# Quality Assurance Project Plan

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# Fecal Coliform Bacteria TMDL for Oakland Bay-Hammersley Inlet and Tributaries

by
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September 2004

### 303(d) Listings Addressed in this Study:

| Main Waterbody Name (New ID, Old ID) | Tributary Name (New ID, Old ID) |
|---|---|
| Oakland Bay (390KRD, WA-14-0110) | Campbell Creek (BH46CN, WA-14-1850) |
| | Uncle John Creek (No New ID, WA-14-1800) |
| | Malaney Creek (ZY55KI, No Old ID) |
| Shelton Harbor (390KRD, WA-14-0050) | Shelton Creek (JZ99VQ, WA-14-1650) |
| | Goldsborough Creek (M194TV, WA-14-1600) |
| Hammersley Inlet (390KRD, WA-14-0100) | |

## Ecology User Study ID:  AAHM0003

**Approvals**

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# Abstract

Oakland Bay and Hammersley Inlet and several of its tributaries have been placed on the federal 303(d) list (1996, 1998, and proposed 2002/2004) for not meeting state water quality standard for fecal coliform bacteria. Therefore, in accordance with the Federal Clean Water Act, Total Maximum Daily Loads (TMDLs) for fecal coliform bacteria and temperature must be established to bring these tributaries into compliance with water quality standards. This report describes the approach to be used to develop TMDLs for the listed waterbodies and presents a monitoring plan to gather necessary data for completion of the TMDL.

For tributaries, a simple roll-back method will be used to establish target fecal coliform bacteria reductions necessary to meet water quality standards. Existing data, although useful, is deemed not sufficient in setting target reductions, particularly when considering different seasons. Therefore, additional data collection is proposed for a period of one year.

For Oakland Bay and Hammersley Inlet, the 303(d) listing will be addressed through a three-dimensional (3-D) hydrodynamic and water quality model. The roll-back loadings for the various tributaries, discussed above, will be used as a first cut in the 3-D model to predict if marine fecal coliform standards are met. If not, successive reductions will be assumed at the various tributaries until the marine standards are predicted to be met. Additional marine data on tides, currents, bathymetry, fecal coliform bacteria, and salinity will be collected over a year to cover all seasons.

Ecology will work cooperatively with the Squaxin Island Tribe, Department of Health, and Mason County to coordinate field work.

A final report will be available in August 2006.

# Project Description

Oakland Bay, Hammersley Inlet, and selected tributaries in Mason County have been included in the list of waterbodies in Washington that are not meeting the water quality standard for fecal coliform bacteria (Table 1). These waterbodies have been included in the 303(d) list either in 1996, 1998, or the proposed 2002/2004 list. Under the Federal Clean Water Act of 1972, a TMDL cleanup plan must be developed and implemented to address these impairments and bring the waterbody segment into compliance with the standards. This report is intended to discuss data needs for development of a TMDL, evaluate existing data to establish data gaps, and finally recommend a monitoring plan to obtain necessary data.

**Table 1. Segments in the Oakland Bay-Hammersley Inlet Watershed Included on the 1996, 1998, and Proposed 2002/2004 303(d) List.**

| Waterbody | Old Waterbody ID | New Waterbody ID | Listing | Reference | Lat/long or River Mile | Proposed 2002/2004 | 1998 | 1996 |
|---|---|---|---|---|---|---|---|---|
| Oakland Bay | WA-14-0110 | 390KRD | Fecal coliform | DOH Station 129, (2001) near mouth of Malaney Ck | 47.255/123.025 | Y | N | Y |
| Hammersley Inlet | WA-14-0100 | 390KRD | Fecal coliform | DOH Station 100 (2001 ) near mouth of Mill Ck | 47.195/122.995 | Y | Y | Y |
| Shelton Harbor | WA-14-0050 | 390KRD | Fecal coliform | Michaud, 1987, Inner harbor, near mouth of Goldsborough Ck | 47.205/123.095 | Y | Y | Y |
| Campbell Creek | WA-14-1850 | BH46CN | Fecal coliform | SIT 2002, Station 1, near mouth (Agate loop bridge) | RM0 | Y | Y | Y |
| | WA-14-1850 | BH46CN | Fecal coliform | RM 0.5, Brown and Caldwell, 1990 | RM 0.5 | Y | Y | Y |
| | WA-14-1850 | BH46CN | Fecal coliform | SIT 2002, Station 2, at Agate Rd culvert | RM 1.4 | Y | Y | Y |
| Uncle John Creek | WA-14-1800 | | Fecal coliform | Brown and Caldwell, 1990 | RM 0.1 – RM 2.2 | Y | Y | Y |
| Malaney Creek | | ZY55KI | Fecal coliform | SIT 2002, Malaney 1 (Agate Rd culvert) | ---- | Y | N | N |
| Shelton Creek | WA-14-1650 | JZ99VQ | Fecal coliform | Michaud, 1988, near mouth of Ck | RM0, RM0.2 | Y | Y | Y |
| Goldsborough Creek | WA-14-1600 | M194TV | Fecal coliform | Michaud, 1988, mouth of Ck | RM0 | Y | Y | Y |

DOH = Department of Health
SIT = Squaxin Island Tribe

# Study Area

The Oakland Bay and Hammersley Inlet Watersheds are located in Water Resources Inventory Area (WRIA) 14, in Mason County, Washington (Figure 1). Much of the landscape has been carved by glaciers that formed broad, low plains punctuated by low hills and ridges. Soils are comprised predominantly of unconsolidated glacial material or compacted till. Stream courses in the area are relatively short (approximately four to sixteen miles) and of low gradient, except for the upper Goldsborough and Mill Creek watersheds which extend into the western side of the Black Hills (Figure 1).
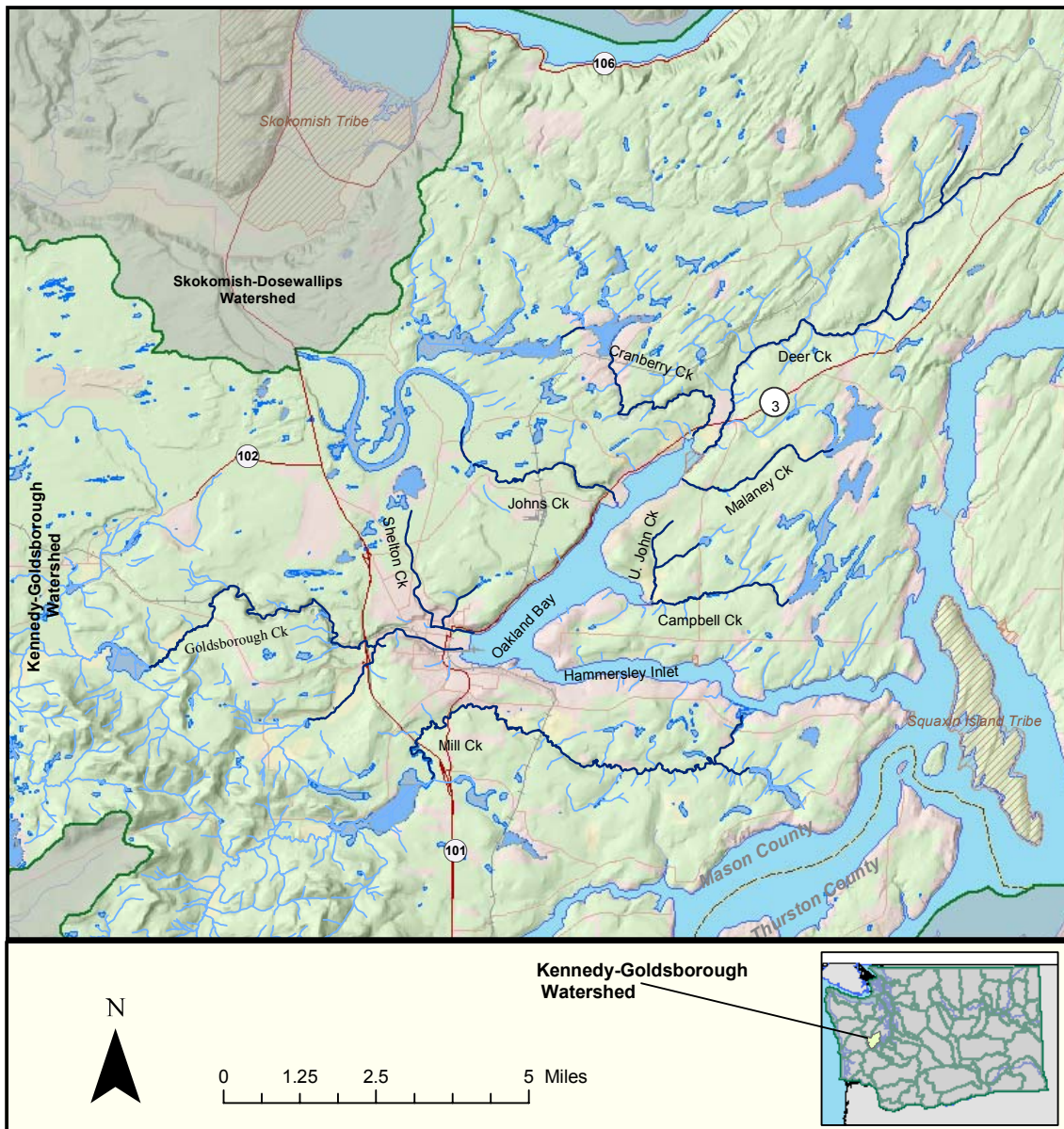


**Figure 1. Oakland Bay-Hammersley Inlet and Tributaries.**

Oakland Bay and Hammersley Inlet are typical of the narrow, shallow embayments that characterize South Puget Sound.  While highly productive areas for shellfish and salmonids, low flushing rates also make these areas very sensitive to human impacts.  For over one hundred years, Oakland Bay's protected waters have made it an ideal port for the city of Shelton, which has based its economy on the lumber and pulp mills that dominate the waterfront.  The city of Shelton operates a domestic wastewater treatment plant that discharges treated sewage into Oakland Bay near Eagle Point.

Land use is primarily commercial forest, with a much smaller percentage dedicated to residential development and agriculture.  Shorelines are heavily developed, both marine and lacustrine, such that nearly all of the lakes are bordered with homes.  Agricultural lands are dominated by small hobby farms.

## Oakland Bay and Tributaries

Oakland Bay is a short, narrow bay that angles abruptly northeast from its connection with Hammersley Inlet to the south.  The bay ranges in width from 1000 feet to one mile and covers approximately 5.4 square miles.  The surrounding hillslopes are relatively low, and the head of the bay consists of extensive mudflats.  Several creeks drain into the bay. These are discussed below:

- Campbell Creek begins at 110-acre Phillips Lake, but also receives flow from Timber and Little Timber Lakes as it flows west into Oakland Bay at Chapman Cove located along the east shore of Oakland Bay, near Sunset Road and Agate Loop Road. Timber Lake was created in the early 1970s by dredging wetlands and is approximately 82 acres (Taylor et al., 2000). Like many area lakes, it has been extensively developed. Much of the channel below Timber Lakes remains undeveloped and is characterized by numerous beaver ponds.  Nearly the entire channel is accessible to fish.  On Agate Road, Campbell Creek runs through a farm containing domestic waterfowl.

- Uncle John Creek, with a total drainage area of only 1.4 square miles, originates in a marsh and flows into Oakland Bay near Chapman Cove and the mouth of Campbell Creek. Uncle John Creek has two forks with the east fork originating at a wetland and the west fork essentially fed by groundwater. Although nearly the full length of channel is accessible to fish, the habitat has been considerably degraded.  Much of the lower channel flows through a roadside ditch, while the middle and upper reaches have been subject to livestock trampling and bank stabilization with scrap metal. Potential sources of fecal coliform bacteria are hobby farms (goats, horses) and failing septic tanks. Some unnamed creeks are also located along Chapman Cove. Land is mainly forested with some homes and hobby farms (cattle, horses).

- Malaney Creek, located on the Agate Peninsula, flows southwest into the upper end of Oakland Bay.  The creek originates at the 230-acre Spencer Lake, which is heavily developed with residential homes that are on septic systems.  Although it is only 2.9 miles in length, Malaney Creek is a productive salmonid stream flowing through forested land from Spencer Lake to its mouth, although a county-owned culvert on Agate Road creates a partial fish barrier.  Summer flows are low, often as little as one cfs.

- Cranberry Creek originates in a series of lakes, flowing southeast to join Oakland Bay to the northwest of Johns Creek. Cranberry and Limerick Lakes comprise the upper watershed. Lake Cranberry is a natural lake. However, Lake Limerick was created in 1966 by damming a wetland (Smith and Rector 1994). Steelhead and Coho pass through the lake via a fish ladder while Chum use the lower channel. Juvenile sockeye have also been trapped below the dam (Squaxin Island Tribe Unpublished Data, 1999). Most of the land along Cranberry Creek, below Lake Limerick, is forested with a few homes on septic systems.

- Deer Creek originates at 82-acre Lake Bensen and drains southwest into the head of Oakland Bay. At least 150 housing tracts with septic systems surround the lake (Taylor et al., 2000). The east fork originates at a spring/wetland. Most of Deer Creek lies in forested land with the channel accessible to fish.

- Johns Creek begins in a series of wetlands, following a low-gradient, meandering course through glacial outwash before descending through a deep canyon at a gradient of approximately two to three percent to enter Oakland Bay through a wide delta. The five-mile wetland at headwaters is the largest in Mason County. The wetland has the largest beaver population known in the area. Some of the most productive shellfish beds in the bay are located at the mouth of Johns Creek. Most of the channel is accessible to fish.

- Goldsborough is the largest sub-drainage, comprising about 35% of the total area of the Oakland Bay-Hammersley Inlet Watershed. The upper end is divided into north and south forks and incorporates approximately 2000 acres of lakes and wetlands. Major lakes include Hanks, Catfish, Armstrong, Goose, and Panhandle. At river mile 2.1, a diversion dam owned by Simpson Timber Company, which was a partial barrier to steelhead, coho, and cutthroat, has since been removed (Bill Young, 2004). The lower several miles pass through the city of Shelton and are extensively developed, channelized, and lacking any natural estuarine area. Above city limits, the Goldsborough Creek Watershed is mostly forested. Part of Shelton Creek flows are diverted to Goldsborough Creek during high winter flows.

- Shelton Creek has its headwaters at 108-acre Island Lake to the northwest of Shelton. The lake feeds into the creek indirectly through wetlands and groundwater movement, as well as through intermittent surface flow. Shelton Springs joins the mainstem approximately one mile south of the lake, although most of its flow has been diverted for Shelton's domestic water needs. An additional diversion located further downstream traps debris and limits streamflow to 55 cfs with extra flow diverted to Goldsborough Creek (Taylor et al., 2000). Upon crossing the city limits, Shelton Creek is joined by two tributaries. The western branch, also known as City Spring Creek, originates from the Mountain View Addition. The eastern branch, know as Canyon Creek or Town Creek, originates in a marshy area north of the Capitol Hill development and flows through a steep canyon into the business district. Canyon Creek accounts for about one third of the flow in Shelton Creek (Michaud, 1987; Taylor et al., 2000). Shelton Creek and its tributaries have been extensively channelized. Nevertheless, the creek is utilized by coho, chum, and sea-run cutthroat trout, and chum may be seen spawning in the lower half mile of creek among parking lots and businesses.

## Hammersley Inlet and Its Tributaries

Hammersley Inlet is one of the shallowest and narrowest of all inlets in South Puget Sound.  The inlet is approximately 6 miles long with an estimated surface of 2.2 square miles and a basin area of 9.4 square miles, exclusive of other watersheds.  Maximum basin elevation is 200 feet at Little Timber Lake.  Mill Creek is the largest tributary with a drainage area of 29 square miles.

Gosnell Creek flows out of the Black Hills feeding Lake Isabella, which is the source for Mill Creek. The lake is approximately 200 acres with extensive wetlands at both the inlet and outlet. Mill Creek is about 9 miles long and meets Hammersley Inlet east of Walker Park.  Forbes Lake, a 39-acre lake about 1.5 miles west of the unincorporated area of Arcadia, also drains into Mill Creek (Taylor et al., 2000).  Along Mill and Lower Gosnell Creeks, landuse is primarily agricultural and residential, while Upper Gosnell and its largest tributary, Rock Creek, are surrounded by commercial timberlands. Between the mouth and river mile 3, there are houses on septic systems and hobby farms (horses).

# Sources of Pollution

Oakland Bay and Hammersley Inlet and some of its tributaries are not meeting the state fecal coliform standard. Sources of pollution are both nonpoint and point sources.

## Nonpoint Sources

Animal management practices and failing septic systems are likely major contributors of fecal coliform loads in Oakland Bay-Hammersley Inlet Watershed. The watershed is characterized predominantly by unconsolidated glacial material or compacted till.  On-site sewage disposal systems function poorly in this type of soil.

The Oakland Bay Watershed Management Plan (Brown and Caldwell, 1990) identified animal management practices as likely sources of fecal coliform bacteria in Uncle John and Campbell Creeks.  Michaud (1987; 1988) documented stormwater runoff contaminated by fecal coliform bacteria entering both Shelton and Goldsborough Creeks.  This source of contamination has since been at least partially eliminated by improvements to Shelton's stormwater collection system, resulting in a marked decline in marine bacterial counts (Determan, 1999).

Campbell Creek, Uncle John Creek, Malaney Creek, Shelton Creek, and Goldsborough Creek have been identified as not meeting the water quality standards for fecal coliform bacteria and contributing bacterial loading to the Oakland Bay-Hammersley Inlet watershed.

The Department of Health (DOH) (Berbells, 2003) identified a population of harbor seals hauling-out on the log rafts within the shellfish prohibited area of the Inner Shelton Harbor. A seasonal population of waterfowl was also identified in the bay with no specific locations. In addition, Berbells (2003) also identified 35 Canada Geese at the mouth of John Creek and 25 Canada Geese at the mouth of Campbell Creek.  However, Berbells (2003) believes that wildlife is not a significant source of fecal coliform bacteria.

## Point Sources

The city of Shelton operates a wastewater treatment plant that discharges treated and disinfected domestic wastewater to Oakland Bay near Eagle Point. There are no provisions for Combined Sewer Overflows (CSOs) in the city.  However, the city has a Sanitary Sewer Overflow (SSO) problem where lines surcharge and manholes overflow (Dougherty, 2004).  The SSO events are reported to Ecology and DOH.  In recent years, the problem has improved partly due to efforts in controlling infiltration and inflow (I & I).  In the winter of 2003, only one SSO occurred during a record rainfall in October when about 6-8 manholes overflowed.  Limited bacteria testing of the SSO showed high (Too Numerous To Count, TNTC) fecal coliform bacteria counts. Quantities of SSOs were not monitored.  SSO events increase bacterial loads to Goldsborough Creek and stormwater drainage systems.

Figure 2 shows fecal coliform bacteria concentrations in the city of Shelton Wastewater Treatment Plant (WWTP) effluent. Over the last five years the WWTP has been in compliance with the effluent limitations of 200 cfu/100mL and 400 cfu/100 mL monthly and weekly geometric means, respectively. The effluent limits were based on using chlorination as a technology for disinfection. The water quality standard for Class B marine waters (a geometric mean of 100 cfu/100 mL) are

met at the effluent limitations due to a dilution factor of 1 to 94 at the edge of an approved mixing zone.
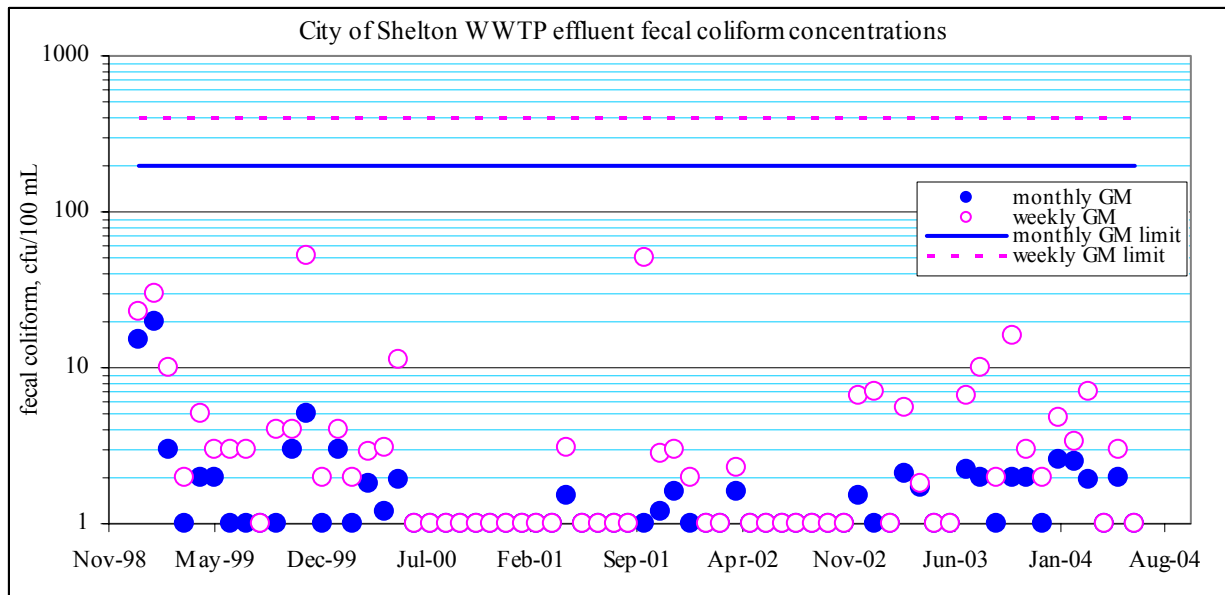


**Figure 2. Fecal Coliform Concentrations in City of Shelton WWTP Effluent, 1999-2004.**

Other point sources include stormwater outfalls draining the urban areas of the City of Shelton. However, the city of Shelton does not qualify for a Phase-II stormwater permit since the population is less than 10,000 people. The estimated April 2004 population is 8,695 people (http://www.ofm.wa.gov/pop/april1/finalapril12004popofcities.pdf ). The population of Mason County as of April 2004 is 50,800. This meets the *greater than 10,000 people* criteria for a Phase II stormwater permit. However, it does not meet the 1000 people per 1 square mile criteria. Thus, Mason County is also exempt from the Phase II stormwater permit.

The watershed is traversed by two major highways. Highway 101 crosses north-south over Mill Creek and Goldsborough Creek, near Shelton. Highway 3 crosses the watershed southwest-northeast and connects with Highway 101 near the confluence of Lake Isabella and Mill Creek, south of Shelton. Highway 3 runs along the northern shore of Oakland Bay and crosses Goldsborough, Shelton, Johns, Cranberry, and Deer creeks. There are many roadside storm-drains along Highway 101 and Highway 3 (Figure 3) that belong to the Washington Department of Transportation (WSDOT). An inventory of stormwater outfalls along highways in Washington is available at http://www.wsdot.wa.gov/mapsdata/geodatacatalog/Maps/24k/DOT_EAO/outfall.htm.

WSDOT is required by state and federal regulations to have a stormwater permit in areas covered by Phase I and Phase II of the municipal stormwater permit program. However, WSDOT agreed to a statewide permit to avoid having a piecemeal stormwater program and to promote better management of stormwater runoff from all state highways. The permit will cover stormwater runoff from state highways, rest areas, weigh stations, scenic view points, park-and-ride lots, ferry

terminals, and maintenance facilities. This permit will replace WSDOT's current coverage under the current Phase I general permit.

In March 2003, WSDOT applied for a state-wide stormwater NPDES permit to cover stormwater discharges from all state highways and WSDOT facilities such as maintenance yards and park-and-ride lots. The target date for issuance of the new permit and approval of WSDOT Stormwater Management Program (SWMP) is in summer 2005.
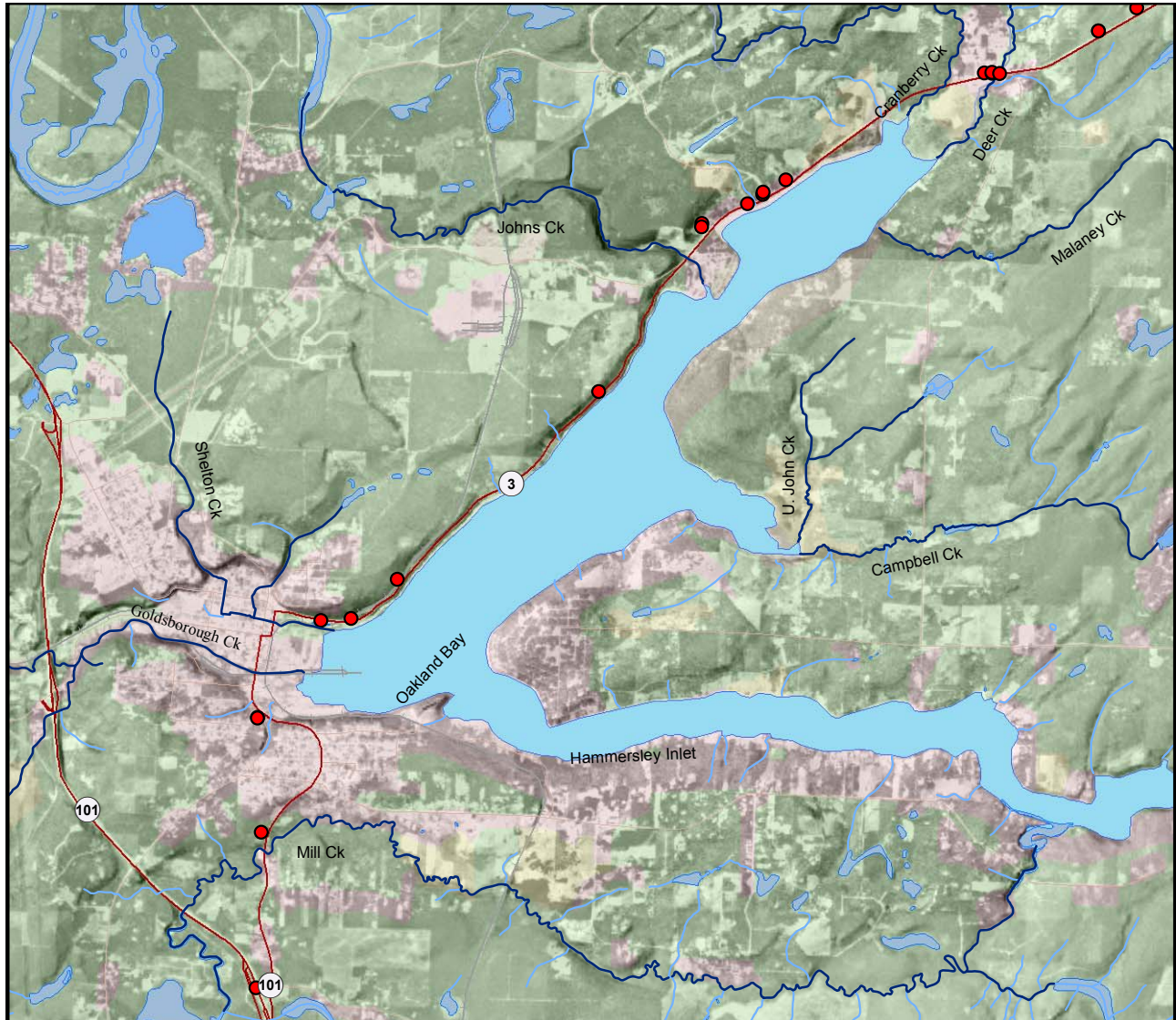


**Figure 3. WSDOT Stormwater Outfalls Along Highway 101 and Highway 3.**

The Department of Ecology has issued several industrial stormwater permits, boatyard permits, construction stormwater permits, and sand and gravel stormwater permits for facilities in the area. These facilities are not likely sources of fecal coliform bacteria.

# Water Quality Standards

Oakland Bay-Hammersley Inlet and their tributaries are classified as Class A waterbodies except for Inner Shelton Harbor, which is classified as Class B (Figure 4). This classification is as per Washington Administrative Code (WAC) Chapter 173-201A. Classification for the tributaries and the associated criteria for fecal coliform bacteria is summarized in Table 2.
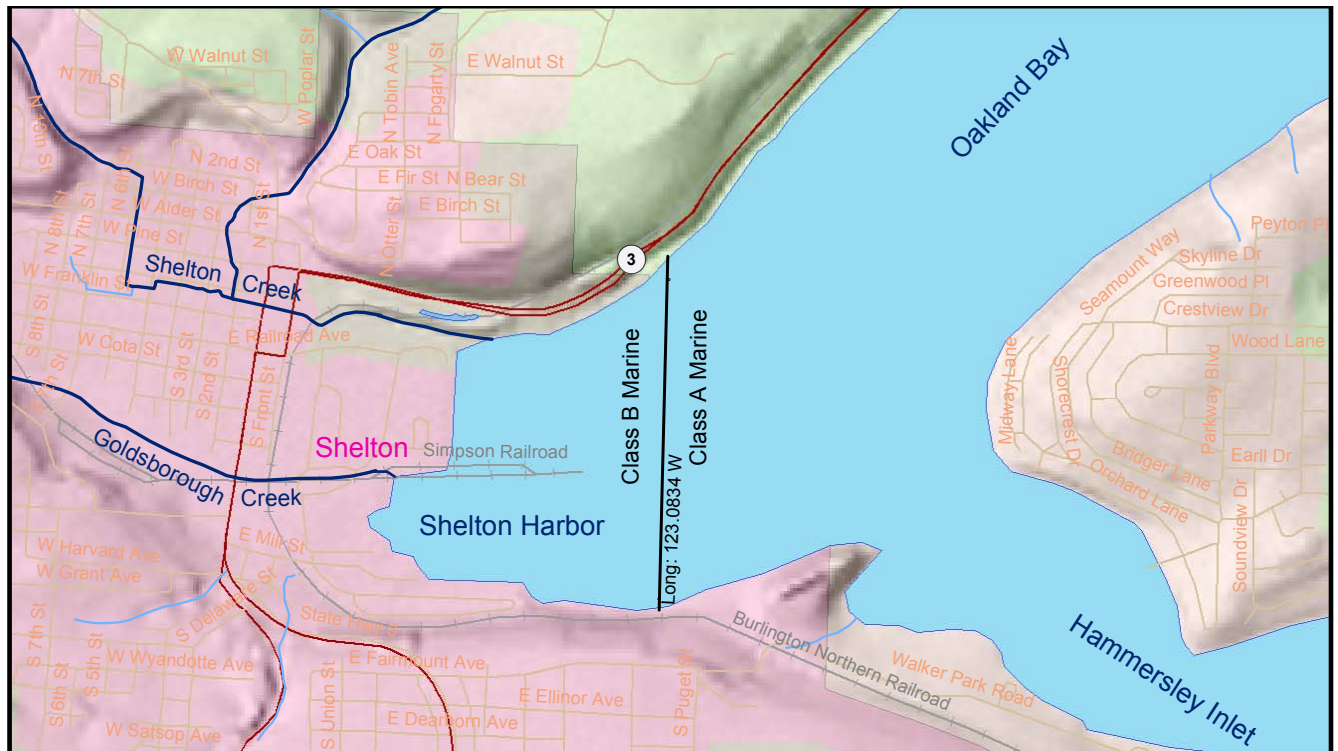


**Figure 4. Oakland Bay Waterbody Classification. as Per WAC 173-201A.**

**Table 2. Classification of Selected Waterbodies in Oakland Bay-Hammersley Inlet Watershed.**

| Waterbody | Classification | Fecal Coliform Standard, cfu/100 mL | |
|---|---|---|---|
| | | geometric mean | 10% samples exceeding |
| Oakland Bay | Marine A | 14 | 43 |
| Hammersley Inlet | Marine A | 14 | 43 |
| Campbell Creek | A | 100 | 200 |
| Uncle John Creek | A | 100 | 200 |
| Malaney Creek | A | 100 | 200 |
| Mill Creek | A | 100 | 200 |
| Johns Creek | A | 100 | 200 |
| Cranberry Creek | A | 100 | 200 |
| Shelton Harbor (inner) | Marine B | 100 | 200 |
| Shelton Creek | A | 100 | 200 |
| Goldsborough Creek | A | 100 | 200 |

Beneficial uses for Class A waters include water supply (domestic, industrial, and agricultural); stock watering; fish migration; fish and shellfish rearing, spawning, and harvesting; wildlife habitat; primary contact recreation; sport fishing; boating and aesthetic enjoyment; and commerce and navigation. Water quality of this class shall meet or exceed the requirements for all, or substantially all, uses.

Beneficial uses for Class B waters include water supply (industrial and agricultural); stock watering; fish migration; fish and shellfish rearing, spawning, and harvesting; wildlife habitat; secondary contact recreation; sport fishing; boating and aesthetic enjoyment; and commerce and navigation. Water quality of this class shall meet or exceed the requirements for most uses.

## Proposed New Rule

A new rule on Washington's Water Quality Standards (WAC 173-201A), adopted in July 2003 (not yet approved by EPA) designates primary contact recreation as a beneficial use for all the tributaries in the Oakland Bay-Hammersley Inlet Watershed. The fecal coliform bacteria standard for this beneficial use is 100 cfu/100 mL with no more than 10 percent of samples greater than 200 cfu/100 mL. This is the same as the existing Class A criteria for fresh waterbodies.
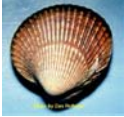
The beneficial use in the Inner Shelton Harbor has been designated as secondary contact recreation in the proposed new rule. The criteria for protection of secondary contact recreation uses limit enterococci organism levels to a geometric mean of 70 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 208 colonies/100 mL. This is different than the existing criteria which limit fecal coliform bacteria to a geometric mean of 100 cfu/100 mL with no more than 10 percent of samples exceeding 200 cfu/100 mL. The current listing for Shelton Harbor is not for enterococcus bacteria and no data is available for this organism in the inner harbor. Since the existing rule still applies, the TMDL will address the 303(d) listing for fecal coliform bacteria. If in the future, as data on enterococci becomes available that shows exceedance of the proposed criteria and the proposed rule becomes final, Ecology will address the exceedances through the TMDL process.

For shellfish protection, the fecal coliform standard in the proposed new rule is 14 cfu/100 mL with no more than 10 percent samples greater than 43 cfu/100 mL. This criterion is the same in the existing rule.

## Shellfish Protection

Shellfish harvesting areas exist throughout Oakland Bay and Hammersley Inlet. Shellfish species found in Oakland bay are shown in Table 3 (Taylor et al., 2000). The Department of Health oversees the commercial harvesting of shellfish in this watershed to protect the health of the consumers.

**Table 3. Shellfish Species with Known or Potential Distributions in Oakland Bay and Hammersley Inlet. (WDF 1992; Quayle 1988).**

| Common Name | Scientific Name | Habitat/Substrate | Comments |
|---|---|---|---|
| Native Littleneck  | *Protothaca staminea* | Intertidal; firm substrate | Common; recreational and commercial harvest |
| Manila Littleneck  | *Tapes philippinarum* | Intertidal; gravel/mud/sand | Introduced commercial species |
| Butter Clam  | *Saxidomus giganteus* | Intertidal and subtidal; porous sand/shell/mud/gravel | Recreational harvest |
| Cockle  | *Clinocardium nuttallii* | Intertidal; soft sand/mud, eelgrass beds | Recreational harvest |
| Piddock  | *Zirfaea pilsbryi* | Subtital; bores into shale, clay, or wood | Edible boring clam |
| Horse Clam  | *Tresus capax, T. nuttalli* | Subtidal; sand/shell | Abundant; recreational and small commercial harvest |
| Pacific Oyster  | *Crassostrea gigas* | Intertidal; firm substrate gravel/silt/shell, rocks and pilings; require clean substrate | Introduced commercial species |
| Olympia Oyster  | *Ostrea lurida* | Intertidal; solid rock/mud w/moderate currents | Native commercial species |

Currently, DOH classifies shellfish harvest in Upper Oakland Bay (Figure 5) as *Conditionally Approved,* meaning it is closed to shellfish harvest for at least five days following rainfall of one inch or more in a 24-hour period due to associated elevated fecal coliform bacteria concentrations in the bay. Rainfall data is collected by Taylor United at the Flupsy dock in Oakland Bay. These conditions are delineated in the Department of Health's April 2004 Oakland Bay Conditionally Approved Area Management Plan (Berbells, June, 2004). In 2003, there were eight conditional rainfall closures of the shell fish harvesting areas totaling 55 days (Berbells, June, 2004). Shellfish harvesting in the Lower Oakland Bay and Upper Hammersley Inlet (as delineated by the two sanitary lines: one in Lower Oakland Bay and the other in Upper Hammersley Inlet, Figure 5) is prohibited at this time due to the likelihood of elevated fecal coliform bacteria concentrations. The city of Shelton municipal wastewater treatment plant is in this area. Designated restricted shell fish harvesting areas do not meet water quality standards and are closed for shellfish harvesting going directly to market. The area in Hammersley Inlet, near the mouth of Mill Creek (Figure 5), has this designation. Approved Shellfish harvesting areas are designated for the rest of the Hammersley Inlet.
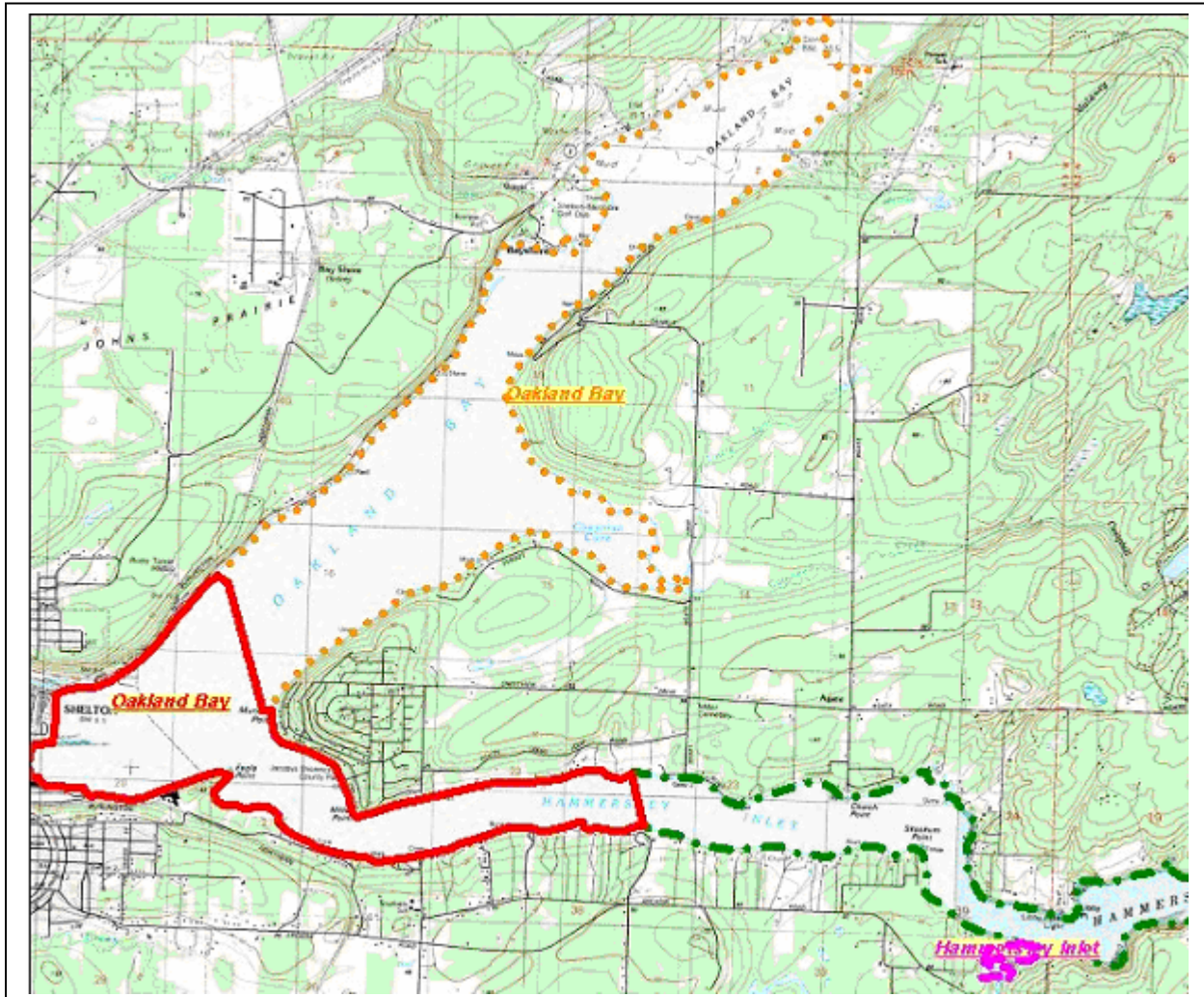
**N** *Prohibited* areas are based on sanitary survey that indicates that fecal material, pathogenic microorganisms, or poisonous or harmful substances may be present in concentrations that pose a health risk to shellfish consumers.

*Conditionally Approved* areas are *Approved* areas, but only during predictable periods. *Approved* area is not subject to contamination that presents an actual or potential public health hazard. *Restricted* areas do not meet water quality standards for an Approved classification, but only a limited degree of pollution exists from non-human sources.

**Figure 5. Designated Restrictions on Shellfish Harvesting Areas In Oakland Bay and Hammersley Inlet.**

# Historical Data Review

Several organizations collected fecal coliform data in the Oakland Bay-Hamersley Inlet Watershed. These include Department of Health, Squaxin Island Tribe, Mason County, and the Department of Ecology.

## Washington State Department of Health

To protect the health of citizens who consume shellfish, the Department of Health monitors fecal coliform bacteria on a monthly basis in Oakland Bay and on a bi-monthly basis in Hammersley Inlet. The standard for approved shellfish growing waters is fecal coliform geometric mean not greater than 14 organisms/100 ml and an estimate of the 90th percentile not greater than 43 organisms/100 ml.

Table 4 shows the fecal coliform data collected at various stations (Figure 6) in Hammersley Inlet (Melvin, 2003). Within the approved areas for shellfish harvesting (see Figure 5), the fecal coliform concentrations are well within the standard. In the prohibited area, i.e. in the upper Hammersley Inlet (station 105), fecal coliform concentrations as high as 350 cfu/100 mL have been measured. However, the geometric mean and 90th percentile concentrations are within the water quality standards. In the restricted area near the mouth of Mill Creek, the 90th percentile fecal coliform concentration is in excess of the approved classification water quality standard of 43 cfu/100 mL (station 100). This area is on the 303(d) list for fecal coliform bacteria.

**Table 4.  Fecal Coliform Concentrations at Various DOH Sites in Hammersley Inlet – 2002.**

| Station | Geometric mean | 90th Percentile | Meets Std. ? |
|---------|---------------|-----------------|--------------|
| 97 | 2.3 | 4 | Yes |
| 98 | 2.8 | 7 | Yes |
| 99 | 2.8 | 8 | Yes |
| 101 | 2.5 | 5 | Yes |
| 102 | 2.3 | 5 | Yes |
| 103 | 2.9 | 8 | Yes |
| 104 | 2.8 | 6 | Yes |
| 111 | 3.2 | 9 | Yes |
| 112 | 2.9 | 7 | Yes |
| 113 | 2.6 | 6 | Samples < 30 |
| 105 | 4.9 | 22 | Yes |
| 100 | 11.6 | 57 | No |
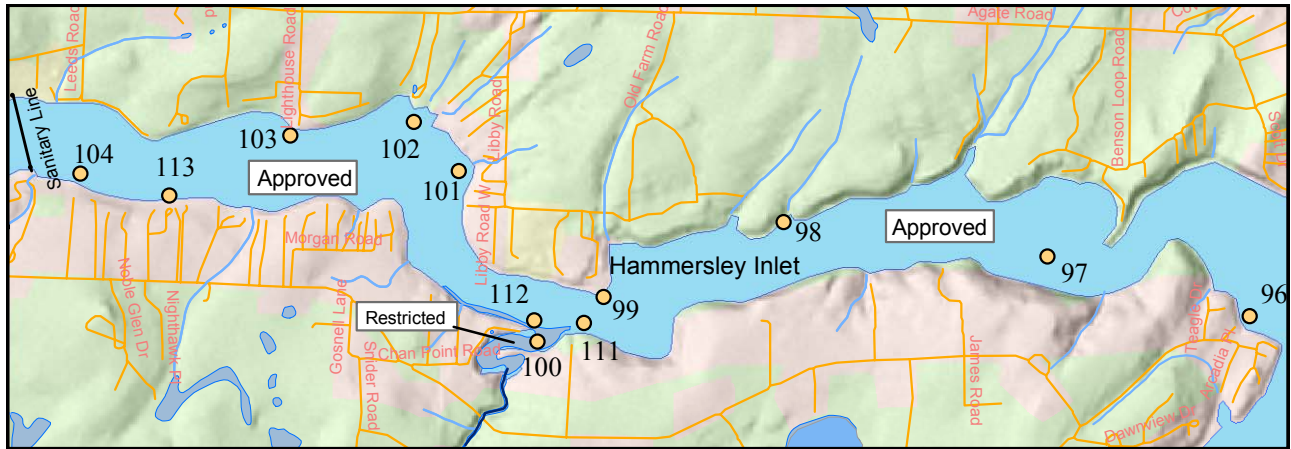
**Figure 6. DOH Stations in Hammersley Inlet and Shellfish Harvesting Zone Restrictions.**

Table 5 shows the fecal coliform data at various stations (Figure 7) in Oakland Bay. Within the conditionally approved and prohibited shellfish harvesting areas (see Figure 5), the fecal coliform concentrations were well within the standard. However, the data were gathered when the conditionally approved area was open for shellfish harvesting.

For stations 614, 615, and 639 the number of data points were less than 15 and, therefore, remain *unclassified* pending collection of further data. The area at station 129 has been placed on the 303(d) list (1996 and the proposed 2002/2004 list) for fecal coliform bacteria. Although concentrations in Table 5 show compliance with the standards, data collected prior to December 2001 showed a geometric mean of 7 cfu/100 mL with 13 percent of the data exceeding 43 cfu/100 mL. This was the basis for the proposed 2002/2004 listing.

**Table 5. Fecal Coliform Concentrations at Various DOH Sites in Oakland Bay 2001 – 2003.**

| Station | Geometric mean | 90th percentile* | Meets std? |
|---------|----------------|------------------|------------|
| 114 | 6 | 26 | yes |
| 115 | 5 | 26 | yes |
| 122 | 4 | 14 | yes |
| 124 | 4 | 12 | yes |
| 116 | 3 | 6 | yes |
| 117 | 3 | 11 | yes |
| 118 | 4 | 16 | yes |
| 119 | 4 | 16 | yes |
| 120 | 3 | 11 | yes |
| 121 | 3 | 11 | yes |
| 123 | 3 | 10 | yes |
| 125 | 4 | 15 | yes |
| 126 | 4 | 12 | yes |
| 127 | 4 | 17 | yes |
| 128 | 5 | 18 | yes |
| 129 | 5 | 23 | yes |
| 614 | 10 | 70 | samples <30 |
| 615 | 14 | 107 | samples <30 |
| 639 | 7 | 24 | samples <30 |

*DOH reported the Oakland Bay data in terms of percent exceeding 43 cfu/100 mL. However, the 90th percentile is reported in Table 5 so that it may be comparable to data in Table 4.
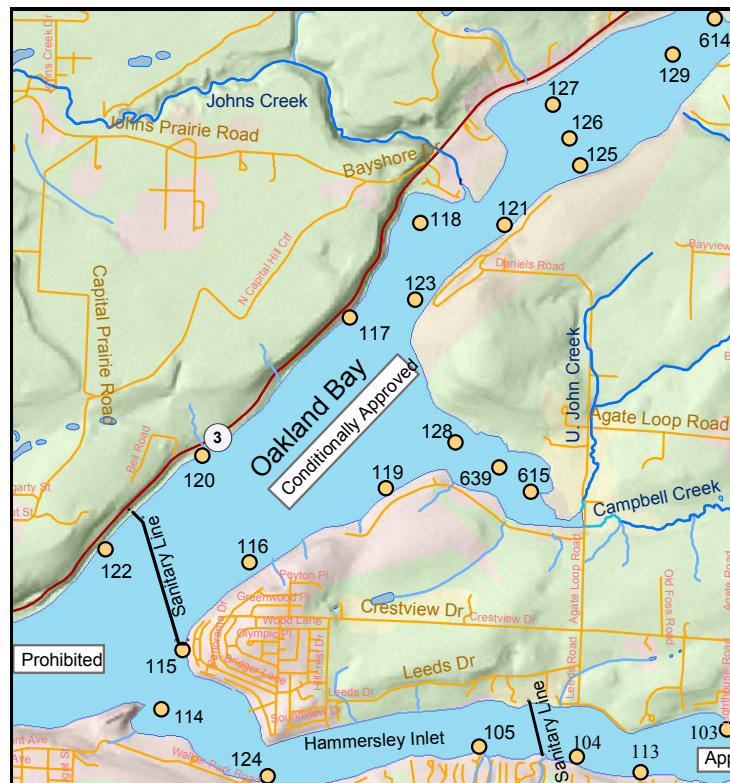
**Figure 7. DOH Stations in Oakland Bay and Shellfish Harvesting Zone Restrictions.**

The Department of Health also conducted a shoreline survey between July 2002 and February 2003 to evaluate 71 different drainage/discharge points, 126 developed parcels (119 evaluated), and 102 agricultural activities (94 evaluated) along 12 marine shoreline miles and upland areas of the Oakland Bay Shellfish growing area (Berbells, 2003). Figure 8 shows the drainage/discharge systems (i.e. stormwater culverts and creeks) surveyed. WSDOT stormwater outfalls as listed in http://www.wsdot.wa.gov/mapsdata/geodatacatalog/Maps/24k/DOT_EAO/outfall.htm are also included in Figure 8. Berbells (2003) located more stormwater outfalls along Highway 3 than are present in the WSDOT database. The ownership information for all the culverts and outfalls was not available at the time this report was written. As part of the reconnaissance survey proposed under this study, the ownership of all discharge points will be established.

Twenty one out of 71 drainage/discharge points were evaluated for flow and fecal coliform bacteria. Highest fecal coliform concentrations were observed at station 083 (920 cfu/100 mL at a flow of 5 gpm), station 070 (540 cfu/ 100 mL at a flow of < 5 gpm), and station 024 (540 cfu/100 mL at a flow of 24 gpm). The fecal coliform concentrations at the mouth of the major tributaries (Johns, Cranberry, Malaney, Deer, and Campbell Creeks) were relatively low (maximum of 130 cfu/100 mL) except for Uncle John Creek with a high concentration of 920 cfu/100 mL. Based on relative significance, the total flow from all the drainage systems (stormwater culverts, etc.) monitored was 2 percent of the total flow from all the major tributaries along the shoreline surveyed. In terms of fecal coliform loading, the drainage systems monitored contributed only 3 percent of the fecal coliform loading to the bay compared to the combined loading from the major tributaries.
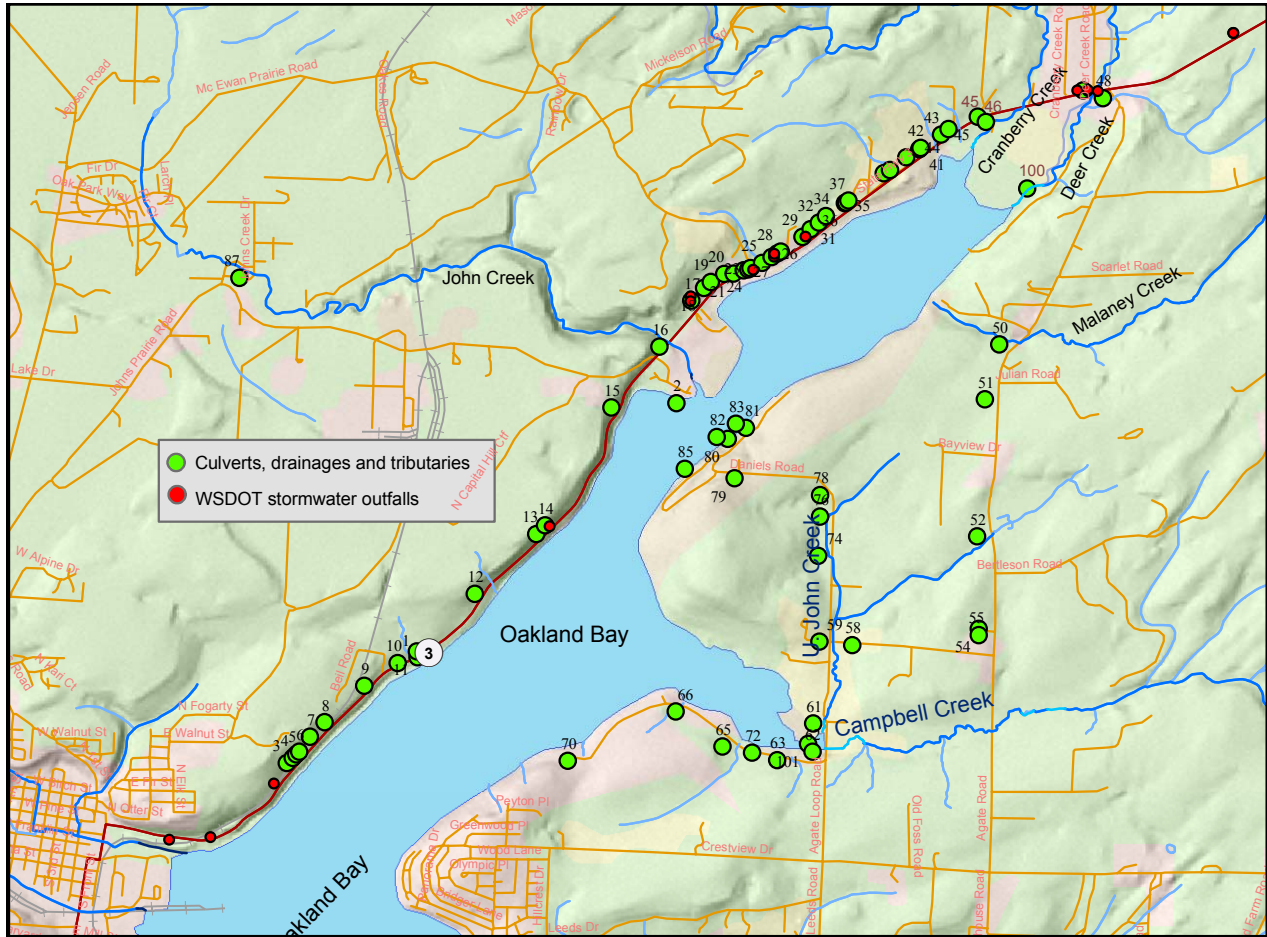
**Figure 8. Locations of Culverts, Drainages, and Creeks within the Conditionally Approved Area of Oakland Bay (Berbells, 2003) and WSDOT Stormwater Outfalls.**

Mason County evaluated 94 of the 102 agricultural activities identified that could potentially impact shellfish growing areas. Twenty-seven percent of the 94 agricultural sites evaluated had direct access to the bay via a stream, creek, or drainage ditch and twenty percent had farm plans approved by the conservation district. Uncle John and Campbell Creeks contained 37 percent of all agricultural sites in the Upper Oakland Bay area surveyed. Twenty-two percent of all agricultural sites were in Johns Creek, fifteen percent in Deer Creek, eleven percent in Cranberry Creek, and six percent in Malaney Creek. The rest of the agricultural activities were within the Oakland Bay Basin outside the watershed limits of the tributaries. Figure 9 shows the locations of the agricultural activities identified in this study (Berbells, 2003).

**Figure 9. Location of Agricultural Sites Identified by DOH in the Upper Oakland Bay Shoreline Areas (Berbells, 2003).**

One hundred and twenty six developed parcels were identified by DOH (Berbells, 2003) along the Upper Oakland Bay shoreline that used on-site sewage treatment and disposal systems. Of the 126 parcels, 119 were evaluated for on-site sewage treatment and disposal practices. The other 7 seven sites could not be evaluated due to access restrictions or inspection refusal by home owner. Thirty-nine of the 119 on-site sewage treatment and disposal sites were deemed potential sources of pollution based upon age, location, and/or type. Figure 10 shows 28 of these on-site sewage treatment and disposal sites. Some of the on-site sewage systems are located in Alderwod gravelly sand loam that supports a cemented till at a depth of up to 3 feet that restricts the downward movement of wastewater.

**Figure 10. On-Site Sewage Disposal and Treatment Systems Deemed to be Potential Sources of Pollution.**

## Squaxin Island Tribe

In 2000, the Squaxin Island Tribe (SIT) completed a comprehensive report on watershed assessment of Oakland Bay and Hammersley Inlet (Taylor et al., 2000). This report provides in-depth information on natural resources (fish and shellfish) that needs to be protected in the watershed through reduction in fecal coliform bacteria and temperature. The need for water quality monitoring was assessed with data gaps identified. The Squaxin Island Tribe began monitoring water quality in the Oakland Bay-Hammersley Inlet Watershed in January, 2001. Fecal coliform concentrations were evaluated along each of the tributaries in the Oakland Bay-Hammersley Inlet Watershed. Sampling was sporadic with some samples taken in winter and summer months. During the monitoring period (2001-2004), the number of data points gathered at each station varied from 4 and 24, depending on when monitoring began for a particular station. The stations sampled were along the following tributaries:

Mill Creek = MIL
Coffee Creek = COF (tributary to Goldsborough Creek)
Johns Creek = JOH
Deer Creek = DEE
Malaney Creek = MAL
Pipes and unnamed tributaries near Uncle John creek = SIM
Unnamed tributaries along Sunset Road = SUN

Goldsborough Creek = GOL
Shelton Creek = SHE
Cranberry Creek = CRA
Spring at Agate Road crossing = SPR
Uncle John Creek = UNC
Campbell Creek = CAM

Figure 11 shows that several of the tributaries including Shelton, Johns, Cranberry, Uncle John, and Campbell Creeks as well as some of the unnamed tributaries exceeded the water quality standards. It should be noted that neither Johns Creek nor Cranberry Creek is on the 303(d) list for fecal coliform bacteria. The listing was based upon data gathered in 2001. The new data shows exceedances of the water quality standards at the mouths of these creeks. A target reduction will be estimated for both these creeks as part of the TMDL study. Additional data at all SIT stations on a more frequent basis will provide for seasonality evaluation and establishment of fecal coliform reduction targets.
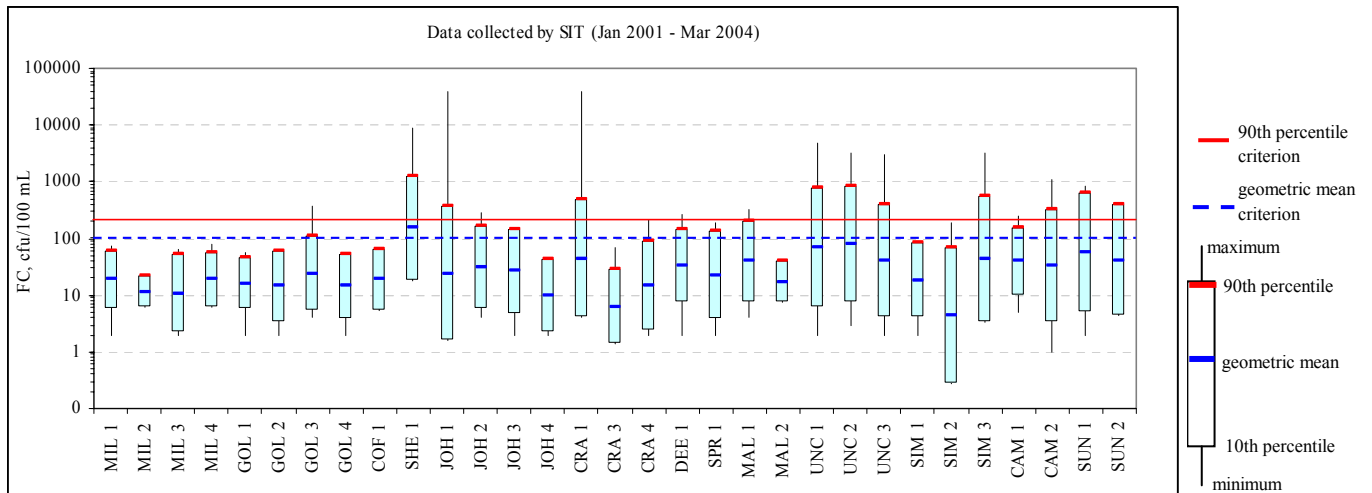
**Figure 11. Fecal Coliform Distribution at Selected Locations Along Tributaries (Data Collected by SIT 2001 - 2004).**

## Mason County

Under a grant from Ecology, Mason County has been monitoring for fecal coliform bacteria at culverts, ditches, and seepages that discharge to Oakland Bay since the fourth quarter of 2003. Figure 12 shows 22 freshwater monitoring stations that were sampled twice a month under this grant. High counts have been found at a number of sample sites, especially on November 18, 2003, after the first significant rain (Kenny, 2004). The sites that were in compliance were discontinued.
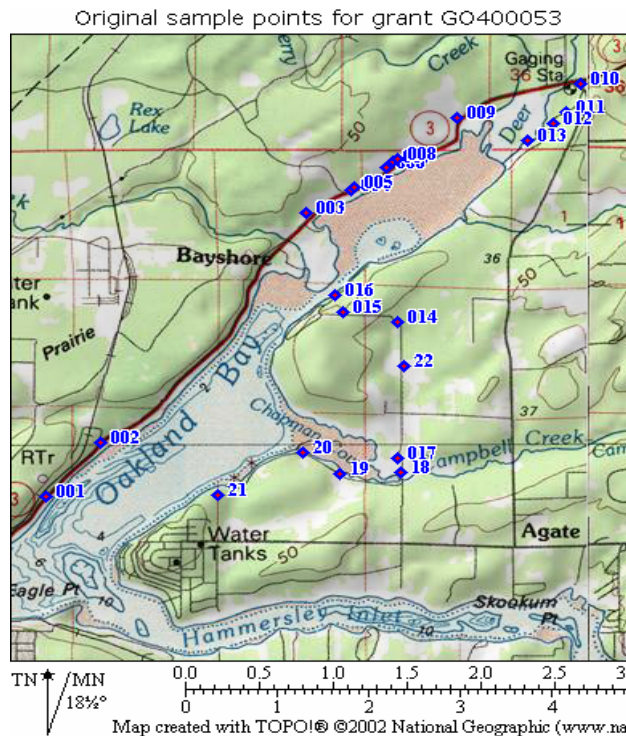


**Figure 12. Mason County Monitoring Stations in the Upper Oakland Bay.**

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The sites that were not in compliance with water quality standards are being investigated further. Sample sites 7 and 18 are in need of more sampling and will be dropped if good counts continue. Sample sites 9 and 22 are culverts that had multiple high counts during the first flush period but currently have low counts. They will continue to be monitored. Sample site 17 in the Uncle Johns Creek area frequently exceeds water quality standards.  Squaxin sampling data showed other points on Uncle Johns Creek that exceeded the water quality standards multiple times.  On that basis, Mason County is currently focusing efforts on Uncle John Creek and tributaries.

As part of the grant, Mason County also provided two public training sessions: Pasture, Livestock and Manure Management in February 2004 and Onsite Sewage System Operation and Maintenance in March 2004.  Information about onsite sewage systems operation and management is provided at the internet web site http://mason.wsu.edu/Onsites.htm.

On and prior to January 15, 2004, sewage solids from a septic tank were pumped on a Malaney Creek property. The solids appear to have been applied as close as ten feet from the creek. Mason County collected samples twice a week for a month following land application of septic solids. The results suggest that the sediment at this location is not a significant fecal coliform reservoir (Kenny, 2004).

## Washington State Department of Ecology

Ecology maintains a long-term monitoring station in Oakland Bay west of Munson Point and north-west of Eagle Point at Latitude 47.21333 and Longitude -123.077.  Data from this station is shown in Figure 13.
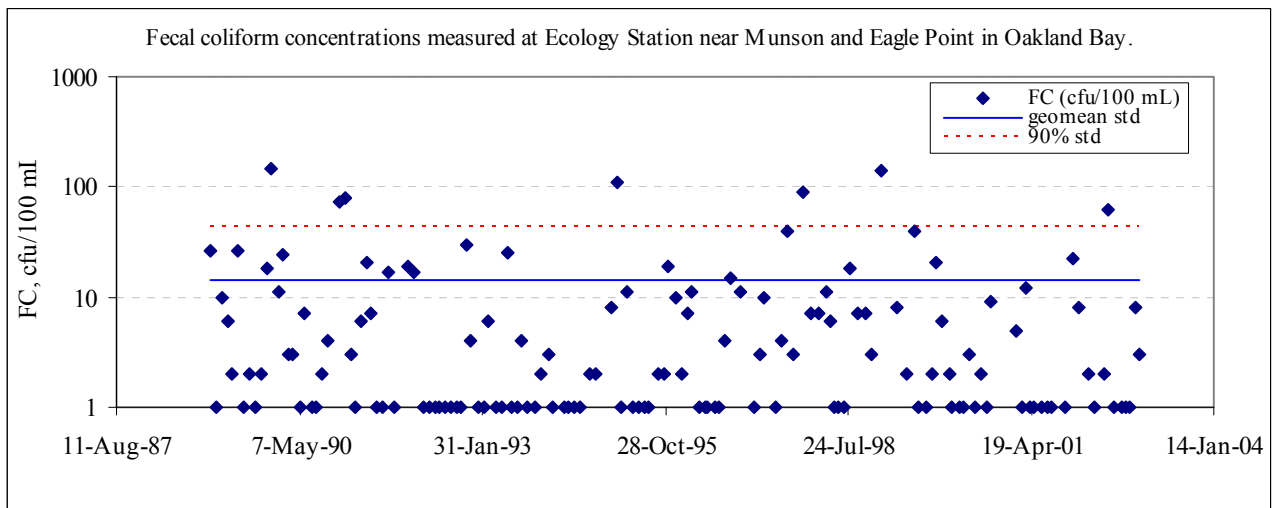


**Figure 13.  Fecal Coliform Concentrations Measured at Ecology's Long-Term Monitoring Station in Oakland Bay.**

Ecology also developed a computer model of Hammersley Inlet and Oakland Bay to establish the impact of increased flow at city of Shelton's WWTP on shellfish harvest areas (Albertson 2004).

The increased flow at the WWTP would result from servicing the Port of Shelton, Washington State Department of Corrections, and other areas. To address the issue, the United States Food and Drug Administration instigated a dye study to better understand the circulation patterns in Hammersley Inlet and Oakland Bay. To complement the dye study, Ecology developed a three-dimensional hydrodynamic model of the embayment using a sigma-coordinate primitive equation model called the Environmental Fluid Dynamics Code, or EFDC (Hamrick, 1992, 1996). Rhodamine dye was released from the city of Shelton's WWTP on April 15, 2003, for a period of 24.8 hours (i.e. one full tidal cycle). Several ISCO samplers were fixed on moorings at several locations in Oakland Bay and Hammersley Inlet, and hourly water samples were collected for subsequent analysis by a laboratory fluorometer to measure dye concentrations.

The EFDC model was calibrated to recreate the dye study and then the various proposed WWTP discharges were evaluated. Model results show that if the WWTP releases fecal coliform bacteria at a concentration of 46,300 cfu/100 mL (DOH effluent criteria) and at a flow of 2.6 MGD, the concentrations would dilute to 14 cfu/100 mL (or the Class A marine fecal coliform criteria) at the sanitary lines. However, if the flow is increased to 6.7 MGD, the necessary dilution was not available. At intermediate flows (4 to 4.6 MGD), necessary dilution was available but depended on diffuser configuration and discharge timing relative to the tide. It should be noted that, the NPDES permit for the WWTP limits the fecal coliform concentration in the discharge to 200 cfu/100 mL and 400 cfu/100 ml as monthly and weekly averages, respectively. These limitations are technology based (chlorine is used for disinfection) and are protective of water quality standards based on a dilution factor of 1 to 94 at the edge of the mixing zone. Historically, the effluent concentration of fecal coliform bacteria has been very low, in the order of 5 cfu/100 mL on a monthly average basis (David Dougherty, 2004). The purpose of the dye study and modeling was to evaluate conditions of plant upset, when high concentrations of fecal coliforms are likely to be present.

## TMDL Approach

1. The TMDL is designed to ensure, at a minimum, that the water quality standards for fecal coliform bacteria corresponding to designated waterbody classifications are met.

2. The TMDL for the various point and non-point sources to Oakland Bay-Hammersley Inlet will be established by first calibrating and verifying a three-dimensional hydrodynamic and water-quality model of Oakland Bay and Hammersley Inlet. This will be followed by using the model to establish loads and wasteloads such that the water quality standards are met throughout the Oakland Bay and Hammersley Inlet.

3. The Inner Shelton Harbor west of Longitude 123° 05' W is a Class B marine waterbody and has a water quality geometric mean standard for fecal coliform bacteria of 100 cfu/100 mL.

4. East of this line, Oakland Bay and Hammersley Inlet, is classified as Class A marine waters with a fecal coliform standard of a geometric mean of 14. In this TMDL, it would be assumed that the model grid cells at this boundary would meet the marine standard of 14 cfu/100 mL.

5. The tributaries and any known point sources would be assumed to be input to the grid as point sources.

6. As a first cut, the tributaries will be assumed to be meeting the respective water quality standards (i.e. the standard based upon the respective waterbody classification), hereafter referred to as the *roll-back loading* (see item 7 below).

   a) Since some of the streams are on the 303(d) list for temperature, the model will be run with streams at the water quality standard for temperature. Since bacterial die-off is lower at lower temperatures, this approach will be conservative during the implementation phase of the temperature TMDL.

   b) The model will be used to predict the average fecal coliform concentration in each grid cell in the bay to which a tributary/point source is an input. The predicted concentration will be compared to the applicable marine standard (i.e. 14 cfu/100 mL for Class A marine water and 100 cfu/100 mL for Class B marine water).

   c) If predicted fecal coliform concentration in grid cells exceeds the standard, the loading from the tributaries/point source will be successively reduced beyond the roll-back loading until the grid-cell concentration is within the standard. The corresponding loading will be the target load allocation for tributaries, point sources, and drainages.

   d) The percentage of reduction at the mouth of the tributary as obtained through the previous step (i.e. beyond the initial roll-back loading, will be applied throughout the upstream reach of the tributary).

7. Bacterial target reductions for the tributaries will be established through the use of the *roll-back* method (Ott, 1995). The roll-back method assumes that the distribution of fecal coliform bacteria concentrations follows a log-normal distribution. The cumulative probability plot of the observed data gives an estimate of the geometric mean and 90th percentile which then can be compared to the fecal coliform bacteria standards. The roll-back procedure is as follows:

   a) The data are plotted on a log-scale against a linear cumulative probability function. A straight line signifies a log-normal distribution of the data.

   b) The geometric mean of the data has a cumulative probability of 0.5.

   c) The 90th percentile of the data has a cumulative probability of 0.9. This is equivalent to the *no more than 10% samples exceeding* .... criterion in the fecal coliform standard (WAC 173-201A).

   d) Alternately, the 90th percentile can also be estimated by using the following statistical equation:

$$90^{th} \text{ percentile} = 10^{(\mu_{log} + 1.28 * \sigma_{log})}$$

where: $\mu_{log}$ = mean of the log transformed data; $\sigma_{log}$ = standard deviation of the log transformed data

   e) The target percent reduction required is the highest of the following two comparisons. either:

$$\left[ \frac{90th \text{ percentile} - 200 \text{ cfu}/100mL}{90th \text{ percentile}} \right] x100 \quad \text{or:} \quad \left[ \frac{\text{geometric mean} - 100 \text{ cfu}/100mL}{\text{geometric mean}} \right] x100$$

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f) As *Best Management Practices* (BMPs) for non-point sources are implemented and the target reductions are achieved, a new but similar distribution (same coefficient of variation) of the data is assumed to be realized with the previous mean and standard deviation reduced by the target percent reductions.

g) If the data do not meet the 90<sup>th</sup> percentile criteria, then the goal would be to meet a 90th-percentile FC of 200 cfu/100 mL, and no goals would be set for the geometric mean since, with the implementation of the target reductions, the already low geometric mean (<100 cfu/100mL) would only get better. Similarly, if the data do not meet geometric mean criteria, the goal would be to achieve a geometric mean of 100 cfu/100mL with no goal for the already low (<200 cfu/100mL) 90<sup>th</sup> percentile.

h) For this approach to work, sufficient data must be available to establish a log-normal distribution of fecal coliform bacteria. Target reductions based on data from the critical season will be more realistic in driving an implementation plan towards meeting water quality standards. Flow data may be used to establish loads which could be used as a management tool to prioritize areas where BMPs are needed.

i) Additional reductions beyond the *roll-back* method may be necessary in order to meet the marine standard in Oakland Bay and Hammersley Inlet as outlined in item 6 above.

## Project Objectives

The objective of this project plan is to provide a clear approach on how the TMDL will be completed, delineate data needs, define how and where data will be collected, define who will collect the data, and define requirements for the data to be credible.

Specific objectives of the proposed study are as follows:

- Characterize fecal coliform bacteria concentrations and loads from all tributaries, point sources and drainages into Oakland Bay and Hammersley Inlet.

- Collect sufficient hydrodynamic and water quality data to support modeling of Oakland Bay and Hammersley Inlet.

- Establish maximum acceptable fecal coliform loads and concentrations for tributaries, drainages, and point and non-point sources (i.e. establish TMDL wasteloads and load allocations).

# Study Design

The project objectives will be met through a combination of:

- Monitoring water quality and flow.

- Modeling fate and transport of fecal coliform bacteria in Oakland Bay and Hammersley Inlet.

- Analysis of various loading scenarios and resulting water quality to establish critical season(s) for establishing wasteload and load allocations.

## Monitoring of Water Quality and Quantity

Water quality monitoring to address the fecal coliform bacteria listings in Oakland Bay-Hammersley Inlet will consist of monitoring fecal coliform concentrations at the mouths of all tributaries, point sources, significant drainage/discharges, and key locations within Oakland Bay and Hammersley Inlet. Flow will be continuously monitored at the mouths (upstream of tidal influence) of the major tributaries where feasible. For tributaries that do not have a continuous recording gage, flows will be measured or estimated at the time of sampling. Monitoring stations under tidal influences should be monitored under ebb tide so that the fecal coliform samples taken reflect the actual fresh water input. Water quality monitoring to address the fecal coliform 303(d) listing of the five tributaries (Campbell, Uncle John, Malaney, Shelton, and Goldsborough Creeks) will consist of monitoring fecal coliform concentrations at various stations along each of these tributaries.

### Major Tributaries

Table 6 shows the monitoring locations, frequency, and parameters to be monitored at various stations along the different stream reaches. For the bacteria model of Oakland Bay and Hammersley Inlet, data from the mouths of these tributaries will be used. For fecal coliform bacteria TMDL for all creeks, data collected at all the stations will be used. Sampling locations are shown in Figures 14, 15, 16, 17, 18, and 19.

The tributaries will be sampled by Ecology and the Squaxin Island Tribe. The biweekly samples will be collected and analyzed alternately by Ecology and SIT.

The stations recommended for monitoring during ebb tide are those that are flooded during a flood tide. In addition to the mouth of the tributaries, samples will also be collected along the creeks to establish areas where fecal coliform concentrations are high and need BMPs to reduce bacterial loads.

Flow, temperature, and conductivity measurements at the mouth of the tributaries, in conjunction with those measured within the Oakland Bay and Hammersley Inlet will be used to calibrate a three-dimensional hydrodynamic model of the embayment.

Continuous temperature monitoring devices will be installed by Ecology at mouths of all tributaries. However, bi-weekly temperature (and conductivity) readings will be taken at these locations during each sampling event.

**Table 6.  Tributary Sampling Location, Parameters, and Frequency of Sampling.**

| Creek | Station | Flow | Temperature | Temperature | Conductivity | Fecal coliform | Fecal Coliform Method |
|---|---|---|---|---|---|---|---|
| Cranberry | CRA0 | | | bi-weekly | bi-weekly | bi-weekly | MF |
| | CRA1 | continuous | continuous | bi-weekly | bi-weekly | bi-weekly | MF |
| Deer | DEE0 | | | bi-weekly | bi-weekly | bi-weekly | MF |
| | DEE1 | bi-weekly[1] | continuous | bi-weekly | bi-weekly | bi-weekly | MF |
| Malaney | MAL0 | | | bi-weekly | bi-weekly | bi-weekly | MF |
| | MAL1 | bi-weekly[1] | continuous | bi-weekly | bi-weekly | bi-weekly | MF |
| | MAL2-a | | | | | bi-weekly | MF |
| | MAL2-b | | | | | bi-weekly | MF |
| Uncle John | UNC1 | | | bi-weekly | bi-weekly | bi-weekly | MF |
| | UNC2 | bi-weekly[1] | continuous | bi-weekly | bi-weekly | bi-weekly | MF |
| | UNC3 | | | | | bi-weekly | MF |
| Campbell | CAM1 | | | bi-weekly | bi-weekly | bi-weekly | MF |
| | CAM2 | bi-weekly[1] | continuous | bi-weekly | bi-weekly | bi-weekly | MF |
| | CAM3 | | | | | bi-weekly | MF |
| Johns | JOH0 | | | bi-weekly | bi-weekly | bi-weekly | MF |
| | JOH1 | bi-weekly[2] | continuous | bi-weekly | bi-weekly | bi-weekly | MF |
| | JOH2 | continuous | | | | bi-weekly | MF |
| Shelton | SHE0 | | | bi-weekly | bi-weekly | bi-weekly | MF |
| | SHE 1 | bi-weekly[1] | continuous | bi-weekly | bi-weekly | bi-weekly | MF |
| | SHE2 | | | | | bi-weekly | MF |
| | SHE3 | | | | | bi-weekly | MF |
| Goldsborough | GOL0 | | | bi-weekly | bi-weekly | bi-weekly | MF |
| | GOL1 | Continuous (New USGS gage Oct, 2004) | continuous | bi-weekly | bi-weekly | bi-weekly | MF |
| | GOL2 | continuous | | | | bi-weekly | MF |
| | GOL3 | | | | | bi-weekly | MF |
| | GOL4 | | | | | bi-weekly | MF |
| | COF1 | | | | | bi-weekly | MF |
| Mill | MIL0[3] | | | bi-weekly | bi-weekly | bi-weekly | MF |
| | MIL1a | bi-weekly[4] | continuous | bi-weekly | bi-weekly | bi-weekly | MF |
| | MIL3 | continuous | | | | bi-weekly | MF |

[1] Currently there is no flow gage.
[2] Continuous flow will be estimated by developing a relationship with continuous gaged flow at station, JOH2, on John Creek Drive.
[3] This is an old Ecology station, previously named MIL04. Name has been changed to prevent confusion with Squaxin Island Tribe station MIL4 which is located above Lake Isabella on Gosnell Creek.
[4] Continuous flows will be estimated by developing a relationship with continuous gaged flow at station MIL3, on Highway 3.
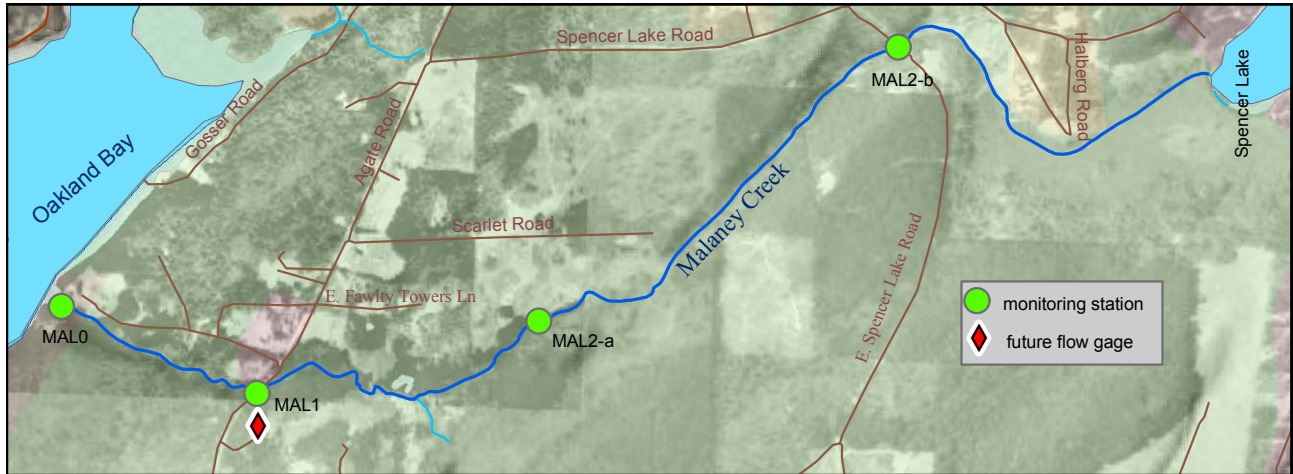
**Figure 14. Monitoring Stations in Malaney Creek. MAL1 and MAL2 are SIT Stations. MALO, MAL2-a, and MAL2-b are Proposed Monitoring Stations. Station MAL1 Does Not Currently Have a Flow Gage.**
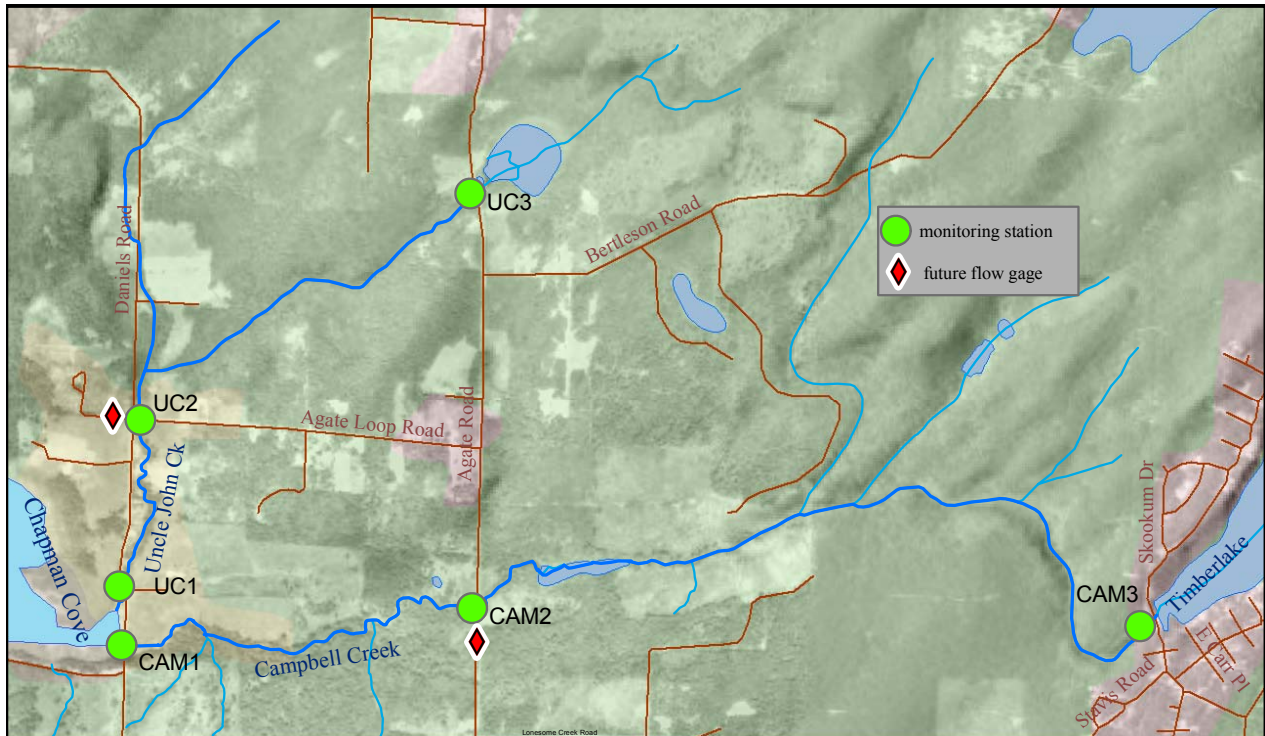


**Figure 15. Monitoring Stations in Uncle John and Campbell Creeks. All but CAM3 Are Existing SIT Stations. Stations UC2 and CAM2 Do Not Currently Have Flow Gages.**

**Figure 16. Monitoring Stations in Shelton Creek. SHE1 is an existing SIT Station Without a Flow Gage. Stations SHE2 and SHE3 and SHE0 are New.**
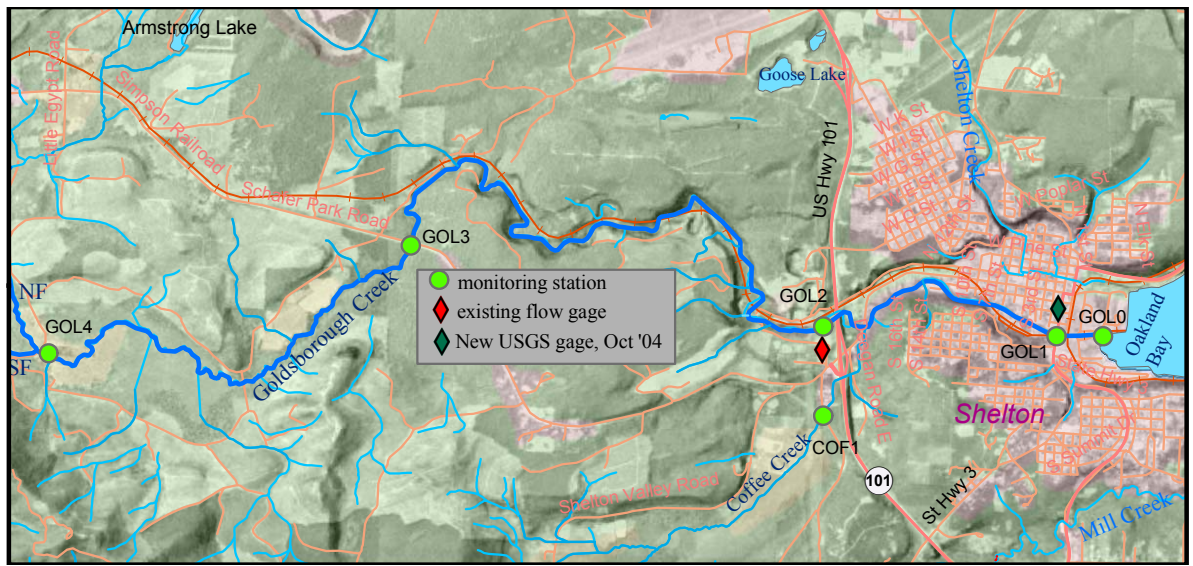


**Figure 17. Monitoring Stations in Goldsborough Creek. GOL0 is a New Station. The Rest are Currently Being Monitored by SIT.**
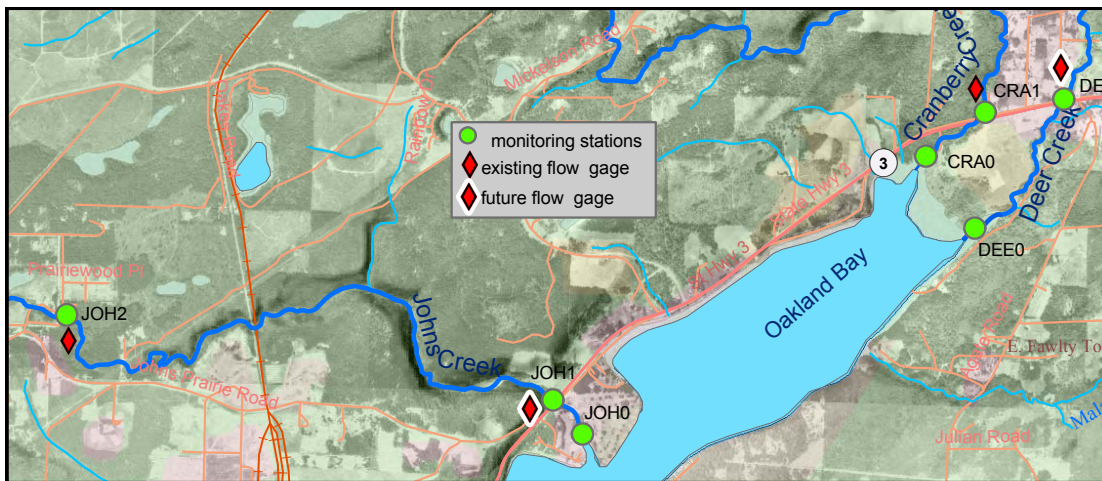
**Figure 18. Monitoring Stations in Johns, Cranberry, and Deer Creeks.**
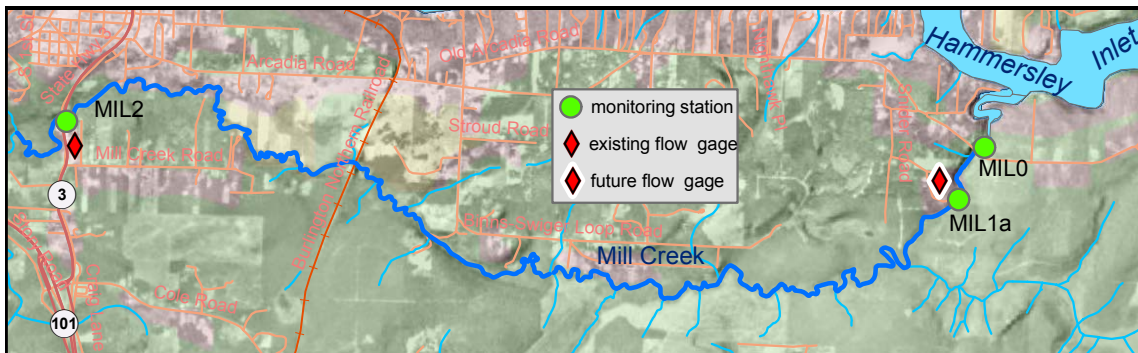


**Figure 19. Monitoring Stations in Mill Creek. MIL0 and MIL1a are New Stations. MIL2 is a SIT Station.**

## Major Point Sources

The major point source discharging into Oakland Bay is the city of Shelton municipal WWTP. The outfall is located at Eagle's Point, within the prohibited shellfish harvesting area. Flow, temperature, and fecal coliform data will be obtained from the facility's monthly discharge monitoring reports (DMRs) submitted to Ecology.

## Significant Drainage/Discharges

As indicated earlier, the shoreline has many small drainage/discharge points in addition to the major tributaries. These include storm water culverts, unnamed tributaries and direct runoff points from agricultural activities. As discussed earlier, the contribution of flow and fecal coliform loading from these sources are 2 percent and 3 percent, respectively, of the contribution from all the major tributaries monitored along the Upper Oakland Bay shoreline surveyed by DOH (Berbells, 2003). Two of the most significant drainage/discharges in terms of fecal coliform loading were the natural drainage-ways at DOH station 083 (see Figure 8), opposite the mouth of John Creek and DOH station 024 between Cranberry and John Creek. The shoreline along the Lower Oakland Bay and Hammersley Inlet has not been surveyed. A reconnaissance survey will be conducted prior to commencement of field monitoring to locate stormwater outfalls, drainages etc. along this shoreline. This survey will be done in coordination with Mason County, DOH, city of Shelton and the Squaxin Island Tribe. Following this survey, a map will be developed showing locations of all

drainage/discharges that will be sampled. During sampling of these locations, several teams will be established (consisting of Ecology, Squaxin Island Tribe, and Mason County) that will sample different areas of the shoreline.

The Squaxin Island Tribe has also been routinely monitoring several unnamed tributaries and pipes. Among these are the pipes and culverts near the mouth of Uncle John Creek, between Uncle John and Campbell Creeks, and along Sunset Road below Chapman Cove. The most significant of these, in terms of fecal coliform concentrations, are SIT Station SIM3 (see Figure 11), near Agate Loop Road; and SIT stations SUN1 and SUN2 on Sunset Road. Flow was not measured at these locations, therefore a load could not be estimated.

Sampling will be conducted once every three months at culverts and natural drainage systems along the shoreline to establish relative fecal coliform bacteria loadings. Winter monitoring will be done following significant storm events. It is likely that many of these drainage/discharge points will have no flow during the summer season.

## Oakland Bay and Hamersley Inlet

Key locations in Oakland Bay and Hammersley Inlet will be monitored for temperature, salinity, tidal elevations, current, and fecal coliform bacteria to calibrate the **G**eneralized **E**nvironmental **M**odeling **S**ystem for **S**urface waters (GEMSS) hydrodynamic and water quality model.

Table 7 shows the locations of monitoring stations in Oakland Bay and Hammersley Inlet. Currently, DOH monitors 31 stations for fecal coliform bacteria in Oakland Bay and Hammersley Inlet. Samples collected by DOH at selected locations (Table 7) will be split between DOH and Ecology. The Ecology split sample will be analyzed for fecal coliform bacteria using the MF method.

The marine monitoring stations are also shown in Figure 20. Conductivity, temperature, and depth (CTD) measurements described in Table 7 will be vertical profiles in the water column. In addition, a continuous CTD data logger, or other similar instrument, will be installed near Cape Cod, at the mouth of Hammersley Inlet (Figure 20). This will establish the boundary condition data for the model. Tide gages and current meters (S4, InterOcean Systems, Inc. or equivalent) will be deployed at a minimum of two locations:  Cape Cod (near DOH station 96) and the northern shore of Lower Oakland Bay (near DOH station 120).

In addition, a bottom mounted Acoustic Doppler Current Profile (ADCP) meter will be installed in Hammersley Inlet (latuitude 47.2055 and longitude 123.0522, Figure 20), downstream of Eagle Point, to continuously measure vertical velocity gradients for 29 days in January and 29 days in August 2005. This was recommended by Albertson (2004) for estimating flushing rate of the estuary.

No new dye study is being recommended. A dye study for the discharge at the Shelton WWTP was completed in 2003 (Albertson 2004). GEMSS will be calibrated to this dye study to compare its results to the **E**nvironmental **F**luid **D**ynamics **C**ode (EFDC) model used by Albertson (2004).

**Table 7.  Site Locations, Parameters, and Frequency of Sampling in Oakland Bay and Hammersley Inlet.**

| Waterbody | DOH Station # or new | Station location | LAT | LONG | fecal coliform | fecal coliform method | temperature | conductivity | depth | tide gage | current gage |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oakland Bay | 129 | Upper Oakland Bay – above Malaney Creek | 47.25553 | 123.02098 | monthly | MF | monthly | monthly | monthly | | |
| | 128 | at Chapman Cove | 47.22726 | 123.0425 | monthly | MF | monthly | monthly | monthly | | |
| | 126 | Upper Oakland (middle)-- above John and below Malaney | 47.24928 | 123.0316 | monthly | MF | monthly | monthly | monthly | | |
| | 123 | Upper Oakland (south shore): Off Daniels Road - Beaver Lane | 47.23737 | 123.0473 | monthly | MF | monthly | monthly | monthly | | |
| | 120 | Middle Oakland Bay (near north shore along Highway 3) | 47.2257 | 123.0691 | monthly | MF | monthly | monthly | continuous | yes | yes |
| | 115 | Lower Oakland Bay (near south shore at Munson point) | 47.21174 | 123.0706 | monthly | MF | monthly | monthly | monthly | | |
| | SH1 | Middle Shelton Harbor: Off the mouth of Goldsborough Creek | 47.2089 | 123.0861 | monthly | MF | monthly | monthly | monthly | | |
| | SH2 | Middle Shelton Harbor: Off the mouth of Goldsborough Creek | 47.21143 | 123.0867 | monthly | MF | monthly | monthly | monthly | | |
| Hammersley Inlet | 124 | Inner Hammersley Inlet: On the south shore opposite Miller Point | 47.2029 | 123.0612 | Bi-monthly | MF | Bi-monthly | Bi-monthly | Bi-monthly | | |
| | 104 | In upper Hammersley inlet, between Miller and Church Points | 47.20501 | 123.0287 | Bi-monthly | MF | Bi-monthly | Bi-monthly | Bi-monthly | | |
| | 100 | Lower Hammersley Inlet – mouth of Mill Creek | 47.19716 | 122.99395 | Bi-monthly | MF | Bi-monthly | Bi-monthly | Bi-monthly | | |
| | 99 | In Middle Hammersley inlet at Libby Point | 47.19955 | 122.9891 | Bi-monthly | MF | Bi-monthly | Bi-monthly | Bi-monthly | | |
| | 97 | At the lower Hammersley inlet near Cannery Point | 47.20234 | 122.9558 | Bi-monthly | MF | Bi-monthly | Bi-monthly | Bi-monthly | | |
| | 96 | at the mouth of Hammersley Inlet near Cape Cod | 47.1996 | 122.9405 | Bi-monthly | MF | continuous | continuous | continuous | yes | yes |
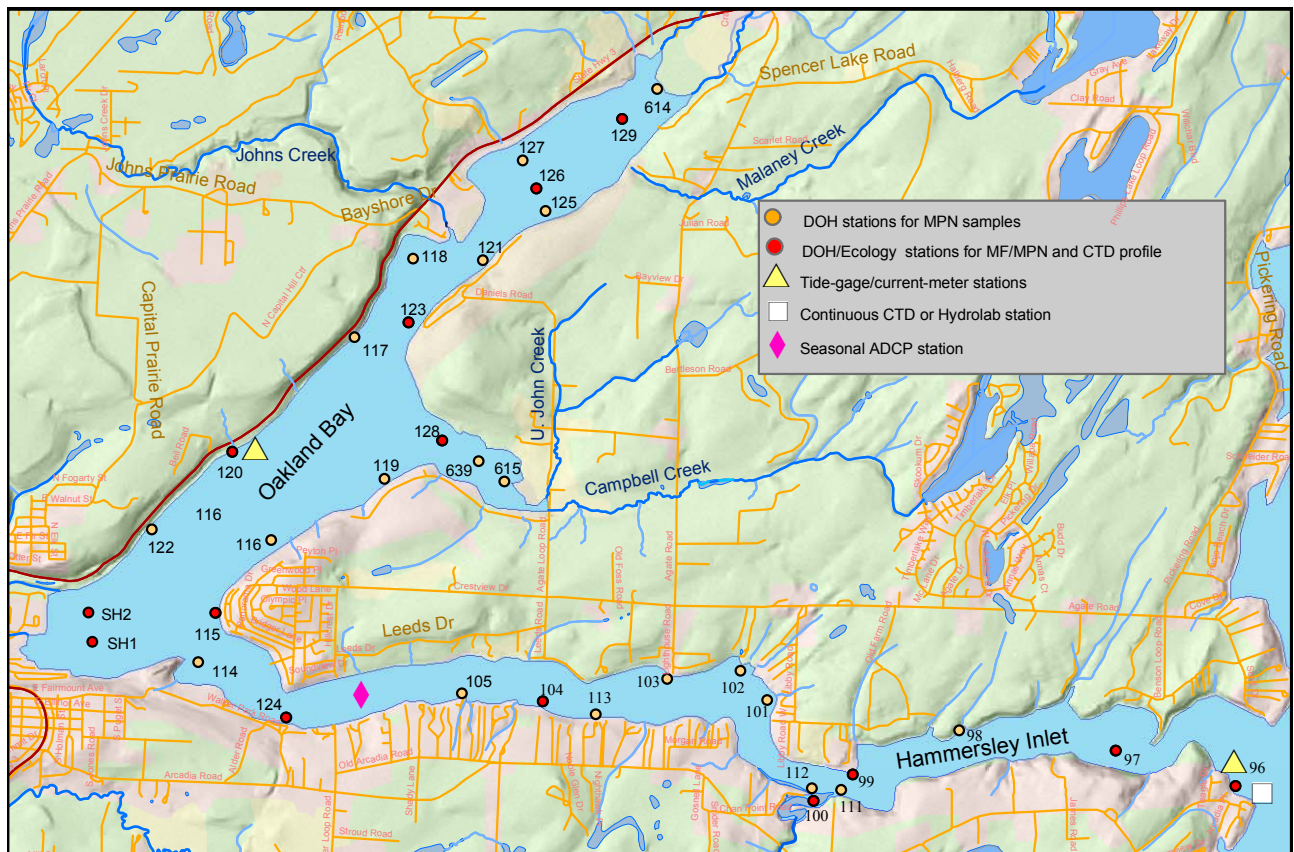


**Figure 20.  Monitoring Stations in Oakland Bay and Hammersley Inlet.**

## Data Analysis and Modeling

All project data will be entered in Microsoft Excel spreadsheets and Ecology's Environmental Information Management (EIM) system. Statistical calculations will be made using database spreadsheets (Excel) and by importing the data from the spreadsheets to either SYSTAT (SPSS Inc, 1997) or WQHYDRO (Aroner, 1992) statistical software.

## Modeling of Fecal Coliform Bacteria

A three-dimensional hydrodynamic/water quality model will be used to simulate the behavior of fecal coliform bacteria in Oakland Bay and Hammersley Inlet.  A three-dimensional Hammersley Oakland Bay Oceanographic (HOBO) model has been previously developed by Albertson (2004) based on the Environmental Fluid Dynamics Code (EFDC), a three-dimensional hydrodynamic computer primitive equation model (Hamrick 1992, 1996). The three-dimensional grid used in the HOBO model was generated using the grid generator of **G**eneralized **E**nvironmental **M**odeling **S**ystem for **S**urface waters (GEMSS), an integrated system of 3-D hydrodynamic and transport models. Both EFDC and GEMSS models will be considered in modeling of fecal coliform bacteria in Oakland Bay and Hammersley Inlet.

**GEMSS**

A **G**eneralized **E**nvironmental **M**odeling **S**ystem for **S**urface waters is an integrated system of three-dimensional hydrodynamic and transport models embedded in a geographic information and environmental data system (GIS), grid generator and editor, control file generator, two-dimensional and three-dimensional post processing viewers and additional tools that include meteorological data processor, and a USGS flow data processor to support three-dimensional modeling. Customization of the suite of hydrodynamic, transport and water quality models is achievable through the use of modular design reflecting the needs of each user's application.

The GEMSS software uses GLLVHT (Generalized, Longitudinal-Lateral-Vertical Hydrodynamic and Transport) as the main kernel, which is a state-of-the-art three-dimensional numerical model that computes time-varying velocities, water surface elevations, and water quality constituent concentrations in rivers, lakes, reservoirs, estuaries, and coastal waterbodies. The computations are done on a horizontal and vertical grid that represents the waterbody bounded by its water surface, shoreline, and bottom. The water surface elevations are computed simultaneously with the velocity components. The water quality constituent concentrations are computed from the velocity components and elevations. Included in the computations are boundary condition formulations for friction, wind shear, turbulence, inflow, outflow, surface heat exchange, and water quality kinetics. The model can be used to analyze system dynamics and predict the impacts of actual events or possible design or management alternatives.

The GLLVHT model has been peer reviewed and published (Edinger and Buchak, 1995; Edinger, et al., 1994 and 1997). The fundamental computations are an extension of the well known longitudinal-vertical transport model (GLVHT) that was developed by J. E. Edinger Associates, Inc. beginning in 1974 and summarized in Buchak and Edinger (1984). This model forms the

hydrodynamic and transport basis of the Corps of Engineers' Water Quality Model CE-QUAL-W2 (U. S. Army Corps of Engineers Waterways Experiment Station, Environmental and Hydraulics Laboratories, 1986).

GEMSS uses the z-coordinate system which deals with drying in shallow areas by completely eliminating associated surface layers in succession. Thus, more layers may be necessary when using the z-coordinate system.

**EFDC**
An Environmental Fluid Dynamics Code is an open source, public domain, surface water modeling system incorporating fully integrated hydrodynamic, water quality, and sediment-contaminant simulation capabilities. EFDC can be used for one, two, or three-dimensional simulation of rivers, lakes, estuaries, coastal regions, and wetlands. EFDC can be used with a water quality component that is based on water quality kinetics from the Chesapeake Bay Water Quality Model or CE-QUAL-ICM (Cerco and Cole, 1994).

The EFDC model solves the three-dimensional, vertically hydrostatic, free surface, turbulent averaged equations of motions for a variable density fluid. The model uses a stretched or sigma vertical coordinate and Cartesian or curvilinear, orthogonal horizontal coordinates. Dynamically coupled transport equations for turbulent kinetic energy, turbulent length scale, salinity, and temperature are also solved. The EFDC model allows for drying and wetting in shallow areas by a mass conservative scheme. The sigma-coordinate system maintaines the same number of vertical layers, during drying of shallow layers, by reducing the individual layer thickness.

## Hydrodynamic Model Calibration
The hydrodynamic calibration of the model will entail the following:

- Establishing the bathymetry and geometry of Oakland Bay and Hammersley Inlet.

- Establishing daily freshwater inflows to Oakland Bay and Hammersley Inlet.

- Establishing tides at the entrance to Hammersley inlet at hourly intervals.

- Calibration to tides with adjustments to bottom friction.

- Calibration to salinity data with minor adjustments to geometry.

- Calibration to temperature data.

**Bathymetry and Geometry**

- A model of Oakland Bay and Hammersley Inlet, HOBO, has already been developed by Albertson (2004) based on the Environmental Fluid Dynamics Code (EFDC) and calibrated to dye released at the city of Shelton's wastewater treatment plant outfall in March-April 2002. The same model grid will be used in the GEMSS model.

- The dye study data will be re-used to calibrate the GEMSS model while incorporating the recommendations of Skip Albertson (2004).

- Model selection (EFDC or GEMSS) will be based on appropriateness and ease of use following an initial evaluation of observed data and model calibration.

- The three-dimensional model will be extended to all the months of the year.

- The bathymetry and geometry employed by Albertson (2004) will be reviewed and compared to the latest available data from National Oceanic and Atmospheric Administration (NOAA) and the U.S. Army Corp of Engineers (ACOE).

**Flow**

Continuous flow data will be gathered, where possible, for all tributaries for one year. Where continuous flow gaging stations are not present, other options to developing a time series of flow data will be considered. These include establishing staff-gage at un-gaged tributaries, developing stage discharge relationships based on cross-section and velocity measurements at the staff-gage locations, relationship between flows from gaged and un-gaged sites, and/or ratio estimators based on watershed areas and precipitation records for sites where no flow data were collected.

Flow at drainage/discharge locations established during the Department of Health's shoreline survey (Scott Berbells, 2003) and follow-up reconnaissance survey will be collected, every three months, by Ecology, Mason County, and/or the Squaxin Island tribe. The measured flow will be compared with estimated flows based on rainfall and respective drainage areas.

For point sources with an NPDES permit, flow data will be obtained from DMR data.

**Tides**

The hydrodynamic model calibration will be checked by comparing predicted tides from the model with those measured in the field. The seven sinusoidal components (Duxbury, 1971) of the predicted tides will be compared with those of the NOAA predictions, using Nautical Software (1996), to further check agreement between the two predictions.

**Salinity/Conductivity**

Salinity will be measured, on a monthly basis, at several locations in Oakland Bay, Hammersley Inlet, mouth of the Hammersley Inlet, and the tributaries. These data will be used to calibrate the model.

**Temperature**

Continuous temperature will be measured at the mouth of Hammersley Inlet (Cape Cod) at several depths. Continuous temperature will also be measured at key locations throughout the bay and tributaries. Model predictions and observed data will be matched through a model calibration process where the unknown heat constants will be successively varied, within acceptable range, until the model is calibrated.

## Water Quality Model

Although several factors are responsible for bacteria die-off, including temperature (Ahmed and Sorensen, 1995), salinity (Pike et al., 1970), UV-radiation from sunlight (Al-Azawi, 1986), pH (Watson, 1980), predation and parasitism (Enzinger and Cooper, 1976), and heavy metal toxicity (Jones, 1964), the overall die-off may be represented as a first-order decay process (Bowie et al., 1985). The reported first order decay rate constant has a wide range varying from 0.05/day to 4/day (Brown and Barnwell, 1987).

The fecal coliform bacteria first-order, die-off rate ($K_{20}$) for Oakland Bay and Hammersley Inlet will be estimated through calibration to get the best fit of model predictions and observed bacteria concentrations at the various marine stations. The model automatically converts the first-order die-off rate constant, $K_{20}$, at 20˚C to that at the temperature of the grid cell. The monthly bacteria data collected will be transformed to an estimated daily load using the process outlined in the following section.

Following calibration, the monthly geometric mean and 90th percentile of predicted daily maximum bacteria concentrations will be estimated and compared to the respective water quality standards for each grid cell. Loadings to the bay and the inlet will be successively reduced until water quality standards are met in all the grid cells. This will lead to the establishment of reduction targets for the tributaries. Rduction targets will be established for both the rainy, as well as the non-rainy, season depending on whether fecal coliform standards were exceeded in both the seasons.

**Fecal Coliform Loads**

Bi-weekly bacteria concentrations and daily flows measured at all the tributaries, point sources, and drainages will be used to estimate daily fecal coliform loads. Additional fecal coliform data will be collected by the DOH at its current sampling locations.

Pelletier and Seiders (2000) successfully used the log-linear regression model of Cohen et al. (1992) to accurately represent fluvial loads of fecal coliform bacteria to Gray's Harbor. The log-linear regression model is of the type shown below and contains a constant, a linear and quadratic fit to the logarithm of flow, and sinusoidal (Fourier) functions to remove the effect of annual seasonality.

$Log[FC] = \beta_0 + \beta_1 Log[Q] + \beta_2 Log[Q]^2 + \beta_3 \sin[2\pi T] + \beta_4 \cos[2\pi T] + \beta_5 \sin[4\pi T] + \beta_6 \cos[4\pi T] + \varepsilon$

where:   Log[FC] = logarithm of fecal coliform (number of organisms per 100 ml),
$\quad\quad\quad$ Log[Q]  = logarithm of flow (cubic meters per second),
$\quad\quad\quad$ T = time measured in years.
$\quad\quad\quad$ $\varepsilon$ = error term assumed to be independent and normally distributed with a mean of zero
$\quad\quad\quad$ $\beta$-terms = parameters of the model estimated through multiple regression

Pelletier and Seiders (2000) omitted the use of the terms $\beta_2$, $\beta_5$, and $\beta_6$ since these were found to be statistically insignificant.   The regression model therefore simplifies to the form shown below:

$$Log[FC] = \beta_0 + \beta_1 Log[Q] + \beta_3 \sin[2\pi T] + \beta_4 \cos[2\pi T] + \varepsilon$$

The regression model is then used, in conjunction with record of daily flows, to predict daily loading of fecal coliform bacteria. However, to do this, the logarithm of fecal coliform must be re-transformed into real units of fecal coliform concentration. This creates an error and must be corrected through a *smearing estimate* (Duan, 1983), a non-parametric re-transformation function appropriate for non-normal error distributions to correct the re-transformed predicted concentrations for potential biases that can otherwise occur due to log-transformation. This method has been recommended by Thomas (1985), Koch and Smillie (1986), and successfully used by Pelletier and Seiders (2000).

$$FC = K_{se} \left\{ 10^{(\beta_0 + \beta_1 Log(Q) + \beta_3 \sin[2\pi T] + \beta_4 \cos[2\pi T])} \right\}$$

Where: Kse = *smearing estimate* = mean value of the antilogs of the regression residuals.

The potential bias of predicted versus observed total loads, integrated over all sampling days, will be tested using the t-test method described by Cohn et al., 1992.

**Predicted Response to Storm Event Loading**
Daily rainfall data will be obtained from the Taylor United gage on Flupsy Dock on Oakland Bay. The predicted daily fecal coliform load from all tributaries and drainages will be plotted against daily rainfall data to visualize the impact of storm events on fecal coliform loadings to the Oakland Bay-Hamersley Inlet Watershed. In order to evaluate the effect of storm events, daily geometric mean and 90th-percentile hourly predictions will be compared to the criteria for each cell of the grid to answer the following questions:

- What is the impact of storm events on concentrations of fecal coliform bacteria in the bay?

- How long does it take for the bay-inlet to flush out the effects of storm events?

- How much reduction in non-point sources in the watershed needs to take place in order to meet the water quality standard in the bay?

# Data Quality Objectives

Experience at Ecology has shown that duplicate field thermometer readings consistently show a high level of precision, rarely varying by more than 0.2°C. Therefore, replicate field thermometer readings were not deemed to be necessary and will not be taken. Accuracy of the thermograph data loggers and the field thermometers will be maintained through pre- and post-calibration in accordance with Timber-Fish-Wildlife (TFW) Stream Temperature Survey Manual (Schuett-Hames et al., 1999) to document instrument bias and performance at representative temperatures. A certified reference thermometer will be used for the calibration. The certified reference thermometer, manufactured by HB Instrument Co. (Part No. 61099-035, Serial No. 2L2087) is certified to meet ISO9000 standards and calibrated against National Institute of Standards and Technology (NIST) traceable equipment. The field thermometer is a Brooklyn Alcohol Thermometer (Model No. 67857). If there is a temperature difference of greater than 0.2°C, the field thermometer's temperature readings will be adjusted by the mean difference.

Manufacturer specifications for Onset Stowaway report an accuracy of ±0.2°C in the temperature range of -5°C to +37°C and ±0.4°C in the temperature range of -20°C to +50°C. If the mean difference between the NIST thermometer and the thermal data loggers differs by more than the manufacturer's reported specifications, the thermal data logger will not be used during field work. Accuracy of the Onset Stowaway will be evaluated by comparing the downloaded data to reference temperature readings taken with a calibrated field thermometer during site visits throughout the sampling season. The mean difference between the downloaded data and the reference thermometer readings will be calculated. Data are only acceptable if they do not exceed a maximum mean difference of 0.2°C.

Representativeness of the data is achieved by a sampling scheme that accounts for land practices, flow contribution of tributaries, and seasonal variation of in-stream flow and temperatures in the basin. Extra calibrated field thermometers and thermograph data loggers will be taken in the field during site visits and surveys to minimize data loss due to damaged or lost equipment.

Other parameters to be measured and the quality objectives are presented in Table 8. The laboratory's quality control procedures are documented in the Manchester Environmental Laboratory (MEL) Lab User's Manual (MEL, 2003). Accuracy includes both precision and bias. Precision is a measure of data scatter due to random error, while bias is a measure of differences between a parameter value and the true value due to systematic errors. Precision can be quantified using a number of parameters, including relative percent difference (RPD)[1], standard deviation (s)[2], pooled standard deviation ($s_P$)[3], or percent relative standard deviation (%RSD)[4]. For paired results, %RSD = RPD/$\sqrt{2}$. The %RSD will be used to assess data quality, as listed in the table. Since random error affects the determination of bias, bias qualification is very difficult. Adherence with established protocols will eliminate most sources of bias (Lombard and Kirchmer, 2001).

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[1] Based on data-pair $x_1$ and $x_2$, as $200*(x_1 - x_2)/(x_1 + x_2) = 100*(x_1 - x_2)/(avg\ [x_1\ and\ x_2])$.
[2] Based on data-pair, $x_1$ and $x_2$, as $(x_1 - x_2) / sqrt(2)$.
[3] Based on several data-pairs $s_p = sqrt(\Sigma\ D^2 / 2\ m)$, where $\Sigma\ D^2$ =sum of squares of the differences between m data-pairs.
[4] Based on data-pair, $x_1$ and $x_2$, as $100*s /(avg\ [x_1\ and\ x_2])$, where s is the standard deviation.

**Table 8. Summary of Field and Laboratory Methods with Precision and Reporting Limits.**

| Parameter | Method and Reference (1) | Precision, relative percent difference (RPD) | Reporting Limit |
|---|---|---|---|
| **Field Measurements** | | | |
| Velocity | WAS, 1993 - Swoffer current meter | within 20% | 0.05 feet/second |
| Conductivity | WAS, 1993 - Beckman bridge | +/- 20 umhos/cm @ 25C | 1 umhos/cm @ 25 C |
| Water Temperature | WAS, 1993 - Red liquid thermometer | +/- 0.2 C | 0.1 C |
| **Lab Measurements** | | | |
| Fecal Coliform bacteria | SM9222D – MF SM9222E – MPN | 30% | 1 cfu/100 mL |

# Analytical and Sampling Procedures

Field sampling and measurement protocols will follow those described in the TFW Stream Temperature Survey Manual (Schuett-Hames et al., 1999) and the Watershed Assessment Section (WAS) Protocol Manual (WAS, 1993). Temperature recorders will be installed in the water in areas which are representative of the surrounding environment and are shaded from direct sunlight. To safeguard against data loss, data from the loggers will be downloaded midway through the sampling season.

For bacteria analysis, laboratory methods available from MEL are appropriate for the data quality objectives and expected concentrations. Grab samples will be collected directly into pre-cleaned, sterilized 250 mL bottles supplied by MEL and described in MEL (2003). An extra set of sample containers will be available should any of the bottles be lost or contaminated. During sampling, the bottles are filled to the shoulder and stored at 4°C. While the hold time for fecal coliform samples will meet the 30-hour limit specified in the Watershed Assessment Section Protocols (WAS, 1993), samples will exceed the 6-hour hold time recommended in Standard Methods (Greenberg, et al., 1992) for legal actions. However, most samples should meet the 24-hour hold time recommended in Standard Methods (Greenberg, et al., 1992) for samples collected for purposes other than legal actions.

For fecal coliform data comparability and to establish whether inter-laboratory bias is present, ten split samples will be separately analyzed by Ecology and SIT using the MF method. If inter-laboratory data shows no-bias, or random-bias, further split samples will not be taken during the course of the project and each party will continue to analyze samples independently. If there is a definite positive or negative bias, further samples will be analyzed by Ecology using the MF method.

# Quality Control Procedures

Variation for field sampling will be addressed with a field check of the instruments with a handheld thermometer at all thermograph sites upon deployment, retrieval, and also once during the sampling

season (mid-August).  Field sampling and measurements will follow quality control protocols described in the WAS Protocol Manual (WAS, 1993) and the TFW Stream Temperature Manual (Schuett-Hames et al., 1999).  The Onset Stowaway Tidbits will be pre- and post-calibrated in accordance with TFW stream temperature survey protocol to document instrument bias and performance at representative temperatures.  A certified reference thermometer will be used for the calibration.

Total variation for field sampling and analytical variation will be assessed by collecting duplicate samples in addition to lab duplicates and comparing to data quality objectives.  Field duplicate samples will be collected for fecal coliform bacteria for every five samples.

# Field Monitoring Responsibilities

Several parties will be responsible for collecting and analyzing samples for fecal coliform bacteria; taking field measurements; installing staff-gages, temperature devices; and deploying Hydrolab or CTD, tide-gages, current meters, and ADCP. This is summarized in Table 9.

**Table 9.  Field Monitoring Responsibilities.**

| Location | Parameter | Required Frequency | Responsible Party | Frequency of Sampling |
|---|---|---|---|---|
| Freshwater | fecal coliform | bi-weekly | SIT | 1/month |
| | | | Ecology | 1/month |
| | instantaneous temperature | bi-weekly | SIT | 1/month |
| | | | Ecology | 1/month |
| | instantaneous conductivity | bi-weekly | SIT | 1/month |
| | | | Ecology | 1/month |
| | continuous temperature | continuous | Ecology | devices installed at beginning of project at selected locations |
| | flow at ungaged tributaries (Deer, Malaney, Uncle John, Campbell creeks) | bi-weekly | SIT | 1/month |
| | | | Ecology | 1/month |
| | flow at mouths of  Shelton, Johns, and Mill  creeks | bi-weekly | Ecology | bi-weekly |
| Unnamed tributaries, drainage/ discharge/ seepages | fecal coliform | quarterly | Ecology | quarterly |
| | flow | quarterly | Ecology | quarterly |
| Marine water | fecal coliform/CTD, Oakland Bay | monthly | DOH/Ecology | monthly |
| | fecal coliform/CTD, Hammersley Inlet | bi-monthly | DOH/Ecology | bi-monthly |
| | tidegage/current meter (S4) | continuous | Ecology | devices installed at beginning of project at selected locations |
| | temperature | continuous | Ecology | devices installed at beginning of project at selected locations |
| | conductivity-temperature (Hydrolab) | continuous | Ecology | devices installed at beginning of project at selected locations |
| | Vertical velocity gradient (ADCP) | 2/year | Ecology | devices installed in January and August |

# Project Organization

The roles and responsibilities of Ecology staff involved in this project are provided below:

*Anise Ahmed, Project Manager, Watershed Ecology Section, Environmental Assessment Program.* Responsible for overall project management.  Defines project objectives, scope, and study design. Responsible for writing the project Quality Assurance (QA) Project Plan, data evaluation, modeling, and final technical report.  Manages data collection program.  Oversees and coordinates field sampling. Writes TMDL technical study report.

*Lawrence Sullivan*, *Field Investigator*, *Water Quality Studies Unit, Environmental Assessment Program.*  Responsible for data collection; data entry into the EIM system; and writing sections of the technical report related to data collection, field methods, and data quality review.

*John Konovsky, Lead Field Investigator for Freshwater*. *Squaxin Island Tribe.*  Responsible for review and approval of the QA Project Plan. Coordinates and conducts freshwater field investigations.

*Christine Hempleman, TMDL Lead, Water Quality Program, Southwest Regional Office (SWRO).* Reviews and comments on QA Project Plan and report.  Coordinates local outreach and information exchange about the technical study and local development of implementation and monitoring plans between Ecology and local planning groups. Supports data collection as part of the TMDL implementation monitoring.

*Kim McKee, Unit Supervisor, Water Cleanup Unit,  Water Quality Program, (SWRO).*  Responsible for review and approval of the QA Project Plan and final report.

*Kelly Susewind, Section Manager, Water Quality Program, SWRO.*   Responsible for approval of TMDL submittal to EPA.

*Karol Erickson, Unit Supervisor, Water Quality Studies Unit, Environmental Assessment Program.* Responsible for review and approval of the QA Project Plan and final report.

*Will Kendra, Section Manager, Watershed Ecology Section, Environmental Assessment Program.* Responsible for approval of the QA Project Plan and final report.

*Stewart Lombard, Quality Assurance Officer, Environmental Assessment Program.*   Responsible for review and approval of QA Project Plan.  Available for technical assistance on quality assurance issues and problems during the implementation and assessment phases of the project.

*Stuart Magoon**, Director, Manchester Laboratory,  Environmental Assessment Program.*  Provides laboratory staff and resources, sample processing, analytical results, laboratory contract services, and QA/QC data.  Reviews sections of the QA Project Plan relating to laboratory analysis.

# Project Schedule

Table 10 lists the proposed schedule for data collection, analysis, modeling, and reporting.

**Table 10. Proposed Schedule for TMDL Study.**

| Document or Activities | Dates |
|---|---|
| Final QA Project Plan | September 2004 |
| Reconnaissance survey | September 2004 |
| Field instrumentation setup | October 2004 |
| Data collection and EIM data-entry | October 2004-September 2005 |
| Analyses and modeling | September 2005 – March 2006 |
| Draft TMDL technical report for client review | April 2006 |
| Draft TMDL technical report for external review | May 2006 |
| Final TMDL technical report | September 2006 |

# Laboratory Budget

The laboratory budget in Table 11 includes all analyses to be conducted by Manchester Environmental Laboratory and the costs include a 50 percent discount. This primarily includes fecal coliform bacteria analysis.

**Table 11. Oakland Bay-Hammersley Inlet and Tributaries FC TMDL Laboratory Cost Estimate for 2004-2005 Monitoring Period.**

| Waterbody (Sampling Frequency) | Fecal Coliform: MF Method | | | | Cost/ MF Analysis | Cost/ Year |
|---|---|---|---|---|---|---|
| | Every month | Every 2-months | Every 3-months | Once | | |
| Tributaries (bi-weekly) | 29* | | | | $21 | $7308 |
| Duplicate samples, tributaries | 6 | | | | $21 | $1512 |
| Split samples for inter-laboratory bias | | | | 10 | $21 | $210 |
| Culverts, drainage etc. (once every 3-months) | | | Unknown** | | $21 | Unknown** |
| Marine (monthly) | 7 | | | | $21 | $1764 |
| Marine, (bi-monthly) | | 6 | | | $21 | $756 |
| Duplicate samples, marine | 1 | 1 | | | $21 | $378 |
| | | | | | Total | $11,928 *** |

* One bi-weekly sample will be analyzed by the Squaxin Island Tribe. This number represents the other bi-weekly sample to be analyzed by Ecology. However, if inter-laboratory bias is present, Ecology will analyze all bi-weekly samples (i.e. 58 samples).

**The number of samples and cost will be finalized following reconnaissance survey.

*** Total cost will change depending upon additional number of samples following reconnaissance survey and whether inter-laboratory bias is present.

# References

Ahmed, A. U. and D. L. Sorensen. Kinetics of Pathogen Destruction During Storage of Dewatered Biosolids. *Water and Environment Research*. 1995. Vol 69, No. 2, pp 143.

Al-Azawi, S. K. A.  1986.  Bacteriological Analysis of Stored Aerobic Sewage Cake.  Agricultural Wastes 16:77-87.

Berbells, S. 2003. 2003 Shoreline Survey of the Oakland Bay Shellfish Growing Area. Department of Health. Olympia, WA.

Berbells, S. 2004. Personal Communication, Office of Food Safety & Shellfish Programs. Washington State Department of Health, Olympia, WA.

Bowie, G. L., W. B. Mills, D. B. Porcella, C. L. Campbell, J. R. Pagenkopf, G. L. Rupp, K. M. Johnson, P. W. H. Chan, and S. A. Gherini. 1985. Rates Constants and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). EPA/600/3-85/040. Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. Athens, GA.

Brown and Caldwell Consultants. 1990. Oakland Bay Watershed Management Plan.  Final Report. December 1990.

Brown, L. C. and T. O. Barnwell. 1987.  The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS.  EPA/600/3-87/007.  Environmental Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency. Athens, Georgia.

Buchak, E. M. and J. E. Edinger. 1984. Generalized, Longitudinal-Vertical Hydrodynamics and Transport:  Development, Programming, and Applications.  Prepared for U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Miss. Contract No. DACW39-84-M-1636. Prepared by J.  E. Edinger Associates Wayne, PA. Document No. 84-18-R. June.

Cerco, C. F., and T. M. Cole. 1994. Three-Dimensional Eutrophication Model of Chesapeake Bay. Volume 1:  Main Report. Technical Report EL-94-4.  U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Miss. May 1994.

Determan, T.  1999.  Trends in Fecal Coliform Pollution in Eleven Puget Sound Embayments. Report for the Puget Sound Ambient Monitoring Program.  Office of Shellfish Programs, Washington Department of Health, Olympia, WA.

Dougherty, D. 2004. Personal Communication,  Ecology NPDES Permit Writer, Southwest Region Water Quality Program, Washington State Department of Ecology, Olympia, WA.

Edinger, J. E. and E. M. Buchak. 1995. Numerical Intermediate and Far Field Dilution Modelling. Journal Water, Air and Soil Pollution 83: 147-160,1995. Kluwer Academic Publishers, The Netherlands.

Edinger, J. E., E. M. Buchak, and M. D. McGurk. 1994. Analyzing Larval Distributions Using Hydrodynamic and Transport Modelling. Estuarine and Coastal Modeling III. American Society of Civil Engineers, New York.

Edinger J. E., J. Wu, and E. M. Buchak. 1997.  Hydrodynamic and Hydrothermal Analyses of the Once-Through Cooling Water System at Hudson Generating Station. Prepared for Public Service Electric and Gas (PSE&G). Prepared by J. E. Edinger Associates, Inc., June 1997.

Enzinger, E. M., and R. C. Cooper. 1976. Role of Bacteria and Protozoa in the Removal of Escherichia Coli from Estuarine Waters. Appl. Environ. Microbiol. 31:758-763.

Hamrick, J. M. 1992. A Three-Dimensional Environmental Fluid Dynamics Computer Code: Theoretical and Computational Aspects.  The College of William and Mary, Virginia Institute of Marine Science. Special Report 317.

Hamrick, J. M. 1996. A User's Manual for the Environmental Fluid Dynamics Computer Code (EFDC).  The College of William and Mary, Virginia Institute of Marine Science. Special Report 331.

Jones, G. E. 1964.  Effect of Chelating Agents on the Growth of Escherichia Coli in Seawater. J. Bacteriol. 87: 484-499.

Kenney, S. 2004.  WRIA 14 Water Quality Grant – GO400053 Oakland Bay Restoration & Shellfish Protection.  Report of Grant Activities January 1 through March 31 2004.  Mason County Dept. of Health Services, Water Resource Protection Program.

Lombard, S. and C. J. Kirchmer. 2001. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies.  Environmental Assessment Program, Washington State Department of Ecology. Manchester, Washington.

Manchester Environmental Laboratory. 2003.  Laboratory User's Manual, 7th Edition. Washington State Department of Ecology, Port Orchard, WA.

Melvin, D. 2003. Personal Communication. Restoration Program Lead, Office of Food Safety & Shellfish Programs. Department of Health., Olympia, WA.

Michaud, J. 1987. Sources Affecting Bacteria Quality in Oakland Bay.  Final Report. Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Ambient Monitoring Program, Olympia, WA.

Ott, W. R.  1995.  Environmental Statistics and Data Analysis. CRC Press LLC. Boca Raton, FL, 313 Pages.

Pike, E. B., A. H. L. Gameson, and D. J. Gould. 1970.  Mortality of Coliform Bacteria in Seawater Samples in the Dark. Rev. Int. Oceanogr. Med 18/19:97-107.

Schuett-Hames, D., H. Flores, and I. Child. 1996. An Assessment of Salmonid Habitat and Water Quality for Streams in the Eld, Totten-Little Skookum, and Hammersley Inlet-Oakland Bay Watersheds in Southern Puget Sound, Washington, 1993-1994. Squaxin Island Tribe Natural Resources, Shelton, WA.

Smith, K. A. and J. Rector. 1994. Water Quality Assessments of Selected Lakes Within Washington State. Publication No. 97-307. Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Ambient Monitoring Program, Olympia, WA.

Squaxin Island Tribe. 1999. 1999 Squaxin Island Smolt Trapping Data. Squaxin Island Tribe, Shelton, WA.

Taylor, K., Moreland, T., and M Stevie. 2000. Oakland Bay-Hammersley Inlet Watershed Assessment. Squaxin Island Tribe, Shelton.

U.S. Army Engineer Waterways Experiment Station, Environmental and Hydraulics Laboratories. 1986. "CE-QUAL-W2: A Numerical Two-Dimensional, Laterally Averaged Model of Hydrodynamics and Water Quality; User's Manual," Instruction Report E-86-5, U.S. Army Engineer Waterways Experiment Station, Vicksburg, Miss. NTIS No. AD A172 930.

U.S. Geological Survey. 1998. Determination of Upstream Boundaries on Western Washington Streams and Rivers Under the Requirements of the Shoreline Management Act of 1971. Water-Resources Investigation Report 96-4208. U.S. Geological Survey, Tacoma, WA.

Washington Department of Ecology. 1983. In-Stream Resources Protection Program: Kennedy-Goldsborough Water Resource Inventory Resource Area (WRIA) 14. WWIRPP Series No. 27. Washington Department of Ecology, Water Resources Planning and Management Section, Olympia, WA.

Washington Department of Fisheries (WDF), Washington Department of Wildlife (WDW), and Western Washington Treaty Indian Tribes (WWTIT). 1993. 1992 Washington State Salmon and Steelhead Stock Inventory (SASSI). Wash. Dep. Fish Wildl., 212 p. + Three Appendices. Appendix 1: Hood Canal and Strait of Juan de Fuca (December 1994, 424 p.), North Puget Sound (June 1994, 418 p.), and South Puget Sound (September 1994, 371 p.) Volumes. Appendix 2: Coastal stock (August 1994, 587 p.). Appendix 3: Columbia River Stocks (June 1993, 580 p.). Washington Department of Fish and Wildlife, Olympia, WA.

Watson, D. C. 1980. The Survival of Salmonella in Sewage Sludge Applied to Arable Land. WPC (G.B.) 79:11-18.

Williams, R. W., R. M. Laramie, and J. J. Ames. 1975. A Catalog of Washington Streams and Salmon Utilization.  Volume 1:  Puget Sound Region.  Washington Department of Fisheries, Olympia, WA.

Young, B. 2004. Personal Communication. Southwest Puget Sound Watershed Council, Shelton, WA.