CITY OF BAINBRIDGE ISLAND

Water Quality and Flow Monitoring Program

Final
SAMPLING AND ANALYSIS PLAN
Bainbridge Island, Washington

April 2008

CoBI Contract No. – 250130

Final

Sampling and Analysis Plan

Water Quality and Flow Monitoring Program

City of Bainbridge Island

Washington

April 2008

Prepared For:
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Water Resources Program
City of Bainbridge Island, Washington

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ACRONYMS AND ABBREVIATIONS

°C	Degrees Celsius
AKART	All Known, Available, And Reasonable Methods Of Prevention, Control & Treatment
BIBI	Benthic Index Of Biological Integrity
BMP	Best Management Practices
BOD	Biochemical Oxygen Demand
$CaCO_3$	calcium carbonate
CAO	Critical Areas Ordnance
cfs	cubic feet per second
CoBI	City of Bainbridge Island
CSO	combined sewer outfall
CWA	Clean Water Act
CWP	Center for Watershed Protection
DDT	dichloro-diphenyl-trichloroethane
DO	dissolved oxygen
DOC	dissolved organic carbon
Ecology	Washington State Department of Ecology
EIA	effective impervious area
EMC	event mean concentration
ESA	Endangered Species Act
ESC	erosion and sediment control
FC	fecal coliform
FL	Fork Length
GIS	Geographic Information System
GMA	Growth Management Act
GPS	Global Positioning System
IGDO	intra-gravel dissolved oxygen
KCl	potassium chloride
LULC	land use land cover
LWD	large woody debris
m	metersmg/l milligrams per liter
mf	membrane filter
MPN	Most Probable Number
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NPS	Non-Point Source
NRC	National Research Council
NTU	nephelometric turbidity unit
PAH	polycyclic aromatic hydrocarbon

ACRONYMS AND ABBREVIATIONS (CONTINUED)

PCB	polychlorinated biphenyl
PFC	properly functioning condition
PPM	parts per million
PPT	parts per thousand
PSAT	Puget Sound Action Team
PSL	Puget Sound Lowland
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RCW	Revised Code of Washington
SAP	sampling and analysis plan
SAV	submerged aquatic vegetation
SMP	Shoreline Management Master Program
SSO	Sanitary Sewer Outfall
SWPPP	stormwater pollution prevention plan
TDS	total dissolved solids
TIA	total impervious area
TMDL	total maximum daily load
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency
WADOH	Washington Department of Health
WDFW	Washington Department of Fish And Wildlife
WLF	water level fluctuation
WQFMP	Water Quality and Flow Monitoring Program
WWTP	wastewater treatment plant
WQS	Washington State water quality standards

1.0 INTRODUCTION

1.1 BAINBRIDGE ISLAND

Bainbridge Island is located in Kitsap County, Washington in the Puget Sound. The jurisdiction of the City of Bainbridge Island (CoBI) encompasses the entire island and surrounding waters (Figure 1-1).

1.2 WATER QUALITY AND FLOW MONITORING PROGRAM

The primary goal of this CoBI Water Quality and Flow Monitoring Program (WQFMP) is to monitor the freshwater and marine nearshore water quality of Bainbridge Island to support CoBI efforts to protect and restore beneficial uses associated with water quality on the Bainbridge Island. Activities essential to accomplishing this goal are:

- Documenting historic water quality conditions and establishing current baseline water quality conditions for the surface and nearshore waters of Bainbridge Island;
- Providing Water Quality data to support the community in making sustainable choices that reduce or prevent water pollution, including point-source pollution from wastewater treatment plants (WWTP), stormwater non-point source pollution, and aquatic habitat degradation, as well as minimizing threats to human health;
- Providing the framework for a long-term WQFMP to ensure that unimpaired waters remain in compliance with water quality standards and designated beneficial uses of impaired waters are restored; and
- Developing a water quality trend analysis program that will support implementation of management actions to protect and restore impaired waters.

There are a number of state and federal regulations that address ambient water quality monitoring. Section 305(b) of the US Clean Water Act (CWA) (Title 33 US Code Chapter 26) requires that states report to the United States Environmental Protection Agency (USEPA) on how well waters of the state support their designated beneficial uses and section 303(d) requires states to identify waters that do not meet water quality standards. The National Pollution Discharge Elimination System (NPDES) requirements also address the need for water-quality monitoring. The Washington State Department of Ecology (Ecology) requires water quality monitoring by those municipalities regulated under USEPA Phase I and II discharge permits to ensure that the designated beneficial uses of receiving waters are protected (Washington Administrative Code 173-201A-170). The Puget Sound Action Team (PSAT) Puget Sound Restoration and Recovery Plan (PSAT 2005) and the Puget Sound Initiative (PSAT 2006) both emphasize water quality monitoring and cleanup efforts.

In addition to federal and state regulations, several CoBI ordinances and programs emphasize the importance of protecting and restoring a high level of water quality in the freshwater and marine-nearshore environment of the island. These programs include the CoBI Comprehensive Plan, the Bainbridge Island Watershed Management Plan, the CoBI Salmon Recovery Plan, and the CoBI Stormwater Management Plan. The mission statement of the CoBI also addresses water quality as a primary community value.

This Sampling and Analysis Plan (SAP) is one of the main guidance documents of the CoBI WQFMP and has the following objectives:

- Characterize the water quality (chemical, physical, and biological) conditions in Bainbridge Island streams, lakes, wetlands, and nearshore areas;

- Identify short-term changes or long-term trends in water quality conditions;
- Collect water quality data related to surface and stormwater regulatory requirements (e.g. NPDES Program);
- Gather information for use in developing pollution prevention measures or water quality treatment best management practices (BMP);
- Determine if water quality program goals are being met and whether water bodies on and surrounding CoBI comply with water quality regulations;
- Provide opportunities for public outreach and water quality data to support public education programs;
- Support reporting of water quality conditions to the general public, including shellfish harvest restrictions, recreational beach closures, and drinking water advisories;
- Determine the effectiveness of pollution prevention measures and water quality treatment BMP systems; and
- Respond to emergency situations such as oil spills, chemical leaks, sewage spills, and flooding events.

Water quality monitoring data can also be used to support a number of other activities. These activities include load assessment to support Total Maximum Daily Load (TMDL) investigations or water quality cleanup programs, wastewater discharge permitting, water resource management, and watershed management by local government.

The WQFMP outlined in this plan is designed to address all applicable regulatory obligations related to water and natural resource management, as well as public health requirements. Because of budgetary constraints, manpower limitations, and logistical issues, future water quality monitoring tasks will need to be prioritized based on need and resource availability.

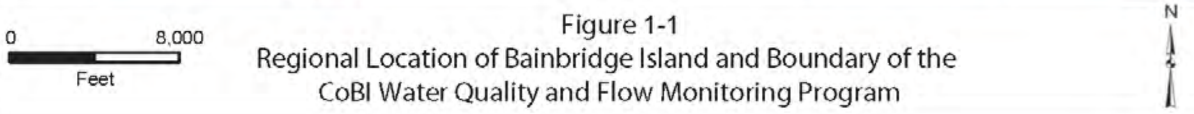

Figure 1-1
Regional Location of Bainbridge Island and Boundary of the CoBI Water Quality and Flow Monitoring Program

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2.0 BACKGROUND

As defined in the CWA, water quality includes chemical, physical, and biological components. Therefore, a comprehensive WQFMP also needs to address each of those same components in order to fully assess water quality conditions. In accordance with the CWA, the surface and nearshore waters of Bainbridge Island must meet established water quality standards and support the designated beneficial uses. These designated beneficial uses include:

- Contact Recreation
- Drinking Water Supply
- Fishing and Shellfish Harvest
- Aquatic Biota and Habitat

The Bainbridge Island WQFMP is designed so as to ensure that these designated beneficial uses are supported and that the waters of Bainbridge Island meet Washington State water quality standards established for these uses. Ultimately, this program will assist the CoBI in meeting the goals of the CWA to protect and restore the chemical, physical, and biological integrity of the waters of Bainbridge Island.

To be an effective tool in achieving the proper water quality for the intended beneficial uses described above, the WQFMP is designed to systematically collect physical, chemical and biological information, and analyze, interpret and report those measurements based on a carefully planned program, which follows a standardized framework (Figure 2-1). This SAP, coupled with the Quality Assurance Project Plan (QAPP) (Volume III) are integral to each other and together provide the foundation of the Bainbridge Island WQFMP. The SAP includes standard methods and protocols for fieldwork. The QAPP describes the laboratory components of the monitoring program. The QAPP also addresses occupational health and safety issues, as well as quality-assurance (QA) and quality-control (QC) procedures. Data analysis includes statistical and trend analysis, as well as interpretation of results based on water quality standards and criteria. It is important to remember that the design of a monitoring program is an iterative process (feedback and adaptive management), as indicated in Figure 2-1, and that earlier components in the structure should be refined on the basis of findings in later stages.

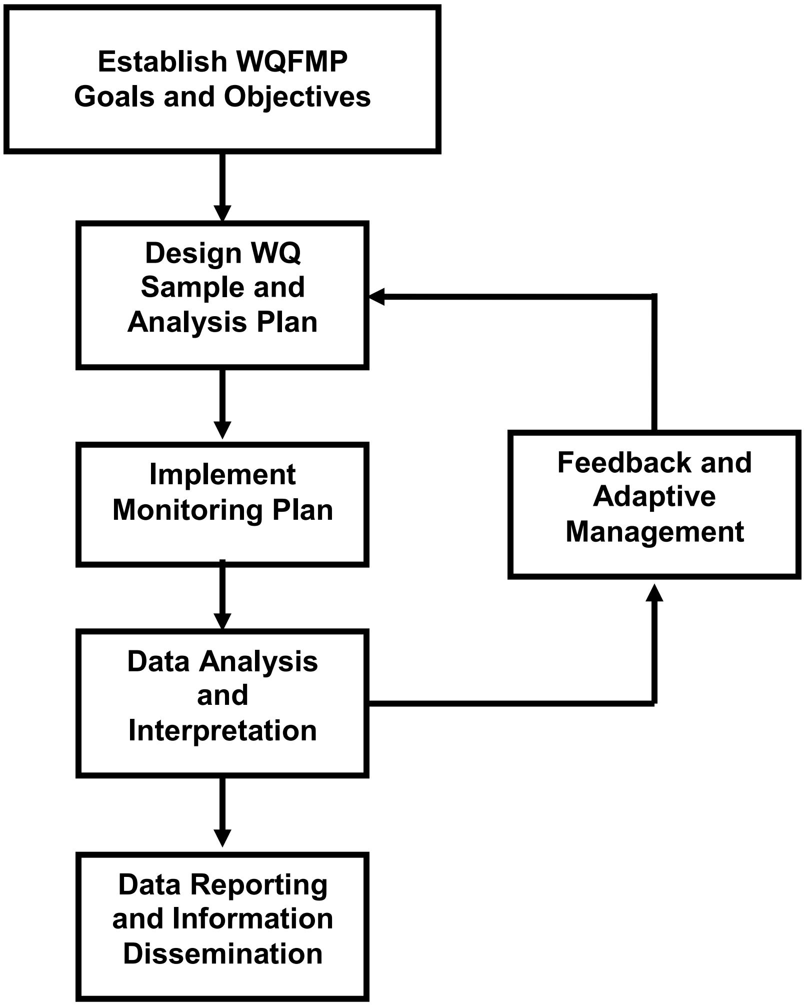

Figure 2-1. Conceptual Framework for Water Quality and Flow Monitoring Program

3.0 WATER QUALITY AND FLOW MONITORING PROGRAM STRATEGY

This section summarizes the overall CoBI WQFMP strategy and its main reference; notably the current application of theCWA. The need for a holistic watershed and receiving water body monitoring approach, including indicators of biological integrity, as a measure of total ecological health is discussed. The concept of "designated beneficial uses of water bodies" is explained and is used as the basis for overall watershed health. System health indicators (condition and stressor) are detailed. The reasons for instituting a WQFMP are reviewed. Tables 3-1 and 3-2 present the recommended water quality indicators and activities for monitoring watershed beneficial uses. Further, this section outlines the intended use of volunteers to aid the CoBI WQFMP in the collection of various types of field data. The recruitment process for volunteers is also discussed.

3.1 PROGRAM STRATEGY

In accordance with the 1972 Federal Water Pollution Control Act and its amendments, collectively known as the CWA, the objective of water resource management efforts in the United States should be to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." These three components together are commonly referred to as "ecological integrity." Regulations promulgated by the USEPA to enforce these acts are based on the concepts of "designated beneficial uses" and "best attainable conditions." After the passage of the CWA, tremendous progress was made in efforts to clean up polluted waters throughout the country. Point sources of pollution, such as sewage treatment plants and industrial discharges were the primary targets of the first phase of this effort. Current water pollution programs concentrate on non-point source (NPS) pollution as the primary concern. NPS pollution includes urban stormwater runoff, agricultural pollution, and other sources dispersed throughout watersheds. In addition, until recently, most surface freshwater monitoring programs focused almost entirely on chemical "water quality" monitoring. However, in spite of these efforts, the quality of the nation's aquatic resources has continued to decline (Karr 1991).

A recent National Research Council (NRC 2001) report stated that certain aspects of the USEPA water quality standards program and the approach currently used to list "impaired waters" under section 303(d) of the CWA should be revised to reflect "best available science." The NRC report recommended that jurisdictions be required to first develop appropriate designated beneficial uses for water bodies and then use that as a basis for logically defining the criteria to be used to measure whether the use is met. The NRC report also stated that a narrow focus on chemical water pollutants was not in keeping with the goals of the CWA or with the current level of scientific knowledge; physical habitat conditions and other ecological factors should also be taken into account when designating and evaluating water bodies for management. Moreover, the report stated that any water resource management program should "consider biological criteria to determine whether a water body is meeting its designated uses or is impaired." The report went on to state that biological criteria tend to be more closely related to designated beneficial uses than traditional chemical water pollution criteria.

Clearly a more integrated approach to what is commonly called "water quality" monitoring is needed. This approach should include all aspects of ecological integrity (chemical, physical, and biological). This is particularly true in the Pacific Northwest where concerns about native salmon and Endangered Species Act (ESA) listings of these valuable aquatic resources have pushed water quality issues into the forefront of environmental policy decisions. Because declining ecological conditions have many potential causes (e.g., chemical pollutants, degraded habitat structure, modified hydrologic regime, alterations in watershed landscape, and biotic interactions), a broader perspective is needed (Karr and Chu 1999). Monitoring approaches that focus only on the sources of degradation (the stressors) rather than directly measuring the aquatic ecosystem conditions, including native biota and physical habitat (the response), often substantially underestimate degradation to receiving waters (Yoder and Rankin 1998). This holistic approach implies that the assessment of physical habitat conditions (both quantitative and qualitative) and biological integrity should be used along with the more traditional chemical water quality criteria, to determine whether designated beneficial uses are attainable. Recognizing this, more than 31 states have adopted some form of biological criteria into their water quality standards over the past decade (USEPA 1998). In addition, the USEPA has made it a priority that biological criteria be a key component in the water quality programs of all 50 states by the year 2005 (USEPA 1998). Physical habitat monitoring has also been adopted as a standard assessment procedure in a number of regions and states. In addition, the condition of the watershed as a whole must be established to serve a landscape level context for more detailed assessment and analysis.

One of the main reasons for instituting a WQFMP includes the need to verify if water resources are supportive of designated uses (condition monitoring). Monitoring also provides data that can be used to determine if there are significant trends in water quality due to human activities in the watershed (trend monitoring) or for use in pollutant-loading estimates for use in TMDL programs. Additionally, water quality monitoring provides a means for detecting pollution problems and contamination of natural systems due to anthropogenic impacts (impact monitoring). This type of monitoring often includes the assessment of reference conditions in natural, unimpacted water bodies for use in comparison with impacted sites. In most cases, water quality monitoring is multi-objective in nature, with the data being utilized for a variety of purposes.

Consistent with USEPA and Ecology water quality monitoring guidance, two principal types of indicators, condition and stressor, will be utilized in the Bainbridge Island WQFMP. Condition indicators are physical, chemical, or biological characteristics of an ecosystem that can provide a measure of the condition of water resources with respect to some environmental reference value, such as ecological integrity. Stressor indicators are characteristics of the environment that are expected to change the condition of water resources if their intensity or magnitude is altered (USEPA 1998). Landscape-level measures of land-use and land-cover (LULC) are examples of this type of indicator.

Because the protection and restoration of designated beneficial uses is a primary goal of the WQFMP, it is important that the selected indicators specifically address the designated uses of each water body. Table 3-1 lists the water quality indicators recommended by the USEPA for the support of typical beneficial uses of receiving waters. The recommended indicators are prioritized into “core” (primary) and “supplemental” (back-up) indicators based on accuracy, reliability, representiveness, and cost-effectiveness (USEPA 2003). Based on USEPA guidance, a typical WQFMP is generally composed of three focus areas: freshwater (streams, wetlands, and lakes), marine and nearshore areas, and stormwater. Table 3-2 outlines the water quality monitoring activities applicable to each of these focus areas. Follow-on sections of this document will address each of these focus areas in more detail.

The Bainbridge Island WQFMP will utilize several of these indicators to measure water quality on the island. The parameters selected will depend on the water body being monitored and the designated beneficial uses that are applicable. In general, the suite of indicators utilized will include a mixture of physical, chemical, and biological parameters.

3.2 USE OF VOLUNTEERS

The successful outcome of the CoBI WQFMP relies on the use of volunteers to augment the efforts of the City. The CoBI WQFMP will use volunteers to aid in the collection of various types of field data. These collection activities could include, but are not limited to rainfall and related weather data, stream gauging (level and flow) data, nearshore grab sampling and physio-parameter measurement tasks (for those sites that involve land access), lake and wetland surveys, stream physio-parameter surveys, and stream macroinvertebrate specimen collection.

The CoBI Water Resources Program plans to conduct various yearly training sessions, depending on current programmatic needs. The City intends to advertise the WQFMP volunteer needs via local news media (newspaper, radio, and local cable television) and on the CoBI WQFMP website. The City also intends to use the Bainbridge Island Watershed Council as a recruitment resource and as a venue to notify the public of opportunities to aid the WQFMP. In addition, the City of Bainbridge Island and the Bainbridge Island School District will continue to coordinate student involvement in the area of water quality and flow monitoring through in-class programs and after school Earth Science Clubs.

Table 3-1. USEPA Recommended Water Quality Indicators for Monitoring Designated Beneficial Uses

Designated Beneficial Uses	Aquatic Biota & Habitat	Contact Recreation	Drinking Water	Fishing & Shellfish Harvest
Core Indicators	•Biological Integrity[1] •Dissolved Oxygen (DO) •Temperature •Conductivity •Salinity •Turbidity •pH •Physical Habitat •Streamflow •Nutrients •Eutrophic Condition •Transparency (Secchi Depth) •Wetland Water-Level Fluctuation •Sediment Contamination •Landscape Characteristics -LULC[2]	•Pathogens •Litter •Nuisance-Plant Growth •Chlorophyll-A •Eutrophic Condition •Transparency (Secchi Depth) •Streamflow •Nutrients •Turbidity •Sediment Contamination •Landscape Characteristics -LULC[2]	•Pathogens •Trace Metals •Hydrocarbons •Organics •Water Toxicity •Nutrients •Salinity •Sediment - TSS[4] & TDS[5] •Streamflow •Landscape Characteristics -LULC[2]	•Pathogens •Mercury[3] •Trace Metals[3] •Chlordane[3] •DDT[3] •PCB[3] •PAH[3] •Sediment Contamination •Landscape Characteristics -LULC[2]
Supplemental Indicators	•Water Toxicity •Sediment Toxicity •Trace Metals •Hydrocarbons •Organics	•Water Toxicity •Sediment Toxicity •Trace Metals •Hydrocarbons •Organics		•Sediment Toxicity •Water Toxicity

Notes:
1. USEPA recommends at least two biological communities be monitored, with at least two assemblages per community utilized.
2. LULC = Land use and land cover characteristics as measured using a geographic information system (GIS).
3. As measured in fish or shellfish tissue.
   DDT = Dichloro-diphenyl-trichloroethane.
   PCB = Polychlorinated biphenyl
   PAH = Polycyclic aromatic hydrocarbon
4. TSS = Total suspended solids.
5. TDS = Total dissolved solids.

Source: US EPA 2003.

Table 3-2. US EPA Recommended Water Quality Monitoring Activities

Indicator Type	Water- Quality Monitoring Activity	Monitoring Objectives
Stressor	Watershed-Scale Landscape Assessment	• Track changes in landscape LULC • Monitor GMA compliance • Public Education
	Riparian-Scale Landscape Assessment	• Track changes in riparian LULC • Monitor CAO effectiveness • Public Education
	Nearshore-Scale Landscape Assessment	• Track changes in shoreline LULC • Monitor SMP effectiveness • Public Education
	Exotic & Invasive Species Survey	• Track extent of exotic species • Identify areas to focus future control measures • Monitor the effectiveness of control efforts • Public Education
Physical	Nearshore & Shoreline Physical Habitat Assessment	• Monitor physical habitat quality • Identify potential restoration sites • Monitor restoration and conservation effectiveness • Identify potential sources of pollution • Public Education
	Stream & Wetland Physical Habitat Assessment	• Monitor physical habitat quality • Identify potential restoration sites • Monitor restoration and conservation effectiveness • Identify potential sources of pollution • Public Education
	Stream Flow Monitoring	• Monitor stream hydrologic regime • Identify potential problems
	Water-Level Fluctuation Monitoring	• Monitor wetland hydrologic regime • Identify potential problems
	Lake & Wetland Transparency Monitoring	• Monitor lake quality • Identify potential problems • Public Education
Biological	Stream Benthic Macroinvertebrate Surveys	• Monitor stream biological integrity • Identify potential problems • Public Education
	Stream Adult Salmonid Spawning Surveys	• Monitor salmonid productivity • Identify potential problems • Public Education
	Stream Juvenile Salmonid Surveys	• Monitor salmonid utilization • Identify potential problems • Public Education
	Nearshore Beach-Seine Surveys	• Monitor salmonid utilization • Identify potential problems • Public Education

Table 3-2. US EPA Recommended Water Quality Monitoring Activities

Indicator Type	Water- Quality Monitoring Activity	Monitoring Objectives
Water Chemistry	Construction Site Stormwater Erosion and Sediment Control (ESC) Monitoring	• Identify potential water quality problems • Regulatory reporting requirements • Evaluate stormwater BMP effectiveness • Public Education
	Stream Water-Chemistry Sampling	• Identify potential water quality problems • Regulatory reporting requirements • Public Education
	Lake-Wetland Water-Chemistry Sampling	• Identify potential water quality problems • Regulatory reporting requirements • Public Education
	Nearshore-Marine Water-Chemistry Sampling	• Identify potential water quality problems • Regulatory reporting requirements • Public Education
	Stormwater Water-Chemistry Sampling	• Identify potential water quality problems • Regulatory reporting requirements • Evaluate stormwater BMP effectiveness • Public Education
Fecal Coliform	Stream Bacterial (FC) Sampling	• Identify potential water quality problems • Regulatory reporting requirements • Public Education
	Lake-Wetland Bacterial (FC) Sampling	• Identify potential water quality problems • Regulatory reporting requirements • Public Education
	Nearshore-Marine Bacterial (FC) Sampling	• Identify potential water quality problems • Regulatory reporting requirements • Public Education
	Stormwater Bacterial (FC) Sampling	• Identify potential water quality problems • Regulatory reporting requirements • Evaluate stormwater BMP effectiveness • Public Education
Sediment	Stream Sediment Sampling	• Monitor sediment contamination • Regulatory reporting requirements • Public Education
	Lake-Wetland Sediment Sampling	• Monitor sediment contamination • Regulatory reporting requirements • Public Education
	Nearshore-Marine Sediment Sampling	• Monitor sediment contamination • Regulatory reporting requirements • Public Education
	Stormwater Sediment Sampling	• Monitor sediment contamination • Regulatory reporting requirements • Evaluate stormwater BMP effectiveness • Public Education

GMA = Growth Management Act
CAO = Critical Areas Ordinance
SMP = Shoreline Management Master Program
GIS = Geographic Information System
FC = Fecal Coliform
LULC = Land Use and Land Cover

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4.0 WATERSHED APPROACH

Watershed-based management programs have been recognized as the most effective way to provide stewardship for our aquatic resources (USEPA 2005). Both the scientific and political communities have broadly accepted these programs as the most effective method of managing aquatic resources. Effective watershed stewardship requires the use of adaptive management to provide continuous feedback on and refinement of management activities. An essential element of this feedback loop is a well-designed WQFMP. It has been widely recognized that a comprehensive evaluation of watershed aquatic resources requires an integrated physical, chemical, and biological assessment program (Figure 4-1).

There is a sound scientific basis for a multi-parameter (physical, chemical, and biological) approach to monitoring ecosystem quality, including the stream ecosystems that support native salmon and trout in the Pacific Northwest. Natural, undisturbed ecosystems normally have a high level of ecological integrity. These ecosystems possess both the structural and functional characteristics required to support a diverse array of native biota, often referred to as biodiversity. In order to gain an understanding of ecosystem strengths and problems, monitoring parameters that reflect the full array of structural and functional elements are necessary. Instream physical habitat tends to be more structural in nature, but also responds to ecosystem (function) processes as well and is a critical component when evaluating aquatic ecosystems that support native salmonids.

There is a great deal of interest in understanding the mechanisms by which watershed LULC characteristics influence aquatic ecosystems such that a more effective watershed management approach can be developed to protect or recovery the ecological integrity of receiving waters. The cumulative effects of human land use can be a significant factor influencing the environment of developing watersheds. The difficulty in addressing cumulative impacts is due to the fact that multiple stressors are typically involved and these stressors often act at multiple scales (both spatial and temporal) within the environment. Empirical models relating changes in LULC to water quality, habitat quality, and biological integrity can be useful for long-range planning.

The watershed-based approach to ecosystem-watershed management also requires an understanding of the effects of scale on the relationships between land use and aquatic ecosystem structure and function. To better anticipate the long-term effects of land-use activities and growth, watershed managers need to be able to estimate how landscape changes will affect ecosystem processes and biological communities across multiple spatial and temporal scales.

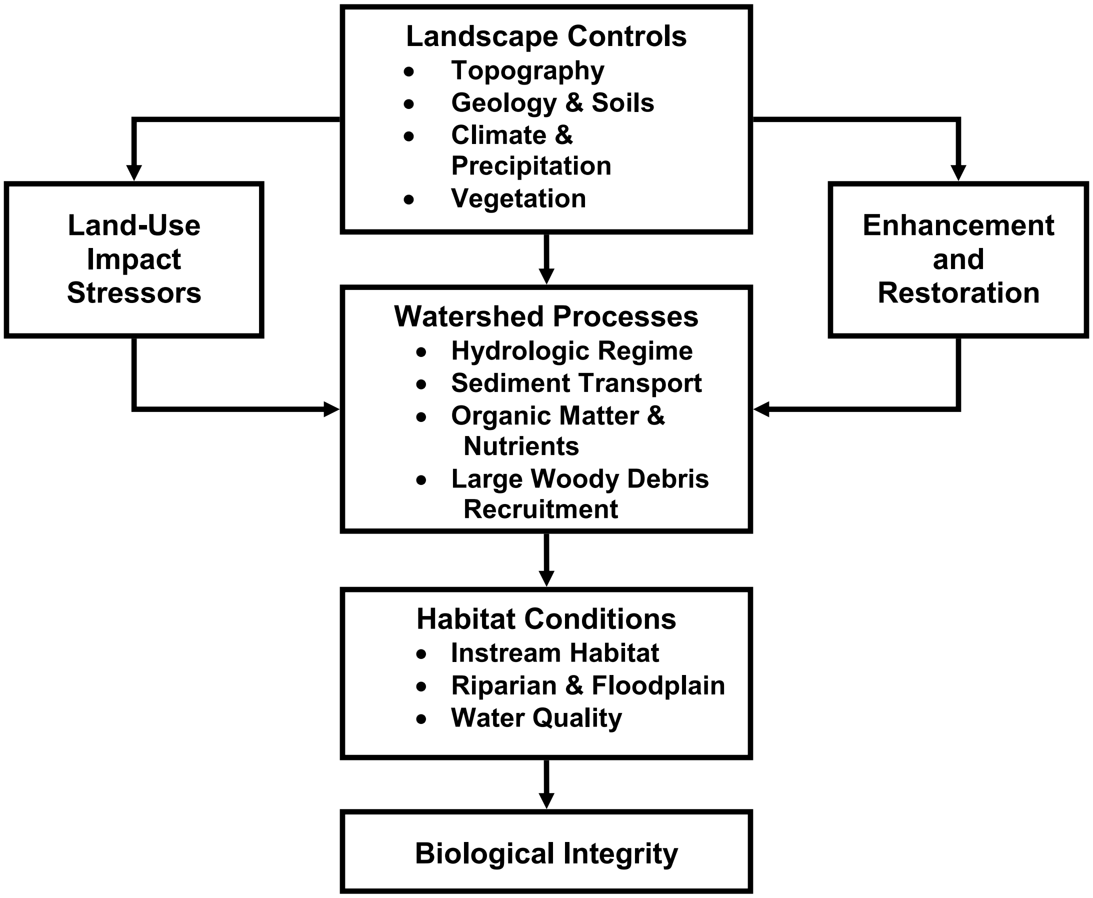

Figure 4-1. Watershed Conceptual Model

4.1 EFFECTS OF URBANIZATION

The impacts of watershed urbanization across the United States have been well documented (Leopold, 1968; Hammer, 1972; Hollis, 1975; Klein, 1979; Arnold et al., 1982; Booth, 1991; Schueler, 1995; Richards et al. 1996; Johnson and Gage 1997; Paul and Meyer 2001; Brown et al. 2005). They include extensive changes in basin hydrologic regime, channel morphology, and physiochemical water quality. Research in urbanizing areas of the country indicates that there is generally a recognizable relationship between watershed landscape characteristics and the ecological integrity of receiving waters. In addition to natural environmental factors such as climate, geography, soils, and land–cover (e.g., native vegetation) characteristics, the cumulative impacts of human land-use activities can also have a significant influence on watershed health.

In the Pacific Northwest region in general and in the Puget Sound lowland eco-region specifically, a history of timber harvest and agricultural activity, followed by urbanization (i.e. residential, commercial, and industrial development) has led to an incremental degradation of the physical, chemical, and biological integrity of streams and wetlands (Booth and Jackson 1997; May et al. 1997; Zandbergen 1998; Finkenbine et al. 2000; Horner and May 1999). The cumulative effect of these alterations has produced an instream habitat that is significantly different from that in which salmonids and associated fauna have evolved in the Pacific Northwest. In addition, development pressure has a negative impact on riparian forests and wetlands, which are essential to natural stream ecosystem functioning and salmonid survival.

Modifications of the natural landscape during the development process can produce tremendous changes in the patterns and the processes of the watershed, especially in the hydrologic regime. These changes result from clearing vegetation, compacting soil, ditching and draining, and finally covering the land surface with impervious rooftops and roads. The infiltration capacity of these impervious areas is significantly reduced, and much of the remaining soil-covered area may also be compacted to a near-impervious state (e.g., lawns, golf course, sports fields, etc.). Compacted soil and other impervious surfaces also tend to have lower storage volumes, and so even if precipitation can infiltrate, the soil reaches surface saturation more rapidly and more frequently, resulting in more runoff and more frequent flood events. These cumulative impacts result in pervasive changes to water quantity, water quality, and the associated ecological function of streams, wetlands, and riparian ecosystems.

In the Pacific Northwest, the urbanization process generally includes a significant loss of natural land-cover (e.g., native forest and wetlands) at the expense of an increase in impervious surfaces (e.g., roads, rooftops, and sidewalks). These modifications of the natural landscape typically result in an altered hydrologic regime (Figure 4-2). During the development process, the loss of natural vegetation is typically accompanied by the removal or compaction of highly absorbent native soil layers and the replacement with impervious materials such as asphalt and concrete. Compounding these changes in land-cover is the loss of natural depressional storage as wetland areas are lost. This modification of the land surface during urbanization can produce changes in both the magnitude and the type of runoff processes. More frequent and more severe flooding events, higher peak stream flows, more frequent bankfull flows, and longer duration of high-flow events are among the changes seen in urbanizing watersheds (Booth et al. 2002). In addition, Wigmosta and others (1994) found that the impervious unit-area runoff was only 20% greater than that from pervious areas, primarily thin sod lawns over glacial till, in a western Washington residential subdivision.

The shift in the watershed land-cover from a forested landscape to a mosaic of developed land uses has had a profound affect on the aquatic ecosystems. For example, alteration of stream flow regime, which affects biota through a range of direct and indirect effects on physical channel conditions (Poff et al. 1997; Bunn and Arthington 2002; Konrad et al. 2005), is generally a function of basin-wide processes (Steedman, 1988; Allan et al., 1997, Hunsaker and Levine, 1995; Roth et al., 1996; Richards and Host, 1994; Richards et al., 1996; Wang et al., 1997).

In the Pacific Northwest, the fundamental hydrologic effects of urban development include the loss of forest canopy interception, the reduction in vegetative evapo-transpiration, and the loss of water storage in the soil column. Therefore, in urbanized watersheds, precipitation tends to reach the stream channel with a typical delay of just a few minutes, instead of what had been a lag of hours, days, or even weeks. The result is a dramatic change in flow patterns in the downstream channel, with the largest flood peaks doubled or more, and more frequent storm discharges increased by as much as an order of magnitude (Wissmar et al. 2004).

In the pre-development forested condition, the abundant but low-intensity rainfall characteristic of this region was conveyed to streams almost entirely as sub-surface flow. In urbanized basins now covered largely by impervious surfaces, a shift from sub-surface to overland flow has significantly altered the delivery of water and sediment to the stream channel (Booth, 1996; Booth and Jackson, 1997; Dunne and Leopold 1978; Horner and May, 1999). The flow regime of developed basins commonly displays an increase in magnitude, duration, and frequency of peak winter flow, and may also show a marked decrease in summer baseflow (Booth and Jackson, 1997; Hollis, 1975; Booth et al. 2002; Konrad et al. 2002; Wissmar et al. 2004). Increased runoff also provides greater opportunity for sediment delivery to the channel, especially when there is land clearing, construction, or agricultural activity in the basin. Local scale effects, often influenced by streamside soil and plant cover and local land use practices, include stream bank erosion, channelization, stream bank hardening, streamside vegetation loss, and use of toxic chemicals.

In addition to changes in how rainfall is absorbed or runs off of watershed upland hillslopes, land development affects other elements of the drainage system. Roadside ditches, gutters, storm drains, and storm sewers are laid in the urbanized area to convey runoff rapidly off roads and developed properties and into stream channels. This results in a significant increase in drainage-density of the watershed, further altering the natural hydrologic regime. In addition, natural channels are often straightened, deepened, or lined with concrete to make them hydraulically more suited to conveying stormwater. Each of these changes increases the “efficiency” of the channel, transmitting the stormwater runoff downstream faster and with less interaction with the channel. This results in less energy dissipation by natural channel features and more erosive stream power acting on the channel. The findings of hydrologic research in urbanizing watersheds indicate that this altered hydrologic regime also has a profound impact on stream channel geomorphology (Savini and Kammerer 1961; Leopold 1968; Hammer 1972; Hollis 1975; Klein 1979; Whipple et al. 1981; Booth 1990; Booth 1991; May et al. 1997; Henshaw and Booth 2000; Booth et al. 2002). Channel incision, stream bank erosion, and instream physical habitat degradation or destruction are all consequences of this alteration of the natural hydrologic regime. The end-result is that the stream channel gradually “unravels” and instream habitat is destroyed or degraded to the extent that it will no longer support native stream biota (Booth and Jackson 1997; May et al. 1997; Booth et al. 2002).

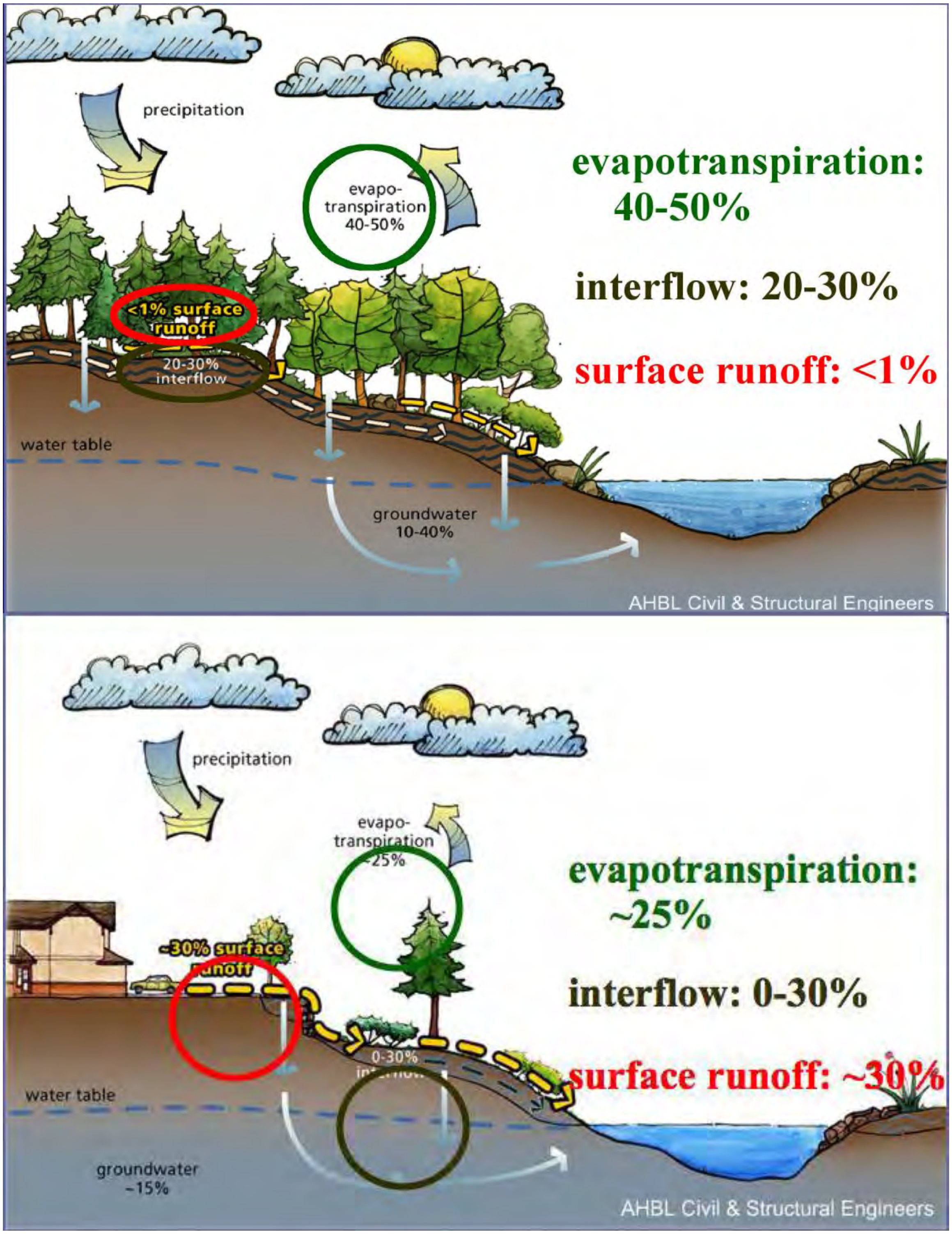

Figure 4-2. Comparison Of Natural (Upper) And Developed (Lower) Hydrologic Regime Showing The Effects Of The Loss Of Native Forest Land-Cover And The Increase In Imperviousness On The Components Of The Hydrologic Cycle (PSAT 2005).

Watershed development or urbanization is one of the most significant threats to the ecological health of aquatic ecosystems in the Puget Sound Lowland (PSL) region (May et al. 1997). The trend is similar across the rest of the United States (Paul and Meyer 2001; USGS 2004; Brown et al. 2005). The degradation and loss of physical habitat as a result of direct human manipulation of stream systems (e.g., stream bank armoring, channelization, and dredging), as well as the impact of hydrologic changes discussed earlier can be significant. These physical changes typically include both a loss of habitat area (quantity) and a decline in habitat quality. (Horner et al. 1996; Richards et al. 1996 & 1997; May et al. 1997; Horner and May 1999; Nerbonne and Vondracek 2001). In the Pacific Northwest, physical instream habitat degradation in urbanizing streams include stream channel incision, streambed scour, elevated levels of stream bank erosion, and fine sediment deposition. In addition, there is generally a decline in stream habitat complexity and diversity that results from increased watershed development. In comparison to non-impacted streams, urbanizing streams tend to have much lower instream complexity due to less large woody debris (LWD). This loss of natural instream complexity often results in lower habitat diversity, with highly urbanized streams more resembling a drainage ditch than a functional ecosystem (Horner et al. 1997; May et al. 1997; Finkenbine et al. 2000).

Physical instream habitat characteristics such as LWD, streambed substrate composition, channel morphology, and stream bank stability can be influenced by the landscape characteristics of their urbanizing watersheds (Richards and Host 1994; Horner et al. 1997; May et al. 1997; Finkenbine et al. 2000).

In addition, the physio-chemical water quality of a stream system is also largely determined by the characteristics of the contributing watershed landscape (Osborne and Wiley 1988; Zampella 1994; Johnson et al. 1997; May et al. 1997; Wang et al. 1997; Gove et al. 2001; Brett et al. 2005; Meyer et al. 2005).

Based on the current body of research, the linkage between watershed landscape LULC characteristics and physical habitat conditions and physio-chemical water quality is well established. These landscape-level relationships tend to be slightly different based on the eco-region of interest, but they appear to be consistent within each region.

It is generally accepted that aquatic biota are linked to instream physical habitat conditions and physio-chemical water quality characteristics. Based on the previous discussion, it is understood that habitat conditions and water quality attributes are influenced by watershed LULC characteristics. Therefore, the linkage between landscape conditions and biological integrity should be clear. Several research studies in several eco-regions have identified and quantified these relationships. There have been studies that focused on the impacts of timber harvest and others that have studied agricultural watersheds. However, most of these studies have focused specifically on the impacts of watershed development (or urbanization), including rural, suburban, and urban land uses, on biological integrity of aquatic ecosystems, which is of interest here.

Most of these studies utilize some percent of imperviousness as the primary landscape parameter or LULC metric. Imperviousness is generally defined as some measure of total impervious area (TIA) within a watershed. Imperviousness represents an integrated landscape-scale measure of all land-use types (i.e., rural, suburban, and urban residential, commercial, and industrial) found within the watershed.

In Maine, an abrupt change in community structure of benthic macroinvertebrates (aquatic insects) was observed at a percent-TIA above a level of approximately 6% (Morse et al. 2002). In contrast to the apparent threshold relationship between percent-TIA and stream insect taxonomic richness, both habitat quality and water quality tended to decline as linear functions of percent-TIA (Morse et al. 2002). Klein (1979) first identified this relationship between watershed urbanization and its effects on the aquatic insect community in Maryland streams, indicating a threshold of significant impact at percent-TIA = 10%. Jones and Clark (1987) described a similar range of impact on stream macroinvetebrates in the 15-25% range of imperviousness in urbanizing stream watersheds in northern Virginia. Schueler (1994) found a similar relationship between watershed percent-TIA (~15%) and macroinvertebrates for urban streams in the Washington D.C. area.

In a long-term study of streams in Wisconsin and Minnesota, macroinvertebrate communities were consistently impacted at impervious levels greater than 10% (Wang and Kanehl 2003). The results of this research indicated that LULC characteristics within the riparian corridor of study streams were even more influential than whole watershed conditions (Wang and Kanehl 2003).

In a related study of urbanizing Wisconsin streams, Wang and others (2001) found that instream habitat and fish community composition declined significantly at an impervious level of 8-12%. This study concluded that at this level of development, a minor increase in watershed urbanization could result in a major change in instream habitat quality and could significantly impact the abundance, species richness, and diversity of the native fish community. As with the previous study of macroinvertebrates, riparian LULC was as important as overall watershed characteristics. This study recommended the conservation of native forest cover on a watershed scale and the establishment of forested riparian buffers as a means of protecting biological integrity of urbanizing streams (Wang et al. 2001).

A study in Georgia (Roy et al. 2005) established a clear linkage between the changes in the hydrologic regime of urbanizing streams and the native fish community. Imperviousness was again used as the primary metric for measuring the level of watershed urbanization. In a similar study in Maryland, watershed urbanization was linked to a reduction in abundance and lower species richness in the native fish community (Morgan and Cushman 2005). In both of these studies, no critical “threshold” of imperviousness or urbanization was identified. Instead, the decline in biological integrity appears to progress continuously as watershed urbanization increases.

Research in the Puget Sound lowland eco-region also indicates a close relationship between watershed urbanization and biological integrity. Both benthic macroinvertebrates and the native salmonid species of fish have been shown to decline in abundance and diversity as watershed development progresses (May et al. 1997; Booth et al 2002; Pess et al. 2002; Booth et al. 2004).

Although most landscape-habitat-biota analyses focus only on LULC characteristics at the watershed scale, several studies have identified the stream riparian corridor as a key landscape feature that should be considered (Steedman 1988; Richards and Host 1994; Kershner 1997; Finkenbine et al. 2000; Moser et al. 2000; Stein and Ambrose 2001; Wang and Kanehl 2003; Synder et al. 2003; Meador and Goldstein 2003). This complimentary (and perhaps synergistic) relationship between the riparian and watershed scales of landscape assessment has also been observed for urbanizing streams in the Puget Sound lowland eco-region (May et al. 1997; Horner and May 1999; May and Horner 2000).

Research in nearshore and estuarine areas also indicates that similar relationships as found in freshwater watersheds and riparian corridors, also apply to coastal zones of marine ecosystems (Greer and Stow 2003; Hale et al. 2004; Jantz et al. 2005).

Based on current research, it appears that the strongest linkages between LULC and ecological metrics (physio-chemical water quality, physical habitat, hydrologic, and biological) occur at the watershed scale. However, most research also shows a strong correlation with riparian-scale LULC metrics (Roth et al. 1996; Allan et al. 1997; May et al. 1997; Gove et al. 2001; Frimpong et al. 2005; McBride and Booth 2005; Vondracek et al. 2005). In some cases, reach-scale or locally measured LULC parameters also have been utilized. The reach-scale relationships between landscape and ecological metrics can also be important in specific circumstances, but generally are not as influential as the watershed or riparian linkages. It is often argued that because riparian areas are closer to the stream than upland areas, they are more influential. This can be true for some ecological attributes such as LWD, but may not hold for others. Focusing only on riparian buffer width ignores the fact that land-use activities throughout the watershed can produce impacts that can be propagated downstream (i.e., stormwater runoff and water quality pollutants).

The conclusion of a majority of landscape-based studies is that the watershed or sub-watershed scale of analysis is critical and is typically the most overall influential scale. However, these studies also show that the riparian scale must also be incorporated into the landscape assessment process (Roth et al. 1996; Allen et al. 1997; May et al. 1997; Gove et al. 2001; Frimpong et al. 2005; McBride and Booth 2005; Vondracek et al. 2005).

Because of the complex nature of aquatic ecosystems and the diverse interactions with the upland landscape within the watershed, the scale of measurement must be considered carefully. Research indicates that the strength of relationships between LULC and ecological metrics (i.e.,water quality, habitat, or biota) will depend on the scale of observation. Therefore, the appropriate scale of measurement depends on the ecological metric of interest. The complexity of cumulative impact stressors within the urbanizing landscape also compounds the difficulty in defining these linkages. In addition, the complexity of bio-geo-chemical and hydrologic interactions within a watershed makes it extremely difficult to scale up from process-based studies of individual stream reaches to sub-basin or riparian scales over long periods of time (Gove et al. 2001). Better defining the relationships between landscape characteristics and ecological integrity, as well as the defining the proper scale to monitor each attribute, will allow watershed resource managers to make better decisions with regard to land-use planning.

4.2 WATERSHED ASSESSMENT

Watershed assessment is an on-going process of compiling and analyzing technical information on watershed conditions, and the effect of human activities on those conditions. It is the first step in a long-term watershed management program. Ultimately, watershed management, including conservation and restoration efforts, will be a key local building block in integrated regional ecosystem management efforts. Because data availability and technical resources vary across geographic areas, the way watershed assessment tasks are approached and the time frame for accomplishing them varies.

A single assessment method or tool will likely not provide all the information needed to effectively manage a watershed based on multiple beneficial uses. However, a standardized assessment framework is needed to bring together different assessment elements, improve consistency, and synthesize data for more effective watershed management. A science-based watershed assessment analyzes the past and current state of the watershed, captures its unique physical, chemical, and biological characteristics, and compares these conditions to those in natural “reference” watersheds. It should explicitly identify uncertainty of information and be supported by written records that provide a basis for decision-making. Assessments help determine how well a watershed is functioning and how it responds to natural and human disturbances. Assessment data provides an understanding of how a watershed "works" and how a watershed has changed as a result of human activities.

A watershed assessment should describe the physical, biological, and chemical attributes of the watershed (i.e., geology, climate, topography, hydrology, and soil structure). Watershed characterization is the description of the current natural and human-related attributes of the basin. Typical parameters utilized in watershed assessment include:

- Natural features of the watershed that affect ecosystem function and biological integrity (e.g., natural vegetation patterns and characteristics – wetlands, riparian corridors, upland forests, and other native vegetation).
- Watershed attributes such as geologic, soil, and topographic characteristics. Hydrologic conditions - low flows, peak flows, water use, land cover, land-use, and impervious surfaces.
- Key land-use features and land-cover patterns, including roads, forested areas, and development levels, usually on a map.
- Municipal jurisdictions and regulatory responsibilities within each watershed.
- Current and historic salmonid utilization for each stream system in the watershed.
- Beneficial uses common to the watershed and their relative importance.
- Unique or critical resource issues and problems.
- Water-resource management programs that currently exist.
- Human activities (land-use) that affect the physical, biological, and chemical attributes of the watershed.
- Biological communities – aquatic and terrestrial biota.
- Water quality conditions – chemical characteristics and pollutants of concern.

The characterization of landscape characteristics for purposes of evaluating and assessing watershed condition is a key component of the watershed assessment process (Roth et al 1996; Allan et al. 1997; Allan and Johnson 1997; Johnson and Gage 1997; McMahon and Cuffney 2000). Typically, aerial photographic analysis has been the primary tool for watershed assessment. Recently, remotely sensed data from satellites has been used to provide an alternative data source for quantifying landscape conditions. The traditional approach to classifying remotely sensed data from satellites into discrete LULC classes involves a lengthy process of automated classification, clustering of spectral signatures, much fine-tuning, and an eventual supervised classification (Hill et al., 2003). This process is continually being refined, and so the methodologies are evolving.

Although multiple ILULC categories have great utility, there is particular appeal in a single "index" variable, such as percent-TIA, which characterizes the magnitude of urban development in a watershed. Patterns can be readily displayed, correlations are simplified, and communications between scientists and decision-makers are enhanced. However, development comes in many patterns, occurs on many different types of landscapes, and is accompanied by a variety of best management practices designed to mitigate its negative effects on aquatic resources. Therefore, any simple correlation between any single measure of urbanization and aquatic-system condition is unlikely to tell the whole story. Past efforts to quantify the degree of urban development have not always been consistent, but have focused on using percent-TIA as the overall measure of watershed development (Schueler, 1995). Other studies, especially those involving hydrologic modeling typically use “effective” impervious area (percent-EIA) rather than percent-TIA.

The main hydrologic limitation of percent-TIA is that it includes some paved surfaces that may not contribute runoff to the storm-runoff response of the downstream channel because they are not “connected” to the natural drainage system by a conveyance route. These so-called connected impervious areas can be quantified as “effective” imperviousness. Some impervious areas may also be located or designed such that runoff is dispersed into areas that allow for natural infiltration. However, where development is more intense and covers progressively greater fractions of the watershed, the more likely that the intervening green spaces have been stripped and compacted during construction and only imperfectly rehabilitated for their hydrologic functions during subsequent “landscaping” operations.

Total impervious area is the “intuitive” definition of imperviousness: that fraction of the watershed covered by constructed, non-infiltrating “hard” surfaces such as concrete, asphalt, and buildings. This measure may also include nominally “pervious” surfaces that are sufficiently compacted or otherwise so low in permeability that the rate of runoff is similar or indistinguishable from pavement. Effective impervious area is that portion of the total imperviousness that is directly connected to the natural drainage network. Thus any part of the total imperviousness that drains onto pervious or naturally vegetated, “green” areas is excluded from the measurement of percent-EIA. Percent-EIA is the parameter normally used to characterize urban development in hydrologic models. However, the direct measurement of percent-EIA is complicated by the array of conveyance pathways typically found in developed watersheds. Studies designed specifically to quantify this parameter must make direct, independent measurements of both percent-TIA and percent-EIA. The results can then be generalized either as a correlation between the two parameters or as a “typical” value for a given land use. (Alley and Veenhuis, 1983). For example, measured ecological conditions in lowland streams are regularly presented in terms of the TIApercentage of the contributing watershed. Land cover is also a primary input parameter for numerical hydrologic models that are widely used by the storm/surface water management agencies of the region (May et al. 1997; Booth et al. 2002; Hill et al 2003).

Because of the profound effect of watershed development on the physical, chemical, biological integrity aquatic systems, characterizing watershed landscape characteristics is critical for a variety of resource management related reasons. In the Pacific Northwest, watershed-scale landscape characterization has been used most commonly to correlate the intensity of human activity with physical habitat conditions, flow regime, biological health, and chemical water quality. This analysis provides data that can be used to predict the health of the aquatic ecosystem, to prioritize conservation and restoration activities, or to guide the allocation of mitigation efforts.

In order to characterize watershed conditions that may be contributing to water quality of each sub-watershed on Bainbridge Island, sub-basins were delineated and analyzed using standard watershed assessment protocols. Table 4-1 and Figure 4-3 summarize the current status of watershed landscape conditions on Bainbridge Island.

The landscape data obtained using this type of watershed assessment procedure can be utilized to develop relationships with selected water-quality parameters (physical, chemical, and biological) or water quality trends developed during the implementation of the CoBI water quality Monitoring Program. These empirical “models” can be useful to water resource managers and decision-makers in planning for future growth or prioritizing water-resource related projects.

Landscape characterization should be up-dated at least every 2-3 years, but may be up-dated more frequently if the rate of watershed development warrants more frequent revision. Remote-sensing landscape data is available from a number of sources, including U.S. Geological Survey, University of Washington, and National Aeronautics and Space Administration.

Table 4-1. Bainbridge Island Watershed Landscape Summary (based on 2001 land-use and land-cover data).

Watershed Name /Code	Watershed Area (Acres)	Watershed Size Ranking	Breakdown of Total Watershed Landcover (% of Total Area)								
			Forest	Wetlands	Natural	Grass & Turf	Bare Ground	% Total Impervious Area	Developed	Surface Water	Other
Agate Passage / AGPS	599.96	12	79.52	2.75	82.28	4.25	3.08	9.17	16.51	0.17	1.04
Blakely Harbor / BLKH	1,369.73	7	87.04	1.08	88.13	2.25	3.62	5.75	11.62	0.22	0.04
Eagledale / EGDL	1,094.12	9	65.10	2.95	68.04	8.83	4.36	18.45	31.63	0.33	0.00
Fletcher Bay / FLBY	2,114.01	3	75.83	1.09	76.92	8.60	6.04	7.89	22.52	0.56	0.00
Gazzam Lake / GZLK	886.45	10	83.96	0.79	84.74	3.96	1.86	7.82	13.64	1.62	0.00
Manzanita Bay / MZBY	2,296.34	1	72.25	1.92	74.18	9.76	6.76	8.85	25.37	0.46	0.00
Murden Cove / MDCV	2,046.36	4	73.65	2.34	75.99	7.65	6.46	9.48	23.58	0.43	0.00
North Eagle Harbor / NEGH	2,184.91	2	50.64	2.46	53.11	8.30	10.57	26.95	45.82	0.44	0.63
Pleasant Beach / PLBH	1,437.63	5	70.66	3.00	73.66	6.01	6.64	13.56	26.21	0.13	0.00
Port Madison / PTMD	1,388.31	6	81.85	1.18	83.03	6.26	3.75	6.36	16.37	0.30	0.31
South Beach / SHBH	711.89	11	76.59	1.20	77.79	4.16	10.88	6.54	21.58	0.63	0.00
Sunrise / SNRS	1,342.24	8	79.08	1.92	81.00	4.49	6.41	7.97	18.87	0.13	0.00
TOTAL ACREAGE	**17,471.95**		12,760.44	333.49	**13,093.92**	1,194.76	1,089.27	1,994.28	**4,278.31**	**74.84**	**24.88**

** Statistical sources include: Battelle Marine Sciences GIS database, CoBI GIS data, and CoBI Level II Assessment (Kato & Warren, 2000)

Figure 4-3. Bainbridge Island Land Use and Land Cover
(based on 2001 land-use and land-cover data).

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5.0 FRESHWATER RESOURCES

5.1 FRESHWATER MONITORING

This section focuses on the freshwater resources of Bainbridge Island. These resources include the streams (perennial and seasonal), wetlands, and lakes located on the island. The designated beneficial uses associated with the freshwater ecosystems on Bainbridge Island include fishing and contact recreation, as well as aquatic biota and habitat.

As was discussed in the previous section, a watershed approach is recommended for managing freshwater ecosystems (USEPA 2005) and that is the approach that will be utilized for water quality monitoring on Bainbridge Island. The watersheds of Bainbridge Island are shown in Figure 5-1. There are a number of perennial and seasonal streams located on the island, several of which support native salmonid (salmon and trout) species (WCC 2000). In addition, the streams, lakes, and wetlands of Bainbridge Island support numerous other species of interest or concern, including birds, amphibians, insects, and mammals. Currently, none of the freshwater ecosystems on Bainbridge Island provide critical habitat for any threatened or endangered species (NMFS 2005).

The watershed-based monitoring approach for Bainbridge Island streams, lakes, and wetlands is illustrated in Figure 5-2 This approach can be characterized as an integrated, goal-driven monitoring scheme. The individual components of the freshwater water quality-monitoring plan are discussed in detail later in this section. In general, the approach will be similar for streams, lakes, and wetlands. Biological, physical, and chemical components will be integrated into each monitoring plan.

The water quality monitoring plan is subject to the principles of adaptive-management. Utilizing adaptive management means that there must be a continuous feedback loop between the results of water quality monitoring, the goals and objectives of the watershed-based program, and the overall effectiveness of watershed protection and restoration efforts. If monitoring indicates that a BMP is not effective, a decision must be made as to how to improve that BMP to accomplish the water quality objective it was implemented to address. By the same token, if a previously unknown or an emerging problem is detected by water quality monitoring, then the goals and related watershed protection activities of the program may need to be revised. In addition, water quality parameters being monitored may need to be periodically adjusted as new information becomes available. This reevaluation process should occur relatively frequently, for each watershed, and should involve CoBI staff, volunteers, and watershed residents.

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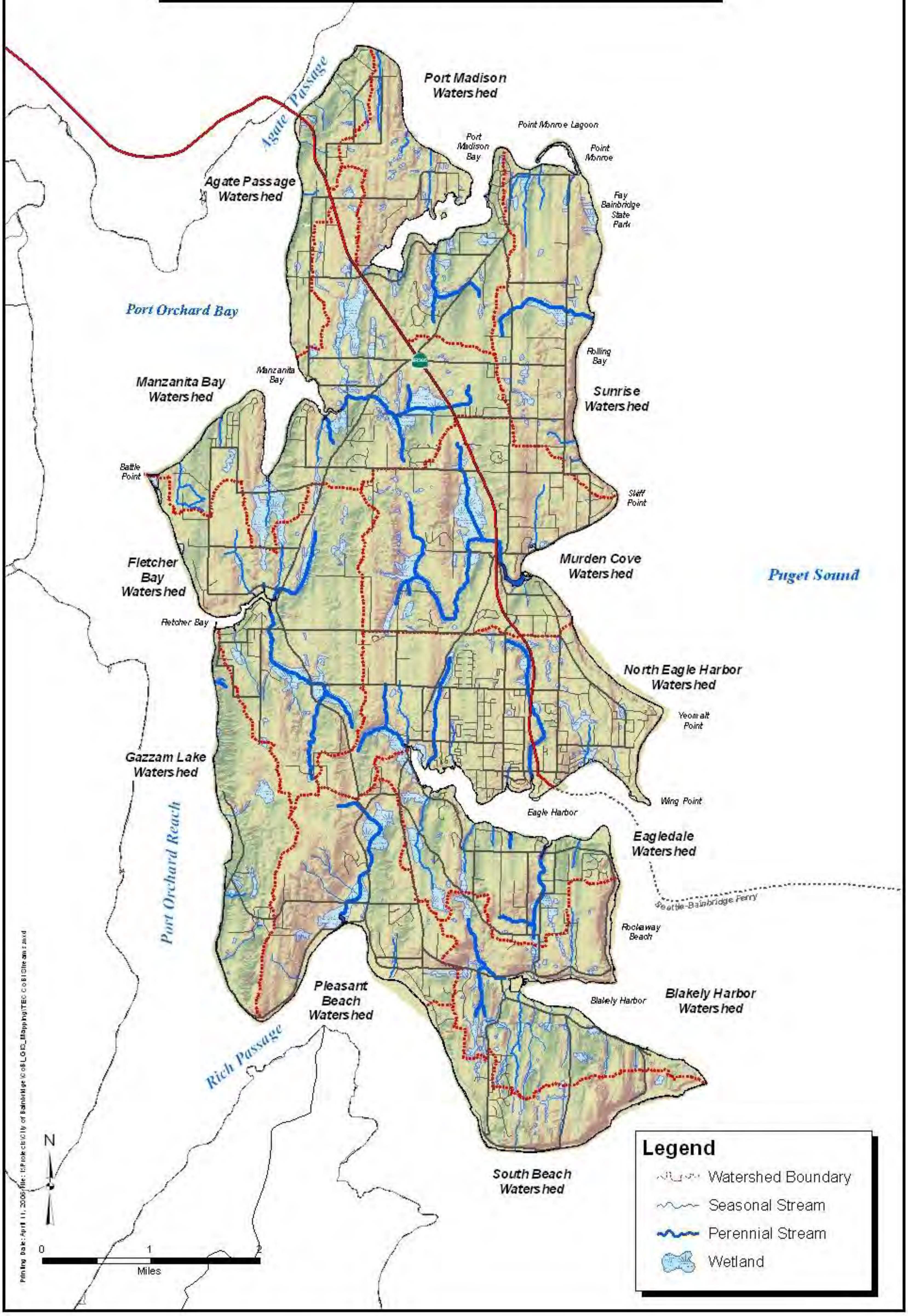
Figure 5-1. Bainbridge Island Watersheds



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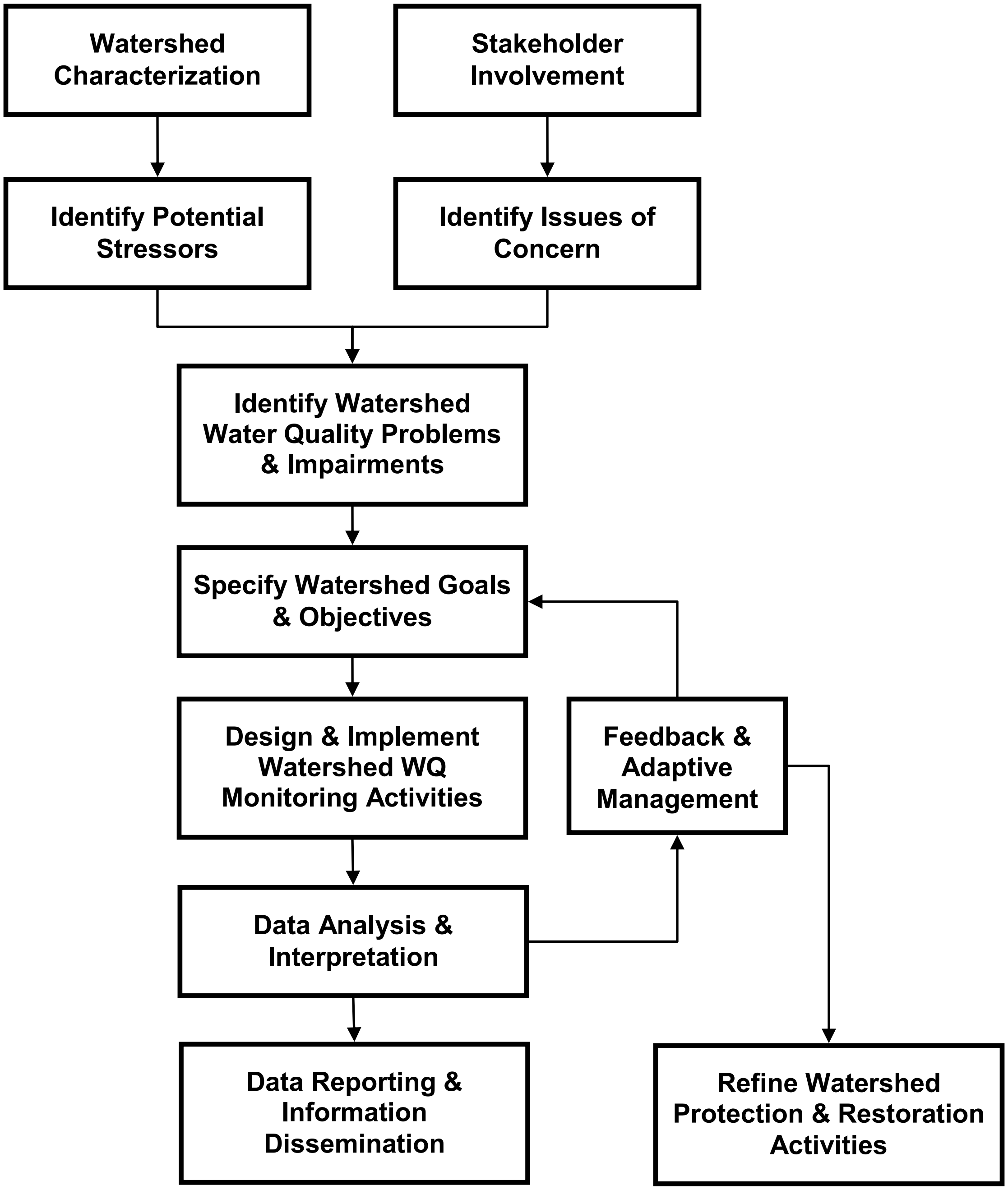

Figure 5-2. Conceptual Model of Watershed Monitoring Program

5.2 BAINBRIDGE ISLAND STREAM WATER QUALITY MONITORING

The streams and wetlands of Bainbridge Island are shown in Figure 5-3 and listed in Table 5-1. For the purposes of this report, commonly accepted names for these creeks were used when an official name was not assigned (see Elfendahl 1996). Streams are classified as perennial or seasonal. Specific objectives of the stream monitoring program are as follows:

1. Determine whether water quality at sampling sites exceeds water quality standards. This objective is intended to address section 303(d) of the CWA, as well as the specific requirements of CoBI programs. Results will be compared to Washington State Water Quality Standards (WQS) established to support designated beneficial uses. In some cases, individual results are compared to a numeric or narrative water quality criterion, in other cases, aggregation of data may be required. This program will also provide timely and high-quality data for use by the CoBI in managing water resources. Each use will have its own minimum data quality requirements, but the data quality established for this program will be appropriate for most related uses. Examples of possible uses of water quality data include support for TMDL analyses, waste discharge permitting where receiving water data is required, and for NPDES Phase II stormwater permitting.
2. Assess the status of Bainbridge Island streams, lakes, and wetlands. This objective is intended to address section 305(b) of the CWA, as well as the specific requirements of CoBI programs. A monitoring program with this objective might best be designed to sample a randomized subset of all island streams. However, this approach is neither logistically nor financially feasible. Access to the randomly chosen sites is often difficult because of private-property issues. In most cases, specific locations for sampling will be established based on professional judgment, with watershed-specific factors and logistic considerations also taken into account. In addition, monitoring at randomly selected frequencies also tends to be impractical if not impossible. In practice, the monitoring design will emphasize major, perennial streams as the primary focus of long-term monitoring, but will sample smaller, seasonal streams often enough such that problems are detected and adequate data are available. Poor water quality at a particular station may indicate an overall, cumulative problem in the watershed, but may not necessarily identify the extent of the problem. Additional sampling may then be necessary.
3. Provide analytical water quality data that describes current conditions and allows for the evaluation of water quality trends. Long-term monitoring at fixed stations followed by periodic statistical analysis of the data and interpretive reports of the results are one of the mainstays of a well-designed ambient monitoring network. The data requirements for trend analysis are quite rigorous. Several years of data collection may be required to conduct statistically significant and scientifically meaningful trend analysis. However, individual data-points are extremely valuable because they provide the most efficient and sensitive means for the early detection of emerging water quality problems. The data quality objectives are based primarily on the objective of early detection of deteriorating water quality conditions. These requirements are also adequate for the detection of improving water quality conditions in degraded water bodies. Assessments of current conditions are site-specific and include various measures of central tendency, variability, and dispersion, non-parametric statistics such as cumulative frequency plots. Trend assessment is most commonly performed using statistical methods such as the non-parametric seasonal Kendall test for trend with a confidence level specified at 90 or 95% (Zar 1984).

Table 5-1. Bainbridge Island Streams

Stream ID No.	Stream Name	Alternate Names	Type	Watershed
1	East Fork Hawley Creek		*Seasonal*	NEGH
2	West Fork Hawley Creek		*Seasonal*	NEGH
3	Hawley Creek		*Seasonal*	NEGH
4	Ravine Creek	Winslow Ravine	**Perennial**	NEGH
5	Madrone Creek		*Seasonal*	NEGH
6	Weaver Creek	Strawberry or Cannery	*Seasonal*	NEGH
7	Sportsman's Club Creek	Hirakawa	**Perennial**	NEGH
8	East Fork Cooper Creek		*Seasonal*	NEGH
9	North Fork Cooper Creek		**Perennial**	NEGH
10	Cooper Creek	Head-of-the-Bay	**Perennial**	NEGH
11	Cougar Creek	Blueberry	*Seasonal*	EGDL
12	McDonald Creek		*Seasonal*	EGDL
13	Rose Creek		*Seasonal*	EGDL
14	Whiskey Creek		**Perennial**	EGDL
15	Creosote Creek	South Eagle Harbor	*Seasonal*	EGDL
16	Blakely Falls Creek		*Seasonal*	BLKH
17	South Fork Mac's Dam Creek		**Perennial**	BLKH
18	Mac's Dam Creek		**Perennial**	BLKH
19	Tani Creek	Yama	*Seasonal*	BLKH
20	Sunny Hill Creek		*Seasonal*	BLKH
21	Crane Lake Creek		*Seasonal*	BLKH
22	Toe Jam Hill Creek		*Seasonal*	BLKH
23	South Beach Creek		*Seasonal*	SHBH
24	Lytle Creek		*Seasonal*	PLBH
25	Schel-Chelb Creek	Edenharter	**Perennial**	PLBH
26	Middle Fork Schel-Chelb		*Seasonal*	PLBH
27	South Fork Schel-Chelb		*Seasonal*	PLBH
28	Point White Creek		*Seasonal*	PLBH
29	Linquist Creek		*Seasonal*	GZLK
30	Crystal Springs Creek		*Seasonal*	GZLK
31	Gazzam Lake Creek		*Seasonal*	GZLK

Table 5-1. Bainbridge Island Streams

Stream ID No.	Stream Name	Alternate Names	Type	Watershed
32	Foster's Creek		*Seasonal*	FLBY
33	South Fork Springbrook Creek		**Perennial**	FLBY
34	Springbrook Creek	Fletcher or Springridge Brook	**Perennial**	FLBY
35	Issei Creek	East Fork Issei	**Perennial**	FLBY
36	West Fork Issei Creek		*Seasonal*	FLBY
37	North Fletcher Bay Creek		*Seasonal*	FLBY
38	Battle Point Creek		*Seasonal*	MZBY
39	Fairy Dell Creek		*Seasonal*	MZBY
40	South Manzanita Creek		*Seasonal*	MZBY
41	South Fork Manzanita Creek		**Perennial**	MZBY
42	Manzanita Creek		**Perennial**	MZBY
43	North Fork Manzanita Creek		*Seasonal*	MZBY
44	Young Cedars Creek	Huhuhup-Piyots	*Seasonal*	AGPS
45	Agate Pass Creek		*Seasonal*	PTMD
46	Oots-Aht-Ub Creek		*Seasonal*	PTMD
47	Nature Preserve Creek	Bloedel	*Seasonal*	PTMD
48	Tochhookwap Creek		*Seasonal*	PTMD
49	Hidden Cove Creeklet		*Seasonal*	PTMD
50	Hidden Cove Creek		*Seasonal*	PTMD
51	Coho Creek	Port Madison	**Perennial**	PTMD
52	Heron Creek		*Seasonal*	SNRS
53	Dripping Water Creek		**Perennial**	SNRS
54	Rolling Bay Creek		*Seasonal*	SNRS
55	Manitou Beach Creek		*Seasonal*	MDCV
56	Meigs Creek		**Perennial**	MDCV
57	Middle Fork Woodward Creek		**Perennial**	MDCV
58	Woodward Creek		**Perennial**	MDCV
59	Murden Creek	Grisdale	**Perennial**	MDCV

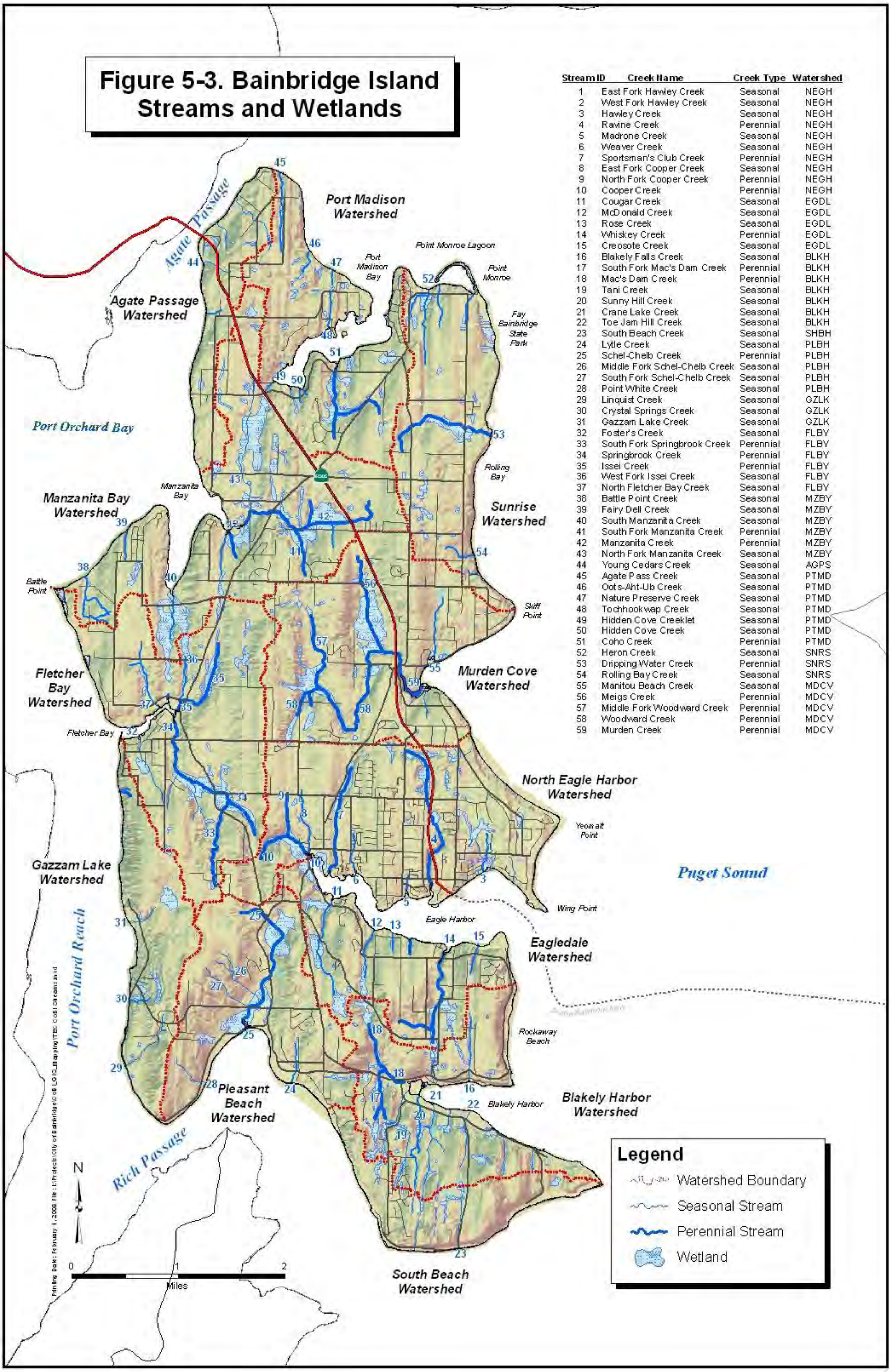

Figure 5-3. Bainbridge Island Streams and Wetlands

Stream ID	Creek Name	Creek Type	Watershed
1	East Fork Hawley Creek	Seasonal	NEGH
2	West Fork Hawley Creek	Seasonal	NEGH
3	Hawley Creek	Seasonal	NEGH
4	Ravine Creek	Perennial	NEGH
5	Madrone Creek	Seasonal	NEGH
6	Weaver Creek	Seasonal	NEGH
7	Sportsman's Club Creek	Perennial	NEGH
8	East Fork Cooper Creek	Seasonal	NEGH
9	North Fork Cooper Creek	Perennial	NEGH
10	Cooper Creek	Perennial	NEGH
11	Cougar Creek	Seasonal	EGDL
12	McDonald Creek	Seasonal	EGDL
13	Rose Creek	Seasonal	EGDL
14	Whiskey Creek	Perennial	EGDL
15	Creosote Creek	Seasonal	EGDL
16	Blakely Falls Creek	Seasonal	BLKH
17	South Fork Mac's Dam Creek	Perennial	BLKH
18	Mac's Dam Creek	Perennial	BLKH
19	Tani Creek	Seasonal	BLKH
20	Sunny Hill Creek	Seasonal	BLKH
21	Crane Lake Creek	Seasonal	BLKH
22	Toe Jam Hill Creek	Seasonal	BLKH
23	South Beach Creek	Seasonal	SHBH
24	Lytle Creek	Seasonal	PLBH
25	Schel-Chelb Creek	Perennial	PLBH
26	Middle Fork Schel-Chelb Creek	Seasonal	PLBH
27	South Fork Schel-Chelb Creek	Seasonal	PLBH
28	Point White Creek	Seasonal	PLBH
29	Linquist Creek	Seasonal	GZLK
30	Crystal Springs Creek	Seasonal	GZLK
31	Gazzam Lake Creek	Seasonal	GZLK
32	Foster's Creek	Seasonal	FLBY
33	South Fork Springbrook Creek	Perennial	FLBY
34	Springbrook Creek	Perennial	FLBY
35	Issei Creek	Perennial	FLBY
36	West Fork Issei Creek	Seasonal	FLBY
37	North Fletcher Bay Creek	Seasonal	FLBY
38	Battle Point Creek	Seasonal	MZBY
39	Fairy Dell Creek	Seasonal	MZBY
40	South Manzanita Creek	Seasonal	MZBY
41	South Fork Manzanita Creek	Perennial	MZBY
42	Manzanita Creek	Perennial	MZBY
43	North Fork Manzanita Creek	Seasonal	MZBY
44	Young Cedars Creek	Seasonal	AGPS
45	Agate Pass Creek	Seasonal	PTMD
46	Oots-Aht-Ub Creek	Seasonal	PTMD
47	Nature Preserve Creek	Seasonal	PTMD
48	Tochhookwap Creek	Seasonal	PTMD
49	Hidden Cove Creeklet	Seasonal	PTMD
50	Hidden Cove Creek	Seasonal	PTMD
51	Coho Creek	Perennial	PTMD
52	Heron Creek	Seasonal	SNRS
53	Dripping Water Creek	Perennial	SNRS
54	Rolling Bay Creek	Seasonal	SNRS
55	Manitou Beach Creek	Seasonal	MDCV
56	Meigs Creek	Perennial	MDCV
57	Middle Fork Woodward Creek	Perennial	MDCV
58	Woodward Creek	Perennial	MDCV
59	Murden Creek	Perennial	MDCV

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Stream monitoring stations were selected to provide sites that are representative of conditions within contributing sub-watershed. Sites were also selected to meet data requirements outlined in the monitoring objectives. Examples of typical stream sample sites include:

1. Perennial Stream Mouths – to provide an overall measure of watershed conditions.
2. Major Tributary Junctions – to provide data on conditions in each tributary sub-basin.
3. Seasonal Stream Mouths – to provide an overall measure of watershed conditions.
4. Upstream and Downstream Locations – to allow for impact evaluation with respect to specific human (e.g. land-use) activities in the watershed.
5. Reference Streams – to provide reference data on non-impacted, natural streams for comparison with degraded system.

Figure 5-4 illustrates the components of the integrated water quality-monitoring (physical, chemical, and biological) approach to be used for streams on Bainbridge Island.

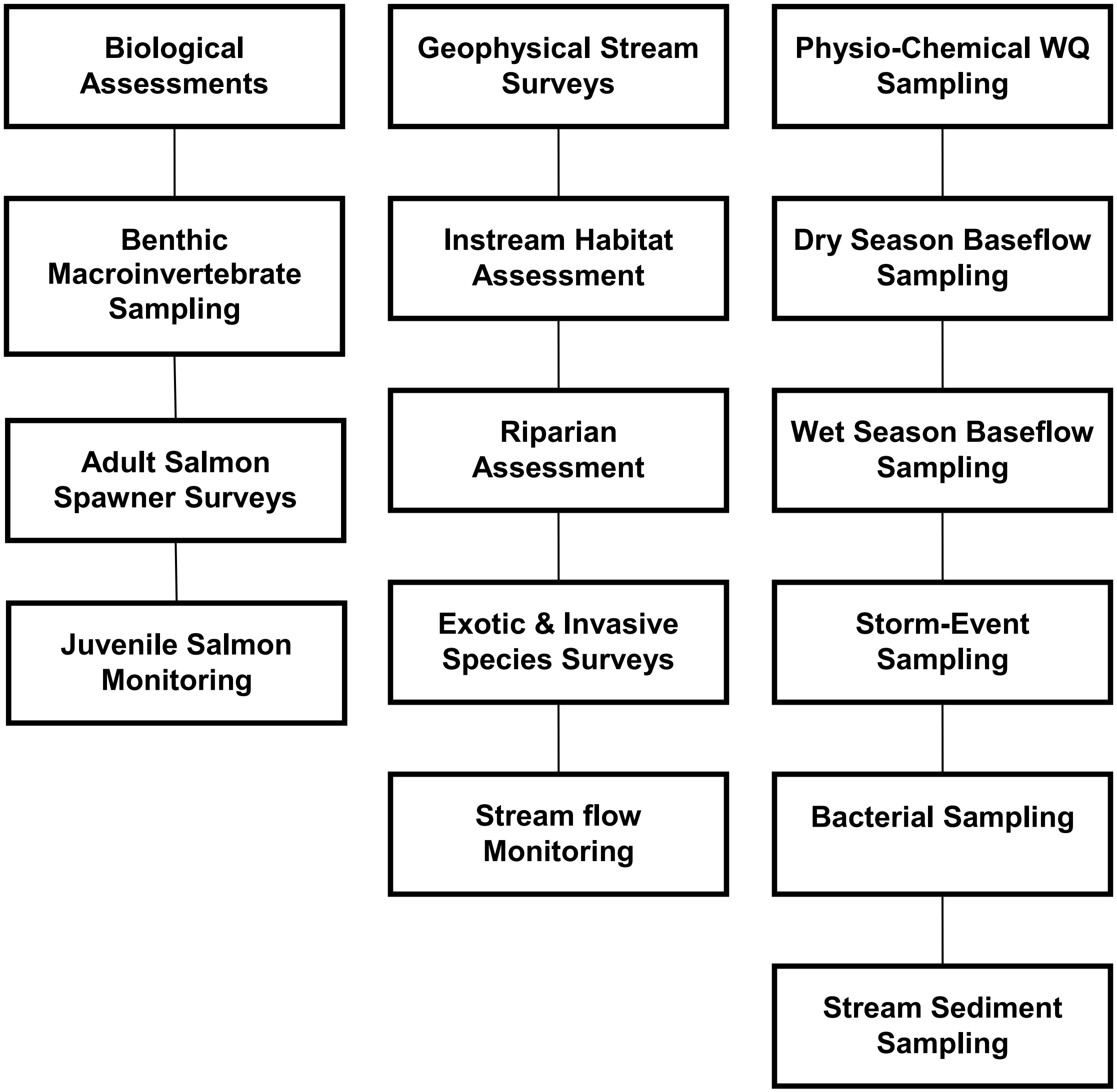


Figure 5-4. Comprehensive Stream Water Quality Monitoring Approach for Bainbridge Island

5.3 BIOLOGICAL ASSESSMENTS

The ultimate goal of the CWA is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. In this context, integrity refers to an unimpaired condition, a state of being complete or undivided. Biological integrity has been defined as the ability to support and maintain a balanced, integrated adaptive assemblage of organisms having species composition, diversity, and functional organization comparable to that of natural habitat of the region (Karr et al. 1986). As a result of evolution, each organism is adapted to the environmental conditions in its native eco-region. An environment that supports an assemblage of organisms similar to that produced by these long-term evolutionary processes is said to have high biological integrity. Changes that result from human activities cause a divergence from biological integrity, that is, a decline in biological condition.

The community structure, species diversity, abundance, and condition of biota within a stream ecosystem provide a direct and accurate measure of the biological condition and ecosystem health. Biological criteria are narrative or quantitative expressions that describe the biological integrity of natural or reference (unimpaired or minimally impaired) streams. This level of biological integrity indicates that the stream fully supports the designated aquatic life use. Biocriteria are set by regulatory-based measurements from “reference” streams within an eco-region and are typically based on the abundance and diversity of organisms present. Biocriteria are often expressed as an index that includes multiple metrics that measure a variety of characteristics of the biological community being monitored. A typical multi-metric index of biological integrity could include measures of species diversity, abundance, the presence of pollution-tolerant or sensitive organisms, as well as measures of community structure or function. Biological assessments are an evaluation of the biological condition (integrity) of an aquatic ecosystem. Bioassessment data are compared to biocriteria to determine the level of water quality impairment. Bioassessments are the primary tool for quantifying the biological condition of a water body and can be used as a screening tool to identify stressors, provide an early warning of water quality problems, and to trigger more detailed sampling activities (USEPA 2002).

Biological monitoring or bioassessments allow us to understand more of the processes occurring in stream watersheds by determining what organisms are found in a stream and comparing it to what organisms are expected to be present. Biological integrity of streams is directly influenced by human activities such as forestry, agriculture, and urban development. Measuring biological integrity provides an insight to the human impacts upon stream systems and provides clues regarding where we need to protect streams or where we can start helping to restore their integrity (Karr and Chu 1997). A typical biological integrity monitoring approach consists of five steps: 1) defining biological condition in a minimally disturbed area - what the natural condition in the area should be, 2) defining biological attributes that change along the gradient of human influence, 3) associating those changes with specific human impacts, 4) identifying management practices for improving biological integrity, and 5) communicating results to decision-makers and the public.

In the Pacific Northwest and the Puget Sound in particular, salmon are the primary species of concern. However, because of their complex life history, monitoring salmon is difficult. Therefore, benthic macroinvertebrates will be utilized as the primary biological monitoring tool for freshwater ecosystems on Bainbridge Island.

5.3.1 Benthic Index of Biological Integrity

Benthic macroinvertebrates have been chosen to measure biological integrity because they are long-term inhabitants of streams, relatively immobile, easy to collect, and represent an assemblage that responds predictably to human induced stress. Furthermore, using benthic macroinvertebrates as indicator organisms has the additional advantage of being able to detect the cumulative impacts of human influence upstream of any sampling site (Karr and Chu 1998). In other words, what has happened upstream is reflected in the biotic communities downstream. Our ability to protect biological resources depends on our ability to identify and predict the effects of human actions on biological systems, especially our ability to distinguish between natural and human-induced variability in biological condition (Karr and Chu 1998). As human influence and impact increase along a gradient from high to low, indices of biological integrity mirror this gradient.

The Benthic Index of Biological Integrity (BIBI) was developed for use in the PSL eco-region (Karr and Chu 1997). The BIBI includes a synthesis of diverse biological information, which numerically depicts associations between human influence and biological attributes. It is composed of several biological attributes or metrics that are sensitive to changes in biological integrity caused by human activities. The multi-metric approach compares what is found at a monitoring site to what is expected using a regional baseline condition that reflects little or no human impact (Karr 1996). Just as doctors use data from a check-up (e.g., blood samples, temperature, weight, blood pressure, etc.) to compare against what is considered healthy in humans, a multi-metric index such as the BIBI utilizes a variety of measurements to assess the biological condition, or health, of streams.

Trained CoBI staff and/or volunteers can easily conduct benthic macroinvertebrate sampling. The field sampling protocols and general QA requirements are discussed in this section. A certified laboratory should conduct analysis of BIBI samples.

First, identifying and counting all benthic macroinvertebrates found from a stream sample develop the BIBI score. Various metrics are then tabulated using these raw data. After the metrics are calculated, they are each converted to a score of 1, 3, or 5 in order to facilitate comparisons between streams and between sample dates. A value of "5" is assigned for the range of expected results (i.e., for each metric) in a natural (non-impacted), reference site. A value of "3" is designated for results expected from a moderately degraded site, and a value of "1" is assigned for values expected in severely degraded sites. The individual metric scores are added together for a Total BIBI score. In the genus-level ten-metric BIBI, a total score can range from 10 (severely degraded) to 50 (non-impacted, natural conditions). The Total BIBI score can then be assessed using a qualitative coding system (see Table 5-2). The following ten metrics are calculated based on the stream-sample taxonomic identification:

1. Total Taxa Richness = the total number of unique taxa is identified in each replicate. Taxa richness is a measure of biological diversity. The numbers from the three replicates are then averaged for this metric.

2. Ephemeroptera Taxa Richness = the total number of unique mayfly (Ephemeroptera) taxa is identified in each replicate. The numbers from the three replicates are then averaged for this metric.

3. Plecoptera Taxa Richness = the total number of unique stonefly (Plecoptera) taxa is identified in each replicate. The numbers from the three replicates are then averaged for this metric.

4. Tricoptera Taxa Richness = the total number of unique caddis fly (Tricoptera) taxa is identified in each replicate. The numbers from the three replicates are then averaged for this metric.
5. Number of Long-Lived Taxa = the cumulative number of unique long-lived taxa identified across all three replicates.
6. Number of Intolerant Taxa = the cumulative number of unique pollution-intolerant or sensitive taxa identified across all three replicates.
7. Percent Tolerant Individuals = the total number of pollution-tolerant individuals counted in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates are then averaged for this metric.
8. Number of Clinger Taxa = the total number of “clinger” taxa is identified in each replicate. Clingers are a group of organisms that live on the surface of bottom substrata. The loss of these organisms tends to be indicative of streams where flows are higher than normal due greater inputs of impervious surface runoff. The numbers from the three replicates are then averaged for this metric.
9. Percent Predator Individuals = the total number of predator individuals counted in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates are then averaged for this metric.
10. Percent Dominance = the sum of individuals in the three most abundant taxa in each replicate, divided by the total number of individuals in that replicate, multiplied by 100. The percentages from the three replicates are then averaged for this metric.

As was detailed above, the output of the Puget Sound BIBI is a number between 10 and 50. The overall BIBI score is a measure of stream biological condition (i.e., health). Each of the individual metrics reflects the condition of an important individual biological component. These components provide insight and clues about the types of degradation responsible for changes within the biological community of benthic macroinvertebrates. A value close to 50 indicates that the stream's biology is equivalent to what would be found in a "natural" stream of that area. A value close to 10 indicates a poor biotic condition within the stream. Most scores will fall somewhere in between these two extremes.

It is important to not only look at the final BIBI score, but to look at the individual metric scores for clues to the types of impacts affecting the final score. For example: Did you have a high percentage of pollution tolerant taxa? Were long-lived taxa present? Were sediment tolerant taxa present? The individual metrics will help explain the processes occurring within and around the sampling site and can provide the opportunity to investigate the types of influences acting upon a watershed. However, keep in mind that human disturbances act upon stream systems in complex ways and thus the resulting BIBI scores should, in general, also be interpreted based on the overall score (Karr and Chu 1998). For example, a sampling site may possess high diversity (i.e., total taxa richness) and thus indicate a high biological integrity score. However, if the species contributing to a high diversity are pollution tolerant species, the overall biological integrity of the system may be poor. Understanding the stream ecology of the different taxa associated with PSL streams will also aid in the interpretation of the data and the resulting BIBI.

Table 5-2. Scoring Criteria for the Benthic Index of Biotic Integrity (BIBI) for Puget Sound Lowland Streams (Karr and Chu 1998).

BIBI Metrics	BIBI Metric Scoring Criteria		
	1	3	5
Taxa Richness and Taxa Composition			
Total number of taxa	<14	14-28	> 28
Number of Ephemeroptera (mayfly) taxa	<3.5	3.5-7.0	> 7.0
Number of Plecoptera (stonefly) taxa	<2.7	2.7-5.3	> 5.3
Number of Trichoptera (caddisfly) taxa	<2.7	2.7-5.3	> 5.3
Number of long-lived taxa	<4	4-8	> 8
Pollution Tolerance			
Number of intolerant taxa	<2	2-4	> 4
% of individuals in tolerant taxa	> 44	27-44	< 27
Feeding Ecology (Functional Feeding Group)			
% of predator individuals	<4.5	4.5-9.0	> 9.0
Number of clinger taxa	<8	8-16	> 16
Population Attributes			
% dominance (top 3 taxa)	> 75	55-75	<55

Table 5-3 shows the cut-off values for the BIBI scores and their qualitative interpretations. These interpretations are based on ecosystem attributes (structure and function) as compared to natural, reference (non-impacted) and, specifically, with respect to support for native salmonid populations.

Table 5-3. Scoring Categories for the Benthic Index of Biotic Integrity (BIBI) for Puget Sound Lowland Streams (Karr and Chu 1998).

Score	Grade	Definition
50-46	Healthy	Ecologically intact, supporting native biota, including native salmonids and the most sensitive organisms.
44-36	Compromised	Showing signs of ecological degradation. Impacts expected to one or more salmon life-stages.
34-28	Impaired	Healthy ecosystem functions demonstrably impaired. Cannot support self-sustaining salmon populations.
26-18	Highly impaired	Highly adverse to salmon and other native organisms. Ecosystem degradation well underway.
16-10	Critically impaired	Unable to support a large proportion of native organisms. In general, only tolerant organisms present. Significant ecosystem degradation.

5.3.2 Benthic Macroinvertebrate Sampling and Analysis

Benthic macroinvertebrates will be utilized as the primary measure of stream biological integrity. Benthic macroinvertebrate sampling and the BIBI obtained from this sampling will also be used as the primary WQ-screening tool for the CoBI WQ-Monitoring program. The BIBI scores will aid in identifying those streams that should be monitored for WQ problems or altered flow regime.

1. Sample Sites – Potential stream macroinvertebrate sampling sites are listed in Table 5-4. Sample sites have been selected at locations that are logistically accessible and will provide measurements that are representative of contributing sub-watershed conditions. There is at least one sample site located in each of the main island watersheds. Major streams typically have multiple sample sites located on tributary streams or at multiple locations along the mainstem channel so as to be able to measure changes in biological integrity due to human activities located upstream of the chosen sample site. Additional sample sites can be added or sites dropped as necessary based on the evaluation of data and in response to adaptive management feedback. Figure 5-5 shows the general location of each potential BIBI site.
2. Sample Frequency – All of the major, perennial streams should be sampled annually for the first three years of the monitoring program. This will aid in establishing baseline conditions for each sub-watershed. Thereafter, streams can be samples at 2-3 year intervals, depending on the level of human disturbance occurring in each sub-watershed. Sampling should also be conducted prior to and after the implementation of any significant watershed restoration projects. Seasonal streams and tributaries should also be sampled on the same schedule, however, flow must be present in the stream to conduct macroinvertebrate sampling, so it is likely that sampling in these streams will be limited to “wet” years only. Based on this approach, approximately 30 stream BIBI sites would be sampled each year for the first three years of the monitoring program. Thereafter, 10-15 BIBI sites should be sampled annually. Selection of sites to sample each year should be made by CoBI staff based on the priorities that exist at the time of sampling.
3. Sample Timing – Benthic macroinvertebrate sampling should be conducted in late summer to early fall (August 15 to October 15), but should always be completed prior to salmon spawning season.
4. Sampling & Analysis Methods – The sampling and analysis protocols of the BIBI have been developed for use in PSL streams (see Section 5.3.3 & 5.3.4). This system is recommended for use on Bainbridge Island.
5. Sample Team – Trained teams of CoBI staff and volunteers can easily conduct benthic macroinvertebrate sampling. Proper training on sampling protocols and QA requirements is essential.

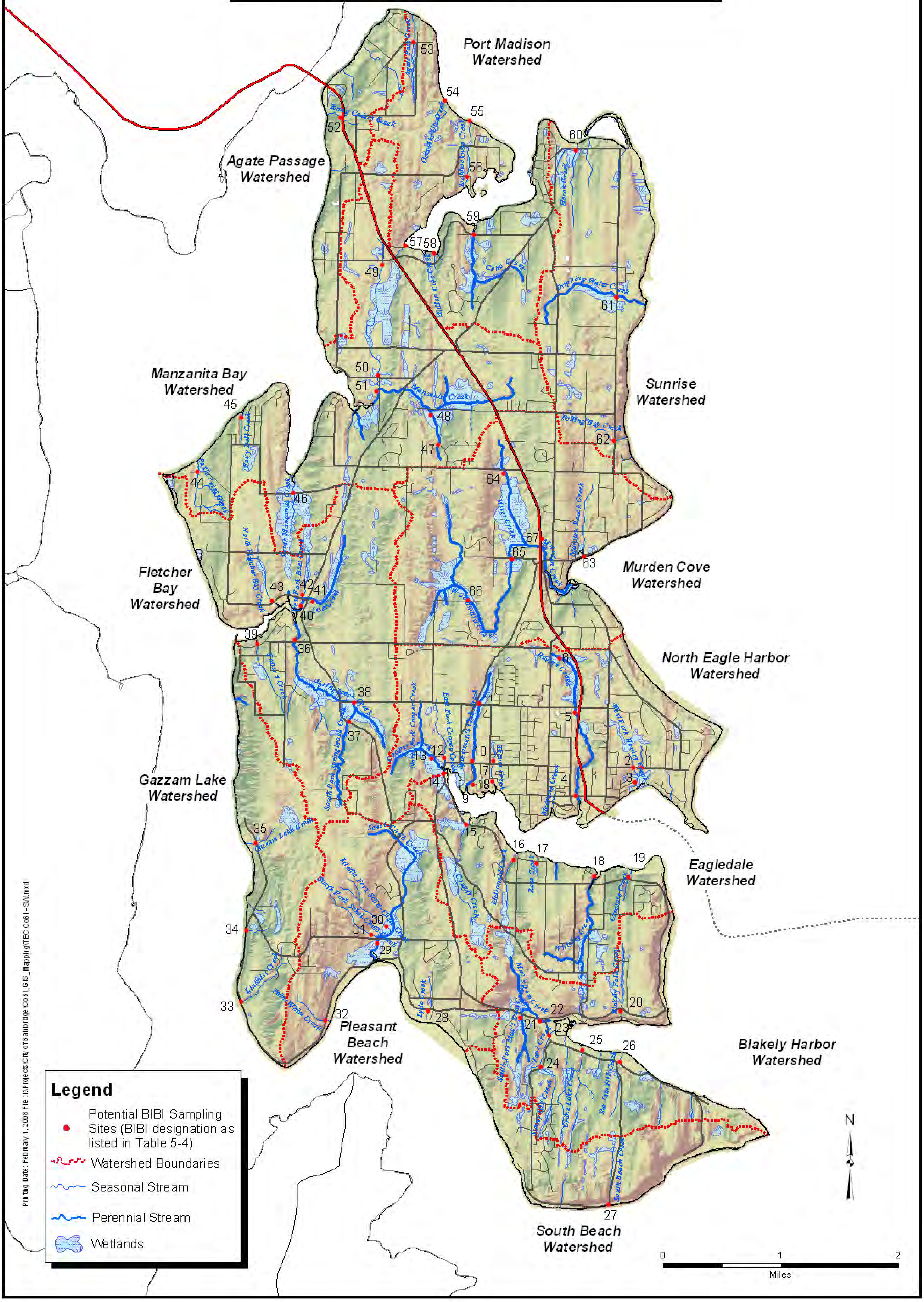
Table 5-4. Potential Bainbridge Island Stream BIBI Sample Sites

BIBI ID No.	Stream Name	Type	Watershed
BIBI 1	East Fork Hawley Creek	*Seasonal*	NEGH
BIBI 2	West Fork Hawley Creek	*Seasonal*	NEGH
BIBI 3	Hawley Creek (Mainstem)	*Seasonal*	NEGH
BIBI 4	Lower Ravine Creek (@ Winslow Way)	**Perennial**	NEGH
BIBI 5	Middle Ravine Creek (@ SR-305)	**Perennial**	NEGH
BIBI 6	Upper Ravine Creek (@ High School Road)	**Perennial**	NEGH
BIBI 7	Upper Weaver Creek (@ Wyatt Avenue)	*Seasonal*	NEGH
BIBI 8	Lower Weaver Creek (@ Sheppard Road)	*Seasonal*	NEGH
BIBI 9	Lower Sportsman's Club Creek (@ Gowen Road)	**Perennial**	NEGH
BIBI 10	Middle Sportsman’s Club Creek (@ Wyatt Avenue)	**Perennial**	NEGH
BIBI 11	Upper Sportsman's Club Creek (@ High School Road)	**Perennial**	NEGH
BIBI 12	East Fork Cooper Creek	*Seasonal*	NEGH
BIBI 13	North Fork Cooper Creek	**Perennial**	NEGH
BIBI 14	Cooper Creek (Mainstem)	**Perennial**	NEGH
BIBI 15	Cougar Creek	*Seasonal*	EGDL
BIBI 16	McDonald Creek	*Seasonal*	EGDL
BIBI 17	Rose Creek	*Seasonal*	EGDL
BIBI 18	Whiskey Creek	**Perennial**	EGDL
BIBI 19	Creosote Creek	*Seasonal*	EGDL
BIBI 20	Blakely Falls Creek	*Seasonal*	BLKH
BIBI 21	South Fork Mac's Dam Creek	**Perennial**	BLKH
BIBI 22	Mac's Dam Creek	**Perennial**	BLKH
BIBI 23	Tani Creek	*Seasonal*	BLKH
BIBI 24	Sunny Hill Creek	*Seasonal*	BLKH
BIBI 25	Crane Lake Creek	*Seasonal*	BLKH
BIBI 26	Toe Jam Hill Creek	*Seasonal*	BLKH
BIBI 27	South Beach Creek	*Seasonal*	SHBH
BIBI 28	Lytle Creek	*Seasonal*	PLBH
BIBI 29	Schel-Chelb Creek (Mainstem)	**Perennial**	PLBH
BIBI 30	Middle Fork Schel-Chelb	*Seasonal*	PLBH
BIBI 31	South Fork Schel-Chelb	*Seasonal*	PLBH
BIBI 32	Point White Creek	*Seasonal*	PLBH
BIBI 33	Linquist Creek	*Seasonal*	GZLK
BIBI 34	Crystal Springs Creek	*Seasonal*	GZLK
BIBI 35	Gazzam Lake Creek	*Seasonal*	GZLK
BIBI 36	Lower Springbrook Creek (@ Fletcher Bay Road)	**Perennial**	FLBY
BIBI 37	South Fork Springbrook Creek (@ Johnson Farm)	**Perennial**	FLBY
BIBI 38	Upper Springbrook Creek (@ High School Road)	**Perennial**	FLBY
BIBI 39	Foster's Creek	*Seasonal*	FLBY

Table 5-4. Potential Bainbridge Island Stream BIBI Sample Sites

BIBI ID No.	Stream Name	Type	Watershed
BIBI 40	Issei Creek (Mainstem @ Battle Point Drive)	**Perennial**	FLBY
BIBI 41	East Fork Issei Creek	**Perennial**	FLBY
BIBI 42	West Fork Issei Creek	*Seasonal*	FLBY
BIBI 43	North Fletcher Bay Creek	*Seasonal*	FLBY
BIBI 44	Battle Point Creek	*Seasonal*	MZBY
BIBI 45	Fairy Dell Creek	*Seasonal*	MZBY
BIBI 46	South Manzanita Creek	*Seasonal*	MZBY
BIBI 47	Upper South Fork Manzanita Creek	**Perennial**	MZBY
BIBI 48	Lower South Fork Manzanita Creek	**Perennial**	MZBY
BIBI 49	Upper North Fork Manzanita Creek	*Seasonal*	MZBY
BIBI 50	Lower North Fork Manzanita Creek	*Seasonal*	MZBY
BIBI 51	Manzanita Creek (Mainstem)	**Perennial**	MZBY
BIBI 52	Young Cedars Creek	*Seasonal*	AGPS
BIBI 53	Agate Pass Creek	*Seasonal*	PTMD
BIBI 54	Oots-Aht-Ub Creek	*Seasonal*	PTMD
BIBI 55	Nature Preserve Creek	*Seasonal*	PTMD
BIBI 56	Tochhookwap Creek	*Seasonal*	PTMD
BIBI 57	Hidden Cove Creeklet	*Seasonal*	PTMD
BIBI 58	Hidden Cove Creek	*Seasonal*	PTMD
BIBI 59	Coho Creek	**Perennial**	PTMD
BIBI 60	Heron Creek	*Seasonal*	SNRS
BIBI 61	Dripping Water Creek	**Perennial**	SNRS
BIBI 62	Rolling Bay Creek	*Seasonal*	SNRS
BIBI 63	Manitou Beach Creek	*Seasonal*	MDCV
BIBI 64	Meigs Creek	**Perennial**	MDCV
BIBI 65	Lower Woodward Creek	**Perennial**	MDCV
BIBI 66	Upper Woodward Creek	**Perennial**	MDCV
BIBI 67	Murden Creek (Mainstem @ SR-305)	**Perennial**	MDCV

Figure 5-5. Bainbridge Island Potential Stream Benthic Macroinvertebrate (BIBI) Sampling Sites



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5.3.3 Benthic Macroinvertebrate Sampling Equipment

- 1 complete Surber sampler
- 2 buckets, marked “clean” and “dirty”
- 2 500-micron sieves, also “clean” and “dirty”
- 2 rubber dishpans
- 3 weighted-markers with flagging tape attached
- 1 weeding fork to disturb substrate
- 1 timepiece with second hand
- 1 decanter with handle
- 2 angled-spout wash bottles (one for water, one for alcohol)
- 2 squirt bottles (one for water, one for alcohol)
- 1 plastic spatula
- 2 forceps (tweezers)
- 1 magnifying glass
- Wide-mouth (plastic) sample jars with tight lids
- Sample labels
- Alcohol
- Data sheet and clipboard
- Field Key to Macroinvertebrate Identification
- Permanent (Sharpie) markers
- Reach map for each sample site
- Measuring tape
- Digital camera with photo log
- Tarp

5.3.4 Benthic Macroinvertebrate Field Sampling Procedure

1. Sampling should be conducted within the established monitoring reach. Collect three replicate Surber samples at each sample site.
2. Sample at least 50 meters(m) upstream or 100m downstream of a bridge or other large human-made structure, even if you have to go outside of your reach to do so. Find riffles (fast, turbulent water) within the main flow and near the middle of the stream. The best substrate would be large gravel and cobble, with smaller gravel underneath. Do not sample in muddy or silty substrates or in areas with boulders or exposed bedrock. Look for an area with the most representative overhead canopy and riparian vegetation for that stream. An ideal riffle would be large enough to accommodate all three placements of the Surber sampler. If there is no single riffle large enough, sampling from adjacent riffles may be

nessecary. Depth, flow, and substrate type should be similar for all sampling locations. If water levels are high during or after a heavy rain, it is best to wait until the water level recedes, for both safety and data-quality purposes. If sampling when water levels are up, avoid sampling a riffle that would have been dry before the rain.

3. To collect a replicate Surber sample:

   a) Begin downstream and move upstream with replicate sampling. Avoid disturbing the streambed upstream of your sampling site.

   b) Frame out the Surber sampler and place it on the selected spot with the opening of the nylon net facing upstream and the net stretched out behind. Hold the frame firmly on the stream bottom. The current should move directly into the net.

   c) Lift the larger rocks resting within or beneath the frame and holding them in the water in front of the net, brush off any crawling or loosely attached organisms so that they drift into the net. After cleaning the rocks, place them in a dishpan. Once these rocks have been removed, the frame should be squarely on the stream bottom. At this point, note the water depth on the data sheet.

   d) Once the larger rocks are removed, disturb the substrate vigorously with the weeding fork for 60 seconds, to a depth of about 4 inches. When digging, detritus should wash into the net.

   e) Lift the Surber sampler out of the water. Keeping the open end pointing upstream, tilt it up out of the water, to help wash organisms into the bottom of the net.

   f) Mark the area of this replicate sampling with one of the flagged weighted markers.

   g) Pour a little alcohol in the sample collection jar and begin examining the large rocks collected in the dishpan, using a magnifying glass. Using a forceps, gently remove any organisms found and place them in the sample jar. After examining each rock, wash it over the pan with filtered water then set it on the bank. When all rocks have been cleaned, pour the water from the dishpan through the clean sieve. Rinse the pan, agitate and pour again. This should filter out any invertebrates that washed off of the rocks. Then return the rocks to the stream in the area of the sampling site.

   h) Begin processing the Surber sampler. With the opening out of the water, rotate the net around in the water so that most of the objects inside wash into the bottom of the net. Continue rinsing the contents of the net until all material is in the bottom end of the net. Use the decanter or bucket to pour unfiltered (“dirty”) water into the net from the outside, or pour filtered (“clean”) water down the sides of the net from the inside. (Make clean water by filtering it from the “dirty” bucket, through the “dirty” sieve, into the “clean” bucket.) Turn the net “inside-out” and empty the contents of the net into a clean dishpan. Clean the neck and collar of the sampler over the dishpan to collect any critters that may remain inside. Rinse the net untilit is completely empty.

   i) Pick out large debris (sticks and leaves) from the material in the sieve. Using a magnifying glass and squirt bottle or tools, pick off any organisms and return them to the sieve or sample jar before discarding these pieces.

   j) Pour some clean water into the dishpan and swirl the sample around in it. While the water is still agitated, pour it off into the clean sieve. Most of the organic matter should enter the sieve with the water, while the rocks stay at the bottom. Repeat this decanting procedure until the water is completely clear and there are no invertebrates still crawling around in the debris in the dishpan. When only rocks and sand are left in the dishpan, discard the contents.

k) Transfer the remaining contents of the clean sieve into the sample jar. It is possible to get most of the contents of the sieve down at one end by dipping the sieve at an angle in clean water in one of the dishpans. Use gentle forceps, a spatula, and/or a squirt bottle to move the remaining contents of the clean sieve into the sample jar. Fill the jar no more than halfway with "stream stuff," (i.e., organisims) then fill to near the top with alcohol. Close the jar tightly and place a label on the lid (include date, stream, reach number, and replicate number on the label). If the material will not fit in one jar, put it into two or more jars, and add "Jar 1 of 2" to the labels.

4. Collect two more replicates, following the same procedure as above. Remember to keep moving upstream.
5. At each flagged replicate location, measure and record the following information about the area in which you collected each replicate:
   a) Record the average water depth of the three spots the replicate was collected.
   b) Record the length and width of the riffle in the area where the replicate was collected.
6. Photograph the sampling sites in the following manner (complete the photo log for each photo):
   a) If all three replicates were taken from the same riffle or riffle sequence, one set of photos will suffice.
   b) Replicates that were taken far apart or from areas that look very different should have separate sets of photos. Use personal judgment here. Collect flagging as you go.
   c) A set of photos consists of the following:
      - A photograph of the riffle area itself, ideally showing some of the substrate; if the gravel is visible, try to hold a familiar object near it to help gauge its size.
      - Photographs of the riparian corridor taken upstream and downstream from the sampling area.
      - If possible, take a photo of the team actually doing the sampling.
      - Complete a photo log for each photo taken.

7. Clean and store the equipment. Make sure the net and sieves are clean - use the brush in the kit to clean them if necessary.

5.3.5 Fish Resource Monitoring

Bioassessment surveys should include an evaluation of fish resources, especially highly valued salmon and trout (salmonid) species. The Suquamish Tribe and the Washington Department of Fish and Wildlife (WDFW) currently conduct some salmonid surveys in Bainbridge Island streams. Table 5-5 lists the known salmonid streams on Bainbridge Island. Stream surveys for salmonids are covered in detail in the Bainbridge Island Salmon Recovery Plan (CoBI 2005) and will not be addressed in detail in the WQ Monitoring Plan. The following salmonid related data are typically gathered:

- Species composition (adult and juvenile)

- Spawning areas utilized
- Adult spawning numbers
- Timing of spawning activity
- Juvenile rearing areas and general distribution
- Relative abundance of juveniles in selected areas
- Juvenile size (length) distribution
- Age classes of juveniles (based on lengths)
- Smolt production

This is considered "baseline" information that provides a general assessment of fish presence, distribution, and habitat utilization within a stream. It is essential to know what fish species exist within a stream and particularly the status of "target" species, such as salmonids. The upstream range of adult spawners and juveniles is also important information for planning habitat enhancement work within a stream. Relative abundance of a species may suggest trends in past or future population numbers. Age classes of juveniles may indicate the quality of summer and winter rearing habitat. The amount of habitat being utilized or not being utilized by adults and juveniles is useful information for quantifying habitat deficiencies and determining potential solutions. It should be emphasized that absence of a species from a stream cannot conclusively be determined from any single sample of that stream. Long-term, consistent monitoring is required. Table 5-5 lists the known fish-bearing streams on Bainbridge Island.

All salmonid-monitoring activities must be approved and coordinated with WDFW and the Suquamish Tribe. Permits are required for any technique involving capture, handling, tagging, or removal of fish from a natural water body. Most general fish-related bioassessment information can be obtained using non-capture, observational techniques. In some instances, specialized capture techniques (e.g., trapping or electro-fishing) may be useful to obtain length, weight, and species identification data. However, most fish capture methods, including trapping and especially electro-fishing, have a high potential for causing fish mortality if used improperly. It is recommended that fish capture be avoided whenever possible and observation techniques be employed to collect as much information as possible. The data collected by observational methods are intended for useful descriptions of fish presence, relative abundance, and habitat utilization. In general, these techniques are not intended to produce statistically based population estimates of adult spawners, juveniles, or smolt productivity. Details on these techniques are available from WDFW and the Suquamish Tribe.

Table 5-5. Known Fish-Bearing Streams of Bainbridge Island

Stream ID[1]	Stream	Salmonid Species[2]
45	Agate Passage Creek (15.0319)	Cutthroat
51	Coho Creek (15.0319A)	Coho & Cutthroat
53	Dripping Water Creek (15.0320)	Cutthroat
59	Murden Creek (15.0321)	Coho, Chum, & Cutthroat
56	Meigs Creek (15.0322)	Coho & Cutthroat
58	Woodward Creek (15.0323)	Coho & Cutthroat
4	Ravine Creek (15.0324)	Coho & Cutthroat
6	Weaver Creek (15.0324A)	Cutthroat
7	Sportsman's Club Creek (15.0325)	Coho & Cutthroat
10	Cooper Creek (15.0326)	Coho & Cutthroat
11	Cougar Creek (15.0327)	Cutthroat
14	Whiskey Creek (15.0328)	Cutthroat
15	Creosote Creek (15.0329)	Cutthroat
16	Blakely Falls Creek (15.0330)	Coho & Cutthroat
18	Mac's Dam Creek (15.0331)	Coho & Cutthroat
19	Tani Creek (15.0332)	Coho & Cutthroat
20	Sunny Hill Creek (15.0333)	Cutthroat
22	Toe Jam Hill Creek (15.0334)	Cutthroat
25	Schel-Chelb Creek (15.0335)	Coho, Chum, & Cutthroat
28	Point White Creek (15.0336)	Cutthroat
29	Linquist Creek (15.0337)	Cutthroat
30	Crystal Springs Creek (15.0338)	Cutthroat
31	Gazzam Lake Creek (15.0339)	Cutthroat
34	Springbrook Creek (15.0340)	Coho, Chum, & Cutthroat
35	Issei Creek (15.0341)	Coho & Cutthroat
32	Foster's Creek (15.0342)	Cutthroat
37	North Fletcher Bay Creek (15.0343)	Cutthroat
42	Manzanita Creek (15.0344)	Coho, Chum, & Cutthroat

Notes:
1 Comple listing of CoBI Stream IDs are presented in Figure 5-3
2 Salmonid data based on Washington Stream Catalog (WDFW 1975), East Kitsap (WRIA-15) Limiting Factors Analysis (LFA) Report (WCC 2000), and Kitsap Refugia Report (May and Peterson 2003)

5.4 FRESHWATER PHYSIO-CHEMICAL WATER QUALITY MONITORING

5.4.1 Physio-Chemical Water-Quality Parameters

There are numerous physio-chemical water quality parameters that could be monitored, but there are several that have ecological significance. These include the parameters listed below. As a whole, there are still fewer water quality parameters that can be easily and reliably measured in the field. Typical field water quality measurements include temperature, dissolved oxygen, pH, conductivity, and turbidity. Most other water quality parameters require laboratory analysis.

- Temperature
- DO
- Total and Dissolved Organic Carbon (TOC and DOC)
- Biochemical Oxygen Demand (BOD)
- Alkalinity and Hardness
- pH
- Conductivity
- Turbidity or Total Suspended Solids (TSS)
- Nutrients (Nitrogen and Phosphorus)
- Metals
- Petroleum Hydrocarbons
- Organics (Pesticides and Herbicides)

<u>Temperature</u>

Temperature is a critical habitat variable for cold-water fish such as salmonids. Under natural conditions, the streams of the Pacific Northwestare kept cool throughout the year due mainly to their well-shaded conditions maintained by a forested riparian corridor. In addition, groundwater and wetland recharge of streams also helps to maintain cool water temperatures, even during the warm summer months. An increase in stream temperature can increase the metabolic activity of aquatic organisms and may alter their behavioral patterns. Reproductive events are usually the most thermally restrictive of all life phases. Even natural short-term temperature fluctuations can cause reduced reproduction of fish and invertebrates. Adults and juveniles are much better able to withstand fluctuations in temperature. Furthermore, juvenile and adult fish usually thermoregulate behaviorally by moving to water having temperatures closest to their thermal preference. This provides a thermal environment, which approximates the optimal temperature for many physiological functions, including growth. In most cases, a small increase in water temperature may have a short-term positive influence on stream organisms, but higher than normal stream temperatures may also have long-term negative impacts.

In addition, an important physical relationship exists between the amount of dissolved oxygen in a body of water and its temperature. Simply put, the warmer the water, the less dissolved oxygen, and vice versa. For this reason, heat or "thermal pollution" may be a problem, especially in shallow slow-moving streams, embayments, or lakes, which can get very warm in mid-summer. Most cold-water fish (such as salmonids) will have difficulty surviving warm water and/or low levels of dissolved oxygen.

Currently Washington water quality criteria require daily-maximum stream temperatures to be maintained at <16 degrees Celsius (WAC 173-201A-030) to support properly functioning salmonid habitat conditions. The recommended criteria are designed to protect the key life-stages of adult holding, spawning and incubation, juvenile rearing, smoltification, and adult migration. The criteria have also been set to avoid significant increases in the risks of warm water fish diseases and parasites. In reality, each salmonid species has a slightly different “preferred” or “optimal” temperature range for each life-stage, which makes establishing appropriate water quality criteria very problematic. In general, the optimal temperature range for most salmonid species and life-stages is approximately 12-14˚C. If observed temperatures are consistently greater than 16˚C, there is likely a problem, which should be investigated. Likely causes of high instream temperature include a loss of riparian shade, inputs of warm wastewater, and lack of adequate flow due to impoundments (dams), or water withdrawal for human consumption or irrigation. Temperature should be measured only with a calibrated thermometer.

Dissolved Oxygen and Biochemical Oxygen Demand

DO analysis measures the amount of gaseous oxygen dissolved in an aqueous solution. DO is one of the most important physio-chemical water quality parameters in aquatic ecosystems. DO is an absolute requirement for the metabolism of aerobic organisms and also influences inorganic chemical reactions. Therefore, knowledge of the solubility and dynamics of oxygen distribution is essential to interpreting both biological and chemical processes within water bodies. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a waste product of photosynthesis. The amount of DO gas is highly dependent on temperature. Atmospheric pressure also has an effect onDO. The amount of oxygen (or any gas) that can dissolve in pure water (saturation point) is inversely proportional to the temperature of water. The warmer the water, the lessDO.

When sampling for DO, only grab samples should be used and the analysis should be performed immediately. Therefore, this is a field test that should be performed on site. The DO level can be determined using a calibrated, in-situ DO probe (part of a typical data-logger meter system). The temperature of the water and the atmospheric pressure must to be known in order to calculate parts per million (ppm) of DO in the sample. The oxygen probe usually contains a solution of potassium chloride (KCl), which will absorb oxygen. As more oxygen is diffused into the solution, more current will flow through the cell. Lower oxygen pressure (less diffusion) will mean less current. DO can also be measured using a field (“Winkler” method) test kit. This is a multi-step chemical method that involves adding a chemical, which reacts with the DO or "fixes" it. Other steps include addition of reagents that develop color. Then the amount of that compound is determined by addition (drop by drop) of a second chemical solution of known concentration until a color change occurs. The amount of chemical used in the last step is used to calculate the amount of DO in the sample.

DO is a critical water quality parameter to ensure a “properly functioning condition” (PFC) for salmonid habitat. DO is the quantity of oxygen dissolved in the water and available to aquatic organisms for respiration and metabolism. The capacity of water to hold oxygen is inversely proportional to the water temperature. When DO is at “saturation” it means that it is at equilibrium with the atmosphere and no more oxygen can be dissolved in the water at that temperature. Oxygen is dissolved in water through contact with the air and aeration caused by turbulent flow. The actual DO concentration (typically expressed in milligrams per liter [mg/l]) in water depends not only on temperature, but also on DO sinks or sources. The primary DO sinks are biotic respiration and decomposition of organic matter, commonly referred to as BOD. The primary DO sources include photosynthesis by aquatic vegetation and the aeration process discussed above.

DO is closely linked to temperature because as temperature rises, saturation concentration is depressed and BOD increases. In general, natural streams in the Pacific Northwest have cool temperatures, high aeration rates, and relatively low BOD levels; thus instream DO is normally at or very close to saturation. This is the optimal habitat condition for native salmonids as well. Streams in low gradient areas that have low stream flow, streams that lack riparian shade, and those with high levels of organic matter (or wastewater) that result in high BOD levels, are more likely to have problems with low DO.

Current Washington water quality criteria call for DO to be maintained above 9.5 mg/l (WAC 173-201A-030). Salmonids may become impaired if DO goes below 6 mg/l for extended periods and lack of DO can be lethal at levels less than 3 mg/l. However, any DO levels less than saturation are likely to have chronic affects on fish development and metabolism. In general, DO should be maintained as close to saturation as possible for optimal, long-term salmonid habitat. Instream DO can be measured using a calibrated DO meter or by the “Winkler” method using an approved chemical test-kit. A DO level that is consistently significantly below saturation level (or < 6 mg/l) for the temperature should be investigated for possible sources of BOD.

The DO concentrations can vary between the surface of the water column and at depth due to a variety of environmental influences, including temperature, BOD, and biotic interactions. The DO available to benthic organisms and salmonid eggs/embryos can also vary depending on the amount of fine sediment or “silt” deposited on and in the streambed substrate. This is commonly referred to as intra-gravel DO (IGDO). This is very important to the survival of salmonids during their embryonic or “alevin” life-stage. Oxygen replenishment of the intra-gravel habitat comes primarily from the exchange of well-aerated surface water known as hyporheic flow. IGDO concentration depends on many of the same factors as surface water, but is also controlled by the streambed permeability. Excessive levels of fine sediment or “fines” will hinder hyporheic flow and can result in increased salmonid egg-embryo mortality or reduced growth and development of alevins. IGDO measurements can be used as a surrogate for the amount of interstitial fines and as an indicator of streambed spawning-gravel quality. Salmonids can greatly modify spawning gravel conditions, particularly the amount of interstitial fine sediment, through the re-building process. In fact, it is generally thought that large numbers of spawning salmon, as are common in areas not impacted by human activity, are capable of “cleaning” the streambed of fine sediment during spawning periods. Therefore, IGDO monitoring sites must be carefully selected to represent actual intra-gravel DO conditions that salmonid eggs-embryos will experience.

pH

The acidity or basic nature of a solution is expressed as the pH. The pH is dependent on temperature and chemical composition of the water. The concentration of the hydrogen ion [H+] in a solution determines the pH. Mathematically this is expressed as:

$$\mathrm{pH} = -\log[\mathrm{H}^+]$$

The pH value is the exponent to the base 10 of the hydrogen ion concentration. The more acidic the solution, the lower the pH; the more basic, the higher the pH. Each change in pH unit represents a tenfold change in acidity.

The pH of a water body results from the ratio of H+ to OH-. In natural waters this usually is dependent on the carbonic acid equilibrium. When carbon dioxide from the air enters freshwater, small amounts of carbonic acid are formed which then dissociate into hydrogen ions and bicarbonate ions. This increase in H+ ions makes the water more acidic and lowers the pH. If CO_2 is removed (as in photosynthesis) the reverse takes place and pH rises. This process is also related to the presence of carbonates, of calcium, or other ions such as magnesium as discussed under alkalinity.

Based on the alkalinity or acidity of the water, pH is an indirect measure of the "buffering" capacity of the water or its ability to neutralize acids and bases. In order to fully measure the acid neutralizing capacity of water, alkalinity must also be measured. The most important buffering agent in freshwater is CO_2. pH can have direct and indirect effects on instream water chemistry and on aquatic biota. Low (acidic) pH conditions can reduce salmonid egg production, decrease embryonic development, and delay alevin emergence. pH can also influence the "speciation" of other chemicals found in the water. Metals and other chemicals can shift from particulate form to dissolved form and back as pH and temperature changes. Based on this, the toxicity of specific chemicals can change as pH changes. Current Washington water quality criteria call for pH to be maintained between 6.5 and 8.5 in order to support optimal salmonid habitat conditions (WAC 173-201A-030).

Alkalinity and Hardness

Alkalinity refers to the capability of water to neutralize acid. This is really an expression of buffering capacity. A buffer is a solution to which an acid can be added without changing the concentration of available H+ ions (i.e., without changing the pH) appreciably. It essentially absorbs the excess H+ ions and protects the water body from fluctuations in pH. In most natural water bodies the buffering system is carbonate-bicarbonate. The presence of calcium carbonate ($CaCO_3$) or other compounds such as magnesium carbonate contribute carbonate ions to the buffering system. Alkalinity is often related to hardness because the main source of alkalinity is usually from carbonate rocks (limestone), which are mostly $CaCO_3$. If $CaCO_3$ actually accounts for most of the alkalinity, hardness in $CaCO_3$ is equal to alkalinity. Since hard water contains metal carbonates (mostly $CaCO_3$) it is high in alkalinity. Conversely, unless carbonate is associated with sodium or potassium, which don't contribute to hardness, soft water usually has low alkalinity and little buffering capacity. So, generally, soft water is much more susceptible to fluctuations in pH from acid rains or acid contamination.

Alkalinity is important for fish and aquatic life because it protects or buffers against rapid pH changes. Living organisms, especially aquatic life, function best in a neutral pH range. Alkalinity is a measure of how much acid can be added to a liquid without causing a large change in pH. Higher alkalinity levels in surface waters will buffer acid rain and prevent pH changes that are harmful to aquatic life. The most important impact of hardness on fish and other aquatic life appears to be the affect the presence of these ions has on the other more toxic metals such as copper, lead, cadmium, chromium, and zinc. Generally, the harder the water, the lower the toxicity of other metals to aquatic life. In hard water some of the metal ions form insoluble precipitates and drop out of solution and are not available to be taken in by the organism. Large amounts of hardness are undesirable mostly for economic or aesthetic reasons. If a stream or river is a drinking water source, hardness can present problems in the water treatment process. Hardness must also be removed before certain industries can use the water. For this reason, the hardness test is one of the most frequent analyses done by facilities that use water.

Currently, Washington water-quality criteria do not address alkalinity or hardness (WAC 173-201A-030).

Conductivity

Conductivity is a measurement of the ability of an aqueous solution to carry an electrical current. An ion is an atom of an element that has gained or lost an electron, which will create a negative or positive state. Conductivity (or specific conductance) is a measure of the quantity of dissolved ionic material in water. In general, conductivity is a non-specific measure of dissolved pollutants in natural waters. It can also be an indirect measure of salinity and total dissolved solids. Conductivity is measured with a calibrated conductivity meter. It is easy to measure in the field and is very useful as an early-warning water quality tool. Research has indicated that as NPS pollution and stormwater runoff increases, that amount of dissolved ionic material also increases, as does conductivity. Streams draining forested watersheds in the Pacific Northwest normally have a conductivity level well below 100 micro Siemens per centimeter (µS/cm). Streams draining more urbanized watersheds are likely to be greater than 100 µS/cm, especially if there are significant sources of water pollution present. A significant increase in conductivity, an increasing trend, or an unusually high reading should trigger additional water chemistry analyses (nutrients, metals, organics, etc.) and an investigation for possible sources of pollution.

Currently, Washington water-quality criteria do not address conductivity (WAC 173-201A-030).

Turbidity

Turbidity or TSS is a measure of the amount of particulate material in water. The amount of suspended sediment in a stream will depend primarily on the particle size distribution of sediment and the stream flow. The quantity of fine sediment carried by a stream has several potentially significant impacts on ecological integrity. As was discussed earlier, fine sediment that is deposited in streambed spawning gravel can impact the early life-stages of salmonids. Nutrients and potentially toxic chemicals can also be adsorbed onto fine sediment particles. Excessive suspended sediment loads can also inhibit migration, cause gill irritation, and impair feeding behavior in salmonids. One method for measuring the quantity of fine sediment is by filtering a prescribed volume of water through a specific size membrane-filter and measuring the mass of sediment captured. This is known as TSS. A more common method, which can be done in the field, is to measure the amount of light scattered or absorbed by the sediment particles in a sample of water. This is known as turbidity and can be accomplished in lab or in the field using a calibrated turbidimeter. These devices measure turbidity in nephelometric turbidity units (NTU).

Suspended solids can clog fish gills, either killing them or reducing their growth rate. They also reduce light penetration. This reduces the ability of algae and aquatic plants to produce food and oxygen. When the water slows down, the suspended sediment settles out and drops to the bottom, a process called siltation. This causes the water to clear, but as the silt or sediment settles it may change the benthic environment of a stream, lake, or wetland. The silt may smother bottom-dwelling organisms, cover breeding areas, and smother eggs. Indirectly, the suspended solids affect other parameters such as temperature and DO. Because of the greater heat absorbency of the particulate matter, the surface water becomes warmer and this tends to stabilize the stratification of surface waters. This, in turn, interferes with mixing, decreasing the dispersion of oxygen and nutrients to deeper layers.

Suspended solids interfere with effective drinking water treatment. High sediment loads interfere with coagulation, filtration, and disinfection. More chlorine is required to effectively disinfect turbid water. They also cause problems for industrial users. Suspended sediments also interfere with recreational use and aesthetic enjoyment of water. Poor visibility can be dangerous for swimming and diving. Siltation, or sediment deposition, eventually may close up channels or fill up the water body converting it into a wetland. A positive effect of the presence of suspended solids in water is that toxic chemicals such as pesticides and metals tend to adsorb to them or become complexed with them which makes the toxics less available to be absorbed by living organisms.

Currently, the Washington water quality criteria for turbidity states that turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU (WAC 173-201A-030). The background turbidity represents the natural ambient conditions for that stream and must be established prior to monitoring or may be determined based on reference stream conditions.

Total Organic Carbon and Dissolved Organic Carbon

Organic contaminants (natural organic substances, insecticides, herbicides, and other agricultural chemicals) enter waterways in rainfall runoff. Domestic and industrial wastewaters also contribute organic contaminants in various amounts. Therefore, it is important to know the organic content in a waterway. TOC and DOC measurements provide this information.

By using TOC and DOC measurements, the number of carbon-containing compounds in a source can be determined. This is important because knowing the amount of carbon in a freshwater stream is an indicator of the organic character of the stream. The larger the carbon or organic content, the more oxygen is consumed. A high organic content means an increase in the growth of microorganisms, which contribute to the depletion of oxygen supplies. The source of this organic material could be a wastewater treatment plant releasing treated sewage into the stream. Both the plant effluent and the stream must be monitored for organic levels. Industrial waste effluent may contain carbon-containing compounds with various toxicity levels. Both of these situations can create unfavorable conditions for aquatic life, such as the depletion of oxygen and the presence of toxic substances.

TOC provides a measure of the degree of organic contamination. A carbon analyzer using an infrared detection system is used to measure total organic carbon. Organic carbon is oxidized to CO_2. The CO_2 produced is carried into an infrared analyzer that measures the absorption wavelength of CO_2. The instrument utilizes a microprocessor that will calculate the concentration of carbon based on the absorption of light in the CO_2. The amount of carbon will be expressed in mg/L. Measurement of BOD also provides organic contamination information. However, TOC provides a more direct expression of the organic chemical content of water than BOD.

Currently, Washington water-quality criteria do not address TOC or DOC (WAC 173-201A-030).

Nutrients

Phosphorus is one of the key elements necessary for growth of plants and animals. Phosphates are formed from this element. Phosphates exist in three forms: orthophosphate, metaphosphate (or polyphosphate), and organically bound phosphate. Each compound contains phosphorous in a different chemical formula. Ortho-P forms are produced by natural processes and are found in sewage. Poly-P forms are used in detergents. In water, they change into the ortho-P form. Organic-P forms are also important in nature. Their occurrence may result from the breakdown of organic pesticides, which contain phosphates. They may exist in solution, as particles, loose fragments or in the bodies of aquatic organisms.

Runoff can cause varying amounts of phosphates to wash from exposed soils into nearby waterways. Phosphates will stimulate the growth of plankton and aquatic plants, which provide food for fish. This may cause an increase in the fish population and improve the overall water quality. However, if an excess of phosphate enters the waterway, algae and aquatic plants will grow excessively and use up large amounts of DO when they die and decompose. This condition is known as eutrophication or over-fertilization of receiving waters. This process in turn causes the death of aquatic life because of the lowering of DO levels. In general, phosphates are not toxic to people or animals unless they are present in very high levels.

Nitrogen is one of the most abundant elements. About 80 percent of the air we breath is nitrogen. It is found in the cells of all living things and is a major component of proteins. Inorganic nitrogen may exist in the free state as a gas or as nitrate NO_3-, nitrite NO_2- or ammonia NH_3. Organic nitrogen is found in proteins and is continually recycled by plants and animals.

Nitrogen-containing compounds act as nutrients in streams, estuaries, and lakes. The major routes of entry of nitrogen into bodies of water are municipal and industrial wastewater, septic system failures, sewage discharges, animal wastes (including birds and fish), runoff from fertilized agricultural fields and lawns, and discharges from car exhausts. Bacteria in water quickly convert nitrites (NO_2-) to nitrates (NO_3 -) and this process uses up DO. High nitrates in drinking water can cause human health problems. The major impact of nitrates and nitrites on receiving waters is that of enrichment or eutrophication. Nitrates stimulate the growth of algae and other plankton, which provide food for higher organisms (invertebrates and fish); however, an excess of nitrogen can cause over-production of plankton and as they die and decompose they use up the oxygen, which may cause other oxygen-dependent organism to die.

The nutrients of concern include phosphorus (P) and nitrogen (N). Currently, Washington water-quality criteria do not address either of these nutrients (WAC 173-201A-030).

<u>Pollutants of Concern</u>

The primary chemical pollutants of concern to water quality include metals, petroleum hydrocarbon compounds, and organic chemicals, including pesticides, herbicides, pharmaceuticals, and industrial chemicals such as polychlorinated biphenyls. Metals include calcium, magnesium, and iron which play major roles in water chemistry. Other metals include aluminum, barium, cadmium, chromium, copper, lead, manganese, sodium, and zinc, which tend to be present in smaller amounts. The toxicity of metals is dependent on their solubility and this in turn, depends heavily on pH and on the presence of different types of anions and other cations. Polycyclic aromatic hydrocarbon (PAH) compounds are found in all petroleum products. All of these toxic chemicals can enter natural waters from spills, leakage, wastewater discharges, industrial outfalls, and from stormwater runoff.

Washington water-quality criteria (WAC 173-201A-240) states that potentially toxic substances shall not be introduced above natural background levels in waters of the state that have the potential to adversely affect beneficial uses, cause acute or chronic toxicity to the most sensitive biota dependent on those waters, or adversely impact public health. Biological assessments and chemical analysis, along with acute and chronic toxicity testing are all used to evaluate compliance with water quality criteria with respect to toxic chemicals.

5.4.2 Physio-Chemical Water-Quality Sampling

Traditional water quality sampling efforts are typically conducted to characterize a water body for comparison with established water quality standards. Sampling is most often driven by permit requirements from regulatory agencies. Stormwater runoff sampling should be conducted to evaluate the effectiveness of treatment BMP's or construction site runoff monitoring.

Stormwater sampling can also be done to evaluate the effectiveness of ESC practices . Sampling can also be instigated to identify and quantify a known or suspected water quality problem. Periodic sampling in receiving waters (especially where contact recreation or shellfish harvest is a designated beneficial use) for bacterial fecal coliform (FC) pollution in areas serviced by on-site wastewater treatment systems (e.g., septic systems) is a good example of that situation.

Depending on the objective of the water quality monitoring effort, a number of different sampling strategies will be appropriate. From a temporal standpoint, sampling can be conducted on a periodic basis, seasonally, or event-based (e.g., storm-event sampling). Most water quality sampling activities will also have some spatial aspect (i.e., end-of-pipe sampling for stormwater outfalls). The selection of sampling sites is typically based on a number of factors, including water quality constituents of interest, site access and safety considerations, and, most importantly, ensuring the “representativeness” of the sample. CoBI stream sample sites are listed in Table 5-6. Figure 5-6 presents those stream sample sites that are proposed for program use. Sample stations are usually located near the bottom end of the stream and thus are expected to represent the impact of cumulative effects in the watershed.

How the sample is collected is also a prime consideration. In some cases, grab samples are appropriate. In other situations, multiple samples should be collected over time and a composite sample created. In some cases, a special type of composite sample is appropriate, a so-called “flow-weighted” composite sample. This type of composite sample consists of multiple samples each collected at specific times and each sample weighted by volume in proportion to the flow at the time the sample is collected. In general, when analyzed, composite samples are used to determine an event-mean concentration (EMC) for a specific period of time or, most commonly, for a single storm event. Most composite sampling is conducted using an automated sampling system. Flow-weighted composite (samples are especially useful in pollutant loading calculations (combining concentration and flow to get load) such as is needed to determine a TMDL.

The CoBI stream water quality sampling plan will include both grab samples and flow-weighted composite samples. Both of these methods will be used to characterize the physio-chemical water quality of CoBI streams. The constituents that will be analyzed for may vary depending on the objectives of each sampling effort, but the basic suite of water quality constituents for which samples will be collected are listed in the QAPP. Monitoring is focused primarily on conventional constituents (e.g., sediment, nutrients, bacteria, metals, and petroleum hydrocarbons). When monitoring objectives dictate and funding allows, monitoring for organics (i.e., industrial chemicals, pesticides, and herbicides) at some stations will be necessary. Freshwater sampling water quality constituents and water quality standards are listed in the QAPP. Toxicity testing is typically not part of a routine WQFMP, but may be called for under certain circumstances.

5.4.3 Stream Baseflow Sampling And Analysis

The CoBI stream water quality sampling program will include two types of baseflow samples. Baseflow samples will be collected during the dry season and during the wet season. Seasonal baseflow samples will be used to represent the non-storm wet and dry season characteristics of the stream system.

1. Sample Sites – Based on yearly programmatic goals, a subset of all potential streams, listed in Table 5-6, will be sampled to establish baseflow conditions during both the dry and wet seasons (see Figure 5-6).

2. Sample Frequency – Stream baseflow samples should be collected at least once every 3 to 5 years, depending on the level of development activity within the watershed. More frequent sampling may be warranted if a known or suspected water quality problem arises.
3. Sample Timing – Dry season samples should be collected between July and September. Wet season baseflow samples should be collected between November and February. No baseflow samples should be collected within 72 hours of a significant (>0.5" of rainfall in 24-hours) storm event.
4. Sample Techniques – Baseflow samples will be collected as grab samples (see section 5.4.4 and 5.4.5). The number and type of sample bottles required will depend on the water quality parameters to be analyzed. CoBI staff will determine the water quality parameters to be sampled based on the objectives of each sampling event.
5. Sample Teams – Trained teams of CoBI staff and volunteers can collect baseflow water quality samples. Proper training on sampling protocols and QA requirements is essential.

5.4.4 Baseflow Grab-Sampling Equipment

- Field Data Sheets, Clipboard, and Pencils
- Sample Site Map and Directions
- Sterile Bottles (for samples and replicate samples as required)
- Watch
- Latex Gloves
- Waterproof Marker and Sample Labels
- Water-quality Data-Logger Probe
- Sampling Wand
- Cooler and Ice

5.4.5 Baseflow Grab-Sampling Procedure

1. Stream grab-samples for specific water quality parameters will be collected as necessary based on the determination of CoBI staff.
2. The objective of stream water quality sampling is to sample the combined freshwater and any stormwater runoff in the stream, not seawater that may surge in on a high tide. To avoid tidal interference in streams where tidal influence is a concern, the sampling team should check the tide tables before planning their collection day. Samples taken near the mouths of streams should be taken on an outgoing tide. In general, sample one-half hour after mean high tide, defined as the point halfway between the high-low tide and low-high tide for the day. If a salinity meter is available, take it along and measure salinity at the time of sampling. Note the reading on the field data sheet. Be sure that the water is flowing downstream when sampling. If the tide has turned anda tidal upsurge is noticed, do not collect a sample and note that on the data sheet. Sites that are well above the stream mouth should have no problem with tidal interference. Samples should be collected so that holding-time requirements are met (see QAPP) and so that samples can be delivered to the lab during regular working hours.

3. Quality control procedures require that at one sampling point out of every ten (or 10%), a second sample be collected as a field replicate sample. Field replicates give an indication of how much variability there is in the sampling techniques and environment. To perform and record field replicates, the team leader will determine how many replicate samples need to be collected, randomly select sites for sampling, and then notify team members where to collect replicates. Replicate samples should be collected simultaneously with the regular site sample. Gloves are optional but preferred and a sampling wand can be used to avoid having to wade in the stream. If not using the sampling wand, enter the stream downstream of the proposed sampling location (or use the sample wand with a sample bottle attached) to avoid contaminating the sample with stirred-up sediment. Sample at the designated sample site at a mid-point portion of the creek where the stream is flowing, well mixed, and preferably at least 6” deep. If these conditions cannot be met at the designated sample site, it is permissible to go outside the reach, but note the location on the field data sheet. Choose a spot that appears undisturbed and has little or no sediment stirred up in the water. In most cases, it is preferable to use a sampling wand, as there is less chance of stirring up the bottom than walking in the creek.
4. Uncap the sample bottle while holding the bottle near the bottom and the cap near the top edge. Do not let anything touch the inside of the cap. Do not set the cap down. Prior to collecting a sample, the sample bottle should be rinsed with ambient water. When sampling, hold the bottle near its base and plunge it below the water surface with the opening pointing downward. Collect the sample about 6” below the surface of the water. If the water is shallow, collect midway between the bottom and the surface. Turn the bottle underwater into the current and away from you. In slow-moving stream reaches, push the bottle underneath the surface and away from you in an upstream direction. Remove the bottle from the water when it is filled up to the shoulder. If the bottle comes out with the water level below the shoulder, pour out the water and try again. If the bottle comes out full, recap it, shake, uncap, then quickly flick the bottle until the water level decreases to the shoulder. If a deep-water location is not available, several other options are available. Samples should be collected in shallow, fast-moving water, preferably at a point where the water is forced between larger rocks. Hold the bottle facing upstream so as to catch the moving water in it. Avoid hitting the bottom. If there is a drop-off somewhere, as from a cascade or culvert, sample from this drop-off so long as the bottle touches nothing but the falling water. Recap the bottle carefully, without touching the inside.
5. Dry the outside of the bottle and attach a label. Mark the sample with the date and time of the sample, the site name and sample identification number, and “rep” if the sample is a field replicate. Record the same information on the field data sheet. Place the sample bottle in the cooler. When finished sampling, bring all samples and forms directly to the laboratory. On your field data sheet, enter the time the samples were turned in, and have an individual from the laboratory initial the time that the samples were received. Have the lab make a copy of the data sheet(s), and bring the original data sheets, along with the equipment, back to the CoBI office. The signed data sheets provide a “chain-of-custody” record that is a QA/QC requirement. The lab will process the samples and submit results to CoBI staff, who will enter the data into the CoBI water quality database and then issue a report.

5.4.6 Stream Storm Event Sampling And Analysis

The CoBI stream water quality sampling program will utilize automated sampling equipment to collect composite samples from streams during selected storm events. These composite samples will be analyzed and used to calculate an EMC. Each stream will be sampled during multiple storm events.

1. Sample Sites – Based on yearly programmatic goals, a subset of all potential streams listed in Table 5-6 will be sampled to establish stormflow water quality characteristics (see Figure 5-6).
2. Sample Frequency – Stream stormflow samples should be collected at least once every 3 to 5 years, depending on the level of development activity within the watershed. More frequent sampling may be warranted if a known or suspected water quality problem arises.
3. Sample Timing – Storm event samples should be collected between October and March. Storm events must meet the minimum criteria of 0.1" of rainfall within a 24-hour sampling period. Storms will be classified as "small" (<0.5" in 24 hours), "medium" (0.5-1.0"), and "large" (> 1.0"). Because small and medium storms are more common in this region, these storm events should be targeted. However, large storm events should also be represented in the suite of storms that are sampled.
4. Sample Techniques – Stormflow samples will be collected, using automated sampling equipment, as composite samples using the protocols in the USEPA NPDES Stormwater Sampling Guidance Manual (USEPA 1992). The number and type of sample bottles required will depend on the water quality parameters to be analyzed. CoBI staff will determine the water quality parameters to be sampled based on the objectives of each sampling event.
5. Sample Teams – Trained teams of CoBI staff and volunteers can collect stormflow water quality samples. Proper training on sampling protocols and QA requirements is essential.

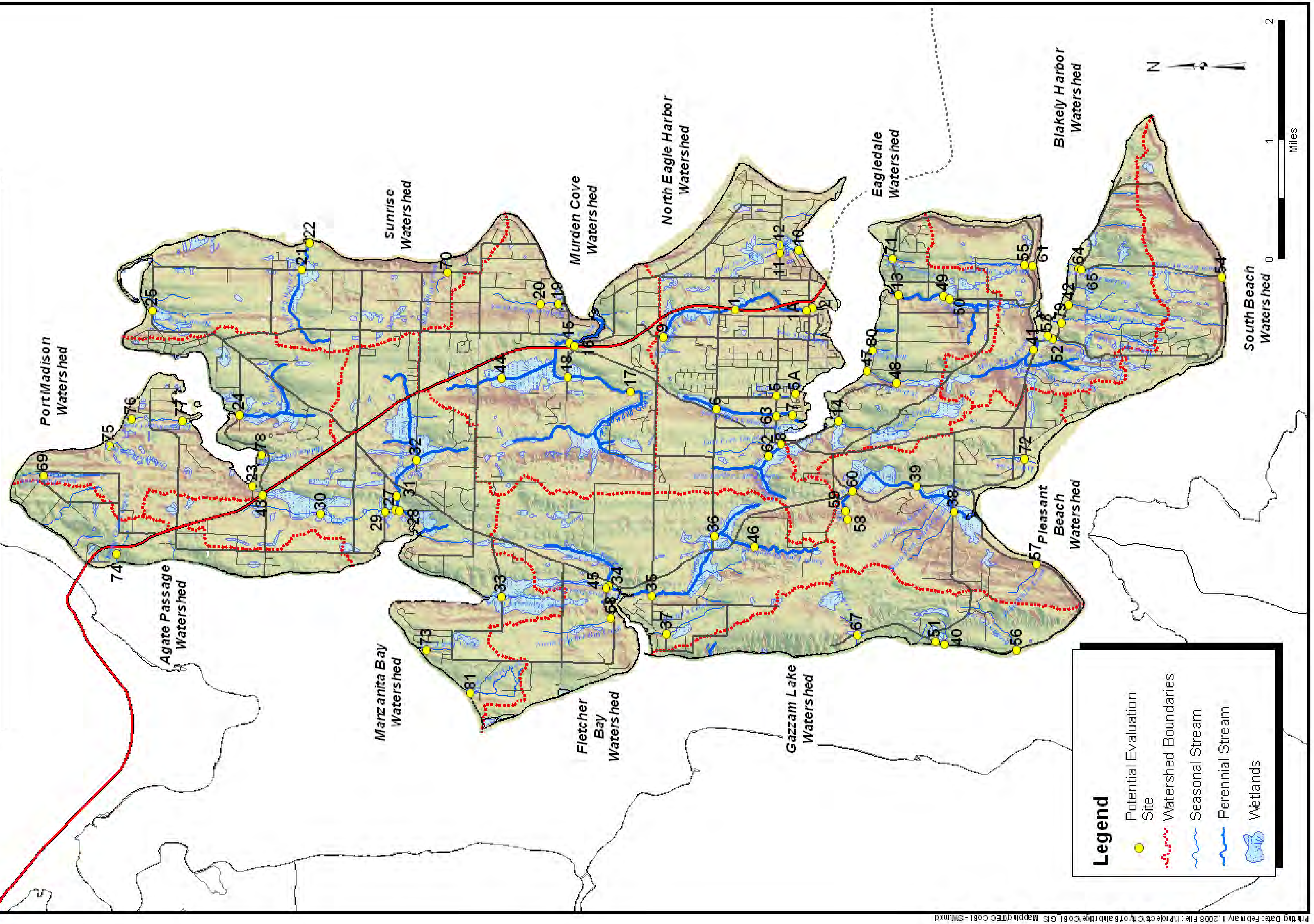

Figure 5-6. Bainbridge Island Potential Stream Physio-Chemical Water Quality Sampling Sites

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Table 5-6. Potential Bainbridge Island Stream Water Quality Sample Sites

Location ID	Site Description	Comments	Watershed Code
SE1	The Ravine Creek at SR-305 below Safeway complex	Potentially good site for monitoring urban runoff. Stream location may be in pipe bypassing stormwater ponds. Access issue could exist, steep.	NEGH
SE1A	**Ravine Creek at north side Winslow Ave crossing**	**Creek entrance to hexagonal box culvert on the north side of the Winslow Ave under-crossing**	**NEGH**
SE5	Weaver Creek at Strawberry Plant	Site could be located anywhere downstream of Sheppard Road.	NEGH
SE5A	**Weaver Creek at Sheppard Road**	**Weaver Creek culvert outfall on south side of street, pipe carries combined creek flow and road / ditch runoff.**	**NEGH**
SE6	Sportsman's Club Creek at High School Road	Downstream of wetland, dammed pond, and stormwater pond.	NEGH
SE7	Sportsman's Club Creek at Gowen Road	Dammed pond near stream mouth. Access creek below weir outfall. Access to site restricted, private property and tidally influenced	NEGH
SE8	Cooper Creek at Eagle Harbor Drive	Tidal influence at this site.	NEGH
SE9	The Ravine Creek at Madison Avenue North	Creek headwaters, carries only partial contaminant load, no highway impact.	NEGH
SE10	**Hawley Creek below confluence**	**Site somewhere below confluence. Mostly wetland, may not have defined channel. Location intercepts east and west fork inputs.**	**NEGH**
SE11	**Hawley Creek West Fork at Wing Point Way**	**Site may be difficult to access. Better access may exist from below through City property.**	**NEGH**
SE12	**Hawley Creek East Fork at Wing Point Way**	**May be difficult access. Better access may be from below through City property.**	**NEGH**
SE13	Whiskey Creek at Eagle Harbor Drive	Likely best site for lower watershed. Steep ravine with only possible trail access on private property on upstream/west side. Previously monitored (Stream Team). May be accessed as a nearshore approach, sampled as either nearshore or SW location depending on station position relative to tide line. Access and tidal issues.	EGDL
SE14	Cougar Creek at Eagle Harbor Drive	Tidally influenced at public access point	EGDL
SE15	Murden Creek Mouth	Difficult Access. Site can be located along a ROW stretch south of Manitou Beach Road. Likely tidally influenced - could be a nearshore location	MDCV
SE16	**Murden Creek (Grisdale Creek) crossing at SR-305**	**Creek, all three main stems combined + highway runoff combined. Sampling stations at either east or west side of road. Hexagonal box culvert used for under-road crossing.**	**MDCV**

Table 5-6. Potential Bainbridge Island Stream Water Quality Sample Sites

Location ID	Site Description	Comments	Watershed Code
SE17	Woodward Creek below Sakai Intermediate School	Previously monitored (School). This point intercepts the main and middle fork branches of Woodward Creek, (2 of 3 main creek branches). Upland location.	MDCV
SE18	Woodward Creek at Wardwell Road	Location intercepts tow of three main creek branches. Further downstream from SE17. Does not incorp. 3rd branch, Megis Crk.	MDCV
SE19	Manitou Beach Creek near mouth	Tidally influence wetland area. Upper reach may be good site, but may be on private property.	MDCV
SE20	**Manitou Beach Creek at Beach Crest Drive**	**Perennial stream. Narrow public access and non-tidal location.**	**MDCV**
SE21	**Dripping Water Creek at Sunrise Drive**	**City access along road shoulder, non-tidal**	**SNRS**
SE22	Dripping Water Creek near mouth	Driveway parallels creek on north side. Site below horse farm. Private property. Access issue	SNRS
SE23	Hidden Cove Creeklet near mouth	Accessible alongside driveway (public ROW) just upstream of mouth. Tidally influenced.	PTMD
SE24	**Coho Creek at Hidden Cove Road.**	**There were several sites along this creek that were previously sampled - see reports for locations. Trails provide access to upstream location. Station could be established below footbridge.**	**PTMD**
SE25	Heron Creek at Larayette Avenue	Low flow seasonal stream.	SNRS
SE27	**Manzanita Creek at Peterson Hill Road**	**Recent culvert replacement here. Good location to capture all main flow branches. City access and non-tidal.**	**MZBY**
SE28	Manzanita Creek below confluence	Private property, access issue.	MZBY
SE29	Manzanita Creek North Fork at Bergman Road	Downstream north fork location, carries only partial system load (NF only).	MZBY
SE30	Manzanita Creek North Fork in Manzanita Park	Site may be difficult to access - north fork branch only	MZBY
SE31	Manzanita Creek at Waterfall Gardens B&B	Private property, but owner is dedicated stream steward. Could be a potential access issue at difficult crucial times. South fork only.	MZBY
SE32	Manzanita Creek at Lovgreen Road	Up-stream south fork location. Would carry only partial pollutant load. Upland location.	MZBY
SE33	South Manzanita Creek	Low flow seasonal stream.	MZBY
SE34	**Issei Creek (East Fork)**	**Sample downstream of large culvert outfall. Carries stream load emerging from Bainbridge Forest.**	**FLBY**

Table 5-6. Potential Bainbridge Island Stream Water Quality Sample Sites

Location ID	Site Description	Comments	Watershed Code
SE35	**Springbrook Creek at Fletcher Bay Road**	**Previously monitored (Health District, ENVVEST, City). Sampling and flow monitoring station currently established at this site.**	**FLBY**
SE36	Springbrook Creek at High School Road	Mid creek course, carries only partial pollutant load	FLBY
SE37	Foster's Creek at Foster Road	Seasonal most years. Access issues.	FLBY
SE38	**Schel-Chelb Creek at Baker Hill Road**	**Previously monitored (Claiborne, others?)**	**PLBH**
SE39	Schel-Chelb Creek at Lynwood Center Road	Pond downstream of road. Mid-creek course, carries only partial load.	PLBH
SE40	Crystal Springs Creek at Crystal Springs Drive	Low flow seasonal stream.	GZLK
SE41	**Mac's Dam Creek at Country Club Road**	**Drains Island Wood campus. May have been previously monitored (Island Wood, Schools). Sample at either side of the road - culverted under-road crossing.**	**BLKH**
SE42	**Crane Lake Creek at Country Club Road.**	**Principle drainage out of "The Summit" subdivision. Naming confusion, originally tagged as Sunny Hill Creek.**	**BLKH**
SE43	SR-305 Stormwater Discharge at Hidden Cove Road Intersection	Need to search for sampling location. Ephemeral, overland drainage. Difficult access.	PTMD
SE44	Meigs Creek in Meigs Farm Park	May be difficult to access. Will Need Steve Morse to provide directions. Upland location, carries only single branch of system.	MDCV
SE45	**Issei Creek West Fork**	**Forks converge short distance downstream of outfall.**	**FLBY**
SE46	Springbrook Creek at Johnson Farm	Dammed pond on private property. Creek headlands, partial load and flow only.	FLBY
SE47	**McDonald Creek at road-end**	**Access down path on public ROW. Ditch culvert outfalls to creek prior to mouth. Sample site on private property. Stream loc may be tidally influenced.**	**EGDL**
SE48	McDonald Creek at Eagle Harbor Drive	Agricultural activities upstream of this site. Access issue.	EGDL
SE49	Whiskey Creek at Taylor Avenue	May be good site for upper watershed. Alternate site just around corner. Private property - no coordinated access.	EGDL
SE50	Whiskey Creek at Taylor Avenue	May be good site for upper watershed. Alternate site just around corner. Private property - no coordinated access.	EGDL
SE51	Pipe Discharge at Crystal Springs Drive near Baker Hill Road	Perennial discharge, likely spring. Site access issues.	GZLK

Table 5-6. Potential Bainbridge Island Stream Water Quality Sample Sites

Location ID	Site Description	Comments	Watershed Code
SE52	**Tani Creek at Country Club Road in Blakely Harbor Park**	**Secondary drainage from "The Summit" subdivision, Culverted beneath Country Club road**	**BLKH**
SE53	Tani Creek in Blakely Harbor Park	Could be alternate location to road crossing upstream. Tidally influenced.	BLKH
SE54	South Beach Creek at corner of Toe Jam Hill Road and South Beach Drive	Previously Monitored (Health District). Low flow seasonal stream.	SHBH
SE55	**Blakely Falls Creek at Halls Hill Road**	**Possible alternative location would be down stream on Seaborn Drive. City access and non-tidal at this location.**	**BLKH**
SE56	Lindquist Creek at Crystal Springs Drive near Pt. White Dock	Seasonal flows and tidally influenced at public access point	GZLK
SE57	Point White Creek at Pt White Drive	Small wetland upstream of road, seasonal and tidally influenced at public access point.	PLBH
59	Vincent Road Landfill Discharge	Site on private property. Alternate site downstream.	PLBH
SE60	Schel-Chelb Creek at Lynwood Center Road near Fletcher Bay Road Intersection	This site could be used as an alternate for the Vincent Road Landfill discharge. Upland location.	PLBH
SE61	Blakely Falls Creek at Seaborn Road	Alternate location to upstream site at Halls Hill Road. Access unknown and tidally influenced	BLKH
SE62	**Cooper Creek near Head-of-the-Bay well field**	**Site could be at well field or somewhere upstream accessible by trail. Does not capture north fork.**	**NEGH**
SE63	**Sportsman's Club Creek at Wyatt Way**	**Alternate location to Gowen Road site. City access, non-tidal.**	**NEGH**
SE64	Toe Jam Hill Creek at Country Club Road	Alternate site located just upstream at Toe Jam Hill Road. Low flow seasonal stream.	BLKH
SE65	Toe Jam Hill Creek at Toe Jam Hill Road	Alternate site located just downstream at County Club Road. Likely tidally influenced.	BLKH
SE67	Gazzam Lake Creek	Low flow seasonal stream.	GZLK
SE68	North Fletcher Bay Creek	Low flow seasonal stream	FLBY
SE69	Agate Pass Creek	Northern tip of the Island, low flow seasonal stream	PTMD
SE70	Rolling Bay Creek	South of Dripping Water Creek and north of Skiff Point. Low flow seasonal stream	SNRS
SE71	Creosote Creek (South Eagle Harbor Creek)	Easternmost creek along the south shore of Eagle Harbor (west of Wyckoff site), access unknown (likely private) and tidal at sample point.	EGDL
SE72	Lytle Creek	South central shoreline of Pleasant Beach watershed. Tidal at sample location.	PLBH
SE73	Fairy Dell Creek	Small creek flowing north into Port Orchard Bay discharging at Arrow Point. Low flow seasonal, tidally	MZBY

Table 5-6. Potential Bainbridge Island Stream Water Quality Sample Sites

Location ID	Site Description	Comments	Watershed Code
		at mouth.	
SE74	Young Cedars Creek	Central Agate Passage watershed, just to the south of SR-305 (road crosses creek). Empties into Port Orchard Bay. Low seasonal flow, private property and likely tidal at sample point.	AGPS
SE75	Oots-Aht-Ub Creek	Next creek south-southeast of Agate Pass Creek, wetlands near nature preserve. Low seasonal flow, private property and likely tidal at sample point.	PTMD
SE76	Nature Preserve Creek (Bloedel Creek)	Creek flowing from West Port Madison Nature Preserve, north of Gordon Dr NE. Access issue and low seasonal flow.	PTMD
SE77	Tochhookwap Creek	Small creek flowing south into Port Madison Bay, south of NE Country Park Road. Access issue and low seasonal flow.	PTMD
SE78	Hidden Cove Creek	Small creek that flows north into Hidden Cove (Pt Madison Bay back end) north of Hidden Cove Road near Running Springs Place NE. Difficult access and low seasonal flow.	PTMD
SE79	Sunny Hill Creek	Seasonal stream between Tani Creek and Crane Lake Creek. Public access at Country Club Road. Low flows.	BLKH
SE80	**Rose Creek at bottom of Rose Loop**	**Creek crosses beneath Rose Loop via culvert, sample at downstream side. Difficult access and logistics**	**EGDL**
SE81	Battle Point Creek	North of Olallie Lane NE, east of NE of Battle Point. Low flow seasonal stream, difficult access.	MZBY

1 Coordinates are WA State Plane - north 4601 - (NAD 83)
BOLDED = Sites where detailed inspections were completed, described in WQFMP Volume I, SER.

5.5 FRESHWATER BACTERIAL POLLUTION SAMPLING AND ANALYSIS

The presence of some types of microbes indicates only a potential risk for water contamination. Other microbes/bacteria are pathogens themselves (i.e., known to cause disease). Pathogenic enteric bacteria enter the freshwater and nearshore environment from human and animal waste products. Direct contact with contaminated water or consumption of contaminated shellfish or finfish can lead to human health problems. Public health organizations, state environmental agencies, and the USEPA have developed several water quality criteria to protect human health.

The most commonly utilized measure of fecal pathogenic bacteria is fecal coliform (FC) abundance. FC bacteria, in general, are only an indicator of potential public health risk and are not actual pathogens (Dadswell, 1993). Typically, the geometric mean of all FC samples must be less than a specified level and no more than 10% of all FC samples must be below a higher level based on the beneficial uses of the waters in question (see Table 5-7). <u>All CoBI streams are classified as "extraordinary primary contact" waters</u>. In addition to ecological impacts, fecal bacterial contamination of nearshore areas has a direct economic impact to coastal and estuarine communities through the loss of shellfish revenues and the restrictions placed on recreational uses.

Table 5-7. Washington State Freshwater Water Quality Standards for Bacterial Pollution (WAC 173-201A-200).

Fecal Coliform	Extraordinary Primary Contact	FC organism levels must not exceed a geometric mean value of 50 colonies / 100ml, 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 / 100ml.
Fecal Coliform	Primary Contact	FC organism levels must not exceed a geometric mean value of 100 colonies / 100ml, 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 / 100ml.
Fecal Coliform	Secondary Contact	FC organism levels must not exceed a geometric mean value of 200 colonies / 100ml, 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 / 100ml.

Note: All CoBI streams are classified as "Extraordinary Primary Contact

Sources of fecal bacterial contamination include humans, domestic animals, and wild animals. The highest FC levels are typically collected in agricultural areas and in urbanized watersheds (Center for Watershed Protection [CWP] 1999). Studies using genetic analysis have shown that up to 95% of the FC found in stormwater runoff is from nonhuman sources, mostly dogs and livestock (Lim and Oliveri 1982; Trial 1993; Van der Wel 1995; Alderiso et al. 1996; Samadpour and Checkowitz 1998). Recent studies also indicate that levels of FC contamination in nearshore areas is strongly correlated with human population, the level of watershed development, and the quantity of impervious surfaces within a drainage area (Bannerman et al. 1993; Varner 1995; Weiskel et al. 1996; CWP 1999; Young and Thackston 1999; Mallin et al. 2000). Studies also show that FC is often highly correlated with water column turbidity and nutrient concentration as well as being inversely correlated with salinity (Mallin et al. 2000).

Fecal bacteria can enter nearshore waters directly from waterfowl or marine mammal excretion. Although the annual loading of FC into coastal and estuarine waters from waterfowl and other wildlife can be significant, the effects are generally mitigated by the often seasonal nature of these inputs, their wide distribution across the marine surface area, and the apparent limited dispersal from their fecal pellets (Weiskel et al. 1996). The elution of fecal bacteria from shoreline deposits of decaying vegetation (often called "wrack") also contributes to FC loading. In addition, release of FC bacteria during the re-suspension of nutrient-rich, sub-tidal sediments was found to be a minor source of FC contamination (Weiskel et al. 1996). High FC levels have also been found in sediments from stormwater drain-inlets and piping systems (Marino and Gannon 1991). In addition, sediment from stormwater ponds (Pitt 1998) and from roadside gutters (Bannerman et al. 1993) may also be a source of FC contamination. Direct inputs from human sources include combined sewer outfall (CSO) overflows, sanitary sewer outfall (SSO) overflows, illicit sewage-stormwater connections, boat discharges, sewage conveyance spills, and sewage treatment plant outfalls.

In general, on-site sewage treatment (septic) systems are often the largest potential FC source in a watershed-nearshore area (Duda and Cromartie 1982; Pitt 1998; Young and Thackston 1999), but due to attenuation and filtering during subsurface transport very little fecal bacterial contamination usually reaches receiving waters from these widely dispersed sources. The exception to this is when septic systems have failed, are improperly designed or installed, or in areas where septic system density has overwhelmed the assimilative capacity of the native soils. The most extreme bacteria (FC) concentrations found in stormwater typically are associated with inappropriate human sewage discharges, such as failed septic systems, sanitary sewer overflows or leaks, and illicit connections to the storm drainage network. In these rare and serious situations, FC levels can be several orders of magnitude above water quality standards (Pitt 1998). Generally, human sources of sewage should be suspected when FC levels are consistently between 103 and 106 colonies per 100 ml (Pitt 1998). Typically, however, FC levels in freshwater streams and drainage channels are relatively low except for stormwater runoff events or so-called "wet-weather" flows (CWP 1998).

As was discussed earlier, another human-related source of fecal bacterial contamination is agricultural runoff from livestock (e.g., horses, cattle, sheep, etc.) wastes. This can be a significant source in watersheds where farming or livestock production is a major land use (Samadapour and Checkowitz, 1998). However, in most developed areas, the most significant source of FC input to the nearshore environment is from stormwater runoff or NPS pollution (CWP, 1999). This surface runoff can flow directly into estuaries or nearshore waters from developed shoreline areas via storm drain outfalls or as overland flow. In addition, fecal bacteria contamination and other NPS can indirectly enter the nearshore via streams that drain developed upland watersheds. Recent studies have shown that stormwater runoff from impervious surfaces (roads, parking lots, etc.) and from stormwater drainage networks (drain-inlets, stormwater piping, and outfalls) are the most significant sources of FC contamination in urbanizing watersheds and nearshore drainages (Weiskel et al., 1996; Moorhead et al., 1998; Young and Thackston, 1999; Mallin et al., 2000).

Bacterial contamination will generally settle from the water column during low-flow periods and settle into sediments. Here they can persist for weeks or even months if the sediment is moist and rich in organic material (Burton et al., 1987). As a result, streams and drainage ditches that drain urban watersheds can be significant sources of fecal bacterial contamination to the nearshore environment. In urban watersheds, bacteria contamination can come form human sources or from domestic animals or wildlife.

The transport pathway of FC contamination in developed watersheds is generally quite simple. When fecal material is deposited on or near an impervious surface, such as a road or driveway, the fecal contamination and other NPS pollutants (e.g., litter, sediment, nutrients, metals, organics, etc.) are provided with a means of concentration and rapid conveyance to downstream water bodies. During “dry” periods, fecal material accumulates on impervious areas, with little decline in FC density for up to 30 days and possibly longer, depending on ambient conditions (Weiskel et al. 1996).

When storm events occur, these pollutants are washed off the impervious surfaces and transported downstream with stormwater runoff. The conveyance network may be in the form of roadside ditches or vegetated swales in rural watersheds. In suburban and urban watersheds, however, the stormwater conveyance system is often much more “efficient”, including curbs and gutters, drain-inlets or catch basins, and a storm-drain piping network that routes runoff directly to streams, rivers, and lakes, as well as into nearshore marine waters. Therefore, it is not just the intensity or level of development that is important to downstream pollutant loading, but the type of land-use activity, the location of that development, the amount of impervious surface area, and the type of stormwater infrastructure present (White et al. 2000). In a study of a shallow New England embayment, it was found that FC bacterial yields were 2-3 orders of magnitude greater from impervious areas served by stormwater drainage piping networks than from areas of rural or low-intensity residential land-use that were served by “unimproved” stormwater conveyance systems (Weiskel et al. 1996). A Wisconsin study (Bannerman et al. 1993) found that residential lawns, driveways, sidewalks, and streets were the major sources of bacterial contamination. As was discussed earlier, the source of this suburban FC contamination is mostly nonhuman (i.e., domestic dogs, cats, and livestock). Except in cases where inappropriate human sewage discharge is present in an urbanized watershed, most of the bacteria present in stormwater runoff is generally from non-human sources (CWP 1998).

It has also been shown that fecal bacteria counts are generally higher in urbanized watersheds that are served by sanitary sewers than in non-sewered basins (Young and Thackston 1999). In these situations, FC densities are typically related to human population level, the density of development, the percentage of percent-TIA, and the domestic animal population (the so-called “Fido” hypothesis).

As has been discussed, this fecal material deposited on and near impervious surfaces, such as roads and driveways, as well as residential lawns and park areas, is transported by stormwater runoff into natural streams and stormwater systems. From there, it is transported downstream to estuaries or nearshore waters. If the conveyance route includes vegetated drainage swales, vegetated filter strips, or wetland areas, the level of bacterial contamination can be significantly reduced (Weiskel et al. 1996; Young and Thackston 1999; Mallin et al. 2000). In addition, if the runoff can be infiltrated and allowed to flow through the shallow groundwater layer prior to reaching downstream receiving waters (much as septic systems are designed to do), the level of FC contamination can typically be reduced even further (Weiskel et al. 1996; CWP 1999; Young and Thackston 1999; Mallin et al. 2000).

In summary, the sources of bacterial contamination in developed watersheds are ubiquitous and widespread. In most cases, impervious areas such as roads, driveways, sidewalks, and lawns act as source areas, collecting and concentrating pollutants during dry weather. Rainstorms tend to wash these pollutants, including fecal material, into the stormwater drainage system and from there on into the natural drainage network and ultimately into receiving waters. In general, bacterial contamination is higher in more developed residential areas and in rural areas where livestock are present. In addition, failing on-site septic systems are also a major source of bacterial contamination. Finally, stormwater runoff is the key mobilization and transport mechanism for bacterial contamination. Therefore, it is recommended that streams, lakes, and estuaries be monitored for FC contamination at least monthly, with storm events targeted for more frequent monitoring.

In recent years NPS pollution (e.g., agricultural and urban stormwater runoff) has surpassed point sources (e.g., wastewater treatment plant discharges) as the major source of fecal contamination to receiving waters. The water quality standards for surface waters in Washington State currently use FC bacteria as an indicator of fecal contamination because FC bacteria are a sub-group of bacteria that grow mainly in the intestines of warm-blooded animals, including human sources. To control microbial pollution sources it is important to be able to identify the source of bacterial pollution so clean-up efforts can be targeted and effective. Bacterial indicators such as FC do not give us information on the specific source of pollution. There is currently no easy, low-cost method for differentiating between human and non-human sources of microbial contamination. Quantifying the contribution from different sources is also as yet not possible, although there are several promising techniques currently in use (Woodruff 2003). Aside from these innovative, experimental methods of microbial source tracking, the best approach for an investigator at this time is to consider the land uses and sources under investigation, and tailor the method or methods to fit the situation (WA-DOE 2003).

5.5.1 Freshwater Bacterial Pollution Sampling And Analysis

1. Sample Sites – Streams listed in Table 5-8 (see Figure 5-7) will be sampled for microbial pollution on a rotating basis as determined by CoBI staff. Samples can only be collected if water is flowing in the creek. Streams included in the sampling rotation will be based on water quality priorities established by CoBI staff. Additional streams can be added to the sampling plan if water quality problems are suspected.
2. Sample Frequency – FC samples should be collected at selected stations at least once each month. This sampling frequency was chosen, based on experience, in order to optimize the probability of statistically detecting trends while minimizing both auto-correlation between consecutive samples and the cost of collection.
3. Sample Timing – Sample timing should be randomized within each month within the logistic constraints of the CoBI.
4. Sample Techniques – In the case of microbial pollution sampling for FC, near-surface grab samples should be collected in sanitized collection bottles (see QAPP for details).
5. Sample Teams – Trained teams of CoBI staff and volunteers can collect FC samples. Proper training on sampling protocols and QA requirements is essential.

5.5.2 Freshwater Bacterial Pollution Grab-Sampling Equipment:

- Field data sheets, clipboard, and pencils
- Sample site map and directions
- Sterile bottles (for samples and replicate samples as required)
- Watch
- Latex gloves
- Waterproof marker and sample labels
- Thermometer
- Sampling wand
- Cooler and Ice (maintain sample temperatures below 39°F/4°C)

5.5.3 Freshwater Bacterial Pollution Grab-Sampling Procedure:

1. Monthly samples for FC bacteria will be collected on designated streams. In the case of an identified problem or special-project request, additional sites may be sampled.
2. The objective of stream FC sampling is to sample the combined freshwater and any stormwater runoff in the stream, not what might surge in on a high tide. To avoid tidal interference the sampling team should check the tide tables before planning their collection day. Samples taken near the mouths of streams should be taken on an outgoing tide. In general, you can one-half hour after mean high tide, defined as the point halfway between the high-low tide and low-high tide for the day. If a salinity meter is available, take it along and measure salinity at the time of FC sampling. Note the reading on the field data sheet. Be sure that the water is flowing downstream when sampling. If the tide has turned and tidal upsurge is noticed, do not collect a sample and note that on the data sheet. Sites that are well above the stream mouth should have no problem with tidal interference. Because the holding time for FC samples is only 24 hours (if kept on ice), samples should be collected between 0600 and 1400 so that samples can be delivered to the lab no later than 1600. The lab typically does not accept samples on Fridays.
3. Quality control procedures require that at one sampling point out of every ten (or 10%), a second sample be collected as a field replicate sample. Field replicates give an indication of how much variability there is in the sampling techniques and environment. To perform and record field replicates, the team leader will determine how many replicate samples need to be collected, randomly select sites for replicates, and then notify team members where to collect replicates. Replicate samples should be collected simultaneously with the regular site sample. Gloves are optional but preferred, and a sampling wand can be used to avoid having to wade in the stream. Enter the stream downstream of where the sample will be taken (or use the sample wand with a sample bottle attached), to avoid contaminating the sample with stirred-up sediment. Sample at the designated sample site at a mid-point portion of the creek where the stream is flowing, well mixed, and preferably at least 6 inches deep. If these conditions cannot be met at the designated sample site, it is permissible to go outside the reach, but note the location on the field data sheet. Choose a spot that appears undisturbed and has little or no sediment stirred up in the water. In most cases, it is preferable to use a sampling wand, as there is less chance of stirring up the bottom than walking in the creek.

4. Uncap the sample bottle while holding the bottle near the bottom and the cap near the top edge. Do not let anything touch the inside of the cap. Do not set the cap down. Do not rinse the bottle or cap. If the bottle becomes contaminated, discard it. Hold the bottle near its base and plunge it below the water surface with the opening pointing downward. Collect the sample about 6 inches below the surface of the water. If the water is shallow, collect midway between the bottom and the surface. Turn the bottle underwater into the current and away from you. In slow-moving stream reaches, push the bottle underneath the surface and away from you in an upstream direction. Remove the bottle from the water when it is filled up to the shoulder. If the bottle comes out with the water level below the shoulder, pour out the water and try again. If the bottle comes out full, recap it, shake, uncap, then quickly flick the bottle until the water level decreases to the shoulder. If a deep water location is not available, there are several other options. Sample in shallow, fast-moving water, preferably at a point where the water is forced between larger rocks. Hold the bottle facing upstream so as to catch the moving water in it. Avoid hitting the bottom. If there is a drop-off, as from a cascade or culvert, sample from this drop-off as long as the bottle touches nothing but the falling water. Recap the bottle carefully, without touching the inside.
5. Dry the outside of the bottle and attach a label. Mark the sample with the date and time of the sample, the site name and sample identification number, and “rep” if the sample is a field replicate. Record the same information on the field data sheet. Place the sample bottle in the cooler.

   When finished sampling, bring all samples and forms directly to the laboratory. FC samples must be tested within 24 hours of sampling. On the field data sheet, enter the time thatthe samples were turned in, and have someone from the laboratory initial the time the samples were received. Have the lab make a copy of your data sheet(s), and bring the original data sheets, along with the equipment, back to the CoBI office. The signed data sheets provide a “chain-of-custody” record that is a QA/QC requirement. The lab will process the samples and submit results to CoBI staff, who will enter the data into the CoBI WQ database. FC colonies will be counted by laboratory technicians using standard methods; either the membrane filtration (MF) or most probable number (MPN) methods.

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Table 5-8. Potential Bainbridge Island Stream FC Sample Sites

Site ID	Stream Name	Type	Watershed
FC 1	East Fork Hawley Creek	*Seasonal*	NEGH
FC 2	West Fork Hawley Creek	*Seasonal*	NEGH
FC 3	Hawley Creek (Mainstem)	*Seasonal*	NEGH
FC 4	Lower Ravine Creek (@ Winslow Way)	**Perennial**	NEGH
FC 5	Middle Ravine Creek (@ SR-305)	**Perennial**	NEGH
FC 6	Upper Ravine Creek (@ High School Road)	**Perennial**	NEGH
FC 7	Upper Weaver Creek (@ Wyatt Avenue)	*Seasonal*	NEGH
FC 8	Lower Weaver Creek (@ Sheppard Road)	*Seasonal*	NEGH
FC 9	Lower Sportsman's Club Creek (@ Gowen Road)	**Perennial**	NEGH
FC 10	Middle Sportsman’s Club Creek (@ Wyatt Avenue)	**Perennial**	NEGH
FC 11	Upper Sportsman's Club Creek (@ High School Road)	**Perennial**	NEGH
FC 12	East Fork Cooper Creek	*Seasonal*	NEGH
FC 13	North Fork Cooper Creek	**Perennial**	NEGH
FC 14	Cooper Creek (Mainstem)	**Perennial**	NEGH
FC 15	Cougar Creek	*Seasonal*	EGDL
FC 16	McDonald Creek	*Seasonal*	EGDL
FC 17	Rose Creek	*Seasonal*	EGDL
FC 18	Whiskey Creek	**Perennial**	EGDL
FC 19	Creosote Creek	*Seasonal*	EGDL
FC 20	Blakely Falls Creek	*Seasonal*	BLKH
FC 21	South Fork Mac's Dam Creek	**Perennial**	BLKH
FC 22	Mac's Dam Creek	**Perennial**	BLKH
FC 23	Tani Creek	*Seasonal*	BLKH
FC 24	Sunny Hill Creek	*Seasonal*	BLKH
FC 25	Crane Lake Creek	*Seasonal*	BLKH
FC 26	Toe Jam Hill Creek	*Seasonal*	BLKH
FC 27	South Beach Creek	*Seasonal*	SHBH
FC 28	Lytle Creek	*Seasonal*	PLBH
FC 29	Schel-Chelb Creek (Mainstem)	**Perennial**	PLBH
FC 30	Middle Fork Schel-Chelb	*Seasonal*	PLBH
FC 31	South Fork Schel-Chelb	*Seasonal*	PLBH
FC 32	Point White Creek	*Seasonal*	PLBH
FC 33	Linquist Creek	*Seasonal*	GZLK
FC 34	Crystal Springs Creek	*Seasonal*	GZLK
FC 35	Gazzam Lake Creek	*Seasonal*	GZLK
FC 36	Lower Springbrook Creek (@ Fletcher Bay Road)	**Perennial**	FLBY
FC 37	South Fork Springbrook Creek (@ Johnson Farm)	**Perennial**	FLBY
FC 38	Upper Springbrook Creek (@ High School Road)	**Perennial**	FLBY

Table 5-8. Potential Bainbridge Island Stream FC Sample Sites

Site ID	Stream Name	Type	Watershed
FC 39	Foster's Creek	*Seasonal*	FLBY
FC 40	Issei Creek (Mainstem @ Battle Point Drive)	**Perennial**	FLBY
FC 41	East Fork Issei Creek	**Perennial**	FLBY
FC 42	West Fork Issei Creek	*Seasonal*	FLBY
FC 43	North Fletcher Bay Creek	*Seasonal*	FLBY
FC 44	Battle Point Creek	*Seasonal*	MZBY
FC 45	Fairy Dell Creek	*Seasonal*	MZBY
FC 46	South Manzanita Creek	*Seasonal*	MZBY
FC 47	Upper South Fork Manzanita Creek	**Perennial**	MZBY
FC 48	Lower South Fork Manzanita Creek	**Perennial**	MZBY
FC 49	Upper North Fork Manzanita Creek	*Seasonal*	MZBY
FC 50	Lower North Fork Manzanita Creek	*Seasonal*	MZBY
FC 51	Manzanita Creek (Mainstem)	**Perennial**	MZBY
FC 52	Young Cedars Creek	*Seasonal*	AGPS
FC 53	Agate Pass Creek	*Seasonal*	PTMD
FC 54	Oots-Aht-Ub Creek	*Seasonal*	PTMD
FC 55	Nature Preserve Creek	*Seasonal*	PTMD
FC 56	Tochhookwap Creek	*Seasonal*	PTMD
FC 57	Hidden Cove Creeklet	*Seasonal*	PTMD
FC 58	Hidden Cove Creek	*Seasonal*	PTMD
FC 59	Coho Creek	**Perennial**	PTMD
FC 60	Heron Creek	*Seasonal*	SNRS
FC 61	Dripping Water Creek	**Perennial**	SNRS
FC 62	Rolling Bay Creek	*Seasonal*	SNRS
FC 63	Manitou Beach Creek	*Seasonal*	MDCV
FC 64	Meigs Creek	**Perennial**	MDCV
FC 65	Lower Woodward Creek	**Perennial**	MDCV
FC 66	Upper Woodward Creek	**Perennial**	MDCV
FC 67	Murden Creek (Mainstem @ SR-305)	**Perennial**	MDCV

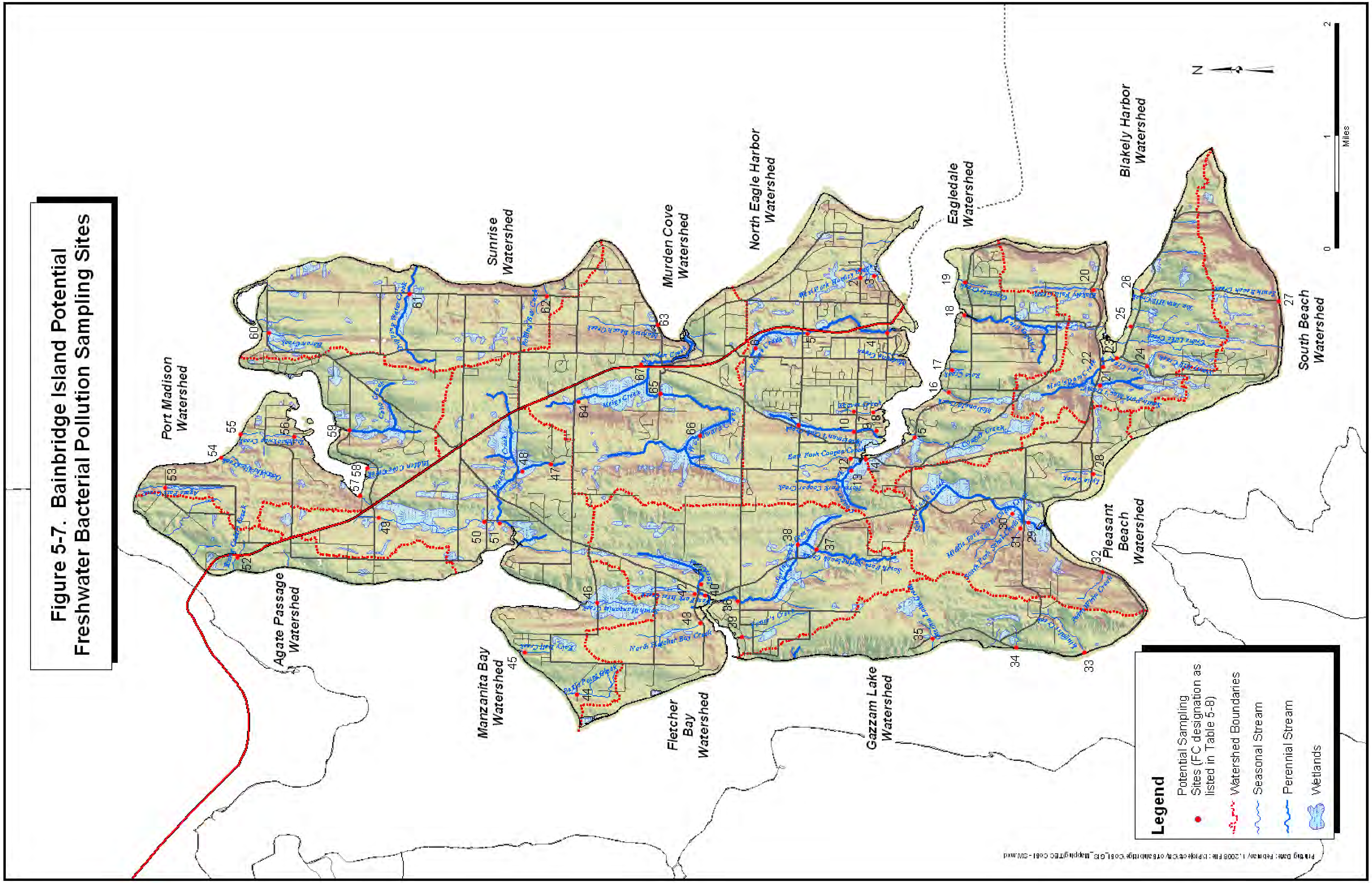

Figure 5-7. Bainbridge Island Potential Freshwater Bacterial Pollution Sampling Sites

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5.6 FRESHWATER SEDIMENT SAMPLING AND ANALYSIS

Because of the depositional nature of solids and the affinity of many pollutants (i.e., metals, organics, nutrients, and hydrocarbons) for particulates, sediments tend to be a repository of long-term pollutant loading. Sediment contamination also tends to be a common problem in areas of intense industrial land-use and other human activities. Therefore, sediment sampling is an effective tool for monitoring the long-term, cumulative impacts on aquatic resources. Establishing current sediment quality also provides baseline for comparison of future sampling results.

1. <u>Sample Sites</u> – Selected CoBI streams will be sampled for sediment quality. CoBI staff will determine the priority of stream sediment sampling sites. Samples should be collected at the mouth of each creek in depositional areas. The following streams are recommended for sediment sampling for the initial phase of the CoBI Waste Quality Monitoring Program:
    - Winslow Ravine Creek
    - Sportsman's Club Creek
    - Weaver Creek
    - Cooper Creek
    - Schel-Chelb Creek
    - Springbrook Creek
    - Manzanita Creek
    - Coho Creek
    - Murden Cove Creek
2. <u>Sample Frequency</u> – Samples should be collected at all stations on a 3 to 5 year interval.
3. <u>Sample Timing</u> – Samples should be collected during the late summer or early fall after an extended period of low flow.
4. <u>Sample Techniques</u> – Samples should be collected using stainless steel or non-metallic sampling equipment. Three replicate sediment cores will be collected at each site. Field decontamination of sampling gear should be conducted between each sample site. Normally, these replicates will be combined into a single composite sample representative of that site. In some cases, individual cores may be analyzed independently to assess the spatial extent of sediment contamination.
5. <u>Sample Teams</u> – Trained teams of CoBI staff and volunteers can collect sediment quality samples. Proper training on sampling protocols and quality-assurance requirements is essential.

5.7 LAKE AND WETLAND WATER QUALITY MONITORING

Lake and wetland water quality sampling should be targeted towards identifying potential eutrophication problems. Eutrophication can be natural, but is often due to the cultural increase in nutrient input to lentic (non-flowing) freshwater lakes and wetlands. Standard water quality parameters to monitor for this condition include nutrients and chlorophyll-A. A secchi-disc can also be utilized to monitor for water transparency, which often declines with increased eutrophication. Excessive water level fluctuation (WLF) should also be monitored for in cases where stormwater runoff may be impacting a lake or wetland.

1. Sample Sites – Gazzam Lake is currently the only lake or wetland that has public contact recreation beneficial use. Other lakes or wetlands that are utilized for contact recreation activities or are of concern can be added to the sampling list as necessary.
2. Sample Frequency – Initially, nutrient, chlorophyll-A, and conventional water quality samples should be collected seasonally during the Spring (April-May), Summer (July-August), Fall (October-November), and Winter (January-February). After initial sampling, annual lake water quality sampling should be adequate. FC samples should be collected at least once each month.
3. Sample Timing – Sample timing should be randomized within each season or month within the logistic constraints of the CoBI. Secchi-depth and WLF readings should be taken on a monthly basis if feasible. If possible, WLF readings should be taken before and immediately after significant storm events.
4. Sample Techniques – For lake sampling, a central location within the lake is recommended so as to obtain a representative water quality sample. These should be “mid-depth” samples. In the case of microbial pollution sampling for FC, near-surface grab samples should be collected in sanitized collection bottles. Gazzam Lake should be equipped with a WLF gauging station.
5. Sample Teams – Trained teams of CoBI staff and volunteers can collect lake water quality samples. Proper training on sampling protocols and QA requirements is essential.

5.8 STREAMFLOW MONITORING

Discharge (or stream flow) is a measure of the volume of water flowing through a stream channel at a given point in time and space. Discharge or flow is typically measured in the field using a flow meter. If available, a stream stage-gage can also be used to monitor flow continuously. Because, hydrologic change is the driving force behind the main disturbance regime in streams, flow measurements made under a variety of conditions (e.g., flood, storm, baseflow, etc.) are very useful for making management decisions.

1. Sample Sites – All perennial stream systems on Bainbridge Island should be monitored for flow. Stream flow gage stations should be established on the major perennial streams. CoBI staff will determine the priority of establishing long-term stream gage stations. The following streams are recommended for stream flow monitoring for the initial phase of the CoBI Water Quality Monitoring Program (see Figure 5-3 for stream locations):
    - Winslow Ravine Creek
    - Sportsman’s Club Creek
    - Cooper Creek
    - Whiskey Creek
    - Mac’s Dam Creek
    - Schel-Chelb Creek
    - Dripping Water Creek
    - Springbrook Creek (stream flow monitoring station already established)
    - Issei Creek
    - Manzanita Creek
    - Coho Creek
    - Murden Cove Creek
    - Meigs Creek
    - Middle Fork Woodward Creek
    - Woodward Creek
    - Murden Creek
2. Sample Frequency – Routine field water quality monitoring surveys (such as monthly FC sampling, physio-chemical water quality sampling, or BIBI sampling) should include a discharge (flow) measurement. This is especially useful if the stream is gauged, as calibration measurements of actual flow under various conditions are needed to develop the

stage-discharge curves for the stream. These water quality related flow measurements can also be utilized in determining pollutant loading if required.

3. Sample Timing – Flow measurements should be obtained during baseflow and stormflow conditions throughout the year, during all seasons.
4. Sample Techniques – Standard discharge measurement procedures should be used (see Pleus 1999).
5. Sample Teams – Trained teams of CoBI staff and volunteers can conduct discharge measurements. Proper training on sampling protocols and quality-assurance requirements is essential.

5.8.1 Flow Measurement Equipment

- Velocity Meter and Depth-Staff
- Measuring Tape
- Pocket Calculator and Watch
- Field Data Sheet, Clipboard, and Pencil

5.8.2 Flow Measurement Procedure

1. This procedure involves measuring depth and velocity at 15-20 points across the stream and using this data to calculate discharge or flow (volume/time). This procedure is best performed by two people, one taking measurements and the other recording. Generally, flow measurements will be made each time water quality sampling activities are performed. In addition, flow measurements will be taken periodically to calibrate fixed flow-gauging stations.
2. Measure flow at a point in the designated stream reach where most of the channel cross-section is at least two inches deep, the flow is fairly straight, and the water is moving as uniformly as possible but not turbulently. The streambed should be relatively uniform. Look for variations in the amount of water flowing along the length of your reach, and measure at a spot where the flow is maximized. A suitable site should not have side-channels, undercut banks, or flow obstructions such as boulders, logs, or aquatic vegetation. If a large rocks are in the way, move them downstream if possible. If there is still water or eddy currents at the edges, select another site. If there is no suitable site within reach, walk outside the reach as long as no water leaves or enters the stream in between. While still on dry land, remove the velocity meter and staff from its case and set up the meter for measurement using the operational manual.
3. Determine the average interval for the measurements using the following steps. At the point where it is decided to measure flow, stretch a tape across and above the wetted portion of the stream channel perpendicular to the direction of flow. Use spring clamps, rocks, or stakes to secure the tape at the margins of the stream channel. Determine the area along this line where velocity can be measured and note the distances on the tape corresponding to this measurement area. On your field data sheet, divide this length by 20, then round up to the nearest tenth of a foot. This will provide an average interval that will yield 15 - 20 measuring points across the stream channel. For example, if the area is 13-feet wide, 13/20 = 0.65 feet for the measurement interval. Round up to 0.7 feet and calculate 13/0.7 or 18 measuring points. Record on your field data sheet the date and time, the starting point (zero-point), the distance, depth, and velocity for each measurement point across the

channel. At both wetted edges, record the tape reading, the depth as zero, and the velocity also as zero.

4. The general procedure for measuring flow in water between 0.25 and 2.5 feet deep is outlined in this step. Set the depth-staff on the stream bottom and record the tape reading on the field data sheet, to the nearest tenth of a foot. Adjust the moveable rod as needed to set the tip of the velocity probe at water level. The staff should be vertical. Read the stream depth from the large scale on the moveable rod, at the point where it enters the top of the slide fitting. Note that the scale reads downward, intervals are in tenths of a foot. Record the water depth from the staff, to the nearest hundredth of a foot. Estimate between the 0.1' markings on the staff. Place the probe at 6/10 the distance from the water surface to the stream bottom. This is easily done by lowering the moveable rod until the top of the slide fitting matches the marking for your stream depth on the smaller rod. For example, if the depth is 0.4 feet, slide the rod down to the fourth notch on the smaller rod. Take the measurement with the velocity probe facing into the current. The velocity meter should be in the "averaging" mode (a setting between 15 and 30 seconds is a good averaging interval to use). Press and release the "reset" button to zero the display. After approximately 15-30 seconds, the meter will display a velocity and should stabilize. Record this reading in the "velocity" column on the field data sheet. Proceed across the stream channel taking readings at each predetermined measurement point, ending at the far wetted edge. If any velocity reading is different by a factor of two than the previous one, the recorder should ask the sampler to confirm that reading. If you have a gage at the site, record the water level on the flow field data sheet. If water depth is greater than 2.5 feet, you will need to measure and record velocity at 2/10 and 8/10 of total depth.
5. Calculate discharge in cfs based on the sum of your individual velocity measurements and the channel cross-sectional area.

5.9 INSTREAM & RIPARIAN HABITAT ASSESSMENT

Surveys of physical habitat characteristics and quality within the stream-riparian ecosystem are an important component of the overall water quality assessment program. These surveys include monitoring instream and riparian habitat features identified by resource agencies as being critical for salmonid survival, as well as other characteristics (i.e., exotic or invasive vegetation) of interest to those involved with habitat restoration and enhancement activities. For this component of the CoBI-WQFMP it is recommended that the CoBI staff and volunteers utilize the existing Kitsap County Stream Habitat Assessment Guidelines (see Appendix C in May and Peterson 2003). The details of instream and riparian habitat assessment procedures are included in the CoBI Salmon Recovery Plan (CoBI 2005).

6.0 MARINE-NEARSHORE RESOURCES

6.1 MARINE-NEARSHORE MONITORING

This section of the CoBI WQFMP focuses on the marine aquatic resources of Bainbridge Island. These resources include the nearshore and estuarine areas located on the island, as well as marine waters surrounding the island. The designated beneficial uses associated with the estuarine, nearshore, and marine ecosystems of Bainbridge Island include contact recreation (fishing, boating, and swimming), as well as shellfish harvest, aquatic biota, and habitat.

6.2 MARINE-NEARSHORE ENVIRONMENT

Puget Sound estuarine and nearshore habitats take many forms and include eelgrass meadows, kelp forests, sand and mudflats, tidal marshes, stream or river mouths and deltas, sand spits, beach and backshore areas, banks and bluffs, and marine riparian areas. These habitats perform important functions within an ecosystem and play a critical role in the life history and ecology of important resources in the region, such as salmon (Williams and Thom, 2000). These habitats also provide many critical functions for invertebrates, juvenile and adult marine fish, as well as foraging opportunities for birds and mammals. Water quality is a critical component of the marine-nearshore environment.

Nearshore riparian habitats occur at the interface between terrestrial and aquatic ecosystems and are characterized by coniferous and deciduous native vegetation. Riparian vegetation affects the quality of aquatic habitats by increasing slope stability, providing erosion protection, and buffering against pollution and sediment runoff (Broadhurst 1998).

Marine riparian vegetation also performs a number of increasingly recognized habitat functions at the interface between aquatic and terrestrial zones. For example, overhanging riparian vegetation provides shading that regulates microclimates important to intertidal invertebrate distribution (Foster et al. 1986) and surf smelt spawning (Williams and Thom 2000). Vegetated riparian zones also deliver organic matter and invertebrate prey to the nearshore (Williams and Thom 2000) and create complex structures (e.g., large woody debris accumulations) that are important for fish (e.g., shade for beach spawning) and wildlife (e.g., bird nesting and roosting).

Estuaries and nearshore areas also include many of the above listed habitat types, as well as salt and freshwater marsh habitats that experience tidal inundation. The ecological functions of these nearshore habitats encompass those commonly listed for wetlands, which include: primary production, fish and wildlife support, groundwater recharge, nutrient cycling, flood attenuation, and water quality improvement (Williams and Thom 2000).

Nearshore areas and estuarine environments are critical habitat for native salmonids. Juvenile salmon have been shown to reside in tidal marshes and estuaries. These nearshore areas provide a critical corridor for migration, spawning, rearing, and feeding for a variety of marine organisms, including salmon. Salmonids tend to exhibit substantial growth while foraging on prey resources both produced in, and imported to, the estuarine ecosystem (Williams and Thom 2000).

One of the most interesting features of salmonid utilization of the nearshore environment is the extraordinary variability that exists with respect to its use. The nearshore habitats used by juvenile and adult salmonids have four primary functions. First, these areas function as foraging habitat. The food selected by salmonids tends to vary with species, age, and size. Detritus-based food webs are important for young salmonids, whereas larger prey is more important to older, larger juveniles. Even with the potentially large selection of prey, only a limited suite of prey is utilized by salmonids (Williams and Thom 2000).

Secondly, nearshore areas are also critical refuge habitat for adult and juvenile salmonids. Shallow, turbid nearshore areas provide excellent cover for juvenile salmonids to avoid predation. Historically, the nearshore areas of Puget Sound and Hood Canal were dominated by eelgrass beds and complex intertidal habitat (Williams and Thom 2000). A third function of nearshore areas is as a physiological transition zone for smolts moving from the freshwater to the marine environment (Williams and Thom 2000). Finally, adult and juvenile salmonids utilize the nearshore as a migration corridor as they move to and from the ocean environment (Williams and Thom 2000). The use of nearshore and estuary areas by salmonid populations is an important part of how they have been able to persist over the long-term in the changing Pacific Northwest environment.

As a result of the variable patterns of nearshore and estuarine use that exist within the salmonid community, the significance of these refugia areas varies within and among species. Among salmonid researchers and fisheries biologists, it is generally agreed that chinook, chum, and cutthroat are the most dependent on nearshore areas, although there is also evidence that coho utilize these areas extensively (Groot and Margolis 1991; Stouder et al. 1997; Williams and Thom 2001). It would appear to be no mere coincidence between this ecological link and the current listing of chinook and summer chum based on the extensive changes that have occurred in the nearshore environment of Puget Sound. The construction of docks, seawalls, and other human modifications of the nearshore area, as well as degraded water quality due to sewage, stormwater, and industrial runoff appear to have adversely impacted this critical salmonid habitat. The cumulative impacts of these changes have affected the structure of prey communities, reduced the refuge habitat area available, and dramatically modified the ecological functions of the nearshore environment (NRC 1996).

As pressure to develop shoreline and floodplain areas increases, there is increasing loss of natural shoreline and channel processes that maintain habitat, provide flood protection, and LWD recruitment. Nearshore development including, bulkheads, filling of near shore areas, erosion onto beaches, installation of docks, and loss of shoreline vegetation, has reduced and eliminated nearshore habitat. Bulkheads tend to increase the rate of beach erosion, modifying and eliminating suitable habitat (Williams and Thom 2000). Bulkheads and docks also tend to force fish into deeper water where they are subjected to increased predation by birds, marine mammals, and other fish species. Installation of bulkheads reduces available habitat for salmon prey as well. Bulkheads and filling of nearshore habitat also tends to eliminate eelgrass beds and salt marshes, important rearing and feeding habitats. Removal of shoreline vegetation reduces shade, shoreline LWD, and increases erosion onto beaches, all of which are important factors in the survival of prey and baitfish. Shoreline vegetation is also an important source of terrestrial salmon prey. Dock installation through filling, shading, and physical disturbance of the beach eliminates eelgrass beds, macro algae, disrupts salmon migration, increases predation by forcing salmon into deep water, displaces prey species, and disrupts beach spawning of prey species. If not properly managed, shoreline development can also degrade marine-nearshore water quality (Williams and Thom 2000).

6.3 BAINBRIDGE ISLAND MARINE-NEARSHORE WATER-QUALITY MONITORING

The nearshore, estuarine, and marine sampling locations on Bainbridge Island are shown in Figure 6-1 and listed in Tables 6-1 and 6-2. Specific objectives of the marine and nearshore WQFMP are as follows:

1. Determine whether water quality at sampling sites exceeds water quality standards. This objective is intended to address the 303(d) section of the CWA, as well as the specific requirements of CoBI programs. Results will be compared to Washington State WQS established to support designated beneficial uses (see WAC). In some cases, individual results are compared to a numeric or narrative water quality criterion, in other cases, aggregation of data may be required. This program will also provide timely and high-quality data for use by the CoBI in managing water resources. Each use will have its own minimum data quality requirements, but the data quality established for this program will be appropriate for most related uses. Examples of possible uses of water quality data include support for TMDL analyses, waste discharge permitting where receiving water data is required, and for NPDES Phase II stormwater permitting.
2. Assess the status of nearshore, estuarine, and marine waters. This objective is intended to address the 305(b) section of the CWA, as well as the specific requirements of CoBI programs. A monitoring program with this objective might best be designed to sample a randomized (non-biased) subset of all island streams. However, this approach is neither logistically nor financially feasible. Access to the randomly chosen sites is often difficult because of private-property issues. In most cases, specific locations for sampling will be established based on professional judgment, with watershed-specific factors and logistic considerations also taken into account. In addition, monitoring at randomly selected frequencies also tends to be impractical if not impossible. In practice, the monitoring design will emphasize major, perennial streams as the primary focus of long-term monitoring, but will sample smaller, seasonal streams often enough such that problems are detected and adequate data are available. Poor water quality at a particular station may indicate an overall, cumulative problem in the contributing shoreline area, but may not necessarily identify the extent of the problem. Additional sampling may then be necessary.
3. Provide analytical water quality data that describes current conditions and allows for the evaluation of water quality trends. Long-term monitoring at fixed stations followed by periodic statistical analysis of the data and interpretive reports of the results are one of the mainstays of a well-designed ambient monitoring network. The data requirements for trend analysis are quite rigorous. Several years of data collection may be required to conduct statistically significant and scientifically meaningful trend analysis. However, individual data-points are extremely valuable because they provide the most efficient and sensitive means for the early detection of emerging water quality problems. The data quality objectives are based primarily on the objective of early detection of deteriorating water quality conditions. These requirements are also adequate for the detection of improving water quality conditions in degraded nearshore, estuarine, or marine receiving waters. Assessments of current conditions are site-specific and include various measures of central tendency, variability, and dispersion, non-parametric statistics such as cumulative frequency plots. Trend assessment is most commonly performed using statistical methods such as the non-parametric seasonal Kendall test for trend with a confidence level specified at 90 or 95% (Zar 1984).

Marine, estuarine, and nearshore monitoring stations are chosen, based on specific criteria, including selection of sites that are representative of conditions within contributing shoreline areas. Sites were also selected to meet data requirements outlined in the monitoring objectives. Examples of typical marine-nearshore sample sites include:

1. Marine Waters – to provide an overall measure of water quality conditions in marine waters.
2. Stream Sub-Estuaries – to provide an overall measure of contributing upland watershed conditions.
3. Developed Nearshore Areas – to provide data on conditions in nearshore areas with shoreline development.
4. Reference Nearshore Areas – to provide reference data on non-impacted, natural streams for comparison with degraded system.
5. Permit Related Sites – to support the waste discharge or NPDES permitting process.

Figure 6-2 illustrates the components of the integrated water quality-monitoring (physical, chemical, and biological) approach to be used for Bainbridge Island marine, estuarine, and nearshore receiving waters.

Table 6-1. Potential Bainbridge Island Nearshore Sampling Sites

Nearshore Sample Site Description	Site ID#
Winslow City Dock and Public Boat Ramp (Eagle Harbor)	CoBI NS-1
WSDOT Maintenance Yard (Eagle Harbor)	CoBI NS-2
Winslow Marina (Eagle Harbor)	CoBI NS-3
Eagle Harbor Marina (Eagle Harbor)	CoBI NS-4
Eagle Harbor Live-Aboard Area (Eagle Harbor)	CoBI NS-5
Inner Eagle Harbor	CoBI NS-6
Eagledale Marina (Eagle Harbor)	CoBI NS-7
Hall Cove (Eagle Harbor)	CoBI NS-8
Wykoff Point (Eagle Harbor)	CoBI NS-9
Hawley Wetland Beach (Eagle Harbor)	CoBI NS-10
Wing Point (Eagle Harbor)	CoBI NS-11
Outer Eagle Harbor	CoBI NS-12
Murden Cove	CoBI NS-13
Manitou Beach Nearshore	CoBI NS-14
Brackenwood Nearshore (Rolling Bay)	CoBI NS-15
Point Monroe Lagoon	CoBI NS-16
Point Monroe Nearshore	CoBI NS-17
Port Madison Bay	CoBI NS-18
Seattle Yacht Club Marina (Port Madison)	CoBI NS-19
Port Madison Marina (Port Madison)	CoBI NS-20
Hidden Cove (Port Madison)	CoBI NS-21
Little Manzanita (Mosquito) Bay	CoBI NS-22
Big Manzanita Bay	CoBI NS-23
Fletcher Bay	CoBI NS-24
Point White Nearshore (Public Pier)	CoBI NS-25
Lynwood Center Nearshore	CoBI NS-26
Pleasant Beach Nearshore	CoBI NS-27
Fort Ward Nearshore	CoBI NS-28
Fort Ward Net-Pens	CoBI NS-29
Rockaway Beach Nearshore (CoBI Park)	CoBI NS-30
BEACH Program Sites (Ecology, incorporated into the WQFMP)	
Location Name	**Site ID**
Fay Bainbridge State Park	KIT023A
Fay Bainbridge State Park	KIT023B
Fay Bainbridge State Park	KIT023C
Eagle Harbor Waterfront Park	KIT031A
Eagle Harbor Waterfront Park	KIT031B
Eagle Harbor Waterfront Park	KIT031C

Table 6-2. Bainbridge Island Potential Marine Sampling Sites (WA DOH)

WA DOH Marine Stations:		
Agate Passage		
Station #	**Latitude (HARN ’83)**	**Longitude (HARN ’83)**
597	47.71997	-122.55452
Port Blakely		
Station #	**Latitude**	**Longitude**
413	47.60285	-122.49721
414	47.59635	-122.49743
415	47.59611	-122.50393
416	47.59679	-122.50733
417	47.59626	-122.51224
418	47.59465	-122.51058
419	47.5944	-122.50444
420	47.5923	-122.50046
421	47.61348	-122.49568
Port Madison		
Station #	**Latitude**	**Longitude**
515	47.70352	-122.50587
516	47.70606	-122.52704
517	47.7064	-122.51895
518	47.6856	-122.50074
519	47.66695	-122.50435
520	47.65465	-122.50096
521	47.64132	-122.49908
522	47.6941	-122.50139
638	47.72059	-122.54678
637	47.7102	-122.53964
648	47.7061	-122.51608
Port Orchard Passage		
Station #	**Latitude**	**Longitude**
437	47.70111	-122.56465
438	47.69046	-122.56754
439	47.67674	-122.57043
440	47.67176	-122.58243
441	47.66434	-122.59211
448	47.59456	-122.5744
449	47.6536	-122.58662
450	47.64134	-122.57939
451	47.62166	-122.57867
452	47.60072	-122.57758
455	47.59832	-122.577
456	47.60399	-122.57751
457	47.64486	-122.58055
461	47.5889	-122.53293

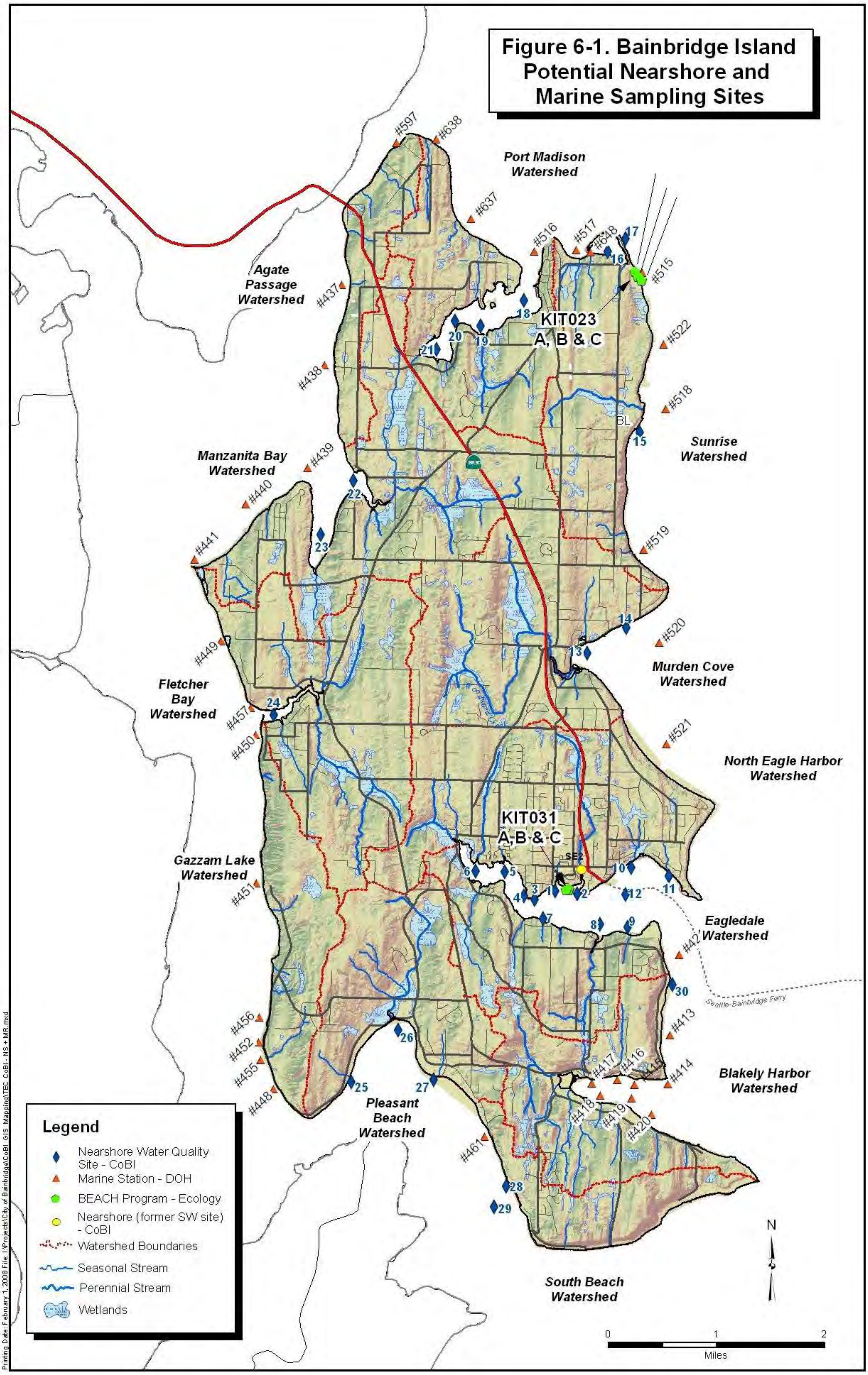

Figure 6-1. Bainbridge Island Potential Nearshore and Marine Sampling Sites

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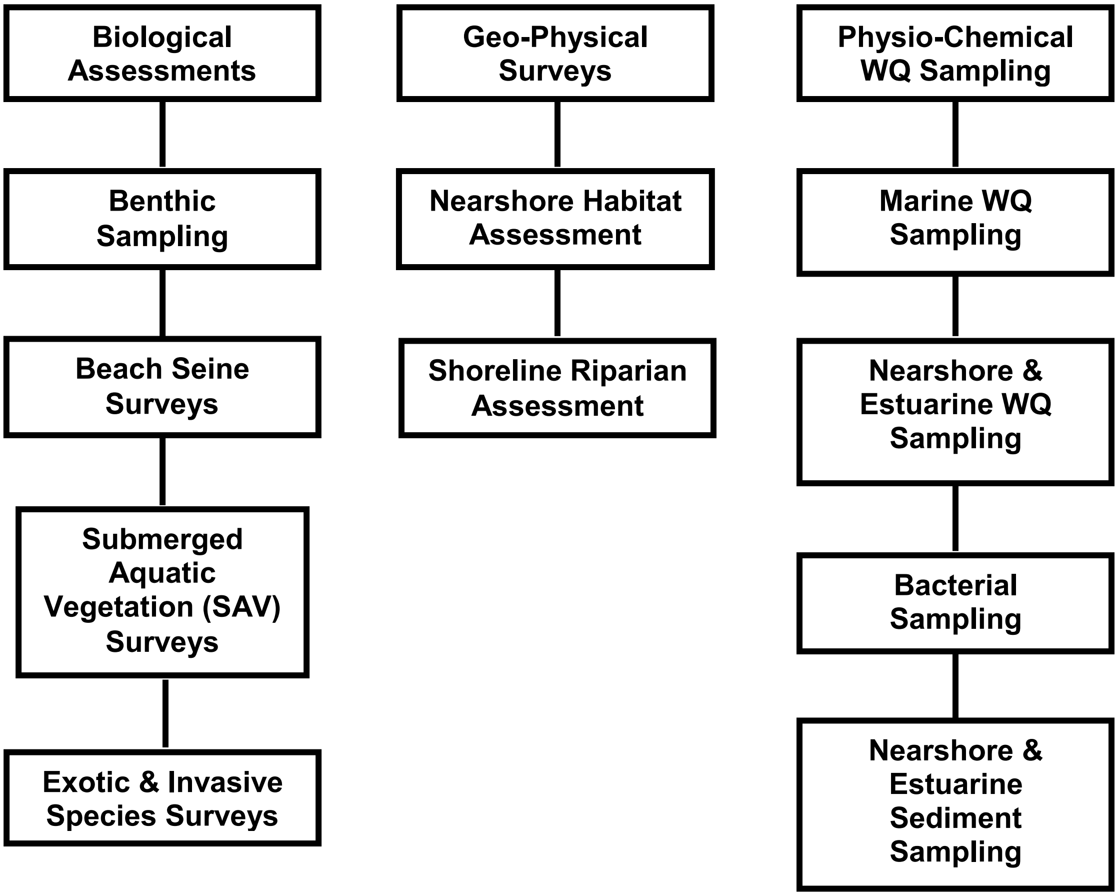

Figure 6-2. Comprehensive Marine-Nearshore Water-Quality Monitoring Approach For Bainbridge Island.

6.4 MARINE-NEARSHORE ECOLOGICAL ASSESSMENTS

The objective of the CWA is to "maintain and restore the chemical, physical, and biological integrity of our waters." Biological assessments and criteria, in addition to chemical, physical and toxicity criteria, are an important tool for maintaining and restoring the health of our waters. Many natural resource agencies are using bioassessments and biocriteria.

The recognition that physio-chemical water quality analyses do not adequately predict or reflect the condition of all aquatic resources has led to the development of measures of biological integrity expressed by biological criteria. Biological surveys, criteria, and assessments complement physical habitat and physio-chemical assessments of water quality by reflecting the cumulative effects of human activities, and natural disturbances on a water body including the possible causes of these effects. The biological approach is best used for detecting generalized and non-specific impairments to biological integrity, and for assessing the severity of those impairments. Then, chemical and toxicity tests, and more refined habitat assessments, can be used to identify probable causes and their sources, and to suggest corrective measures (USEPA 2000).

Biological assessments can be conducted to determine the biological condition of a water body. When bioassessments are conducted at a number of unimpaired sites in similar water bodies, a reference condition is derived that describes the biological integrity of those water bodies. Using the reference condition, biocriteria can be established that will protect the desired biological condition of a specific water body (USEPA 2000).

Bioassessments and biocriteria can be used to better understand the existing quality of the aquatic resources, to define and protect aquatic life, to detect problems other water quality measurements may miss or underestimate, to help water resource managers set priorities for management, and to assess the effectiveness of management actions and to track long term trends in water quality.

Biological assessment in estuaries focus on assessing two key ecosystem components: the biota and their habitat. The condition of the biota depends on the quality of their habitat, including both physical and chemical quality. Habitat sampling and characterization includes common mapped information as well as water column water quality and sediment quality (USEPA 2000).

Estuaries and coastal marine waters span a range of sizes from small sub-estuaries, embayments, and coastal lagoons to large estuaries and nearshore waters. The design of the sampling program should take these factors into consideration. Sampling methods are derived from those commonly used along the coastal United States. Issues that need to be considered when sampling for biological assessment include the assemblages that will be sampled, design strategies, and logistical considerations.

Sampling methods and candidate metrics are developed for four core groups of biological indicator assemblages. These include benthic macroinvertebrates, fish, aquatic macrophytes, and phytoplankton (USEPA 2000). Benthic macroinvertebrates and aquatic macrophytes (plants) have been the most widely utilized indicators of nearshore health (USEPA 2000).

Reference conditions are expectations of the status of biological communities in the absence of anthropogenic disturbances and pollution. They reflect the biotic potential for estuaries and coastal marine waters. Reference conditions can be established with an evaluation of historical data, by sampling other reference sites, based on model prediction, and through expert consensus. In practice, most estuarine bioassessments have used reference sites and expert consensus (USEPA 2000). Criteria for reference sites may include absence of sediment contamination, absence of sediment or water column toxicity, no known dredging or spoil disposal, little, if any, human disturbance, and DO levels meeting water quality criteria. Biocriteria development requires identification of natural factors that control the composition of biological assemblages. The most important factors affecting nearshore organisms are salinity, substrate (sediment) characterization, water depth, wave energy regime, and biogeographic province (USEPA 2000).

A key concept underlying this approach to nearshore bioassessment is that of biological integrity. Biological integrity is defined as "...the condition of the aquatic community inhabiting unimpaired waterbodies of a specified habitat as measured by community structure and function" (USEPA 2000). Biological integrity is an ideal or "natural" condition that estuarine and coastal marine communities can approach when they are minimally impaired by human activities. In order to determine the degree to which these communities approach biological integrity, it is necessary to measure attributes (or indicators) of community structure and function and to be able to distinguish between natural variations and anthropogenic impacts. Various techniques can be used at any level to document the effects of anthropogenic perturbations on biological communities. These techniques include using measures of community condition and change, the presence or absence of indicator taxa, and the use of indexes to compile and evaluate large amounts of biological data for evaluation. Whenever possible, two or more biological assemblages should be utilized because different organism groups react differently to perturbation (USEPA 2000).

Bioassessment is intended to detect biological responses to pollution and perturbation. Routine water quality monitoring for example, can detect effects of nutrient enrichment, but normally is not designed to detect trace levels of toxicants or contaminants, ephemeral pollution events (e.g., episodic oil spills, short-lived toxicants and pesticides, short-term sediment loading), or combined or synergistic impacts. Bioassessment, by monitoring organisms that integrate the effects of environmental changes, may in time detect these effects (USEPA 2000).

Bioassessment, coupled with habitat assessment (i.e., physical and chemical measurements) helps identify probable causes of impairment not detected by conventional physio-chemical water quality monitoring alone. The detection of water resource impairment, accomplished by comparing biological assessment results to the biological criteria, leads to more definitive physio-chemical investigations, which should reveal the cause of the degradation. This, in turn, should prompt regulatory and other management action to alleviate the problem. Continued biological monitoring, with the data collected compared to the biocriteria, can help determine the relative success of the management efforts (USEPA 2000).

6.4.1 Benthic Macroinvertebrates

Because of their tendency to be more sedentary (and therefore are most likely to respond to local environmental impacts) and thus more reliable long-term site indicators compared to fish and plankton, nearshore benthic infauna (macroinvertebrates) are frequently used for water quality assessments. Benthic infauna are also sensitive to disturbances of habitat as they respond fairly quickly with changes in species composition and abundance. Benthic organisms are also important components of the nearshore food web and often act to transport not only nutrients, but also toxicants, to the rest of the ecosystem. In general, monitoring benthic infauna provides an in situ measure of relative biotic integrity and habitat quality. In addition, a larger body of data has been accumulated for this assemblage. Examination of benthic community structure and function is a valuable tool for evaluating the condition of benthic habitats, for monitoring rates of recovery after environmental perturbations and potentially to provide an early warning of developing impacts to the system (USEPA 2000).

There are, however, some limitations related to benthic infauna sampling. Relatively few WQFMPs have the necessary in-house taxonomic expertise to fully support extensive monitoring activities. Current methods can distinguish severely impaired sites from those that are minimally impaired. However, it can be difficult to discriminate between slightly or moderately impaired areas, particularly in estuaries (due to their natural spatial and temporal variability). The condition of benthic habitats can vary over relatively small scales. Therefore, if too few samples are collected from a specified area, the ambient heterogeneity to be expected may be missed, potentially leading to incorrect conclusions regarding the biological and water quality conditions in the area. The cost and effort to sort, count, and identify benthic invertebrate samples can be significant, requiring tradeoffs between expenses and the desired level of confidence in decisions based upon the collected data (USEPA 2000).

6.4.2 Fish

Fish are an important component of nearshore, estuarine, and coastal marine communities because of their economic, recreational, aesthetic, and ecological roles. The abundance and health of the fish community is also the primary indicator used by the public to discern the health of a water body. Fish are good indicators of ecological health because they are relatively sensitive to most habitat disturbances. Being mobile, sensitive fish species may avoid stressful environments, leading to measurable population patterns reflecting that stress. Fish are also important in the linkage between benthic and pelagic food webs. Fish are generally long-lived and are therefore good indicators of long-term environmental effects and they may exhibit physiological, morphological, or behavioral responses to stresses. In addition, fish may exhibit obvious external anatomical pathology due to chemical pollutants. To be useful, fish data may require integration with other data (e.g., water quality or habitat) to be useful for bioassessment purposes (USEPA 2000).

There are some limitations on the use of fish in community bioassessments. Fish represent a relatively high trophic level, and lower level organisms may provide an earlier indication of water quality problems. Some fish are resident species with relatively limited lifetime spatial ranges. Others, like anadromous salmonids, have relatively large ranges, making it difficult to isolate probable causes of degradation that could occur anywhere within their range. Thus, the spatial scale of sampling is an issue and because of seasonal, open water migrations, temporal adjustments may also be necessary. Mobile organisms such as fish may avoid stressful environments, reducing their exposure to toxic or other harmful conditions. Fish surveys may be biased because of recreational and commercial fishing pressures on the same or related fish assemblages. In addition, hatchery stocks can influence native fish populations. Some fish are very habitat selective and their habitats may not be easily sampled. Since they are mobile, spatial variability is very high, requiring a large sampling effort to adequately characterize the fish assemblage (USEPA 2000).

6.4.3 Aquatic Macrophytes

Aquatic macrophytes, including submerged aquatic vegetation (SAV) in estuarine, nearshore, and coastal marine waters may include vascular plants and algae. Vascular aquatic macrophytes, such as eelgrass, are a vital resource because of their value as extensive primary producers in estuaries and nearshore areas. They are a food source for waterfowl, a habitat and nursery area for commercially and recreationally important fish species, a protection against shoreline erosion, and a buffering mechanism for excessive nutrient loadings. The primary productivity that has been observed for SAV communities in estuaries and nearshore areas is among the highest for any aquatic system (USEPA 2000).

Excessive nutrient loadings can lead to prolific phytoplankton and epiphytic macro-algal growth on seagrass, which out-compete the seagrass through shading, as evidenced by the decline of eelgrass in Chesapeake Bay and Puget Sound. Because of the combined high productivity and habitat function of this plant community, any or all of the other estuarine or coastal marine biota can be affected by the presence or absence of macrophytes (USEPA 2000).

Some of the advantages of using aquatic macrophytes in biological surveys include the fact that plants are a sessile community. There is essentially no mobility to rooted vascular or holdfast-established algal plant communities, so expansion or contraction of seagrass beds can be readily measured as an environmental indicator. Measurement of the extent of the SAV community and relative density can be fairly easily accomplished by remote means, such as aerial photography, if the water is clear or shallow. Sampling frequency is reduced because of the relatively low community turnover compared to other biota such as benthic invertebrates or fish. Taxonomic identification in a given area is generally consistent and easily accomplished (USEPA 2000).

Some of the disadvantages of macrophyte surveys include the relatively slow response by the plant community to perturbations making this a delayed indicator of physio-chemical water quality impacts. This could be critical if prompt management responses are needed. Successional blooms of some macrophytes means seasonal cycles need to be identified and accommodated by the survey schedule to avoid misinterpretation of data and false assumptions of water quality impacts. Changes in abundance and extent of SAV are not necessarily related to changes in water quality conditions. Aquatic macrophytes do not stand alone as an indicator of ecosystem condition. Additional parameters, such as water column nutrient concentrations, light penetration, and substrate type are required to properly interpret macrophyte data (USEPA 2000).

6.4.4 Phytoplankton

Many estuaries, nearshore areas, and coastal marine waters can be considered plankton-dominated ecosystems. Therefore plankton assemblages can provide valuable information in assessing ecosystem condition. Plankton provide the most notable indication of eutrophication in estuarine and nearshore environments. Changes in nutrient concentrations can result in long-term changes in estuarine community structure and function and planktonic primary producers are one of the earliest communities to respond. Changes in plankton primary production will in turn affect higher trophic levels of macroinvertebrates and fish. Chlorophyll-a is often monitored as part of water quality monitoring due to the ease and relatively low cost of analysis. Plankton have generally short life cycles and rapid reproduction rates making them valuable indicators of short-term impact (USEPA 2000).

6.4.5 Nearshore-Estuarine Habitat

The condition of the biota depends in part on the quantity and quality of the physio-chemical environment of estuaries, nearshore areas, and coastal marine waters. Habitat conditions are influenced by natural disturbance events and human activities. Climate factors include seasonal variations in precipitation, temperature shifts, and wind or wave patterns. Introduced or exotic species able to influence the environment are also part of habitat. Other habitat related factors include shifts in sedimentation or scouring patterns, dredging and filling, shoreline filling or construction, bulkheading and jetty construction, and a variety of shoreline land-use and navigational practices.

Influence is based on an understanding of the causal mechanisms of natural and anthropogenic stress effects in estuarine, nearshore, and coastal marine ecosystems. Estuaries and nearshore areas integrate ecological processes because they receive and retain matter and energy released in the watershed. Many human activities directly affect aquatic habitat including discharges from agriculture and urban land-use, which contribute materials (e.g., sediment, nutrients, contaminants) to the water body. Biological communities are directly affected by their physical habitat and water quality conditions, and also by direct human activities such as harvesting.

Habitat components include the watershed, the nearshore zone, the water column, and the sediment. An integrated assessment evaluates the condition of estuaries and coastal marine waters by aggregating data on components of both habitat and biota. The habitat component may be damaged by physical stress or chemical degradation from pollution. Thus, habitat studies may help identify causes of biological decline as well as being the important determinant of the types of biotic communities to be expected. This classification function is crucial to proper biocriteria development. Habitat characterization is essential to the proper classification of sites. Although estuaries are by definition transitional zones between fresh water and the sea, and both estuaries and coastal marine waters incorporate many environmental gradients (e.g., salinity, sediment grain size, depth), individual locations and conditions are often defined categorically (USEPA 2000).

6.5 MARINE-NEARSHORE ECOLOGICAL MONITORING

All marine, estuarine, and nearshore ecological monitoring is addressed within existing Bainbridge Island programs and will not be discussed in the CoBI Water Quality Monitoring Plan. Nearshore and estuarine physical habitat assessment is covered in detail in the Bainbridge Island Nearshore Assessment Strategy (Williams et al. 2004) and biological assessments are covered in the Bainbridge Island Salmon Recovery Plan (CoBI 2005). Physio-chemical water quality monitoring guidance is provided in Section 6.6 of this report.

6.6 MARINE PHYSIO-CHEMICAL WATER QUALITY MONITORING

6.6.1 Physio-Chemical Water-Quality Parameters

Monitoring the physio-chemical water quality of the marine-nearshore receiving waters of Bainbridge Island will involve periodic sampling of the water column at selected sites. The main objective of water column sampling is to obtain representative samples from discrete depths at the established sampling point. Water column samples are usually collected with a remote-activated water-bottle sampler. These samplers typically consist of a cylindrical tube with stoppers at each end, along with a closing device that is activated from the surface by a messenger or an electrical signal. Niskin, Van Dorn, and Kemmerer samplers are some of the samplers most commonly used in Puget Sound. Multiple water samplers may be either sequentially attached to a hydro-wire so that several discrete depths can be sampled during one cast, or they may be mounted on a rosette-type frame, which allows replicate sampling at the same depth. Water samples may also be collected with a pump, the intake of which has been deployed to a known and desired sampling depth. Regardless of the sampler type, it should have sufficient capacity to supply adequate volume for the tests required. It is also important for inner surfaces that come in contact with the sample to be made of inert, non-contaminating materials (PSAT 1997). Surface water quality samples can be obtained without the use of water-column sampling devices, using standard grab-sample techniques. Both surface and discrete-depth (water-column) samples will be collected as part of this program.

There are numerous physio-chemical water quality parameters that could be monitored, but there are only a few that have ecological significance. These include the parameters listed below. As a whole, there are still fewer water quality parameters that can be easily and reliably measured in the field. Typical field water quality measurements include temperature, DO, pH, salinity, and turbidity.

- Temperature
- DO
- TOC And DOC
- BOD
- Alkalinity and Hardness
- pH
- Salinity or Conductivity
- Transparency

- TSS
- Nutrients (Nitrogen And Phosphorus)
- Metals
- Petroleum Hydrocarbons
- Organics (Pesticides And Herbicides)

Each of these water quality parameters was discussed in detail in the freshwater section of this report. Therefore, only specific parameters related to marine-nearshore water quality sampling will be discussed here.

Temperature

Water temperature in marine waters shall exceed 13°C (WAC 173-201A-030).

Dissolved Oxygen

DO in marine waters shall not exceed 7.0 mg/l (WAC 173-201A-030).

pH

The pH in marine waters shall be within the range of 7.0 to 8.5 (WAC 173-201A-030).

Salinity

Salinity may be measured in the field with a salinity meter. The meter should be calibrated prior to use according to manufacturer's directions using a standard of known salinity (in parts per thousand [ppt]). The salinity of the standard should be close to the expected salinity of the sampling site. When measuring a sample for salinity, the sample should be swirled or stirred until the meter stabilizes and a measurement is recorded. Salinity may also be calculated from the measured conductivity and temperature of a sample. The conductivity is measured with a conductivity meter that has been calibrated according to manufacturer's directions to known conductivity standards (in µS/cm). Salinity is calculated from the conductivity and temperature according to Standard Method 2520B (APHA, 1985). Gross salinity measurements may also be taken with a field-portable refractometer. This instrument will provide salinity measurements with an accuracy of 1 to 2 ppt(PSAT 1997).

Transparency

Water column transparency is measured with a Secchi disk. A Secchi disk is a weighted, black and white or all white disk lowered into the water body on a calibrated rope or line. The disk is lowered until it is just visible to the sampler and the depth, as measured from the water surface, is recorded in feet or meters. The all-white disk may be preferable in marine waters when the water transparency is high. Either disk, however, is acceptable to use (PSAT 1997).

6.6.2 Marine-Nearshore Physio-Chemical Water-Quality Sampling

The Bainbridge Island marine-nearshore water quality sampling program will include seasonal sampling to establish baseline conditions, periodic sampling for trend analysis, and situational sampling if water quality problems arise or are suspected.

1. Sample Sites – Potential marine and nearshore sample-site locations listed in Table 6-1 (Figure 6-1) will be sampled on a priority basis as established by CoBI staff.
2. Sample Frequency – Nearshore water quality samples should be collected at least once every 2-3 years, depending on the level of development activity within contributing shoreline

area. More frequent sampling may be warranted if a known or suspected water quality problem arises.

3. Sample Timing – Dry season samples should be collected between July and September. Wet season samples should be collected between November and February. In some cases it may be desirable to collect storm-event samples. For example, sampling a nearshore area during or immediately after a storm event to coincide with sampling of a nearby stream or stormwater outfall can provide useful data on the impact of pollution sources on marine-nearshore receiving waters and their potential assimilative capacity.
4. Sample Techniques – All samples will be collected as grab samples using the techniques established in the Puget Sound protocols (PSAT 1997).
5. Sample Teams – Trained teams of CoBI staff and volunteers can collect nearshore water quality samples. Proper training on sampling protocols and QArequirements is essential.

6.6.3 Marine-Nearshore Bacterial Pollution Sampling

The rationale and background information related to FC bacterial pollution monitoring was discussed in the freshwater section and will not be repeated here. All of the CoBI marine and nearshore waters are classified as “primary contact” for bacterial pollution monitoring. Table 6-3 outlines the WQS for marine waters for bacterial (FC) pollution. These WQS are primarily based on protecting the beneficial use of shellfish harvesting.

1. Sample Sites – Potential marine and nearshore sample-site locations listed in Tables 6-1 and 6-2 (see Figure 6-1) will be sampled for microbial pollution. Note, the sites listed in Table 6-2 are currently covered by the Washington Department of Helath (WDOH) Shellfish Monitoring Program and need not be sampled separately by CoBI.
2. Sample Frequency – FC samples should be collected at all stations at least once each month. This sampling frequency was chosen, based on experience, in order to optimize the probability of statistically detecting trends while minimizing both auto-correlation between consecutive samples and the cost of collection.
3. Sample Timing – Sample timing should be randomized within each month within the logistic constraints of the CoBI.
4. Sample Techniques – In the case of microbial pollution sampling for FC, near-surface grab samples should be collected in sanitized collection bottles.
5. Sample Teams – Trained teams of CoBI staff and volunteers can collect FC samples. Proper training on sampling protocols and quality-assurance requirements is essential.

Table 6-3. Water-Quality Standards for Bacteria in Marine Receiving Waters.

Fecal Coliform	Primary Contact	FC organism levels must not exceed a geometric mean value of 14 colonies / 100ml, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 41 col / 100ml.
	Secondary Contact	Enterococci organism levels must not exceed a geometric mean value of 70 colonies / 100ml, with not more than 10 percent of all samples (or any single sample when less than 10 sample points exist) obtained for calculating the geometric mean value exceeding 208 colonies / 100ml.

Note: CoBI marine receiving water sites are considered as “Primary Contact”

FC Grab-Sampling Equipment:

- Field Data Sheets, Clipboard, and Pencils
- Sample Site Map and Directions
- Sterile Bottles (for samples and replicate samples as required)
- Latex Gloves
- Waterproof Marker and Sample Labels
- Thermometer
- Sampling Wand
- Cooler and Ice (maintain sample temperatures below 39°F/4°C)

FC Grab-Sampling Procedure:

1. Monthly samples for bacteria (FC) will be collected at each marine-nearshore site (see Table 6-1). In the case of an identified problem or special-project request, additional sites may be sampled.
2. The objective of marine-nearshore FC sampling is to sample a representative section of marine-nearshore water. If possible, sampling should be conducted during “slack-tide” tidal conditions. In any case, the tidal condition should be noted on the field data sheet.
3. Quality control procedures require that at one sampling point out of every ten (or 10%), a second sample be collected as a field replicate sample. Field replicates give an indication of how much variability there is in the sampling techniques and environment. To perform and record field replicates, the team leader will determine how many replicate samples need to be collected, randomly select sites for replicates, and then notify team members where they will need to collect replicates. Replicate samples should be collected simultaneously with the regular site sample. Gloves are optional but preferred and the sampling wand may be used if desired.
4. Uncap the sample bottle while holding the bottle near the bottom and the cap near the top edge. Do not let anything touch the inside of the cap. Do not set the cap down. Do not rinse the bottle or cap. If the bottle becomes contaminated, discard it. Hold the bottle near its base and plunge it below the water surface with the opening pointing downward. Collect the sample about 6 inches below the surface of the water. If the water is shallow, collect midway between the bottom and the surface. Remove the bottle from the water when it is filled up to the shoulder. If the bottle comes out with the water level below the shoulder, pour out the water and try again. If the bottle comes out full, recap it, shake, uncap, then quickly flick the bottle until the water level decreases to the shoulder. Recap the bottle carefully, without touching the inside.
5. Dry the outside of the bottle and attach a label. Mark the sample with the date and time of the sample, the site name and sample identification number, and “rep” if the sample is a field replicate. Record the same information on the field data sheet. Place the sample bottle in the cooler. The holding time for FC samples is only 24 hours (if kept on ice). Samples collection and delivery should be coordinated closely with the laboratory, especially on weekends and holidays, to ensure proper protocol and analytical methods are followed. FC samples must be tested within 24 hours of sampling. On the field data sheet, enter the time thesamples were turned in, and have an individual from the laboratory initial the time that

the samples were received. Have lab personnel make a copy of the data sheet(s), and bring the original data sheets, along with the equipment, back to the CoBI office. The signed data sheets provide a "chain-of-custody" record that is a QA/QC requirement. The lab will process the samples and submit results to CoBI staff, who will enter the data into the CoBI water quality database. FC colonies will be counted by laboratory technicians using the MF or MPN method, using Standard Methods.

6.6.4 Nearshore Sediment Sampling And Analysis

Because of the depositional nature of solids and the affinity of many pollutants (i.e., metals, organics, nutrients, and hydrocarbons) for particulates, sediments tend to be a repository of long-term pollutant loading. Sediment contamination also tends to be a common problem in areas of intense industrial land-use and other human activities. Therefore, sediment sampling is an effective tool for monitoring the long-term, cumulative impacts on aquatic resources. Establishing current sediment quality also provides baseline for comparison of future sampling results.

Recommended methods for measuring the following conventional sediment variables in Puget Sound are contained in the PSAT Guidance Manual (PSAT 1986):

- Particle Size Distribution
- Total Solids
- Total Volatile Solids
- TOC
- Oil and Grease
- Total Sulfides
- Total Nitrogen
- BOD

This guidance provides standardized methods for sediment collection and analysis in Puget Sound. If these protocols are followed, most data collected in Puget Sound should be directly comparable and thereby capable of being integrated into a sound-wide database. Such a database is necessary for developing and maintaining a comprehensive water quality management program for Puget Sound. Each recommended protocol describes the use and limitations of the respective variable; the field collection and processing methods; and the laboratory analytical, QA/QC, and data reporting procedures. The general collection and holding recommendations for each variable are presented in the QAPP.

1. Sample Sites – Nearshore areas listed in Table 6-1 (see Figure 6-1) should be sampled for sediment quality. Samples should be collected in depositional areas. CoBI staff will determine the priority of nearshore sediment sampling sites.
2. Sample Frequency – Samples should be collected at all stations on a 3-5 year interval.
3. Sample Timing – Samples should be collected during the late summer or early fall during extreme low tide periods.
4. Sample Techniques – Samples should be collected using stainless steel or non-metallic sampling equipment. Three replicate sediment cores will be collected at each site. Field decontamination of sampling gear should be conducted between each sample site. Normally, these replicates will be combined into a single composite sample representative of

that site. In some cases, individual cores may be analyzed independently to assess the spatial extent of sediment contamination. See PSAT (1986 and 1997) guidance manuals for protocol details.

5. Sample Teams – Trained teams of CoBI staff and volunteers can collect sediment quality samples. Proper training on sampling protocols and QA requirements is essential.

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7.0 STORMWATER MONITORING

7.1 STORMWATER

Stormwater is the water that runs off surfaces such as rooftops, paved streets, highways, and parking lots. It can also come from hard, grassy surfaces including lawns, play fields, as well as graveled roads and parking lots. Stormwater is a problem because it is often polluted and can harm human health, drinking water, and fish habitat. Untreated stormwater can contain toxic metals, organic compounds, and bacterial and viral pathogens. It is not safe for people to drink, and is not recommended for swimming. Virtually all of our urban creeks, wetlands, lakes, and rivers are harmed by urban stormwater runoff. Stormwater is the leading contributor to water quality pollution of urban waterways. Urban development causes significant changes in patterns of stormwater runoff, leading to increased flooding during the wet season and decreased stream flows during the dry season. In addition, in some areas, gravelly outwash soils allow rapid infiltration of stormwater. Untreated stormwater discharging to the ground could contaminate aquifers that are used for drinking water.

In 1987, Congress amended the federal CWA by declaring the discharge of stormwater (traditionally considered a non-point source) from certain industries and municipalities to be a point source of pollution requiring NPDES permits or water quality discharge permits. Washington State is delegated authority by the USEPA to implement the water quality permit program. The USEPA stormwater regulations establish two phases for the stormwater permit program. Under Phase I, Ecology has issued stormwater NPDES General Permits to cover stormwater discharges from certain industries and construction sites involving five or more acres, and municipalities with a population of more than 100,000.

NPDES Phase II, which went into effect in 2006, covers smaller municipalities, such as Bainbridge Island. The Phase II regulations expand the requirement for stormwater permits to all municipalities located in urbanized areas and to construction sites between one and five acres. The expansion of the construction site permit is likely to affect thousands of sites. The rule also requires an evaluation of cities outside of urbanized areas that are more than 10,000 in population to determine if a permit is necessary for some or all of these cities. The Phase II municipal general permit must include provisions for public education and outreach, public participation and involvement, illicit discharge detection and elimination, construction site runoff controls, post-construction runoff controls, pollution prevention, and good housekeeping practices.

Ecology has revised its Stormwater Management Manual for western Washington. The manual has been updated to contain new information and technical standards and to expand the applicability beyond Puget Sound to all of western Washington. The objective of the manual is to provide a commonly accepted set of standards and guidance for stormwater control measures. These measures are to be used by local governments, state agencies, and private businesses to control runoff from new development and redevelopment activities. It is generally expected that when these management measures are applied to new development and redevelopment activities the stormwater runoff produced will comply with water quality standards. Significant changes in the manual include changing the thresholds for selection of BMP technology to require nearly all projects to use appropriate on-site stormwater management techniques, increased flow control requirements to address both peak flows and duration of high flows, and the requirement for higher levels of treatment for discharges from some commercial and industrial sites.

7.1.1 Stormwater Outfalls

Typically, engineered (piped) stormwater systems are found in urbaned watersheds when development reaches the medium-density suburban to urban range of intensity. In the rural to low-density suburban range of development, roadside ditches and swales are more common, with stormwater runoff typically directed to surrounding natural areas. At some point in the development continuum, engineered stormwater treatment facilities, stormwater runoff control ponds, and engineered conveyance (piping) networks become the dominant drainage feature of the built environment.

In these urbanized areas, stormwater is generally routed to an outfall(s), which discharges treated or untreated stormwater runoff into a receiving water body (marine or freshwater). In general, stormwater outfalls are ubiquitous features of urbanizing watersheds in Puget Sound. Stormwater outfalls can have relatively small drainage areas, with few land uses. Outfalls that drain roadside ditches or street catch basins are an example of a single-source type of outfall. Outfalls that drain individual parking areas, such as a commercial development would also fit into this type of outfall. On the other end of the urban drainage spectrum, outfalls that drain, via extensive drain-inlet and piping systems, large urbanized areas can collect runoff from a complex mixture of land-use types (i.e., residential, commercial, industrial, and transportation). These outfalls can have multiple sources of pollution and stormwater runoff from these areas often contains a mixture of pollutants.

Figure 7-1 shows the locations of stormwater outfalls within the CoBI. A majority of these outfalls are small in size and are located in the residential areas of the island. Most CoBI outfalls typically drain relatively small drainage areas and most serve a single parcel or land-use type. Many of the CoBI outfalls also drain the perimeter roads that circle much of the island. There are a few outfalls in Winslow that service relatively large drainage basins and collect runoff from urbanized areas. One outfall in the Point Monroe area is representative of roadside, residential and recreational area runoff. Table 7-1 lists the major stormwater outfalls located on Bainbridge Island.

Table 7-1. Major CoBI Stormwater Outfalls Draining To Marine Receiving Waters.

Outfall Location Name and ID	Outfall Diameter (inches)	Dominant Land-Use
Lower Madison (OFL 145)	24	Urban Commercial, HD Residential
Bjune-Madrona (OFL169)	42	Urban Commercial, HD Residential
Eagle-Ferncliff (OFL178)	12	Urban Commercial, HD Residential
Fay Bainbridge (OFL166)	18	LD Residential, Recreational, Forested, roadside runoff
Lynwood Center (OFL50)	24	LD Residential, Lt Commercial, Lowlands

HD = high density
LD = low density
Lt = light
OFL = outfall

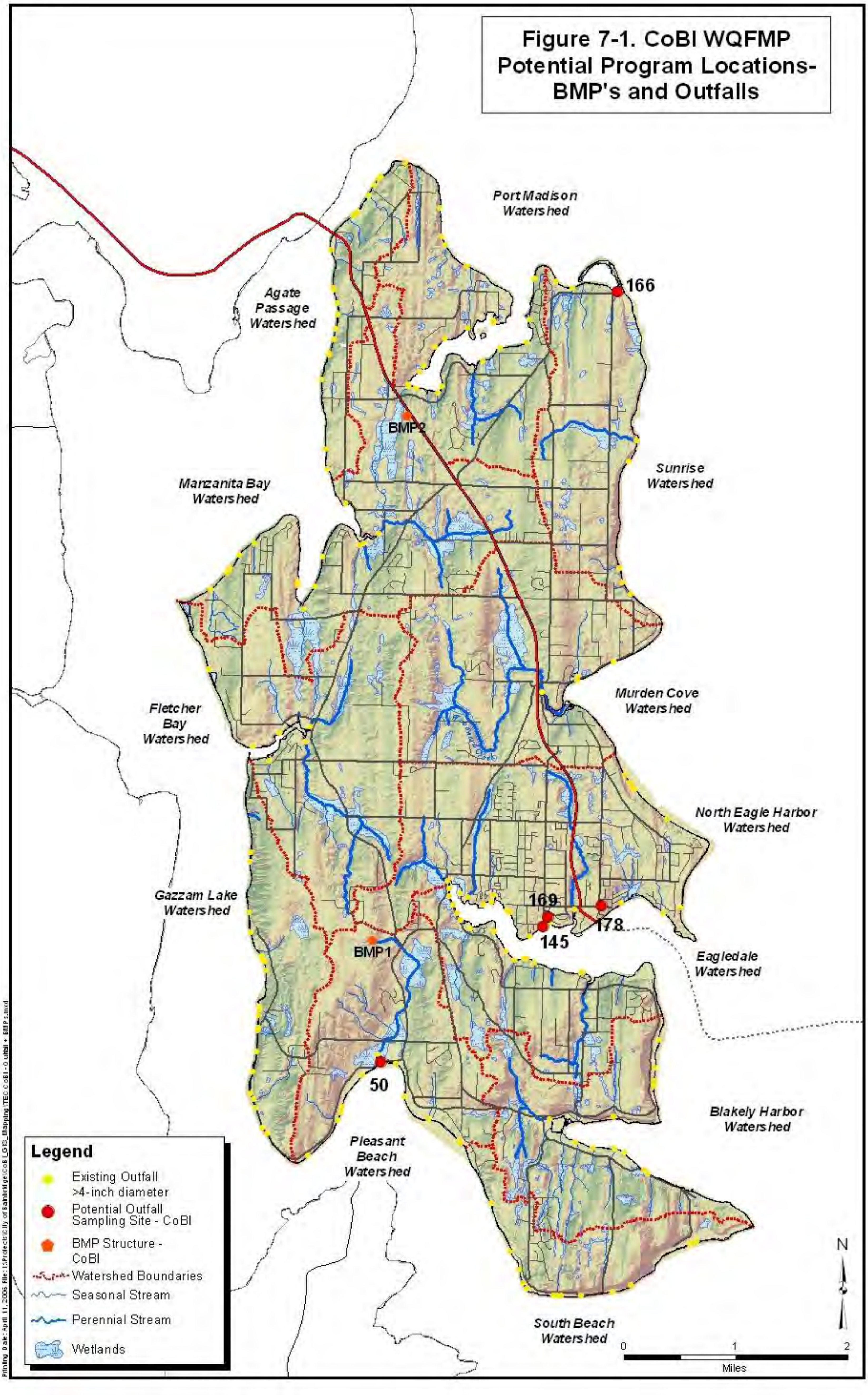

Figure 7-1. CoBI WQFMP Potential Program Locations- BMP's and Outfalls

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7.1.2 Stormwater Best Management Practices

The second main component of capturing, monitoring and sampling stormwater runoff is done through the use of various BMP structures and facilities. Figure 7-1 shows only the locations of stormwater BMP structures and facilities within the jurisdiction of the City of Bainbridge Island that are proposed for sampling. Table 7-2 lists all of the public stormwater BMP facilities located on Bainbridge Island.

Table 7-2. Bainbridge Island Public Stormwater BMP Facilities

Stormwater BMP Structures - CoBI Owned			
BMP ID	**BMP Description**	**BMP Coordinates**	
		Easting	**Northing**
BMP1	Vincent Rd Decant and Recycle Center - 7215 NE Vincent Rd	1216172.77	230855.93
BMP2	CoBI Operation and Maintenance Yard Facility - near intersection of Hidden Cove Rd and SR305	1217787.98	255736.94
BMP3	Asher/Krause	NA	NA
BMP4	Hidden Cove Estates* - Sumanee Pl, Teem Loop Rd, Millstone Pl, Fairfield Pl, Chatri Pl, Trail Heights Ct, and Cambridge Crest Wy on Phelps Rd.	NA	NA
BMP5	Sunrise Estates/ Misty Vale (Keating) – Misty Vale Pl, Chesapeake Pl, and Spray Falls St on Sunrise Dr.	NA	NA
BMP6	Conifer Glade* - Abies Dr, Pinyon Ave, Larix Pl, and Matsu Pl on Koura Rd	NA	NA
BMP7	Koura Farm	NA	NA
BMP8	Public Works Facility (Lamphere Contract Services)	NA	NA
BMP9	Toad Holler	NA	NA
BMP10	Albendan – Daniel Ct on N. Madison Ave.	NA	NA
BMP11	Idel Weis* - Lovgreen and N. Madison Ave.	NA	NA
BMP12	Murden Cove* - Murden Cove Dr on Manitou Beach Rd.	NA	NA
BMP13	Timberlane P.U.D. (Rhoady Lee,III) – Timberlane Pl on N. Madison Ave.	NA	NA
BMP14	Islandwood Estates – Justin Ct on Miller Rd	NA	NA
BMP15	Broodkfield / Castalia (Rob Gilmer)* - Grisdale Ln, Trimble Ave, Hudson Ct, and Stager Ct on New Brooklyn Rd.	NA	NA
BMP16	Fletcher Bay – Water Storage Reservoir	NA	NA
BMP17	Fletcher Bay Estates – Bligh Ct and Pitcairn Pl on Springridge Rd and Miller Rd.	NA	NA
BMP18	Naefurhold* - New Holland Ct on Finch Road	NA	NA
BMP19	Stetson Ridge* - Haley Loop and Ridge Ln on Bucklin Hill Rd.	NA	NA
BMP20	Bainbridge Green (John Burns) – New London Ct on Finch Rd.	NA	NA
BMP21	Chatham Gardens (F.H.A. Builders) – Nakata Ave, Ihland way, and Wallace way.	NA	NA
BMP22	Commodore Lane, 3rd Edition (Ronald Whited) – Commodore Ln on Highschool Rd.	NA	NA
BMP23	Commodore West Div. 2 (Chaffey Corporation)* - Capstan Dr on Highschool Rd.	NA	NA
BMP24	Fernbrook* - Brookcliff Ln on Ferncliff Ave.	NA	NA
BMP25	Fir Acres (Eric Cleaver) – Fir Acre Dr on Grow Ave.	NA	NA
BMP26	Hillandale Phases 1&2* - Village Circle on Weaver Rd.	NA	NA
BMP27	Inner Harbor (Bay View / Midden Pt.)* - Eakin Dr on Wyatt Way	NA	NA
BMP28	Leslie Landing (Dick & Kath Bowen)* - Bromely Pl on Shepard Way	NA	NA
BMP29	Lightmoor P.U.D. (Mark Salo) – Lightmoor Ct on Sportsman Club Rd.	NA	NA

Table 7-2. Bainbridge Island Public Stormwater BMP Facilities

Stormwater BMP Structures - CoBI Owned			
BMP ID	**BMP Description**	**BMP Coordinates**	
		Easting	**Northing**
BMP30	McLauchlan Highlands* - Nakata Pl and Ihland way.	NA	NA
BMP31	Port Blakely Tree Farms (Brainerd / Kuhn) – Halls Hill Rd and Seaborn Rd.	NA	NA
BMP32	Samson Short Plat, Lovell Avenue – Moji Ln on Lovell Ave.	NA	NA
BMP33	Taurnic Subdivision – Taurnic Pl on Wallace Way	NA	NA
BMP34	Tiffany Meadows* - Tiffany Meadows Dr on Ferncliff Ave.	NA	NA
BMP35	Weaver Creek Subdivision – Strawberry Ln and Moji Ln on Weaver Rd.	NA	NA
BMP36	Weaver Landing (John & Alice Tawresey)* - Rosario Pl on Weaver Rd.	NA	NA
BMP37	Wing Point Greens* - Azalea Ave on Wing Point Way.	NA	NA
BMP38	Wing Point On The Green / Fair View (Triad Partnership)* - Cherry Ave, Alder Ave, Park Ave and Dingley Rd.	NA	NA
BMP39	Winslow Landing (Tawresey)* - Kilickitat Pl on Ferncliff Ave.	NA	NA
BMP40	Winslow's Cove* - Cosgrove Ave and Cosgrove St. on Wyatt Way.	NA	NA
BMP41	Woodland Village – Garibaldi Loop on Ferncliff Ave.	NA	NA
BMP42	Blakely Hill Tracts – Corner of Baker Hill Rd and Blakely Ave.	NA	NA
BMP43	Blakely Heights – Blakely Heights DR, Blakely Heights Ct, and Blakely Ct on Baker Hill Rd	NA	NA
BMP44	Emerald Heights – Diamond Pl, Pearl Ct, Ruby Pl, and Emerald Way on Lynwood Center Rd.	NA	NA
BMP45	Pleasant Beach Village / Lynwood Center Condominiums (Harley Unruh)* - Corner of Point White Dr. and Pleasant Beach Dr.	NA	NA
BMP46	Blakely Hill Large Lot (Kelly Samson)* _- Alpena Pl and Barkentine Rd on Blakely hill Rd.	NA	NA
BMP47	Mill Heights Subdivision (Kelly Samson)* - Mill Heights Circle on Rockaway Bluff Rd.	NA	NA
BMP48	Wacky Nut Way As-Built	NA	NA
BMP49	Country Club Road Drainage Project	NA	NA
BMP50	Country Club Road Realignment	NA	NA
BMP51	Heritage Pointe – Belfair Ave, Douglas Dr, Hilltop Dr, Parkview Dr, and Radio School Rd.	NA	NA
BMP52	Sunny Hill	NA	NA
BMP53	West Blakely Development (Samson Family Land Co.) – Kono Rd and Tani Creek Rd on W. Blakely Ave	NA	NA
BMP54	Highway 305 roadside runoff collection ditch outfall pipe (north side of creek) adjacent to surface water collection station at Murden Creek (SW2)	**1224019.52**	**242820.63**

*Declaration of Covenants, Conditions, and Restrictions on-file at COBI Engineering Department

7.2 STORMWATER QUALITY MONITORING

Traditional water quality sampling efforts are typically conducted to characterize a water body for comparison with established water quality standards. Sampling is most often driven by permit requirements from regulatory agencies. Stormwater runoff sampling should be done to evaluate the effectiveness of treatment BMP's or construction site runoff monitoring. Stormwater sampling can also be done to evaluate the effectiveness of ESC practices. A sampling program can also be instituted to identify and quantify a known or suspected water quality problem. Periodic sampling in receiving waters (especially where contact recreation or shellfish harvest is a designated beneficial use) for bacterial (FC) pollution in areas serviced by on-site (septic) wastewater treatment systems is a good example of that situation.

Depending on the objective of the water quality monitoring effort, a number of different sampling strategies will be appropriate. From a temporal standpoint, sampling can be conducted on a periodic basis, seasonally, or event-based (e.g., storm event sampling). Most water quality sampling activities will also have some spatial aspect (i.e., end-of-pipe sampling for stormwater outfalls). The selection of sampling sites is typically based on a number of factors, including water quality constituents of interest, site access and safety considerations, and, most importantly, ensuring the "representativeness" of the sample. Bainbridge Island stormwater outfall sample sites are listed in Table 7-1. Sampling of stormwater treat BMP facilities should also be a component of the overall stormwater monitoring program.

How the sample is collected is also a prime consideration. In some cases, grab samples are appropriate. In other situations, multiple samples should be collected over time and a composite sample created. In some cases, a special type of composite sample is appropriate, a so-called "flow-weighted" composite sample. This type of composite sample consists of multiple samples each collected at specific times and each sample weighted by volume in proportion to the flow at the time the sample is collected. In general, when analyzed, composite samples are used to determine an EMC for a specific period of time or, most commonly, for a single storm event. Most composite sampling is conducted using an automated sampling system. Flow-weighted composite (EMC) samples are especially useful in pollutant loading calculations (combining concentration and flow to get load) such as is needed to determine a total maximum daily load or TMDL.

The Bainbridge Island stormwater outfall sampling plan will include both grab samples and flow-weighted composite samples. Both of these methods will be used to characterize the physio-chemical water quality of individual outfalls. Monitoring is focused primarily on conventional constituents (e.g., sediment, nutrients, bacteria, metals, and petroleum hydrocarbons). When monitoring objectives dictate and funding allows, monitoring for organics (e.g., industrial chemicals, pesticides, and herbicides) at some stations will be necessary. Toxicity testing is typically not part of a routine WQFMP, but may be called for under certain circumstances. Data from the stormwater sampling effort can be used to characterize stormwater quality as part of the NPDES permit process, evaluate the effectiveness of stormwater treatment BMP systems, and/or identify sources of pollution as part of a pollution identification and correction effort. The constituents that will be analyzed for may vary depending on the objectives of each sampling effort, but the basic suite of water quality constituents for which samples will be collected are listed in Table 7-3.

7.3 STORMWATER STORM-EVENT SAMPLING & ANALYSIS

7.3.1 Stormwater Outfall Water Quality Sampling And Analysis

The Bainbridge Island stormwater water quality sampling program will utilize automated sampling equipment to collect composite samples from stormwater outfalls during selected storm events. These water quality samples will be analyzed for a suite of stormwater constituents (to be determined by CoBI, depending on the situation). These composite samples will be analyzed and used to calculate an EMC. Each of the selected stormwater outfalls will be sampled during multiple storm events.

1. Sample Sites – Selected stormwater outfalls will be sampled to establish stormwater water quality characteristics.
2. Sample Frequency – Stormwater outfall stormflow samples should be collected at least once every 3-5 years, depending on the level of development activity within the watershed. More frequent sampling may be warranted if a known or suspected water quality problem arises.
3. Sample Timing – Storm event samples should be collected between October and March. Storm events must meet the minimum criteria of 0.1” of rainfall within a 24-hour sampling period. Storms will be classified as “small” (<0.5” in 24 hours), “medium” (0.5-1.0”), and “large” (> 1.0”). Because small and medium storms are more common in this region, these storm events should be targeted. However, large storm events should also be represented in the suite of storms that are sampled.
4. Sample Techniques – Stormwater samples will be collected using automated sampling equipment, as composite samples using the protocols in the USEPA NPDES Stormwater Sampling Guidance Manual (USEPA 1992).
5. Sample Teams – Trained teams of CoBI staff and volunteers can collect stormflow water quality samples. Proper training on sampling protocols and QA requirements is essential.

7.3.2 Stormwater BMP Water Quality Sampling And Analysis

The Bainbridge Island stormwater water quality sampling program will periodically collect representative grab samples from selected stormwater BMP facilities. These water quality samples will be analyzed for a suite of stormwater constituents (to be determined by CoBI, depending on the situation). Each of the selected stormwater BMPs will be sampled during multiple storm events.

1. Sample Sites – Selected stormwater BMP structures and facilities will be sampled to establish stormwater water quality characteristics.
2. Sample Frequency – Water quality Samples from stormwater BMP facilities should be analyzed at once every least every 3-5 years. More frequent sampling may be warranted if a known or suspected water quality problem arises.
3. Sample Timing – Grab samples should be collected after significant (> 0.5” rainfall in 24 hours) storm events.
4. Sample Techniques – Stormwater BMP water quality samples will be collected by grab sample techniques.
5. Sample Teams – Trained teams of CoBI staff and volunteers can collect stormwater water quality samples. Proper training on sampling protocols and QArequirements is essential.

Based on field evaluations and inspections, only two stormwater BMP facilities are currently recommended for water quality sampling. These are the stormwater retention ponds at the CoBI Public Works Operations and Maintenance Facility and the CoBI Decant Facility. All stormwater BMP facilities should be inspected and maintained on a routine basis and water quality sampling conducted if inspections indicate that the facility may not be functioning as designed.

7.3.3 Stormwater BMP Sediment Sampling And Analysis

Because of the depositional nature of solids and the affinity of many pollutants (i.e., metals, organics, nutrients, and hydrocarbons) to adhere to particulates; sediments tend to be a repository of long-term pollutant loading. Sediment contamination also tends to be a common problem in areas of intense industrial land-use and other human activities. Therefore, sediment sampling is an effective tool for monitoring the long-term, cumulative impacts on aquatic resources. Establishing current sediment quality also provides baseline for comparison of future sampling results. Periodic sampling of sediments from stormwater catch basins or stormwater treatment BMP facilities (i.e., vaults, ponds, swales, etc.) can provide valuable data on the removal effectiveness of stormwater treatment systems. This data is also required for disposal of stormwater BMP sediment.

1. <u>Sample Sites</u> – Selected stormwater BMP structures and facilities will be sampled for sediment quality (Table 7-3).
2. <u>Sample Frequency</u> – Samples should be collected at all stations on a 3-5 year interval or when periodic maintenance is being conducted that will result in sediment disposal.
3. <u>Sample Timing</u> – Samples should be collected during the late summer or early fall after an extended period of low flow.
4. <u>Sample Techniques</u> – Samples should be collected using stainless steel or non-metallic sampling equipment. Three replicate sediment cores will be collected at each site. Field decontamination of sampling gear should be conducted between each sample site. Normally, these replicates will be combined into a single composite sample representative of that site. In some cases, individual cores may be analyzed independently to assess the spatial extent of sediment contamination.
5. <u>Sample Teams</u> – Trained teams of CoBI staff and volunteers can collect sediment quality samples. Proper training on sampling protocols and QA requirements is essential.

Ecology promulgated aquatic sediment standards (Chapter 173-204 WAC) to protect aquatic biota and human health. These standards require that jurisdictions evaluate the potential for a discharge to cause a violation of applicable standards (WAC 173-204-400). Stormwater BMP systems are expected to eliminate or minimize the potential contamination of stormwater and comply with aquatic sediment standards.

Table 7-3. Stormwater Treatment BMP Facilities Selected for Sediment Sampling

BMP Description	Drainage Area (acres)	Type of BMP Facility	Dominant Land-Use
BMP1 (former SE58)	~100	Recycle and decant (Vincent Rd)	Lt. Industrial, municipal, capped landfill
BMP2	~40	CoBI Maint. & Operations Yard Stormwater Retention Pond	Lt. Industrial, municipal

Lt. = light

7.4 CONSTRUCTION SITE STORMWATER RUNOFF

Stormwater runoff from active construction sites can have a significant detrimental impact on receiving waters if not properly controlled and treated.

Ecology recently revised the NPDES and State Waste Discharge General Permit for Stormwater Discharges Associated with Construction Activity (Construction Stormwater General Permit). The Construction Stormwater General Permit authorizes the discharge of stormwater and non-stormwater associated with construction activity. Construction activity refers to the clearing, grading, excavation, and other land disturbing activities which result in the disturbance of one or more acres, as well as disturbance of less than one acre of total land area that is part of a larger common plan of development or sale, if the larger common plan will ultimately disturb one acre or more. The Construction Stormwater General Permit limits the discharge of pollutants to surface waters under the authority of the CWA and limits the discharge of pollutants to surface and groundwater under the authority of Chapter 90.48 Revised Code of Washington (RCW).

In 1990, NPDES Phase I Stormwater regulations addressed construction activities that disturbed five or more acres of land. Ecology issued its first stormwater general permit on November 18, 1992, covering both industrial and construction activities. When reissued in 1995, Ecology decided to move construction activities into a separate permit. The 2005 Construction Stormwater General Permit includes some significant changes. The most significant change is implementing the USEPA NPDES Phase II stormwater rule, which drops the permitting threshold from five acres down to one acre of soil disturbance. Also, the proposed permit includes basic monitoring and reporting requirements to comply with RCW 90.48.555. In addition, construction sites discharging to waterbodies with a TMDL or on the 303(d) list for turbidity, fine sediment, high pH, phosphorus, or other applicable water quality parameters are required to verify, through sampling and analysis, that discharges are not causing or contributing to violations of water quality standards.

The Construction Stormwater General Permit clearly states that stormwater discharges must comply with water quality standards and provides for the presumption that discharges are in compliance with water quality standards if construction sites are in compliance with permit conditions, unless site-specific information shows otherwise. Due to the inherent variability in construction sites, management practices, and weather, it is not possible to characterize the stormwater from construction activities in terms of the average rate or frequency of discharges, or the average or estimated range in pounds per day, of pollutants.

Construction activity involves land-disturbing operations such as clearing, grading, and excavation. Disturbed soils that are exposed to precipitation are subject to erosion resulting in runoff contaminated with suspended sediment. Suspended sediment is the primary constituent in construction stormwater and is commonly measured as TSS and/or turbidity. The current freshwater surface water quality standards (Chapter 173-201A-030) state that turbidity shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10 percent increase in turbidity when the background turbidity is more than 50 NTU (Class AA and A waters).

Construction stormwater may become contaminated from alkaline construction materials (e.g.. concrete grinding or pouring) resulting in high pH. Alkaline construction materials include concrete, mortar, lime, cement kiln dust, Portland cement treated base, fly ash, recycled concrete, and masonry work. The surface water quality standards for pH states that pH shall be within the range of 6.5 to 8.5 (freshwater) or 7.0 to 8.5 (marine water) with a human-caused variation within a range of less than 0.2 units for Class AA waters and 0.5 for Class A waters.

Phosphorus is a potential constituent of construction stormwater because it occurs naturally as a nutrient in native soils. If erosion and sediment control measures are inadequate to prevent the discharge of suspended sediment, phosphorus is likely to contaminate the stormwater. Generally, if turbidity and TSS are controlled with BMP, phosphorus will not be discharged in a significant amount. Total phosphorus criteria are dependant on the trophic state and ambient total phosphorus of the water body.

Petroleum Products such as oil, grease, and gasoline/diesel fuels may contaminate stormwater if they are spilled or leaked from heavy equipment, pumps, fuel tanks, or vehicles. Historical contamination or natural soil conditions may contribute other pollutants to stormwater. Examples might include pesticides, metals (e.g., arsenic, lead, etc.), PCBs, and herbicides.

Federal and state regulations require that effluent limitations set forth in an NPDES permit be either technology-based or water quality-based. Technology-based limitations are based on the treatment methods available to treat specific pollutants or to prevent/minimize the introduction of pollutants. Technology-based limitations are set by regulation or developed on a case-by-case basis (40 CFR 125.3, and Chapter 173-220 WAC). Water quality-based limitations are established to ensure compliance with the surface water quality standards (Chapter 173-201A WAC), groundwater quality standards (Chapter 173-200 WAC), sediment management standards (Chapter 173-204 WAC), or the National Toxics Rule (40 CFR 131.36). The more stringent of these two limits must be chosen for each parameter of concern.

The Construction Stormwater General Permit establishes water quality-based numeric effluent limitations for construction activities that discharge to waters that are either listed as impaired under Section 303(d) of the CWA or with a USEPA-approved TMDL determination. All references and permit requirements associated with Section 303(d) of the CWA pertain to the most current USEPA-approved 303(d) listing of impaired waters that exists when a complete application for coverage is submitted to Ecology. Numeric effluent limitations apply to sites that discharge to waterbodies that are impaired for the following parameters:

- Suspended sediment
- Elevated pH
- Phosphorus

For these sites, a numeric effluent limitation is assigned that is equal to the applicable water quality standards at the point of discharge. For all suspended sediment parameters (turbidity, fine sediment, etc.), Ecology has determined that turbidity is the appropriate surrogate parameter. Therefore the effluent limitation will be equal to the turbidity criterion set forth in the surface water quality standards (WAC 173-201A-030).

The Construction Stormwater General Permit also contains a technology-based narrative effluent limitation, which requires permitted operations to implement all known, available, and reasonable methods of prevention, control, and treatment (AKART) in the form of appropriate BMP technologies for construction activity prior to the discharge of stormwater or non-stormwater to waters of the state. The narrative effluent limitation requires the permittee to prepare and implement an adequate Stormwater Pollution Prevention Plan (SWPPP), with all appropriate ESC BMP technologies installed and maintained in accordance with the SWPPP and the terms and conditions of the Construction Stormwater General Permit.

ESC practices to control construction stormwater, including stormwater treatment systems, must be properly designed, constructed, maintained, and operated to:

1. Prevent pollution of state waters and protect water quality, including compliance with state water quality standards.
2. Satisfy state requirements for application of AKART to wastes (including construction stormwater runoff) prior to discharge to waters of the state.
3. Satisfy the federal technology-based treatment requirements under 40 CFR Part 125.3.

Stormwater discharges are difficult to predict and highly variable in both volume and concentration. Therefore, proper stormwater management is primarily a preventative activity. When a storm occurs, it is often too late to put a source control BMP in place. Once stormwater becomes polluted it is also more difficult and expensive to treat. Permittees who choose to follow the stormwater management practices contained in approved stormwater technical manuals, including the proper selection, implementation, and maintenance of appropriate BMP technologies, including, but not limited to, sampling, monitoring, adaptive management mechanisms, reporting and record keeping (as defined in RCW 90.48.555) are presumed to have satisfied this demonstration requirement and do not need to include within the SWPPP the technical basis which support the performance claims for the BMP technologies being used. This is considered the presumptive approach.

RCW 90.48.555(8)(a) requires Ecology to establish an enforceable adaptive management mechanism in the permit. Adaptive management includes monitoring benchmarks. The Construction Stormwater General Permit contains a turbidity benchmark value of 25 NTU. The turbidity benchmark was established for four primary reasons:

1. Suspended sediment (typically expressed as turbidity or TSS) is the most common pollutant associated with discharges from construction sites.
2. Turbidity it is relatively inexpensive to sample and does not require analysis at an accredited laboratory.
3. Turbidity is an objective indicator used to determine the effectiveness of BMP technologies.
4. Turbidity monitoring is an effective management tool for evaluating and adequately addressing the often highly variable construction stormwater discharges and associated impacts on the beneficial uses of the receiving water.

The benchmark value does not represent water quality criterion or a numeric effluent limit; rather it is a narrative effluent limit. Discharges from a construction site at or below the turbidity benchmark will not cause a water quality violation in the receiving water in most discharge situations. Discharges at or below the turbidity benchmark typically, but not always, indicate that ESC BMP systems are functioning effectively to protect water quality and the beneficial uses in the receiving waters.

Site-specific conditions must still be considered to determine if a discharge of stormwater from a construction site is causing a water quality violation. These conditions include the background turbidity of the receiving water, and the relative volume of the discharge compared to the receiving water. Construction sites change rapidly and have highly variable stormwater discharges (in pollutant concentrations and volumes). For this reason, Ecology purposes a weekly sampling regime for these sites when stormwater is discharged from the site.

If the benchmark is exceeded in a stormwater discharge, the draft permit requires the permittee to take appropriate actions to identify and correct the problem(s) causing the turbidity benchmark exceedence. These adaptive management actions ensure that:

1. Aquatic life and the other beneficial uses of state waters are adequately protected by minimizing the concentrations and volumes of construction stormwater pollutants discharged into surface waters. The effects of turbidity and suspended solids on salmonids (Bash, et al., 2001) was also taken into consideration.
2. Permittees will meet AKART and the requirements of RCW 90.48.555.
3. Permittees who discharge stormwater off site can demonstrate ongoing compliance with the CWA and Chapter 90.48 RCW.
4. Permittees who discharge stormwater off site have greater regulatory certainty in responding to Ecology inspections and citizen lawsuits filed under the CWA.
5. Equity exists between those with coverage under this permit and those with coverage under the Industrial Stormwater General Permit.

In addition to sediment, pH is a recognized pollutant of concern from construction activities. The pH benchmark monitoring is consistent with RCW 90.48.555(8)(a) as an appropriate adaptive management indicator. WA-DOE is concerned with pH at construction sites because these sites typically use or have alkaline materials (e.g., concrete, cement, mortar, etc.). When fresh alkaline materials are exposed to stormwater runoff, they can quickly raise the pH of the stormwater. Several factors play a role in the impact of high pH on surface water quality, such as size of the receiving water and its availability to buffer high pH, quantity of fresh concrete pours (i.e. surface area of exposed concrete), volume of discharge, time of day, exposure to rain, etc. Ecology believes that use of a matrix of parameters to define a trigger for sampling is unworkable. Therefore, Ecology is proposing simple pH sampling triggers that were designed from best professional judgment and data provided by the Washington State Department of Transportation. These triggers are:

1. Greater than 1000 cubic yards poured concrete;
2. Greater than 1000 cubic yards recycled concrete; and
3. The use of soil amendments (engineered soils) such as Portland cement treated base, cement kiln dust, fly ash, etc.

All of these activities, if exposed to rainwater, have the potential to significantly alter the pH in runoff, and potentially in the receiving water. When one of the triggers listed above occurs, the operator must sample pH, at a frequency of at least weekly, but at a duration as determined in condition S4.F, at the location where runoff from the affected area is collected (typically a sediment pond, or other impounded body of water onsite) prior to discharge from the site. The permittee will be required to neutralize the pH if it is over 8.5 standard units, prior to discharging such waters. The first sample should be collected after the first rainfall interacts with the recently applied alkaline material, because that is when pH will be the highest and therefore has the greatest potential to adversely impact the receiving water.

ESC operations and maintenance personnel should be trained and equipped properly. All ESC and BMP systems require some level of maintenance. All construction projects must have a designated ESC supervisor available 24 hours per day/7 days per week. ESC BMP systems will be inspected a minimum of once per week during the wet season and within 24 hours of a significant storm event that produces runoff from the site (0.5" of precipitation in 24 hours). Inspections must be documented and records kept on site. It is recommended that pre-storm inspections be conducted to ensure ESC BMP systems are installed and operating properly. Many jurisdictions require specific ESC materials (such as silt fence, sand bags, straw mulch, etc.) be kept on-site for emergency use.

7.4.1 Construction Site Stormwater Sampling And Analysis

The property owner or developer is responsible for collecting and analyzing construction site stormwater samples from site discharge points during all qualifying storm events. These samples should used to evaluate the effectiveness of on-site ESC practices. Construction site water quality data and ESC BMP effectiveness results will be reported to the CoBI.

1. Sample Sites – All construction sites will be monitored to ensure that proper ESC measures are being utilized.
2. Sample Frequency – All construction sites will be monitored for turbidity at all discharge points at least weekly when there is runoff from the site (identify sample points on SWPPP). Discharges with a turbidity <25 NTU will be considered in compliance with water quality standards and indicate proper ESC BMP operation. More frequent sampling may be warranted if a known or suspected water quality problem arises.
3. Sample Timing – All construction sites will be monitored prior to, during, and after all storm events with > 0.25” of rainfall in a 24-hour period.
4. Sample Techniques – Stormwater samples will be collected using “grab” sample techniques at all construction site discharge points. Turbidity readings >25 NTU, but <250 NTU indicate that ESC BMP(s) are not working properly and must be corrected and/or enhanced. The developer must take immediate action to correct the problem(s) on site and continue to sample until turbidity is <25 NTU. In addition, the results and corrective action will be reported to CoBI staff. If the problem persists for three consecutive days, additional ESC treatment must be initiated. Discharges with a turbidity >250 NTU will be considered a gross violation of water quality standards and indicate poor ESC practices or a major failure of ESC BMP techniques. Notify Ecology and take corrective action immediately (initiate w/in 24 hrs) - continue to monitor turbidity until <25 NTU.
5. Sample Teams – The owner-developer and/or contractor are responsible for collecting construction site runoff samples. Proper training on sampling protocols and quality-assurance requirements is essential. Qualified “third-party” sampling teams can be used to sample construction site runoff.

8.0 BAINBRIDGE ISLAND WATER QUALITY MONITORING PLAN SUMMARY

Due to the complexity of factors that determine water quality and the large number of potential water quality parameters that could be used to characterize the condition of a watershed, its water courses and/or its other water bodies and subsequent receiving waters, the difficulty selecting the most appropriate suite of water quality monitoring parameters is apparent. Table 8-1 lists the recommended water quality monitoring activities and shows the frequency of the water quality monitoring components for Bainbridge Island.

Routine physical water quality field measurements can be collected using a hand-held water quality meter and data-logger. Obtaining analytical water quality data generally requires the collection of a sample and subsequent laboratory analysis. Freshwater water quality field measurements should be obtained during monthly FC sampling, during any targeted water quality sampling, during stream flow measurements or water level fluctuation monitoring, and during annual benthic macroinvertebrate sampling. Marine-nearshore water quality field measurements should be obtained during monthly FC sampling and during any targeted water quality sampling. Flow monitoring data can be collected at those stations where automated equipment has been previously set-up in advance. Other flow data could be collected by manual means at established stations or via spot measurements. Tables 8-2, 8-3, and 8-4 summarize the water quality monitoring components for Bainbridge Island.

Table 8-5 presents the sites intended for specific programmatic uses that will be utilized during the initial phase of the CoBI WQFMP. Periodic updates to these tables, in the form of a technical memorandum, will be issued as programmatic requirements change.

Table 8-1. Recommended Water-Quality Monitoring Activities for Bainbridge Island

Monitoring Activity	Monitoring Frequency	Monitoring Equipment	QA/QC[1] Requirements
Landscape Assessment	2-3 Years	• GIS	• Utilize established protocols • Watershed, riparian, and shoreline scales • Independent data review
Stream flow Monitoring	Weekly to Monthly	• GPS Unit • Digital Camera • Flow-Monitor • Flow-Meter • Field Data Forms	• Utilize established protocols • Fieldwork training • Independent data review
Outfall Flow Monitoring	Weekly to Monthly	• GPS Unit • Digital Camera • Flow-Monitor • Flow-Meter • Field Data Forms	• Utilize established protocols • Fieldwork training • Independent data review
Lake & Wetland Water-Level Fluctuation Monitoring	Weekly to Monthly	• GPS Unit • Digital Camera • Stage Gage • Field Data Forms	• Utilize established protocols • Fieldwork training • Independent data review
Lake & Wetland Transparency Monitoring	Annual (Summer)	• GPS Unit • Digital Camera • Secchi Disk • Field Data Forms	• Utilize established protocols • Fieldwork training • Independent data review
Stream Macroinvertebrate Surveys	Annual (Fall)	• GPS Unit • Digital Camera • Surber Kit • Field Data Forms	• Utilize established protocols • Fieldwork training • Independent data review
Stream Water-Chemistry Sampling	Targeted	• GPS Unit • Digital Camera • Data-Logger • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review
Lake-Wetland Water-Chemistry Sampling	Targeted	• GPS Unit • Digital Camera • Data-Logger • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review
Nearshore-Marine Water-Chemistry Sampling	Targeted	• GPS Unit • Digital Camera • Data-Logger • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review

Table 8-1. Recommended Water-Quality Monitoring Activities for Bainbridge Island

Monitoring Activity	Monitoring Frequency	Monitoring Equipment	QA/QC[1] Requirements
Stormwater Water-Chemistry Sampling	Targeted	• GPS Unit • Digital Camera • Data-Logger • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review
Stream Bacterial (FC) Sampling	Monthly	• GPS Unit • Digital Camera • Data-Logger • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review
Marine-Nearshore Bacterial (FC) Sampling	Monthly	• GPS Unit • Digital Camera • Data-Logger • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review
Stream Sediment Sampling	3-5 Years	• GPS Unit • Digital Camera • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review
Lake-Wetland Sediment Sampling	3-5 Years	• GPS Unit • Digital Camera • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review
Nearshore-Marine Sediment Sampling	3-5 Years	• GPS Unit • Digital Camera • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review
Stormwater Sediment Sampling	3-5 Years	• GPS Unit • Digital Camera • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review
BMP Structure Sampling	Targeted	• GPS Unit • Digital Camera • Sampling Gear • Field Data Forms	• Utilize established protocols • Fieldwork training • Laboratory QA/QC • Independent data review

GPS = Global Positioning System

Table 8-2. Bainbridge Island Freshwater Water-Quality Parameters

Water Quality Parameter	Stream Baseflow	Stream Stormflow	Lakes & Wetlands	Freshwater Sediments
Temperature	X	X	X	
pH	X	X	X	
Conductivity and/or TDS	X	X	X	
Turbidity and or TSS	X	X	X	
Dissolved Oxygen (DO)	X	X	X	
Oxidation Reduction Potential (ORP or eH)				X
Hardness	X	X	X	
Total Organic Carbon (TOC)	X	X	X	X
Fecal Coliform (FC) Bacteria	X	X	X	
Total Phosphorus (TP)	X	X	X	X
Total Nitrogen (TKN)	X	X	X	X
Ammonia-Nitrogen (NH_4)	X	X	X	
Nitrate-Nitrogen (NH_3)	X	X	X	
Total Metals	X	X	X	X
Dissolved Metals	X	X	X	X
Polycyclic Aromatic Hydrocarbons (PAH)	X	X	X	X
Organics (semi-volatiles)	X	X	X	X
Total Petroleum Hydrocarbons (TPH)	X	X	X	X
Pesticides		X	X	X
Flow and Water Level Measurements	X	X		
Water Level Fluctuation (WLF)			X	
Secchi Depth Transparency			X	
BIBI	X			

Notes:
BOLD = Routine Field Measurements (may also be parameters analyzed by a laboratory**)**

Table 8-3. Bainbridge Island Marine-Nearshore Water-Quality Parameters

Water Quality Parameter	Water Column	Storm Event	Sediment
Temperature	X	X	
pH	X	X	
Conductivity and/or TDS	X	X	
Turbidity and/or TSS	X	X	
Dissolved Oxygen (DO)	X	X	
Salinity	X	X	
Secchi Depth Transparency	X		
Total Organic Carbon (TOC	X	X	X
Total Suspended Solids (TSS	X	X	
Fecal Coliform (FC) Bacteria	X	X	
Total Phosphorus (TP)	X	X	X
Total Nitrogen (TKN)	X	X	X
Ammonia-Nitrogen (NH_4)	X	X	
Nitrate-Nitrogen (NH_3)	X	X	
Total Metals	X	X	X
Dissolved Metals	X	X	X
Polycyclic Aromatic Hydrocarbons (PAH)	X	X	X
Total Petroleum Hydrocarbons (TPH)	X	X	X
Organics (semi-volatiles)			X
Tidal Condition	X	X	X
Oxidation Reduction Potential (ORP or eH)			X

Notes:
BOLD = Routine Field Measurements (may also be parameters analyzed by a laboratory**)**

Table 8-4. Bainbridge Island Outfall and BMP Water-Quality Parameters

Water Quality Parameter	Outfall Water Samples	BMP Water Samples	BMP Sediments
Temperature	X	X	
pH	X	X	
Conductivity and/or TDS	X	X	
Turbidity and/or TSS	X	X	
Dissolved Oxygen (DO)	X	X	
Oxidation Reduction Potential (ORP or eH)			X
Hardness	X	X	
Total Suspended Solids (TSS)	X	X	
Total Organic Carbon (TOC)	X	X	X
Fecal Coliform (FC) Bacteria	X	X	
Total Phosphorus (TP)	X	X	X
Total Nitrogen (TKN)	X	X	X
Ammonia-Nitrogen (NH_4)	X	X	
Nitrate-Nitrogen (NH_3)	X	X	
Total Metals	X	X	X
Dissolved Metals	X	X	X
Polycyclic Aromatic Hydrocarbons (PAH)	X	X	X
Total Petroleum Hydrocarbons (TPH)	X	X	X
Organics (semi-volatiles)	X	X	X
Pesticides	X	X	X
Flow and Water Level Measurements	X		
Floatable Material and/or Litter (Gross Solids)	X	X	X

Notes:
BOLD = Routine Field Measurements (may also be parameters analyzed by a laboratory**)**

Table 8-5. BI WQFMP Representative Sites and Associated Use

Site Information				CoBI WQFMP Site Use Catagories																
Site Name	**Site ID**	**Site Type**	**Watershed**	**BMP Structure Sampling**	**[1]Stream Bacterial (FC) Sampling**	**[1]Stream Flow Monitoring**	**Stream Macro-invertebrate Surveys**	**Stream Sediment Sampling**	**[1]Stream WQ / Chemistry Sampling**	**Marine - Nearshore Bacterial (FC) Sampling**	**Nearshore - Marine WQ / Chemistry Sampling**	**Nearshore Marine Sediment Sampling**	**Outfall Flow Monitoring**	**Outfall WQ Monitoring and Sampling**	**Outfall Bacterial (FC) Sampling**	**Lake - Wetland Water Chemistry Sampling**	**Lake & Wetland Transparency Monitoring**	**Lake & Wetland Water Level Flucuation Monitoring**	**Lake-Wetland Sediment Sampling**	**Landscape Assessment**
Pilot Study Use																				
Ravine (Winslow) Creek	SE01	Surface Water	NEGH		X	X	X	X	X											
Murden (Grisdale) Creek	SE16	Surface Water	MDCV		X	X	X	X	X											
WA Maint. Yrd Eagle Harbor	CoBI NS2	Nearshore / Marine	NEGH							X	X	X								
Murden Cove	CoBI NS13	Nearshore / Marine	MDCV							X	X	X								
Lower Madison / Brien-Bjune (LMBB)	OFL169	Outfall	NEGH										X	X	X					
CoBI O&M Facility Pond	BMP2	BMP	MZBY	X																
HWY 305 Drainage @SE16	BMP54	BMP	MDCV	X																
Long-Term Use																				
Land Use/ Land Cover	TBD	Other	Various																	X
Lake and Wetland Sites (Sec 5.7)	See Annual WQFMP Yearly Program Monitoring Goals Memorandum for Specific Details Pertaining to Site Selection and Analytical Information	SW	Various													X	X	X	X	
Stream BIBI (Tbl 5-4)		SW	Various				X													
Stream WQ Sites (Tbl 5-6)		SW	Various					X	X											
Stream FC Sites (Tbl 5-8)		SW	Various		X															
Stream Flow Mon. Sites (Sec 5.8)		SW	Various			X														
Nearshore Sampling Sites (Tbl 6-1)		NS	Various							X	X	X								
Marine Sampling Sites (Tbl 6-2)		MR	Various							X	X	X								
Outfall Monitoring Sites (Tbl 7-1)		OFL	Various										X	X						
Outfall FC Sites (Sec. 5.5 & 7.3.1)															X					
BMP Sites (Tbls 7-2 & 7-3)		BMP	Various	X																
Construction Site Stormwater Runoff (Sec. 7.4)		BMP		X																

[1] These activities to be conducted during background and storm conditions

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