

3.0 WATER and SEDIMENT QUALITY

3.1 WATER QUALITY STANDARDS INTRODUCTION

The Washington State Department of Ecology (WA-DOE) is responsible for administering the state water-quality management program under the authority of Washington state law and under the direction of the federal Clean Water Act (CWA) and the US Environmental Protection Agency (US-EPA). To that end, WA-DOE has established surface water quality standards (WQS) to protect the beneficial water uses of the state such as contact recreation (swimming and boating), fish and shellfish harvesting, aquatic life habitat, and domestic water supplies. These WQS establish goals for lakes, rivers, and marine waters by assigning appropriate combinations of beneficial uses to each water body, and by setting criteria to ensure those uses are protected. These criteria are often quantitative limits on how much of a particular toxic chemical or other pollutant can exist in a water body without harming the various beneficial uses. Section 303(d) of the Federal Clean Water Act (CWA) and US-EPA regulations (40 CFR Part 130) require that states prepare a list of water body segments that do not attain state WQS. Surface waters for which at least one characteristic or designated use is impaired, as evidenced by failure to attain the applicable water quality standard for one or more pollutants can be placed on the 303(d) list. A Water Clean-up Plan is required for each water-body on this list, in accordance with the CWA, to guide efforts to bring it back into attainment. A determination of impairment can be made based on either numeric or narrative information. Contaminants in fish and shellfish (either measured or extrapolated from bioaccumulation factors) that pose a human risk via consumption can also result in a closure of shellfish beds by the Washington Department of Health (WA-DOH).

The following Liberty Bay water-bodies are currently on the WA-DOE 303d list for microbial or bacterial pollution:

- Liberty Bay Marine Waters
- Daniels Creek
- Dogfish Creek
- Johnson Creek
- Little Scandia Creek
- Big Scandia Creek
- Bjorgen Creek
- Lemolo (Kleabal) Creek

3.2 MICROBIAL POLLUTION

Degradation of water quality due to contamination by microbial pollution, including bacterial contamination and potential pathogens represents a health risk and economic loss to many parts of Puget Sound. In general, pathogens are a serious concern for water resource managers because excessive quantities of fecal bacteria in human sewage and NPS runoff have been known to indicate an increased risk of pathogen-induced illness in humans (Kay et al., 1994; Fleisher et al., 1998; Haile et al., 1999). The bacteria and associated pathogens of primary concern to humans are the disease causing bacteria and viruses. Some of these bacteria are free-living organisms able to survive on their own and grow in an aquatic habitat. Viruses, on the other hand, can grow only inside of a suitable host. Of the many different viruses associated with fecal material, most are responsible for causing gastrointestinal illness, but some can also cause other significant illnesses. Pathogenic bacteria found in fecal material are responsible for a variety of diseases.

Public health organizations, state environmental agencies, and the US-EPA have developed several water quality criteria to protect human health. Over 100 different enteric pathogens may be found in sewage, including viruses, parasites, and bacteria (NRC, 1993). However, it is very difficult and expensive to directly measure the presence of pathogenic organisms (viruses, bacteria, and protozoans). Because public health agencies are not able to measure the entire host of human pathogens directly, they have relied on “indicator” organisms to assess the probability of the presence of pathogens. The most commonly utilized measure of fecal pathogenic bacteria is fecal coliform (FC) bacteria abundance. Measurements of fecal indicator bacteria (FIB) have been used as the basis of regulatory action back to the 1920s (Dadswell, 1993; Jagals et al., 1995; Pitt, 1998; NRC, 2004).

Not all natural bacteria pose a human health or water quality problem. Of human health concern, is the coliform bacteria group, which consists of several genera of bacteria belonging to the family *enterobacteriaceae*. FC bacteria are a member of this family. Large numbers of FC bacteria are present in the intestinal tracts and fecal material of all warm-blooded animals including mammals, birds, and humans. Coliform bacteria and others may also be naturally present in soils and sediments. FC themselves are not usually pathogenic, but are often found associated with other organisms that do cause disease in humans. When predetermined concentrations of FC are reached, the area is considered unsafe for certain uses. If a large number of FC bacteria are present in a water body, it is possible that pathogenic organisms are also present in the water. For this reason, FC is the primary FIB used in Washington (WA-DOE, 2003). An excellent review of microbial pathogens found in the coastal environment can be found in the National Research Council Report (NRC, 1993).

Contact with bacterial-contaminated water increases the risk of developing an illness or infection from pathogens entering the body through ingestion, inhalation, or skin contact via open wounds. The presence of FIB (FC) is an indicator of the Possible presence of pathogens. In all cases, the concentration of FIB is significantly greater than pathogens. Waterborne diseases that could be contacted from contaminated water include the following (US-EPA, 2001c):

- Viral Hepatitis or Hepatitis A
- Viral Gastroenteritis
- Hemorrhagic colitis (*Escherichia coli*)
- Campylobacteriosis or Gastroenteritis (*Campylobacter jejuni*)
- Dysentery or Shigellosis (*Shigella*)
- Salmonellosis (*Salmonella spp.*)
- Legionellosis (*Legionella pneumophila*)
- Leptospirosis (*Leptospira spp.*)
- Typhoid Fever (*Salmonella typhi*)
- Cholera (*Vibrio cholerae*)
- Peptic Ulcer (*Helicobacter pylori*)
- Amebiasis (*Entamoeba histolytica*)
- Giardiasis (*Giardia lamblia*)
- Cryptosporidiosis (*Cryptosporidium parvum*)

Research has also indicated that there may be an increased risk of adverse health outcomes associated with swimming in waters that are contaminated by untreated stormwater runoff (Stevenson, 1953; Cabelli et al., 1979; Cabelli et al., 1982; Corbett et al., 1993; Fleisher et al., 1993; Kay, 1994; Haile et al., 1999; Noble et al., 2000; Hendrickson et al., 2001; Lipp et al., 2001; Gaffield et al., 2003). In addition, these health risks are generally higher for those swimming in close proximity to stormwater outfalls (Haile et al., 1999; Noble et al., 2000; Schiff et al., 2003; Ackerman and Weisberg, 2004; Noble et al., 2004a) or areas of high septic system density (Lipp et al., 2001).

Pathogenic enteric bacteria typically enter the freshwater and nearshore environment from human and animal waste products discharged from wastewater treatment systems, entrained in agricultural runoff, or carried in stormwater runoff (Maiolo and Tschetter, 1981; Gannon and Busse, 1989; Pitman, 1995; Macfarlane, 1996; Pitt, 1998; Mallin et al., 2000; Lipp et al., 2001; Mallin et al., 2001; Gaffield et al., 2003). The pathogen *Cryptosporidium*, a protozoan parasite, can be found in surface waters, especially those containing high amounts of sewage contamination or animal waste (Atherholt et al., 1998). *Giardia* is another commonly identified pathogen in surface waters (Atherholt et al., 1998). *Giardia* is the intestinal parasite that causes the disease giardiasis.

Viruses in animal waste also pose a potential health threat to humans. Pathogenic, enteric viruses are the most significant virus group affecting water quality and human health (Griffin et al., 2003). Enteric viruses may be found in livestock excrement from barnyards, pastures, rangelands, feedlots, and uncontrolled manure storage areas; and areas of land application of manure and sewage bio-solids (US-EPA, 2001). When animal waste is applied to agricultural land for irrigation or fertilization purposes, enteric viruses can survive in soil for periods of weeks or even months (US-EPA, 2001). Enteric viruses in land applied manure or sewage sludge can leach into ground water and/or eventually be transported by overland flow into surface water bodies, thus creating a potential for the contamination of water resources.

Consumption of contaminated water or consumption of contaminated shellfish or finfish can lead to human health problems (Craun et al., 1997; Lipp and Rose, 1997; Lees, 2000; White et al., 2000; Lipp et al., 2001). Shellfish beds are especially vulnerable to bacterial contamination because they are often located in close proximity to shoreline development and human activities that are potential sources of bacterial pollution (Maiolo and Tschetter, 1981; Pitman, 1995; Macfarlane, 1996; Pitt, 1998; Mallin et al., 2000; Lecaster and Weisberg, 2001; Lipp et al., 2001; Mallin et al., 2001; PSAT, 2002).

Numerous studies have been conducted that show an increased health risk from exposure to water containing high levels of indicator bacteria (see Pruss, 1998 for an excellent review). However, the results of these epidemiology studies of FIB and health risks are not always consistent and have provoked some controversy, leading to discussion of the appropriateness of current FIB as compared to other indicators such as enterococci or *E. coli* bacteria (Valiela et al., 1991; Ferguson et al., 1996; Elliot, 1997; Schiff et al., 2001; Schiff et al., 2003; Noble et al., 2003a; Noble et al., 2003b; Noble et al., 2004c; Nobel et al., 2004d). While, the relationship between FIB, such as FC, and the risk to public health may not be without some uncertainty, there is still cause for concern when any FIB level is above the normal ambient, background level (Ferguson et al., 1996; Schiff et al., 2001; Turbow et al., 2004). Some of the inherent problems with current FIB include the following (NRC, 2004):

- FIB levels may not reflect pathogen levels or risk of disease;
- Natural populations of FIB can be found in soil and plants;
- FIB survival times in water may be less than some pathogens;
- Current FIB methods cannot distinguish between sources;

- FIB is not a good indicator for the presence of bio-toxins;
- Indicators are not good models for viruses or protozoans.

For this project, FC was used as the FIB, based on current Washington Department of Health (WA-DOH) and Department of Ecology (WA-DOE) standards. Sinclair and Dyes Inlets, as well as several contributing tributary streams are listed on the current section 303(d) list for high microbial contamination.

A healthy, balanced estuary is teeming with bacteria, minute organisms that enter into the many biological processes from digestion to nutrient cycling. Bacteria are essential members of a functioning ecosystem. Too many of the wrong kinds of bacteria, however, can indicate trouble. A sudden input of large numbers of bacteria can deplete the oxygen supply affecting sensitive animals such as fish. Certain pathogenic (disease causing) bacteria can accumulate in invertebrates such as shellfish and cause human illnesses. Fecal coliform bacteria normally grow in the intestinal tracts of mammals, humans included. They are present in large numbers in human sewage and have thus become an indicator of contaminated water. They can enter water systems in several ways: directly from boats, from on-site sewage systems, septic tanks, drain fields which are not working properly, from sewage treatment plants, and from pets and livestock (cows in a stream or inadequate storage and spreading of manure). The presence of coliform bacteria is not a problem in itself. In fact, coliform bacteria generally do not reproduce outside of the digestive tract. They may indicate problems, however, since they indicate the possible presence of harmful bacteria and the contamination of water by sewage or livestock.

3.3 DESIGNATED BENEFICIAL USES

In accordance with Washington State WQS, Liberty Bay has the following freshwater designated beneficial uses (WAC 173-201A-200):

- Aquatic Life Uses
- Recreational Uses
- Water Supply Uses

In accordance with Washington State WQS, Liberty Bay Inlet has the following marine water designated beneficial uses (WAC 173-201A-210):

- Aquatic Life Uses
- Recreational Uses
- Shellfish Harvest Uses

Aquatic life uses specifically identify the protection of salmon and trout spawning, rearing, and migration habitat, as well as other associated aquatic life. The water quality criteria that apply to aquatic life include temperature, dissolved oxygen (DO), turbidity, and pH.

With respect to bacterial pollution, Liberty Bay is designated for primary contact recreation for both freshwater (WAC 173-201A-200) and marine water (WAC 173-201A-210) areas (see **Tables 5 & 6**). In addition, marine waters in the Liberty Bay watershed are subject to shellfish harvest bacterial criteria. The nearshore and marine waters of Liberty Bay are also within the “usual and accustomed” fishing and shellfishing areas of the Suquamish Tribe. Tribal subsistence harvest and consumption of fish and shellfish is considered part of this beneficial use. In addition, commercial and recreational shellfishing is a designated beneficial use of these waters.

3.4 WATER QUALITY STANDARDS & WACS

The purpose of WAC 173-201A is to establish water quality standards for surface waters of the state of Washington consistent with public health and public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife, pursuant to the provisions of chapter 90.48 RCW. Surface waters of the state include lakes, rivers, ponds, streams, inland waters, saltwater, wetlands, and all other surface waters and watercourses within the jurisdiction of the Washington State. All surface waters are protected by narrative criteria, designated beneficial uses, and an anti-degradation policy. Based on the use designations, numeric and narrative criteria are assigned to a water body to protect the designated uses.

WAC 173-201A describes the designated water uses and criteria for the state of Washington. These criteria were established based on existing and potential water uses of the surface waters of the state. Consideration was also given to both the natural water quality potential and its limitations. Compliance with the surface water quality standards of the state of Washington requires compliance with WAC 173-201A, WQS for surface waters of the state of Washington, WAC 173-204, sediment management standards, and other applicable federal regulations.

The Washington WQS are currently undergoing revision and approval by US-EPA. Because the revised WQS are expected to be approved in the near future, the revised standards are being used throughout this report for comparison purposes only. Under these WQS, the marine waters of Liberty Bay are designated *primary contact recreation* (WAC 173-201A-200) with respect to bacterial contamination. Freshwater resources in Liberty Bay are also designated *primary contact recreation* (WAC 173-201A-200) with respect to bacterial contamination. All waters designated *primary contact recreation* must meet the following WQS for FC bacterial contamination indicator organisms (see **Tables 5 & 6**):

- A. Freshwater - fecal coliform organism levels shall both not exceed a geometric mean value obtained for calculating the geometric mean value exceeding 100 fecal colonies/100 ml, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 fecal colonies/100 ml.
- B. Marine water - fecal coliform organism levels shall both not exceed a geometric mean value of 14 colonies/100 ml, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 43 fecal colonies/100 ml.

3.5 SHELLFISH HARVESTING STANDARDS

In addition to the WA-DOE WQS, Washington Department of Health (WA-DOH) has its own bacterial WQ criteria for marine-nearshore waters that are used for shellfish harvesting. The WA-DOH has adopted the guidelines set by the National Shellfish Sanitation Program (NSSP) water classification system (ISSC, 1999). This system requires an adequate distribution of bacterial sampling stations and a minimum of 30 samples taken under a variety of environmental (season, weather, and tidal) conditions. WA-DOH classifies all commercial shellfish growing areas in Washington State as *Approved*, *Conditionally Approved*, *Restricted*, or *Prohibited*. These classifications have specific standards associated with them, which are derived from the NSSP (ISSC, 1999). The following key NSSP shellfish *growing area standards* (GAS) are used as shellfish harvest criteria (WA-DOH, 2003):

- A. The geometric mean shall not exceed 14 MPN/100ml (MPN=most probable number FC method, using at least 30 samples).
- B. The 90th Percentile (calculated using the NSSP formula, using at least 30 samples) shall not exceed 43 MPN/100ml.

To support the shellfish harvest designated beneficial use, an area must meet these GAS. WA-DOH classifies a shellfish area as *approved*, *conditionally approved*, *restricted*, or *prohibited*.

WA-DOH classifies a shellfish area as *approved* if all GAS criteria are met and no significant pollution sources (e.g. sewage treatment plant outfalls) are present. An area may also be classified as *approved* when a sanitary survey shows that the area is not subject to contamination that presents an actual or potential public health hazard. An *approved* classification authorizes shellfish harvesting. In Approved areas, the growing and harvesting of shellfish for direct marketing is allowed. WA-DOH may classify a growing area as *approved* when pollution source evaluations and the bacteriological water quality data show that fecal material, pathogenic microorganisms, and poisonous or deleterious substances are not present in dangerous concentrations. The bacteriological quality of marine water samples collected from an *approved* growing area must satisfy both parts of the GAS shown above.

Even if the *approved* criteria are met for FC bacteria, WA-DOH may classify a growing area as *conditionally approved*, *restricted*, or *prohibited* (see definitions below) if pollution source investigations show that contamination may impact the sanitary condition of shellfish in the area. Because FC bacteria are not always good indicators of the presence of disease-causing viruses and other pathogens, WA-DOH depends on thorough evaluations of all potential pollution sources. In some cases, WA-DOH will temporarily close *approved* shellfish growing areas when events such as floods or bio-toxin blooms occur.

An area may be classified as *Conditionally Approved* when it meets *approved* criteria, but only during predictable periods. For example, during dry weather a growing area may meet *approved* water quality standards, but after a certain size rainfall event the water quality declines. In this example, the *conditionally approved* area is temporarily closed to harvest for a set period of time after a rainfall event. The length of closure is predetermined for each *conditionally approved* area, and is based on water sample data that shows the amount of time it takes for water quality to recover and again meet *approved* criteria. Once that time period has elapsed, the area is reopened for shellfish harvesting.

A *restricted* classification is used for areas that do not meet water quality standards for an *approved* classification, but the sanitary survey indicates only a limited and unpredictable degree of pollution from non-human sources. Shellfish harvested from *restricted* growing areas cannot be marketed directly. They must be transplanted to an approved growing area for a specified amount of time, allowing shellfish to naturally cleanse themselves of contaminants before they are harvested. The cleansing period required is generally a few weeks to several months. *Restricted* classifications are only considered where levels of pollution are low and relay times are shown to purify the shellfish prior to marketing.

A growing area must be classified as *prohibited* when pollution is chronically excessive and unpredictable. A growing area is also classified as *prohibited* when the sanitary survey indicates that fecal material, pathogenic microorganisms, or poisonous or harmful substances may be present in concentrations that pose a health risk to shellfish consumers. Growing areas adjacent to WWTP outfalls, marinas, and other persistent or unpredictable pollution sources may be classified as *prohibited*. Growing areas that have not undergone a sanitary survey are also typically classified as *prohibited*. Commercial shellfish harvests are not allowed from *prohibited* areas.

Currently, the east side of Liberty Bay, adjacent to the City of Poulsbo downtown area, is classified as *Prohibited*. Lemolo Bay is classified as *Approved*. The remainder of Liberty Bay is *Unclassified*. There is currently a health advisory issued recommending against recreational shellfish harvesting in Liberty Bay.

Table 5. Revised Washington Department of Ecology (WA-DOE) Water Contact Recreation Bacteria Water Quality Criteria for Freshwater (WAC 173-201A-200).

Table 200 (2)(b)	
Water Contact Recreation Bacteria Criteria in Fresh Water	
Category	Bacteria Indicator
Extraordinary Primary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 50 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.
Primary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100 mL.
Secondary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 200 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 400 colonies /100 mL.

Table 6. Revised Washington Department of Ecology (WA-DOE) Water Contact Recreation Bacteria Water Quality Criteria for Marine Waters (WAC 173-201A-200)

Table 210 (3)(b)	
Water Contact Recreation Bacteria Criteria in Marine Water	
Category	Bacteria Indicator
Primary Contact Recreation	Fecal coliform organism levels must not exceed a geometric mean value of 14 colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 41 colonies/100 mL.
Secondary Contact Recreation	Enterococci organism levels must not exceed a geometric mean value 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.

3.6 LBNS PROJECT FC DATA

As part of the Liberty Bay Nearshore Assessment Project, water-quality (WQ) sampling was conducted in the marine waters of Liberty Bay and in tributary streams that drain to the bay. In addition, stormwater outfalls that drain to Liberty Bay were also sampled. Sampling was conducted from 2001 through 2003. **Table 7** lists the WQ sample sites in Liberty Bay and **Figure 24** shows the locations of sample sites in the bay for 2001-3. Sampling by the Liberty Bay Project team concentrated on the wet-weather or storm-season months during the sample 2001-2 and 2002-3 sampling periods. This differs from the KCHD sampling strategy, which is based on a randomized monthly sampling scheme that is designed to provide accurate and consistent WQ-trend analysis. In addition to fecal coliform (FC) sampling, water-quality monitoring included the following physio-chemical parameters:

- Temperature
- Dissolved Oxygen (DO)
- Conductivity or Salinity
- pH
- Turbidity or Transparency

All WQ sampling was conducted in accordance with the protocols and methods established in the project QAPP (see **Appendix A**). The QAPP includes detailed information on the water quality monitoring approach and laboratory protocols, including types of data and samples to be collected, sample location, sampling frequency, sampling procedures, analytical methods, quality control procedures, data handling protocols, and data assessment procedures. Water samples requiring laboratory analysis (e.g. fecal coliform bacteria) were analyzed by the Kitsap County Health District (KCHD) environmental laboratory. The QAPP includes laboratory operations, data quality objectives, analytical procedures, internal quality control checks, data assessment procedures, performance audits, and quality assurance reports.

Temperature is an important indicator. Many other characteristics of water depend on temperature. Many other monitoring parameters depend on temperature. For example:

- Cold water holds more oxygen than warm water.
- The rates of metabolism and photosynthesis increase as water temperature rises.
- Organisms are limited to certain temperature ranges and may be more susceptible to disease or poisoning from toxins when the temperature rises.
- Human activities can upset the temperature balance in an estuary.

The pH of a water body is also a measure of the chemical conditions that support life. Most organisms do not survive for long in water that is too acidic or too basic. The typical range for pH under normal conditions is 6.5-8.0.

Conductivity is a measure of the total dissolved material in the water. This could include salts, metals, nutrients, and any other ionic material, both natural and pollutants.

For most estuary and nearshore organisms, dissolved oxygen (DO) in water is vital. Oxygen levels often determine which organisms can live in an area. Oxygen can enter the water directly from the air by diffusion, or is supplied by the photosynthesis of plants. Many things affect the amount of DO in water, including:

- Temperature - - Cold water holds more DO than warm water,
- Aeration - - Water stirred by currents and winds picks up extra DO,
- Photosynthesis - - Plants and algae produce oxygen daily as they turn sunlight into food.
- Plankton growth - - Plankton blooms caused by excess nutrients deplete the DO when the microorganisms die and decay,
- Organic matter - - Decomposing organic matter takes DO from the water. Organic matter can come from decaying organisms, urban and agricultural runoff, sewage treatment plants, and other organic wastes (dairies, fish pens, lumber mills, paper plants, food processing plants, etc.).

Organisms such as bacteria and fungi decompose organic matter (OM) in nearshore areas. This decomposition process removes oxygen from the water. If too much OM comes into an estuary, DO levels can be depleted to the point that aquatic organisms may be killed. Fish kills are often the result of the sudden discharge of too much OM that, as it decomposes, uses up all the available oxygen in the water. Continually low DO levels in a body of water can eliminate most biota. Excessive nutrient inputs into an estuary, especially one that does not flush well, can cause algal blooms. This excess primary production can lead to DO depletion as the algae dies and begins to decompose. This process is referred to as *eutrophication*. Nitrogen is generally the “limiting” nutrient in estuarine and nearshore waters, such that excess nitrogen from human sewage, plant fertilizers, and animal manure can cause eutrophication. Urbanizing estuarine or nearshore watersheds have been found to be prone to eutrophication problems that result from human land-use activities (Castro et al., 2003).

Turbidity refers to the amount of particles suspended in water, or how cloudy the water is. Clear water has low turbidity (high clarity). Cloudy water has high turbidity (low clarity). Life in estuaries depends on plant production for much of its energy. Plants, in turn, depend on sunlight for photosynthesis. When the water is too turbid, too much light is diffused, not enough penetrates the water column and reaches the plants that need it, and production decreases. Too many suspended solids reduce the growth of invertebrates such as clams and oysters. Development of eggs and embryos is slowed or stopped when water contains too much silt. Eelgrass, an ecologically important species, cannot grow where turbidity is too high. High turbidity can have several causes. Moving water carries more suspended solids than still water. Waves and tides can cause turbidity. Human activities such as logging, dredging, farming, and development result in more fine sediment entering the water. Large numbers of phytoplankton can also cause turbidity, which may be a sign of a healthy, productive environment, or a sign of eutrophication. Turbidity is often measured with a Secchi disc. It consists of a weighted disc that is lowered into the water until it disappears. This “vanishing point” is where there are so many suspended particles between the disc and the viewer that the disc can no longer be seen. This will be deeper in less turbid water and shallower in more turbid water. Alternatively, a “turbidity tube” can be used to measure turbidity of nearshore water.

Initial results of fecal coliform (FC) monitoring during the 2001-2002 storm season indicated that stormwater outfalls and small tributary streams were likely the primary sources of bacterial contamination into Liberty Bay nearshore receiving waters. Stormwater runoff from suburban residential developments and rural residential areas is the likely source of this bacterial contamination. In these areas, failing on-site sewage (septic) treatment systems are likely a major contributor to nearshore bacterial pollution. This includes residential along the creeks that drain to Liberty Bay, as well as nearshore residences. In the recent past, the KCHD has documented several cases of failed septic systems along the shorelines of Liberty Bay, although most, if not all, of these identified problems have been corrected.

Upon entering the receiving waters of Liberty Bay, this bacterial pollution is somewhat diluted and inhibited by the marine environment. In addition, natural die-off of FC bacteria also occurs. However, there are still high enough levels of FC bacteria to restrict shellfish harvesting and limit contact recreation (swimming, boating, etc.). Bacterial contamination appears to be the most significant source of impairment for the beneficial uses of Liberty Bay with regard to the requirements of the Clean Water Act (CWA).

The WQ monitoring of Liberty Bay by project-team volunteers during 2001-2002 (in addition to historic data from the KCHD) has identified the most significant potential sources of FC contamination. Dogfish Creek, Big Scandia Creek, Little Scandia Creek, Daniels Creek, and Johnson Creek have already been identified by KCHD as sources of FC contamination to Liberty Bay. The principle source of this FC pollution appears to be runoff from rural-residential farms and failing septic. The KCHD has conducted a Pollution Identification and Correction (PIC) Program to identify individual sources and to begin correcting existing problems in Dogfish Creek.

Sampling by the Liberty Bay Project team also identified two other small creeks as significant potential sources of FC contamination into Liberty Bay. These are Bjorgen and Lemolo (Kleabal) Creeks. Stormwater runoff and failing on-site sewage (septic) systems, as well as hobby farms, are the likely sources of FC contamination in these creeks that drain directly into Liberty Bay. Bjorgen Creek has its headwaters in the City of Poulsbo and includes portions of the Poulsbo High School and Junior High School campus, as well as Poulsbo Elementary School and Strawberry Field sports fields. In addition, stormwater runoff from several residential neighborhoods, including the development of Deer Run drains to Bjorgen Creek. The middle and lower sections of the watershed are in unincorporated Kitsap County, including residential areas to the west of Noll Road and a portion of the Lemolo area. Lemolo Creek is a smaller watershed that drains the east side of Noll Road (including several horse/hobby farms) and flows into the bay between Lemolo and Ni Se Ka. Stormwater runoff, failing on-site sewage (septic) systems, and livestock runoff from hobby farms are the most probable sources of bacterial contamination in these sub-basins of the Liberty Bay watershed. In addition, several stormwater outfalls within the City of Poulsbo have been identified as potential FC pollution sources.

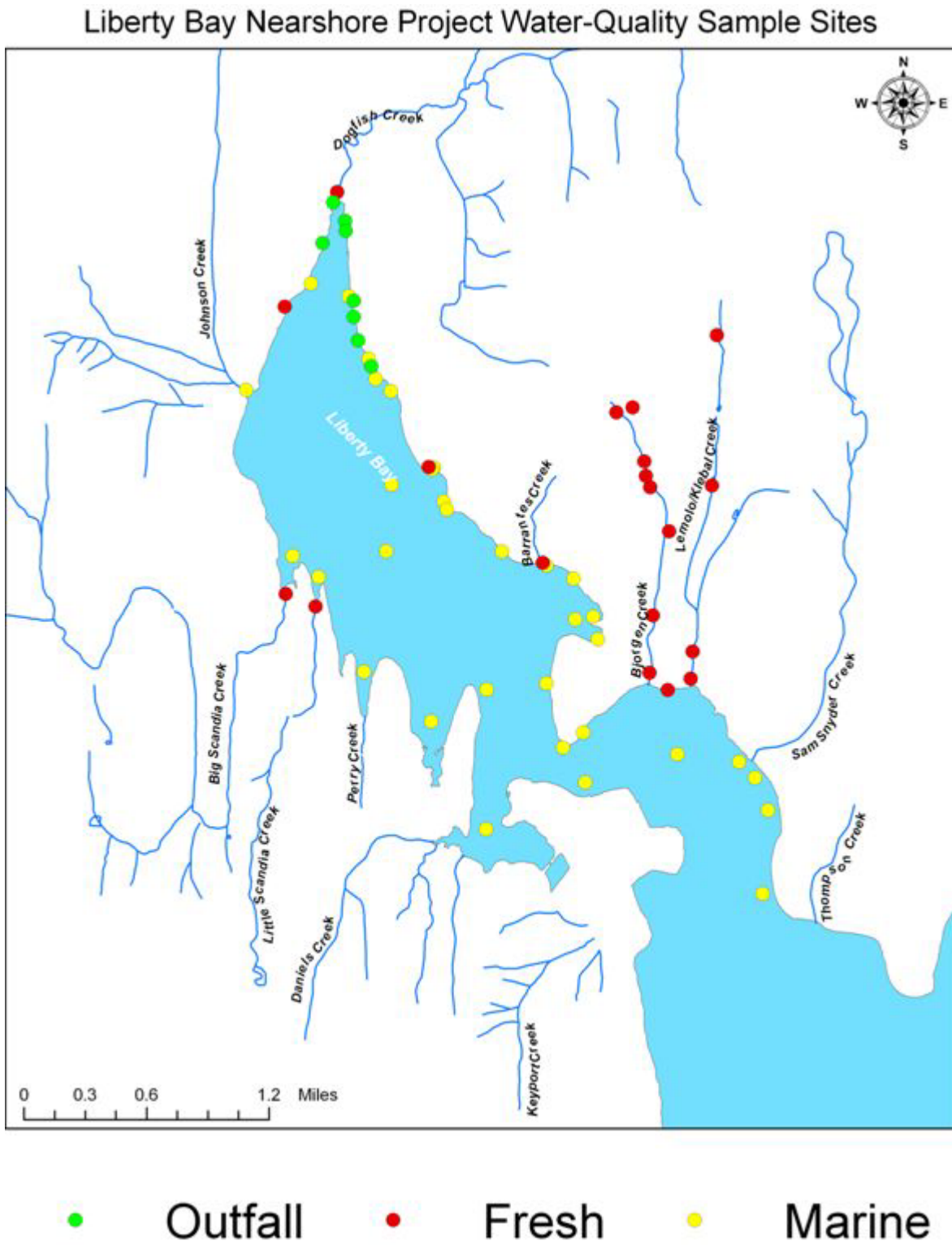
Based on the findings of the initial round of sampling, the WQ monitoring station coverage was revised to concentrate more on quantifying sources of bacterial pollution from stormwater outfalls and to identify sources of FC contamination in the Bjorgen and Lemolo Creek watersheds. In order to accomplish these tasks, several additional sample sites were added on Lemolo and Bjorgen Creeks for the 2002-3 sampling period. Several upstream WQ-sample sites were added on these creeks to enable the team to localize pollution problems on the creeks.

The results of the FC sampling effort in the Liberty Bay watershed for the 2001-2003 sampling period are summarized in **Table 8**.

Table 7: Liberty Bay Project Water-Quality Sample Sites.

LBNS Site#	Site Location/Description	Site Type
LBNS-1	Mouth of Dogfish Creek behind Liberty Bay Auto Center (@ culvert outlet)	Freshwater
LBNS-2	Head of Liberty Bay west shore at Bayview Fitness parking lot (@ stormwater outfall)	Stormwater
LBNS-3	Head of Liberty Bay east shore at Nelson Park shoreline trail access point (@ stormwater outfall)	Stormwater
LBNS-4	Head of Liberty Bay east shore off Nelson Park	Nearshore
LBNS-5	Head of Liberty Bay east shore at apartment complex (@stormwater outfall)	Stormwater
LBNS-6	Upper Liberty Bay east shore at Liberty Shores beach access point (@stormwater outfall)	Stormwater
LBNS-7	Upper Liberty Bay east shore near of the mouth of Johnson Creek	Nearshore
LBNS-8	Upper Liberty Bay west shore at Legion Park shoreline trail access point (@ north stormwater outfall)	Stormwater
LBNS-9	Upper Liberty Bay west shore off Legion Park	Nearshore
LBNS-10	Upper Liberty Bay west shore at Legion Park shoreline trail access point(@ south stormwater outfall)	Stormwater
LBNS-11	City of Poulsbo waterfront - north end of town just off boardwalk just north of SON Hall	Stormwater
LBNS-12	City of Poulsbo waterfront - central area near Poulsbo Marina fueling dock	Nearshore
LBNS-13	City of Poulsbo waterfront - end of boat-launch ramp near Poulsbo MSC	Nearshore
LBNS-14	City of Poulsbo waterfront - mid-bay along bluffs off-shore below Net- Shed Park	Marine
LBNS-15	City of Poulsbo waterfront - south end of town @ Poulsbo Yacht Club	Nearshore
LBNS-16	City of Poulsbo waterfront - Poulsbo Creek @ Yacht Club (@ Stormwater outfall)	Stormwater
LBNS-17	City of Poulsbo waterfront - south end of town @ Oyster Park	Nearshore
LBNS-18	City of Poulsbo waterfront - south end of town @ Liberty Bay Marina	Nearshore
LBNS-19	City of Poulsbo waterfront - south end of town @ city limits (sheep farm)	Nearshore
LBNS-20	City of Poulsbo waterfront - south end of town @ city mid-bay	Marine
LBNS-21	Lemolo @ Barrantess Creek (@ Stormwater outfall)	Stormwater
LBNS-22	Lemolo @ undeveloped shoreline (just north of Barrantes Creek)	Nearshore
LBNS-23	Lemolo @ Nearshore restoration site (Best property)	Nearshore
LBNS-24	Lemolo Cove on north side of point (Horder property)	Nearshore
LBNS-25	Lemolo Cove @ mid-bay	Marine
LBNS-26	Lemolo Cove on south side of point (Benham property)	Nearshore
LBNS-27	Lemolo Point north shore (Klinikowsky property)	Nearshore
LBNS-28	Lemolo Point @ point mid-channel (off Bushnell/Stimac beach)	Marine
LBNS-29	Lemolo Point south shore (Deits property)	Nearshore
LBNS-30a	Bjorgen Creek @ Lemolo Shore Drive crossing (access @ Lemolo Store)	Freshwater
LBNS-30b	Bjorgen Creek @ Lemolo Shore Drive Culvert (Access from Lemolo Store)	Freshwater
LBNS-30c	Bjorgen Creek @ SR-305 Culvert	Freshwater
LBNS-30d	Bjorgen Creek @ Anderson Pump House	Freshwater
LBNS-30e	Bjorgen Creek @ Storhoff Rd - Noll Road Extension Culvert (Downstream of Deer Run Development)	Freshwater
LBNS-30f	Bjorgen Creek @ Deer Run Culvert	Freshwater
LBNS-30g	Bjorgen Creek @ Deer Run Retention Pond Outlet	Freshwater
LBNS-30h	Bjorgen Creek @ PJHS Horticulture Pond Outlet	Freshwater
LBNS-30i	Bjorgen Creek @ PJHS Stormwater Outfall	Freshwater
LBNS-31a	Lemolo Creek @ estuary mouth	Freshwater
LBNS-31b	Lemolo Creek @ Estuary (Downstream of Lemolo Shore Drive)	Freshwater
LBNS-31c	Lemolo Creek @ SR-305 Culvert	Freshwater
LBNS-31d	Lemolo Creek @ Allaire Farm Pond (Headwaters)	Freshwater
LBNS-31e	Lemolo Creek @ Noll Road (Headwaters)	Freshwater
LBNS-32	Sam Snyder Creek @ estuary mouth	Freshwater
LBNS-33	Ne Si Ka Bay @ Ne Si Ka development	Nearshore
LBNS-34	Ne Si Ka Bay mid-bay	Marine
LBNS-35	Ne Si Ka Point mid-bay	Marine

Figure 24: Liberty Bay Nearshore Project Water-Quality Sample Sites



**Table 8: Results of FC sampling in Liberty Bay
(WQS) of 14 cfu/100ml).**

LBNS Site#	Sample Site Location	Sample Site Type	FC Geo-Mean (cfu/100ml)	N	%>WQS
LBNS-1	Dogfish Creek Outlet	Freshwater	102	21	57%
LBNS-2	Bayview Outfall	Stormwater	67	17	N/A
LBNS-3	Nelson Park Outfall	Stormwater	26	26	N/A
LBNS-4	Nelson Park Nearshore	Marine	9	9	11%
LBNS-5	Apartment Outfall	Stormwater	54	29	N/A
LBNS-6	Liberty Shores Outfall	Stormwater	38	26	N/A
LBNS-7	Johnson Creek Mouth	Marine	98	10	80%
LBNS-8	Legion Park North Outfall	Stormwater	65	24	N/A
LBNS-9	Legion Park Nearshore	Marine	9	9	11%
LBNS-10	Legion Park South Outfall	Stormwater	75	27	N/A
LBNS-11	Poulsbo (SON) Nearshore	Marine	16	23	35%
LBNS-12	Poulsbo (Marina fuel Dock) Nearshore	Marine	22	26	38%
LBNS-13	Poulsbo (MSC Boat Ramp) Nearshore	Marine	25	24	38%
LBNS-14	Poulsbo Yacht Club Nearshore	Marine	34	6	33%
LBNS-15	Poulsbo (Net Shed Park) Nearshore	Marine	5	10	10%
LBNS-16	Poulsbo Creek Outlet	Stormwater	89	25	N/A
LBNS-16a	Yacht Club Cove-Nearshore	Marine	62	12	42%
LBNS-17	Poulsbo Oyster Park Nearshore	Marine	15	24	29%
LBNS-18	Poulsbo Liberty Bay Marina Nearshore	Marine	8	25	12%
LBNS-19	Poulsbo (Sheep Farm) Nearshore	Marine	17	14	36%
LBNS-20	Poulsbo (City Limits) Mid-Bay	Marine	7	6	17%
LBNS-21	Barrantes Creek Outlet	Stormwater	57	23	N/A
LBNS-22	Lemolo (Meat Market) Nearshore	Marine	11	23	13%
LBNS-23	Lemolo (Best Property) Nearshore	Marine	10	13	8%
LBNS-24	Lemolo (Horder) Nearshore	Marine	21	25	36%
LBNS-25	Lemolo Cove Mid-Bay	Marine	4	9	11%
LBNS-26	Lemolo (Benham) Nearshore	Marine	31	25	44%
LBNS-27	Lemolo (Klinikowsky) Nearshore	Marine	10	25	4%
LBNS-28	Lemolo Point Mid-Channel	Marine	3	6	17%
LBNS-29	Lemolo (Deits) Nearshore	Marine	26	29	31%
LBNS-30a	Bjorgen Creek Outlet	Freshwater	140	30	57%
LBNS-30b	Bjorgen Creek @ SR-305 Culvert	Freshwater	44	14	14%
LBNS-30c	Bjorgen Creek @ Anderson Property	Freshwater	61	17	35%
LBNS-30d	Bjorgen Creek @ Storhoff Road (extension of Noll Road)	Freshwater	99	18	50%
LBNS-30e	Bjorgen Creek @ Deer Run Culvert	Freshwater	9	16	13%
LBNS-30f	Bjorgen Creek @ Outlet of Deer Run Stormwater Pond	Stormwater	47	15	N/A
LBNS-30g	Bjorgen Creek @ Headwaters - Outlet of PJHS Horticulture Pond	Stormwater	15	8	N/A
LBNS-30h	Bjorgen Creek @ Headwaters - Outlet of PJHS Stormwater Vault	Stormwater	88	8	N/A
LBNS-30i	Nearshore between Bjorgen and Lemolo Creeks	Marine	21	5	20%
LBNS-31a	Lemolo/Klaebel Creek Outlet	Freshwater	96	30	47%
LBNS-31b	Lemolo Creek @ SR-305 Culvert	Freshwater	25	16	25%
LBNS-31c	Lemolo Creek @ Allaire Farm Pond	Freshwater	21	12	17%
LBNS-31d	Lemolo Creek @ Upper Noll Road	Freshwater	15	2	50%
LBNS-32	Sam Synder Creek Mouth	Marine	5	10	0%
LBNS-33	Ne Si Ka Bay Nearshore (Development)	Marine	4	9	11%
LBNS-34	Ne Si Ka Bay Mid-Bay	Marine	5	5	0%
LBNS-35	Ne Si Ka Bay Nearshore (Tribal Property)	Marine	3	10	0%

3.7 KITSAP COUNTY HEALTH DISTRICT (KCHD) FC DATA

The Kitsap County Health District (KCHD) has been sampling the marine waters and freshwater tributaries of Liberty Bay since 1996. Overall, KCHD sampling indicates that Liberty Bay water quality is improving; however, there are still several problem areas, especially for bacterial pollution. Increased development, failing on-site sewage (septic) treatment systems and poor animal waste management appear to be the primary causes of bacterial pollution in the watershed. Daniels Creek is considered so polluted that KCHD advises against water contact (KCHD, 2005). According to the KCHD, a pollution identification and correction (PIC) investigation is scheduled to be initiated in this creek in 2005.

The *Dogfish Creek Water Quality Restoration Project* was completed in 2004. During this effort, KCHD located and corrected eight (8) failing septic systems, as well as correcting poor livestock management practices at seventeen (17) sites on the creek. These actions greatly improved water quality in Dogfish Creek, including reducing FC pollution and turbidity (KCHD, 2004).

With the support of the City of Poulsbo, KCHD also completed the *South Fork Dogfish Creek Non-point Pollution Impact Assessment Project* (KCHD, 2002). This project focused on identifying and correcting FC and turbidity problems associated with development within Poulsbo and was mainly targeted on failing sewage treatment infrastructure and stormwater outfalls. This study found that there are eleven (11) stormwater outfalls that discharge untreated stormwater into Dogfish Creek from the City of Poulsbo. No failing septic systems were found during that study, however, 87% of all stormwater sampled was found to contribute excessive FC pollution to Dogfish Creek (KCHD, 2002), which, in turn, drains to Liberty Bay. Stormwater was also found to contribute high turbidity and high levels of zinc to the creek (KCHD, 2002). Several stormwater outfalls were also found to be in need of maintenance and cleaning. KCHD is continuing to work with the City of Poulsbo on identifying and correcting pollution problems in the South Fork of Dogfish Creek.

Table 9 lists the KCHD water-quality sample sites in Liberty Bay. **Figure 26 & 32** show the locations of the KCHD sites. The results of KCHD sampling and trend analysis indicate that the following sites do not meet WQS:

- Big Scandia Creek (BS01) – FC & Temperature
- Daniels Creek (DC01) – FC
- Dogfish Creek (DF01) – FC
- South Fork Dogfish Creek (SF01) – FC & DO
- Johnson Creek (JC01) – FC
- Liberty Bay – FC, DO, pH, & Temperature (Figures 27-31)

In general, the KCHD WQ sampling data indicates an improving trend for most creeks and a significantly improving trend for marine waters with respect to bacterial pollution in Liberty Bay (KCHD, 2005).

Kitsap County Health District (KCHD) Water-Quality Sample Sites located in the Liberty Bay Watershed.

<i>Type</i>	<i>Water Body</i>	<i>Station ID</i>	<i>Location Description</i>
Freshwater	BIG SCANDIA CREEK	BS01	ACCESS @ 17139 SCANDIA CT
Freshwater	DANIELS CREEK	DC01	UPSTRM CULVERT @ 14510 HWY 308
Freshwater	DOGFISH CREEK	DF01	ACCESS @ LIBERTY BAY DENTAL OFF BOND RD
Freshwater	DOGFISH CREEK-EAST FORKED01	ED01	DWNSTRM CULVERT @ 20919 LITTLE VALLEY RD
Freshwater	JOHNSON CREEK	JC01	DOWNSTRM VIKING WAY CULVERT SO. OF NORFIN
Freshwater	KLEBEAL CREEK	KL01	ACCESS @ 16057 HWY 305
Freshwater	DOGFISH CREEK-SOUTH FORK	SF01	DWNSTRM CULVERT @ BOND/BONDWOOD
Freshwater	DOGFISH CREEK-WEST FORK	WD01	W. FORK DWNSTRM LITTLE VALLEY RD CULVERT
Marine	LIBERTY BAY	LB03	NEARSHORE LEMOLO BAY
Marine	LIBERTY BAY	LB05	NEARSHORE NORTH END POULSBO MARINA
Marine	LIBERTY BAY	LB06	MID CHANNEL HEAD OF LIBERTY BAY
Marine	LIBERTY BAY	LB08	MID-CHANNEL EAST OF JOHNSON CREEK
Marine	LIBERTY BAY	LB10	NEARSHORE PEARSON POINT
Marine	LIBERTY BAY	LB12	MID-BAY DOGFISH BAY
Marine	LIBERTY BAY	LB13	MID-CHANNEL WEST OF POINT BOLIN

Figure 25: Kitsap County Health District (KCHD) WQ monitoring sites

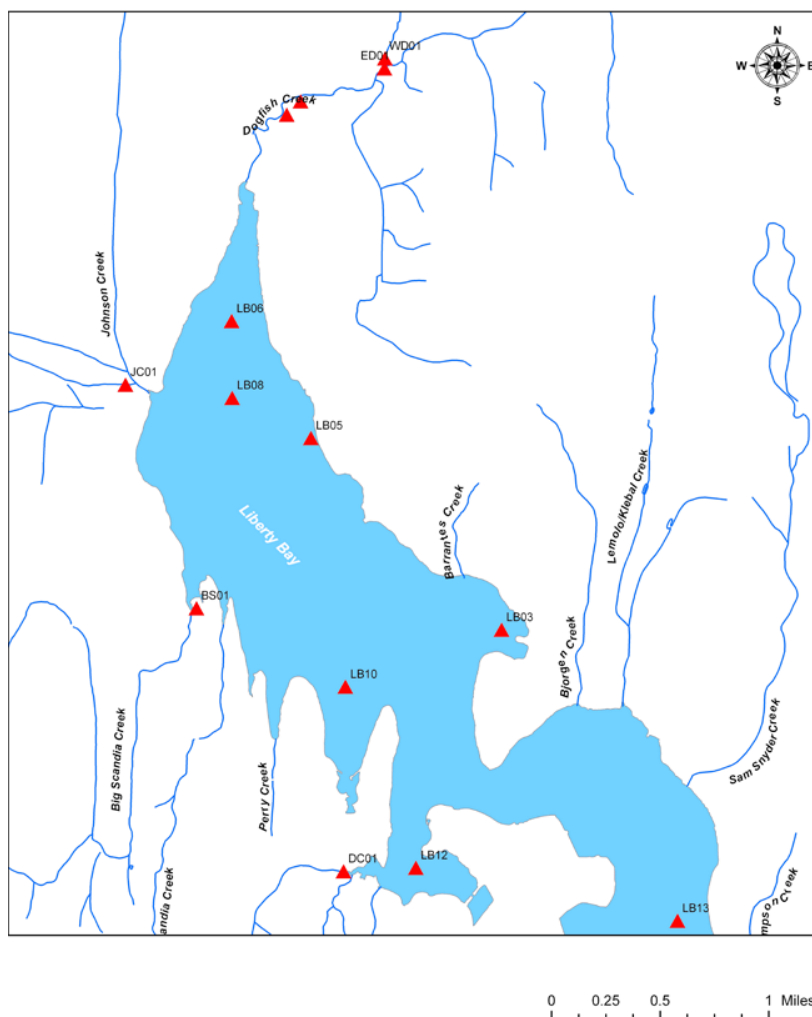


Table 9: Results of FC Sampling for Marine-Nearshore Sites in Liberty Bay

LBNS Site#	Sample Site Location	FC Geo-Mean (cfu/100ml)	N	%>WQS
LBNS-4	Nelson Park Nearshore	9	9	11%
LBNS-7	Johnson Creek Mouth	98	10	80%
LBNS-9	Legion Park Nearshore	9	9	11%
LBNS-11	Poulsbo (SON) Nearshore	16	23	35%
LBNS-12	Poulsbo (Marina fuel Dock) Nearshore	22	26	38%
LBNS-13	Poulsbo (MSC Boat Ramp) Nearshore	25	24	38%
LBNS-14	Poulsbo Yacht Club Nearshore (N)	34	6	33%
LBNS-15	Poulsbo (Net Shed Park) Nearshore	5	10	10%
LBNS-16a	Poulsbo Yacht Club Cove-Nearshore (S)	62	12	42%
LBNS-17	Poulsbo Oyster Park Nearshore	15	24	29%
LBNS-18	Poulsbo Liberty Bay Marina Nearshore	8	25	12%
LBNS-19	Poulsbo (Sheep Farm) Nearshore	17	14	36%
LBNS-20	Poulsbo (City Limits) Mid-Bay	7	6	17%
LBNS-22	Lemolo (Meat Market) Nearshore	11	23	13%
LBNS-23	Lemolo (Best Property) Nearshore	10	13	8%
LBNS-24	Lemolo (Horder) Nearshore	21	25	36%
LBNS-25	Lemolo Cove Mid-Bay	4	9	11%
LBNS-26	Lemolo (Benham) Nearshore	31	25	44%
LBNS-27	Lemolo (Klinikowsky) Nearshore	10	25	4%
LBNS-28	Lemolo Point Mid-Channel	3	6	17%
LBNS-29	Lemolo (Deits) Nearshore	26	29	31%
LBNS-30i	Nearshore between Bjorgen and Lemolo Creeks	21	5	20%
LBNS-32	Sam Synder Creek Estuary	5	10	0%
LBNS-33	Ne Si Ka Bay Nearshore (Development)	4	9	11%
LBNS-34	Ne Si Ka Bay Mid-Bay	5	5	0%
LBNS-35	Ne Si Ka Bay Nearshore (Tribal Property)	3	10	0%
LBNS-37	Big Scandia Bay Mid-Bay	17	10	20%
LBNS-39	Little Scandia Bay Mid-Bay	13	10	30%
LBNS-40	North Pearson Bay Mid-Bay	15	6	17%
LBNS-41	South Pearson Bay Mid-Bay	4	6	17%
LBNS-42	Dogfish Bay Mid-Bay	6	6	17%
LBNS-43	Virginia point (Ingels Property) Nearshore	4	10	10%
LBNS-44	Keyport Marina Nearshore	4	10	10%
LBNS-45	Keyport Naval Station Nearshore	4	6	0%

Figure 26: Summary of FC Geometric Mean (cfu/100ml) Data.

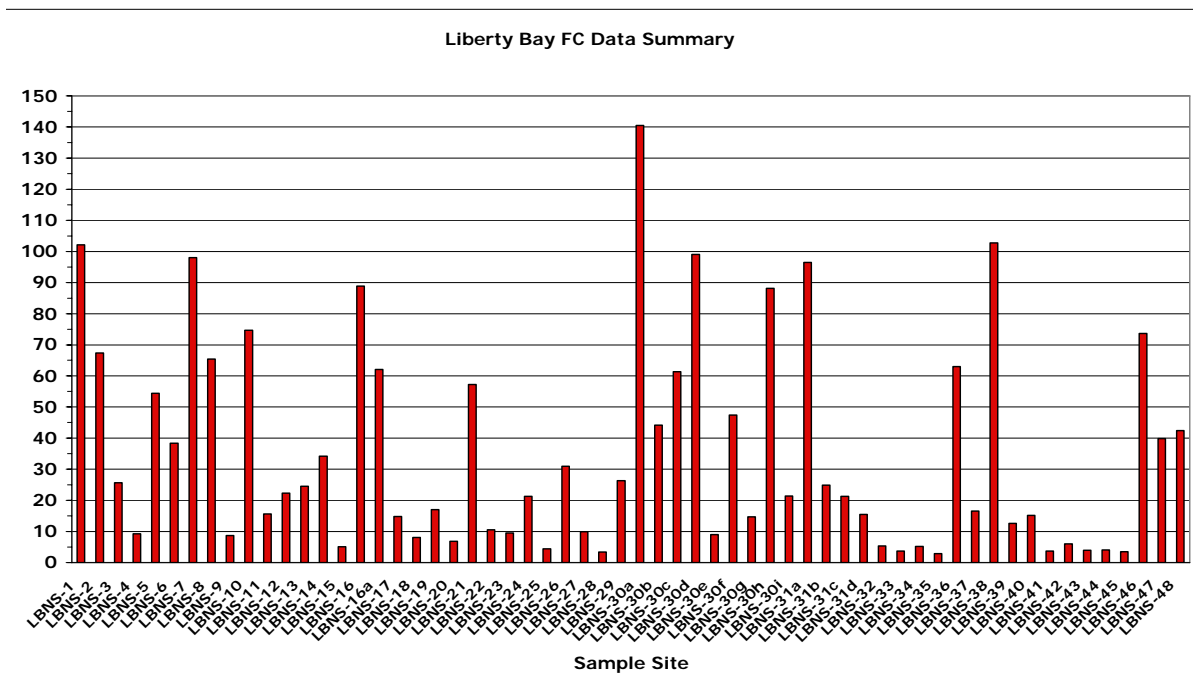


Figure 27: Nearshore FC (geometric mean cfu/100ml) data for Liberty Bay (Red dashed-line indicates the Part I water quality standard)

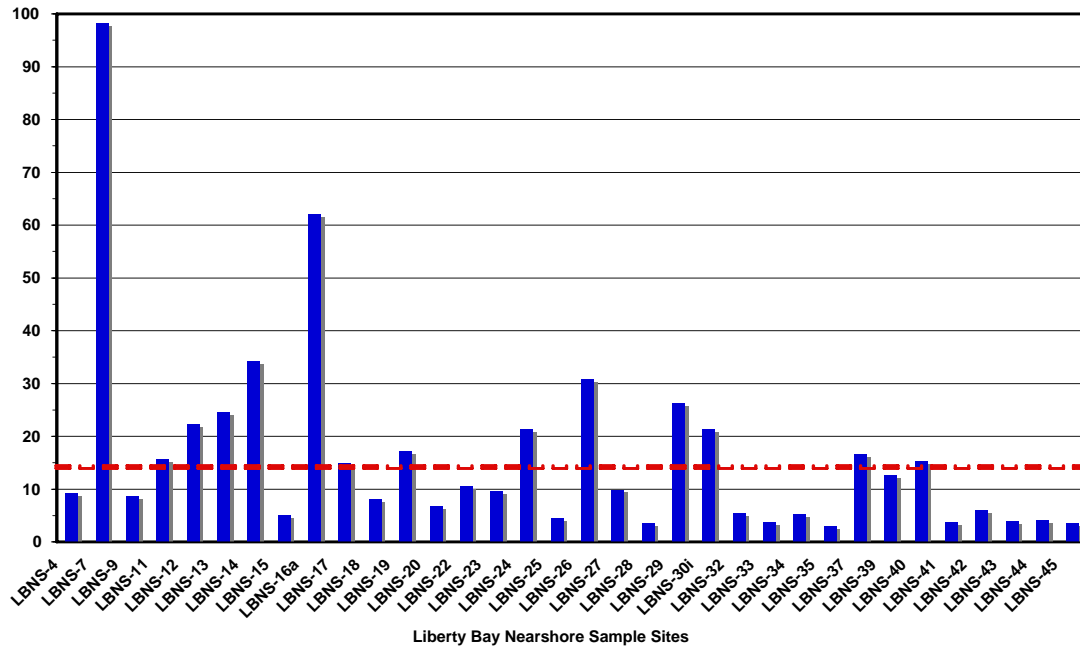


Figure 28: Nearshore FC (% Samples > 43 cfu/100ml) data for Liberty Bay (Red dashed-line indicates the Part II water quality standard (WQS) of 10%)

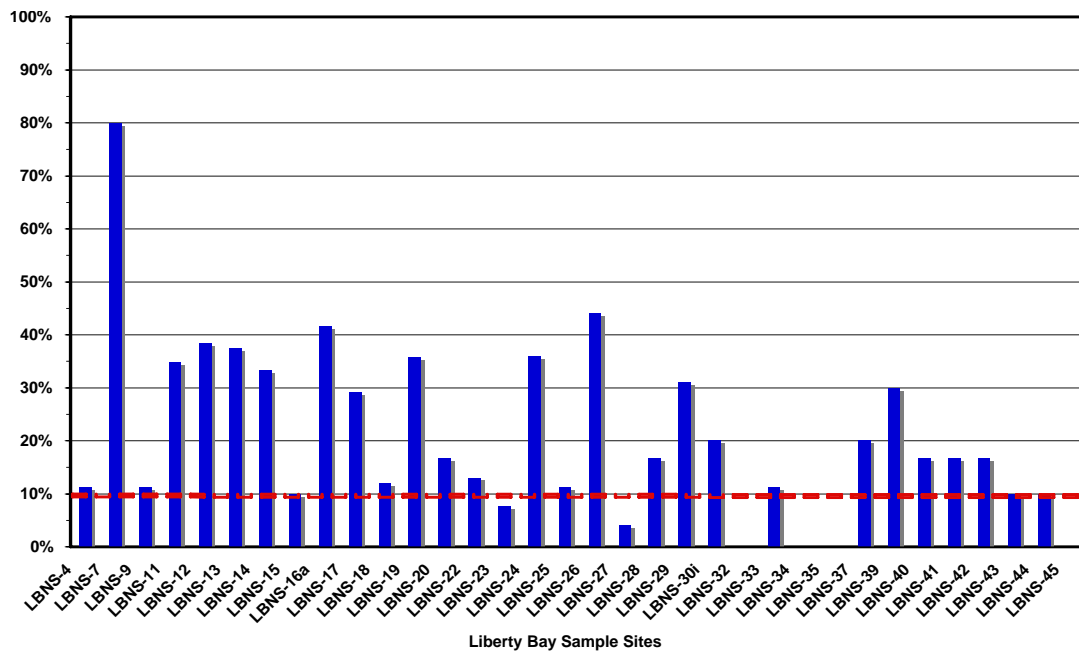


Table 10: Results of FC Sampling for stream sample sites in Liberty Bay. Red values indicates those that do not meet Part I of freshwater water-quality standards (WQS).

LBNS Site#	Sample Site Location	FC Geo-Mean (cfu/100ml)	N	%>WQS
LBNS-1	Dogfish Creek Outlet	102	21	57%
LBNS-30a	Bjorgen Creek Outlet	140	30	57%
LBNS-30b	Bjorgen Creek @ SR-305 Culvert	44	14	14%
LBNS-30c	Bjorgen Creek @ Anderson Property	61	17	35%
LBNS-30d	Bjorgen Creek @ Storhoff Road (extension of Noll Road)	99	18	50%
LBNS-30e	Bjorgen Creek @ Deer Run Culvert	9	16	13%
LBNS-31a	Lemolo Creek Outlet	96	30	47%
LBNS-31b	Lemolo Creek @ SR-305 Culvert	25	16	25%
LBNS-31c	Lemolo Creek @ Allaire Farm Pond	21	12	17%
LBNS-31d	Lemolo Creek @ Upper Noll Road	15	2	50%
LBNS-36	Big Scandia Creek Outlet	63	11	27%
LBNS-38	Little Scandia Creek Outlet	103	8	38%

Table 11: Results of FC Sampling for stormwater outfall sample sites in Liberty Bay. There is no applicable water-quality standard (WQS) for stormwater.

LBNS#	Outfall#	Outfall Location	FC Geo-Mea All Samples (cfu/100ml)	N (All)	FC Geo-Mea Storm Event (cfu/100ml)	N (Storms)
LBNS-2	PSW36	Bayview Outfall	67	17	287	4
LBNS-3	PSW37	Nelson Park Outfall	26	24	46	8
LBNS-5	PSW38	Apartment Outfall	54	24	75	10
LBNS-6	PSW39	Liberty Shores Outfall	38	24	29	10
LBNS-8	PSW32	Legion Park North Outfall	65	22	155	10
LBNS-10	PSW31	Legion Park South Outfall	75	23	78	9
LBNS-16	PSW25	Poulsbo Creek Outlet	89	24	217	9
LBNS-46	PSW30	Legion Park Outfall (Gran Kirk)	74	10	80	6
LBNS-47	PSW34	Poulsbo Place Outfall (CDS)	40	8	37	3
LBNS-48	PSW28	Poulsbo Downtown Outfall	42	2	42	2
LBNS-30F	PSW44	Deer Run Stormwater Pond Outlet	47	12	150	4
LBNS-30G	PSW40	PJHS Horticulture Pond Outlet	15	8	144	2
LBNS-30H	PSW46	PJHS Stormwater Vault Outlet	88	8	229	2

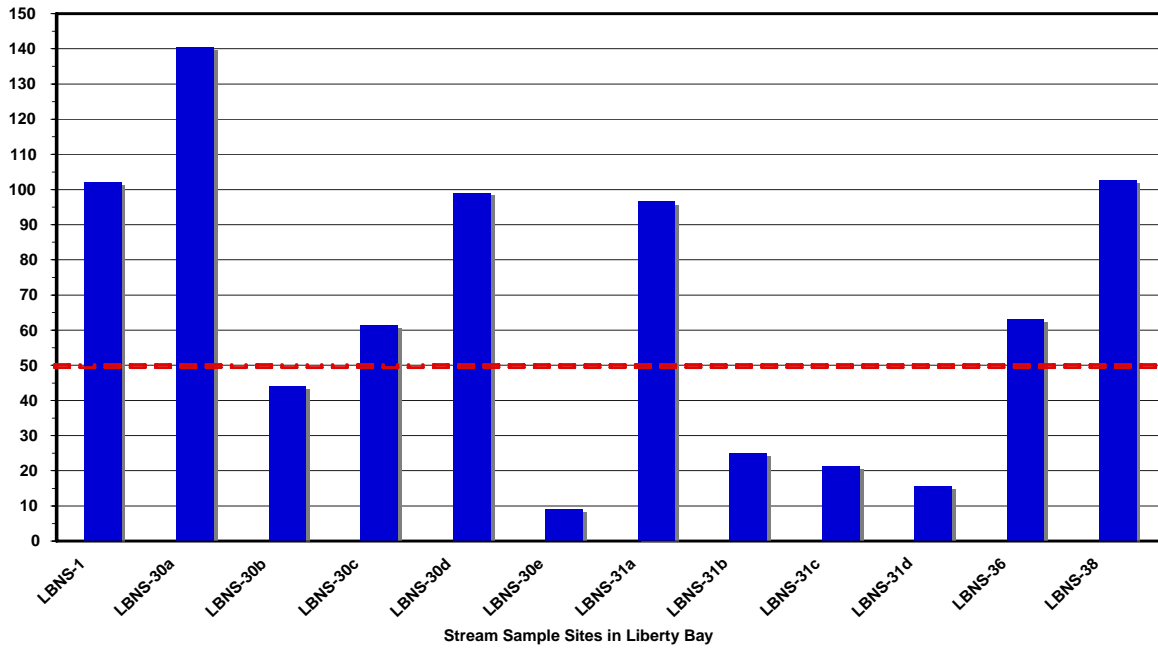


Figure 29: Stream FC (geometric mean cfu/100ml) data for Liberty Bay. Red dashed-line indicates the Part I freshwater water quality standard (WQS) of 50 cfu/100ml.

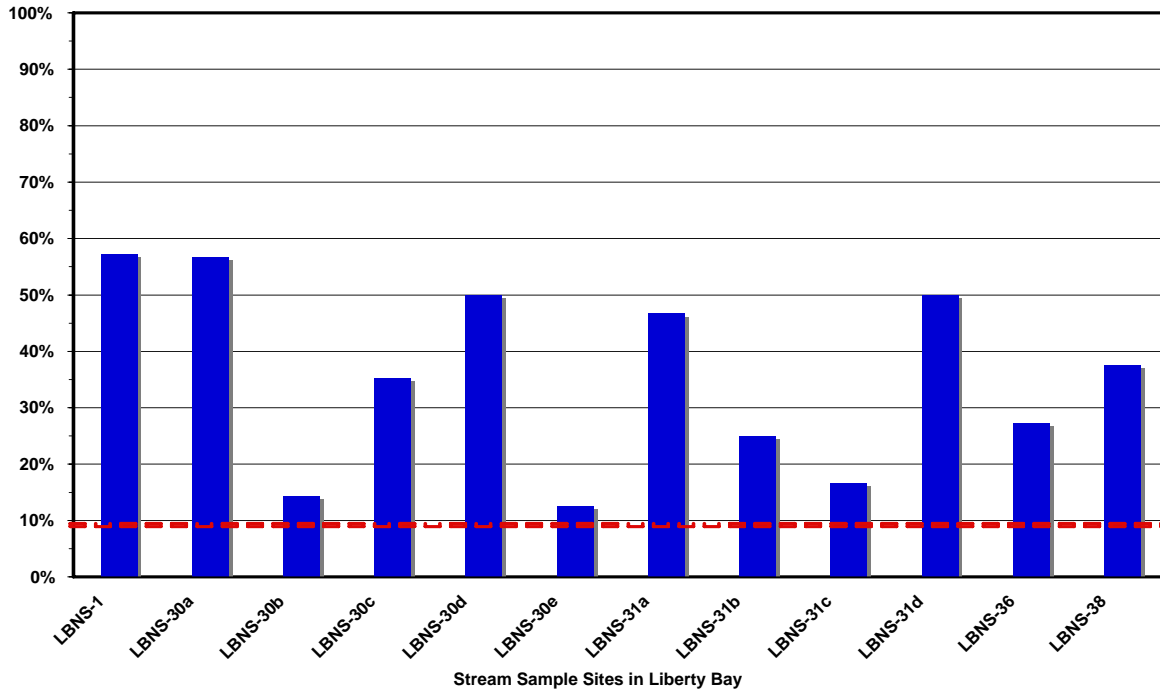


Figure 30: Stream FC (% Samples > 100 cfu/100ml) data for Liberty Bay. Red dashed-line indicates the Part II freshwater water quality standard (WQS) of 10%.

Figure 31: Stormwater FC (100 cfu/100ml) data for Liberty Bay. There is no applicable water-quality standard (WQS) for stormwater

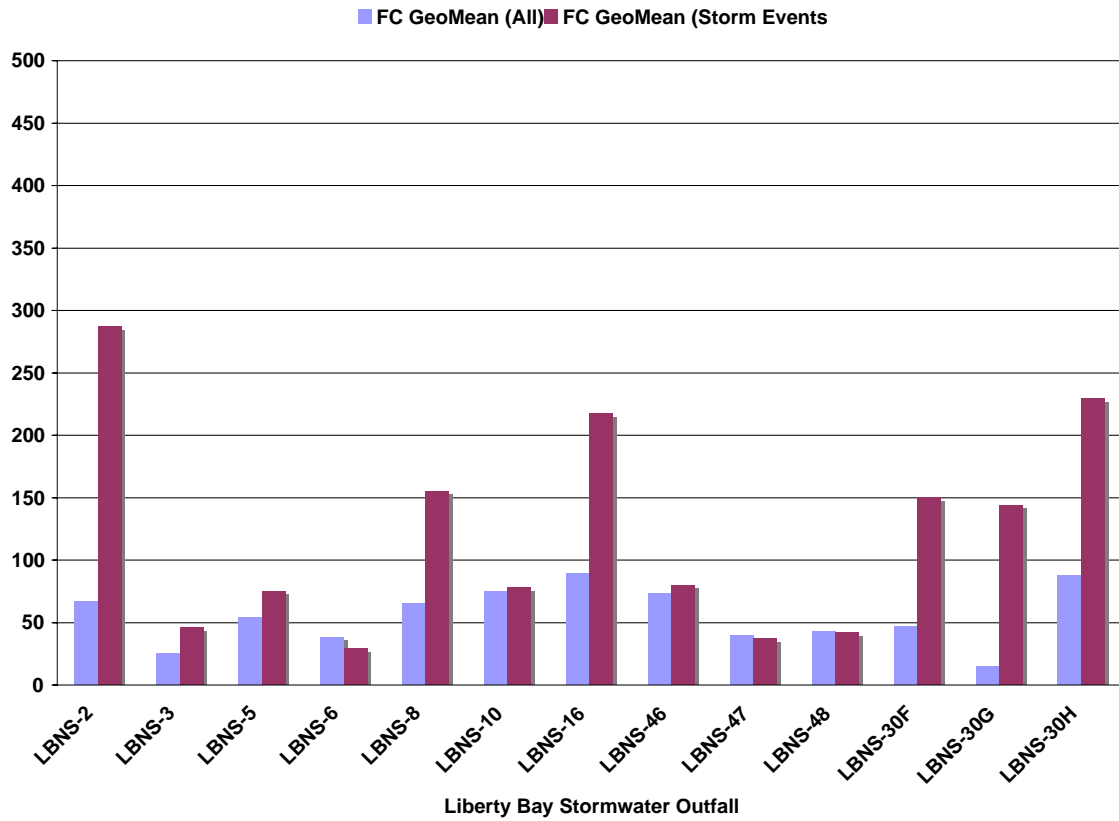
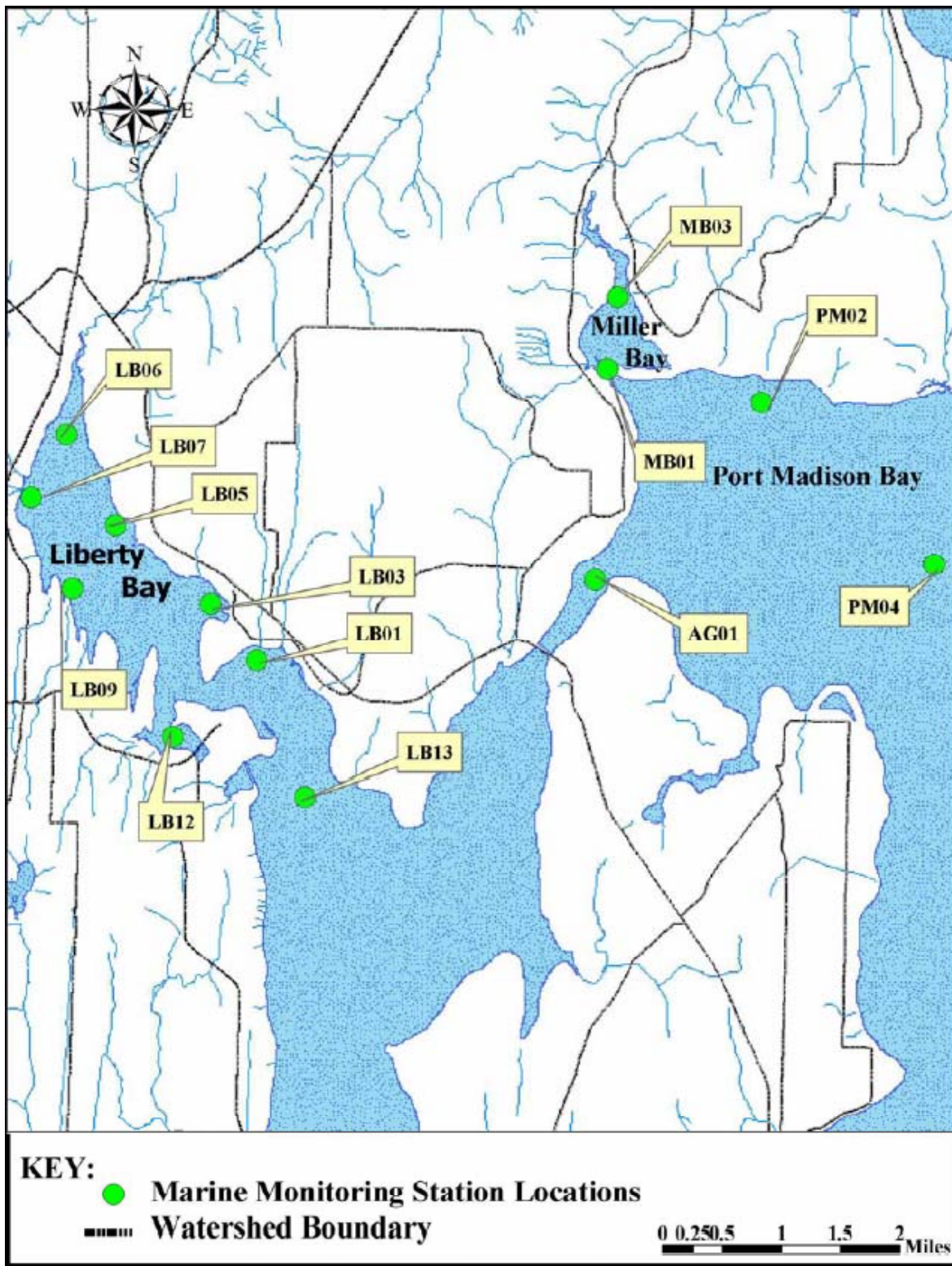


Figure 32: Kitsap County Health District (KCHD) Water-Quality Freshwater Sample Sites located in Liberty Bay Watershed.



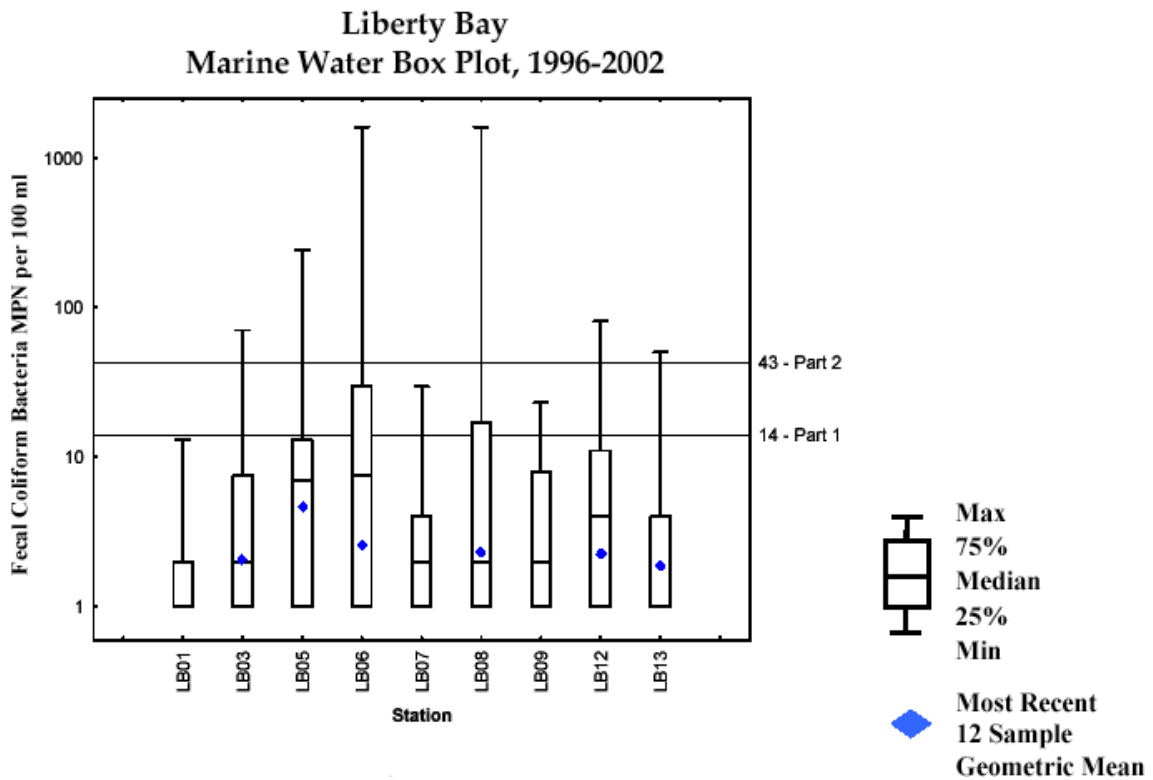


Figure 33: KCHD Liberty Bay FC Sample Results (KCHD, 2004).

3.8 WA-DOH FC DATA

The Washington Department of Health (WA-DOH) also samples for bacterial pollution in Liberty Bay, as part of their shellfish harvest area monitoring program. The locations of the WA-DOH sample sites combined with several other agencies' monitoring sites in the watershed are shown in **Figure 34** and the results of an analysis of the WA-DOH available data is shown in **Table 13**. Based on the available data, none of the WA-DOH sample sites currently violate WQS.

Figure 34: Washington State Department of Health and all other agencies Water-Quality Sample Sites in Liberty Bay

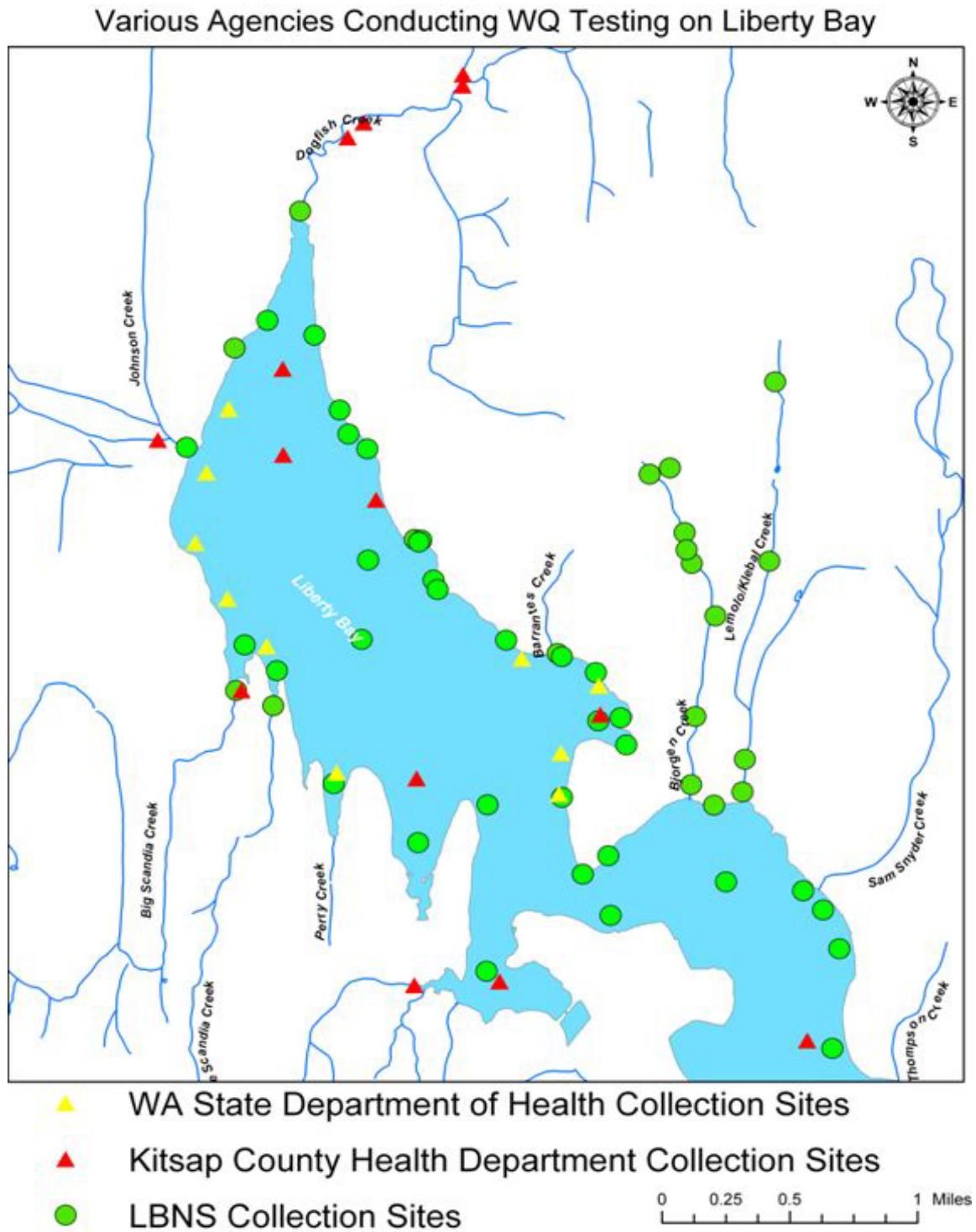


Table 13: Washington State Department of Health Water-Quality Sample Sites in Liberty Bay

Site#	Period of Record	# Samples	Geometric Mean FC (cfu/100ml)	% Samples > 43 cfu/100ml
493	9/1988 – 5/1996	82	9.8	9.8%
494	9/1988 – 5/1996	82	5.3	3.4%
495	9/1988 – 5/1996	82	4.8	5.9%
496	9/1988 – 5/1996	82	4.6	9.8%
497	12/1998 – 7/2000	2	6.4	5.0%
498	7/1993 – 11/2002	78	2.9	2.6%
499	7/1993 – 11/2002	78	4.0	5.1%
500	9/1988 – 11/2002	117	3.5	5.9%
501	7/1993 – 11/2002	78	3.6	7.8%
502	9/1988 – 5/1996	82	9.5	6.8%
503	9/1988 – 5/1996	80	3.3	7.5%

3.9 SEDIMENT SAMPLING

Sediment samples were collected in conjunction with the benthic biological sampling effort (*See next Section “4.0 Biological Monitoring” for more sampling procedures and photos taken during these events*). **Figure 35** shows the locations of the sediment samples. Samples were collected in October 2003, May 2004 and October 2004. Three (3) replicate samples were taken from each site and a set of standard QA-QC checks were conducted by the laboratory (Columbia Analytical Services). Only two (2) samples fell outside the QA-target for relative percent difference (RPD) for replicate analysis. Both of these results were attributed to the highly heterogeneous nature of the samples from these sites. Only one (1) laboratory matrix spike fell outside of control criteria, again because of the highly heterogeneous nature of the sample. Details of the sampling protocols and analysis methods can be found in the QAPP (see **Appendix A**). Sediment samples were analyzed for metals only, using the US-EPA Method 200.8/6020 (see **Table 14**). Sediment sample analysis results were compared to the SED-QUAL regional database and to representative crustal values (**Table 15**). The complete sediment analysis results are contained in **Appendix F**.

In general, the sediment quality (with respect to metals) of Liberty Bay appears to be relatively clean. The Nelson Park site had several samples with elevated metals levels, but did not exceed any sediment quality criteria. This site is located directly below a stormwater outfall, which may account for some of the higher metals results. The data for Arsenic (As), Cadmium (Cd), Mercury (Hg), Chromium (Cr), Copper (Cu), Silver (Ag), and Zinc (Zn) were relatively low for all sites in comparison to crustal values (see **Table 15**) and in comparison to other sites sampled in Puget Sound (SED-QUAL). It should be noted that the analysis protocol used for this project utilizes a digestion method that may result in an underestimation of some metal levels. In addition, several samples were found to be very close to the detection limit of the analysis method. One replicate Pb sample (Site 13) was relatively high, indicating that perhaps this sample may have included a paint chip or some other lead

material that just happened to be collected with the sample. This result is probably an anomaly rather than an indication of any problem at that site.

Sediment bound metals can be bioavailable depending on the physio-chemical conditions of the contaminated marine sediment. These sediment metals can be assimilated by benthic infauna such as bivalve mollusks, including shellfish such as clams, mussels, and oysters. In fact, marine bivalve mollusks are often used as bio-indicators of coastal contamination. Both suspension-feeding and deposit-feeding bivalves can accumulate metals from sediment pore-water and water overlying contaminated sediment (Griscom and Fisher, 2004).

Based on the data collected in this study, it is unlikely that the sediment-metal concentrations found in Liberty Bay are currently a significant problem. However, this dataset does provide a baseline for measuring future sediment quality as land-use and human activities expand within the watershed.

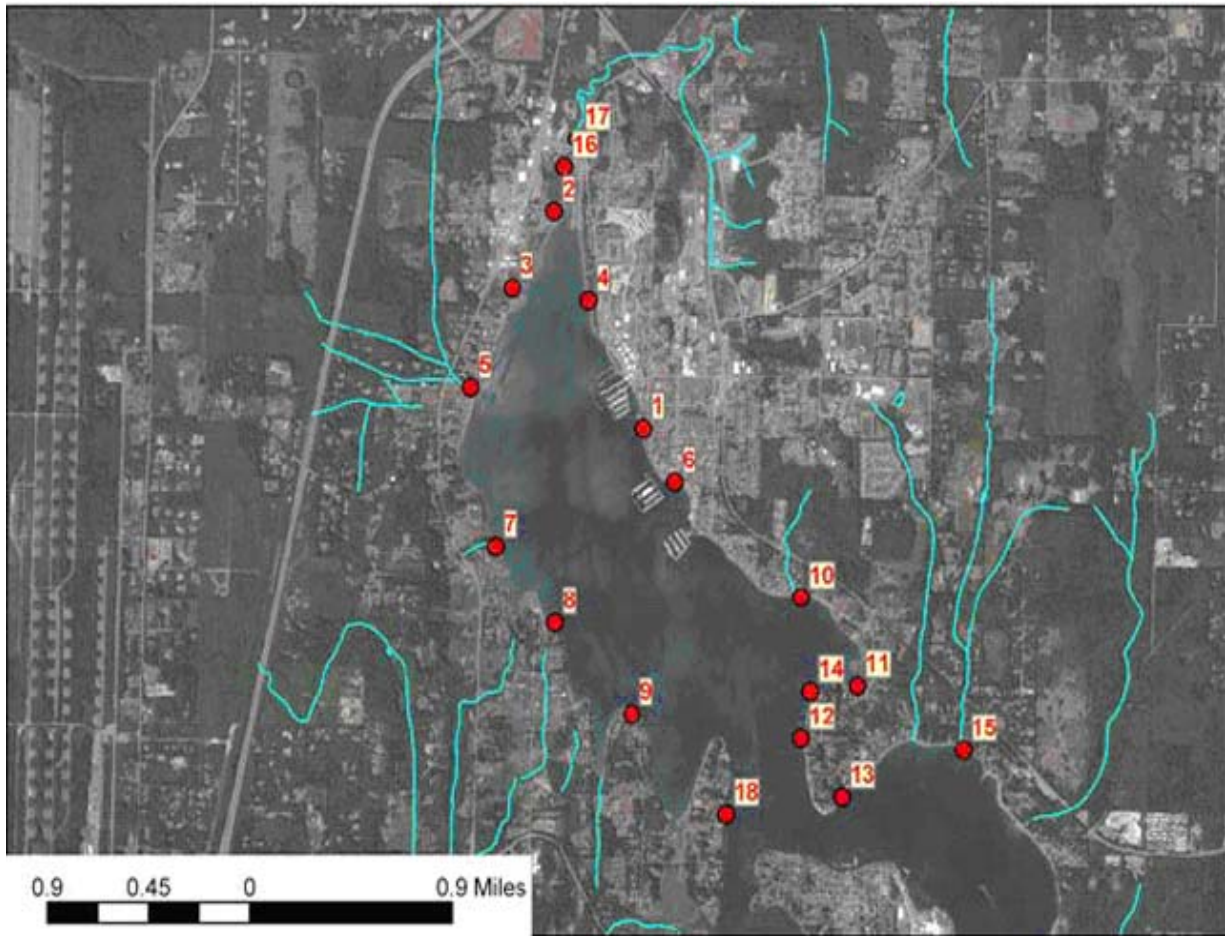


Figure 35: Sediment Sample Site Map

Table 14: Laboratory metals analysis information

EPA Method 200.8/6020						
Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)						
Method Detection Limits (MDLs) & Method Reporting Limits (MRLs)						
<u>Analyte</u>	<u>Water (µg/L)</u>		<u>Soil/Sediment (mg/Kg)</u> (Dry Wt. Basis)		<u>Tissue (mg/Kg)</u> (Wet Wt. Basis)	
	<u>MDL</u>	<u>MRL</u>	<u>MDL</u>	<u>MRL</u>	<u>MDL</u>	<u>MRL</u>
Aluminum	0.6	2	2	2	0.02	0.4
Antimony	0.02	0.05	0.05	0.05	0.002	0.01
Arsenic	0.2	0.5	0.1	0.5	0.04	0.1
Barium	0.02	0.05	0.01	0.05	0.002	0.01
Beryllium	0.006	0.02	0.01	0.02	0.0008	0.004
Cadmium	0.05	0.05	0.02	0.05	0.002	0.01
Chromium	0.05	0.2	0.03	0.2	0.08	0.1
Cobalt	0.005	0.02	0.01	0.02	0.002	0.004
Copper	0.05	0.1	0.04	0.1	0.004	0.02
Lead	0.006	0.02	0.03	0.05	0.0008	0.004
Manganese	0.05	0.05	0.01	0.02	0.004	0.01
Molybdenum	0.009	0.05	0.01	0.05	0.002	0.01
Nickel	0.03	0.2	0.02	0.2	0.008	0.04
Selenium	0.8	1	0.2	1	0.04	0.04
Silver	0.007	0.02	0.01	0.02	0.0006	0.004
Thallium	0.004	0.02	0.004	0.02	0.0008	0.004
Uranium	0.003	0.02	0.04	0.05	0.002	0.01
Vanadium	0.05	0.2	0.02	0.2	0.006	0.2
Zinc	0.08	0.5	0.1	0.5	0.01	0.1

*Chromium and Vanadium in tissue are analyzed by ICP-OES, Selenium is analyzed by GFAAS.
Lower limits are available for Selenium when using Hydride AAS.

EPA Method 1631M - Mercury by Atomic Fluorescence MDLs and MRLs				
	<u>Water (µg/L)</u>		<u>Sediment (mg/Kg)</u>	
	<u>MDL</u>	<u>MRL</u>	<u>MDL</u>	<u>MRL</u>
Mercury	0.0001	0.001	0.0002	0.002

EPA Method 7471A - Mercury by CVAAS MDLs and MRLs *

	<u>Sediment (mg/Kg)</u> (Dry Wt. Basis)		<u>Tissue (mg/Kg)</u> (Wet Basis)	
	<u>MDL</u>	<u>MRL</u>	<u>MDL</u>	<u>MRL</u>
Mercury	0.01	0.02	0.002	0.004

*Lower detection limit for Hg in tissue is available. Call for specifications.

Table 15: Representative regional sediment quality values

Metal	Crustal Abundance ppm (µg/g dry wt.)	SED QUAL ppm (µg/g dry wt.)
As	1.8	57
Cd	0.2	5.1
Cr	100	260
Cu	55	390
Pb	12.5	450
Hg	0.08	0.41
Ag	0.07	6.1
Zn	70	410