North Ocean Beaches Fecal Coliform Bacteria Source Investigation Study

Water Quality Study Design (Quality Assurance Project Plan)

May 2014

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DEPARTMENT OF ECOLOGY
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Publication and Contact Information

Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

The plan for this study is available on the Department of Ecology's website at https://fortress.wa.gov/ecy/publications/SummaryPages/1403108.html

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Cover photo: View of beach at Ocean Shores, Washington. (Source unknown)

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EAP: Environmental Assessment Program
EIM: Environmental Information Management database

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Abstract

Three nearshore marine zones on Washington's Pacific Ocean coast (two near the mouth of the Moclips River and one near the mouth of Elk Creek) were included on the State's 2012 303(d) list of impaired water bodies for bacteria violations of water quality standards.

In 2011, the Washington State Department of Health (DOH) Office of Shellfish and Water Protection reclassified formerly *Approved* (for shellfish harvesting) portions of the Pacific Coast shellfish growing area to *Conditionally Approved*. Recent data collected by DOH also indicate declining bacterial water quality in nearshore ocean waters near the communities of Illahee and Oyehut (just north of Ocean Shores). In July 2013, DOH downgraded the shellfish harvesting area here to *Prohibited*.

The popularity of shellfish harvesting and recreation in this area, coupled with declining bacterial water quality, have prompted the Washington State Department of Ecology to initiate a study to investigate possible sources of fecal contamination.

The goal of the proposed study is to identify sources of fecal coliform bacteria loading to ocean beaches in the study area and to inform a water quality improvement plan that will protect and improve shellfish harvesting and recreational opportunities.

Why is Ecology Conducting a Study in This Watershed?

Background

In July 2013, DOH reclassified the public shellfish digging beach near Oyehut/Illahee from *Approved* (open all year for shellfish harvesting) to *Prohibited* (closed to shellfish harvesting) because of high fecal coliform (FC) concentrations found there. Bacterial sources have not been confirmed. Other areas of concern include beaches near the mouths of the Moclips River and Joe Creek, which were downgraded to *Conditionally Approved* (closed to shellfish harvesting in the summer) by the Washington State Department of Health (DOH) Office of Shellfish and Water Protection in 2011. Several study-area water bodies are also included on the Washington State Department of Ecology's (Ecology's) 303(d) list of impaired waters for fecal contamination, including three marine grid cells; two near the mouth of the Moclips River and one near the mouth of Elk Creek.

Ecology plans to sample bacteria at strategic locations along the entire 22-mile stretch of beaches to augment existing data from DOH, Grays Harbor County, and the Quinault Indian Nation and to help better understand sources and help prioritize areas for cleanup.

Grays Harbor County Shellfish Protection District

In August 2011, DOH notified Grays Harbor County that the classification for portions of the Pacific Coast shellfish growing area were downgraded from *Approved* (open all year for harvesting) to *Conditionally Approved* (closed during the summer months). The shellfish growing areas around DOH stations 11, 195, and 197 are shown in Appendix A. In response to this classification downgrade, Grays Harbor County created a Shellfish Protection District per RCW 90.72.045. Among other things, a Shellfish Protection District gives the County:

- Authority to establish and fund programs to protect and restore water quality in shellfish growing areas.
- Ability to address local water quality needs, including stormwater runoff, onsite septic systems(OSSs), farm animal wastes, boater wastes, water quality monitoring, and public education.

Ecology's study in the North Pacific Ocean Beaches area will help Grays Harbor County further characterize sources of fecal pollution and refine initial Shellfish Protection District response efforts to reduce fecal loading in the shellfish growing area. Grays Harbor County also plans to develop a public education and outreach effort, as resources allow (GHCEHD, 2012).

Study area

The study area consists of approximately 22 miles of continuous open ocean beach shoreline extending north from the mouth of Grays Harbor to the mouth of the Moclips River. The area north of the Moclips River to Point Grenville, is owned by the Quinault Indian Nation and will not be studied closely due to the historically low FC concentrations found there and low human population in the area. Significant drainages include, in order of longest to shortest, the Copalis River, Moclips River, Joe Creek, Connor Creek, Boone Creek, and Elk Creek (Figure 1).

The study area lies within two Water Resource Inventory Areas (WRIAs): 21 and 22. Because this study is geared more towards finding sources of FC near the Pacific Ocean nearshore zone, Ecology will likely focus its sampling resources near the mouths of streams and drainages. The exception may be on larger streams, where FC may be coming from sources farther upstream. Figure 1 shows fixed stations Ecology is planning to sample throughout the course of the study. When tracking FC for source identification, we will investigate several other sites, but it is impossible to know where these sites will be until sampling and preliminary data analyses have commenced.

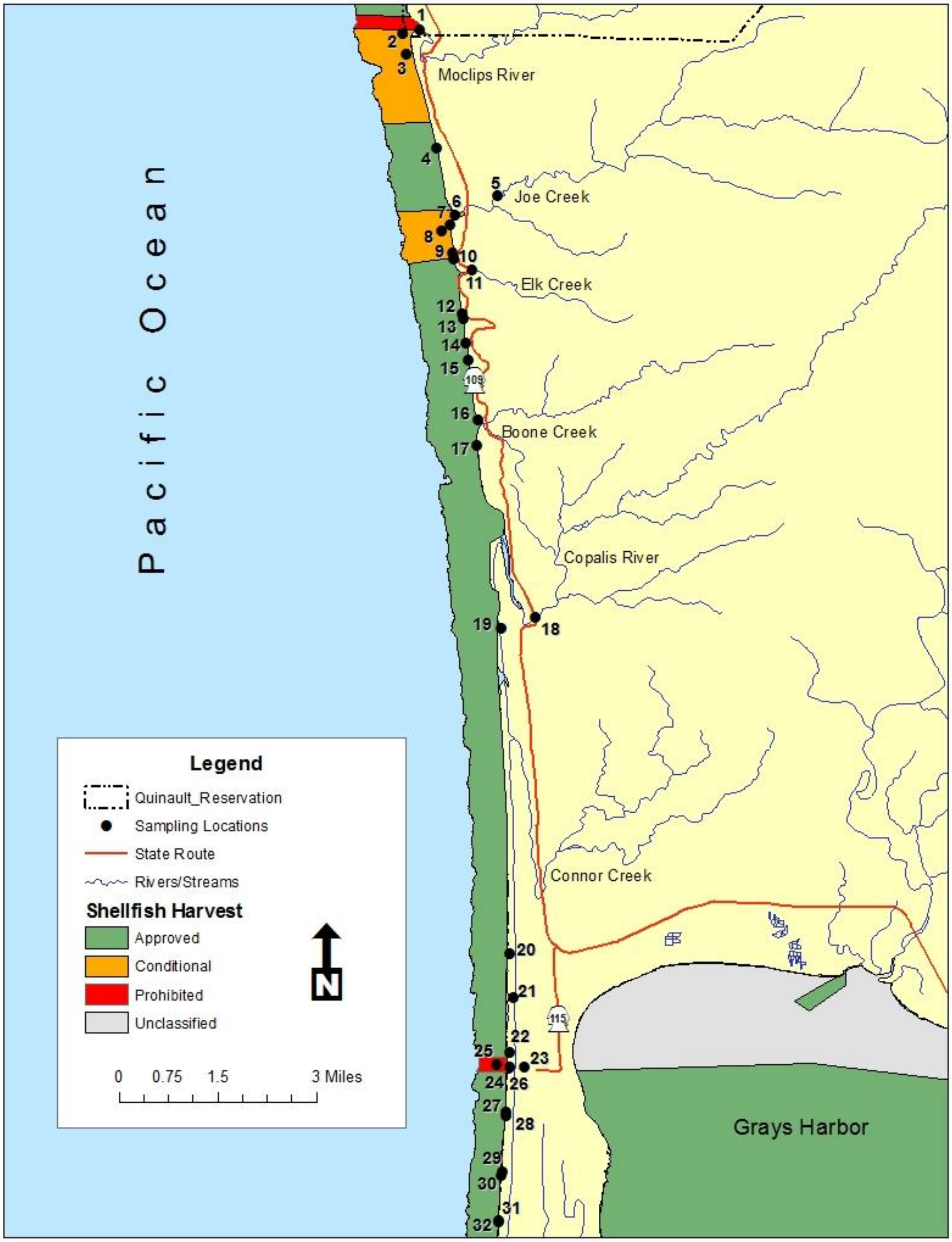

Figure 1. North Ocean Beaches study area with sampling sites and 2013 DOH shellfish classifications.

Numbers reference sample locations in Table 8.

Water Resource Inventory Area (WRIA) and 8-digit Hydrologic Unit Code (HUC) numbers for the study area

WRIAs

- 21 – Queets-Quinault
- 22 – Lower Chehalis

HUC numbers

- 17100102 – Queets-Quinault watershed
- 17100105 – Grays Harbor watershed

Impairments addressed by this study

Designated beneficial uses in the study area include *Shellfish Harvesting* and *Primary and Secondary Contact Recreation*. *Primary and Secondary Contact Recreation* in both fresh and marine waters include people coming into contact with water through swimming, boating, fishing, wading, and other water-related activities. *Primary Contact* includes activities where a person would have direct contact with water to the point of complete submergence. *Secondary Contact* includes activities where a person's water contact would be limited (e.g., wading or fishing) to the extent that bacterial infections of eyes, ears, respiratory or digestive systems would normally be avoided. Table 1 shows the Category 5 listings on the state Water Quality Assessment for FC in the Pacific Ocean, Water Resource Inventory Areas (WRIA) 21, approved by the U.S. Environmental Protection Agency (EPA) in 2012 (Ecology, 2014). There are no Category 5 listings in WRIA 22.

Table 1. Category 5 listings for fecal coliform located in the North Ocean Beaches study area.

Water-body Name	WRIA[1]	Water-body ID	Marine Grid Cell	2012 Assessment Listing ID	Latitude Longitude
Pacific Ocean	21	1239693482477	47124C2D2	15926	47.235 -124.225
Pacific Ocean	21	1239693482477	47124C2E1	15927	47.245 -124.215
Pacific Ocean	21	1239693482477	47124B2I0	15931	47.185 -124.205

WRIA: Water Resource Inventory Area

How will the results of this study be used?

Since a major goal of this study is to identify the main sources or source areas of pollution, Ecology and local partners will use sampling results to assess where to focus water quality improvement activities. The study may suggest areas for follow-up sampling to further pinpoint sources for cleanup.

Water Quality Standards and Numeric Targets

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

Freshwater and marine water bodies are required to meet water quality standards based on the designated uses of the water body. Numeric criteria for specific water quality parameters are intended to protect designated uses. Pacific Ocean coastal waters in the study area are classified as *Primary Contact Recreation* water. All tributaries flowing into the Pacific Ocean in Washington are classified as *Extraordinary Primary Contact Recreation* waters.

Fecal coliform bacteria

The FC criteria have two statistical components: a geometric mean and an upper limit value that 10% of the samples cannot exceed. In Washington, 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.

The Pacific Ocean and its tributaries are available to the public for *Primary* (e.g., swimming) and *Secondary* (e.g., wading) *Contact Recreations*. Recreational and tribal/commercial shellfish harvestings occur in the approved sections of Washington coastal beaches.

Freshwater criteria

Bacteria targets in the water quality standards are set to protect people who work and play in the water from waterborne illnesses, and to protect tributaries flowing to shellfish harvesting areas. In Washington, surface water quality standards use FC as an "indicator bacteria" for the state's freshwaters (e.g., lakes and streams). FC bacteria in water indicate the presence of waste from humans and other warm-blooded animals, which is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. Ecology's selection of FC bacteria as the indicator for pathogens in surface waters is explained in *Setting Standards for the Bacteriological Quality of Washington's Surface Water Draft Discussion Paper and Literature Summary* (Hicks, 2002). The paper reviews the use of FC as an indicator bacteria and epidemiological studies of indicator bacteria in both fresh and marine waters.

The designated use of *Extraordinary Primary Contact* 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 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100 colonies/100 mL." [WAC 173-201A-200] (Table 2). The upper limit criterion (i.e., the level that not more than 10 percent of the samples shall exceed) has been interpreted in this study as the 90th percentile of sample values.

Table 2. Freshwater fecal coliform criteria for tributaries to the Pacific Ocean.

Freshwater Criteria (Extraordinary Primary Contact)	Geometric Mean	Not more than 10% (90th Percentile)
Freshwater tributaries to Pacific Ocean	50 cfu/100 mL	100 cfu/100 mL

cfu: colony-forming units

Marine water criteria

In marine waters, water quality standards for bacteria are set to protect shellfish consumption and people who work and play in and on the water. Marine water criteria apply when the salinity is ten parts per thousand (17,700 umhos) or greater. 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 Recreation*, 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.

To protect either *Shellfish Harvesting* or *Primary Contact Recreation* in the study area: "Fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 43 colonies/100 mL." [WAC 173-201A-210] (Table 3). The upper limit criterion (i.e., the level that not more than 10% of the samples shall exceed) has been interpreted in this study as the 90th percentile of sample values.

Table 3. Marine fecal coliform criteria for the study area.

Marine Criteria	Geometric Mean	Not more than 10% (90th Percentile)
North Ocean Beaches - Pacific Ocean (*Shellfish Harvesting & Primary Contact Recreation*)	14 cfu/100 mL	43 cfu/100 mL

cfu: colony-forming units

The criteria levels set to protect *Shellfish Harvesting* and *Primary Contact Recreation* on Pacific Ocean beaches are consistent with federal shellfish sanitation rules. FC concentrations in Washington's 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 criteria to protect both *Shellfish Harvesting* and *Primary Contact* uses in the state standards.

Compliance with criteria

Results of water samples collected randomly from one site and analyzed for bacteria typically follow a lognormal distribution, which is why the geometric mean is used for central tendency of the data set. The geometric mean is a mathematical expression of central tendency (average) of multiple sample values in a group of lognormal sample values. This average dampens the effect of extreme values that could bias an arithmetic average.

Compliance with bacteria water quality standards is based on meeting both the geometric mean criterion and the "10 percent of samples" criterion. If ten or fewer total samples exist, then no single sample may exceed the 90^{th} percentile. These two measures used in combination ensure that bacterial pollution in a water body will be maintained at a set level of 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 data sets.

If FC concentrations in the water exceed the numeric criteria, human activities that would increase concentrations above the criteria need to be managed in order to allow waters to meet standards. The state, in collaboration with local governments, tribes, and watershed stakeholders, will work to ensure that human activities are conducted in a manner that will bring FC concentrations back into compliance with water quality standards.

If natural levels of FC (from wildlife, for example) cause criteria to be exceeded, no allowance exists for human sources to measurably increase bacterial pollution beyond natural levels. Though the presence of bacterial contamination from wildlife is typical in most environments, there still may be a risk of human illness. For example, EPA recently published summary reports on the risk of human illnesses associated with the presence of water-borne pathogens from animals and birds (EPA, 2009, and EPA, 2011).

Study Area Description

The study area consists of approximately 22 miles of continuous open ocean beach shoreline extending north from the mouth of Grays Harbor to the Moclips River. The area north of the Moclips River to Point Grenville is owned by the Quinault Indian Nation and will not be included in this study due to the historically low FC concentrations found there and the need for Ecology's limited resources to be allocated to more polluted areas.

Significant drainages flowing across the study area, from north to south, include the Copalis River, Moclips River, Joe Creek, Connor Creek, Boone Creek, and Elk Creek. Many smaller drainages flow across the beaches as well. Ecology only plans to sample far enough upstream in freshwater drainages to track sources of FC affecting beaches and nearshore ocean waters.

The following nine paragraphs describing the study area were taken from DOH's Shoreline Survey of Pacific Coast (DOH, 2005):

The area is characterized by sand beaches that are exposed to an open ocean surf line. The beaches are shallow and a large intertidal area is exposed at low tide. Freshwater streams from minor drainages and larger watersheds run across the surface of the beach and into the surf zone at numerous locations along the length of the area (Figure 1).

Land use in the area is a mix of urban, rural residential, recreational, and forest land. Seven beachfront communities are located along the length of the North Pacific Coast shellfish area. These communities, from north to south are: Moclips, Sunset Beach, Pacific Beach, Copalis Beach, Ocean City, Oyehut, and Ocean Shores. Three ocean beach State Parks; Pacific Beach State Park, Griffiths-Priday State Park, and Ocean City State Park are located within the boundaries of the shellfish area. The northern end of the shellfish area, extending approximately four miles from the northern side of the mouth of the Moclips River to Point Grenville, is part of the Quinault Indian Reservation and will not be sampled by Ecology.

Sewage treatment and disposal in the area is accomplished with OSSs and three community wastewater treatment plants (WWTPs). A WWTP that serves the Moclips River Estates development, located on the Quinault Indian Reservation, discharges treated effluent to the Moclips River. A WWTP closure zone (for harvesting shellfish) extends 300 yards north and 300 yards south of the mouth of the Moclips River. A WWTP that serves the towns of Moclips and Pacific beach discharges its treated effluent to a tributary of Joe Creek. A WWTP closure zone extends 100 yards north and 100 yards south of the mouth of Joe Creek. A third WWTP serving the town of Ocean Shores discharges treated effluent outside of the Pacific Coast shellfish area near the mouth of Grays Harbor. The residences and businesses that are not connected to one of these three WWTPs use OSSs for the treatment and disposal of sewage.

The Pacific Coast shellfish area supports a large population of Pacific Razor Clams that are harvested commercially and recreationally. The beaches from the mouth of Grays Harbor north to the mouth of the Moclips River are open periodically to public recreational harvest. Commercial harvest occurs along the entire length of the area.

Horseback riding is a popular activity on beaches throughout the shellfish area. Four horse rental businesses operate in the area on a seasonal basis. Other activities include wading, swimming, flying kites, biking, fishing, and other beach activities.

The beach environment provides habitat for several species of waterfowl and shorebirds that are often present in large flocks around freshwater streams or feeding on the intertidal expanses that are exposed during low tides.

The Pacific Coast is subject to mixed tides, predominantly semi-diurnal, characterized by a large inequality in the high water heights, low water heights, or both. There are usually two high and two low tides each day but occasionally the tidal pattern will result in only one high or one low tide in a single day.

Tide heights for the ocean beaches, using the Point Grenville reference point, range from an extreme high of 10.2 feet above the zero foot mark to an extreme low of -2.7 feet below the zero foot mark.

Annual Average Precipitation recorded at the Hoquiam Airport weather station for the period 1953 to 2005 is 69.68 inches.

Potential sources of contamination

Point sources

Stormwater

Stormwater runoff from roads and other impervious surfaces has potential to impact surface water quality in the study area. Ecology plans to sample FC bacteria in ditches along beach access roads near Ocean Shores and Illahee/Oyehut during times of surface runoff (Table 8). Stormwater runoff not directly flowing to the beaches will not be sampled unless it is suspected to significantly increase bacteria loading in streams flowing to beaches in the study area.

Urban areas that collect stormwater runoff in municipal separate storm sewers (MS4s) and discharge it to surface waters are required to have a permit under the federal Clean Water Act. EPA stormwater regulations established two phases – Phase I and Phase II – for the municipal stormwater permit program.

Ecology develops and administers National Pollutant Discharge Elimination System (NPDES) municipal stormwater permits in Washington. However, because the study area is not in a Phase I or II area, Ecology has not administered any NPDES municipal stormwater permits here.

The Washington State Department of Transportation maintains roads that have potential to impact waters in the study, but roads not covered by an NPDES permit include SR 109 and SR 115.

Ecology's Stormwater Management Manual is available on the internet at www.ecy.wa.gov/programs/wq/stormwater/manual.html.

Wastewater treatment plants (WWTPs)

Permitted facility information was taken from the Ecology Permit and Reporting Information System database and EPA's website. There are currently three WWTPs operating in the study area. Two of the WWTPs are run by local jurisdictions and are permitted by Ecology. The third, Moclips River Estates WWTP, is run by the Quinault Indian Nation and is permitted by EPA.

One of the Ecology-permitted facilities is run by the City of Ocean Shores under NPDES permit number WA0023817. The Ocean Shores sewer system consists of a combination of gravity and vacuum sewer collection lines with pump stations. The wastewater is delivered to the WWTP, which uses secondary treatment with ultraviolet (UV) light disinfection. Effluent from the WWTP discharges to the entrance of Grays Harbor Estuary near the seaward edge of the North Jetty. Although this WWTP is within the study area, it does not discharge to any waters that are in direct contact with harvest areas.

The second Ecology-permitted facility is run by the City of Pacific Beach under NPDES permit number WA0037095. Pacific Beach's sewer system consists of force mains connected to four pump stations that carry wastewater from the City of Pacific Beach, Pacific Beach State Park, and parts of the City of Moclips. Wastewater is delivered to the WWTP, which uses secondary treatment with UV disinfection. Effluent from the WWTP discharges directly to Joe Creek downstream of the Ocean Beach Road bridge. Joe Creek flows to the Pacific Ocean. The area at the mouth of Joe Creek is *Conditionally Approved* for shellfish harvesting.

The third WWTP (Moclips River Estates) is operated by the Quinault Indian Nation and is permitted by EPA under NPDES permit number WA0026603. Domestic sewage from the Moclips River Estates at the Qui-nai-elt Village is collected by a gravity system. At the time of permit application in 2009, a total of 15 homes were being serviced with an additional 32 homes to be serviced in the future. Wastewater is delivered to the WWTP, which uses secondary treatment with UV disinfection. Effluent is discharged to the Moclips River, 90 meters upstream of the Quinault Indian Reservation boundary. The Moclips River flows into the Pacific Ocean at the City of Moclips. A shellfish harvest prohibition zone extends 300 yards north and south from the mouth of the Moclips River.

Nonpoint pollution sources

Nonpoint pollution sources are dispersed and thus not controlled through discharge permits. Potential nonpoint sources within the Pacific Coast shellfish area include:

- Residential properties adjacent to the creeks and beaches
- Pet waste (including horses)
- Human waste
- Failing OSSs
- Excessive wildlife waste

- Recreation

Nonpoint source contributions are important to understand because they affect stream and beach water quality and are a major component of stormwater runoff. Some of the different categories of nonpoint sources will be discussed in more detail in the following sections.

Septic systems

Over time, the cities of Ocean Shores and Pacific Beach have connected properties with failing septic systems to the municipal wastewater collection and treatment facilities that they operate. Even with the effort from both of these municipalities, there are still failing septic systems in unincorporated areas. Of particular note is the area immediately north of Damon Road in Ocean Shores, known as Illahee and Oyehut. Many of these properties were developed prior to any regulatory oversight of septic design and installation. As a result, most of the septic systems in the area are not functioning, due to a high water table that inundates septic drainfields and, at times, septic tanks (GHCEHD, 2011). These failing or non-functioning septic systems likely have potential to impact the Pacific Coast shellfish area in the vicinity of Ocean Shores.

Wildlife

There is a variety of wildlife within the Pacific Coast shellfish area. Warm-blooded mammals and birds present a potential source of FC bacteria. On and around the beaches, birds are especially likely to be a potential source of FC bacteria because of the area's plentiful feeding and roosting grounds.

Usually, these sources are dispersed and do not elevate FC levels enough to violate state criteria. However, animal populations can occasionally become concentrated and impair water quality. Concentrated wildlife in the watershed will be noted during sampling surveys.

Recreation and pet waste

Recreational activities in the watershed are extensive and include clamming, fishing, beach combing, birding, flying kites, horse riding, walking dogs, and many other activities associated with the ocean beach. Most relevant to this study is razor clam digging, associated with the Pacific Coast shellfish area.

Every year thousands of people recreate on the ocean beaches. Unfortunately, this can also result in the inappropriate disposal of human waste and pet waste (including horses). Dog and horse waste can accumulate on the beaches, especially during summer months, and contribute bacteria to nearshore zones. Any inappropriate disposal of human waste and pet and horse waste will be noted during sampling surveys.

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 FC/100 mL. If this standard is exceeded, the area around the affected station is given a *Prohibited* designation and no shellfish can be harvested. When an area meets *Approved* criteria some of the time, but does not during predictable periods, then the area is designated as *Conditionally Approved.*

If an area has degraded marine water quality or the presence of a potential pollution source, it can be given a *Threatened* or *Concerned* status. These areas can be downgraded in classification if marine water quality does not improve or the potential pollution sources are not managed. *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 majority of the Pacific Coast shellfish growing area is classified as *Approved* for commercial shellfish harvest. There are two closure (*Prohibited*) zones as well as two *Conditionally Approved* zones. Marine stations 197 and 195 have been given a status of *Threatened* and *Concerned*, respectively. See Appendix A for maps of DOH sampling station locations and growing area classifications.

2005 shoreline survey

DOH conducted shoreline survey in 2005 as part of the routine re-evaluation of the Pacific Coast commercial growing area. They evaluated 62 freshwater drainage/discharge points (Figure 2a on page 7 of the 2005 shoreline survey), shoreline development activities, and recreational horse use areas along 28 miles of the Pacific Coast shellfish growing area (DOH, 2005). Water samples were collected and analyzed at 13 of the 62 identified drainage/discharge locations.

The DOH report concluded that there were no direct or indirect impacts from the freshwater sampling locations that would prohibit the ongoing commercial harvest of shellfish. Data from all 13 sampling stations ranged from <1.8 to 350 FC/100 mL with the majority of the results below 33 FC/100 mL. All of the sampling data are available in Table 2 on page 11 of the 2005 shoreline survey (DOH, 2005). Of note were slightly elevated FC results from samples collected after the first significant rainfall events of the season (DOH, 2005). Water sampling station 62, near marine water station 7, was identified as a location that needed further investigation.

Evaluation of development activities showed that most wastewater was dealt with by sewer systems and wastewater treatment facilities. Those properties not served by sewer systems have OSSs. Individual systems were not evaluated because it was concluded that there would be little impact because of the distance to the shellfish harvest areas and the sandy soils (DOH, 2005). Recreational horse use was evaluated and data indicate that there is no significant, ongoing impact to the shellfish growing area. Recreational horse use will be discussed in greater detail below.

2006 sanitary survey

In 2006, DOH conducted a sanitary survey of the Pacific Coast. The sanitary survey is part of the routine re-evaluation of commercial shellfish growing areas. The sanitary survey summarizes the results of the 2005 shoreline survey discussed above and analyzes data from April 2001 to February 2006 (DOH, 2006). A summary of the data organized by station is presented in Table 1 on page 11 of the sanitary survey (DOH, 2006). Included in the table is the classification, number of samples, geometric mean, and variability factors, and compliance with NSSP standards. DOH analyzed how the bacterial loads were impacted by meteorological and hydrographic conditions and assessed variability in the data.

Results showed that bacterial loads were low under the expected meteorological and hydrographic conditions. The assessment of variability showed that there was little variability in water quality and that elevated bacteria levels in samples were infrequent and random (DOH, 2006). There were no recommendations for improvements in the monitoring schedule, sampling locations, or the number of sampling stations. It was also concluded that the current sanitary conditions indicate that the area was appropriately classified for commercial shellfish harvest (DOH, 2006).

In May of 2011, DOH released an addendum to the 2006 Sanitary Survey. The addendum provides data that shows that marine stations 11 and 197 failed to meet NSSP standards for an *Approved* classification (DOH, 2011). These stations were reclassified as *Conditionally Approved* and will close June 1 and reopen September 1 each year. Data were analyzed using SRS criteria and are summarized in Table 1 on page 2 of the addendum (DOH, 2011). The data sets used in the analysis are provided in Table 2 on page 3 and Table 3 on page 4 of the addendum. Seasonal summary tables are provided in Tables 4 and 5 on page 7 of the addendum.

2012 annual growing area review

During 2012, DOH sampled the Pacific Coast shellfish growing area 12 times, using the SRS method (DOH, 2013). Grays Harbor County formed a Shellfish Protection District, due to reclassification of the growing area. More information on the Shellfish Protection District is provided in subsequent sections. DOH continued to evaluate the area around marine station 9, because it failed to meet NSSP standards for an *Approved* classification (DOH, 2013). *Conditionally Approved* portions of the Pacific Coast growing area were closed from June 1 to August 31. In addition, station 197 has a *Threatened* status and station 195 has a *Concerned* status. The growing area review recommends a downgrade of station 9 (DOH, 2013). See Appendix A for maps of DOH sampling station locations and growing area classifications.

Current information

Table 4 presents summary data for the four downgraded classification areas in the Pacific Coast growing area. Data were collected between 2002 and 2013. The data represent a larger number of samples than DOH uses to calculate geometric means and estimated 90th percentiles for the SRS method. These data are presented in this way for informational purposes only.

Table 4. Summary of DOH fecal coliform data collected at five stations in the four downgraded classification areas in the Pacific Coast shellfish growing area, collected from 2002 to 2013.

Station	Classification	Number of Samples	Range (FC/100 mL)	Geometric Mean (FC/100 mL)	Est. 90th Percentile (FC/100 mL)
9	Prohibited*	70	1.7 – 2400	4.4	23.0
11	Conditionally Approved	70	1.7 – 350	5.0	25.6
12	Prohibited	106	1.7 – 540	12.4	79.0
195**	Conditionally Approved	125	1.7 – 350	4.5	23.0
197	Conditionally Approved	86	1.7 – 350	6.2	49.0

*Station 9 was reclassified to *Prohibited* in July 2013.
** Station 195 is in the same *Conditionally Approved* zone as station 11.

Most of the Pacific Coast growing area is currently classified as *Approved* for commercial shellfish harvest. There are two *Prohibited* zones, as described in the Watershed Description section as well as two *Conditionally Approved* zones (stations 11 and 195 are in the same *Conditionally Approved* zone). In July 2013, a third area (around marine station 9) was downgraded to *Prohibited*, because it did not meet DOH standards (Schultz, 2014). It appears that since 2005, FC contamination has increased, causing downgrades in the classification of shellfish harvesting areas.

Grays Harbor County

Septic survey

People have recently expressed concern about OSS impacts to ground and surface water quality in and around the Illahee/Oyehut area. In response to those concerns, Grays Harbor Board of Commissioners directed Grays Harbor County Environmental Health Division (GHCEHD) to conduct a survey of the area to better characterize the current situation (GHCEHD, 2011). The survey area was designated to include all properties with OSSs north of the Ocean Shores city limits to the end of Chickamin and Oyehut Road. This area covered 123 developed properties that use OSSs.

Many OSSs in the survey area were installed before regulations and permits governed their design, installation, and maintenance (GHCEHD, 2011). Many septic systems in the survey area were not installed with adequate separation between the drainfield and the water table, especially during the wet season. This design causes improper treatment of sewage effluent, and when the water table inundates the drainfield, no more waste can be discharged. A total of 80 water quality samples were collected as a part of the survey. Although high bacteria concentrations were found at some locations sampled in the study, GHCEHD concluded that the condition of the OSSs in the survey area are not creating an immediate public health risk (GHCEHD, 2011).

Shellfish Protection District

In August 2011, DOH reclassified a part of the Pacific Coast growing area from *Approved* to *Conditionally Approved.* Under RCW 90.72.045, the action by DOH required Grays Harbor County to create a Shellfish Protection District. The District covers 22 miles of coastline from the North Jetty in Ocean Shores to the southern boundary line of the Moclips River closure area (GHCEHD, 2012). To better communicate response efforts, the district is split into three areas (north, central, south).

Along with creating the Shellfish Protection District, the County initiated a water quality monitoring program. Data from this monitoring program will be used to characterize nonpoint sources of fecal pollution and develop or expand response activities (GHCEHD, 2012). District activities also focus on outreach to property owners and the public on the importance of water quality stewardship.

Recent data

Table 5 presents a summary of data from GHCEHD that were collected between March 19, 2012 and May 28, 2013. Data were collected weekly during this time period. All FC summary statistics were calculated from over 50 samples. Four of the seven sampling sites did not meet 90^{th} percentile (cannot exceed 43 FC/100 mL) criterion. One of the stations (Joe Creek at Pacific Beach State Park) also slightly exceeded the geometric mean (cannot exceed 14 FC/100 mL) criterion.

Table 5. Summary of fecal coliform data collected by Grays Harbor County in the Shellfish Protection District during March 2012 through May 2013.

Location	Number of Samples	Range (FC/100 mL)	Geometric Mean (FC/100 mL)	Est. 90th Percentile (FC/100 mL)
Moclips River at SR 109 Bridge	55	1 - 98	8.9	30.6
Moclips River at mouth	56	1 - 260	11.4	53.0
Joe Creek at Pacific Beach State Park	56	1 - 246	14.2	66.5
Joe Creek at Ocean Beach Road	58	1 - 209	7.4	40.8
Beaver Creek	56	1 - 262	11.1	72.5
Elk Creek	54	1 - 295	6.5	35.4
Analyde Gap	56	1 - >2400	7.1	123.0

FC: Fecal coliform
SR: State Route

Quinault Indian Nation

The Quinault Indian Nation samples the Moclips River for Escherichia coli (E. coli) using the MPN method and has provided Ecology with data from 2002 to 2013. There are three main sampling locations, one near the mouth of the Moclips River, one downstream of the Moclips River Estates WWTP outfall (~ river mile 2.5), and a third upstream of the WWTP outfall (Aloha Mainline site). Table 6 presents a summary of the data collected by the Quinault Indian Nation. Data show E. coli geometric means and 90^{th} percentiles increasing from upstream to downstream. There are no outlier data driving up the summary statistics.

Table 6. Summary of E. coli data collected from the Moclips River by the Quinault Indian Nation from 2002 to 2013.

Location	Number of Samples	Range (EC/100 mL)	Geometric Mean (EC/100 mL)	Est. 90th Percentile (EC/100 mL)
Moclips River at Aloha Mainline	34	0-65	9.4	31.7
Moclips River downstream of WWTP	28	0-70	12.4	39.4
Moclips River near mouth	165	0-411	16.4	87.2

EC: E. coli
WWTP: Wastewater treatment plant

Washington State Department of Ecology

On January 30, 2013, Ecology sampled five ditch locations along both sides of the Damon Road beach access in Ocean Shores. This beach access is located near DOH marine sampling station 9. Three samples were collected in the north ditch and two samples were collected in the south ditch (Rountry, 2013). These ditches carry runoff from the city of Ocean Shores and an RV park adjacent to the north ditch. Samples from the north ditch sampling locations N#1, N#2, and N#3 were 4, 9, and 15 FC/100 mL, respectively. Results from the south ditch sampling locations S#1 and S#2 were 3 and 210 FC/100 mL, respectively. Samples showed an increase in FC bacteria moving from the city of Ocean Shores toward the beach. The samples were collected over approximately 1/10th of a mile stretch from the RV park to the dunes on the beach (Rountry, 2013). Both ditches had small positive beachward flow, with greatest velocities occurring closest to the beach.

Master's thesis on horse impacts

Horseback riding is a seasonal recreational and commercial activity on the Pacific Coast beaches. In 2003, a graduate student from the University of Denver conducted a research project on the environmental and human health impacts of horse riding on the Pacific Coast beach between Point Brown and the Ocean City beach access. Research showed that three to four horseback riding businesses operated during the summer months (Undelhoven, 2003). In addition, there were many individuals riding their own horses on the beach during the project. The project estimated that 62 horses per day (private and rental) were riding on the beach during the operating season (Undelhoven, 2003).

A number of metrics were assessed or sampled during this project, but of particular interest were the water quality samples. Samples were collected at three existing DOH stations (8, 9, and 10) as well as one Ecology station (95). The project team attempted to collect samples on five separate occasions but was only able to collect samples four times during the month of July. Sample results ranged from 0 to 30 FC/100 mL (Undelhoven, 2003). FC results for the four sampling stations are shown in Table 7. Results did not identify any direct impacts to the area of the beach being studied.

Table 7. Fecal coliform data from samples collected during the Undelhoven (2003) project (FC/100 mL).

Date	Sampling Location and Results			
	DOH008	DOH009	ECY095	DOH010
7/6/2003	3	4	23	0
7/13/2003	0	3	0	0
7/22/2003	5	4	2	0
7/28/2003	30	4	4	4
8/4/2003	-	-	-	-

Goals and Objectives

Project goals

The goal of the proposed study is to identify sources of FC bacteria loading to ocean beaches in the study area and to inform a water quality improvement plan that will protect and improve shellfish harvesting and recreational opportunities.

Study objectives

Objectives of the study are:

- Maintain a fixed network of sampling sites for data comparison purposes, while also allowing for sampling flexibility when further investigation is necessary.
- Sample the five DOH marine stations in *Prohibited* and *Conditionally Approved* areas at the same time freshwater sites are sampled, for comparison and correlation purposes.
- Sample under all seasonal and hydrological conditions, including during storm events.
- Identify sources of FC contamination by allocating more sampling resources to areas thought to contribute to nearshore FC contamination and shellfish growing area classification downgrades.
- Locate possible sources of human-derived FC bacteria through the strategic use of optical brightener sensors.
- Collect high quality data to support the development of a strategic, site-specific cleanup plan.

Study Design

Overview

The study objectives will be met through characterizing annual and seasonal FC bacteria concentrations and, where appropriate, loads in streams and outflows to shorelines of the study area. FC concentrations will be monitored at multiple locations in major streams and outflows and at other key locations within the study area from April 2014 through March 2015. When possible, streamflow will be measured at key sites at the time of sampling, or a staff gage will be installed and a rating curve will be developed. This will allow accurate estimation of flows when direct measurement is not possible, e.g., during high flows and time-restricted sampling events.

The freshwater component of the study includes (1) a fixed network of sites sampled twice monthly throughout the sampling period, and (2) investigation sampling when high FC concentrations are found. Investigation sampling will use a targeted or bracketed sampling approach. This method of sampling will help find sources of FC in areas with higher FC contamination.

Where appropriate, Ecology will also use optical brightener sensors to help detect or confirm the presence of human-derived FC pollution. Optical brighteners are commonly used in laundry detergents, and their presence or absence is an indication of human wastewater sources of FC bacteria.

Ecology will conduct several storm event surveys during times of heavy rainfall. These surveys will help further characterize seasonal and rain event FC contributions to the beaches.

Details

Fixed-network sampling

Data from the fixed network will provide an estimate of the annual and seasonal geometric mean and 90th percentile statistics. The schedule should provide at least 24 samples per fixed site to develop the annual statistics, including 8 samples per site during the dry season (June – September) and 16 samples per site during the wet season (October – May). Streamflow estimates will provide FC load comparisons to help prioritize sources for cleanup. This data will also help identify areas of bacteria loading in streams where more than one sampling site exists.

The fixed-network sites will be sampled twice monthly from April 2014 through March 2015. However, if no significant FC contamination is found during a particular season at a fixed site, sampling may be reduced to once per month to allow for prioritized sampling elsewhere. The proposed locations of the fixed-network water sites are listed in Table 8 and shown in Figure 1. Sites were selected based on historical site locations and data collection, areas where high FC is a concern, and ease of access.

Ecology will not attempt to directly sample the WWTPs on the Moclips River and Joe Creek unless high downstream FC concentrations in the streams warrant further investigation.

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 8. Proposed sampling sites for the North Ocean Beaches project.

Map #s reference Figure 1.

Site Name[1]	Map #	Latitude	Longitude	Site Description	Seasonal?	Parameters[3]
21-NOB-01[2]	1	47.24453	-124.21553	Moclips River near Mouth, tidal influence	No	FCMF,FCMPN,EC MPN, %Klebsiella
21-DOH-195	2	47.24341	-124.22108	Department of Health marine sampling station 195	No	FCMPN
21-DOH-11	3	47.23891	-124.21966	Department of Health marine sampling station 11	No	FCMPN
21-NOB-02	4	47.21886	-124.20842	Mouth of creek at Analyde Gap Rd	No	FCMF
21-NOB-03	5	47.20879	-124.18808	Joe Creek above Pacific Beach WWTP	No	FCMF
21-NOB-04	6	47.20432	-124.20139	Joe Creek at Pacific Beach State Park	No	FCMF, %Klebsiella
21-NOB-05	7	47.20207	-124.2027	Creek that crosses Diamond Drive	Possibly	FCMF
21-DOH-197	8	47.20059	-124.20546	Department of Health marine sampling station 197	No	FCMPN
21-NOB-06	9	47.19593	-124.20172	Below confluence of 2 creeks draining N Seabrook	No	FCMF
21-NOB-07	10	47.19444	-124.20121	Creek that drains from S Seabrook at staircase	Yes	FCMF
21-NOB-08	11	47.19225	-124.19524	Elk Creek on the downstream side of Hwy 109	No	FCMF, %Klebsiella
21-NOB-09	12	47.18262	-124.19744	Creek on the N side of Hwy 109 curve	No	FCMF
21-NOB-10	13	47.18152	-124.19718	Creek on the S side of Hwy 109 curve	No	FCMF
21-NOB-11	14	47.17625	-124.19602	Creek approx. 60 meters N of Roosevelt Beach Rd	No	FCMF
21-NOB-12	15	47.17237	-124.19497	Creek approx. 360 meters S of Roosevelt Beach Rd	No	FCMF
21-NOB-13	16	47.15948	-124.19107	Boone Creek at Iron Springs Resort below bluff	No	FCMF
21-NOB-14	17	47.15378	-124.19072	Creek that drains neighborhood S of Boone Creek	No	FCMF
21-NOB-15	18	47.11665	-124.16958	Copalis River at Hwy 109 bridge	No	FCMF, %Klebsiella
21-NOB-16	19	47.11407	-124.18045	Connor Creek at Benner Rd	No	FCMF, %Klebsiella
21-NOB-17	20	47.04255	-124.17285	Creek at Quinault Casino	Yes	FCMF
21-NOB-18	21	47.03287	-124.17074	Mouth of creek at Ocean City State Park	No	FCMF
21-NOB-19	22	47.02089	-124.171346	Wet area between Illahee/Oyehut and the beach	Possibly	FCMF, %Klebsiella
21-NOB-20	23	47.01793	-124.16628	Ditch on Chickamin Ave S of RV park septic tank	Possibly	FCMF
22-NOB-21	24	47.01751	-124.17155	N ditch on Damon Rd	Yes	FCMF
22-DOH-9	25	47.01809	-124.17552	Department of Health marine sampling station 9	No	FCMPN
22-NOB-22	26	47.01739	-124.17157	S ditch on Damon Rd	Yes	FCMF
22-NOB-23	27	47.00777	-124.17154	N ditch on W Chance A La Mer NW	Yes	FCMF
22-NOB-24	28	47.00706	-124.17154	S ditch on W Chance A La Mer NW	Yes	FCMF
22-NOB-25	29	46.99466	-124.17192	N ditch on Pacific Blvd NW	Yes	FCMF
22-NOB-26	30	46.99386	-124.17193	S ditch on Pacific Blvd NW	Yes	FCMF
22-NOB-27	31	46.98393	-124.1722	N ditch on Ocean Lake Way SW	Yes	FCMF
22-NOB-28	32	46.98348	-124.17221	S ditch on Ocean Lake Way SW	Yes	FCMF

[1] Sites are listed from north (top) to south (bottom)
[2] This site is the same as DOH's station 12.
[3] Total organic carbon (TOC) will be sampled where optical brightener sensors are deployed. Locations are not yet known.

Bacteria sampling

FC samples taken by DOH and GHCEHD, and E. coli samples taken by the Quinault Indian Nation, are analyzed using the most probable number (MPN) method. Saltwater samples are typically analyzed using the MPN method, because of regulatory reasons. Some researchers also believe the MPN method is better at enumerating organisms that are injured or stressed and organisms in turbid or saline waters. Ecology typically uses the MF method in freshwater 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 2).

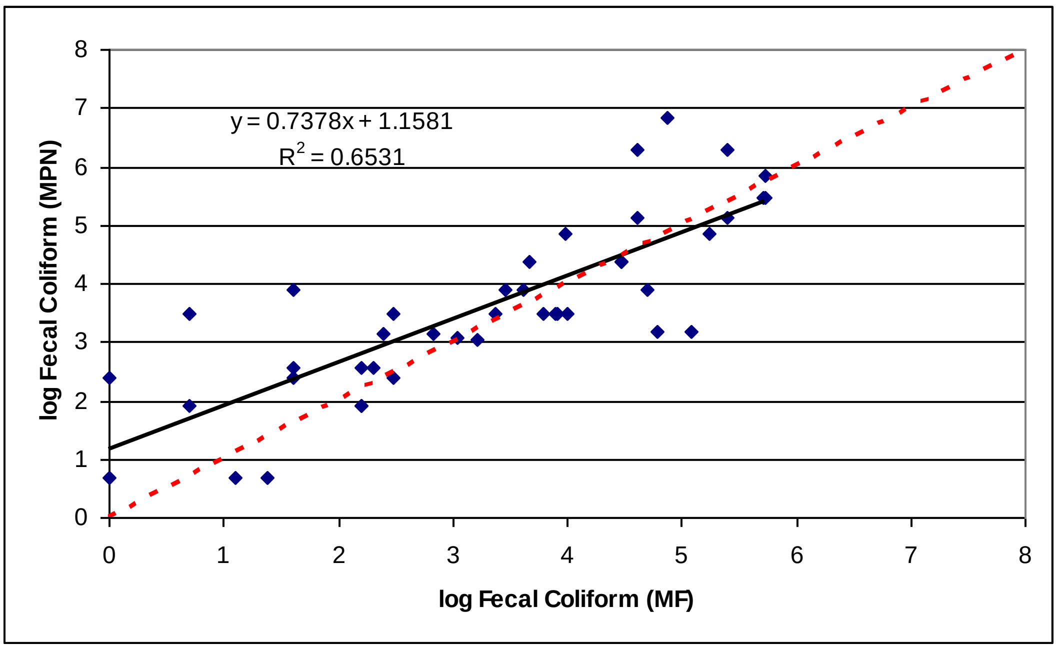

Figure 2. A comparison of 40 paired FC samples analyzed using the most probable number (MPN) and membrane filter (MF) techniques during the Samish Bay TMDL study.
Dashed line denotes 1:1 relationship.

Escherichia coli (E. coli) and percent Klebsiella (see Glossary for more information) will be collected from selected sites once a month. E. coli and percent Klebsiella will help to characterize wastes from various sources. For example, samples with a large number of E. coli would more likely come from an animal source than those with a high percentage of Klebsiella. A higher percentage of Klebsiella would indicate bacteria from decaying vegetation. Future decisions about the types of best management practices (BMPs) and specific source identification procedures could be influenced by this information.

Investigation, source tracking, and optical brightener surveys

Ecology may investigate other small outflows if resources and conditions allow. If investigation sampling finds high FC concentrations in an area, staff may continue sampling that area throughout the remainder of the project.

Targeted and bracketed sampling

If regular sampling confirms high FC concentrations at a site, staff may further investigate the area using targeted sampling to find FC pollution sources. Targeted sampling involves multiple samplings over ever-decreasing distances to identify sources of FC pollution.

The following illustrates how targeted sampling might be used to find a FC source:

Ecology finds high FC concentrations at a regularly sampled site on a stream and notices that the site is below a cow pasture and there are several OSSs upstream of the pasture and a wildlife reserve even farther upstream. The next regularly sampled upstream sampling site is just above the wildlife reserve and it shows little FC contamination. In theory, FC could be coming from any of the three sources. Depending on the severity of the confirmed downstream FC contamination, staff may choose to investigate further and sample upstream of the pasture, but downstream of the OSS. If high FC concentrations are still present, staff might sample above the OSS and below the wildlife area. If the FC concentrations come down above the OSS and stay low with further sampling, staff conclude that the FC pollution is most likely coming from the OSS and decide to concentrate cleanup efforts in that area.

A similar approach to targeted sampling is bracketed sampling. Bracketed sampling is simply targeting an area thought to have high FC concentrations by sampling upstream and downstream of the area in ever-decreasing distances until the source of the FC is found or further bracketing is deemed unnecessary.

Optical brightener (OB) sampling

In conjunction with targeted sampling and where appropriate, Ecology plans to use fluorometry as an inexpensive and practical bacterial source tracking (BST) method to identify or confirm *human* sources of fecal contamination. Fluorometry is a chemical BST method which identifies human fecal contamination by detecting OBs, also known as fluorescent whitening agents. OBs are added to most laundry detergents and represent about 0.15% of the total detergent weight (Hartel et al., 2008). Because household plumbing systems mix effluent from washing machines and toilets together, OBs are associated with human sewage in septic systems and WWTPs (Hartel et al., 2008).

Ecology will deploy two Turner Designs Cyclops 7 OB sensors to test for concentrations of OBs over predetermined amounts of time, depending on resources and site characteristics. Staff will install one sensor upstream of the suspected source and one sensor downstream. If OBs are present and the upstream sensor records significantly lower OB concentrations than the downstream sensor, staff will assume that anthropogenic (human-derived) fecal contamination is entering the water somewhere between the sensors. This information, coupled with land use data and field observations, will give us more certainty about whether FC sources are from failing or malfunctioning OSS or WWTPs. Some possible scenarios staff may find in the field include:

- High FC and high OBs (suggests malfunctioning OSS or WWTP or leaky sewer pipe).
- High FC and low OBs (suggests other warm-blooded animals or human sources, such as an outhouse, that don't mix gray water and toilet water).

Unlikely scenarios (Ecology will only sample OBs when high FC is found):

- Low FC and high OBs (suggests gray water in the stormwater system).
- Low FC and low OBs (suggests no source of FC contamination).

One concern with OB detection is in OB's relation to organic matter. Organic matter can fluoresce and interfere with OB detection, especially if the total organic carbon (TOC) concentration is over 40 mg/L (Hartel et al., 2008). Because organic matter has broadband, featureless spectra and the emission spectra of OBs are in the 415 to 445 nm range (Hartel et al., 2008), Turner Designs OB sensors use a narrow emission spectrum of 445 nm. This allows for more confidence that only OBs are detected and not organic matter. Because most streams in western Washington have TOC concentrations well below 40 mg/L and the OB sensor is designed to eliminate most of the organic matter interference, the small amount of interference in some waters with organic matter is acceptable in this study. To ensure that any possible interference is minimal, TOC will be sampled as necessary when OB sensors are deployed.

It should also be noted that OBs degrade quickly (minutes to hours) in UV light (Hartel et al., 2007); although some studies conflict on their photo-decay rates (Tavares et al., 2008). Confirmation of OBs in waters likely means that a source of OBs is nearby. Deployed Turner OB sensors instantaneously detect OBs in the field, so UV degradation during sample collection and transport will not be an issue.

OBs can persist in sediment (Hartel et al., 2007), so Ecology may find that OB concentrations increase during storm events from sediment resuspension. Storms may inundate any OSS installed below the high water mark. This could cause OBs to move more quickly from malfunctioning OSS to waterways. Also, storms can carry OBs more quickly downstream without as much time for UV attenuation, and more turbid waters may also decrease UV degradation. These factors may complicate analyses, but Ecology is planning multiple sampling events during wet and dry seasons to allow for a clear and complete analysis of the data.

This is a new BST method for Ecology's Directed Studies Unit and should prove useful as long as staff follow appropriate protocols and interpret data correctly. To ensure proper OB sampling techniques are followed, Ecology has recently developed a standard operating procedure (SOP) for OB sampling (Swanson and Anderson, 2014).

Storm monitoring

The purpose of storm monitoring is to better characterize potential sources of FC to the study area. Historical data from other studies in Washington show that higher FC concentrations and loading can occur during rain events. Depending on the weather, Ecology will try to capture at least two storms during the wet season (October through May) and one storm during the dry season (June through September). If storm sampling results show a significant increase in FC concentrations or loading at regularly sampled sites, Ecology may further investigate the area during subsequent storms.

Ecology's goal is to sample three storm events, with a storm event defined as a minimum 0.2 inch of rainfall in a 24-hour period preceded by no more than trace rainfall in the previous 24 hours. 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 throughout the course of one day. If appropriate, teams may choose to investigate and sample more outfalls and creeks from the beaches than those listed in Table 8.

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.

Practical constraints and logistical problems

Although rare, logistical problems such as excessive precipitation during typically dry periods, scheduling conflicts, sample bottle delivery errors, vehicle or equipment problems, site access issues, or the limited availability of personnel or equipment may interfere with sampling. Any circumstance that interferes with data collection and quality will be noted and discussed in the final report.

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 Ecology's Manchester Environmental Laboratory (MEL) and described in the MEL *Lab Users Manual* (MEL, 2008). Sample parameters, containers, volumes, preservation requirements, and holding times are listed in Table 9. Bacteria samples will be tagged, stored on ice, delivered to MEL via Ecology courier, and analyzed by MEL within 24 hours of collection.

Table 9. Containers, preservation requirements, and holding times for samples collected during the North Ocean Beaches project (MEL, 2008).

Parameter	Sample Matrix	Container	Preservative	Holding Time
Fecal coliform (MF and MPN)	Surface water, WWTP effluent, runoff	250 or 500 mL glass/poly autoclaved	Cool to 0°C to 6°C	24 hours
E. Coli (MF and MPN)	Surface water, WWTP effluent, runoff	250 or 500 mL glass/poly autoclaved	Cool to 0°C to 6°C	24 hours
% Klebsiella	Surface water, WWTP effluent, runoff	250 or 500 mL glass/poly autoclaved	Cool to 0°C to 6°C	24 hours
Total Organic Carbon	Surface water, WWTP effluent, runoff	60 mL clear poly	1:1 HCl to pH<2; Cool to 0°C to 6°C	28 days

WWTP: Wastewater treatment plant

Freshwater and marine grab samples will be collected using the EAP SOPs for bacteria (Ward and Mathieu, 2011) and grab sampling (Joy, 2013). 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 in freshwater outflows. Marine samples will be collected by walking out to 3 feet of water depth and submerging a bottle under the surface of the water. A sampling pole may be used to ensure no disturbed sediment is collected.

FC bacteria are sensitive to saltwater, and die-off rates change when they enter estuarine waters. Monitoring of freshwater 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.

Because the MPN method is used by DOH to enumerate bacteria, Ecology will use the MPN method on all saltwater samples. The MF method will be applied to all freshwater samples. The MPN method will also be used at the mouth of the Moclips River for data comparison purposes.

Field measurements will be taken at all sampling sites and recorded in a notebook. Measurements will include conductivity and temperature using a calibrated YSI conductivity/temperature meter or Hydrolab MiniSonde® following the EAP Hydrolab SOP (Swanson, 2010) and manufacturer's recommendations. Site name, time, and any pertinent observations or problems with sampling will be noted in the notebook as well.

All flow measurements taken in the field will also be recorded in a notebook. Estimation of instantaneous flow measurements will follow the EAP SOP (Kardouni, 2013). A flow rating curve will be developed for sites with a staff gage. 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.

Invasive species

Ecology field crew will follow EAP's SOP on minimizing the spread of invasive species (Parsons et al., 2012). The North Ocean Beaches study area is not in a region of extreme concern. Areas of extreme concern have, or may have, invasive species like New Zealand mud snails that are particularly hard to remove from equipment and are especially disruptive to native ecological communities. For more information, please see Ecology's website on minimizing the spread of invasive species at www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html.

Quality Objectives

Quality objectives are statements of the precision, bias, and lower reporting limits necessary to meet project objectives. Precision and bias together express data accuracy. Other considerations of quality objectives include representativeness and completeness. Quality objectives apply equally to laboratory and field data collected by Ecology, to data used in this study collected by entities external to Ecology, and to other analysis methods used in this study.

Measurement quality objectives

Field sampling procedures and laboratory analyses inherently have associated uncertainty which results in data variability. Measurement quality objectives (MQOs) state the acceptable data variability for a project. *Precision* and *bias* are data quality criteria used to indicate conformance with measurement quality objectives. The term *accuracy* refers to the combined effects of precision and bias (Lombard and Kirchmer, 2004).

Precision is a measure of the variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Precision for laboratory duplicate samples will be expressed as relative percent difference (RPD). Precision for field replicate samples will be expressed as the relative standard deviation (RSD) for the group of duplicate pairs (Table 10).

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of quality control (QC) procedures. Bias in field measurements and samples will be minimized by strictly following Ecology's measurement, sampling, and handling protocols.

Field sampling precision and bias will be addressed by submitting replicate samples. Manchester Laboratory will assess precision and bias in the laboratory through the use of duplicates and blanks.

Table 10 outlines analytical methods, expected precision of sample duplicates, and method reporting limits. The targets for precision of field replicates are based on historical performance by MEL for environmental samples taken around the state by EAP (Mathieu, 2006). The reporting limits of the methods listed in the table are appropriate for the expected range of results and the required level of sensitivity to meet project objectives. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL *Lab Users Manual* (MEL, 2008).

Table 10. Targets for precision and reporting limits for the measurement systems.

Parameter	Method/ Equipment	Precision - Field Replicates (mean)	Expected Range	Lab Duplicate MQO	Reporting Limits and Resolution
Field Measurements					
Discharge Volume	SonTek FlowTracker® or Marsh McBirney Flow-Mate® Flowmeter	10% RSD	0.05 - 5.0 ft/s	n/a	0.01 ft/s
Water Temperature[1]	Hydrolab MiniSonde® or YSI conductivity/ temperature meter	+/- 0.2° C	0 - 30° C	n/a	0.01° C
Specific Conductivity	Hydrolab MiniSonde® or YSI conductivity/ temperature meter	5% RSD	0 - 50,000 umhos/cm	n/a	0.1 umhos/cm
Optical Brighteners	Turner Designs Cyclops 7	10% RSD	0-500 ppb	n/a	0.1 ppb
Laboratory Analyses					
Fecal Coliform – MF	SM 9222 D	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD[2]	1 - 10,000 cfu/100 mL	40% RPD	1 cfu/100 mL
Fecal Coliform – MPN	SM 9221 E2	50% of replicate pairs < 50% RSD 90% of replicate pairs <100% RSD[2]	1.8 - 10,000 cfu/100 mL	40% RPD	1 cfu/100 mL
E. Coli – MPN	EPA 1104	50% of replicate pairs < 50% RSD 90% of replicate pairs <100% RSD[2]	1.8 - 10,000 cfu/100 mL	40% RPD	1 cfu/100 mL
% Klebsiella	Manchester Lab SOP	50% of replicate pairs < 50% RSD 90% of replicate pairs <100% RSD[2]	0 - 100%	40% RPD	0-100%
Total Organic Carbon	SM 5310B	10% RSD	1-10 mg/L	20% RPD	0.1 mg/L

[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.
MQO: measurement quality objective
SM: Standard Methods for the Examination of Water and Wastewater, 20th Edition (APHA et al., 1998).
MPN: most probable number
MF: membrane filtered
EPA: Environmental Protection Agency
RSD: Relative standard deviation
RPD: Relative percent difference

Representative sampling

The study is designed to have enough sampling sites and sufficient sampling frequency to meet study objectives. Bacteria 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 bacteria 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 certain calculations.

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 North Ocean Beaches study is to correctly collect and analyze 100% of the samples for each of the sites. However, problems occasionally arise during sample collection that cannot be controlled; thus a completeness of 95% is acceptable. Example problems are flooding, site access problems, or sample container shortages.

Comparability

Ecology will sample some of the same marine sites DOH currently samples, as well as additional freshwater sites (Figure 1). Data from both agencies will be compared to ensure similar FC concentrations and trends exist in both data sets. If FC data sets are not similar, Ecology will investigate further for possible reasons.

Marine water FC samples taken by DOH are analyzed using the MPN method. Ecology will use the MPN method for all marine samples to compare with DOH sample results.

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 with other FC data analyzed using the MPN method. One exception to this is at Ecology's site near the mouth of the Moclips River. DOH and the Quinault Indian Nation sample bacteria here. DOH samples FC and uses the MPN method for enumeration and the Quinault Nation samples E. coli and analyzes samples using MPN. For comparison purposes, Ecology will sample FC and use both MF and MPN methods of enumeration and will sample and analyze E. coli using the MPN method.

Quality Control

Total variability for field sampling and laboratory analysis will be assessed by collecting replicate samples. Replicate samples are a type of quality assurance/quality control (QA/QC) method. Sample precision and bias will be assessed by collecting replicates for 20% of all bacteria samples and 10% of all TOC samples. MEL routinely duplicates sample analyses in the laboratory to determine laboratory precision. The difference between field variability and laboratory variability is an estimate of the sample field variability.

Laboratory

MEL will analyze all samples. The laboratory's measurement quality objectives and QC procedures are documented in the MEL *Lab Users Manual* (MEL, 2008). Field sampling and measurements will follow QC protocols described in Ecology (1993). If any of these QC 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.

Field

Instantaneous streamflow measurements will be replicated as necessary to determine precision. Multiple flow meters may be compared to check for instrument bias or error. If a significant difference is found between flow meters (>5%), the instruments will be recalibrated or not used.

Standard Methods (APHA et al., 1998) 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. MEL has a maximum holding time for microbiological samples of 24 hours (MEL, 2008). Microbiological samples analyzed beyond the 24-hour holding time are qualified with a "J" qualifier code, indicating the sample result is an estimate.

Hydrolab MiniSonde® and YSI conductivity sensors will be calibrated according to manufacturer's recommendations and the Hydrolab SOP (Swanson, 2010). The temperature sensors are factory-calibrated on both instruments. Hydrolabs will be calibrated before each sampling survey and checked afterward using certified standards and reference solutions. Because the YSI conductivity sensor will only be used by North Ocean Beaches field crew, and conductivity is not a parameter of concern in this study, YSI sensors will be calibrated every other survey or once a month. Conductivity and temperature results will be accepted, qualified, rejected, or corrected, as appropriate.

Corrective actions

QC results may indicate problems with data during the course of the project. The lab will follow prescribed procedures to resolve the problems. Options for corrective actions might include:

- Retrieving missing information.
- Re-calibrating the measurement system.
- Re-analyzing samples within holding time requirements.
- Modifying the analytical procedures.
- Requesting collection of additional samples or taking of additional field measurements.
- Qualifying results.

Data Management Procedures

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in MEL's *Lab 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 *Lab 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 as soon as practical after returning from the field. 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.

Data received from MEL through 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 or downloaded tables from Ecology's EIM system. Field replicate sample results will be compared to quality objectives in Table 10. 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 entered into the EIM system.

EIM data will be independently reviewed by another EAP 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 four months throughout the 12-month data collection period of the project.

An EIM study identification number (TSWA0005) 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

Throughout the course of the study, bacteria sample results of over 200 cfu/100 mL will be sent via email by the project manager or principal investigator to all interested parties within one week of laboratory analysis. Quarterly reports describing sampling results and significant changes to the sampling regime or issues occurring during the study will be sent out by the project manager or principal investigator every four months, according to the project schedule (Table 12). The project manager will be responsible for submitting the final technical study report to Ecology's Water Quality Program TMDL coordinator for this project, according to the project schedule.

Data Verification and Validation

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 staff will verify field measurements before leaving the site.

After verifying data, Ecology will conduct a detailed examination of the data package, using statistics and professional judgment to determine whether the MQOs have been met. The project manager will examine 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® sensor 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.

Any water quality data from outside this study used in the data analysis must meet requirements of the agency's credible data policy (www.ecy.wa.gov/programs/wq/qa/wqp01-11-ch2_final090506.pdf). This requirement does not apply to non-quality data such as flow or meteorological data.

Project Organization

Table 11 lists people involved in this project. All are employees of Ecology.

Table 11. Organization of project staff and responsibilities.

Staff (EAP staff unless noted otherwise)	Title	Responsibilities
Dustin Bilhimer Water Quality Program SW Regional Office Phone: 360-407-7543	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 the QAPP and technical report. Prepares and implements the water quality improvement plan.
Andrew Kolosseus Water Quality Program SW Regional Office Phone: 360-407-7543	Unit Supervisor of Project Lead	Approves the QAPP and approves the water quality improvement plan.
Rich Doenges Water Quality Program SW Regional Office Phone: 360-407-6271	Section Manager of Project Lead	Approves the QAPP and approves the water quality improvement plan.
Trevor Swanson Directed Studies Unit Western Operations Section Phone: 360-407-6685	Project Manager	Writes the QAPP and technical sections of the study report and water quality improvement plan. Oversees field sampling. Conducts QA review of data and analyzes and interprets data.
Paul Anderson Directed Studies Unit Western Operations Section Phone: 360-407-7548	Field Lead	Co-authors QAPP and technical sections of the study report and water quality improvement plan. Collects field samples and records field information under the supervision of the project manager. Enters data into EIM. Assists project manager with project duties as needed.
George Onwumere Directed Studies Unit Western Operations Section Phone: 360-407-6730	Unit Supervisor of Project Manager and Field Lead	Reviews and approves the QAPP, staffing plan, technical study budget, and the technical sections of the water quality improvement plan.
Robert F. Cusimano Western Operations Section Phone: 360-407-6596	Section Manager of Project Manager and Field Lead	Approves the QAPP and technical sections of the study report and water quality improvement plan.
Joel Bird Manchester Environmental Laboratory Phone: 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 Phone: 360-407-6964	Ecology Quality Assurance Officer	Provides technical assistance on QA/QC issues. Reviews and approves the draft QAPP and the final QAPP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management system
QAPP: Quality Assurance Project Plan

Project Schedule

Table 12. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Field and laboratory work	Due date	Lead/Support staff
Field work completed	April 2015	Paul Anderson/Trevor Swanson
Laboratory analyses completed	May 2015	
Environmental Information System (EIM) database		
EIM Study ID	TSWA0005	
Product	Due date	Lead staff
EIM data loaded	July 2015	Paul Anderson
EIM quality assurance	August 2015	Trevor Swanson
EIM complete	August 2015	Paul Anderson
Quarterly reports		
Author lead/support staff	Paul Anderson/Trevor Swanson	
Schedule		
1st quarterly report	July 2014	
2nd quarterly report	October 2014	
3rd quarterly report	January 2015	
4th quarterly report	April 2015	
Final report		
Author lead/support staff	Trevor Swanson/Paul Anderson	
Schedule		
EAP non-TMDL technical report -- Draft due to EAP supervisor.	December 2015	
EAP non-TMDL technical report -- Draft due to project lead and technical peer reviewer.	January 2016	
Report draft due to external reviewer(s).	February 2016	
Final (all reviews done) due to publications coordinator.	March 2016	
Final non-TMDL technical report posted on web.	April 2016	

EAP: Environmental Assessment Program

Laboratory Budget

The estimated laboratory budget and number of lab samples shown in Table 13 is based on the proposed schedule in Table 12. 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 storm survey work, seasonality of some sites, and add-on investigation sites. Efforts will be made to keep the submitted number of samples within the estimate; however, because not all storm and investigation sites have been selected yet, this is an estimate only.

Table 13. The number of sample submittals for each analysis, an estimate of the analytical costs, and the total analytical cost estimate for the project, 2014-15.

Parameter	Cost/ sample	# of sites	# of samples (including field QA) per survey	# of surveys per month	Total # of samples	Total cost
FC-membrane filtered	$25	32	39	2	936	$23,334
FC-most probable number	$47	5	6	2	144	$6,710
EC-most probable number	$53	1	2	2	48	$2,549
% Klebsiella	$18	6	7	1	84	$1,548
Total organic carbon (TOC)	$39	5	6	2	12	$468
FC: Fecal coliform					Subtotal	$34,610
EC: E. coli						
					Three storm events	$4,461
					Total for project	$39,071

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Appendices

Appendix A. DOH Sampling Stations

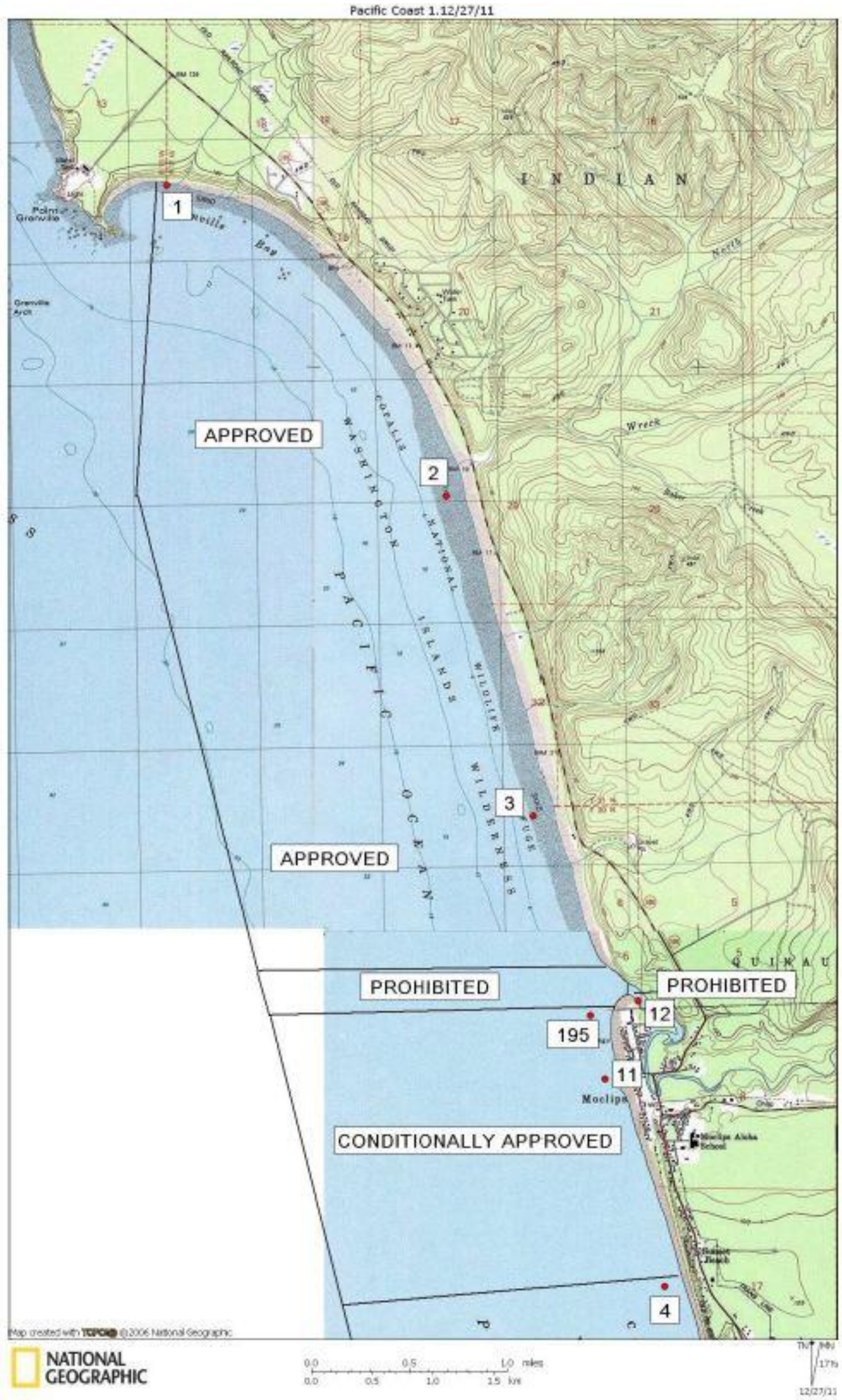

Figure A1. DOH sampling sites and shellfish harvesting classifications in the study area (map 1 of 4) (DOH, 2013).

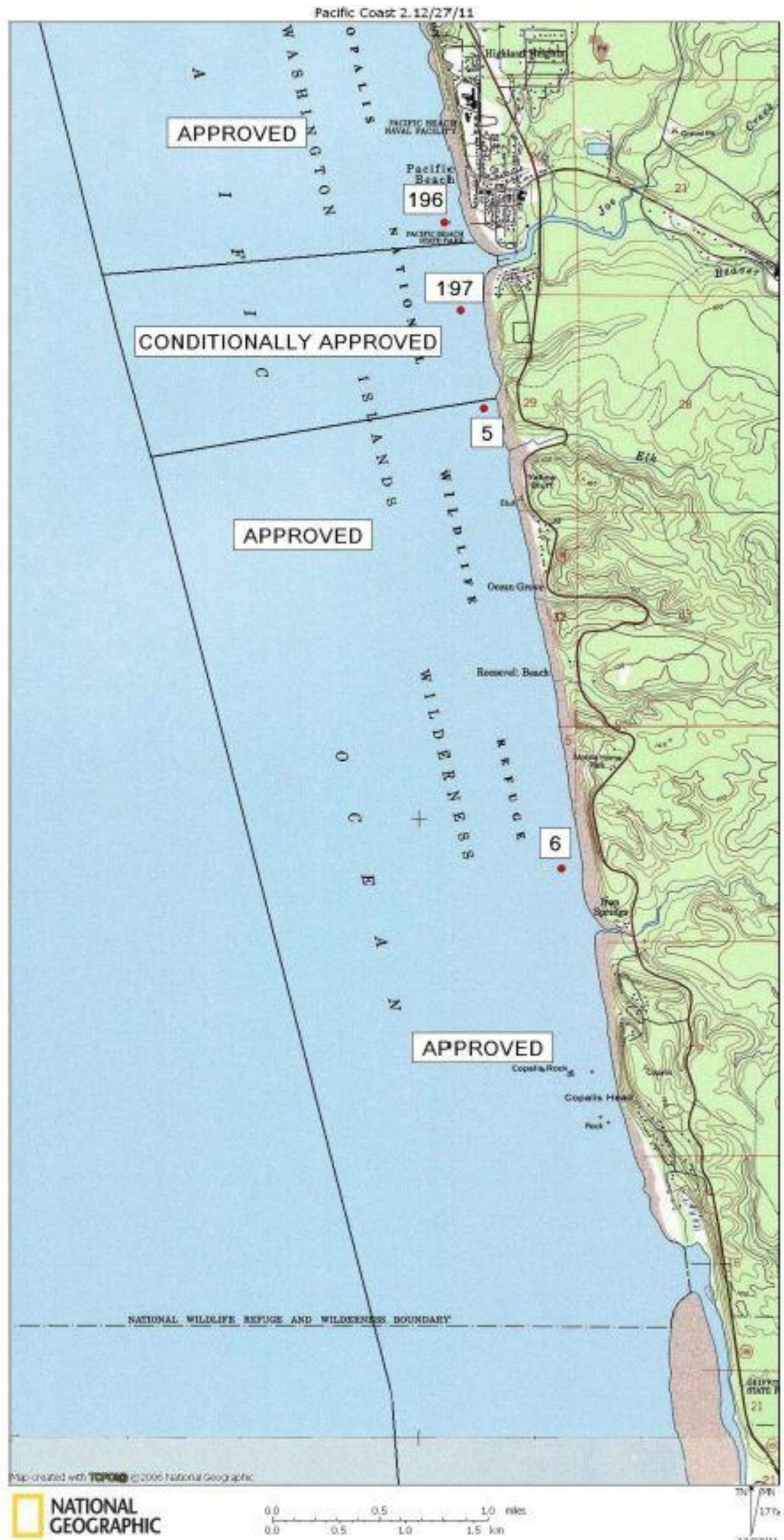

Figure A2. DOH sampling sites and shellfish harvesting classifications in the study area (map 2 of 4) (DOH, 2013).

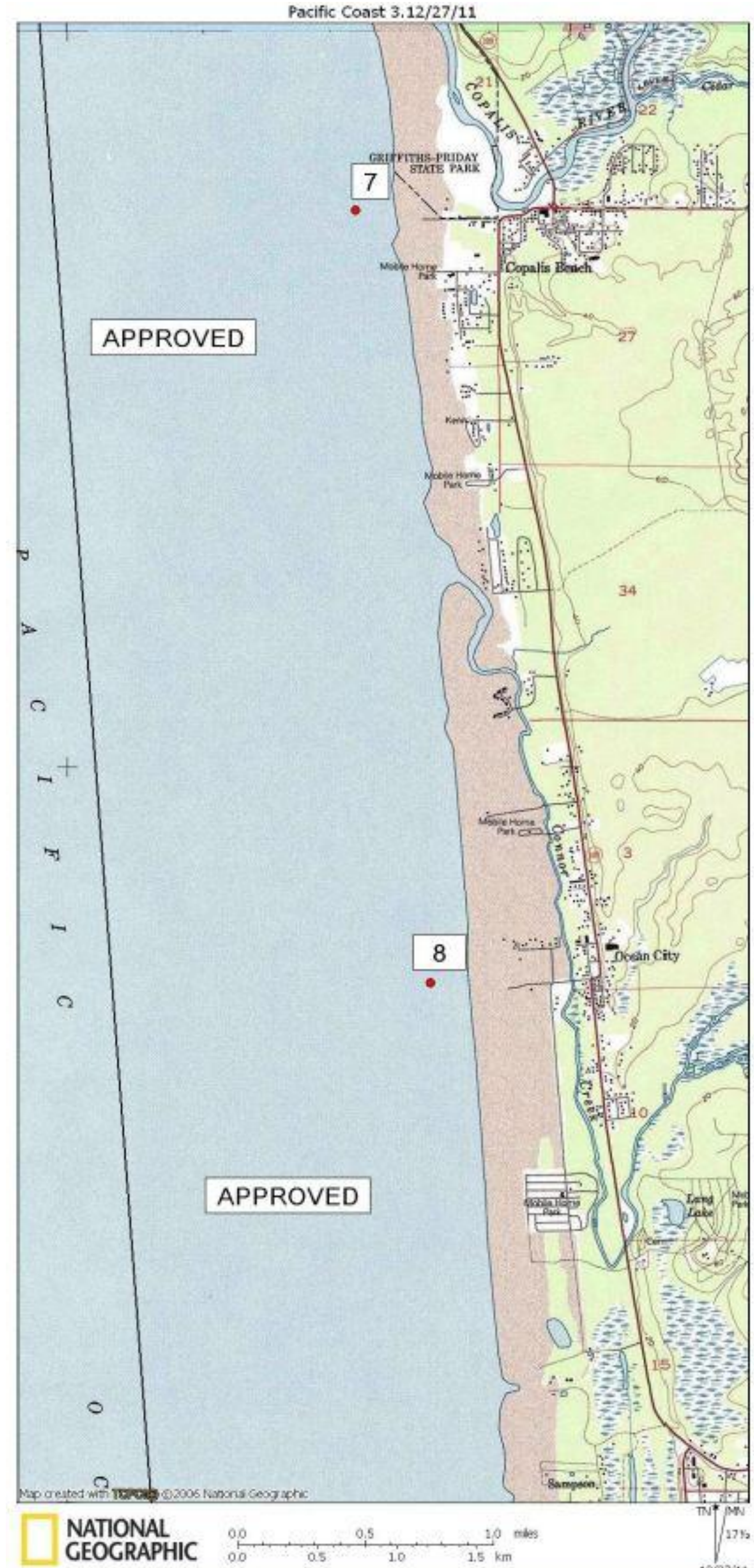

Figure A3. DOH sampling sites and shellfish harvesting classifications in the study area (map 3 of 4) (DOH, 2013).

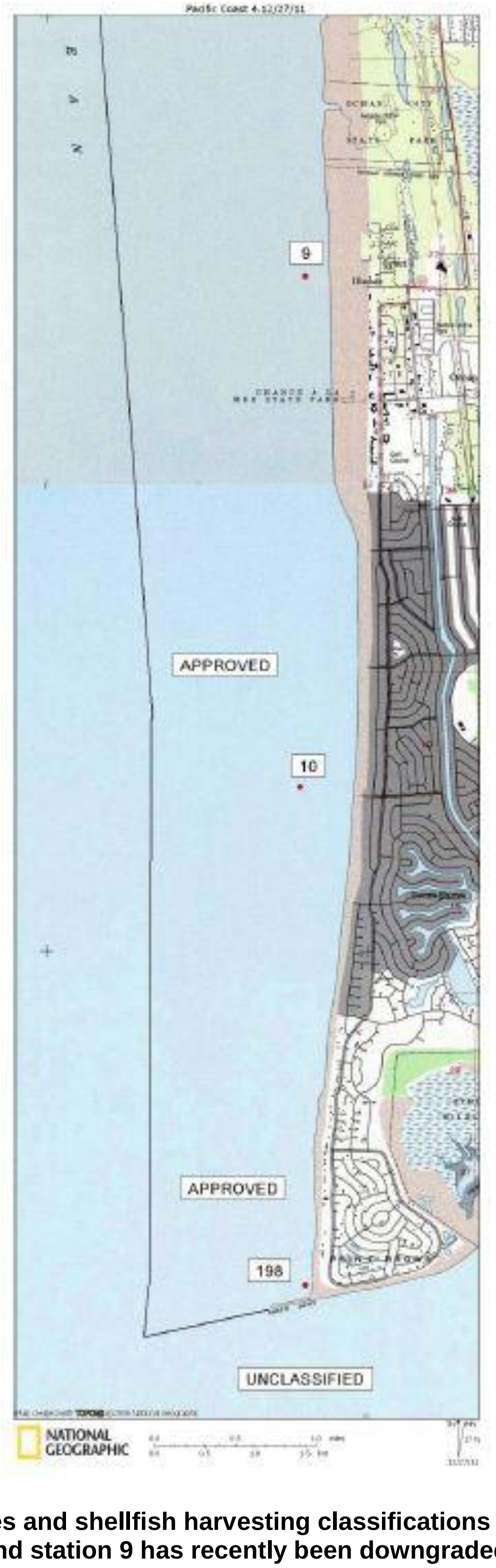

Figure A4. DOH sampling sites and shellfish harvesting classifications in the study area (map 4 of 4) (DOH, 2013). The area around station 9 has recently been downgraded to *Prohibited*. See Figure 1.

Appendix B. Glossary, Acronyms, and Abbreviations

Glossary

Anthropogenic: Human-caused.

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.

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

E. coli: *Escherichia coli* (commonly abbreviated E. coli) is a Gram-negative, rod-shaped bacterium that is commonly found in the lower intestine of warm-blooded organisms. Most E. coli strains are harmless, but some serotypes can cause serious food poisoning in their hosts. The harmless strains are part of the normal flora of the gut, and can benefit their hosts by producing vitamin K2, and preventing colonization of the intestine with pathogenic bacteria.

Effluent: An outflowing of water from a natural body of water or from a man-made structure. For example, the treated outflow from a wastewater treatment plant.

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

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.

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. FC 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.

Klebsiella: A genus of non-motile, rod-shaped bacteria with a prominent polysaccharide-based capsule. *Klebsiella* species are ubiquitous in nature. This is thought to be due to distinct sublineages developing specific niche adaptations, with associated biochemical adaptations which make them better suited to a particular environment. They can be found in water, soil, plants, animals and humans. Klebsiella can sometimes mimic FC bacteria on incubation plates, and be counted as part of the total fecal coliform count in the lab. This is why Ecology is sampling percent Klebsiella in places thought to be rich in decaying vegetation. State and federal FC criteria do not make allowances for the type or organisms reported as FC. Identifying specific types of organisms within the FC group is helpful for identifying probable sources and planning methods for their control.

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.

Parameter: Water quality constituent being measured (analyte).

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

Phase I stormwater permit: The first phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to medium and large municipal separate storm sewer systems (MS4s) and construction sites of five or more acres.

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: Source of pollution that discharges 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: 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 are 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.

Secondary contact recreation: Activities where a person's water contact would be limited (e.g., wading or fishing) to the extent that bacterial infections of eyes, ears, respiratory or digestive systems, or urogenital areas would normally be avoided.

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 water courses within the jurisdiction of Washington State.

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

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

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.

90^{th} percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90^{th} percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and Abbreviations

BST	Bacterial Source Tracking
DOH	Washington State Department of Health
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management System
EPA	U.S. Environmental Protection Agency
GHCEHD	Grays Harbor County Environmental Health Division
LIMS	Laboratory Information Management System

MEL	Manchester Environmental Laboratory
MF	Membrane Filtered
MPN	Most Probable Number
MQO	Measurement Quality Objective
NPDES	(See Glossary above)
NSSP	National Shellfish Sanitation Program
OB	Optical Brightener
OSS	Onsite Septic System
QA	Quality Assurance
QC	Quality Control
RCW	Revised Code of Washington
RPD	Relative percent difference
RSD	Relative standard deviation
SM	Standard Methods
SOP	Standard Operating Procedure
SRS	Systematic Random Sampling
TMDL	Total Maximum Daily Load
TOC	Total Organic Carbon
UV	Ultraviolet
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area
WWTP	Wastewater treatment plant

Units of Measurement

°C	degrees centigrade
cfu	colony forming units
ft	feet
mg/L	milligrams per liter (parts per million)
mL	milliliters
umhos	micromhos