Quality Assurance Project Plan

Eastern Padilla Bay Tributaries Fecal Coliform Bacteria Total Maximum Daily Load

April 2016

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DEPARTMENT OF ECOLOGY
State of Washington

Publication 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.

This Quality Assurance Project Plan is available on Ecology's website at https://fortress.wa.gov/ecy/publications/SummaryPages/1603105.html.

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm. Search Study ID jfie0001.

Ecology's Activity Tracker Code for this study is 15-016.

Federal Clean Water Act 1996 303(d) Listings Addressed in this Study:

- Padilla Bay, Fidalgo Bay, and Guemes Channel LLID: 1229892484144 Listings 52931, 61030, 7153: Bacteria
- Joe Leary Slough LLID: 1223055485235 Listing: 39607: Bacteria
- Joe Leary Slough LLID: 1224747485194 Listing: 39608, 39609, 45827: Bacteria
- No Name Slough LLID: 1224715484801 Listing: 7158: Bacteria
- Big Indian Slough LLID: 1224570484472 Listing: 45711: Bacteria
- Indian Slough LLID: 1229892484144 Listing: 7149: Bacteria

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Cover photo: Little Indian Slough at Bay View - Edison Road, by Jacqueline Renée Fields

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EAP: Environmental Assessment Program
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2.0 Abstract

Areas of Padilla Bay and segments of Joe Leary Slough, No Name Slough, Little Indian Slough, and Big Indian Slough have been listed under Section 303(d) of the federal Clean Water Act for non-attainment of Washington State fecal coliform bacteria (FC) criteria. These listings in east Padilla Bay watershed are based on sampling by the Padilla Bay Estuarine Research Reserve, the Skagit County Monitoring Program, the Skagit Stream Team, and the Washington Department of Ecology's BEACH Program. Bacterial contamination in the Padilla Bay watershed affects beneficial uses, such as contact recreation and shellfish harvesting.

To address these listings, the Washington State Department of Ecology (Ecology), with assistance from Skagit County, the Skagit Stream Team, the Padilla Bay Estuarine Research Reserve, the BEACH Program, and the Washington State Department of Health, will conduct a FC TMDL study for tributaries in the eastern Padilla Bay watershed.

Each study conducted by Ecology must have a Quality Assurance Project Plan (QAPP). The QAPP describes the objectives of the study and procedures to be followed to achieve these objectives. The goal of this TMDL is to ensure that impaired waters in the eastern Padilla Bay watershed attain Washington State water quality standards for FC and that the water quality of Padilla Bay supports primary contact recreation and shellfish harvest. After completion of the study, a final report describing the study results will be published and posted to the Internet.

3.0 Background

Washington State Department of Ecology (Ecology) is conducting a TMDL study for fecal coliform bacteria (FC) on the freshwater tributaries to Padilla Bay. Ecology will collect bacteria samples from freshwater sloughs and ditches in the area from Joe Leary Slough in the north to Big Indian Slough in the south. Extensive data show bacterial contamination. The contamination is affecting beneficial uses in the area, such as shellfish harvesting and recreation. Several water bodies in eastern Padilla Bay and its watershed are included on Ecology's 303(d) list of impaired waters. On the list of impaired waters are parts of Padilla Bay, Joe Leary Slough, No Name Slough, Indian Slough, and Big Indian Slough.

The Washington State Water Quality Standards regulation WAC 173-201A specifies Designated Uses of the State's waters includes Fresh Water and Marine FC criteria to protect those uses. FC criteria in the Standards have two statistical components: a geometric mean and an upper limit value that 10% of the samples should not exceed.

For the protection of Padilla Bay, WAC 173-201A-612 specifies the Designated Uses of Shellfish Harvesting and *Primary Contact Recreation* (e.g., swimming). To protect primary contact recreation and shellfish harvesting in the marine waters of Padilla Bay, FC levels must not exceed a geometric mean value of 14 cfu/100 mL and must not exceed 43 cfu/100 mL in more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value. When averaging bacteria sample data for comparison to the geometric mean criteria, it is preferable to average by season and include five or more data collection events each period.

For the protection of the tributaries to Padilla Bay, WAC 173-201A-612 specifies the Designated Use of *Primary Contact Recreation* (e.g., swimming). To protect primary contact recreation in the fresh waters of the tributaries, FC levels must not exceed a geometric mean value of 100 cfu/100 mL and must not exceed 200 cfu/100 mL in more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value.

Marine criteria apply when salinity is 10 parts per thousand (ppt) or greater, and fresh water criteria apply for salinities below 10 ppt. Therefore, tributaries to Padilla Bay may need to meet a target more stringent than the fresh water criteria in order to meet marine criteria when they are diluted with marine water to 10 ppt. The locations where the marine or fresh water criteria apply is determined based on the vertically averaged daily maximum salinity.

The BEACH program uses the following numeric criteria, which are based on U.S. Environmental Agency (EPA) guidance but not specified in the Washington State Water Quality Standards:

- The Geometric Mean (GM) shall not exceed 35 Enterococci/100 mL

This criterion is based on results from a minimum of five weekly samples (and includes all samples).

The minimum beach swimming advisory level or Beach Action Value (BAV) protective bacterial standard for marine recreation beaches used for primary contact recreation is:

> The beach arithmetic average (of the three samples collected at a single beach) for the sampling day should not exceed 104 Enterococci/100 mL.

The critical warning level (Beach Swimming Closure) protective standard for marine recreational beaches used for primary contact recreation is:

The beach arithmetic average for the sample day should not exceed 276 Enterococci/100 mL.

3.1 Study area and surroundings

Geographic Setting

Figure 1 shows the location of the study area on the northwest coast in Skagit County.

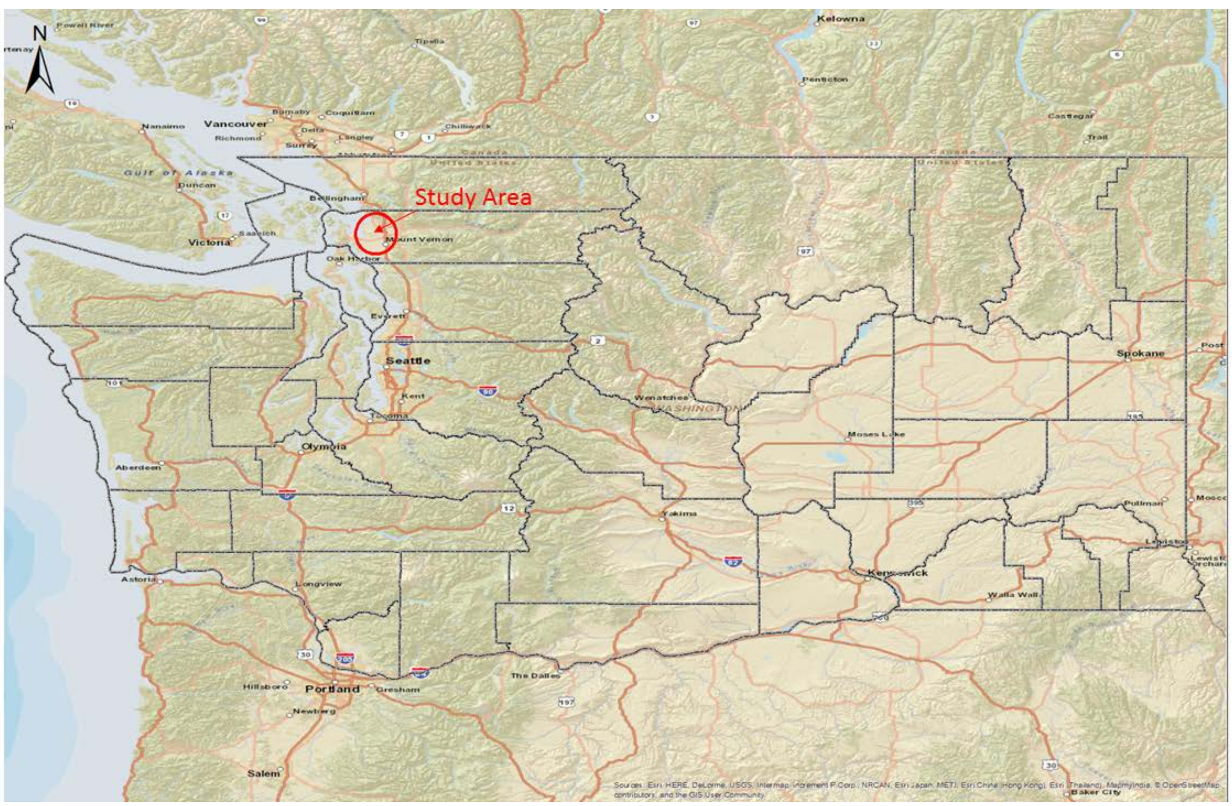

Figure 1. The location of the Padilla Bay watershed in Skagit County, Washington.

The study area includes freshwater tributaries and ditches in the eastern watershed that discharge into Padilla Bay (Figure 2). Four sloughs in the eastern watershed are on the 303(d) list for FC. Sloughs listed for FC include: Joe Leary, No Name, Little Indian, and Big Indian. Although parts of Padilla Bay are listed for FC, this study does not include the bay itself or the Swinomish Channel and Fidalgo Island.

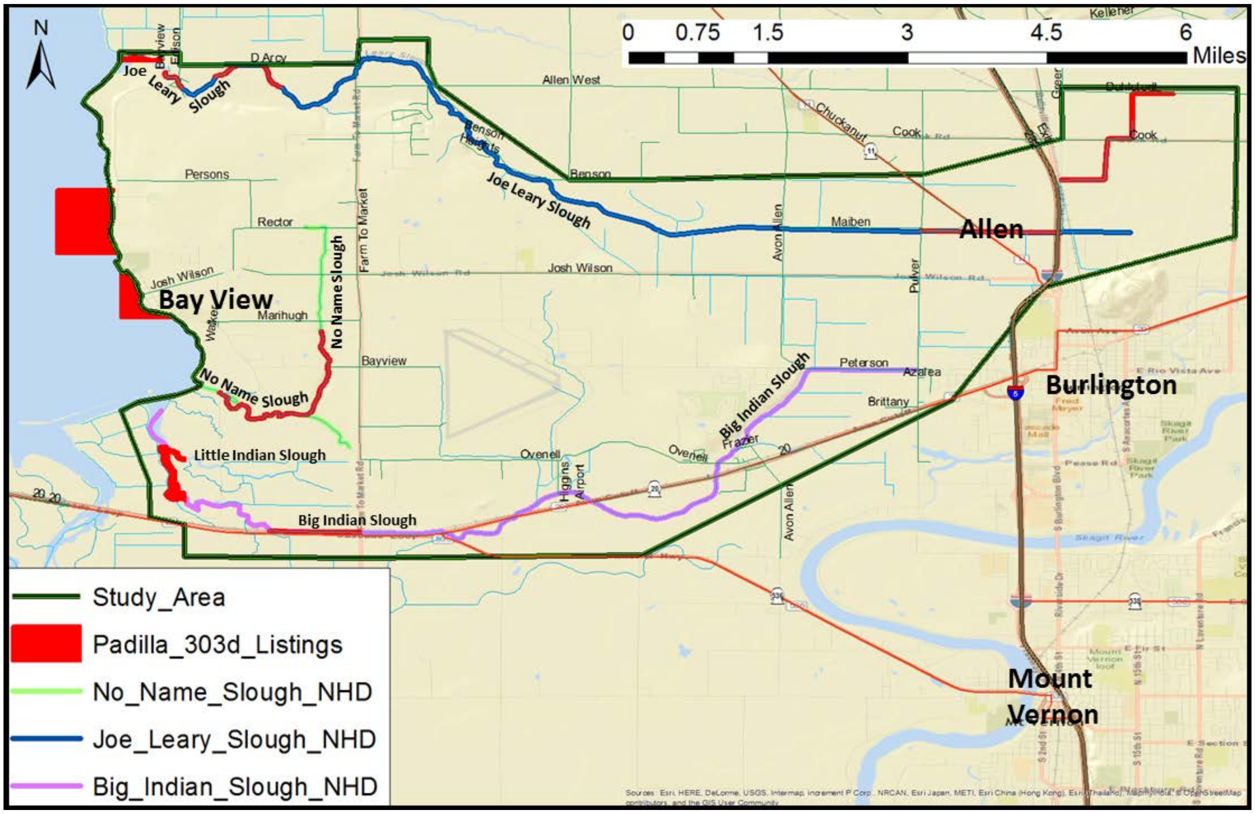

Figure 2. Map of eastern Padilla Bay watershed from Joe Leary to Big Indian Slough, which is the extent of TMDL study area.

Most of the uplands in the small coastal watershed (9,300 ha) draining to the eastern shore of the bay are used for agriculture such as livestock and irrigated and dryland crops. The area is predominantly rural, with more dense residential, commercial, and industrial development in the village of Bay View on the shoreline and on the outskirts of Burlington and Allen. Four sloughs and various ditches and canals drain the watershed to discharge freshwater into the east side of the bay. The Swinomish Channel separates the study area on the eastern mainland shore from March Point and Fidalgo Island. Tesoro Corporation operates the Anacortes Refinery on March Point.

TMDL Study Area

Figure 2 illustrates the tributaries in the eastern Padilla Bay watershed listed for bacteria and also identifies the area that will be the primary focus of this TMDL study. This study focuses on freshwater sloughs and ditches that discharge into the bay, not the bay itself. All sites that will be regularly sampled (once or twice a month) are located inside the study area. Investigatory samples may be collected outside the main study area in other parts of the watershed for source identification purposes.

Freshwater Hydrology

Four sloughs and various drainage ditches drain the eastern watershed (Figure 2). The four major sloughs are Joe Leary, Big Indian, Little Indian, and No Name. Sloughs generally flow through agricultural fields that lack streamside vegetation.

Maintained drainage ditches run along roads in much of the watershed. Skagit County Public Works dredges sediment and vegetation from ditches along roadways. Many ditches also drain pastures, fields, and forest areas to flow into roadside ditches or directly into sloughs. The main source of sedimentation in the ditches and sloughs on the flats is soil eroded from agricultural fields (Bulthuis, 2013).

The largest sub-basin in the watershed is Joe Leary Slough, which drains about 4,700 ha. The upper portions of Joe Leary Slough are field and roadside ditches that originate on the floodplain fields about 48 km east of Padilla Bay near Sedro Woolley. These ditches come together and flow west under Interstate 5 to form the mainstem. The mainstem is a straight ditch, sometimes called Maiben Ditch, which flows to the base of Bay View Ridge. From there the main channel follows a meandering channel that collects some water from the Bay View Ridge before it flows to the dike near the mouth. The dike has twelve 48" pipes with tidegates. During high tide, the gates close and freshwater collects in a small reservoir that has been dredged (Figure 3). The main tidegate (TG) at the dike is marked with a yellow star. Other tidegates exist at the pump station and at the confluence of ditches and channels with Joe Leary Slough. At low tide, the tidegates open and freshwater water flows into the bay. The pump station (PS) pumps water during high flows from the channel to the north of Joe Leary Slough.

The second largest sub-basin in the Padilla Bay watershed is Big Indian Slough (2,025 ha). Big Indian Slough drains a significant part of Bay View Ridge, including industrial and residential areas, a small airport, and a golf course before flowing through the agricultural floodplain to the dike. At low tide, freshwater discharges into Padilla Bay through six tidegates as well as two vertical turbine pumps. The pump station (PS) only operates during peak storm events that coincide with high tides. A series of floats control the pump station.

Figure 3. Tidegates and pump station at Joe Leary Slough.

Little Indian Slough (220 ha) drains a small industrial area of Bay View Ridge and flows through several fields to the same dike as Big Indian Slough. Figure 4 shows the tidegates (main tidegates at the dike are indicated with a yellow star).

No Name Slough (990 ha) flows through the Bay View Ridge, where there is low intensity agricultural use and rural housing. From Bay View Ridge, the slough meanders a short distance through the floodplain and to the bay. According to the Department of Fish and Wildlife, Coho salmon, cutthroat trout, and resident fish historically used the No Name watershed (Skagit Conservation District and Padilla Bay Estuary Research Reserve, 2005). Coho salmon smolts have been documented as far upstream as Bayview Road (Duggar, 2000). Figure 5 shows that the main tidegate (indicated with a yellow star) and pump station at No Name Slough are near the mouth. The freshwater flow into the bay is controlled by tidegates and two vertical turbine pumps. The pump station at Big Indian Slough (located at the same location as the main tidegate) only operates during peak storm events that coincide with high tides. It is controlled by floats.

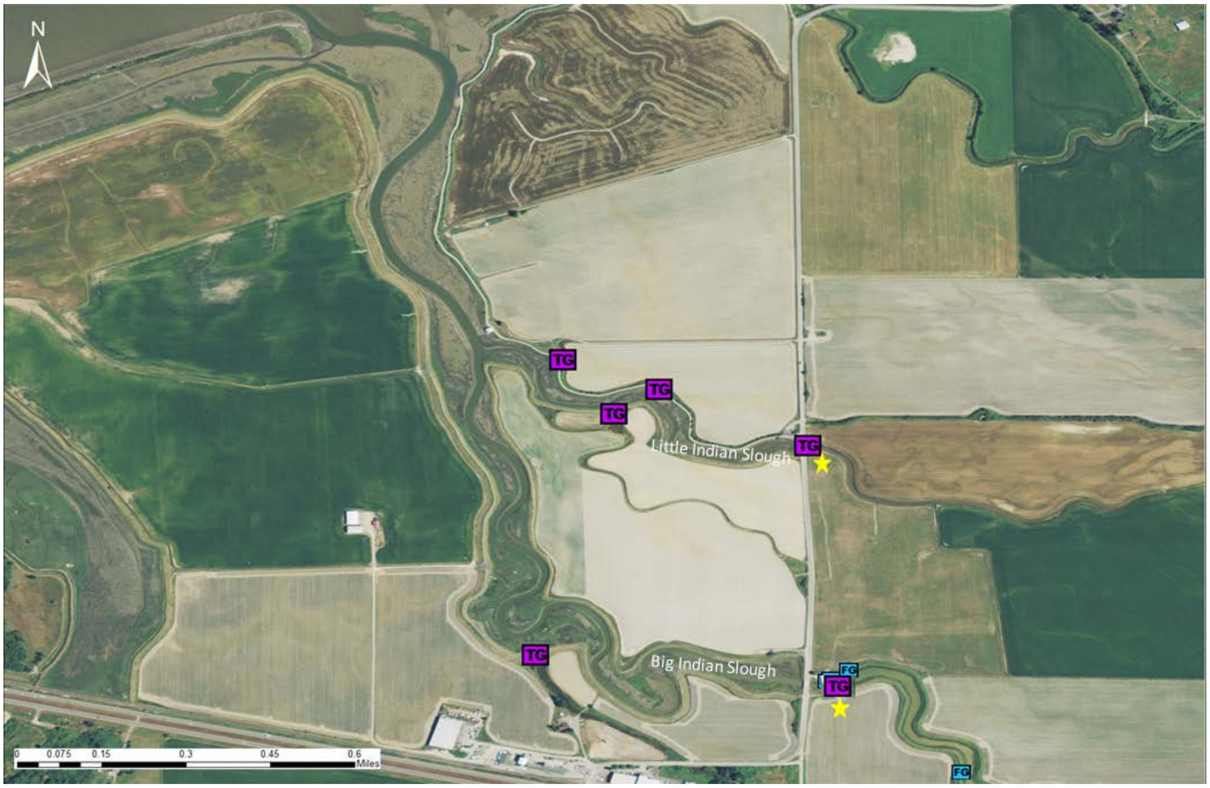

Figure 4. Tidegates at Little and Big Indian Sloughs.

Figure 5. Tidegates and pump station at No Name Slough.

Two groundwater systems have been identified in the No Name slough watershed. A partially confined aquifer occurs at approximately sea level. Well drilling logs on record with Ecology indicate that a confined aquifer exists between 10 feet above to 10 feet below sea level. This aquifer is located in the sand, sand-gravel, gravel-clay strata and is confined above and below by clay. A seasonal perched water table exists on the uplands and flats. Seepage from upland slopes has been observed during wet seasons

As previously mentioned, flow from all of these is controlled by tidegates. Also, during high flows water is pumped over the dikes and into the bay. Tidegates are pipes that extend under dike/dam and have hinged caps on the marine side that allow freshwater to flow out during low tide and prevent salt water flow into sloughs during high tide. However, seawater does enter the sloughs by seepage through the dikes and tidegates (Skagit Conservation District and Padilla Bay Estuary Research Reserve, 2005). Salinity in the lower sloughs varies daily with the tidal cycle and also seasonally. Salinity is lower during the wet season when rain and low tides bring freshwater to the mouths of the sloughs. During the dry season, salinity in the lower sloughs is often the same as Padilla Bay.

The quantity of freshwater discharge into Padilla Bay reflects the seasonal rainfall. Peak discharge is typically from November to February. From July to October, discharge is low (Bulthuis, 2013). Local water quality monitors and farmers have said that although some crops are irrigated, the sloughs often have very little to no flow by the end of the dry period. Often during the dry season, water discharging from the tidegates into the bay is marine water that previously leaked through to the freshwater side (Skagit Conservation District and Padilla Bay Estuary Research Reserve, 2005). Bulthuis (2013) estimated the maximum daily freshwater discharged into Padilla Bay from drainages in the watershed to be less than 1% of daily total exchange in Padilla Bay. Most of the freshwater that enters the bay is exchanged with the Strait of Georgia.

Padilla Bay Marine Waters

Padilla Bay is a large, shallow embayment of the Salish Sea in north Puget Sound (Figure 6). The bay is about eight miles long (north to south) and three miles across with a large, flat intertidal area. Figure 3 shows the areas on the 303(d) list for FC (outlined in red).

Padilla Bay is shallow and the bottom is flat and muddy. Bulthuis (2013) estimated that 85% of the bay is intertidal sand and mudflats (5,000 hectares). Water depths average around 5 to 6 feet. The intertidal flats are dissected with tidal channels. Some channels are 10 to 15 feet deep.

The estuary at Padilla Bay is meso-tidal (Bulthuis, 2013). A meso-tidal estuary has a tidal range of 2 to 4 meters (Davies, 1964). The tides are mixed semi-diurnal. Two high tides and two low tides occur each day (semi-diurnal). The high and low tides at Padilla Bay are not the same height. When the high and low tides differ in height, the pattern is called mixed tides.

Figure 6. Map of Padilla Bay area.

A large tidal prism is exchanged daily (Bulthuis, 2013). The tidal prism is the volume of water in an estuary between mean high and mean low tide, or the volume of water leaving the estuary at low tide. The tidal prism affects the residence time of water and pollutants in the estuary. The shallow estuary at Padilla Bay flushes out most of the water each day. Therefore, residence time is low. The bay is well mixed, due to the large tidal prism, shallow depth, and low freshwater inflow (Bulthuis, 2013).

Sixty percent of the bay is exposed at low tide (Padilla Bay/Bay View Watershed Management Committee and Skagit County Department of Planning and Community Development, 1995). The central portion of some intertidal flats in the northern part of the bay appears to be elevated slightly above the surrounding flats. Water tends to drain faster from the elevated area during ebbing tides (Bulthuis, 2013). Between Padilla Bay and Guemes Island, the flats drop off to deep troughs. There is no detailed bathymetry of the intertidal flats.

Figure 7 is a map of the vegetative communities of Padilla Bay (Bulthuis, 1991).

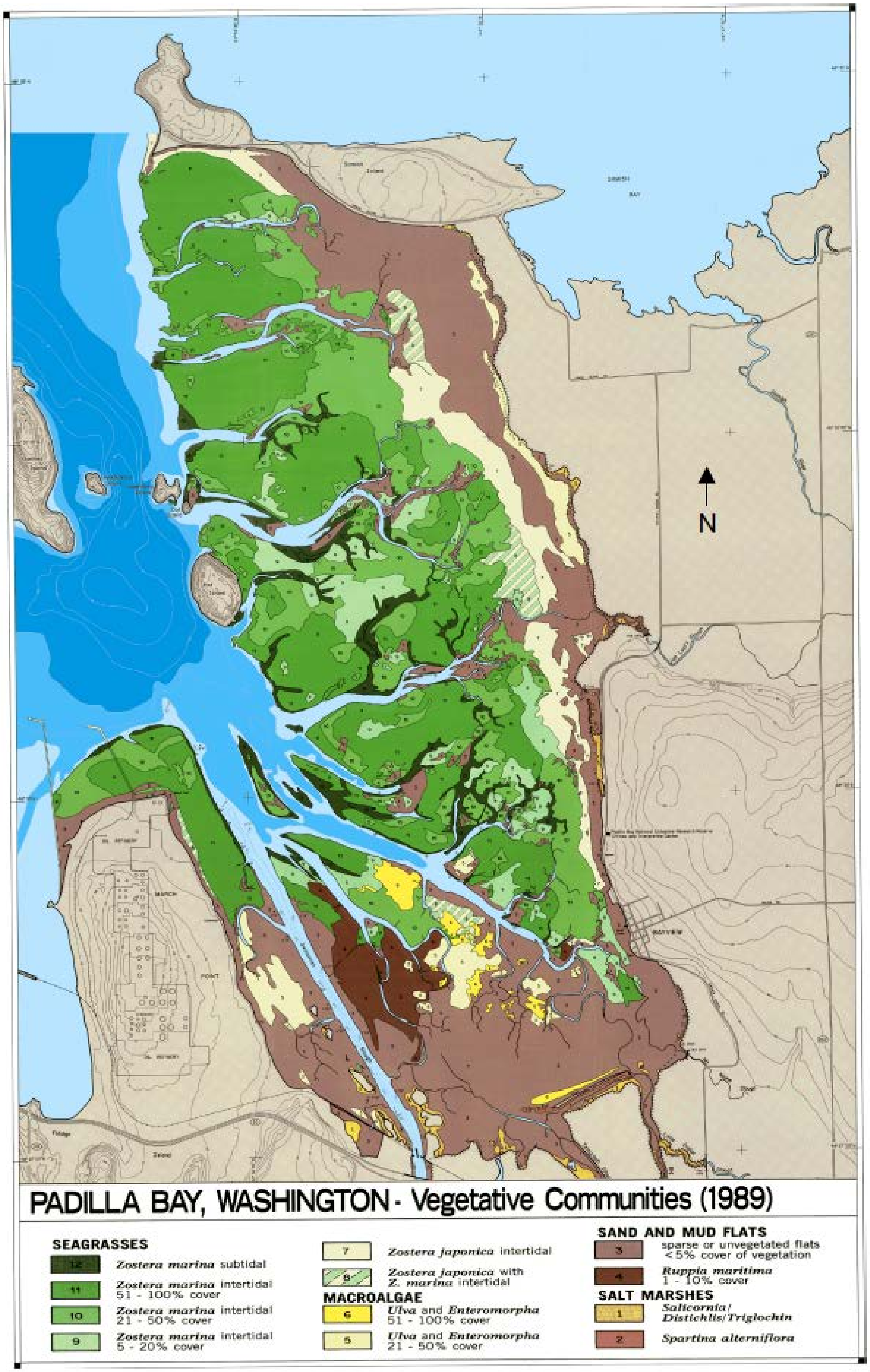

Figure 7. Map of vegetative communities from Bulthuis, 1991.

Bulthuis (2013) described main habitat types in Padilla Bay. They include:

- Rocky habitats - no area estimate
- Salt marshes - 47 to 58 hectares (Schull and Bulthuis, 2002; Bulthuis and Schull, 2006).
- Unvegetated channels and deep areas - 700 hectares
- Bare flats - 1,350 hectares
- Eelgrass Communities - 3,800 to 4,000 hectares

Intertidal and subtidal rocky habitats are sparsely distributed along the bedrock shorelines of Hat, Saddlebag, and Dot Islands (Bulthuis, 2013). Intertidal rock rubble is scattered along the shorelines of these islands and south of Bay View and Samish Island (Kueler, 1979).

Salt marshes line the mouths of sloughs, seaward of tidegates. The tidegate at No Name Slough is closest to the mouth (approximately 525 feet from the mouth), so very little salt marsh has formed. The dike at Big and Little Indian Sloughs was constructed far enough away (over 6000 feet) from the shoreline to allow salt marsh to form along the edges of the low tide channel. The tidegate is approximately 3,000 feet from the mouth of Joe Leary Slough. Narrow bands of salt marsh occur seaward of the dike. Also, narrow bands of salt marsh fringe the sand islands formed from dredge spoils along the Swinomish Channel (Bulthuis, 2013).

Estuarine channels and a deep area off Hat Island provide subtidal, unvegetated habitat. The bottom sediments are unstable, shifting sand. Dungeness, rock, and red crab, English sole, and multiple species of sculpin are found in the estuarine channels (Bulthuis, 2013).

Bare intertidal flats are primarily located between the dikes and ridges that border Padilla Bay and the eelgrass intertidal flats. Some bare patches occur along the channel edges and near the headwaters of the tidal channels.

The most extensive habitat type is the intertidal eelgrass community. In fact, Padilla Bay has of the largest contiguous stands of eelgrass along the Pacific Coast of North America (Bulthuis, 1995). In 1980, Padilla Bay was recognized for its biological productivity by becoming part of the National Estuarine Research Reserve System (Ecology, 1984).The eelgrass community includes both *Zostera marina* and *Z. japonica* and associated macroalgae, epiphytes, infauna, epifauna, plankton, and nekton (Bulthuis, 2013).

Crabs and fish use the eelgrass community as a nursery. Eelgrass provides protection, substrate and food organisms for early instars of the Dungeness crab (Pauley et al., 1986; McMillan et al., 1995). Three species of salmon, chum, pink, and ocean-going Chinook, use the nearshore eelgrass estuarine habitat at Padilla Bay (Bulthuis, 2013). Eelgrass communities have a high density of epibenthos, including prey items for juvenile salmon. Juvenile salmon forage for amphipods in eelgrass beds (Simenstad et al., 1988). Nearshore eelgrass also provides cover for juvenile salmon to avoid predators (Bulthuis, 2013).

The sheltered bays and sloughs of this watershed provide critical wintering and migratory areas for seabirds, ducks and geese. The Audubon Society estimates that Padilla Bay provides wintering and migratory habitat for 20,000 shorebirds (National Audubon Society, 2013). Eelgrass is important to large numbers of dabbling ducks during the winter (Jeffrey, 1976).

Diving ducks and piscivorous birds such as herons, loons, and grebes also forage in the eelgrass habitats.

Eelgrass beds make Padilla Bay an ideal wintering area for the brant. The brant is a goose that consumes eelgrass during migration. A study of brant in British Columbia (25 miles north of Padilla Bay) showed that 98% of the diet is eelgrass (Baldwin and Lovvorn, 1994). Brants forage most of the day (58−87%) on marine plants to replace fat reserves expended during migration (Derksen and Ward, 1993). Eelgrass is their primary food source. The entire global population of the Western High Artic Brant (subspecies) is thought to winter in Padilla Bay (Derksen and Ward, 1993). Degradation and loss of important staging and winter estuarine habitats are largely responsible for population reductions in British Columbia and the Pacific coastal states (Pacific Flyway Council, 2002).

Skagit County is host to one of the highest concentrations of wintering raptors in North America (National Audubon Society, 2013). Many diverse raptor species use farmland and flatlands around Padilla Bay. About 10,000 Trumpeter and Tundra swans, 100,000 Snow geese, and thousands of mallard and other dabbling ducks use Skagit farmland for food and habitat. (WSU, 2014).

Climate

The climate at Padilla Bay is characterized by mild, cloudy, wet winters and relatively dry summers. The wet season begins in October and lasts through April (Figure 8, Tables 1 to 3). About 75% of the annual average precipitation occurs from October to April. Typically, rainfall is light to moderate intensity and continuous over a time period rather than brief heavy rainfall. The driest months of the year are July to August.

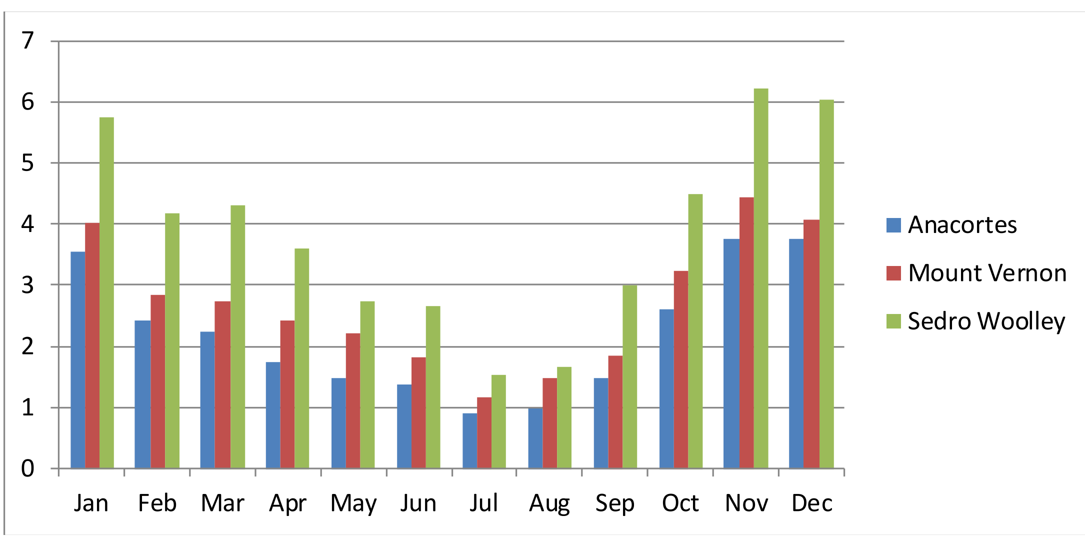

Figure 8. Average total precipitation (inches) for three weather stations near the Padilla Bay watershed: Anacortes (450176), Mount Vernon (455678), and Sedro Woolley (457507).

Table 1. Climate summary from Anacortes Station (450176) from January 1, 1931 to December 31, 2005.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	45.5	48.7	52.3	57.7	63.5	68.1	72.1	72	67.3	59.2	50.9	46.4	58.6
Average Min. Temperature (F)	35.2	36.3	38.5	42	46.3	50.3	52.4	52.6	49.9	44.9	39.6	36.5	43.7
Average Total Precipitation (in.)	3.56	2.42	2.25	1.74	1.47	1.38	0.9	0.99	1.47	2.61	3.75	3.75	26.28
Average Total Snowfall (in.)	2	0.6	0.4	0	0	0	0	0	0	0	0.5	0.9	4.4
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 2. Climate summary from Mount Vernon 3 WNW Station (455678) from January 1, 1956 to January 31, 2005.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (°F)	45.5	49.2	52.8	57.7	63.9	68.6	73.2	73.8	68.6	59.4	50.7	45.9	59.1
Average Min. Temperature (°F)	33.6	35.1	37.1	39.9	44.7	48.8	50.6	50.9	47	41.9	37.8	34.6	41.8
Average Total Precipitation (in.)	4.02	2.84	2.73	2.43	2.21	1.83	1.16	1.49	1.84	3.23	4.43	4.08	32.3
Average Total Snowfall (in.)	1.5	0.5	0.4	0	0	0	0	0	0	0	0.1	1.2	3.7
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 3. Climate summary from Sedro Woolley 1 E Station (457507) from January 1, 1931 to December 31, 2005.

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (°F)	45	49.1	53.4	59.2	65.2	69.5	74.2	74.7	69.3	60.5	50.8	45.8	59.7
Average Min. Temperature (°F)	32.8	34.2	36.8	40.3	44.8	49.2	51	51.1	47.8	42.6	37.4	34.2	41.8
Average Total Precipitation (in.)	5.74	4.18	4.3	3.61	2.74	2.66	1.53	1.67	2.99	4.5	6.23	6.03	46.19
Average Total Snowfall (in.)	2.9	1.1	1.4	0	0	0	0	0	0	0	0.6	2.2	8.3
Average Snow Depth (in.)	0	0	0	0	0	0	0	0	0	0	0	0	0

Geology and Soils

Padilla Bay is located on the northwest edge of a flat delta formed by river, volcanic, and glacial sediments. Although it is on a north delta of the Skagit River, over the last 5,000 years the river has flowed into Padilla Bay only during major episodic flooding (Bulthuis, 2013). In the 1880s, the Skagit River was diked, fixing the river channel in its present location, and since that time it has not discharged into Padilla Bay during floods (Bortleson et al., 1980). Small sloughs and ditches drain the floodplain and raised terraces of the watershed, with tidegates the release drainage at low tide.

The major topographic features are raised marine terraces. They are called that because they were formerly the shoreline of the sea and the delta floodplains. Examples of the marine terraces include Bay View Ridge, Samish Island, and March Point. Holocene river deposits of the delta floodplain represent the flat farmlands that cover 55% of the watershed. Figure 9 shows the geologic formations. The delta floodplain is non-glacial alluvium (Qa). The raised marine terraces are glaciomarine drift (Qgdm), till (Qgt), or outwash (Qgo) (Dragovich et al., 2002).

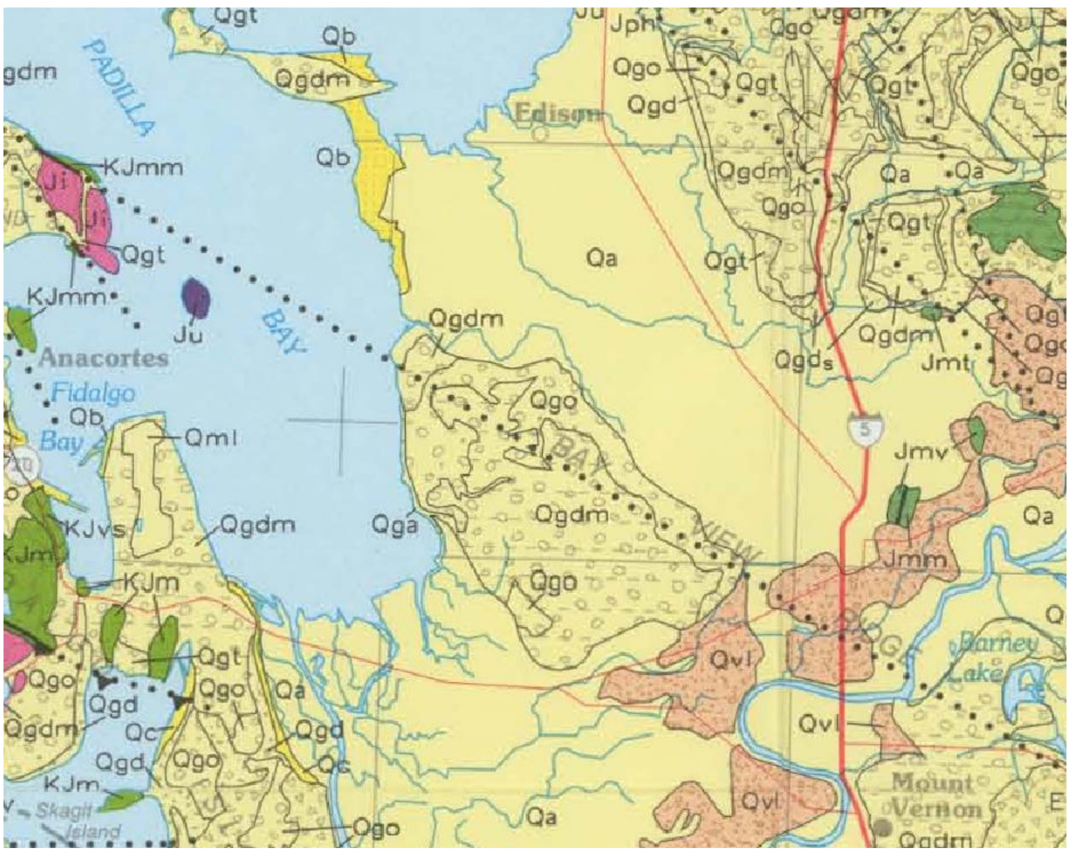

Figure 9. Padilla Bay watershed from the Geological Map of Northwest Washington, Washington State Department of Natural Resources.

There are three main types of soils in the Padilla Bay watershed. On the flat farmlands are Skagit-Sumas-Field and Larush-Pilchuck soils. In sharp contrast, Bow-Cloverland-Swinomish glacial till soils occur on raised marine terraces. In the floodplain, the water table is seasonally high and the soils are generally deep, poorly drained, with a high clay content (USDA Soil Conservation Service, 1989). These are important soils for agriculture and are used for annual crops, fruit, berries, seed crops, and pasture (Padilla Bay/Bay View Watershed Management Committee and Skagit County Department of Planning and Community Development, 1995).

Geology and soil characteristics are important considerations in evaluating the susceptibility of a water body to bacterial contamination. In the Padilla Bay/Bay View area, the soils are relatively thin. One to three feet below the surface is hardpan and/or the water table. Therefore, treatment of septic effluent by the soil is limited. Most new systems or repairs to older systems require some sort of pre-treatment of sewage before the effluent reaches native soil. A number of older systems in the area do not have any pre-treatment, so untreated or partially treated effluent can easily get into the water table and possibly into Padilla Bay (personal communication, Skagit County Health Department). In addition, the ability of soils to assimilate bacteria is limited, and saturation is likely to occur rapidly, resulting in surface runoff of materials on the soil surface.

Land Use

Agricultural data specific to the study area were not available. However, data were available for Skagit County, which is provided to give some insight into possible land uses in the study area. U.S. Department of Agriculture (USDA) Census from 2012 estimates that Skagit County farmers produced about $300 million worth of crops, livestock, and dairy products on approximately 90,000 acres of land. Over 90 different crops were grown in Skagit County. The average farm size was 99 acres, but most farms were under 50 acres (USDA, 2012). Figure 10 shows USDA agricultural land use from 2013 in the study area.

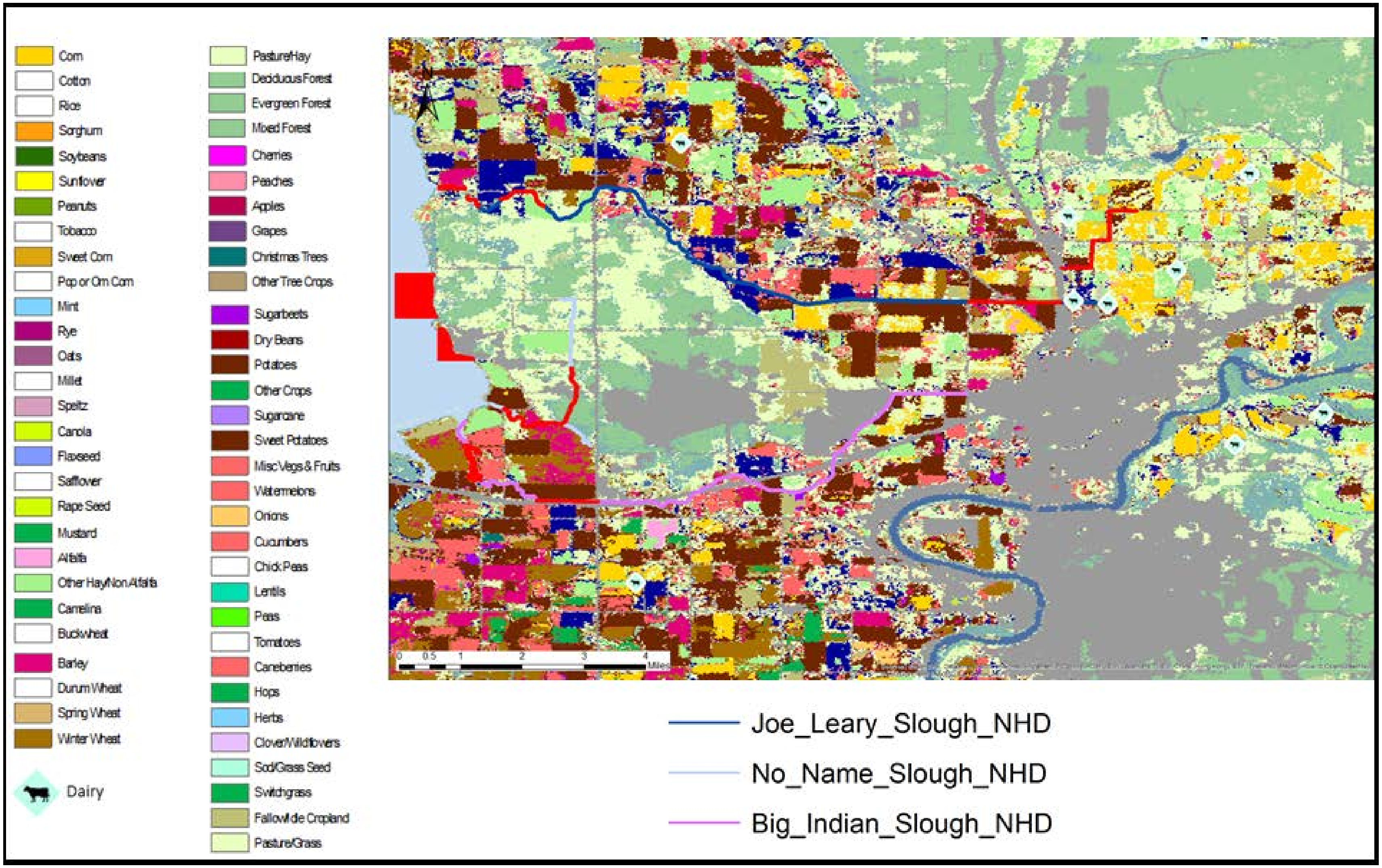

Figure 10. USDA agricultural land use in the Padilla Bay area.

In July and August of 2014, irrigation was used on approximately 17,000 acres of cropland in Skagit County. Summer rainfall was low, and irrigation use was slightly above average for the County. The main crops irrigated were grass pasture, berries, potatoes, vegetable seed crops and tree fruits. Over 60% of land use in 2012 was for cropland (USDA, 2012).

Crops grown in the study area include blueberries, potatoes, vegetable seed, and hay.

In 2012, USDA agriculture census reports over 30,000 cattle and calves, 4,000 poultry, 50,000 hogs and pigs, 200 sheep and goats, 500 horses, ponies, mules, and donkeys in Skagit County. Pastureland was 14% of the agricultural land use (USDA, 2012).

Nearly 300,000,000 pounds of milk was produced by Skagit dairies in 2014 (WSU, 2014). Figure 11 shows the locations of dairies in the study area in 2012. Some dairies are located in the vicinity of upper Joe Leary Slough. One dairy is located south of Big Indian Slough.

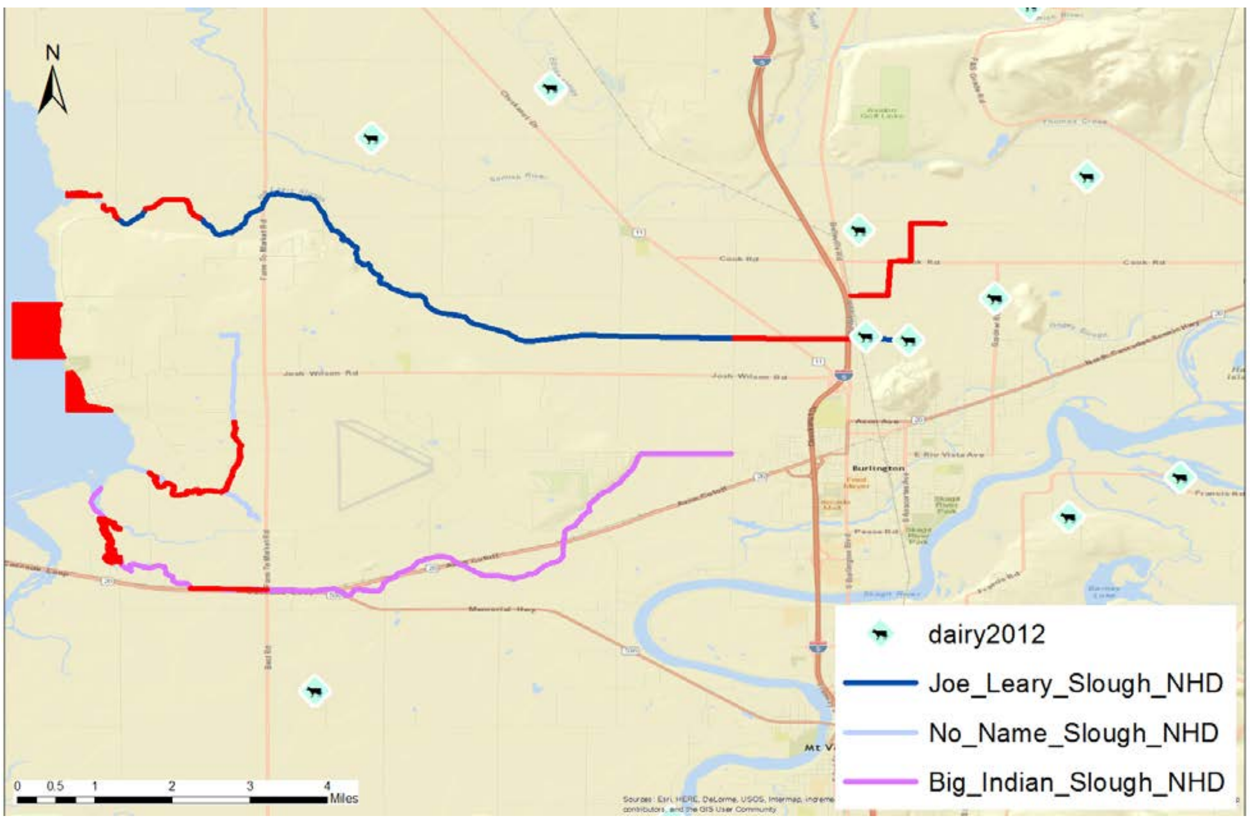

Figure 11. Location of dairies in the study area.

Figures 12 and 13 show the Concentrated Animal Feeding Operations (CAFO) near the study area (Western Environmental Law Center, 2015). Joe Leary and Big Indian Sloughs have CAFO in the vicinity. Two CAFO shallow lagoons (0 to 2 feet deep) are located within 500 feet of upper Joe Leary Slough.

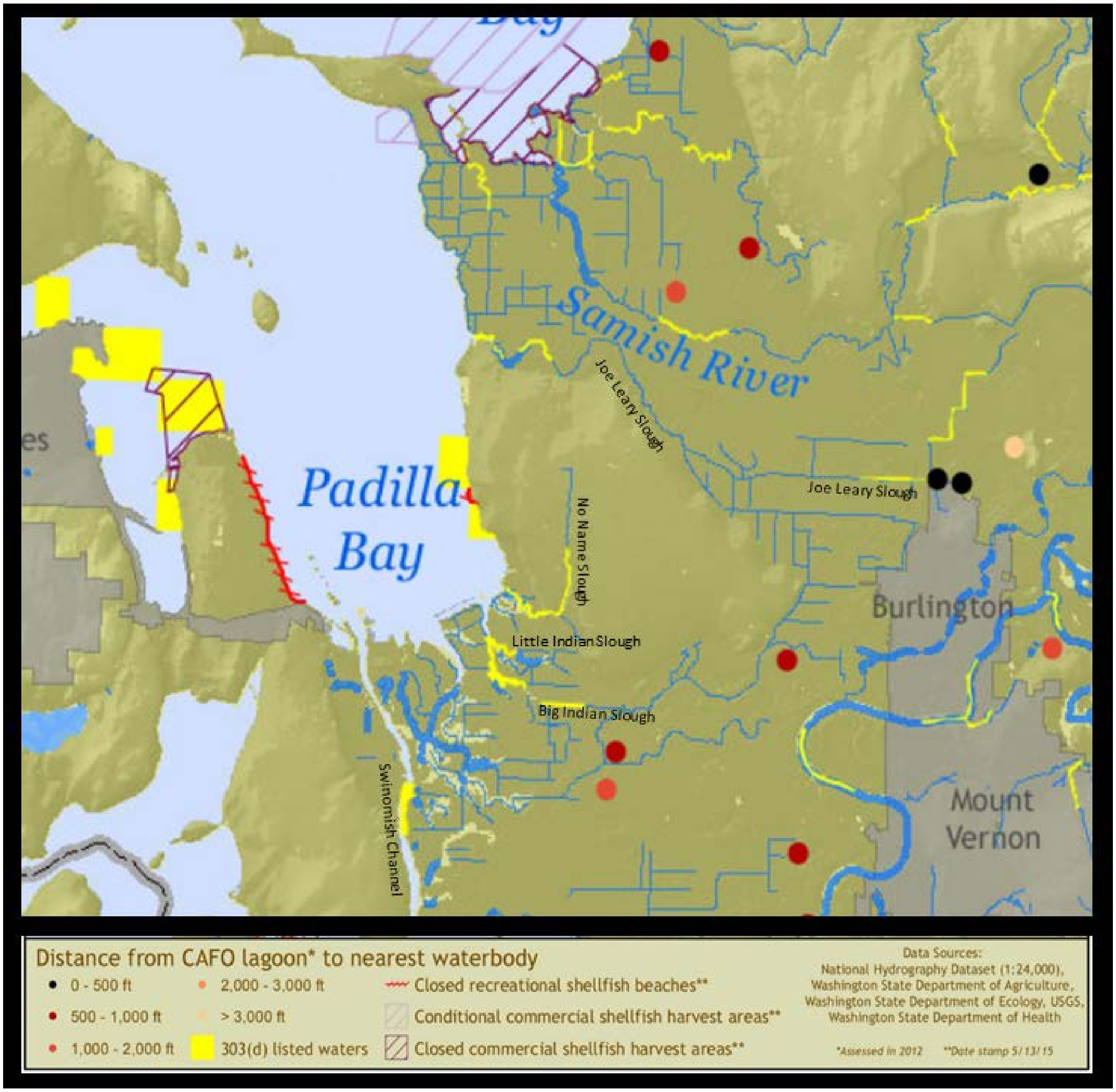

Figure 12. CAFO lagoon distance to the nearest water body near the study area.
Map date May 2015.

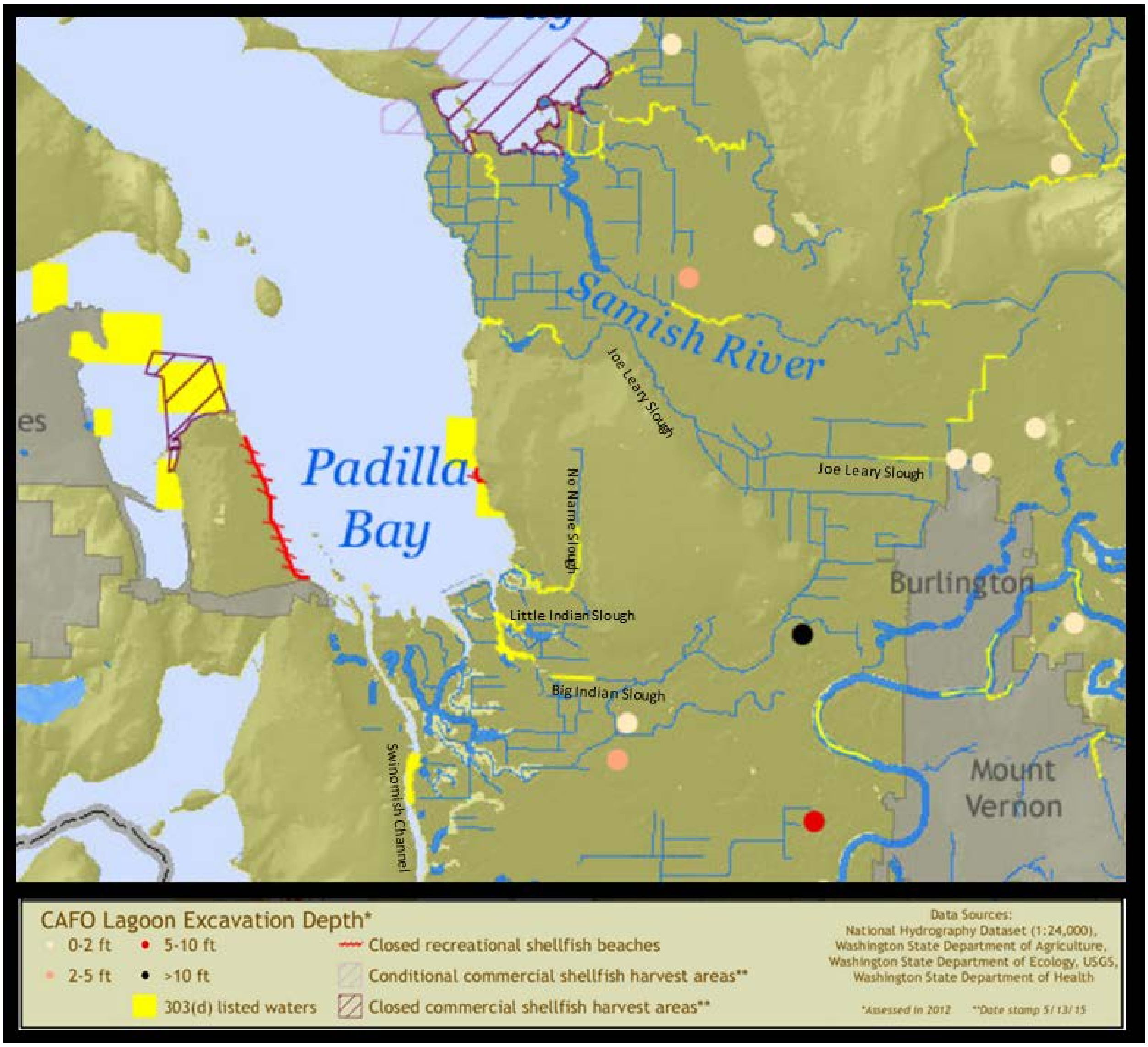

Figure 13. CAFO lagoon excavation depth near the study area (map date May 2015).

According to a land cover classification of the Padilla Bay watershed from 1993 (Figure 14), a majority of the watershed was used for agriculture (65%). Vegetables, seeds, grains potatoes, and silage corn were grown in the watershed. Almost half of the land use in the watershed was commercial agriculture (46%). Commercial agriculture is farming at a larger scale than rural agriculture with the intent to sell the farm product. The report does not define the size of commercial agriculture farms, but does say that commercial agriculture was located primary in the floodplain bottomlands. Rural agriculture (19%) and rural woodlots (16%) accounted for over one third of the land use. Rural agriculture is defined as a mixture of a small amount of commercial agriculture with small-scale farms, single family residences, pastures, and hay fields. Rural agriculture was found on Bay View Ridge. Rural woodlots are areas of second-growth forest. Upland pasture areas were primarily used for cattle grazing and growing hay, but isolated thickets of wild rose and shrubs provided habitat for mammals and birds.

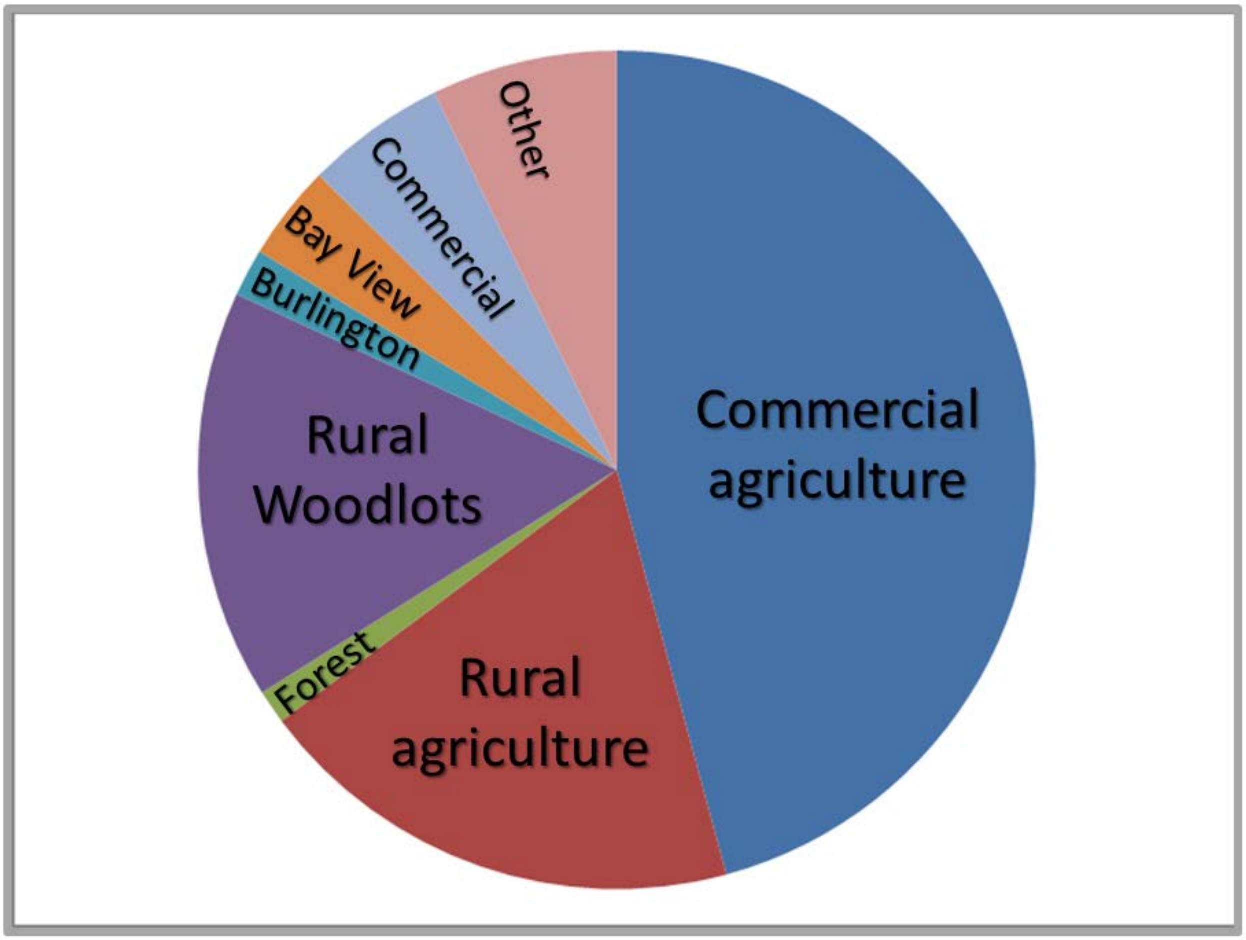

Figure 14. Land use in the Padilla Bay watershed in 1993 from *The Padilla Bay/Bay View Watershed Planning Committee and Skagit County Department of Planning and Community Development, 1994.*

The 1993 report states that residential areas were fragmenting pasture land and second growth forests in some parts of the watershed. When this land use classification was done in 1993, the urban areas of Bay View Ridge (4%) and the City of Burlington (2%) occupied small parts of the watershed. However, both of these communities have grown since that time. Forested areas have been cleared on Bay View Ridge for residential or light industrial use. The City of Burlington has expanded onto floodplain lands once used for agriculture (Skagit County Department of Planning and Community Development, 1994).

Vegetation

Sloughs generally flow through agricultural fields with very little native streamside vegetation to provide shade. Temperature tends to fluctuate daily and seasonally, with the daily maximum above 18° C, the Washington State water quality standard for Class A waters (Bulthuis, 1993 and 1996).

Potential Pollutant Sources of Bacteria

Both point and non-point sources may be contributing to water quality problems at Padilla Bay.

NPDES-Permitted Point Sources

FC can be present in a variety of municipal and industrial wastewater and stormwater sources. No practical method is 100% effective at removing bacteria all the time, so bacteria can enter receiving waters from these sources, unless a source has negligible bacteria levels to begin with (such as a gravel pit). FC and other potential contaminants from industrial and municipal sources are regulated by various National Pollution Discharge Elimination Systems (NPDES) and general permits from Ecology (Ecology, 2009a).

The Phase II Municipal Stormwater Permit rule extends the coverage of the National Pollutant Discharge Elimination System (NPDES) program to certain "small" municipal separate stormwater sewer systems (MS4s).

Both Skagit County and the City of Burlington have NPDES Phase II municipal separate storm sewer system (MS4) permits. The permit areas are located near the headwaters of Joe Leary and No Name Sloughs. Two water courses drain the Higgins Airport and flow toward Big Indian Slough (Figure 15). Some of the tributaries to these sloughs may drain these areas. These areas will be investigated in the field to determine if the permit area drains into the Padilla Bay watershed.

Washington State Department of Transportation (WSDOT) highways and facilities also are required to be covered under a MS4 permit.

Table 4 lists the 45 Point Source Pollution Sources exist in the eastern Padilla Bay watershed.

Table 4. List of water quality permits in the study area.

Permit Type	Name
Municipal Stormwater Permit, Phase II	Skagit County, Bay View Ridge Unincorporated UGA
Municipal Stormwater Permit, Phase II	Skagit County, Mount Vernon Unincorporated UGA
Municipal Stormwater Permit, Phase II	Skagit County, Burlington Unincorporated UGA
Municipal Stormwater Permit, Phase II	City of Burlington, Incorporated UGA
Industrial NPDES IP	Hughes Farms
Industrial NPDES IP	SULEX INC MOUNT VERNON
Industrial NPDES IP	INMAN LANDFILL
Sand and Gravel GP	CEMEX BUTLER PIT
Sand and Gravel GP	Skagit Ready Mix McFarland Road
Sand and Gravel GP	NORTH HILL RESOURCES
Construction SW GP	Skagit DID14 Drainage System Improvement
Construction SW GP	Improve Runway 11-29 Safety & Object Free Area & Install Perimeter Fencing
Construction SW GP	Port of Skagit Lots 42-46, 51
Construction SW GP	Skagit Valley Malting
Construction SW GP	East Ridge Produce Processing Plant
Construction SW GP	Lauts Recycle Yard
Construction SW GP	BAY MEADOWS SUBDIVISION
Construction SW GP	BAY MEADOWS SUBDIVISION
Construction SW GP	BAY MEADOWS SUBDIVISION
Construction SW GP	BAY MEADOWS SUBDIVISION
Construction SW GP	Team Corporation
Construction SW GP	SKAGIT COUNTY PORT
Industrial SW GP	Gielow Pickles NW LLC
Industrial SW GP	TRI COUNTY TRUSS INC
Industrial SW GP	Lautenbach Recycle Park
Industrial SW GP	FEDEX Express ODW
Industrial SW GP	LINDAL BUILDING PRODUCTS
Industrial SW GP	Rolling Frito Lay Sales LP Burlington
Industrial SW GP	RSA MICROTECH WESTAR LANE
Industrial SW GP	NORDIC TUGS INC HUGGINS AIRPORT WAY
Industrial SW GP	EDCO INC
Industrial SW GP	Skagit Soils Inc.
Industrial SW GP	The Euclid Chemical Company
Industrial SW GP	Bayview Edison Industries Mt Vernon
Industrial SW GP	BURLINGTON LUMBER FACILITY

Permit Type	Name
Industrial SW GP	CARGILL ANIMAL NUTRITION
Industrial SW GP	SKAGIT COUNTY PORT
Industrial SW GP	WASTE MGMT SKAGIT CO HAULING
Industrial SW GP	Connextion The
Industrial SW GP	Skagit Cnty Transfer & Recycling Station
Industrial SW GP	Dri Eaz Products Inc.
Industrial SW GP	WASHINGTON ALDER
Industrial SW GP	FedEx Ground Bay Ridge Dr.
Industrial to POTW/Private SWD	PSE Fredonia
Industrial to POTW/Private SWD	INMAN LANDFILL

Figure 15 shows areas around Padilla Bay that are covered by a city or county MS4 permit.

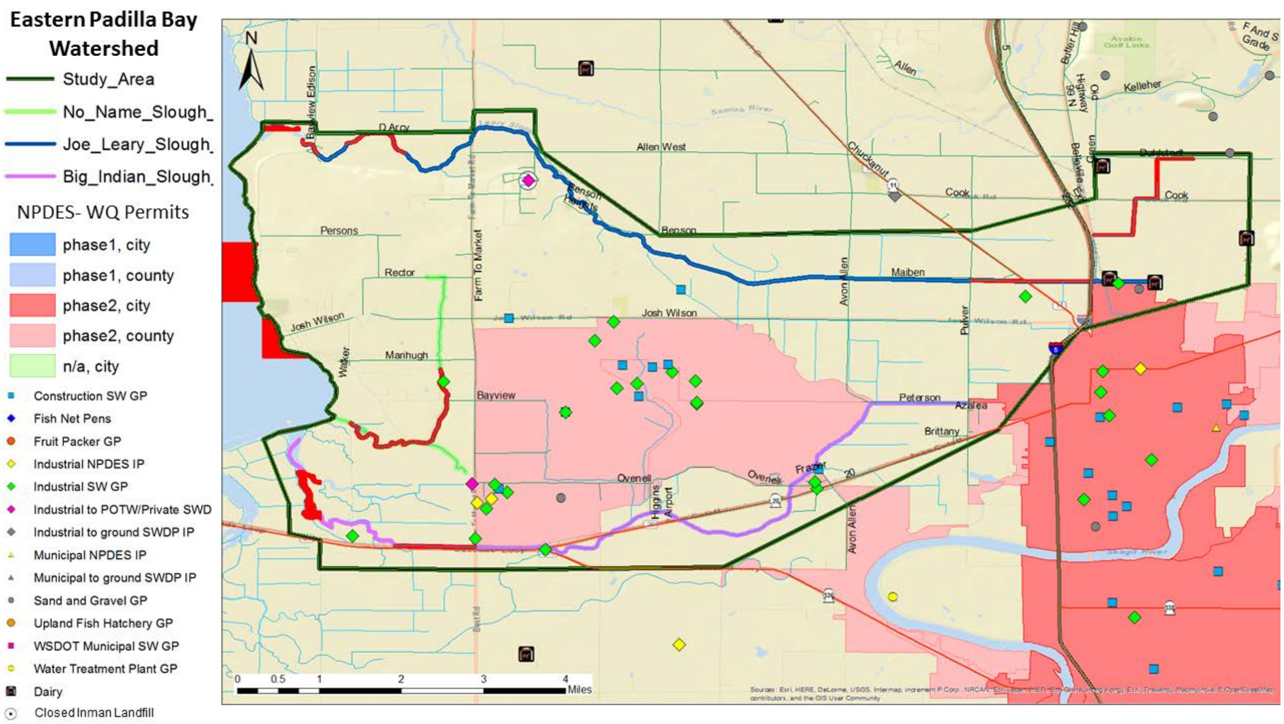

Figure 15. Washington State Municipal Stormwater Permit areas.

Nonpoint Sources

Nonpoint pollution sources and practices are dispersed and not regulated by discharge permits. Several types of potential nonpoint sources are present in the study area.

Agriculture

Range and pastured livestock with direct access to water bodies can be a source of FC contamination. Another source can be poor manure management in which manure deposited on the land's surface is transported to the receiving waters. Manure can enter the water with fluctuating water levels, surface runoff, or trampling by livestock. Swales, sub-surface drains, and flooding through manure storage areas, fields, and pastures can carry FC from sources to waterways. Manure used as fertilizer can also carry FC to waterways. Sometimes livestock are locally concentrated and can cause elevated counts.

Onsite Sewage Systems

Malfunctioning, poorly designed, or antiquated onsite sewage systems (OSS) can leak FC into waterways through surface or subsurface flow. Ecology has requested OSS information from the Skagit Department of Health, but it was not available at the time of this report.

Recreation

Padilla Bay offers many opportunities for recreation. If toilet facilities are not available or not used, human waste may not be properly disposed and enter Padilla Bay waters.

Wildlife and Background Sources

Wildlife is a potential source of FC in the Padilla Bay watershed. Birds, raccoon, deer, muskrat, beaver, otter, and other wildlife live in the watershed. Over-wintering swans, snow geese, ducks, and other wildlife may eat crop residue. Raptors and waterfowl are especially abundant in the fall and winter. Brant geese migrate to Padilla Bay each fall to feed on eelgrass. Some birds nest in the watershed. The great blue heron colony at March Point is one of the largest in western North America with an estimated 600 nests.

Many wildlife sources are dispersed and do not elevate FC counts over state criteria. Sometimes wildlife are locally concentrated and can cause elevated counts.

Other Nonpoint Sources

Stormwater from roads, parking lots, lawns, and other sources not covered by a stormwater NPDES permit can add FC to waters flowing into Padilla Bay as well.

3.1.1 Logistical problems

See Section 4.7.

3.1.2 History of study area

Dikes were constructed on the Skagit River delta and shoreline of Padilla Bay from the 1880s to early 1900s (Bortleson et al., 1980).

The dikes on the Skagit River delta fixed the river channel in its present position. Prior to construction of the dikes, the Skagit River discharged into Padilla Bay during periods of very high flows. After the diking and draining of the Skagit River delta, Padilla Bay was cut off from direct flow from the Skagit River under almost all flow conditions.

Around the same time, the eastern shore of Padilla Bay from Joe Leary Slough to Samish Island was established with diking. The wetlands east of the dikes were drained for agriculture. Prior to the construction of dikes, the intertidal marsh area was much more extensive (Thom and Hallum, 1990; Collins, 2000; Collins and Sheikh, 2005). Collins and Sheikh estimated that about 90% of the historic wetlands (about 4,500 ha) have been lost in the "North Coast and San Juan Island" area of Puget Sound that included Padilla Bay. The remaining intertidal marshes are mainly narrow bands located seaward of the dikes, lining the sloughs seaward of the tidal gates and fringing the sand islands formed by dredged spoils along the Swinomish Channel. In 1989, Bulthuis (1991) estimated there were 62 ha of native salt marshes in Padilla Bay. Estimates in 2000 and 2004 indicate that native marshes occupied 47 to 58 ha in Padilla Bay (Shull and Bulthuis, 2002; Bulthuis and Shull, 2006).

Currently, most of the freshwater flow into Padilla Bay in the eastern watershed comes from four sloughs. The headwaters of these sloughs are field-side, dike-side, or road-side ditches that are irregularly maintained. In addition to sloughs, numerous road-side or field-side ditches flow into Padilla Bay.

3.1.3 Parameters of interest

The parameter of interest in this study is FC. Data show bacterial contamination in the east shore tributaries to Padilla Bay and in Padilla Bay itself, which is affecting beneficial uses in the area, such as shellfish harvesting, public health, and recreation.

3.1.4 Results of previous studies

Washington Department of Health (DOH)

Although this study is not addressing FC contamination in Padilla Bay, this information is presented to explain the importance of cleaning up the freshwater tributaries that are contributing to the bacterial contamination in the bay. Harmful bacteria and viruses can accumulate in shellfish and cause illness in humans.

DOH collects and analyzes FC to protect consumers from eating contaminated shellfish. The National Shellfish Sanitation Program (NSSP) prescribes two methods to evaluate bacteria levels in shellfish harvesting areas: Systematic Random Sampling (SRS) and Adverse Pollution Conditions (APC). Both use a minimum of 30 samples. DOH uses a multiple tube fermentation procedure with A-1 broth (method 9221 E in APHA, et al., 2006). DOH applies the following criteria, which are identical to Ecology's criteria in the Water Quality Standards:

1. The concentration of FC cannot exceed a geometric mean of 14 organisms per 100 milliliters (14 organisms/mL)
2. The estimated 90th percentile cannot exceed 43 organisms/100 mL

If either of the predefined methods is exceeded, no shellfish can be directly harvested from the area around that marine water station.

A shellfish growing area is classified as Conditionally Approved if NSSP water quality criteria are met, except during pollution events that are episodic and predictable, such as rain-related run-off.

An area is classified as Restricted if it is subject to limited pollution. Shellfish from Restricted Areas cannot be harvested directly. They may be "relayed" under strict supervision to clean waters for natural cleansing.

Figure 16 shows the shellfish growing area at Padilla Bay that is classified as Conditionally Approved.

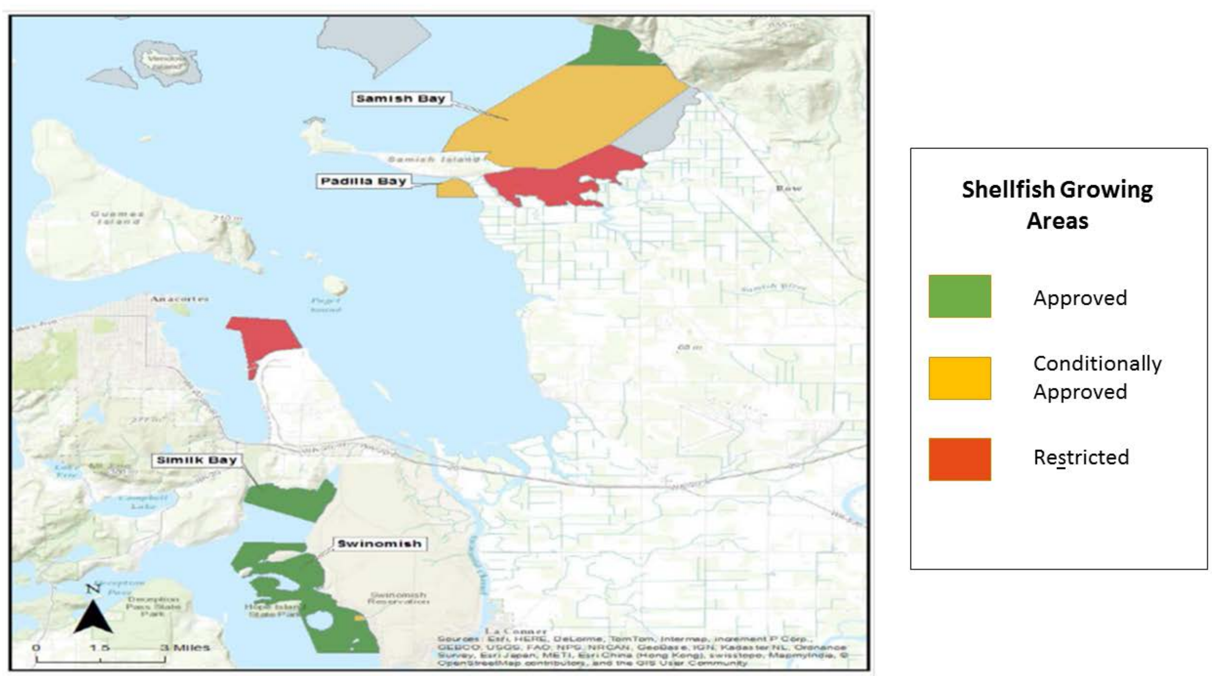

Figure 16. DOH shellfish harvest classified areas in North Puget Sound.

The Health standards have not been evaluated in other areas in Padilla Bay. These are Unclassified areas.

In 2010, the DOH changed the classification of approximately 146 acres near Samish Island from Restricted to Conditional Approved (Appendix A). In the Conditionally Approved area harvest is restricted from November 1 to January 31 due to elevated FC. On the map (Figure 16), the orange area shows the Conditionally Approved growing area to the north near Samish Island. Shellfish harvested during the restricted period must be relayed to Samish Bay.

To the south, the restricted area (off March Point near Anacortes) is classified as prohibited due to a wastewater discharge.

DOH collects monthly marine data in Padilla Bay for FC, temperature, and salinity. DOH has used seven sites in eastern Padilla Bay (only two are currently active). Table 5 lists DOH stations in Padilla Bay. Figure 17 shows the locations of DOH stations.

Table 5. DOH stations in Padilla Bay.

Station #	Station Descriptions	Classification
*316	March Point, North of launch ramp	Unclassified
*317	March Point, Offshore of launch ramp	Unclassified
*318	March Point, South of launch ramp	Unclassified
*319	Fidalgo Bay, At single piling at SW end of Crandall Spit	Unclassified
*320	Fidalgo Bay, At outfall of pond on north side of Crandall Spit	Unclassified
323	10 meters north of a long row of upright pilings roughly parallel to and 10 meters seaward of riprap wall	Conditionally Approved
324	Seaward of a cluster of 10-15 upright pilings set adjacent to riprap wall	Conditionally Approved

*Inactive stations

DOH uses data to analyze the status and trends in FC pollution in shellfish growing areas. To perform the analysis, DOH uses "estimated 90th percentiles." DOH developed a "fecal pollution index" (FPI) as a simple tool to quantify fecal pollution impact. The FPI is a unit-less number that describes the degree of fecal pollution. The FPI ranges from 1.0 (100% of 90th percentiles are GOOD, i.e., negligible impact) to 3.0 (100% of 90th percentiles are BAD, maximum impact). The FPI may be applied at the level of the sampling station, growing area, or over larger regional areas (DOH, 2011).

The annual 2011 FPI for Padilla Bay was low ($1.00<FPI\leq1.50$). See Appendix A for trends (as of 2011) for each of the stations monitored by DOH.

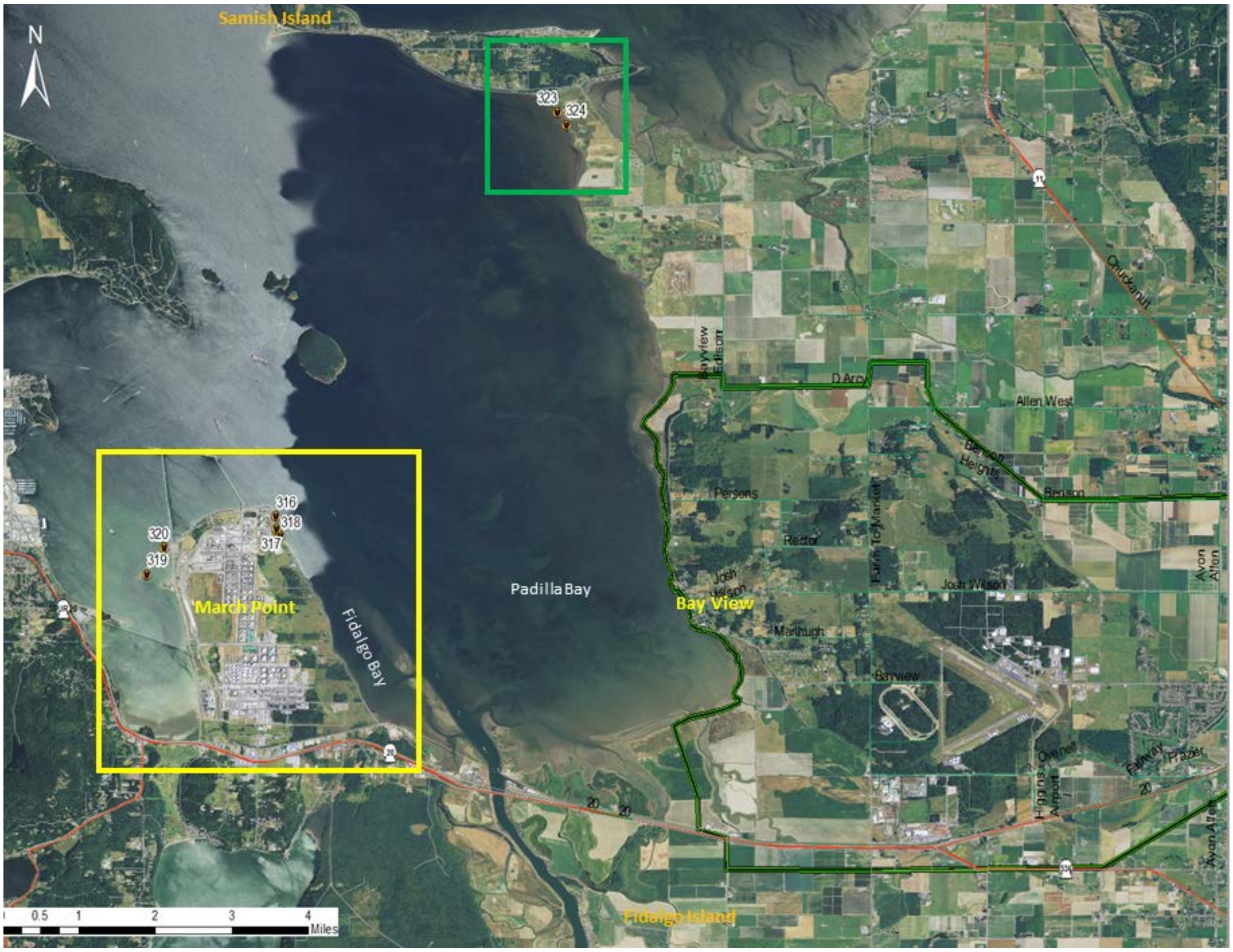

Figure 17. DOH monitoring stations in the Padilla Bay area.

Figure 18 shows the status and trends for the March Point and Fidalgo Bay sites (316 to 320). The status for all sites was negligible (FPI = 1.00). The trend was "getting better" for all sites, except site 317, which had "no trend."

Figure 19 shows the status and trends for the northern sites near Samish Island (sites 323 and 324). The status of both sites was low (1.00 > FPI ≥ 1.50). The trend for both sites was "getting better."

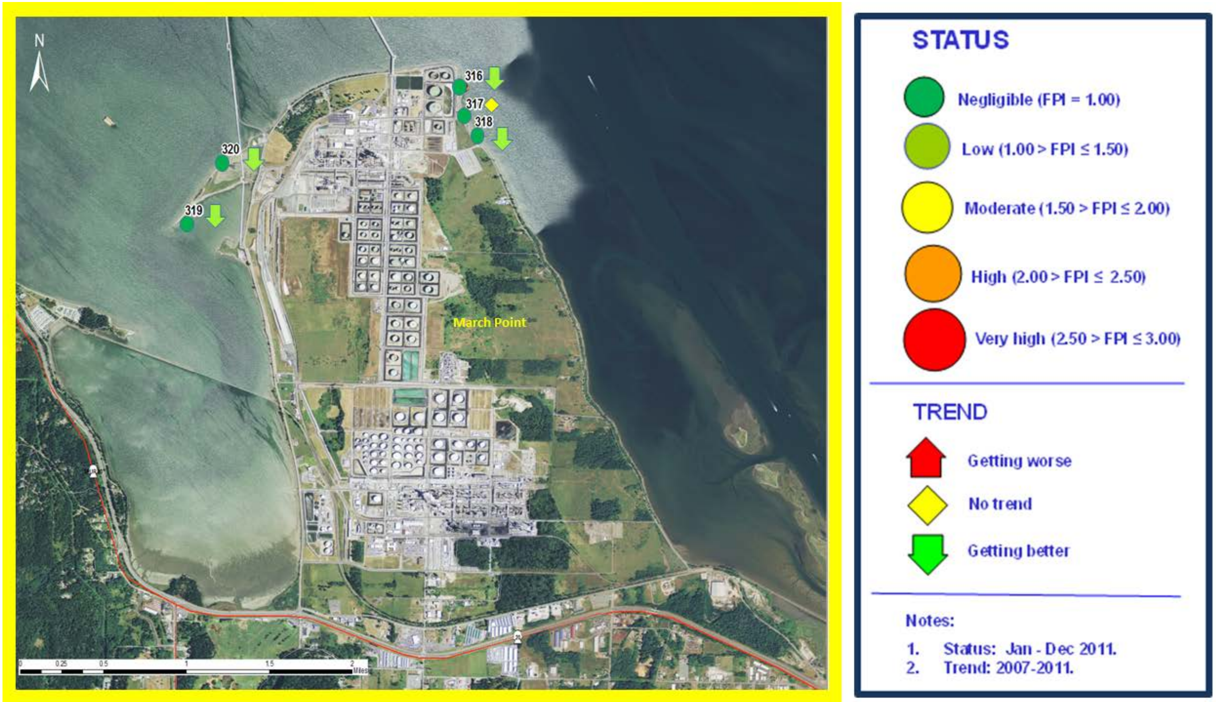

Figure 18. DOH monitoring stations at March Point and trends in 2011.

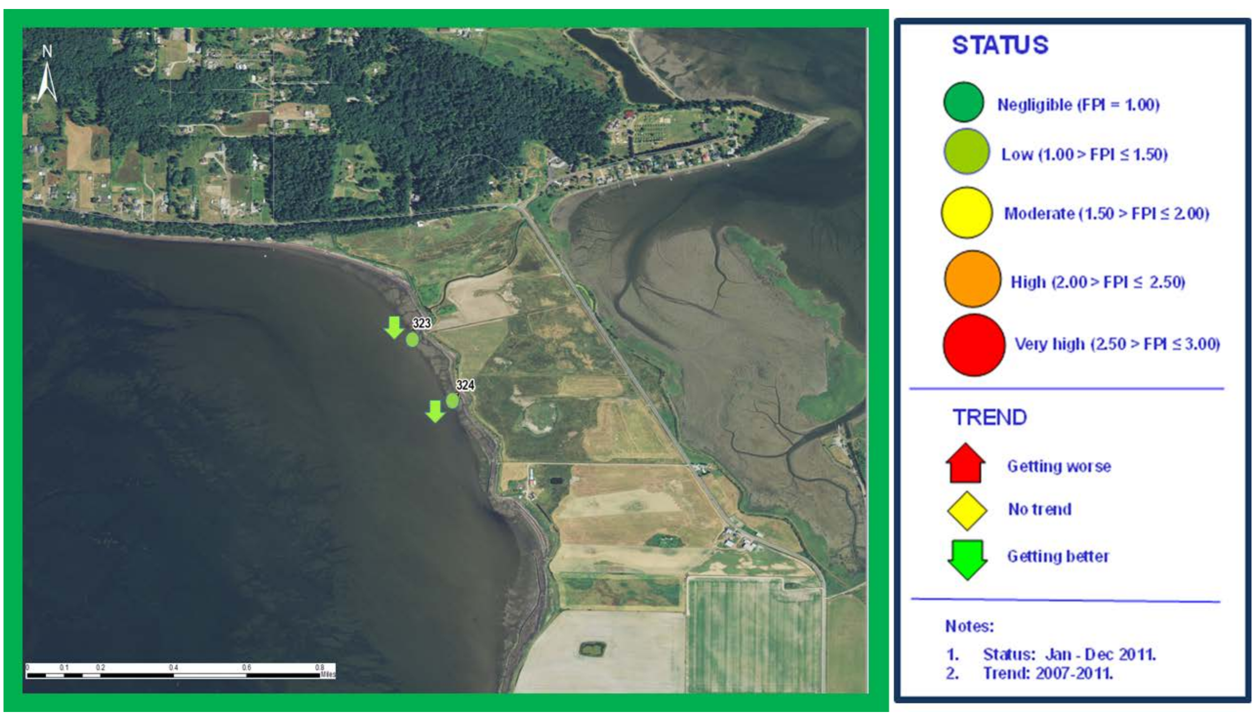

Figure 19. DOH monitoring stations near Samish Island and trends in 2011.

Washington State BEACH Program

Although this study is not addressing bacterial contamination in marine water, this information is provided to show the importance of cleaning up tributaries that discharge into recreational areas. The Washington State BEACH Program samples high risk - high use marine beaches weekly from Memorial Day through Labor Day for enterococcus bacteria to determine if water is safe for primary contact recreation (activities such as swimming, diving, surfing, water skiing, and wading by children, where there is a significant risk of ingestion). Bay View State Park was sampled at seven sites from 2003-2009 and 2011-2014 (Appendix B). Since 2011, enterococcus bacteria levels have increased, causing several swimming closures or advisories throughout the swim season. From 2011 to 2014, swimming closures or advisories due to high bacteria levels increased from two to four a year. Figure 20 summarizes yearly enterococcus data for the Memorial through Labor Day period. Since 2011, this beach has not met EPA's 1986 Recreational Water Quality Criteria of a geometric mean $\leq$ 35 cfu/100 mL and an estimated 90th percentile of $\leq$ 276 cfu/100 mL (EPA, 1986).

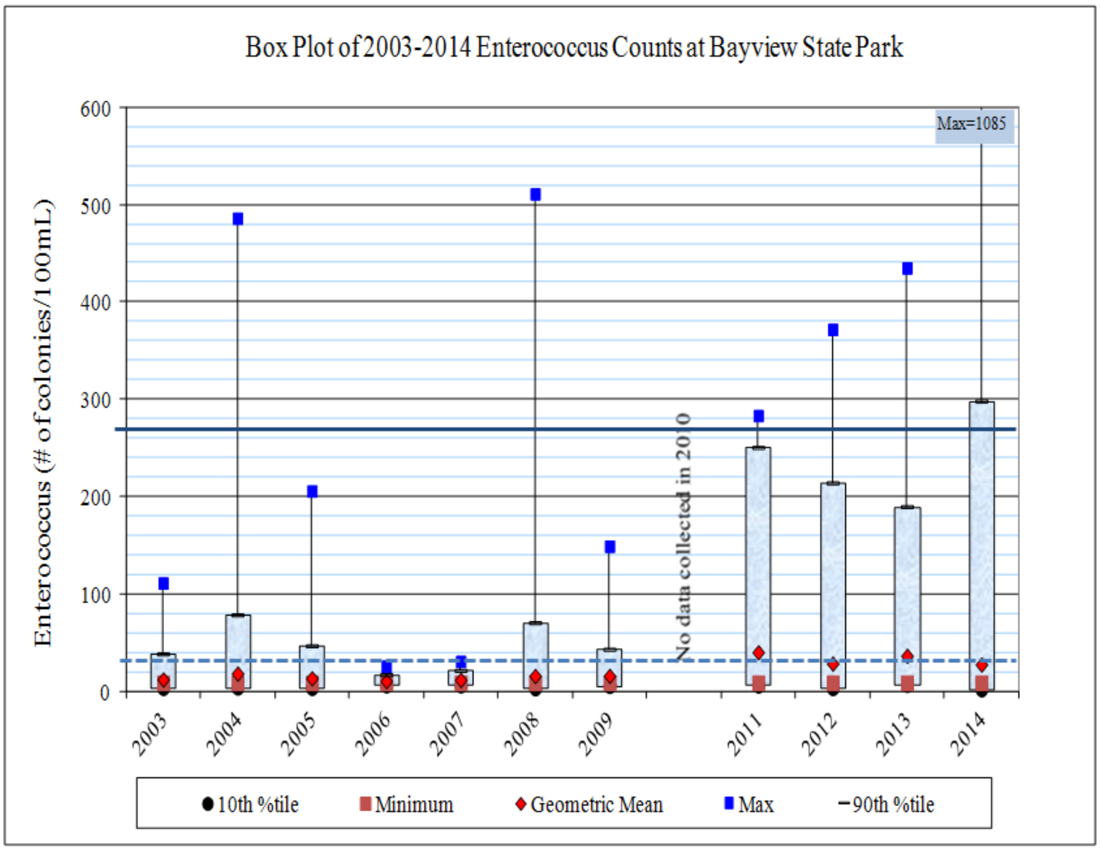

Figure 20. BEACH Program yearly enterococcus data for Memorial Day to Labor Day swim seasons 2003 to 2014.

Dashed line represents geometric mean criteria of 35 cfu/100 mL.
Bold line represents 90th percentile criteria of 276 cfu/100 mL.

Skagit County Water Quality Monitoring Program

The Skagit County Water Quality Monitoring Program (SCMP) was established in 2003 to track trends in water quality within the county's agricultural areas. Each sampling site is visited every two weeks to measure temperature, dissolved oxygen, FC, and other parameters to develop a comprehensive view of the status and trends in water quality at each site. Nutrient analysis is conducted on a quarterly basis.

In the Padilla Bay watershed, there is one downstream site in the three different sloughs that flow into Padilla Bay: Joe Leary, No Name, and Big Indian. All three sloughs are monitored to determine the status and trends at the downstream end of a watercourse in an agricultural area (Table 6, Figure 21).

Table 6. SCMP Site in the Padilla Bay watershed.

Water body	Site Number	Location Description	Latitude	Longitude
Joe Leary	35	D'Arcy Road	48.520	-122.462
No Name	34	Bayview-Edison Road	48.468	-122.464
Big Indian	40	Bayview-Edison Road	48.447	-122.457

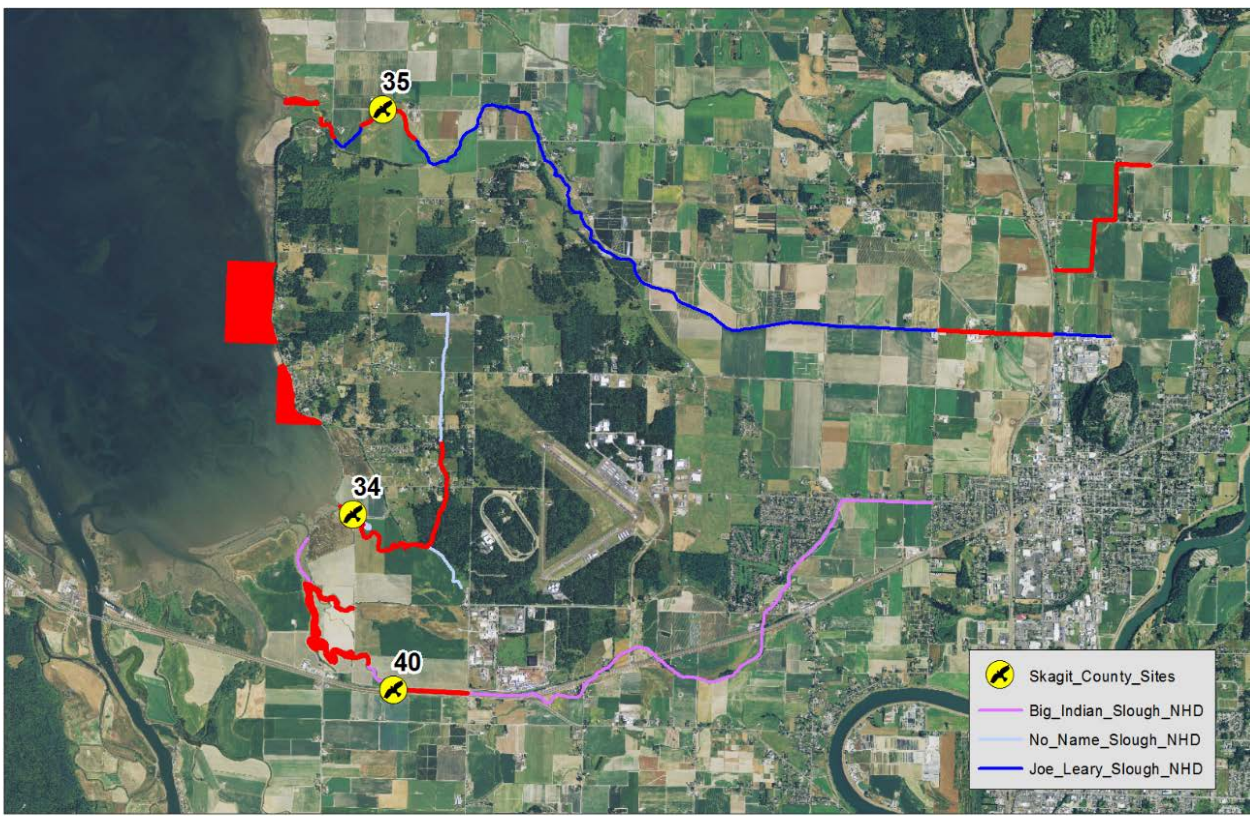

Figure 21. Skagit County monitoring sites in the Padilla Bay watershed.

Skagit County collects samples for FC every two weeks and submits samples to the Skagit County Health Department Water Lab (2003-2008) or Edge Analytical (2009-2013) for analysis using the Most Probable Number (MPN) method. Table 7 and Figures 22 and 23 show FC data for Water Years 2009 to 2013.

Table 7. Geometric mean (GM) FC/100 mL and percent of samples over 200 cfu/100 mL (%) for FC collected by SCMP for sloughs in Padilla Bay watershed during Water Years 2009 to 2013.

Site Name	Site Number	2009		2010		2011		2012		2013	
		GM	%	GM	%	GM	%	GM	%	GM	%
Joe Leary	35	103	28	85	8	54	12	56	17	125	28
No Name	34	198	50	216	42	102	38	110	42	131	31
Big Indian	40	132	40	122	38	104	23	55	15	43	15

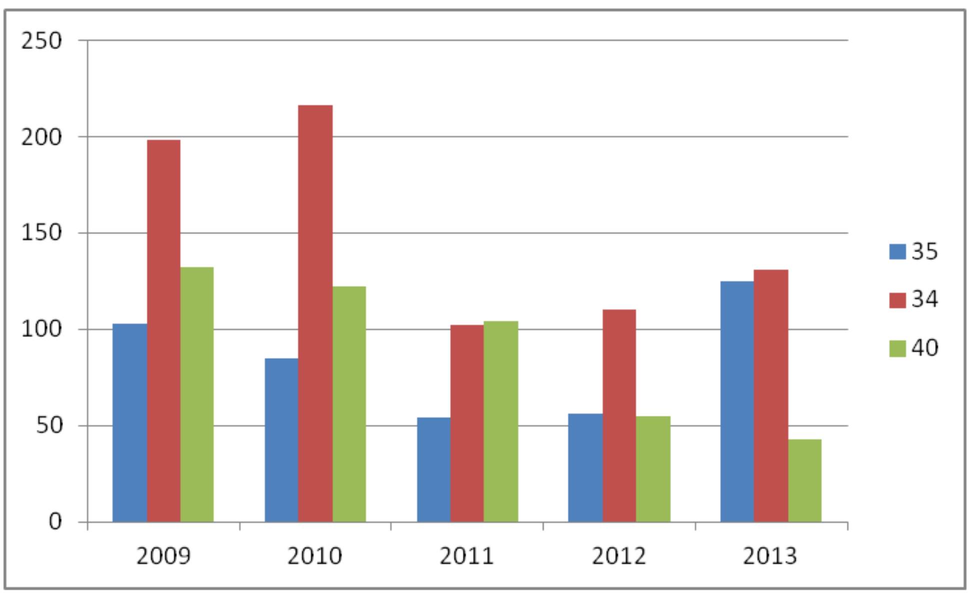

Figure 22. FC geometric means (FC/100 mL) for sites 34, 35, and 40 from 2009 to 2013 from SCMP.

Figure 23. Percent of FC samples over 200 cfu/100 mL for sites 34, 35, and 40 from 2009 to 2013 from SCMP.

SCMP calculates the Water Quality Index (WQI) score for monitored sites. The Washington Department of Ecology developed the WQI as an overall indicator of water quality. It is a unitless number ranging from 1 to 100. A higher number is indicative of higher water quality. For temperature, pH, FC, and dissolved oxygen, the index expresses results relative to levels required to maintain uses according to criteria specified in WAC 173-201A. For nutrient and sediment measures, where standards are not specific, results are expressed relative to expected conditions in a given Ecoregion. Multiple constituents are combined and results aggregated over time to produce a single score for each sample station. In general, stations scoring 80 and above, meet expectations for water quality and are of “lowest concern.” Scores from 40 to less than 80 indicate “marginal concern.” Scores below 40 do not meet expectations and are of “highest concern” (Hallock, 2002).

The WQI summarizes raw data and is useful for comparing sites and for answering general questions about water quality. However, the WQI has limitations which make it less useful in answering specific questions. For example, a water body may be impaired by constituents not included in the index. Another limitation of the WQI is the reliance on ambient data. Some sites on the Samish River, located near Padilla Bay, have adequate WQI scores based on ambient sampling. These same sites are severely impaired during storm flows (Skagit County Public Works, 2013). Another limitation of the WQI is that aggregation of data may conceal or exaggerate short-term water quality problems (Hallock, 2002).

The WQI results (Table 8) show that all three sloughs - Joe Leary, No Name, and Big Indian fall into the “highest concern” category.

Table 8. WQI scores calculated by SCMP for Joe Leary, No Name, and Big Indian Sloughs for Water Years 2009 to 2013.

Site Name	Site Number	2009	2010	2011	2012	2013
Joe Leary	35	15	9	24	22	14
No Name	34	14	11	31	22	13
Big Indian	40	11	3	13	19	4

SCMP analyzes trends using the Seasonal Kendall's Test. This test is designed to determine overall trends in water quality for parameters that vary seasonally. SCMP completed trends analyses for nine years of data (October 2003 to September 2013) via the Seasonal Kendall's Test for 19 key parameters or calculated factors at each sampling location. The tested parameters include pH, dissolved oxygen, percent oxygen saturation, temperature, turbidity, FC, ammonia, nitrate+nitrite, total phosphorus, orthophosphate, total Kjeldahl nitrogen (TKN, an estimate of the total available nitrogen), total suspended solids, and water quality index.

The WQI index score is increasing at Joe Leary Slough, with a trend of decreasing temperature and FC. Phosphate is increasing.

The trend analysis at No Name Slough reveals decreasing ammonia and increasing phosphate and orthophosphate.

At Big Indian Slough, the trend is toward increasing dissolved oxygen levels and decreasing water temperature. On the other hand, trends are toward increasing turbidity, FC, and phosphate levels.

Many locations in Skagit County show a trend of increasing orthophosphate levels. Observations are widespread and include both areas with human activities and locations with less human influence. Due to the widespread nature of these trends, both within and external to the agricultural areas, Skagit County is examining the data set and lab activities to determine if changes in lab procedures may explain these orthophosphate trends.

Skagit County monitoring reports are located at: http://www.skagitcounty.net/Departments/PublicWorksSurfaceWaterManagement/monitoringfieldandlab.htm.

Skagit County Pollution Identification and Correction Program

Locations identified with poor water quality are investigated by the Skagit County Pollution Identification and Correction (PIC) Program and/or local partners (Ecology, Washington State Department of Agriculture, and the Samish Indian Nation). Inspectors explore the area with windshield surveys and bracket sampling to narrow down the source of pollution. Letters are sent to landowners to ask for permission to access the water bodies where access is needed. If a pollutant source is located, the investigator will request a site visit with area landowners. For suspected septic issues, the Skagit Health Department will request to perform a dye test to determine whether the septic system is leaking. If a dye test is positive, showing leakage, the investigator instructs the landowner to repair the system. If the pollution source is livestock, the investigator instructs the landowner to contact the Skagit Conservation District for technical assistance. The PIC Program and their partners (Skagit Conservation District, Skagit Fisheries Enhancement Group, Skagit Conservation Education Alliance, and Coastal Volunteer Partnership) also provide outreach and education.

Skagit County contracted with Environmental Canine Services (ECS) of Maine in April 2015 for the use of a sewage-sniffing dog to look for human sources of FC in the Bay View area (Figure 24). Crush, the dog, was accompanied by her trainer and ECS Project Manager Karen Reynolds. The work with Crush took two forms: (1) in the field, Crush examined ditches, streams, and seeps for human sewage, and (2) in the Skagit County parking lot, Crush tested samples brought in from the Samish Basin, in "bucket tests". The accompanying map shows where Crush detected human sewage (marked with red points) as well as those locations where Crush did not detect human sewage (green points). Skagit County is investigating the positive locations to determine the source of the sewage. In August 2015, a dye test was conducted on the large on-site system at Bay View State Park. The dye test was partially inconclusive because not all dye packets were retrieved. The dye packet that was found was negative for dye.

Figure 24. Map of Bay View area investigated by sewage-sniffing dog in April 2015.

Skagit County Stream Team

The Skagit County Stream Team Program was established in 1998 to educate and involve local citizens in the protection and stewardship of local streams. Volunteers measure FC, dissolved oxygen, water temperature, turbidity, and total depth.

Two teams monitor each sub-basin in the Padilla Bay watershed. The sub-basins are:

- Joe Leary Slough
- No Name Slough
- Bay View

Water quality is monitored at four sites in each sub-basin (Appendix C). At each site, samples are usually taken twice monthly. The Stream Team uses the FC-MF method to determine bacteria concentration at the Padilla Bay volunteer lab. Table 9 shows the comparison of FC results with both parts of state standards.

Table 9. Comparison of the FC annual geometric mean for each site in 2013 to 2014 to the Washington State standards.

Part 1 is if the geometric mean exceeds 100 cfu/100 mL.
Part 2 is whether the percentage is greater than 200 cfu/100 mL.

Water Body	Site 1		Site 2		Site 3		Site 4	
	Met GM Standard	Met 10% not to exceed	Met GM Standard	Met 10% not to exceed	Met GM Standard	Met 10% not to exceed	Met GM Standard	Met 10% not to exceed
Joe Leary Slough	yes	no	no	no	yes	yes	no	no
Bay View drainage	yes	yes	yes	yes	yes	yes	yes	yes
No Name Slough	no	no	no	no	yes	yes	no	no

Skagit County supplemented water quality data collected by the Stream Team volunteers with expanded FC storm sampling in winter 2010 and spring 2011 (Figure 25).

Selected Skagit Stream Team Water Quality Reports and contact information can be found on the internet at: http://www.skagitcd.org/ and http://www.padillabay.gov/involvestreamteam.asp.

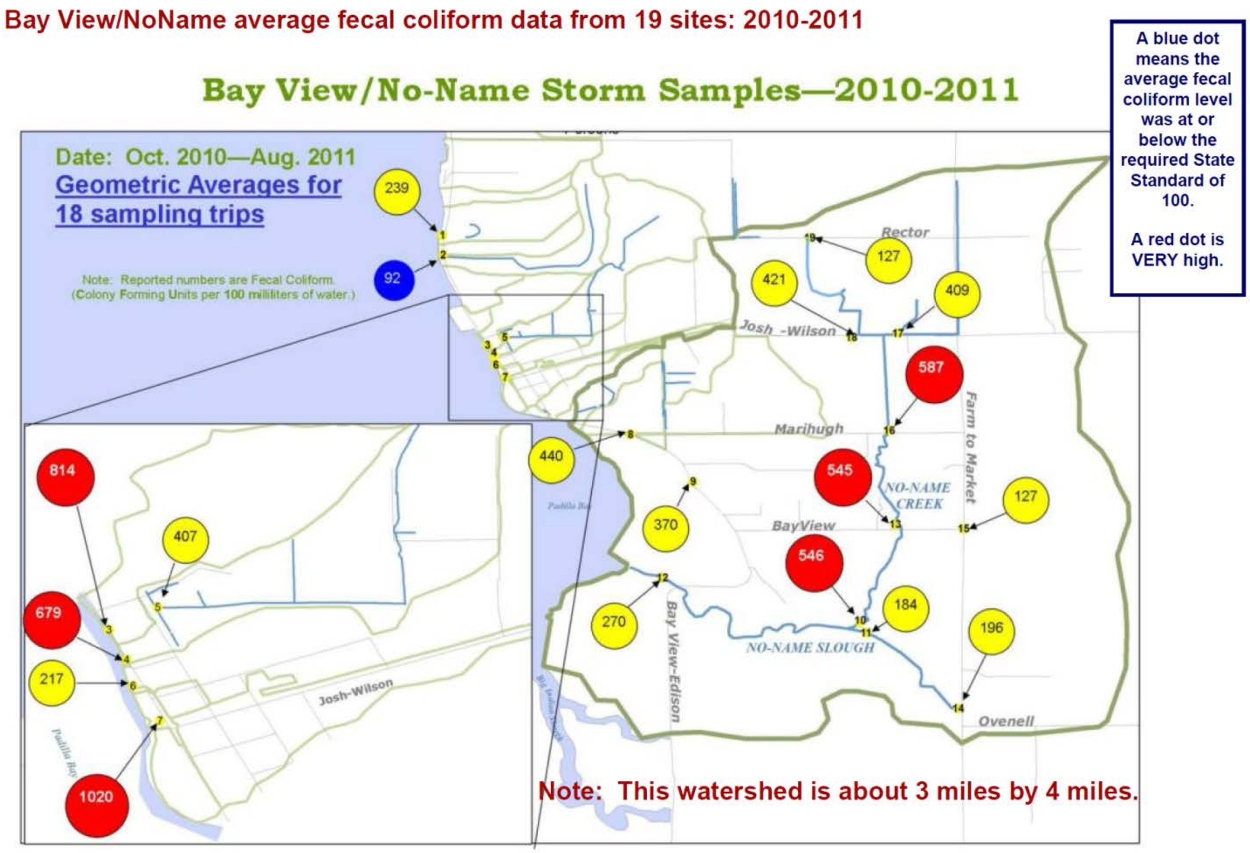

Figure 25. Geometric means for FC samples (cfu/100 mL) collected during 2010 to 2011 storm events by Skagit Stream Team at Bay View and No Name Slough.

Padilla Bay National Estuarine Research Reserve

One of the purposes of the Padilla Bay National Estuarine Research Reserve (PBERR) is to promote, conduct, and coordinate various research studies and monitoring throughout the bay. Scientists, including reserve staff and students from various universities, conduct research and monitoring projects in Padilla Bay and its watershed. Bulthuis (1993) summarized water quality data for Padilla Bay. Joe Leary, Big Indian, and No Name Slough did not meet FC water quality standards in 1986. Little Indian Slough met the state standards when it was sampled in July and August 1986. The report states that although the data were limited, Joe Leary Slough in particular had significant FC problems. Bulthuis also produced a report about suspended sediments in Joe Leary Slough (1996). These reports and other publications about Padilla Bay are available at: http://www.padillabay.gov/publications.asp.

3.1.5 Regulatory criteria or standards

Marine Water

Padilla Bay is designated excellent quality marine water. Beneficial uses include excellent aquatic life use and primary contact recreation, including shellfish harvest. Other beneficial uses include wildlife habitat, fishing, commercial/navigation, boating, and aesthetics.

In marine waters, bacteria criteria are set to protect shellfish consumption and people who work and play in and on the water. In waters protected for both *Primary Contact Recreation* and *Shellfish Harvesting*, the state uses FC as indicator bacteria to gauge the risk of waterborne diseases. The presence of these bacteria in the water indicates the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals.

(1) To protect either *Shellfish Harvesting* or *Primary Contact Recreation* (swimming or water play): "FC 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(3) (b), 2011 edition].

(2) The criterion level set to protect *Shellfish Harvesting* and *Primary Contact Recreation* is consistent with federal shellfish sanitation rules. FC concentrations in our marine waters that meet shellfish protection requirements also meet the federal recommendations for protecting people who engage in primary water contact activities. Thus, Ecology uses the same criterion to protect both *Shellfish Harvesting* and Primary Contact Recreation uses in the state standards.

Freshwaters

In Washington State, Ecology's water quality standards use FC as indicator bacteria for the state's freshwaters (e.g., lakes and streams). FC in water indicates the presence of waste from humans and other warm-blooded animals. Waste from warm-blooded animals is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals. The FC criteria are set at levels that are shown to maintain low rates of serious intestinal illness (gastroenteritis) in people.

(1) The *Primary Contact* use is intended for waters "where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and waterskiing." More to the point, however, the use is designated to any waters where human exposure is likely to include exposure of the eyes, ears, nose, throat, and urogenital system. Since children are also the most sensitive group for many of the waterborne pathogens of concern, even shallow waters may warrant primary contact protection. To protect this use category: "FC organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200/colonies mL" [WAC 173-201A-200(2)(b), 2011 edition].

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

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

The distinction between freshwater and marine Water Quality Criteria for FC depends on the salinity of the particular water body (Mathieu and Brown, 2011; [WAC 173-201A-300, 2011 edition]).

In brackish waters of estuaries, where the fresh and marine water quality criteria differ within the same classification, the criteria shall be applied on the basis of vertically averaged salinity. The freshwater criteria shall be applied at any point where ninety-five percent of the vertically averaged salinity values are less than or equal to ten part per thousand. Marine criteria shall apply to all other locations [WAC 173-201A-260(3) (e)].

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

3.2 Total Maximum Daily Load studies

What is a Total Maximum Daily Load (TMDL)?

A TMDL is a numerical value representing the highest pollutant load a surface water body can receive and still meet water quality standards. Any amount of pollution over the TMDL level needs to be reduced or eliminated to achieve clean water.

Federal Clean Water Act requirements

The Clean Water Act established a process to identify and clean up polluted waters. Each state is required to have its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of (1) designated uses for protection, such as cold water biota and drinking water supply, and (2) criteria, usually numeric criteria, to achieve those uses.
The Water Quality Assessment (WQA) and the 303(d) List

Every two years, states are required to prepare a list of water bodies that do not meet water quality standards (Ecology, 2012). This list is called the Clean Water Act 303(d) list. In Washington State, this list is part of the Water Quality Assessment (WQA) process.

To develop the WQA, Ecology compiles its own water quality data along with data from local, state, and federal governments, tribes, industries, and citizen monitoring groups. All data in this WQA are reviewed to ensure that they were collected using appropriate scientific methods before they are used to develop the assessment. The list of waters that do not meet standards [the 303(d) list] is the Category 5 part of the larger assessment.

The WQA divides water bodies into five categories. Those not meeting standards are given a Category 5 designation, which collectively becomes the 303(d) list.

Category 1 – Waters that meet standards for parameter(s) for which they have been tested.

Category 2 – Waters of concern.

Category 3 – Waters with no data or insufficient data available.

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

- 4a. – Have an approved TMDL being implemented.
- 4b. – Have a pollution-control program in place that should solve the problem.
- 4c. – Are impaired by a non-pollutant such as low water flow, dams, and culverts.

Category 5 – Polluted waters that require a TMDL – the 303(d) list.

Further information is available at Ecology's Water Quality Assessment website (http://www.ecy.wa.gov/programs/wq/303d/).

The Clean Water Act requires that a Total Maximum Daily Load (TMDL) be developed for each of the water bodies on the 303(d) list.

TMDL process overview

Ecology uses the 303(d) list to prioritize and initiate TMDL studies across the state. The TMDL study identifies pollution problems in the watershed, and it specifies how much pollution needs to be reduced or eliminated to achieve clean water. Ecology, with the assistance of local governments, tribes, agencies, and the community then develops a strategy to control and reduce pollution sources and a monitoring plan to assess effectiveness of the water quality improvement activities. Together, the study and implementation strategy comprise the *Water Quality Improvement Report* (WQIR).

Ecology submits the WQIR to EPA for approval. Once the EPA approves the WQIR, Ecology develops a *Water Quality Implementation Plan* (WQIP) within one year. The WQIP identifies specific tasks, responsible parties, and timelines for reducing or eliminating pollution sources and achieving clean water.

Who should participate in this TMDL?

Nonpoint source pollutant load targets will likely be set in this TMDL. Because nonpoint pollution comes from diffuse sources, all upstream watershed areas have potential to affect downstream water quality. Therefore, all potential nonpoint sources in the watershed must use the appropriate best management practices (BMPs) to reduce impacts to water quality. The area that will be subject to the TMDL is the eastern watershed, bounded by Joe Leary Slough to the north and Big Indian Slough to the south.

Similarly, all point source dischargers (listed in Section 3.1 *Potential Pollutant Sources*) in the watershed must also comply with the TMDL.

Bacterial contamination in the Padilla Bay watershed may come from diffuse, non-point sources. All sources of bacterial contamination and areas contributing stormwater must use BMPs to reduce impacts to water quality. Ecology will contact major stakeholders including the tribe, affected cities and counties, WSDOT, and environmental groups such as listed below:

- Bay View State Park
- Breazeale-Padilla Bay Interpretive Center
- City of Sedro Woolley
- City of Burlington
- Coastal Volunteer Partnership
- Padilla Bay Estuarine Research Reserve
- Samish Indian Nation
- Skagit Conservation District
- Skagit Conservation Education Alliance
- Skagit County
- Skagit County Cattleman's Association
- Skagit Fisheries Enhancement Group
- Swinomish Tribe
- Washington Department of Health
- Washington State Department of Agriculture

Elements the Clean Water Act requires in a TMDL

Loading Capacity, Allocations, Seasonal Variation, Margin of Safety, and Reserve Capacity

A water body's *loading capacity* is the amount of a given pollutant that a water body can receive and still meet water quality standards. The loading capacity provides a reference for calculating the amount of pollution reduction needed to bring a water body into compliance with the standards.

The portion of the receiving water's loading capacity assigned to a particular source is a *wasteload* or *load* allocation. If the pollutant comes from a discrete (point) source subject to a National Pollutant Discharge Elimination System (NPDES) permit, such as a municipal or industrial facility's discharge pipe, that facility's share of the loading capacity is called a *wasteload allocation*. If the pollutant comes from diffuse (nonpoint) sources not subject to an NPDES permit, such as general urban, residential, or farm runoff, the cumulative share is called a *load allocation*.

The TMDL must also consider *seasonal variations*, and include a *margin of safety* that takes into account any lack of knowledge about the causes of the water quality problem or its loading capacity. A *reserve capacity* for future pollutant sources is sometimes included, as well.

Therefore, a TMDL is the sum of the wasteload and load allocations, any margin of safety, and any reserve capacity. The TMDL must be equal to or less than the loading capacity.

Why is Ecology conducting a TMDL study in this watershed?

Background

Ecology is conducting a TMDL study in this watershed because there are data showing bacterial contamination that is impairing beneficial uses in the area, such as shellfish harvesting and *Primary Contact Recreation*.

Impairments addressed by this TMDL

Section 303(d) of the federal Clean Water Act periodically requires Washington State to prepare a list of all surface waters in the state that do not meet water quality standards and are not expected to improve within the next two years. Figure 26 and Table 10 show the water bodies in the Padilla Bay watershed on Ecology's 2012 303(d) list for FC (Ecology, 2012). The water bodies listed for FC include segments of:

- Padilla Bay
- Big Indian Slough
- Indian Slough (confluence of Big and Little Indian Sloughs)
- No Name Slough
- Joe Leary Slough

Ecology will be looking at the Padilla Bay watershed more thoroughly and may find other water bodies impaired by FC.

There are other 303(d) listed segments in the watershed (Table 11), but this report does not address them. The study design and best management practices to address these impairments are much different than those needed to address FC contamination.

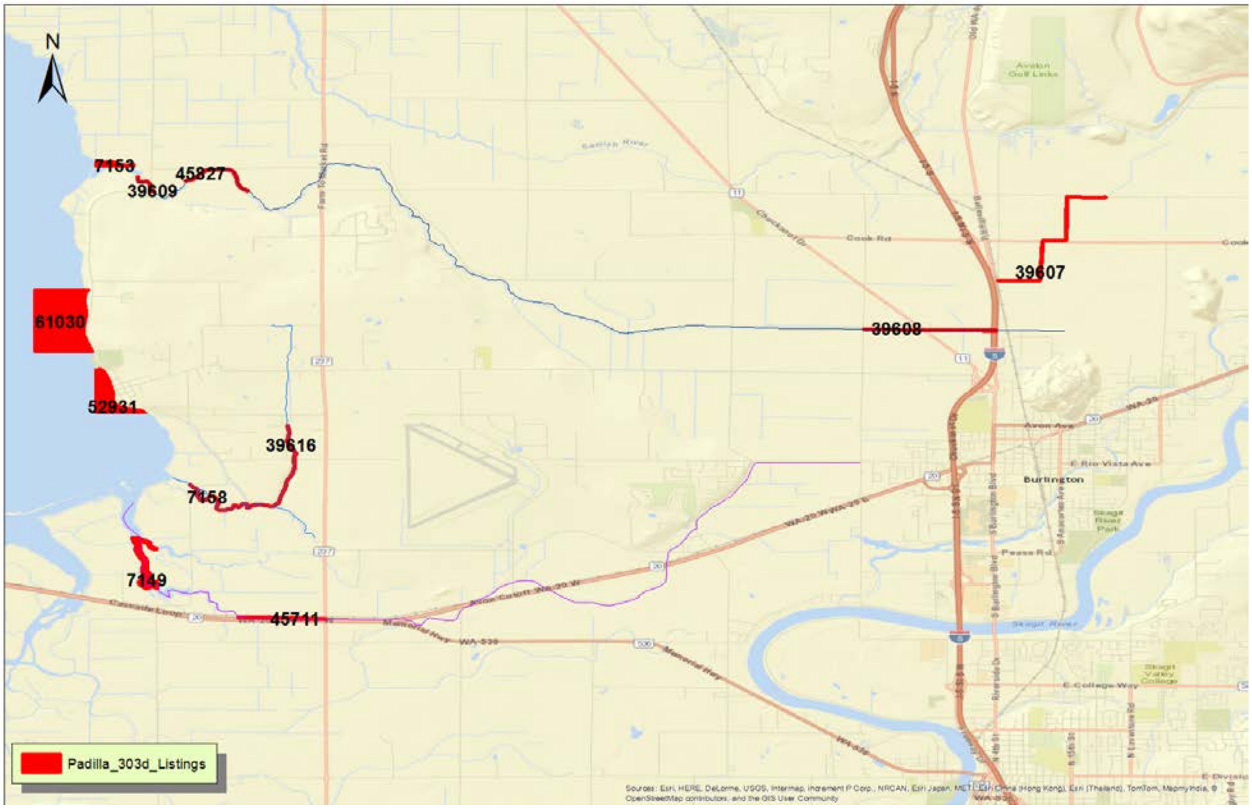

Figure 26. Water bodies listed for FC in the Padilla Bay watershed.

Table 10. Category 5 (impaired) water bodies for bacteria from the 2012 Water Quality Assessment.

Water Body Name	Parameter	Listing ID	WBID Code	Latitude	Longitude	NHD Reachcode	Grid Cell	Township Range Section
Big Indian Slough	Bacteria	45711	1224570484472	48.44665	-122.44998	17110002000331	None	34N-3E-8
Indian Slough	Bacteria	7149	1229892484144	48.45155	-122.47127	None	48122E4F7	None
No Name Slough	Bacteria	7158	1224715484801	48.46566	-122.45187	17110002000314	None	34N-3E-5
No Name Slough	Bacteria	39616	1224715484801	48.47332	-122.44882	17110002000314	None	35N-3E-32
Padilla Bay, Fidalgo Bay, and Guemes Channel	Bacteria	52931	1229892484144	48.48137	-122.47968	None	48122E4I7	None
Joe Leary Slough	Bacteria	39608	1224747485194	48.49331	-122.33891	17110002001748	None	35N-4E-30
Padilla Bay, Fidalgo Bay, and Guemes Channel	Bacteria	61030	1229892484144	48.49513	-122.48654	None	48122E4J8	None
Joe Leary Slough	Bacteria	39607	1223055485235	48.51458	-122.32106	17110002000523	None	35N-4E-20
Joe Leary Slough	Bacteria	39609	1224747485194	48.51686	-122.47264	17110002000031	None	35N-3E-18
Joe Leary Slough	Bacteria	45827	1224747485194	48.51913	-122.45976	17110002000031	None	35N-3E-17
Padilla Bay, Fidalgo Bay, and Guemes Channel	Bacteria	7153	1229892484144	48.52015	-122.47968	None	48122F4C7	None

Table 11. Other listed water bodies in Padilla Bay watershed.

Water Body Name	Parameter	Listing ID	WBID Code	Latitude	Longitude	NHD Reachcode	Grid Cell	Township Range Section	Category
Big Indian Slough	DO	47652	1224570484472	48.44665	-122.44998	17110002000331	None	34N-3E-8	5
Indian Slough	DO	48971	1229892484144	48.45063	-122.46966	None	48122E4F6	None	5
Indian Slough	DO	7150	1229892484144	48.45155	-122.47127	None	48122E4F7	None	5
No Name Slough	DO	39621	1224715484801	48.46566	-122.45187	17110002000314	None	34N-3E-5	5
Joe Leary Slough	DO	39611	1224747485194	48.49331	-122.33891	17110002001748	None	35N-4E-30	5
Joe Leary Slough	DO	39610	1223055485235	48.51458	-122.32106	17110002000523	None	35N-4E-20	5
Joe Leary Slough	DO	39612	1224747485194	48.51686	-122.47264	17110002000031	None	35N-3E-18	5
Joe Leary Slough	DO	47663	1224747485194	48.51913	-122.45976	17110002000031	None	35N-3E-17	5
Padilla Bay, Fidalgo Bay, and Guemes Channel	DO	7151	1229892484144	48.52015	-122.47968	None	48122F4C7	None	2
Big Indian Slough	pH	51091	1224570484472	48.44665	-122.44998	17110002000331	None	34N-3E-8	2
No Name Slough	pH	51088	1224715484801	48.46566	-122.45187	17110002000314	None	34N-3E-5	5
Joe Leary Slough	pH	51094	1224747485194	48.51913	-122.45976	17110002000031	None	35N-3E-17	1
Indian Slough	Temperature	48931	1229892484144	48.45063	-122.46966	None	48122E4F6	None	2
Indian Slough	Temperature	7148	1229892484144	48.45155	-122.47127	None	48122E4F7	None	2
No Name Slough	Temperature	39626	1224715484801	48.46566	-122.45187	17110002000314	None	34N-3E-5	2
Padilla Bay, Fidalgo Bay, and Guemes Channel	Temperature	7152	1229892484144	48.52015	-122.47968	None	48122F4C7	None	2

DO: Dissolved oxygen

How will the results of this study be used?

A TMDL study identifies how much pollution needs to be reduced or eliminated to achieve clean water. Ecology assesses the situation, recommends practices to reduce pollution, and establishes limits for permitted facilities contributing to the pollution. Where the study identifies major sources or source areas of pollution, Ecology and local partners will use these results to figure out where to focus water quality improvement activities. Sometimes the study suggests areas for follow-up sampling to further pinpoint sources for cleanup.

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

The resulting TMDL technical report will be used to develop FC TMDLs in the tributaries to Padilla Bay. The TMDLs will set water quality targets to meet FC criteria, identify key reaches for source pollution, and allocate pollutant loads to nonpoint sources. The TMDL study will be conducted by Ecology's Environmental Assessment Program with collaboration from Washington Department of Health, Skagit County, and other local entities.

Water Quality Standards and Numeric Targets

See Section 3.1.5.

4.0 Project Description

4.1 Project goals

The goal of this TMDL is to ensure that impaired tributary waters in the eastern Padilla Bay watershed attain Washington State water quality standards for fecal coliform bacteria (FC). Cleaning up the bacterial contamination in the freshwater tributaries will help protect primary contact recreation (such as swimming, diving, surfing, and children wading) and Padilla Bay shellfish harvest.

4.2 Project objectives

Objectives of this study are to:

- Identify and characterize FC concentrations and loads from all major listed tributaries, point sources, and drainages into eastern Padilla Bay under various seasonal and hydrological conditions, including stormwater contributions
- Identify FC loading capacities of sloughs and drainages in the study area
- Recommend FC load and wasteload allocations that will meet the water quality criteria in order to protect the beneficial uses of primary contact recreation and shellfish harvesting
- Identify relative contributions of FC loading to the bay so cleanup activities can focus on the largest sources

The results of this study will help Ecology and stakeholders focus on priority pollution sources in the study area. The project's desired conditions are:

- High quality FC data that promote confidence in the TMDL process
- Increased public awareness of the level of and reasons for FC reductions that are needed
- Improved management of resources to control nonpoint source pollution
- Attainment of Washington State water quality standards for FC in the watershed
- Protection of primary contact recreation and shellfish harvest uses of marine water

4.3 Information needed and sources

Meeting these goals requires a comprehensive list of pollution control measures implemented to protect or restore water quality. This information will be needed from Skagit County, the City of Burlington, the community of Bay View, Skagit County Conservation district, and non-profit organizations involved in implementing TMDL and Shellfish Protection District plan recommendations. Access to locations and/or information about point and non-point sources would be valuable. Information includes: locations and conditions of OSS, livestock operations, stormwater outfalls, and various point sources. Also required are historical and current historical and current FC, precipitation, salinity, flow, and other covariate data from regional monitoring programs, to assess trends over time.

4.4 Target population

The target population for this study is FC in the surface freshwaters within the eastern Padilla Bay watershed.

4.5 Study boundaries

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

WRIA: 3 – Lower Skagit-Samish

HUC number: 17110002

4.6 Tasks required

Data analysis will include evaluation of data distribution characteristics and, if necessary, appropriate distribution of transformed data. Streamflow data will be frequently reviewed during the field data survey season to check longitudinal water balances. FC mass balance calculations will be performed on a reach basis. Estimation of univariate statistical parameters and graphical presentation of the data (box plots, time series, and regressions) will be made using WQHYDRO (Aroner, 2003) and EXCEL® (Microsoft, 2013) software.

Data will be applied to several TMDL methods of evaluation. The statistical rollback method (Ott, 1995) will be applied to FC data distributions to determine target count reductions along key reaches of each water body during critical conditions. Ideally, at least 20 data are needed from a broad range of hydrologic conditions to determine an annual FC distribution. If sources of FC vary by season and create distinct critical conditions, seasonal targets may be required. Fewer data will provide less confidence in FC reduction targets, but the rollback method is robust enough to provide general targets for planning implementation measures.

4.7 Practical constraints

Logistical problems are rare, but could interfere with sampling. These problems could include: excessive precipitation during typically dry periods, sampling around low tide schedule, tidegates, irregular operation of pump stations, scheduling conflicts, sample bottle delivery errors, vehicle and equipment problems, site access issues, road safety, meeting 24-hour holding time when shipping samples by air or bus, and/or limited availability of personnel or equipment. Contact with bacteria contaminated water presents health concerns for field staff. Any circumstance that interferes with data collection and quality will be noted and discussed in the final report.

Collecting flow measurements will be a challenge, for safety and accuracy. Many of the sites at road crossings are not ideal for measuring stream discharge. The sloughs tend to be wider and deeper under the bridges. Deep mud prevents a safety hazard in many locations and will prevent collecting a flow measurement by wading. In some locations the water is deep, too deep for the standard 4-foot wading rod. Sometimes the current is swift, especially near open tidegates in the wet season. Vegetation may interfere with the accuracy of stage and flow measurements. Vegetation grows in the ditches and slough during the dry season. Cut vegetation often clogs the waterways at other times of the year. In addition, most bridges do not have wide shoulders and lack railings.

In order to have more time to deal with practical constraints and lack of staff, Ecology has scheduled three days every other week for sample collection (Monday to Wednesday). If staff cannot safely use flow meters while wading or from a boat, they will use a neutrally buoyant object to estimate velocity. The project manager has requested use of an Acoustic Doppler Current Profiler (ADCP) from another program to improve flow measurements; however, this resource may not be available during the study period. In addition to collecting flow measurements, Ecology will install Reference Points (RP) to measure the water surface elevations at sample sites. RPs are fixed points on a bridge or other structure from which a measurement can be made to the surface of the water for all flow conditions.

4.8 Systematic planning process

This QAPP represents the systematic planning process.

5.0 Organization and Schedule

Table 12 shows key project staff and responsibilities.

5.1 Key individuals and their responsibilities

Table 12. Organization of project staff and responsibilities.

Staff (all are EAP except client)	Title	Responsibilities
Danielle DeVoe Water Quality Program Northwest Regional Office Phone: 425-649-7036	EAP Client	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Jacqueline Renée Fields Modeling TMDL Unit Phone: 360-407-7680	Project Manager, Principal Investigator, Field Lead	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Dave Garland Water Quality Program Northwest Regional Office Phone: 425-649-7031	Client Unit Supervisor	Reviews and approves the final QAPP and report.
Kevin Fitzpatrick Water Quality Program Northwest Regional Office Phone: 425-649-7033	Client Section Manager	Reviews and approves the final QAPP and report.
To be determined	Field Assistant	Helps collect samples and records field information.
Cristiana Figueroa-Kaminsky Modeling & TMDL Unit Phone: 360-407-7392	Unit Supervisor for the Project Manager	Reviews the project scope and budget, tracks progress, provides internal review of the QAPP, approves the budget, and approves the final QAPP and report.
Dale Norton Western Operations Section Phone: 360-407-6596	Section Manager for the Project Manager	Reviews and approves the final QAPP and report.
Joel Bird Manchester Environmental Laboratory Phone: 360-871-8801	Director	Reviews and approves the final QAPP.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

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

5.2 Special training and certifications

Lead staff involved have the necessary training and relevant experience. Any staff helping in the field that lack experience will always be paired with someone who does have the training and experience needed. The experienced person will lead the field data collection and oversee/mentor the less experienced staff.

A licensed professional engineer or hydrogeologist will review the technical analysis and modeling elements of the study before the project report and results are finalized.

5.3 Organization chart

See Table 12.

5.4 Project schedule

Table 13 presents the proposed schedule for completing field and laboratory work.

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

Field and laboratory work	Due date	Lead staff
Field work completed	May 2017	Jacqueline Renee Fields
Laboratory analyses completed	July 2017	Manchester Laboratory staff
Environmental Information System (EIM) database		
EIM Study ID	jfie0001	
Activity	Due date	Lead staff
EIM data loaded	August 2017	Jacqueline Renee Fields
EIM data entry review	September 2017	Nuri Mathieu or alternate
EIM complete	October 2017	Jacqueline Renee Fields
Study report		
Author lead / Support staff	Renee Fields / Danielle DeVoe	
Schedule		
Draft due to supervisor	February 2018	
Draft due to client/peer reviewer	March 2018	
Draft due to external reviewer(s)	May 2018	
Final (all reviews done) due to publications coordinator	July 2018	
Final report due on web	August 2018	

5.5 Limitations on schedule

Changes in project prioritization and workload for both EAP and WQP could affect the schedule. Comments, both external and internal, during review could lead to additional work or the need for policy decisions. These factors can cause delays. Field-related constraints are addressed in Section 4.7. Any unforeseen limitations that would affect the project schedule will be discussed with the appropriate supervisor as needed.

5.6 Budget and funding

The estimated budget in Table 14 is based on the Study Design in Section 7.1. Since all months have more than one survey that occur on different weeks, monthly and weekly laboratory needs should not overload the microbiological units at Manchester Environmental Laboratory (MEL). The greatest uncertainty in the laboratory load and cost estimate is with the shoreline and stormwater sampling events. Efforts will be made to keep the submitted samples within the estimate. However, because the number of active shoreline sites will vary based on weather condition, this is only an estimate. Also, many sites are intermittent, so the number of sites sampled during the dry season may be much lower than during the wet season. The budget allows for 10 intermittent sites to be sampled each month. Most likely, many intermittent sites will be dry from May until September. If that is the case, more samples would be taken at intermittent sites during the wet season.

Table 14. Project budget and funding.

Parameter	Number of Weeks	Type of Sample	Number of Sites	Number of Samples	Field Duplicates	Field Blanks	Total Number of Samples	Cost per Sample	Subtotal
FC-MF	24	Fixed-Network	22	528	120	NA	648	$25	$16,200
FC MPN	12	10% Fixed-Network	3	36	12	NA	48	$47	$2,256
FC-MF	2	Stormwater Event	45	90	18	NA	108	$25	$2,700
FC-MF	2	Shoreline Survey	40	80	16	NA	96	$25	$2,400
FC-MF	12	Intermittent	12	144	48	NA	192	$25	$4,800
Turbidity	12	One Upstream Site and Downstream Site at 4 Sloughs	8	96	12	12	120	$12	$1,440
Specific Conductance	24	QA for Field Measurements	3	72	24	24	120	$10	$1,200
E. coli	12	Freshwater Sites	11	132	36	NA	168	$40	$6,720
Enterococci	12	Marine Sites	4	48	12	NA	60	$35	$2,100
TOC	12	As needed	1	12	2	2	16	$36	$576

TOC: Total Organic Carbon

TOTAL $40,392

6.0 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 methods used in this study.

6.1 Decision Quality Objectives

Decision Quality Objectives (DQOs) are not needed for this project. The TMDL process includes assessment of the uncertainty and assignment of a Margin of Safety.

6.2 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 variability for a project. Precision and bias are data quality criteria used to indicate conformance with MQOs. The term accuracy refers to the combined effects of precision and bias (Lombard and Kirchmer, 2004).

6.2.1 Targets for precision, bias, and sensitivity

6.2.1.1 Precision

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 is usually assessed by analyzing duplicate laboratory samples or field measurements).

Field sampling precision will be addressed by submitting replicate samples (Mathieu, 2006).

A quality control (QC) sample will be collected for 20% of FC samples collected. The bacteria QC sample is collected as a duplicate pair of samples collected in either a side-by-side manner or sequentially with the second sample collected immediately following the initial sample. This sample represents the total variability due to sample collection and laboratory analysis.

Precision for replicates will be expressed as percent relative standard deviation (% RSD) or absolute error and assessed following the MQOs outline in Table 15.

Table 15. MQOs for precision in field and laboratory analyses.

Parameter	Equipment/Method	Precision - Field replicate MQO (median)	Lab duplicate MQO	Reporting limits and resolution
Field Measurements				
Streamflow	SOP EAP024	10% RSD	NA	0.01 ft/s
Specific conductivity	SOP EAP033	5% RSD	NA	10 µS/cm
Water temperature	SOP EAP033	+/-0.2° C	NA	0.01° C
pH	SOP EAP033	±0.2 standard unit	NA	0.01 standard unit
Dissolved oxygen	SOP EAP033	5% RSD	NA	0.01 mg/L
Dissolved oxygen	Winkler Method SM 4500OC	+/-0.2 mg/L	NA	0.1 mg/L
Optical Brighteners[1]	SOP EAP091	10% RSD	NA	0.1 ppb
Laboratory Analyses				
FC - MF	SM 9222 D	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD[3]	40% RPD	1 cfu/100 mL
FC - MPN	SM 9221 E	50% of replicate pairs < 50% RSD 90% of replicate pairs <100% RSD[3]	40% RPD	1.8 MPN/100 mL
Escherichia coli	SM 9222G	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD[3]	30% RSD	1 cfu/100 mL
Enterococci	ASTM D 6503-99	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD[3]	40% RSD	1 cfu/100 mL
TOC[2]	SM 5310 B	10% RPD	20% RSD	1 mg/L
Turbidity	SM 2130 B	0.5 NTU	20%	0.5 NTU
Conductivity	SM 2510 B	1 µmhos/cm	10%	1 µmhos/cm

[1]Optical Brightener measurements will be collected only in areas where consistently high FC results are found.
[2]TOC samples will be collected in conjunction with OB measurements only when TOC is suspected to be high (>20 mg/L).
[3] Replicate results with a mean of less than or equal to 5X the reporting limit will be evaluated separately.

6.2.1.2 Bias

Bias is the difference between the population mean and the true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of QC procedures. Bias in field measurements and samples will be minimized by following Ecology's measurement, sampling, and handling protocols (Ecology, 1993; Ecology, 2009b and 2009c). Field bias is not possible to quantify since no standard is available. MEL will assess bias in the laboratory through the use of blanks (in Section 10.1).

For field measurements, EAP staff will:

- Measure temperature in the field with NIST-traceable thermometer at 10% of sites to compare to probe measurements.
- Collect Winkler dissolved oxygen (DO) samples at 10% of sites to compare to probe measurements.
- Conductivity will be checked with grab samples at 10% of sites.
- Collect replicate stream flow measurement for 10% of sites.
- Minimize bias in the Hydrolab MiniSonde® or YSI® probe field measurements by pre-calibrating before each run using National Institute of Standards and Technology (NIST) certified standards.
- Assess any potential bias for probe measurements by post-checking the instrument.

Table 16 contains the measurement quality objectives for Hydrolab MiniSonde® or YSI® post checks.

Table 16. MQOs for Hydrolab MiniSonde® or YSI® post checks.

Parameter	Units	Accept	Qualify	Reject
Specific Conductance	µS/cm	≤ +/- 5%	> +/- 5% and ≤ +/- 15%	> +/- 15%
Temperature	°C	≤ +/- 0.2	> +/- 0.2 and < or = +/- 0.8	> +/- 0.8
Dissolved Oxygen	% saturation	≤ +/- 5%	≥ +/- 5% and ≤ +/- 15%	> +/- 15%
pH	standard units	≤ +/- 5%	> 5% and ≤ +/- 15%	> +/- 15%

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as detection limit. In a regulatory sense, the method detection limit (MDL) is usually used to describe sensitivity. Targets for field and lab measurement sensitivity required for the project are listed in Table 16.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

To attempt to improve comparability to previously collected Ecology data, field staff will strictly follow EAP protocols, adhere to data quality criteria, and all field measurements will follow approved EAP SOPs.

Ecology may compare data collected during this study to data collected by other entities or for other projects, if it meets these requirements: (1) data were collected with approved Quality Management Plan, QAPP(s), and SOP(s) and (2) accredited laboratories analyzed the data.

6.2.2.2 Representativeness

The study is designed to have enough sampling sites at 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 QC 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 seasonal loading calculations and modeling estimates.

6.2.2.3 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 Padilla Bay 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. Potential problems are flooding, inadequate rain for storm sampling, site access problems, or sample container shortages.

A lower limit of five samples per season is required for comparison to state criteria, which will be met with the current sampling design:

- 14 samples collected during the wet season (October to April) per site
- 10 samples collected during the dry season (May to September) per site

WAC 173-201A states:

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

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

7.0 Sampling Process Design (Experimental Design)

7.1 Study design

The study objectives will be met through characterizing freshwater and seasonal FC concentrations. A fixed-network of sites is located at Joe Leary, No Name, and Big Indian Sloughs. Loads in Joe Leary and Big Indian Sloughs will be determined in locations with adequate streamflow measurements.

Loads will be determined for segments of No Name and Little Indian Slough, if enough samples and flow measurements can be collected. The upper reaches of No Name Slough sites are intermittent. Little Indian Slough has only one accessible site above the tidally influenced area, which may only flow intermittently.

FC concentrations will be monitored at TMDL target locations and other key locations within the study area from April 2016 to May 2017. The fixed network of FC monitoring sites will be sampled biweekly whenever they are flowing. Additional monitoring during storm events (>0.3 inch rain) will occur if insufficient events are not captured within the sampling schedule.

Fixed-network

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

- Provide an estimate of the annual and seasonal geometric mean and 90th percentile statistics FC counts. The schedule should provide at least 24 opportunities to collect samples at each site to develop the annual statistics, including 10 samples per site during the dry season (May-September) and 14 samples per site during the wet season (October-April). Many of these sites are intermittent during the dry season.
- Provide FC load and concentration comparisons of the sloughs and ditches to define areas of increased FC loading (e.g., malfunctioning on-site systems, livestock, wildlife, or manure spreading) or FC decreases (e.g., settling with sediment, die-off, dilution, or diversion). With accurate streamflow monitoring, tributary and source loads also can be estimated.
- Determine if certain land uses affect instream changes in FC loads.

Source Identification and Optical Brightener (OB) Surveys

If regular sampling confirms 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.

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 distance, within the constraints of time and money. This continues until the source of the FC is found and further bracketing is deemed unnecessary.

In conjunction with targeted sampling and where appropriate, Ecology plans to use fluorometry as an inexpensive and practical bacteria source tracking (BST) method to identify or confirm human sources of fecal contamination. Fluorometry is a chemical BST method that identifies human fecal contamination by detecting optical brighteners (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 with effluent from washing machines and toilets together, OBs are associated with human sewage in septic systems and wastewater treatment plants (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 another sensor downstream. If OBs are present and the upstream sensor records significantly lower OB concentrations than the downstream sensor, staff will infer that anthropogenic (human-derived) fecal contamination is likely entering the water somewhere between the sensors. This information, coupled with land use data and field observations, will give staff more certainty about whether FC sources are from failing or malfunctioning onsite sewage systems or wastewater treatment plants. Staff may find these scenarios:

- High FC and high OBs (suggests malfunctioning onsite sewage systems or wastewater treatment plant or leaky sewer pipe).
- High FC and low OBs (suggests other warm-blooded animals or human sources, such as an outhouse that does not mix gray water and toilet water).

Staff is unlikely to find these 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).

High levels of salinity and organic matter may limit the use in many locations. OB detection can be less effective in the presence of organic matter. Organic matter can fluoresce and compromise 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 assess possible interference, TOC will be sampled as necessary when OB sensors are deployed. OB values will be rejected for sites with TOC samples over 40 mg/L.

OBs degrade quickly−within minutes to hours−in UV light (Hartel et al., 2008), although some studies indicate conflict on their photo-decay rates (Tavares et al., 2008). Confirmation of OBs in waters likely means that a source of OBs is nearby.

Optical brighteners can persist in sediment (Hartel et al., 2008), so Ecology may find that OB concentrations increase during storm events from sediment re-suspension. Storms may inundate any onsite sewage systems installed below the high water mark. This could cause OBs to move more quickly from malfunctioning onsite sewage systems 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 that should prove useful, if staff follow appropriate protocols and interpret data correctly. To ensure proper OB sampling techniques are followed, Ecology has recently developed and adopted a standard operating procedure (SOP) for OB sampling (Anderson and Swanson, 2014).

Storm Monitoring

The purpose of storm monitoring is to better characterize potential sources of FC loading to the study area streams and the bay. Historical data show higher FC loading during rain events in late spring and fall. If weather permits, storm sampling will occur two times, once in the wet season and once in the dry season. These surveys are tentatively scheduled for May or August, and October or November. If sufficient rain and runoff do not occur during these months, the schedule will be adjusted.

Previous Ecology TMDL studies (Swanson, 2006; Collyard and Anderson, 2014) have defined a storm event as a minimum 0.3 inches of rainfall in a 24-hour period, preferably preceded by no more than trace rainfall in the previous 24 hours. Statistical analysis of storm data may show that this threshold is higher or lower for individual drainages. Site-specific conditions such as percent impervious surfaces, stormwater conveyance infrastructure, soil types, and depth to the water table can influence the level of runoff to a water body. Storm sampling will likely consist of multiple teams sampling all sites throughout the course of one day.

The stormwater sampling sites will include Bay View culverts, intermittent and core fixed-network sites on the sloughs (upstream and downstream of NPDES areas wherever possible), plus any accessible outfalls under NPDES Phase II permits. Figure 27 shows 45 storm event sites. Sites may be added or eliminated during the course of the study, in an effort to collect samples that best represent stormflow from areas with NPDES permits. Stormwater NPDES permits are required to have corresponding Wasteload Allocations (WLAs) set in TMDL studies. Therefore, this study must determine WLAs for each permit holder (i.e., for each Phase II permit jurisdiction).

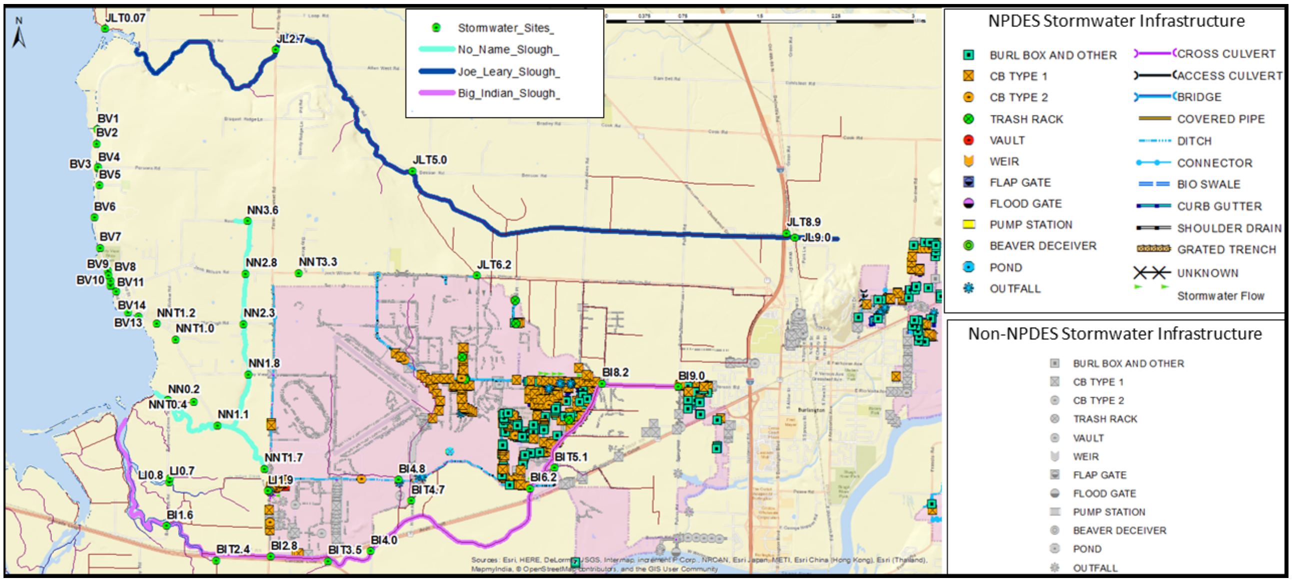

Figure 27. Map of stormwater monitoring sites.

After regular monitoring has commenced and land use and locations with higher fecal contamination have been characterized more thoroughly, investigatory FC samples may be collected in additional areas during storm monitoring.

Shoreline Surveys

In addition to sloughs, the Padilla Bay also receives water from smaller unnamed canals, ditches, and stormwater outfalls. In order to better assess the contribution of FC loading from these smaller drainages, Ecology will conduct two shoreline discharge surveys during normal flow conditions, one in the wet season and one in the dry season. These surveys are tentatively scheduled for July and December 2016.

Additional FC Analysis

Escherichia coli (*E. coli*) and Enterococci (see Glossary for more information) will be collected from selected sites once a month. E. coli is a species of FC that is specific to feces from humans and other warm-blooded animals. The EPA recommends E. coli as the best indicator of health risk from contact recreation in freshwater.

Enterococci are distinguished by their ability to survive in salt water, and in this respect they more closely mimic many pathogens than do the other indicators. Enterococci are typically more human-specific than the larger fecal streptococcus group (EPA, 1986). EPA recommends enterococci as the best indicator of health risk in salt water used for recreation.

In order to characterize the public health risk from contact recreation in Padilla Bay, Enterococci samples will be collected from select marine sites.

Turbidity

Turbidity is a measure of water clarity. It is the result of light being scattered and absorbed rather than transmitted through the water. The higher the intensity of scattered light, the higher the turbidity. It is an indicator of suspended particles such as clay, silt, organic matter, and small organisms.

Turbidity samples will be collected at one upstream and one downstream site once a month at the following sloughs: Joe Leary, No Name, Little Indian, and Big Indian. At the downstream sites, samples will be collected during ebb tide when the tidegates are open. Another sample will be collected at the farthest upstream site that is flowing.

7.1.1 Field measurements

Streamflow Data

The Padilla Bay watershed has four sloughs and many canals and ditches that discharge water to the bay. FC loading from these sources may be significant, but historical streamflow data are lacking due to the difficulty of measuring flows in tidal areas, especially from tidegates and pumps where drainage water may back up and not be flowing, or outflows may represent stored water and not incoming flow.

Many of the sites at road crossings are not ideal for measuring stream discharge. The sloughs tend to be wider and deeper under the bridges. Deep mud is a problem in many locations. Also, most bridges do not have wide shoulders or railings. The presence of vegetation may complicate stage and flow measuring. Vegetation grows in the channels during the dry season. Cut vegetation clogs channels at other times of the year.

To improve Ecology's ability to estimate flow into Padilla Bay, access to more locations on the sloughs is necessary.

Discharge Measurements at Non-Tidally Influenced Sites

Staff will estimate discharge and collect instantaneous flow measurements for non-tidally influenced sites, following the TMDL protocols (Kardouni, 2013). When flows cannot be taken, stage estimates will be recorded and regression will be used to calculate streamflow. If staff gages are not available or an appropriate rating curve has not been developed, sites will be regressed with a similar site where flow was taken and results will be marked as estimates.

During reconnaissance, Ecology found two staff gages in the watershed. Both are gages located in the upper reaches of sloughs, Joe Leary and No Name, where flow is intermittent. Before starting the study, Ecology will determine locations to estimate stage. Stage will be estimated by using an existing reference point such as a bridge, and/or installing a reference point like a staff gage at streamflow measurement locations.

Discharge Measurements at Tidally Influenced Sites

Special streamflow surveys will be conducted in addition to regular sampling surveys. All fixed-network sites that are intertidal will be surveyed during the following flow conditions:

- High Flows in the winter (monthly precipitation typically over three inches).
- Medium Flows in the spring and early fall (monthly precipitation typically two to three inches).
- Low Flows in the summer (monthly precipitation typically one to two inches).

During the flow surveys at the tidegates, the following information will be collected:

- Tide height when the gates open and close.
- Flows measurements during low tide when the gates are open and outflow stage level has reached a minimum.

Flow will be measured one to three times over the course of each gate's discharge period and averaged (if more than one flow was measured). The results for each flow period will be multiplied by the total time the gates are open and discharging to the bay, then divided by the number of days in each period to get average daily flow (cfs) for each low-, medium-, and high-flow periods.

Pump stations

For each pump station, Ecology will determine:

- The percentage of the time the pumps are on and off.
- Changes related to seasonal, tidal, and streamflow in pump station operation.
- The rate of discharge into the bay.

Discharge will be calculated at all pump station outlets using the specifications for each pump (volume of water pumped per time unit) and the amount of time the pump is actively pumping water into the bay.

Figure 28 shows that three different drainage districts are responsible for dikes, drainage, and irrigation in the study area: District 5, District 12, and District 19.

District 5 operates and maintains the pump station and tidegates for Joe Leary Slough. During high flow conditions, water from District 5 is pumped in a channel (not Joe Leary Slough) from a pump station near Bayview-Edison Road to the pump station near the mouth of Joe Leary Slough. The pump station at the mouth of Joe Leary Slough has one 25 horsepower (HP) pump runs at a constant rate to an 18-inch pipe. No electrical records are available. Ecology will need to install a logger on the pump to determine pump time.

District 12 operates and maintains the pump station and tidegates for No Name Slough. The pump station has two pumps: one 25 HP and one 50 HP. The 25 HP pump runs more often. The pumps run at a constant rate. District 12 records the hours of pump time and has offered to share this information with Ecology.

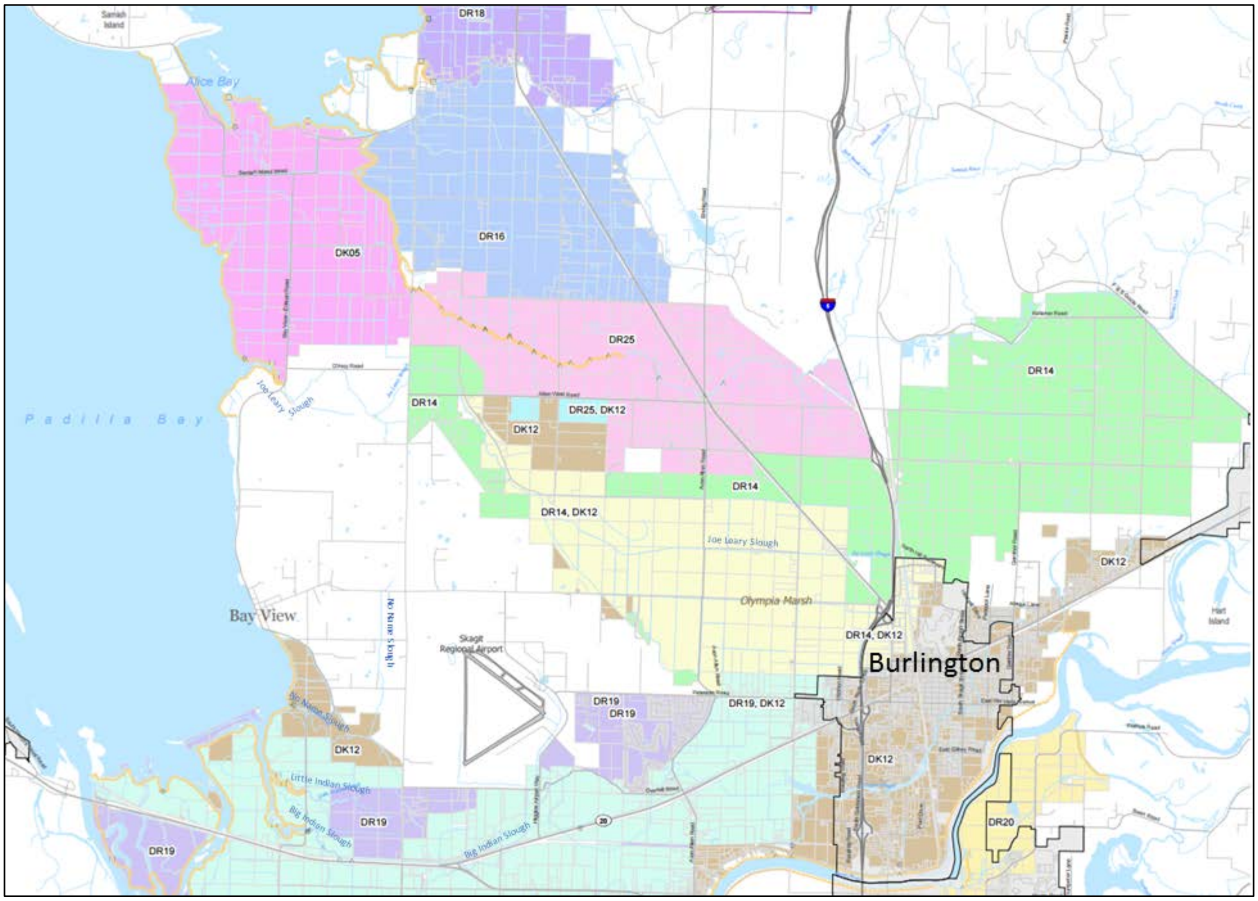

Figure 28. Map of drainage and irrigation districts in the study area.

District 19 operates and maintains the pump station and tidegates for Big Indian Slough. The pump station has two pumps: one 15 HP and one 25 HP. The 15 HP runs more often. The pumps run at a constant rate. District 19 records the hours of pump time and has offered to share this information with Ecology.

Salinity

Because FC are sensitive to saltwater, die-off rates change when they enter marine and estuarine waters. Freshwater stations under tidal influence will be monitored during low tide so FC samples reflect the freshwater input. Ecology will measure specific conductivity at all sites and develop a regression between salinity and conductivity. The freshwater criteria shall be applied at any point where the vertically averaged salinity values are less than or equal to ten parts per thousand.

7.1.2 Sampling location and frequency

Fixed-Network Sites

The fixed-network sites will be sampled twice monthly from April 2016 through April 2017. The locations of proposed fixed-network water quality stations are listed in Table 17 and can be seen in Figure 29. Sites may be removed or added from the sampling plan, depending on access and new information provided during the QAPP review, field observations, and preliminary data analysis. DOH currently samples 2 stations in Padilla Bay on a monthly basis. Ecology will coordinate with the DOH and attempt to sample on the same week as DOH. Stations were selected based on historical site locations and FC results. There are 22 fixed network sites (Figure 20):

- 6 sites for Joe Leary Slough
- 7 sites for No Name Slough
- 3 sites for Little Indian Slough
- 6 sites for Big Indian Slough

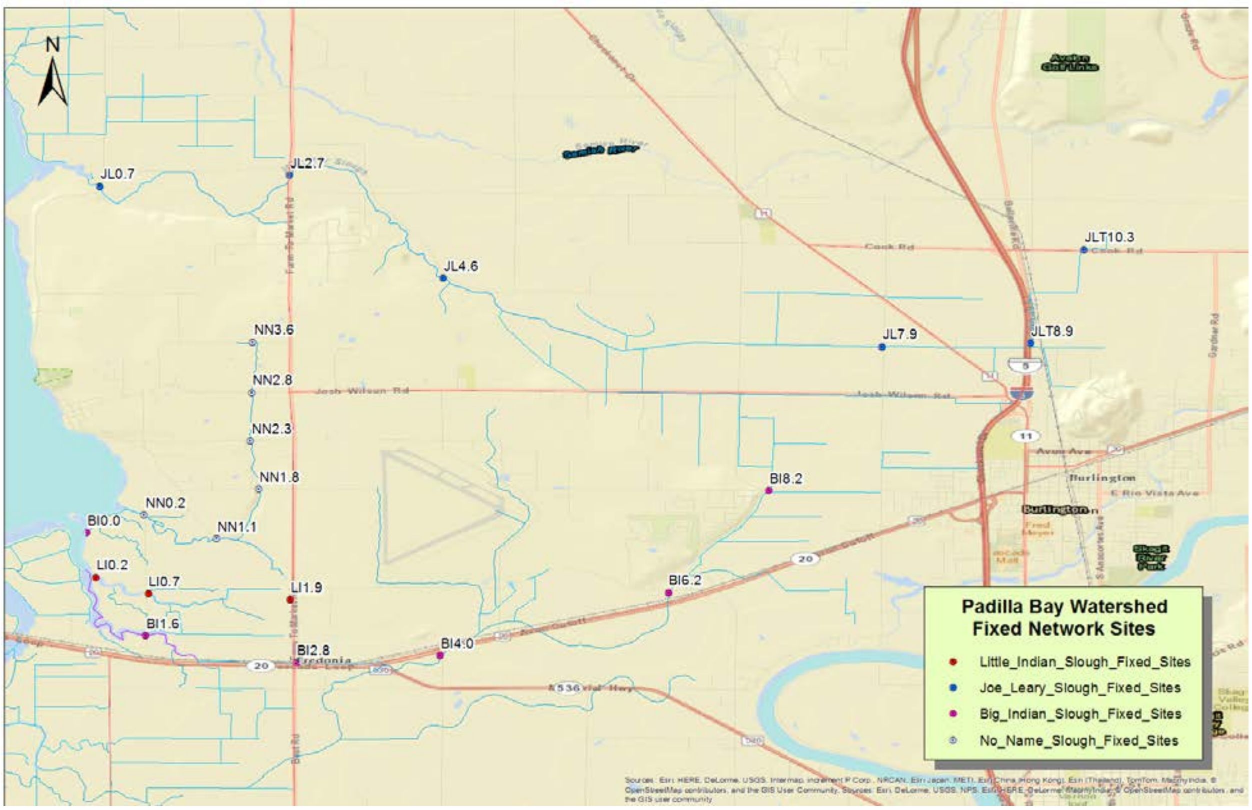

Figure 29. Fixed network sites in the Padilla Bay watershed.

Some of these sites, particularly No Name slough sites, stop flowing during the dry season (Table 17).

Table 17. Fixed network sites.

Site ID	Fixed Network Site Description	Sample Location	Latitude	Longitude
JL0.7	Joe Leary at Bayview-Edison Rd	bridge; intertidal	48.517	-122.473
JL2.7	Joe Leary at FM 237	bridge	48.519	-122.444
JL4.6	Joe Leary at Benson Heights Pl	bridge	48.503	-122.422
JL7.9	Joe Leary at Pulver Rd	bridge	48.493	-122.357
JL9.0	Joe Leary at I-5 at Gear Rd	culvert; intermittent	48.494	-122.335
JL10.3	Joe Leary at Cook Rd	bridge; intermittent	48.508	-122.327
NN0.1	No Name upstream of tidegates and downstream of Bayview-Edison Rd	bridge; intertidal	48.469	-122.466
NN0.2	No Name at Bayview-Edison Rd	culvert; intertidal	48.468	-122.465
NN1.1	No Name at Egbers-Kalso Rd	bridge; intermittent	48.465	-122.455
NN1.8	No Name at Bay View Rd	culvert; intermittent	48.472	-122.447
NN2.3	No Name at Marihugh Rd	culvert; intermittent	48.479	-122.450
NN2.8	No Name at Josh Wilson Rd	culvert; intermittent	48.487	-122.450
NN3.6	No Name at Rector Rd	culvert; intermittent	48.494	-122.450
LI0.2	Little Indian upstream of confluence with Big Indian	intertidal	48.459	-122.473
LI0.7	Little Indian at Bay View-Edison Rd	intertidal	48.465	-122.457
LI1.9	Little Indian at FM 237	culvert; intermittent	48.456	-122.444
BI0.0	Big Indian at mouth	intertidal	48.466	-122.475
BI1.6	Big Indian at Bay View-Edison Rd	bridge; intertidal	48.451	-122.465
BI2.8	Big Indian at FM 237	bridge	48.447	-122.444
BI4.0	Big Indian at Bradshaw Rd	culvert	48.448	-122.422
BI6.2	Big Indian downstream of Ovenell Rd	culvert	48.457	-122.389
BI8.2	Big Indian at Peterson Rd and Avon Allen Rd	culvert	48.473	-122.374

Locations for FC fixed-network sampling sites were selected based on 303(d) listed segments, access, and target locations identified by the Skagit County Water Quality Monitoring Program, Pollution Identification Control, and Stream Team. Ecology will collect bacteria samples and flow measurements from the fixed-network sites a minimum of twice monthly from April 2016 to April 2017. Additional monitoring during storm events (>0.3 inch rain) will occur if insufficient events are not captured in the sampling schedule.

Data from the fixed-network will provide information to complete the following actions:

- Characterize and compare FC concentrations, impacts from stormwater and discharge; provide temperature, DO, pH, and conductivity information.
- Provide data to calculate the FC annual and seasonal geometric mean and 10% of data to compare to the water quality criteria. The schedule plans for 24 sampling visits per site, 10 during the dry season (May to September) and 14 during the wet season (October to April). Some of these sites may not have flow all year.
- Provide reach-specific FC concentration comparisons in the watershed to define areas where FC concentrations increase or decrease. Loads will be estimated using streamflow monitoring.
- Determine if certain land uses affect FC concentrations and relative loads.

Intermittent Sites

The Padilla Bay watershed has a network of ditches and canals that drain streets, agricultural, and residential areas. These ditches flow into sloughs and the bay. Many only flow intermittently. The budget allows for 10 intermittent sites to be sampled once a month. However, it is likely that most samples will be collected at intermittent sites during the wet season.

Many ditches in the Bay View area discharge directly into Padilla Bay (Figure 30, Table 18). These ditches flow after rain events. These sites will be sampled as frequently as the budget allows.

Figure 30. Bay View area sites.

Table 18. Ditches that drain directly into Padilla Bay in the Bay View area.

Site ID	Site Description	Sample Location	Latitude	Longitude
BV1	Culvert on east side of Bayview-Edison Rd; 0.37 mi. North of Persons Rd (MP 4.972)	culvert; intermittent	48.507	-122.482
BV2	Culvert on west side of Bayview-Edison Rd; 0.23 mi. North of Persons Rd (MP 4.834)	culvert; intermittent	48.505	-122.482
BV3	Culvert on east side of Bayview-Edison Rd; 11 ft. South of Persons Rd (MP 4.602)	culvert; intermittent	48.501	-122.482
BV4	Culvert on west side of Bayview-Edison Rd; 69 ft South of Persons Rd (MP 4.591)	culvert; intermittent	48.501	-122.482
BV5	Culvert on east side of Bayview-Edison Rd on SE corner Cemetery Rd (MP 0.003P)	culvert; intermittent	48.499	-122.482
BV6	Culvert on west side of Bayview-Edison Rd; near Padilla Bay Estuary Research Reserve (MP4.099)	culvert; intermittent	48.494	-122.483
BV7	Culvert on east side of Bayview-Edison Rd; 0.16 mi. North of Bay View SP Entrance (MP 3.795)	culvert; intermittent	48.489	-122.481
BV8	Culvert on southeast corner of Bayview-Edison Rd and Farnham St	culvert; intermittent	48.487	-122.480
BV9	Culvert (somewhat buried) north of mailbox 11043	culvert; intermittent	48.486	-122.479
BV10	Culvert on the west side of Bayview-Edison Rd at the end of B Street	intertidal culvert; intermittent	48.485	-122.479
BV11	Culvert on east side of Bayview-Edison Rd; south of public boat ramp	intertidal culvert; intermittent	48.484	-122.479
BV12	Culvert on NE corner Bayview-Edison Rd and Josh Wilson Rd	culvert; intermittent	48.484	-122.478
BV13	Culvert on NW corner of Bayview-Edison Rd and 2nd St	culvert; intermittent	48.481	-122.475
BV14	Culvert on east side of Bayview-Edison Rd at Padilla Bay trailhead (MP 2.983)	culvert; intermittent	48.480	-122.473

The upper reaches of the slough and many tributaries are intermittent. Figure 31 shows the location of 21 intermittent sites that, depending on budget and time, will be sampled monthly to determine whether they contribute to FC and to help track sources. Many of these sites flow only after rain events or during the wet season.

Sites that drain NPDES areas near the Higgins Airport (BIT 4.7 and BIT4.8) will be sampled during high flows after storm events. The pump station (JLT0.07) will be sampled only when the pump is discharging water from the ditch adjacent to Joe Leary slough.

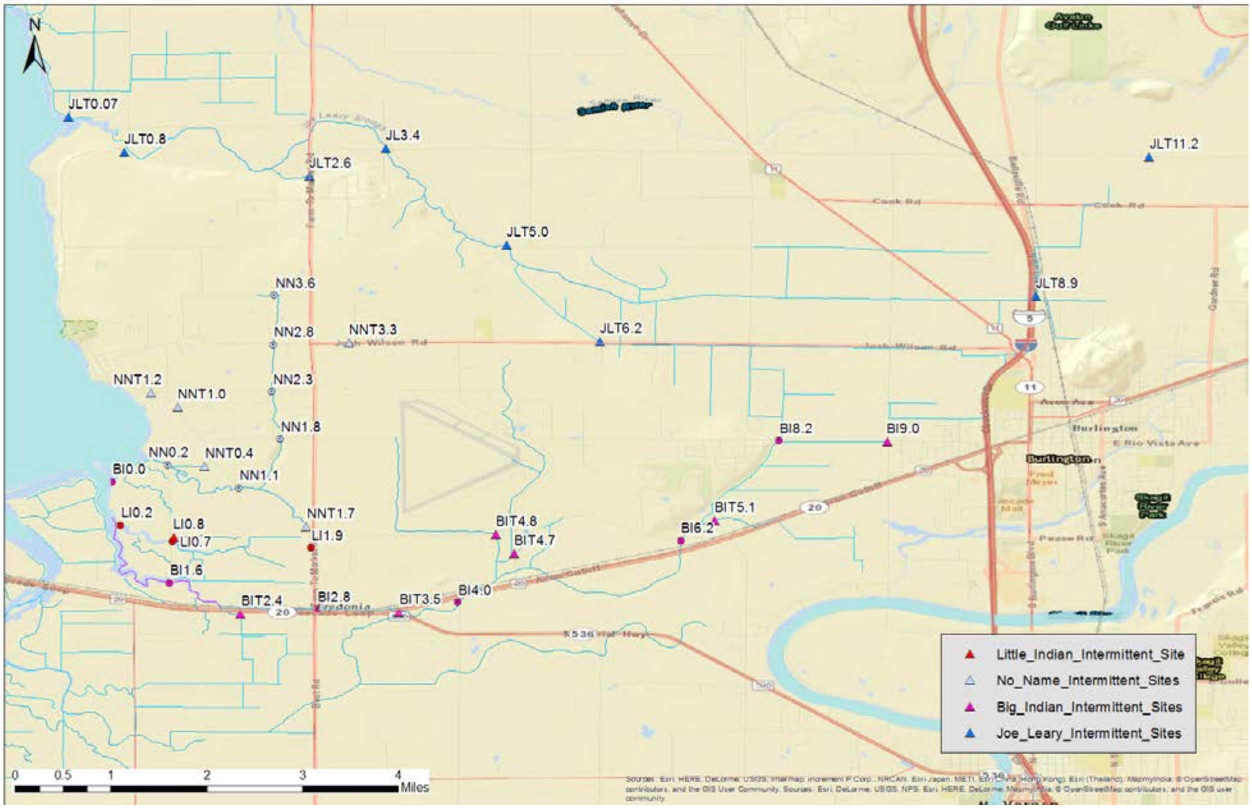

Figure 31. Site locations for intermittent sampling locations on the sloughs and tributaries to the sloughs.

Table 19 is a list of intermittent sites that may be sampled monthly depending on flow. Sites may be eliminated or added, depending on what bacteria data reveal and budget constraints.

Table 19. Sites on tributaries to slough and Padilla Bay.

Site ID	Tributary Site Description	Sample Location	Latitude	Longitude
JLT0.07	Joe Leary at Pump Station	intertidal; high flows only	48.521	-122.481
JLT0.8	Joe Leary Tributary on Leatherwood Ln	culvert; intermittent	48.517	-122.473
JLT2.5	Joe Leary Tributary at FM 237	culvert; intermittent	48.512	-122.445
JL3.4	Joe Leary on Allen West east of T-Loop Rd	culvert	48.516	-122.433
JLT5.0	Joe Leary Tributary/Ditch off Benson Rd	culvert; intermittent	48.501	-122.415
JLT6.2	Joe Leary tributary at Josh Wilson Rd and Jensen Ln	culvert	48.487	-122.401
JLT9.0	Joe Leary Tributary on Gear Rd upstream of I-5 under RR bridge	bridge; intermittent	48.493	-122.333
JL11.2	Joe Leary at Dahlstedt Rd	culvert; intermittent	48.513	-122.315
JLT5.0	Joe Leary Tributary/Ditch off Benson Rd	culvert; intermittent	48.501	-122.415
NNT0.4	Culvert on west side of Bayview-Edison Rd	culvert; intermittent	48.468	-122.460
NNT1.0	Culvert on west side of Bayview-Edison Rd across from Bridgeview Way	culvert; intermittent	48.477	-122.465
NNT1.2	Culvert (flow split) on west side of Bayview-Edison Rd across from Marihugh Rd	culvert; intermittent	48.479	-122.469
NNT1.7	No Name tributary at FM 237	culvert; intermittent	48.459	-122.445
NNT3.3	Culvert on Josh Wilson Rd west of Bay Meadows Ln	culvert; intermittent	48.487	-122.439
LIT0.8	Tributary to Little Indian upstream of tidegates	intertidal	48.465	-122.457
BIT2.4	Big Indian tributary on south side of Highway 20	culvert; intermittent	48.446	-122.455
BIT3.5	Big Indian tributary on west side of FM 536 just south of Highway 20	culvert; intermittent	48.446	-122.431
BIT4.7	Big Indian tributary on west side of Higgins Airport Way between Ovenell Rd and Highway 20	culvert intermittent	48.455	-122.414
BIT4.8	Big Indian tributary on north side of Ovenell Rd; near second trail east of Higgins Airport Way	culvert, intermittent	48.458	-122.417
BIT5.1	Big Indian tributary at Avon Allen	culvert; intermittent	48.460	-122.383
BI9.0	Big Indian at Pulver Rd	culvert; intermittent	48.472	-122.357

Sampling Schedule

The tentative field sampling schedule for each season is listed below (Tables 20 to 23). Some dates will likely change, due to unanticipated circumstances.

Table 20. Proposed temporal distribution of fixed-network bacterial sampling, intermittent site sampling, synoptic storm event sampling, and shoreline surveys in the spring and summer of 2016.

	April Week 3	April Week 5	May Week 2	May Week 3	May Week 4	June Week 2	June Week 3	June Week 4	July Week 3	July Week 4	July Week 5	August Week 2	August Week 4
Season	**Wet**	**Wet**	**Dry**	**Dry**	**Dry**	**Dry**	**Dry**	**Dry**	**Dry**	**Dry**	**Dry**	**Dry**	**Dry**
Fixed Network	1	1	1		1	1		1	1		1	1	1
Intermittent Sites	BV, NN, JL	BV, LI, BI	BV, NN, JL		BV, LI, BI	BV, NN, JL		BV, LI, BI	BV, NN, JL		BV, LI, BI	BV, NN, JL	BV, LI, BI
Synoptic Storm Event				1			1						
Shoreline Survey										1			

Table 21. Proposed temporal distribution of fixed-network bacterial sampling, intermittent site sampling, synoptic storm event sampling, and shoreline surveys in the summer and fall of 2016.

	Sept Week 3	Sept Week 5	Oct Week 2	Oct Week 3	Oct Week 5	Nov Week 1	Nov Week 2	Nov Week 5
Season	**Dry**	**Dry**	**Wet**	**Wet**	**Wet**	**Wet**	**Wet**	**Wet**
Fixed Network	1	1		1	1		1	1
Intermittent Sites	BV and NN	JL, LI, BI		BV and NN	JL, LI, BI		BV and NN	JL, LI, BI
Synoptic Storm Event			1					
Shoreline Survey						1		

Table 22. Proposed temporal distribution of fixed-network bacterial sampling, intermittent site sampling, synoptic storm event sampling, and shoreline surveys in the winter of 2016 and spring of 2017.

	Dec Week 3	Jan Week 2	Jan Week 3	Jan Week 4	Feb Week 2	Feb Week 5
Season	**Wet**	**Wet**	**Wet**	**Wet**	**Wet**	**Wet**
Fixed Network	1	1		1	1	1
Intermittent Sites	JL, LI, BI, BV and NN	BV and NN		JL, LI, BI	BV and NN	JL, LI, BI
Synoptic Storm Event			1			
Shoreline Survey						

Table 23. Proposed temporal distribution and total sampling visits of fixed-network bacterial sampling, intermittent site sampling, synoptic storm event sampling, and shoreline surveys in the spring of 2017.

	March Week 3	March Week 5	April Week 3	**Total**	**Total**	Backup April Week 5 or May Week 1
Season	**Wet**	**Wet**	**Wet**	**Dry**	**Wet**	**Wet or Dry**
Fixed Network	1	1	1	**10**	**14**	1
Intermittent Sites	BV and NN	JL, LI, BI	JL, LI, BI, BV and NN	**12 each sub-basin**	**12 each sub-basin**	JL, LI, BI, BV and NN
Synoptic Storm Event				**2**	**2**	1
Shoreline Survey				**1**	**1**	1

7.1.3 Parameters to be determined

See Section 8.2

7.2 Maps or diagram

See Section 3.1 and Section 7.1.2.

7.3 Assumptions underlying design

This design assumes that:

- A relationship can be developed between stage and discharge in the sloughs.
- The collection of replicates will account for the variability in bacteria concentration.
- The samples will provide sufficient information to be representative and allow the attainment of project goals.

7.4 Relation to objectives and site characteristics

Measuring freshwater discharge into Padilla Bay will be difficult because of the hydrology of the watershed, which will contribute to uncertainty in estimating bacteria load. Measurement of flow will be affected by tides, tidegates, pump stations, access to good flow sites on private property, vegetation, the multitude of ditches and diversions in this agricultural area, and safety issues with measuring discharge in deep, muddy sloughs.

The challenges characterizing bacterial concentrations in this watershed include: scheduling sample collection in tidal areas with tidegates, the multitude of ditches and culverts, comparing the different laboratory methods, scheduling collection and shipping to meet bacteria holding times, and the variability of bacterial results.

7.5 Characteristics of existing data

See Section 3.1.2 in this QAPP.

8.0 Sampling Procedures

8.1 Field measurement and field sampling SOPs

Standard Operating Procedures (SOPs) that will be used for field sampling and field analyses are available on Ecology's QA Website: http://www.ecy.wa.gov/programs/eap/quality.html.
The following SOPs will be used:

- EAP015 Manually Obtaining Surface Water Samples (Joy, 2006)
- EAP023 Standard Operating Procedures for the Collection and Analysis of Dissolved Oxygen (Ward and Mathieu, 2013)
- EAP024 Estimating Streamflow (Kardouni, 2013)
- EAP030 Collection of Fecal Coliform Bacteria Samples in Surface Water (Ward and Mathieu, 2011)
- EAP033 Hydrolab DataSonde® and MiniSonde® Multiprobes (Swanson, 2007)
- EAP075 Measuring Vertically Averaged Salinity in Brackish Waters (Mathieu, 2013)
- EAP091 Turner Designs Cyclops-7 Submersible Optical Brightener Sensors and Precision Measurement Engineering, Inc. Cyclops-7 Loggers (Anderson and Swanson, 2014)
- EAP025 Saltwater Sampling (Bos, 2010)

Freshwater samples will be collected using Ecology's SOPs EAP030 for bacteria and EAP015 grab sampling. A field QC sample will be collected for 20% of all bacteria samples collected. The field QC sample is collected as a duplicate sample either simultaneously (side by side) or sequentially with the duplicate immediately following the initial sample. This sample represents the total variability due to sample collection and laboratory analysis. Samples will be collected in as close to the thalweg as possible, and just under the water's surface in freshwater outflows. A sampling pole or bottle carrier on a rope may be used due to access logistics and to ensure no disturbed sediment is collected.

Field measurements will be taken at all fixed-network and intermittent sampling sites and recorded in a notebook or equivalent electronic field form. Measurements for water temperature, conductivity, pH and dissolved oxygen will be collected using a calibrated YSI Exo or Hydrolab MiniSonde®, following Ecology's SOP EAP033 (Swanson, 2007) and manufacturer's recommendations. A vertical profile of conductivity will be collected at tidally-influenced stations.

Where significant fecal contamination is identified or suspected, OB sensors may be used to help determine the source of the contamination. OBs will be measured following Ecology SOP EAP091.

8.2 Containers, preservation methods, holding times

Table 24 shows the sample containers, preservation, and holding times required to meet the goals and objectives of this project.

Table 24. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity Required	Container	Preservative	Holding Time
FC - MF	Water	250 mL	250 or 500 mL glass/poly autoclaved	Cool to ≤6° C	24 hours
FC – MPN	Water	500 mL	500 mL glass/poly autoclaved	Cool to ≤6° C	24 hours
E. coli	Water	250 mL	250 or 500 mL glass/poly autoclaved	Cool to ≤6° C	24 hours
Enterococci	Water	250 mL	250 or 500 mL glass/poly autoclaved	Cool to ≤6° C	24 hours
TOC	Water	50 mL	125 mL poly	1:1 HCl to pH<2; Cool to ≤ 6° C	28 days
Turbidity	Water	500 mL	500 mL w/m poly	Cool to ≤6° C	48 hours
Conductivity	Water	300 mL	500 mL w/m poly or general chemistry container	Cool to ≤6° C	28 days

8.3 Invasive species evaluation

Field staff will follow EAP's SOP EAP070 on minimizing the spread of invasive species (Parsons, 2012). The Padilla Bay study area is not in an area of extreme concern. Areas of extreme concern have, or may have invasive species like New Zealand mud snails that are particularly hard to clean off 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: http://www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html.

8.4 Equipment decontamination

Not applicable. There is no expectation that a sampler or sampling equipment will come in contact with high levels of contaminants requiring decontamination. Established Ecology procedures will be followed if an unexpected contamination incident occurs.

8.5 Sample ID

Ecology's Manchester Environmental Laboratory (MEL) will provide the field lead with work order numbers for all scheduled sampling dates. The work order number will be combined with a field ID number that is given by the field lead. This combination of work order number and field ID number constitute the sample ID. All sample IDs will be recorded on sample containers and sample tags, in field logs, and in an electronic spreadsheet for tracking purposes.

8.6 Chain-of-custody, if required

Once collected, samples will be stored in coolers in the sampling vehicle. When field staff is not in the sampling vehicle, it will be locked to maintain chain-of-custody. Samples will be shipped by air via Alaska Airlines Air Cargo, Horizon Airlines Goldstreak, FedEx, or UPS or by Greyhound to MEL in order to meet bacteria holding times. Standard chain-of-custody forms and procedures will be followed. Ecology staff will remain with samples to prevent tampering until security inspections have been completed. Then, coolers will be taped shut and shipped to the lab.

8.7 Field log requirements

A field log will be maintained by the field lead and used during each sampling event. The following information will be recorded during each visit to each site:

- Name of location
- Field staff
- Environmental and site conditions
- Date, Time, Sample ID, samples collected, identity of QC samples
- Field measurement results
- Pertinent observations
- Any problems with sampling

Data collected using the OB sensor and/or logger will be recorded electronically. However, a separate log sheet will be maintained for each location that the OB sensor is used. If the OB sensor is being used to collect real time data the following information will be recorded:

- Name of location
- Field staff
- Environmental conditions
- Date, start and stop time
- Location of deployment (logger only)
- Description of area covered
- Pertinent observations
- Any problems with the OB sensor

8.8 Other activities

Any field staff new to the type of sampling being conducted for this study will be trained by senior field staff or the project manager, following relevant Ecology SOPs. Any maintenance needed for the YSI Exo, Turner Designs Cyclops 7 or Hydrolab MiniSonde® will be performed by trained field staff, following Ecology's SOP EAP033 and manufacturer instructions and recommendations. Before sampling begins, staff will send MEL a schedule of sampling events. This will allow the lab to plan for the arrival of samples. All samples will be collected between Sunday and Wednesday so that holding times will be met for all fecal samples. The lab will be notified immediately if there will be any deviations from the scheduled date of sampling. To ensure that the appropriate number and type of required sample containers are available, the field lead will work with the laboratory courier to develop a schedule for delivery of sampling containers.

9.0 Measurement Methods

9.1 Field procedures table/field analysis table

Table 25 shows the field and laboratory measurement methods required to meet the goals and objective of this project.

Table 25. Measurement methods (field and laboratory).

Analyte	Sample Matrix	# of Samples	Expected Range of Results	Method	Method Detection Limit
Field Procedures					
Flow Measurements	Water	22 sites twice a month; 5 sites are tidal (3 times per year)	<0.1-10 cfs	SOP EAP024	0.01 cfs
Optical Brighteners[1]	Water	As needed[1]	0-500 ppb	SOP EAP091	0.1 ppb
Specific Conductance	Water	27 sites every two weeks (Fixed-Network and Intermittent Sites)	1-31,000 µS/cm	SOP EAP033	0.1 µS/cm
Laboratory Procedures					
Fecal Coliform – MF	Water	approximately 27 sites twice monthly; plus storm and shoreline surveys	1-10,000 cfu/100 mL	SM 9222 D	1 cfu/100 mL
Fecal Coliform – MPN	Water	3 sites once a month	1-15,000 cfu/100 mL	SM 9221 E	1 cfu/100 mL
E. coli	Water	once monthly at 11 sites	1-10,000 cfu/100 mL	SM 9222 G1	1 cfu/100 mL
Enterococci	Water	once monthly at 8 sites	1-1200 cfu/100 mL	ASTM D 6503-99	1 cfu/100 mL
Total Organic Carbon[2]	Water	As needed[2]	1-10 mg/L	SM 5310 B	1.0 mg/L
Turbidity	Water	once monthly at 8 sites	0-1000 NTU	SM 2130 B	0.5 NTU
Conductivity	Water	3 sites twice a month	1-31,000 µS/cm	SM 2510B	0.1 µS/cm

[1]Optical brightener measurements will be taken only in areas where consistently high FC results are found.
[2]Total organic carbon (TOC) samples will be collected in conjunction with OB measurements only when TOC is suspected to be above high (>20 mg/L).

9.2 Lab procedures table

See Section 9.1.

9.3 Sample preparation method(s)

Winkler samples will be prepared and processed according to EAP 023 (Ward and Mathieu, 2013). Collection and preservation of samples that will be analyzed at the laboratory will be prepared according to the MEL *Lab User's Manual* (MEL, 2008).

9.4 Special method requirements

Not applicable.

9.5 Lab(s) accredited for method(s)

All bacterial and chemical analysis will be performed at MEL, which is accredited for all methods.

10.0 Quality Control Procedures

10.1 Table of field and lab quality control required

Table 26 shows the quality control (QC) requirements for this project.

Table 26. Quality control samples, types, and frequency.

Parameter	Field		Laboratory			
	Blanks	Replicates	Check Standards	Method Blanks	Analytical Duplicates	Matrix Spikes
Fecal Coliform – MF	NA	20%	NA	1/batch	1/20 samples	NA
Fecal Coliform – MPN	NA	20%	NA	1/batch	NA	NA
E. coli	NA	20%	NA	1/batch	1/20 samples	NA
Enterococci	NA	20%	NA	1/batch	1/20 samples	NA
Total Organic Carbon	10%	20%	1/batch	1/batch	1/batch	1/batch
Turbidity	5%	20%	1/batch	1/batch	1/batch	NA
Conductivity	5%	20%	1/batch	1/batch	1/batch	NA

See Section 6.2 for a description of field and lab QC.

10.2 Corrective action processes

Total variation for field sampling and laboratory analysis will be assessed by collecting replicate samples. Bacteria samples tend to have a high relative standard deviation (RSD) between replicates compared to other water quality parameters. Bacteria sample precision will be assessed by collecting replicates for approximately 20% of samples in each survey. Total organic carbon (TOC) and turbidity sample precision will be assessed by collecting replicates for approximately 10% of samples in each survey. 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.

All samples will be analyzed at MEL. The laboratory's measurement quality objectives and QC procedures are documented in the MEL *Lab User's Manual* (MEL, 2008). MEL will follow standard QC procedures (MEL, 2008). Field sampling and measurements will follow QC protocols described in Ecology's standard operating procedures. 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. 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 as estimates with a J qualifier code. MEL accepts samples Monday through Friday, which means Ecology can sample Sunday through Thursday.

Minor adjustments to the field plan (not changing objectives, methods, or costs) will be noted in the final report. Major changes in the project will be addressed in a QAPP Addendum that will be completed following standard procedures.

11.0 Data Management Procedures

11.1 Data recording/reporting requirements

Staff will record all field data in a field notebook or an equivalent electronic collection platform. Before leaving each site, staff will check field notebooks or electronic data forms for missing or improbable measurements. Staff will enter field-generated data into Microsoft (MS) Excel® spreadsheets (Microsoft, 2013) as soon as practical after they return from the field. If data were collected electronically, data will be backed up on Ecology servers when staff returns from the field. The field assistant will check data entry against the field notebook data for errors and omissions. The field assistant will notify the field lead or project manager of missing or unusual data.

Lab results will be checked for missing and/or improbable data. MEL will send data through Ecology's Laboratory Information Management System (LIMS). The field lead will check MEL's data for omissions against the "Request for Analysis" forms. The project manager will review data requiring additional qualifiers. Summary statistics for all data will be generated using MS Excel®.

11.2 Laboratory data package requirements

Laboratory-generated data reduction, review, and reporting will follow the procedures outlined in the MEL *Lab User's Manual* (MEL, 2008). Variability in lab duplicates will be quantified using the procedures outlined in the *User's 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.

11.3 Electronic transfer requirements

See 11.2.

11.4 Acceptance criteria for existing data

All third-party data used in this study will be assessed for data quality to understand data uncertainty when used in the TMDL study, and to ensure that data used in the study is in compliance with Washington's Credible Data law (RCW 90.48.580 http://app.leg.wa.gov/rcw/default.aspx?cite=90.48.580) and Ecology's credible data policy (WQP Policy 1-11 http://www.ecy.wa.gov/programs/wq/qa/wqp01-11-ch2_final090506.pdf).

11.5 EIM/STORET data upload procedures

All FC, total suspended solids (TSS), TOC, turbidity, specific conductance, dissolved oxygen, temperature, and pH data will be entered into EIM, following all existing Ecology business rules and the EIM User's Manual for loading, data quality checks, and editing.

Department of Ecology is a participant in the Water Quality Exchange network. The timeframe to upload data collected for this work will be part of future data exchange network updates from Ecology's Information Management System.

12.0 Audits and Reports

12.1 Number, frequency, type, and schedule of audits

Ecology may perform an audit of field procedures. If sufficient QA resources are not available for a field audit, a field consistency review by another experienced EAP field staff will be conducted during the period of this project. The aim of the field consistency review is to improve field work consistency, improve adherence to SOPs, provide a forum for sharing innovations, and strengthen our data QA program.

12.2 Responsible personnel

See Section 12.1.

12.3 Frequency and distribution of report

Throughout the course of the study, the project manager or principal investigator will electronically send bacteria sample results of over 100 cfu/100 mL for freshwater and 14 cfu/100 mL for marine samples to all interested parties within one week of laboratory analysis. A final report will be published according to the project schedule in Section 5.4.

12.4 Responsibility for reports

See Section 5.4 Table 13.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

The field lead will verify initial field data before leaving each site. This process involves checking the data sheet for omissions or outliers. If measurement data are missing or a measurement is determined to be an outlier, the measurement will be repeated.

After each sampling week, the field lead/assistant will compare all field data to determine compliance with MQOs. The field lead/assistant will note values that are out of compliance with the MQOs and will notify the project manager. At the conclusion of the study, the field lead will compile a summary of any out-of-compliance values and provide it to the project manager for a decision on usability.

13.2 Lab data verification

MEL staff will perform the laboratory verification following standard laboratory practices. After the laboratory verification, project staff will perform a secondary verification of each data package. This secondary verification will entail a detailed review of all parts of the laboratory data package with special attention to laboratory QC results. The project manager will resolve any discovered issues.

Field measurement data that was verified by the project manager will be verified by a different Ecology staff member.

After data entry and data verification tasks are completed, all field, laboratory, and flow data will be entered into the EIM system. EIM data will be independently reviewed by another staff member for errors at an initial 10% frequency. If significant entry errors are discovered, a more intensive review will be undertaken.

13.3 Validation requirements, if necessary

No independent, third party data validation is required for bacteria data.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining whether project objectives have been met

After all laboratory and field data are verified, the project manager will thoroughly examine the data package, using statistics and professional judgment, to determine if MQOs have been met. The project manager will examine the entire data package to determine if all the criteria for MQOs, completeness, representativeness, and comparability have been met. If the criteria have not been met, the project manager will decide if affected data should be qualified or rejected based upon the decision criteria from the QAPP. The project manager will decide how any qualified data will be used in the technical analysis, in compliance with the Credible Data law and policy.

14.2 Data analysis and presentation methods

Bacteria concentration targets for streams in the Padilla Bay watershed will be based on an analysis of FC data collected during the study period. Excel® spreadsheets will be used to evaluate the data, including statistical analyses and plots.

Loading Capacity

EPA recommends that all TMDLs and associated load and wasteload allocations be expressed in terms of daily time increments. In addition, TMDL submissions may include alternative, non-daily pollutant load expressions in order to facilitate implementation of the applicable water quality standards, account for seasonal variations, and include a margin of safety. Washington State bacteria TMDLs use a combination of loading (counts per day), statistical concentration targets, and percent (%) reductions to define loading capacities. However, the statistical concentration targets serve as a surrogate measure that is more appropriate for comparison with standards, compliance, and implementation. This is because count-per-time units (loads) do not adequately define periods of FC criteria violations.

Bacteria sources are quite variable and different sources can cause water quality violations under different conditions (e.g., poor dilution of contaminated sources during low-streamflow conditions or increased loading during runoff events). Comparisons of loads along a stream, or between seasons at a site, can be instructive for identifying changes in FC source intensity, and for evaluating impacts to water bodies. However, concentrations and percent reductions are the most practical for identifying trends and tracking implementation progress.

The statistical concentration targets are referenced in the Washington State FC criteria and provide a better measure of loading capacity during the dry and wet seasons. The Padilla Bay watershed bacteria loading capacities will be subjected to the applicable two statistics in the state FC criteria (i.e., the geometric mean and the value not to be exceeded by more than 10% of the samples) as applied to freshwater. The 90th percentile value of samples is used in TMDL evaluations for the latter criterion statistic.

Statistical Rollback Method

The statistical rollback method (Ott, 1995) will be used to establish FC reduction targets for stream segments. The rollback method simply compares monitoring data to standards, and the difference is the percentage change needed to meet the standards.

The method has been applied by Ecology in other bacteria TMDL evaluations (Cusimano and Giglio, 1995; Pelletier and Seiders, 2000; Joy, 2000; Coots, 2002; Joy and Swanson, 2005; Swanson, 2009).

Ideally, at least 20 samples taken throughout the year are needed from a broad range of hydrologic conditions to determine an annual FC distribution. If sources of bacteria vary significantly by season and create distinct critical conditions, seasonal targets may be required. Fewer data provide less confidence in bacteria reduction targets, but the rollback method is robust enough to provide pollutant allocations and targets for planning implementation measures using smaller data sets. Compliance with the most restrictive of the dual bacteria standard criteria determines the bacteria reduction needed at a stream sampling site.

The rollback method is applied as follows:

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

The rolled-back geometric mean or 90th percentile FC value then becomes the recommended *target* FC value for the site. The term *target* is used to distinguish these estimated numbers from the actual water quality criteria. The degree to which the distribution of FC counts is *rolled-back* to the target value represents the estimated percent of FC reduction required to meet the FC water quality criteria and *Extraordinary Primary Contact Recreation* water quality standards.

The TMDL targets for bacteria are only in place to assist water quality managers in assessing the progress toward compliance with the bacteria water quality criteria. Compliance is ultimately measured as meeting both parts of the water quality standards criteria. Any water body with FC TMDL targets is expected to: (1) meet both the applicable geometric mean and "not more than 10% of the samples" criteria, and (2) protect designated uses for the category.

Analysis of Distribution

The Shapiro-Wilk test will be used to determine whether FC data are normally distributed. The Shapiro-Wilk test, which is one of the most powerful tests available for detecting departures from a hypothesized normal distribution for data sets less than or equal to 50. A rejection of the null hypothesis indicates that the distribution of the data is significantly different than that of a normal distribution.

The null-hypothesis of the Shapiro-Wilk Normality Test is that the population is normally distributed. The null hypothesis is rejected if the *p*-value is less than the chosen alpha level (0.05). If the *p*-value is less than the chosen alpha level, the data are not normally distributed. If the *p*-value is greater than 0.05, the null hypothesis that the data came from a normally distributed population cannot be rejected. Because the test is biased by sample size, a Q–Q plot is required for verification in addition to the test.

All data will be $\log_{10}$ transformed before test unless otherwise stated.

H_0 = data come from a normal distribution
H_a = data do not come from a normal distribution

If the p-value is below the significance threshold (typically 0.05), then the null hypothesis is rejected and the alternative hypothesis is accepted.

Wilcoxon Mann Whitney Test

Ecology will use the Wilcoxon Mann Whitney test to determine if there is a significant difference between FC concentrations in dry and wet seasons. It is a non-parametric test for independent samples. The Wilcoxon Mann Whitney test is used to determine if two independent samples of observations are drawn from the same distribution. The test uses the relative position of the data in a rank ordering.

- It must be reasonable to regard the data as a random sample from their respective populations.
- Observations within each sample must be independent of one another.
- The two samples must be independent of one another.

14.3 Treatment of non-detects

Any non-detects will be included in the study analysis. To do this, the non-detect will be replaced by the reporting limit.

14.4 Sampling design evaluation

The project manager will decide whether the data package meets the MQOs, criteria for completeness, representativeness, and comparability, and whether meaningful conclusions (with enough statistical power) can be drawn from summary statistics. If so, the sampling design will be considered effective.

14.5 Documentation of assessment

In the technical report, the project manager will include a summary of the data quality assessment findings. This summary is usually included in the data quality section of reports. The final report will also provide the results of the TMDL analysis, an analysis of TMDL uncertainty, and the margin of safety.

15.0 References

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16.0 Appendices

Appendix A. Washington Department of Health – Status and Trends in FC Pollution at Padilla Bay

Table A-1 gives a summary of marine FC data for station 232 and 324 from 2007 to 2010. An analysis of the marine FC data for the area shows a correlation between seasonal data collection and dramatic improvement in the overall statistical evaluation when seasonal data are removed. Table A-2 summarizes the geometric mean values calculated at both marine water stations by month. Approved classifications require a geometric mean value of 14 FC/100 mL or less based on a minimum of the last 30 marine water samples. This data shows higher FC results in the marine water during the higher rainfall months (November, December, and January).

Table A-1. Summary of marine FC data (n=30) for stations 323 and 324 for 2007 to 2010.

Station	Classification	Date Range	Data Range (FC/100 mL)	Geometric Mean (FC/100 mL)	Estimated 90th Percentile (FC/100 mL)
323	Restricted	6/12/2007 – 6/23/2010	<1.8 – 240	5.4	33
324	Restricted	5/15/2007 – 6/23/2010	<1.8 – 240	6.1	46

Table A-2. FC Geometric Mean value for Padilla Bay stations 323 and 324 by month (May 2006 to June 2010).

The bold values exceed the 14 FC/100 mL or less approved standard (based on a minimum of 30 samples). The value in parentheses (n) = number of samples used to calculate geometric mean.

Month	Marine Water Station	
	323	324
January	**26.4 (3)**	**17.3 (3)**
February	2.3 (4)	4.5 (4)
March	3.7 (3)	1.8 (3)
April	5.6 (3)	2.4 (3)
May	7.2 (3)	5.5 (3)
June	1.8 (4)	3.8 (4)
July	2.6 (3)	3.0 (3)
August	5.9 (3)	8.9 (3)
September	2.8 (4)	1.8 (3)
October	2.9 (4)	2.8 (4)
November	**22.9 (4)**	**30.1 (4)**
December	7.9 (5)	**15.0 (5)**

In 2010, the DOH classified the Restricted portion of the Padilla Bay shellfish growing area as Conditionally Approved for the commercial harvesting of shellfish based on the pollution source information available and the marine water quality data at the existing stations. A thorough evaluation of the existing marine water data showed a seasonal impact to this area (Tables A-3 to A-6 and Figures A-1 to A-7). The area is managed by closing commercial shellfish harvesting during the months of November, December, and January each year. The area remains Open during the remaining months.

Table A-3. Summary of marine FC data collected during the months with the greatest marine water impact.

Station	Classification	Seasonal (November, December, & January)			
		n	Data Range (FC/100 mL)	Geometric Mean (FC/100 mL)	Est. 90th Percentile (FC/100 mL)
323	Restricted	12	<1.8 – 240	15	116
324	Restricted	12	<1.8 – 170	20	150

Table A-4. Summary of marine FC data based on seasonal closure, eliminating data collected during November, December, and January.

Station	Classification	Date Range	Data Range (FC/100 mL)	Geometric Mean (FC/100 mL)	Est. 90th Percentile (FC/100 mL)
323	Restricted	6/22/06 – 6/23/10	<1.8 – 110	3	13
324	Restricted	5/25/06 – 6/23/10	<1.8 – 240	3	15

Table A-5. Summary of marine FC data for November to January for 2007 to 2013.

Date Range	Station	n	Range (FC/100 mL)	Geometric Mean (FC/100 mL)	Est. 90th Percentile (FC/100 mL)
1/25/2007 – 12/31/2013	323	14	1.7-240	12.77	100.53
1/25/2007 – 12/31/2014	324	14	1.7-170	19.80	162.57

Table A-6. Summary of marine FC data for February to October for 2008 to 2013.

Date Range	Station	n	Range (FC/100 mL)	Geometric Mean (FC/100 mL)	Est. 90th Percentile (FC/100 mL)
2/19/2008 – 12/31/2013	323	32	1.7-110	2.6	8.7
2/19/2008 – 12/31/2013	324	32	1.7-49	2.3	5.5

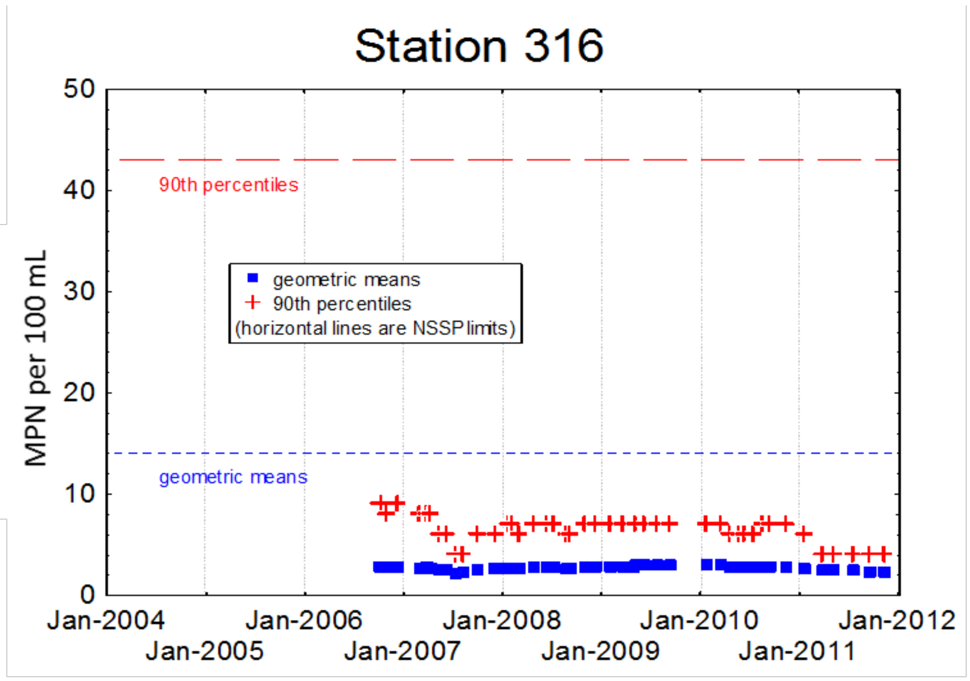

Figure A-1. Summary of marine FC data at DOH station 316, where the trend is decreasing FC contamination.

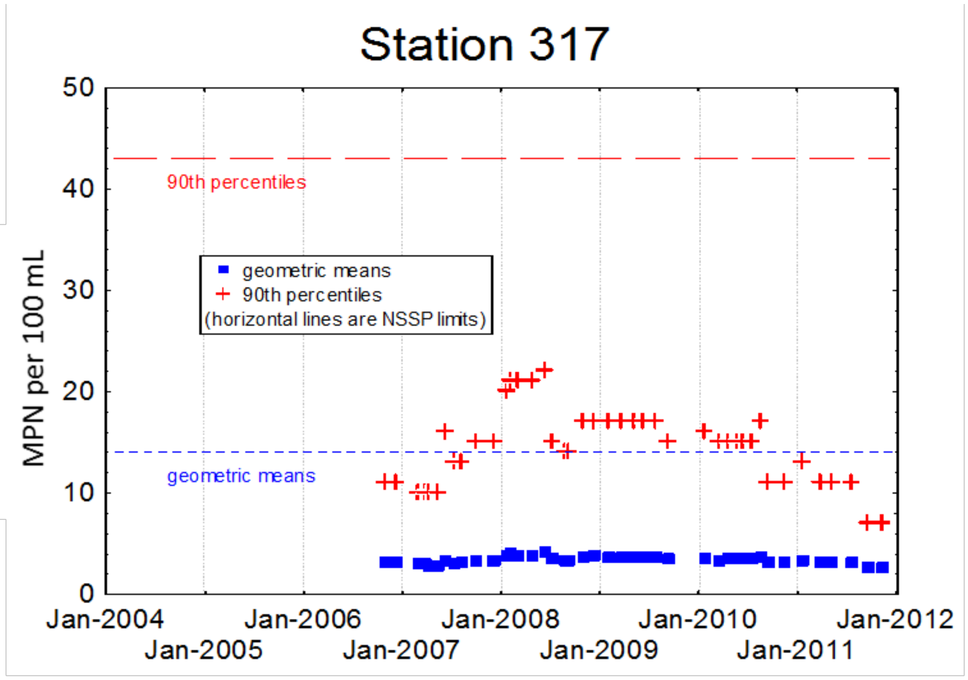

Figure A-2. Summary of marine FC data at DOH station 317, where there is no trend of increasing or decreasing FC contamination.

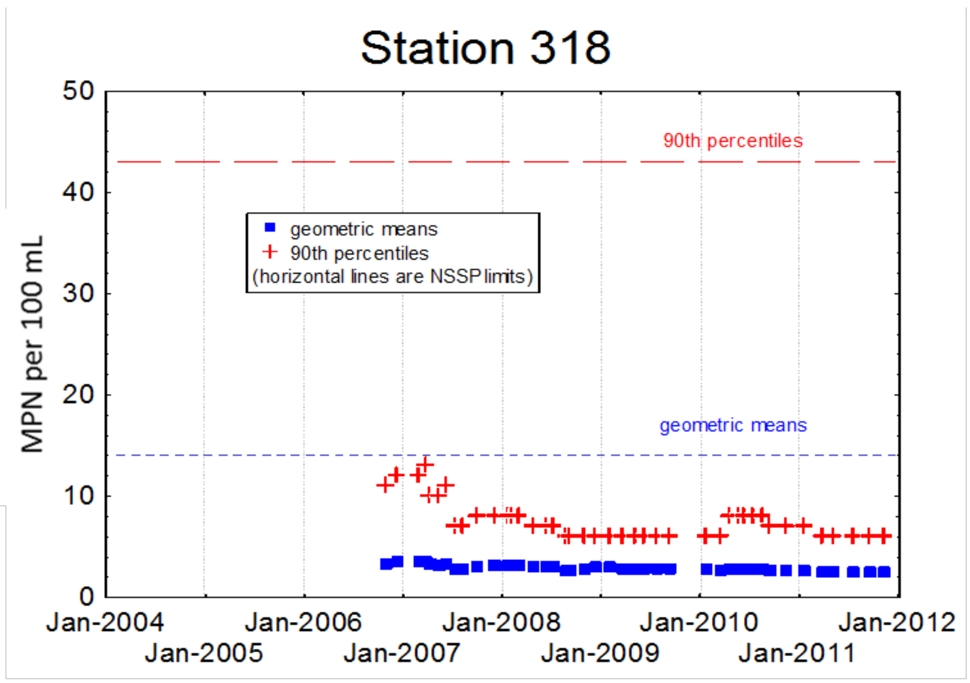

Figure A-3. Summary of marine FC data at DOH station 318, where there is a trend of decreasing FC contamination.

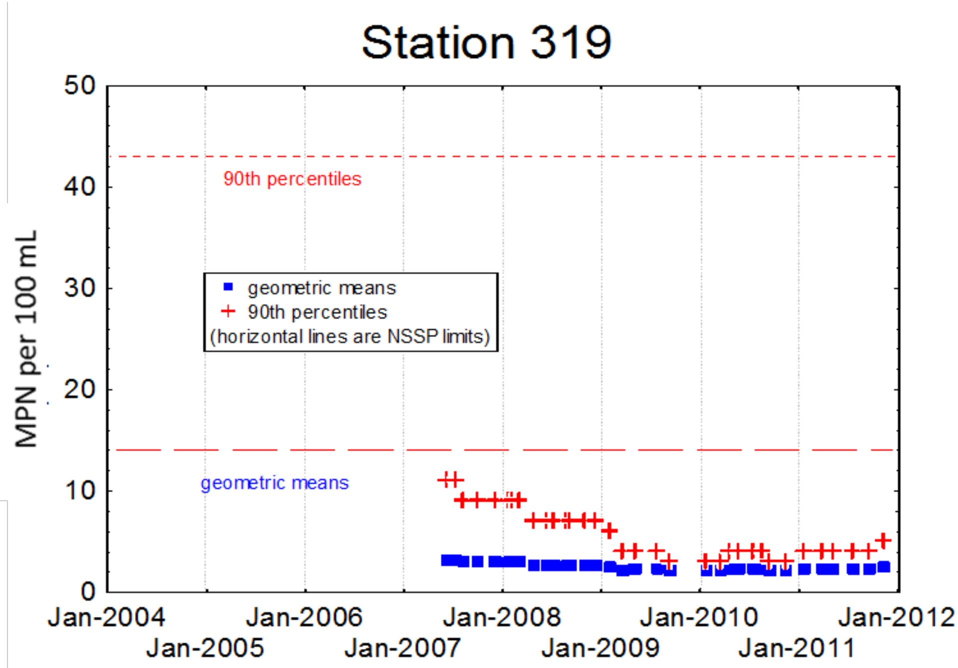

Figure A-4. Summary of marine FC data at DOH station 319, where there is a trend of decreasing FC contamination.

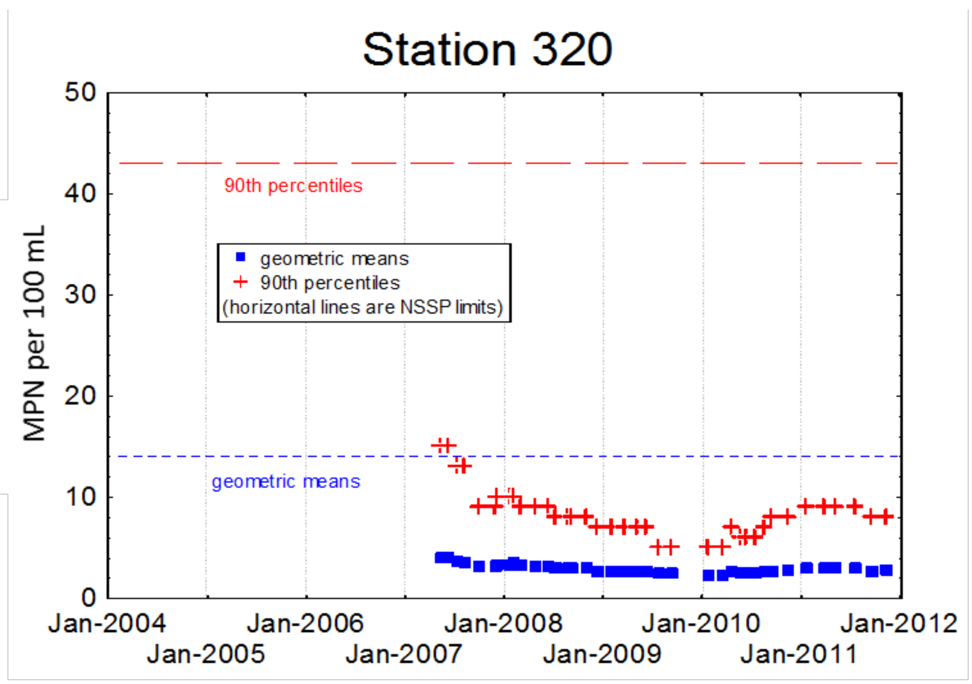

Figure A-5. Summary of marine FC data at DOH station 320, where there is a trend of decreasing FC contamination.

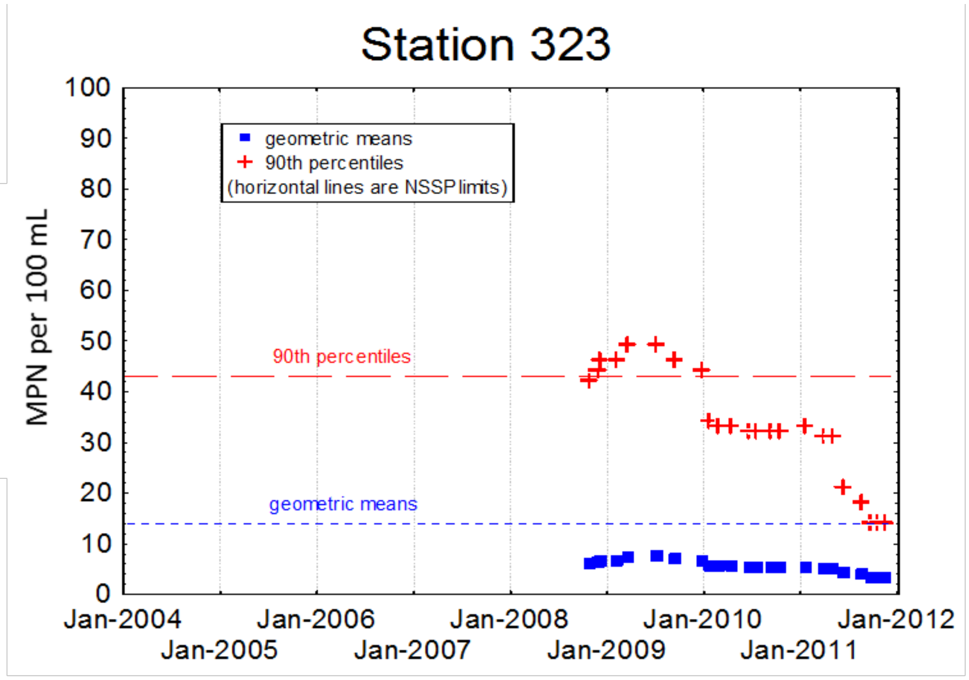

Figure A-6. Summary of marine FC data at DOH station 323, where there is a trend of decreasing FC contamination.

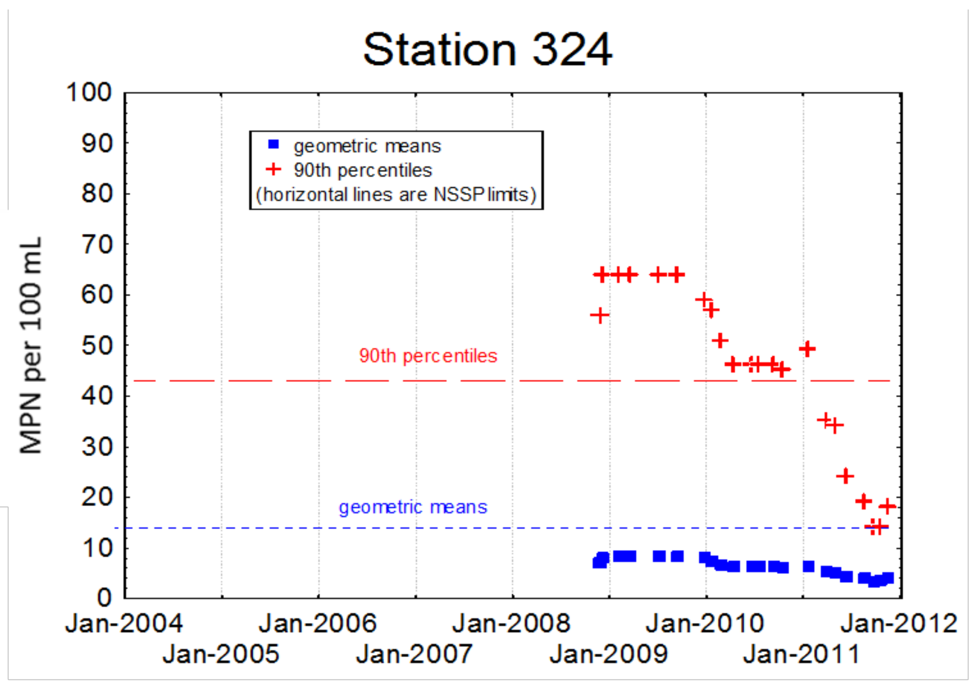

Figure A-7. Summary of marine FC data at DOH station 324, where the trend is decreasing FC contamination.

Appendix B. Washington Department of Ecology BEACH Program

Figure B-1 shows BEACH sampling locations at Bay View State Park.

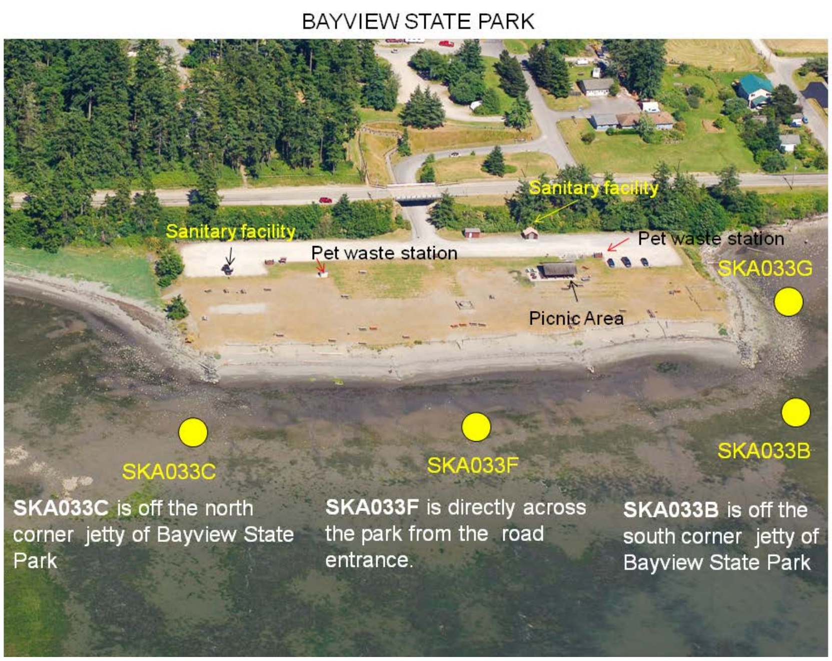

Figure B-1. BEACH sampling locations at Bay View State Park.

Figure B-2 shows BEACH sampling locations near the public boat ramp in Bay View.

Figure B-2. BEACH sampling locations at Bay View boat launch.

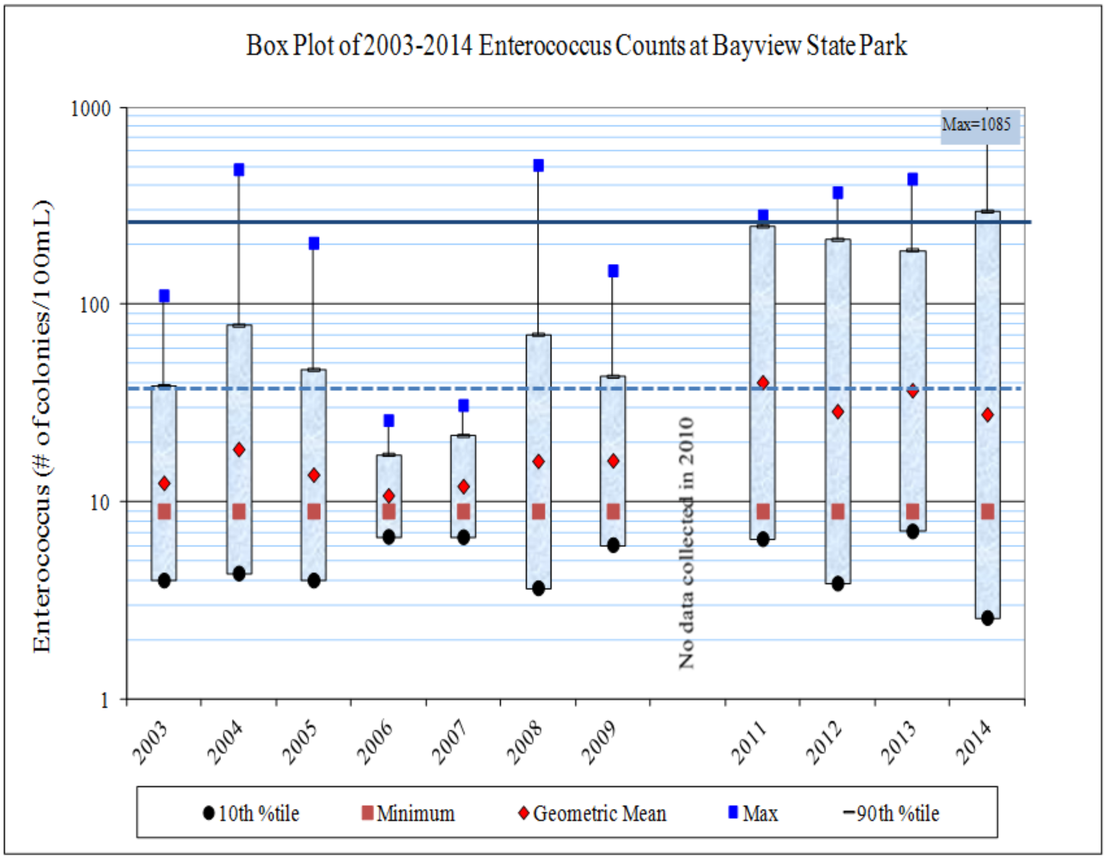

Figure B-3. BEACH Program yearly enterococcus data (log transformed) for Memorial Day to Labor Day swim seasons 2003 to 2014.

Dashed line represents geometric mean criteria of 35 cfu/100 mL.
Bold line represents 90th percentile criteria of 276 cfu/100 mL.

Appendix C. Skagit Stream Team

Table C-1 lists Skagit Stream Team monitoring sites on Joe Leary Slough.

Table C-1. Skagit Stream Team sites on Joe Leary Slough.

Site Name	Location Description	Coordinates
JL1	Dahlstedt Road	N48°30’53.35 W122°19’2.46
JL2	Hwy 99	N48°29’35.37 W122°20’6.61
JL3	Wilson Rd and Avon-Allen Rd.	N48°29’11.33 W122°22’41.96
JL4	Tide Gate	N48°31’4.90 W122°28’27.87

Figure C-1 shows the locations of Skagit Stream Team monitoring sites on Joe Leary Slough.

Figure C-1. Skagit Stream Team sites on Joe Leary Slough.

Table C-2 lists Skagit Stream Team monitoring sites on No Name Slough.

Table C-2. Skagit Stream Team sites on No Name Slough.

Site Name	Location Description	Coordinates
NN1	Marihugh Road Culvert	N48º17’53. W122º17’31
NN2	Bay View Road Ravine	N48º18’121 W122º17’41
NN3	Egber’s Field Bridge	N48º18’30.W122º17’53
NN4	Field Culvert, Bay View-Edison Road	N48º19’11W122º19’47

Figure C-2 shows the locations of Skagit Stream Team monitoring sites on No Name Slough.

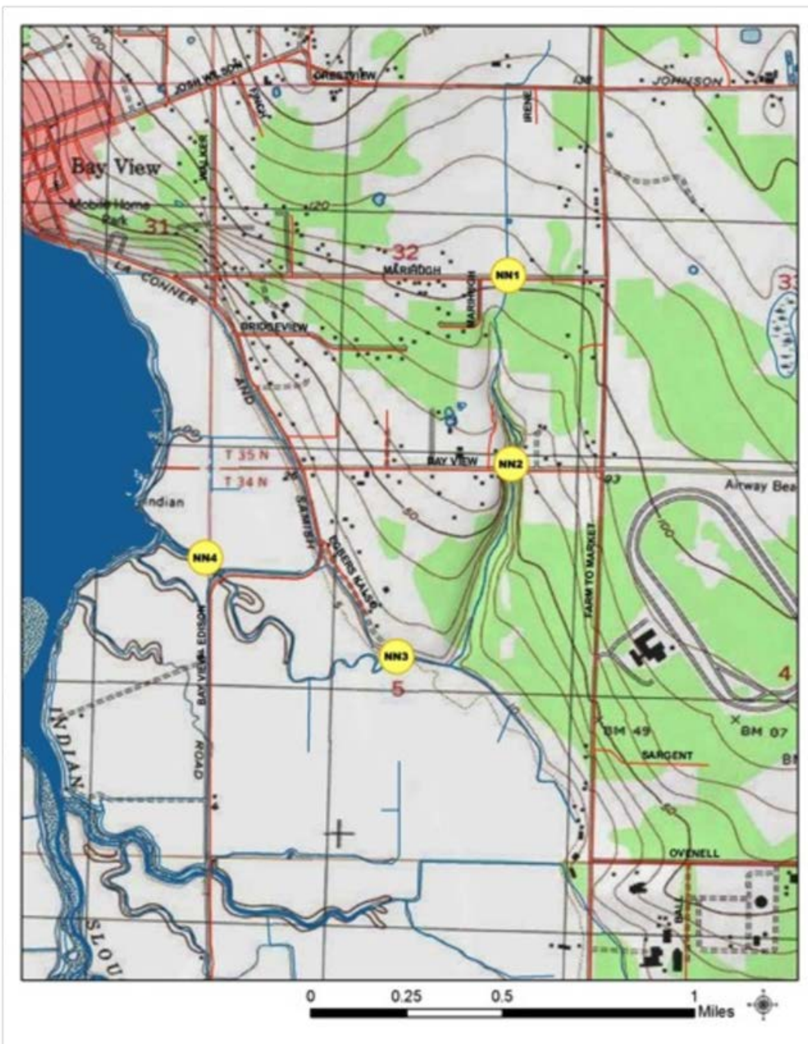

Figure C-2. Skagit Stream Team sites on No Name Slough.

Table C-3 lists Skagit Stream Team monitoring sites in the Bay View watershed.

Table C-3. Skagit Stream Team sites in the Bay View drainage.

Site Name	Location Description	Coordinates
BV1	Wilson Road and Walker Road	N48°29’11.94 W122°27’58.92
BV2	Wilson Road and C Street	N48°29’6.3 W122°28’19.26
BV3	Culvert at Boat Launch	N48°29’4.02 W122°28’43.2
BV4	Beach at Bay View State Park	N48°29’13.02 W122°28’53.04

Figure C-3 shows the locations of Skagit Stream Team monitoring sites in the Bay View watershed.

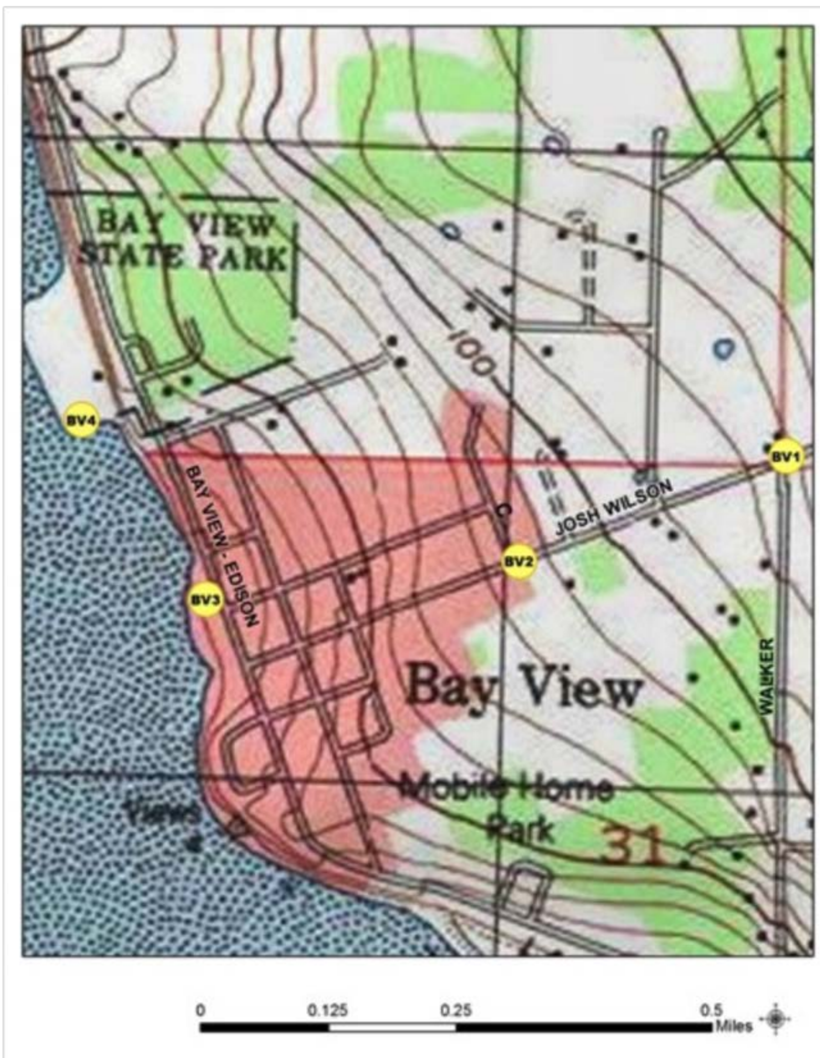

Figure C-3. Skagit Stream Team sites in the Bay View drainage.

Figures C-4 to C-6 show the annual geometric mean calculated for each site from 2008 to 2014.

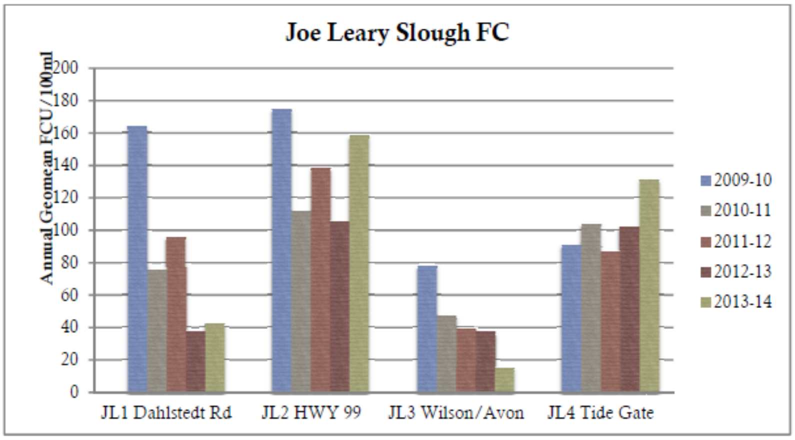

Figure C-4. FC annual geometric mean for Joe Leary Slough from 2009 to 2014.

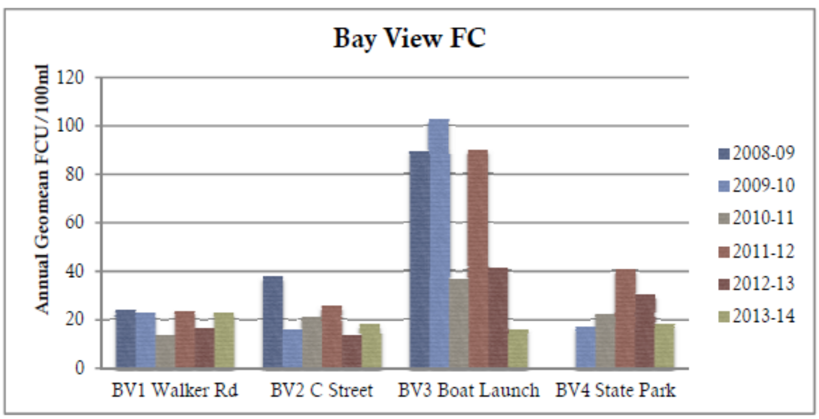

Figure C-5. FC annual geometric mean at Bay View drainage from 2008 to 2014.

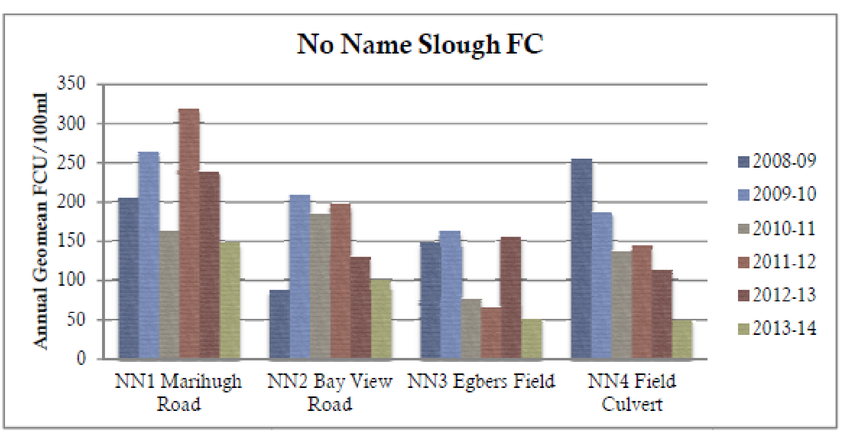

Figure C-6. FC annual geometric mean (cfu/100 mL) at No Name Slough from 2008 to 2014.

Appendix D. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

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.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

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

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 bacteria (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 are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100 mL).

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

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

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

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

Municipal separate storm sewer systems (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, manmade channels, or storm drains): (1) owned or operated by a state, city, town, borough, county, parish, district, association, or other public body having jurisdiction over disposal of wastes, stormwater, or other wastes and (2) designed or used for collecting or conveying stormwater; (3) which is not a combined sewer; and (4) which is not part of a Publicly Owned Treatment Works (POTW) as defined in the Code of Federal Regulations at 40 CFR 122.2.

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.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

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

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

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 where more than 5 acres of land have been cleared.

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.

Reach: A specific portion or segment of a stream.

Riparian: Relating to the banks along a natural course of water.

Salmonid: Fish that belong to the family *Salmonidae*. Any species of salmon, trout, or char.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

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.

Streamflow: Discharge of water in a surface stream (river or creek).

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.

Thalweg: The deepest and fastest moving portion of a stream.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (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.

Total suspended solids (TSS): Portion of solids retained by a filter.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

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

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

303(d) list: Section 303(d) of the federal Clean Water Act, requiring 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.

90th percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th 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

BMP	Best management practice
CAFO	Concentrated Animal Feeding Operation
Ecology	Washington State Department of Ecology
e.g.	For example
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
FC	Fecal coliform bacteria
i.e.	In other words
MEL	Manchester Environmental Laboratory
MF	Membrane Filtration
MPN	Most Probable Number
MQO	Measurement quality objective
NPDES	(See Glossary above)
QA	Quality assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RM	River mile
RPD	Relative percent difference
RSD	Relative standard deviation
SCMP	Skagit County Monitoring Program
SOP	Standard operating procedures
TMDL	(See Glossary above)
TOC	Total organic carbon
USGS	United States Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQA	Water Quality Assessment
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming units
ft	feet
g	gram, a unit of mass
mg	milligram
mL	milliliter
NTU	Nephelometric Turbidity Units
psu	practical salinity units
s.u.	standard units
umhos/cm	micromhos per centimeter
uS/cm	microsiemens per centimeter, a unit of conductivity

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms precision and bias be used to convey the information associated with the term accuracy. (USGS, 1998)

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella. (Kammin, 2010)

Bias: The difference between the population mean and the true value. Bias usually describes a systematic difference reproducible over time, and is characteristic of both the measurement system, and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI). (Kammin, 2010; Ecology, 2004)

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process. (USGS, 1998)

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured. (Ecology, 2004)

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards, but should be referred to by their actual designator, e.g., CRM, LCS. (Kammin, 2010; Ecology, 2004)

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator. (USEPA, 1997)

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator. (USEPA, 1997)

Continuing Calibration Verification Standard (CCV): A QC sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run. (Kammin, 2010)

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system. (Kammin, 2010; Ecology 2004)

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean. (Kammin, 2010)

Data Integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading. (Kammin, 2010)

Data Quality Indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity. (USEPA, 2006)

Data Quality Objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.
(USEPA, 2006)

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010)

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment, and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier, data is usable for intended purposes.
- J (or a J variant), data is estimated, may be usable, may be biased high or low.
- REJ, data is rejected, cannot be used for intended purposes (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set. (Ecology, 2004)

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero. (Ecology, 2004)

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis. (USEPA, 1997)

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport. (Ecology, 2004)

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples. (Kammin, 2010)

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. (USEPA, 1997)

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects. (Ecology, 2004)

Measurement Quality Objectives (MQOs): Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness. (USEPA, 2006)

Measurement result: A value obtained by performing the procedure described in a method. (Ecology, 2004)

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed. (EPA, 1997)

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples. (Ecology, 2004; Kammin, 2010)

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

%RSD = (100 * s)/x

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010)

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all "parameters." (Kammin, 2010; Ecology, 2004)

Population: The hypothetical set of all possible observations of the type being investigated. (Ecology, 2004)

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator. (USGS, 1998)

Quality Assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data. (Kammin, 2010)

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives. (Kammin, 2010; Ecology, 2004)

Quality Control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data. (Ecology, 2004)

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

[Abs(a-b)/((a + b)/2)] * 100

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled. (USGS, 1998)

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator. (USGS, 1998)

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population. (USGS, 1998)

Sample (statistical): A finite part or subset of a statistical population. (USEPA, 1997)

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit. (Ecology, 2004)

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method. (USEPA, 1997)

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency. (USEPA, 1997)

Split sample: A discrete sample that is further subdivided into portions, usually duplicates. (Kammin, 2010)

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity. (Kammin, 2010)

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis. (Kammin, 2010)

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning. (USEPA, 2006)

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