Liberty Bay Tributaries Fecal Coliform Bacteria Total Maximum Daily Load

Water Quality Study Design (Quality Assurance Project Plan)

By Trevor Swanson

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Study Codes

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Federal Clean Water Act 2008 303(d) Listings Addressed in this Study: See Table 1

Waterbody Numbers: See Table 1

Cover photo: Looking across Liberty Bay at Poulsbo from a small inlet near Perry Creek (photo by Mark Von Prause).

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Abstract

The Washington State Department of Ecology (Ecology) is required, under section 303(d) of the federal Clean Water Act and U.S. Environmental Protection Agency (EPA) regulations, to develop and implement Total Maximum Daily Loads (TMDLs) for impaired waters. A TMDL analyzes how much pollution a waterbody can assimilate without violating Washington State water quality standards. EPA requires states to set priorities for cleaning up 303(d) listed waters and to establish a TMDL for each.

Liberty Bay is located in Kitsap County, south of the city of Poulsbo. Liberty Bay and Johnson, Big Scandia, Little Scandia, Lemolo, Bjorgen, and Barrantes Creeks were listed by Ecology for exceeding fecal coliform (FC) bacteria standards. Additional 303(d) listings exist within the Liberty Bay watershed for various toxic substances, pH, and dissolved oxygen. This TMDL study is limited to FC bacteria.

Each TMDL study conducted by Ecology must have an approved Quality Assurance (QA) Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. The objectives include (1) identifying and characterizing FC bacteria concentrations and loads from all major inputs to Liberty Bay (2) and developing target reductions of FC bacteria to support establishing load and wasteload allocations.

While the overall goal of the TMDL is to improve water quality in Liberty Bay, this study will focus on the analysis of the freshwater creek and stormwater FC contributions to the bay. Ecology will target freshwater sources most likely to contribute to marine saltwater FC. But the TMDL cannot provide an estimate of the resulting change in FC concentrations in the bay.

The Liberty Bay FC TMDL study will be conducted by Ecology's Environmental Assessment Program. After completion of the study, a final report describing the study results will be posted to the Internet.

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, each state is required to have 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, as well as criteria (usually numeric) 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. To develop the list, the Washington State Department of Ecology (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 the data are used to develop the 303(d) list. The 303(d) list is part of the larger Water Quality Assessment.

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 five categories:

Category 1 – Meets standards for the parameter (or parameters) for which it has been tested

Category 2 – Waters of concern

Category 3 – Waters with no data available

Category 4 – Polluted waters that do not require a TMDL because:

- 4a. – Has an approved TMDL and it 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 – the 303(d) list.

TMDL process overview

The Clean Water Act requires that a TMDL be developed for each of the waterbodies on the 303(d) list. The TMDL identifies pollution problems in the watershed and specifies how much pollution needs to be reduced or eliminated to achieve clean water. Then Ecology works with the local community to develop an overall approach to control the pollution, called the Implementation Strategy, and a monitoring plan to assess effectiveness of the water quality improvement activities. Once the TMDL has been approved by the U.S. Environmental Protection Agency (EPA), a *Water Quality Implementation Plan* must be developed within one year. This Plan identifies specific tasks, responsible parties, and timelines for achieving clean water.

Elements required in a TMDL

The goal of a TMDL is to ensure the impaired water will attain Washington State 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 (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 the pollutant comes from a set of diffuse (nonpoint) sources 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.

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.

TMDL = Loading Capacity = sum of all wasteload allocations + sum of all load allocations + margin of safety.

What Part of the Process Are We In?

The steps and a rough timeline included in developing any TMDL are as follows:

Year 1:	Identify priority areas where TMDLs are necessary (in this case, Liberty Bay).
Years 2 & 3:	Design and carry out the TMDL process (includes Quality Assurance Project Plan writing and sampling).
Year 4:	Develop the TMDL and write the technical TMDL report.
Year 5:	Implement TMDL recommendations and monitor for effectiveness.

Currently, Ecology is collecting fecal coliform samples, streamflow data, and other field data necessary to complete a TMDL analysis of the Liberty Bay watershed. Current and historical data from other agencies and groups may be used in the analysis as well.

Why is Ecology Conducting a TMDL Study in This Watershed?

Overview

Ecology is conducting a Total Maximum Daily Load (TMDL) study in this watershed because there is strong evidence of bacterial contamination that is affecting beneficial uses in the area, such as shellfish harvesting and *Primary Contact Recreation*.

Section 303(d) of the federal Clean Water Act periodically requires Washington State to prepare a list of all surface waters in the state that do not meet water quality standards and are not expected to improve within the next two years. Liberty Bay and Johnson, Big Scandia, Little Scandia, Lemolo, Bjorgen, and Barrantes Creeks are on Ecology's 2008 303(d) list for fecal coliform (FC) bacteria (Ecology, 2008).

TMDL evaluations are required to identify the maximum amount of each pollutant to be allowed into these waterbodies so as not to impair beneficial uses of the water. The TMDL is then used to determine the (1) wasteload allocations among sources with wastewater and stormwater permits and (2) load allocations among various nonpoint diffuse sources that do not have permits.

The resulting TMDL technical report will be used to develop FC bacteria TMDLs in the tributaries to Liberty Bay. The TMDLs will set water quality targets to meet FC bacteria criteria, identify key reaches for source pollution reduction, and allocate pollutant loads to nonpoint sources. The TMDL study will be conducted by Ecology's Environmental Assessment Program in cooperation with Ecology's Water Quality Program, Washington State Department of Health, Suquamish Tribe, Kitsap County Health District, and other local entities.

Study area

Liberty Bay and its tributaries are located in Kitsap County near the city of Poulsbo in Water Resource Inventory Area (WRIA) 15 (Figure 1). Keyport is located to the south of Liberty Bay and is home to the U.S. Navy's Undersea Weapons Center. Rural communities surrounding Liberty Bay include Lemolo, Virginia, Pearson, and Scandia.

Dogfish Creek is the largest tributary to Liberty Bay, but other creeks and storm drains also contribute freshwater to the bay. The study area includes all creeks and drains to Liberty Bay, including Lemolo, Bjorgen, and Sam Snyder Creeks in Nesika Bay. Keyport and Thompson Creeks, which flow into Port Orchard near the southern end of Nesika Bay, are not included in the study area; however, these two creeks may be investigated as resources allow.

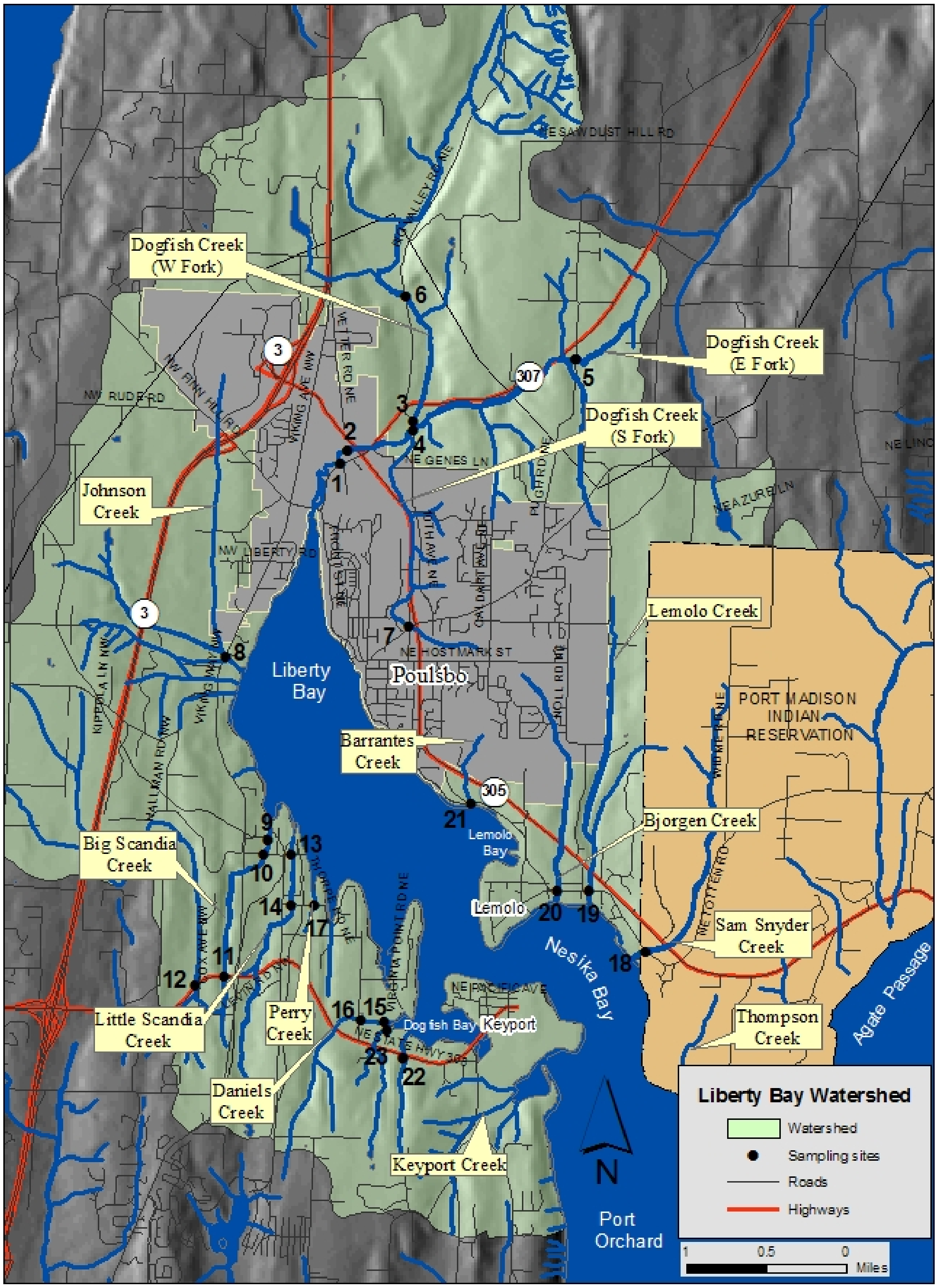

Figure 1. Map of Liberty Bay and Nesika Bay watersheds, including tributaries to Agate Passage and Port Orchard Bay. Numbers reference Table 8.

Pollutants addressed by this TMDL

This TMDL will address FC bacteria concentrations and loads in tributaries to Liberty Bay, including Dogfish, Johnson, Big and Little Scandia, Perry, Daniels, Lemolo, Bjorgen, and Sam Snyder Creeks.

Impaired beneficial uses and waterbodies on Ecology's 303(d) List of impaired waters

Beneficial uses for protection by this TMDL include shellfish harvesting and primary and secondary recreations in Liberty Bay and its tributaries. Shellfish harvesting is threatened by high fecal coliform bacteria levels in the bay. Most of the bacteria are suspected to come from nonpoint sources near tributary creeks or near Liberty Bay. *Primary and Secondary Contact Recreations* in both the marine waters and freshwaters include people coming into contact with water through boating, fishing, wading, swimming, and other water-related activities. Table 1 lists 303(d) Category 5 listings for FC in Liberty Bay and its tributaries.

Dogfish Creek has eight 303(d) Category 4B listings (has a pollution control plan in place that should solve the problem). Ecology and the EPA approved Kitsap County's plan for pollution control in Dogfish Creek. Daniels Creek has two 4B listings and also has an approved Kitsap County pollution control plan underway.

Table 1. Study area 303(d) Category 5 listings for fecal coliform.

Waterbody	WASWIS	Old Waterbody Numbers	Listing ID	Latitude/Longitude or Section, Township, Range	Marine Grid Cell
Liberty Bay	390KRD	WA-15-0100	38687 23704 23708 23709 23707 23705 23701 23700 13931 45224	47.725 -122.655 47.715 -122.655 47.735 -122.655 47.745 -122.655 47.735 -122.645 47.725 -122.635 47.705 -122.635 47.705 -122.625 47.715 -122.625 47.745 -122.645	47122H6C5 47122H6B5 47122H6D5 47122H6E5 47122H6D4 47122H6C3 47122H6A3 47122H6A2 47122H6B2 47122H6E4
Johnson Creek	VD71BW	WA-15-2036	38663	26.0N - 01.0E - 22	
Big Scandia Creek	CC82SQ	--	38444	26.0N - 01.0E - 27	
Little Scandia Creek	II47ZW	--	23692	26.0N - 01.0E - 27	
Lemolo Creek	AO74VW	--	23544	26.0N - 01.0E - 25	
Bjorgen Creek	IS22QB	--	23693 45032	26.0N - 01.0E – 25 26.0N - 01.0E - 24	
Barrantes Creek	--	--	45535	26.0N - 01.0E - 26	

WASWIS – WA Surface Water Identification System

This study will be looking at the Liberty Bay watershed more thoroughly and may find other waterbodies impaired by FC bacteria.

This watershed has other water quality issues that will not be addressed in this TMDL. Table 2 lists additional 303(d) listings for parameters other than FC occurring in the study area. But these parameters are not addressed in this study.

Table 2. Additional 303(d) Category 5 listings not addressed by this study.

Waterbody	Parameter	Medium	WASWIS	Listing ID	Latitude/Longitude or Section, Township, Range	Marine Grid Cell
Liberty Bay	D.O.	Water	390KRD	23537 23541 10268 38682	47.715 -122.625 47.725 -122.645 47.735 -122.645 47.735 -122.655	47122H6B2 47122H6C4 47122H6D4 47122H6D5
	Multiple toxics	Sediment	390KRD	Multiple listings	Multiple locations, mostly southern Liberty Bay	(See comment to left)
Dogfish Creek	D.O.	Water	OQ62QE	23529	26.0N - 01.0E - 14	
Dogfish Creek, East Fork	D.O.	Water	AE23TW	38539	26.0N - 01.0E - 11	
Johnson Creek	D.O.	Water	VD71BW	38662	26.0N - 01.0E - 22	
Big Scandia Creek	D.O.	Water	CC82SQ	38443	26.0N - 01.0E - 27	
Little Scandia Creek	D.O.	Water	II47ZW	23672	26.0N - 01.0E - 27	
Daniels Creek	D.O.	Water	--	52977	26.0N - 01.0E - 35	
Sam Snyder Creek	pH	Water	YL66GE	23715	26.0N - 01.0E - 36	
Lemolo Creek	D.O.	Water	AO74VW	23671 48043	26.0N - 01.0E - 25 26.0N - 01.0E - 24	
Bjorgen Creek	D.O.	Water	IS22QB	23673 48045	26.0N - 01.0E - 25 26.0N - 01.0E - 24	
Barrantes Creek	D.O.	Water	--	48046	26.0N - 01.0E - 26	

D.O. – Dissolved oxygen
WASWIS – WA Surface Water Identification System

Why are we doing this TMDL now?

Reducing FC bacteria in the creeks that drain to Liberty Bay will (1) increase opportunity to open shellfish beds for recreational and commercial harvest and (2) improve water quality of the creeks and the bay for both aquatic life and human uses.

Two citizens groups, the Liberty Bay Foundation (www.libertybayfoundation.com/homepage.htm) and the Puget Sound Restoration Fund (www.restorationfund.org), have worked actively in recent years to bring attention to water quality problems in Liberty Bay and to undertake projects to restore harvestable shellfish.

The Liberty Bay Foundation monitored water quality in marine and nearshore areas of the bay as well as outfalls and creeks, concentrating on the wet weather seasons of 2001-2003. Their water quality report was published in 2005 and is available on their website.

The Puget Sound Restoration Fund selected Liberty Bay as one of several Puget Sound locations for restoring native Olympia oysters. In 2007, the Restoration Fund spread oyster shells on the bottom sediments of Liberty Bay near Poulsbo to provide appropriate substrate for native Olympia oyster spat (larvae) growth.

These examples of local interest and support made it an opportune time for Ecology to commit resources to addressing freshwater and marine listings for bacteria (Table 1).

How will the results of this study be used?

A TMDL study identifies how much pollution needs to be reduced or eliminated to achieve clean water. This is done by assessing pollution problems and then recommending practices to reduce pollution, and by establishing limits for facilities that have permits. Since the study may also identify the main sources or source areas of pollution, Ecology and local partners can figure out where to focus water quality improvement activities. Or, sometimes the study suggests areas for follow-up studies to further pinpoint sources for cleanup.

Water Quality Standards and Beneficial Uses

The Washington State Water Quality Standards, set forth in Chapter 173-201A of the Washington Administrative Code (WAC), include designated beneficial uses, waterbody classifications, and numeric and narrative water quality criteria for surface waters of the state.

Freshwater and marine waterbodies are required to meet water quality standards based on the beneficial uses of the waterbody. Numeric criteria for specific water quality parameters are intended to protect designated uses. Liberty Bay is classified as *Primary Contact Recreation* water. All tributaries flowing into the bay are classified as *Extraordinary Primary Contact Recreation* waters.

Bacteria

WAC 173-201A-060 describes the application of freshwater and marine water quality standards on the basis of salinity. Where 95% of the salinity values are less than one part per thousand (ppt), the freshwater standards apply. The marine water quality standard applies where salinity is 10 ppt or greater. If data shows a 95th percentile conductivity of 17,700 micromhos, equivalent to salinity greater than 10 ppt, marine FC standards apply.

The FC criteria have two statistical components: a geometric mean and an upper limit value that 10% of the samples cannot exceed. Fecal coliform samples collected randomly follow a lognormal distribution. In Washington State FC TMDL studies, the upper limit statistic (i.e., not more than 10% of the samples shall exceed) has been interpreted as a 90th percentile value of the log-normalized values (Cusimano, 1997; Joy, 2000; Sargeant, 2002).

Liberty Bay and its tributaries are available to the public for *Primary* (e.g., swimming) and *Secondary* (e.g., wading) *Contact Recreation.* The Liberty Bay watershed is available to recreational fishermen, water sports enthusiasts, swimmers, boaters, beach goers, and children, and it has limited opportunities for recreational shellfish harvesting. Currently, no commercial shellfish harvesting exists in the approved but inactive section of Liberty Bay.

Freshwaters

Bacteria criteria are set to protect people who work and play in and on the water from waterborne illnesses. In Washington State water quality standards, FC 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 FC criteria are set at levels that are shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

The *Extraordinary Primary Contact* use is intended for waters capable of "providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas." To protect this use category: "Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100/colonies mL" [WAC 173-201A-200(2)(b), 2003 edition].

Compliance 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 FC are based on allowing no more than the pre-determined risk of illness to humans that 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 FC 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 FC concentrations back into compliance with the standard.

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

Marine waters

In marine (salt) waters, bacteria criteria are set to protect shellfish consumption and people who work and play in and on the water. Ecology uses two separate bacterial indicators in the state's marine waters. In waters protected for both *Primary Contact Recreation* and *Shellfish Harvesting*, the state uses FC bacteria as indicator bacteria to gauge the risk of waterborne diseases. In water protected only for *Secondary Contact*, enterococci bacteria are used as the indicator bacteria. The presence of these 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.

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% 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" [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, Ecology uses the same criterion to protect both *Shellfish Harvesting* and *Primary Contact* uses in the state standards.

Compliance 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 must be used in combination to ensure that the bacterial pollution in a waterbody will be maintained at levels that will not cause a greater risk to human health. 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.

Once the concentration of FC in the water reaches the numeric criterion, the state does not allow human activities that would increase the concentration above that criterion. If the criterion is exceeded, the state requires that human activities are conducted in a manner that will bring bacterial concentrations back into compliance with the standards.

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

Watershed Description

Liberty Bay and its tributaries are located in Kitsap County near the city of Poulsbo in Water Resource Inventory Area (WRIA) 15 (Figure 1). Keyport is located to the south of Liberty Bay and is home to the U.S. Navy's Undersea Weapons Center. Rural communities surrounding Liberty Bay include Lemolo, Virginia, Pearson, and Scandia.

Liberty Bay is about 4 miles long and ¾ miles wide. The deepest point (~39 feet) is at its center. Extensive tideflats cover much of northern Liberty Bay at low tide. Circulation is somewhat limited due to the enclosed shape of the bay.

Nesika (Ne Si Ka) Bay is connected to the southeast portion of Liberty Bay (Figure 1). Thompson and Keyport Creeks, flowing into the southern portion of Nesika Bay and northern portion of Port Orchard Bay will not be regularly sampled in this TMDL study due to their distance from Liberty Bay. However, samples may be taken to investigate any major fecal coliform (FC) problems in Keyport Creek. Thompson Creek is located on Port Madison Indian Reservation (Suquamish Tribe) land and is not suspected to be a significant source of FC.

The climate in Kitsap County is much like the rest of the Puget Sound basin with mild, wet winters and warm, dry summers. The Liberty Bay watershed receives about 30 to 50 inches of precipitation a year. The wettest month of the year is usually December.

The watershed is about 22,000 acres (May et al., 2005). Over 50% of the historically forested watershed is now developed, with over 17% of that area classified as impervious (May et al., 2005). Most of the highly developed areas are concentrated near Poulsbo and Keyport. Concentrated forests and small farms cover the rest of the watershed. Table 3 shows major creeks in the watershed and their approximate lengths and subbasin land-use patterns.

Table 3. Significant drainages in Liberty Bay with corresponding sizes and land-use patterns.

Subwatershed	Approximate size (mainstem river miles)	Primary land use
Little Scandia Creek	2	Rural- residential/agricultural
Big Scandia Creek	3	Rural- residential/agricultural
Bjorgen Creek	1.5	Dense/rural-residential
Daniels Creek	2	Rural- residential/agricultural
Dogfish Creek (all major tributaries included)	7	Rural and urban-residential/agricultural/ commercial and light industrial
Johnson Creek	4	Rural- residential/agricultural

At 4,700 acres, the largest drainage in the watershed is Dogfish Creek, which forms the head of Liberty Bay. Other drainages include Johnson, Big Scandia, Little Scandia, Bjorgen, Daniels, Sam Snyder, Lemolo, Barrantes, Keyport, and Thompson Creeks (Figure 1).

About 80% of the watershed is drained by streams, and the remaining 20% drains directly to marine waters (May et al., 2005). Most of the impervious surface areas not drained by streams are urbanized areas in Poulsbo and Keyport.

Various species of salmon, trout, and other fish are still found in Liberty Bay and its creeks. Until recently, these fish were the major source of food for the Suquamish Tribe for over 15,000 years (May, et al., 2005).

Liberty Bay was an important shellfish harvesting area until pollution and habitat degradation took its toll in the mid to late 1900s. Coast Seafoods was the largest producer of oysters in the bay, operating until the company sold its remaining holding in 1993. Shellfish harvesting is now restricted to the small bay near Lemolo. This area is currently inactive.

European settlement and subsequent development in the watershed began in the late 1800s with an influx of mostly Norwegians and Swedes who harvested timber and fish and carved out farmland from forested land (May et al., 2005).

The human population near Liberty Bay has grown quickly throughout the 1900s, and the cumulative effects of urbanization and development have caused concerns for the health of the watershed.

In 1999, the National Oceanic and Atmospheric Association (NOAA) National Marine Fisheries Service listed the Puget Sound Chinook as endangered (NOAA, 2008). Coho salmon and several bottom fish in Puget Sound are under study for possible listing. Additional listings will increase the concern for how future development occurs within the Puget Sound basin, including Kitsap County.

The Poulsbo Urban Growth Area (UGA) falls within the Liberty Bay watershed. The UGA contains stream basins including Dogfish, Johnson, Big Scandia, and Little Scandia Creeks (Forsyth, 1995).

The Port Madison Indian Reservation (Suquamish Tribe) is located in the southeastern portion of the watershed and includes Thompson Creek and upper Sam Snyder Creek (Figure 1).

Potential sources of contamination

Point Sources

Stormwater

Ecology uses a permit system to establish management practices for air, water, and land. For stormwater, these management practices protect human health and the environment. The practices are guideposts that allow management of stormwater to protect beneficial uses such as swimming, drinking water, recreation, and marine habitat.

As part of the federal Clean Water Act, Congress established the National Pollution Discharge Elimination System (NPDES), which requires that facilities discharging stormwater into surface waters have a permit. Under the NPDES, pipes, ditches, and other conveyances that carry runoff from state highways and related facilities are considered municipal storm sewer systems. Therefore, The Washington State Department of Transportation (DOT) is required to have a municipal stormwater permit for many of its facilities (DOT, 2008). DOT-maintained roads that potentially impact the Liberty Bay watershed through stormwater runoff include State Routes 3, 305, 307, and 308.

In Washington, the Department of Ecology (Ecology) is the delegated authority to issue and administer NPDES permits. Ecology's Stormwater Management Manual is available on the internet at www.ecy.wa.gov/programs/wq/stormwater/manual.html.

Ecology issued the Western Washington Phase II Municipal Stormwater Permit in January 2007. Under the Phase II permit, Kitsap County must follow the prescribed guidelines to manage stormwater before it discharges to surface water. Permit requirements fall under five basic categories: public education and outreach, public involvement and participation, illicit discharge detection and elimination, the control of runoff from development, and pollution prevention (Kitsap County Public Works, 2008).

The City of Poulsbo operates under a separate Phase II permit.

Keyport's Naval Undersea Warfare Center (NUWC) is covered under an EPA NPDES Stormwater Multi-Sector General Permit for Industrial Activities, permit number WAR05A64F. The permit is managed by the Commander, Navy Region Northwest (CNRNW), located on the Bangor Subbase (Van Beynum, 2008).

Other permittees

Keyport Undersea Charter and Salvage is also a NPDES permittee. The permit number for this boatyard is WAG030073C.

Poulsbo sewer system

Poulsbo's transmission and conveyance system is comprised of seven wastewater lift stations, together with the central interceptor, connecting the City of Poulsbo's system with the Kitsap County Wastewater Treatment Plant.

The City contracts with Kitsap County for treatment of its wastewater. Wastewater is received by the County from the City at the County's Johnson Road metering station location on Johnson Way and State Route 305. At this point, the Central Interceptor connects to a 14-inch gravity/force main. The force main continues south to the two, 12-inch Lemolo siphons where it crosses under Liberty Bay to Keyport. At Keyport, it continues south through Pump Station 16 and southwest through a 16-inch force main to Pump Station 15. From Pump Station 15, it discharges through a 24-inch force main past Aeration Unit No. 2 and is discharged into the Central Kitsap Wastewater Treatment Plant (City of Poulsbo, 2008).

The Central Kitsap Wastewater Treatment Plant, located outside of Poulsbo on the Brownsville Highway, treats wastewater from Poulsbo, the naval bases at Keyport and Bangor, and unincorporated Central Kitsap. Other waste streams treated at the plant include septage and biosolids from the outlying smaller treatment plants at Kingston, Manchester, and Suquamish (Kitsap County Public Works, Wastewater Division, 2006).

No city wastewater is currently discharged into Liberty Bay, although spills have occurred in the past. In September 2003, approximately 20,000 gallons of sewage was discharged onto a road and into a small stream that runs through the Keyport Naval Station when a county pump failed. An additional 330,000 gallons of sewage was discharged into Nesika Bay when a county pump station in Keyport was shut down to allow emergency repairs. The problem was quickly corrected and all sewage on the surface of the ground was cleaned up. Residents were told to stay out of contact with the waters of Nesika and Liberty Bays for seven days (KCHD, 2003).

The City of Poulsbo reported an estimated 5,000 gallon sewage spill from a broken sewer line at the head of Liberty Bay in March 2006. The broken line was repaired by the City on the same day. As a result, the Kitsap County Health District issued a health advisory for all of Liberty Bay out to Keyport for four days. Residents were advised to avoid any contact with the water, and shellfish harvesting in the advisory area was closed (KCHD, 2006).

A newly built sewer line and pump station in this area will likely be used in conjunction with, or in lieu of, the old line in the future. The older line that runs parallel to the northeast shore of Liberty Bay is still being used.

Due to flooding in early December 2007, the Kitsap County Health District issued a "No Contact" order for all Kitsap County surface waters and for the harvesting of shellfish from recreational shellfish beaches. The "No Contact" order was issued due to excessive surface runoff and several sewage spills that affected water quality throughout the county (KCHD, 2007a). The same storm caused massive sewer overflows from the Poulsbo sewer system into Liberty Bay on December 3, 2007 (Zimny, 2008).

Wildlife and background sources

There is a variety of wildlife within the Liberty Bay watershed. Warm-blooded wildlife presents a potential source of FC bacteria. Open fields, riparian areas, and wetlands provide feeding and roosting grounds for some birds whose presence can increase FC counts.

Usually these sources are dispersed and do not elevate FC levels enough to violate state criteria. However, animal populations can occasionally become concentrated and cause problems. Concentrated wildlife (i.e., nutria, raccoons, beaver, and birds) in the watershed will be noted during sampling surveys.

Nonpoint sources

Agriculture

Nonpoint diffuse sources and practices are dispersed and not regulated under discharge permits. Potential nonpoint agricultural sources are present in the study area. Range and pastured livestock with direct access to streams can be a source of FC contamination. Poor livestock or pet manure management on non-commercial farms and in residential areas is another potential source.

Fecal coliform bacteria from nonpoint sources are transported to the creeks by direct and indirect means. Manure that is spread over fields during certain times of the year can enter streams directly by poor spreading practices or via surface runoff or fluctuating water levels. Often livestock have direct access to water. Manure is deposited in the riparian area of the access points where fluctuating water levels, surface runoff, or constant trampling can bring the manure into the water. Swales, sub-surface drains, and flooding through pastures and near homes can carry FC bacteria from sources to waterways.

The Kitsap County Health District has corrected some of these problems, most notably in the Dogfish Creek area, but areas of concern still exist and will be bracketed with sampling sites if possible.

Septic systems

The Kitsap County Health District has investigated and corrected many of the septic systems in the nearshore zone of Liberty Bay. However, failing onsite sewage systems undoubtedly continue to contribute at least some bacterial contamination to the bay and the streams feeding it. Live-aboards and commercial fishing boats can also contribute bacteria directly to marine waters.

Recreation

Recreational opportunities in the watershed are extensive and include fishing, hiking, boating, birding, and other activities. Unfortunately, human feces may be disposed of inappropriately while recreating, potentially entering the waters of the Liberty Bay basin.

Historical Data Review

Washington State Department of Health

The National Shellfish Sanitation Program (NSSP) prescribes methods to evaluate FC levels at water sampling stations to classify shellfish growing areas. The Washington State Department of Health (DOH) uses Systematic Random Sampling (SRS), which uses a minimum of the last 30 samples for FC analysis. With the SRS method, the 90th percentile cannot exceed 43 FC/100 mL, and the geometric mean cannot exceed 14 cfu/100 mL. If this standard is exceeded, no shellfish can be directly harvested from the area of that station (Lennartson, 2005).

Threatened or concerned status is generally based on water quality but may also be based on the identification of pollution sources. Threatened status is assigned in SRS growing areas when a water sampling station's 90th percentile is between 30 and 43 FC/100 mL. Concerned status is assigned when a water sampling station's 90th percentile is greater than 20, but less than 30.

Currently, the only approved portion of Liberty Bay is the area near the community of Lemolo known as Lemolo Bay (Figure 2). DOH's classification status for Lemolo Bay is "Meets standards but some concerns" (DOH, 2008). Table 4 lists DOH sampling stations in Lemolo Bay with classifications and FC data. Figure 3 shows the most recent (2003-07) five-year trend in FC pollution at station 501.

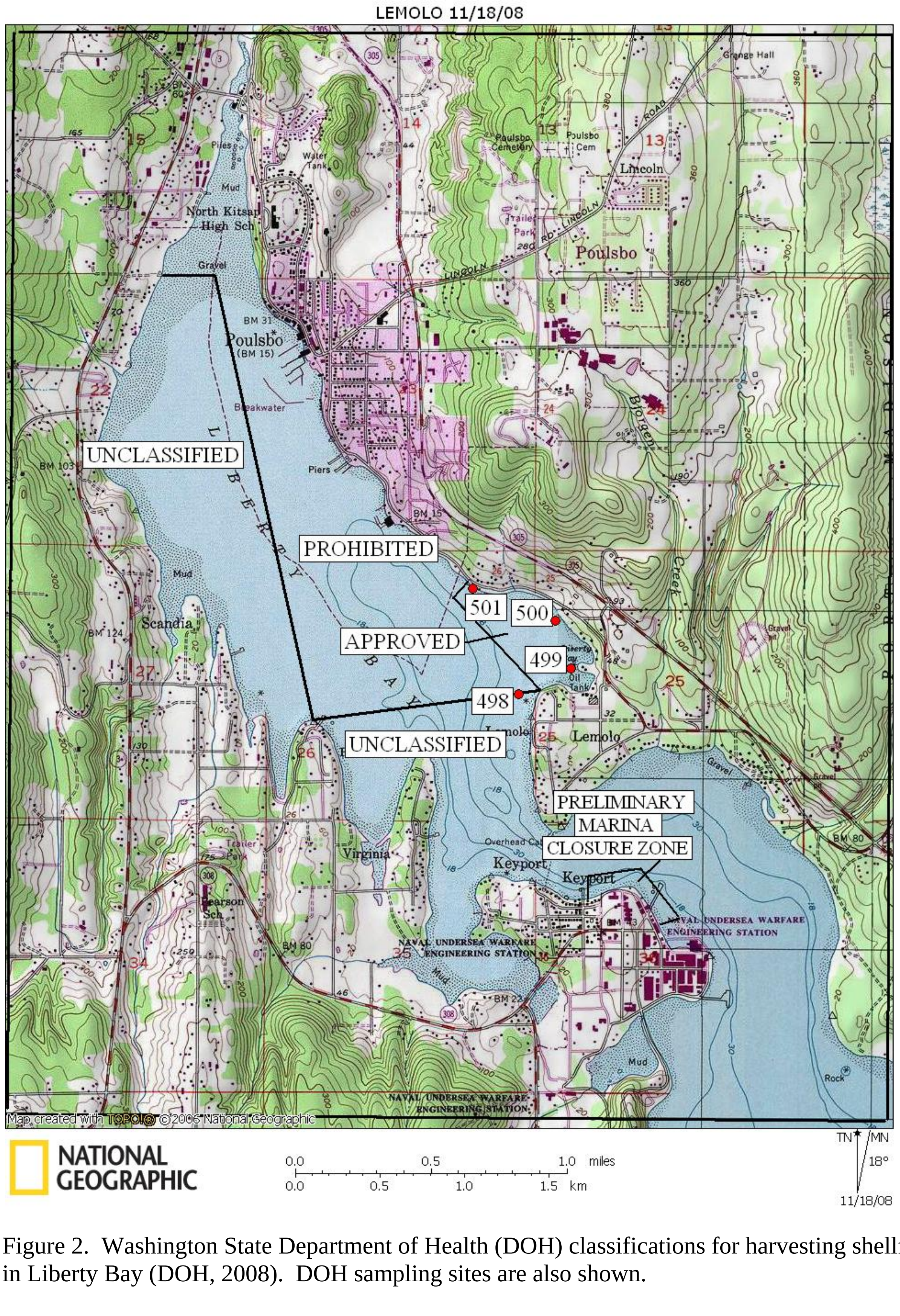

Figure 2. Washington State Department of Health (DOH) classifications for harvesting shellfish in Liberty Bay (DOH, 2008). DOH sampling sites are also shown.

Table 4. Department of Health's summary of shellfish growing areas; fecal coliform study results (#/100 mL) for Lemolo Bay, January 2003 to December 2007.

Station Number	Classification	Number of Samples	Range	Geometric Mean	Est. 90th Percentile	Meets Standard
498	Prohibited	30	1.7 - 49.0	2.6	7	Yes
499	Approved	30	1.7 – 130	4.1	17	Yes
500	Approved	30	1.7 - 11.0	2.4	4	Yes
501	Approved	30	1.7 – 1,600	4.3	23	Yes

SRS criteria require a minimum of 30 samples from each station
Source: DOH; Annual Growing Area Review

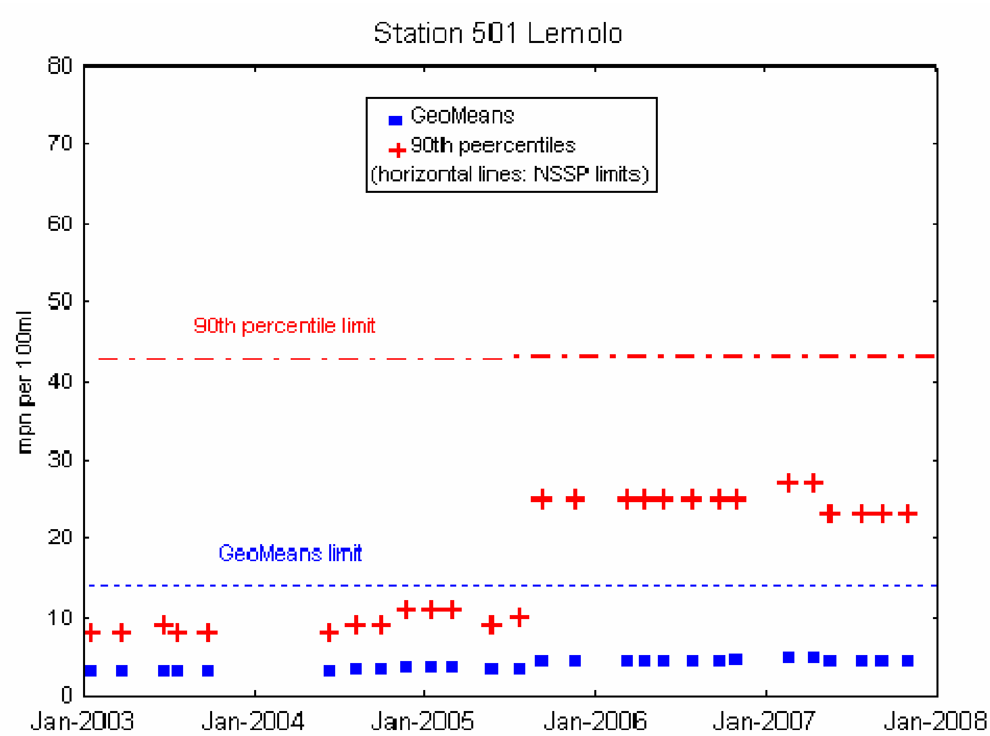

Figure 3. Department of Health's most recent five-year trend in fecal coliform pollution at station 501.

Kitsap County Health District

The Kitsap County Health District (KCHD) has been regularly sampling FC in freshwaters of the Liberty Bay watershed since 1996. Overall water quality is poor but appears to be improving. Continued water quality improvements are expected in response to FC pollution source reduction projects performed by the KCHD, mostly in the Dogfish Creek system, but also in Daniels Creek and in stormwater discharges from the City of Poulsbo (KCHD, 2007b). For more information, see KCHD's *Liberty Bay/Miller Bay Watershed 2007 Water Quality Monitoring Report* (KCHD, 2007b).

Table 5 lists the major subwatersheds and their respective FC trends as well as 2007 KCHD annual geometric mean values. KCHD uses the most probable number (MPN) method to enumerate FC organisms in their water samples.

Table 5. Significant drainages to Liberty Bay with corresponding fecal coliform trends and geometric mean values. Data based on KCHD monthly sampling from 1996 through 2007.

Subwatershed	Short-term trend	Long-term trend	2007 FC geometric mean (cfu/100 mL)
Little Scandia Creek	LSD*	LSD*	88
Big Scandia Creek	stationary	stationary	45
Bjorgen Creek	LSD*	LSD*	85
Daniels Creek	stationary	stationary	145
Dogfish Creek (all tributaries included)	stationary	improving	51
Dogfish Creek, South Fork	stationary	improving	44
Johnson Creek	stationary	stationary	24

* Lacking sufficient data for trend analysis.

KCHD also regularly samples the marine waters of Liberty Bay at seven locations. For the most recent 12 samples, stations LB06 near Dogfish Creek; LB07 near Johnson Creek; LB09 near Big Scandia Creek; and LB12 near Daniels Creek exceeded the 90th percentile criterion for FC, indicating bacteria levels were elevated occasionally. According to Kitsap County's *2007 Water Quality Monitoring Repor*t, the overall marine FC trend in Liberty Bay is stationary (KCHD, 2007b).

KCHD's marine monitoring station LB05, near the north end of the Poulsbo Marina, and DOH's station 501, northwest of Barrantes Creek outlet, were examined for seasonal FC concentration patterns. Figure 4 shows higher geometric mean FC concentrations during October through January, when contaminated stormwater was more likely to enter Liberty Bay. Both stations were located near the eastern shore of Liberty Bay less than ¾ miles apart.

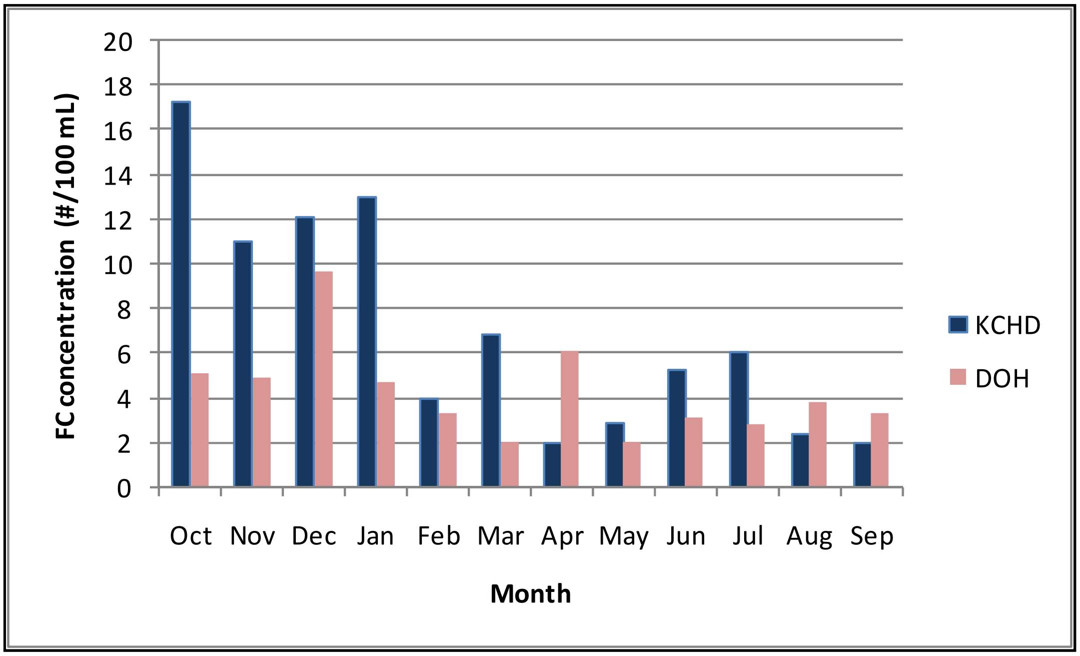

Figure 4. KCHD (station LB05) and DOH (station 501) monthly geometric mean fecal coliform concentrations (MPN method). Bars represent 2 to 6 sample geometric means from KCHD (2002-06) and 6 to 15 sample geometric means from DOH (1988-2008).

The *Liberty Bay/Miller Bay Watershed Nonpoint Source Pollution Baseline Water Quality Assessment* was released by KCHD in 1995 (Forsyth, 1995). During the 1994-95 study, a "wet condition events" FC loading analysis was performed on five creeks in the watershed. Data from the two wet events showed that these creeks contributed approximately the following amounts of FC organisms to Liberty Bay every second:

- Dogfish Creek – 8 million
- Daniels Creek – 3 million
- Big Scandia Creek – 1 million
- Little Scandia Creek – 250,000
- Johnson Creek – 300,000

Comparing dry and wet condition data showed that FC concentrations and loading increased substantially in marine waters and freshwaters of the Liberty Bay watershed during rain and runoff events.

Although the watershed has changed since 1995, Kitsap County's baseline FC loading data will help Ecology prioritize sampling efforts. The data will also be useful when looking at long-term wet event trends in the watershed.

Current data from KCHD does not include streamflow and thus loading data. Ecology plans to fill this data gap with its TMDL sampling efforts.

Liberty Bay Nearshore Habitat Evaluation and Enhancement Project

The Lemolo Citizens Club and Liberty Bay Foundation published the Liberty Bay Nearshore Habitat Evaluation and Enhancement Project final report in 2005 (May et al., 2005). Among other topics, this report detailed the project's water, sediment, and biological monitoring in Liberty Bay and its tributaries. Marine and freshwater FC sampling occurred in the wet season, unlike KCHD's random monthly sampling. Wet season FC results from 2001 to 2003 showed significant FC pollution from all creeks, stormwater outlets, and marine stations sampled. This information will further help Ecology to prioritize sampling efforts. For a more comprehensive summary of FC results for this project, see the final report (May et al., 2005).

Project Goal and Study Objectives

Goal

The overall goal of the TMDL project is to ensure that impaired waters of the Liberty Bay watershed will attain Washington State water quality standards for fecal coliform (FC) bacteria.

Objectives

Objectives of the proposed study are as follows:

- Identify and characterize FC bacteria concentrations and loads from all major tributaries, point sources, and drainages into Liberty Bay under various seasonal or hydrological conditions, including stormwater contributions.
- Develop target reductions of FC bacteria to support establishing load and wasteload allocations to meet freshwater water quality criteria and protect beneficial uses of the tributaries (creeks) and the bay.
- Identify relative contributions of FC loading to the bay so clean-up activities can focus on the largest sources.

The results of this study will help Ecology and stakeholders focus efforts on priority pollution sources within the study area. The project's 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.
- Attainment of Washington State water quality standards for FC bacteria.

Study Design

Overview

The study objectives will be met through characterizing annual and seasonal FC bacteria loads in tributaries and significant outflows to Liberty Bay. FC concentrations will be monitored at multiple locations in the tributaries and at other key locations within the Liberty Bay watershed from August 2008 through August 2009. When possible, streamflow will be measured at all sites at the time of sampling, or a staff gage will be installed and a rating curve will be developed. This will allow the accurate estimation of flows when direct measurement is not possible (e.g., high flows and time-restricted sampling events). Flow will be measured above tidally influenced areas, at the point of sampling.

The freshwater component of the Liberty Bay TMDL study includes (1) a fixed network of sites sampled twice monthly and (2) several synoptic sampling events during the dry season and periods of heavy rainfall (storm event sampling). These synoptic surveys include two “dry storm event” beach surveys and two to three “wet storm event” beach surveys to help further characterize seasonal and rain event FC contributions to the bay.

Liberty Bay will be sampled monthly by the Kitsap County Health District (KCHD) and once every two months by the Washington State Department of Health (DOH) at strategic locations. Ecology will coordinate with KCHD and DOH and encourage freshwater sampling on the same days as bay sampling occurs.

TMDL allocations will be set based on a statistical analysis of measured data. The rollback method (described in Appendix B) will be used to determine how much (in terms of percentage) FC concentrations need to be reduced at each freshwater sampling site to meet Washington State State criteria.

Details

Fixed-network sampling

Data from the fixed network will provide FC data sets to meet the following needs:

- Provide an estimate of the annual and seasonal geometric mean and 90th percentile statistics FC counts. The schedule should provide at least 24 samples per site to develop the annual statistics, including 6 samples per site during the dry season (July – September) and 18 samples per site during the wet season (October – June).
- Provide reach-specific FC load and concentration comparisons in Liberty Bay tributaries to define areas of increased FC loading (e.g., malfunctioning on-site systems, livestock, wildlife, or manure spreading) or FC decreases (e.g., settling with sediment, die-off, dilution, or diversion). With accurate streamflow monitoring, tributary and source loads also can be estimated.

The fixed-network sites will be sampled twice monthly from August 2008 through August 2009 (Table 6). The locations of the fixed-network water quality stations are listed in Table 7 and 8 and can be seen in Figure 1. Stations were selected based on historical site locations, FC results, and ease of access.

Table 6. Proposed schedule of fixed-network and synoptic storm event sampling surveys, 2008-09.

Survey	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Fixed Network	2	2	2	2	2	2	2	2	2	2	2	2	2
Synoptic Events (wet and dry)*		1 dry				1 wet	1 wet	1 wet					1 dry

*Wet and dry synoptic sampling may occur in different months than shown.

Sites may be added or removed from the sampling plan depending on access and new information provided during the QA Project Plan review, field observations, and preliminary data analysis.

Table 7. Fixed-network sites in the Liberty Bay watershed. Staff gage locations are also shown.

Field ID w/ river mile	Staff gage?	Site description
Dogfish Creek		
15-DOG-0.6	Y	Mainstem behind dental office on Bond Rd, downstream of Hwy 305 crossing.
15-SFD-0.0	Y	South fork at Bond Rd and 1st Ave., 50 ft. downstream of culvert.
15-SFD-1.3	--	South fork at 8th Ave and Iverson, upstream side of culvert.
15-EFD-0.0	Y	East fork at Little Valley Rd, downstream side of culvert.
15-EFD-1.2	--	East fork off Bond Rd at Pugh Rd, upstream side of culvert.
15-WFD-0.0	Y	West fork at Little Valley Rd, downstream side of culvert.
15-WFD-0.9	Y	West fork at first Big Valley Rd crossing near Living Waters Farm.
Johnson Creek		
15-JOH-0.1	Y	Mainstem just south of Norfin Lane, downstream side of culvert.
Big Scandia Creek		
15-BSC-0.0		Mainstem at mouth near the end of Scandia Ct. at private property. Trail to ck.
15-BSC-0.1	Y	Mainstem at Scandia Rd, upstream side of culvert.
15-BSC-1.1	--	Mainstem at Hwy 308 between Viking Way and Cox Ave, downstream of culvert.
15-BSC-1.6	Y	Mainstem at Hwy 308 just west of Cox Ave, upstream side of culvert.
Little Scandia Creek		
15-LSC-0.1		Mainstem at Scandia Rd behind church, upstream side of culvert.
15-LSC-0.4	Y	Mainstem at Blomster Way, upstream side of culvert.
Daniels Creek		
15-DAN-0.0	--	Mainstem off Hwy 308, near residence at 14510, upstream side of culvert.
15-DAN-0.2	--	Mainstem at Virginia Loop Rd, approximately 30 ft. below culvert.
Perry Creek		
15-PER-0.1	Y	Mainstem at 90 deg. right turn in Thorpe Rd, upstream side of culvert.
Sam Snyder Creek		
15-SAM-0.1	--	Mainstem at Lemolo Shore Dr, downstream side of culvert (dry during dry season).
Lemolo Creek		
15-LEM-0.1	--	Mainstem at Lemolo Shore Dr, east of Delate Rd access from first private drive east of creek, 75 ft. upstream of culvert.
Bjorgen Creek		
15-BJO-0.1	--	Mainstem at Lemolo Shore Dr by market, downstream side of culvert.
Barrantes Creek		
15-BAR-0.0	--	Mainstem at Lemolo Shore Dr, downstream of culvert. Sample at low tide.
Unnamed tributaries to Liberty Bay		
15-UNN-0.1	Y	Tributary east of Daniels Ck at Hwy 308 near "Support Our Troops" sign. 30 ft. upstream of culvert.
15-UNN-0.0	--	Tributary flowing into bay right next to Daniels Ck mouth. Sample at low tide.

Table 8. GPS coordinates and Figure 1 reference numbers for fixed-network sites in the Liberty Bay watershed.

Field ID w/ River Mile	Latitude (100 ft. accuracy)	Longitude (100 ft. accuracy)	Figure 1 reference number
Dogfish Creek			
15-DOG-0.6	47.75222	-122.64764	1
15-SFD-0.0	47.75086	-122.64816	2
15-WFD-0.0	47.75499	-122.63884	3
15-EFD-0.0	47.75415	-122.63875	4
15-EFD-1.2	47.76107	-122.61712	5
15-WFD-0.9	47.76633	-122.64069	6
15-SFD-1.3	47.73638	-122.63815	7
Johnson Creek			
15-JOH-0.1	47.73324	-122.66284	8
Big Scandia Creek			
15-BSC-0.0	47.71757	-122.65655	9
15-BSC-0.1	47.71549	-122.65736	10
15-BSC-1.1	47.70456	-122.66203	11
15-BSC-1.6	47.70372	-122.6657	12
Little Scandia Creek			
15-LSC-0.1	47.71559	-122.65345	13
15-LSC-0.4	47.71112	-122.65321	14
Daniels Creek			
15-DAN-0.0	47.70073	-122.64057	15
15-DAN-0.2	47.70095	-122.64362	16
Perry Creek			
15-PER-0.1	47.71124	-122.65026	17
Sam Snyder Creek			
15-SAM-0.1	47.70835	-122.60308	18
Lemolo Creek			
15-LEM-0.1	47.71307	-122.61369	19
Bjorgen Creek			
15-BJO-0.1	47.71306	-122.61799	20
Barrantes Creek			
15-BAR-0.0	47.72067	-122.6297	21
Unnamed tributaries to Liberty Bay			
15-UNN-0.1	47.69789	-122.63778	22
15-UNN-0.0	47.70054	-122.64027	23

Investigatory sampling

Other small creeks and drainages will be investigated if resources and conditions allow. If an investigatory creek or drainage is found to contain high levels of FC, sampling will likely continue for the remainder of the study. These waterways may include, but are not limited to:

- Keyport Creek.
- Two small seasonal ditches flowing into Daniels Creek just above station 15-DAN-0.2.
- Small stream flowing into Liberty Bay northwest of Barrantes Creek at yacht club, unofficially named Donna Jean's Creek.
- Small, unnamed stream flowing into the bay near American Legion Park.
- Small, unnamed stream flowing into Dogfish Bay, east of station 15-UNN-0.1.
- Small unnamed seasonal stream flowing into Liberty Bay ~300 feet east of Big Scandia Creek.
- Small stream flowing through Fish Park into Dogfish Creek near mouth, below station 15-DOG-0.6.
- Small stream flowing into lower Johnson Creek, just below sampling site.
- Small seasonal stream flowing into Liberty Bay east of Perry Creek at Thorpe Rd. NE.
- Other small streams or drainages that may contribute significant amounts of FC to the bay.

Storm (rain-event) monitoring

The purpose of storm monitoring is to better characterize potential sources of FC loading to Liberty Bay. Historical Liberty Bay and statewide data show that higher FC loading occurs during rain events. Depending on the weather, storm sampling will occur during November through May. If sufficient rain and runoff do not occur during these months, the schedule will be adjusted. Runoff from areas such as range, agriculture, and residential areas will be targeted and bracketed by sites where possible.

Two to three events will be sampled, with a storm event defined as a minimum 0.3 inch of rainfall in a 24-hour period preceded by no more than trace rainfall in the previous 24 hours. In the Liberty Bay watershed, this amount of rain should be sufficient to cause runoff from impervious surface areas and raise creek levels (based on previous sampling in similar watersheds).

Timing will vary with the timing of the storm. For example, if a strong storm occurs in the early morning hours of Day 1, sites could be sampled in the afternoon of Day 1. However, if the storm occurs in the afternoon or evening hours of Day 1, samples may be collected in the morning of Day 2. Storm sampling will likely consist of two teams of two people sampling all sites one to two times over the duration of the event, sampling as many stormwater outfalls as possible. If appropriate, teams may choose to sample outfalls and creeks from the beaches of Liberty Bay. If possible, a second set of samples from the same storm will be collected to better characterize the storm's total bacteria component.

Two “dry-storm” sampling events are planned for late summer 2008 or 2009 to establish baseline FC loading data. Each event will include a synoptic (performed in one day) survey of all freshwater inputs to Liberty Bay. Ecology will measure streamflow and take FC samples from all outlets to Liberty Bay flowing at this time.

Open channel and pipe streamflow will be measured using a Marsh McBirney flowmeter or estimated using stage and rating curves or relationships with other monitoring locations when grab samples are collected. An online flow calculator will be used to calculate streamflow measured in circular pipes and culverts: www.marsh-mcbirney.com/flow_calc.html.

If storm outfall flows cannot be measured directly, they will be estimated, qualified as “estimates” in Ecology’s Environmental Information Management System (EIM), and used appropriately during data analysis. Daily rainfall data will be obtained from local sources.

Within the City of Poulsbo, there are 19 stormwater outfalls that drain directly to Liberty Bay. There are also 22 outfalls that dump into Dogfish Creek and 6 outfalls that empty into Bjorgen Creek (May et al., 2005). Stormwater sampling sites will include all fixed network sites plus significant outfalls under NPDES Phase II permits. The City of Poulsbo has suggested sampling several major residential and commercial outfalls within the Poulsbo city limits that flow directly to the bay (Table 9 and Figure 5). The suggestions were based on land use type and size of subbasin drained (Funk, 2008).

Table 9. City of Poulsbo stormwater sampling outfalls that will be sampled by Ecology during rain events if conditions allow.

Name of outfall	Location	Land use	Latitude	Longitude
Bay St. outfall	Bay Street	Commercial	47.74026	-122.65497
PSW37	Nelson Park bioswale	Residential and commercial	47.74613	-122.65296
PSW31	19265 Front St., American Legion Park	Residential	47.73816	-122.64998
PSW30	Below the Gran Kirk, Martha and Mary, and Front St.	Commercial and parking lot/road	47.73701	-122.64974
PSW28	Parking lot on Anderson Pkwy, near 18925 Front St. NE	Commercial	47.73455	-122.64753
PSW25 (Donna Jean’s Ck)	6th Ave. NE and Fjord Dr.	Residential and highway	47.72728	-122.64178

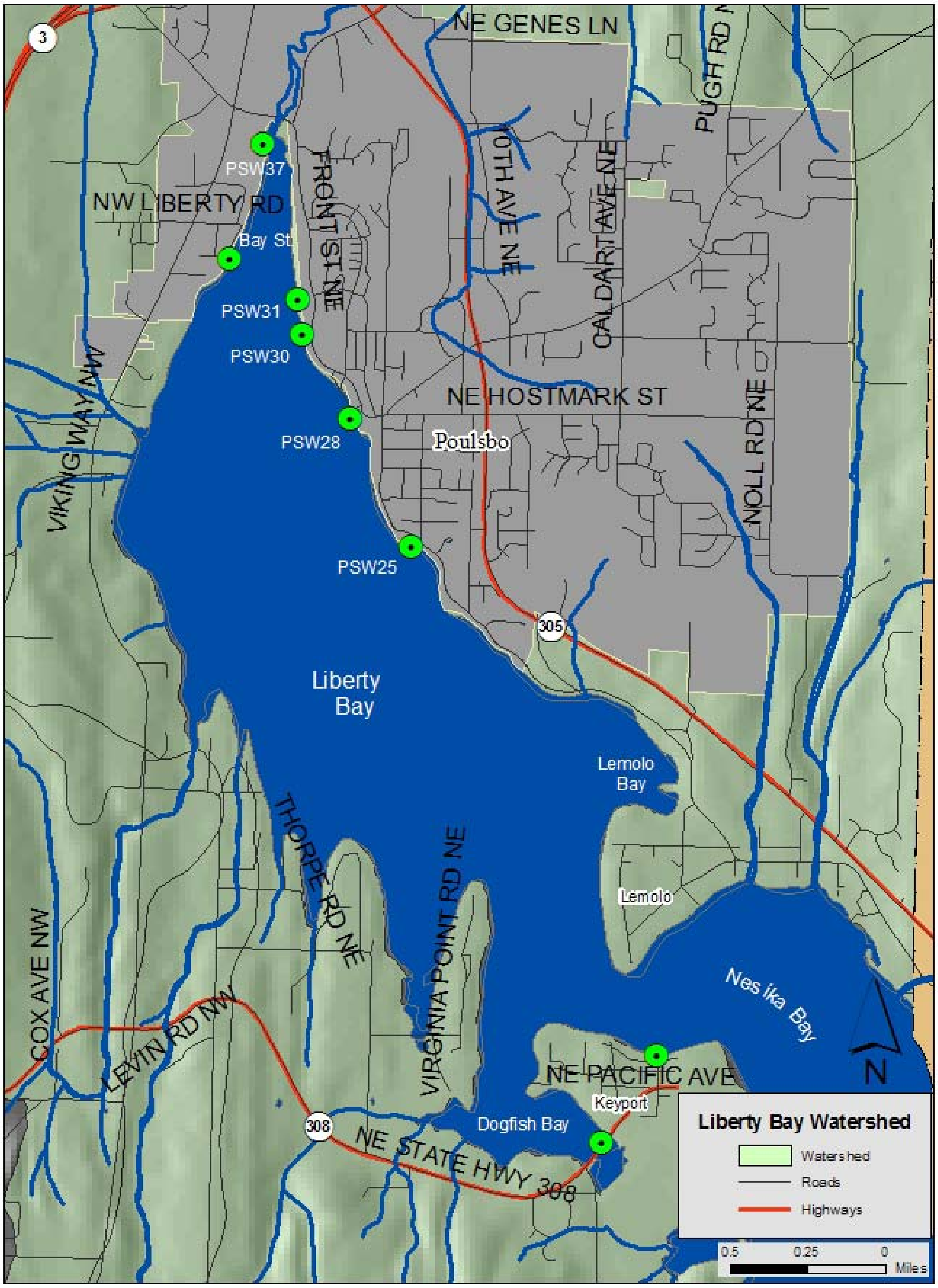

Figure 5. Major stormwater outfall locations in Poulsbo and Keyport.

The town of Keyport presently has a limited storm drainage system that is primarily centered around flows to the north via Washington Avenue NE and flows to the south via State Route 308 (Figure 5) (KCDCD, 2007). There are six outfalls to Dogfish Bay, one to Liberty Bay/Nesika Bay, and one that empties into Port Orchard Bay (KCDCD, 2007).

Stormwater sampling locations at the Naval Undersea Warfare Center (NUWC) will be investigated further while in the field and during a stormwater tour planned for January or February 2009.

Other outfalls to Liberty Bay and Nesika Bay outside of Poulsbo and Keyport will be investigated, but their exact locations are not known and will be further investigated while in the field. For a map of stormwater outfalls in Kitsap County, excluding Poulsbo and the NUWC in Keyport, see www.kitsapgov.com/sswm/monitoring.htm.

As of 2007, Kitsap County must meet the requirements of the Western Washington Phase II Municipal Stormwater Permit. Poulsbo has a separate Phase II permit and the NUWC has a NPDES general permit for stormwater issued by the EPA. NPDES stormwater permits are required to have corresponding wasteload allocations set in TMDL studies. Therefore, this study must determine wasteload allocations for each permit holder, i.e., for each Phase II permit jurisdiction.

After regular monitoring has commenced and land use is characterized more thoroughly, adjustments to the storm monitoring schedule and site locations may be necessary. Any adjustments will be addressed through Quarterly Reports and sent to the appropriate parties. The ability to quickly and safely access some sites and obtain a representative sample will be a challenge. Permission to sample runoff at some locations is required.

Sampling and Measurement Procedures

Field sampling and measurement protocols will follow standard operating procedures (SOPs) developed by Ecology's Environmental Assessment Program (EAP). Grab samples will be collected directly into pre-cleaned containers supplied by the Manchester Environmental Laboratory (MEL) and described in the MEL User's Manual (MEL, 2008). Sample parameters, containers, volumes, preservation requirements, and holding times are listed in Table 10. Bacteria samples will be tagged, stored on ice, delivered to MEL via Ecology courier, and analyzed by MEL within 24 hours of collection.

Table 10. Containers, preservation requirements, and holding times for samples collected (MEL, 2008).

Parameter	Sample Matrix	Container	Preservative	Holding Time
Fecal coliform	Surface water, WWTP effluent, runoff	250 or 500 mL glass/poly autoclaved	Cool to 4ºC	24 hours

WWTP – wastewater treatment plant

Grab samples will be collected using the EAP SOPs for bacteria (Mathieu, 2006a) and grab sampling (Joy, 2006). Twenty percent of FC samples will be replicated in the field in a side-by-side manner to assess field and laboratory variability. Samples will be collected in the thalweg and just under the water's surface.

Fecal coliform bacteria are sensitive to saltwater, and die-off rates change when entering estuarine waters. Monitoring of stations under tidal influence will occur during low tide so FC samples reflect the freshwater input. Conductivity will be checked to ensure that fresh stream water is sampled.

Field measurements will be taken at all freshwater sampling sites and will include conductivity and temperature using a calibrated Hydrolab MiniSonde® following the EAP Hydrolab SOP (Swanson, 2007).

Estimation of instantaneous flow measurements will follow the EAP protocol (Sullivan, 2006). A flow rating curve will be developed for sites with a staff gage (Table 7). Regression analysis (comparing upstream and downstream sites or one creek to another) may be used when flow measurements are not possible. Local cooperating agencies may provide additional flows at other sites. Instantaneous FC loads will be estimated at each site using the best available streamflow data. No flow stations are under tidal influence.

Data Quality Objectives

Measurement quality objectives (MQOs) state the level of acceptable error in the measurement process. Precision is a measure of random error, usually determined through the use of replicate measurements (Lombard and Kirchmer, 2004). This random error includes error inherently associated with field sampling and laboratory analysis. Field and laboratory errors are minimized by adhering to strict protocols for sampling and analysis. Precision for replicates will be expressed as percent relative standard deviation (%RSD).

Microbiological and analytical methods, precision targets, and method resolution or reporting limits are listed in Table 11. The reporting limits of the methods listed in the table meet the expected range of results and the required level of sensitivity to meet project objectives. The laboratory's MQOs are documented in the MEL Lab Users Manual (MEL, 2008).

Table 11. Targets for precision and reporting limits for the measurement systems.

Analysis	Method/Equipment	Field Replicate MQO	Lab Duplicate MQO	Reporting Limits and Resolution
Field Measurements				
Discharge Volume	Marsh McBirney Flow-Mate Flowmeter	10% RSD	n/a	0.01 ft/s
Water Temperature[1]	Hydrolab MiniSonde®	+/- 0.2° C	n/a	0.01° C
Specific Conductivity	Hydrolab MiniSonde®	10% RSD	n/a	0.1 µmhos/cm
Laboratory Analyses				
Fecal Coliform – MF (membrane filtered)	SM 9222D	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD[2]	40% RPD	1 cfu/100 mL

[1] as units of measurement, not percentages.
[2] replicate results with a mean of less than or equal to 20 cfu/100 mL will be evaluated separately.
SM = Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA et al., 1998).

The targets for analytical precision of laboratory analyses in Table 11 are based on historical performance by MEL for environmental samples taken around the state by the Ecology's Environmental Assessment Program (Mathieu, 2006b).

Bias is defined as the difference between the population mean and the true value of the parameter being measured (Lombard and Kirchmer, 2004). Bias is also a component of data accuracy; however, bias from the true value is very difficult to determine for this set of parameters. Calibration standards for microbiological analyses are not available. Bias in field measurements will be minimized by strictly following sampling and handling protocols.

Representative sampling

The study is designed to have enough sampling sites and sufficient sampling frequency adequate to meet study objectives. Fecal coliform values are known to be highly variable over time and space. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting quality control samples, but natural spatial and temporal variability can contribute greatly to the overall variability in the parameter value. Resources limit the number of samples that can be taken at one site spatially or over various intervals of time. Laboratory and field errors are further expanded by estimate errors in seasonal loading calculations.

Comparability

Ecology will sample the same sites Kitsap County currently samples, as well as additional sites. Data from both agencies will be compared to ensure similar FC concentrations and trends exist in both datasets. If FC datasets are not similar, Ecology will investigate further for possible reasons.

Freshwater and marine water FC samples taken by Kitsap County Health and marine samples taken by DOH are analyzed using the MPN method. Saltwater samples are analyzed using the MPN method because of regulatory reasons. Most probable number results have a wider confidence interval than the membrane filtration (MF) method. Some researchers believe the MPN method is better at enumerating injured or stressed organisms, and organisms in turbid or saline waters. Ecology typically uses the MF method in streams because of its practicality and precision.

Past studies (Joy, 2000; Swanson, 2008) have shown that MPN and MF results are comparable. For example, the overall relationship between MPN and MF pairs taken during the Samish Bay FC TMDL study was significant after lognormal transformation, but not highly correlated (R^2=0.653) (Figure 6).

Because of the predictable relationship between MPN and MF, splitting samples and analyzing them using both methods will not be necessary to assess method and result comparability.

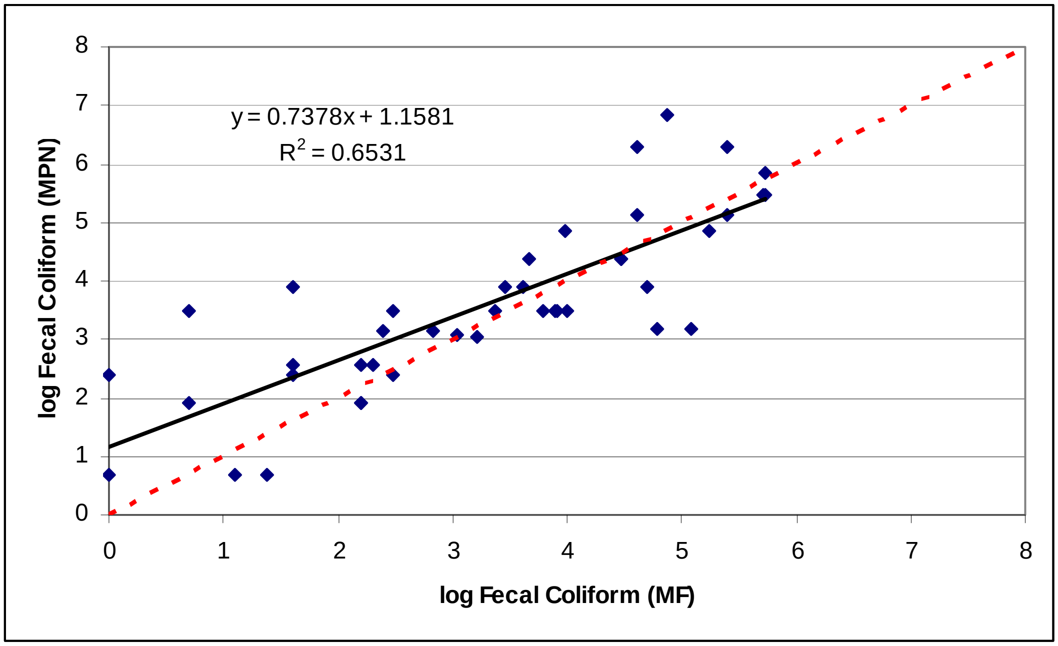

Figure 6. A comparison of 40 paired FC samples that were analyzed using the most probable number (MPN) and membrane filter (MF) techniques during the Samish Bay TMDL study. Dashed line denotes 1:1 relationship.

Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system (Lombard and Kirchmer, 2004). The goal for the Liberty Bay TMDL is to correctly collect and analyze 100% of the FC samples for each of the 26 sites, and 100% of the storm event samples. However, problems occasionally arise during sample collection that cannot be controlled which can interfere with this goal. Example problems are flooding, inadequate rain for storm sampling, site access problems, or sample container shortages. A lower limit of five samples per season per site will be required for comparison to Washington State criteria, which should easily be met with the current sampling design. WAC 173-201A states:

"When averaging bacteria sample data for comparison to the geometric mean criteria, it is preferable to average by season and include five or more data collection events within each period….and [the period of averaging] should have sample collection dates well distributed throughout the reporting period."

Investigatory samples may be collected at sites not included in this QA Project Plan, or, if necessary, a site may be added to further characterize FC problems in an area. Such sampling that does not meet the lower limit criteria of five samples per season (wet or dry) per site will still be useful for source location identification, recommendations, or other analyses. But such sampling will not be used to set load or wasteload allocations.

Quality Control

Total variation for field sampling and laboratory analysis will be assessed by collecting replicate samples. Bacteria samples tend to have a high relative standard deviation (RPD) between replicates compared to other water quality parameters. Bacteria sample precision will be assessed by collecting replicates for approximately 20% of samples in each survey. MEL routinely duplicates sample analyses in the laboratory to determine laboratory precision. The difference between field and laboratory variability is an estimate of the sample field variability.

All samples will be analyzed at MEL. The laboratory's measurement quality objectives (MQOs) and quality control procedures are documented in the MEL Lab Users Manual (MEL, 2008). Field sampling and measurements will follow quality control protocols described in their individual SOPs. If any of these quality control procedures are not met, the associated results may be qualified by MEL or the project manager and used with caution, or not used at all.

Standard Methods (APHA et al., 1998) recommends a maximum holding time of eight hours for microbiological samples (six hours transit and two hours laboratory processing) for non-potable water tested for compliance purposes. MEL has a maximum holding time for microbiological samples of 24 hours (MEL, 2008). Standard Methods recommends a holding time of less than 30 hours for drinking water samples and less than 24 hours for other types of water tested when compliance is not an issue. Microbiological samples analyzed beyond the 24-hour holding time are qualified with a "J" qualifier code, indicating the sample result is an estimate.

To identify any problems with holding times, two comparison studies were conducted during the Yakima Area Creeks TMDL (Mathieu, 2005). A total of 20 FC samples were collected in 500-mL bottles and each split into two 250-mL bottles. The samples were driven to MEL within 6 hours. One set of the split samples was analyzed upon delivery. The other set was stored overnight and analyzed the next day. Both sets were analyzed using the MF method. Replicates were compared to the MQOs in Table 11.

The combined precision results between the different holding times yielded a mean RSD of 19%. This is comparable to the 23% mean RSD between field replicates for twelve Environmental Assessment Program TMDL studies using the MF method (Mathieu, 2005), suggesting that a longer (i.e., 24 hour) holding time has little effect on FC results processed by MEL. Samples with longer holding times did not show a significant trend towards higher or lower FC counts compared to the samples analyzed within 6-8 hours.

Data Management Procedures

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL Users Manual (MEL, 2008). Lab results will be checked for missing and/or improbable data. Variability in lab duplicates will be quantified using the procedures outlined in the MEL Users Manual. Any estimated results will be qualified and their use restricted as appropriate. A standard case narrative of laboratory QA/QC results will be sent to the project manager for each set of samples.

Field notebooks will be checked for missing or improbable measurements before leaving each site. Field-generated data will be entered into EXCEL® spreadsheets (Microsoft, 2007) as soon as practical after returning from the field. The EXCEL® Workbook file will be labeled "DRAFT" until data verification and validation are completed. Data entry will be checked by the field assistant against the field notebook data for errors and omissions. Missing or unusual data will be brought to the attention of the project manager for consultation. Valid data will be moved to a separate file labeled "FINAL."

As soon as FC data are verified by MEL, the laboratory microbiologist will notify the project manager of FC results greater than 200 cfu/100 mL. The project manager will notify Ecology's NWRO Client Staff Contact and Water Quality Section Manager by e-mail of these elevated counts in accordance with Environmental Assessment Program Policy 1-03. The Client Staff Contact will notify local authorities or permit managers as appropriate.

Data received from MEL by Ecology's Laboratory Information Management System (LIMS) will be checked for omissions against the "Request for Analysis" forms by the field lead. Data can be in EXCEL® spreadsheets (Microsoft, 2007) or downloaded tables from Ecology's EIM system. These tables and spreadsheets will be located in a file labeled "DRAFT" until data validation is completed. Field replicate sample results will be compared to quality objectives in Table 11. Data requiring additional qualifiers will be reviewed by the project manager. After data verification and data entry tasks are completed, all field and laboratory data will be copied into a file labeled "FINAL," and then into the EIM system.

EIM data will be independently reviewed by another Environmental Assessment Program employee for errors at an initial 10% frequency. If any entry errors are discovered, a more intensive review will be undertaken. At the end of the field collection phase of the study, the data may be compiled in a data summary or organized on a website. Quarterly progress reports will be available every 3-4 months throughout the 13-month data collection period of the project.

An EIM user study identification number (TSWA0002) has been created for this TMDL study, and all monitoring data will be available via the internet once the project data have been validated. The URL address for this geospatial database is: www.ecy.wa.gov/eim/index.htm. All data will be uploaded to EIM by the EIM data engineer after the data has been reviewed for quality assurance and finalized.

Audits and Reports

The project manager will be responsible for submitting quarterly reports and the final technical study report to Ecology's Water Quality Program TMDL coordinator for this project, according to the project schedule.

Data Verification

Data verification requires adequate documentation of the process. Data verification involves examining the data for errors, omissions, and compliance with quality control (QC) acceptance criteria. MEL staff is responsible for performing laboratory data verification. Field measurements will be verified by field staff before leaving the site.

A detailed examination of the data package using professional judgment to determine whether the method quality objectives (MQOs) have been met will follow data verification. The project manager examines the complete data package to determine compliance with procedures outlined in the QA Project Plan and SOPs. The project manager will also ensure that the MQOs for precision, bias, and sensitivity are met.

Data Usability Assessment

The field lead or project manager will verify that all measurement and data quality objectives have been met for each monitoring station. The field lead or project manager will make this determination by examining the data and all of the associated QC information. If the objectives have not been met (e.g., the percent RSD for sample replicates exceeds the MQO or a Hydrolab® probe was not working properly), the field lead and project manager will decide how to qualify the data and whether or not it can be used in the technical analysis.

The field investigator or project manager will produce a station quality assurance report that will include site descriptions and data quality assurance notes to document this assessment.

Data Analysis

Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution of transformed data. Streamflow data will be frequently reviewed during the field data collection process to check longitudinal water balances. Fecal coliform mass balance calculations will be performed on a reach basis. Trend analyses and graphical presentations of the data (box plots, time series, regressions) will be made using WQHYDRO (Aroner, 2003) and EXCEL® (Microsoft, 2007) software.

Data will be applied to several TMDL methods of evaluation. The statistical rollback method (Ott, 1997) will be applied to FC data distributions to determine target count reductions along key reaches of each waterbody during critical conditions. Ecology will evaluate the need for setting a lower FC target (lower than the standard) at the mouths of major tributaries to ensure that marine water quality and the shellfish resources are protected.

Ideally, at least 20 data are needed from a broad range of hydrologic conditions to determine an annual FC distribution. If sources of FC vary by season and create distinct critical conditions, seasonal targets may be required. Fewer data will provide less confidence in FC reduction targets, but the rollback method is robust enough to provide general targets for planning implementation measures.

Project Organization

Table 12 outlines Ecology staff involved in this project.

Table 12. Organization of project staff and responsibilities.

Staff (EAP unless noted otherwise)	Title	Responsibilities
Sally Lawrence Water Quality Program Northwest Regional Office (425) 649-7036	Overall Project Lead	Acts as point of contact between EAP staff and interested parties. Coordinates information exchange. Forms technical advisory team and organizes meetings. Reviews and approves the QAPP and technical report. Prepares and implements TMDL report for submittal to EPA.
Dave Garland Water Quality Program Northwest Regional Office (425) 649-7031	Unit Supervisor of Project Lead	Approves QAPP and the TMDL report for submittal to EPA.
Trevor Swanson Directed Studies Unit Western Operations Section (360) 407-6685	Project Manager	Writes the QAPP. Coordinates field surveys with regional staff, and oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the technical sections of the draft and final report.
George Onwumere Directed Studies Unit Western Operations Section (360) 407-6730	Unit Supervisor of Project Manager	Reviews and approves the QAPP, staffing plan, technical study budget, and the technical sections of the TMDL report.
Bob Cusimano Western Operations Section (360) 407-6596	Section Manager of Project Manager	Approves the QAPP and technical sections of the TMDL report.
Kevin Fitzpatrick Northwest Region Water Quality Program (425) 649-7033	Section Manager of Project Lead	Approves the QAPP and technical sections of the TMDL report.
Stuart Magoon EAP, Manchester Environmental Laboratory (360) 871-8801	Director	Provides laboratory staff and resources, sample processing, analytical results, laboratory contract services, and quality assurance/quality control (QA/QC) data. Approves the QAPP.
William R. Kammin (360) 407-6964	Ecology Quality Assurance Officer	Provides technical assistance on QA/QC issues. Reviews the draft QAPP and approves the final QAPP.

EAP – Environmental Assessment Program
EIM – Environmental Information Management system
QAPP – Quality Assurance Project Plan
TMDL – Total Maximum Daily Load

Project Schedule

Table 13 shows the proposed project schedule.

Table 13. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	
Field work completed	August 2009
Laboratory analyses completed	September 2009
Environmental Information System (EIM) system	
EIM data engineer	Trevor Swanson
EIM user study ID	TSWA0002
EIM study name	Liberty Bay Fecal Coliform TMDL
Data due in EIM	January 2010
Quarterly reports	
Author lead	Trevor Swanson
Schedule	
1st quarterly report	January 2009
2nd quarterly report	April 2009
3rd quarterly report	July 2009
4th quarterly report	October 2009
Final report	
Author lead	Trevor Swanson
Schedule	
Draft due to supervisor	June 2010
Draft due to client/peer reviewer	July 2010
Draft due to external reviewer	September 2010
Final report due on web*	November 2010

*If the technical report becomes a joint report with an implementation strategy, the final due date will likely be May 2011).

Laboratory Budget

The estimated laboratory budget and number of lab samples shown in Table 14 is based on the proposed schedule in Table 6. Since all months have more than one survey that occur on different weeks, monthly and weekly sample loads should not overload the microbiological units at MEL.

The greatest uncertainty in the laboratory load and cost estimate is with the synoptic storm survey work. Efforts will be made to keep the submitted number of samples within the estimate; however, because not all storm sites have been selected yet, this is an estimate only.

Table 14. The number of monthly sample submittals for each analysis, an estimate of the monthly analytical costs, and the total analytical cost estimate[1] for the project, 2008-09.

Month	FC (MF)	Reps.	Cost
August	52	10	$1,426
September (plus dry storm)	66	14	$1,840
October	52	10	$1,426
November	52	10	$1,426
December	52	10	$1,426
January (plus storm)	92	19	$2,553
February (plus storm)	92	19	$2,553
March (plus storm)	92	19	$2,553
April	52	10	$1,426
May	52	10	$1,426
June	52	10	$1,426
July	52	10	$1,426
August (plus dry storm)	66	14	$1,840
Totals	824	165	$22,747

FC = fecal coliform
MF = membrane filtered
Reps. = replicates for 20% of the preceding column

[1] Costs include 50% discount for Manchester Laboratory

References

APHA, AWWA, and WEF, 1998. Standard Methods for the Examination of Water and Wastewater 20th Edition. American Public Health Association, Washington, D.C.

Aroner, E.R., 2003. WQHYDRO: Water Quality/Hydrology Graphics/Analysis System. Portland, OR.

City of Poulsbo, 2008. City of Poulsbo Public Works: Sewer System. www.cityofpoulsbo.com/works/ssystem.asp

Cusimano, R., 1997. Water Quality Assessment of Tributaries to the Snohomish River and Nonpoint Source Pollution TMDL Study. Washington State Department of Ecology, Olympia, WA. Publication No. 97-334. www.ecy.wa.gov/biblio/97334.html. 52 pgs.

DOH, 2008. Washington State Department of Health, Office of Shellfish and Water Protection: Annual Growing Area Review. www.doh.wa.gov/ehp/sf/Pubs/gareports/lemolo.pdf.

DOT, 2008. Washington State Department of Transportation, Stormwater Permit Questions and Answers. www.wsdot.wa.gov/Environment/WaterQuality/StormwaterPermitQandA.htm.

Ecology, 2005. 2004 Water Quality Assessment (Final) – Category 5 Listings. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/wq/303d/2002/2002-index.html.

Ecology, 2008. 2008 Water Quality Assessment Process. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/wq/303d/2008/index.html.

EPA, 2001. Protocols for Developing Pathogen TMDLs. U.S. Environmental Protection Agency.

Forsyth, S., 1995. Liberty Bay/Miller Bay Watershed Nonpoint Source Pollution Baseline Water Quality Assessment. Bremerton-Kitsap County Health District, Environmental Health Division, Water Quality Program. Bremerton, WA.

Funk, A., 2008. Personal communication. November 2008. Senior Engineering Technician. City of Poulsbo Public Works. Poulsbo, WA.

Joy, J., 2000. Lower Nooksack River Basin Bacteria Total Maximum Daily Load Evaluation. Washington State Department of Ecology, Olympia, WA. Publication No. 00-03-006. www.ecy.wa.gov/biblio/0003006.html. 60 pgs.

Joy, J., 2006. Standard Operating Procedure for Manually Obtaining Surface Water Samples. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/eap/quality.html.

KCHD, 2003. Kitsap County Health District News Release: Large Sewage Spill Affects Liberty Bay. www.kitsapcountyhealth.com/docs/press_release_sewagespill091903.pdf.

KCHD, 2006. Kitsap County Health District News Release: Sewage Spill in Liberty Bay. www.kitsapcountyhealth.com/docs/press_release_sewage_spill_libertybay20060323.pdf.

KCHD, 2007a. Liberty Bay/Miller Bay Watershed 2007 Water Quality Monitoring Report. Kitsap County Health District.

KCHD, 2007b. Kitsap County Health District News Release: "No Contact" Order Issued for County Surface Waters. www.kitsapcountyhealth.com/docs/press_releases/2007/20071203floodpress1.pdf

KCDCD, 2007. Keyport Community Plan. Kitsap County Department of Community Development. www.kitsapgov.com/dcd/community_plan/subareas/keyport/

Kitsap County Public Works, Wastewater Division, 2006. Request for Qualifications, #2006-143, Central Kitsap Wastewater Treatment Plant Phase 3 Upgrades. Kitsap County Public Works.

Kitsap County Public Works, 2008. Surface and Stormwater Management Program; National Pollutant Discharge Elimination System (NPDES) Western Washington Phase II Municipal Stormwater Permit. www.kitsapgov.com/sswm/npdes.htm.

Lennartson, D., 2005. Personal communication, June-November, 2005. Public Health Advisor, Office of Food, Safety, and Shellfish Programs. Division of Environmental Health, Washington State Department of Health, Olympia, WA.

Lombard, S. and C. Kirchmer, 2004. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Washington State Department of Ecology, Olympia, WA. Publication No. 04-03-030. www.ecy.wa.gov/biblio/0403030.html.

Mathieu, N., 2005. Yakima Area Creeks Fecal Coliform TMDL Quarterly Progress Report #3 (July 2005 through September 2005**).** Environmental Assessment Program, Washington State Department of Ecology, Olympia, WA.

Mathieu, N. 2006a. Standard Operating Procedure for Sampling Bacteria in Water – Provisional. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/eap/quality.html.

Mathieu, N. 2006b. Replicate Precision for Twelve Total Maximum Daily Load (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.

May, W., K. Byrne-Barrantes, and L. Barrantes, 2005. Liberty Bay Nearshore Habitat Evaluation and Enhancement Project. Prepared for the Lemolo Citizens Club and Liberty Bay Foundation, Poulsbo, WA.

MEL, 2008. Manchester Environmental Laboratory Lab Users Manual, Ninth Edition. Washington State Department of Ecology, Manchester, WA.

Microsoft, 2007. Microsoft Office Excel 2007 (2). Microsoft Corporation.

NOAA, 2008. NOAA Fisheries; Office of Protected Resources. National Oceanic and Atmospheric Administration. www.nmfs.noaa.gov/pr/species/fish/.

Ott, W., 1997. Environmental Statistics and Data Analysis. Lewis Publishers, New York, NY.

Sargeant, D., 2002. Dungeness River and Matriotti Creek Fecal Coliform Bacteria Total Maximum Daily Load Study. Washington State Department of Ecology, Olympia, WA. Publication No. 02-03-014. www.ecy.wa.gov\biblio\0203014.html. 46 pgs.

Sullivan, L., 2006. Standard Operating Procedures for Estimating Streamflow – Provisional. Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/programs/eap/quality.html.

Swanson, T., 2007. Standard Operating Procedure (SOP) for Hydrolab® DataSonde® and MiniSonde® Multiprobes, Version 1.0. Washington State Department of Ecology, Olympia, WA. SOP Number EAP033. www.ecy.wa.gov/programs/eap/quality.html.

Swanson, T., 2008. Samish Bay Fecal Coliform Bacteria Total Maximum Daily Load: Volume 1, Water Quality Study Findings. Washington State Department of Ecology, Olympia, WA. Publication No. 08-03-029. www.ecy.wa.gov/biblio/0803029.html 115 pgs.

Van Beynum, R., 2008. Personal communication (forwarded email), November 2008. Stormwater Pollution Prevention point-of-contact for the Naval Undersea Warfare Center (NUWC), Division Keyport. Keyport, WA.

WAC 173-201A. Water Quality Standards for Surface Waters in the State of Washington Washington State Department of Ecology, Olympia, WA. www.ecy.wa.gov/laws-rules/ecywac.html.

Zimny, J., 2008. Personal communication (e-mail), November 2008. Senior Environmental Health Specialist. Kitsap County Health District. Bremerton, WA.

Appendices

Appendix A. Glossary and Acronyms

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

303(d) list: Section 303(d) of the federal Clean Water Act requires Washington State to periodically 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.

Clean Water Act: A 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.

Enterococci: A subgroup of the fecal streptococci that includes *S. faecalis, S. faecium, S. gallinarum,* and *S. avium*. The enterococci are differentiated from other streptococci by their ability to grow in 6.5% sodium chloride, at pH 9.6, and at 10 degrees C and 45 degrees C.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

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 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria 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/100 mL).

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 10 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.

Load allocation: The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a waterbody can receive and still meet water quality standards.

Margin of safety: Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving waterbody.

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 NPDES 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.

Phase II stormwater permit: The second phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

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. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or is likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) 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.

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, salt waters, wetlands and all other surface waters and watercourses within the jurisdiction of Washington State.

Synoptic: Performed in one day.

Thalweg: Deepest flowing longitudinal section of a stream.

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.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocations constitute one type of water quality-based effluent limitation.

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.

Acronyms and Abbreviations

DOH	Washington State Department of Health
EAP	Environmental Assessment Program (Ecology)
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database (Ecology)
EPA	U.S. Environmental Protection Agency
KCHD	King County Health Department
MF	Membrane filter
MPN	Most probable number
MQO	Measurement quality objective
NSSP	National Shellfish Sanitation Program
NUWC	Navy Undersea Weapons Center at Keyport, WA
NWRO	Northwest Regional Office (Ecology)
QA	Quality assurance
QC	Quality control
RSD	Relative standard deviation
RPD	Relative percent difference
SOP	Standard operating procedure
WAC	Washington Administrative Code

Appendix B. Statistical Rollback Method

The Statistical Rollback Method (Ott, 1997) will be used to determine if fecal coliform (FC) distribution statistics for individual sites meet the water quality criteria in the Liberty Bay Watershed. The method has been successfully applied by Ecology in many other FC bacteria TMDL evaluations.

The method is applied as follows:

The geometric mean (approximately the median in a lognormal distribution) and 90th percentile statistics are calculated and compared to the FC criteria. If one or both do not meet the criteria, the whole distribution is "rolled-back" to match the most restrictive of the two criteria. The 90th percentile criterion usually is the most restrictive.

The rolled-back geometric mean or 90th percentile FC value then becomes the "target" FC value for the site. (The term "target" is used to distinguish these estimated numbers from the actual water quality criteria.) The amount a distribution of FC counts is "rolled-back" to the target value is stated as the estimated percent of FC reduction required to meet the FC water quality criteria and "contact recreation" water quality standards.

It is important to remember that the FC TMDL targets are only in place to assist water quality managers in assessing the progress toward compliance with the FC water quality criteria. Compliance is measured as meeting water quality criteria. Any waterbody with FC TMDL targets is expected to meet both the applicable geometric mean and "not more than 10% of the samples" criteria and also to meet beneficial uses for the category.

Statistical Theory of Rollback

The statistical rollback method proposed by Ott (1997) describes a way to use a numeric distribution of a water quality parameter to estimate the distribution after abatement processes are applied to sources. The method relies on basic dispersion and dilution assumptions and their effect on the distribution of a chemical or a bacterial population at a monitoring site downstream from a source. It then provides a statistical estimate of the new population after a chosen reduction factor is applied to the existing pollutant source. In the case of the TMDL, compliance with the most restrictive of the dual FC criteria will determine the reduction factor needed.

As with many water quality parameters, FC counts collected over time at an individual site usually follow a lognormal distribution. That is, over the course of sampling for a year, or multiple years, most of the counts are low, but a few are much higher. When monthly FC data are plotted on a logarithmic-probability graph, they appear to form nearly a straight line.

The 50th percentile (an estimate of the geometric mean) and the 90th percentile (a representation of the level over which 10% of the samples lie) can be located along a line plotted from an equation estimating the original monthly FC data distribution.

The following is a summary of the major theorems and corollaries for the Statistical Theory of Rollback from *Environmental Statistics and Data Analysis* by Ott (1997).

1. If Q = the concentration of a contaminant at a source, and D = the dilution-diffusion factor, and X = the concentration of the contaminant at the monitoring site, then X = Q*D.

2. Successive random dilution and diffusion of a contaminant Q in the environment often result in a lognormal distribution of the contaminant X at a distant monitoring site.

3. The coefficient of variation (CV) of Q is the same before and after applying a “rollback” (i.e., the CV in the post-control state will be the same as the CV in the pre-control state). The rollback factor = r, a reduction factor expressed as a decimal (a 70% reduction would be a rollback factor of 0.3). The random variable Q represents a pre-control source output state and rQ represents the post-control state.

4. If D remains consistent in the pre-control and post-control states (long-term hydrological and climatic conditions remain unchanged), then CV(Q)*CV(D)=CV(X), and CV(X) will be the same before and after the rollback is applied.

5. If X is multiplied by the rollback factor, then the variance in the post-control state will be multiplied by r^2, and the post-control standard deviation will be multiplied by r.

6. If X is multiplied by the rollback factor, the quantiles of the concentration distribution will be scaled geometrically.

7. If any random variable is multiplied by r, then its expected value and standard deviation also will be multiplied by r, and its CV will be unchanged. (Ott uses “expected value” for the mean.)