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Willapa River Fecal Coliform Bacteria Verification Study

Water Quality Monitoring Report

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Water Quality Monitoring Report

by
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Abstract

The Washington State Department of Ecology is required, under Section 303(d) of the federal Clean Water Act and U.S. Environmental Protection Agency regulations, to (1) develop and implement Total Maximum Daily Loads (TMDLs) for impaired waters, and (2) evaluate the effectiveness of the water cleanup plan to achieve the needed improvement in water quality.

The Willapa River and several tributaries are on the 1998 303(d) list of impaired waterbodies due to violations of one or more Washington State water quality criteria. The mainstem and several tributaries exceed (do not meet) the water quality criteria for fecal coliform bacteria, dissolved oxygen, and temperature. The EPA requires states to develop and implement cleanup programs through the development of TMDLs for listed parameters and to periodically monitor progress toward compliance with TMDL targets.

This assessment verifies current conditions and compares the data with results from previous studies conducted since 1997. Fecal coliform concentrations during a 1997-98 study by Ecology found that only five of 30 sites sampled met Washington State water quality standards for fecal coliform bacteria. 2004 data show that conditions improved significantly in many parts of the basin, especially in the lower stretch of the river. Results from this 2006 study verify where the river meets standards. The data will be used to help focus local efforts on areas where bacteria problems continue to exist.

The objectives of the study are to: (1) clarify general areas of fecal coliform bacteria pollution and compare current conditions to Washington State water quality criteria for fecal coliform bacteria, (2) compare current and previous monitoring data to determine direction of change, and (3) provide data for TMDL revision and for decisions on local TMDL implementation planning/responses.

Most of the sampling stations met both water quality criteria for fecal coliform bacteria; however, several stations exceeded the second part of the water quality standard. Nine of the 24 stations sampled did not meet standards.

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What is a Total Maximum Daily Load (TMDL)?

Federal Clean Water Act requirements

The Clean Water Act established a process to identify and clean up polluted waters. Under the Clean Water Act, every state has its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection, such as cold water biota and drinking water supply, and criteria, usually numeric criteria, to achieve those uses.

Every two years, states are required to prepare a list of waterbodies – lakes, rivers, streams, or marine waters – that do not meet water quality standards. This list is called the 303(d) list or water quality assessment. To develop the list, Ecology compiles its own water quality data along with data submitted by local state and federal governments, tribes, industries, and citizen monitoring groups. All data are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the 303(d) list.

TMDL Process Overview

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the waterbodies on the 303(d) list. A TMDL identifies how much pollution needs to be reduced or eliminated to achieve clean water. The local community then works with Ecology to develop a strategy to control the pollution and a monitoring plan to assess the effectiveness of the water quality improvement activities.

Elements Required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain water quality standards. A TMDL includes a written, quantitative assessment of water quality problems and of the pollutant sources that cause the problem. The TMDL determines the amount of a given pollutant that can be discharged to the waterbody and still meet standards (the loading capacity) and allocates that load among the various sources.

If the pollutant comes from a discrete source (referred to as a point source) such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a wasteload allocation. If it comes from a set of diffuse sources (referred to as a nonpoint source) such as general urban, residential, or farm runoff, the cumulative share is called a load allocation.

The TMDL must also consider seasonal variations and include a margin of safety that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A reserve capacity for future loads from growth pressures is sometimes included as well. The sum of the wasteload and load allocations, the margin of safety, and any reserve capacity must be equal to or less than the loading capacity.

Water Quality Assessment / Categories 1-5

The 303(d) list identifies polluted waters in Washington. The Water Quality Assessment is a list that tells a more complete story about the condition of Washington's water. This list divides waterbodies into one of five categories:

- Category 1 – Meets tested standards for clean water.
- Category 2 – Waters of concern.
- Category 3 – No data available.
- Category 4 – Polluted waters that do not require a TMDL since the problems are being solved in one of three ways:
  - 4a – Has a TMDL approved and is being implemented.
  - 4b – Has a pollution control plan in place that should solve the problem.
  - 4c – Is impaired by a non-pollutant such as low water flow, dams, culverts.
- Category 5 – Polluted waters that require a TMDL – on the 303(d) list.

TMDL Analyses: Loading Capacity

Identification of the contaminant loading capacity for a waterbody is an important step in developing a TMDL. EPA defines the loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (EPA, 2001). The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a waterbody into compliance with standards. The portion of the receiving water's loading capacity assigned to a particular source is a load or wasteload allocation. By definition, a TMDL is the sum of the allocations, which must not exceed the loading capacity.

Background

Study Area

The Willapa River drains a basin of about 260 square miles before discharging into northeastern Willapa Bay, Washington (Figure 1). Rate of flow in the Willapa River has been recorded since 1947 (continuously since 1961) at USGS station 12013500 (Willapa River near Willapa, WA), which has a contributing area of about 130 square miles. Mean monthly flow is highest in December (1,509 cubic feet second (cfs)) and lowest in August (48.7 cfs). The mean annual flow at the USGS station is 636 cfs.

Major sub-basins include numerous sloughs and creeks that are tributaries to the Willapa River. The largest of these are the South Fork Willapa River, and Wilson, Mill, Trap, Fork, and Fern Creeks. The Upper Willapa River is mostly freshwater while the lower river is a tidal estuary characterized by a mixture of Willapa Bay marine waters and freshwater from the mainstem river and tributaries. Tidal effects on river height can be observed near Camp One Road at river mile (RM) 14.5 which indicates that saline marine water probably forms a wedge 10 miles or more up the river (Pickett, 1998).

The primary land cover and activities in the Willapa River watershed are forest (80%), agriculture (8%), and other (12%) that comprise non-forest, developed land, open water, or wetlands. The upper, steeper part of the watershed is dominated by commercial forest that is managed by a mixture of private owners, state, and federal agencies. With the decreasing slope and at lower elevation, a relatively wide valley floor develops, and the primary land cover changes to agriculture with dairy farms dominating the land use (Gove et al., 2001). There are about four large dairy operations in the basin and numerous other livestock operations for beef and young stock.

The population of Pacific County is 20,984 according to the 2000 U.S. Census. With the exception of the cities of Raymond and South Bend on the lower river, the Willapa River basin is largely rural. Timber and seafood (mostly oysters) are the principal industries in these cities, while agricultural land uses dominate the rest of the river valley with silviculture as the main practice. There are several small towns along the upper river (Pickett, 1998).

Pollutants Addressed by This TMDL

In 1997, the Southwest Regional Office (SWRO) Water Quality Program of the Department of Ecology (Ecology) conducted a Watershed Needs Assessment that included the Willapa River watershed. The Willapa River was identified as high priority for a Total Maximum Daily Load (TMDL) technical study for fecal coliform bacteria, dissolved oxygen, and temperature problems. TMDL cleanup plans were completed in 2005 for temperature and in 2006 for dissolved oxygen. The river is currently listed under section 303(d) of the federal Clean Water Act as not meeting water quality standards for FC bacteria. Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) regulations require states to develop and implement TMDLs for impaired waters, and to evaluate the effectiveness of the water cleanup plan in achieving the needed improvement in water quality.

Bacteriological indicators have been used to determine the health of surface waters and their suitability for drinking, human contact recreation, and shellfish harvesting. For example, fecal coliform (FC), total coliform (TC), and, fecal streptococci (FS) are frequently used as indicator bacteria in testing for the presence of pathogenic bacterial contamination. Washington State's water quality criterion for bacteriological pollutants is currently based on FC bacteria as an indicator organism for human or other warm-blooded animal contamination. Effects on humans from bacteriological contamination include gastrointestinal distress, respiratory infection, and symptoms such as skin irritations (from contact recreation). Environmental impacts include commercial and recreational shellfish beach closures.

Potential sources of bacteria in the Willapa River basin include both point and nonpoint sources. There are five permitted NPDES dischargers – two wastewater treatment plants (WWTPs) and three seafood processing plants – that release treated effluents to the Lower Willapa River in the study area. These facilities have the potential to affect FC bacteria. Table 1 lists permitted facilities in the watershed (Pickett, 1998).

Table 1. Permitted Point Sources of Bacteria.

Facility Name	NPDES ID	Permit Flow (mgd)	Permit FC Bacteria (cfu/100ml)	Max. FC Reported 1998-2002 (cfu/100ml)
City of Raymond WWTP	WA000023329	1.500	200	502
City of South Bend WWTP	WA0037591	0.375	200	532
South Bend Packers	WA0040941	0.010	*	1,600
East Point Seafood	WA0001104	0.320	*	2,200
Coast Seafood	WA0002186	0.099	*	44,000

NPDES = National Pollutant Discharge Elimination System.
* = Presently no permit limit; only monitoring required. Limits will be set in 2007 or 2008.

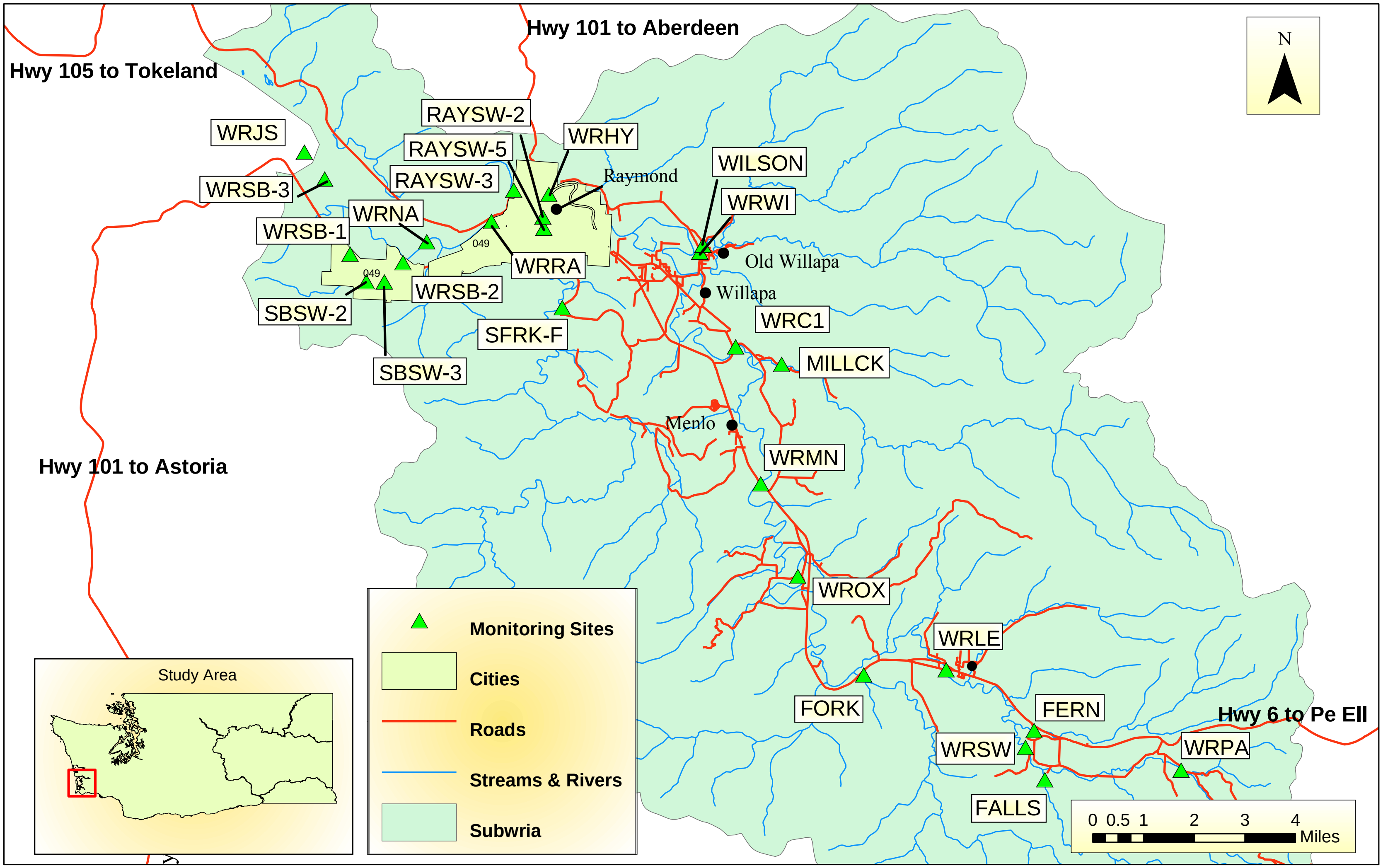

Figure 1. Willapa River Fecal Coliform Monitoring Sites.

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Potential nonpoint sources of bacteria in the basin include:

- Onsite septic systems
- Urban stormwater run-off
- Boats and marina areas
- Livestock
- Wildlife

Sanitary surveys in the early 1990s reported a high rate of failure (about one-third) for onsite septic systems in the Willapa River basin. Many of these problems have been corrected, yet unsewered residential areas are still possible sources of bacteria, especially under saturated soil conditions (Pickett, 1998). Seyferlich and Joy (1993) researched and described these sources in detail.

Urban stormwater runoff can carry a variety of pollutants from urban areas including bacteria from pet wastes, surface wastewater from failing septic tank systems, and excess nutrients from lawns and gardens, metals, oil and grease, and other pollutants associated with activities such as car washing and sidewalk cleaning. Urban areas such as Raymond and South Bend have been identified as possible bacteria sources. Apart from urban stormwater runoff, concentrated moorage facilities such as South Bend Boat Haven and the Port of Willapa docks may be potential sources of bacteria (Pickett, 1998).

There are about four commercial dairies and numerous small livestock operations in the Willapa River basin. Data collected by the Pacific Conservation District in 1990 estimated a total of about 5800 head of cattle in the basin, with only about one-third accounted for by the dairies. With recent trends in the dairy industry, it is likely that the number of head at the dairies has increased. The Pacific Conservation District has been active in the basin helping farms to develop and implement farm nutrient management plans (Pickett, 1998).

According to an upper watershed study done for Pacific County by Herrera Environmental (2005), wildlife is another source of FC bacteria loading in this watershed. The specific levels of FC loading from wildlife and other human or livestock sources are uncertain, but all sources were confirmed.

Water Quality Protection and Restoration Activities

The Pacific Conservation District (PCD) is responsible for educating farmers on agricultural practices in the Willapa River watershed. The PCD works with landowners on a voluntary basis to (1) provide technical assistance to landowners for farm plan development, and (2) suggest and design best management practices (BMPs) like roof runoff, livestock access to waterways, rotational grazing, bridges, and alternative water sources.

The dominant land-use activity in the Willapa River watershed is rural/agricultural, which makes nonpoint contribution the primary source of contamination. Actions throughout the watershed that prevent FC bacteria from entering surface water will help to improve water quality. Local activities and efforts for bacteria pollution control are evident as water quality continues to improve in the Willapa basin.

Management measures that are effective in reducing FC bacteria stream pollution include:

- Prevent domestic animals' access to streams. Livestock are the primary problem, but pets also contribute.
- Maintain an adequate riparian buffer to help filter stormwater runoff and reduce bank erosion.
- Apply field manure at recommended rates and times.
- Provide adequate manure storage capacity to prevent bacteria transport by stormwater during rainfall or flood events.
- Maintain pastures and animal-keeping areas to minimize overland run-off.
- Maintain septic systems, including pumping and inspecting septic systems regularly.
- Manage human and pet waste properly during camping or fishing events, including burying wastes at least 6" deep and away from streams.
- Adherence to NPDES permits and state waste discharge permits (for point sources).

Water Quality Standards and Beneficial Uses

The Willapa River and its tributaries in the study area are compared to Class A freshwater standards, with the exception of the downstream 1.8 miles that are compared to Class A marine water standards. The water quality standards for Washington State are found in WAC 173-201A.

The freshwater Class A standards apply to the Upper Willapa River above river mile 1.8:

> *"Fecal coliform organism levels shall both not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL."*

The marine Class A water quality standards apply to the lower 1.8 miles of the Willapa River as specified in WAC 173-201A-140 Specific classifications-Marine water. (26) Willapa Bay seaward of a line bearing 70 degrees true through Mailboat Slough light (Willapa River, river mile 1.8):

> *"Fecal coliform organism levels shall both not exceed a geometric mean value of 14 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 43 colonies/100 mL."*

Waterbodies that do not meet these applicable water quality standards despite the presence of technology-based pollutant controls are listed as impaired under Section 303(d) of the Clean Water Act. Several segments of the Willapa River watershed were listed in 1998 for exceeding the FC bacteria water quality standard. The listing requires development of a TMDL intended to provide guidance for the protection of beneficial uses within the basin.

Bacteria

Freshwaters

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In the Washington State water quality standards, fecal coliform is used as an "indicator bacteria" for the state's freshwaters (e.g., lakes and streams). Fecal coliform in water "indicates" the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The fecal coliform criteria are set at levels that have been shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

The following uses are designated for protection in the Willapa River watershed:

1. Aquatic life uses. Aquatic life uses are designated based on the presence of, or the intent to provide protection of, all indigenous fish and nonfish aquatic species.

2. Recreational use. The main recreational use is for primary contact recreation.
3. Water supply uses. The water supply uses are domestic, agricultural, industrial, and stock watering.
4. Miscellaneous uses. The miscellaneous freshwater uses are wildlife habitat, harvesting, commerce and navigation, boating, and aesthetics.

The primary contact use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." More to the point, however, the use is to be designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, and throat. Since children are also the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category: "Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL" [WAC 173-201A-200(2)(b), 2003 edition].

Marine Waters

In marine waters, bacteria criteria are set to protect shellfish consumption as well as people who work and play in and on the water. The Willapa River estuary waters are protected for both primary contact recreation and shellfish harvesting. Fecal coliform bacteria are used as indicator bacteria to gauge the risk of waterborne diseases. The presence of FC bacteria in the water indicates the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals.

The following uses are designated for protection in Willapa River marine surface water:

1. Aquatic life uses. Protection of all indigenous fish and nonfish aquatic species aquatic life uses are designated using the following general categories. It is required that all indigenous fish and nonfish aquatic species be protected in waters of the state.
2. Shellfish harvesting.

   (a) General criteria. General criteria that apply to shellfish harvesting uses for marine water are described in WAC 173-201A-260 (2)(a) and (b), and are for:

   (i) Toxic, radioactive, and deleterious materials. (ii) Aesthetic values.

   (b) Shellfish harvesting bacteria criteria. To protect shellfish harvesting, fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL, and not have more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 43 colonies/100 mL.

3. Recreational uses. The overriding recreational use being protected is primary contact recreation.

4. Miscellaneous uses. The miscellaneous marine water uses are wildlife habitat, harvesting, commerce and navigation, boating, and aesthetics.

To protect either *Shellfish Harvesting* or *Primary Contact Recreation* (swimming or water play): "Fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 43 colonies/100mL" [WAC 173-201A-210(3)(b), 2003 edition].

The criterion level set to protect shellfish harvesting and primary contact recreation is consistent with federal shellfish sanitation rules. Fecal coliform concentrations in our marine waters that meet shellfish protection requirements also meet the federal recommendations for protecting people who engage in primary water contact activities. Thus the same criterion is used to protect both "shellfish harvesting" and "primary contact" uses in the state standards.

Compliance to both fresh and marine water quality standards is based on meeting both the geometric mean criterion and the 10% of samples (or single sample if less than ten total samples) limit. These two measures used in combination ensure that bacterial pollution in a waterbody will be maintained at levels that will not cause a greater risk to human health than intended. While some discretion exists for selecting sample averaging periods, compliance will be evaluated for both monthly (if five or more samples exist) and seasonal (summer versus winter) data sets.

The criteria for fecal coliform are based on allowing no more than the pre-determined risk of illness to humans who work or recreate in a waterbody. The criteria used in the state standards are designed to allow seven or fewer illnesses out of every 1,000 people engaged in primary contact activities. Once the concentration of fecal coliform in the water reaches the numeric criterion, human activities that would increase the concentration above the criteria are not allowed. If the criterion is exceeded, the state will require that human activities be conducted in a manner that will bring fecal coliform concentrations back into compliance with the standard.

If natural levels of fecal coliform (from wildlife) cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution further. While the specific level of illness rates caused by animal versus human sources has not been quantitatively determined, warm-blooded animals (particularly those that are managed by humans and thus exposed to human-derived pathogens as well as those of animal origin) are a common source of serious waterborne illness for humans.

Goals and Objectives

Project Goals

The project goals are to (1) determine attainment of water quality standards or TMDL targets, and (2) support the systematic review and improvement of water quality.

Study Objectives

To meet project goals, the following steps were taken.

1. Clarify general areas of FC bacteria pollution and compare current conditions to Washington State water quality criteria for FC bacteria.
2. Compare current and previous monitoring data to determine direction of change.
3. Provide data for TMDL revision and for decisions on local TMDL implementation planning/responses.

The results of this study will help Ecology and basin stakeholders focus efforts on priority pollution sources within the study area. The project desired outcomes are:

- Collection of high quality FC data that promotes confidence in the TMDL process.
- Public awareness on the level of FC bacteria reductions required and why.
- Management of resources to control nonpoint pollution.

Methods

The Quality Assurance Project Plan (Onwumere, 2006) for this study describes procedures that were followed for the collection and analysis of laboratory samples and for measurements made in the field. Sample site locations are shown in Figure 1 and Table 2. Monitored field parameters were temperature and conductivity, and the laboratory parameter was FC bacteria.

Table 2. Willapa River Sampling Locations, Parameters, and Frequency.

River Mile	Sampling Station	Site Code	Parameter and Frequency		
			FC Bacteria	Temperature	Conductivity
41.2	Willapa R below Patton Creek	WRPA	M	M	M
37.7	Falls Creek above Retreat Center	FALLS	M	M	M
37.1	Willapa R at Swiss Picknik Road	WRSW	M	M	M
36.2	Fern Creek at Elk Prairie Road	FERN	M	M	M
33.2	Willapa R at Lebam	WRLE	M	M	M
30.5	Fork Creek at State Hatchery	FORK	M	M	M
25.2	Willapa R at Oxbow Road	WROX	M	M	M
21.4	Willapa R at SR 6 near Menlo	WRMN	M	M	M
17.9	Mill Creek at 1st Mill Creek Road Br	MILLCK	M	M	M
17.5	Willapa R at Camp One Road	WRC1	M	M	M
13.7	Willapa R at Willapa Road	WRWI	M	M	M
12.0	Wilson Creek near Willapa	Wilson	M	M	M
7.7	Willapa R at Hwy 101 Bridge	WRHY	M	M	M
7.2	**Riverdale Creek at Lions Club Park**	**RAYSW-3**	M during rainy season	M during rainy season	M during rainy season
7.1	So Fk Willapa R at Golf Course Road	SFRK-F	M	M	M
6.4*	Willapa R at Raymond (near Port)	WRRA	M	M	M
5.9	**Raymond SW at Delaware St.**	**RAYSW-2**	M during rainy season	M during rainy season	M during rainy season
5.0*	Willapa R at the Narrows	WRNA	M	M	M
4.5*	Willapa R at South Bend – 2 (inlet to Upper Mailboat Slough)	WRSB-2	M	M	M
3.0*	Willapa R at South Bend – 1 (1 Mile Upstream Potter Slough)	WRSB-1	M	M	M
1.5*	Willapa R at South Bend – 3 (Downstream Potter/Mailboat Sloughs)	WRSB-3	M	M	M
3.75	**S Bend SW Pipe at SB Packers**	**SBSW-3**	M during rainy season	M during rainy season	M during rainy season
3.1	**Creek at Coast Seafoods**	**SBSW-2**	M during rainy season	M during rainy season	M during rainy season
0.40*	Willapa R at Johnson Slough	WRJS	M	M	M

M = Monthly – January – December 2006.
* = Requires a boat.
Bolded Sites = Stormwater drain locations (6 months sampling during rainy season – November 2005 to April 2006).

Twenty-four sites in the Upper and Lower Willapa River were sampled for fecal coliform bacteria on a monthly basis between January through December 2006 (see Table 2).

Field sampling and measurement protocols followed those described in *Sampling Protocols for River and Stream Water Quality Monitoring* (Ward, 2001) and *Field Sampling and Measurement Protocols for the Watershed Assessments Section* (Cusimano, 1993).

Bacteria grab samples were collected directly into pre-cleaned containers supplied by the laboratory and described in Manchester Environmental Laboratory (MEL, 2005). Samples were collected from the stream thalweg (center of flow) whenever possible. This may be achieved by instream wading, wading with a grab-pole to extend reach, or using a sampling-bucket to hold the sample container, lowered from a bridge by rope. Direct collection was preferred over bridge sampling whenever given a choice. Samples were collected at approximately six inches below the surface of the water, with the sampler standing downstream from the collection point. Caution was exercised not to stir up sediment in streams with slow current velocities.

Each bacteria sample was labeled, transferred to a cooler as soon as possible, placed in crushed or cube ice, and kept at greater than 0°C and no more than 4°C until the sample cases were opened by the laboratory. All samples were received at the laboratory no later than 24 hours following collection.

Laboratory analyses for fecal coliform bacteria were performed in accordance with MEL (2005) protocols. All samples were analyzed using the Membrane Filter (MF) method, except for one station where both the MF and the "most probable number" (MPN) methods were used.

Table 3 gives the measurement quality objectives (MQOs) for this project.

Table 3. Field and Laboratory Measurement Quality Objectives.

Analysis	**Accuracy** (% deviation from true value)	**Precision** (relative percent difference)	**Bias** (% deviation from true value)	**Lower Reporting Limits or Range**
Field Measurements				
Temperature	0.2 °C	N/A	N/A	1 to 40 °C
Conductivity	25	10	5	0.1 umhos/cm
Laboratory Analyses				
Fecal Coliform (MF)	N/A	< 40%	N/A	1 cfu/100 mL
Fecal Coliform (MPN)	N/A	28.3 *	N/A	1.8 MPN/100 mL

* Based on Manchester Environmental Laboratory relative standard deviation for fecal coliform and *E. coli* analysis.
N/A = not applicable.

All laboratory results, including case narratives, numerical results, and data qualifiers, were reported to the project manager. Field and laboratory data were compiled and organized using Excel spreadsheet software as the primary project data management system. Data verification, validation, and Quality Assurance evaluation (see Appendix B) were performed by staff before final data entry into the Ecology's Environmental Information Management (EIM) database. Statistical calculations were made using Excel software. Duplicate sampling results were averaged before they were used in the geometric mean and 90^{th} percentile calculations. Analysis in this report is limited to evaluation of FC bacteria.

Results and Discussion

The measurement quality objective (MQO) used by Manchester Laboratory and specified in the Quality Assurance (QA) Project Plan (Onwumere, 2006) and Table 3 for FC bacteria laboratory duplicates is 40% relative percent difference (RPD), or the percent difference between the duplicate sample concentrations. The QA evaluation (see Appendix B) indicated that the MQOs established for the laboratory duplicates were met for this project. The bacterial concentration using the MF method was within the 95^{th} percent confidence limits of the MPN method (Ahmed and Rountry, 2007).

Summary of Historical Data

Historical data from Ecology's Environmental Assessment Program showed ambient monitoring data from three freshwater stations and two marine water stations in and around the Willapa River watershed. FC bacteria data analysis from these stations showed that the highest FC levels were generally found from March through November, with the lowest levels in February. This pollution pattern shows concentrations that are repeated among years in the river. The resulting higher levels during the dry months relate to low instream dilutions during this period. Comparison of FC data from the freshwater stations to antecedent precipitation shows no significant relationship (Pickett, 1998). This is evidence that bacteria sources are better characterized as continuous sources rather than related to rainfall runoff.

A major review of bacteria issues and findings in the Willapa Bay watershed are reported in Seyferlich and Joy (1993). In addition, a more current review in the Willapa River TMDL Study Data Summary Report (Pickett, 2000) shows the following results:

- Only five sites met water quality standards for bacteria in the Willapa River watershed: the headwaters site on the mainstem Willapa River below Patton Creek, Trap and Stringer Creeks, and upstream sites on Ward and Wilson Creeks.
- Twenty-five stations exceeded the water quality standards for FC bacteria: 11 on the mainstem Willapa River and 14 on tributaries.

Summary of 2006 Freshwater Sampling Results

The freshwater Class A standards apply upstream of river mile 1.8. Figure 2 shows the geometric mean and 90^{th} percentile of data collected at each station during this study along with the water quality standard of a geometric mean of 100 cfu/100 mL and the 90^{th} percentile standard of 200 cfu/100 mL in these freshwater sampling stations.

Geometric means of FC concentrations at all stations, on an annual basis, were below the water quality standard of 100 cfu/100 mL. The geometric mean values ranged from 7 cfu/100 mL at Raymond Stormwater at Delaware Street. (RAYSW-2) to 87 cfu/100 mL at the Willapa River at Lebam (WRLE), as shown in Appendix D, Table D1. An unusually heavy rainfall occurred just

2 days before the November 2006 sampling event. Apart from the November sampling events with high FC bacteria levels at all stations, other sites with elevated FC bacteria levels were:

- Willapa River at Swiss Picknik Rd (WRSW) in July (490 cfu/100 mL), September (350 cfu/100 mL), and October (2,000 cfu/100 mL).
- Fern Creek at Elk Prairie Rd (FERN) in March (240 cfu/100 mL) and August (480 cfu/100 mL).
- Fork Creek at State Hatchery (FORK) in April (230 cfu/100 mL).
- Willapa River at Camp One Rd (WRC1) in September (210 cfu/100 mL).
- Willapa River at Willapa Rd (WRWI) in January (520 cfu/100 mL).
- Wilson Creek near Willapa (Wilson) in September (400 cfu/100 mL).
- Riverdale Creek at Lions Club Park (RAYSW-3) in February (240 cfu/100 mL).
- Creek at Coast Seafoods (SBSW-2) in April (400 cfu/100 mL).

The unusually high FC bacteria counts obtained at all sampling stations in November coincided with an isolated rain storm event that resulted in major flooding throughout Western Washington.

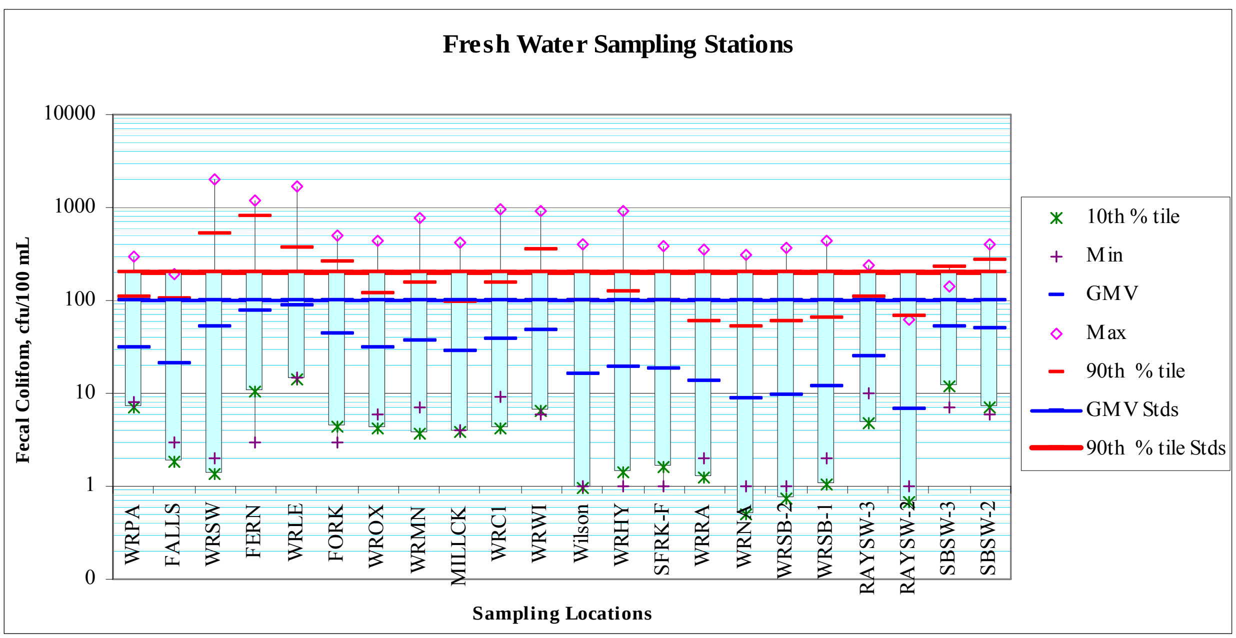

Figure 2. Fecal Coliform Bacteria Concentration Distribution at the Upper Freshwater Sampling Stations, January – December 2006. (%tile = percentile; GMV = geometric mean value)

The second part of the water quality standard that states "*not to have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL"* was exceeded at several stations. Of the 24 stations, 9 exceeded the 90th percentile water quality standard: Willapa River at Swiss Picknik Rd (WRSW), Fern Creek at Elk Prairie Rd (FERN), Willapa River at Lebam (WRLE), Fork Creek at State Hatchery (FORK), Willapa River at Willapa Rd (WRWI), South Bend stormwater pipe at SB Packers (SBSW-3), Creek at Coast Seafoods (SBSW-2), Willapa River at South Bend – 3 (WRSB-3), and Willapa River at Johnson Slough (WRJS). The highest 90th percentile exceedence occurred at the station FERN (806 cfu/100 mL), as indicated in Table D1, Appendix D.

Most of the stations meeting both criteria also had individual concentrations in excess of 200 cfu/100 mL except stations FALLS, RAYSW-2, and SBSW-3. Overall, 13 sites met both parts of the water quality standards for bacteria: 9 on the mainstem Willapa River, 3 on tributaries, and the South Fork Willapa River site. 9 stations exceeded the water quality standards for FC bacteria: 5 on the mainstem Willapa River, 2 on tributaries, and 2 stormwater sampling sites.

Summary of 2006 Stormwater Sampling Results

Only 6 samples were taken for each of the stormwater sampling sites: Riverdale Creek at Lions Club Park (RAYSW-3), Raymond Stormwater at Delaware St., South Bend stormwater pipe at SB Packers (SBSW-3) and Creek at Coast Seafoods (SBSW-2). Two of these sites – Riverdale Creek at Lions Club Park and Raymond Stormwater at Delaware Street – met both parts of the water quality standards for bacteria. The other two sites – South Bend stormwater pipe at SB Packers and Creek at Coast Seafoods – exceeded standards (see Figure 2). The small sampling size may have affected the overall data analysis since it is recommended that a minimum of 10 samples be taken for data analysis.

Summary of 2006 Marine Water Sampling Results

The marine Class A water quality standards apply downstream of river mile 1.8 of the Willapa River as specified in WAC 173-201A-140 Specific classifications-Marine water. Figure 3 shows the geometric mean and 90th percentile of data collected at each station, along with the water quality standard of a geometric mean of 14 cfu/100 mL and the 90th percentile standard of 43 cfu/100 mL in the Upper Willapa River.

Geometric means of FC concentrations at the two marine water sampling stations, on an annual basis, were within the water quality standard of 14 cfu/100 mL, as illustrated in Figure 3. The geometric mean values were 8 cfu/100 mL at the Willapa River at South Bend – 3 (WRSB-3) and 10 cfu/100 mL at the Willapa River at Johnson Slough (WRJS).

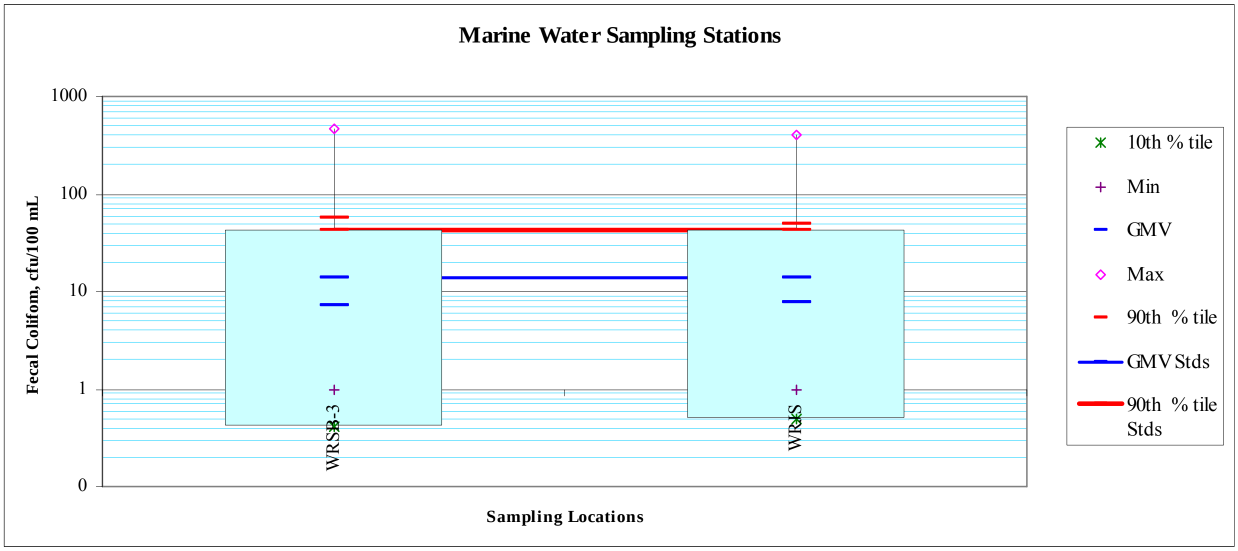

Figure 3. Fecal Coliform Bacteria Concentration Distribution at the Marine Water Sampling Stations, January – December 2006. (%tile = percentile; GMV = geometric mean value)

Elevated FC bacteria levels were only detected at these two stations during the November 2006 sampling event. This coincided with an isolated rain storm event that resulted in major flooding throughout Western Washington.

The second part of the water quality standard that states "*not to have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 43 colonies/100 mL*" was exceeded at both stations, as indicated in Figure 3. Overall, neither of the marine water sampling sites met both parts of the water quality standards for bacteria.

Marine Flight Water Sampling Stations

The Coastal and Estuarine Assessment Unit (CEAU)[1] within Ecology's Environmental Assessment Program typically conducts monthly marine flight water quality sampling studies along the Pacific Coast and South Puget Sound (see map in Appendix C, Figure C1). For the 2006 project period, the marine staff did not sample these two Willapa River stations early in the year, January – May 2006. For the remainder of the period, the staff had limited data due to bad storm conditions which prevented the floatplane from getting out to the coast.

Table 4 shows the Marine Flight water quality sampling analysis. The observed FC bacteria values were all less than 13 cfu/100 mL. Overall, the two marine flight water quality sampling sites met both parts of the water quality standards for FC bacteria.

[1] During May 2007, the name of this unit was changed to the "Marine Monitoring Unit."

Table 4. Marine Flight Fecal Coliform Bacteria Data Summary

Dates	Willapa River @ Raymond (WPA001) (cfu/100 mL)	Willapa River @ Johnson Slough (WPA003) (cfu/100 mL)
19-Jun-06	--	2
26-Jul-06	4.5	1
28-Aug-06	2	1
25-Sep-06	1	1
25-Oct-06	12	1
10th % tile Study Data	**1**	**1**
Minimum Study Data	1	1
GMV Study Data	**3**	**1**
Maximum Study Data	12	2
90th % tile Study Data	**11**	**2**
GMV Standard	100	14
90th % tile Standard	**200**	**43**

GMV = geometric mean value

The Willapa River at the Johnson Slough (WRJS) site was monitored by both studies, the marine flight and this 2006 verification study. The site met the second part of the water quality standard (90^{th} percentile criterion) in the marine flight study but failed to meet it with this study (Figure 3). This discrepancy may be due to the limited data associated with the marine flight study.

Overall, data from this study are comparable to previous studies with a pollution pattern that shows the highest FC levels were generally found from March through November, with the lowest levels in February.

Conclusions

A previous draft TMDL was based on data that were almost ten years old. The data collected in this 2006 study will be used in establishing target reductions, or numeric cleanup goals, for nonpoint sources of bacteria pollution as well as for present and future NPDES-permitted facilities to help the Willapa River meet state water quality standards.

Apart from more improvement in water quality results, data from this study are comparable to previous studies with a pollution pattern that shows the highest fecal coliform (FC) levels were generally found from March through November, with the lowest levels in February.

At the freshwater sampling stations, the geometric mean of FC concentrations at all stations, on an annual basis, were below the water quality standard of 100 cfu/100 mL for a class A waterbody. Occasionally, elevated FC bacteria levels were observed at individual stations during the sampling period. The unusually high FC bacteria counts detected at all sampling stations during the November 2006 sampling run coincided with an isolated rain storm event. This storm resulted in major flooding incidents throughout Western Washington. Even though most of the stations (15 sites) met both criteria, 9 sampling stations exceeded the second part of the water quality standard:

- 5 freshwater stations - Willapa River at Swiss Picknik Rd (WRSW), Fern Creek at Elk Prairie Rd (FERN), Willapa River at Lebam (WRLE), Fork Creek at State Hatchery (FORK), and Willapa River at Willapa Road (WRWI).
- 2 marine water stations - Willapa River at South Bend (WRSB-3) and Willapa River at Johnson Slough (WRJS).
- 2 stormwater drain systems - South Bend stormwater pipe at SB Packers (SBSW-3) and Creek at Coast Seafoods (SBSW-2).

FC concentrations in freshwater appear to have continuous sources of pollution with minor contribution from storm events.

At the two marine flight sampling stations, the observed FC bacteria values were all less than 13 cfu/100 mL. Overall, the two sites met both parts of the water quality standards for FC bacteria. However, the sample size was small.

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References

Ahmed, A. and D. Rountry, 2007. Willapa River Fecal Coliform Bacteria Total Maximum Daily Load – Water Quality Improvement Report. Washington State Department of Ecology, Olympia, WA. Publication No. 07-03-021. www.ecy.wa.gov/biblio/0703021.html

Cusimano, R., 1993. Field Sampling and Measurement Protocols for the Watershed Assessments Section. Washington State Department of Ecology, Olympia, WA. Publication No. 93-e04. www.ecy.wa.gov/biblio/93e04.html

EPA, 2001. Overview of Current Total Maximum Daily Load - TMDL - Program and Regulations. U.S. Environmental Protection Agency. www.epa.gov/owow/tmdl/overviewfs.html

Gove, N.E., R.T. Edwards, and L.L. Conquest, 2001. Effects of scale on land use and water quality relationships: a longitudinal basin-wide perspective. Journal of American Water Resources Association 37(6):1721-1734.

Herrera Environmental, 2005. Monitoring Report – Upper Willapa River Microbial Source Tracking Study.

Jensen, N., 2007. Personal communication. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA. Email, February 1.

Manchester Environmental Laboratory, 2005. Lab Users Manual. Manchester Environmental Laboratory, Washington State Department of Ecology, Manchester, WA. Eighth Edition.

Mathieu, N., 2006. Replicate Precision for 12 TMDL Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters. Washington State Department of Ecology, Olympia, WA. Publication No. 06-03-044. www.ecy.wa.gov/biblio/0603044.html

Onwumere, G.C., 2006. Quality Assurance Project Plan: Willapa River Fecal Coliform Bacteria Verification Study. Washington State Department of Ecology, Olympia, WA. 23 pages. Publication No. 06-03-202. www.ecy.wa.gov/biblio/0603202.html

Pickett, P.J., 1998. Willapa River Fecal Coliform Bacteria Total Maximum Daily Load Study Quality Assurance Project Plan. Environmental Assessment Program, Washington State Department of Ecology, Olympia, WA.

Pickett, P.J., 2000. Willapa River Total Maximum Daily Load Study Data Summary Report. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-005. www.ecy.wa.gov/biblio/0003005.html

Seyferlich, H. and J. Joy, 1993. Willapa Bay Watershed Bacterial Evaluation and Preliminary Control Strategy. Washington State Department of Ecology, Olympia, WA. Publication No. 93-64. www.ecy.wa.gov/biblio/9364.html

Ward, W.J., 2001. Stream Sampling Protocols for the Environmental Monitoring and Trends Section. Washington State Department of Ecology, Olympia, WA. Publication No. 01-03-036. www.ecy.wa.gov/biblio/0103036.html

Appendices

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Appendix A. Glossary and Acronyms

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

Best Management Practices (BMPs): Physical, structural, and/or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

Clean Water Act: Federal Act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Designated Uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each waterbody or segment, regardless of whether or not the uses are currently attained.

Fecal Coliform (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within twenty-four hours at 44.5 plus or minus 0.2 degrees Celsius. FC are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100mL).

Geometric Mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from ten to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

MQO: Measurement quality objective.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Nonpoint Source: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

Point Source: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Pollution: Such contamination, or other alteration of the physical, chemical, or biological properties, of any waters of the state, including change in temperature, taste, color, turbidity, or odor of the waters, or such discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state as will or is likely to create a nuisance or render such waters harmful, detrimental, or injurious to the public health, safety, or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation: Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

RM: River mile.

RPD: Relative percent difference.

RSD: Relative standard deviation.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, saltwaters, wetlands and all other surface waters and water courses within the jurisdiction of the state of Washington.

Total Maximum Daily Load (TMDL): A distribution of a substance in a waterbody designed to protect it from exceeding water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Appendix B. Willapa River Fecal Coliform Quality Assurance Data Evaluation

Twenty-four sites in the Upper and Lower Willapa River were sampled for fecal coliform bacteria on a monthly basis from January through December 2006. All samples were analyzed using the *Membrane Filter* (MF) method, except one station where both the MF and the *Most Probable Number* (MPN) method were used. The bacterial concentration using the MF method was within the 95th percent confidence limits of the MPN method (Ahmed and Rountry, 2007).

The **Upper Willapa River** extends from RM 17.5 at Camp One Road (Station WRC1) through RM 41.2 at the confluence with Patton Creek (station WRPA) as shown in Figure B1. In 2006, ten monitoring stations in the Upper Willapa River were sampled. Six of these stations were in the mainstem Willapa River while the remaining four stations were in the tributaries. Table B1 describes the location of each station.

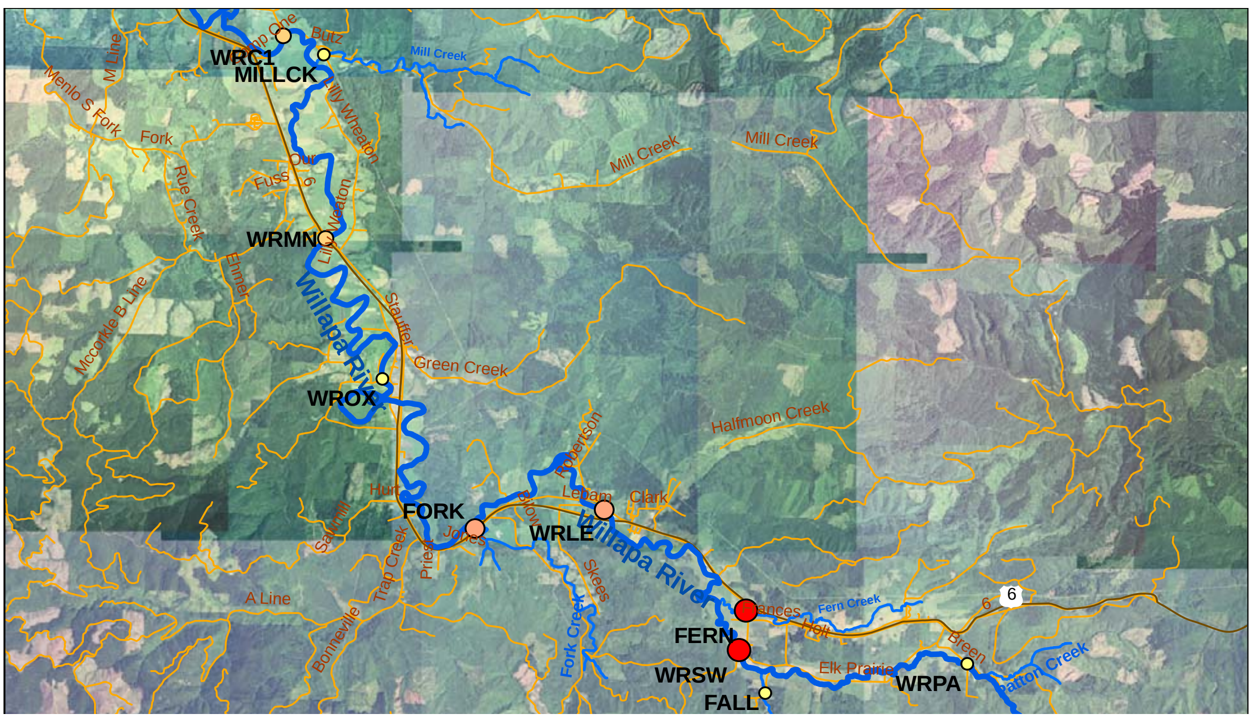

Figure B1. Upper Willapa River (RM 17.5 – 41.2) showing stations monitored in 2006.

Table B1. Location of monitoring stations in the Upper Willapa River.

Station	Location	River RM	Trib RM
WRPA	Below Patton Creek, off of Breen Road	41.2	
FALLS	Falls Ck, Retreat Cntr, on Falls Ck Road	37.5	0.3
WRSW	Swiss Picknik Road	37.1	
FERN	Fern Ck at Elk Prairie Road	36.2	0.4
WRLE	at Lebam Road	33.2	
FORK	Forks Ck at State Hatchery on Highway 6	30.5	0.2
WROX	at Oxbow Road	25.2	
WRMN	at Highway 6 bridge near Menlo	21.4	
MILLCK	Mill Creek on Mill Ck Road bridge	17.9	0.3
WRC1	on Camp One Road	17.5	

The **Lower Willapa River** can be divided into two sections. The first section extends from station WRC1 (RM 17.5) to downstream of Mailboat Slough (RM 1.8). In this section the freshwater quality standards apply. The second section extends from RM 1.8 to the mouth of the river (RM 0) beyond Johnson Slough and here the marine standards apply. This line of demarcation is established in WAC 173-201A-612. In 2006, ten mainstem stations and four tributaries were sampled in the Lower Willapa. Two of mainstem stations were seaward of RM 1.8. Figure B2 and Table B2 show the Lower Willapa River monitoring stations.

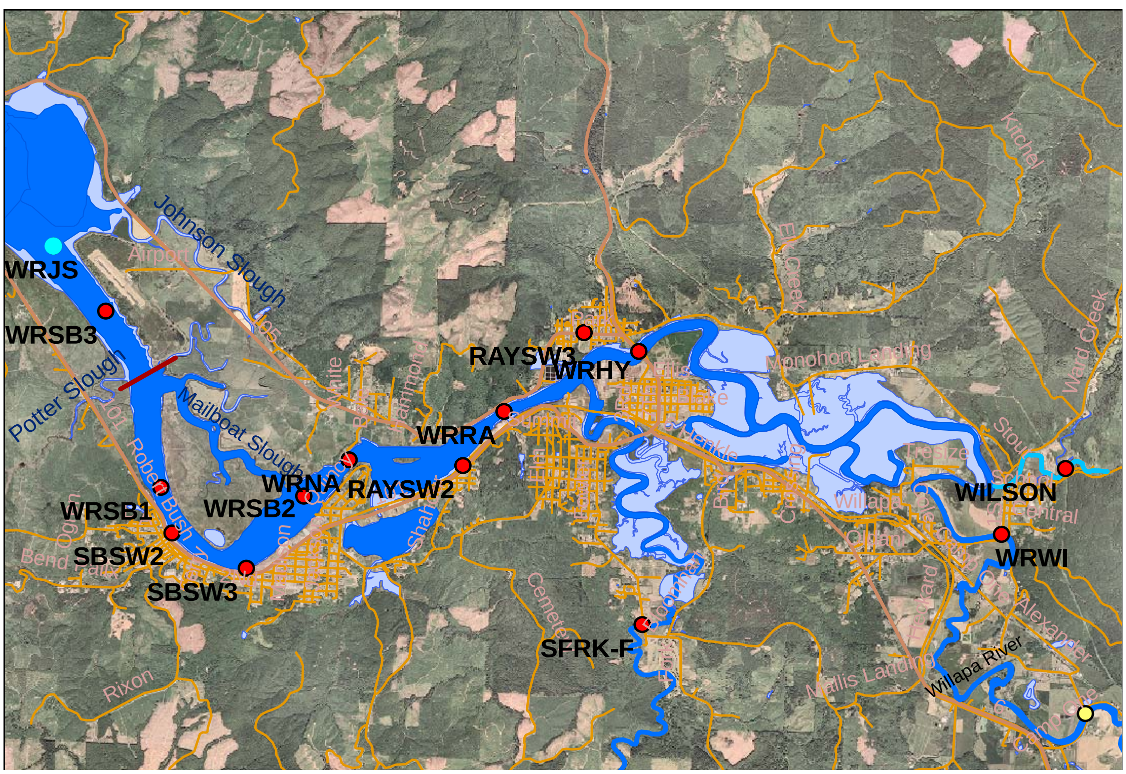

Figure B2. Lower Willapa River showing stations mentioned in 2006.

Table B2. Location of monitoring stations in the Lower Willapa River.

Station	Location	River RM	Trib RM
WRWI	at Willapa Road	13.7	
Wilson	at Wilson Creek Road bridge	12	1.45
WRHY	at Highway 101 bridge	7.7	
SFRK-F	SF at Golf course (bridge on Fowler St)	7.1	4.2
WRRA	near Port in Raymond	6.4	
WRNA	at Narrows	5	
WRSB-2	in South Bend near inlet to Upper Mailboat Slough	4.5	
WRSB-1	in South Bend, 1 mile upstream of Potter Slough	3	
WRSB-3	in South Bend, downstream of Potter Slough	1.5	
WRJS	at Johnson Slough	0.4	
RAYSW-3	Riverdale Creek at Lions Club Park	7.2	
RAYSW-2	Raymond drain, Off of Delaware St	5.9	
SBSW-3	South Bend drain, at SB Packers	3.75	
SBSW-2	Creek at Coast Seafood	3.1	

Measurement Quality Objective

Laboratory Duplicates

The measurement quality objective (MQO) used by Manchester Laboratory for fecal coliform laboratory duplicates is 40% relative percent difference (RPD), or the percent difference between the duplicate sample concentrations (Jensen, 2007). Duplicates with concentrations of 20 cfu/100 mL or less are not considered in this evaluation. Table B3 shows data for the laboratory duplicates for samples collected in the Willapa River in 2006. The laboratory analyzed 31 duplicate samples and found 23 duplicates with counts greater than 20 cfu/100 mL, and they were within the 40% RPD required for meeting the laboratory MQO. Of the 8 samples exceeding 40% RPD, the bacterial counts in all the samples were less than 20 cfu/100 mL. The MQOs established for the laboratory duplicates were met for this project (Ahmed and Rountry, 2007).

Table B3. Fecal coliform data for laboratory duplicates, Willapa River, 2006.

station	sampling date	sample, #/100 mL	duplicate, #/100 mL	mean	%RPD	IF %RPD>40, is #/100 mL>20?
RAYSW-2	6-Feb-06	1	1	1	0	
WRSB-2	6-Sep-06	2	2	2	0	
WRJS	4-Apr-06	3	3	3	0	
WRSB-1	18-Jan-06	140	140	140	0	
MILLCK	7-Aug-06	28	27	28	4	
SFRK-F	6-Nov-06	670	630	650	6	
WRC1	3-Apr-06	10	11	11	9	
WRNA	10-Jul-06	10	9	10	10	
WRPA	17-Jan-06	28	25	27	11	
WRMN	6-Mar-06	9	8	9	11	
MILLCK	6-Feb-06	7	8	8	13	
WROX	17-Jan-06	40	46	43	13	
MILLCK	9-Oct-06	79	93	86	15	
WROX	5-Jun-06	50	61	56	18	
WRHY	10-Jul-06	40	32	36	20	
WRSB-2	7-Feb-06	9	7	8	22	
WRC1	10-May-06	12	9	11	25	
WRJS	8-Nov-06	330	480	405	31	
WRPA	3-Apr-06	15	10	13	33	
RAYSW-3	10-May-06	15	10	13	33	
SFRK-F	17-Jan-06	9	14	12	36	
WRSB-3	8-Aug-06	11	7	9	36	
WRHY	5-Sep-06	10	6	8	40	
WRSB-2	9-May-06	1	2	2	50	no
FALLS	6-Mar-06	4	9	7	56	no
WRJS	6-Jun-06	7	3	5	57	no
WRJS	5-Dec-06	12	5	9	58	no
WRSB-3	10-Oct-06	28	11	20	61	no
SFRK-F	6-Mar-06	4	11	8	64	no
Wilson	4-Dec-06	4	1	3	75	no
WRRA	7-Mar-06	4	1	3	75	no

Quality Assurance (QA) Samples

The QA samples are blind field duplicates with no identification provided to the laboratory. There were 53 QA samples collected during the course of sampling in 2006. Of the 53 samples, 32 had a mean FC concentration greater than 20 cfu/100 mL.

The recommended MQO for quality assurance samples established by Ecology's Environmental Assessment Program requires that 50% of the QA samples be below a 20% relative standard deviation (RSD) and 90% of the samples be below a RSD of 50% (Mathieu, 2006). The RSD is defined as the percent standard deviation divided by the mean or percent coefficient of variation for the duplicate QA samples. None of the samples used to assess the MQO should have mean concentrations of 20 cfu/100 mL or less. Figures B3 and B4 show the plot for the QA results for samples with a mean concentration of more than 20 cfu/100 mL. The samples met the MQO prescribed for the QA samples (Ahmed and Rountry, 2007). Tables B4 and B5 show data for the QA samples.

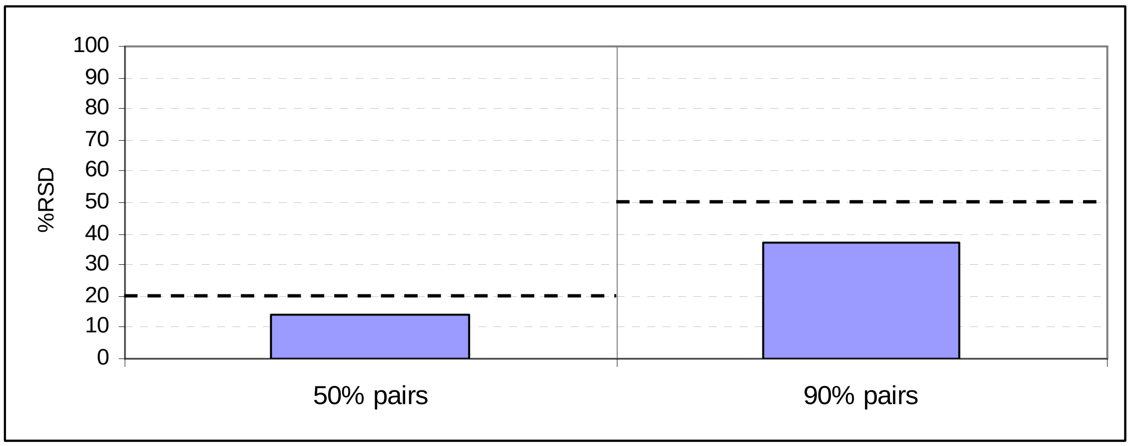

Figure B3. Percent RSD for QA samples (cfu/100 mL > 20) in the Willapa River (2006).

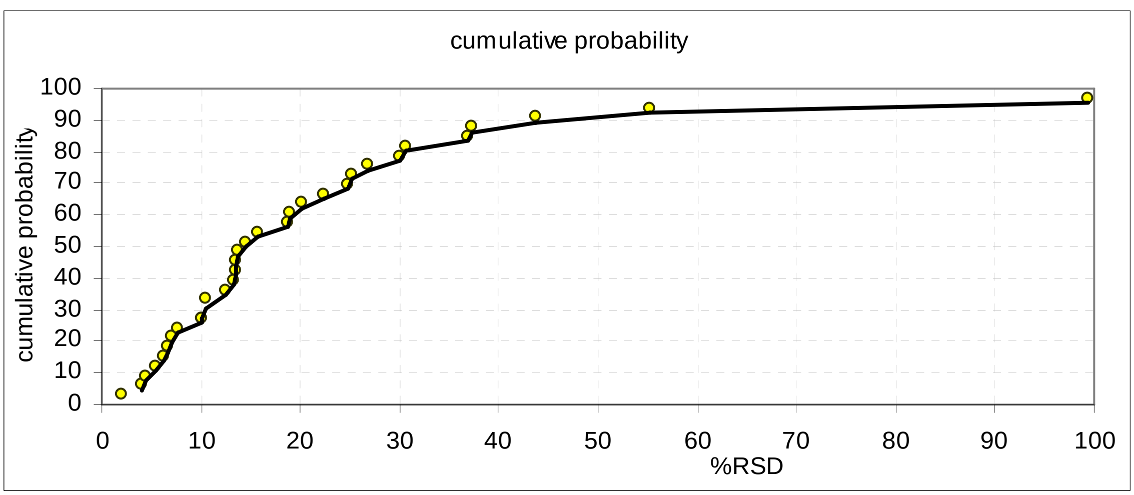

Figure B4. Cumulative probability distribution of %RSD for the QA samples with cfu/100 mL > 20.

Table B4. Fecal coliform data for QA samples with mean cfu/100 mL > 20, Willapa River, 2006.

station	sample date	sample, #/100 mL	QA, #/100 mL
WRPA	6-Mar-06	49	46
FALLS	7-Aug-06	29	17
WRSW	5-Sep-06	350	360
FERN	5-Jun-06	480	580
FERN	9-Oct-06	120	92
WRLE	10-May-06	110	75
WRLE	10-Jul-06	130	170
WRLE	6-Nov-06	1700	1400
FORK	5-Jun-06	47	52
FORK	7-Aug-06	150	130
WROX	6-Mar-06	25	27
WROX	5-Sep-06	33	47
WRMN	10-Jul-06	44	49
WRMN	9-Oct-06	110	80
MILLCK	10-May-06	32	14
WRC1	6-Nov-06	970	800
WRWI	17-Jan-06	520	550
WRWI	10-Jul-06	76	92
Wilson	5-Jun-06	33	23
Wilson	5-Sep-06	400	300
WRHY	6-Feb-06	37	31
SFRK-F	9-Oct-06	61	75
SFRK-F	6-Nov-06	390	670
WRNA	8-Aug-06	20	22
WRSB-2	18-Jan-06	100	80
WRSB-3	10-Oct-06	28	18
WRSB-3	8-Nov-06	470	430
RAYSW-3	6-Feb-06	240	208
RAYSW-3	4-Dec-06	36	31
SBSW-2	17-Jan-06	55	29
SBSW-2	3-Apr-06	400	260
SBSW-2	10-May-06	63	11

Table B5. Fecal coliform data for QA samples with mean cfu/100 mL ≤ 20, Willapa River, 2006.

station	sample date	sample, #/100 mL	QA, #/100 mL
WRPA	4-Dec-06	8	3
FALLS	6-Feb-06	4	2
WRSW	17-Jan-06	8	7
WRLE	3-Apr-06	16	10
MILLCK	17-Jan-06	11	20
MILLCK	4-Dec-06	15	3
WRC1	6-Feb-06	16	19
WRC1	3-Apr-06	13	10
WRHY	7-Aug-06	5	9
SFRK-F	6-Mar-06	4	3
SFRK-F	3-Apr-06	9	8
SFRK-F	4-Dec-06	3	3
WRRA	6-Jun-06	11	6
WRNA	6-Sep-06	3	5
WRSB-2	7-Feb-06	10	9
WRSB-1	7-Mar-06	2	3
WRSB-1	9-May-06	2	1
WRJS	4-Apr-06	1	3
WRJS	10-Jul-06	3	1
WRJS	5-Dec-06	11	12
RAYSW-2	6-Mar-06	1	3

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Appendix C. 2006 Marine Flight Water Quality Sampling Sites

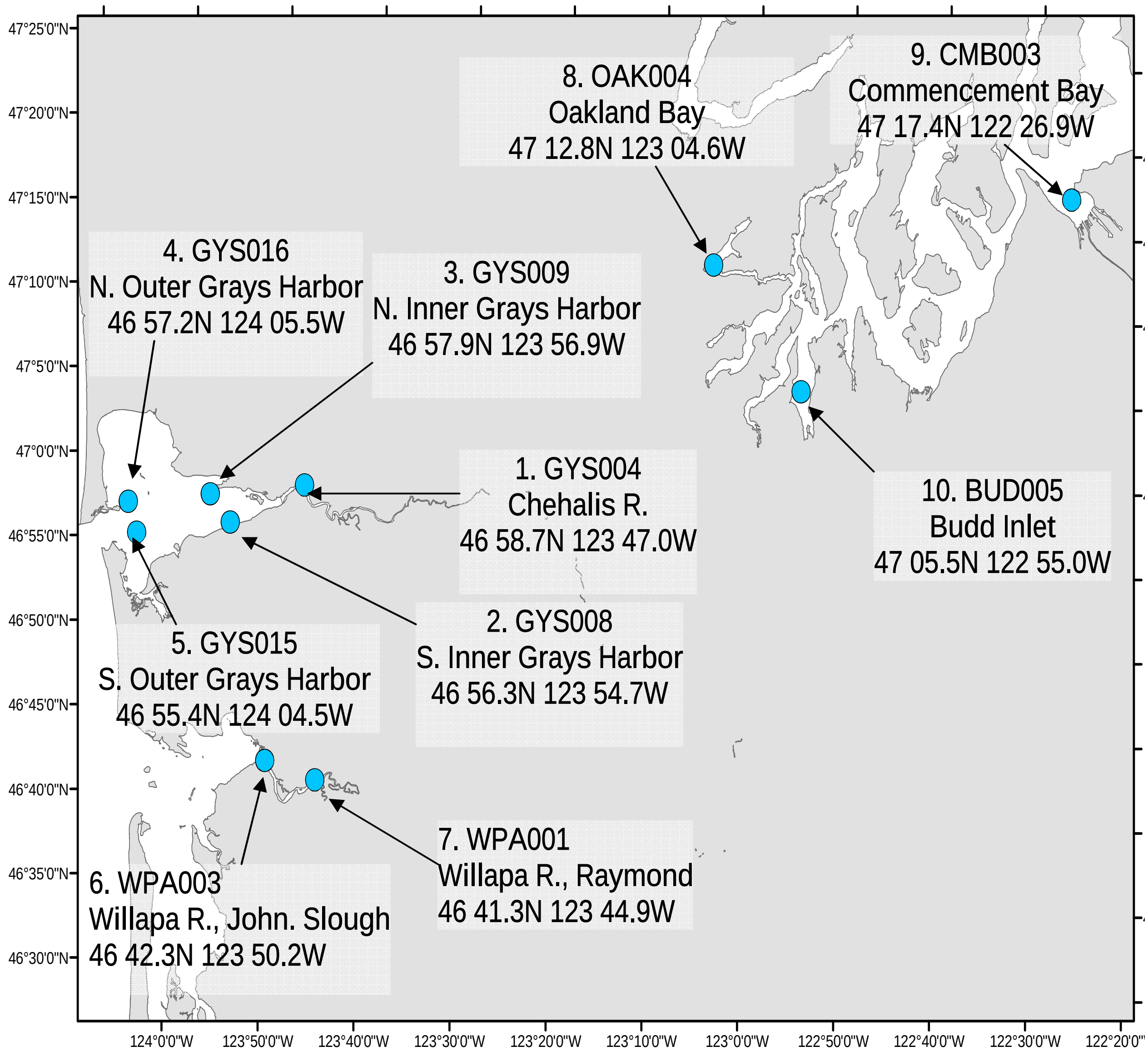

Figure C1. 2007 marine flight water quality sites for the Pacific Coast and South Puget Sound.

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Appendix D. Willapa River Water Quality Data (Jan-Dec, 2006)

Table D1. Fecal coliform data (cfu/100 mL) at all stations in the Willapa River (Jan-Dec, 2006).

Date	WRPA	FALLS	WRSW	FERN	WRLE	FORK	WROX	WRMN	MILLCK	WRC1	WRWI	Wilson	WRHY	SFRK-F	WRRA	WRNA	WRSB-2	WRSB-1	WRSB-3	WRJS	RAYSW-3	RAYSW-2	SBSW-3	SBSW-2
Jan-06	27	4	8	160	57	10	43	63	11	92	520	3	140	12	53	80	100	140	110	110	19	61	7	55
Feb-06	8	4	8	160	57	8	8	7	8	16	26	6	37	7	7	8	10	14	14	14	240	1	28	6
Mar-06	49	7	8	240	140	68	25	9	25	12	13	3	6	8	3	1	3	2	4	2	11	1	120	19
Apr-06	13	5	2	10	16	230	7	7	4	13	11	1	18	9	3	1	4	4	2	1	10	48	140	400
May-06	24	11	69	92	110	3	8	16	32	11	13	16	1	1	2	1	2	2	1	1	13	5	120	63
Jun-06	27	50	80	480	180	47	56	120	88	80	150	33	10	51	11	4	5	7	3	5				
Jul-06	120	180	490	40	130	59	49	44	32	32	76	64	36	51	19	10	3	6	1	3				
Aug-06	37	29	86	48	40	150	51	47	28	27	88	40	5	53	24	20	19	16	9	8				
Sep-06	16	75	350	3	57	92	33	100	23	210	43	400	8	28	5	3	2	6	1	3				
Oct-06	62	100	2000	120	180	120	150	110	86	40	27	34	39	61	44	36	30	21	20	11				
Nov-06	300	190	890	1200	1700	490	430	760	420	970	930	130	900	390	360	310	370	430	470	405				
Dec-06	8	3	3	15	15	6	6	8	15	9	6	3	8	3	20	10	10	9	8	11	36	7	55	93

Statistics	WRPA	FALLS	WRSW	FERN	WRLE	FORK	WROX	WRMN	MILLCK	WRC1	WRWI	Wilson	WRHY	SFRK-F	WRRA	WRNA	WRSB-2	WRSB-1	WRSB-3	WRJS	RAYSW-3	RAYSW-2	SBSW-3	SBSW-2
10th %	7	2	1	11	14	4	4	4	4	4	6	1	1	2	1	1	1	1	0	0	5	1	12	7
Min	8	3	2	3	15	3	6	7	4	9	6	1	1	1	2	1	1	2	1	1	10	1	7	6
Geomean	31	21	53	75	87	44	31	37	28	39	48	16	19	18	14	9	10	12	7	8	25	7	53	49
Max	300	190	2000	1200	1700	490	430	760	420	970	930	400	900	390	360	310	370	430	470	405	240	61	140	400
90th %	111	106	525	806	363	260	121	157	95	154	352	99	127	101	59	53	58	64	58	50	108	68	233	272

Table D2. Temperature data (°C) at all stations in the Willapa River basin (Jan-Dec, 2006).

Date	WRPA	FALLS	WRSW	FERN	WRLE	FORK	WROX	WRMN	MILLCK	WRC1	WRWI	Wilson	WRHY	SFRK-F	WRRA	WRNA	WRSB-2	WRSB-1	WRSB-3	WRJS	RAYSW-3	RAYSW-2	SBSW-3	SBSW-2
Jan-06	8.1	7.6	7.8	7.8	7.6	7.5	7.6	7.4	7.4	7.6	7.6	7.4	7.4	8.0	7.6	7.5	7.5	7.6	7.6	7.5	8.3	8.2	7.5	7.5
Feb-06	6.9	6.0	6.3	6.3	6.3	6.3	6.4	6.6	6.4	6.7	6.5	6.2	6.6	7.3	6.9	7.1	7.5	7.4	7.5	7.6	8.3	8.4	7.9	7.2
Mar-06	6.1	6.2	6.4	6.6	6.8	6.7	6.8	7.0	6.7	7.0	7.1	6.7	6.8	6.7	6.8	6.8	6.8	6.9	6.9	6.9	8.5	9.1	8.7	6.7
Apr-06	7.2	7.3	7.7	7.8	8.1	7.9	8.0	8.1	8.3	8.5	8.3	8.1	10.3	8.5	9.4	9.6	9.6	9.6	9.5	9.5	8.9	9.4	9.8	9.9
May-06	6.3	6.3	6.8	9.2	8.4	7.4	9.1	10.0	11.1	8.9	12.8	8.6	13.6	9.0	14.1	14.2	13.7	14.4	14.5	14.7	9.6	11.4	13.6	13.6
Jun-06	10.3	11.2	11.8	13.3	12.9	11.1	12.8	13.3	13.0	14.0	14.5	12.6	15.9	12.3	16.6	16.8	16.9	17.1	17.1	17.2	--	--	--	--
Jul-06	11.3	12.3	13.2	15.4	15.7	13.3	16.4	18.0	14.1	17.9	18.5	14.3	18.2	13.6	20.4	20.3	20.0	20.1	20.1	20.0	--	--	--	--
Aug-06	--	--	--	--	--	--	--	--	--	--	--	--	--	--	9.7	9.6	9.4	9.3	8.9	9.0	--	--	--	--
Sep-06	12.0	12.7	14.0	13.0	15.8	14.2	17.3	18.7	15.4	18.0	18.7	14.4	18.5	14.9	--	--	--	--	--	--	--	--	--	--
Oct-06	9.9	10.2	10.8	10.3	11.4	10.7	11.7	12.6	11.2	12.6	13.7	9.9	14.5	10.8	14.1	13.9	13.1	13.5	13.3	13.1	--	--	--	--
Nov-06	10.5	10.7	10.7	11.1	10.7	10.2	10.5	10.2	10.7	10.7	10.7	10.5	10.7	10.9	10.7	11.0	10.9	11.1	11.2	11.2	--	--	--	--
Dec-06	6.5	6.1	6.0	5.9	5.8	5.9	5.7	5.8	5.2	5.6	5.0	4.9	6.0	7.0	5.7	5.8	5.7	5.8	5.9	5.9	7.3	8.1	7.3	5.9

Statistics	WRPA	FALLS	WRSW	FERN	WRLE	FORK	WROX	WRMN	MILLCK	WRC1	WRWI	Wilson	WRHY	SFRK-F	WRRA	WRNA	WRSB-2	WRSB-1	WRSB-3	WRJS	RAYSW-3	RAYSW-2	SBSW-3	SBSW-2
Average	8.7	8.8	9.2	9.7	10.0	9.2	10.2	10.7	10.0	10.7	11.2	9.4	11.7	9.9	11.1	11.1	11.0	11.2	11.1	11.1	8.5	9.1	9.1	8.5
Minimum	6.1	6.0	6.0	5.9	5.8	5.9	5.7	5.8	5.2	5.6	5.0	4.9	6.0	6.7	5.7	5.8	5.7	5.8	5.9	5.9	7.3	8.1	7.3	5.9
Maximum	12.0	12.7	14.0	15.4	15.8	14.2	17.3	18.7	15.4	18.0	18.7	14.4	18.5	14.9	20.4	20.3	20.0	20.1	20.1	20.0	9.6	11.4	13.6	13.6
Sample #	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	6	6	6	6

Table D3. Electrical conductivity data (umhos/cm) at all stations in the Willapa River (Jan-Dec, 2006).

Date	WRPA	FALLS	WRSW	FERN	WRLE	FORK	WROX	WRMN	MILLCK	WRC1	WRWI	Wilson	WRHY	SFRK-F	WRRA	WRNA	WRSB-2	WRSB-1	WRSB-3	WRJS	RAYSW-3	RAYSW-2	SBSW-3	SBSW-2
Jan-06	54	37	42	65	50	41	47	48	55	48	47	50	74	54	78	357	1,478	2,050	4,290	5,460	76	91	107	60
Feb-06	55	39	45	66	51	45	50	52	57	53	54	57	83	56	4,600	7,690	13,220	12,830	15,160	14,670	75	100	172	82
Mar-06	52	43	48	79	59	49	55	58	65	60	61	65	6,720	68	12,880	19,520	22,100	22,000	21,600	21,000	87	166	640	251
Apr-06	54	43	48	77	56	48	53	55	65	57	59	66	2,620	63	14,900	19,440	22,200	21,800	22,100	21,400	83	135	375	15,080
May-06	57	50	53	98	62	55	60	63	65	73	66	74	21,100	74	21,600	24,700	27,800	27,700	29,800	29,500	86	200	188	31,100
Jun-06	53	50	51	102	62	49	56	58	74	60	62	73	12,160	68	17,870	21,300	21,700	24,000	26,100	26,400	--	--	--	--
Jul-06	57	54	57	126	64	72	65	68	86	73	14,550	88	31,500	79	32,900	35,200	37,300	39,100	41,000	37,200	--	--	--	--
Aug-06	59	55	58	140	62	67	68	72	93	76	8,980	93	35,500	78	36,300	38,500	39,400	41,000	43,000	43,200	--	--	--	--
Sep-06	57	56	58	166	62	67	69	76	101	81	16,390	94	38,400	76	41,000	42,400	43,000	43,600	45,100	45,800	--	--	--	--
Oct-06	61	59	60	175	63	69	70	73	102	80	13,280	100	40,300	262	34,700	38,900	40,300	41,900	43,300	44,400	--	--	--	--
Nov-06	52	41	38	93	53	38	46	48	73	52	51	71	6,960	52	--	--	--	--	--	--	--	--	--	--
Dec-06	57	43	49	80	58	50	56	59	65	62	71	73	500	70	3,780	8,120	9,660	13,690	15,730	16,840	106	116	678	191
Statistics	**WRPA**	**FALLS**	**WRSW**	**FERN**	**WRLE**	**FORK**	**WROX**	**WRMN**	**MILLCK**	**WRC1**	**WRWI**	**Wilson**	**WRHY**	**SFRK-F**	**WRRA**	**WRNA**	**WRSB-2**	**WRSB-1**	**WRSB-3**	**WRJS**	**RAYSW-3**	**RAYSW-2**	**SBSW-3**	**SBSW-2**
Average	56	48	50	105	59	54	58	61	75	65	4,473	75	16,326	83	20,055	23,284	25,287	26,334	27,925	27,806	85	116	360	7,794
Minimum	52	37	38	65	50	38	46	48	55	48	47	50	74	52	78	357	1,478	2,050	4,290	5,460	75	165	107	60
Maximum	61	58	60	175	64	72	70	76	102	81	16,390	100	40,300	262	41,000	42,400	43,000	43,600	45,100	45,800	106	91	678	31,100
Sample #	12	12	12	12	12	12	12	12	12	12	12	12	12	12	11	11	11	11	11	11	6	6	6	6