. Waste load allocations for all point sources in the Lower Willamette Subbasin were calculated to using a HUA of 0.3˚C and 25% of the 7Q10 low flow.

During non-critical periods, temperature limits must still be set to avoid violating water quality standards in the receiving stream or in water bodies down stream of the receiving stream. Existing and future thermal point sources in the subbasin may be permitted to discharge under the following conditions:

1) They do not cause more than a 0.3°C increase in stream temperature above the applicable criteria after mixing with 25 percent of the stream flow or at the edge of a defined mixing zone, whichever is more restrictive.

2) The sum of waste load and load allocations result in an increase in stream temperature of no greater than 0.3°C above the applicable criteria after complete mixing and at the point of maximum impact.

Pollutant trading opportunities may be available to new or existing point sources in order to offset temperature impacts.

The following equations were used to determine allowable point source heat loads and effluent temperatures. They are the basis for setting flow-based temperature limitations:

Maximum Effluent Temperature

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

where:

T_R: Temperature Criterion or upstream potential river temperature (°C or °F)
T_{WLA}: Maximum allowable point source effluent temperature (°C or °F)
ΔT_{ZOD}: Change in river temperature at edge of zone of dilution - 0.3 °C or 0.54°F allowable
Q_{ZOD}: Upstream river flow volume through zone of dilution - ¼ of 7Q10 low flow statistic (cfs)
Q_{PS}: Point source effluent discharge flow volume (cfs)

Heat Load in kcals/day

$$\text{Load (kcal/day)} = (\Delta T * 5/9) * (Q_{PS}+Q_R) * (86400000/35.3)$$

ΔT = allowable increase (0.54°F)
Q_R = ¼ of the 7Q10 Low Flow (cfs)
Q_{PS} = Point Source Flow (cfs)

The equation uses ¼ of the 7Q10 low flow as a conservative assumption. Actual instream flows are likely to be higher most of the time. Permit writers, when calculating permit limits, may base effluent limitations on actual instream and effluent flow volume at the point and time of discharge.

Margin of Safety

The Clean Water Act requires that each TMDL be established with a margin of safety (MOS). The statutory requirement that TMDLs incorporate a MOS is intended to account for uncertainty in available data or in the actual effect controls will have on loading reductions and water quality. A MOS is expressed as unallocated assimilative capacity or conservative analytical assumptions used in establishing the TMDL (e.g., derivation of numeric targets, modeling assumptions or effectiveness of proposed management actions).

The MOS may be implicit, as in conservative assumptions used in calculating the Loading Capacity, Waste Load Allocations, and Load Allocations. The MOS may also be explicitly stated as an added, separate quantity in the TMDL calculation. In any case, assumptions should be stated and the basis behind the MOS documented. The MOS is not meant to compensate for a failure to consider known sources. **Table 5.10** presents six approaches for incorporating a MOS into TMDLs.

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

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

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

Table 5.10. 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 MOS.
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.

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

Reserve Capacity

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

In those situations where the point source allocation is less than 0.2˚C or if there are no point sources, the remaining portion of the Human Use Allowance will be set aside as reserve capacity. The nonpoint source allocation will remain at 0.05˚C unless special circumstances exist that require a larger or smaller allocation.

Surrogate Measures – 40 CFR 130.2(l)

The Lower Willamette Subbasin temperature TMDLs incorporate measures other than "*daily loads*" to fulfill requirements of §303(d). These measures are termed surrogate measures. The applied surrogate measure in this temperature TMDL is percent effective shade expressed as a shade curve. Shade curves have been developed for each ecoregion within the subbasin and determine the nonpoint source load allocation. A description of this methodology is provided in the *Effective Shade Curves* section of this chapter.

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

Shade curves represent general relationships between the percent effective shade reaching the stream surface, solar radiation loading of the stream, system potential vegetation, stream aspect from north, and the width of the channel. The channel width is the distance from the edge of right bank vegetation to the edge of left bank vegetation. The definition of effective shade allows direct measurement of the solar radiation loading capacity, see Appendix C.

Because factors that affect water temperature are interrelated, the surrogate measure (percent effective shade) relies on restoring or protecting riparian vegetation to increase stream surface shade levels, reducing stream bank erosion, stabilizing channels, reducing the near-stream disturbance zone width and reducing the surface area of the stream exposed to radiant processes. Effective shade screens the water's surface from direct rays of the sun. Highly shaded streams often experience cooler stream temperatures due to reduced input of solar energy (Brown 1969, Beschta et al. 1987, Holaday 1992, Li et al. 1994).

Excess Load

The excess load is the difference between the actual pollutant load and the loading capacity of a water body. Load allocations for nonpoint sources are based on solar radiation loading under system potential riparian vegetation conditions. Point source wasteload allocations were established where appropriate to assure that the allowable heat load will not exceed the loading capacity of the receiving water body.

Columbia Slough

Table 5.15 shows that the Columbia Slough has excess load of 8.85×10^8 kilocalories per day. This amounts to a 25% increase above system potential shade conditions. In other words, the excess solar radiation loading due to anthropogenic impacts on shade increases solar radiation loading by 25%. Nonpoint source loading must decrease by 25% and point sources must meet the wasteload allocations provided in **Table 5.19** in order to achieve the TMDL.

Johnson Creek

Table 5.21 shows that Johnson Creek has excess load of 0.78×10^8 kilocalories per day. This amounts to a 51% increase above system potential shade conditions. In other words, the excess solar radiation loading due to anthropogenic impacts on shade increases solar radiation loading by 51%.

COLUMBIA SLOUGH AND FAIRVIEW CREEK WATERSHED

Seasonal Variation

The Columbia Slough experiences warming starting in late spring and extending into the fall. Maximum temperatures typically occur in June, July and August (**Figures 5.24 and 5.25)**. Exceedance of the 18.0 °C (64.4°F) numeric criterion typically occurs throughout the summer months in the lower Slough and in Fairview Creek. Again, Fairview Creek is not 303d listed for temperature, but watershed-wide temperature targets developed to achieve the Columbia Slough temperature TMDL will also apply to the Fairview Creek Watershed.

Figure 5.24. 7-Day Average of the Daily Maximum Stream Temperature in the Columbia Slough at NE 21st Avenue (Data collected by the City of Portland)

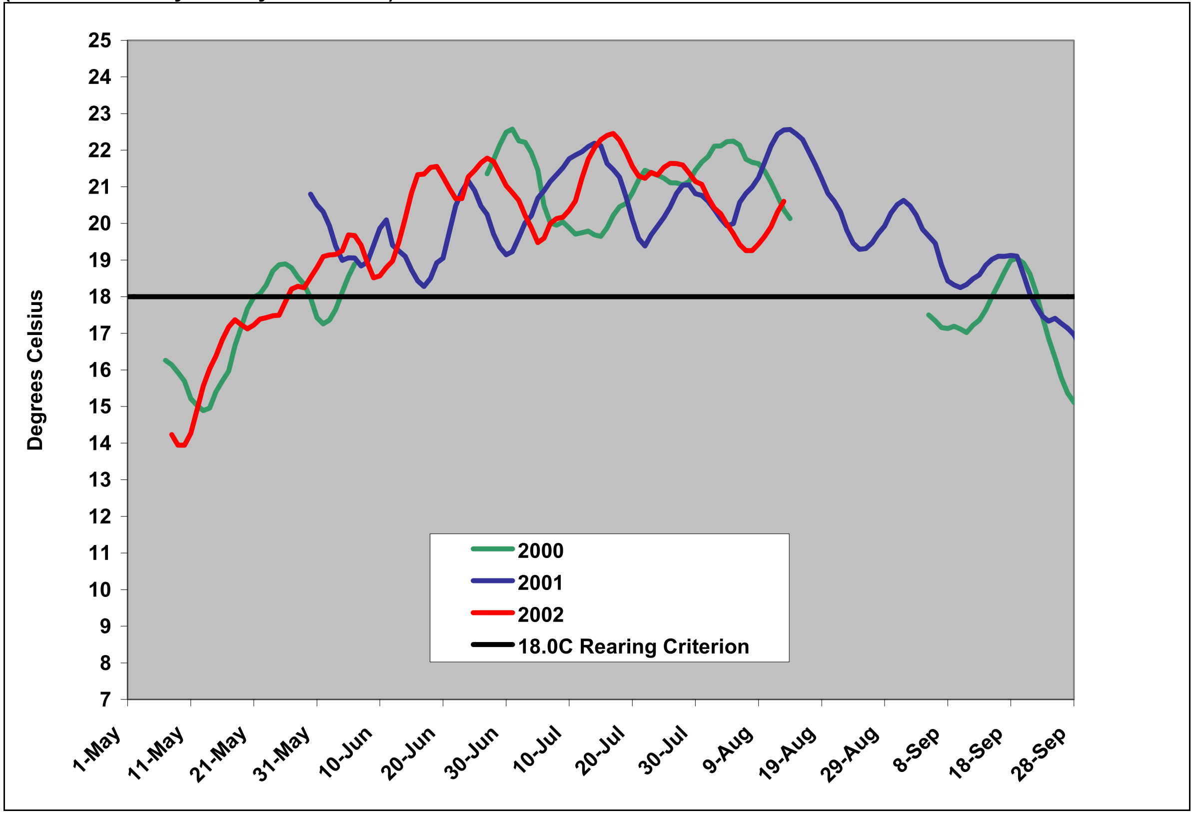
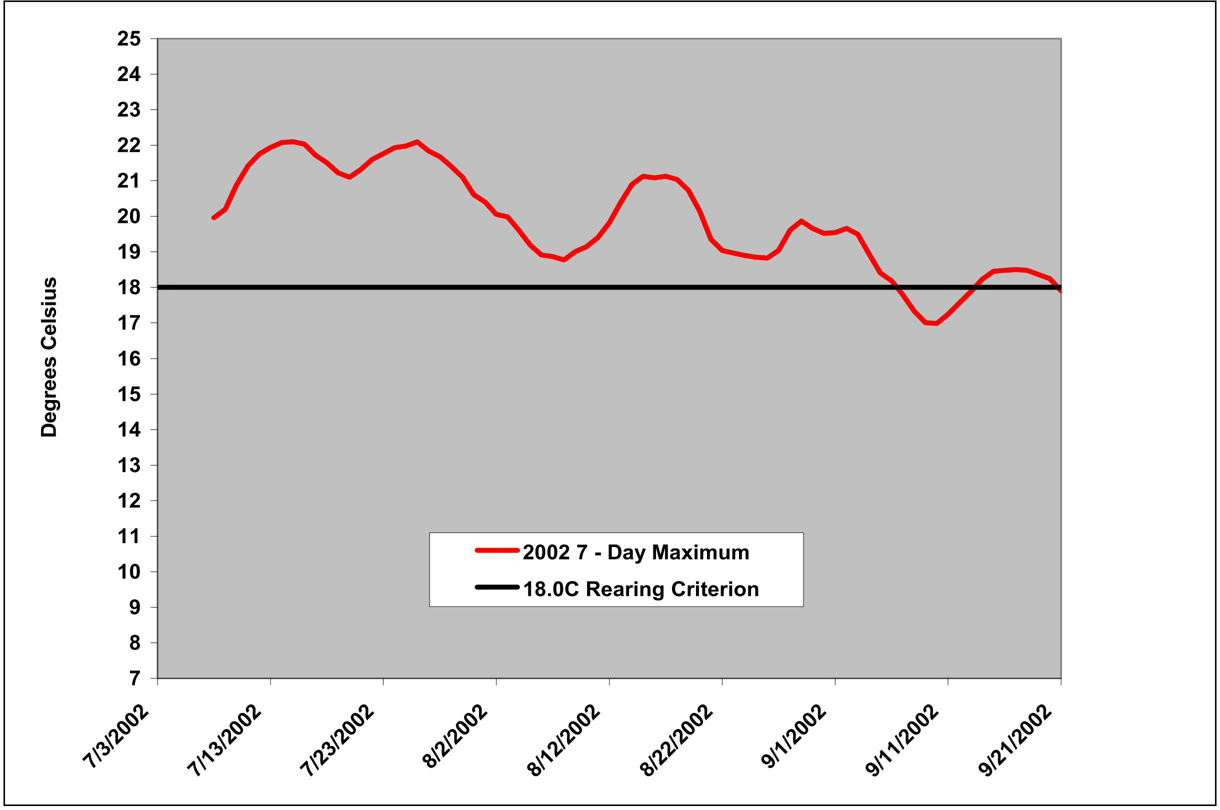


Figure 5.25. 7-day Average of the Daily Maximum Stream Temperature in Fairview Creek at City of Fairview (Country Inn) (Data collected by the Student Watershed Research Project)



Existing Heat Sources

Nonpoint Sources

Settlement in the Columbia Slough Watershed, starting in the mid-1800s, brought about significant changes in the near stream vegetation and hydrologic characteristics of the watershed. Historical development, agricultural and logging practices altered the stream morphology and hydrology and decreased the amount of riparian vegetation. Timber harvest and flood control activities cleared streams and riparian corridors of fallen trees and large woody debris, with riparian areas logged down to the stream banks. Drainage and stream channelization has occurred throughout the watershed.

More recently, increases in population have resulted in urbanization of much of the watershed. Conversion of forest and pasture to residential and commercial development is extensive, which resulted in reduced riparian vegetation and radically altered hydrology.

Riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, riparian condition, channel morphology and hydrology are affected by land use activities and the current “plumbing” of the Slough.

Specifically, the elevated summertime stream temperatures attributed to anthropogenic nonpoint sources result from:

1. ***Near stream vegetation disturbance or removal*** *reduces stream surface shading via decreased riparian vegetation height, width and/or density, thus increasing the amount of solar radiation reaching the stream surface (shade is commonly measured as percent effective shade or open sky percentage). Riparian vegetation also plays an important role in shaping the channel morphology, resisting erosive high flows and maintaining floodplain roughness.*

2. ***Channel modifications and widening** (increased width to depth ratios) increases the stream surface area exposed to energy processes, namely solar radiation. Near-stream disturbance zone (NSDZ) widening decreases potential shading effectiveness of shade-producing near-stream vegetation. Undersized culverts in several areas of the Slough prevent timely movement of water through the system, increasing exposure to solar radiation.*
3. ***Macrophyte (rooted aquatic plants) growth** can significantly affect temperatures in the Columbia Slough because the greater channel friction raises water levels and increases travel time. The growth of aquatic macrophytes is certainly not entirely attributable to anthropogenic activity, but their management may be an important tool in improving temperature conditions in the Slough and they were therefore included in the modeling and analysis for this TMDL.*

Point Sources

Point source discharges can be sources of localized stream heating in the Columbia Slough. The temperature standard specifies that when the applicable temperature criterion is exceeded, there shall be no more than a 0.3°C increase – the practical limit of measurability - in stream temperature due to anthropogenic (human) activities. Point source dischargers to the Columbia Slough are discussed fully in the "**Loading Capacity**" section of this chapter.

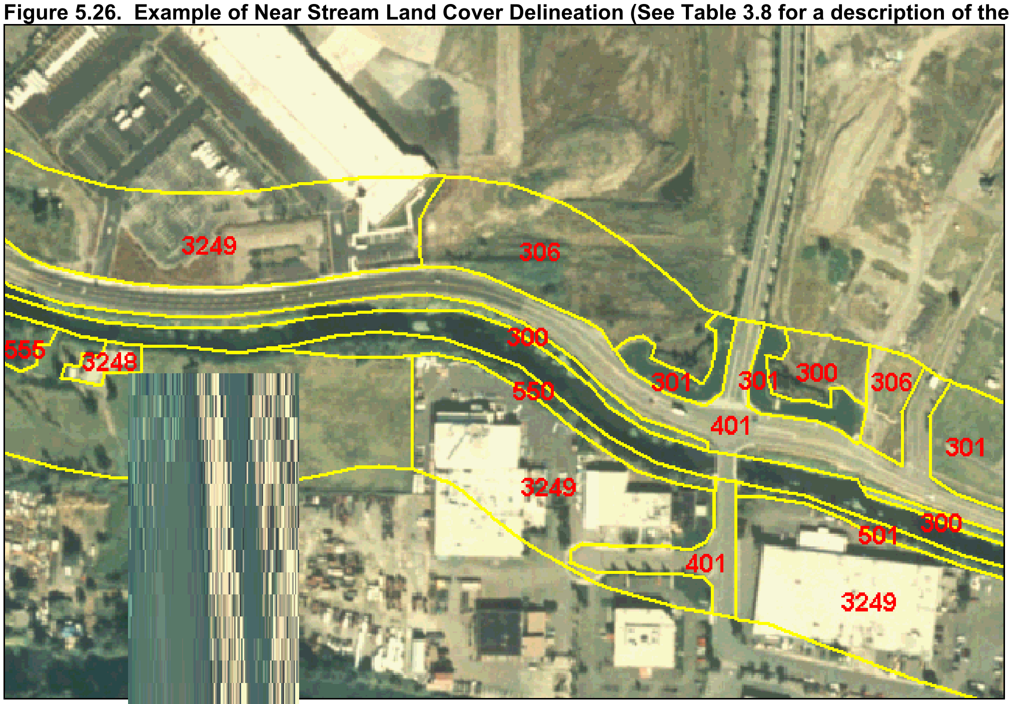
Riparian Vegetation Analysis

Riparian vegetation plays an important role in controlling stream temperature change. Near stream vegetation height, width and density combine to produce shadows that when, cast across the stream, reduce solar radiant loading. Bank stability is largely a function of riparian vegetation. Riparian corridors often produce a microclimate that surrounds the stream where cooler air temperatures, higher relative humidity and lower wind speeds are characteristic. Riparian corridors containing mature vegetation in the Columbia Slough watershed are generally very narrow and in some cases nonexistent. Forested lowland areas commonly contain cottonwood, Oregon ash, willow and red-osier dogwood, while cottonwood, red alder, hawthorne, Pacific dogwood and Garry oak are the dominant shade producing species in upland areas. Most of these uplands have been cleared and used for residential, commercial and industrial purposes (Portland 1989).

Current Condition

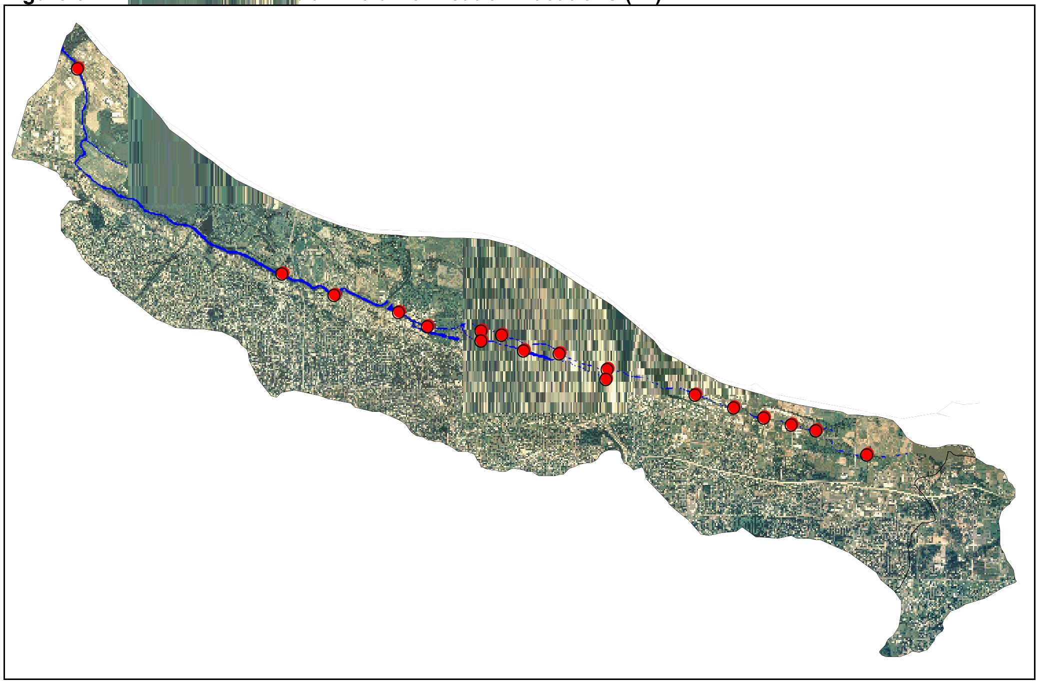
Current condition riparian vegetation was characterized using digitally rectified color aerial photographs taken in 1997. The photographs are part of the RLIS geographic information system database developed by the Metro Data Resource Center and purchased by ODEQ. Vegetation polygons were digitized in the near stream area (300 feet on either side of the stream channel) and classified by vegetation type. All classifications included an average riparian vegetation height, overhang and canopy density, which are described in **Table 5.11**. **Figure 5.26** shows an example of the aerial photography, digitized polygons and classification codes used in the analysis of Columbia Slough near stream land cover.

Figure 5.26. Example of Near Stream Land Cover Delineation (See Table 3.8 for a description of the numeric codes)



Every near[illegible]ation code was quality checked against aerial photographs by ODEQ. Ground level meas[illegible]e collected by ODEQ during the summer of 2001 at 17 locations throughout the watershed [illegible]getation classification and quantification (Figure 5.27).

Figure 5.27. [illegible]tion Field Verification Locations (17)



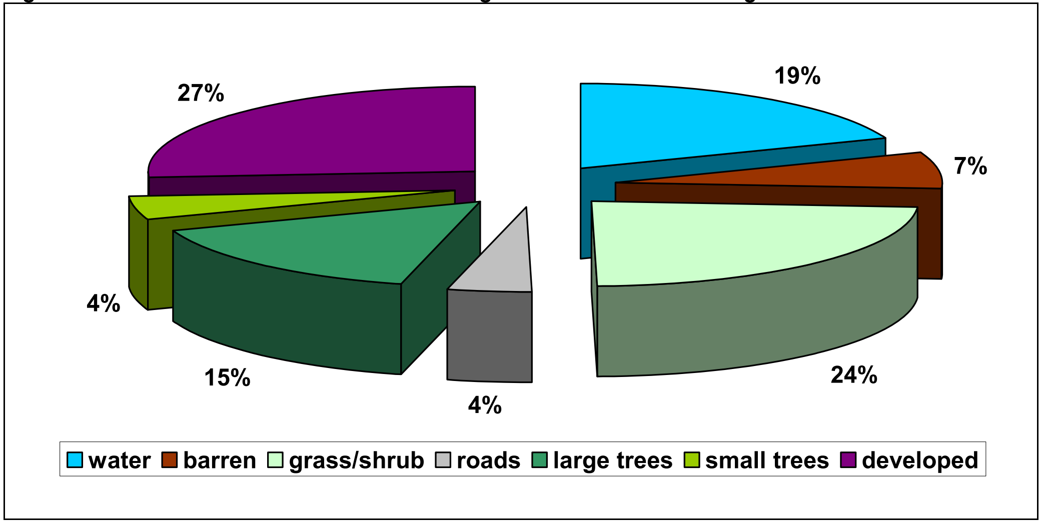
Stream reaches were also digitized from aerial photographs. These stream data layers were then segmented into data points at a 100-foot interval. All river mile designations were calculated using this highly accurate stream delineation and, therefore, may not match historical river mile designations.

These data point layers form the basis for automated sampling performed using Ttools[2]. At every distance node (i.e. every 100 feet) along the stream, vegetation was sampled out to 120 feet from the channel edge at 15-foot intervals for both stream banks. A total of 18 vegetation samples are taken at each stream distance node. These data were then given to Portland State University for incorporation into the CE-QUAL-W2 temperature model developed for the Columbia Slough as part of this TMDL effort.

Automated near stream vegetation sampling was completed for the Lower Slough, North Slough, Middle Slough, Buffalo Slough, Whitaker Slough and the Upper Slough (**Figure 5.4**).

Near stream vegetation was grouped as one of the following: water or floodplains, cultivated fields or grassed areas, forests, scrub/shrub (woody vegetation less than 15 feet high), roads, developed lands (both urban and rural residential and commercial), and barren lands. Within these general vegetation types, near stream vegetation was further classified by observed differences in average tree height (taller vs. shorter forests) and in density (**Table 5.11**). Existing and potential tree heights were determined by ODEQ using ground level data, literature on the basin and professional judgment. Commercial and residential development, followed by grassed areas were the most prevalent land cover type found in the near stream area analyzed (**Figure 5.28**).

Figure 5.28. Near Stream Land Cover Percentages for the Columbia Slough



ODEQ personnel made field measurements of vegetation height at 17 riparian monitoring locations. Forty-seven large trees, almost exclusively large Cottonwood, were measured at locations where large trees appeared to be the dominant riparian vegetation. The average large tree height was 85 feet (26 meters). Thirty-two small trees were measured at locations where small trees appeared to be the dominant riparian vegetation. The average small conifer tree height was 35 feet (11 meters). Large tree heights varied between 55 and 120 feet.

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[2] Ttools is an automated sampling tool that was developed by ODEQ to sample the following spatial data: stream aspect, channel width, near stream vegetation and topographic shade angles. Sampling resolution is user defined and was set at 100 foot intervals longitudinally (i.e. along the stream) and 15 feet in the transverse direction (i.e. perpendicular to the stream).

Potential Condition

System potential effective shade occurs when near stream vegetaion is at a climax life stage. A climax life stage is represented by the following conditions:

- Vegetation is mature and undisturbed;
- Vegetation height and density is at or near the potential expected for the given plant community;
- Vegetation is sufficiently wide to maximize solar attenuation; and
- Vegetation width accommodates channel migrations.

Automated near stream vegetation sampling was repeated to determine the potential condition for each Slough segment, replacing the current condition land cover descriptions and densities with the attributes of high density large hardwood stands (**Table 5.11)**. While riparian vegetation heights likely vary with vegetation zone, disturbance regimes and other factors, ODEQ did not feel that greater accuracy could be attained with more detailed riparian vegetation height estimates. ODEQ field measurements and observations indicated that average height and densities of mature mixed Cottonwood stands is well represented by assuming a composite dimension of 85 feet in height, 75% density and 12.8 feet of overhang. Therefore, vegetation characteristics remain constant between current and potential conditions, but are applied as potential land cover as described in **Table 5.11**. The resultant shade values (calculated by ODEQ using Ttools) were incorporated into the system potential CE-QUAL-W2 temperature model runs.

Table 5.11. Columbia Slough Near Stream Land Cover Attributes and Potential Land Cover

ODEQ Code	Land Cover Description	Height (feet)	Density	Overhang (feet)	Potential Land Cover
300	Grass/Pastures/Field	1.6	75%	1	Large Hardwood
301	Water	0	0%	0	No Change
302	Golf Course	1	75%	0.5	Large Hardwood
305	Barren - Embankment	0	0%	0	Large Hardwood
306	Barren - Developed	0	0%	0	Large Hardwood
309	Barren - Soil	0	0%	0	Large Hardwood
400	Barren - Dirt Road	0	0%	0	Large Hardwood
401	Barren - Road/RR tracks	0	0%	0	Large Hardwood
500	Large Hardwood	85	75%	12.8	No Change
501	Small Hardwood	35	75%	5.3	Large Hardwood
550	Large Hardwood	85	25%	12.8	No Change
551	Small Hardwood	35	25%	5.3	Large Hardwood
555	Large Hardwood	85	10%	12.8	No Change
556	Small Hardwood	35	10%	5.3	Large Hardwood
800	Upland Shrubs	6	75%	1	Large Hardwood
850	Upland Shrubs	6	25%	1	Large Hardwood
3001	Active Channel Bottom	0	0%	0	No Change
3248	Development - Residential	15	100%	0	Large Hardwood
3249	Development - Industrial	30	100%	0	Large Hardwood

To ensure that system potential vegetation characteristics are applied in a geographically appropriate manner, ODEQ utilized ecoregional geographic boundaries to assign appropriate vegetative characteristics throughout the watershed. A description of this methodology is provided in the *Effective Shade Curves* section of this chapter.

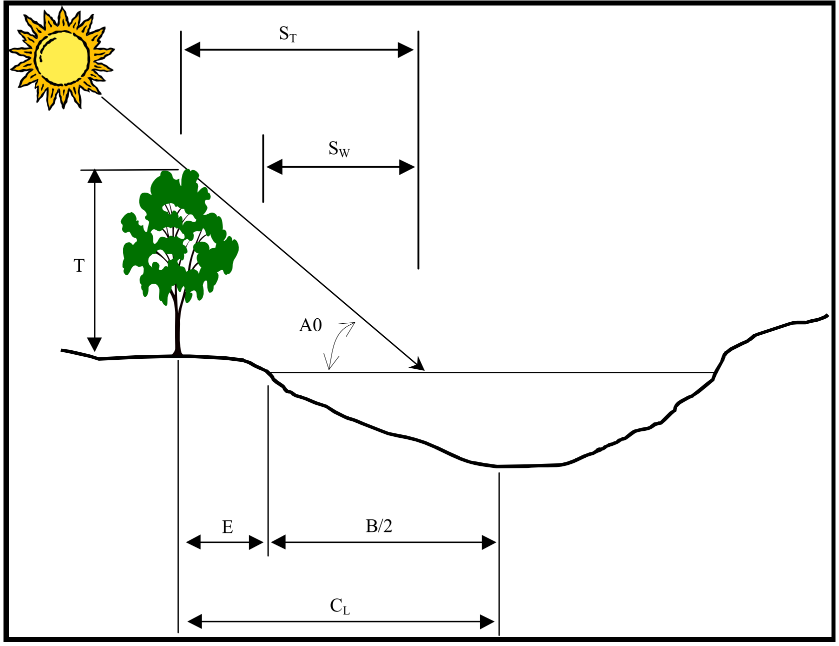
Analytical Methodology and Thermal Response Simulations

To assess the thermal response of stream temperature to changes in vegetation and hydrology in the Slough, simulations were performed by Portland State University to evaluate several potential physical and operational scenarios with respect to stream temperature. The model was a modified version of CE-QUAL-W2 that had been applied to the Columbia Slough by Portland State University for the City of Portland Bureau of Environmental Services. Extensive information on the setup, calibration and verification of the model is available Portland State University (Berger 2000, Berger and Wells 1999, Wells and Berger 1995). Electronic files of the CE-QUAL-W2 model runs used to determine current and system potential conditions are maintained by ODEQ and are available to interested parties by contacting the Water Quality Division at the ODEQ headquarters office in Portland. CE-QUAL-W2 is a laterally averaged U. S. Army Corps of Engineers model that consists of directly coupled hydrodynamic and water quality transport algorithms. Developed for reservoirs and narrow, stratified estuaries, CE-QUAL-W2 can handle a branched and/or looped system with flow and/or head boundary conditions. CE-QUAL-W2 simulates temperature, phytoplankton, dissolved oxygen, pH, organic matter, nutrients and residence time. This modified version included additional macrophyte and shading algorithms. ODEQ near stream land cover analysis, described above, was incorporated into the model. Features of the macrophyte model include the ability to simulate multiple submerged macrophyte species; the transport of nutrient fluxes between plant biomass and the water column and/or sediments; growth limitation due to nutrient, light and temperature; the simulation of the spatial distribution of macrophytes vertically and horizontally; the modeling of light attenuation in the water column caused by macrophyte concentration; and the modeling of channel friction due to macrophytes. The model also simulates groundwater inflows that were the greatest source of inflows during the dry summer months. Cool groundwater generally heats up as it flows into and eventually out of the Columbia Slough.

The Columbia Slough model is composed of 397 longitudinal segments (25-231 m) and 17 vertical layers (layer height of 0.30-0.61 m) and 41 branches (separate water bodies or branches off the main stem), many of which are segregated by culverts. The model includes 51 point source tributaries (storm water, combined sewer overflows and surface runoff), 12 distributed groundwater inflows, 12 irrigation withdrawals, 39 culverts, 4 weirs and 2 pump stations.

The amount of shade predicted by the Columbia Slough model was based upon ODEQ vegetation and land cover classifications. The CE-QUAL-W2 shading algorithm utilizes vegetation density, height, and the vegetation distance from the channel centerline. Channel orientation, sun altitude and azimuth, and cloud cover were also used to predict shade (**Figure 5.29**). Given the type of vegetation adjacent to each model segment on the left and right bank, parameters for the top of tree elevation and vegetation density were input to the model. Vegetation types were translated into vegetation height and density using information provided by ODEQ (**Table 5.11**). The amount of shade predicted for a model segment was used to reduce the amount of short wave solar radiation incident on the water surface in that segment.

Figure 5.29. CE-QUAL-W2 Shade Geometry



Modeling Scenarios

The hydrodynamic and water quality model CE-QUAL-W2 was applied to the Columbia Slough and used to evaluate the temperature effects of 3 scenarios. These scenarios were:

1) The “current conditions” scenario that simulated the Columbia Slough as it existed in 1992, before many of the more recent improvements in shading, culvert upgrades and removal, and bathymetry occurred.
2) The current conditions + improvements scenario simulated the shade effects of recent and planned City of Portland tree planting, culvert upgrades, culvert removals, and the new structure at the outlet of Smith and Bybee Lakes
3) A system potential scenario that assumed riparian vegetation at system potential conditions and the removal of all culverts except for those through the mid-dike levee. Water levels in the Middle and Upper Slough were permitted to fluctuate with those in the Lower Slough as long as the water surface did not fall below 3’ MSL.

The model scenarios chosen for this analysis are summarized in **Table 5.12**. All scenarios used 1992 meteorological and boundary conditions, which corresponds to a very warm year with respect to meteorological conditions. They differ in shading, culvert or bridge specifications; in the water level operations for the Middle and Upper Slough, and in channel bathymetry. The culverts through the mid-dike levee separating the Middle and Upper Sloughs were left open for all simulations. For all runs the weir at the outlet of Fairview Lake was simulated.

Middle and Upper Slough bathymetry for scenarios 2 and 3 was altered to reflect the impact of the U.S. Army Corps of Engineers Columbia Slough “1135 project” plans. The outlet structure between Smith and Bybee Lakes and the North Slough was also simulated. For Scenarios 2 and 3, the proposed structure was modeled where boards maintaining high water levels in the Lakes were removed in the middle of July permitting the two-way exchange of water between the Lakes and North Slough. Water Levels maintained in the Middle and Upper Sloughs for scenarios 1 and 2 reflected current operations with the pumps at Multnomah County Drainage District #1 (MCDD1) where water levels were kept between 5.5 and 6.0 ft MSL. For Scenario 3, the system potential run, water levels were allowed to equilibrate between the Middle and Lower Slough as along as water surface elevation in the Lower Slough did not fall below 3.0 feet MSL. A weir crest at the gravity gates of MCDD1 was set to an elevation of 3.0 feet in order to permit the model to keep running. Otherwise the parts of the Middle and Upper Slough model would begin to dry up.

The culvert specifications for the scenarios were listed in **Table 5.13**. For scenario 2, the culverts were changed to correspond to the 1135 project specifications and for scenario 3 they were all removed except for the culverts through the mid-dike levee.

Shading was simulated using vegetation descriptions supplied by DEQ using the methodology described above. Vegetation heights and densities were input to the shading algorithm described in Berger (2000). Each scenario had a different amount of specified shading. Scenario 1 simulated vegetation that existed prior to any City of Portland (COP) tree plantings. Scenario 2 simulated the additional COP tree plantings, whereas scenario 3 modeled the full shade potential assuming tall, dense trees along the banks.

Table 5.12. PSU-DEQ Model scenario descriptions.

Scenario #	Name	MET Data	Channel Geometry	Shade	Water Level - Upper Slough
1	Current Conditions	1992	Bathymetry before 1135 project, 1992 culvert conditions	Existing vegetation	Target 5.5 – 6 ft MSL on west side, 7-8 ft on east side
2	Current Conditions + improvements	1992	1135 Project plans + all new COP culverts + new COP bridges	Existing + full-extent of COP plantings	Target 5.5 – 6 ft MSL on west side, 7-8 ft on east side
3	System potential	1992	1135 Project plans + all culverts replaced with bridges and restrictions removed	Existing + full shade system potential and not taking into account levee and airport restrictions	Allow MCDD1 to go to the lowest water level based on its weir height and tidal dynamics in the Lower Slough

Table 5.13. Culvert Specifications for Temperature Modeling Scenarios.

		Scenario 1 – Current Conditions			Scenario 2 – Current Conditions + Improvements			Scenario 3 – System Potential		
#	Location	Dia.	Invert Elevation	Length	Dia.	Invert Elevation	Length	Dia.	Invert Elevation	Length
		(in.)	(feet)	(feet)	(in.)	(feet)	(feet)	(in.)	(feet)	(feet)
1	82nd	148	-1.10/-0.05	205	148	-1.10/-0.05	205	Removed		
2	122nd	144	2.53/2.53	108	144	2.53/2.53	108	Removed		
3	Mid-Dike	60	2.62/1.59	315	60	2.62/1.59	315	60	2.62/1.59	315
4	Mid-Dike	60	2.50/1.59	316	60	2.50/1.59	316	60	2.50/1.59	316
5	148th	84	4.01/4.03	100	Removed			Removed		
6	148th	96	2.62/1.72	100	Removed			Removed		
7	158th	96	2.87/2.55	120	Removed			Removed		
8	158th	96	3.43/2.85	120	Removed			Removed		
9	185th	54	5.71/5.60	60	Removed			Removed		
10	185th	72	5.71/5.60	50	Removed			Removed		
11	Ag Crossing	36	7.07/7.13	41	Removed			Removed		
12	Ag Crossing	36	5.96/6.32	42	Removed			Removed		
13	Ag Crossing	36	5.95/5.82	42	Removed			Removed		
14	33rd	48	5.89/5.12	121	Removed			Removed		
15	Golf Course	48	4.92/5.07	40	72	4.50/4.50	40	Removed		
16	Golf Course	36	6.30/5.78	56	72	4.50/4.50	40	Removed		
17	47th	36	7.10/6.50	64	Removed			Removed		
18	47th	36	4.51/3.64	69	Removed			Removed		
19	47th	48	2.06/3.16	62	Removed			Removed		
20	Private Road	60	5.30	35	60	5.30	40	Removed		
21	63rd	72	3.39/2.82	54	72	3.39/2.82	54	Removed		
22	Road	60	4.42/3.62	125	60	4.42/3.62	125	Removed		

Modeling Results

The model predicted average temperatures for the scenarios from June 1 to September 15 time period were shown in **Table 5.14**. There was a difference of approximately 3 degrees Celsius at MCDD1 between Scenarios 1 and 3. Further downstream in the Lower Slough at North Portland Bridge the temperature difference became smaller because residence times had increased and equilibrium temperature was being approached.

Table 5.14. Model predicted average temperatures for scenarios from (June 1 to Sep 15).

Scenario	MCDD1 (°C)	NE 47th Whitaker Slough (°C)	NE 33rd Buffalo Slough (°C)	NE 82nd Main arm (°C)	MCDD#4 (°C)	North Portland Bridge (°C)	St. Johns Landfill Bridge (°C)
1	20.23	19.38	19.58	17.74	22.04	20.78	20.62
2	18.73	18.84	17.27	16.45	22.02	20.04	20.03
3	17.31	17.69	16.14	16.05	21.24	19.23	19.41

The 7 day average of the daily maximum temperature for one of the hottest days of the simulation (August 14, 1992) was plotted in **Figure 5.30** for the main arm. Temperature differences were largest in the main arm of the Middle and Upper Slough. In the Lower Slough, where the water body is wider and less affected by shading, the temperature differences were not as great. Also, temperatures were beginning to approach equilibrium temperature and were becoming less dependent on travel time. **Figure 5.31** and **Figure 5.32** show the 7 day average of the daily maximum temperature for Buffalo Slough and Whitaker Slough, respectively. In Buffalo Slough the model predicted temperatures were as much as 2.5 degrees higher for Scenario 1. A high invert elevation for the culvert at NE 33rd raised water levels and increased residence time, resulting in greater heating. For scenario 2 this culvert was lowered and for scenario 3 it was removed completely.

Figure 5.30. The 7-day Average of the Daily Maximum Temperature for the Main Arm of the Columbia Slough.

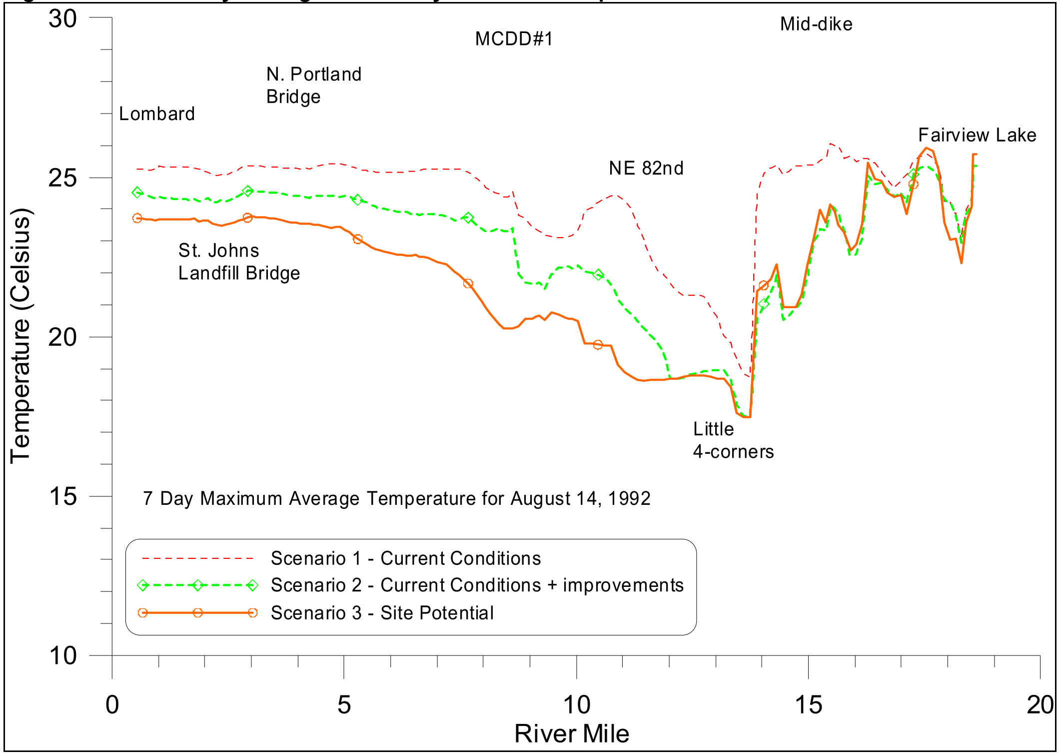


Figure 5.31. The 7 day Average of the Daily Maximum Temperature for Buffalo Slough.

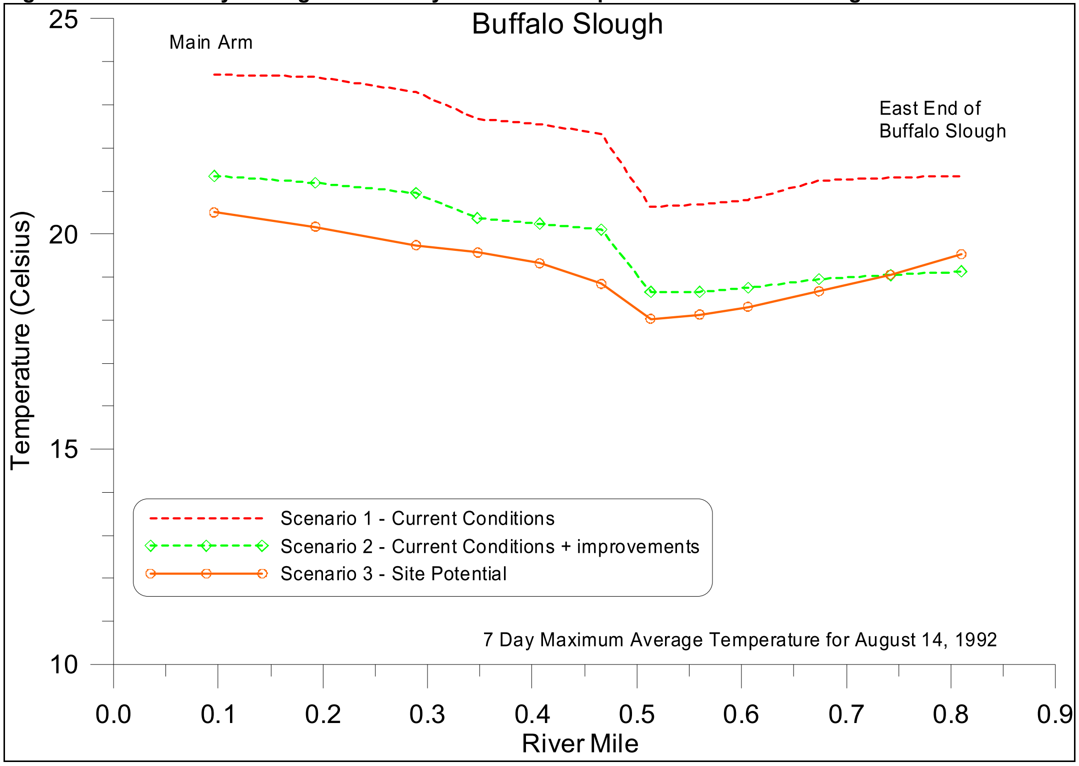
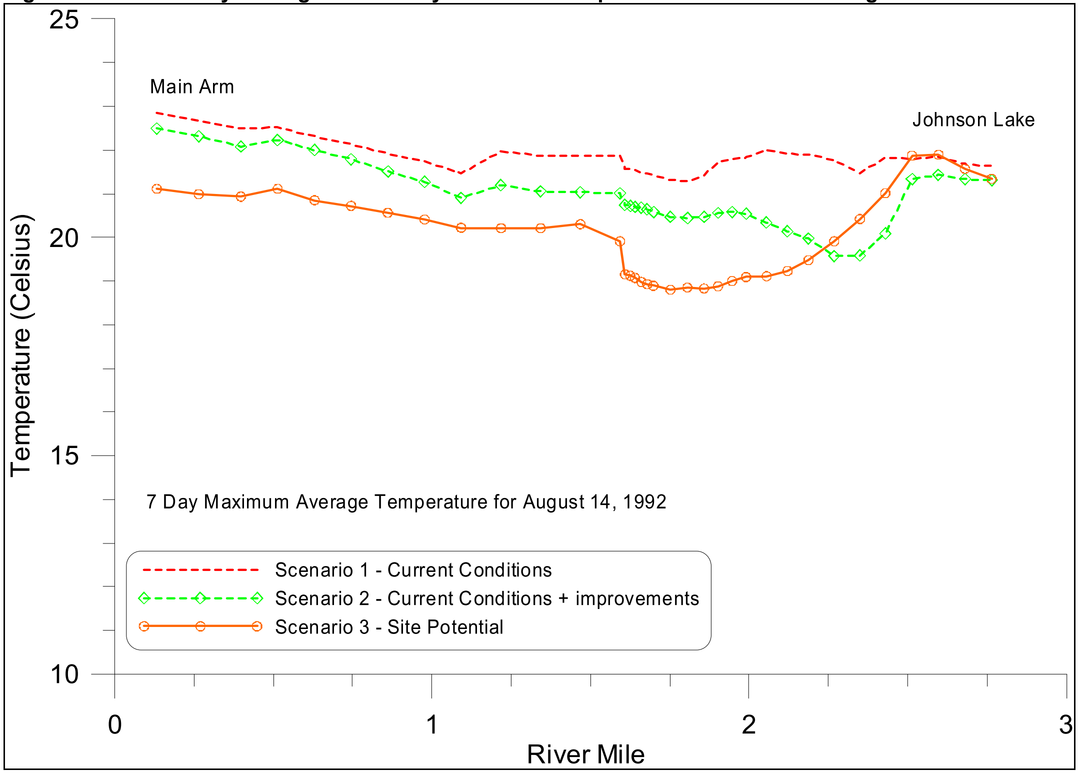


Figure 5.32. The 7 day Average of the Daily Maximum Temperature for Whitaker Slough.



Temperature predictions of the scenarios at NE 82nd (main arm), MCDD1, and St Johns Landfill bridge were shown in **Figure 5.33**, **Figure 5.34**, and **Figure 5.35**, respectively. These continuous temperature plots illustrate the diurnal temperature fluctuations predicted by the model. As expected, scenarios 2 and 3 predicted cooler temperatures because of increased shading and shorter residence times.

Figure 5.33. Predicted Summer Temperatures in the Middle Slough at NE 82nd.

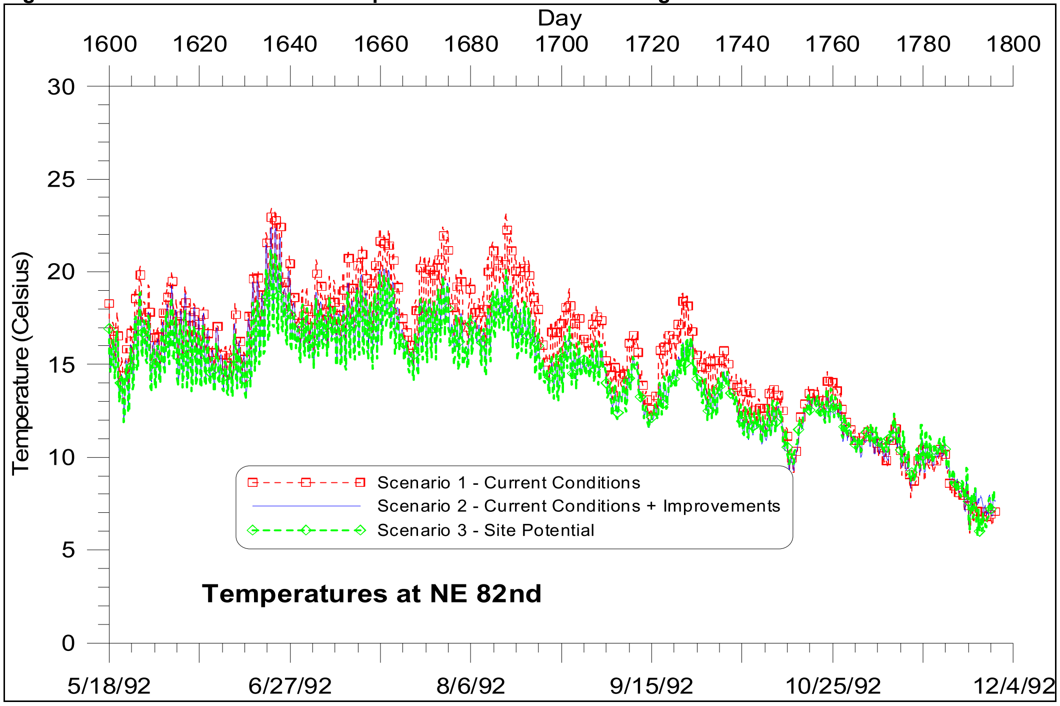


Figure 5.34. Predicted Summer Temperatures in the Middle Slough at MCDD1.

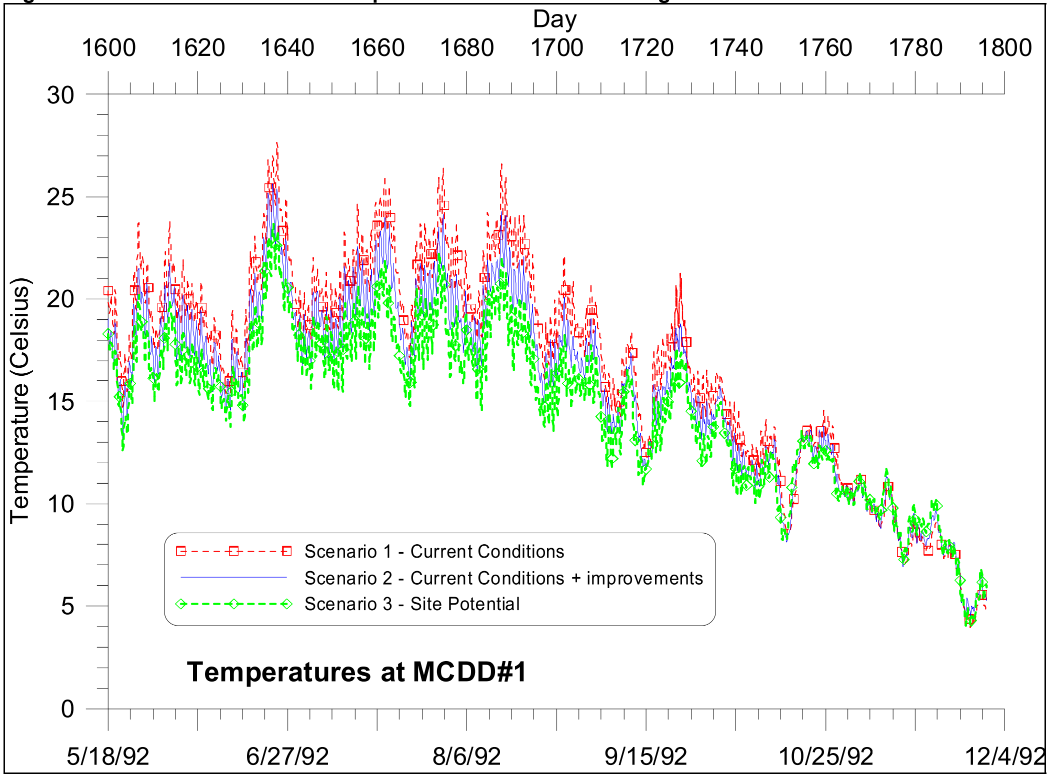
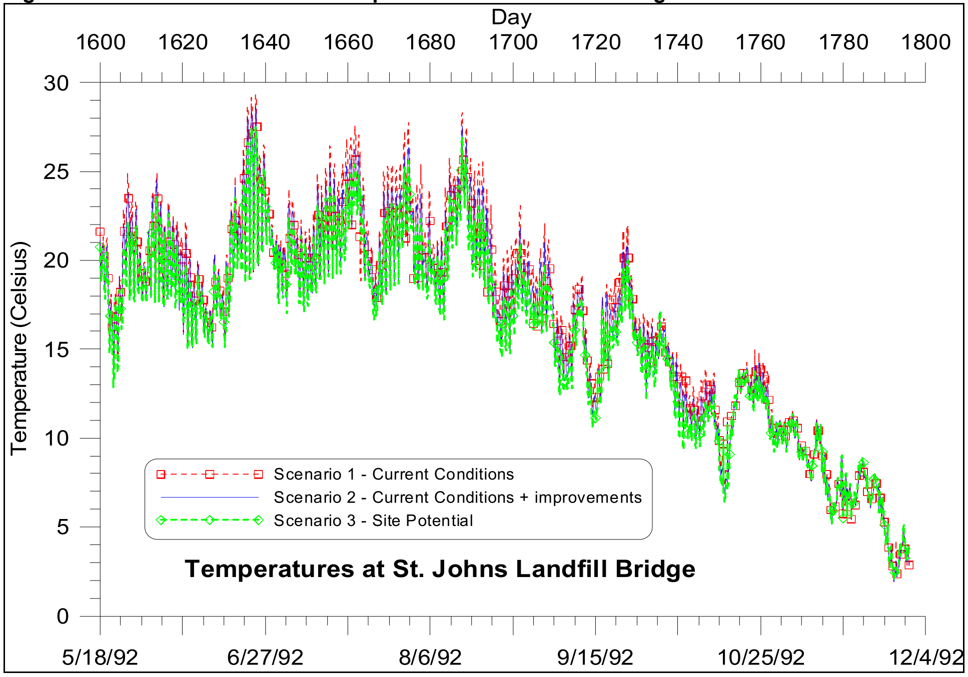


Figure 5.35. Predicted Summer Temperatures in the Lower Slough at the St. Johns Landfill Bridge



Water Level Predictions and Macrophyte Growth

Water level predictions for Middle Slough locations NE 82nd and MCDD1 were shown in **Figure 5.36** and **Figure 5.37**. The effect of macrophyte growth on water levels at NE 82nd can be seen in the increase and then decrease in level over the course of the summer (**Figure 5.36**). NE 82nd is located within a reach of significant macrophyte growth that causes increased channel friction and water levels. The effects of the pumping strategies were apparent in water level predictions at MCDD1 (**Figure 5.37**). For scenarios 1 and 2, water levels were generally kept between 5.5' and 6' MSL. However, scenario 3 water levels in the Middle Slough were allowed to fluctuate with those in the Lower Slough when water levels at MCDD1 did not fall below 3' MSL.

Figure 5.36. Water level predictions at NE 82nd, Middle Slough.

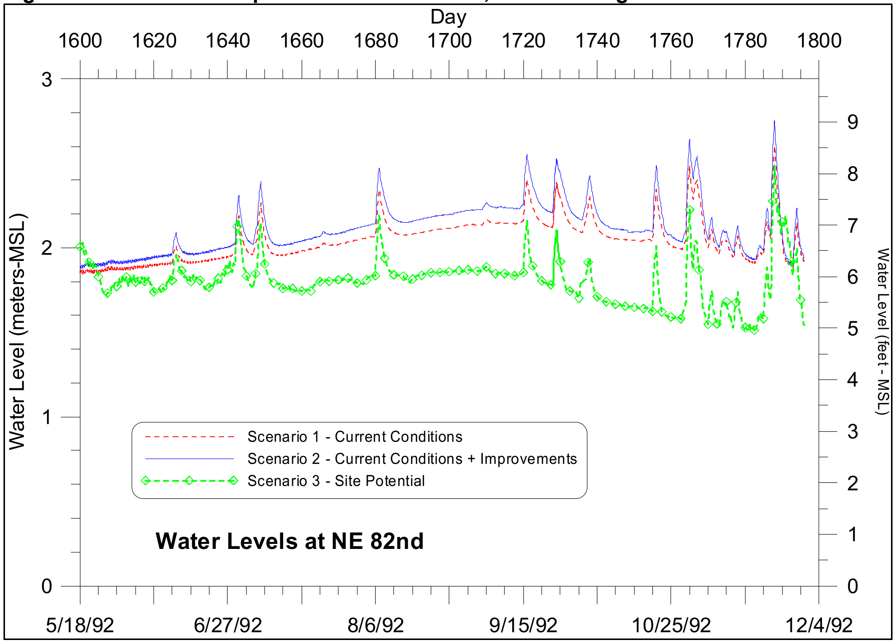
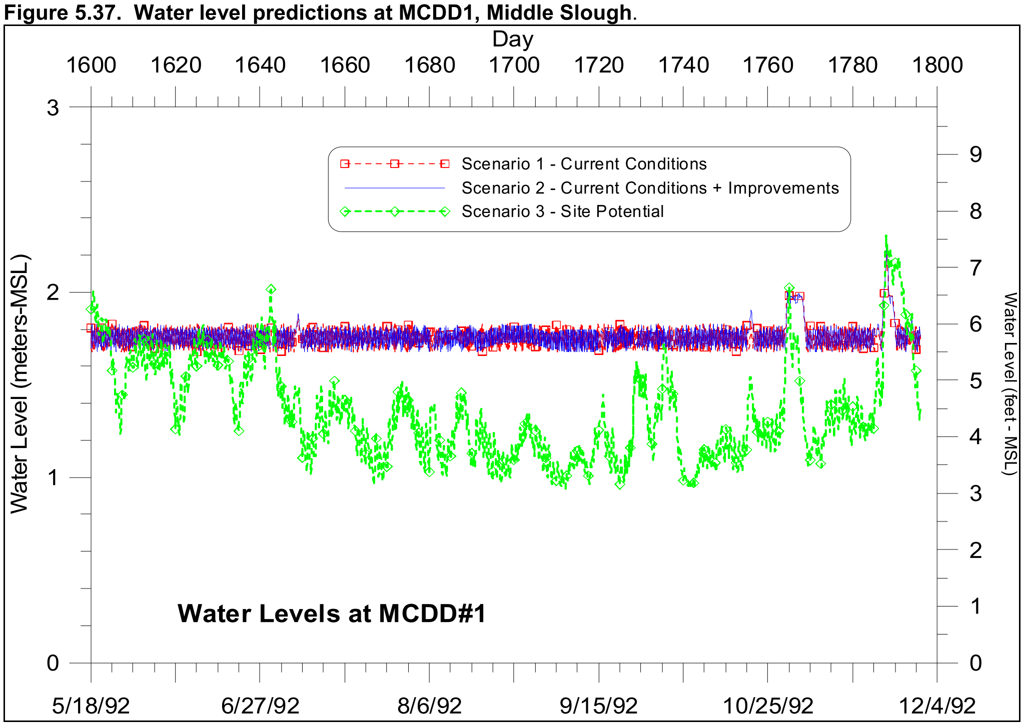


Figure 5.37. Water level predictions at MCDD1, Middle Slough.



Model predicted water levels of the scenarios for Johnson Lake were plotted in **Figure 5.38**. Johnson Lake is located at the upstream end of Whitaker Slough and the impact of culverts and/or bridge improvements can be seen. For scenario 1 water levels were highest because the culverts were simulated using 1992 conditions. Scenario 2 included past and planned culvert resulting in decreased water levels of about 0.5'. Scenario 3 simulated the complete removal of the culverts and water levels were predicted to be 1.5' lower than for Scenario 1. Lower water levels result in shorter residence times and cooler water temperatures.

Water level predictions for Smith and Bybee Lakes were shown in **Figure 5.39**. The proposed operations for the structure separating the Lakes from North Slough were simulated for scenarios 2 and 3. This strategy involved keeping lake water levels high in spring and early summer and then opening the lakes to North Slough around the middle of July. The sharp decrease in water levels that occurred on July 15 were caused by the opening the lakes to the North Slough. Water levels remained high for scenario 1 because this was the operating strategy employed in 1992.

Figure 5.38. Water level predictions at Johnson Lake, Whitaker Slough.

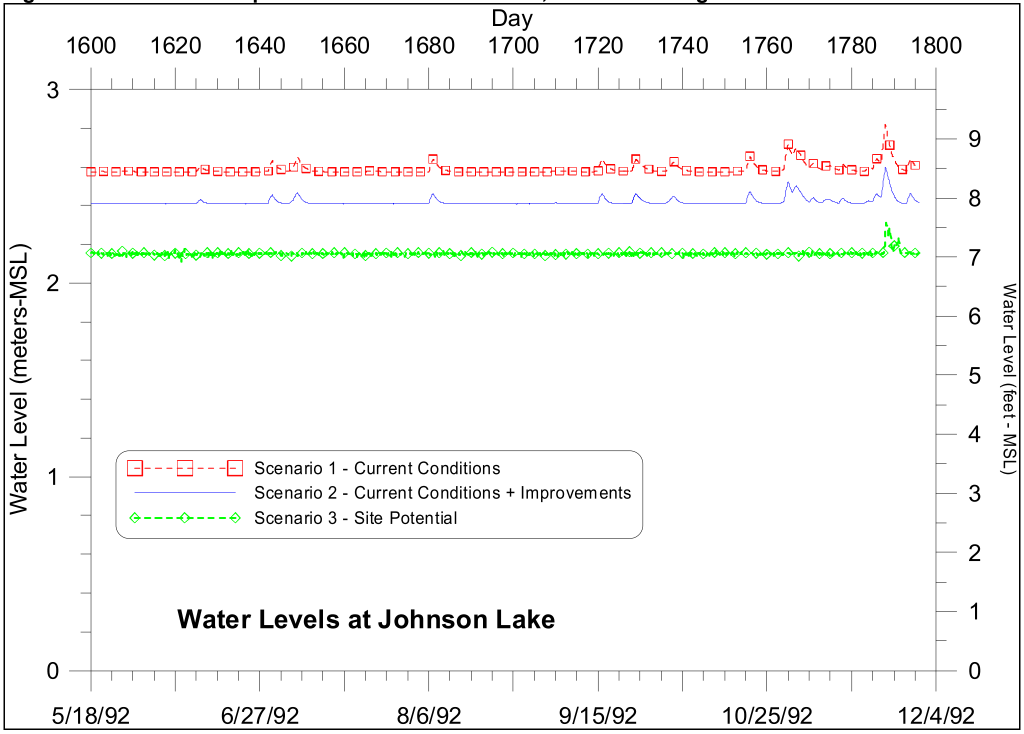
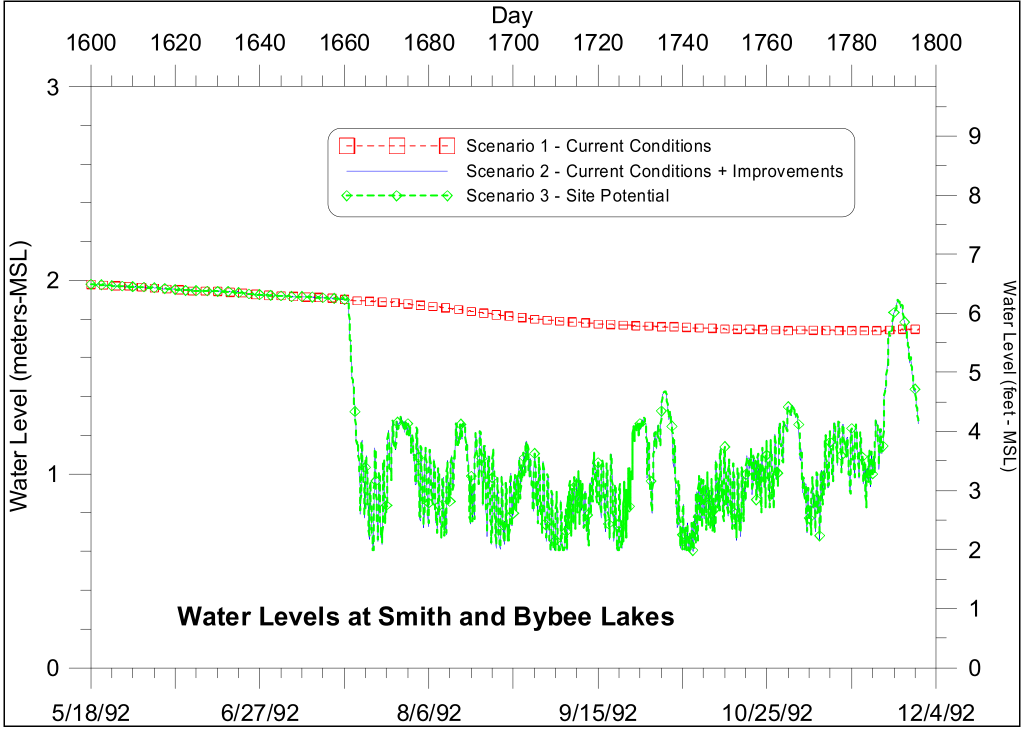


Figure 5.39. Water level predictions at Smith and Bybee Lakes, Lower Slough.



Loading Capacity

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with water quality standards. USEPA's current regulation defines loading capacity as "*the greatest amount of loading that a water can receive without violating water quality standards*." (40 CFR § 130.2(f)). Oregon's temperature standard states that a cumulative surface water temperature increase of no more than 0.3°C is allowed in the Columbia Slough Watershed when surface water temperature criteria are exceeded. The pollutants are human influenced increases in solar radiation loading (nonpoint sources) and heat loading from warm water discharge (point sources).

The loading capacity is dependent on the available assimilative capacity of the receiving water. For nonpoint sources, the loading capacity is the amount of background solar radiation that reaches the stream when the stream is at system potential conditions in terms of riparian vegetation and channel morphology. For rivers whose system potential temperatures are at or above the temperature standard for a given period, there is no available assimilative capacity beyond the 0.3°C human use allowance specified in the temperature standard. The loading capacity is essentially consumed by non-anthropogenic sources.

In this document, the loading capacity is expressed in terms of kilocalories per day (kcals/day). This represents the amount of energy that can be added to a waterbody and still obtain water quality standards.

Nonpoint Sources

The total nonpoint source solar radiation heat load was derived for the various portions of the main arm of the Columbia Slough (**Table 5.15**). Current solar radiation loading was calculated by simulating current stream and vegetation conditions. Background loading was calculated by simulating the solar radiation heat loading that resulted with system potential near stream vegetation. This background condition, based on system potential shade conditions, reflects an estimate of nonpoint source heat load that would occur while meeting the temperature standard. In theory, once the system potential condition with respect to nonpoint source pollution is known, ODEQ could then calculate the amount of additional nonpoint source loading that a waterbody can assimilate without resulting in more than a 0.3°C increase in water temperature at the point of maximum impact. ODEQ did not attempt to calculate this additional allowable heat load or incorporate the information into nonpoint source load allocations. Rather, ODEQ considers the conservative methodology that bases nonpoint source load allocations on system potential conditions to be part of the explicit margin of safety. Moreover, any allocation benefit to nonpoint sources would occur only after restoration efforts had recovered solar radiation to near system potential conditions: a matter of decades in most cases. The relationships below were used to determine solar radiation heat loads for the current condition, anthropogenic contributions and loading capacity derivations based on system potential.

The solar radiation heat load from anthropogenic non-point sources were computed for the Lower, Middle and Upper Columbia Sloughs. The anthropogenic heat load was estimated by calculating the difference between the current condition heat load and the system potential heat load such that

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

where

$H_{Total\ NPS}$: Total solar radiation heat load from all non-point sources (kcal/d)

$H_{SP\ NPS}$: Background non-point source heat load based on system potential (kcal/d)

$H_{Anthro\ NPS}$: Anthropogenic non-point source heat load (kcal/d)

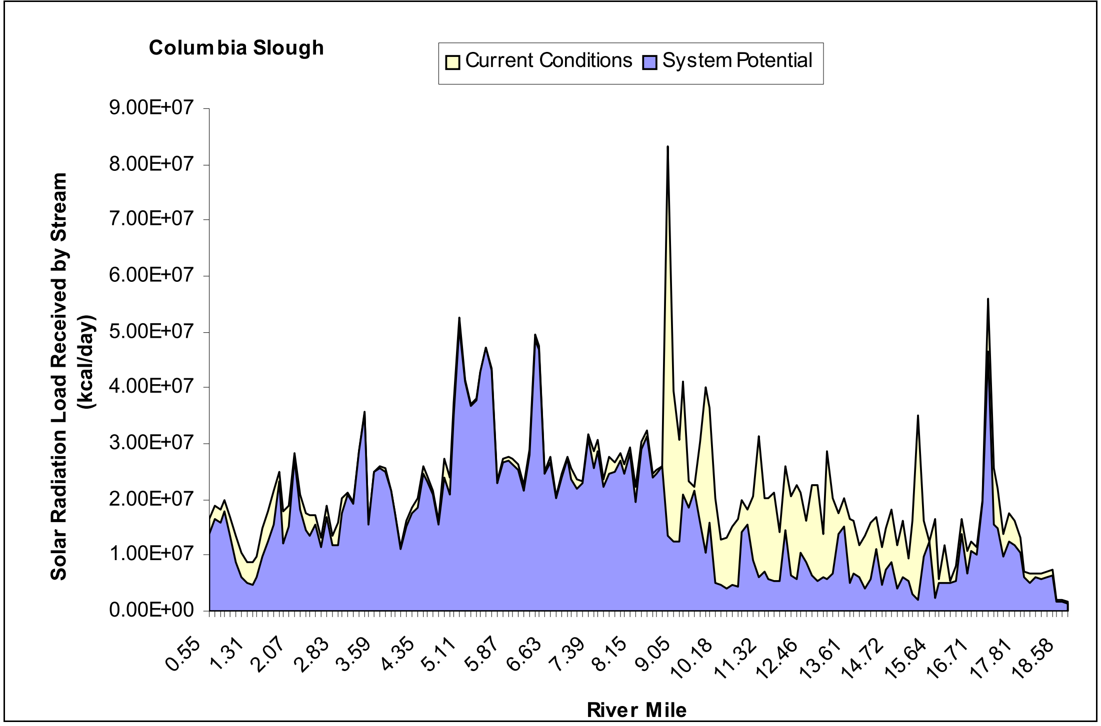
Table 5.15 shows the predicted solar radiation loads for current conditions, system potential and from anthropogenic sources for the Lower, Middle and Upper Columbia Slough. The average daily heat load was computed for the period of June 1 to September 15. For the Columbia Slough 25% of the total heat load results from anthropogenic non-point sources.

Table 5.15. Nonpoint Source Solar Radiation Heat Loading - Current Condition, System Potential (Loading Capacity) and Anthropogenic Contributions

Columbia Slough Section	**Current Condition** (10^8 kcal/d) $H_{Total\ NPS}$	**System Potential (Loading Capacity)** (10^8 kcal/d) $H_{SP\ NPS}$	**Anthropogenic** $H_{Anthro\ NPS}$ (10^8 kcal/d)	Portion from Anthropogenic Nonpoint Sources
Lower Slough	21.2	19.7	1.44	6.8%
Middle Slough	10.7	4.19	6.49	60.7%
Upper Slough	3.60	2.67	0.93	25.7%
Totals	**35.4**	**26.6**	**8.85**	**25.0%**

Figure 5.40 contrasts the longitudinal profile of the current solar radiation heat loading with the solar radiation heat loading that occurs with system potential land cover. Notice that solar radiation loading at system potential (loading capacity) is less than levels currently observed, although the difference varies by stream and stream reach. The anthropogenic non-point source heat load is the difference between the curves and was greatest for the Middle and Upper Sloughs above river mile 9. The solar radiation heat load calculated for system potential near stream vegetation and channel morphology is considered the background condition with anthropogenic sources removed.

Figure 5.40. Solar Radiation Loading – Current Condition and System Potential Condition



NPDES Permits

The eighteen facilities that hold NPDES permits allowing discharge into the Columbia Slough and Fairview Creek are mapped and identified in **Table 5.16** and **Figure 5.41**. (See the *Point Source Methodology* section for explanation.)

Table 5.16. NPDES Permitted Facilities in the Columbia Slough Watershed (Middle and Upper Slough River Mile Designations are Concatenate)

FACILITY NAME	PERMIT TYPE	RECEIVING WATER	RIVER MILE (facility)	MAP NUMBER
PORTLAND, CITY OF (Columbia STP)	NPDES – Wastewater Treatment Permit #100807	Lower Columbia Slough	4.9	1
HERBERT MALARKEY ROOFING COMPANY	GEN 100 – Non Contact Cooling Water	Lower Columbia Slough	5.9	2
DYNEA OVERLAYS	NPDES – Non-contact cooling water Permit #101544	Lower Columbia Slough	6.0	3
MACADAM ALUMINUM & BRONZE CO.	GEN 100 – Non Contact Cooling Water	Lower Columbia Slough	6.9	4
SAPA ANODIZING, INC	GEN 100 – Non Contact Cooling Water	Middle Columbia Slough	0.1	5
HALTON COMPANY	NPDES – Steam Cleaning Permit #100798	Middle Columbia Slough	1.4	6
PORT OF PORTLAND	NPDES – Wastewater Treatment Permit #101588	Middle Columbia Slough	2.7	7
OREGON FRESH FARMS, INC.	NPDES – Wastewater Treatment Permit #101079	Middle Columbia Slough	3	8
VENTURA FOODS, LLC	GEN 100 – Non Contact Cooling Water	Middle Columbia Slough	4.0	9
OWENS-ILLINOIS GLASS CONTAINER INC.	GEN 100 – Non Contact Cooling Water	Middle Columbia Slough	4.2	10
ENTERPRISE RENT-A-CAR	GEN17A – Vehicle Wash Water	Middle Columbia Slough	5.2	11
MILLER PAINT CO INC	GEN 100 – Non Contact Cooling Water	Middle Columbia Slough	6.0	12
PORTLAND, CITY OF	NPDES – Wastewater Treatment Permit #101617	Upper Columbia Slough	7.9	13
BOEING COMPANY	GEN 100 – Non Contact Cooling Water	Upper Columbia Slough	9.4	15
BOEING COMPANY	NPDES – Wastewater Treatment Permit #101761	Upper Columbia Slough	9.4	16
CASCADE CORPORATION	NPDES Permit #101630 – Non-Contact Cooling Water	Osburn Creek	0.3	17
MORSE BROS (Vance Pit)	GEN10 – Gravel Mining	Fairview Creek	4.5	18
OREGON ASPHALTIC PAVING COMPANY	GEN10 – Gravel Mining	Fairview Creek	4.5	19

In addition to the point sources identified above, there are a number stormwater NPDES permits for facilities located within the Columbia Slough watershed. ODEQ did not develop temperature waste load allocations for stormwater permitted facilities because ODEQ has no data that indicates stormwater discharges contribute to stream temperature standards violations. As outlined in the section entitled 'Point Source Methodology', all other facilities in the subbasin were found to not be a significant contributor of heat to Columbia Slough. Therefore, they were found to not have a reasonable potential to contribute to the temperature impairment and require no numeric limits in their NPDES permits. These facilities may continue to discharge at their current heat load.

Figure 5.41. Location of Columbia Slough NPDES Permitted Facilities (See Table 5.16 for facility information by number)

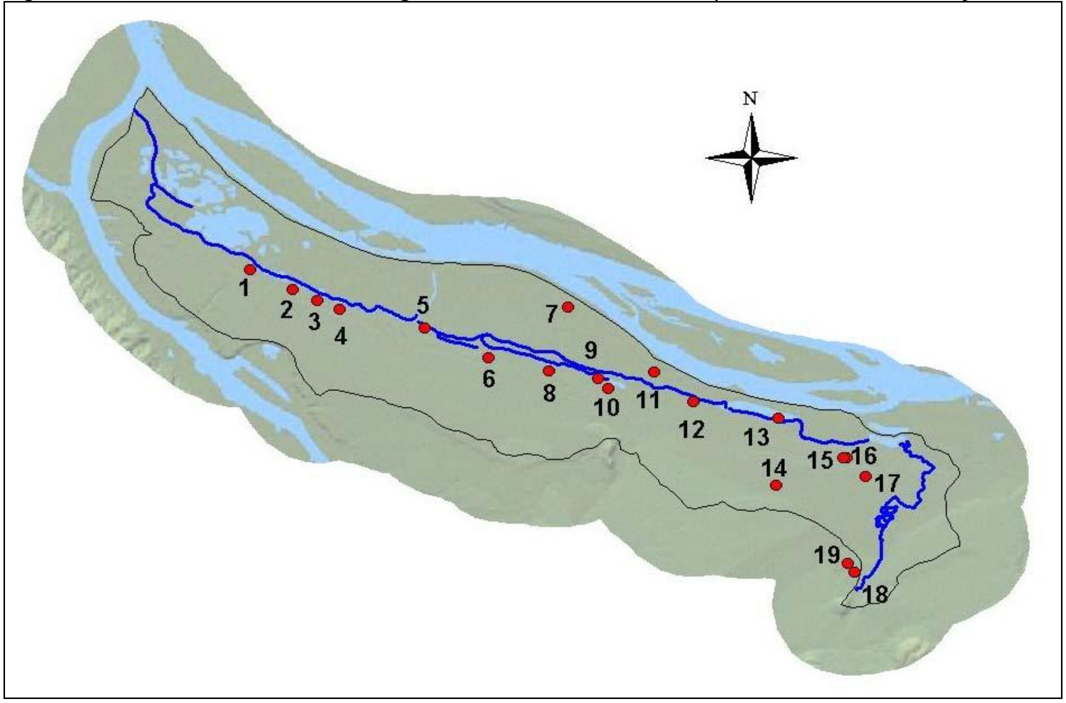


Table 5.17 is a list of the thermal point sources that discharge within the Columbia Slough Watershed and calculated waste load allocations. ODEQ calculated waste load allocations only for those facilities with thermal wastewater discharges.

Discharge flows are those specified as flow limitations in the source's current discharge permit or the maximum reported flows based upon a review of Discharge Monitoring Reports submitted to ODEQ by the permittee.

The Columbia Slough 7Q10 low flow was calculated using flow information collected by various permitted sources and by analysis of flow data collected at the USGS flow gauging station (#1421182) located near the mouth of the Slough at St. Johns. The 7Q10 low flow is 30 cubic feet per second for the lower Slough and 21 cubic feet per second for the middle and upper portions of the Slough.

The calculations used to determine maximum effluent temperature have the potential to yield very high allowable effluent temperatures when sources have very small discharge amounts relative to instream flow volume. The effluent temperature limit of 90°F (32.2 °C) is considered the instantaneous lethal limit for salmonids and is applied in cases where the allowable discharge temperature would exceed 90°F using the methodology described above in the *Point Source Methodology* section.

Table 5.17. Calculated Waste Load Allocations for NPDES Permitted Point Sources in the Columbia Slough Watershed

Source Name	Permit Limit or Maximum Reported Flow (cfs)	Stream Flow (7Q10) (cfs)	Maximum Effluent Temperature (F)/(C)	Waste Load Allocation (kcals/day)
CITY OF PORTLAND (STP)	N/A	N/A	N/A	N/A
HERBERT MALARKEY ROOFING COMPANY	0.36	30	76.2 / 24.6	5.77 X 10^6
DYNEA OVERLAYS	1.6	30	73.6 / 23.1	12.4 X 10^6
MACADAM ALUMINUM & BRONZE CO.	0.007	30	*90 / 32.2	5.51 X 10^6
SAPA ANODIZING, INC	0.014	21	*90 / 32.2	3.87 X 10^6
THE HALTON COMPANY	0.093	21	*90 / 32.2	3.92 X 10^6
PORT OF PORTLAND	**1.0	21	67.8 / 19.9	4.59 X 10^6
OREGON FRESH FARMS, INC.	0.193	21	79.6 / 26.5	4.00 X 10^6
VENTURA FOODS, LLC	0.24	21	76.8 / 24.9	4.03 X 10^6
OWENS-ILLINOIS GLASS CONTAINER INC.	0.065	21	*90 / 32.2	3.90 X 10^6
ENTERPRISE RENT-A-CAR OF OREGON	0.1	21	*90 / 32.2	3.93 X 10^6
MILLER PAINT CO INC	0.02	7	*90 / 32.2	1.30 X 10^6
CITY OF PORTLAND	10	21	65.2 / 18.5	11.2 X 10^6
BOEING (GEN 100)	0.03	21	*90 / 32.2	†4.74 X 10^6
BOEING (NPDES)	1.18	21	67.3 / 19.6	
CASCADE CORPORATION	0.09	N/A	68.0 / 20.0	0.43 X 10^6
MORSE BROS (Vance Pit)	N/A	N/A	N/A	N/A
OREGON ASPHALTIC PAVING COMPANY	N/A	N/A	N/A	N/A
Total				**69.6 X 10^6**

*** Instantaneous Lethal limit for Salmonids**
**** Conservative estimate made in the absence of flow data**
† Boeing discharges combined for a total waste load allocation

Columbia Boulevard Sewage Treatment Plant (City of Portland)

The City of Portland owns and operates the Columbia Boulevard Sewage Treatment Plant at 5001 N. Columbia Blvd., the primary sewage treatment facility for the City of Portland. The plant has two primary permitted outfalls that discharge to the Columbia River and an emergency outfall that can discharge to the Columbia Slough. This outfall would only be used in an emergency that prevented discharge from the two permitted outfall locations for a long enough period of time that flooding of basements would occur.

Only extreme events, such as the 1996-97 floods, would necessitate use of this outfall. Therefore, no waste load allocation will be assigned and future discharges will be evaluated based upon the permit criteria for emergency releases. If those criteria are not met ODEQ will pursue appropriate enforcement actions.

Herbert Malarkey Roofing Company

Malarkey Roofing operates a composition shingle and rolled roofing manufacturing plant at 3131 N. Columbia Blvd in Portland. They operate under a general permit for discharge of non-contact cooling water (GEN 100). They discharge via a city storm sewer to the Columbia Slough. A review of monitoring data submitted to ODEQ shows a maximum effluent temperature of 25.6°C (78°F) in August 1998 and a maximum effluent flow of 160 gallons per minute (0.36 cfs) measured during the same time period. Assuming a 7Q10 low flow of 30 cfs and an effluent flow of 0.36 cfs, yielded a maximum allowable effluent temperature of 24.6°C (76.2°F) and a waste load allocation of 5.77 x 10^6 kilocalories per day.

Dynea Overlays

Dynea Overlays is located at 2301 N Columbia Blvd in Portland and holds individual NPDES industrial permit number 101544. In general, the activities at the site can be separated into two categories: production of phenolic-based resins and the application of resins to paper which is cured in a continuous coating operation. The finished coated paper products are sold for use in the wood products industry as overlays on plywood and waferboard substrates. Excess resins produced on-site is either distributed to other Dynea facilities or sold. Non-contact cooling water from these processes is discharged to the Columbia Slough (Dynea 2002).

Dynea Overlays submitted a temperature management plan (TMP) that has been approved by ODEQ and is therefore in compliance with the Department’s temperature standard. The TMP includes a discussion on timing and presence of salmonids, a summary of available effluent and ambient temperature data, analysis of temperature impacts in the Slough, proposed effluent monitoring, and a discussion of possible alternatives to reduce their effluent heat load. The waste load allocation for Dynea reflects the permit limits developed for their individual NPDES permit (#101544) issued in February, 2003.

Macadam Aluminum & Bronze Company

Macadam Aluminum & Bronze is a metal foundry located at 1255 North Columbia Boulevard. The facility holds a GEN 100 permit for non contact cooling water. The municipal water supply is used to cool oven heating coils and the electrical equipment which supplies power to the ovens. The water flows through the ovens and then to a cooling tower. The cooling water is then recycled back through the system and only overflow water discharges. A review of monitoring data submitted to ODEQ shows a maximum effluent temperature of 28.9°C (84°F) and a maximum effluent flow of 3.2 gallons per minute (0.007 cfs). Assuming a 7Q10 low flow of 30 cfs and an effluent flow of 0.007 cfs yielded a maximum allowable effluent temperature well above the instantaneous lethal limit for salmonids of 32.2°C (90°F) and a waste load allocation of 5.51 x 10^6 kilocalories per day. The facility is currently operating well within their effluent temperature limit and waste load allocation.

Sapa Anodizing

Sapa Anodizing is an aluminum finishing facility located at 7933 NE 21st Ave in Portland. They hold a GEN 100 permit for discharges of non-contact cooling water for their aluminum extrusion process. The facility maintains a current permit but has reported no discharge since January 1997. Sapa Anodizing has submitted a permit renewal application to ODEQ for this discharge. Historical discharge monitoring data was utilized for the purpose of assigning a waste load allocation to this discharge. A review of historical monitoring data submitted to ODEQ shows a maximum effluent temperature of 23.0°C (73.4°F) and a maximum effluent flow of 6.1 gallons per minute (0.014 cfs). Assuming a 7Q10 low flow of 21 cfs and an effluent flow of 0.014 cfs, the maximum allowable effluent temperature is well above the instantaneous lethal limit for salmonids of 32.2°C (90°F). The waste load allocation for this facility is 3.87 x 10^6 kilocalories per day. The facility is not currently discharging under this permit, but is expected to operate well within their effluent temperature limit and waste load allocation should they chose to discharge in the future.

The Halton Company

The Halton Company is located at 4421 NE Columbia Blvd in Portland. They sell heavy construction equipment and provide equipment maintenance and repair services. They hold an individual NPDES permit (#100798) for discharges associated with equipment steam cleaning. Equipment brought in for maintenance must be steam cleaned to remove solids that consist primarily of oil and dirt. Equipment is cleaned on a wash pad and the wash water and soil are collected in a vault where the soil settles out and is removed from the wastewater treatment system. The water is then recycled and reused. There have been no discharges to the Columbia Slough since September of 1996. The Halton Company chose to renew their permit in 2000, maintaining the ability to discharge if they so choose. Historical discharge monitoring data was utilized for the purpose of assigning a waste load allocation to this discharge. A review of historical monitoring data submitted to ODEQ shows that maximum effluent temperatures were not measured under previous permits. Historic monitoring reports showed a maximum effluent flow of 42 gallons per minute (0.093 cfs), which occurred in December 1994. Assuming a 7Q10 low flow of 21 cfs and an effluent flow of 0.093 cfs, the maximum allowable effluent temperature is above the instantaneous lethal limit for salmonids of 32.2°C (90°F). The waste load allocation for this facility is 3.92 x 10^6 kilocalories per day.

Port of Portland

The Port of Portland maintains an Individual NPDES industrial dewatering permit (#101588) for construction site dewatering activities that discharge treated excavation waste water to the Columbia Slough. Discharges from this permit enter the Slough through nine outfalls located in the vicinity of Portland International Airport. Dewatering activities occur on an intermittent basis depending upon conditions encountered during construction within a specific drainage basin. The permit requires temperature and flow monitoring. In order to evaluate this discharge and assign a waste load allocation in the absence of effluent temperature and flow data, ODEQ conservatively assumed a discharge rate of 1.0 cfs (450 gallons per minute) from a single outfall. Assuming a 7Q10 low flow of 21 cfs and an effluent flow of 1.0 cfs resulted in a maximum allowable effluent temperature of 19.9°C (67.8°F) and a waste load allocation of 4.59 x 10^6 kilocalories per day. A flow-based waste load allocation may be developed for this discharge provided flow and temperature monitoring data are provided to ensure compliance with permit limits.

The Port of Portland and co-permittees also maintain an Individual NPDES industrial deicing permit (#101647) for discharge of deicing materials to the Columbia Slough. A deicing discharge control system was constructed in order to address the wasteload allocation for BOD in the dissolved oxygen TMDL developed by ODEQ in 1998. November 1 through April 30th is the permit-designated “deicing season” and summertime monitoring is not a permit requirement. Deicing activity is primarily conducted during the winter and therefore has no reasonable potential to contribute to summertime temperature standard violations. Therefore, the Port of Portland and co-permittees will receive no waste load allocation for this discharge. If summertime discharges are anticipated permit conditions must be modified and a waste load allocation will be assigned.

Oregon Fresh Farms

Oregon Fresh Farms is located at 6849 NE Columbia Blvd in Portland. The facility is a vegetable washing and packaging center. The individual NPDES Industrial permit (#101079) covers the discharge of processed wastewater, vegetable wash water, and stormwater to the Columbia Slough. A review of monitoring data submitted to ODEQ shows that effluent temperatures are not measured under this permit. Monitoring reports showed a maximum effluent flow of 87 gallons per minute (0.193 cfs) which occurred in August 2002. Assuming a 7Q10 low flow of 21 cfs and an effluent flow of 0.193 cfs, the maximum allowable effluent temperature is 26.5°C (79.6°F). The waste load allocation for this facility is 4.00 x 10^6 kilocalories per day.

Ventura Foods

Ventura Foods produces margarine, mayonnaise, shortening and salad dressings. They hold a GEN 100 permit for discharge of non-contact cooling water to the Columbia Slough. A review of recent monitoring data submitted to ODEQ shows a maximum effluent temperature of 31.1°C (88°F) in October 2001 and a maximum effluent flow of 107.5 gallons per minute (0.24 cfs) measured during the same time period.

Assuming a 7Q10 low flow of 21 cfs and an effluent flow of 0.24 cfs, yielded a maximum allowable effluent temperature of 24.9°C (76.8°F) and a waste load allocation of 4.03 x 10^6 kilocalories per day.

Owens-Illinois Glass Container

Owen-Illinois is a glass Container facility located at 5850 NE 92nd Ave in Portland. They hold a GEN 100 permit for discharge of non-contact cooling water, defrost water, heat pump transfer water, and cooling tower blowdown. Cooling water is routed through glass furnace electrodes and air compressors, through a cooling tower, and is recycled back through the system. There have been almost no discharges under this permit, with the exception of a storage tank that is drained at least once per year. A review of recent monitoring data submitted to ODEQ shows a maximum effluent temperature of 32.2°C (90°F) in May 2001 and a maximum effluent flow of 29.2 gallons per minute (0.07 cfs) measured during the same time period. Assuming a 7Q10 low flow of 21 cfs and an effluent flow of 0.07 cfs, the maximum allowable effluent temperature is above the instantaneous lethal limit for salmonids of 32.2°C (90°F). The waste load allocation for this facility is 3.90 x 10^6 kilocalories per day.

Enterprise Rent-A-Car

Enterprise Rent-A-Car is located at 10947 NE Holman St in Portland. The facility holds a GEN 1700A permit which covers the wash water discharges from the exterior washing of their rental cars. Wash water drains into two catch basins which discharge to a sedimentation basin. Settled water is recycled to the car washing equipment. Excess wastewater flows to an oil/water separator and is discharged to a bioswale. The bioswale discharges to a ditch leading to the Oregon Department of Transportation (ODOT) storm sewer system, which then discharges to the Slough near Interstate 205. The GEN 1700A permit does not require temperature or flow monitoring. In order to evaluate this discharge and assign a waste load allocation in the absence of effluent temperature and flow data, ODEQ conservatively assumed a discharge rate of 0.1 cfs (45 gallons per minute). Assuming a 7Q10 low flow of 21 cfs and an effluent flow of 0.1 cfs, the maximum allowable effluent temperature is above the instantaneous lethal limit for salmonids of 32.2°C (90°F). The waste load allocation for this facility is 3.93 x 10^6 kilocalories per day.

Miller Paint

Miller Paint owns and operates a paint manufacturing facility located at 12730 NE Whitaker Way in Portland. The facility holds a GEN 100 permit of the discharge of non-contact cooling water to the Prison Pond arm of the Columbia Slough near NE 122nd Avenue. A review of recent monitoring data submitted to ODEQ shows a maximum effluent temperature of 20.0°C (68°F) in September 2001 and a maximum effluent flow of 9.2 gallons per minute (0.02 cfs) measured in October 2001. Since this facility discharges to the Prison Pond arm of the slough ODEQ conservatively assumed a 7Q10 low flow condition of 7 cfs. The maximum allowable effluent temperature is above the instantaneous lethal limit for salmonids of 32.2°C (90°F). The waste load allocation for this facility is 1.30 x 10^6 kilocalories per day.

City of Portland

The City of Portland owns and operates a groundwater pumping station located at 16400 NE Airport Way, in Portland, Oregon. This facility holds Individual NPDES industrial permit #101617. The primary purpose of the facility is to receive groundwater from 27 wells and pump it to the Powell Butte Reservoir for distribution to the City's water supply system.

Wastewater from well field testing and UV validation activities can be discharged to the Columbia Slough, Columbia River, Blue Lake, and Prison Pond. For the most part, these discharges are non-chlorinated groundwater and any chlorinated groundwater is de-chlorinated using sodium thiosulfate prior to discharge. All well water temperature data submitted shows average temperatures of 15°C (59°F) or less. Discharge of water at this temperature has no reasonable potential to contribute to temperature standards violations in the Columbia Slough.

However, due to the potential volume of this discharge ODEQ established a waste load allocation and maximum effluent temperature. Monitoring reports showed a maximum effluent flow of 1687 gallons per minute for a period of 9 hours (10 cfs) which occurred in November 2002. Assuming a 7Q10 low flow of

21 cfs and an effluent flow of 10 cfs, the maximum allowable effluent temperature is 18.5°C (65.2°F). The waste load allocation for this facility is 1.12 x 10^7 kilocalories per day.

Boeing Company

The Boeing Facility (Boeing Portland) is located at 19000 NE Sandy Blvd. in Gresham, Oregon and holds both a GEN 100 and an Individual NPDES industrial permit (#101761). Both Boeing permits discharge to the Columbia Slough via a stormwater outfall near NE 188th Avenue.

GEN 100 – The Boeing facility holds a GEN 100 permit for the discharge of non-contact cooling water to the upper Columbia Slough via the City of Gresham storm sewer system. The permit covers the discharge from two different pieces of equipment, so the ODEQ chose the conservative approach of summing the maximum effluent flow rates from each and applying the highest reported effluent temperature to the combined flow. The maximum combined flow rate was 13 gallons per minute (0.03 cfs) and the maximum discharge temperature was 22.2°C (72.0°F). The maximum allowable effluent temperature is above the instantaneous lethal limit for salmonids of 32.2°C (90°F).

NPDES – Boeing holds an individual NPDES permit to operate a groundwater recovery and treatment system, in which contaminated groundwater is pumped from several wells and treated in an air stripping tower to remove pollutants. The treated groundwater is then discharged to the Columbia Slough. A review of monitoring data submitted to ODEQ as part of the permit application shows a summertime maximum effluent temperature of 11.7°C (53°F) and an average effluent flow of 530 gallons per minute (1.18 cfs). Discharge of water at this temperature has no reasonable potential to contribute to temperature standards violations in the Columbia Slough.

However, due to the potential volume of this discharge ODEQ established a waste load allocation and maximum effluent temperature. Assuming a 7Q10 low flow of 21 cfs and an effluent flow of 1.18 cfs, the maximum allowable effluent temperature is 19.6°C (67.3°F). Since the GEN 100 and NPDES permitted discharge enter the Slough through a single stormwater outfall, the discharges were combined and the resulting waste load allocation for this facility is 4.74 x 10^6 kilocalories per day.

Cascade Corporation

Cascade Corporation machines, fabricates, and assembles hydraulic lift truck attachments and holds individual NPDES Industrial non-contact cooling water permit #101630. The facility is located at 2201 NE 201st Ave. in Fairview, Oregon. Non contact cooling is used in three areas: the production facility air compressor, the product development test stand, and the production facility hardening machine. The source of this non-contact cooling water is drinking water from the Rockwood Water District. The Cascade Corporation discharges to Osburn Creek via a roadside ditch. A review of recent monitoring data submitted to ODEQ shows a maximum effluent temperature of 22.9°C (73.2°F) and a maximum effluent flow of 39.7 gallons per minute (0.09 cfs) as measured at the discharge point from the facility. The effluent from the Cascade Corporation essentially comprises the entire flow in the roadside ditch during the late summer months, which eventually enters Osburn Creek. Assuming a 7Q10 low flow of 2 cfs in Osburn Creek and an effluent flow of 0.09 cfs yielded a maximum allowable effluent temperature of 20.0°C (68.0°F) and a waste load allocation of 0.43 x $10^{6,}$ as measured at the point of discharge to Osburn Creek.

Morse Bros. (Vance Pit)

Morse Bros (Vance Pit) operate a gravel pit mine at 1339 NW Eastwood Ave in Gresham, Oregon. They hold a GEN 1000 Gravel Mining permit for gravel washing. Process water, and pit water (dewatered by pumping from the sump) drains to a pond in the northeast corner of the property. This pond is a former pit but has since silted in from process water discharged from the wash plant. Excess water in the pond is conveyed via piping to an infiltration gallery in the southwest corner of the site. Water soaks into the subgrade and discharges to the pit as a small perched zones along the face in the southwestern corner of the pit. Storm Water drains internally to the pit and there are no offsite discharges. Since the discharge does not enter surface waters and has no reasonable potential to contribute to water quality standards violations, no waste load allocation will be assigned to this discharge.

Oregon Asphaltic Paving Company

Oregon Asphaltic Paving Company operates a gravel pit mine located at 1300 SE 190TH in Gresham, Oregon. They hold a GEN 1000 Gravel Mining permit. This pit mine is just north of the Vance Pit. The Pit extends about 50 to 60 feet below grade. Under static conditions, the lower 10-20 feet of the pit contains ground water. Groundwater is pumped from active mining cells to inactive ponds within the pit. From these ponds, water is recharged to the ground. There is no discharge to nearby Fairview Creek which lies to the east of the property. According to an August 2002 site inspection there has been no evidence to date of off site impacts from this process. Since the discharge does not enter surface waters and has no reasonable potential to contribute to water quality standards violations, no waste load allocation will be assigned to this discharge.

Allocations – 40 CFR 130.2(g) and 40 CFR 130.2(h)

Load Allocations are portions of the loading capacity divided between natural, human and future nonpoint pollutant sources. **Table 5.18** lists load allocations (i.e. distributions of the loading capacity) according to land-use and location in the watershed. A *Waste Load Allocation* (WLA) is the amount of pollutant that a point source can contribute to the stream without violating water quality criteria.

Table 5.18. Temperature Load Allocation Summary

Source	Loading Allocation
Natural Background + Reserve Capacity	100%
Agriculture	0%
Forestry	0%
Urban	0%
Future Sources	0%

ODEQ used the methodology described in the *Point Source Methodology* section to determine appropriate waste load allocations for point sources discharging in the Columbia Slough Watershed. **Table 5.19** lists specific allocations for nonpoint sources and for each point source.

Table 5.19. Point Source Waste Load and Load Allocations

Subtable A: NPDES Point Source Waste Load Allocations

Facility Name	Receiving Water	Maximum Effluent Temperature (F)/(C)	Waste Load Allocation Allowable Point Source Heat Load kcal/day
MALARKEY ROOFING CO.	Lower Slough	76.2 / 24.6	5.77 X 10^6
DYNEA OVERLAYS	Lower Slough	73.6 / 23.1	12.4 X 10^6
MACADAM ALUMINUM & BRONZE CO.	Lower Slough	**90 / 32.2	5.51 X 10^6
SAPA ANODIZING, INC	Middle Slough	**90 / 32.2	3.87 X 10^6
THE HALTON COMPANY	Middle Slough	**90 / 32.2	3.92 X 10^6
PORT OF PORTLAND	Middle Slough	67.8 / 19.9	4.59 X 10^6
OREGON FRESH FARMS	Middle Slough	79.6 / 26.5	4.00 X 10^6
VENTURA FOODS, LLC	Middle Slough	76.8 / 24.9	4.03 X 10^6
OWENS-ILLINOIS INC.	Middle Slough	**90 / 32.2	3.90 X 10^6
ENTERPRISE RENT-A-CAR	Middle Slough	**90 / 32.2	3.93 X 10^6
MILLER PAINT CO INC	Middle Slough	**90 / 32.2	1.30 X 10^6
CITY OF PORTLAND	Upper Slough	65.2 / 18.5	11.2 X 10^6
BOEING (GEN 100)	Upper Slough	**90 / 32.2	*4.74 X 10^6
BOEING (NPDES)	Upper Slough	67.3 / 19.6	
CASCADE CORPORATION	Upper Slough	68.0 / 20.0	0.43 X 10^6
		Total	**69.6 x10^6**

* Boeing discharges combined for total waste load allocation
** Instantaneous Lethal Limit for Salmonids

Subtable B: Nonpoint Sources

Source	Load Allocation Allowable Nonpoint Source Solar Radiation Heat Load (kcal/day)
All Nonpoint Sources	**2660 X 10^6**

Effective Shade Surrogate Measures

Site specific effective shade surrogates are developed to help translate the nonpoint source solar radiation heat loading allocations. Attainment of the effective shade surrogate measures is equivalent to attainment of the nonpoint source load allocations.

A loading capacity of some heat unit per day is not very useful in guiding nonpoint source management practices. Percent effective shade is a surrogate measure that can be calculated directly from the loading capacity. Additionally, percent effective shade is simple to quantify in the field or through mathematical calculations. **Figures 5.42** to **5.47** display the percent effective shade values that correspond to the loading capacities (i.e., system potential) for portions of the Columbia Slough where a vegetation analysis was conducted. Site specific effective shade surrogates were developed to help translate the nonpoint source solar radiation heat loading allocations. Effective shade levels for the respective sections of the Columbia Slough (**Figures 5.42** to **5.47)** are the allocated condition and represent the targeted riparian condition with respect to shade. Notice that only very modest improvements are possible in the lower Columbia Slough (**Figure 5.42**) with increased shading because the channel is quite wide. Portions of the Middle, South and Upper Sloughs, where channel widths are much narrower and riparian vegetation has been removed due to development, would show greatly increased stream shading conditions with the establishment of system potential riparian vegetation. Buffalo Slough is also quite wide and riparian vegetation improvements are unlikely to significantly improve overall shade conditions as they relate to water temperature. It should be noted that salmonid use of the lower portion of Columbia Slough has been documented and that system potential riparian vegetation, though unlikely to significantly improve summertime stream temperature, may be very important in providing suitable habitat conditions for salmonids.

Figure 5.42. Lower Columbia Slough Effective Shade Surrogate Measure for Nonpoint Sources

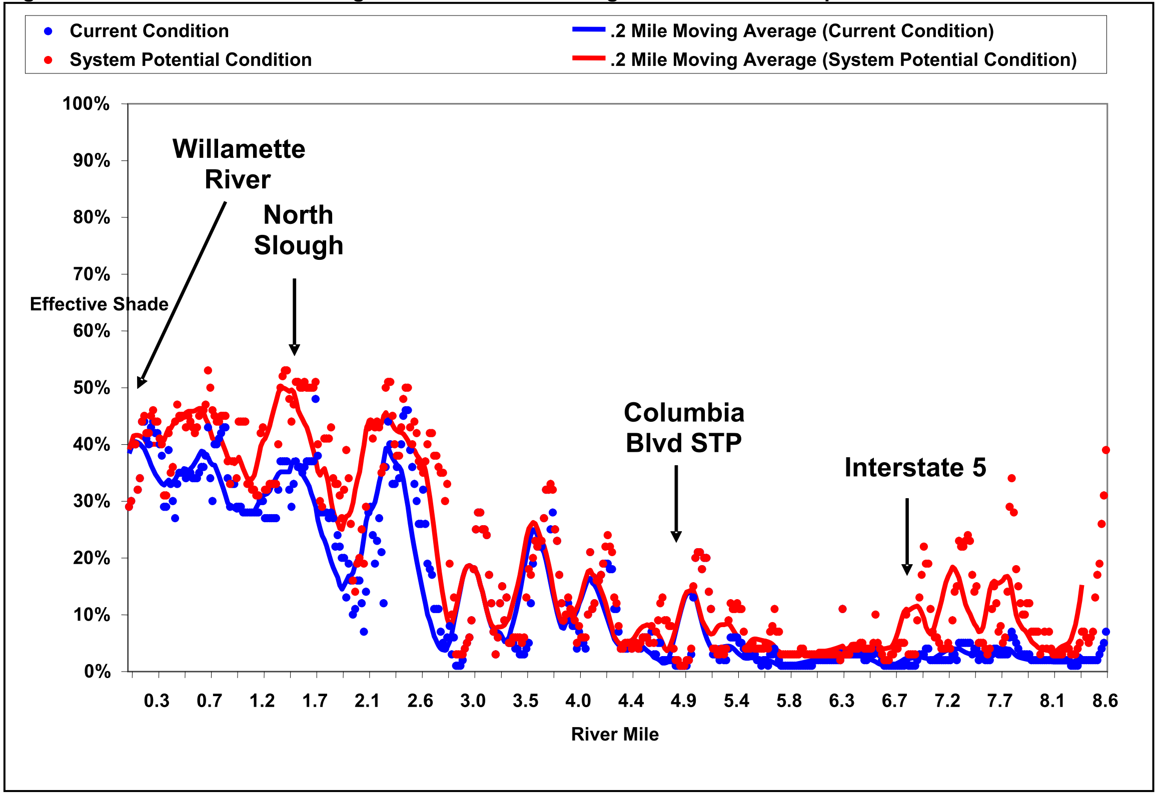


Figure 5.43. North Columbia Slough Effective Shade Surrogate for Nonpoint Sources

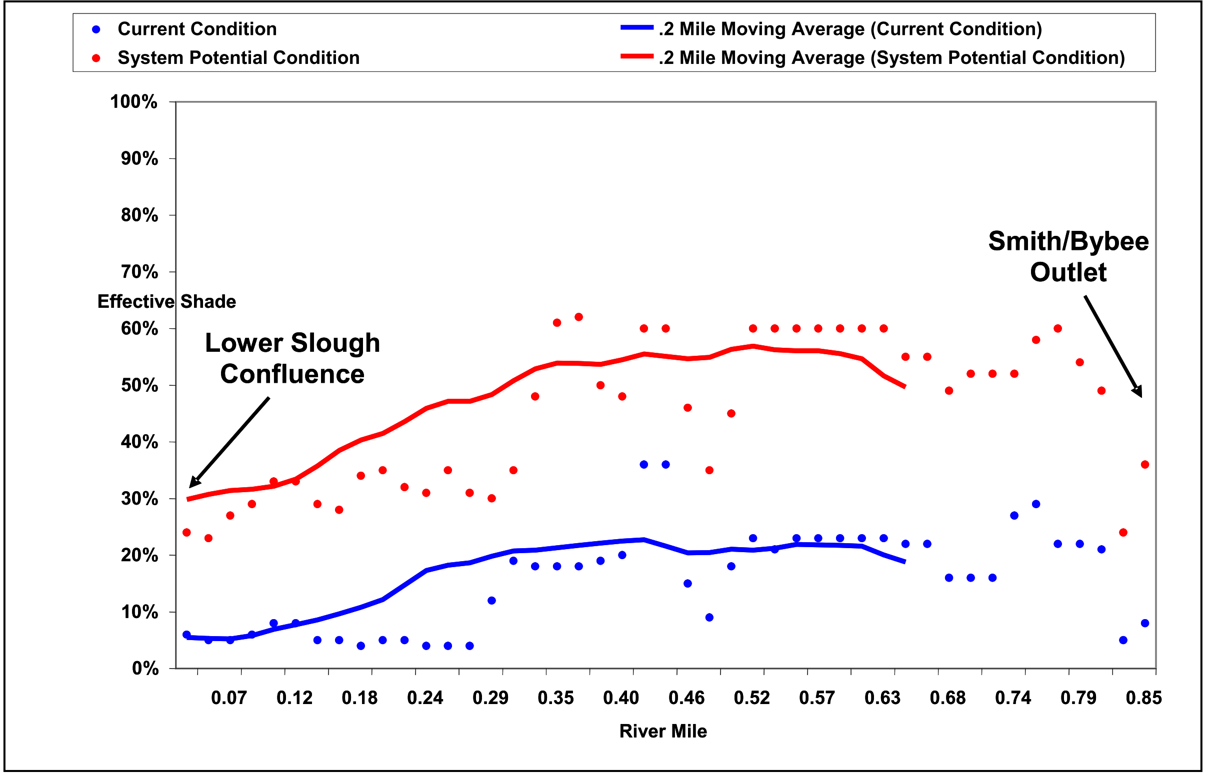


Figure 5.44. Middle Columbia Slough Effective Shade Surrogate for Nonpoint Sources

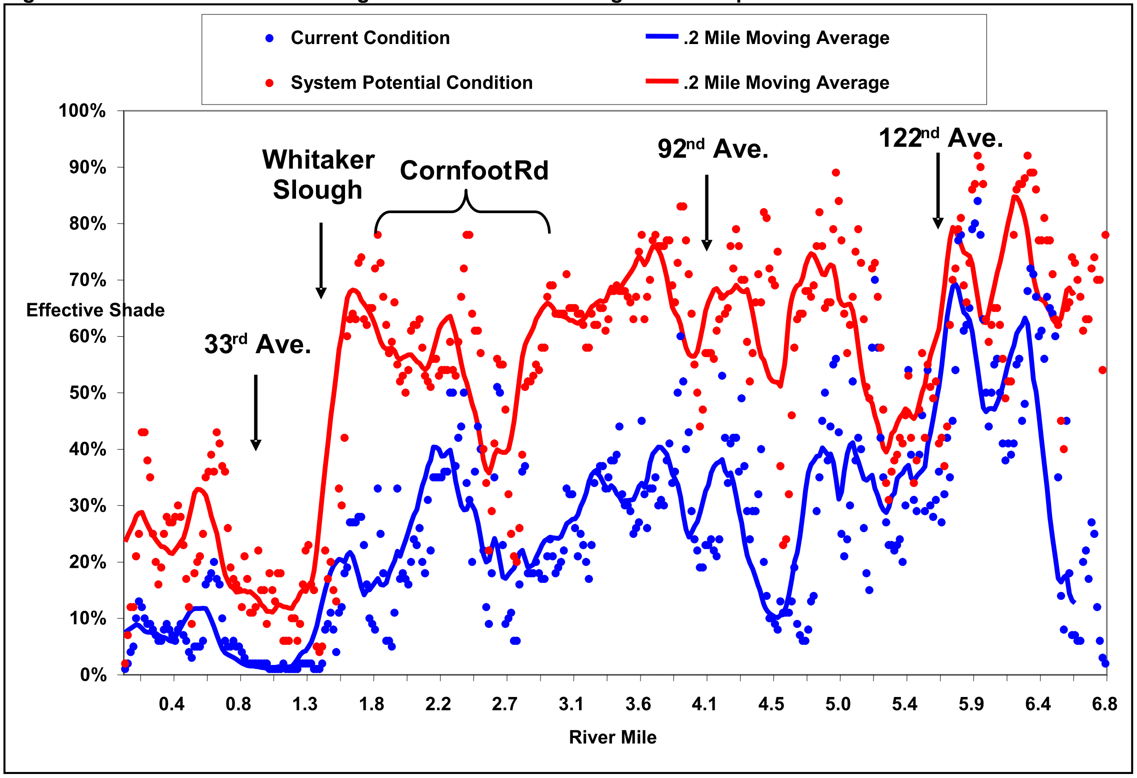


Figure 5.45. Buffalo Slough Effective Shade Surrogate Measure for Nonpoint Sources

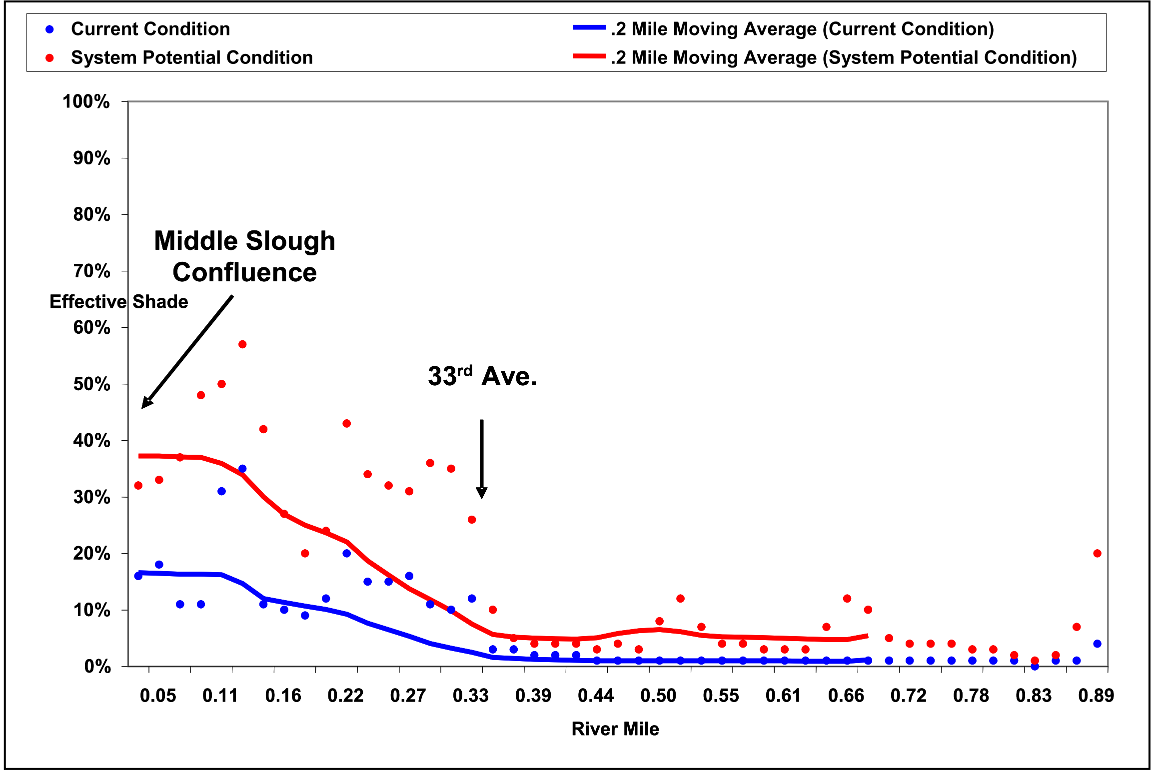


Figure 5.46. South (Whitaker) Slough Effective Shade Surrogate for Nonpoint Sources

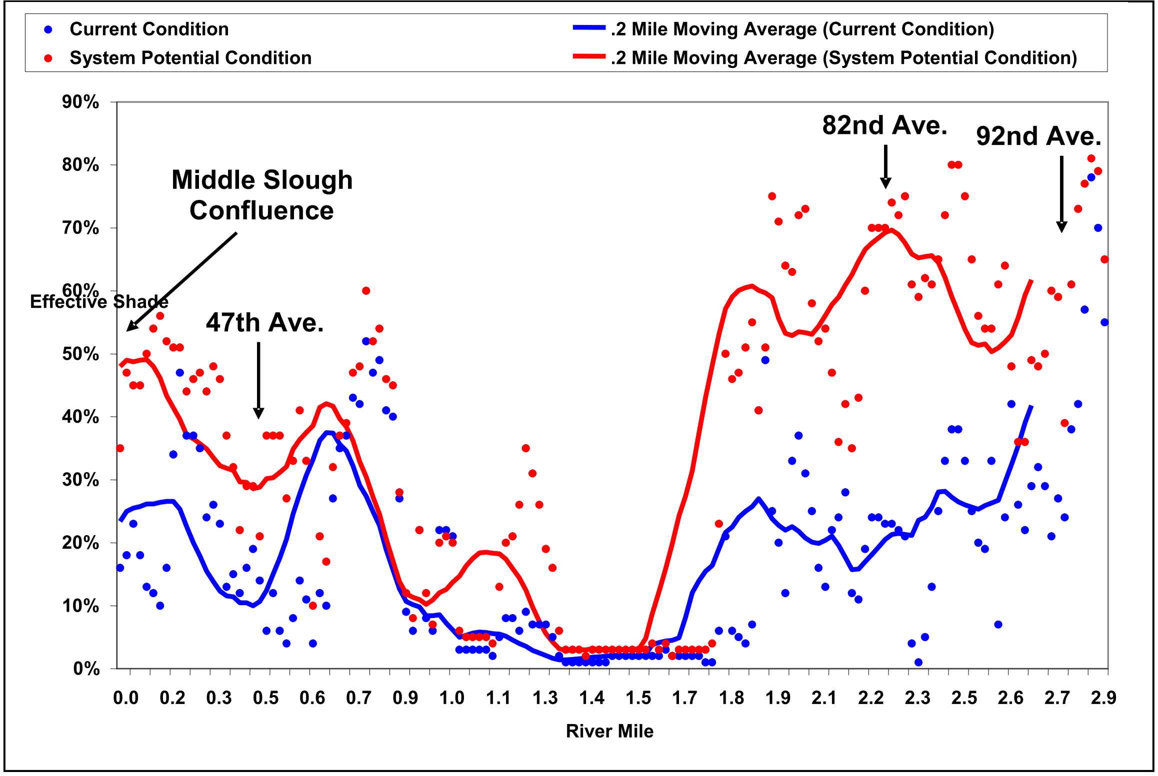
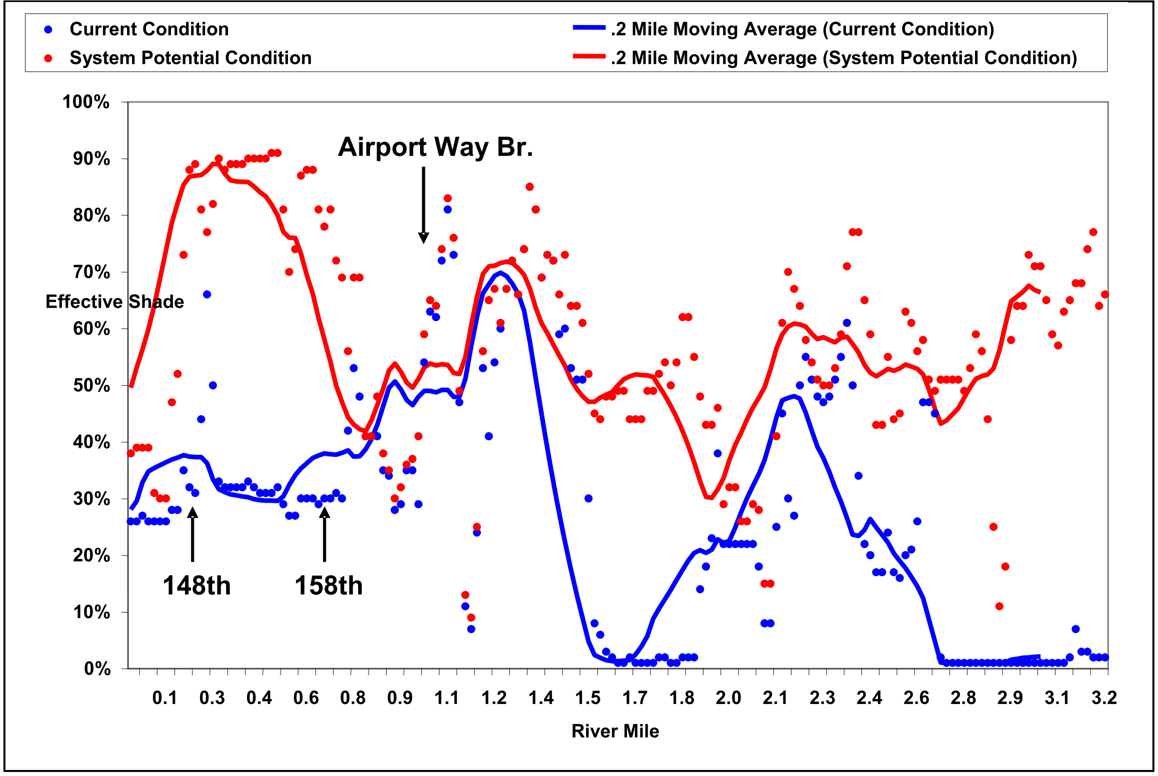


Figure 5.47. Upper Columbia Slough Effective Shade Surrogate for Nonpoint Sources



Effective Shade Curves

The site specific effective shade targets specified above provide reach-specific shade targets for portions of the Columbia Slough where ODEQ performed a detailed analysis of current and site potential vegetation. However, all tributaries within the Columbia Slough watershed must also achieve shade targets in order to achieve compliance with the Oregon's temperature standard and nonpoint source load allocations. To ensure that site potential vegetation characteristics are applied in a geographically appropriate manner, ODEQ utilized ecoregional geographic boundaries to assign appropriate vegetative characteristics throughout the watershed. Where effective shade levels are not specified in **Figures 5.42** to **5.47**, effective shade for the appropriate ecoregion and near stream disturbance zone width shall be applied. In the Columbia Slough watershed the shade curve will apply to arms of the Slough where a vegetation analysis was not performed and also for all streams in the Fairview Creek watershed.

Shade targets for the Columbia Slough Watershed, and a detailed discussion of the methodology, are provided in the ***Effective Shade Curves*** section of this chapter.

Water Quality Standard Attainment Analysis

Simulations were performed to calculate the temperatures that result from the attainment of site potential shade targets as well as hydraulic improvements to the Slough system. The resulting simulated temperatures represent attainment of system potential, and therefore, attainment of the temperature standard.

Generally speaking, the middle and upper portions of the Columbia Slough showed significantly cooler temperatures under site potential (allocated) conditions. This is likely due to the fact that the lower portions of the Slough are very wide and do not benefit from the affects of improved shading conditions.

Stream temperatures that result from the system potential conditions represent attainment of the temperature standard

ODEQ recognizes that it may take several years to several decades after full implementation of shade-producing measures to achieve the shade targets identified in this TMDL. Simply put, wide stream segments typically require taller, older riparian vegetation in order to achieve shade targets and narrow stream segments may achieve the shade targets with shorter, younger riparian vegetation. Site specific shade targets identified in **Figures 5.42** through **5.47** can be used to help guide and prioritize implementation efforts to maximize the near-term effectiveness of implementation efforts. ODEQ expects that DMAs will focus initial implementation efforts on improving shade conditions through establishing and/or enhancing riparian vegetation conditions and in ensuring that existing and future development practices allow the attainment of shade targets.

Table 5.14 and **Figures 5.30** through **5.35** demonstrate the affect that removing anthropogenic sources of stream heating is likely to have on stream temperatures throughout the Columbia Slough.

JOHNSON CREEK WATERSHED

Seasonal Variation

Johnson Creek from the Mouth to Headwaters is designated as temperature limited on Oregon's 1998 303(d) list.

Johnson Creek and its tributaries experience warming starting in late spring and extending into the fall. Maximum temperatures typically occur in July and August (**Figure 5.48).** Exceedance of the 18.0°C (64.4°F) numeric criterion typically occurs during the summer months throughout Johnson Creek and at the mouth of Crystal Springs Creek. Note that the seven day average of the daily maximum stream temperatures at two locations (Johnson Creek at 92nd Ave. and Crystal Springs Creek at the mouth) exceeded the incipient lethal limit for salmonids. Again, Crystal Springs Creek is not 303d listed for temperature, but watershed-wide temperature targets developed to achieve the Johnson Creek temperature TMDL will be applied to all streams in the watershed. **Figure 5.49** shows similar information in a different format. Both figures show that Kelley Creek typically contributes cooler water to Johnson Creek and that Crystal Springs Creek at the mouth is often quite warm relative to Johnson Creek due to the warming caused by upstream impoundments.

It should also be noted that Johnson Creek and its tributaries are also above the 13.0°C (55.4°F) numeric spawning criterion during periods when Steelhead and Cutthroat spawning is likely to occur.

Figure 5.50 shows the location of all TMDL-related continuous temperature monitoring locations.

Figure 5.48. 7-day Average of the Daily Maximum Stream Temperature at Selected Johnson Creek Watershed Monitoring Locations

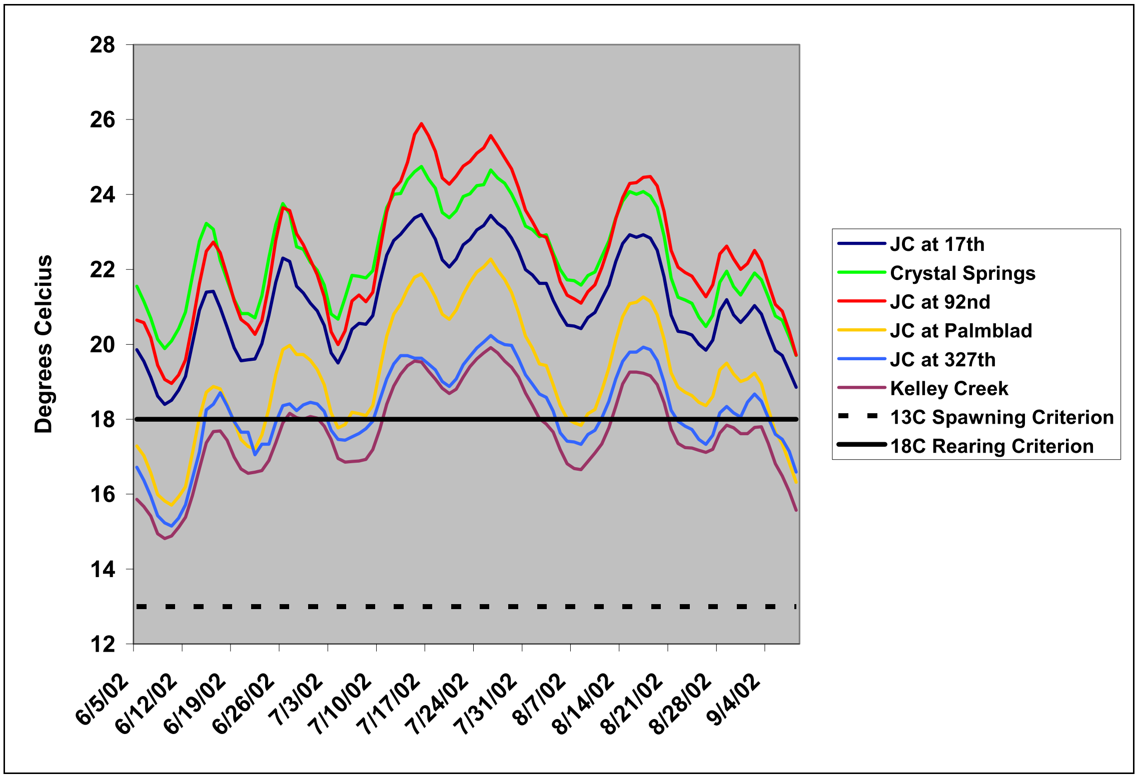


Figure 5.49. Summertime (5/30-9/10, 2002) Average and Absolute Daily Maximum Stream Temperature at Various Locations in the Johnson Creek Watershed

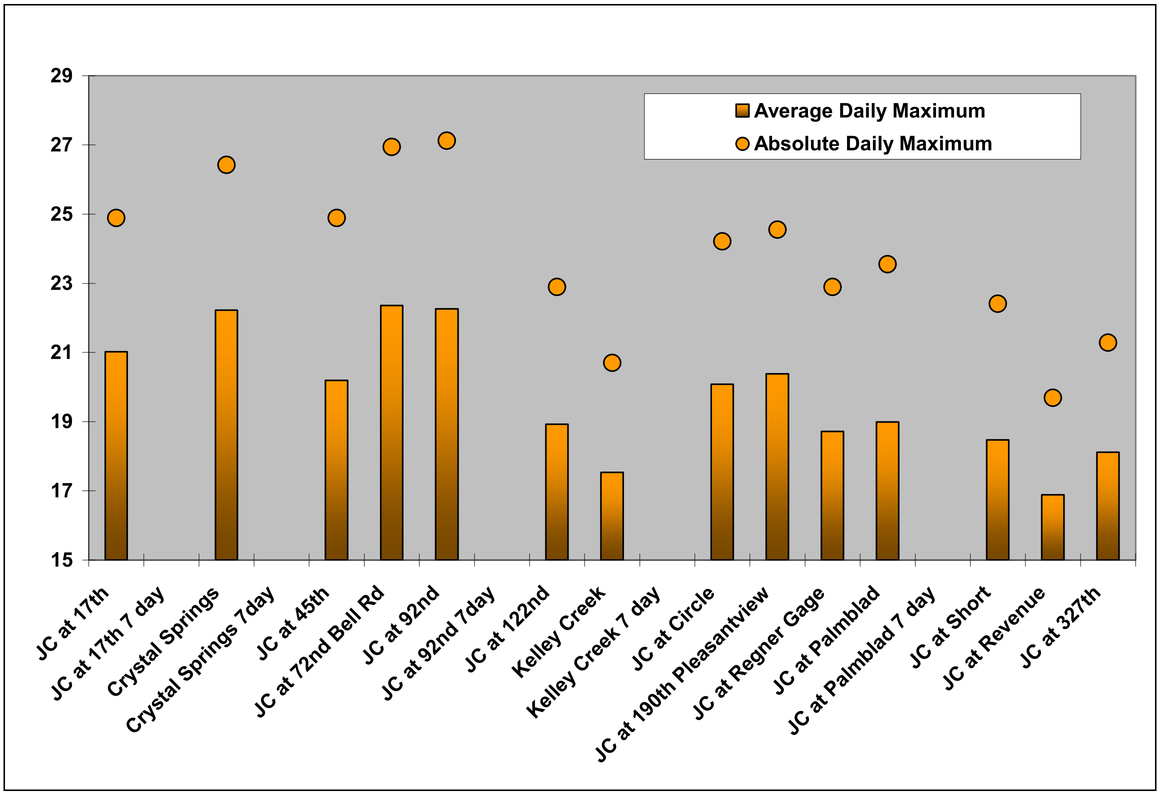
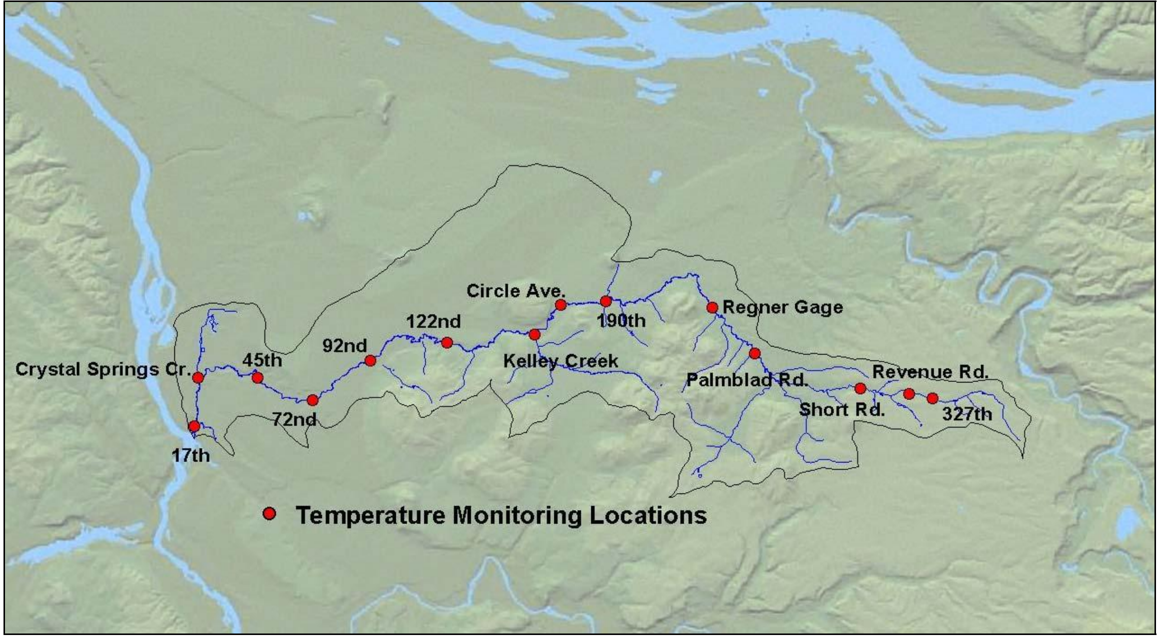


Figure 5.50. Johnson Creek Watershed Temperature Monitoring Locations



Existing Heat Sources

Nonpoint Sources

Settlement around Johnson Creek brought about significant changes in the near stream vegetation and hydrologic characteristics of the watershed. Historical development, agricultural and logging practices altered the stream morphology and hydrology and decreased the amount of riparian vegetation. Timber harvest and flood control activities cleared streams and riparian corridors of fallen trees and large woody debris, with riparian areas logged down to the stream banks. Drainage and stream channelization has occurred throughout the watershed.

More recently, increases in population have resulted in urbanization of much of the watershed. Conversion of forest and pasture to residential and commercial development is extensive, which resulted in reduced riparian vegetation and radically altered hydrology.

Riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, riparian condition, channel morphology and hydrology are affected by human activities.

Specifically, the elevated summertime stream temperatures attributed to anthropogenic nonpoint sources result from:

1. ***Near stream vegetation disturbance or removal*** *reduces stream surface shading via decreased riparian vegetation height, width and/or density, thus increasing the amount of solar radiation reaching the stream surface (shade is commonly measured as percent effective shade or open sky percentage). Riparian vegetation also plays an important role in shaping the channel morphology, resisting erosive high flows and maintaining floodplain roughness.*
2. ***Channel modifications and widening*** *(increased width to depth ratios) increases the stream surface area exposed to energy processes, namely solar radiation. Near-stream disturbance zone (NSDZ) widening decreases potential shading effectiveness of shade-producing near-stream vegetation. Instream ponds, primarily in the upper Johnson Creek and Crystal Springs Creek watersheds, result in the impoundment of water and increased exposure to solar radiation.*

Instream ponds are prevalent within Johnson Creek and in virtually all tributaries in the watershed. Two large instream ponds essentially form the headwaters of Crystal Springs Creek – Reed Lake, with a surface area of approximately 4 acres (174,000 sq. ft.) and Crystal Springs Lake, with a surface area of approximately 10 acres (436,000 sq. ft.). ODFW noted three instream ponds in Kelley Creek during aquatic inventories conducted in 1999 and 2000. ODFW surveys noted that Veterans Creek is heavily impacted by instream ponds and that artificial step-pool sequences create a “fountain-like” atmosphere. Dammed pools comprise 85% of the stream habitat in upper Errol Creek. **Figure 5.51** shows several instream ponds in an area near the headwaters of Johnson Creek While it is possible to calculate the theoretical heat load and temperature increases that result from the instream ponds, ODEQ had insufficient information to quantify the overall impact of instream ponds in this TMDL analysis. **Figure 5.52** shows the theoretical stream heating that results from various sized impoundments given a specified stream flow through the impoundment. Detailed stream temperature and flow information for each stream segment containing instream ponds would be necessary to quantify their impact and **Figure 5.52** is not meant to depict Johnson Creek-specific heating. However, Johnson Creek does exhibit unusually warm stream temperatures in even the highest reaches, which suggests anthropogenic (instream ponds, lack of riparian vegetation, water withdrawals, etc.) heat loading at or near headwater reaches.

Figure 5.51. In-stream and Off-stream Ponds in the Upper Watershed of Johnson Creek.

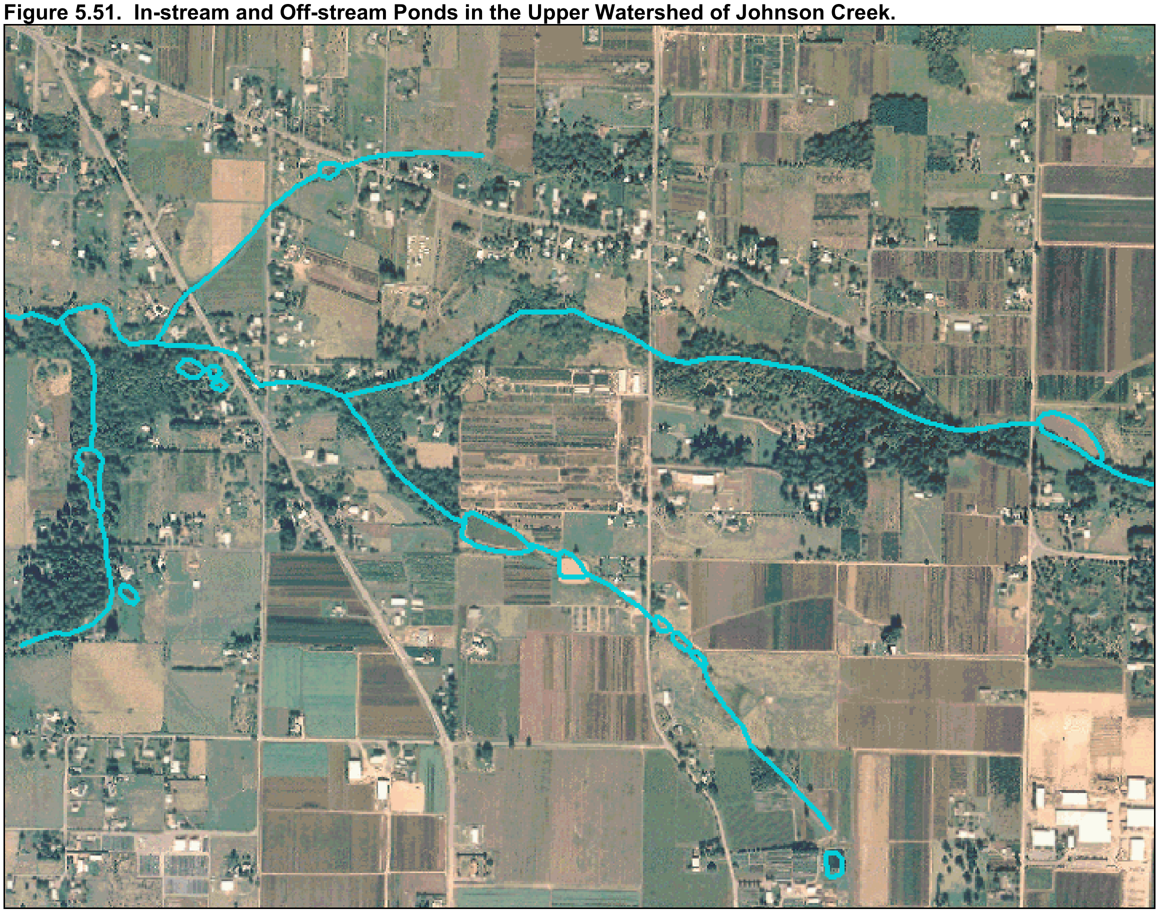
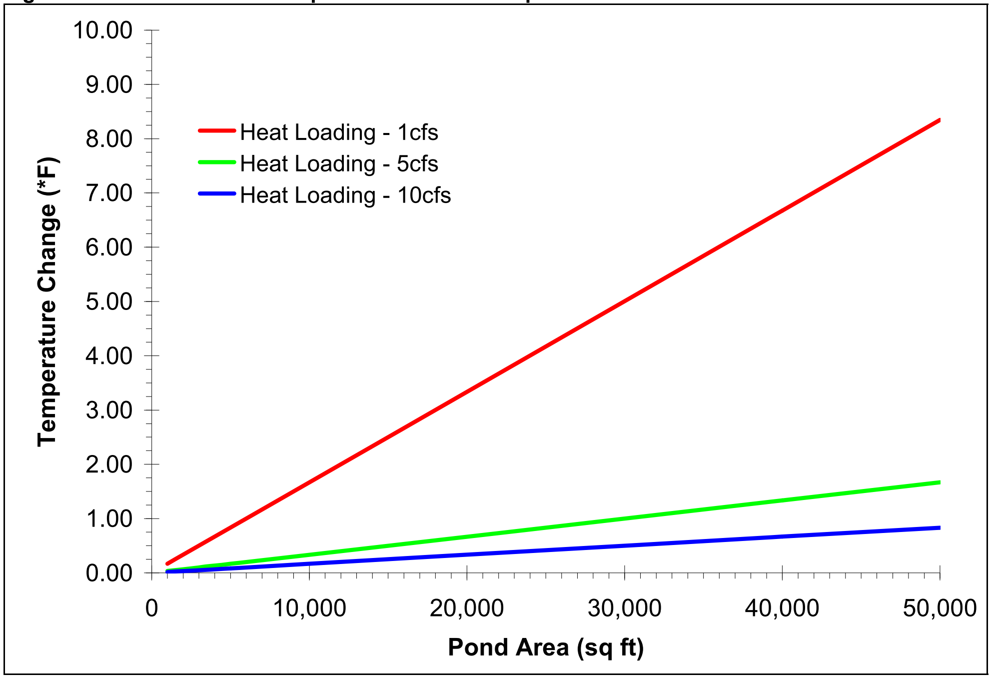


Figure 5.52. Theoretical Example of the Thermal Impact of Instream Ponds



Point Sources of Heat

Point source discharges can be sources of stream heating in the Johnson Creek watershed. Point source dischargers to Johnson Creek and tributaries are discussed fully in the **"Loading Capacity"** section of this document.

Riparian Vegetation Analysis

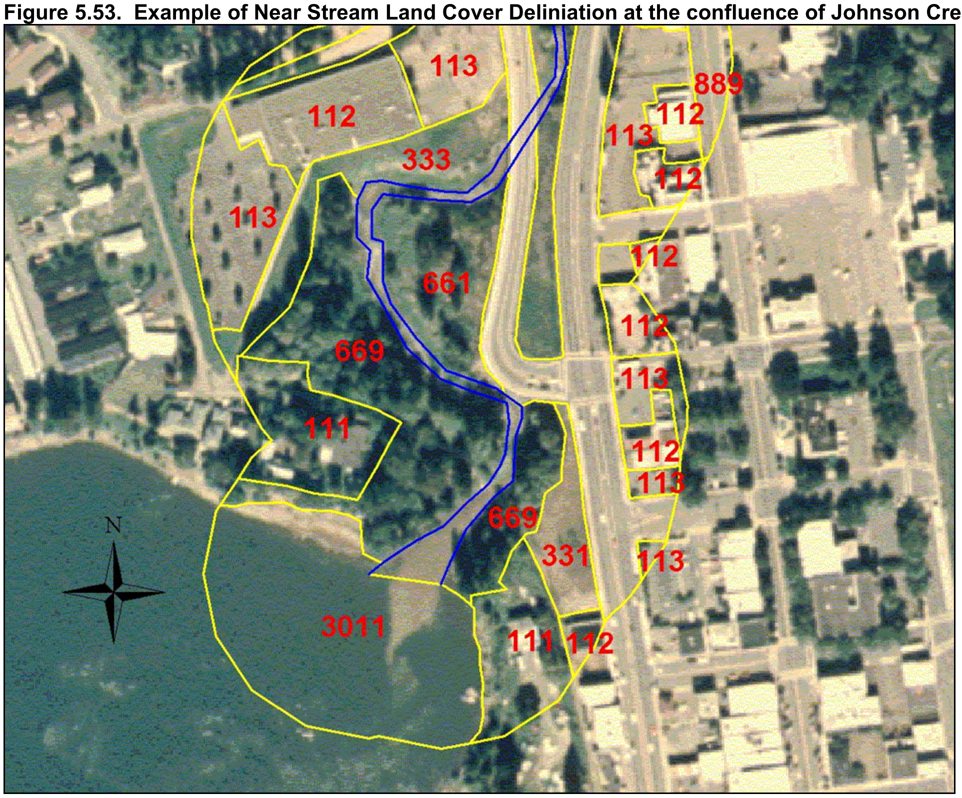
Riparian vegetation plays an important role in controlling stream temperature change. Near stream vegetation height, width and density combine to produce shadows that when, cast across the stream, reduce solar radiant loading. Bank stability is largely a function of riparian vegetation. Riparian corridors often produce a microclimate that surrounds the stream where cooler air temperatures, higher relative humidity and lower wind speeds are characteristic. Riparian corridors containing mature vegetation are generally very narrow and in some cases nonexistent in many portions of the Johnson Creek watershed.

Current Condition

Current condition riparian vegetation was characterized using digitally rectified color aerial photographs taken on September 20, 1997. The photographs are part of the RLIS geographic information system database developed by the Metro Data Resource Center and purchased by ODEQ. Vegetation polygons were digitized in the near stream area (300 feet on either side of the stream channel) and classified by vegetation type. All classifications included an average riparian vegetation height, overhang and canopy density, which are described in **Table 5.20**. **Figure 5.53** shows an example of the aerial photography, digitized polygons and classification codes used in the analysis of Johnson Creek near stream land cover. The area shown is at the confluence of Johnson Creek and the Willamette River. The left and right banks of Johnson Creek are shown in blue. This imagery also shows highly turbid water entering the Willamette River via Johnson Creek.

Near-stream land cover codes were quality checked against aerial photographs by ODEQ. Ground level measurements to assist in riparian land cover classification and quantification were collected by ODEQ during the summer of 2002 at all temperature monitoring locations shown above in **Figure 5.50**.

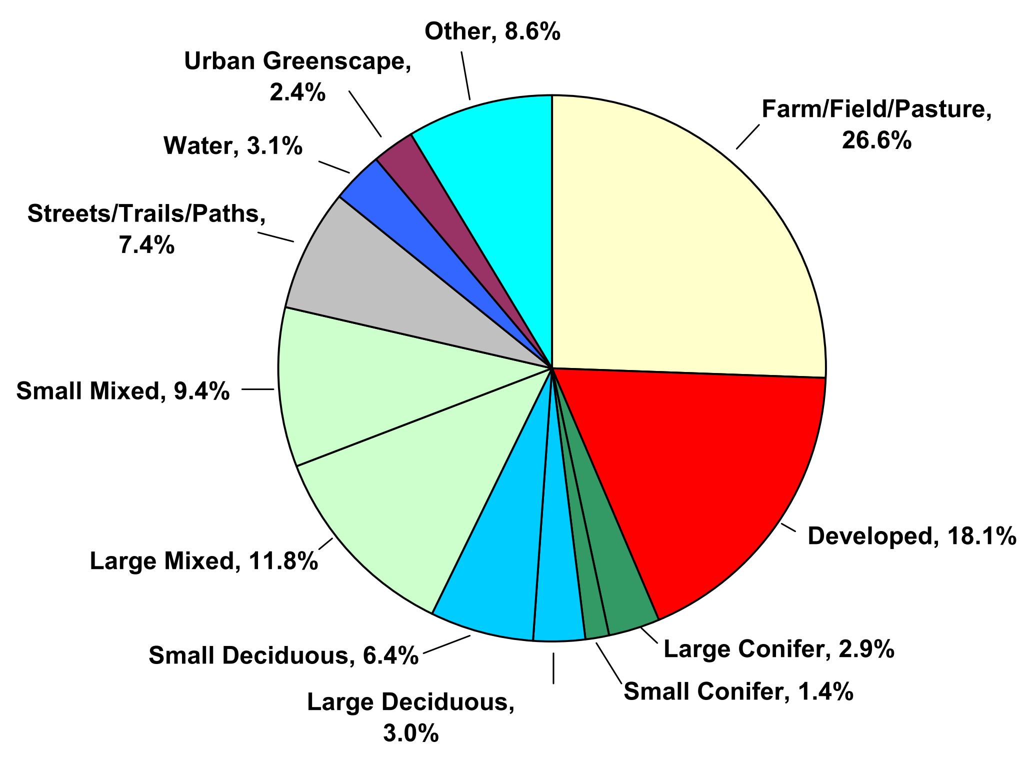
Figure 5.53. Example of Near Stream Land Cover Deliniation at the confluence of Johnson Creek and the Willamette River.



The thalweg, left bank and right bank of Johnson Creek were also digitized from aerial photographs. This stream data layer was then segmented into data points at a 100-foot interval. All river mile designations were calculated using this highly accurate stream delineation and, therefore, may not match historical river mile designations. These data point layers form the basis for automated sampling performed using Ttools. At every distance node (i.e. every 100 feet) along the stream, near stream land cover was sampled out to 120 feet from the channel edge at 15-foot intervals for both stream banks. A total of 18 vegetation samples are taken at each stream distance node (every 100 feet along the length of the stream).

Near stream land cover was grouped as one of the following: water or floodplains, farm and pasture land, fields or grassed areas, forests, shrub (woody vegetation less than 10 feet high), roads, railroad tracks and paths, developed lands (both urban and rural residential and commercial), and barren lands. Within these general vegetation types, near stream vegetation was further classified by observed differences in average tree height (taller vs. shorter forests) and in density (**Table 5.20**). Existing tree heights were determined by ODEQ using ground level measurements. The grouping of farm, pasture and grassed areas, followed by the combination of large and small mixed forest and urban and residential development were the most prevalent land cover type found in the near stream area analyzed (**Figure 5.54**).

Figure 5.54. Near Stream Land Cover Percentages for Johnson Creek



ODEQ personnel made field measurements of vegetation height at 12 temperature monitoring locations from the mouth to headwaters of Johnson Creek. One Hundred and forty large trees and ninety-two small trees were measured at various locations in the watershed. Tree heights for conifer, deciduous and mixed conifer/deciduous categories were calculated based upon heights observed in the field.

Current riparian land cover categories and the height associated with each are displayed in **Table 5.20**.

Potential Condition

System potential effective shade occurs when near stream vegetaion is at a climax life stage. A climax life stage is represented by the following conditions:

- Vegetation is mature and undisturbed;
- Vegetation height and density are at or near the potential expected for the given plant community;
- Vegetation is sufficiently wide to maximize solar attenuation; and
- Vegetation width accommodates channel migrations.

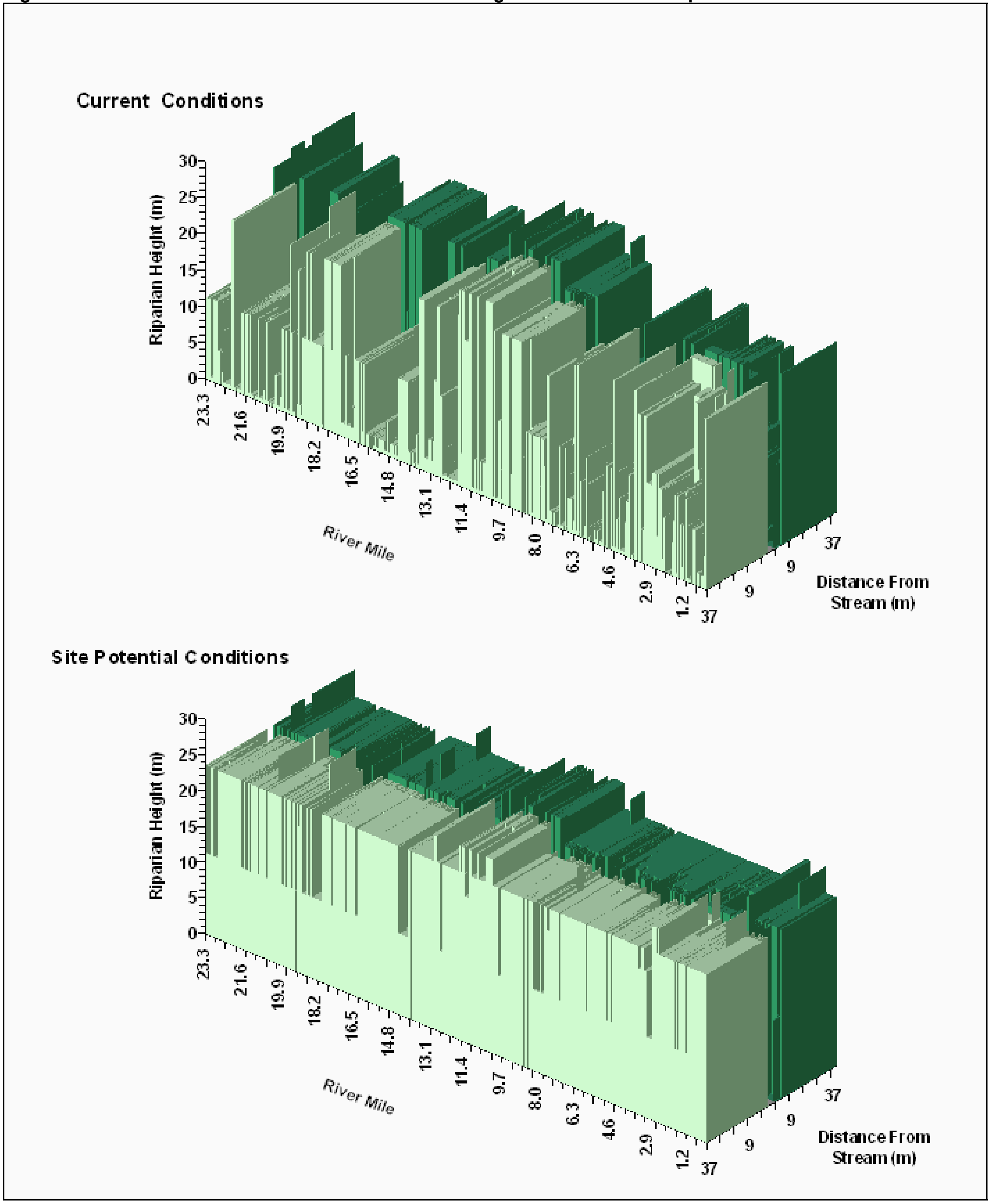
Automated near stream vegetation sampling was repeated to determine the potential condition for each segment of Johnson Creek. While riparian vegetation heights likely vary with vegetation zone, disturbance regimes and other factors, ODEQ did not feel that greater accuracy could be attained with more detailed riparian vegetation height estimates. ODEQ field observations and professional judgment indicated that average height and densities of site potential stands is well represented by assuming a composite dimension of 77 feet in height, 60% density and 7.7 feet of overhang – the attributes assigned to the “large mixed – high density” category. Therefore, vegetation characteristics remain constant between current and potential conditions, but are applied as potential land cover as described in **Table 5.20**.

Table 5.20. Johnson Creek Near Stream Land Cover Attributes and Potential Land Cover

ODEQ Riparian Land Cover Analysis Codes and Attributes					
Code	Description	Height (feet)	Overhang (feet)	Density (%)	Potential Land Cover
111	Development - Residential	15.0	0.0	75%	Large Mix - high
112	Development - Industrial	24.9	0.0	75%	Large Mix - high
113	Development - Parking Lot	0.0	0.0	0%	Large Mix - high
221	Barren - Soil	0.0	0.0	0%	Large Mix - high
222	Farmland/Pastureland	1.6	0.0	30%	Large Mix - high
331	Grasses - upland	1.6	0.0	30%	Large Mix - high
333	Upland shrubs	5.9	0.7	75%	Large Mix - high
441	Small Deciduous - low	37.1	3.7	30%	Small Deciduous - low
443	Small Deciduous - high	37.1	3.7	60%	Small Deciduous - high
447	Large Deciduous - low	66.9	6.7	30%	Large Deciduous - high
449	Large Deciduous - high	66.9	6.7	60%	Large Deciduous - high
551	Small Conifer - low	43.0	4.3	30%	Large Conifer - high
553	Small Conifer - high	43.0	4.3	60%	Large Conifer - high
557	Large Conifer - low	88.9	8.9	30%	Large Conifer - high
559	Large Conifer - high	88.9	8.9	60%	Large Conifer - high
661	Small Mix - low	37.1	3.7	30%	Small Mix - low
663	Small Mix - high	37.1	3.7	60%	Small Mix - high
667	Large Mix - low	77.1	7.7	30%	Large Mix - high
669	Large Mix - high	77.1	7.7	60%	Large Mix - high
777	Urban Greenscape	37.1	3.6	15%	Large Mix - high
885	Bike Path	0.0	0.0	0%	Large Mix - high
886	Railroad Tracks	0.0	0.0	0%	Large Mix - high
887	Springwater Corridor	0.0	0.0	0%	Large Mix - high
888	Local Street	0.0	0.0	0%	Large Mix - high
889	Highway/Interstate	0.0	0.0	0%	Large Mix - high
3011	Active Channel Bottom	0.0	0.0	0%	Active Channel Bottom
301	Water	0.0	0.0	0%	Water

Current riparian vegetation distribution and height and potential riparian vegetation height are displayed in **Figure 5.55**. The vegetation distribution is shown for both the right and left stream banks. Vegetation information presented in these figures was sampled from the GIS vegetation data layer described above and the river miles shown were derived from a 1:5000 stream coverage used for ODEQ simulation purposes and may differ slightly from other sources (such as OWRD or USGS river miles).

Figure 5.55. Johnson Creek near stream land cover height – current and site potential conditions.



Temperature Analytical Methodology

Heat Source was the temperature model utilized by ODEQ to estimate stream network thermodynamics and hydrology. It was developed in 1996 as a Masters Thesis at Oregon State University in the Departments of Bioresource Engineering and Civil Engineering and has been regularly upgraded through 2002 (Boyd, 1996). ODEQ currently supports the Heat Source methodology and computer programming. A more extensive discussion of the methodology for the model is can be found on the ODEQ website at http://www.deq.state.or.us/wq/TMDLs/TMDLs.htm. The model has been peer reviewed and comments are available on the ODEQ website at: http://www.deq.state.or.us/wq/HeatSource/HeatSource.htm.

The temperature model is designed to analyze and predict stream temperature for one day, ideally the warmest day of the year. This Johnson Creek Watershed TMDL is primarily concerned with daily prediction of the diurnal energy flux and resulting temperatures on July 31, 2002. To aid in model calibration and gain a better understanding of stream heating in the watershed, Thermal Infrared Radiometry (TIR) data was collected on the mainstem.

Stream temperature was simulated for 23.4 miles of the mainstem Johnson Creek from the confluence with the Willamette River upstream to near the headwaters. Simulations were performed to assess the stream thermal response to current vs. system potential vegetation.

Results from these simulations show that, on a watershed scale, significant stream temperature cooling will result from site potential riparian land cover conditions. Electronic files of the Heat Source model runs used to determine current and site potential conditions are maintained by ODEQ and are available to interested parties by contacting the Water Quality Division at the ODEQ headquarters office in Portland.

Thermal Infrared Radiometry (TIR)

TIR temperature data are used in this analysis to:

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

As part of this TMDL effort, ODEQ contracted with Watershed Sciences, LLC to map and assess stream temperatures using Thermal Infrared Radiometry (TIR) remote sensing. Johnson Creek was surveyed on July 31 2002 using a TIR sensor attached to the underside of helicopter.

TIR imagery measures the temperature of the outermost portions of the bodies/objects in the image (i.e., ground, riparian vegetation, and stream). The bodies of interest are opaque to longer wavelengths and there is little, if any, penetration of the bodies.

TIR data is remotely sensed from instrumentation mounted on a helicopter that collects digital data and sends it to an on-board computer at a rate that insures the imagery maintains a continuous image overlap of at least 40%. The TIR detects emitted radiation at wavelengths from 8-12 microns (long-wave) and records the level of emitted radiation as a digital image across the full 12-bit dynamic range of the sensor. Each image pixel contains a measured value that is directly converted to a temperature. Each thermal image has a spatial resolution of less than one-half meter/pixel. A visible video sensor mounted next to the TIR sensor captures the same field-of-view as the TIR sensor. GPS time is encoded on the recorded video as a means to correlate visible video images with the TIR images during post-processing.

TIR represents the most accurate and preferred tool for analyzing temperature in streams of sufficient size. Coupling TIR thermal imagery with color videography and geographic positioning systems (GPS) produces spatially continuous temperature imagery. The output data consists of GPS-tagged TIR digital images that cover approximately 100 x 150 meters with less than 1 meter of spatial resolution within 0.5°C accuracy. The spatial continuity of TIR data has made it possible to visually observe many of the thermodynamic processes associated with stream heating as they occur. Significant groundwater interactions with the stream column also register distinctly in the TIR data imagery.

Data collection is timed to capture maximum daily stream temperatures, which typically occur between 14:00 and 18:00 hours. The helicopter is flown longitudinally over the center of the stream channel with the sensors in a vertical (or near vertical) position. In general, the flight altitude is selected so that the stream channel occupies approximately 20-40% of the image frame. A minimum altitude of approximately 300 meters is used both for maneuverability and for safety reasons. If the stream splits into two channels that cannot be covered in the sensor's field of view, the survey is conducted over the larger of the two channels.

In-stream temperature data loggers (Onset Stowaways or VEMCOs) are distributed in each subbasin prior to the survey to ground truth (i.e., verify the accuracy) the radiant temperatures measured by the TIR. Watershed Sciences used data from the in-stream temperature loggers deployed by ODEQ in the basin prior to the survey in order to ground truth (i.e. verify the accuracy of) the radiant temperatures measured by the TIR sensor. In addition to deployment of thermistors, intensive monitoring of flow, wetted width and depth were performed on July 29th and 30th, 2002 in order to provide timely hydrologic conditions at the time of the TIR sampling and for subsequent Heat Source temperature modeling.

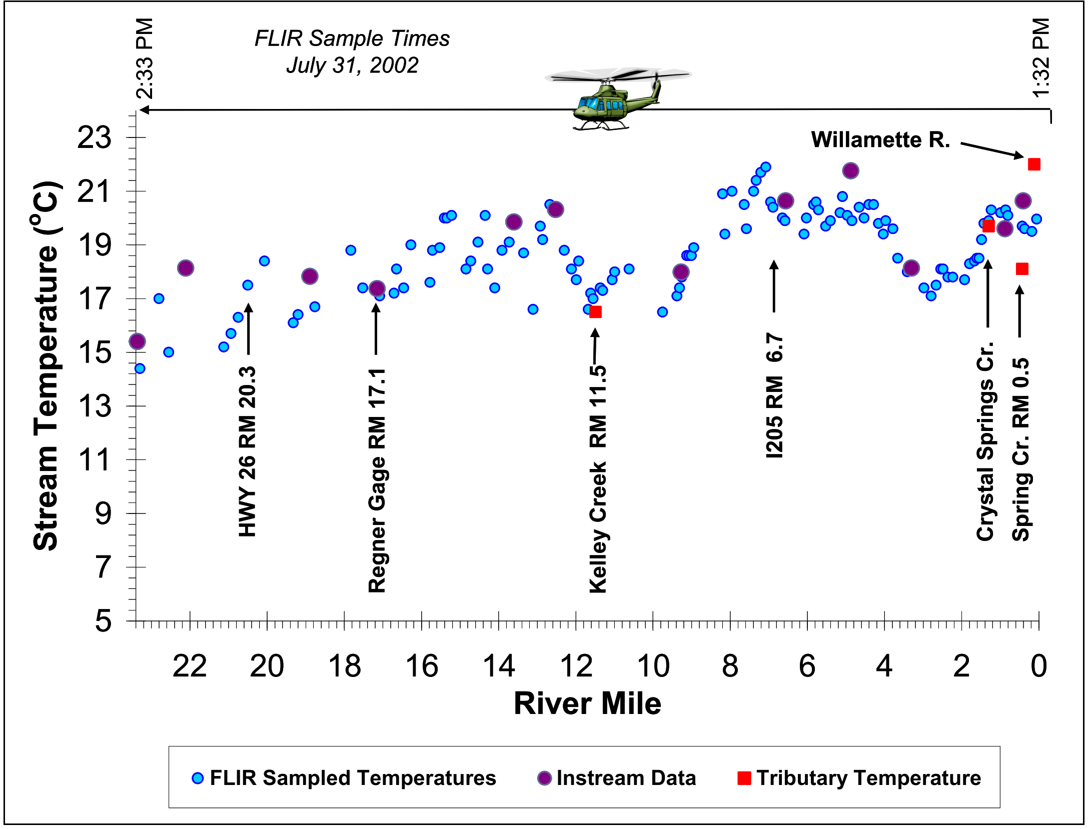
Some portions of Johnson Creek exhibited narrow stream widths (relative to the pixel size of the images) and the stream surface was often masked by riparian vegetation. Radian stream temperatures were sampled in areas where the surface of the stream was clearly visible in the imagery. This resulted in intermittent data on some stream reaches, especially in the upper portions of the watershed. The combination of low flow and riparian conditions made it generally difficult to identify sources of spatial temperature variability since smaller streams tend to show increased spatial temperature variability due to both "noise" and an increased response to small energy transfers (e.g. localized cooling from small ground water inputs). A challenge in TIR image interpretation in small streams is to separate the noise from true thermal response (Watershed Sciences 2003).

Johnson Creek exhibited a general warming pattern from the headwaters at river mile (RM) 23 downstream to 190th Avenue monitoring site (RM 13). However, there was some localized variability, possibly due to sampling noise or the influence of surface groundwater and/or surface water inflow and outflow. Stream temperature decreased between RM 13 and RM 11.5, near the point at which Kelley Creek enters Johnson Creek. Further analysis and field verification may be required to determine the cause of this decrease and the potential biological significance of this location. Kelley Creek is a source of cooling, entering Johnson Creek at RM 11.5. Stream temperatures just below Kelley Creek and the temperature monitoring site at 122nd Avenue (RM 9.2) are similar, though localized variability was noted. Riparian conditions just below the Kelley Creek Confluence and around the 122nd (Leach Botanical Gardens) monitoring site provided good shade, though the stream segment between these two locations showed considerably less than site potential shade. Johnson Creek heated several degrees moving downstream from RM 9.2 to the Johnson Creek Blvd. monitoring site (RM 5). Current riparian conditions in this stream segment are well below site potential conditions, resulting in an increase in stream surface area exposed to direct solar radiation. It appears that an instream pond, constructed to improve habitat conditions, is located at RM 8.6 of this reach. The design and construction of this feature did not incorporate a low-flow channel so summertime low flow conditions result in ponding, increased residence time and a subsequent increase in heating from exposure to direct solar radiation. The design of future restoration projects of this nature should include provisions for low-flow channels and previously constructed projects should be considered for retrofitting. Also, the stream gradient in this section of Johnson Creek is very "flat"; with opportunity for increased residence time and increased exposure to solar radiation (see **Figure 5.130 – Toxics TMDL**). Stream temperatures then decrease significantly between RM 5 and the 45th Avenue monitoring site (RM 3.2). Errol Springs is located in the lower portion of this reach and shade from riparian land cover steadily increases. It is possible that groundwater inputs through this reach and improved shading conditions result in significant stream cooling. The final Johnson Creek stream reach, from RM 3.2 to the confluence with the Willamette River shows a general warming trend and is dominated by the influence of Crystal Springs Creek, which enters Johnson Creek at RM 1.4. Shade producing riparian land cover decreases steadily through this segment.

A more detailed reach-by-reach interpretation of the TIR imagery collected for this TMDL effort was conducted by Watershed Sciences, LLC and is available to the public for review (Watershed Sciences 2003).

Figure 5.56 shows the TIR-derived longitudinal temperature profile (blue dots) along with the measured instream temperature (dark purple dots) for Johnson Creek.

Figure 5.56. Longitudinal Profile of Johnson Creek TIR-derived and Measured Instream Temperatures



Three areas along Johnson Creek were identified as being of particular interest with respect to the TIR data and imagery collected during the summer of 2002. These include the confluence of Johnson Creek and the Willamette River, the confluence of Crystal Springs and Johnson Creeks and the confluence of Kelley and Johnson Creeks. TIR and day video images of these areas were assembled as mosaics and are presented in **Figures 5.57** through **5.59**. Notice that at the time of the TIR imagery (approximately 2:00 p.m.) Johnson Creek was cooler than the Willamette River, Crystal Springs Creek was warmer than Johnson Creek and Kelley Creek was cooler than Johnson Creek. It should also be noted that at the time of the TIR survey Crystal Springs Creek was flowing at approximately 9 cfs, Johnson Creek at 2 cfs and Kelley Creek at 0.25 cfs. Also, the Willamette River likely experiences thermal stratification and the surface temperature measured by TIR may not be representative of the entire water column.

Figure 5.57. Confluence of Johnson Creek and the Willamette River

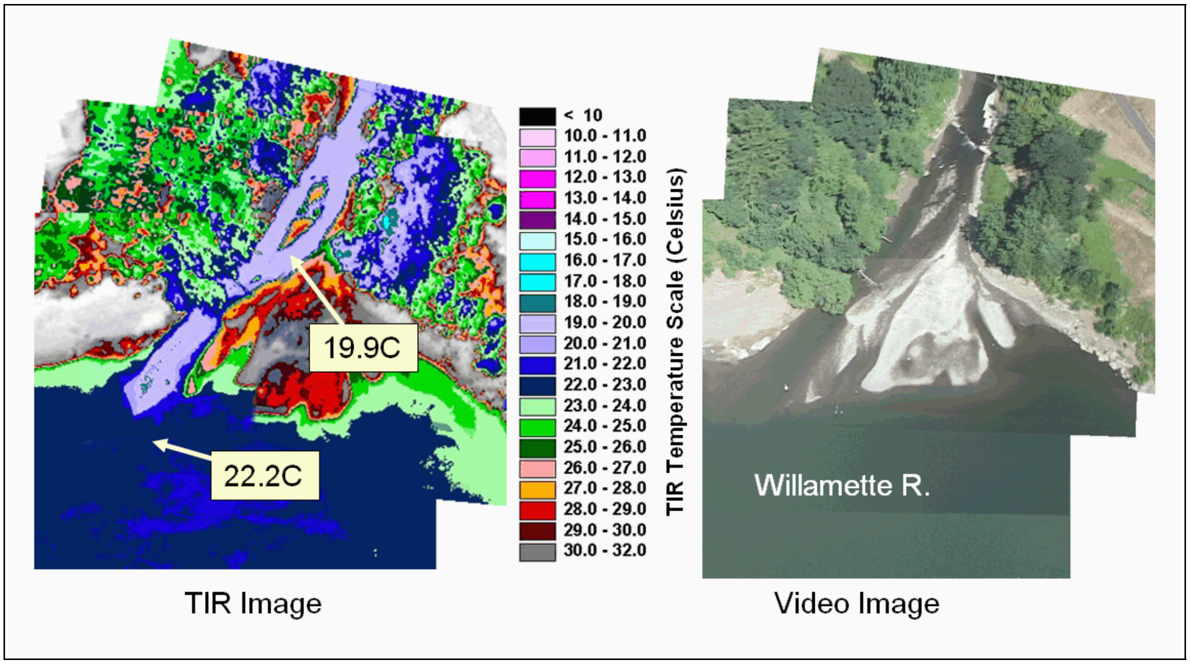


Figure 5.58. **Confluence of Crystal Springs and Johnson Creeks**

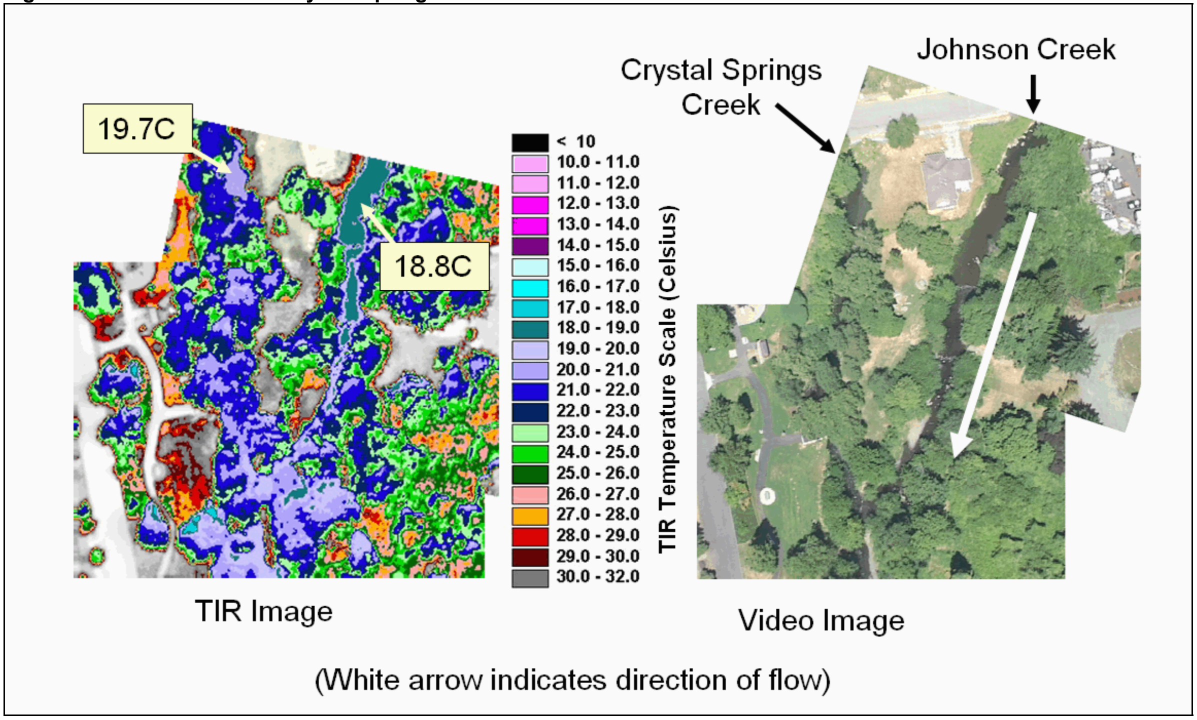
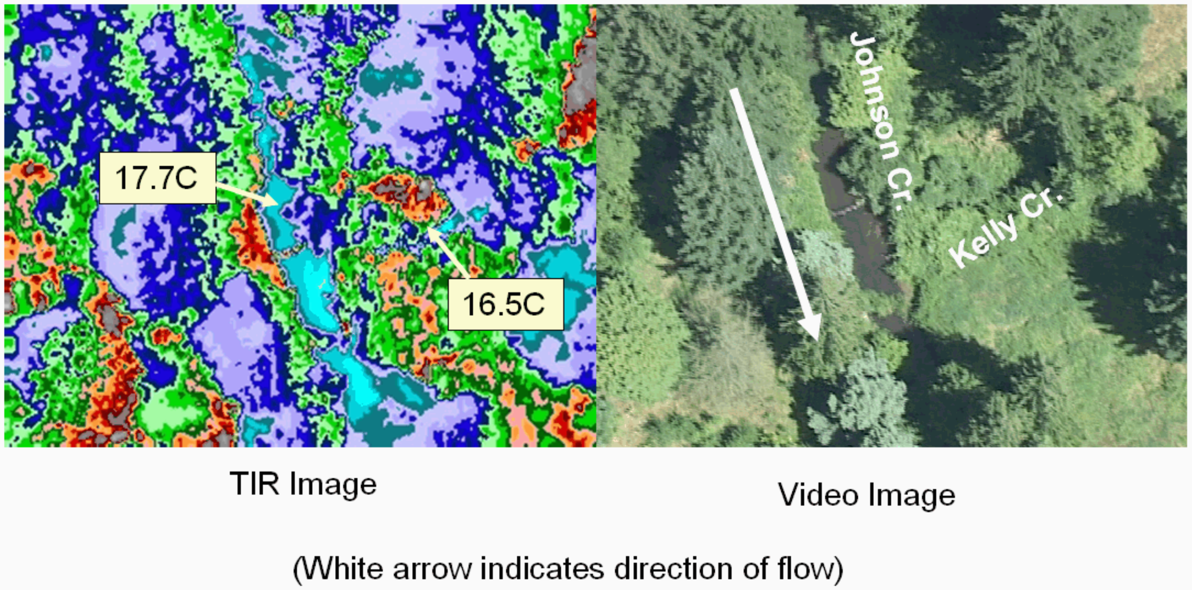


Figure 5.59. **Confluence of Kelley and Johnson Creeks**



Thermal Response Simulations

To assess the thermal response of stream temperature to changes in near stream land cover, simulations were performed with the Heat Source model using current vegetation conditions and system potential vegetation conditions. July 31, 2002 was used to represent critical summer temperature conditions to use in running model simulations. Simulations were performed for the mainstem of Johnson Creek.

The Johnson Creek Heat Source temperature model was calibrated to current conditions using both TIR-derived and measured instream water temperature data (red line in **Figure 5.60**).

Heat Source simulations at system potential were performed by adjusting riparian land cover to potential height, width and density as described in the preceding section of this document. The results of the simulations relative to instream water temperatures are presented in **Figure 5.61**. Note that significant reductions in stream temperature did result from system potential near stream land cover conditions.

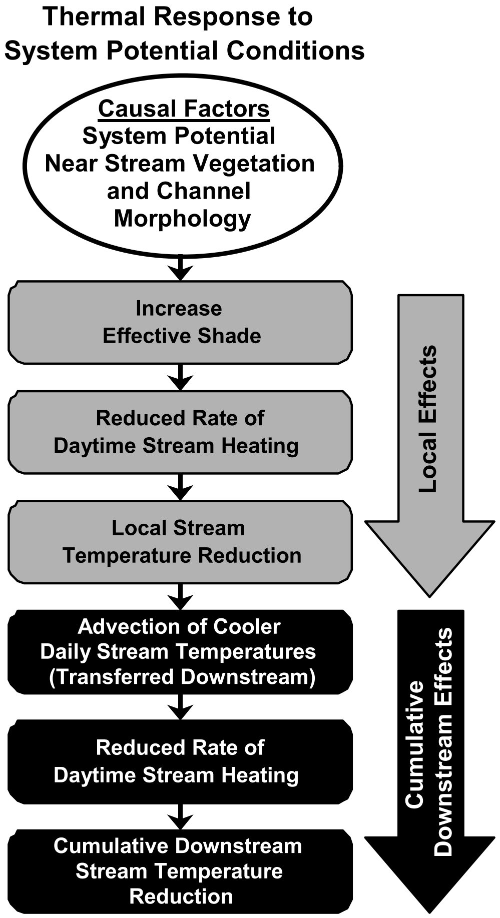


Figure 5.60. TIR, Instream and HeatSource Predicted Stream Temperature

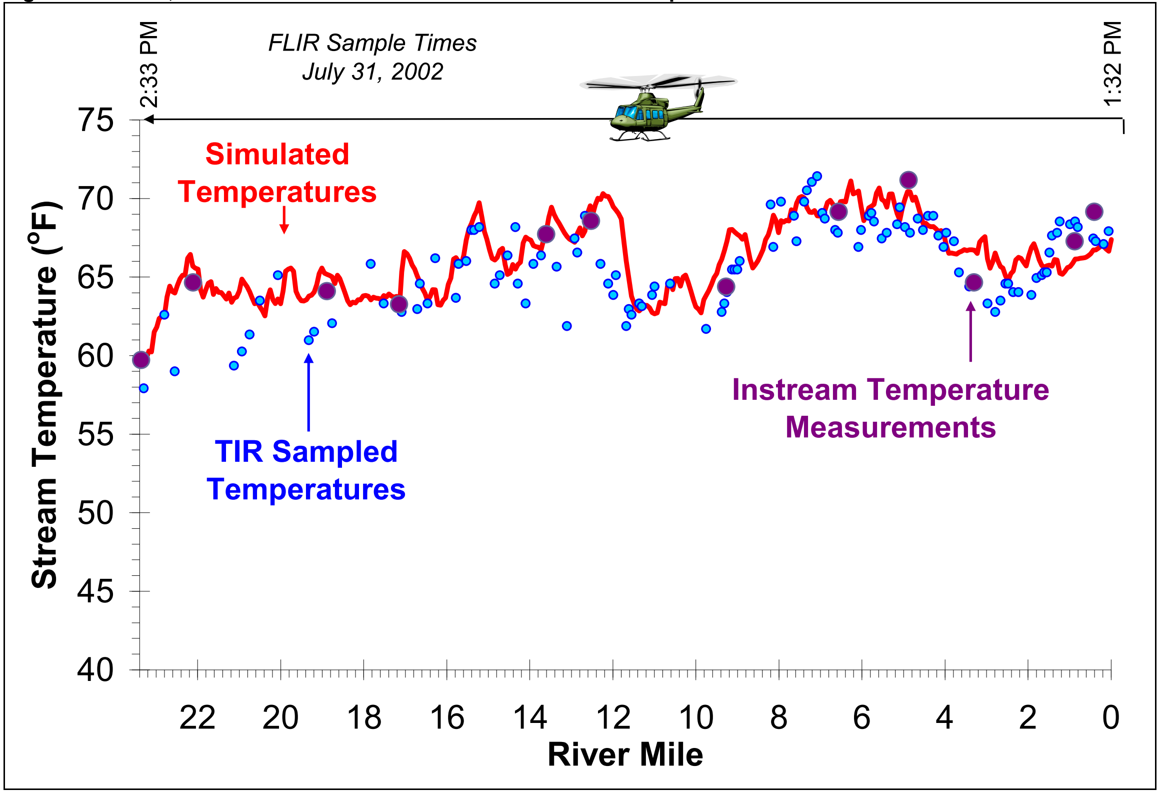
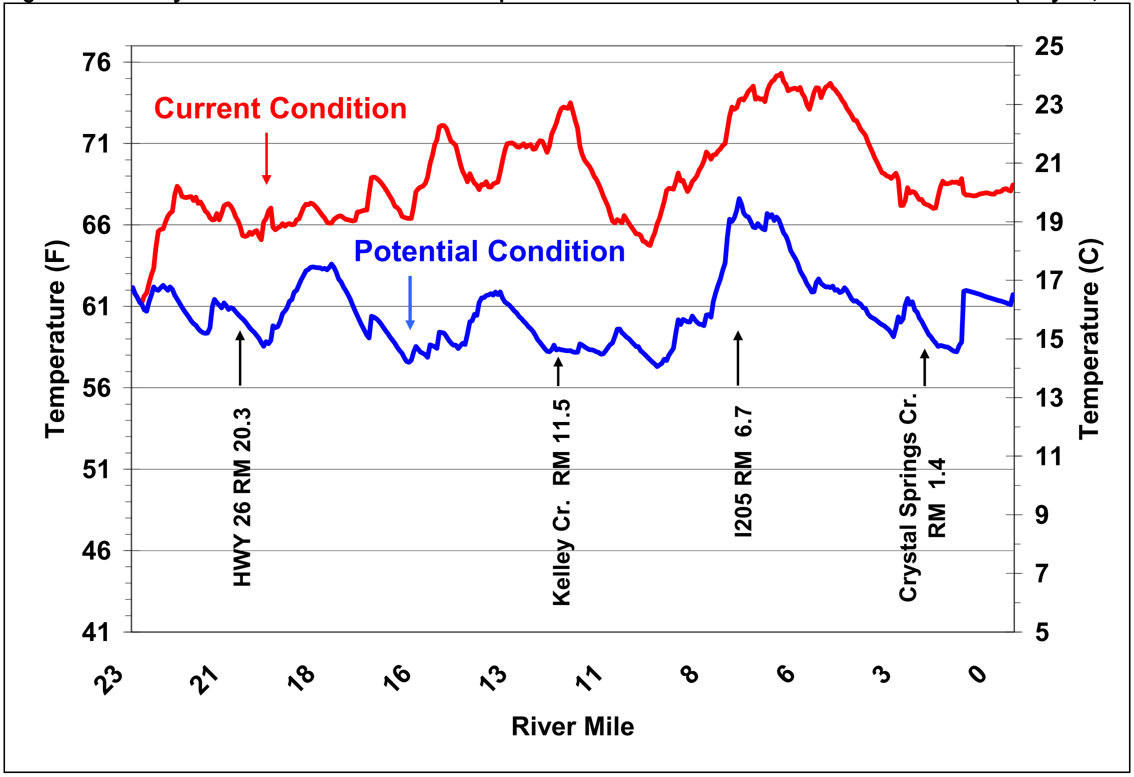


Figure 5.61. Daily Maximum Johnson Creek Temperatures: Current Condition and Potential Shade (July 31, 2002)



Loading Capacity

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with water quality standards. USEPA's current regulation defines loading capacity as "*the greatest amount of loading that a water body can receive without violating water quality standards*." (40 CFR § 130.2(f)). Oregon's temperature standard states that a cumulative surface water temperature increase of no more than 0.3°C is allowed in the Johnson Creek Watershed when surface water temperature criteria are exceeded. The pollutants are human influenced increases in solar radiation loading (nonpoint sources) and heat loading from warm water discharge (point sources).

The loading capacity is dependent on the available assimilative capacity of the receiving water. For nonpoint sources, the loading capacity is the amount of background solar radiation that reaches the stream when the stream is at system potential conditions in terms of riparian vegetation and channel morphology. For streams such as Johnson Creek, whose system potential temperatures are at or above the temperature standard for a given period, there is no available assimilative capacity beyond the 0.3°C human use allowance specified in the temperature standard. The loading capacity is essentially consumed by non-anthropogenic sources.

In this chapter, the loading capacity is expressed in terms of kilocalories per day (kcals/day). This represents the amount of energy that can be added to a waterbody and still obtain water quality standards.

Nonpoint Sources

Current solar radiation loading was calculated by simulating current stream and vegetation conditions. Background loading was calculated by simulating the solar radiation heat loading that resulted with system potential near stream vegetation. This background condition, based on system potential shade conditions, reflects an estimate of nonpoint source heat load that would occur while meeting the temperature standard. In theory, once the system potential condition with respect to nonpoint source pollution is known, ODEQ could then calculate the amount of additional nonpoint source loading that a waterbody can assimilate without resulting in more than a 0.3°C increase in water temperature at the point of maximum impact. ODEQ did not attempt to calculate this additional allowable heat load or incorporate the information into nonpoint source load allocations. Rather, ODEQ considers the conservative methodology that bases nonpoint source load allocations on system potential conditions to be part of the explicit margin of safety. Moreover, any allocation benefit to nonpoint sources would occur only after restoration efforts had recovered solar radiation to near system potential conditions: a matter of decades in most cases. The relationships below were used to determine solar radiation heat loads for the current condition, anthropogenic contributions and loading capacity derivations based on system potential.

Total Solar Radiation Heat Load from All Nonpoint Sources, $H_{\text{Total NPS}} = H_{\text{SP NPS}} + H_{\text{Anthro NPS}} = \Phi_{\text{Total Solar}} \cdot A$

Solar Radiation Heat Load from Background Nonpoint Sources (System Potential), $H_{\text{SP NPS}} = \Phi_{\text{SP Solar}} \cdot A$

Solar Radiation Heat Load from Anthropogenic Nonpoint Sources, $H_{\text{Anthro NPS}} = H_{\text{Total NPS}} - H_{\text{SP NPS}}$

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

where,

$H_{\text{Total NPS}}$: Total Nonpoint Source Heat Load (kcal/day)

$H_{\text{SP NPS}}$: Background Nonpoint Source Heat Load based on System Potential (kcal/day)

$H_{\text{Anthro NPS}}$: Anthropogenic Nonpoint Source Heat Load (kcal/day)

$\Phi_{\text{Total Solar}}$: Total Daily Solar Radiation Load (ly/day)

$\Phi_{\text{SP Solar}}$: Background Daily Solar Radiation Load based on System Potential (ly/day)

$\Phi_{\text{Anthro Solar}}$: Anthropogenic Daily Solar Radiation Load (ly/day)

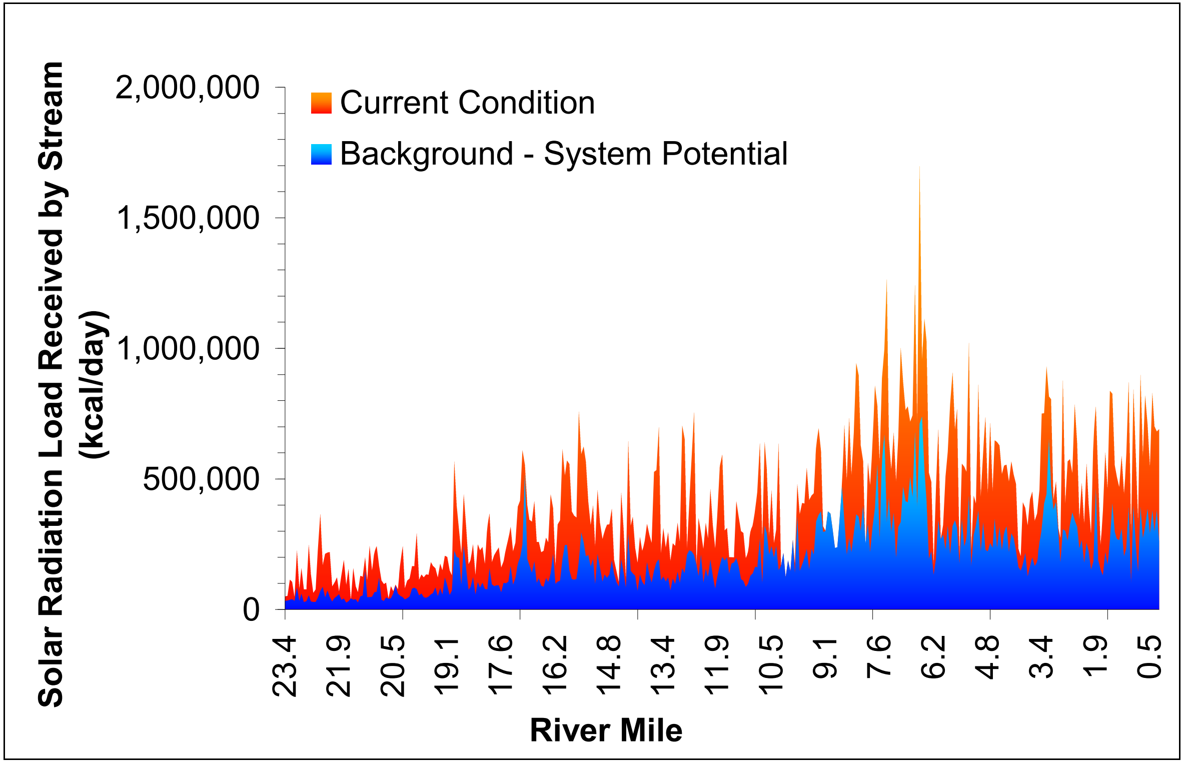
A: Stream Surface Area - calculated at each 100 foot stream segment node (cm^2)

Table 5.21 shows the predicted solar radiation loads for current conditions, system potential and from anthropogenic sources. **Figure 5.62** contrasts the longitudinal profile of the current solar radiation heat loading with the solar radiation heat loading that occurs with system potential land cover. Notice that solar radiation loading at system potential (loading capacity) is less than levels currently observed and that loading peaks in the portion of Johnson Creek where the highest stream temperatures were measured and predicted with Heat Source (**Figure 5.61**) – roughly the area around river mile 6.7 near where Johnson Creek passes beneath Interstate 205 .

Table 5.21. Nonpoint Source Solar Radiation Heat Loading - Current Condition, System Potential and Anthropogenic Contributions.

Stream	**Current Condition** (10^8 kcal/d) $H_{Total\ NPS}$	**System Potential (Loading Capacity)** (10^8 kcal/d) $H_{SP\ NPS}$	**Anthropogenic** $H_{Anthro\ NPS}$ (10^8 kcal/d)	Portion from Anthropogenic Nonpoint Sources
Johnson Creek	1.53	0.75	0.78	51%

Figure 5.62. Johnson Creek Solar Radiation Loading – Current Condition and System Potential (Loading Capacity) Condition.



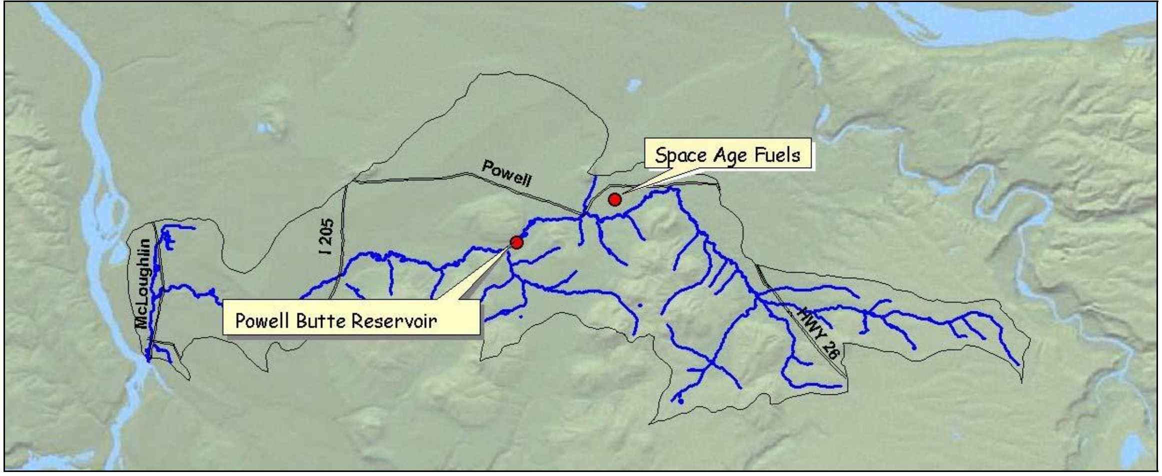
NPDES Permits

Space Age Fuels and the City of Portland Bureau of Water Works currently hold NPDES permits that allow discharge into Johnson Creek or its tributaries. **Figure 5.63** shows their geographic location in the watershed and **Table 5.22** provides additional information on these facilities. The Happy Valley Mobile Home Park, located at 8750 SE 155th Avenue, ceased the discharge of treated sanitary sewage to Mitchell Creek, a tributary to Johnson Creek, in March 2005. The mobile home park is now connected to the Kellogg Creek sewage treatment facility operated by Clackamas Water Environment Services. The Kellogg Creek facility discharges to the Willamette River. Precision Castparts (aka PCC Structurals) formerly held an NPDES permit allowing discharge to Johnson Creek. The discharge was discontinued in the mid-1990's and their permit is no longer active.

Table 5.22. NPDES Permitted Facilities in the Johnson Creek Watershed

FACILITY NAME	PERMIT TYPE	RECEIVING WATER	RIVER MILE (facility)
Space Age Fuels	GEN 15A - Petroleum Hydrocarbon Cleanups	Johnson Creek	14
Powell Butte Reservoir	Individual NPDES Permit #101617	Johnson Creek	10

Figure 5.63. Location of Johnson Creek NPDES Permitted Facilities



Space Age Fuels, Inc., located at 16431 SE Foster Road in Gresham, holds a general NPDES permit (1500A) for the discharge of treated wastewater that results from groundwater petroleum hydrocarbon cleanup operations. This permit allows treated water from a groundwater pump and treatment system to be discharged into Johnson Creek near the Main City Park in Gresham. The permit includes a minimum dilution requirement whereby the discharge flow rate from the cleanup site is regulated to maintain a minimum dilution of 10:1 with the receiving stream at all times. The applicant indicated in the permit application that flow from the treatment facility would not exceed 2160 gallons per day. However, discharge monitoring reports submitted to ODEQ indicate that the facility typically discharges approximately 75 gallons per day during the low flow summer months. Given this extremely low flow rate and since the temperature of treated groundwater is generally around 13°C (55 °F), ODEQ concludes that there is no reasonable potential for this discharge to negatively impact receiving water stream temperatures. Therefore, ODEQ will not assign a wasteload allocation for this permit.

Johnson Creek is the receiving waterbody for the drain and overflow lines from Powell Butte Reservoir, part of the City of Portland's drinking water distribution system. Discharges related to the drinking water system are covered under NPDES permit number 101617, issued to the City of Portland Bureau of Water Works in June 2004. Powell Butte Reservoir water discharges are rare; there have been none over the past five years. Temperature data collected between 1998 and 2003 show an average reservoir water temperature of 14.2 °C during the months of July and August. Reservoir water temperature does not exceed 13 °C, the applicable salmonid spawning criterion, between November and May. It is possible for reservoir water temperature to exceed 13 °C during the last two weeks in October. However, given the infrequency of discharges from this location, there is little reason to believe a discharge will occur during that time. To reduce even that potential risk, the Bureau of Water Works will avoid any non-emergency discharges from Powell Butte reservoir during the spawning season if reservoir temperatures exceed the ambient temperature of Johnson Creek as measured at the Sycamore USGS gaging station. ODEQ concludes that there is no reasonable potential for this discharge to negatively impact receiving water stream temperatures. Therefore, ODEQ will not assign a wasteload allocation for this permit.

In addition to the point sources identified above, there are a number stormwater and construction NPDES permits for facilities and/or properties located within the Johnson Creek watershed. ODEQ did not develop waste load allocations for stormwater permitted facilities because ODEQ has no data that indicates stormwater or construction site discharges contribute to stream temperature standards violations.

Allocations – 40 CFR 130.2(g) and 40 CFR 130.2(h)

Load Allocations are portions of the loading capacity divided between natural, human and future nonpoint pollutant sources. **Table 5.23** lists load allocations (i.e. distributions of the loading capacity) according to land-use and location in the watershed. A *Waste Load Allocation* (WLA) is the amount of pollutant that a point source can contribute to the stream without violating water quality criteria. As explained above, no point sources within the Johnson Creek Watershed were assigned Waste Load Allocations for temperature.

Table 5.23. Temperature Load Allocation Summary

Source	Load Allocation
Natural Background + Reserve Capacity	100%
Agriculture	0%
Forestry	0%
Urban	0%
Future Sources	0%

Table 5.24 shows the allocation for nonpoint sources.

Table 5.24. Nonpoint Source Load Allocations

Nonpoint Sources	
Source	**Load Allocation** **Allowable Nonpoint Source Solar Radiation Heat Load (kcal/day)**
All Nonpoint Sources	**0.75×10^8**

Effective Shade Surrogate Measures

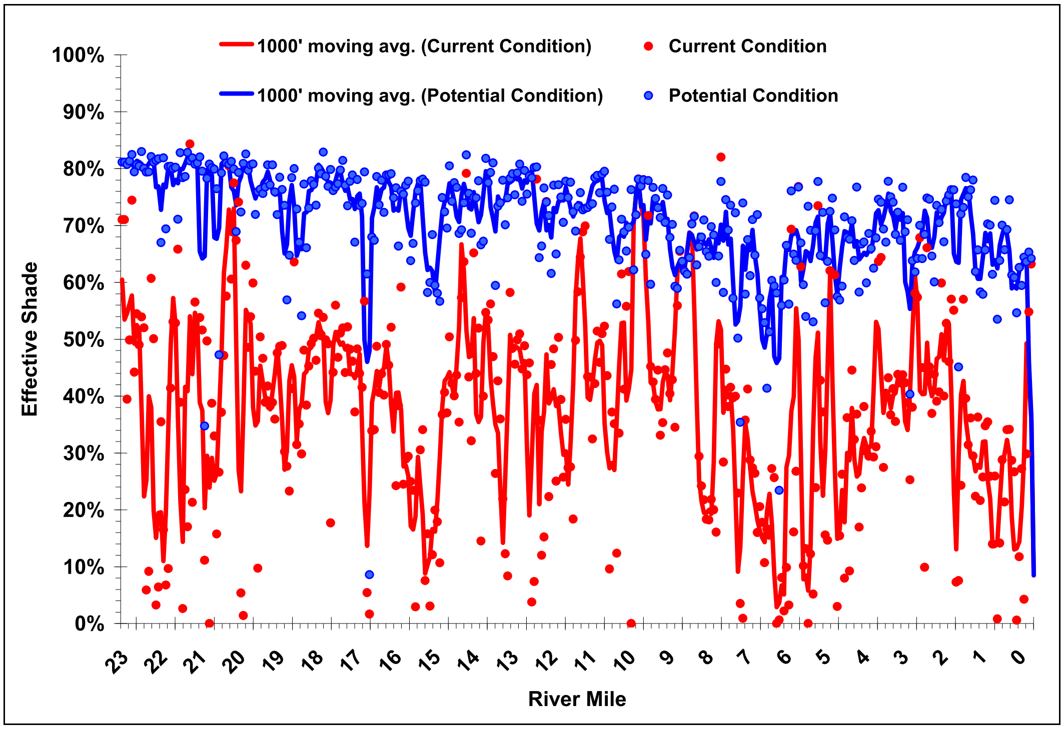
Site specific effective shade surrogates are developed to help translate the nonpoint source solar radiation heat loading allocations. Attainment of the effective shade surrogate measures is equivalent to attainment of the nonpoint source load allocations.

Percent effective shade is a surrogate measure that can be calculated directly from the loading capacity. Additionally, percent effective shade is simple to quantify in the field or through mathematical calculations. **Figure 5.64** shows the percent effective shade values that correspond to the loading capacities (i.e., system potential) for the mainstem of Johnson Creek. Notice that in some areas only modest improvements are possible with improved riparian land cover conditions and that some areas would show greatly increased stream shading conditions with the establishment of system potential riparian vegetation. Site specific effective shade surrogates were developed to help translate the nonpoint source solar radiation heat loading allocations. Effective shade levels for the respective Johnson Creek mainstem river mile shown in **Figure 5.64** are the allocated condition and represent the targeted riparian condition with respect to shade.

Effective Shade Curves

The site specific effective shade curve specified above in **Figure 5.64** provides reach-specific shade targets for portions of the mainstem of Johnson Creek where ODEQ performed a detailed analysis of current and system potential vegetation. However, all tributaries within the Johnson Creek Watershed must also achieve shade targets in order to achieve compliance with the Oregon's temperature standard and nonpoint source load allocations. To ensure that system potential vegetation characteristics are applied in a geographically appropriate manner, ODEQ utilized ecoregional geographic boundaries to assign appropriate vegetative characteristics and shade levels throughout the watershed. The section of this chapter titled **"***Effective Shade Curves"* describes the methodology for developing ecoregion-based shade curves and includes the shade curves applicable to the Johnson Creek Watershed. Where effective shade levels are not specified in **Figure 5.64**, effective shade for the appropriate ecoregion and near stream disturbance zone width shall be applied.

Figure 5.64. Johnson Creek Effective Shade Surrogate Target for Nonpoint Sources



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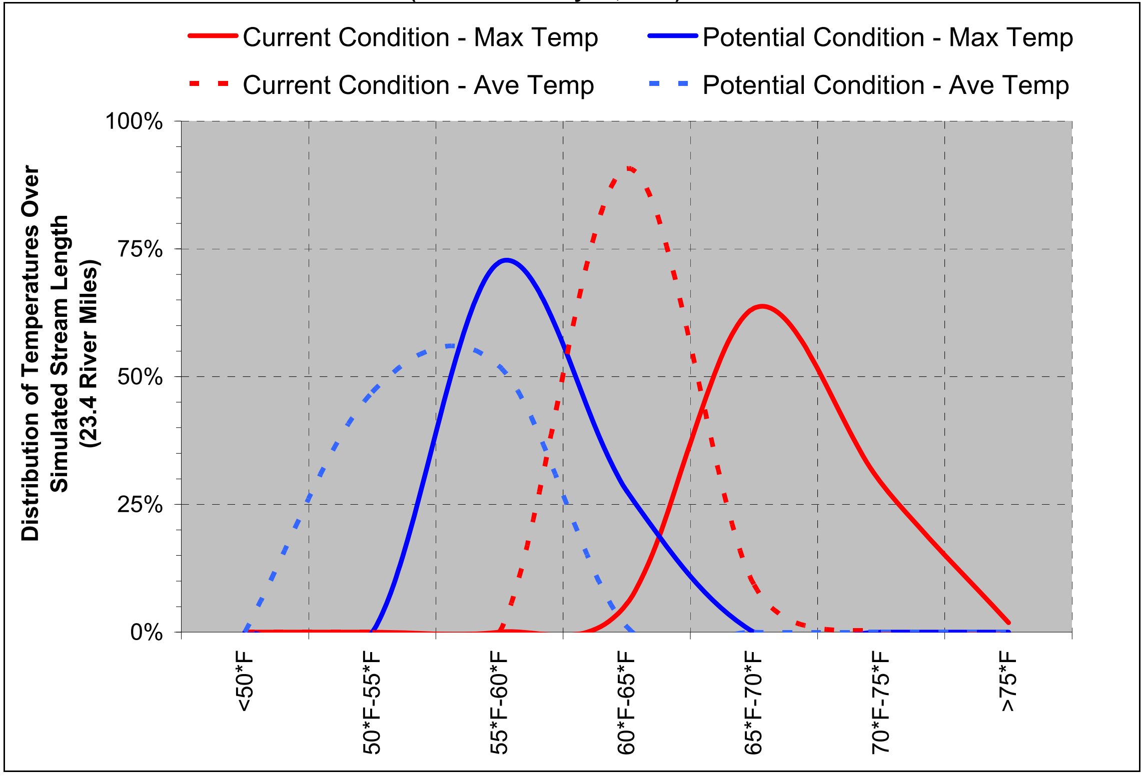
Water Quality Standard Attainment Analysis

Simulations were performed to calculate the temperatures that result with the allocated measures that form the basis for the factors that represent the system potential condition. The resulting simulated temperatures represent attainment of system potential, and therefore, attainment of the temperature standard. Johnson Creek showed significantly cooler temperatures under system potential (allocated) conditions.

Figures 5.61 and **5.65** demonstrate the affect that removing anthropogenic sources of stream heating is likely to have on stream temperatures throughout Johnson Creek. Daily maximum stream temperatures shift from the 65-70 °F range toward the 55-60 °F range.

ODEQ recognizes that it may take several years to several decades after full implementation of shade-producing measures to achieve the shade targets identified in this TMDL. Simply put, wide stream segments typically require taller, older riparian vegetation in order to achieve shade targets and narrow stream segments may achieve the shade targets with shorter, younger riparian vegetation. Site specific shade targets identified in **Figure 5.64** can be used to help guide and prioritize implementation efforts to maximize the near-term effectiveness of implementation efforts. ODEQ expects that DMAs will focus initial implementation efforts on improving shade conditions through establishing and/or enhancing riparian vegetation conditions and in ensuring that existing and future development practices allow the attainment of shade targets.

Figure 5.65. Distributions of Daily Average and Maximum Temperatures for Current Conditions and the Allocated Condition for mainstem Johnson Creek (Modeled for July 31, 2002)



TRYON CREEK WATERSHED

Seasonal Variation

Historic water quality monitoring has shown that water temperatures in Tryon Creek exceed numeric criteria of the State water quality standard, which led to the 303(d) listing. **Figure 5.66** shows several years of summertime water temperatures data collected by the City of Portland at Boones Ferry Road near Tryon Creek State Park and illustrates violations of numeric temperature criteria. Exceedance of the 18.0°C (64.4°F) numeric criterion typically occurs in July and August, sometimes persisting into September. The location of the City of Portland monitoring site is shown in **Figure 5.67**. It should also be noted that Tryon Creek may be above the 13.0°C (55.4°F) numeric salmonid spawning criterion during periods when spawning is likely to occur.

Figure 5.66. 7-day Average of the Daily Maximum Temperatures in Tryon Creek (Data collected at Boones Ferry Road by the City of Portland)

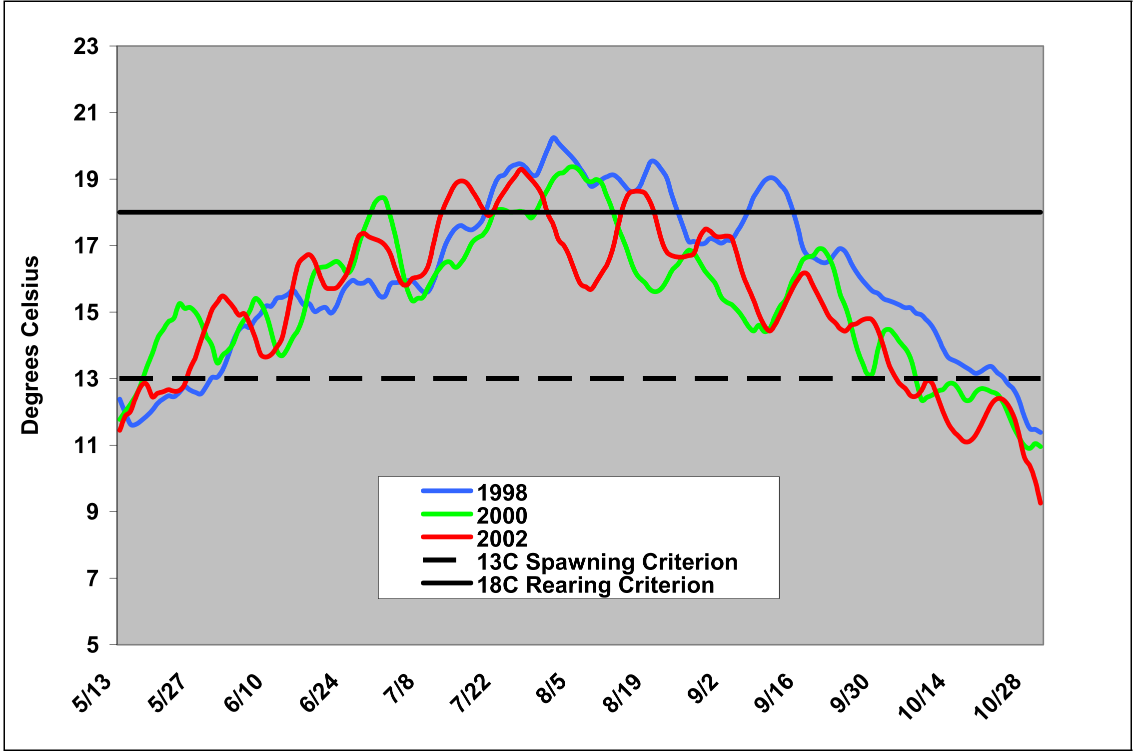
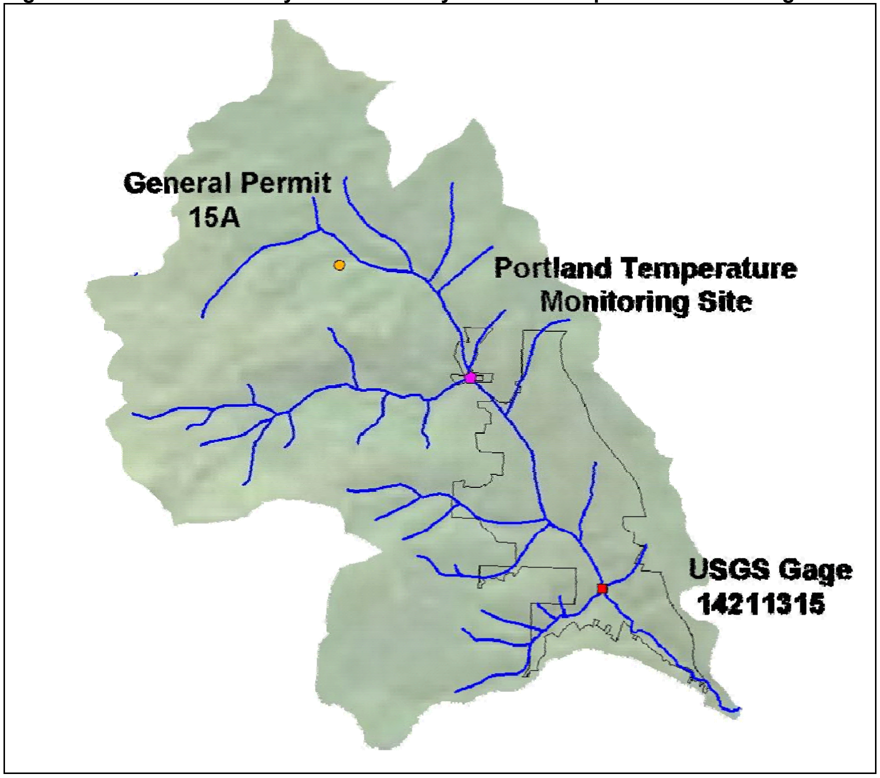


Figure 5.67. Location of City of Portland Tryon Creek Temperature Monitoring Station



Existing Heat Sources

Stream Heating Processes – Background Information

Riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, riparian condition, channel morphology and hydrology are affected by land use activities. Specifically, the elevated summertime stream temperatures attributed to anthropogenic sources in the Tryon Creek Watershed result from the following:

- ✓ Riparian vegetation disturbance, especially in the upper watershed, reduces stream surface shading via decreased riparian vegetation height, width and/or density, thus increasing the amount of solar radiation reaching the stream surface;
- ✓ Reduced summertime base flows due to altered hydrology;

In addition, the following conditions can affect stream temperatures in the Tryon Creek watershed:

- ✓ Reduced summertime base flows from instream withdrawals;
- ✓ Localized channel widening (increased wetted width to depth ratios) increases the stream surface area exposed to energy processes, namely solar radiation; and
- ✓ Localized near-stream disturbance zone[4] (NSDZ) widening decreases potential shading effectiveness of shade-producing near-stream vegetation;

There is some debate over the impacts of urbanization on summertime base flows. Most water quality/quantity professionals agree that is does occur, but it can be very difficult to measure. Some studies have shown that urbanization decreased baseflow in urban streams, while others have failed to measure the phenomenon with statistical rigor. ODEQ makes the conservative assumption that until

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[4] The term "near-stream disturbance zone" is defined for the purposes of the Tryon Creek TMDL as an estimate of the width between shade-producing near-stream vegetation.

studies report otherwise, urbanization reduces base flow in streams and negatively impacts summertime stream temperatures.

Human activities that contribute to degraded water quality conditions in the Tryon Creek Watershed include development-related riparian disturbances, past timber harvest, reduction of summertime base flows due to increased impervious surface, and altered stream hydrology and morphology due to effects of urban development.

Nonpoint Sources

Settlement in the Tryon Creek Watershed brought about changes in the near stream vegetation and hydrologic characteristics of Tryon Creek and other streams in the watershed. Historical logging practices altered the stream morphology and hydrology and decreased the amount of riparian vegetation. Timber harvest cleared streams and riparian corridors of fallen trees and large woody debris, with riparian areas logged down to the streambanks.

More recently, increases in population have resulted in urbanization of much of the watershed. Conversion of forest to residential and transportation uses has resulted in reduced riparian vegetation and altered hydrology.

Riparian vegetation, stream morphology, hydrology, climate, and geographic location influence stream temperature. While climate and geographic location are outside of human control, riparian condition, channel morphology and hydrology are affected by land use activities.

Elevated summertime stream temperatures attributed to nonpoint sources result from riparian vegetation disturbance (reduced stream-surface shade) and reduced base flow

Specifically, the elevated summertime stream temperatures attributed to anthropogenic nonpoint sources result from:

3. ***Near stream vegetation disturbance or removal*** *reduces stream surface shading via decreased riparian vegetation height, width and/or density, thus increasing the amount of solar radiation reaching the stream surface (shade is commonly measured as percent effective shade or open sky percentage). Riparian vegetation also plays an important role in shaping the channel morphology, resisting erosive high flows and maintaining floodplain roughness.*
4. ***Channel modifications and widening*** *(increased width to depth ratios) increases the stream surface area exposed to energy processes, namely solar radiation. Near-stream disturbance zone (NSDZ) widening decreases potential shading effectiveness of shade-producing near-stream vegetation.*
5. ***Reduction of summertime flows*** *decrease the thermal assimilative capacity of streams, causing larger temperature increases in stream segments where flows are reduced.*

Current Condition

Riparian vegetation in the Tryon Creek Watershed has been negatively impacted by past and current land management activities. While portions of the watershed currently support healthy riparian stands, many areas have been identified that are not currently supporting system potential riparian vegetation. This document will not attempt an exhaustive analysis of current riparian conditions but will rely on previously completed assessments and the knowledge of site specific conditions possessed by the Designated Management Agencies.

A detailed description of current riparian vegetation conditions in the Tryon Creek Watershed can be found in several separate reports, variously referenced in this document. These include, but are not limited to the “Comprehensive Management Plan for Tryon Creek within Tryon Creek State Park” (PHS, 1997), “A Profile of the Tryon Creek Watershed” (PSU 2003) and the “Upper Tryon Creek Corridor Assessment” (Portland, 1997).

Pacific Habitat Services (1997) noted that large conifers are virtually absent in the riparian areas immediately adjacent to the creek, indicating a disturbed, immature vegetation assemblage. PHS noted that “the level of stream shading provided by riparian vegetation has been substantially reduced by past logging practices within the Park” and that “these changes, in concert with changes in channel morphology and watershed disturbance…, are having a significant influence on summer maximum stream temperatures”. Similarly, Portland’s evaluation of the upper watershed (1997) noted that “the upper reaches of Tryon Creek and most of Falling Creek were identified as having little structural diversity”. These areas lack any forest canopy and are dominated by residential lawns and shrubs such as Himalayan Blackberry.

Potential Condition

Riparian vegetation plays an important role in controlling stream temperature change. Near stream vegetation height, width and density combine to produce shadows that when, cast across the stream, reduce solar radiant loading. Bank stability is largely a function of riparian vegetation. Riparian corridors often produce a microclimate that surrounds the stream where cooler air temperatures, higher relative humidity and lower wind speeds are characteristic.

System potential effective shade occurs when near stream vegetaion is at a climax life stage. A climax life stage is represented by the following conditions:

- Vegetation is mature and undisturbed;
- Vegetation height and density is at or near the potential expected for the given plant community;
- Vegetation is sufficiently wide to maximize solar attenuation; and
- Vegetation width accommodates channel migrations.

Again, this document will not attempt to describe or prescribe system potential riparian conditions beyond the attainment of system potential shade conditions throughout the watershed as specified in the shade curves presented in the *Effective Shade Curves* section.

Loading Capacity

The loading capacity provides a reference for calculating the amount of pollutant reduction needed to bring water into compliance with water quality standards. USEPA’s current regulation defines loading capacity as “*the greatest amount of loading that a water can receive without violating water quality standards*.” (40 CFR § 130.2(f)). Oregon’s temperature standard states that a surface water temperature increase of no more than 0.3°C is allowed in the Tryon Creek Watershed when surface water temperature criteria are exceeded. The pollutants are human influenced increases in solar radiation loading (nonpoint sources) and heat loading from warm water discharge (point sources). Since there are effectively no point sources in the watershed, only nonpoint sources are considered.

The loading capacity is dependent on the available assimilative capacity of the receiving water. For nonpoint sources, the loading capacity is the amount of background solar radiation that reaches the stream when the stream is at system potential conditions in terms of riparian vegetation and channel morphology. For rivers and streams whose system potential temperatures are at or above the temperature standard for a given period, there is no available assimilative capacity beyond the 0.3°C human use allowance specified in the temperature standard. The loading capacity is essentially consumed by non-anthropogenic sources.

For Tryon Creek, the loading capacity is expressed in terms of attaining system potential shade conditions throughout the watershed. Nonpoint source load allocations for streams identified as exceeding the numeric criteria for water temperature are equal to the background allocation. This background condition, based on system potential vegetation, reflects an estimate of nonpoint source heat load that would occur with no anthropogenic sources of heat. This background allocation also applies to tributary streams to ensure that anthropogenic warming of the receiving streams does not occur. This is especially critical when impaired streams are well above numeric criteria for coldwater aquatic life and tributary streams provide some level of cooling. Direct heat loading from nonpoint sources has not been calculated for the Tryon Creek watershed. Rather, the relationship between system potential vegetation, effective shade levels and channel width expresses acceptable heat loads per day.

NPDES Permits

The Tryon Creek Watershed contains one NPDES permitted point source discharge, shown above in **Figure 5.67**. The Barbur Blvd. Texaco gas station, located at 8604 SW Barbur Blvd., possesses a general NPDES permit (1500A) for the discharge of treated wastewater that results from groundwater petroleum hydrocarbon cleanup operations. This permit allows treated water from a groundwater pump and treatment system to be discharged into Tryon Creek through a stormwater catchbasin at the site. The permit includes a minimum dilution requirement whereby the discharge flow rate from the cleanup site is regulated to maintain a minimum dilution of 10:1 with the receiving stream at all times. The maximum design flow for the treatment facility is 2,444 gallons per day (0.0038 cfs). However, discharge monitoring reports submitted to ODEQ indicate that the facility discharges approximately 250 gallons per day during the low flow summer months. Since the temperature of treated groundwater is generally around 13°C (55 °F), ODEQ concludes that there is no reasonable potential for this discharge to negatively impact receiving water stream temperatures. Therefore, ODEQ will not assign a wasteload allocation for this permit.

In addition to the point sources identified above, there are a number of additional stormwater NPDES permits for facilities located within the Tryon Creek watershed. ODEQ did not develop wasteload allocations for stormwater permitted facilities because ODEQ has no data that indicates stormwater discharges contribute to stream temperature standards violations

Allocations – 40 CFR 130.2(g) and 40 CFR 130.2(h)

Loading capacity will be available for allocation where surface water temperatures throughout a given stream or river and all reaches downstream decrease below the standard by an amount sufficient to accommodate either point source or nonpoint source influences.

Table 5.25 lists load allocations (i.e. distributions of the loading capacity) according to land-use and location in the watershed. Load allocations, expressed as percent effective shade, are expressed as shade curves in the "*Effective Shad Curves*" section of this chapter. Load allocations were developed using an ecoregional approach. Shade curves developed for the Prairie Terraces and Valley Foothills ecoregions are applicable in the Tryon Creek Watershed.

Table 5.25. Tryon Creek Watershed Temperature Allocation Summary

Nonpoint Source	Load Allocation
Natural Background + Reserve Capacity	100%
Agriculture	0%
Forestry	0%
Urban	0%
Future Sources	0%
Point Source	**Waste Load Allocation**
Future Growth	No more than 0.3°C increase with 25% of 7Q10 low flow for mixing

A *Waste Load Allocation* (WLA) is the amount of pollutant that a point source can contribute to the stream without violating water quality criteria. No point source WLA will be given for current sources. Future point sources in the watershed may be allowed to discharge to surface waters in the Tryon Creek Watershed as described above in *Point Source Methodology.*

Surrogate Measures

The Tryon Creek Temperature TMDL incorporates measures other than "*daily loads*" to fulfill requirements of §303(d). Although a loading capacity for heat energy may be derived [e.g. kilocalories per day], it is of limited value in guiding management activities needed to solve identified water quality problems. This TMDL allocates "*other appropriate measures*" (or surrogates measures) as provided under USEPA regulations [40 CFR 130.2(i)].

All tributaries within the Tryon Creek Watershed must achieve shade targets in order to achieve compliance with Oregon's temperature standard. To ensure that system potential vegetation characteristics are applied in a geographically appropriate manner, ODEQ utilized ecoregional geographic boundaries to assign appropriate vegetative characteristics throughout the watershed. Effective shade for the appropriate ecoregion and near stream disturbance zone width shall be applied. Shade targets for the Tryon Creek watershed, and a detailed discussion of the methodology, is provided in the *Effective Shade Curves* section of this chapter.

Water Quality Standard Attainment Analysis

An estimation of stream temperatures that will result from system potential vegetation (attainment of TMDL allocations) was not completed for Tryon Creek. However, the allocations are designed to produce a condition in which anthropogenic sources of heat are removed. The resulting temperatures represent attainment of system potential, and therefore, attainment of the temperature standard.

Stream temperatures that result from the system potential conditions represent attainment of the temperature standard

ODEQ recognizes that it may take several years to several decades after full implementation of shade-producing measures to achieve the shade targets identified in this TMDL. Simply put, wide stream segments typically require taller, older riparian vegetation in order to achieve shade targets and narrow stream segments may achieve the shade targets with shorter, younger riparian vegetation. Shade targets identified in **Figures 5.70** through **5.73** apply to the Tryon Creek Watershed as well as all other watersheds in the Lower Willamette Subbasin and can be used to help guide and prioritize implementation efforts to maximize the near-term effectiveness of implementation efforts. ODEQ expects that DMAs will focus initial implementation efforts on improving shade conditions through establishing and/or enhancing riparian vegetation conditions and in ensuring that existing and future development practices allow the attainment of shade targets.

ECOREGIONAL CHARACTERIZATION OF VEGETATION

To ensure that system potential vegetation characteristics and TMDL targets are applied in a geographically appropriate manner, ODEQ utilized ecoregional geographic boundaries to assign appropriate vegetative characteristics throughout the Lower Willamette Subbasin. The use of ecoregional characteristics in determining stream shade targets in the Lower Willamette Subbasin differs somewhat from the approach used in other parts of the Willamette Basin, where vegetation was predicted based upon geomorphology. The geomorphologic information used in other portions of the basin was not available for the Lower Willamette Subbasin so vegetation predictions were made using an ecoregional approach, which is consistent with other TMDL analyses completed by ODEQ.

The term “ecoregion” is generally understood to describe regions of relative homogeneity in ecological systems or in relationships between organisms and their environments (Omernik and Gallant 1986). Ecoregions are delineated on the premise that ecological regions can be identified through the analysis of the patterns and composition of biotic and abiotic components, such as soil composition, vegetation, climate and topography. Simply, areas within a specific ecoregion are likely to share a common set of ecological characteristics with respect to vegetation, climate, topography, etc. Ecoregions were designed to serve as a spatial framework for environmental resource management, with the most immediate needs for developing regional biologic criteria, water quality standards, and for setting management goals for nonpoint-source pollution.

Currently, there are four levels of ecoregions in the United States, with level I being the coarsest and level IV being the most detailed. **Figure 5.68** shows a map of the level IV ecoregions within the Willamette basin. **Figure 5.69** shows a more detailed map of the Lower Willamette Subbasin ecoregions as well as watershed boundaries for Johnson, Tryon and Fairview Creeks and the Columbia Slough.

Figure 5.68. Ecoregions of the Willamette Basin (Omernik & Gallant, 1986)

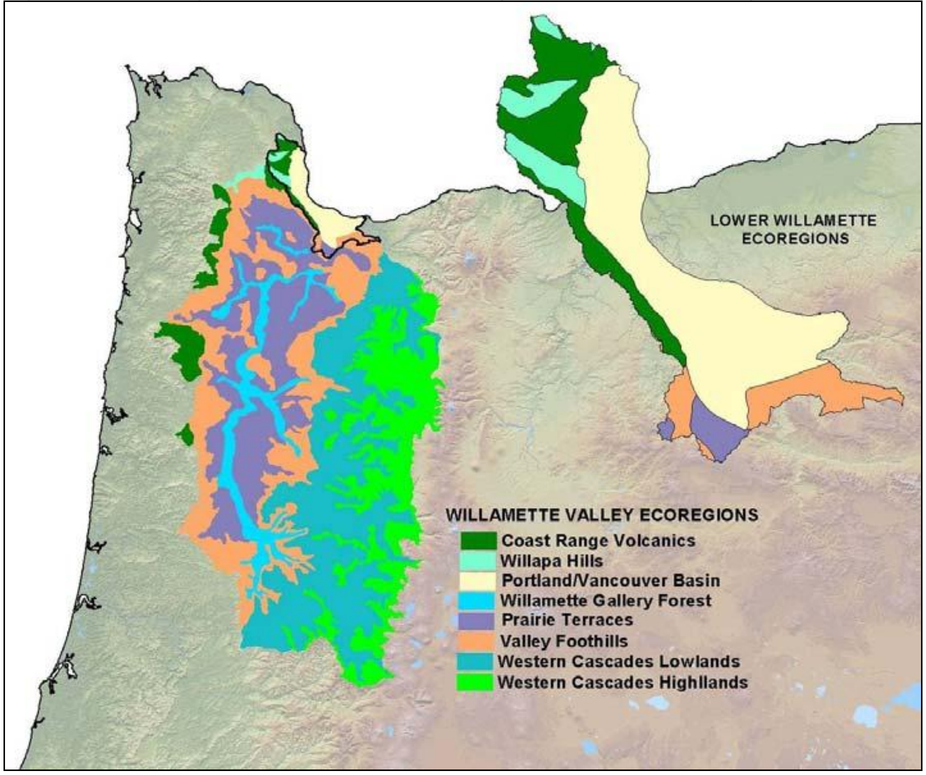
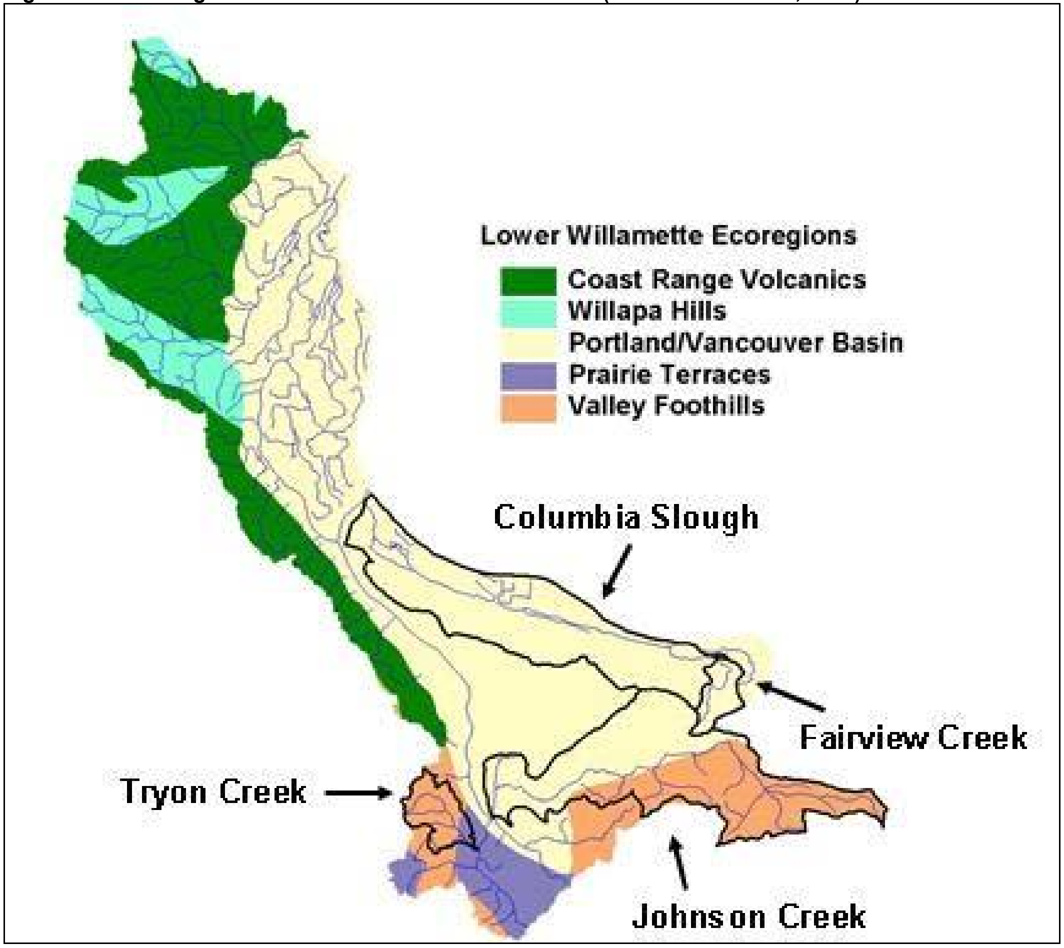


Figure 5.69. Ecoregions in the Lower Willamette Subbasin (Omernik & Gallant, 1986)



Effective Shade Curves – Lower Willamette Subbasin

Where site-specific effective shade levels are not determined via GIS-based land cover analysis and stream temperature modeling, ODEQ chose to develop and apply shade targets based upon ecoregional vegetation characteristics described in **Table 5.26**. For example, detailed riparian vegetation analyses and Heat Source modeling was conducted on the mainstem of Johnson Creek and the results of this effort determined the site-specific shade targets specified in the Johnson Creek Watershed TMDL. However, site specific shade targets are *only* developed by ODEQ on stream segments where intensive Heat Source modeling is conducted. In the case of the Lower Willamette Subbasin, site specific shade targets were identified for the mainstem reaches of Johnson Creek and the Columbia Slough only. ODEQ recognizes that all streams in the watershed contribute to nonpoint source heat loading and, therefore, shade targets must be developed for all streams in the Lower Willamette Subbasin.

Effective shade curves represent general relationships between system potential effective shade and near stream disturbance zone (NSDZ[++]). The curves can be applied to determine effective shade allocations. They are developed using trigonometric equations estimating the shade underneath tree canopies. The NSDZ is the distance from the edge of right bank vegetation to the edge of left bank vegetation. The particular curve that applies to a given reach depends on which ecoregion the stream is located in as well as the width and aspect of the stream segment.

Effective shade targets for the appropriate ecoregion stream aspect and near stream disturbance zone width are provided in **Figures 5.70** through **5.73**. These shade curves apply to all tributaries in the Lower Willamette Subbasin where a detailed vegetation analysis was not performed and site specific shade targets were not developed – all streams except for the mainstem segments of Johnson Creek and the Columbia Slough. Effective shade curves are based upon idealized riparian land cover conditions and should be viewed as a general implementation target rather than a strictly allocated condition. For example, it may not be possible to achieve the height, density and overhang conditions shown in **Table 5.26** in all locations within the subbasin due to natural site specific constraints. The allocated condition is to achieve system potential vegetation, which is defined as the near stream vegetation condition that can grow and reproduce on a site, given elevation, soil properties, plant biology and hydrologic processes.

[++] Near-Stream Disturbance Zone (NSDZ) is defined for purposes of the TMDL as the width between shade-producing near-stream vegetation. This dimension was measured from Digital Orthophoto Quad (DOQ) images and where near-stream vegetation was absent, the near-stream boundary was used, as defined as armored stream banks or where the near-stream zone is unsuitable for vegetation growth due to external factors (i.e., roads, railways, buildings, etc.).

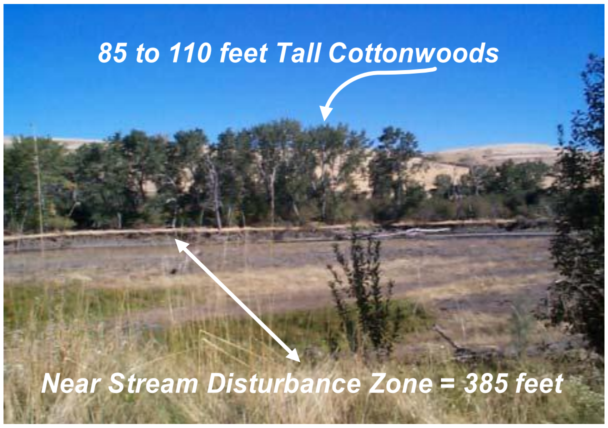


Figure 5.70. Effective Shade Curve - Applicable in Coast Range Volcanics and Willapa Hills

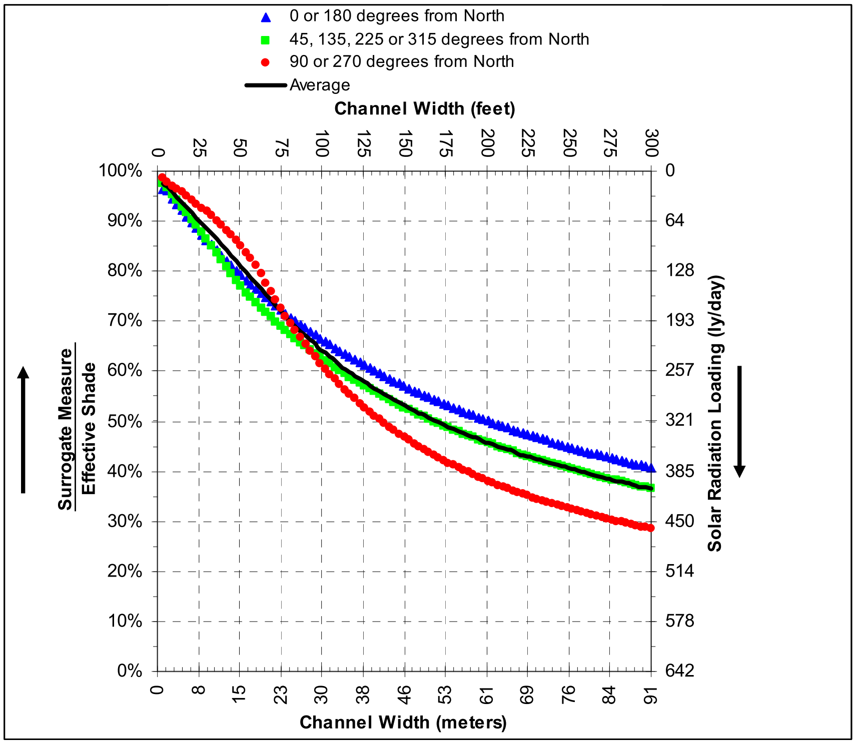


Figure 5.71. Effective Shade Curve - Applicable in Willamette Valley Prairie Terraces

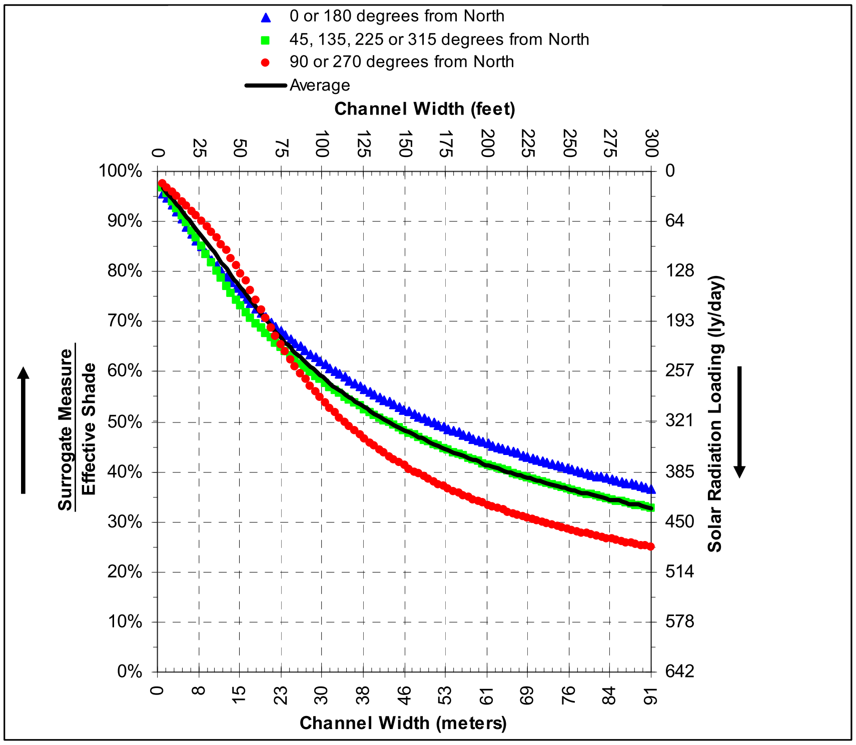


Figure 5.72. Effective Shade Curve - Applicable in Willamette Valley Foothills

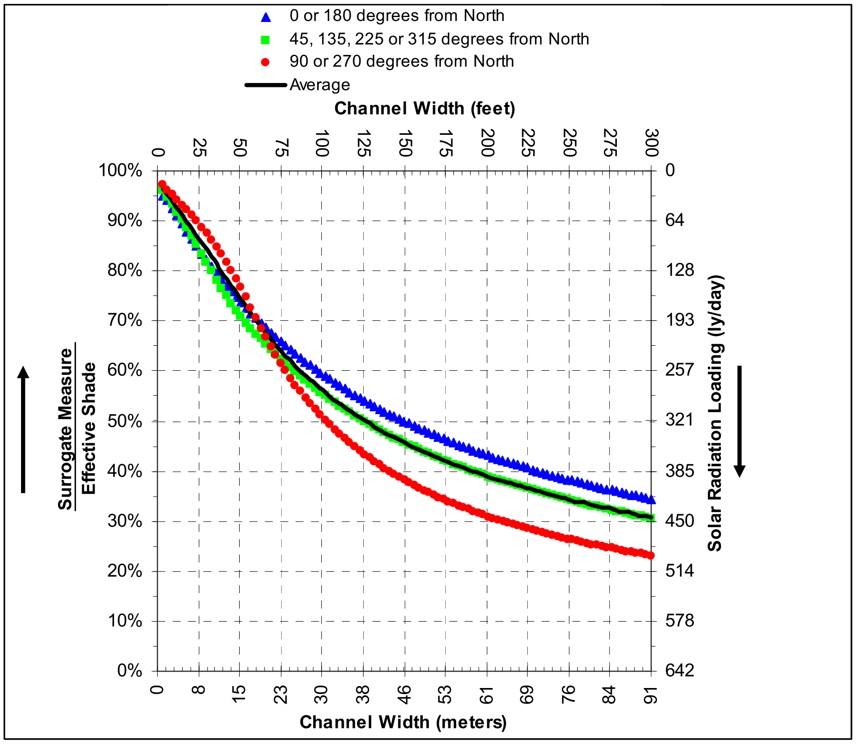


Figure 5.73. Effective Shade Curve - Applicable in Willamette Valley Portland/Vancouver Basin

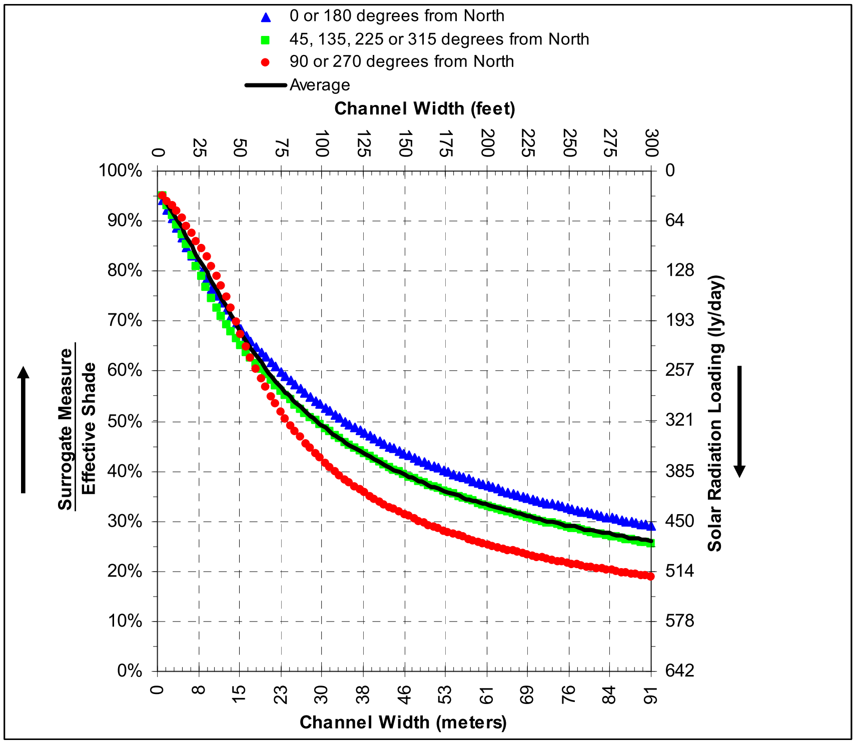
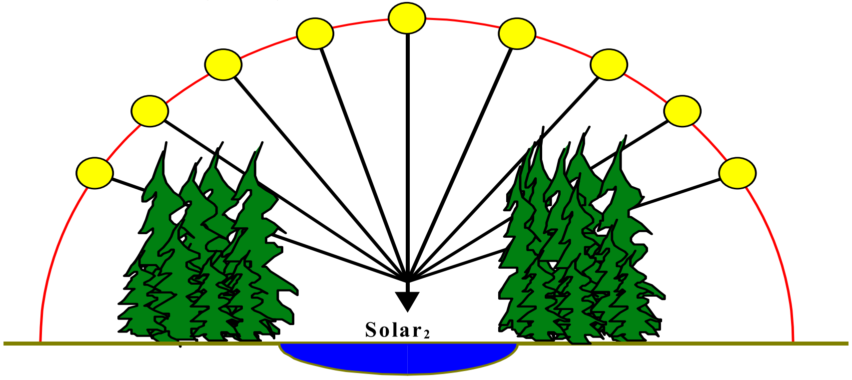


Figure 5.74 demonstrates how effective shade is monitored and calculated. Using solar tables or mathematical simulations, the *potential daily solar load* can be quantified. The *measured solar load (current conditions)* at the stream surface can easily be measured with a Solar Pathfinder© or estimated using mathematical shade simulation computer programs (Boyd, 1996 and Park, 1993).

Figure 5.74. Effective Shade - Defined

Solar$_1$ – Potential Daily Solar Radiation Load

(Adjusted for Solar Altitude and Solar Azimuth)



Effective Shade Defined:

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

Where,

Solar$_1$: Potential Daily Solar Radiation Load
Solar$_2$: Measured Daily Solar Radiation Load at Stream Surface

Ecoregional characteristics and current and historical vegetation data from various watershed assessments were used in determining the dominant shade-producing tree species that are likely to occur along waterways within the Lower Willamette Subbasin. **Table 5.26** provides a short narrative describing the characteristics of the ecoregions of the Lower Willamette Subbasin as well as the specific land cover characteristics (vegetation height, density and overhang) that were used to determine the appropriate shade curve for each ecoregion.

Percent effective shade is perhaps the most straightforward stream parameter to monitor/calculate and is easily translated into quantifiable water quality management and recovery objectives. After applicable curves are developed for each ecoregion, this method is easy to apply to other streams within that particular ecoregion. While the method provides no information on existing shade conditions or the expected system potential stream temperature, it does provide quick and accurate estimates of the allocations necessary to eliminate temperature increases resulting from anthropogenic impacts on shade. For example, a riparian planting project along a segment of Kelley Creek (Johnson Creek Watershed, Willamette Valley Foothills ecoregion) with an average channel width of 10 feet would have a goal of providing approximately 90% effective shade at maturity.

Table 5.26. Lower Willamette Subbasin Ecoregions (Pater et al. 1998 and Hawksworth 1999a)

Level III ecoregion	Level IV ecoregion	Terrain	Potential Overstory Near Stream Vegetation Characteristics				
			Potential Natural Vegetation	Dominant Shade Producing Species	Height	Assumed Overhang	Assumed Canopy Density
Coast Range	Willapa Hills	Low hills and mountains with moderate gradient streams and rivers. Elevation 500-2300 feet.	Western hemlock, Western red cedar, and Douglas fir forest.	Western hemlock Western red cedar Douglas fir Red alder Big leaf maple **Composite Dimension**	120 feet 120 feet 160 feet 100 feet 90 feet **118 feet**	12% of Height **14 feet**	**75%**
	Volcanics	Steeply sloping mountains with moderate to high gradient streams. Elevation 400-2200 feet.	Historically Western hemlock, Western red cedar, and Douglas fir forest. Forests are intensively managed.	Western hemlock Western red cedar Douglas fir Red alder Big leaf maple **Composite Dimension**	120 feet 120 feet 160 feet 100 feet 90 feet **118 feet**	12% of Height **14 feet**	**75%**
Willamette Valley	Prairie Terraces	Undulating hills amid almost level terrain. Sluggish low gradient streams and rivers. Mountains. Dissected by low-gradient, meandering streams and rivers. Elevation 115-200 feet.	Oregon ash and Douglas fir in wetter areas. Prairie and oak woodlands in dryer areas. Today extensively developed for agriculture and urban/rural residential development.	Oregon ash Western red cedar Douglas fir Red alder Big leaf maple **Composite Dimension**	75 feet 120 feet 160 feet 100 feet 90 feet **109 feet**	12% of Height **13 feet**	**75%**
	Valley Foothills	Rolling hills mark the transitional zone between the Willamette Valley and the Coast Range. Elevation 200-1800 feet.	Oregon white oak in dryer areas and Douglas fir in wetter areas were originally dominant. Today rural residential, tree farms, pastureland, and some urbanization.	Oregon white oak Douglas fir Red alder Big leaf maple **Composite Dimension**	60 feet 160 feet 100 feet 90 feet **102 feet**	12% of Height **12 feet**	**75%**
	Portland/Vancouver Basin	Nearly level to undulating terraces and floodplain with low gradient, meandering streams and rivers. Elevation 0-300 feet w/ some higher buttes	Alder, ash and Western red cedar in riparian areas. Ash forests in wet depressions, Black Cottonwood groves on river banks and islands	Oregon ash Western red cedar Douglas fir Red alder Black Cottonwood **Composite Dimension**	75 feet 120 feet 160 feet 100 feet 85 feet **108 feet**	12% of Height **13 feet**	**75%**

BACTERIA TMDLS

TMDL Components Applicable To All Lower Willamette Subbasin Tributaries

The bacteria TMDLs include descriptions of the subbasin and individual watersheds (section *Subbasin Overview*, above), the pollutants responsible for impairments, standards being applied, sources of the pollutants, a description of available data, loading capacity, allocations of loads, and a margin of safety. These features are summarized in **Table 5.27**.

Table 5.27. Lower Willamette Subbasin Bacteria TMDL Components.

Waterbodies	Streams providing recreational contact beneficial uses as defined in OAR 340-41-205 within the HUC (Hydrologic Unit Code) 17090012 – Lower Willamette
Pollutant Identification	*Pollutants:* Fecal bacteria from various sources. Particularly *E. coli* as an indicator of human pathogens for recreational contact and fecal coliform bacteria as an indicator of human pathogens for shellfish harvest in estuarine areas.
Target Identification (Applicable Water Quality Standards) *CWA §303(d)(1)*	(A) Numeric Criteria: Organisms of the coliform group commonly associated with fecal sources (MPN or equivalent membrane filtration using a representative number of samples) shall not exceed the criteria described in subparagraphs (i) and (ii) of this paragraph. Freshwaters and Estuarine Waters: (i) A 30-day log mean of 126 E. coli organisms per 100 ml, based on a minimum of five (5) samples; (ii) No single sample shall exceed 406 E. coli organisms per 100 ml.
Existing Sources *CWA §303(d)(1)*	Multiple, including urban stormwater and nonpoint sources
Seasonal Variation *CWA §303(d)(1)*	Violations of the bacteria standard generally occur throughout the year and under all observed flow conditions. TMDL allocations apply year round.
TMDL Loading Capacity and Allocations *40 CFR 130.2(f)* *40 CFR 130.2(g)* *40 CFR 130.2(h)*	*Loading Capacity:* The loading capacity was determined through the development of load duration curves that determine the maximum bacteria load that will achieve the 126 E. coli organisms per 100 ml water quality criteria under all flow conditions, thereby protecting beneficial uses. *Waste Load Allocations (Point Sources)*: Waste load allocations applicable to municipal stormwater permits are expressed as a percent reduction necessary to meet the numeric criteria – in this case 66% to 80%. Waste load allocations for CAFOs are zero. *Load Allocations (Non-Point Sources)*: Load allocations are expressed as a percent reduction necessary to meet the numeric criteria – in this case 66% to 80%.
Surrogate Measures *40 CFR 130.2(i)*	Translates Nonpoint Source Load Allocations Allocations are in terms of percent reduction needed to achieve the numeric criteria. This translates load allocations into more applicable measures of performance.
Reserve Capacity *OAR 340-42-40(4)(K)*	No reserve capacity is allotted at this time for the Lower Willamette Subbasin. Future permitted sources of bacteria will be required to meet the water quality criteria of 126cfu/100ml as a log mean and no sample greater than 406 cfu/100ml.
Margins of Safety *CWA §303(d)(1)*	*Margins of Safety* are applied as conservative assumptions in the development and interpretation of the load duration curve. No numeric margin of safety is developed.

Pollutant Identification

The pollutant causing impairment of 303(d) listed waters is *E. coli* bacteria (a subset of fecal coliform bacteria). These bacteria are produced in the guts of warm-blooded vertebrate animals, and indicate the presence of pathogens that cause illness in humans.

All data analyzed for development of this TMDL was of *E. coli* concentrations, though in some cases fecal coliform data are still collected. The methods of bacterial analysis have changed over time, with some samples analyzed using the Most Probable Number (MPN) technique and some analyzed using the membrane filtration technique (MF). The MF technique results are reported as “Colony Forming Units” (CFU) per 100ml, whereas the MPN technique results are reported as “Most Probably Number” (MPN) per 100ml. According to *Bacterial Indicators of Pollution* (Pipes, 1982) “the differences between MPN estimates and MF counts were not of any practical significance mainly because of the inherently low degree of reproducibility of the MPN estimates.” Regardless of the analytical technique, all available *E. coli* data have been combined for this report.

Beneficial Use Identification

Oregon Administrative Rules (OAR 340 – 41 – 442, Table 6) lists the beneficial uses occurring within the Willamette Basin tributaries. Numeric and narrative water quality standards are designed to protect the most sensitive beneficial uses. Water contact recreation is the most sensitive beneficial use related to bacteria in the Lower Willamette Subbasin. The 30-day log mean of 126 *E. coli* organisms per 100 milliliters criterion was used as the target concentration in the TMDL for determining the loading capacity of a waterbody. This criterion was selected as it most directly relates to illness rates[1] and potential impacts on the beneficial use of water contact recreation.

Target Criteria Identification

Bacterial criteria for Oregon’s waters are contained in the Oregon Administrative Rules, section 340-41. Bacteria impair the recreational use of rivers when concentrations exceed those determined through epidemiological studies to cause illness through body contact at a rate of 8 or more cases per 1000 swimmers. In 1996 Oregon replaced fecal coliform bacteria with *Escherichia coli (E. coli)* in State water quality standards. The revision followed recommendations from the U.S. Environmental Protection Agency (USEPA, 1986a) and was based upon a study that demonstrated a statistically significant relationship between the rate of swimming-related illness and the concentrations of *E. coli* and enterococci at freshwater beaches (Dufour, 1984). *E. coli* was determined to be a good indicator of fecal contamination in water and wastewater because it has met a number of important criteria, including: (1) it is present in the feces of humans and warm-blooded animals at numbers exceeding those of pathogens; (2) it shows minimal growth in aquatic systems and at slower rates than pathogens; (3) it is readily detectable by simple procedures that result in unambiguous identification of the fecal coliform group; (4) it is consistently present when pathogens are present; and (5) it shows increased resistance to disinfectants as opposed to pathogens (Elmund et al., 1999). The criteria shown in **Table 5.28** are designed to achieve those concentrations, both for a single day exposure and over a long term (30-day) exposure period. Only *E. coli* data collected after 1996 were considered for this assessment.

Table 5.28. Bacteria Water Quality Standards Applicable in the Lower Willamette Subbasin

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[1] From Implementation Guidance for Ambient Water Quality Criteria for Bacteria (USEPA, EPA-823-B-02-003, May 2002 Draft, pg 7): “For the purpose of analysis, the data collected at each of these sites were grouped into one paired data point consisting of an averaged illness rate and a geometric mean of the observed water quality. These data points were plotted to determine the relationships between illness rates and average water quality (expressed as a geometric mean). The resulting linear regression equations were used to calculate recommended geometric mean values at specific levels of protection (e.g., 8 illnesses per thousand). Using a generalized standard deviation of the data collected to develop the relationships and assuming a log normal distribution, various percentiles of the upper ranges of these distributions were calculated and presented as single sample maximum values.

EPA recognizes that the single sample maximum values in the 1986 criteria document are described as “upper confidence levels,” however, the statistical equations used to calculate these values were those used to calculate percentile values. While the resultant maximum values would more appropriately be called 75th percentile values, 82nd percentile values, etc., this document will continue to use the historical term “confidence levels” to describe these values to avoid confusion.”

Beneficial Use	Description
Recreational Contact in Water OAR 340-41-445 (2)(e)(A):	Prior to March 1996: a geometric mean of five fecal coliform samples should not exceed 200 colonies per 100 ml, and no more than 10% should exceed 400 colonies per 100 ml. Effective March 1996 through present: a 30-day log mean of 126 *E. coli* organisms per 100 ml, based on a minimum of five samples; and no single sample shall exceed 406 *E. coli* organisms per 100 ml.

Description of General Bacteria Sources

The following sections of this chapter describe many likely sources of bacteria, but this source assessment is not exhaustive or specific to a particular watershed. Watershed managers from the designated management agencies must conduct further investigations of watershed-specific bacteria sources in order to develop an effective overall strategy for bacteria control.

Sources of Bacteria Associated with Runoff Events

The following is a list of potential runoff related bacteria sources in the Lower Willamette Subbasin:

Urban Runoff

In some cases instream bacteria values are significantly higher during runoff events. This, coupled with the facts that much of the lower portion of the Johnson Creek Watershed is urbanized and that urban stormwater is known to contain high bacteria concentrations, points to urban runoff as a significant bacteria source. The ultimate sources of urban bacteria are multiple and may include:

- Pet and other animal waste
- Illegal dumping of sanitary waste
- Failing septic systems
- Sanitary sewer overflows

It is important to note that urban runoff, especially stormwater discharged via a system of pipes, may include bacteria from a variety of sources, both human and non-human in origin. Bacteria originating from ducks, geese, raccoons and other wildlife may well be present in large numbers in urban stormwater runoff. However, the paths that bacteria from these sources take and the time in which it takes to reach a nearby stream are often greatly altered by modern stormwater conveyance systems. For example, it is conceivable that waste (human, wildlife or domesticated animal) deposited several hundred feet away from a stream could be transported to the stream in minutes via an urban storm system – a path that may take several days under natural overland flow conditions. Since die-off rates for bacteria are typically in the order of days, the bacteria in the waste would likely contribute to stream standards violations when transported quickly via the storm system, but would be much less likely to survive natural overland transport – as evidenced by the low bacteria numbers seen in forested watersheds with abundant wildlife.

Rural Runoff

Rural runoff may contain bacteria from the same sources as urban runoff, with the possible exception of sanitary sewer overflows. Additional potential sources are “hobby” farms, horse pastures, ranchettes and man-made instream ponds that attract wildlife. The density of septic systems is often relatively high in rural areas on the fringe of urban areas and therefore the possibility of failing systems is often quite high.

Agricultural Runoff

The primary source of bacteria in agricultural runoff is most likely animal waste. Livestock grazing is not a major land use in the Lower Willamette Subbasin, but approximately 24% of the Johnson Creek Watershed remains in some form of agricultural use and some level of agricultural use is found in almost every watershed. Since a strong correlation between bacteria and suspended solids concentrations has been shown to exist in many watersheds with agricultural land uses, erosion prevention and control may be the best way to reduce bacteria runoff from agricultural lands.

Sources of Bacteria NOT Associated with Runoff Events

The following is a list of potential non-runoff related bacteria sources in the Johnson Creek Watershed:

Urban Sources

Non-runoff sources of urban bacteria may include such things as sanitary sewer cross connections, illicit discharge of sanitary waste from septage vacuum trucks and recreational vehicles, and episodic or chronic discharges from the local sanitary sewer system. Small scale discharges, a single residential cross connection for example, may not have much of an impact during runoff events or when stream flows are higher, but can cause water quality standards violations during the summer. A review of ODEQ records shows 10 sanitary sewer “upsets” that resulted in a discharge to Johnson Creek were reported between 1996 and 2003. Six of the ten reported upsets resulted in sewage spills of at least 1000 gallons and have the potential to result in violations of water quality standards. However, ODEQ was unable to quantify the impact of these discharges due to a lack of concomitant instream bacteria monitoring and other uncertainties. ODEQ assumes that sanitary sewer upsets periodically impact virtually all urban streams in the Lower Willamette Subbasin that are subject to their discharge.

Failing Septic Systems

Septic systems fail in a variety of different ways and may contribute to water quality problems under both runoff and non-runoff conditions. Some systems only fail when the soil is saturated or when winter storms raise the local water table. Other systems fail year round and, especially those near local streams, contribute bacteria to streams during low flow conditions when there is less assimilative capacity.

Cesspools, which provide very little treatment of waste, are also present in the subbasin and may be located in close proximity to streams. While large cesspools (those serving 20 or more people and/or having a design capacity of more than 2,500 gallons per day) were scheduled to be phased out by April 5, 2005, single family cesspools in the watershed may be in use for many years to come and may contribute bacteria loading to streams.

Direct Deposition

Direct deposition of pet and other animal waste into streams can cause water quality standards violations during low flow conditions. In some instances direct deposition from wildlife, exacerbated by anthropogenic activities, has been identified as a significant bacteria source.

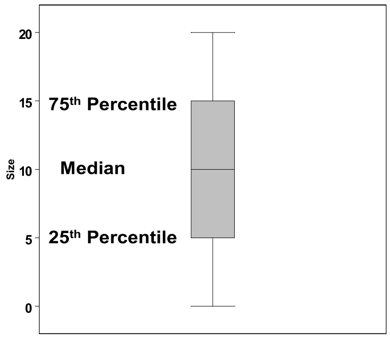
Description of Box Plots

The discussions of bacterial concentrations contained in the individual watershed sections of this chapter present distributions of sample data and, in some instances, use median values as approximations of geometric means. This would not be appropriate for determinations of violations of water quality criteria based on a geometric mean standard, but is a reasonable method of discussing distributions of sample concentrations. The distributions are presented in box and whisker plots, as described in **Figure 5.75**.

Box Plots are used to illustrate the distribution of samples through time or among places. They are the recommended graphical means of displaying data sets containing extreme values or "outliers". Box Plots characterize data using the median as a measure of central tendency and the interquartile range as a measure of spread. The percentile indicates the percentage of sample values less than the value at that point in the distribution. In example 1 (top), 75 percent of sample values are lower than 15 and 25 percent are lower than 5. By definition, the median is the 50th percentile, with 50 percent of values lower and 50 percent of values higher than the median.

Figure 5.75. Description of Box Plots

Box and Whisker Plot Example 1

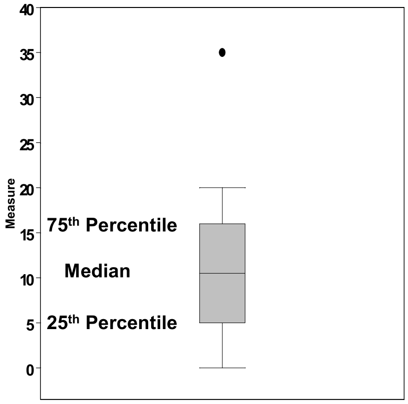


In the Box Plot at left, the numbers 0 through 20 are plotted based on their distribution as a percent of the total.

The median = 10
75th Percentile = 15
25th Percentile = 5

Ends of the "whiskers" are the extreme values in the data excluding "outliers"

Box and Whisker Plot Example 2



In the Box Plot at left, the numbers 0 through 20 are plotted based on their distribution as a percent of the total. An additional number,35, is plotted as an "outlier"

Outliers are greater than 1.5 times the range between the 25th and 75th Percentiles

Bacteria Source Tracking

ODEQ recognizes that, in the long term, it may be difficult to address bacteria water quality impairments in Lower Willamette Subbasin tributaries without a reliable method to determine the source of contamination. However, given the known bacterial sources and the severity of bacterial water quality standards violations, considerable progress can be made toward achieving water quality standards simply by targeting known sources with appropriate Best Management Practices and currently accepted source tracking techniques.

Bacteria Source Tracking is a potentially powerful source assessment tool. It is still largely experimental and proper experimental design is crucial

Bacterial Source Tracking (BST) methods are potentially powerful tools that are increasingly being utilized to identify the animal source of bacteria in surface waters. While ODEQ expects that traditional bacteria source identification and control techniques and BMPs will be employed during the initial implementation phase for TMDLs, BST techniques may provide an important tool for Designated Management Agencies to utilize in future implementation planning efforts.

The central premise of BST is that bacteria exhibit some degree of host specificity – that is bacteria from different host organisms (livestock, humans, wildlife, etc.) can be differentiated and used to identify the sources of bacterial pollution in surface waters (Harwood 2002, Samadpour 2002).

BST techniques fall into two broad categories, molecular and non-molecular. Non-molecular techniques such as Antibiotic Resistance Analysis (ARA) and Carbon Utilization Profile (CUP) use non-genetic characteristics to differentiate the sources of fecal bacteria, while molecular techniques, which are commonly referred to as “DNA fingerprinting”, are based on the unique genetic makeup of different strains of fecal bacteria (USEPA 2002b). BST may use one of several methods to differentiate between bacterial sources, all of which follow a common sequence of analysis. First, a distinguishing characteristic (such as antibiotic resistance or differences in DNA) must be selected to identify various strains of bacteria. A representative library of bacterial strains and their fingerprints must then be generated from the human and animal sources that may impact the water body in question. Bacteria samples from the water body are then compared to those in the library and assigned to the appropriate source category based on fingerprint similarity (USEPA 2002b).

Several BST methodologies are currently being developed and tested, including Pulse Field Electrophoresis (PFGE), Ribotyping (RT), Amplified Fragment Length Polymorphism (AFLP) and ARA. All techniques are considered experimental. A methods comparison study, sponsored by the Southern California Coastal Water Research Project, USEPA, NOAA, USGS, and the Orange County Sanitation District is currently underway.

There are several important considerations for choosing BST methods, namely their relevance to appropriate regulations, geographic areas and the ability to allocate loadings to particular source categories. Obviously, the association accuracy of the method and geographic range of the genetic library used are extremely important, as is the overall experimental design.

Lastly, for BST analyses to be truly useful, they must be conducted over a variety of flow and precipitation regimes over the course of a year and at multiple land use-based locations within a watershed. Samples should also be submitted for BST during times when bacteria water quality standards are not being achieved and must be accompanied by stream flow measurements and bacteria counts for each sample analyzed.

Johnson Creek Watershed

Johnson Creek is included on the 1998 list of water quality impaired waterbodies in the state of Oregon (303d list) due to high levels of E. coli bacteria. Johnson Creek is considered water quality limited year around from its mouth to headwaters.

Analytical Approach – Load Duration Curve

ODEQ chose to use the load duration curve approach to develop the bacteria TMDL for the Johnson Creek Watershed. Load duration curves are a method of determining a flow based loading capacity, assessing current conditions, and calculating the necessary reductions to comply with water quality standards. The methodology is primarily based on TMDLs completed by Kansas Department of Health and Environment and through technical assistance provided by Bruce Cleland of America's Clean Water Foundation (www.acf.org). Load duration curves were chosen because they offer a relatively simple and accurate methodology for determining the degree of water quality impairment and because they are capable of illustrating relative impacts under various flow conditions and can be used in targeting appropriate water quality restoration efforts (Cleland 2002, 2003).

The bacteria TMDL for the Johnson Creek Watershed was developed using water quality monitoring data collected by ODEQ, Clackamas County Water Environment Services and the cities of Gresham and Portland. *E. coli* samples considered for this analysis were collected during a variety of weather and flow conditions between 1996 and 2002. Data reported as "estimate", "less than" or "greater than" values were not considered. **Figure 5.76** shows the location of the bacteria monitoring sites in the watershed and delineates which agency conducted the monitoring. Monitoring site numbers (1 through 16) shown in **Figure 5.76** corresponds with additional site information provided in **Table 5.29**.

Figure 5.76. Location of Johnson Creek Bacteria Monitoring Sites and Associated Monitoring Agency

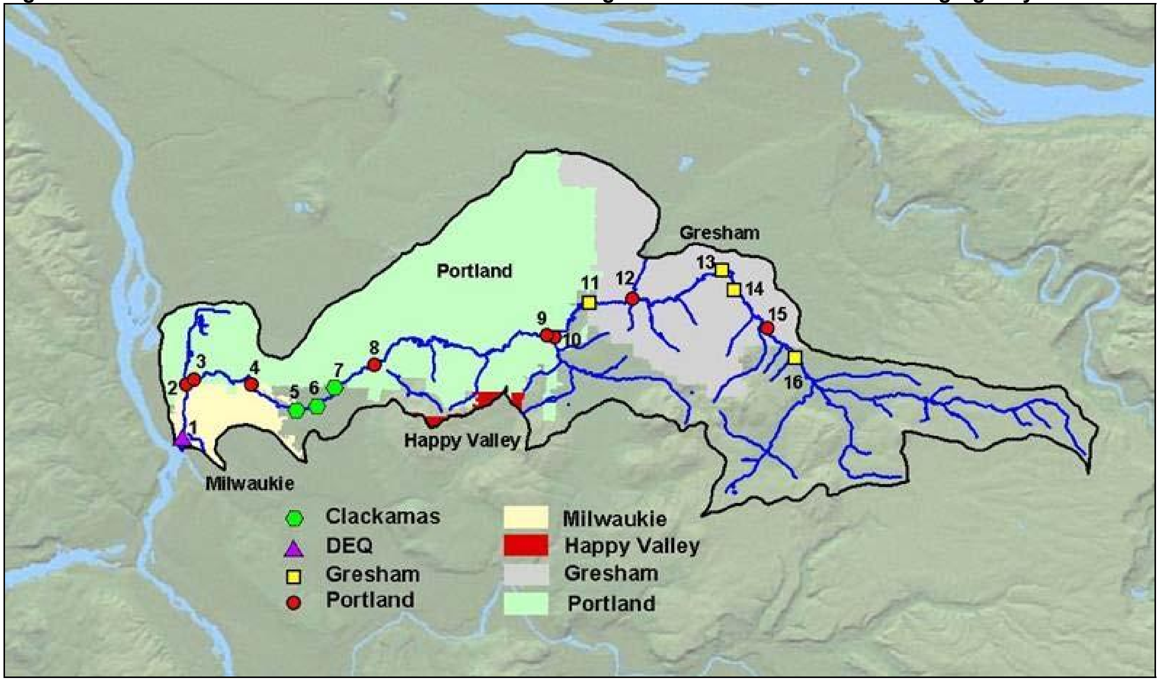


Table 5.29. Johnson Creek Bacteria Monitoring Location Information

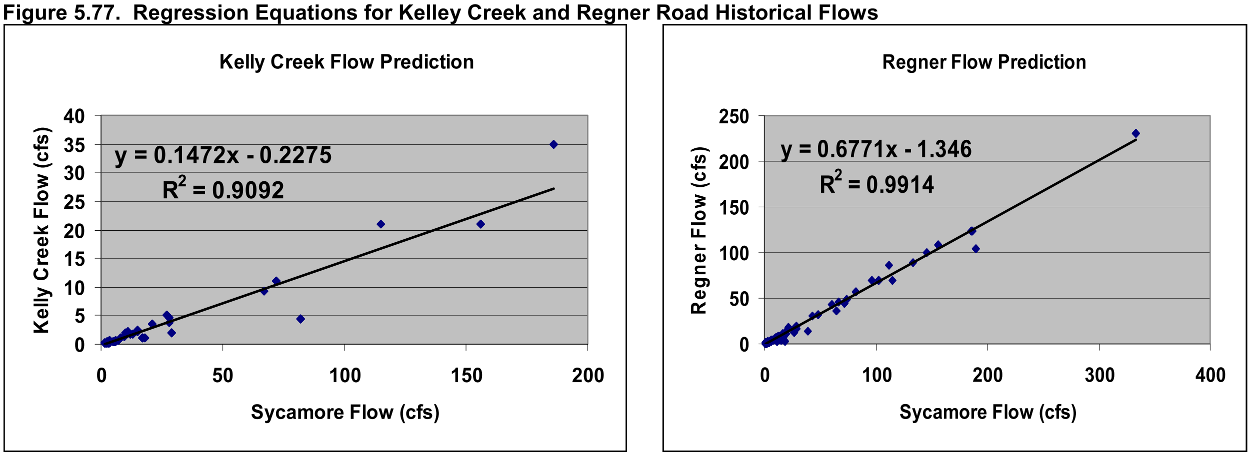
Station Number	Site Description	Agency	Number of Samples
1	Johnson Cr. at 17th Avenue	ODEQ	33
2	Johnson Cr. at SE Umatilla Bridge	Portland	20
3	Crystal Springs Cr. at 21st Ave.	Portland	34
4	Johnson Cr. at 45th Ave.	Portland	33
5	Johnson Cr. at Linwood Ave.	Clackamas WES	32
6	Johnson Cr. at Johnson Cr. Blvd.	Clackamas WES	28
7	Johnson Cr. at Luther Rd.	Clackamas WES	31
8	Johnson Cr. at SE 92nd Ave.	Portland	23
9	Johnson Cr. at SE 158th Ave.	Portland	21
10	Kelley Creek at 159th Ave.	Portland	19
11	Johnson Cr. at SE 174th Ave.	Gresham	20
12	Johnson Cr. at SE 190th Ave.	Portland	24
13	Johnson Cr. at Walters Rd.	Gresham	17
14	Johnson Cr. at Park Ave.	Gresham	21
15	Johnson Cr. at Hogan Rd.	Portland	23
16	Johnson Cr. at Palmblad Rd.	Gresham	26

Flow data from USGS stream gaging stations in the watershed was utilized in the development of load duration curves. Detailed information on the flow gaging stations is provided above in *Subbasin Overview* section above.

The process used to develop load duration curves for this TMDL is described below:

A flow duration curve for the appropriate USGS gage site and/or bacteria monitoring location in the watershed is developed using available streamflow data. Recall that flow duration curves were developed for the three USGS stream flow gages located on the mainstem of Johnson Creek at RM 0.6, 10.3 and 16.3 and that fourteen mainstem and two tributary bacteria monitoring locations were considered in this analysis (**Figure 5.76** and **Table 5.29**). Since Johnson Creek had a number of bacteria monitoring locations and USGS gage locations, stream flows for each monitoring site were calculated based upon measured USGS flows and a correction factor that accounts for the watershed area above the monitoring site. Bacteria samples used in this analysis were collected between 1996 and 2002, but USGS flow measurements at the Regner Road (mainstem) and Kelley Creek (tributary) locations did not begin until 1998 and 2000, respectively. It was therefore necessary to predict historical flows at these sites using a regression equation based upon the relationship between the sites and the Sycamore gage. **Figure 5.77** shows the regression equations used to predict historic flows at the Kelley Creek and Regner Road locations.

Figure 5.77. Regression Equations for Kelley Creek and Regner Road Historical Flows



Bacteria monitoring site-specific flows were determined by applying drainage area-based correction factors to known or predicted stream flows at the appropriate USGS gage site. The sub-watershed for each sample site was digitally delineated using Arcview GIS and drainage area was calculated. The sub-watershed delineations are presented in **Figure 5.78** and the drainage area-based flow conversion factors for each site are shown in **Table 5.30**. The flow of Crystal Springs Creek was assumed to be a constant 12 cfs.

Flow duration curves were developed for each sampling site.

Figure 5.78. Sub-watersheds Delineated by ODEQ for Site-specific Flow Predictions

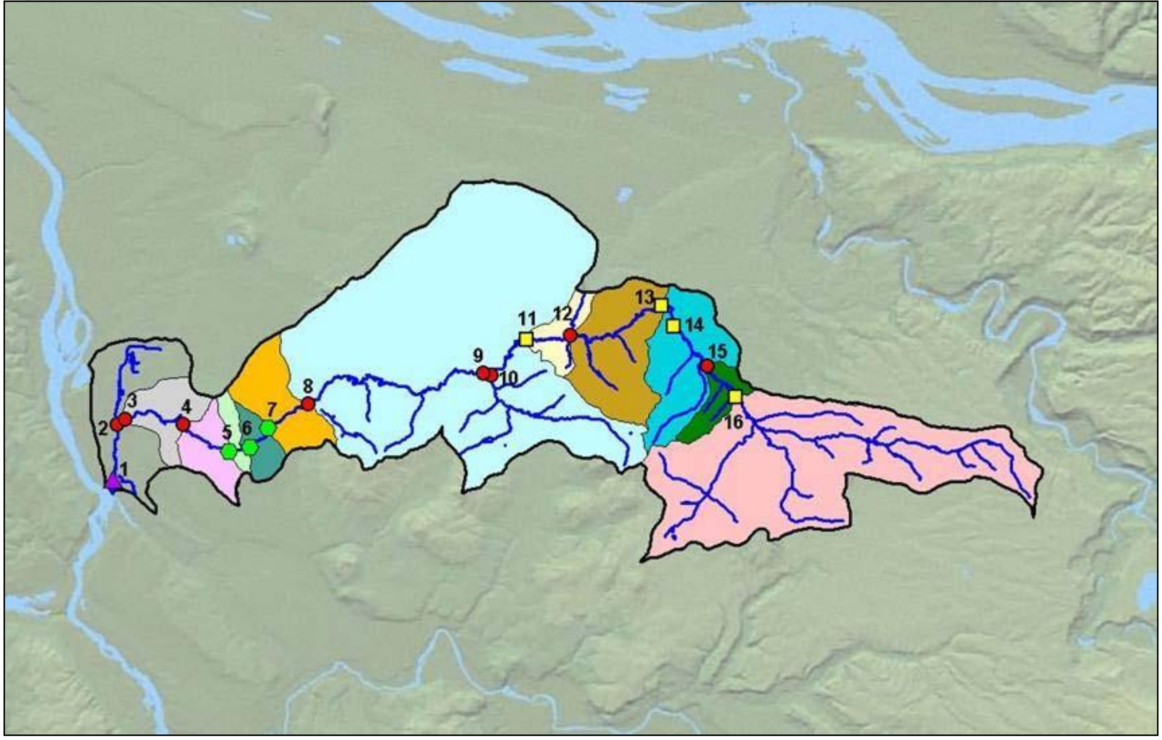


Table 5.30. Site-specific Flow Conversions

Station Number	Site Description	Drainage Area (acres)	Flow Conversion
1	Johnson Cr. at 17th Avenue	34029	Milport Gage only
2	Johnson Cr. at SE Umatilla	31182	Milport – Crystal Springs
3	Crystal Springs Cr. at 21st Ave.	N/A	N/A
4	Johnson Cr. at 45th Ave.	30296	(Milport minus Crystal Springs) X .97
5	Johnson Cr. at Linwood Ave.	29535	(Milport minus Crystal Springs) X .95
6	Johnson Cr. at Johnson Cr.	29255	(Milport minus Crystal Springs) X .94
7	Johnson Cr. at Luther Rd.	28797	(Milport minus Crystal Springs) X .92
8	Johnson Cr. at SE 92nd Ave.	27509	(Milport minus Crystal Springs) X .88
9	Johnson Cr. at SE 158th Ave.	16960	Sycamore Gage only
10	Kelley Creek at 159th Ave.	N/A	Kelley Creek Gage only
11	Johnson Cr. at SE 174th Ave.	13334	Sycamore minus Kelley Creek
12	Johnson Cr. at SE 190th Ave.	12758	Regner Gage X 1.28
13	Johnson Cr. at Walters Rd.	10559	Regner Gage X 1.06
14	Johnson Cr. at Park Ave.	10000	Regner Gage
15	Johnson Cr. at Hogan Rd.	8569	Regner Gage X .86
16	Johnson Cr. at Palmblad Rd.	8033	Regner Gage X .80

The flow duration curve generated for each sample site was translated into a load duration curve. To accomplish this, the flow value was multiplied by the water quality standard and a conversion factor. The resulting loads were graphed and represent the flow-dependent loading capacity for specific numeric criteria. The curves were determined by the target concentration, 126 cfu/100ml in this case, and the flow associated with the recurrence interval. For example, the log mean recreational contact standard for bacteria is 126 colonies per 100 milliliters so the loading capacity is:

$$Loading\ Capcity\,\frac{col}{day}=\overset{\overset{\text{Standard}}{\downarrow}}{126}\frac{col}{100\,ml}*\overset{\overset{\text{Flow}}{\downarrow}}{Q}\frac{ft^3}{s}*\overbrace{283.2\frac{100ml}{ft^3}*86400\frac{s}{day}}^{\text{Conversion factors}}$$

The loading capacity is then plotted against the corresponding flow exceedance probability. There are two lines representing the two numeric targets: log mean of 126 cfu / 100 ml and no samples exceeding 406 cfu / 100 ml. The loading capacity increases with increased flow because of the increased assimilative capacity of the river.

A water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was taken. Measured concentrations of *E. coli* are converted into loads using the equation above and flows from the stream gage. The “event loads” are plotted along with the standard lines to assess current conditions The y-axis becomes the water quality parameter value, load in this case, and the position of the sample on the x-axis illustrates the flow exceedance probability (**Figures 5.79** through **5.83**). Notices that only 5 of the 16 stations sampled are represented in **Figures 5.79** through **5.83**. Four stations are located along Johnson Creek from the mouth to the uppermost monitoring location and one station represents Kelley Creek, a tributary that enters Johnson Creek at river mile 11.5. ODEQ feels that these stations adequately represent bacteria conditions in the watershed and that displaying all 16 would be redundant.

Points that plot above the curve represent deviations from the water quality standard and the permissible loading function. Those plotting below the curve represent compliance with water quality criteria and the appropriate designated use.

When event loads exceed the loading capacity during high flows it is likely that the loading is due to runoff related sources such as urban stormwater, sanitary sewer overflows or runoff containing livestock and/or pet wastes from rural areas.

Bacteria loading may be less during low flow periods; however, the loading capacity of the river has also decreased. Violations of the water quality standard at low flows are not likely runoff related. Warm-blooded animals in streams, failing septic tanks, waste water treatment plants and improper discharge of sewage are possible non-runoff related sources.

Figure 5.79. **Load Duration Curve showing the loading capacity and event loads for Johnson Creek at 17th Avenue (Site #1)**

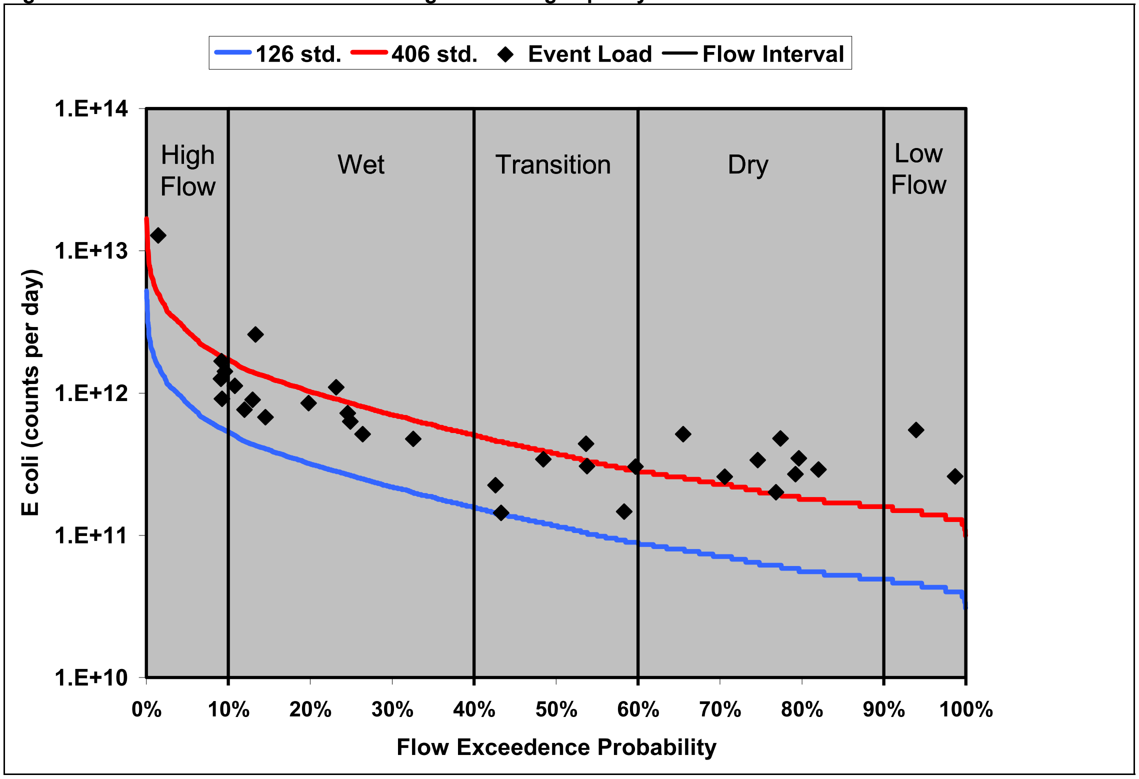


Figure 5.80. Load Duration Curve showing the loading capacity and event loads for Johnson Creek at Luther Rd. (Site #7)

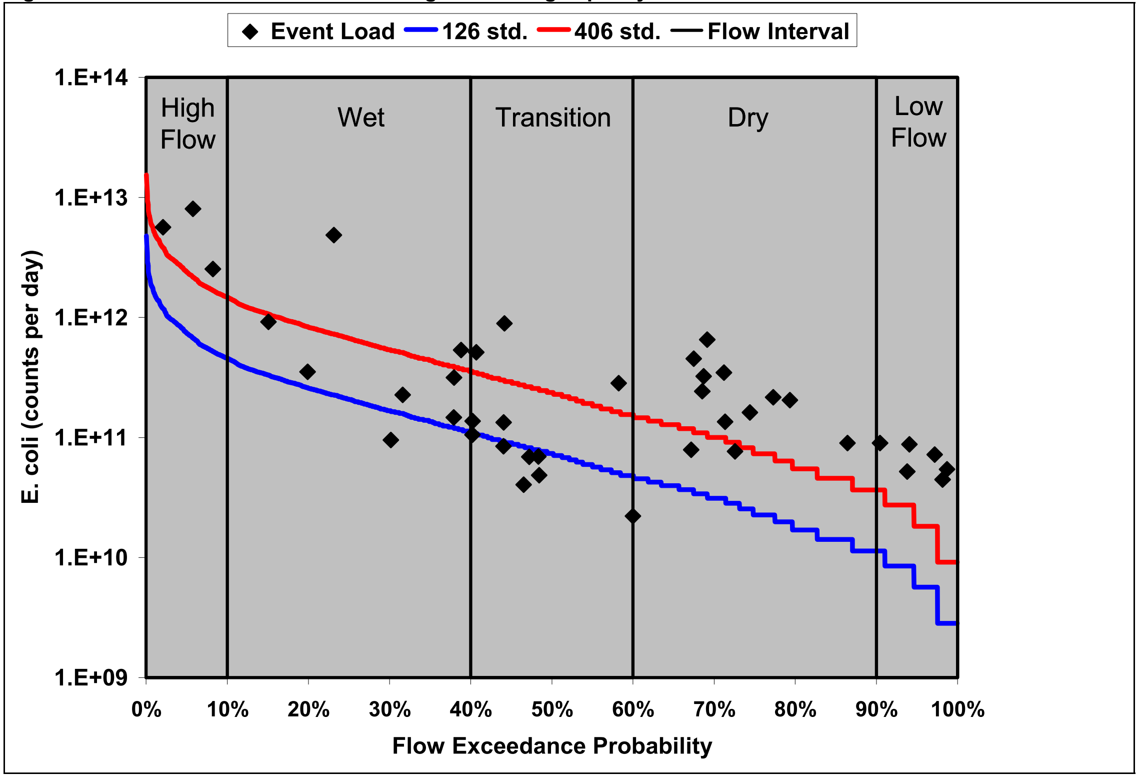


Figure 5.81. Load Duration Curve showing the loading capacity and event loads for Johnson Creek at 174th Avenue (Site #11)

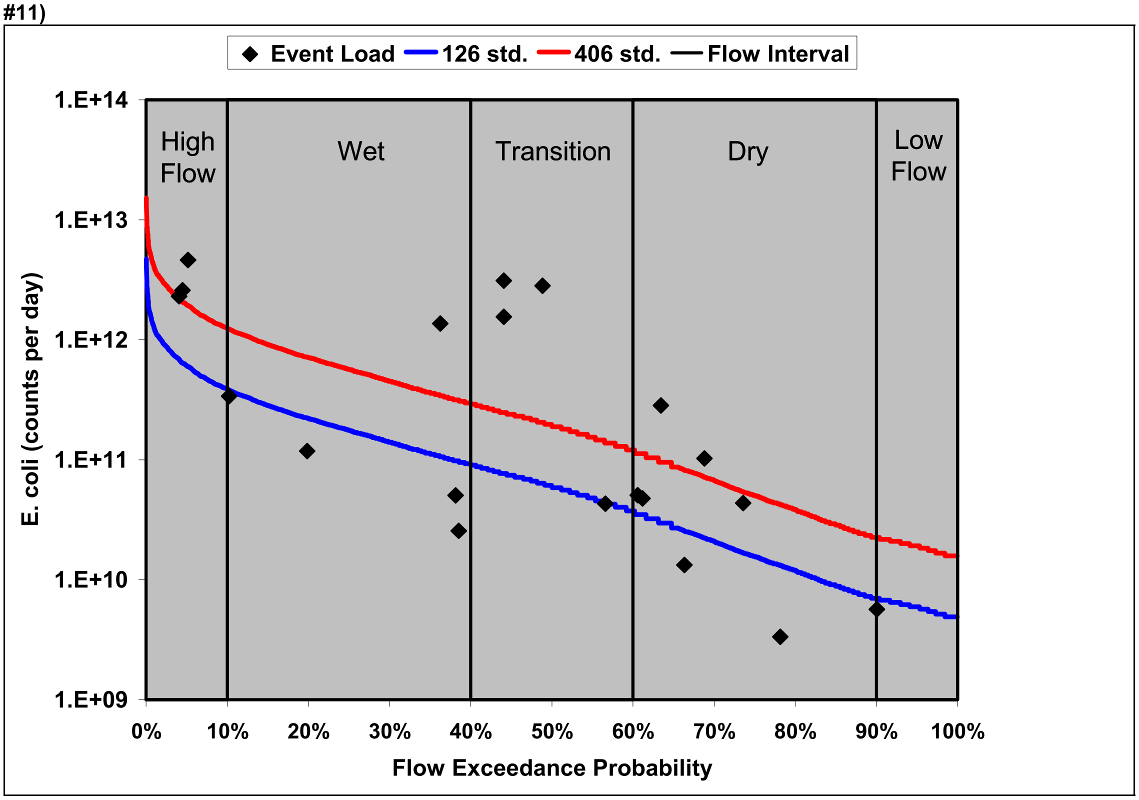


Figure 5.82. Load Duration Curve showing the loading capacity and event loads for Johnson Creek at Palmblad Road (Site #16)

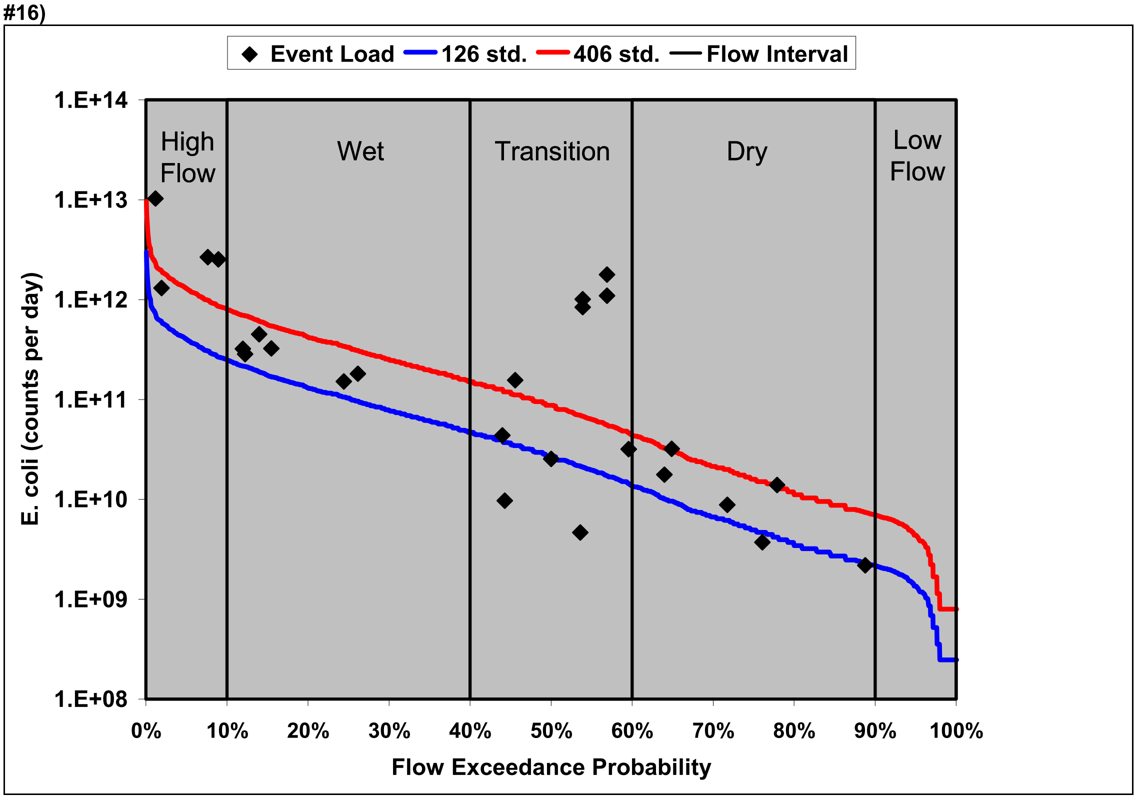
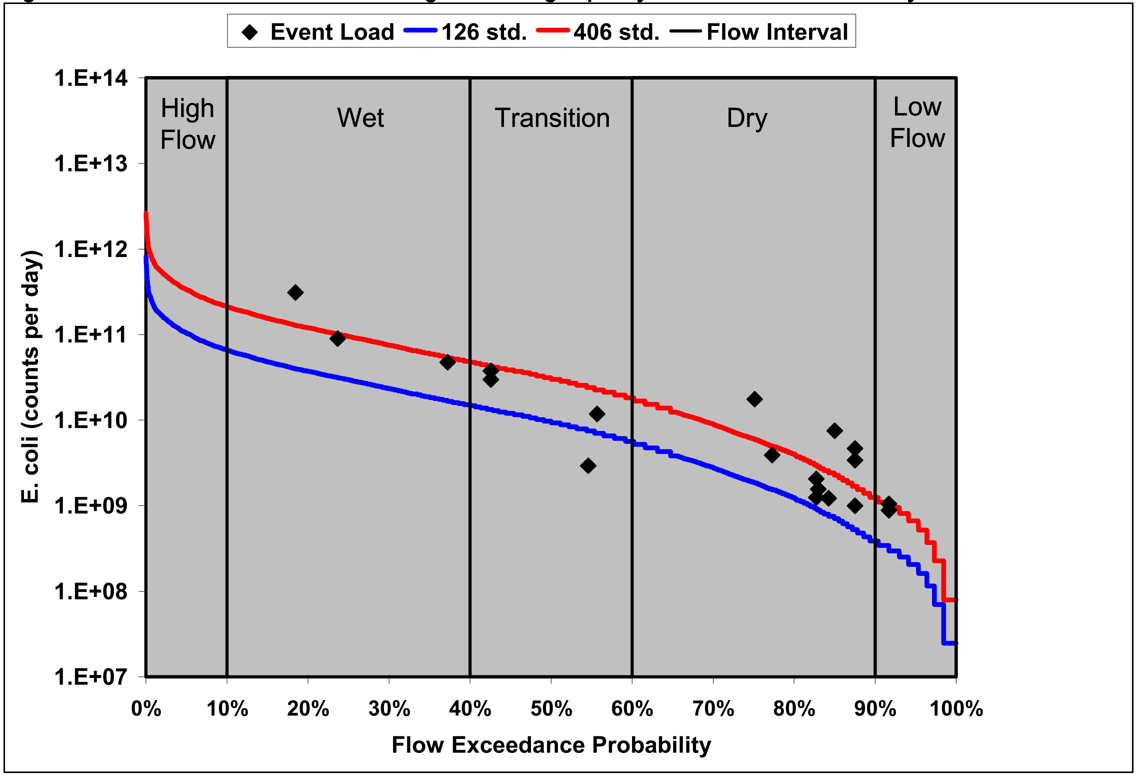


Figure 5.83. Load Duration Curve showing the loading capacity and event loads for Kelley Creek near the Mouth (Site #10)



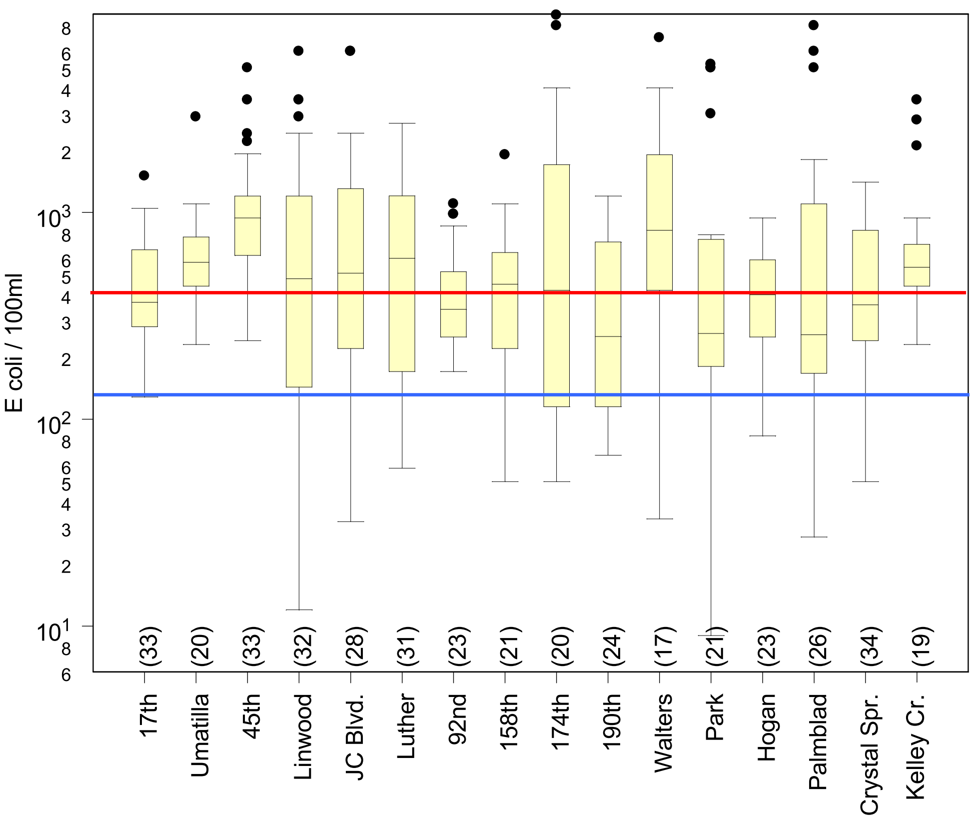
Deviation from Water Quality Standards

The discussion of bacterial concentrations that follows presents distributions of sample data and uses median values as approximations of geometric means. This would not be appropriate for determinations of violations of water quality criteria based on geometric means, but is reasonable as a method of discussing distributions of sample concentrations. The distributions are presented in box and whisker plots (aka boxplots), as described above.

Analysis of bacterial concentrations is based on data collected by ODEQ, Clackamas County Water Environment Services and by the Cities of Gresham and Portland. ODEQ routinely monitors water quality near the mouth of Johnson Creek as part of the statewide ambient water quality monitoring network. The Cities and Clackamas County Water Environment Services also regularly monitor water quality at various locations in the watershed within their jurisdictions. Data from all sites were analyzed and are presented in box plot format (**Figure 5.84**). Overall, violations of water quality standards were common at all locations.

The boxplots shown in **Figures 5.84** and **5.85** clearly illustrate routine violations of bacteria water quality standards, with median concentrations well above the 126 cfu / 100 ml criterion (blue line) and numerous exceedances of the 406 cfu / 100 ml criterion (red line). Note that these boxplots were generated using a variable number of sample results at each location (number in parentheses at bottom of boxplot) and that sample results are displayed on a logarithmic scale. The data presented do not show a clear geographic pattern.

Figure 5.84. **Boxplots Illustrating Johnson Creek Bacteria Concentrations at Various Monitoring Locations (1996-2002)**



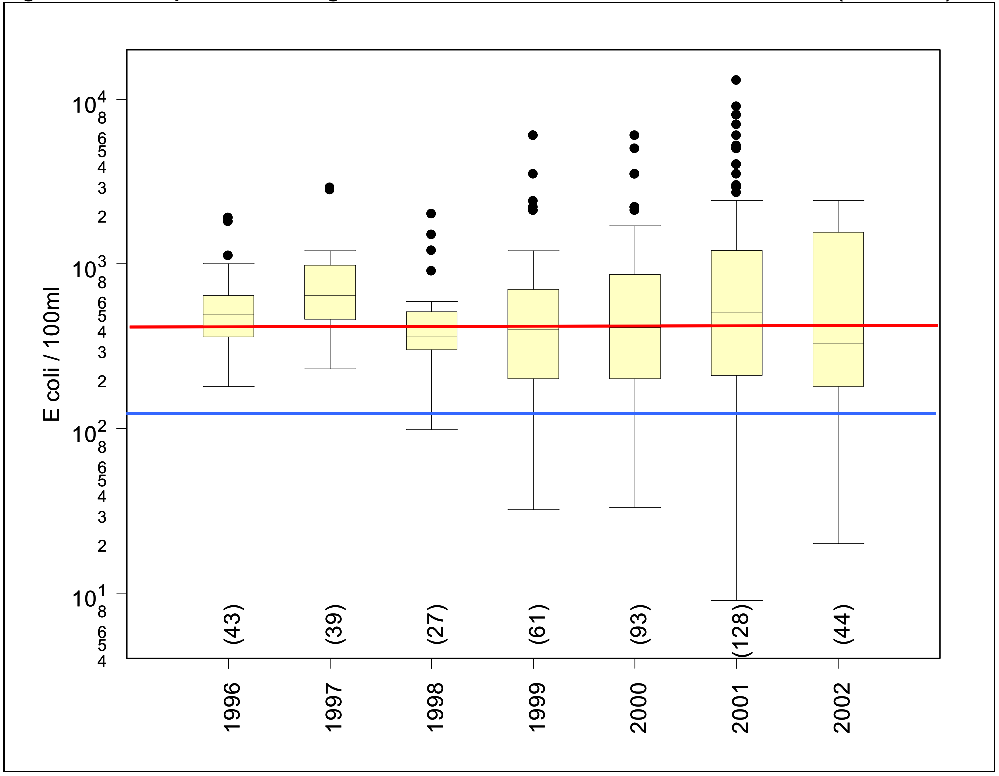
The information provided in **Table 5.31**, particularly the high "maximum" values and a geometric mean well above the 126 cfu/100 ml criteria, shows that all Johnson Creek monitoring locations exhibit elevated bacteria concentrations.

As indicated in the *Subbasin Overview* section of this chapter, overall water quality conditions in Johnson Creek do not show a significant trend toward improvement or further degradation. **Figure 4.10** shows monitoring data collected at all bacteria monitoring locations between 1996 and 2002. The boxplots confirm that there is no apparent trend over time and that bacteria concentrations in Johnson Creek consistently violate state water quality standards.

Table 5.31. Characterization of Johnson Creek *E. coli* Results (1996 – 2002)

Site Description	Geometric Mean (cfu/100 ml)	Median (cfu/100 ml)	Min/Max (cfu/100 ml)	Number of Samples
Johnson Cr. at 17th Avenue	405	368	128 / 1500	33
Johnson Cr. at SE Umatilla	595	573	230 / 2900	20
Crystal Springs Cr. at 21st Ave.	597	534	230 / 3500	34
Johnson Cr. at 45th Ave.	970	940	240 / 5000	33
Johnson Cr. at Linwood Ave.	415	477	12 / 6000	42
Johnson Cr. at Johnson Cr. Blvd.	509	508	32 / 6000	38
Johnson Cr. at Luther Rd.	472	600	58 / 2700	41
Johnson Cr. at SE 92nd Ave.	390	340	170 /1100	23
Johnson Cr. at SE 158th Ave.	377	450	50 / 1900	21
Kelley Creek at 159th Ave.	366	355	50 / 1400	19
Johnson Cr. at SE 174th Ave.	478	420	50 / 9000	20
Johnson Cr. at SE 190th Ave.	287	251	67 / 1200	24
Johnson Cr. at Walters Rd.	780	820	33 / 7000	17
Johnson Cr. at Park Ave.	351	260	9 / 5200	21
Johnson Cr. at Hogan Rd.	375	400	83 / 940	23
Johnson Cr. at Palmblad Rd.	397	256	27 / 13000	26

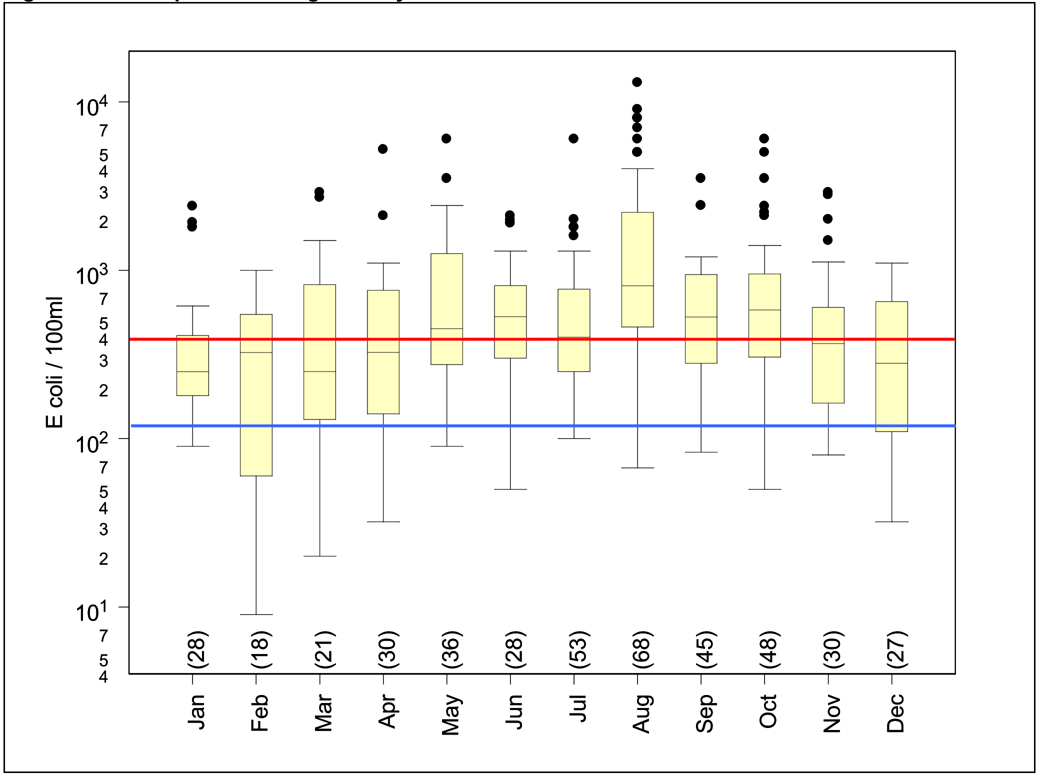
Figure 5.85. **Boxplots Illustrating Annual Johnson Creek Bacteria Concentrations (1996-2002)**



Seasonal Variation

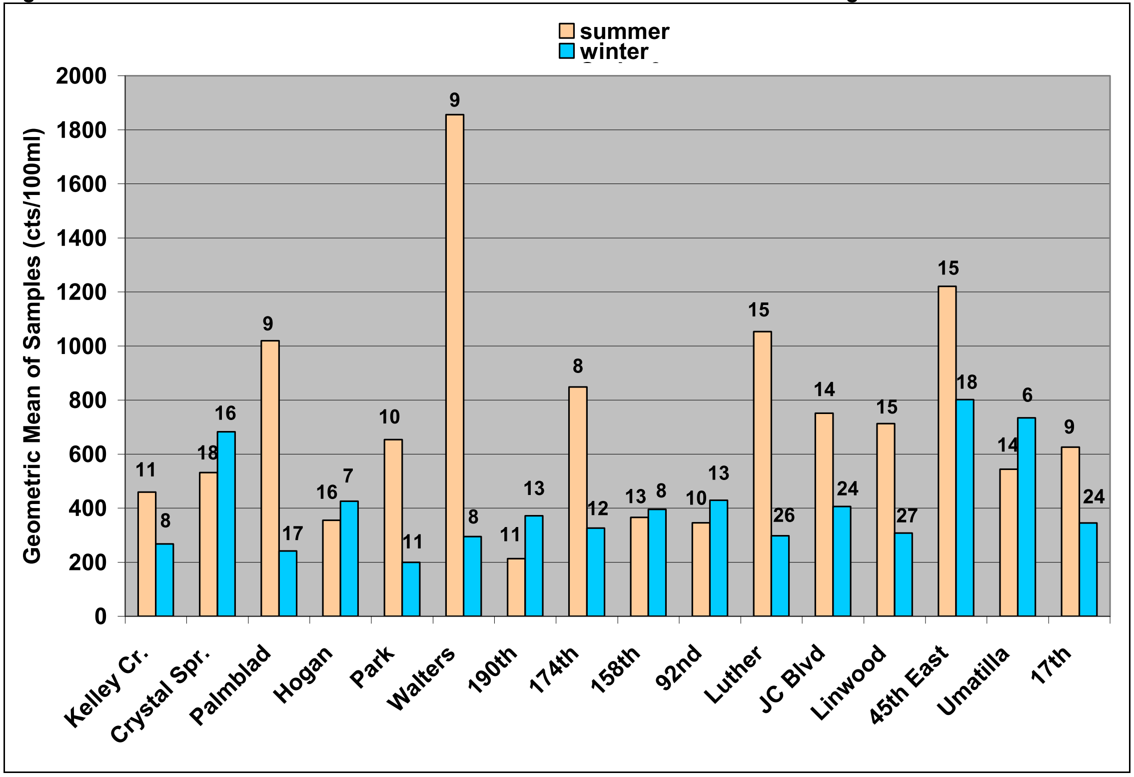
Seasonal variation has been considered in both the analysis of current conditions and in developing loading allocations. ODEQ has the ability to include waterbodies on the 303d list for portions of the year or year round. For 303d listing purposes ODEQ considers bacteria data from two time periods, “Summer” (June 1 to September 30) and “Fall-Winter-Spring” (October 1 to May 31). A stream may be listed for either “season” or year round if data indicates that water quality standards are violated during both time periods. Johnson Creek is considered impaired year around and **Figure 5.86** shows that bacteria water quality standards violations occur year around. This is due to the presence of multiple anthropogenic sources of bacteria in the watershed. Seasonally, bacteria concentrations appear to be higher during the summer months, especially in August. However, the data used to generate these boxplots included sampling that captured an unusual 1-inch storm event that occurred in August, 2001. These results are shown as outliers (black dots) on the August boxplot in **Figure 5.86** and likely skew the August results.

Figure 5.86. Boxplots Showing Monthly Bacteria Concentrations in Johnson Creek



Site specific seasonal geometric mean bacteria concentrations are presented in **Figure 5.87**.

Figure 5.87. Seasonal Variation in Mean of Bacteria Concentrations at all Monitoring Locations



Numbers above each column represent the number of samples used to calculate the geometric mean. The “summer” time period reflects data collected between June 1 and September 30 and the “winter” time period includes data collected October 1 and May 30. Some sites, such as Palmblad and Walters, show clear differences between summer and winter bacteria concentrations, but it is difficult to identify a clear geographic pattern among the sites based upon seasonality.

Another relationship emerges when Johnson Creek bacteria monitoring results are displayed relative to the presence of rainfall. Bacteria sampling events at all locations were paired with rainfall data collected at several HYDRA network rainfall monitoring stations operated by the City of Portland at several locations in the Johnson Creek Watershed along with rainfall information collected at the Portland International Airport (PDX) by the National Weather Service and made available to ODEQ via the Oregon Climatological Service. ODEQ assumed that runoff would occur when the average rainfall on the day of the sampling event and the day before the sampling event was greater than 0.2 inches. Sampling events on days, regardless of season, when appreciable rainfall was recorded resulted in higher bacteria concentrations (**Figures 5.88** and **5.89**).

Summary statistics showing differences between seasons and runoff conditions are provided in **Table 5.32**.

Overall, the analysis of seasonal variation indicates that runoff-related loading is a significant source of bacteria found in Johnson Creek and that the problem is especially evident in the summer months when stream flows are low.

Figure 5.88. Boxplots of Runoff and Non-Runoff Bacteria Concentrations in Johnson Creek.

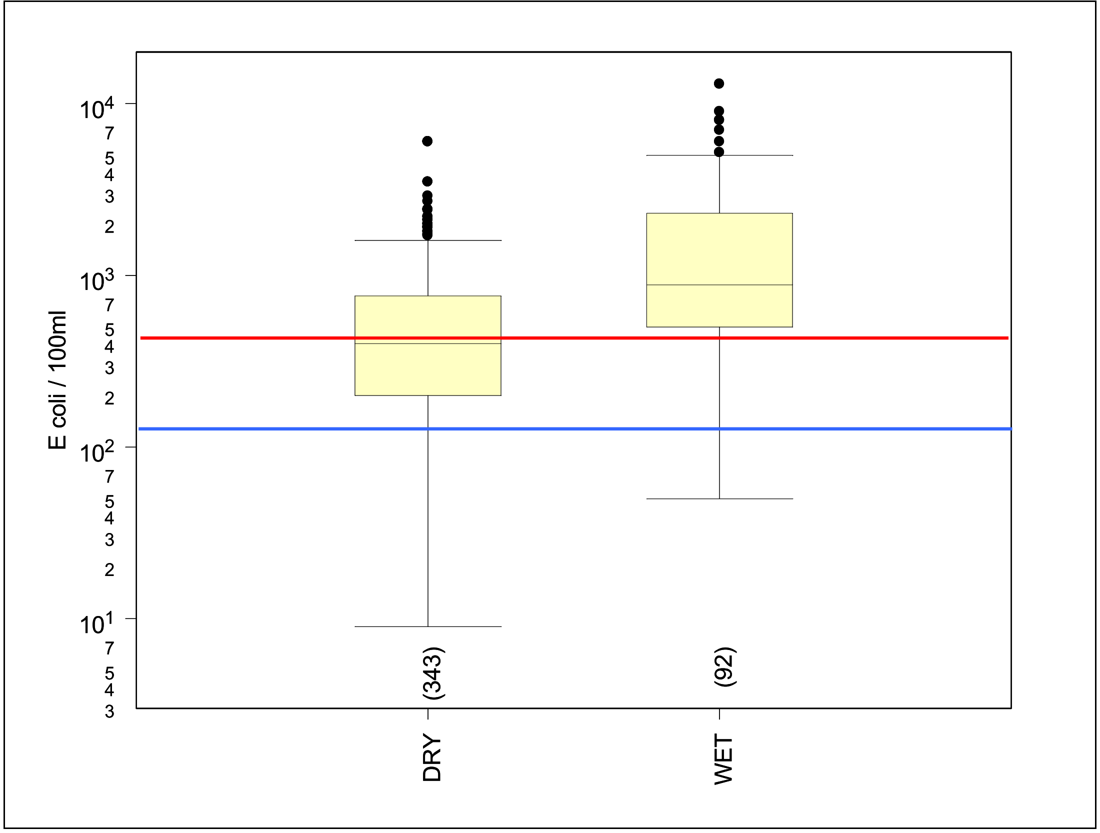


Figure 5.89. Variation in Geometric Mean of Bacteria Concentrations at all Monitoring Locations Relative to Wet and Dry Conditions

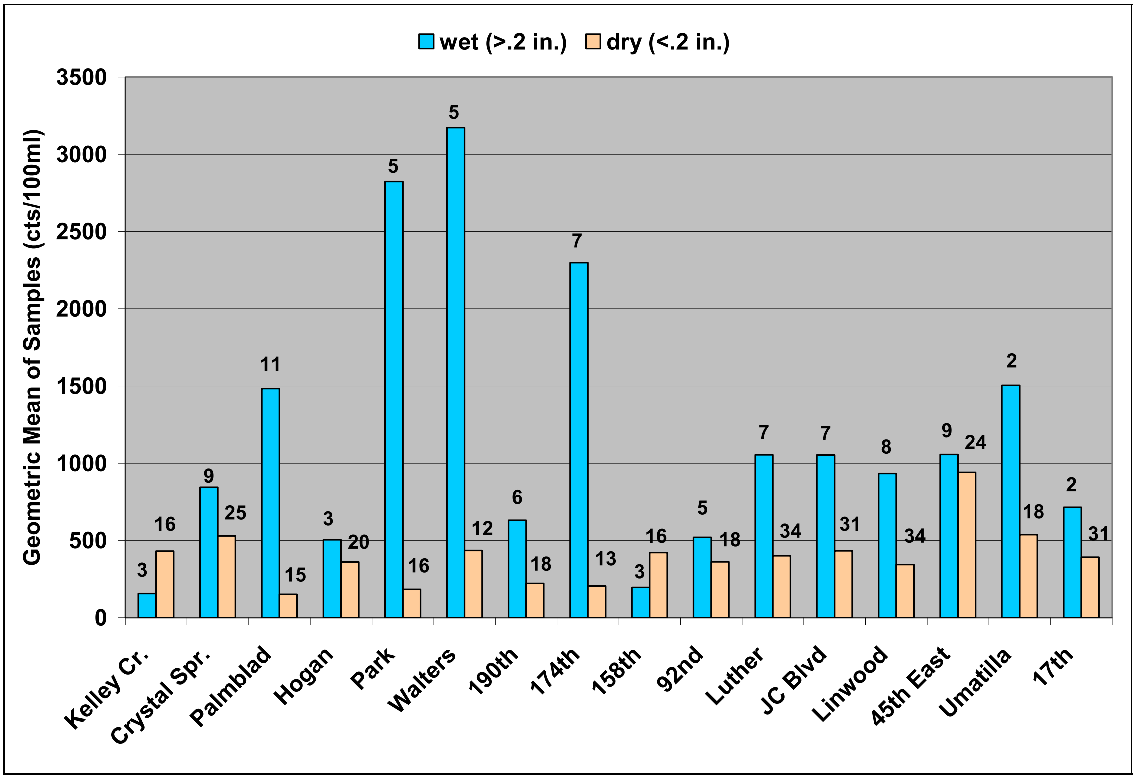


Table 5.32. Summary of Johnson Creek E. coli Concentrations (cfu/100ml)

All Johnson Creek Bacteria Monitoring Locations				
	Fall Winter Spring	Summer	Rainfall	Dry
Geometric Mean	371	617	1019	380
Median	368	600	880	400
Minimum	9	50	50	9
Maximum	6000	13000	13000	6000

Existing Bacteria Sources

High concentrations (and loads) of bacteria in urban watersheds come from many possible human and non-human sources. This TMDL identifies the reductions necessary to meet water quality standards in Johnson Creek and will provide load and wasteload allocations to appropriate sources. The watershed contains one permitted sewage treatment plant, which as the potential to discharge significant bacteria loads. Municipal stormwater, regulated through the NPDES permit program, is a significant point source in the watershed.

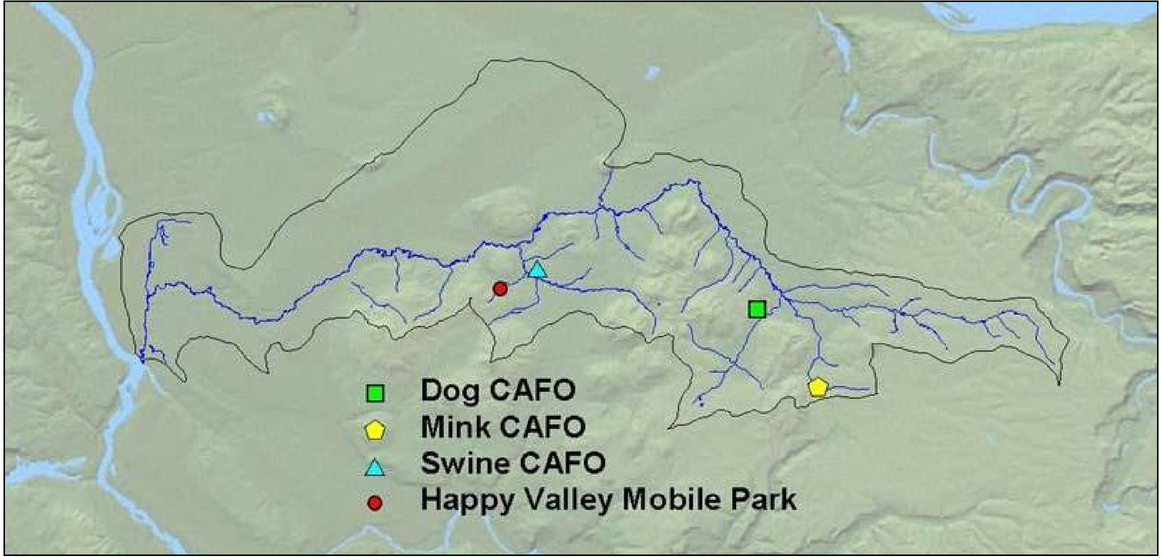
The bacteria data collected in Johnson Creek and presented in various formats show routine standards violations under both high flow and low flow conditions and during dry and wet periods. This indicates that there are multiple sources of bacteria that enter Johnson Creek via a variety of pathways. For example, if violations were only occurring during summertime low flow conditions likely sources may include failing septic systems, livestock (or pets) in or near the stream and/or cross connections between sanitary and storm sewer systems. Those sources could largely be excluded if violations were only occurring during wintertime high flow conditions. Conversely, a large number of violations during higher flows and during rainfall events would suggest sources such as urban stormwater, large sanitary sewer overflows and manure management problems. Those sources could largely be excluded if violations were only occurring during dry summertime conditions. Since violations are clearly occurring under all flow conditions, year round, and in the presence and lack of rainfall, many or all of the sources listed above are likely contributing to the bacteria problem in Johnson Creek.

Point Sources

The Happy Valley Mobile Home Park, located at 8750 SE 155th Avenue, ceased the discharge of treated sanitary sewage to Mitchell Creek, a tributary to Johnson Creek, in March 2005. The mobile home park is now connected to the Kellogg Creek sewage treatment facility operated by Clackamas Water Environment Services. The Kellogg Creek facility discharges to the Willamette River.

There are three confined animal feeding operations (CAFOs) in the Johnson Creek Watershed **(Figure 5.90**). CAFOs, as the name suggests, are facilities that confine and feed a large number of animals for a specified period of time. These facilities operate under a general National Pollutant Discharge Elimination System (NPDES) permit issued by ODEQ and administered by the Oregon Department of Agriculture (ODA). CAFO facilities are considered point sources, and under the terms of these permits, no discharge is allowed from areas of animal confinement, or manure management and storage.

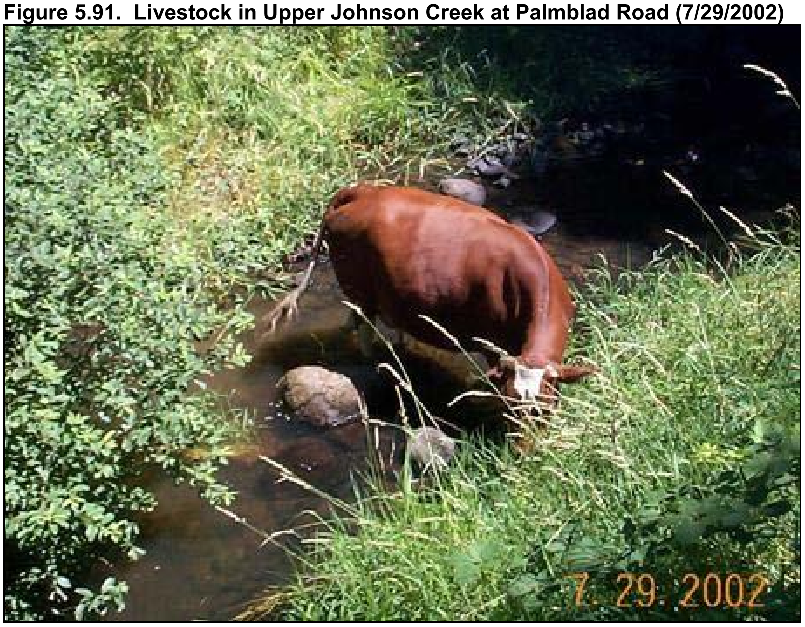
Figure 5.90. Location of Happy Valley Mobile Park and Facilities with a Confined Animal Feeding Operation Permit



Nonpoint Sources

ODEQ personnel documented several areas where livestock are allowed direct access to Johnson Creek during the summer low flow period (**Figure 5.91)**. The City of Portland recently proposed to remove a large man-made instream pond located in Crystal Springs Creek - in part to address the high bacteria levels that result from the high density of migratory and resident water fowl that are attracted to these features.

Figure 5.91. Livestock in Upper Johnson Creek at Palmblad Road (7/29/2002)



Loading Capacity

A flow based loading capacity was determined through the development of a load duration curves at several monitoring locations in the Johnson Creek watershed. The curve (red line in **Figures 5.92** through **5.96**) determines the maximum bacteria load that will achieve the 126 E. coli organisms per 100 ml water quality criteria under all flow conditions, thereby protecting beneficial uses.

ODEQ used a regression of the geometric mean of the event bacteria loads at representative monitoring locations to characterize the overall population relative to the bacteria standard (blue line), calculated the upper 90th confidence interval of that population as a measure of safety (dashed blue line), and calculated the average percent reduction necessary to achieve the 126 E. coli organisms per 100 ml water quality criterion.

Figure 5.92. Load Duration Curve showing the loading capacity, event loads and percent reduction necessary to achieve the loading capacity for Johnson Creek at 17th Avenue (Site #1)

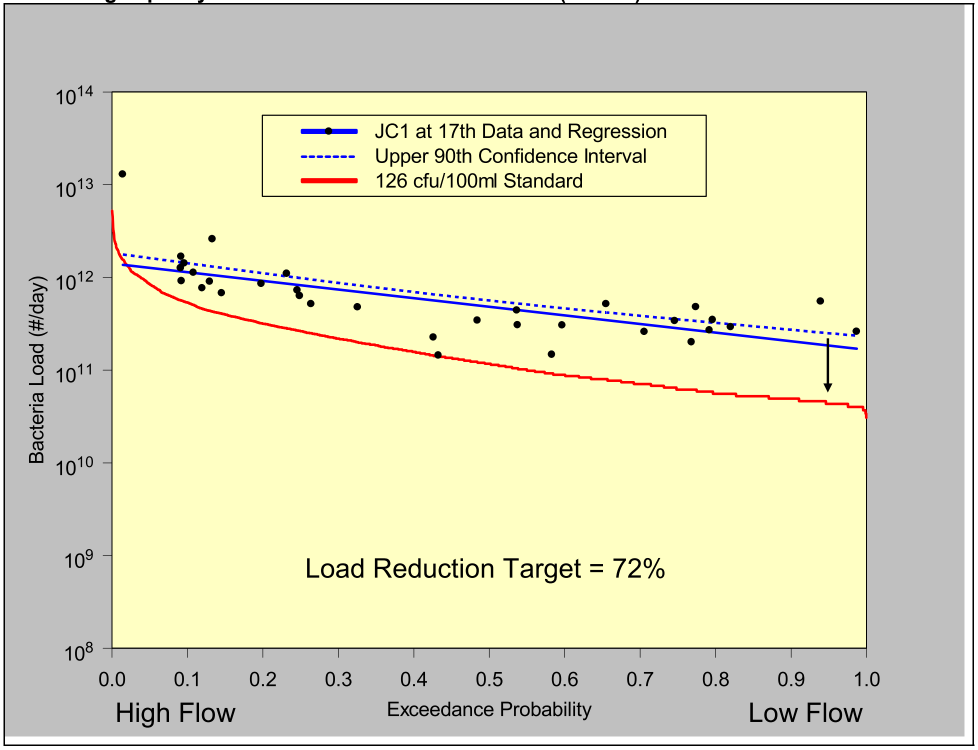


Figure 5.93. Load Duration Curve showing the loading capacity, event loads and percent reduction necessary to achieve the loading capacity for Johnson Creek at Luther Rd. (Site #7)

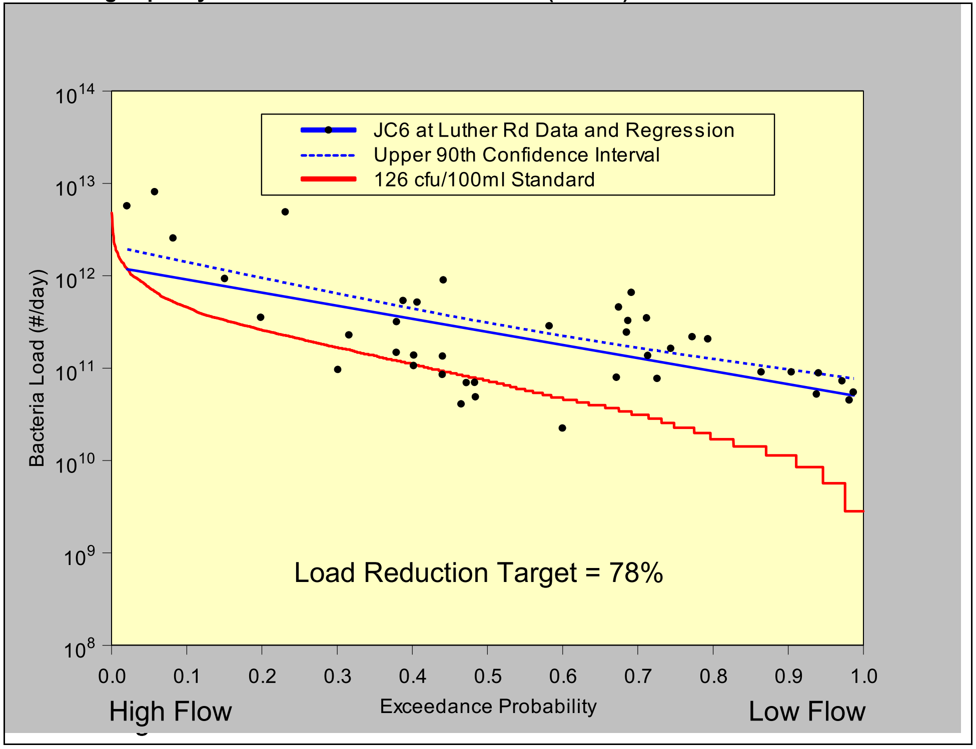


Figure 5.94. Load Duration Curve showing the loading capacity, event loads and percent reduction necessary to achieve the loading capacity for Johnson Creek at 174th Ave (Site #11)

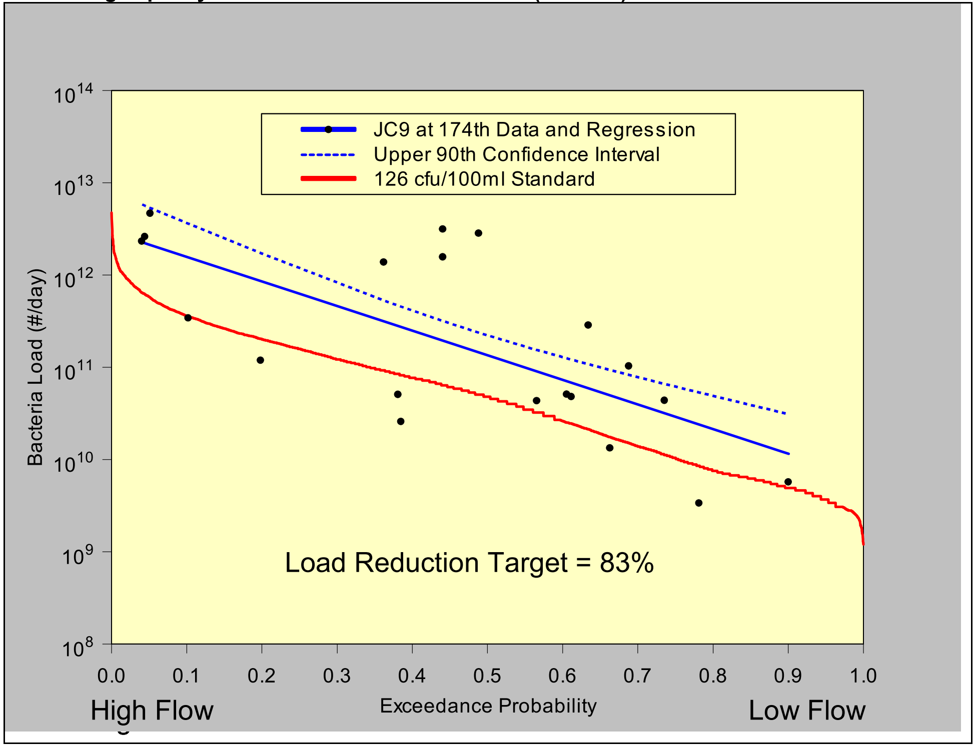


Figure 5.95. Load Duration Curve showing the loading capacity, event loads and percent reduction necessary to achieve the loading capacity for Johnson Creek at Palmblad Rd. (Site #16)

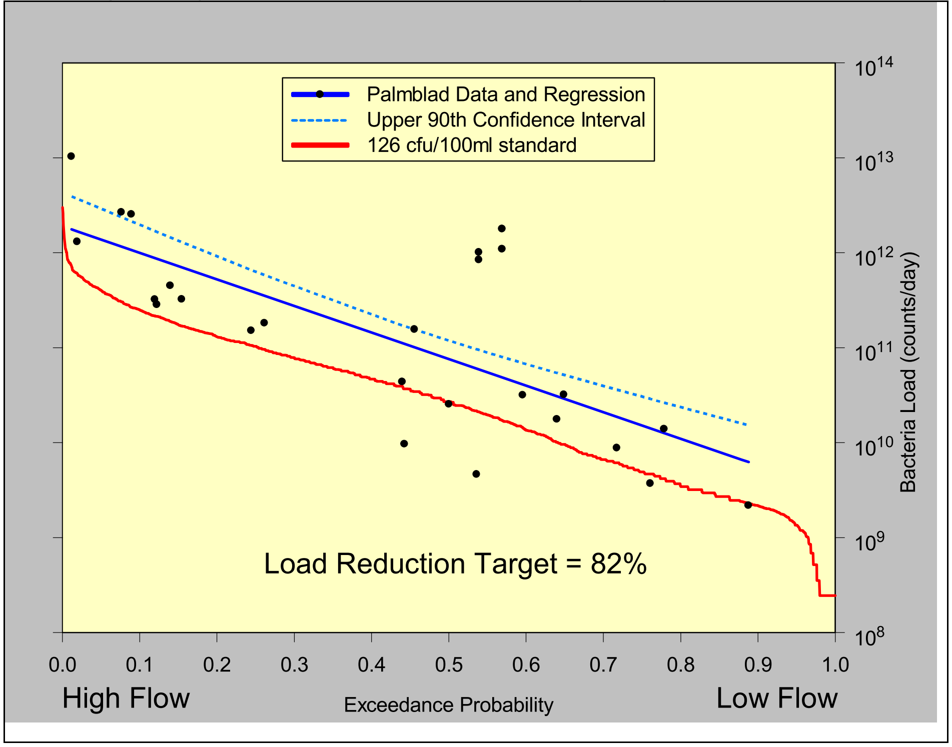


Figure 5.96. Load Duration Curve showing the loading capacity, event loads and percent reduction necessary to achieve the loading capacity for Kelley Creek at Mouth (Site #10)

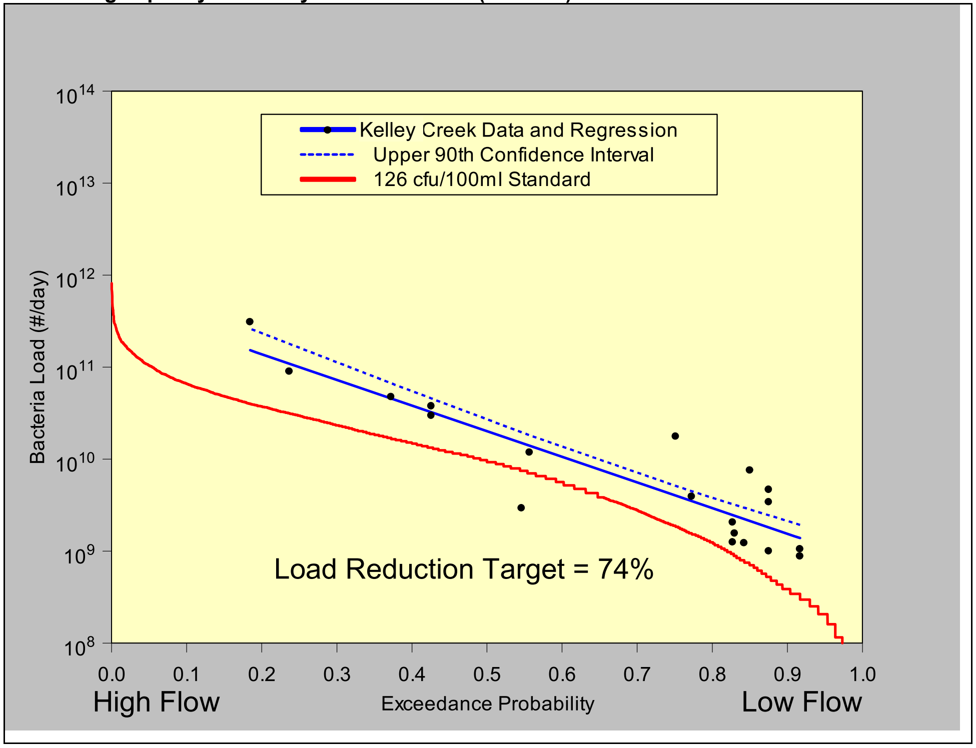


Table 5.33 shows the loading capacity to achieve the 126 cfu/100 ml criteria under several flow scenarios at five monitoring locations in the watershed. Loading capacities were developed for a number of the flow intervals delineated within the load duration curves presented in **Figures 5.79** through **5.83**, above. The flow-based loading capacities shown in **Table 5.33** represent the acceptable bacteria counts per day at a given stream flow (blue line in **Figures 5.79 through 5.83** and red line in **Figures 5.92 through 5.96**).

Table 5.33. Flow Based Loading Capacity to meet 126 cfu/100 ml *E. coli* criteria

Flow (cfs)	Flow Exceedance Probability	Loading Capacity to meet geometric mean of 126 cfu/100 ml (counts per day)
Johnson Creek at 17th Avenue (Site #1)		
16	90%	4.93E+10
29	60%	8.93E+10
51	40%	1.57E+11
175	10%	5.37E+11
Johnson Creek at Luther Rd. (Site #7)		
4	90%	1.13E+10
16	60%	4.82E+10
36	40%	1.11E+11
150	10%	4.59E+11
Johnson Creek at 174th (Site #11)		
1.6	90%	4.90E+09
8.5	60%	2.62E+10
25	40%	7.69E+10
115	10%	3.60E+11
Johnson Creek at Palmblad Rd. (Site #16)		
0.9	90%	2.17E+09
5.5	60%	1.36E+10
19	40%	4.68E+10
100	10%	2.51E+11
Kelley Creek near the Mouth (Site #10)		
0.1	90%	3.88E+08
1.8	60%	5.65E+09
5	40%	1.47E+10
20	10%	6.60E+10

Allocations

Allocations are derived from analyses that determine that amount of bacteria (E. coli) that may enter surface waters without causing a violation of water quality criteria. Allocations are divided among point sources (wasteload allocations) and nonpoint sources (load allocations). Point sources include three Confined Animal Feeding Operations (CAFOs) and urban storm water. Load allocations may be applied to all nonpoint sources and/or land use categories.

CAFO wasteload allocations have been reduced to zero (0) to reflect the permit requirement that no discharge is allowed from the confinement and manure management areas. This is distinguished from pasture lands that may be used by animals for grazing, which are given a load allocation along with other rural bacteria sources. Since the numeric bacteria criteria are concentration based, new and reissued NPDES permit sources discharging at or below both criteria would not be increasing the bacteria load to the waterbody. Therefore, a specific portion of the waste load allocation need not be set aside for new sources to be consistent with this TMDL.

Analysis of the load duration curves developed for the watershed reveals no clearly dominant source of bacteria. That is, similar reductions are necessary under low flow and high flow conditions and the percent reduction necessary from all sources and/or land use categories appears to be similar. While it may be possible to tailor load and wasteload allocations in some watersheds based upon dominant sources identified using the load duration curve approach, the analysis of the load duration curves developed for this TMDL indicates that bacteria loading from urban and rural, low-flow and high-flow sources is similar. Bacteria concentrations in the upper watershed, which includes rural land uses, are similar to those seen in the lower watershed where urban land uses dominate. Therefore, ODEQ chose to calculate the percent reduction necessary to achieve the 126 cfu/ 100 ml criterion and applied this reduction to both stormwater (wasteload) and nonpoint source (load) allocations.

The percent reduction, determined conservatively by using the 90th confidence interval of the mean of the measured samples and averaged over the 5 monitoring sites used in this analysis, is **78%** (**Table 5.34**). Therefore, except for CAFOs, both wasteload and load allocations will be expressed as a **78%** reduction from current levels. ODEQ believes that this approach sets a tangible and common goal for both point and nonpoint source management practices and programs. The analysis completed for this TMDL does not indicate that any particular land use category or source warrants a unique percent reduction. Unless and until additional source assessment work clearly shows that a particular land use or source contributes more or less bacteria than another, a single percent reduction that applies to all land use categories will be applied.

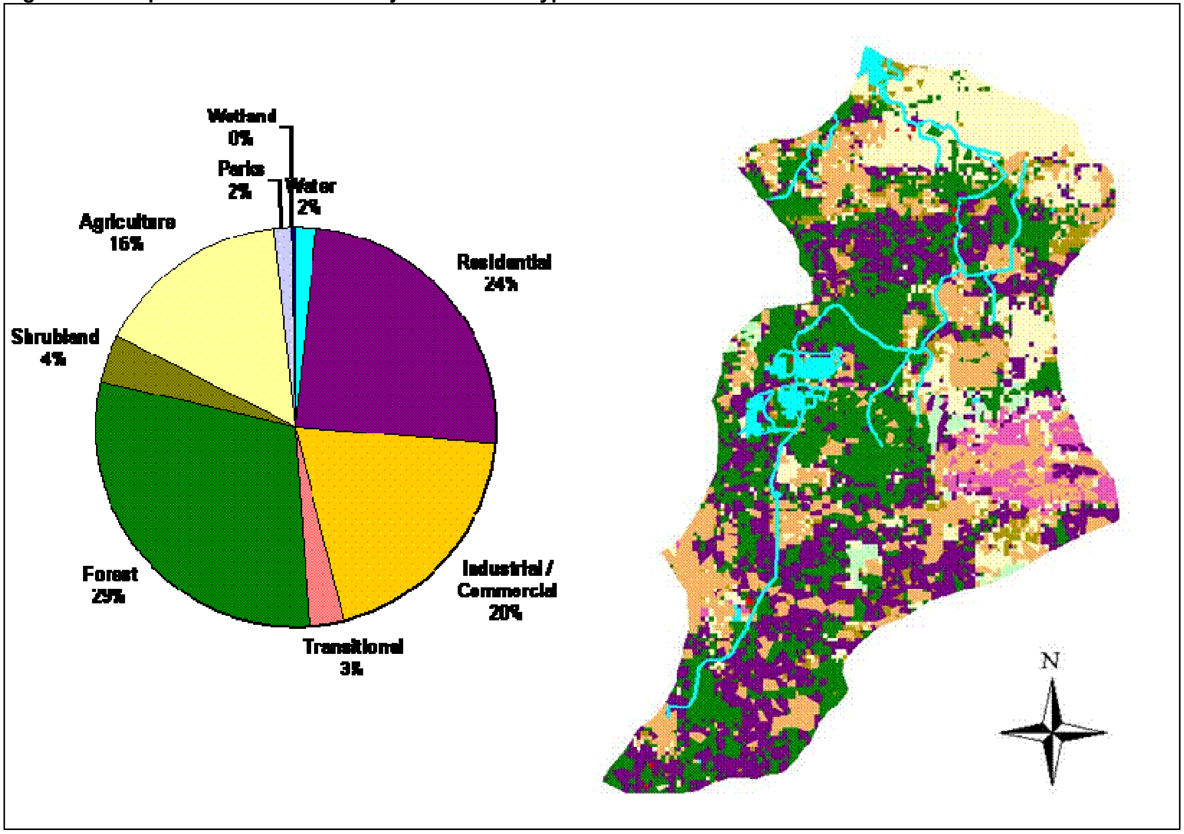
Table 5.34. Bacteria Load and Waste Load Allocations

Subtable A: NPDES Point Source Waste Load Allocations	
Source Name	**<u>Waste Load Allocation</u>**
Confined Animal Feeding Operations	**0 E. coli organisms per 100ml**
Municipal Storm Sewer System	**78% reduction**
Subtable B: Nonpoint Sources	
Source	**<u>Load Allocation</u>** **Percent Reduction**
All land use categories and sources	**78%**

Fairview Creek Watershed

Fairview Creek is a 5-mile (8 km) long urban creek, originating from spring-fed wetlands on the northeast side of Grant Butte in Gresham, Oregon. The creek drains approximately 11 square miles (28 square kilometers), flowing through the towns of Gresham and Fairview, Oregon. The creek receives flow from two tributaries, springs and storm water runoff before flowing into Fairview Lake and eventually the Willamette River via the Columbia Slough (Jacobsen 2002). The watershed is highly developed and experiences a host of water quality problems commonly associated with urbanization. The watershed contains a mix of industrial, residential, agricultural and forest land uses (**Figure 5.97**). Fairview Creek is currently included on the State of Oregon 303(d) list of water quality limited waterbodies for *E. coli* bacteria. The listing applies year-round and from the mouth of Fairview creek to river mile 1.7. Bacteria enter Fairview Creek from three main categories of potential sources: through storm generated overland flow (e.g., urban, residential, and rural stormwater), through constant direct input (e.g., septic systems), and through periodic discharges (upsets) of the urban sanitary sewer system. The only point sources in the watershed that are likely to contribute to bacteria standards violations are municipal and private stormwater outfalls.

Figure 5.97. Spatial Distribution of Major Land Use Types in the Fairview Creek Watershed

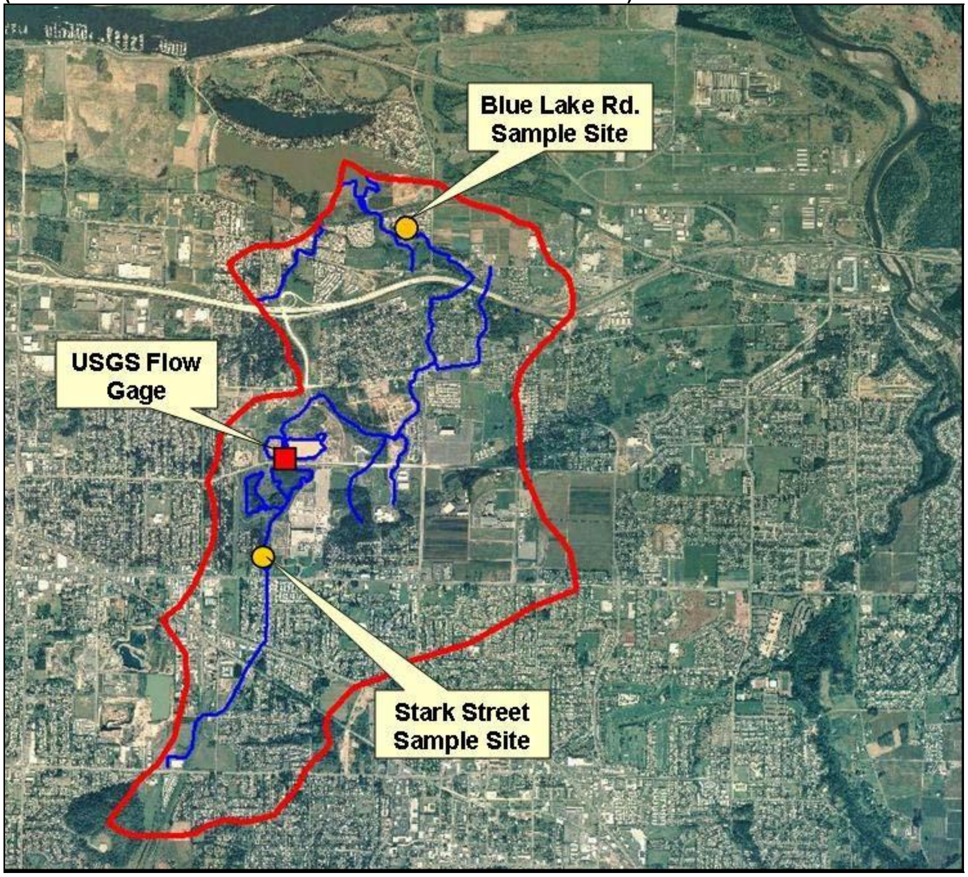


Analytical Approach – Load Duration Curve

ODEQ chose to use the load duration curve approach to develop the bacteria TMDL for the Fairview Creek Watershed. Load duration curves are a method of determining a flow based loading capacity, assessing current conditions, and calculating the necessary reductions to comply with water quality standards. The methodology is primarily based on TMDLs completed by Kansas Department of Health and Environment and through technical assistance provided by Bruce Cleland of America's Clean Water Foundation (www.acwf.org). Load duration curves were chosen because they offer a relatively simple and accurate methodology for determining the degree of water quality impairment and because they are capable of illustrating relative impacts under various flow conditions and can be used in targeting appropriate water quality restoration efforts (Cleland 2002, 2003).

The TMDL for the Fairview Creek Watershed was developed using water quality monitoring data collected by the City of Gresham and flow data the USGS. The City conducted water quality monitoring at a location near Blue Lake Park Road and the USGS has measured stream flow at gage #14211814 since 1992 (**Figure 5.98**). *E. coli* samples considered for this analysis were collected during a variety of weather and flow conditions between 1999 and 2003. Data reported as "estimate", "less than" or "greater than" values were not considered.

Figure 5.98. Location of USGS Flow gage #14211814 and City of Gresham monitoring sites (OWEB9 – West of Blue Lake Road and OWEB3 – Stark Street)



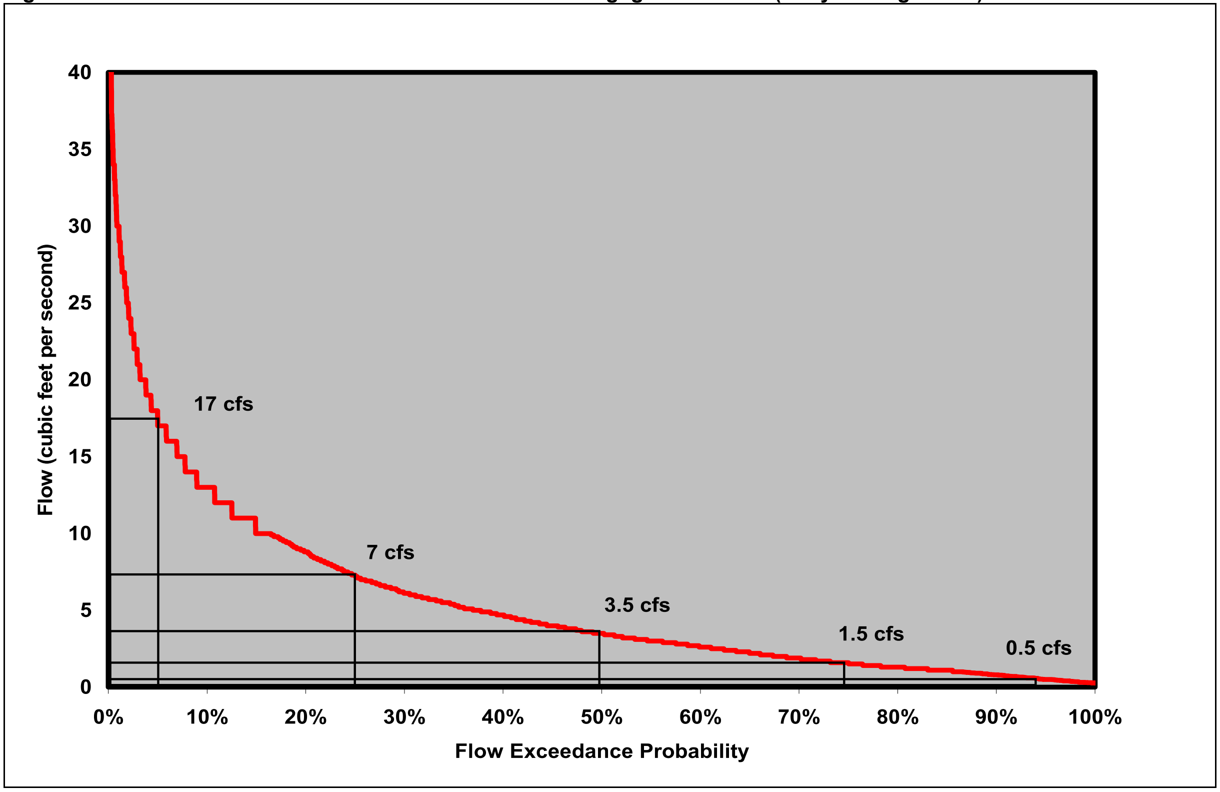
The process used to develop load duration curves for this TMDL is as follows:

A flow duration curve for the appropriate USGS gage site in the watershed is developed using available stream flow data. The flow duration curve is a plot of the frequency of which a flow is exceeded. The flows are ranked from maximum to minimum for the period of record at a particular site, in this case January 1992 through May, 2003. The exceedance probability (EP) for each flow was computed by:

$$EP = \frac{rank}{n+1}$$

where n is number of flow measurements. The “percent of days flow exceeded” is the exceedance probability multiplied by 100. The data are plotted as shown in **Figure 5.99** with the flow exceedance probability on the x-axis. A value of 5% on the x-axis indicates extremely high flows, while a value of 95% indicates drought conditions. For example, a flow of 7 cfs in Fairview Creek corresponds with a flow duration interval of 25%, indicating that 25% of all observed stream discharge values are at or above 7 cfs.

Figure 5.99. **Flow Duration Curve for Fairview Creek USGS gage #14211814 (Daily Average Flow)**

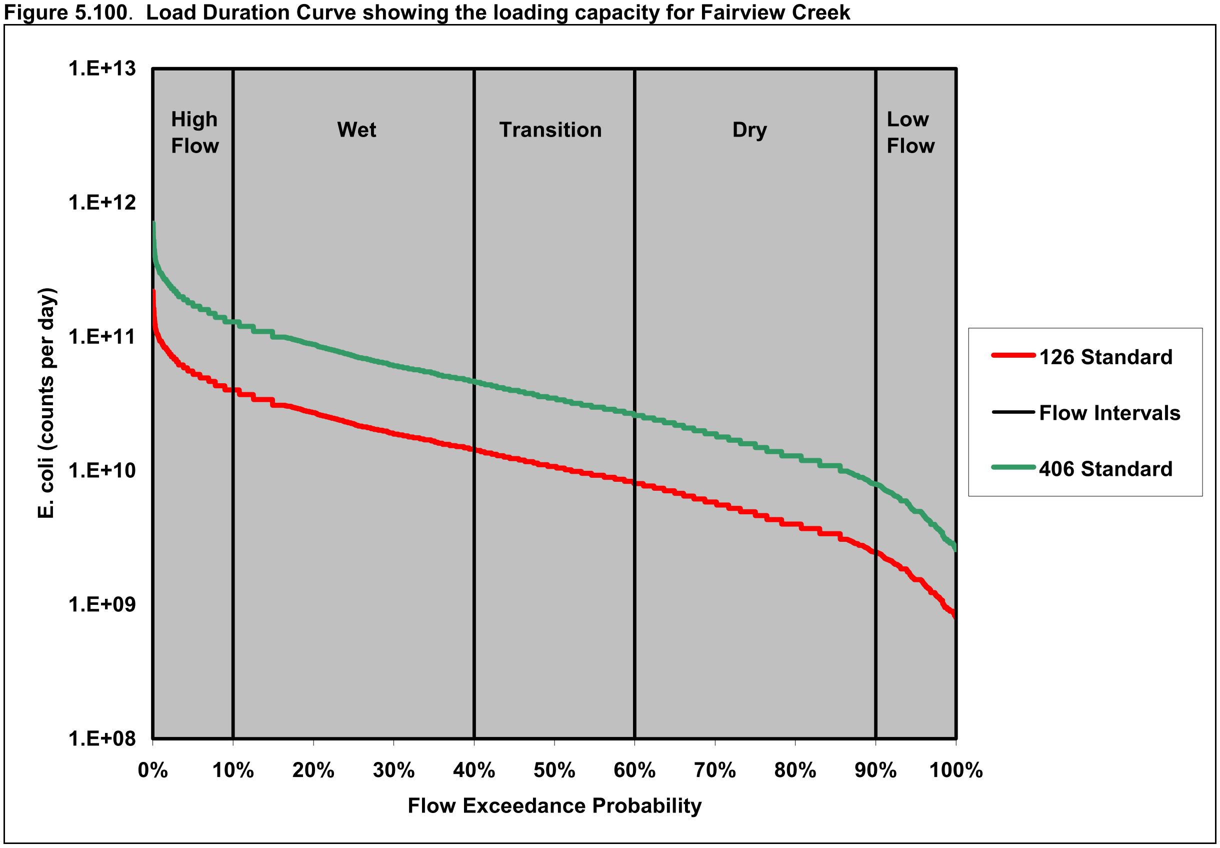


The flow curve is translated into a load duration curve. To accomplish this, the flow value is multiplied by the water quality standard and a conversion factor. The resulting loads are graphed and represent the flow-dependent loading capacity for specific numeric criteria. The curve (**Figure 5.100**) is determined by the target concentration, 126 cfu/100ml in this case, and the flow associated with the recurrence interval. For example, the log mean recreational contact standard for bacteria is 126 colonies per 100 milliliters so the loading capacity is:

$$Loading\ Capcity\,\frac{col}{day} = \overset{\text{Standard}}{\overset{\downarrow}{126\,\frac{col}{100\,ml}}} * \overset{\text{Flow}}{\overset{\downarrow}{Q\,\frac{ft^3}{s}}} * \overbrace{283.2\,\frac{100ml}{ft^3} * 86400\,\frac{s}{day}}^{\text{Conversion factors}}$$

The loading capacity is then plotted against the corresponding flow exceedance probability. There are two lines representing the two numeric targets: log mean of 126 cfu / 100 ml and no samples exceeding 406 cfu / 100 ml. The loading capacity increases with increased flow because of the increased assimilative capacity of the river.

Figure 5.100. **Load Duration Curve showing the loading capacity for Fairview Creek**



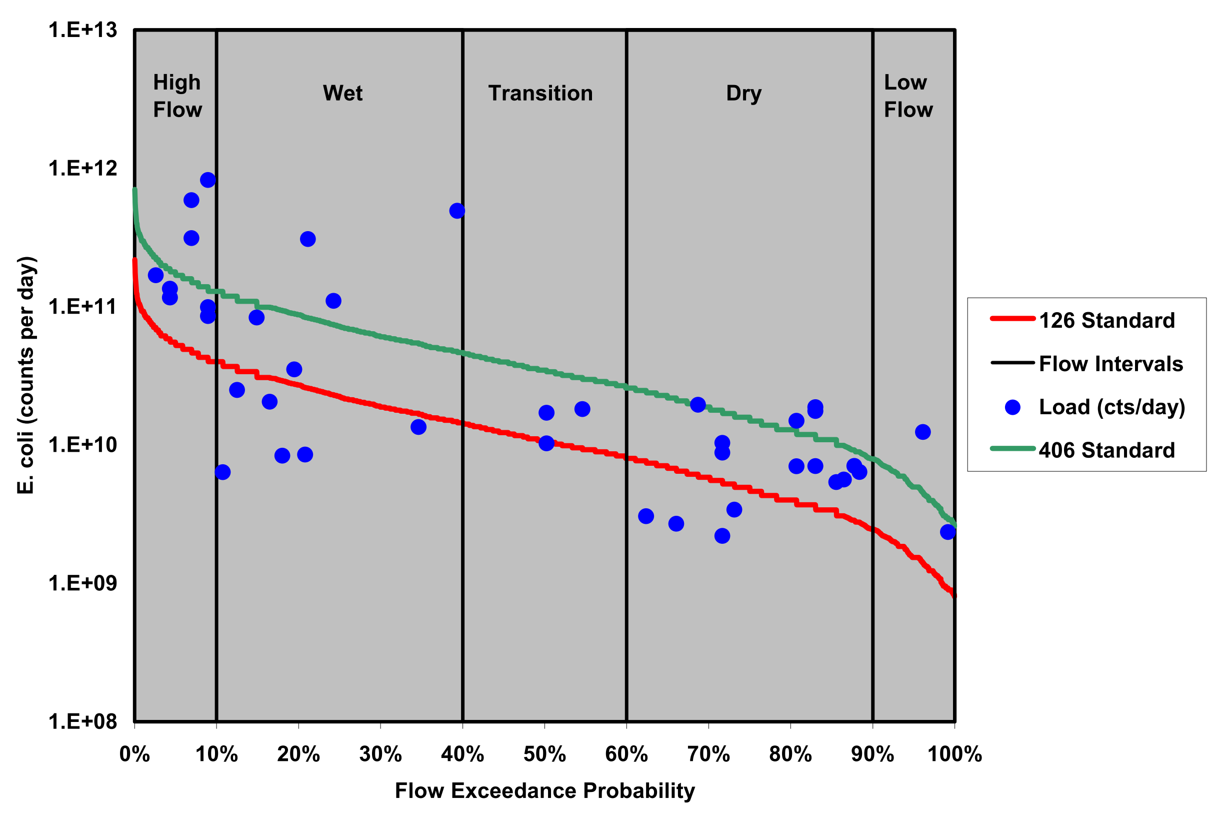
A water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was taken. Measured concentrations of *E. coli* are converted into loads using the equation above and flows from the stream gage. The “event loads” are plotted along with the standard lines to assess current conditions The y-axis becomes the water quality parameter value, load in this case, and the position of the sample on the x-axis illustrates the flow exceedance probability (**Figure 5.101**).

Points that plot above the curve represent deviations from the water quality standard and the permissible loading function. Those plotting below the curve represent compliance with water quality criteria and the appropriate designated use.

When event loads exceed the loading capacity during high flows it is likely that the loading is due to runoff related sources such as urban stormwater, sanitary sewer overflows or combined sewer overflows.

Bacteria loading is usually less during low flow periods, however, the loading capacity of the river has also decreased. Violations of the water quality standard at low flows are not likely runoff related. Warm-blooded animals in streams, failing septic tanks, waste water treatment plants and improper discharge of sewage are possible non-runoff related sources.

Figure 5.101. **Load Duration Curve showing the loading capacity for Fairview Creek and calculated event loads for 41 samples collected by the City of Gresham between 1999 and 2003**



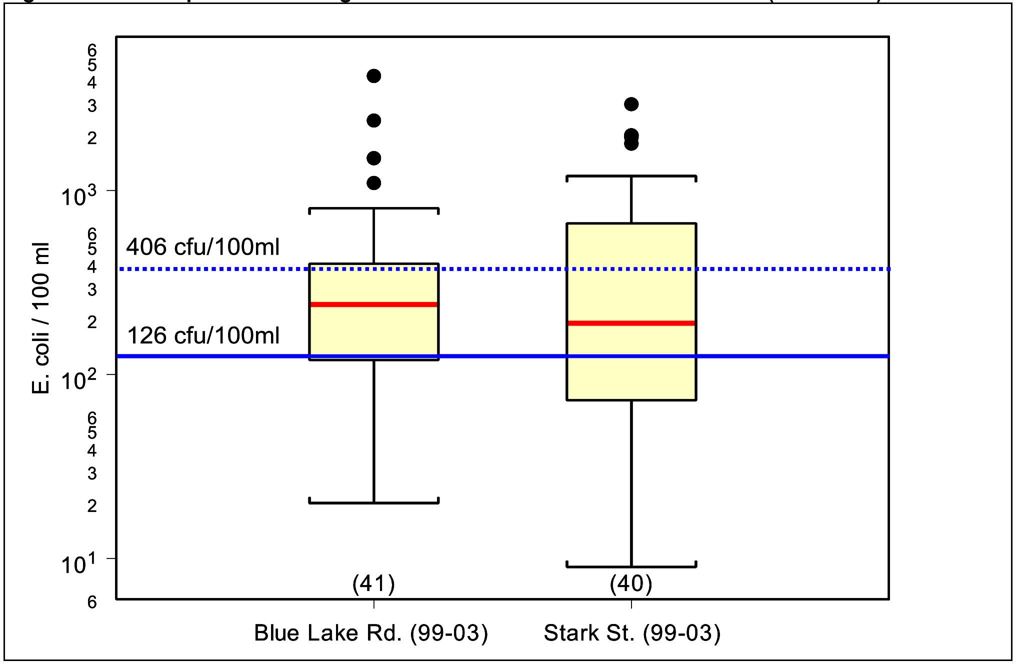
Deviation from Water Quality Standards

Analysis of bacterial concentrations is based on data provided to ODEQ by the City of Gresham. The City has collected periodic water quality measurements at various locations within the Fairview Creek Watershed since approximately 1996. Two Fairview Creek monitoring locations, one near Blue Lake Road and another at Stark Street, have the most data associated with them and will be used to illustrate the deviation from water quality standards. The Blue Lake Road sampling site is near the mouth of Fairview Creek and the Stark Street site is located nearer the headwaters (**Figure 5.98**). Data from both sites were analyzed over the entire period of record and are presented in box plot format (**Figure 5.102**). Overall, violations of water quality standards were common at both locations.

The discussion of bacterial concentrations that follows presents distributions of sample data and uses median values as approximations of geometric means. This would not be appropriate for determinations of violations of water quality criteria based on geometric means, but is reasonable as a method of discussing distributions of sample concentrations.

Boxplots generated using the City of Gresham Fairview Creek data (**Figure 5.102**) clearly illustrate routine violations of bacteria water quality standards, with median concentrations well above the 126 cfu / 100 ml criterion and numerous exceedances of the 406 cfu / 100 ml criterion. Note that these boxplots were generated using forty-one sample results for the Blue Lake Road sampling location and forty sample results for the Stark Street location (number in parentheses at bottom of boxplot). All data were collected between 1999 and 2003. The two sites show similar *E. coli* concentrations, with the median of both populations falling within range of the 25th and 75th percentile of the other.

Figure 5.102. **Boxplots Illustrating Fairview Creek Bacteria Concentrations (1999-2003)**



The information provided in **Table 5.34**, particularly the high "maximum" values and a geometric mean well above the 126 cfu/100 ml criteria, shows that Fairview Creek exhibits the elevated bacteria levels that are typical of a highly urbanized watershed.

Table 5.34. Characterization of Fairview Creek *E. coli* Results (1999 – 2003)

Location	Geometric Mean[1] (cfu/100 ml)	Median (cfu/100 ml)	Minimum/Maximum[1] (cfu/100 ml)	Number of Samples
Blue Lake Road	240	240	20 / 4200	41
Stark Street	221	190	9 / 2950	40

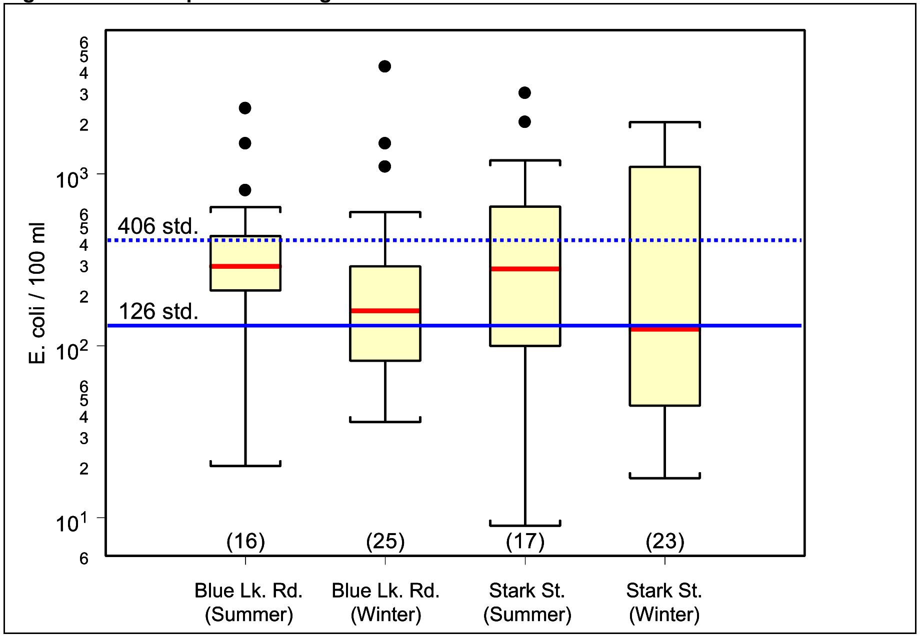
1=Freshwater criteria based on *E. coli*: 126 MPN/100 ml geometric mean; maximum value of 406 MPN/100 ml.

Seasonal Variation

Seasonal variation has been considered in both the analysis of current conditions and in developing loading allocations. ODEQ has the ability to include waterbodies on the 303d list for portions of the year or year round. For 303d listing purposes ODEQ considers bacteria data from two time periods, "Summer" (June 1 to September 30) and "Fall-Winter-Spring" (October 1 to May 31). A stream may be listed for either "season" or year round if data indicates that water quality standards are violated during both time periods. Fairview Creek is considered impaired year round and **Figure 5.103** shows that bacteria water quality standards violations occur year round in Fairview Creek. This is likely due to the presence of multiple anthropogenic sources of bacteria in the watershed. Seasonally, bacteria concentrations at the

Blue Lake Road and Stark Street monitoring locations appear quite similar, especially considering the high variability inherent in bacteria monitoring.

Figure 5.103. Boxplots Showing Seasonal Bacteria Concentrations in Fairview Creek

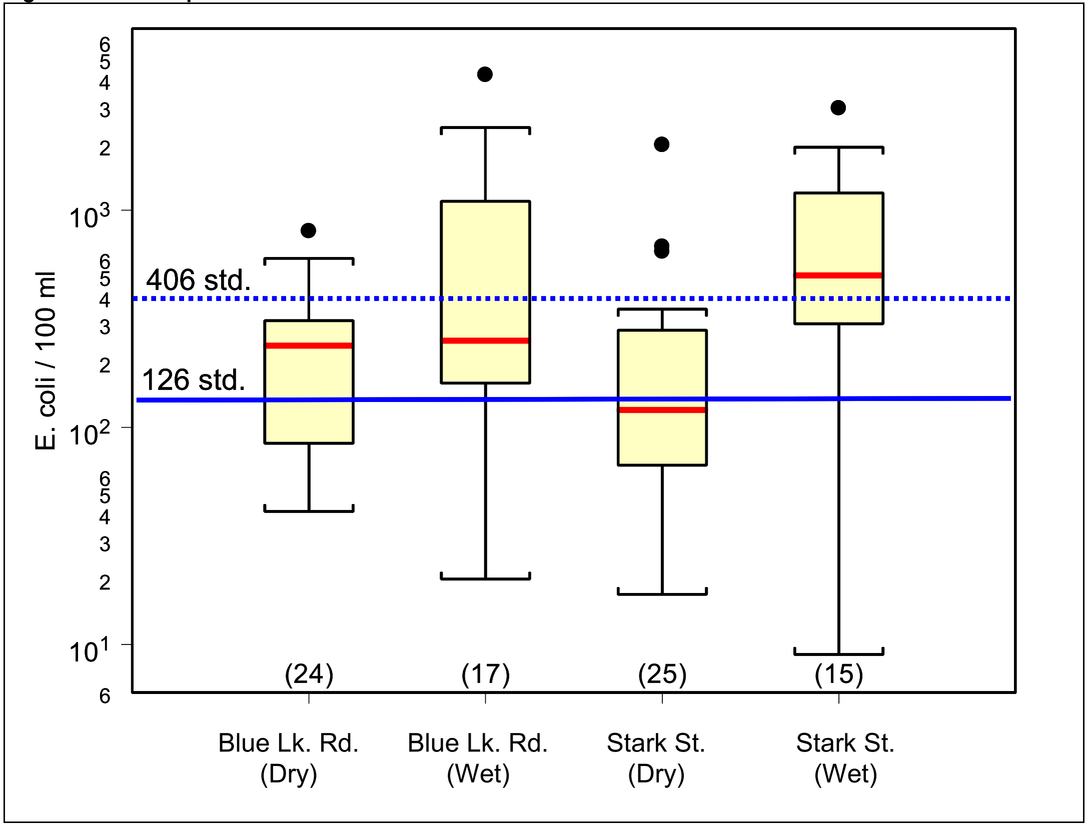


A better relationship emerges when Fairview Creek bacteria monitoring results are displayed relative to the presence of rainfall. Bacteria sampling events at the Blue Lake Road and Stark Street monitoring locations were paired with rainfall data collected at the Portland International Airport (PDX) by the Oregon Climatological Service. ODEQ assumed that runoff would occur when the rainfall on the day of the sampling event was greater than 0.2 inches. Sampling events on days, regardless of season, when appreciable rainfall was measured at PDX resulted in higher bacteria concentrations (**Figure 5.104**). This indicates that runoff-related sources, principally stormwater, are primary sources of bacteria found in Fairview Creek. **Table 5.35** includes many of the bacteria concentration numbers represented by **Figures 5.102** and **5.103**.

Table 5.35 Seasonal Variation of Fairview Creek E. coli Concentrations (cfu/100ml)

	Blue Lake Road		**Stark Street**	
	Fall Winter Spring	**Summer**	**Fall Winter Spring**	**Summer**
Geometric Mean	226	262	253	185
Median	230	270	320	180
Minimum	20	50	9	60
Maximum	4200	640	2950	2000
	Rainfall	**Dry**	**Rainfall**	**Dry**
Geometric Mean	345	184	450	145
Median	245	238	500	120
Minimum	20	41	9	17
Maximum	4200	800	2950	2000

Figure 5.104. Boxplots of Runoff and Non-Runoff Bacteria Concentrations in Fairview Creek.



Load duration curves are also capable of illustrating seasonal and run-off related patterns in bacteria loading. **Figure 5.105** shows a load duration curve developed for the Blue Lake Rd. monitoring location, with winter and summer measurements identified. The load duration curve shows, predictably, that summer measurements were made during low flow conditions and that winter measurements tended to show the largest violations of water quality standards. Coupled with **Figure 5.106**, which shows the same data under dry and runoff conditions, the load duration curves show that the largest violations of water quality standards occur during winter runoff events. However, the data also shows routine standards violations under both high flow and low flow conditions and during dry and wet periods. Again, this indicates that there are multiple sources of bacteria that enter Fairview Creek via a variety of pathways. For example, if violations were only occurring during summertime low flow conditions likely sources may include failing septic systems, livestock (or pets) in or near the stream and/or sanitary sewer/storm sewer cross connections. Those sources could largely be excluded if violations were only occurring during wintertime high flow conditions. Conversely, a large number of violations during higher flows and during rainfall events would suggest sources such as urban stormwater, sanitary sewer overflows and manure management problems. Those sources could largely be excluded if violations were only occurring during dry summertime conditions. Since violations are clearly occurring under all flow conditions, year round, and in the presence and lack of rainfall, many or all of the sources listed above are likely contributing to the bacteria problem in Fairview Creek. The following section will discuss bacteria sources in more detail.

Figure 5.105. Load Duration Curve of Seasonal Bacteria Loads at Blue Lake Rd.

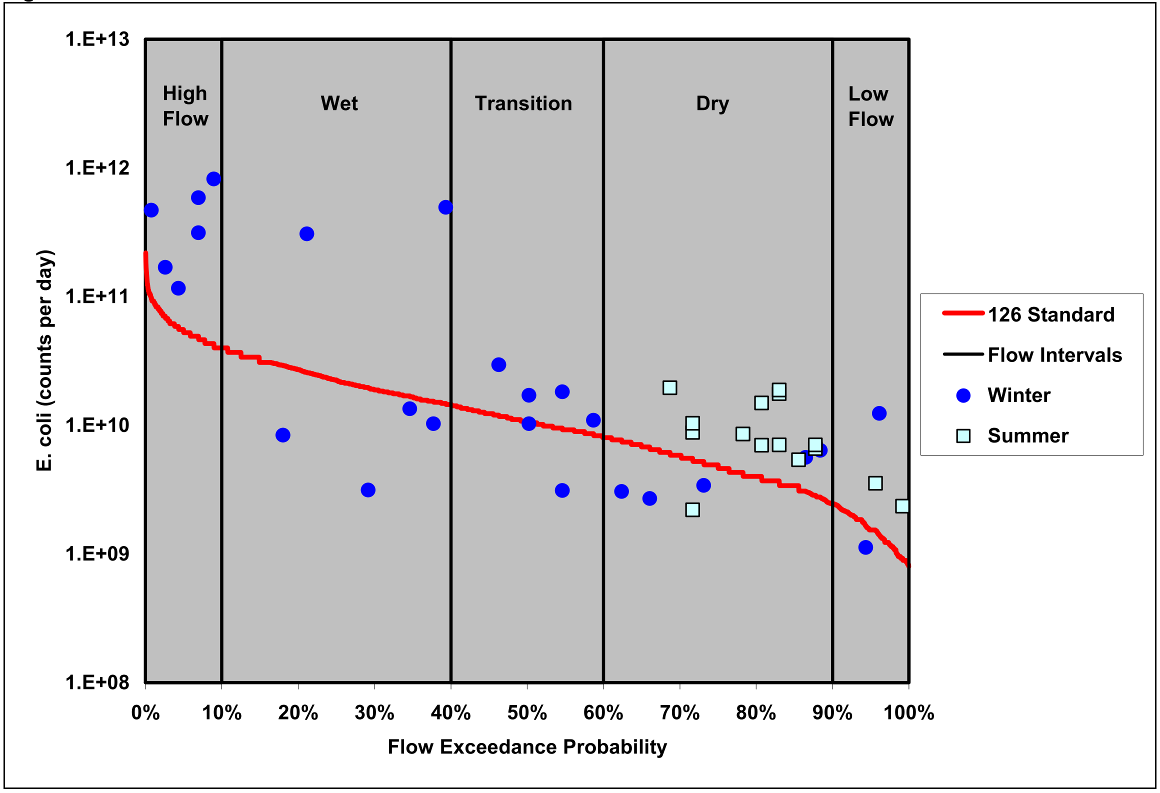
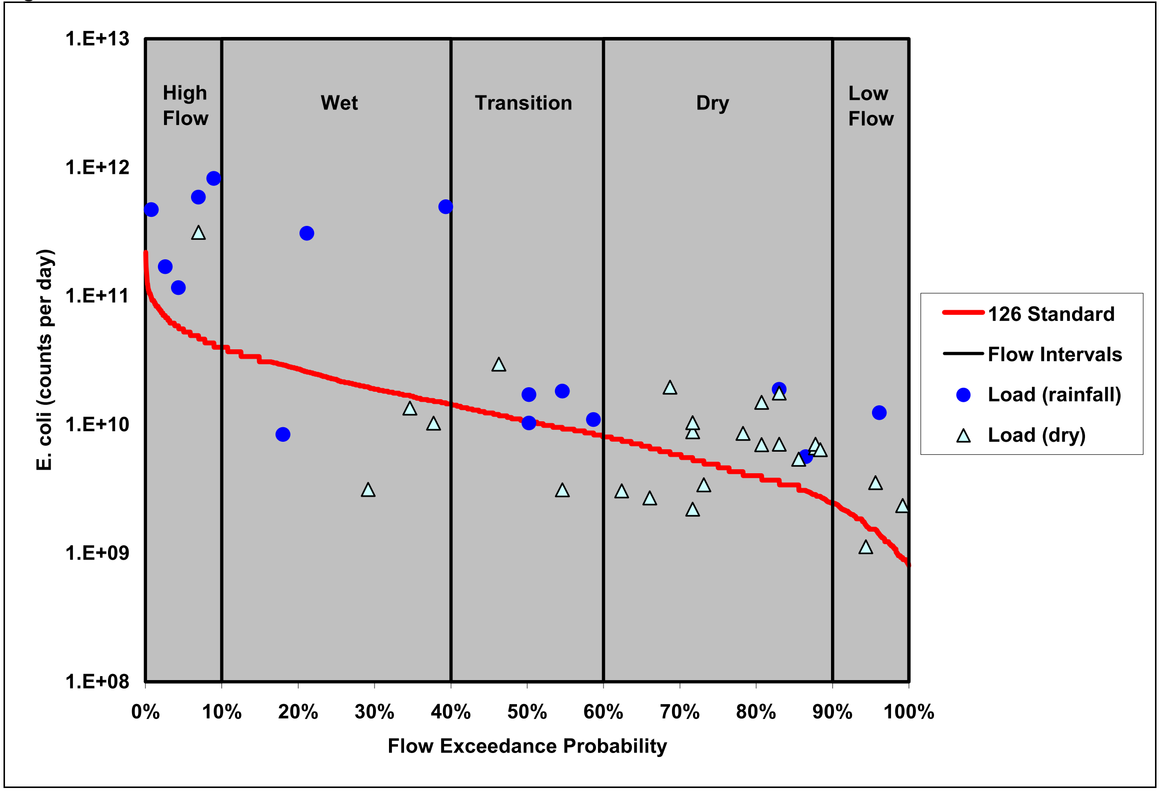


Figure 5.106. Load Duration Curve of Runoff and Non-Runoff Bacteria Loads at Blue Lake Rd.



Existing Sources

The Fairview Creek Watershed does not contain any permitted sewage treatment plants. Stormwater discharged to Springbrook Creek via the municipal separate storm sewer systems (MS4) is the only known NPDES-permitted discharge in the watershed that has the potential to discharge significant bacteria loads.

As seen in **Figures 5.104 through 5.106**, significant water quality standards violations occur during runoff events. This, coupled with the facts that much of the Springbrook Creek Watershed is urbanized and that urban stormwater is known to contain high bacteria concentrations, points to urban runoff as a potentially significant source of bacteria in Fairview Creek.

Livestock grazing is apparently no longer occurring in the Fairview Creek Watershed (Jacobsen 2002), but approximately 16% of the watershed remains in some form of agricultural use. Since a strong correlation between bacteria and suspended solids concentrations has been shown to exist in many watersheds with agricultural land uses, erosion prevention and control may be the best way to reduce bacteria runoff from agricultural lands.

Loading Capacity

A flow based loading capacity was determined through the development of a load duration curve at the Blue Lake Road monitoring location. The curve (red line in **Figure 5.107**) determines the maximum bacteria load that will achieve the 126 *E. coli* organisms per 100 ml water quality criteria under all flow conditions, thereby protecting beneficial uses.

Figure 5.107. Load Duration Curve Showing Loading Capacity and Percent Reduction Necessary to Meet Water Quality Standards for Fairview Creek.

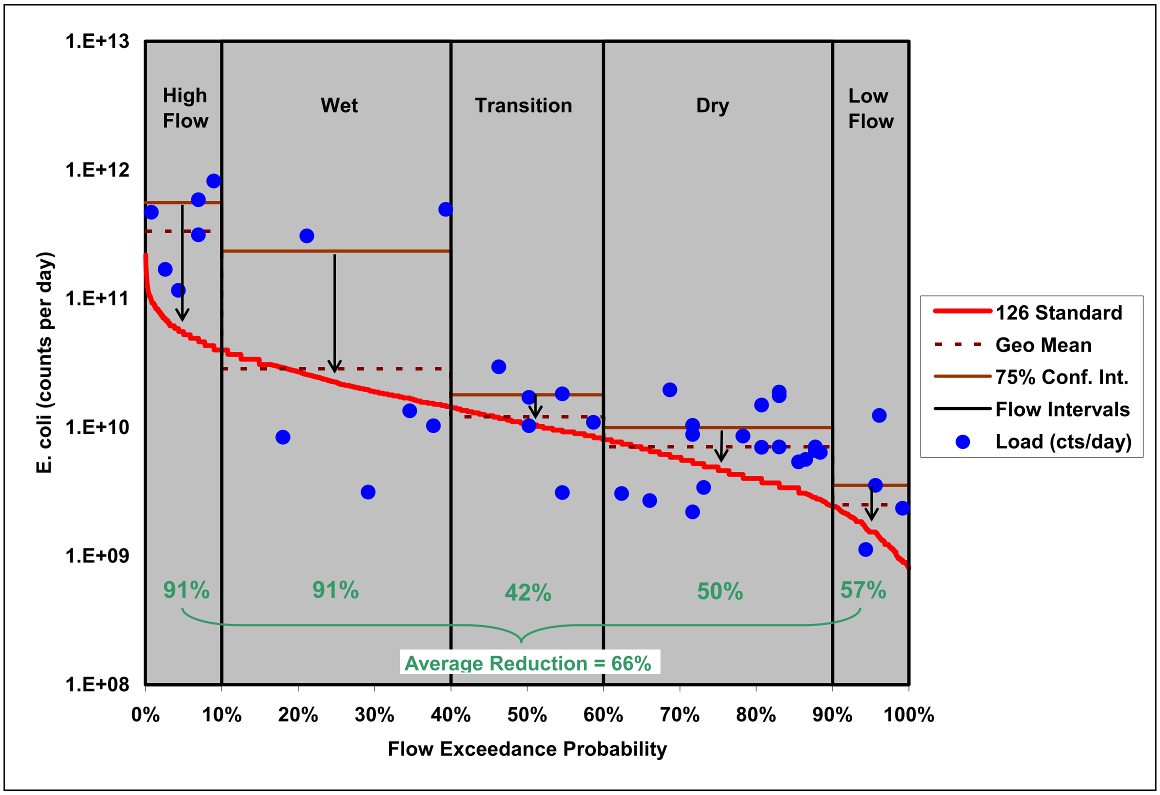


Table 5.36 shows the loading capacity to achieve the 126 cfu/100 ml criteria under several flow scenarios. The same information is presented graphically in **Figure 5.107**, above. Load capacity was developed for each of the flow intervals delineated within the Blue Lake Road monitoring site load duration curve.

Table 5.36. Flow Based Load Capacity to meet 126 cfu/100 ml *E. coli* criteria

Flow (cfs)	Flow Exceedance Probability	Load to meet geometric mean of 126 cfu/100 ml (counts per day)
0.5	95%	1.54E+09
1.5	75%	4.93E+09
3.5	50%	1.05E+10
7.0	25%	2.19E+10
17.0	5%	5.24E+10

Allocations

Wasteload and load allocations are expressed in terms of the percent reduction necessary to achieve the numeric criteria in order to translate the acceptable loads into more applicable measures of performance. Bacteria loading that results in exceedances of water quality criteria in Fairview Creek occurs year round and originates from a variety of sources. Analysis of the load duration curve developed for the Blue Lake Road monitoring location (**Figure 5.107**) reveals no clearly dominant source of bacteria other than those sources that dominate during rainfall events. While it may be possible to tailor load and wasteload allocations in some watersheds based upon dominant sources, urban watersheds such as Fairview Creek do not tend to lend themselves to this type of approach due to the presence of multiple bacteria sources.

ODEQ chose to calculate the percent reduction necessary to achieve the 126 cfu/ 100 ml criterion and applied this reduction to both point source (wasteload) and nonpoint source (load) allocations. The percent reduction, determined conservatively by using the 75th percentile of the measured samples (rather than the geometric mean and calculating the reduction necessary to meet the geometric mean criteria) is **66%** (**Figure 5.107**). Therefore, both wasteload and load allocations will be expressed as a **66%** reduction from current levels. ODEQ believes that this approach will aid in implementation of the TMDL because it sets a tangible and common goal for both point and nonpoint source management practices and programs.

Springbrook Creek Watershed

The Springbrook Creek bacteria TMDL includes a description of the watershed, the pollutants responsible for impairments, standards being applied, probable sources of the pollutants, a description of available data, loading capacity, allocations of loads, and a margin of safety. These features are summarized in **Table 5.27**.

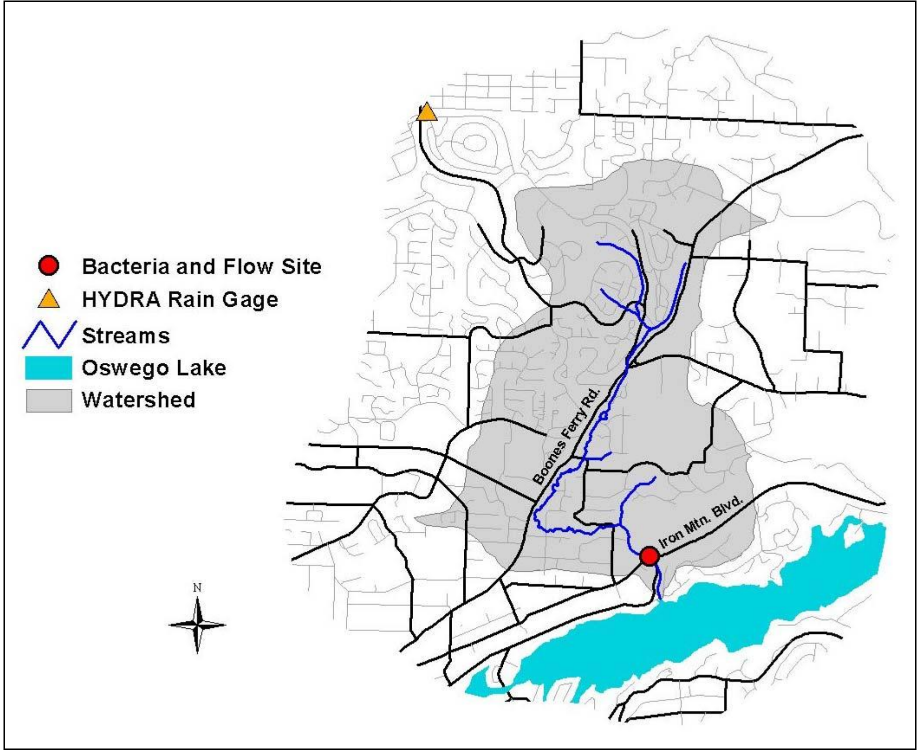
Bacteria (E. coli) data collected in Springbrook Creek between 1997 and 2003 show routine violations of State water quality standards (**Figure 5.113**).

Analytical Approach – Load Duration Curve

ODEQ chose to use the load duration curve approach to develop the bacteria TMDL for the Springbrook Creek Watershed. Load duration curves are a method of determining a flow based loading capacity, assessing current conditions, and calculating the necessary reductions to comply with water quality standards. The methodology is primarily based on TMDLs completed by Kansas Department of Health and Environment and through technical assistance provided by Bruce Cleland of America's Clean Water Foundation (www.acwf.org). Load duration curves were chosen because they offer a relatively simple and accurate methodology for determining the degree of water quality impairment and because they are capable of illustrating relative impacts under various flow conditions and can be used in targeting appropriate water quality restoration efforts (Cleland 2002, 2003).

The TMDL for the Springbrook Creek Watershed was developed using water quality monitoring data collected by the City of Lake Oswego and submitted to ODEQ in annual storm water monitoring reports. The City conducted water quality monitoring at a location near Iron Mountain Boulevard (**Figure 5.108**). The State of Oregon Water Resources Division (WRD), in cooperation with the City of Lake Oswego, operates a stream flow gage in approximately the same location - just downstream of the City's surface water quality monitoring site. *E. coli* samples considered for this analysis were collected during a variety of weather and flow conditions between 1997 and 2003. Data reported as "estimate", "less than" or "greater than" values were not considered.

Figure 5.108. Location of WRD Stream Flow Gage #14211116, City of Lake Oswego Surface Water Monitoring Site and City of Portland HYDRA Rainfall Monitoring Station



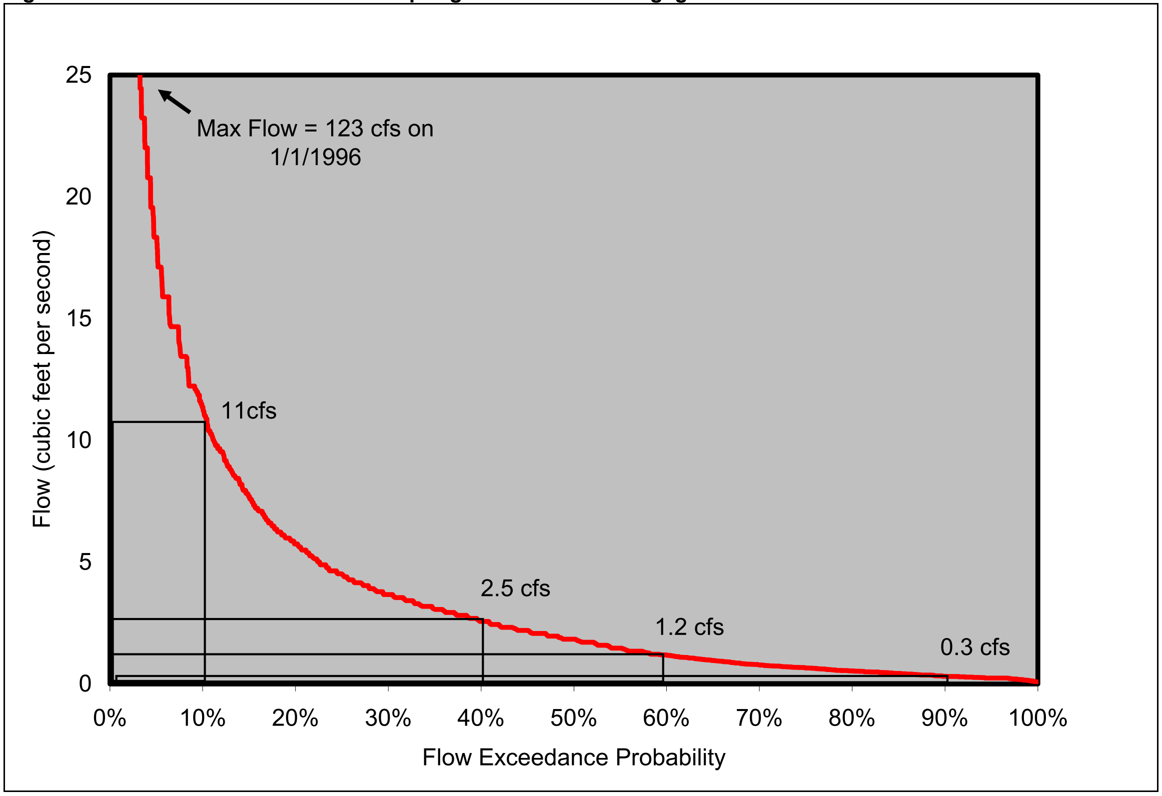
The process used to develop load duration curves for this TMDL is described as follows:

A flow duration curve for the appropriate stream flow monitoring location in the watershed is developed using available stream flow data. The flow duration curve is a plot of the frequency of which a flow is exceeded. The flows are ranked from maximum to minimum for the period of record at a particular site. The exceedance probability (EP) for each flow was computed by:

$$EP = \frac{rank}{n+1}$$

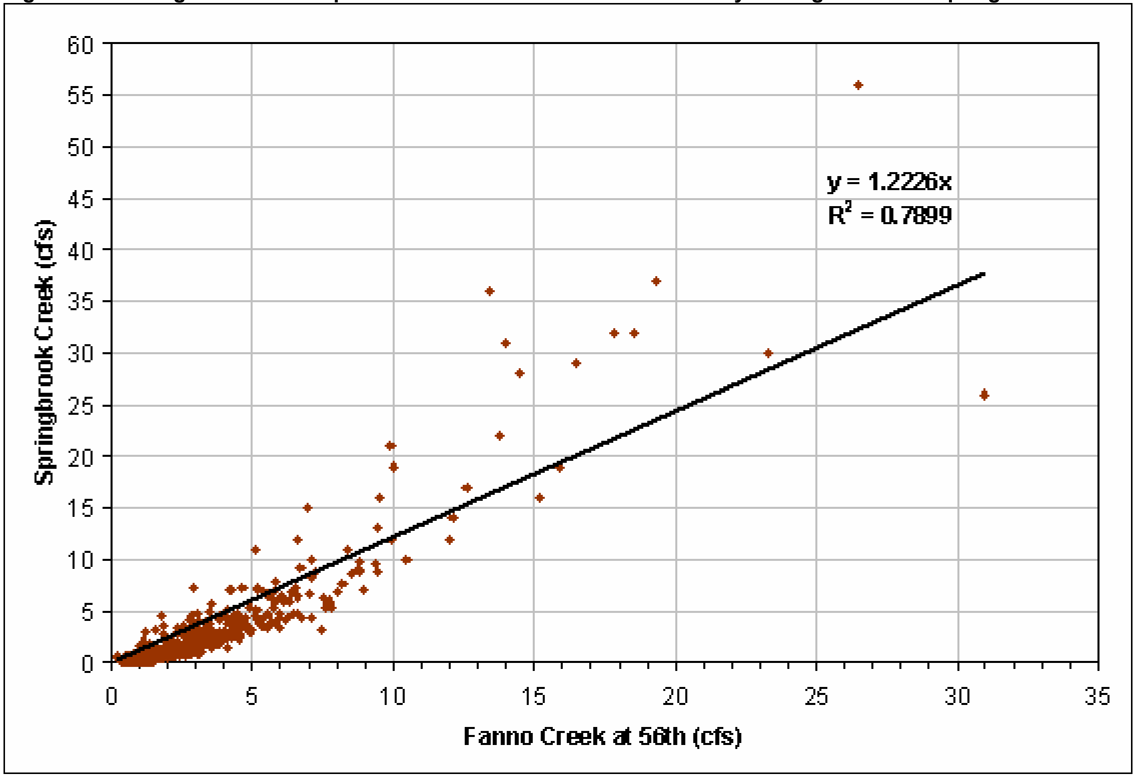
where n is number of flow measurements. The “percent of days flow exceeded” is the exceedance probability multiplied by 100. The data are plotted as shown in **Figure 5.109** with the flow exceedance probability on the x-axis. A value of 5% on the x-axis indicates extremely high flows, while a value of 95% indicates drought conditions. For example, a flow of 2.5 cfs in Springbrook Creek corresponds with a flow duration interval of 40%, indicating that 40% of all observed stream discharge values are at or above 2.5 cfs.

Figure 5.109. Flow Duration Curve for Springbrook Creek WRD gage #14211116



As noted above, a stream flow gage (#14211116) is located very near the City of Lake Oswego’s water quality monitoring location at Iron Mountain Blvd. The station became operational in September, 2001 and flow data are available on the internet at: http://washtech.co.washington.or.us/watermaster. Bacteria samples used in this analysis were collected between 1997 and 2003. In order to calculate event loads for data collected before September, 2001 it was necessary to predict historical flows at the Iron Mountain Blvd. monitoring site using a regression equation based upon the relationship between the site and a nearby long-term USGS gage (#14206900) located on Fanno Creek at 56th Avenue. **Figure 5.110** shows the regression equations used to predict historic flows at the Iron Mountain Blvd monitoring site.

Figure 5.110. Regression and Equation used to Calculate Historical Daily Average Flows in Springbrook Creek

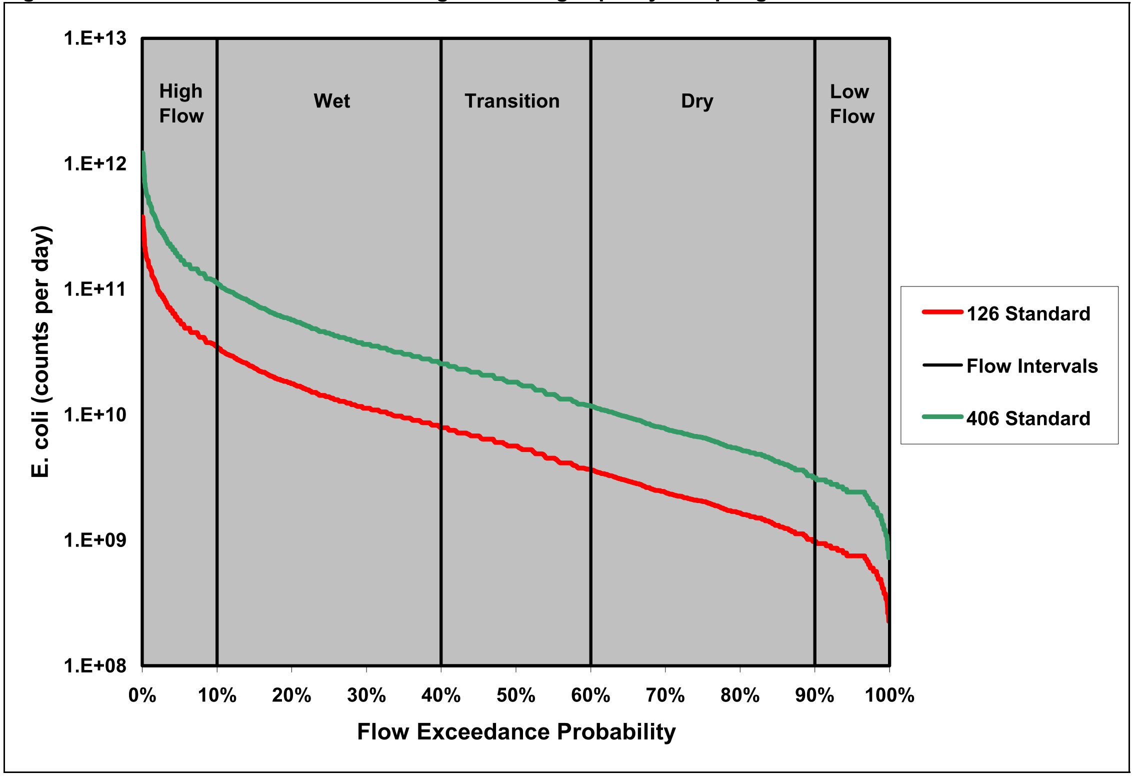


The flow curve is translated into a load duration curve. To accomplish this, the flow value is multiplied by the water quality standard and a conversion factor. The resulting loads are graphed and represent the flow-dependent loading capacity for specific numeric criteria. The curve (**Figure 5.111**) is determined by the target concentration, 126 cfu/100ml in this case, and the flow associated with the recurrence interval. For example, the log mean recreational contact standard for bacteria is 126 colonies per 100 milliliters so the loading capacity is:

$$\text{Loading Capcity}\frac{col}{day} = \overset{\substack{\text{Standard}\\ \downarrow}}{126\frac{col}{100\,ml}} * \overset{\substack{\text{Flow}\\ \downarrow}}{Q\frac{ft^3}{s}} * \overbrace{283.2\frac{100ml}{ft^3} * 86400\frac{s}{day}}^{\text{Conversion factors}}$$

The loading capacity is then plotted against the corresponding flow exceedance probability. There are two lines representing the two numeric targets: log mean of 126 cfu / 100 ml and no samples exceeding 406 cfu / 100 ml. The loading capacity increases with increased flow because of the increased assimilative capacity of the river.

Figure 5.111. Load Duration Curve showing the loading capacity for Springbrook Creek



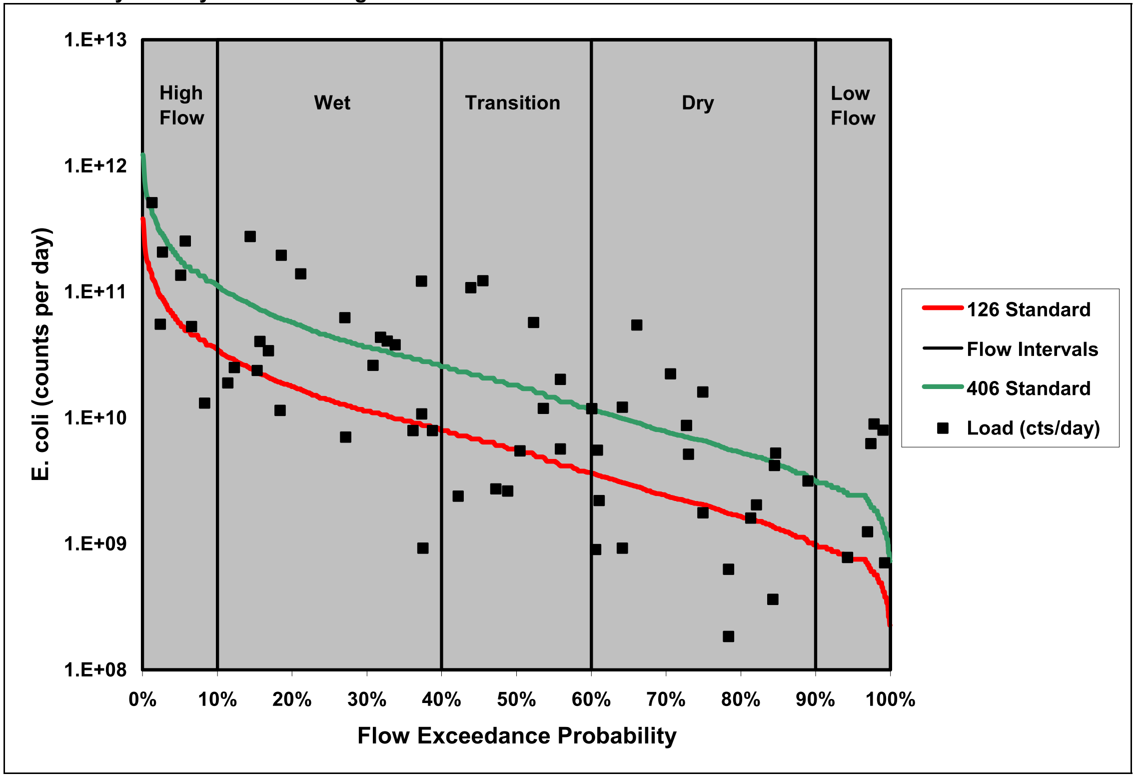
A water quality sample is converted to a load by multiplying the water quality sample concentration by the average daily flow on the day the sample was taken. Measured concentrations of *E. coli* are converted into loads using the equation above and flows from the stream gage. The “event loads” are plotted along with the standard lines to assess current conditions The y-axis becomes the water quality parameter value, load in this case, and the position of the sample on the x-axis illustrates the flow exceedance probability (**Figure 5.112**).

Points that plot above the curve represent deviations from the water quality standard and the permissible loading function. Those plotting below the curve represent compliance with water quality criteria and the appropriate designated use.

When event loads exceed the loading capacity during high flows it is likely that the loading is due to runoff related sources such as urban stormwater, sanitary sewer overflows or combined sewer overflows.

Bacterial loading tends to be less during low-flow periods, however, the loading capacity of the river has also decreased. Violations of the water quality standard at low flows are not likely runoff related. Warm-blooded animals in streams, failing septic tanks, and improper discharge of sewage are possible non-runoff related sources.

Figure 5.112. Load Duration Curve showing the loading capacity for Springbrook Creek and event loads for 63 samples collected by the City of Lake Oswego between 1997 and 2003



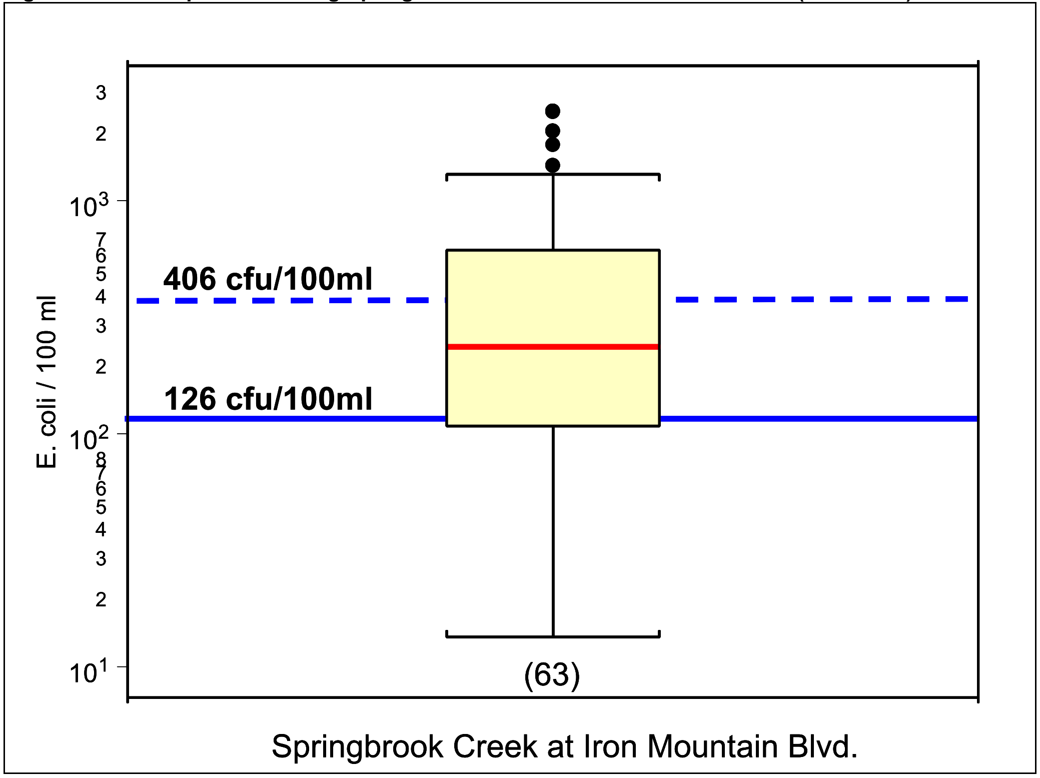
Deviation from Water Quality Standards

Analysis of bacterial concentrations is based on data provided to ODEQ by the City of Lake Oswego via annual reports required under their Municipal Separate Storm Sewer System (MS4) permit. The City has collected periodic water quality measurements within the Springbrook Creek watershed since 1997. These data were collected in the creek at a site near Iron Mountain Rd. (**Figure 5.108**). Data from this site were analyzed over the entire period of record and are presented in box plot format (**Figures 5.113** through **5.115**). Overall, violations of water quality standards were common.

The discussion of bacterial concentrations that follows presents distributions of sample data and uses median values as approximations of geometric means. This would not be appropriate for determinations of violations of water quality criteria based on geometric means, but is reasonable as a method of discussing distributions of sample concentrations.

A boxplot generated using the City of Lake Oswego Springbrook Creek data (**Figure 5.113**) clearly illustrates routine violations of bacteria water quality standards, with median concentrations well above the 126 cfu / 100 ml criterion and numerous exceedances of the 406 cfu / 100 ml criterion. Note that all boxplots were generated using 63 sample results for the Iron Mountain Road sampling location (number in parentheses at bottom of boxplot). All data were collected between 1997 and 2003.

Figure 5.113. **Boxplot Illustrating Springbrook Creek Bacteria Concentrations (1997-2003)**



The information provided in **Table 5.37**, particularly the high "maximum" value and a geometric mean well above the 126 cfu/100 ml criteria, shows that Springbrook Creek exhibits the elevated bacteria levels that are typical of a highly urbanized watershed.

Table 5.37. Characterization of Springbrook Creek *E. coli* Results (1997 – 2003)

Location	Geometric Mean[1] (cfu/100 ml)	Median (cfu/100 ml)	Minimum/Maximum[1] (cfu/100 ml)	Number of Samples
Iron Mountain Blvd.	249	236	13 / 2420	63

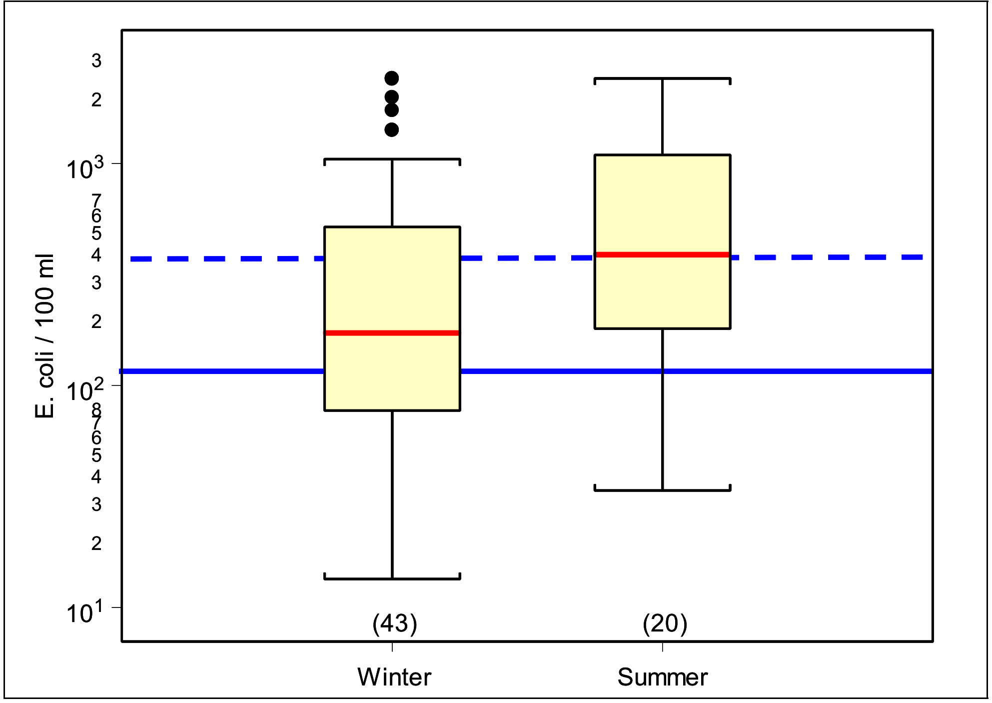
1=Freshwater criteria based on *E. coli*: 126 MPN/100 ml geometric mean; maximum value of 406 MPN/100 ml.

Seasonal Variation

Seasonal variation has been considered in both the analysis of current conditions and in developing loading allocations. ODEQ has the ability to include waterbodies on the 303d list for portions of the year or year round. For 303d listing purposes ODEQ considers bacteria data from two time periods, "Summer" (June 1 to September 30) and "Fall-Winter-Spring" (October 1 to May 31). A stream may be listed for either "season" or year round if data indicates that water quality standards are violated during both time periods. Springbrook Creek is considered impaired year-round and **Figure 5.114** shows that bacteria water quality standards violations occur year-round in Springbrook Creek. This is due to the presence of multiple anthropogenic sources of bacteria in the watershed.

A visual inspection of the seasonal boxplots presented in **Figure 5.114** indicates that bacteria levels are slightly higher during the summer months at the Springbrook Creek monitoring location. ODEQ further determined that seasonal bacteria concentrations in Springbrook Creek are significantly different at the 95 percent confidence interval using both the t-test (following log transformation and assuming unequal variances) and the Mann-Whitney "U" test.

Figure 5.114. Boxplots Showing Seasonal Bacteria Concentrations in Springbrook Creek



A better relationship emerges when Springbrook Creek bacteria monitoring results are displayed relative to the presence of rainfall. Post-1998 bacteria sampling events at the Iron Mountain Road monitoring location were paired with rainfall data collected at a City of Portland HYDRA rainfall gage located just outside of the watershed at 12000 S.W. 49th Ave. in Portland (**Figure 5.108**). Pre-1998 bacteria sampling events were paired with rainfall data collected at Portland International Airport by the Oregon Climatological Service. ODEQ assumed that runoff would occur when the rainfall on the day of the sampling event was greater than 0.15 inches. Sampling events on days, regardless of season, when no appreciable rainfall was measured resulted in slightly higher bacteria concentrations (**Figure 5.115**). ODEQ further determined that seasonal bacteria concentrations in Springbrook Creek are significantly different at the 95 percent confidence interval using both the t-test (following log transformation and assuming unequal variances) and the Mann-Whitney "U" test. Analysis of the seasonal and wet/dry boxplots suggests that, while both runoff-related sources (principally storm water) and non-runoff sources (such as sanitary system cross-connections) are significant sources of bacteria in Springbrook Creek, initial source control strategies should focus on management practices and techniques that address summertime, non-runoff source categories. **Table 5.38** includes many of the bacteria concentration numbers represented by **Figures 5.114** and **5.115**.

Figure 5.115. Boxplots of Runoff and Non-Runoff Bacteria Concentrations in Springbrook Creek.

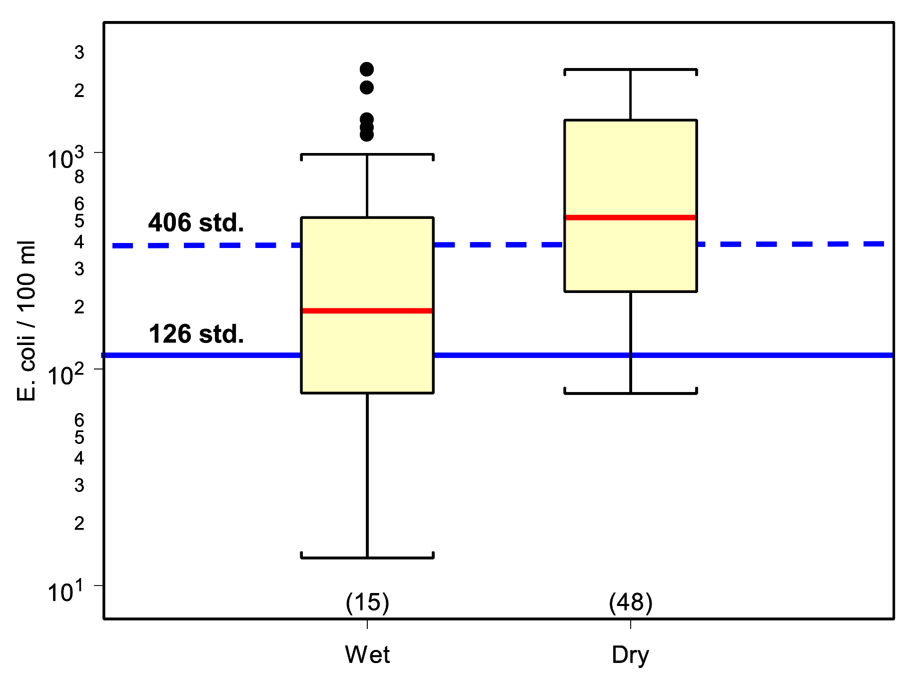


Table 5.38 Seasonal Variation of Springbrook Creek E. coli Concentrations (cfu/100ml)

	Based upon data collected at Iron Mountain Boulevard by the City of Lake Oswego, 1997-2003			
	Fall Winter Spring	**Summer**	**Rainfall Events**	**Dry Weather**
Geometric Mean	208	365	199	511
Median	172	388	186	500
Minimum	13	34	13	77
Maximum	2419	2420	2419	2420

Load duration curves are also capable of illustrating seasonal and run-off related patterns in bacteria loading. **Figure 5.116** shows a load duration curve developed for the Iron Mountain Rd. monitoring location, with winter and summer measurements identified. The load duration curve shows, predictably, that the summer measurements were made during low flow conditions and that the winter measurements were made during wet, higher flow conditions. **Figure 5.117**, which shows the same data under dry and runoff conditions, shows consistent violations of water quality standards during non-runoff periods. The data also show routine standards violations under both high flow and low flow conditions and during dry and wet periods. Again, this indicates that there are multiple sources of bacteria that enter Springbrook Creek via a variety of pathways. For example, if violations were only occurring during summertime low flow conditions likely sources may include failing septic systems, animals including wildlife and pets in or near the stream and/or sanitary sewer/storm sewer cross connections. Those sources could largely be excluded if violations were only occurring during wintertime high flow conditions. Conversely, a large number of violations during higher flows and during rainfall events would suggest sources such as urban stormwater, sanitary sewer overflows and manure management problems. Those sources could largely be excluded if violations were only occurring during dry summertime conditions. Since violations are clearly occurring under all flow conditions, year round, and in the presence and lack of rainfall, many or all of the sources listed above are likely contributing to the bacteria problem in Springbrook Creek. The following section discusses bacteria source categories in more detail.

Figure 5.116. Load Duration Curve of Seasonal Bacteria Loads in Springbrook Creek.

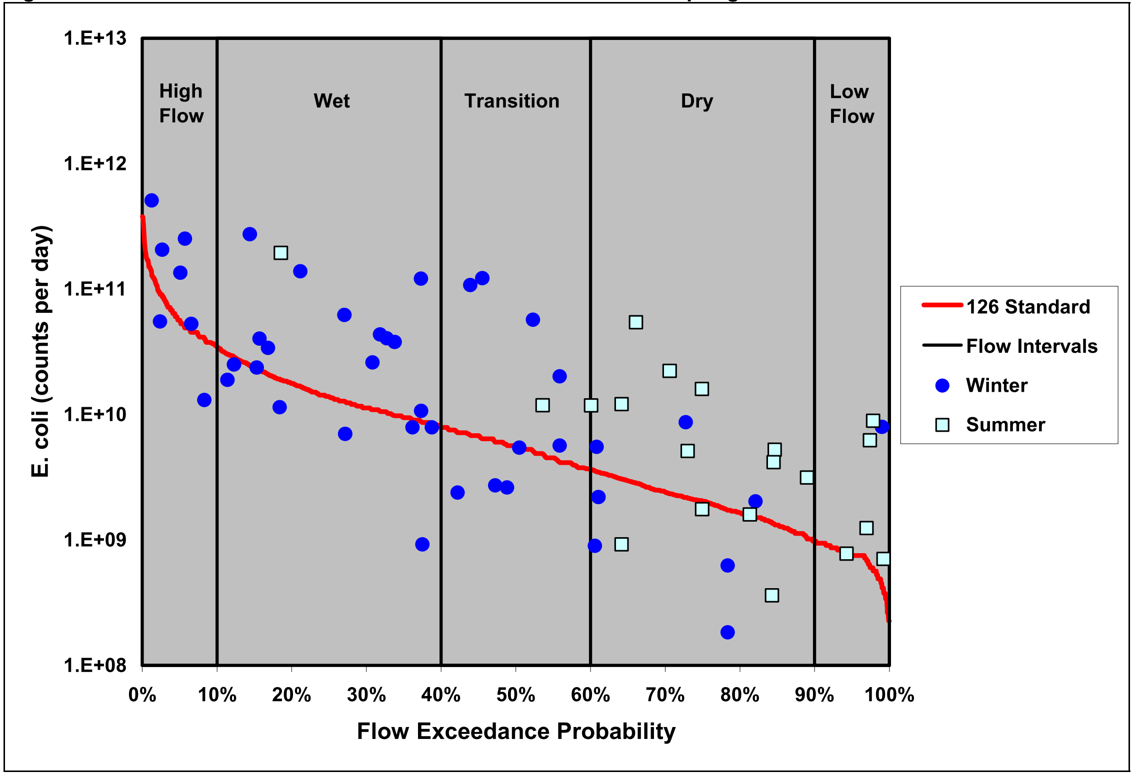
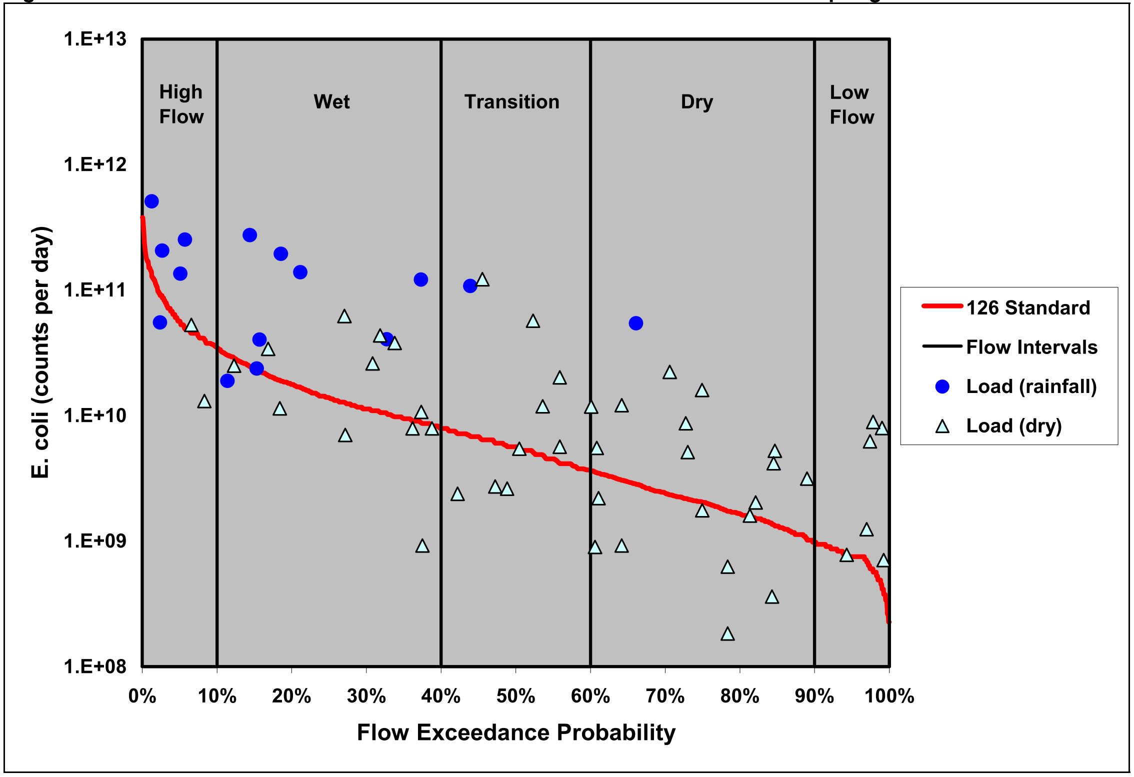


Figure 5.117. Load Duration Curve of Runoff and Non-Runoff Bacteria Loads in Springbrook Creek.



Existing Sources

The Springbrook Creek Watershed does not contain any permitted sewage treatment plants. Stormwater discharged to Springbrook Creek via the municipal separate storm sewer systems (MS4) is the only known NPDES-permitted discharge in the watershed that has the potential to discharge significant bacteria loads.

Water quality monitoring conducted by the Lake Oswego Corporation observed possible bacteria sources to be the proximity of livestock and manure piles next to Springbrook Creek at the Hunt Club (OTAK 1992). Additional potential sources are “hobby” farms, man-made instream ponds that attract wildlife and, perhaps significantly in the Springbrook Creek Watershed, horse pastures.

As seen in **Figures 5.114 through 5.116**, significant water quality standards violations occur during runoff events. This, coupled with the facts that much of the Springbrook Creek Watershed is urbanized and that urban stormwater is known to contain high bacteria concentrations, points to urban runoff as a potentially significant source of bacteria in Springbrook Creek.

Non-runoff sources of urban bacteria may include such things as sanitary sewer cross connections, illicit discharge of sanitary waste from septage vacuum trucks and recreational vehicles, and episodic or chronic discharges from the local sanitary sewer system. Small scale discharges, a single residential cross connection for example, may not have much of an impact during runoff events or when stream flows are higher, but can cause water quality standards violations during the summer months in a stream the size of Springbrook Creek.

Loading Capacity

A flow based loading capacity was determined through the development of a load duration curve at the Iron Mountain Road monitoring location. The curve (red line in **Figure 5.118**) determines the maximum bacteria load that will achieve the 126 *E. coli* organisms per 100 ml water quality criteria under all flow conditions, thereby protecting beneficial uses.

Figure 5.118. Load Duration Curve Showing Loading Capacity and Percent Reduction Necessary to Meet Water Quality Standards in Springbrook Creek.

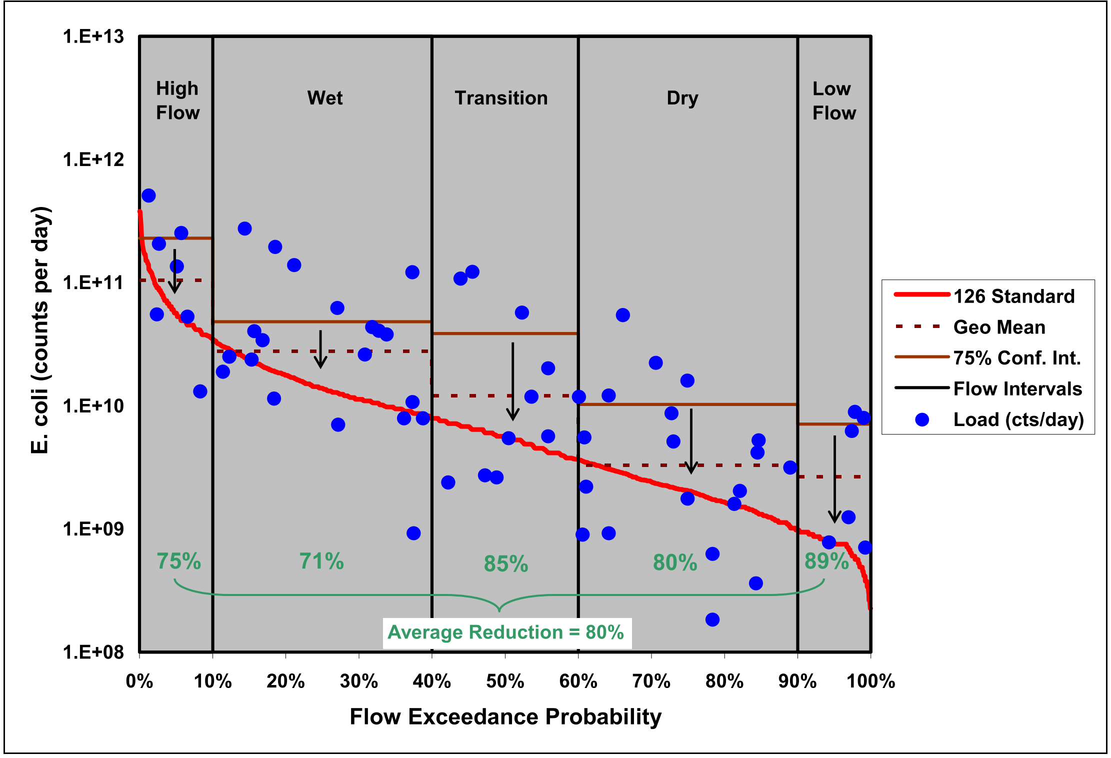


Table 5.39 shows the loading capacity to achieve the 126 cfu/100 ml criteria under several flow scenarios. The same information is presented graphically in **Figure 5.118**, above. Load capacity was developed for each of the flow intervals delineated within the Iron Mountain Road monitoring site load duration curve. Note that the flow based loads presented in **Table 5.39** represent acceptable loads at flows in the middle of the ranges delineated in **Figure 5.118**.

Table 5.39. Flow Based Load Capacity to meet 126 cfu/100 ml *E. coli* criteria

Flow (cfs)	Flow Exceedance Probability	Load to meet geometric mean of 126 cfu/100 ml (counts per day)
0.5	95%	7.53E+08
1.5	75%	2.03E+09
3.5	50%	5.65E+09
7.0	25%	1.39E+10
17.0	5%	5.65E+10

Allocations

Wasteload and load allocations are expressed in terms of the percent reduction necessary to achieve the numeric criteria in order to translate the acceptable loads into more applicable measures of performance. Bacterial loading that exceeds water quality criteria in Springbrook Creek occurs year round and originates from a variety of sources. Analysis of the load duration curve developed for the Iron Mountain Road monitoring location (**Figure 5.118**) reveals no clearly dominant source of bacteria, but suggests that summertime, non-runoff periods experience the highest bacteria concentrations. While it may be possible to tailor load and wasteload allocations in some watersheds based upon dominant sources, urban watersheds such as Springbrook Creek do not tend to lend themselves to this type of approach due to the presence of multiple bacteria sources.

ODEQ chose to calculate the percent reduction necessary to achieve the 126 cfu/ 100 ml criterion and applied this reduction to both point source (wasteload) and nonpoint source (load) allocations. The percent reduction, determined conservatively by using the 75th percentile of the measured samples (rather than the geometric mean and calculating the reduction necessary to meet the geometric mean criteria) is **80%** (**Figure 5.118**). Therefore, both wasteload and load allocations will be expressed as an **80%** reduction from the levels observed in the 1997-2003 data. ODEQ believes that this approach will aid in implementation of the TMDL because it sets a tangible and common goal for both point and nonpoint source management practices and programs.

ALL OTHER TRIBUTARIES

In addition to the watershed-specific allocations described previously, all streams in the Lower Willamette Subbasin receive a load and wasteload allocation. ODEQ chose to apply the **78%** reduction calculated for the Johnson Creek Watershed to all other tributaries in the Lower Willamette Subbasin. The **78%** reduction applies to streams in watersheds not otherwise allocated in previous analyses above on a year round basis and to both agricultural and urban land uses. The Johnson Creek percent reductions were applied to all other streams in the subbasin because the watershed represents both agricultural and urban land uses.

JOHNSON CREEK TOXICS TMDL

Johnson Creek is included on the 1998 list of water quality impaired waterbodies in the state of Oregon (303d list) due to high levels of the pesticides DDT and dieldrin. Johnson Creek is considered water quality limited year around from its mouth to headwaters. Allocations in this TMDL apply to all streams in the Johnson Creek Watershed.

Background and Summary

DDT (dichlorodiphenyltrichloroethane) and dieldrin are toxic organochlorine pesticides. Historically, DDT and dieldrin were used extensively as agricultural insecticides and to control insect disease vectors such as mosquitoes. Both compounds are long-lived in soils and toxic to animals. Both compounds are also highly hydrophobic, which means that they tend to bind to soil particles and fatty tissues rather than dissolve into water. Due to the extensive past use and the persistence of these compounds, these materials are virtually ubiquitous in the environment and have been detected in virtually all media (water, soil, tissue, etc.). Both compounds are carcinogens and suspected endocrine disrupters that may affect reproduction or development of aquatic organisms or wildlife by interfering with natural hormones. DDT was banned from use in the United States in 1972. The use of dieldrin was restricted in 1970 and all uses of products containing dieldrin were banned in 1983 (Joy 2002).

Dieldrin is a long-lived oxidation breakdown product of the organochlorine pesticide aldrin. Aldrin quickly breaks down into dieldrin in the body or in the environment, typically within a matter of days. Thus, the environmental concentrations of dieldrin are a cumulative result of the historic use of both aldrin and dieldrin. Dieldrin is extremely persistent in the environment, and by means of bioaccumulation it is concentrated many times as it moves up the food chain. Its persistence is due to its extremely low volatility and low solubility in water resulting in a high affinity for fat (USEPA 1993, Meyer 1990).

Over time DDT breaks down to form the metabolites DDE and DDD, which are also associated with toxicological effects. All are subject to photodegradation and re-deposition by rain or dry deposition, and are widely dispersed by erosion, runoff and volatilization. On land, they preferentially bind to soil and sediment. In water they are subject to sedimentation, volatilization, photodegradation, and uptake into the food chain. Release of these compounds to water is primarily via transport of particulates contained in runoff. Both DDT and DDE bioaccumulate in organisms, particularly in fatty tissues, and levels are subject to increase as they advance up the food chain.

The quantity and geographic distribution of historical organochlorine pesticide use in the Johnson Creek Watershed has not been well documented. However, it is clear that historical use of the pesticides DDT and dieldrin in the watershed continues to cause violations of water quality standards. These organochlorine pesticides are considered legacy pollutants since it is highly unlikely that significant amounts of the chemicals have been applied in the watershed since the bans in 1972 and 1983.

The Johnson Creek DDT and dieldrin TMDL is summarized in **Table 5.40**.

Table 5.40. Johnson Creek Toxics TMDL Components.

Waterbodies **OAR 340-042-0040(4)(a)**	All streams within the Johnson Creek Watershed portion of HUC (Hydrologic Unit Code) 170900120301
Pollutant Identification **OAR 340-042-0040(4)(b)**	*Pollutants*: dichlorodiphenyltrichloroethane (DDT) and dieldrin
Target Criteria Identification **OAR 340-042-0040(4)(c)** ***CWA §303(d)(1)***	Freshwater Chronic Criteria of 0.001 and 0.0019 micrograms per liter for DDT and dieldrin, respectively. ODEQ predicts that criteria for water and fish ingestion will also ultimately be achieved.
Existing Sources **OAR 340-042-0040(4)(f)** *CWA §303(d)(1)*	Multiple, including urban stormwater and nonpoint sources
Seasonal Variation **OAR 340-042-0040(4)(j)** ***CWA §303(d)(1)***	Violations of water quality standards occur throughout the year and under both low flow and high flow conditions.
TMDL **Loading Capacity and Allocations** ***40 CFR 130.2(f)*** ***40 CFR 130.2(g)*** ***40 CFR 130.2(h)***	*Loading Capacity:* The loading capacity was determined through the development of load duration curves that determine the maximum TSS load that will achieve the 15 mg/l TSS target necessary to achieve the fresh water chronic criteria for DDT, thereby protecting beneficial uses. *Waste Load Allocations (Point Sources)*: Waste load allocations applicable to municipal stormwater permits are expressed as a DDT reduction of 77%. *Load Allocations (Non-Point Sources):* Load allocations are expressed as a TSS target of 15 mg/l or a DDT reduction of 94%.
Surrogate Measures **OAR 340-042-0040(5)(b)** ***40 CFR 130.2(i)***	Translates Load Allocations Total Suspended Solids (TSS) concentrations are used as a surrogate measure of DDT due to the reliable relationship between the two parameters, the relative ease of measuring TSS and in order to express allocations in a way that is consistent with applicable measures of performance (BMP effectiveness, etc.). Data also indicate a positive relationship between TSS and Turbidity, making a Turbidity surrogate possible in the future. DDT and Dieldrin Measured instream concentrations of DDT and dieldrin show them to be effectively equal, while the allowable dieldrin concentration is nearly double that of DDT. Since a good relationship (R^2 = 0.81) exists between instream DDT and dieldrin concentrations, ODEQ believes that achieving DDT criteria will also result in the attainment of dieldrin criteria. Dieldrin was not detected in stormwater samples, so the required DDT reduction of 77% is quite conservative in ensuring that the dieldrin criterion will be achieved in stormwater.
Margins of Safety **OAR 340-042-0040(4)(i)** ***CWA §303(d)(1)***	*Margins of Safety:* The chronic toxics criteria were evaluated on an instantaneous basis rather than a 24-hour average. Statistical analysis of DDT and dieldrin concentrations shows them to be effectively equal. The chronic dieldrin criterion is nearly double that of DDT (0.0019 vs. 0.0010 ug/l). Targeting the percent reduction to achieve the DDT criterion will result in dieldrin concentrations well below the criterion. No numeric margin of safety is developed.
Water Quality Management Plan **OAR 340-042-0040(4)(l)**	The Water Quality Management Plan (WQMP) provides the frame work of management strategies to attain and maintain water quality standards. The WQMP is designed to complement the detailed plans and analyses included in specific DMA implementation plans. Please see Chapter 14.

Target Criteria Identification

Water quality criteria for Oregon's waters are contained in the Oregon Administrative Rules, section 340-41. Acceptable concentrations of toxic compounds are listed in OAR 340-41, Table 20. Selected values for regulatory purposes depend on the most sensitive beneficial use to be protected and what level of protection is necessary for aquatic life and human health. **Table 5.41** shows the water quality criteria for DDT and dieldrin. Criteria provided for the protection of both water and fish ingestion are the most stringent that may be considered.

Table 20 criteria that protect "water and fish ingestion" are the most stringent that may be applied

Table 5.41. Statewide Water Quality Criteria for DDT and dieldrin

Compound	Fresh Water Acute	Fresh Water Chronic	Water and Fish Ingestion
DDT	1.1 micrograms per liter	0.001 micrograms per liter	0.024 nanograms per liter
Dieldrin	2.5 micrograms per liter	0.0019 micrograms per liter	0.071 nanograms per liter

"Water and Fish Ingestion" values represent the maximum ambient water concentration for consumption of both contaminated water and fish or other aquatic organisms.

The chronic fresh water criterion is protective of resident aquatic species and is evaluated based upon a 24-hour average. Surface water concentrations of toxic pollutants should not exceed the acute criterion at any time.

ODEQ has developed conditions to interpret and apply the water quality criteria and determine impact on a beneficial use:

A. Water Quality Criteria Violations occur if:

1. The freshwater chronic criteria for protection of aquatic life contained in OAR Table 20 are violated more than 10% of the time and for a minimum of two values.
2. The chemical is found in sediments at levels which analytical models demonstrate that water quality standards are violated. The analysis and modeling must be reviewed and approved by DEQ.

B. Measure of impairment of a Beneficial Use:

1. A fish or shellfish consumption advisory or recommendation issued by the Oregon State Health Division specifically refers to this chemical.
2. The chemical has been found to cause a biological impairment via a field test of significance such as a bioassay. The field test must involve comparison to a reference condition.
3. The chemical has been detected in more than 10% of available fish tissue samples, and the population mean of the samples exceeds a screening value derived from Table 20. The screening value is developed as follows:

   Fish Tissue Screening Value (mg/kg) = Table 20 Criteria for Protection of Human Health (ng/l) * BCF (1/kg) * (mg/10^6 ng)

   Where BCF = Bioconcentration Factor. BCFs are obtained from the USEPA Region VIII Criteria Chart (July 1993)

Surface water samples collected by the USGS in the early 1990's were evaluated for DDT and dieldrin and resulted in the addition of Johnson Creek to the State 303(d) list of water quality limited waterbodies. Results indicated that concentrations were above the fresh water chronic criteria shown in **Table 5.41**.

Analysis of Crayfish tissue collected by ODEQ in 1991 showed significantly higher (up to 20 times) concentrations of DDT at upstream sampling sites dominated by agricultural land uses. Crayfish tissue concentrations were above USEPA water quality criteria for the protection of aquatic life, but at levels safe for human consumption (ODEQ 1994).

Rinella *et al* (1999) observed high levels of DDT in resident fish tissue in the Yakima River basin where instream DDT values were less than those observed in Johnson Creek. It should be noted, however, that the Yakima River basin and the Johnson Creek Watershed are different in many ways that may impact the relationship between water column and fish tissue concentrations of DDT. For example, portions of the Yakima basin receive considerable TSS input via irrigation return flows during the summer months; whereas it appears the TSS levels in Johnson Creek are generally low during the summer months and elevated only during high flows and during rainfall-generated runoff events. Also, both recent and historic organochlorine pesticide sampling in Johnson Creek has occurred during winter storm events. It is quite possible that resident fish in the Yakima River basin are exposed to elevated water column DDT levels for a much longer period of time over the course of their lives than resident fish in Johnson Creek, resulting in generally higher concentrations in fish tissue.

Edwards (1993) conducted limited organochlorine sediment sampling at several locations during August, 1988. Edwards noted that the highest concentrations of DDT in stream sediments were found at the most upstream sampling site at river mile (RM) 17.4 in the predominantly agricultural land use area. The location of this historical monitoring location is just downstream from the Palmblad Road site (RM 18.5) considered in this TMDL (**Figure 5.120**). In 1991, ODEQ collected and analyzed sediment samples at several locations along Johnson Creek between river mile 1.1 and 17.5. DDT concentrations ranged from 0.011 to 0.51mg/kg-wet weight, with the highest concentrations observed in the upper watershed. Since the sediment data collected by Edwards and ODEQ are now 12 to 15 years old, they were not included in the TMDL development process beyond the qualitative assessment noted above.

The Johnson Creek Watershed Toxics TMDL targets criteria that are protective of resident aquatic species and human health

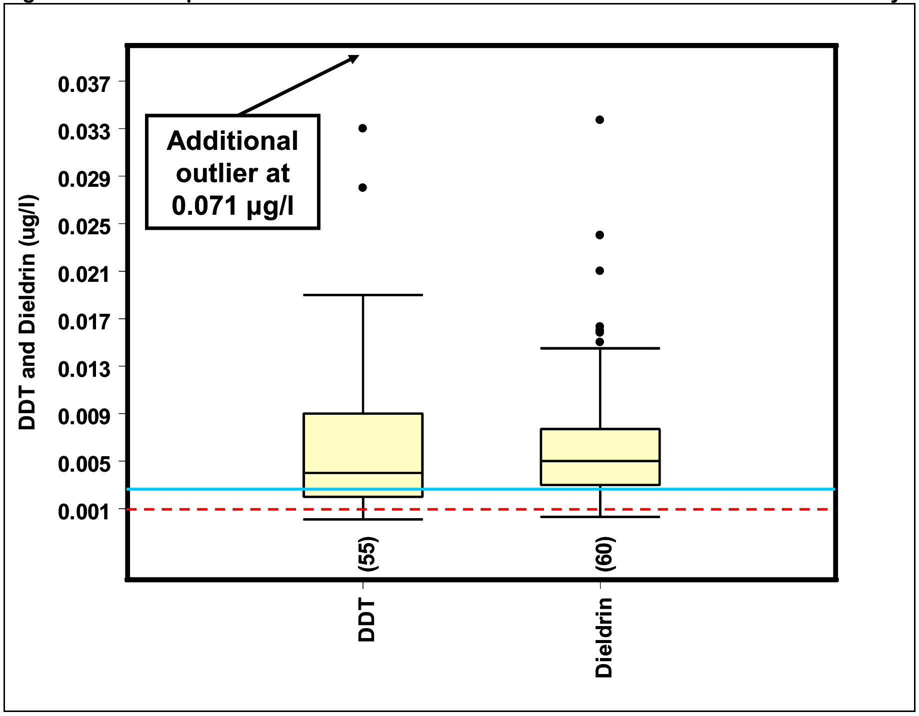
Most recently, ODEQ conducted sediment and fish tissue sampling at a number of locations in the Johnson Creek watershed during the summer of 2004. Fish tissue levels of DDT and dieldrin were relatively low, generally below national baseline levels. For example, the highest concentration found in fish tissue in Johnson Creek was 15 ug/kg, compared to a national baseline level of 29 ug/kg. These levels do not appear to present an unacceptable risk to fish-eating birds. Human fish consumption risks were not evaluated directly because of the absence of edible fish species. Given the lack of recent data showing problematic fish tissue concentrations and the fact that the 303(d) listings were based upon exceedance of the chronic fresh water criteria, ODEQ chose to base this TMDL analysis (and allocations) on the attainment of the fresh water chronic criteria for DDT and dieldrin. For this phase of the TMDL process it will be assumed that if the Table 20 chronic criteria for the protection of aquatic life are not violated, then fish tissue concentrations will also be below levels necessary to demonstrate impairment of beneficial uses. As noted above, fish tissue concentrations are relatively low under current conditions, yet this TMDL requires significant (77 – 94%) reductions to current sources (See "Allocations" section, below). ODEQ believes that the more stringent criteria designed to protect water and fish ingestion will ultimately be achieved through the current TMDL allocations coupled with natural attenuation. See discussions below on historic versus current sampling results and water quality standards attainment analysis for more information on how the water and fish ingestion criteria will be achieved. Continued monitoring will be necessary to track progress toward achieving the allocations as well as tracking long-term attenuation of legacy pesticides.

Deviation from Water Quality Standards

The discussion of DDT and dieldrin concentrations that follows uses box and whisker plots to represent distributions of sample concentrations. Boxplots displayed in this TMDL were generated using a variable number of sample results from each sampling location (number in parentheses at bottom of boxplot). For example, fifty-five DDT and sixty dieldrin samples are represented by the boxplots in **Figure 5.119**.

Dieldrin and DDT data collected from all sites in the watershed between 2001 and 2003 were analyzed and are presented in box plot format in **Figure 5.119**. Overall, violations of water quality standards were common for both DDT and dieldrin, with median concentrations well above the 0.001 µg/l freshwater chronic criterion for DDT (dashed red line) as well as the 0.0019 µg/l criterion established for dieldrin (blue line).

Figure 5.119. Boxplots of DDT and Dieldrin Concentrations in Johnson Creek and Kelley Creek



Based upon an evaluation of the data presented in **Figure 5.119**, ODEQ determined that concentrations of dieldrin and DDT observed during the 2001-03 sampling period were NOT significantly different at the 95 percent confidence interval using both the t-test (following log transformation and assuming unequal variances) and the Mann-Whitney "U" test. In other words, the concentrations of DDT and dieldrin observed in Johnson Creek are effectively equal. Since the aquatic life criterion for dieldrin is nearly twice that of DDT and their chemical behaviors are quite similar, ODEQ assumes that allocations and/or surrogate measures developed to meet the DDT criterion will also be protective of the dieldrin criterion. Additionally, ODEQ is proposing to adopt the USEPA-recommended dieldrin chronic freshwater criterion of 0.056 µg/l (USEPA 2002). Dieldrin concentrations in all samples collected during the 2001-03 sampling period were less than 0.056 µg/l. Given this, and as a matter of practicality, some analyses presented in subsequent sections of this document and the allocations assigned to sources will largely focus on DDT and, where appropriate, the surrogate measure of Total Suspended Solids.

Comparison of Historic and Current Sampling Results

The presence of organochlorine pesticides in the surface waters of Johnson Creek has been documented by several distinct monitoring efforts conducted in the watershed since 1989. Historical investigations conducted by the USGS (Edwards and Curtiss, 1993 and Harrison et al., 1995) revealed levels of organochlorine pesticides well above state and federal water quality standards.

The USGS conducted a study using semi-permeable membrane devices in the Lower Columbia River Basin that included one site on Johnson Creek. Sampling was conducted during late-summer, low-flow conditions in 1997, and again during high-flow conditions in 1998. The Johnson Creek monitoring site was located near the mouth at the Milwaukie USGS flow monitoring gage (RM 0.7). The results of this monitoring were not considered directly in the TMDL development process, but confirmed the presence of organochlorine pesticides in Johnson Creek at concentrations that violate water quality standards during both high- and low-flow conditions (McCarthy and Gale, 1999).

More recent pesticide water quality monitoring has been conducted by the City of Portland, USGS and ODEQ. The City of Portland conducted an independent investigation within the Kelley Creek area of the Johnson Creek Watershed, collecting and analyzing approximately 24 water samples between January 2002 and January 2003.

Additional sampling was conducted by the USGS as part of the TMDL development process, with cooperation and financial support from the cities of Portland, Gresham, and Milwaukie, and Clackamas and Multnomah Counties. Approximately 33 samples were collected in the mainstem of Johnson Creek and 10 samples were collected at two stormwater discharge points in the watershed during a storm event in March 2002 (**Figure 5.120 ,Table 5.42**). ODEQ also collected samples at several locations in Johnson Creek during the winter of 2002. These data, along with the Kelley Creek data collected by the City of Portland, were used to develop the Johnson Creek toxics TMDL.

Figure 5.120. Location of Johnson Creek 2001 – 2003 Toxics Monitoring Sites and Associated Monitoring Agency

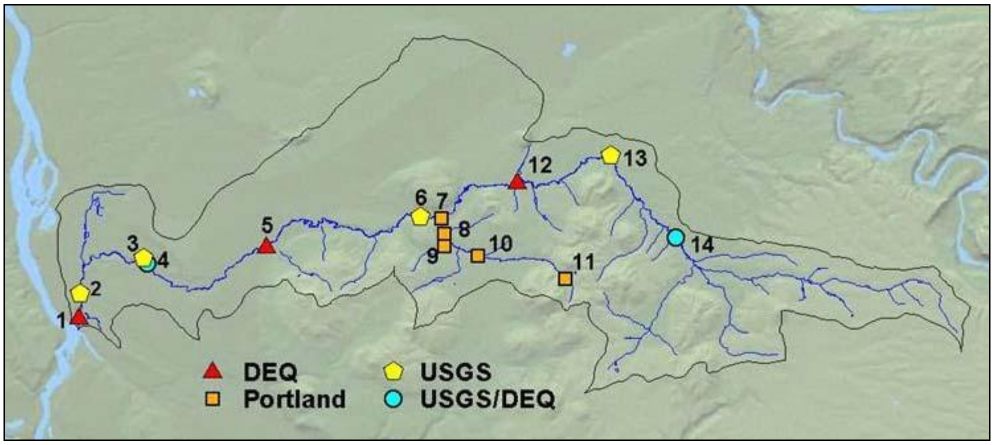


Table 5.42. Johnson Creek 2001- 2003 Toxics Monitoring Location Information

Station #	Site Description	Type	Dates	# of Samples
1	Johnson Cr. at 17th Ave.	Instream / Periodic	12/19/01,1/9/02	2
2	Johnson Cr. at Milport gage	Instream / Storm Event	3/11-3/13/02	6
3	Johnson Cr. near 45th Ave.	Outfall / Storm Event	3/11/02	6
4	Johnson Cr. at 45th Ave. footbridge	Instream / Periodic + Storm Event	12/19/01-3/12/02	6
5	Johnson Cr. at SE 92nd Ave.	Instream / Periodic	12/19/01,1/9/02	2
6	Johnson Cr. at Sycamore gage	Instream / Storm Event	3/11-3/12/02	6
7	Kelley Creek at 159th Ave.	Instream / Periodic	1/7/02-1/29/03	6
8	Kelley Creek at RM 0.5	Instream / Periodic	1/7/02-1/29/03	6
9	Clatsop Creek at mouth	Instream / Periodic	1/7/02-1/29/03	6
10	Kelley Creek at RM 1.2	Instream / Periodic	1/7/02-1/29/03	6
11	Kelley Creek at RM 2.5	Instream / Periodic	1/7/02-1/29/03	6
12	Johnson Cr. at SE 190th Ave.	Instream / Periodic	12/5/01-1/9/02	3
13	Gresham City Park	Outfall / Storm Event	3/11/02	4
14	Johnson Cr. at Palmblad Rd.	Instream / Periodic + Storm Event	12/5/01-3/12/02	8

Comparison of current and historic levels of DDT and dieldrin concentrations in Johnson Creek shows that levels have decreased significantly between the 1989-94 and 2001-03 sampling periods (**Figures 5.121** and **5.122**). As discussed above, DDT and dieldrin have a strong affinity for sediment and degrade at some rate over time. In order to assess this degradation rate between the 1989-94 and 2001-03 sampling periods, both sets of data were normalized for TSS concentration. Since TSS levels were higher during the 1989-94 sampling period (**Figure 5.123**), it is possible that the lower DDT and dieldrin concentrations seen in recent sampling efforts simply reflect the difference in TSS concentration and not necessarily a *reduction in the amount of DDT and/or dieldrin per unit of TSS*. By normalizing the data for TSS the reduction of DDT and dieldrin becomes evident.

ODEQ first established that the old and new TSS-normalized toxics data were significantly different at the 95 percent confidence interval using both the t-test (following log transformation and assuming unequal variances) and the Mann-Whitney "U" test. This statistical analysis showed that the normalized data from the 2001-03 sampling period were significantly lower than data collected during the 1998-94 sampling period. The results show that pesticide concentrations in Johnson Creek are decreasing over time for a given concentration of TSS. Comparison of the median values of the normalized data reveals a 74% reduction in DDT concentrations between the two sampling periods. A similar reduction in dieldrin concentrations was observed. While the reduction observed is encouraging, it may not be appropriate to *predict* a rate of reduction based upon the 74% reduction observed between 1989-94 and 2001-03 because the rate of pesticide decay may not be linear over time. DDT is highly persistent in soils, with a reported half life of 2-15 years, and there are clear indications that its breakdown can take much longer than originally anticipated (Hitch and Day, 1992). However, these results suggest that DDT and dieldrin concentrations have decreased significantly over a 10-year time period.

Summary statistics of DDT and dieldrin concentrations measured during the 1989-94 and 2001-03 sampling periods are provided in **Table 5.43**.

Figure 5.121. Boxplots Showing Historic and Current Dieldrin Concentrations at Johnson and Kelley Creek Monitoring Locations.

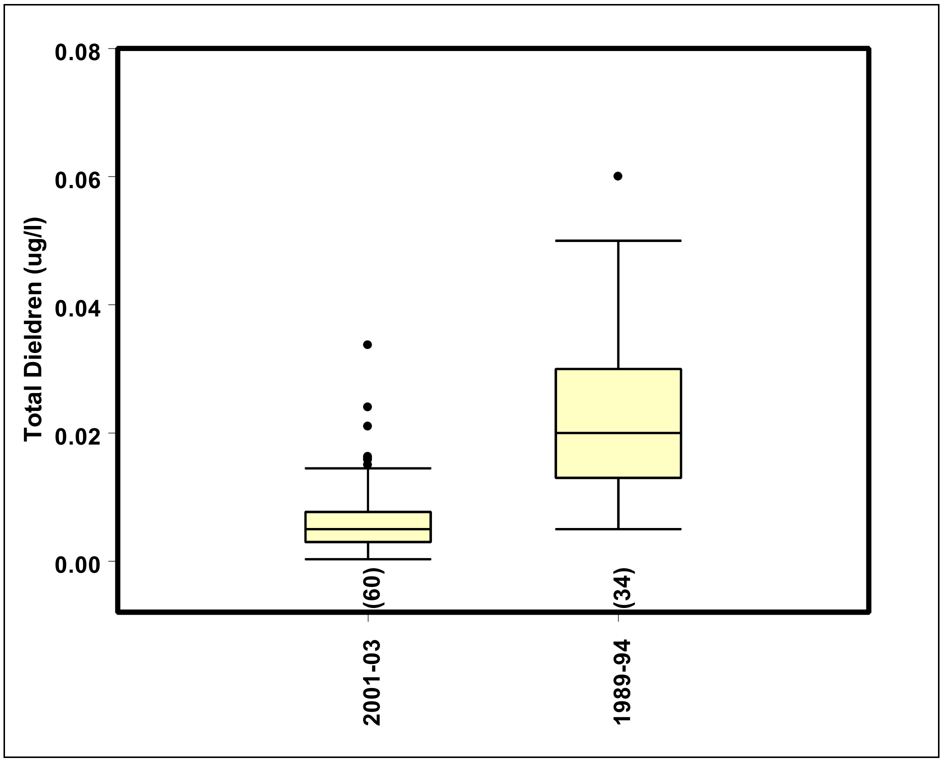


Figure 5.122. Boxplots Showing Historic and Current DDT Concentrations at Johnson and Kelley Creek Monitoring Locations.

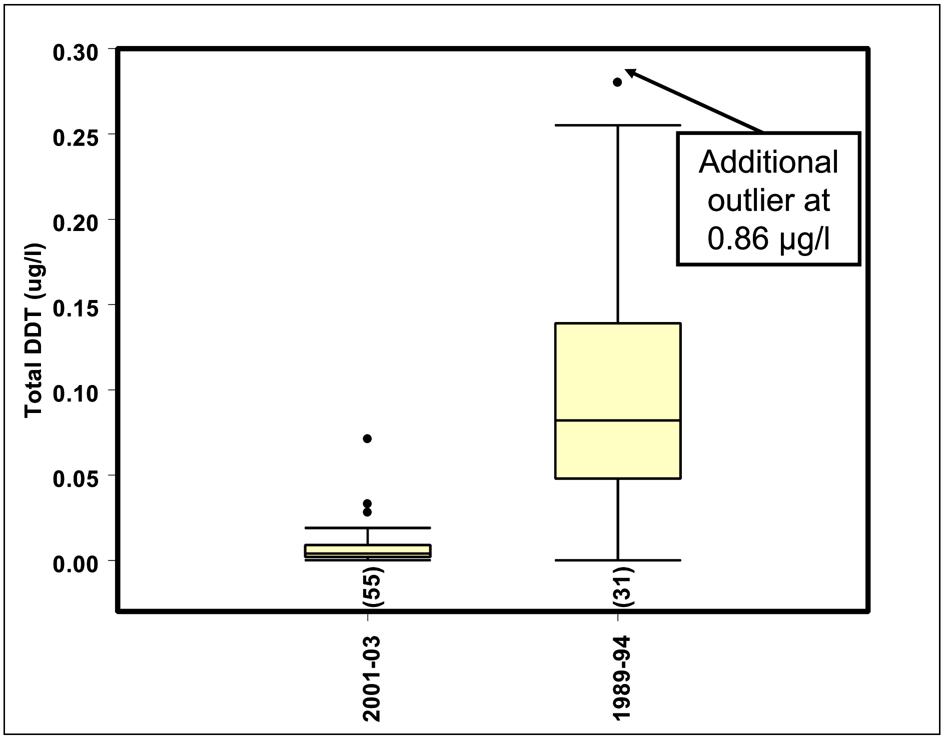


Figure 5.123. Boxplots Showing Historic and Current TSS Concentrations at Johnson and Kelley Creek Monitoring Locations.

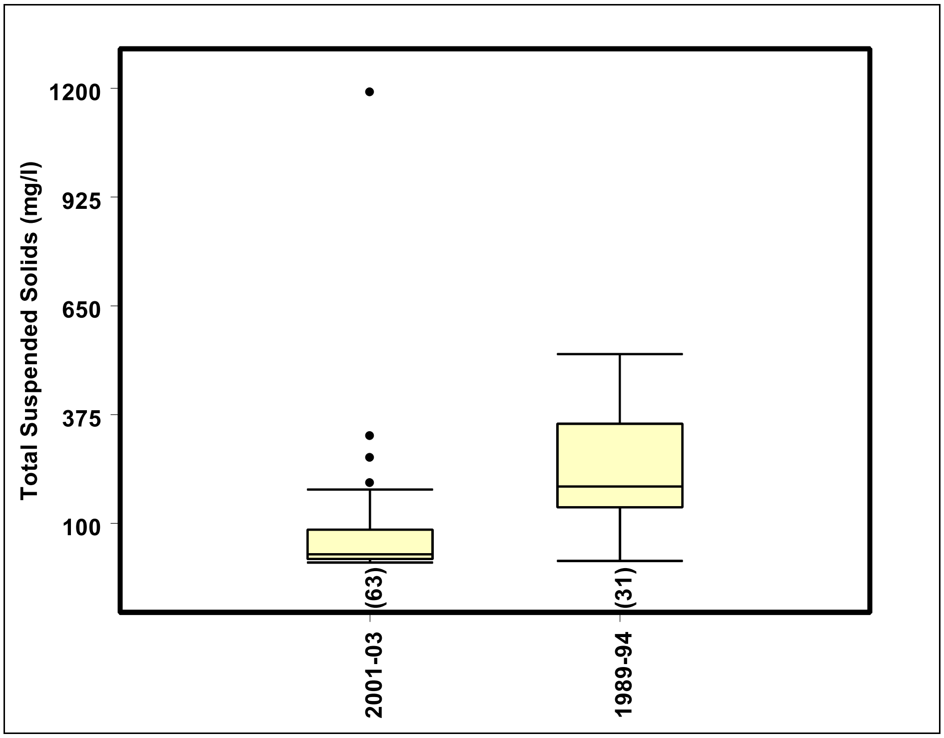


Table 5.43. Summary of Johnson and Kelley Creek DDT and dieldrin Concentrations (µg/l)

DDT		
	2001-03	**1989-94**
Mean	0.0075	0.1187
Median	0.004	0.082
Minimum	0.0001	0.002
Maximum	0.071	0.86
DIELDRIN		
	2001-03	**1989-94**
Mean	0.0070	0.0223
Median	0.0053	0.020
Minimum	0.00026	0.005
Maximum	0.0337	0.06

Surrogate Measures

The Johnson Creek Watershed toxics TMDL incorporates measures other than "*daily loads*" to fulfill requirements of §303(d). Rather than specifying a daily load of DDT and dieldrin, pounds per day of TSS may be identified as a surrogate measure for the loading capacity of the watershed. Based upon an evaluation of the linear regression presented in **Figures 5.124** and **5.125**, ODEQ determined that an instream TSS concentration of 15 mg/l is necessary to achieve the goal of protecting the 0.001 µg/l fresh water chronic DDT criterion. The linear regression is based upon 63 samples and shows a good relationship between the total DDT and TSS measured at instream sampling locations throughout Johnson Creek.

The same procedure was applied to the 10 samples collected from stormwater pipes during the March 2002 storm event in order to evaluate whether a TSS surrogate measure for urban stormwater is appropriate (**Figures 5.126** and **5.127**). The TSS target identified for stormwater was 20 mg/l. However, as shown in **Figure 5.128**, a considerable amount of uncertainty is associated with this target. Clear differences were observed between the instream and water outfall monitoring data sets, showing that the 20 mg/l TSS target determined using the linear regression analysis is inappropriate.

The stormwater monitoring results showed **no** detections for dieldrin, while virtually all instream sampling results showed measurable levels. Additionally, 6 out of 10 stormwater samples were below the DDT detection limit (generally 0.001 µg/l) where only 8 of 63 instream samples were below the detection limit. **Figure 5.127** shows that stormwater sampling resulted in non-detect values at TSS concentrations of up to 86 mg/l. The highest instream concentration of TSS associated with a non-detect value was 28 mg/l. Lastly, the application of a linear regression on stormwater data where only 4 samples had detectable amounts of DDT is potentially problematic. For these reasons ODEQ chose not to assign a TSS surrogate for urban stormwater at this time, but to express wasteload allocations as a percent reduction of DDT.

The analytical costs for organochlorine pesticide sampling are quite high relative to the cost of measuring TSS. ODEQ expects that urban stormwater management agencies will initially focus on achieving the percent reduction allocation given in this TMDL through DDT analysis, while simultaneously developing a more robust data set with which to re-evaluate the TSS surrogate measure allocation. Towards this end, ODEQ is funding a monitoring project that will further characterize both urban stormwater and rural nonpoint contributions of organochlorine pesticides. The Johnson Creek Watershed Council, with cooperation and financial support from local stakeholders, applied for and received funding for the project through ODEQ's 319 Grant Program. Sampling began in the fall of 2003 and was completed in June, 2004. Approximately five samples were collected at up to fifteen locations in the watershed over a 12-month monitoring period – providing an additional 60 samples with which to strengthen the pesticide/TSS relationships in the future.

Figure 5.124. Linear Regression with 95% Confidence Limits Showing Relationship between Recent DDT and TSS Concentrations Observed in Johnson Creek – Y Intercept Set to Zero

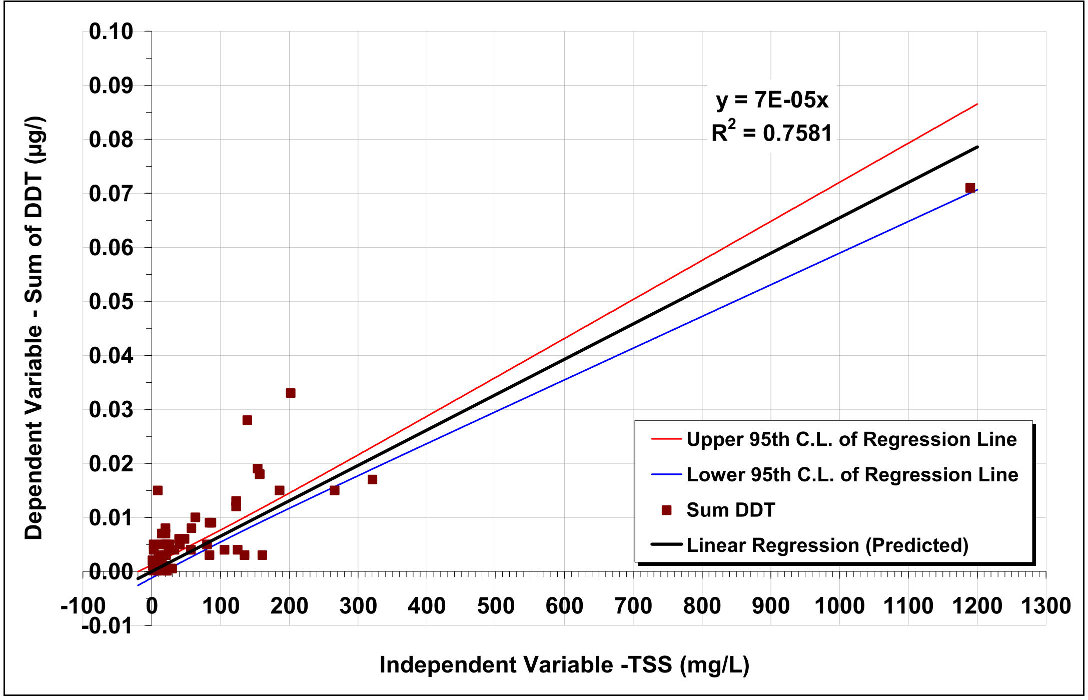


Figure 5.125. Linear Regression depicted above, "zoomed" to show predicted range of TSS necessary to achieve chronic DDT criterion

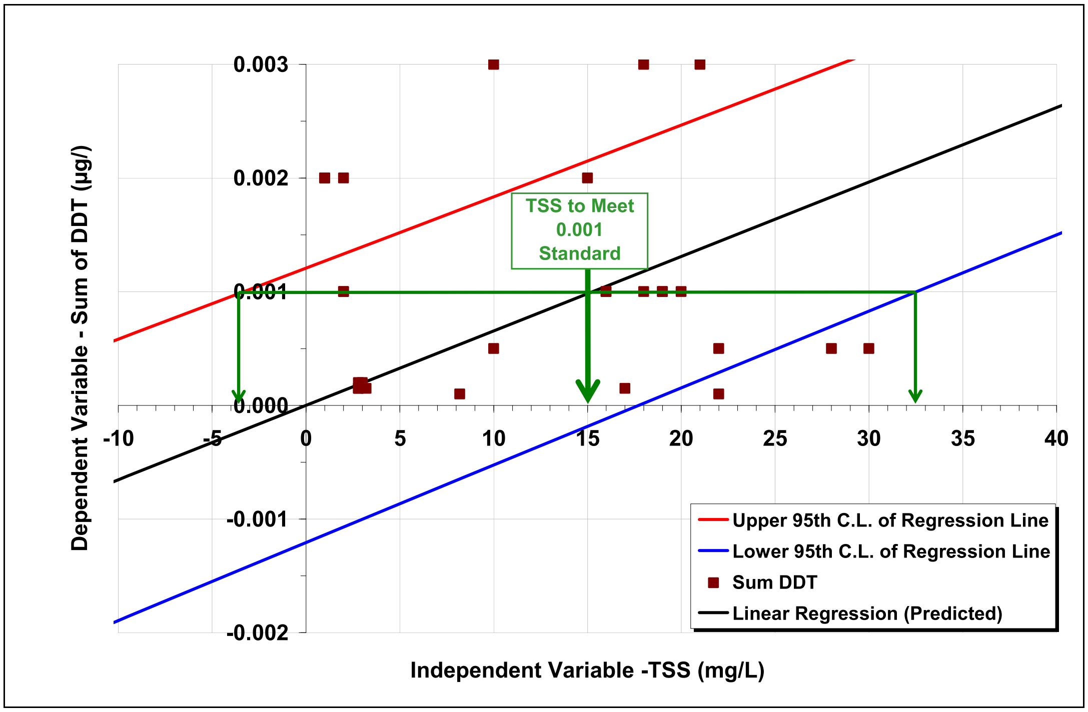


Figure 5.126. Linear Regression Showing Relationship between Recent DDT Concentrations Observed in Stormwater Outfall Monitoring

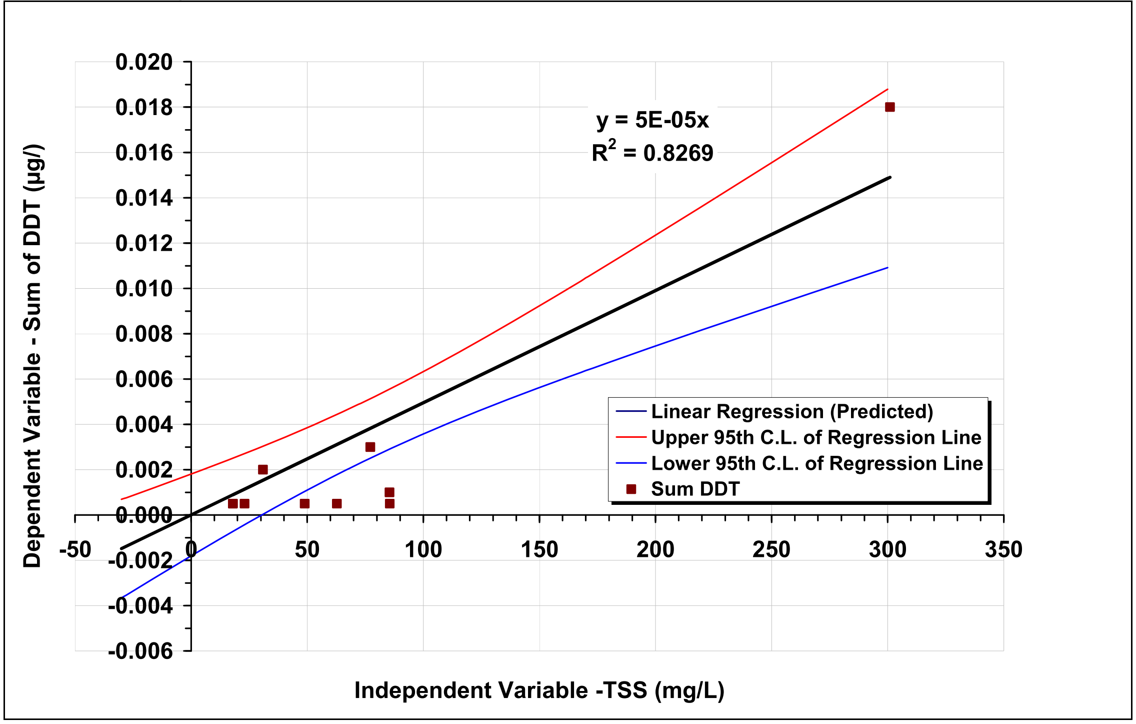
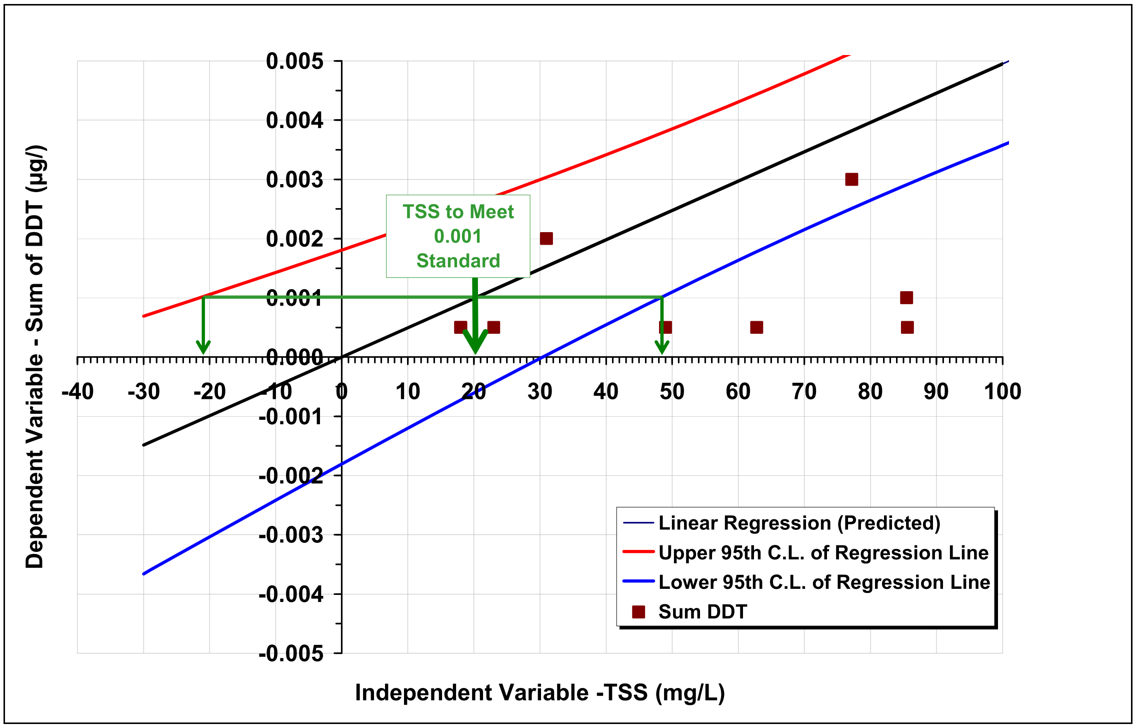
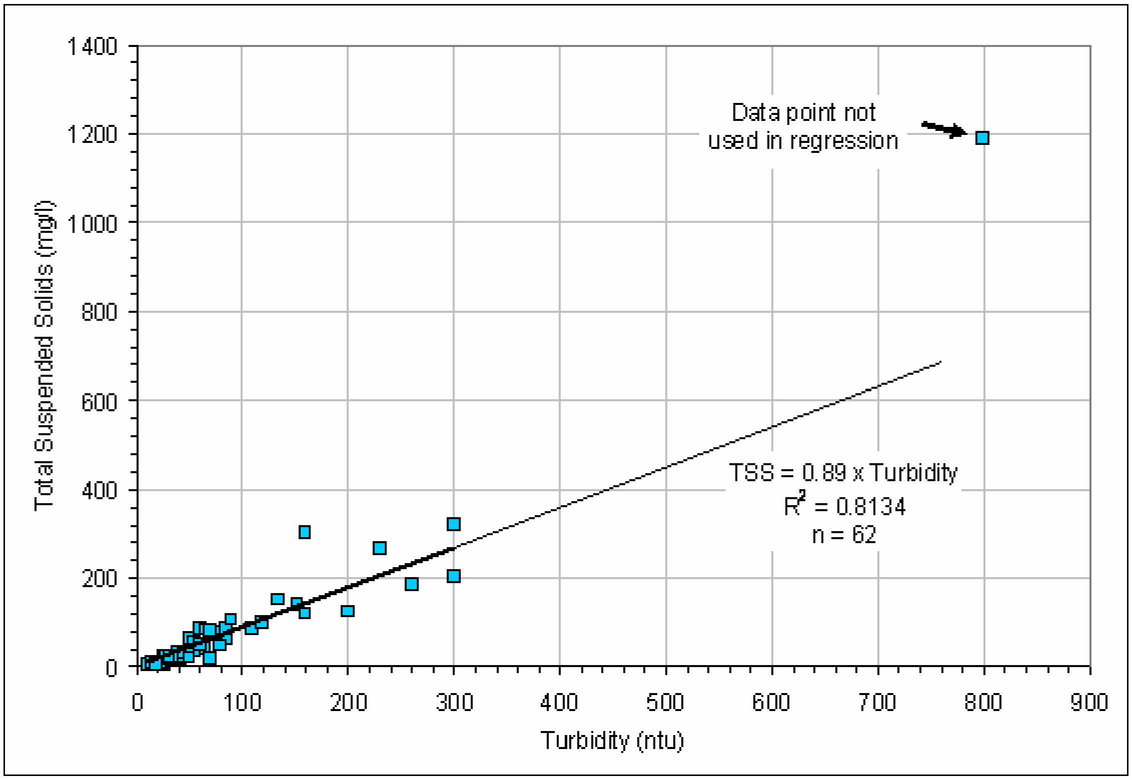


Figure 5.127. Linear Regression depicted above, "zoomed" to show predicted range of TSS necessary to achieve chronic DDT criterion



Lastly, **Figure 5.128** depicts the relationship between TSS and turbidity for sixty-two samples collected in Johnson Creek during the 2001-02 sampling period. The relationship appears strong, which suggests that turbidity may also be considered as an instream surrogate measure for DDT. One potential advantage of using turbidity as a surrogate measure is that it can be measured continuously instream using automated equipment. Analysis of continuous turbidity data could help prioritize TMDL implementation efforts by identifying particular times of year, flow conditions, precipitation conditions, etc. that tend to result in standards violations, allowing stakeholders to implement more effective Best Management Practices.

Figure 5.128 Linear Regression Showing Relationship Between 2001 – 2002 TSS and Turbidity Data– Y Intercept Set to Zero



Sources of Toxic Pollutants

As noted by Joy (2002), agricultural interests likely used DDT and dieldrin/aldrin on crops, livestock operators may have used these pesticides to reduce pests around herds and railroads and warehouses were commonly fumigated with DDT to eliminate pests. Local mosquito control districts commonly used DDT in fields, streets and on waterways.

Dieldrin and DDT enter surface waters in the Johnson Creek watershed primarily through the erosion and transport of contaminated soils. Transport of these soils is likely dominated by soil erosion driven by water, but atmospheric transport due to wind is also a possible mechanism by which contaminated soils enter surface waters. Lastly, since much of the lower watershed is heavily urbanized, the contribution of pesticide-laden sediments via urban stormwater was identified as a potential source to Johnson Creek.

One of the goals of the recent TMDL-related DDT and dieldrin monitoring effort was to differentiate between the contribution of organochlorine pesticides entering Johnson Creek from point and nonpoint sources. Instream monitoring locations, principally the uppermost site at Palmblad Road (**Figure 5.120, Table 5.42**), were selected to characterize the input from nonpoint sources in the upper watershed (load allocation) and two stormwater outfalls were sampled by the USGS during a winter rain event in March, 2002 in an attempt to characterize organochlorine pesticide loading from point sources (wasteload allocation). As discussed above, the results of the stormwater outfall sampling were somewhat inconclusive. ODEQ collected additional samples during the winter of 2001-02 to compliment the storm event sampling conducted by the USGS. ODEQ sampling was intended to characterize general winter conditions, whereas the USGS monitoring was intended to characterize a storm event. Since DDT and dieldrin have a strong affinity for soil particles, the study design included concurrent TSS and organochlorine pesticide measurements.

Recent instream monitoring as well as historic instream, bed sediment and crayfish tissue monitoring results indicate that a substantial load of TSS and organochlorine pesticides appears to come from the upper portions of the watershed where agricultural land uses dominate. **Figures 5.128** and **5.129** show that both DDT and dieldrin concentrations were highest at the Palmblad Road monitoring location, the uppermost in the watershed. Recall that Edwards (1993) noted that organochlorine pesticide concentrations in stream bed sediments were highest at a location just downstream from the Palmblad Road monitoring site and that sediment and crayfish data collected by ODEQ (1994) also followed this pattern.

Figure 5.128 shows DDT concentrations decrease significantly downstream from the Palmblad Road monitoring location. This decrease may be explained by the fact that the gradient of Johnson Creek also decreases below the Palmblad Road site, slowing the water and increasing the potential for in-channel deposition of organochlorine pesticide-laden sediments (**Figure 5.130**). The decrease may also be explained by dilution from stormwater and/or lower tributaries. It is unknown what portion of DDT measured in Johnson Creek during high flow periods is due to re-suspension of previously deposited bed sediments.

Figure 5.128. Boxplots Showing Concentrations of DDT Observed in Johnson Creek during the Winter of 2001-02

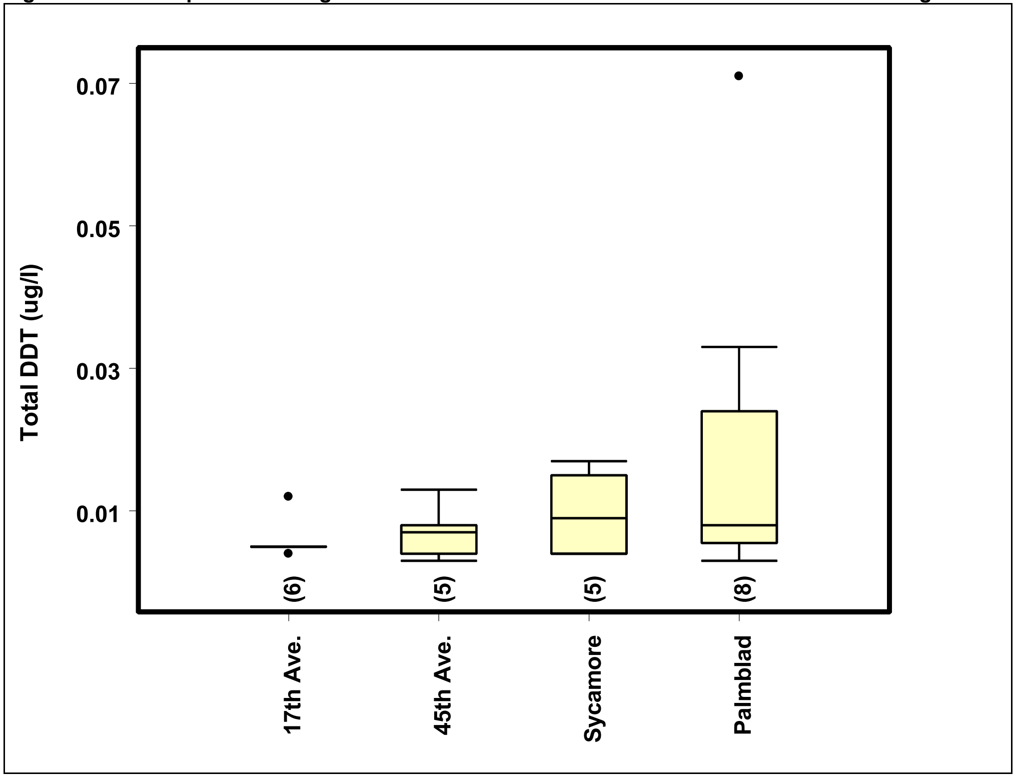


Figure 5.129. Boxplots Showing Concentrations of Dieldrin Observed in Johnson Creek during the Winter of 2001-02

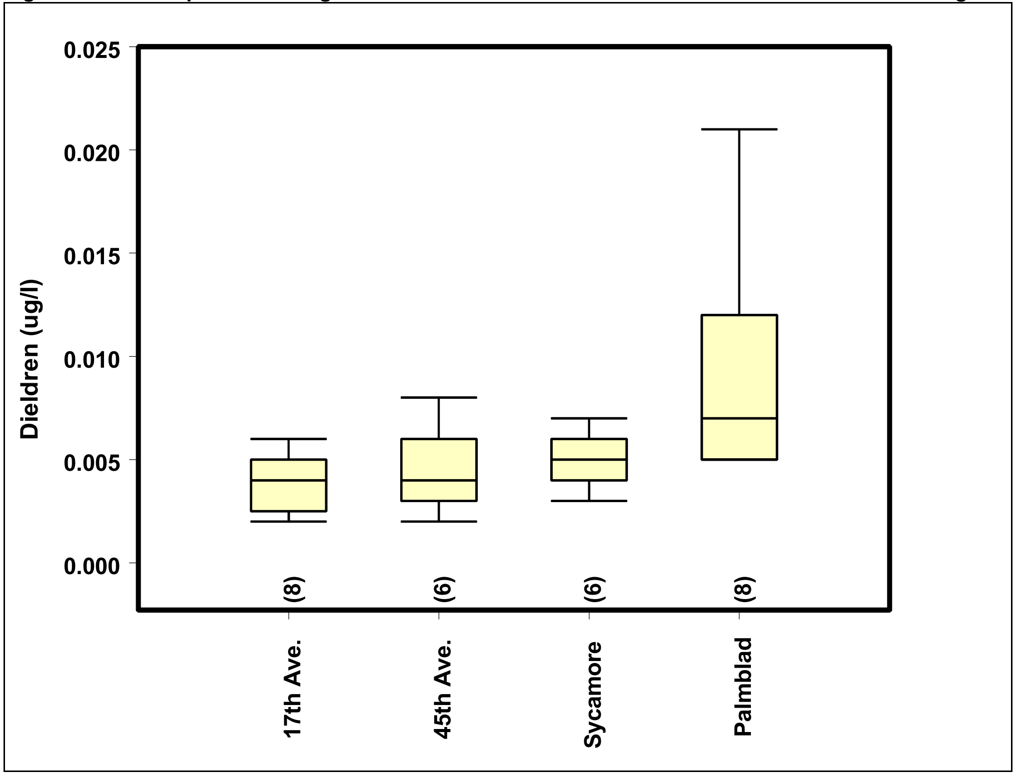
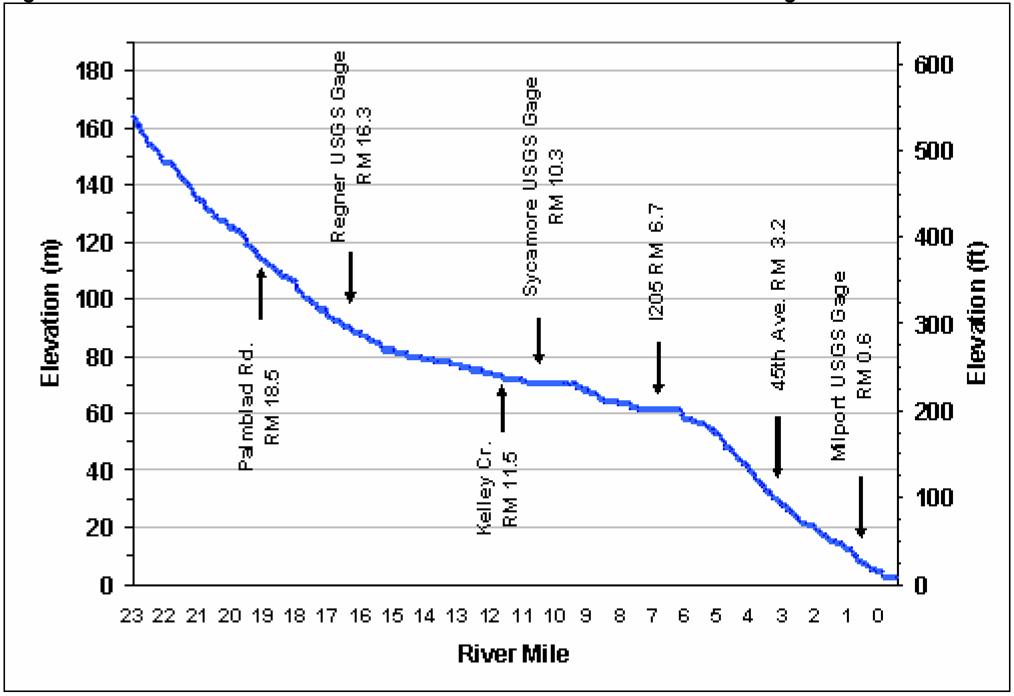


Figure 5.130. Johnson Creek Stream Surface Elevation and Toxics Monitoring Locations



Seasonal Variation and Loading Capacity

Load duration curves showing the surrogate measure of TSS relative to flow and rainfall conditions were used to describe the seasonal variation and loading capacity of Johnson Creek. TSS sampling events at several long-term monitoring locations in the watershed were paired with rainfall data using the same methodology that was used for the bacteria TMDLs in this chapter. Again, ODEQ assumed that runoff would occur when the average rainfall on the day of the sampling event and the day before the sampling event was greater than 0.2 inches. Sampling events during high flow periods and on days when appreciable rainfall was recorded resulted in higher TSS concentrations. Note that the blue line shown in **Figures 5.131** through **5.134** represents the load necessary to achieve the instream target of 15 mg/l TSS, which ensures that the DDT freshwater chronic criterion is achieved.

TSS values presented in **Figures 5.131** through **5.134** were variously collected during routine instream monitoring as well as TMDL-related special studies by the Cities of Portland and Gresham, the USGS and ODEQ between 1996 and 2002.

Overall, the analysis of seasonal variation indicates, predictably, that high flows and runoff-related loading is a significant source of TSS (and by extension DDT and dieldrin) observed in Johnson Creek.

Figure 5.131. Load Duration Curve showing the TSS loading capacity to achieve the chronic DDT criterion and event loads for Johnson Creek at 17th Avenue

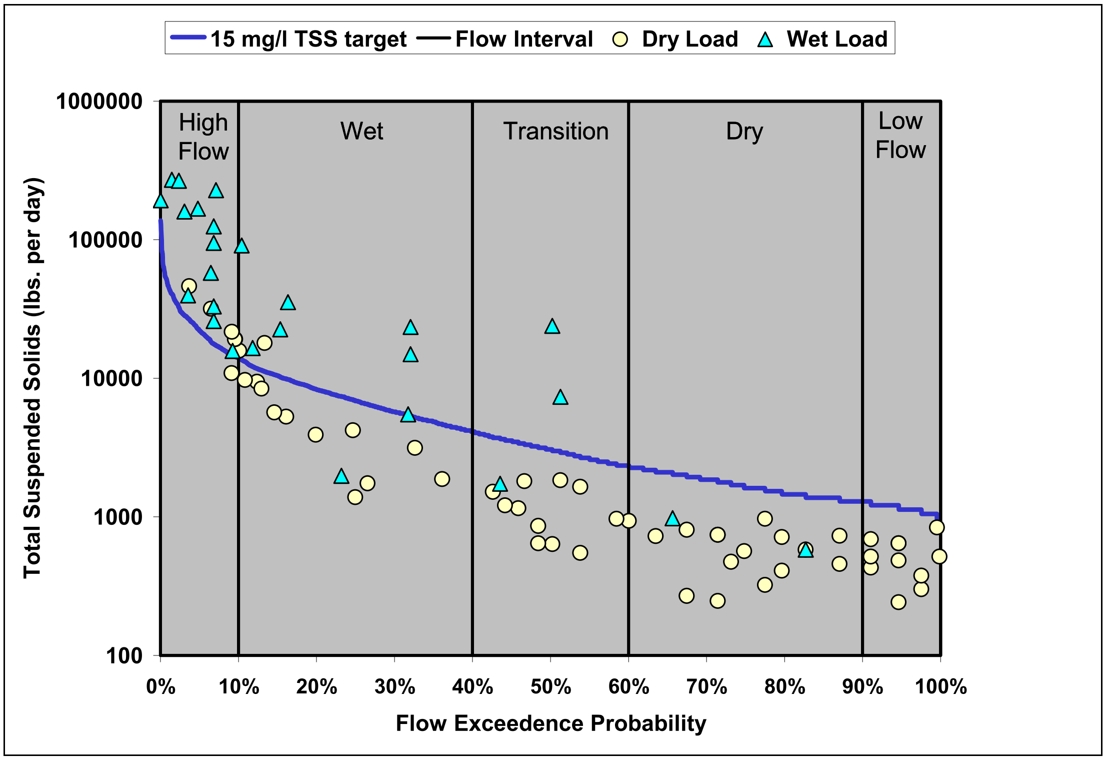


Figure 5.132. Load Duration Curve showing the TSS loading capacity to achieve the chronic DDT criterion and event loads for Johnson Creek at 158th Avenue/Sycamore USGS gage

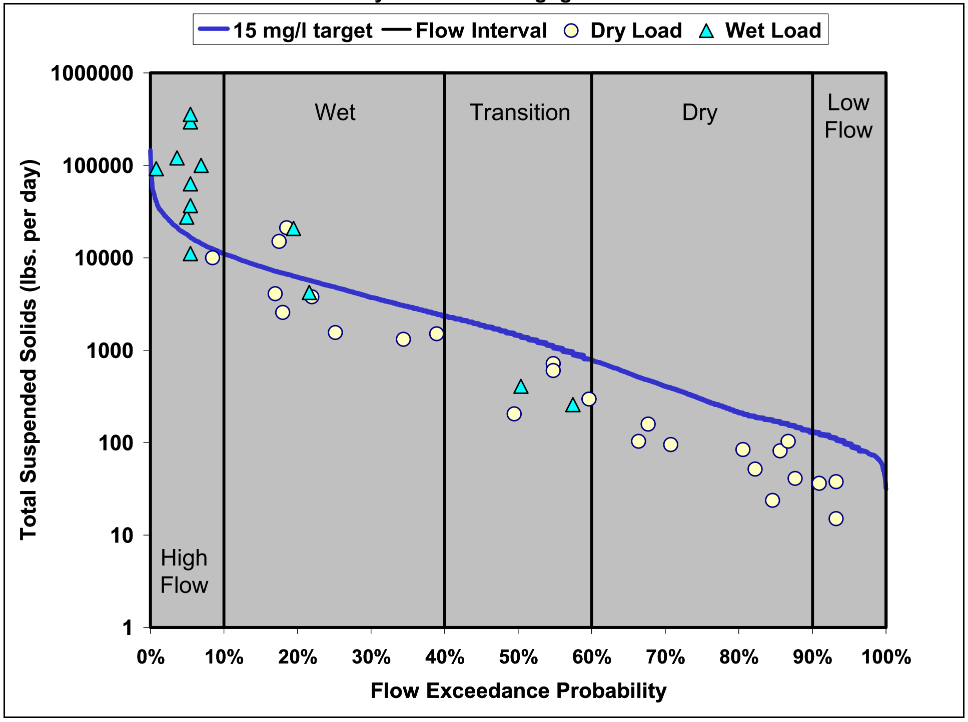


Figure 5.133. Load Duration Curve showing the TSS loading capacity to achieve the chronic DDT criterion and event loads for Johnson Creek at Palmblad Road

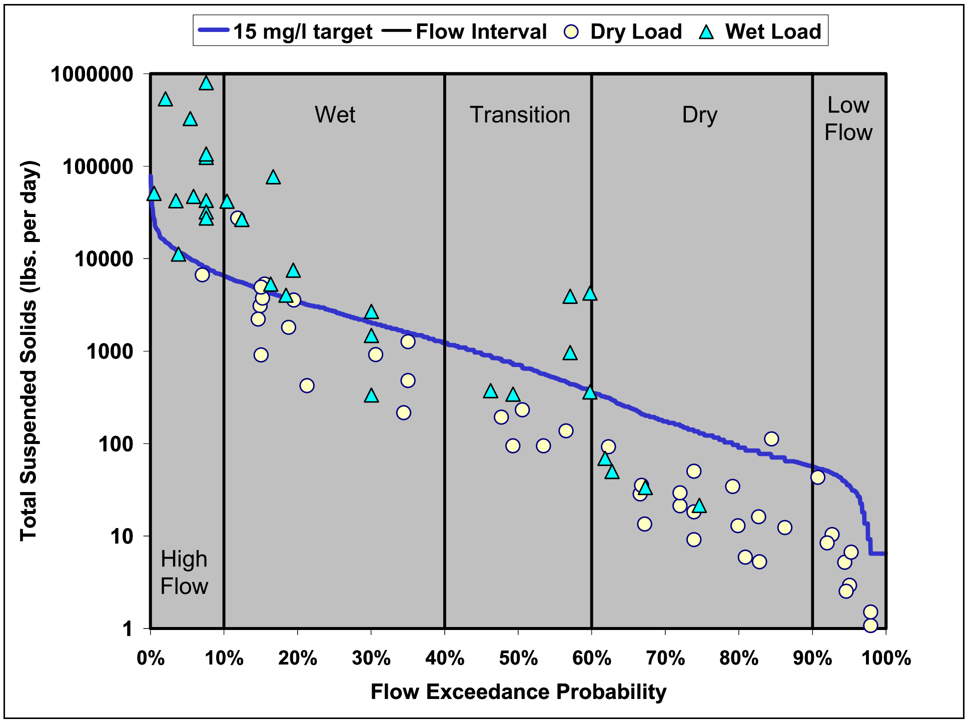


Table 5.44 shows the TSS loading capacity to achieve the DDT criterion under several flow scenarios at four monitoring locations in the watershed. Loading capacities were developed for each of the flow intervals (black vertical lines) delineated within the load duration curves presented in **Figures 5.131** through **5.134**.

Figure 5.134. Load Duration Curve showing the TSS loading capacity to achieve the chronic DDT criterion and event loads for Kelley Creek at 159th

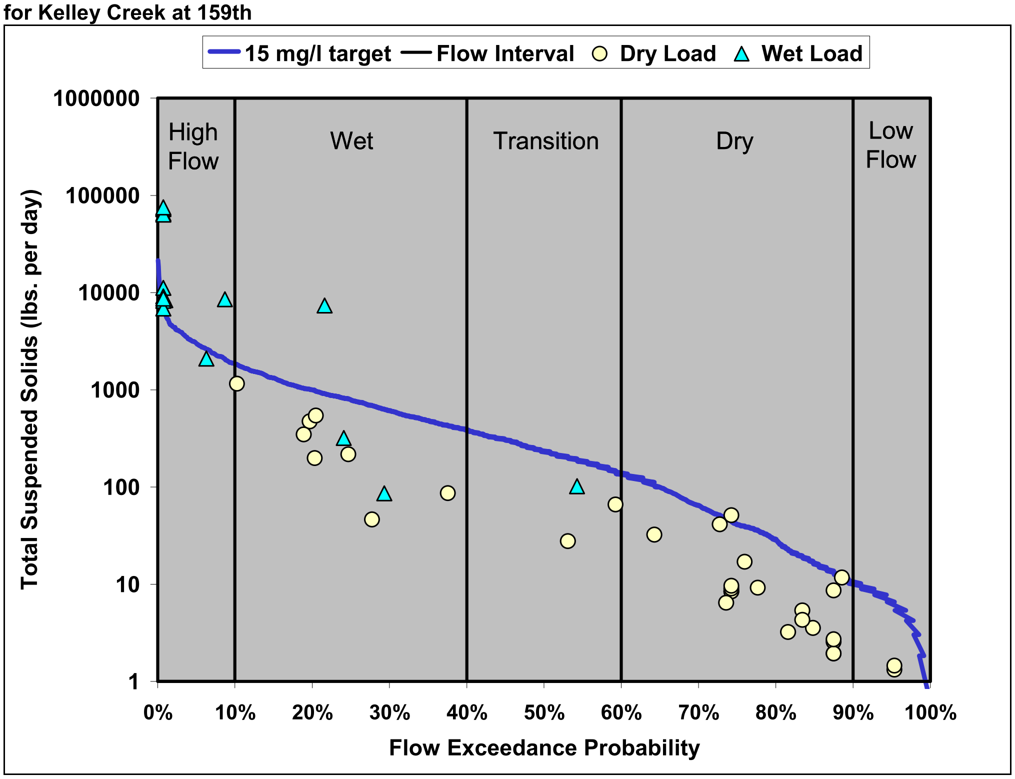


Table 5.44. Flow Based Loading Capacity to achieve the 15 mg/l Total Suspended Solids Surrogate Measure that is Protective of the Chronic DDT Criterion

Flow (cfs)	Flow Exceedance Probability	Load to meet chronic instream DDT criterion expressed as pounds of TSS per day
Johnson Creek at 17th Avenue (Site #1)		
16	90%	1205
29	60%	2184
51	40%	3841
175	10%	13181
Johnson Creek at 158th / Sycamore Gage		
4	90%	301
16	60%	1205
36	40%	2712
150	10%	11298
Johnson Creek at Palmblad Road		
1.6	90%	96
8.5	60%	512
25	40%	1506
115	10%	6929
Kelley Creek at 159th (Site #10)		
0.1	90%	8
1.8	60%	138
5	40%	382
20	10%	1513

Allocations

Allocations are derived either from analyses that determine the amount of total suspended solids that may enter surface waters without causing a violation of water quality criteria or through requiring a percent reduction from current DDT concentrations. Wasteload allocations are expressed as a percent reduction from current concentrations. As described in the Surrogate Measures section above, both a TSS concentration and a percent reduction of DDT may be considered load allocations. Allocations are divided among point sources (wasteload allocations) and non-point sources (load allocations). Urban stormwater is the only point source in the Johnson Creek watershed that is assigned a wasteload allocation. Load allocations may be applied to all nonpoint sources and/or land use categories.

The percent reduction in DDT concentration, determined conservatively by using the 90th percentile of the measured stormwater and instream samples, is **77%** for urban stormwater and **94%** for nonpoint sources (**Table 5.45**). ODEQ believes that this approach is appropriate given the nature of the data considered for this TMDL analysis.

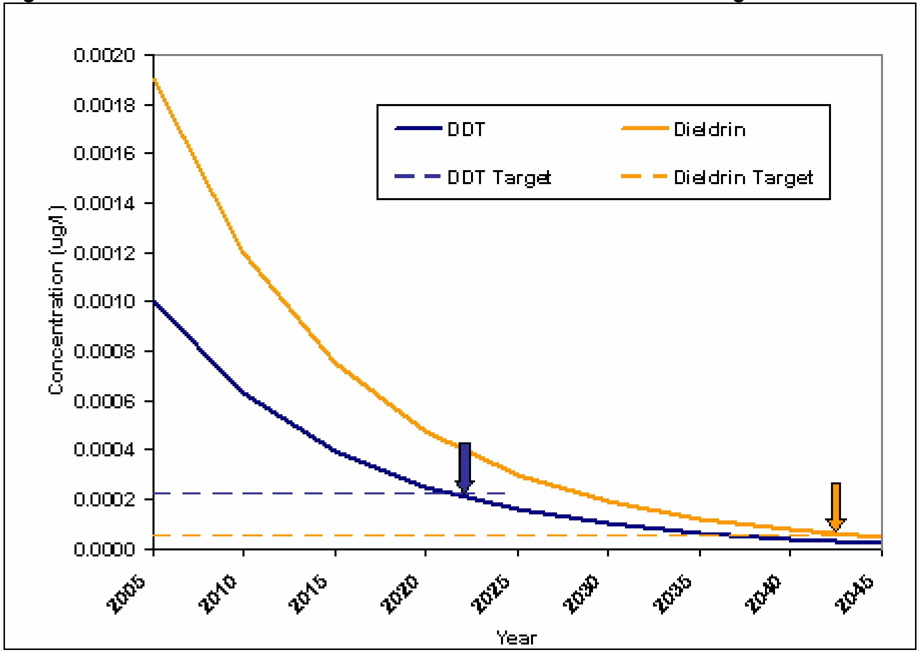
Table 5.45. DDT Load and Waste Load Allocations

Subtable A: NPDES Point Source Waste Load Allocations		
Source Name	**Waste Load Allocation**	
	TSS Target	**DDT Reduction**
Municipal Storm Sewer System	N/A	77%
Subtable B: Nonpoint Sources		
Source Category	**Load Allocation**	
	TSS Target	**DDT Reduction**
All land use categories and sources	15 mg/l	94%

Water Quality Standards Attainment Analysis

Load and wasteload allocations prescribed in this TMDL are designed to achieve the chronic freshwater criteria for DDT and dieldrin in the near term. In addition, ODEQ evaluated when compliance with the more stringent human health criteria is likely to be achieved. As noted above in the section comparing historic and current pesticide concentrations, a 74% reduction in the DDT concentrations per unit of TSS occurred over the last 10 years. In order to evaluate long-term attainment of human health criteria, ODEQ assumed that this rate of decay *is* linear over time and will continue into the future. Coupled with the reductions called for in the TMDL allocations above, ODEQ predicts that the more stringent criteria will be achieved in time. As shown in **Figure 5.135**, the human health criteria are predicted to be achieved by 2025 for DDT and by 2045 for dieldrin. Given the level of uncertainty in this prediction, future monitoring and/or modeling efforts will be needed to confirm that the load reductions and natural attenuation are adequate to achieve the human health criteria for water and fish ingestion.

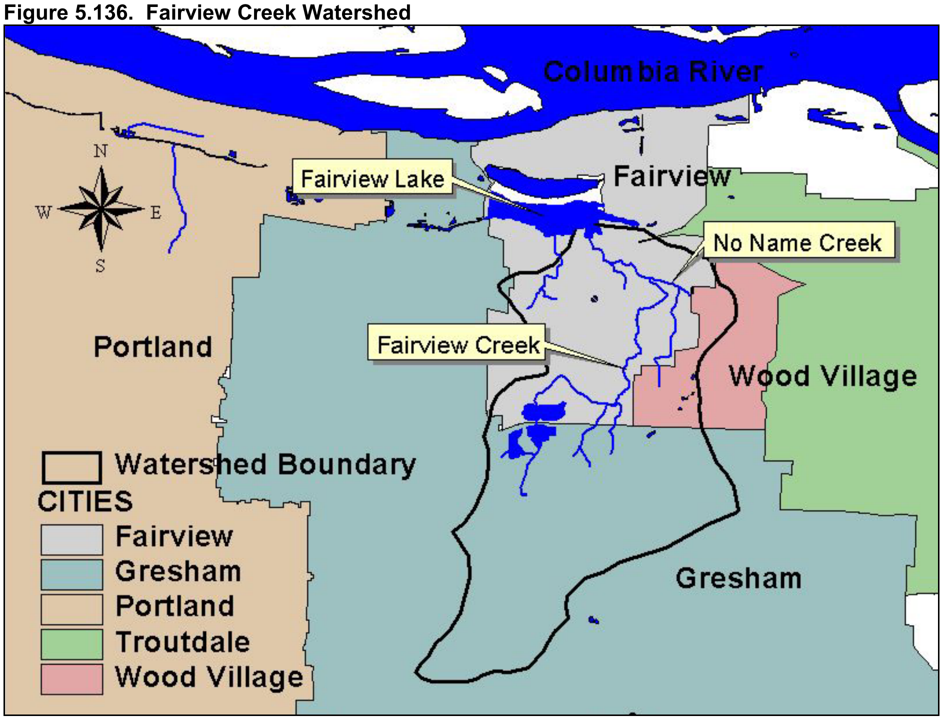
Figure 5.135. Predicted Attenuation Rate and Human Health Criteria Targets.



FAIRVIEW CREEK PH DISCUSSION PAPER

Fairview Creek is a highly urbanized creek that flows through the cities of Gresham and Fairview prior to discharging into Fairview Lake (**Figure 5.136**). The creek is approximately 5.5 miles long and drains a 22,000 acre watershed. No Name Creek, a small tributary that drains portions of the city of Wood Village discharges to Fairview Creek just upstream from Fairview Lake. Fairview Creek is on Oregon's 1998 list of water quality limited waterbodies (303d list) for temperature, bacteria and pH. Temperature and bacteria listings are being addressed through the TMDL development process.

Figure 5.136. Fairview Creek Watershed



Background

Stream pH levels usually fall between 6.5 and 8.5, although wide variations can occur because of local watershed geology. Streams that drain soils with high mineral content usually are alkaline, whereas streams that drain coniferous forests usually are acidic (Allan 1995). Most rainwater has a pH of 5.6 to 5.8, simply due to the presence of carbonic acid (H_2CO_3). The latter is formed from by the interaction of water (H_2O) with atmospheric carbon dioxide (CO_2). Normally these acids are neutralized as rainwater passes through the soil. However, in watersheds with heavy rainfall, little buffering capacity and acidic soils, surface water pH may be largely reflective of the rainwater pH values. Anthropogenic factors including industrial runoff and acid rain may also impact surface water pH within a watershed. Most aquatic organisms, including benthic macroinvertebrates, salmonids and amphibians, are sensitive to pH changes and prefer a pH in the range of 6.0 to 9.0 (USEPA, 1986b).

303(d) Listed Stream Segments

Fairview Creek, from mouth to headwaters, is 303(d) listed due to pH values measuring below the lower criterion of 6.5 pH units during a 1996 water quality study conducted by the City of Gresham.

Beneficial Uses

Oregon Administrative Rules (OAR Chapter 340, Division 41, Table 6) lists the “Beneficial Uses” occurring within the Willamette Basin, including Fairview Creek (**Table 5.46**). Beneficial uses that are generally recognized as occurring in Fairview Creek are marked with a “check”.

Numeric and narrative water quality standards are designed to protect the most sensitive beneficial uses. The pH standard was developed to protect Resident Fish and Aquatic Life, which is the most sensitive beneficial use related to pH occurring in Fairview Creek.

Table 5.46. Beneficial uses occurring in Willamette Basin Tributaries
(OAR 340 – 41 – 442)
Beneficial uses protected by the pH Criteria are marked in gray

Beneficial Use	***Occurring***	***Beneficial Use***	***Occurring***
Public Domestic Water Supply		Salmonid Fish Spawning (Trout)	✓
Private Domestic Water Supply	✓	Salmonid Fish Rearing (Trout)	✓
Industrial Water Supply	✓	Resident Fish and Aquatic Life	✓
Irrigation	✓	Anadromous Fish Passage	
Livestock Watering		Wildlife and Hunting	✓
Boating		Fishing	✓
Hydro Power		Water Contact Recreation	✓
Aesthetic Quality	✓	Commercial Navigation & Transportation	

Target Criteria Identification

The pH standard for the Willamette Basin (OAR 340-41-442) states that pH values shall not fall outside the range of 6.5 to 8.5 pH units. Natural variability outside of the 6.5 to 8.5 pH range is addressed in OAR 340-41-(basin) (3):

> *“Where the naturally occurring quality parameters of waters of the (Basin) are outside the numerical limits of the above assigned water quality standards, the naturally occurring water quality shall be the standard.”*

It should be noted that when natural variability causes values to fall outside the range of pH criteria, there is no remaining assimilative capacity in the waterbody and no anthropogenic change will be allowed.

Data Analysis

Fairview Creek was included on Oregon’s 303(d)list based upon data collected in 1996 by the City of Gresham. Five sites along Fairview Creek were monitored on ten occasions for a variety of water quality parameters, including pH (**Figure 5.137**). One site, (Site 1 – Light Rail Crossing) showed consistently low pH values ranging from 5.5 to 6.2 pH units. Due to the lack of field notes and instrument calibration data, it is difficult to determine the accuracy of these field measurements. At ODEQ’s request, the City of Gresham was asked to review the 1996 data, including QA/QC procedures and whether or not the low pH values were correlated with rainfall events. An analysis by City of Gresham staff shows no correlation between rainfall and low pH. In fact, it appears that the lowest pH measurements were made during periods of little or no rainfall. Gresham did not produce any quality assurance documentation for the data collected in 1996, but did note that Site 1 (Light Rail Crossing) was always the last station sampled during a sampling event and the pH meters used were likely out of calibration.

Sampling Site Descriptions

Monitoring conducted my Metro (1992, 1993) and Gresham (1996, 1999-2003) occurred primarily at the following sampling locations (**Figure 5.137**):

Light Rail Crossing: This uppermost station in the watershed is located at the entry of the culvert conveying Fairview Creek under the Tri-Met light rail crossing just south of Burnside Road and east of Birdsdale Road. Riparian vegetation is primarily Himalayan Blackberry.

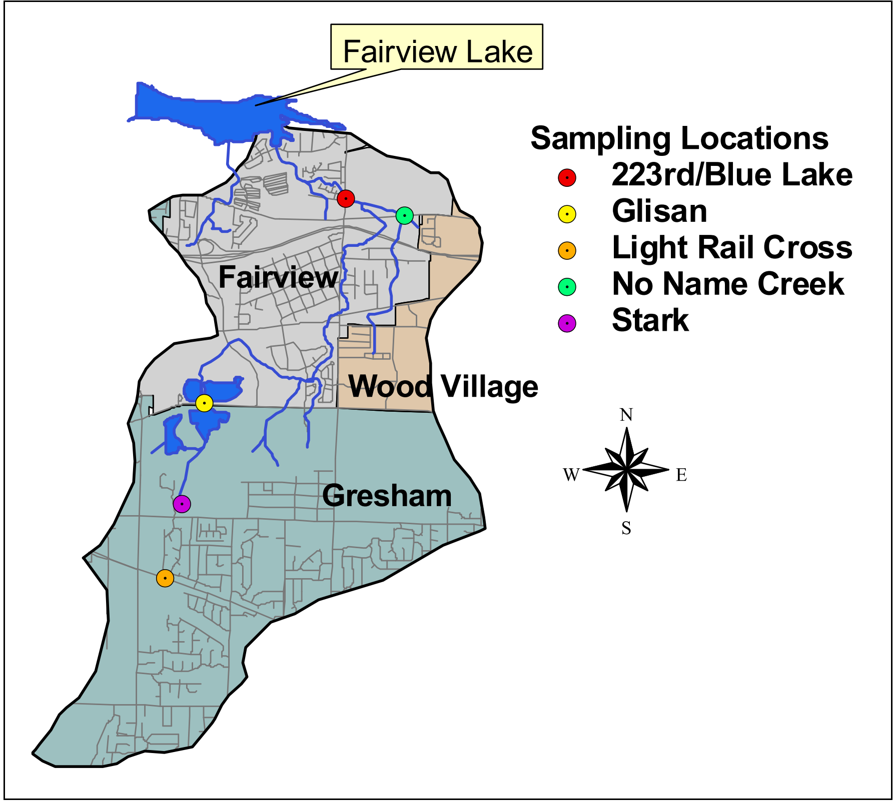
Stark Street: The site is located at the entry of the culvert that conveys Fairview Creek beneath Stark Street east of 198th Avenue. The drainage area is primarily residential with some commercial and open areas. Most of the stream channel has been altered to conform to residential and commercial development, having lost much of its former meanders. Riparian vegetation consists mostly of grasses and blackberries, lacking mature vegetation.

Glisan Street: This site is located at the entrance to the culvert that conveys Fairview Creek under Glisan Street between 201st and 223rd Avenues. The drainage area is mostly brushy land, with some residential and industrial lands. Riparian vegetation offers considerable cover for the majority of this reach. Prior to flowing under Glisan Street, the creek enters an estimated 12-acre pond on the Fujitsu property. During high flows, the creek partially overflows into an adjacent 7-acre pond prior to entering the larger pond. These ponds were originally gravel mining operations but are currently known as the Salish Ponds Wetlands Park. The USGS maintains a staff gage at this site.

No Name Creek: The site is at the upstream side of the culvert that conveys No Name Creek beneath NE Halsey Street.

Blue Lake Road / 223rd Ave.: The sampling site is located upstream of the culvert beneath 223rd. The drainage is predominately residential, with some forest and commercial lands. Until recently a large part of the drainage was agricultural, having been replaced by residential development over the last few years.

Figure 5.137. pH monitoring locations in the Fairview Creek Watershed



pH Data Collected by METRO in 1992 and 1993

METRO, a regional governing body serving the Portland metropolitan area, conducted water quality sampling of Fairview Creek in 1992 and 1993. The 1992 effort collected a total of 33 pH measurements at the Stark Street, Glisan Street and Blue Lake Road sampling sites between May and August (Metro, 1992). Values ranged from 6.8 to 9.0 pH units, with two violations of the upper pH criterion occurring at the Glisan Street station on July 7th (9.0 pH units) and July 23rd (9.0 pH units). No low pH violations were observed. Quality Assurance information is not available for the 1992 data collection effort. However, pH measurements were made using laboratory pH meters rather than with often-troublesome field pH meters. Assuming that sample holding times were within those specified in Standard Methods for the Examination of Water and Wastewater (APHA, 1992), the reported pH values are likely accurate.

Metro repeated sampling in 1993, collecting 33 additional samples at the Stark Street, Glisan Street and Blue Lake Road sampling sites between February and August (Metro 1994). Values ranged from 6.7 to 8.9 pH units, with two violations of the upper pH criterion occurring at the Glisan Street station on March 12th (8.7 pH units) and May 14th (8.9 pH units). No low pH violations were observed. Again, Quality Assurance information is not available for the 1993 data collection effort, but pH measurements were made using laboratory rather than field pH meters.

pH Data Collected by the City of Gresham, 1999-2003

The City of Gresham has been collecting samples at many monitoring locations in the Fairview Creek Watershed in recent years. Since the 303d listings are based upon samples collected in 1996 at the sites listed above in **Table 5.47**, only those sites will be directly scrutinized for this discussion. However, it should be noted that the City made at least 161 pH measurements in the Fairview Creek watershed between November, 1999 and January, 2003. Of those 161 pH measurements, only four (1.8%) fell below the lower pH criterion and five (3.1%) fell above the upper pH criterion. Fairview Creek would not be included on the State's 303d list based upon these monitoring results.

Light Rail Sampling Location

The City of Gresham made 16 pH measurements at the Light Rail sampling site between October 1999 and November 2001 (**Figure 5.138**). One measurement was above the upper criterion (9.0 pH units on 10/27/1999), and one measurement was below the lower criterion (6.1 pH units on 8/21/2001).

Figure 5.138. Light Rail pH measurements – 10/99 to 11/01

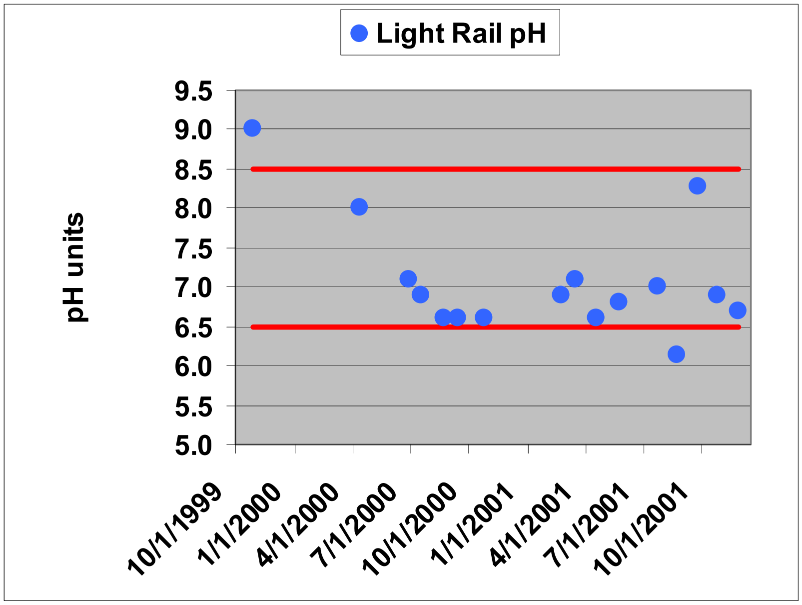


Table 5.47. Fairview Creek Water pH Water Quality Monitoring Results (Various Agencies – 1992-2003)

Site Name	Agency	Year(s) Sampled	Number of Samples	Number of Violations	Notes
Light Rail Crossing	Gresham	1996	10	9 – low pH	Always sampled last
		1999-2001	16	2 – 1 high, 1 low	high: 10/27/99
Stark Street	Gresham	1996	10	3 – low pH	
		1999-2003	37	2 – 1 high, 1 low	high: 10/27/99 low: students
	METRO	1992	11	0	
		1993	11	0	
Glisan Street	Gresham	1996	10	2 – low pH	
		1999-2001	13	2 – high pH	high: 10/27/99
	METRO	1992	11	2 – high pH	
		1993	11	2 – high pH	
No Name Creek	Gresham	1996	10	2 – low pH	
		1999-2001	2	0	
Blue Lake Rd / 223rd	Gresham	1996	9	2 – low pH	
		1999-2003	40	2 – 1 high, 1 low	high: 10/27/99
	METRO	1992	11	0	
		1993	11	0	
TOTAL:		**1996:**	**49**	**18 (37%)**	
		OTHER:	**176**	**12 (6.7%)**	

Stark Street Sampling Location

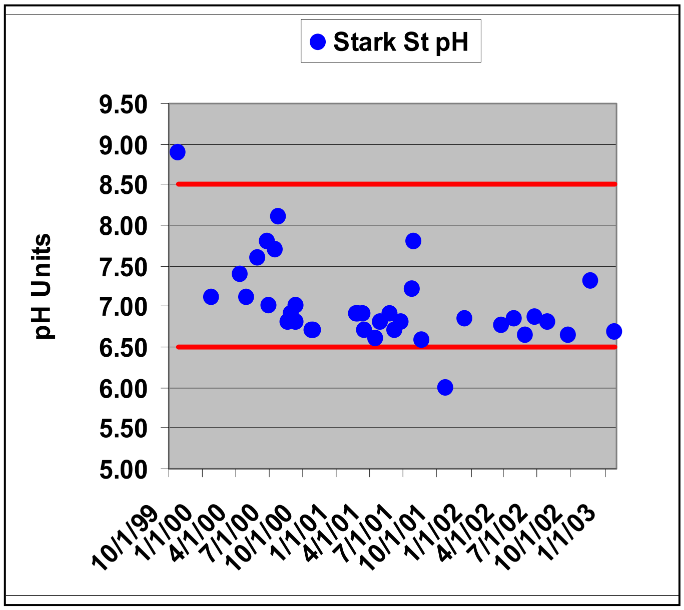


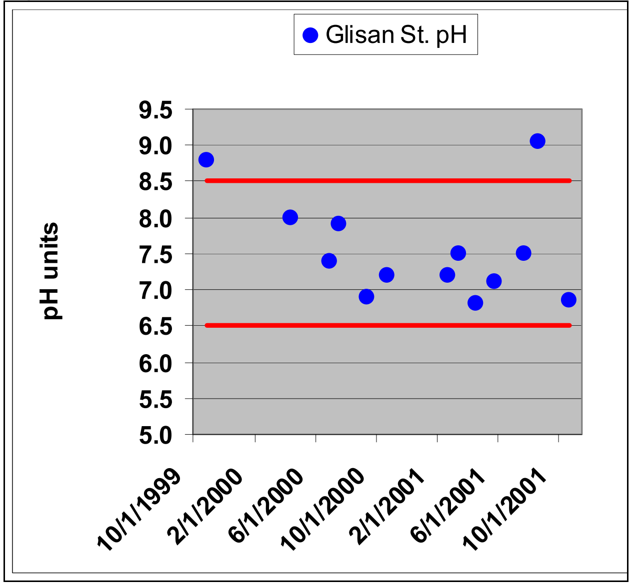
Figure 5.139. Stark Street pH measurements – 10/99 to 1/03

The City of Gresham made 37 pH measurements at the Stark Street sampling site between October 1999 and January 2003 (**Figure 5.139**). One measurement was above the upper criterion (8.9 pH units on 10/27/1999) and one measurement was below the lower criterion (6.0 pH units on 10/23/2001). High School students conducted measurements of pH on 10/23/2001.

Glisan Street Sampling Location

The City of Gresham made 13 pH measurements at the Glisan Street sampling site between October, 1999 and October, 2001 (**Figure 5.140**). Two measurements were above the upper criterion (8. 8 pH units on 10/27/99 and 9.05 pH units on 8/21/2001).

Figure 5.140. Glisan Street pH measurements – 10/99 to 10/01



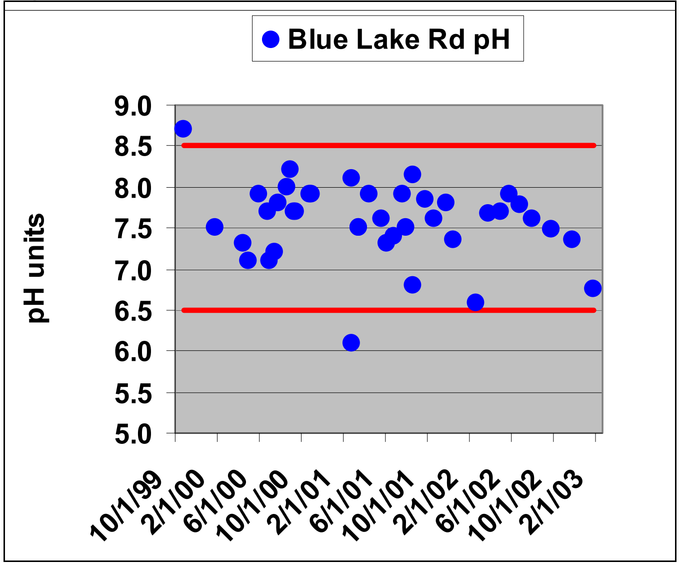
No Name Creek Sampling Location

The City of Gresham has only made 2 pH measurements at the No Name Creek sampling site since the 1996 monitoring that resulted in 303d listing. Measurements of 7.6 and 7.5 pH units were made on 7/24/2001 and 8/21/2001, respectively.

Blue Lake Road Sampling Location

The City of Gresham made 40 pH measurements at the Blue Lake Road sampling site between October, 1999 and February, 2003 (**Figure 5.141**). One measurement was above the upper criterion (8.7 pH units on 10/27/1999) and one measurement was below the lower criterion (6.1 pH units on 2/26/2001).

Figure 5.141. Blue Lake Road pH measurements – 10/99 to 2/03



Summary

Upon closer examination of the data used to list Fairview Creek on the 1998 3039d) list for pH standards violations, it appears that the data collected in 1996 are questionable and inconsistent with subsequent monitoring results. ODEQ feels that a TMDL need not be established for pH at this time. Simple sampling error is the most likely explanation for the low pH values in Fairview Creek during the 1996 study conducted by the City of Gresham. It is likely that poor calibration and maintenance of field pH meters resulted in erroneous and inconsistent measurements. Subsequent monitoring has not demonstrated water quality violations for low pH, rather high pH may be more of a concern at the Glisan Street sampling location (**Table 5.47**).

Measurements taken on 10/27/1999 are consistently high and are either due to a short-duration event (possibly an illicit discharge) or, more likely, improper calibration of the field pH probes.

The City of Gresham continues to monitor pH in Fairview Creek and has employed rigorous QA/QC procedures since 2001. Data will be submitted to ODEQ for consideration in a future 303d listing process. Developing a TMDL for low pH based upon available monitoring data is not warranted at this time.

SMITH AND BYBEE LAKES DISCUSSION PAPER

Introduction

Smith and Bybee Lakes are located near the confluence of the Willamette and Columbia Rivers in Portland, Oregon (**Figure 5.142**). The lakes are part of an interconnected series of shallow lakes and wetlands in the floodplain of the Columbia River. Industrial use and shipping activities occur in the lakes' vicinity where significant portions of land have been artificially filled (Rivergate industrial area). Metropolitan Regional Services (Metro) has overseen the 1,928-acre Smith and Bybee Lakes Management Area since 1990. The Smith and Bybee Lakes Natural Resources Management Plan, adopted by Metro and the City of Portland in 1990, guides lake management. Smith and Bybee Lakes are on Oregon's 2002 list of water quality limited waterbodies (303d list) for pH and aquatic weeds violations. The 1998 303(d) list also included listings for biocriteria, flow modification, habitat modification, and pH for both lakes. In response to the 1998 listing, ODEQ included Smith and Bybee Lakes in the development of the Willamette River total maximum daily load (TMDL).

Figure 5.142. Smith and Bybee Lakes area.

This paper presents background information and analysis supporting ODEQ's proposal that a TMDL for Smith and Bybee Lakes not be developed at this time. Between 1982 and November 2003, a dam altered the wetlands' hydrology and this created favorable conditions for invasive plant species. During the summer and fall of 2003, Metro removed the dam and replaced it with a water control structure better able to mimic natural hydrology.

Background

The Smith and Bybee Lakes drainage basin comprises approximately 1,600 acres. Of that area, the combined area of the lakes ranges from approximately 520 acres to 1,262 acres (Fishman, 1987). While Smith and Bybee Lakes are surface water bodies most of the year, they are more accurately described as wetlands, as this description reflects their natural function (Elaine Stewart, Metro, personal communication, September 2003). All surface drainage to the wetlands is stormwater: culverts and storm water ditches drain to the north side of Smith Lake and Bybee Lake and to the east side of Smith Lake. Until recently, a dam installed at the wetlands' natural outlet to the North Slough, an arm of the Columbia Slough, prevented water from the North Slough and tidal backflow of the Columbia and Willamette Rivers from entering the wetlands unless river levels were higher than the dam (Fishman, 1987). Consequently, the dam held water levels unnaturally low in drought years (2000 – 2002), but unnaturally high during years when North Slough water over-topped the dam (Elaine Stewart, personal communication, September 2003).

Smith and Bybee Lakes and their associated sloughs and wetlands are remnants of formerly extensive river bottomlands that extended from the western terminus of the Columbia Gorge to the mouth of the Columbia River. Modifications to this hydrologic regime over the past 70 years, such as construction of dams and dikes and filling with dredge spoils, have dramatically changed the frequency and duration of flooding in the region's wetlands. Before the development of hydroelectric and flood-control dams on the Columbia and Willamette Rivers (1938-1972), seasonal flooding significantly controlled the hydrology of the wetlands. Water movement into and out of Smith and Bybee Lakes varied along with the seasonal and daily tidal fluctuations. Flooding receded in late winter and early spring. Late spring rains and snowmelt caused water to rise again in the spring freshet, and during summer, large mudflats were exposed as the wetlands dried seasonally (Metro, 1994).

In 1982, the U.S. Fish and Wildlife Service constructed a dam at the wetland's outlet to North Slough. They intended that holding water to create permanent lakes would prevent waterfowl deaths such as those occurring in the Lower Columbia Estuary in the mid to late 1970s, ascribed to avian botulism (Metro, 1996). The dam has been modified or replaced twice, but since 1982, the wetlands have generally functioned as reservoirs with a static water level. This hydrologic alteration has significantly degraded wildlife habitat, while creating ideal conditions for the spread of exotic plants such as reed canary grass. The constant inundation also destroyed more than 300 acres of bottomland forest and virtually eliminated emergent wetland and mudflat habitats (Elaine Stewart, personal communication, March 2002 and September 2003). In 1996, Metro first proposed removing the water control structure and managing the wetlands to mimic natural hydrologic conditions. Metro based this recommendation on several studies conducted between 1992 and 1995, summarized in the Diagnostic and Feasibility Study of Smith and Bybee Lakes (Metro, 1996). The Feasibility Study was partially funded by one of the last Section 314 Clean Lakes Program Grants. Metro undertook restoration in the summer and fall of 2003.

Fishman's (1987) completed water budget (**Table 5.48**) accounted for input to the lakes (at that time) from precipitation, stormwater runoff, and seepage from groundwater, precipitation being dominant. Evaporation accounted for the most significant loss of water from the lakes, though seepage to groundwater balanced the budget. The period over which Fishman (1987) recorded water budget measurements extended from November 8 to August 28, 1986. Net groundwater input only occurred between May 9 and May 28, and again between August 2 and August 15.

Table 5.48. Water Budget from Fishman (1987)

Change in Lake Volume (acre-ft)	Inputs (acre-ft)		Outputs (acre-ft)	
	Precipitation	Run-off	Evaporation	Groundwater Seepage
97.21	62.68	8.18	131.76	36.29

Low permeability overbank flood deposits underlie the wetlands, though they are only a few feet thick in one area under Bybee Lake (Fishman, 1987). These silts contact either Pleistocene sands (under Smith Lake) or gravels (under Bybee Lake). In general, groundwater discharges at the Columbia River, though groundwater mounding creates smaller scale and complex gradients under the St. John's Landfill and Rivergate industrial area (Fishman, 1987; DEQ Consent Order to Metro, 2003).

The St. John's Landfill, located southwest of Bybee Lake in a former wetland, operated between the mid-1930s and 1991. Metro currently manages the landfill and oversees the post-closure operations. Landfill closure included installation of an engineered cap, gas extraction network, and storm water control features. Landfill discharges to surface water comply with the 1200 COLS permit, specific to the Columbia Slough and meeting load allocations in the Columbia Slough 1998 TMDL. Metro conducts semiannual monitoring of groundwater and also regularly monitors surface water and sediment, the latter two generally to satisfy requirements in the Smith and Bybee Lakes Natural Resources Management Plan (Metro, 1990). ODEQ's renewal of the landfill closure permit includes a cleanup consent order that requires a Remedial Investigation/Feasibility Study (RI/FS). The RI/FS will assess the movement of contamination from the landfill to groundwater and surface water including Smith and Bybee Lakes, and evaluate ecological and human health risk (DEQ Order On Consent No. LQSW-NWR-02-14, October 31, 2003).

303(d) Listed Stream Segments

Both Smith and Bybee Lakes are 303(d) listed for pH values measured above the upper criterion of 8.5 pH units during the summer (**Table 5.50**). The 1998 303(d) list also listed both lakes for habitat and flow modification, and for biological criteria. In 2002, ODEQ decided not to list water quality limited segments beyond those that are required by USEPA regulations, e.g., waters where there is no pollutant associated with the impairment, namely habitat and flow modification. Neither the State nor USEPA has an obligation under current USEPA regulations to develop TMDLs for such waters because the waters are not impaired by a pollutant. (Letter from USEPA approving 2002 303(d) list dated March 24, 2003).

Smith and Bybee Lakes were listed for Biological Criteria because of invasive macrophyte growth, and to reflect that, ODEQ changed their 303(d) designation to "Aquatic Weeds and Algae" for the 2002 list. All the current and past listings are related to the wetlands' recent impoundment. The dam installed in 1982 fundamentally altered the flow of water to and from the wetlands, and this alteration led to habitat changes for fish and wildlife as well as exotic weeds dominance.

Table 5.50. 303(d) Listings for Smith and Bybee Lakes

Waterbody	Parameter	Season	Basis for Listing
Bybee Lake	pH	Summer	Metro (1994)
	Aquatic Weeds and Algae	All	
Smith Lake	pH	Summer	Metro (1994)
	Aquatic Weeds and Algae	All	

Beneficial Uses

Oregon Administrative Rules (OAR Chapter 340, Division 41, Table 6) list the "Beneficial Uses" occurring within the Willamette Basin, including Smith and Bybee Lakes (**Table 5.49**). Beneficial uses that commonly occur in Smith and Bybee Lakes are marked with a "check".

Numeric and narrative water quality standards are designed to protect the most sensitive beneficial uses. The pH criterion was developed to protect Resident Fish and Aquatic Life, which is the most sensitive beneficial use related to pH occurring in Smith and Bybee Lakes.

Table 5.49. Beneficial Uses occurring in Willamette Basin Tributaries (OAR 340 – 41 – 442)

Beneficial uses protected by the pH Criteria are marked in gray			
Beneficial Use	***Occurring***	***Beneficial Use***	***Occurring***
Public Domestic Water Supply		Salmonid Fish Spawning (Trout)	
Private Domestic Water Supply		Salmonid Fish Rearing (Trout)	
Industrial Water Supply		Resident Fish and Aquatic Life	✓
Irrigation		Anadromous Fish Passage	
Livestock Watering		Wildlife and Hunting	✓
Boating	✓	Fishing	✓
Hydro Power		Water Contact Recreation	✓
Aesthetic Quality	✓	Commercial Navigation & Transportation	

Target Criteria Identification

The pH criterion for the Willamette Basin (OAR 340-41-442) states that pH values shall not fall outside the range of 6.5 to 8.5 pH units. Natural variability outside of the 6.5 to 8.5 pH range is addressed in OAR 340-41-(basin) (3):

> *"Where the naturally occurring quality parameters of waters of the (Basin) are outside the numerical limits of the above assigned water quality standards, the naturally occurring water quality shall be the standard."*

When natural variability causes values to fall outside the range of pH criteria, the waterbody cannot adapt to further increases or decreases in pH, and the rules prohibit further anthropogenic change.

The pH scale provides a numeric value that describes the intensity of the acidic or basic (alkaline) conditions of a solution. The pH value of a solution is the negative logarithm of the hydrogen-ion concentration in moles per liter. The pH scale runs from 0 to 14, where 7 is "neutral", less than 7 is "acidic," and more than 7 is "basic". Pure water has a neutral pH of 7 at 25°C. The pH scale is logarithmic, so for every one unit change (e.g. from 5 to 4), acidity increases or decreases ten-fold (Sherman and Russikoff, 1988). Most rainwater pH ranges from 5.6 to 5.8 because carbonic acid (H_2CO_3) forms from the interaction of water (H_2O) with atmospheric carbon dioxide (CO_2). Normally, soils neutralize this acidity.

Most aquatic organisms—including benthic macroinvertebrates, salmonids, and amphibians—respond to pH changes and prefer a pH in the range of 6.0 to 9.0 (USEPA, 1986b).

The aquatic weeds criterion for the lower Willamette Basin states that:

> *The development of fungi or other growths having a deleterious effect on stream bottoms, fish or other aquatic life, or which are injurious to health, recreation, or industry shall not be allowed; OAR 340-41-442(2)(h).*

The criterion limiting Nuisance Phytoplankton Growth (OAR 340-41-0150) applies to waterbodies in all basins except for ponds and reservoirs less than ten acres in surface area, marshes, and saline lakes. In natural lakes that do not thermally stratify, reservoirs, rivers and estuaries, average chlorophyll *a* concentrations may not exceed 0.015 mg/L, at which point phytoplankton may impair beneficial uses.

Data Analysis

Metro collected water quality data from Smith and Bybee Lakes from 1992 until the present. While the data presented in the following section do support a listing for summer pH violations, a TMDL for Smith and Bybee Lakes may not be appropriate now for two reasons:

- The implementation of a management plan (Metro, 1990), including replacement of the old dam with a new water control structure, may be a more effective way to address water quality violations. Numerous studies have recommended dam removal to improve water quality as well as habitat (Fishman, 1987; Eilers et al., 1995; Lev et al., 1994). The dam that until recently blocked the connection with the North Slough prevented natural wetland drainage and likely exacerbated the pH problems because nutrients were not flushed from the system, leading to excessive algal production. In addition, non-native aquatic weeds out-compete native plants because the non-native varieties can survive year-round inundation (Metro, 1996).

- ODEQ completed a pH TMDL for the Columbia Slough in 1998—the phosphorus allocations set in the TMDL and the implementation measures would apply to Smith and Bybee Lakes as well as the slough.

pH Data Collected by Metro, 1992 – 2001

Metro has collected water quality data from Smith and Bybee lakes since at least 1992. Metro uses a Hydrolab multi-parameter measuring device to measure pH, and according to their 1997 Environmental Quality Monitoring Plan, they perform a two-point pH calibration before each use when collecting grab sample data. **Figures 5.143** and **5.144** indicate that the upper pH standard is violated at times during the summer months, and occasionally in spring and fall. Two measurements, both taken on Sept. 25, 1992, exceeded 10.5 pH units and are anomalously high. These anomalies may be due to measurement error or Metro may have taken these measurements later in the day than the majority of the remaining measurements; not all the data Metro supplied ODEQ included time of sampling. The pH violations occur mainly in late summer. The dam that until recently impounded the wetlands likely makes late summer and early fall the most hydrologically altered times of year relative to natural conditions. If the dam had not impounded the wetlands during late summer and early fall, the water levels would have been much lower than they were, and large mudflats would have been exposed (Metro, 1996; Lev et al., 1994). The management plan that Metro began implementing during summer 2003 includes installation of a new structure in the dam and restoration of more natural hydrologic conditions. The following section of this report further explains this management plan and its likely effects on water quality.

Metro data do not indicate a strong correlation between chlorophyll and pH or chlorophyll and total phosphorus (**Figures 5.145** and **5.146**), but both phosphorus and chlorophyll a concentrations generally increase from June to August. **Figures 5.147** and **5.148** illustrate total phosphorus and chlorophyll a concentrations from June through September, combining data from 1993 to 2001. High pH measured in June, July, and August probably reflects algal production; Metro's corresponding summer dissolved oxygen measurements do not suggest diurnal fluctuation because of low sampling frequency, but range from <6 mg/L to >11 mg/L. The large range may indicate variable dominance of algal photosynthesis and respiration.

Figure 5.143. Seven summer samples, one fall sample, and one spring sample violated the upper pH standard in Bybee Lake. Data supplied by Metro.

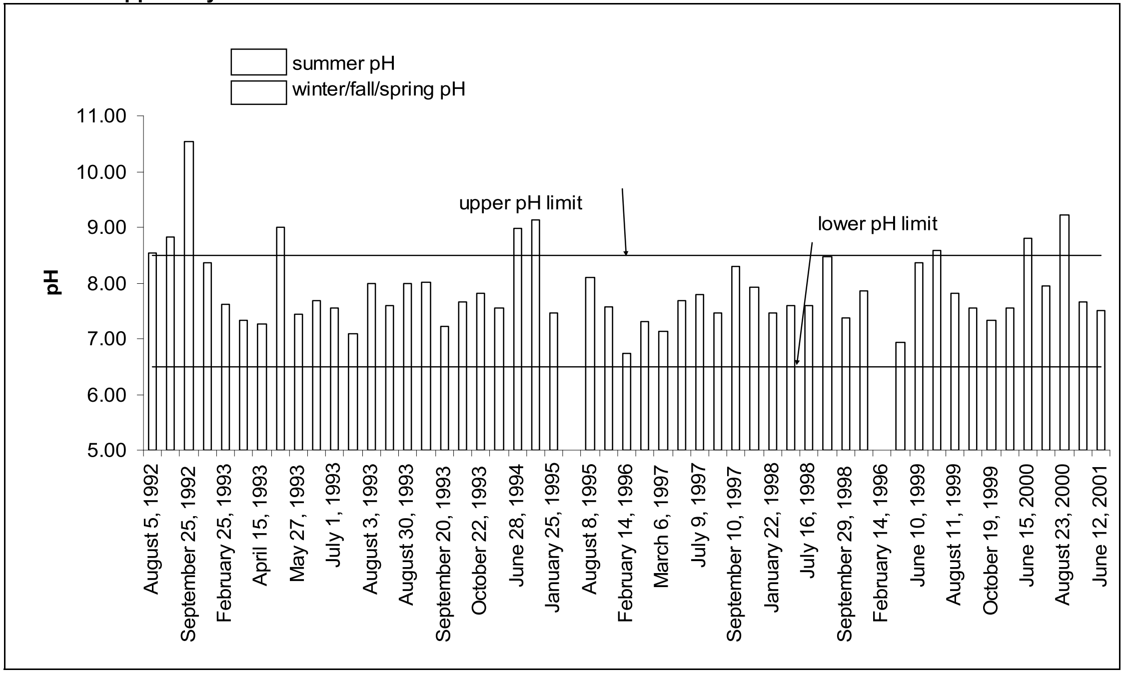


Figure 5.144. Seven summer samples and three fall samples violated the upper pH standard on Smith Lake. Data supplied by Metro.

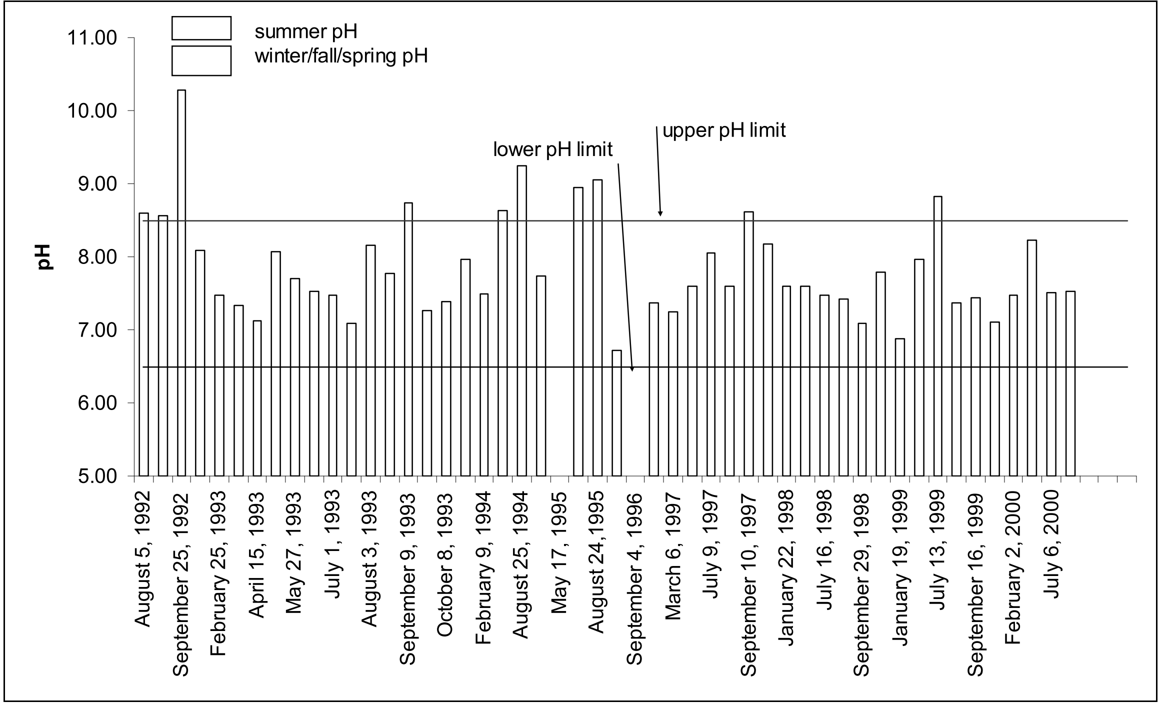


Figure 5.145. Chlorophyll a and pH data from Smith and Bybee Lakes do not show a strong correlation between pH and chlorophyll a. Data supplied by Metro.

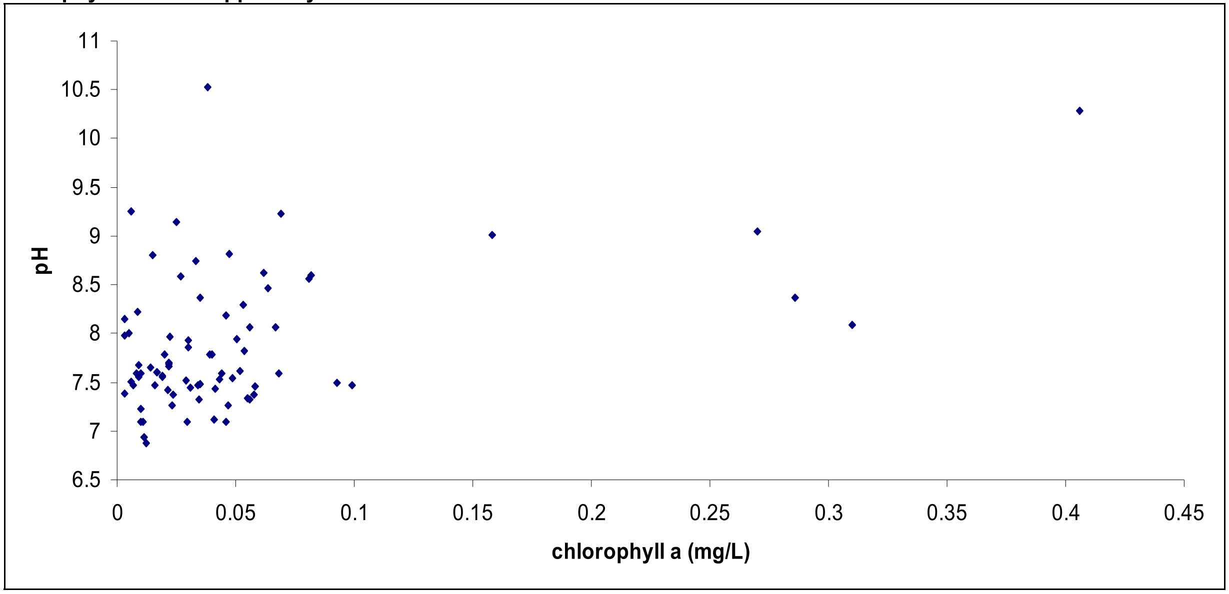


Figure 5.146. Phosphorus and chlorophyll a data from Smith and Bybee Lakes do not show a strong correlation between total phosphorus and chlorophyll a, but both parameters generally increase from June to August, as illustrated in Figures 6 and 7. Data supplied by Metro.

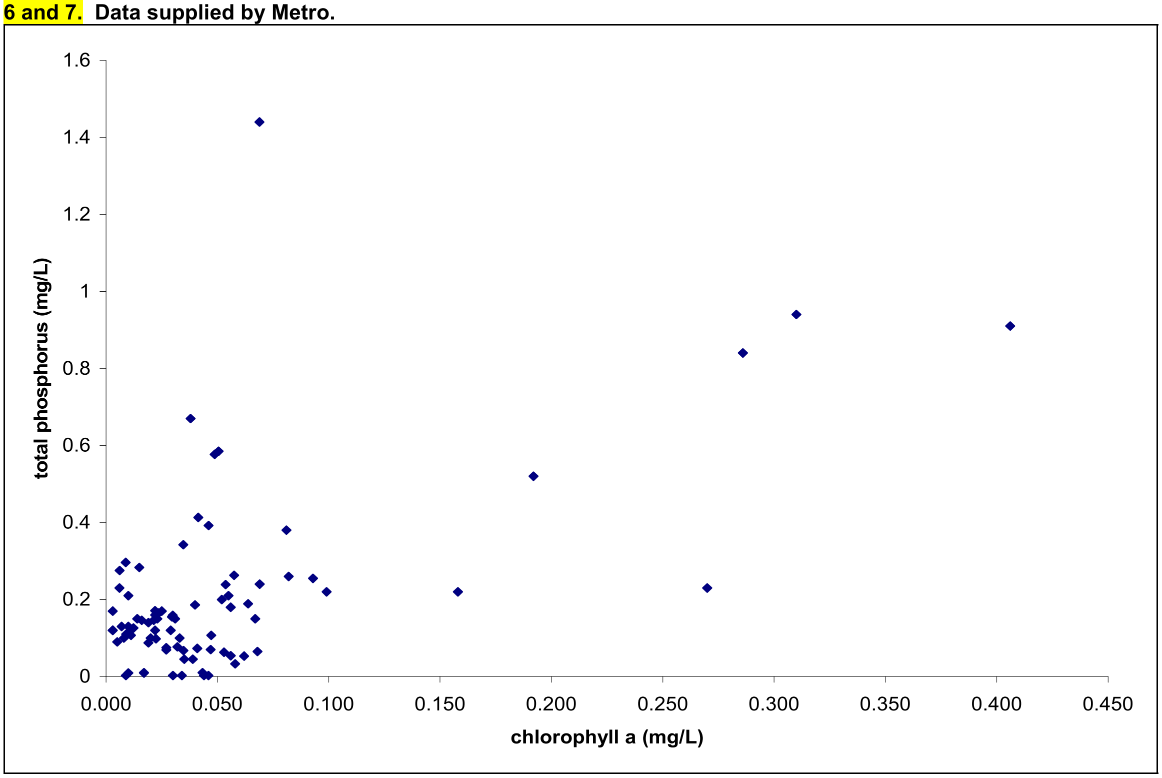


Figure 5.147. Total phosphorus concentrations in Smith and Bybee Lakes measured from June through September, years 1993 to 2001. The median concentration for each month's samples is indicated above the data.

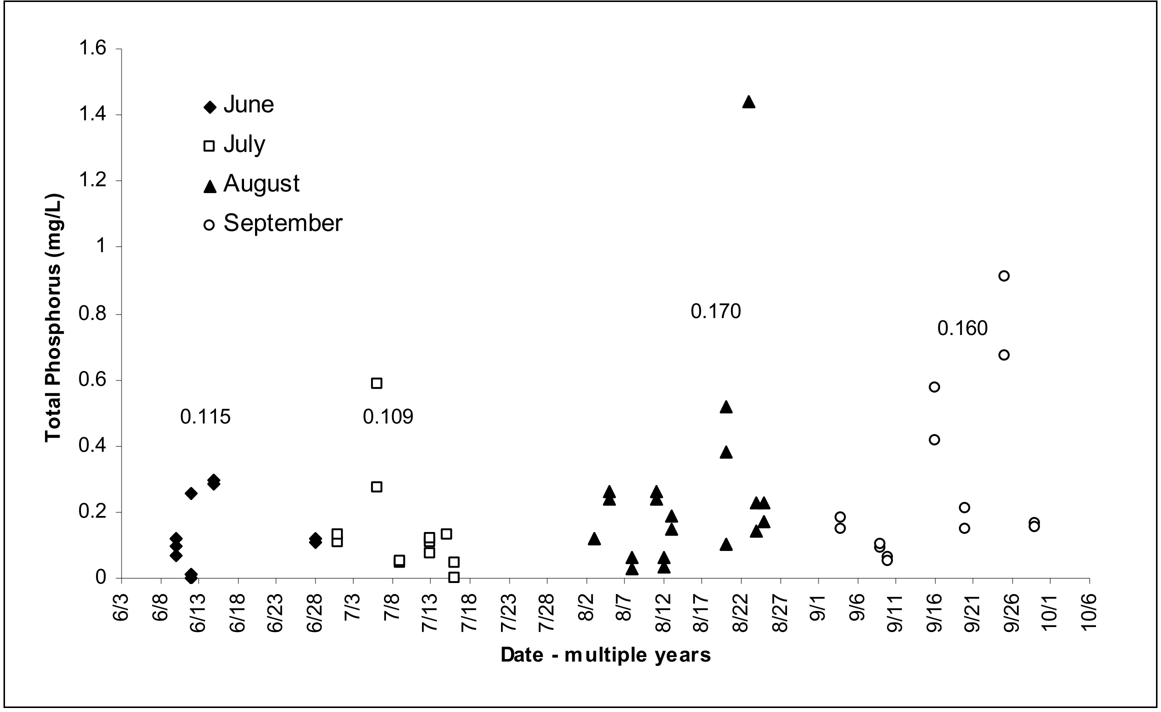
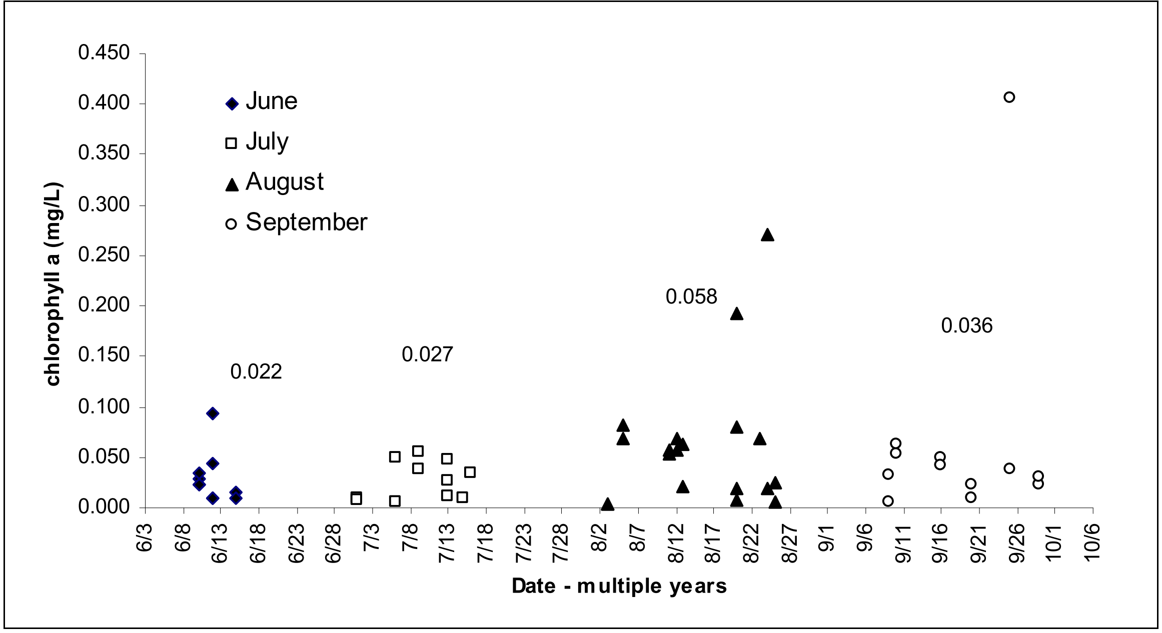


Figure 5.148. Chlorophyll a concentrations in Smith and Bybee Lakes measured from June through September, years 1993 to 2001. The median concentration for each month's samples is indicated above the data.



Management and Monitoring Plans

Metro's Natural Resources Management Plan calls for the removal of the existing structure on the North Slough and replacement with three large box culverts with stop logs and tide gates, plus a fish ladder. This restoration project will allow free and open seasonal and tidal connectivity throughout much of the year while providing a mechanism to improve wetland habitat by controlling water levels. Metro will place stop logs into the water control structure and mimic natural water level changes (i.e. those occurring before Willamette basin flood control impoundments) by prolonging the recession of floodwaters out of the wetlands. The long drawdown period simulates natural conditions by slowly exposing the shallow mudflats late in the spring, during the warming period that favors native plant communities. This is crucial to restoring native vegetation and in controlling reed canary grass because the latter is a cool-season plant that starts growing earlier in the year than the desired native emergent plants.

While the primary purpose of the management plan is to control non-native plants and recreate an area more suitable for wildlife, the water quality will also likely improve. Multiple studies have suggested that the eutrophic state of the lakes was worsened by the old water control structure that prevented communication with the North Slough (Metro, 1996). Fishman (1987) concluded that nutrient enrichment of the lakes resulted from sediment, both through mixing and rooted plants that use nutrients in the sediment, die, then release nutrients back into the water column. As well, Fishman (1987) compared algal density in 1982, prior to dam installation, and that collected for the 1987 study. Impoundment appeared to increase the density of algae, and they concluded that increased volume of water plus high levels of dissolved plant nutrients provided ideal conditions for algal growth.
Eilers et al. (1995) concluded that the old water control structure transformed the lakes from a depositional/erosional system into a purely depositional system, retaining both sediments and nutrients. Eilers et al. (1995) found that the lakes contained no recently deposited sediment, based on lack of cesium-137 (only present from atmospheric deposition after 1954) in the sediment cores. They concluded that tidal action before dam installation eroded sediments regularly from the wetlands. A layer of organic sediment lay on top of old clay deposits, and Eilers et al. (1995) concluded that these sediments were deposited after the installation of the dam in 1982. They predicted that internal cycling of lake nutrients and therefore lake productivity would increase with the continued impoundment of water in lakes.

Metro intends to document water quality in Smith and Bybee Lakes and surrounding surface water with four techniques: high frequency trending at three sites, low frequency trending at six sites, short-term investigations, and tracking effects of hydrologic management. Continuously collected year-round data will record daily and seasonal trends in basic water quality parameters—pH, dissolved oxygen, temperature, specific conductance, and oxidation-reduction potential. Metro will collect grab samples from six sites, six times per year to document long-term changes in basic water quality parameters as well as dissolved metals (a concern because of contaminated St. Johns landfill groundwater). Metro will analyze conventional parameters as well as nutrients, chlorophyll, and biological parameters from water they collected on either side of the old dam and in the same locations post dam replacement.

1998 Columbia Slough TMDL

ODEQ completed a TMDL for the Columbia Slough in 1998 to address pH, chlorophyll *a*, and dissolved oxygen. The TMDL placed limits on phosphorus loading in the watershed which includes Smith and Bybee Lakes. The TMDL studies identified eutrophication from excessive nutrients as the cause of pH violations and developed a loading capacity for phosphate, the limiting nutrient. The TMDL allocated phosphorus among the point and non-point sources with the largest allocation to groundwater, and zero allocations to combined sewer overflows (CSOs) and sewage (then scheduled to be eliminated by 2005). In October 2000, the City of Portland eliminated the last CSO from the Columbia Slough.

In addition to eliminating sewage sources, the implementation measures to control aquatic growth in the Columbia Slough include water level management. The Multnomah County Drainage District manages water levels in the Slough and has worked with ODEQ and the City of Portland to implement the TMDL. Lowering water levels in the Slough should discourage algae by increasing the flushing rate and reducing the surface area available for algal production. ODEQ and the City of Portland found that the increased water clarity and shallower water tends to increase macrophyte growth. The City of Portland continues to monitor the Slough to document effects of water level management on algal abundance.

Industrial stormwater discharges in the area are covered by the specially developed 1200COLS permits. Industrial stormwater discharges, whether they discharge to the Slough or Smith and Bybee Lakes, must attain phosphorus benchmarks in the 1200COLS permits. Meeting those benchmarks will satisfy TMDL requirements and allow the listed water bodies to meet water quality standards.

Many discharges in the area appear to go to the Columbia Slough, though several City of Portland and private outfalls appear to discharge into the ponds, sloughs, and wetlands surrounding Smith and Bybee Lakes (Port of Portland, 1996; City of Portland, April 2003), as well as the lakes themselves. The City outfalls will be covered by the City of Portland's municipal stormwater (MS-4) permit that ODEQ is currently renewing; the renewed permit will address phosphorus wasteload allocations contained in the 1998 Slough TMDLs and loading from stormwater.

Summary

Smith and Bybee Lakes violate pH and aquatic weeds water quality standards. Despite these violations, ODEQ does not believe developing a Smith and Bybee Lakes TMDL is appropriate at this time.

First, several studies have recommended the replacement of the old water control structure to improve water quality as well as habitat in Smith and Bybee Lakes. Fishman (1987), Eilers et al. (1995), and Lev et al. (1994) document worsening water quality and habitat conditions after dam installation in 1982. Water quality problems in the current lakes have probably been exacerbated because the dam prevented nutrient flushing. Invasive aquatic weeds can survive and thrive in year-round inundated conditions, but native vegetation relies on a dry period in the summer. The Smith and Bybee Lakes Natural Resources Management Plan (Metro, 1990) calls for controlling water levels and reestablishing more natural water level fluctuations in the wetlands. Metro intends to track and document water quality changes now that it has removed and replaced the old water control structure.

Second, the 1998 Columbia Slough TMDL and the associated controls to reduce phosphorus loads already apply to Smith and Bybee Lakes because the lakes are in the Columbia Slough Watershed. Benchmarks in area stormwater discharge permits, Slough water level management, and the elimination of combined sewage overflow input to the Slough are effective eutrophication controls already in place. Though a dam at their natural outlet until recently artificially separated the wetlands from the Columbia Slough, Metro replaced this water control structure during summer and fall 2003, and reestablished communication between the wetlands and the Slough.

ODEQ is confident that water quality and habitat conditions in Smith and Bybee Lakes will improve now that Metro has implemented their management plan and the replaced the dam. Metro will continue to track the lakes' response to the new hydrologic setting. ODEQ will consider that data and any new listings for the lakes to evaluate the need for a future TMDL.

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