County: Whatcom
Grant No: SEANWS-2018-WhCoPW-00013

PROJECT TITLE: Whatcom Marine Resources Committee Operation and Projects

DELIVERABLES FOR TASK NO: 3.1 (Chuckanut Pollution Identification and Correction QAPP)

PROGRESS REPORT: [ ] FINAL REPORT [ ]

PERIOD COVERED: 10/1/2018 – 09/30/2019

DATE SUBMITTED: 1/11/2019

This project has been funded wholly or in part by the United States Environmental Protection Agency under Assistance Agreement PC-00J90301. The contents of this document do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

North Chuckanut Bay Pollution Identification and Correction (PIC)
Water Quality Monitoring: Fecal Coliform
Quality Assurance Project Plan

Prepared by
Austin Rose
Whatcom County Public Works – Natural Resources
for
Whatcom County Marine Resources Committee
322 N. Commercial St.
Bellingham, WA 98273

January 2019

County: Whatcom
Grant No: SEANWS-2018-WhCoPW-00013

Purpose and Acknowledgements for Unified QAPP:

This Unified Quality Assurance Project Plan (QAPP) was visioned at a January 19, 2012 ad hoc meeting of local government and non-government organization representatives who sample and/or report on fecal coliform. The group's aim is to help alleviate confusion about the meaning of fecal coliform data, where different interpretations can be given to data which appear similar. These different interpretations stem from differences in sampling techniques, quality control procedures, reporting, and water quality standards.

The group decided that its first task was to start at the beginning of the process: the sampling, analysis, and quality assurance/ quality control procedures for fecal coliform. This decision led to a series of meetings and this unified QAPP, whose purpose is to guide individual QAPPs and to provide for consistency in sampling, analyzing, and quality control.

Co-leads of the Unified QAPP work group:
Erika Douglas, Senior Planner- Marine Resources, Whatcom County Public Works,
Wendy Steffensen, Lead Scientist, North Sound Baykeeper, RE Sources

Work Group Members:
Sue Blake, Washington State University Whatcom County Extension
Charlotte Clausing, Northwest Indian College
Nichole Embertson, Whatcom County Conservation District
Ingrid Enschede, Whatcom County Public Works
Annitra Ferderer, Nooksack Salmon Enhancement Association
Oliver Grah, Nooksack Tribe
Julie Hirsch, Hirsch Consulting
Steve Hood, Washington State Department of Ecology
Michael Isensee, Washington State Department of Agriculture
Mak Kaufmann, Washington State Department of Ecology
Tom Kunesh, Whatcom County Department of Health
Wendy LaRoque, City of Ferndale
Cara McKinnon, Washington State Department of Agriculture
Melissa Roberts, Whatcom County Public Works
Jean Snyder, Nooksack Tribe
Eleanor Hines, Surfrider

Assistance provided by RE Sources North Sound Baykeeper Interns, Ashley Westling and Keturah Witter.

Quality Assurance Project Plan

North Chuckanut Bay Pollution Identification and Correction

Water Quality Monitoring: Fecal Coliform

January 2019

Approved by:

This section should include key personnel involved in oversight of the project (e.g. project lead, organization manager, QAQC staff, grant coordinator, grant agency manager, etc.)

_____ Date: _____
Austin Rose, WCPW/MRC Staff, Project Manager

_____ Date: _____
Gary Stoyka, WCPW Natural Resources Manager

_____ Date: _____
Erika Douglas, WCPW, Water Quality Program Manager

_____ Date: _____
Sasha Horst, Department of Ecology, NWSC Communications Manager

Table of Contents

1.0 Abstract

The Whatcom County Marine Resources Committee works to demonstrate the value of the marine environment from the standpoint of human health and well-being. One of the targeted outcomes of the MRC is that marine water quality is healthy enough to sustain native marine species and habitats, and not threaten human health.

This QAPP provides a comprehensive and coordinated plan for water quality monitoring in the Chuckanut Watershed. It outlines a fecal monitoring program specific to North Chuckanut Bay using methods established through Whatcom County's routine fecal coliform monitoring program for watersheds that discharge to marine waters.

The goal of this study is to characterize fecal coliform levels within the Chuckanut watershed and seasonal variation of those bacteria levels and to identify sources of pollutants to guide water quality improvement projects, attain water quality standards and protect beneficial uses (including recreational shellfish harvesting).

The objectives of this study are:

1) To identify fecal coliform concentrations in the Chuckanut watershed to use as a baseline.
2) Evaluate the effectiveness of water quality improvements projects as they are implemented in the watershed.
3) To monitor fecal coliform concentrations during the wet season in North Chuckanut Bay to better determine the relationship between freshwater and marine waters during this period.
4) To provide water quality data to the public and other interested parties.
5) To create community connections to water quality issues by using volunteer monitors

The routine sampling component of the North Chuckanut Bay fecal coliform monitoring program will use a fixed-network of sites sampled one or two times per month in each area of the marine and freshwater. The geographic areas, watershed characteristics, sampling design and sampling methods are described in this document.

2.0 Project Management

This section describes project organization, individual roles, and timelines.

2.1 Distribution List

This section should include representatives of project partners.

Name: Elizabeth Maier
Organization: Office of Shellfish and Water Protection, Washington State Department of Health
Telephone: 360-236-3308 E-mail: liz.maier@doh.wa.gov

Name: Sasha Horst
Organization: Northwest Straits Commission, Department of Ecology
Telephone: 360-482-1084 E-mail: horst@nwstraits.org

Local Department of Ecology certified lab

Whatcom County Marine Resources Committee Members

2.2 Project Organization

The following individuals are responsible for design and implementation of this project, and/or will be the primary data users and decision makers:

- **Gary Stoyka**, (360) 778-6218, WCPW, Natural Resource Manager. Oversight of project management and implementation.
- **Austin Rose**, (360) 778-6286, WCPW, Planner I/MRC Staff. Project lead responsible for development and implementation of monitoring program, sample collection, and data entry, analysis and reporting. Responsibilities include quarterly and annual reports.
- **WCPW Field Staff**, (360) 778-6286. Field staff responsible for assisting with implementation of monitoring program, sample collection, and coordination of sampling schedule with volunteers and project partners.
- **Department of Ecology Certified Lab,** Local DOE certified lab responsible for laboratory analysis of routine water samples.

2.3 Project Schedule

This study will be conducted between November 2014 and August 2016. Table 1 describes the schedule for conducting project tasks. It is a guideline only as unforeseen circumstances and conditions may require adjustment to some or all of the following proposed dates.

Table 1. Timeline for the North Chuckanut Bay Water Quality Study**.**

Task	2014			2015				2016				2017				2018				2019			
Quarter	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Monitoring Plan			x					x				x				x				x			
Water Quality Sampling				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Lab Analysis				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Progress Reports				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	
Draft and Final Report						x				x				x				x				x	

3.0 Problem Definition/Background

This section provides project background, definition of the study area, beneficial uses, potential pollution sources, historic water quality data, and project goals and objectives.

3.1 Background

Shellfish - those both recreationally and commercially harvested - are a key marine resource for Whatcom County. Water quality degradation has been a concern for shellfish growing areas in Drayton Harbor, Birch Bay, Portage Bay and Chuckanut Bay. North Chuckanut Bay is a recreational shellfish harvesting area that supports many species of clams, including littlenecks, manila, butter, horse, and cockles. There have been concerns about bacteria levels in Chuckanut Bay for the past 20+ years. Initial water quality samples collected between 1989 and 1991 showed elevated bacteria levels at the sampling station closest to the shellfish harvesting area, just outside the railroad trestle. In 1994, the WA State Department of Health conducted a shoreline survey of Chuckanut Bay Park, and the resulting report recommended that the recreational shellfish harvesting area in the bay should be closed because of water quality and sewage disposal conditions. However, the area has always been popular for recreational harvest despite the health advisory and shellfish closure.

Throughout 2008 and 2009, Department of Health began fecal coliform sampling at marine and freshwater sites inside the trestle over North Chuckanut Bay. These sites were chosen to augment freshwater sites already sampled on a monthly basis by the Whatcom Marine Resources Committee. Fecal coliform levels were high in both freshwater and marine sites, especially during the spring and summer months. In July 2009, Department of Health decided to discontinue sampling until further improvements were made to suspected fecal coliform inputs to the bay.

The Whatcom Marine Resources Committee will work with the Whatcom County Health Department, Whatcom County Public Works Natural Resources, Washington Department of Health, citizen volunteers, and the local community to conduct more intensive sampling and community outreach, to a establish community-driven Pollution Identification and Correction (PIC) project in North Chuckanut Bay to restore the recreational shellfish area. Through this effort, the community will identify bacteria sources and implement water quality improvement projects to reduce bacteria levels. The water quality data collected from this study is part of a comprehensive water quality monitoring program administered by the County, and will be made available to the public and other interested parties. An annual report will summarize the bacterial water quality concerns within North Chuckanut Bay, outline the water quality monitoring program, characterize the current status of water quality at each monitoring station, and prioritize areas for water quality improvement projects.

3.1.1 Land Use or Study Area Characteristics

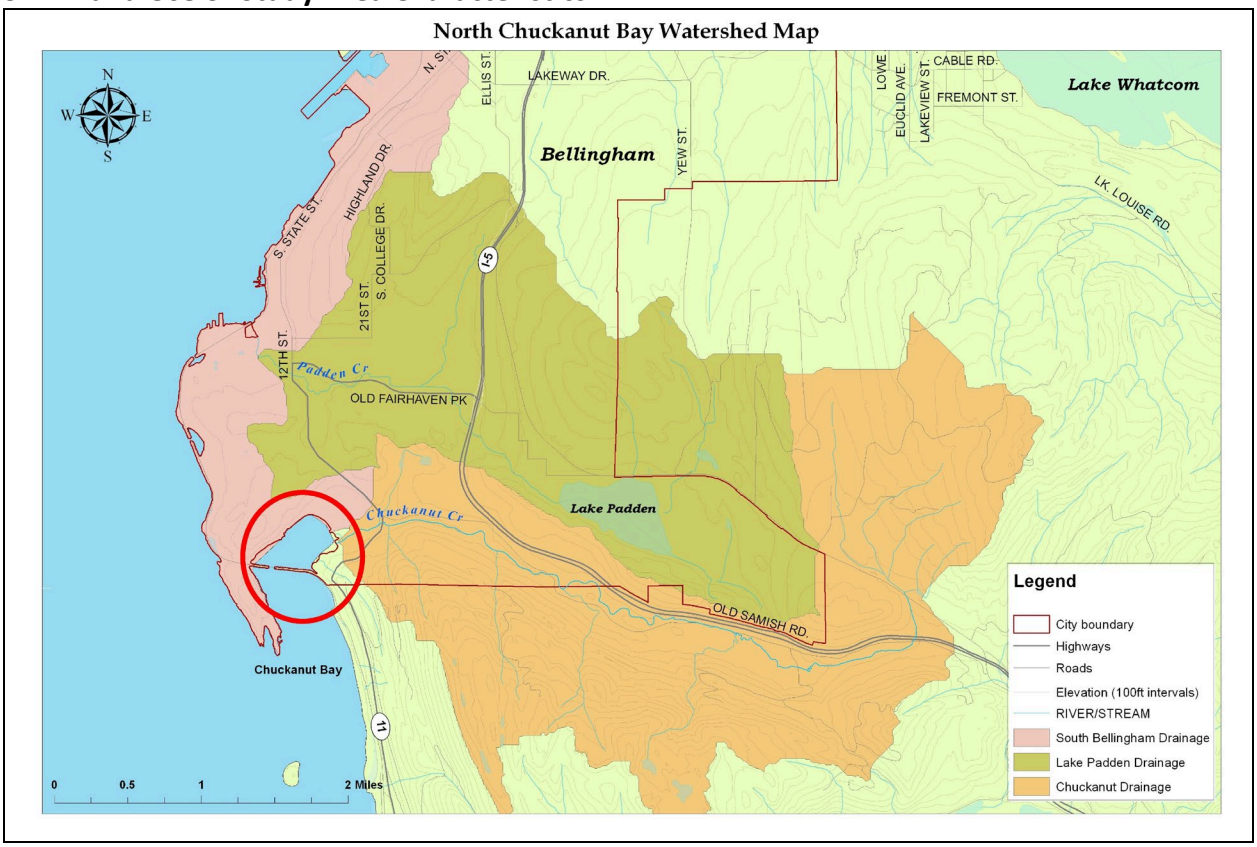

Figure 1. Map of the South Bellingham region depicting Chuckanut Drainage (orange) and North Chuckanut Bay (circled in red).

North Chuckanut Bay, often referred to as Mud Bay, is a small embayment in south Bellingham with a railroad trestle crossing the mouth and restricting tidal circulation. The primary freshwater discharge to this bay is Chuckanut Creek with a seven square mile watershed. There are also smaller drainages from the residential area on the northwest side of the bay and a seasonal creek that runs through the City of Bellingham Woodstock Farm. Land uses in the Chuckanut Creek watershed include a residential area (Chuckanut Village), a forested park with hiking and biking trails (Arroyo Park), and rural residential and forested areas in the upper watershed.

3.1.2 Beneficial Uses

Bacteria criteria are set to protect public health. Department of Ecology water quality standards use fecal coliform as an indicator bacteria. The presence of fecal coliform bacteria indicates the presence of fecal material from human or other warm-blooded animals in the waterbody (Mathieu and Sargaent 2008).

Department of Ecology water quality standards for each watershed are based upon beneficial uses, waterbody classifications, and water quality criteria. Overall, beneficial uses in Whatcom County coastal watersheds include:

- Water supply (domestic, industrial, agriculture, and stock watering)
- Fish, shellfish, and wildlife habitat (including salmonids)
- Recreation including primary contact, sport fishing, boating, and aesthetic

According to Department of Ecology water quality standards (WAC 173-201A) for aquatic life uses, marine waters in Drayton Harbor, Portage Bay, Lummi Island, and Chuckanut Bay are identified as *Excellent Quality* and criteria are set to protect 1) salmonid and other fish migration, rearing, and spawning; 2) clam, oyster, and mussel rearing and spawning; and 3) crustaceans and other shellfish (crabs, shrimp, crayfish, and scallops) rearing and spawning. The Chuckanut watershed is classified as Primary Contact Recreation for bacteria criteria by the Washington State Department of Ecology. In freshwater, the Primary Contact Recreation standards for fecal coliform are 1) a geometric mean of less than 100 FC/100mL and 2) not more than 10% of the samples may exceed 200 FC/100mL. In all marine waters, the standards for fecal coliform are 1) a geometric mean of 14 FC/100mL and 2) an estimated 90th percentile of less than 43 FC/100mL. Table 2 lists water quality standards for marine and freshwater in Whatcom County watersheds.

Table 2. Department of Health Water Quality Standards for Whatcom County watersheds.

Marine Water Standards	**Freshwater Standards (Birch Bay, Terrell Creek, and Cain Creek watersheds)**	**Freshwater Standards (Other Watersheds – including Chuckanut)**
Fecal Coliform Bacteria	Fecal Coliform Bacteria	Fecal Coliform Bacteria
• Geometric Mean- 14 FC/ 100mL • 90th Percentile- 43 FC/100mL	• Geometric Mean- 50FC/ 100mL • Not more than 10% exceed 100 FC/100mL	• Geometric Mean- 100FC/ 100mL • Not more than 10% exceed 200 FC/100mL

Table 3 summarizes how the 2015-2016 fecal coliform results at previously monitored sites in North Chuckanut Bay compare to the applicable state water quality standards for each watershed. The total number of sites, number of sites failing the standard, number of sites partially meeting the standard, and number of sites meeting the standard are summarized.

Table 3. Summary of North Chuckanut monitoring sites in comparison to fecal coliform standards from 2017-2018.

Watershed	**Number of Sites**	**Number of Sites Exceeding Both Parts of Standards[a]**	**Number of Sites Exceeding One Part of Standard[b]**	**Number of Sites Meeting Both Parts of Standards[c]**
Chuckanut Coastal (freshwater)	7	0 (0%)	1 (14%)	6 (86%)
Chuckanut Coastal (marine)	5	1 (20%)	0 (0%)	4 (80%)

a- Indicates frequent elevated fecal coliform levels.
b- Indicates occasional elevated fecal coliform levels (or spikes).
c- Indicates consistently lower fecal coliform levels.

3.1.3 Potential Pollution Sources

The primary cause of pollution in Whatcom County's creeks and marine waters is nonpoint source pollution. Nonpoint source pollution is the term used to describe pollutants that come from many smaller sources, rather than a few large sources. This accumulation of pollutants often results from common activities in both urban and rural areas.

Although there are many types of water pollutants, Whatcom County focuses on fecal coliform bacteria as the primary indicator of surface water quality. Fecal coliform bacteria are found in the fecal matter of human and other warm-blooded animals. While most fecal coliform strains do not cause human illness, detection in a creek or bay do indicate that human and/or animal wastes and the associated harmful pathogens are polluting the water. Examples of pathogen-related illnesses are giardia, salmonella, viral gastroenteritis, hepatitis, and cholera. People are exposed to these pathogens through direct water contact, such as swimming, wading, or eating shellfish from waters with high bacteria levels.

The key potential sources of bacteria that have been identified in Whatcom County coastal drainages are (1) **animal waste** from agricultural operations, domestic pets, waterfowl, and urban wildlife, and (2) **human sewage** from failing on-site sewage systems (OSS), leaking sewers, or cross-connections.

3.1.4 Existing Water Quality Monitoring Data

A variety of water quality monitoring projects have been conducted in Whatcom County over the years providing characterizations of fecal coliform in freshwater systems, stormwater, and marine water. This section provides a brief overview of the freshwater monitoring that has been conducted in North Chuckanut Bay.

<u>Whatcom County Marine Resources Committee - Coastal Drainages</u>

In 2006, the Whatcom Marine Resources Committee began a volunteer water quality monitoring project at Drayton Harbor, Birch Bay, and Chuckanut Bay. Marine Resources Committee members, Whatcom County staff, and volunteers were trained to collect grab surface water samples for fecal coliform analysis and estimate stream flow by time of travel or catchment method. Sample collection and flow measurement occurred monthly during a low tide at up to four sites in Chuckanut Bay dependent on flow conditions. Fecal coliform bacteria was analyzed at a state Department of Ecology certified lab and results were compared to water quality criteria to determine water quality status. Flow data were used to calculate fecal coliform loads.

Table 4 provides a review of the water quality results for the period of August 2006 through October 2014, then February 2015 – December 2017. The fecal coliform water quality

standards include two parts – the geometric mean threshold and the 90th percentile estimate. Geometric means and the percent of samples exceeding the 90th percentile criteria were calculated and compared to applicable water quality standards for each watershed.

- A status of "meets standard" indicates that the site met both parts of the standard.
- A status of "partial" indicates that the one part of the standard was exceeded.
- A status of "exceeds standards" indicates that the site exceeds both parts of the standard.

Table 4. Comparison of Marine Resources Committee Data to Bacteria Criteria for Primary Contact Recreation

		August 2006- October 2014				
Site		**N**	**Geometric Mean**	**% Exceeding 200FC/100mL**	90th Percentile- 43 FC/100mL *(marine)*	**Current Status**
Chuckanut Bay	CB1	69	19.8	15.9		Partial
	CB2	87	25.2	5.7		Meets standard
	CB3	87	68.5	18.4		Partial
	CB4	78	49.7	12.8		Partial
		January 2017 – December 2017				
Chuckanut Bay	CB1	37	11.2	0		Meets standard
	CB2a	57	11.4	0		Meets standard
	CB3	58	14.6	0		Meets standard
	CB4	58	13.2	0		Meets standard
	CB5	35	16.0	0		Meets standard
	CB6	38	29.5	7.7		Meets standard
	CB7	37	48.0	21.4		Partial
	CM1	49	5.5		20.7	Meets standard
	CM2	46	31.2		398.2	Partial
	CM3	47	6.5		31.3	Meets standard
	CM4	49	4.6		17.8	Meets standard
	CM5	48	4.7		15.5	Meets standard

		January 2018- December 2018				
Site		**N**	**Geometric Mean**	**% Exceeding 200FC/100ml**	**90th Percentile- 43FC/100ml (marine)**	**Current Status**
Chuckanut Bay	CB1	47	6.9	0		Meets standard
	CB2a	44	10.4	0		Meets standard
	CB3	45	15.1	6.3		Meets standard
	CB4	45	11.3	0		Meets standard
	CB5	30	15.0	0		Meets standard
	CB6	33	18.9	11.1		Partial
	CB7	25	9.2	8.3		Meets standard
	CM1	37	7.8		36.7	Meets standard
	CM2	34	30.4		283.7	Partial
	CM3	35	6.3		21.0	Meets standard
	CM4	37	5.4		21.7	Meets standard
	CM5	36	6.2		27.3	Meets standard

4.0 Project Description

This QAPP provides the background information used in developing the plan for collection and analysis of water samples from the Chuckanut watershed. The basic field and analytical tasks required to achieve the objectives of this project are 1) collect grab samples of water from designated sites within this watershed and 2) analyze grab samples for the presence/enumeration of fecal coliform. The quality assurance (QA) requirements described in this document are critical to the success of this project and are derived from EPA QA/R-5 EPA Requirements for Quality Assurance Project Plans (EPA 2001) and Washington State Department of Ecology Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies (DOE 2001).

4.1 Overview

This QAPP provides a comprehensive and coordinated plan for water quality monitoring in the Chuckanut Watershed. It outlines a fecal monitoring program specific to North Chuckanut Bay using methods established through Whatcom County's routine fecal coliform monitoring program for watersheds that discharge to marine waters. Whatcom County Public Works (WCPW) coordinates regular monitoring of fecal coliform levels at approximately 90 sites in county watersheds that discharge to marine waters. Water samples are collected by WCPW staff, Northwest Indian College (NWIC) staff, Washington Conservation Corps (WCC) crew members, and trained Marine Resources Committee (MRC) volunteers. Field teams are trained in sampling, storage, and lab delivery protocols. All samples are analyzed at DOE-certified laboratories using standard methods for fecal coliform analysis as described in Section 6.3. Quality control steps are used to measure variability due to sampling methods and conditions. Results are compared against data quality objectives to measure precision of results. Sampling events are pre-scheduled, typically at least a month in advance, and provide data from a broad spectrum of environmental conditions throughout the year. Water quality data are used to prioritize drainages for pollution identification and control projects and to characterize general patterns in declining and improving water quality. The WCPW staff coordinates with County Health, County Planning and Development Services, Whatcom Conservation District, and State departments of Agriculture and Ecology to respond to drainages where elevated bacteria levels are consistently observed.

The routine sampling component of the North Chuckanut Bay fecal coliform monitoring program will use a fixed-network of sites samples one or two times per month in each area. The specific number of sites and frequency of sampling runs are described below for each geographic area. Practical constraints, such as staff or consultant availability, weather conditions, stream flow, and safety concerns may limit the ability to collect the number of samples or at the sampling frequency described in the QAPP.

4.2 Objectives and Goals

The goal of this study is to characterize fecal coliform levels within the Chuckanut watershed and seasonal variation of those bacteria levels and to identify sources of pollutants to guide water quality improvement projects, attain water quality standards and protect beneficial uses (including recreational shellfish harvesting).

The primary objectives of this study are:

1) To identify fecal coliform concentrations in the Chuckanut watershed to use as a baseline.
2) Evaluate the effectiveness of water quality improvements projects as they are implemented in the watershed.
3) To monitor fecal coliform concentrations during the wet season in North Chuckanut Bay to better determine the relationship between freshwater and marine waters during this period.
4) To provide water quality data to the public and other interested parties.
5) To create community connections to water quality issues by using volunteer monitors.

4.3 Study Design

4.3.1 Sampling Component

The North Chuckanut Bay sampling for 2016-2017 will include bi-weekly sampling of 7 freshwater sites and 5 marine sites from October 2016 through September 2017. Monthly sampling will occur if bi-weekly is not possible due to staff or volunteer capacity. Sites (shown in Figure 2) were identified through review of historical monitoring programs, drainage areas, and land use types.

Figure 2. Map of proposed marine and freshwater sampling locations in North Chuckanut Bay

Grab samples will be collected and analyzed for fecal coliform bacteria. This monitoring plan includes sampling freshwater water quality, thus freshwater samples will be collected from the lower Chuckanut Creek sites during low tide to minimize tidal influence, unless conditions do not allow. Salinity will be measured to determine tidal influence.

Data from the routine sampling will provide data sets to meet the following needs:

- Provide an estimate of annual and seasonal geometric mean and 90th percentile for fecal coliform and mean temperature. The schedule should provide at least 5 samples per site during the dry season (April through August) and at least 7 samples per site during the wet season (September through March).

Table 6. North Chuckanut Bay Routine Sampling Stations.

Site ID	Site Location	Lat / Long
CB1	Small Woodstock Farm creek at culvert below dam structure	122°29’.779”W 48°41'59.477"N
CB2a	Chuckanut Creek at Arroyo Park- near stream gage station	122°29'12.814"W 48°42'6.758"N
CB3	Chuckanut Creek 18th Street Alley Bridge	122°29'32.976"W 48°42'3.009"N
CB4	Mouth of Chuckanut Creek @ the end of the footpath from Woodstock	122°29'41.452"W 48°41'58.023"N
CB5	Culvert crossing at Chuckanut Dr.	122°29'15.573"W 48°42'11.053"N
CB6	Small creek under bridge at the end of Fairhaven Ave.	122°29'45.893"W 48°42'8.411"N

CB7	Small outfall by trestle at NW corner of North Chuckanut Bay	122°30'25.547"W 48°41'54.625"N
CM1	Near center of bay within creek channel	122°29'56.511"W 48°41'59.49"N
CM2	Near mouth of Chuckanut Cr.	122°29'51.61"W 48°41'55.77"N
CM3	Just beyond bridge at the end of Fairhaven Ave	122°29'49.051"W 48°42'7.505"N
CM4	Near large boulders along North side	-122°30'6.754"W 48°42'1.977"N
CM5	NW corner of bay near trestle	-122°30'22.837"W 48°41'54.052"N

4.3.2 Sampling Coordination

Field measurements and sampling responsibilities will be shared by Whatcom County Public Works staff, and trained MRC volunteers. Prior to each sampling run, Whatcom County will prepare standard field data sheets, Chain of Custody forms, sample containers, coolers, and sampling equipment as necessary for the sampling groups. All samplers will be trained in the *Whatcom County Fecal Coliform Bacteria Sampling Standard Operating Procedures (SOP)*. All samples will be analyzed by a DOE-certified laboratory in Bellingham, Washington. The quality control comparability section describes the steps that will be taken to ensure consistency between the sampling groups.

5.0 Procedures

This section describes field and laboratory procedures, and sample storage and delivery.

5.1 Field Procedures

Field sampling and measurements will follow SOPs developed for the ad hoc Whatcom County Fecal Coliform Monitoring Group (WCFCMG) or the Washington State Department of Ecology. All SOPs developed for the WCFCMG adhere to Standard Methods (APHA et al. 2005) and are available in the Resource Library of the WRIA1 Watershed Management Project website (http://wria1project.whatcomcounty.org/). Grab samples will be collected directly into sterile bottles supplied by the laboratory. Sample parameters, methods, containers, volumes, preservation requirements, and holding times are listed in Table 7. One field duplicate will be collected in a side-by-side manner, per every "set" of samples to assess field sampling variability. A set equals 10 or fewer samples; thus 8 samples would be considered 1 set and 1 field duplicate would be collected, whereas 11 samples would be considered 2 sets and 2 field duplicates would be collected.

Water samples for laboratory analysis will be delivered to a DOE certified lab within 6 hours of collection, and will be run for analysis within 8 hours of collection.

Prior to grab sample collection, bottles will be labeled with the site identification, date, and time of sample. Site identification, sampling time, field/lab replicates, and other field observation comments will be recorded on the field data sheet. Site numbers, date, and time sampled will be transcribed for each sample to the Chain of Custody form prior to submitting samples to the laboratory.

5.1.1 Grab Samples for Fecal Coliform

Sample collection for fecal coliform analysis will follow the *WCFCMG SOP for Direct Grab Sample Collection with Sample Bottle for Fecal Coliform (2012)*. Water samples for fecal coliform analysis should always be collected prior to other field measurements to minimize opportunities for sample contamination. Sampling methods may vary slightly due to different conditions encountered in the field. Samples should not be collected from stagnant water or eddies. If a sample is collected under low flow conditions (e.g. surface sample) the conditions should be noted. The following is general guidance for sample collection.

Hand Dip Method: This method is typically used to collect samples within reach of the water surface (when standing in or near the stream or from a small boat).

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample.
2. Move to a well mixed location, such as the deepest part of the active channel or another location where a representative sample may be collected. Do not contaminate the sample location by wading upstream of it or by collecting a sample from an area that had been waded. *Note: Use the Extension Pole Method if sampling from a lake.*
3. Hold the base of the sample bottle with one hand and remove the bottle cap. Invert the bottle, reach upstream, submerge the bottle into the water about 6 inches or mid-way between the surface and the bottom if the stream reach is shallow, and then tip the bottle mouth upstream and toward the water surface. Allow the bottle to fill to approximately the shoulder and take it out of the water. If the bottle is overfilled, immediately dump some water from the bottle. *Note: In shallow surface water, ensure that the sample bottle does not touch or disturb the stream bed, potentially contaminating the sample. Submerge the sample bottle to approximately the midpoint of the water column and tip upwards toward the direction of the flow. Samples should be collected far enough below the surface to avoid contamination from surface film and detritus. If a surface sample is unavoidable, note this on the field data sheet.*
4. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

Extension Pole Method: This method is typically used to reach a more representative or undisturbed sample location from the stream bank, or when sampling a lake or slow moving stream.

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample.
2. Secure the sample bottle in the extension pole clamp.

3. Move to a well mixed location, such as the deepest part of the active channel or another location where a representative sample can be reached with the pole.
4. Remove the bottle cap avoiding contamination of the cap or inside of the bottle.
5. Position the bottle over the desired sampling location.
6. Ensure the bottle is on the upstream side of the sampling apparatus while sample is collected. Invert the bottle and in one quick motion submerge the mouth of the bottle into the water column to a depth of approximately six inches or mid-way between the surface and the bottom if the stream reach is shallow. Slowly move the bottle upstream with the bottle mouth tipped toward the surface until the bottle fills to the bottle shoulder. For lake sampling, slowly move the tipped bottle away from the bottle entry point until it fills. If the bottle is overfilled, immediately dump some water from the bottle *Note: In shallow surface water, ensure that the sample bottle does not touch or disturb the stream bed, potentially contaminating the sample. Submerge the sample bottle to approximately the midpoint of the water column and tip upwards toward the direction of the flow. Samples should be collected far enough below the surface to avoid contamination from surface film and detritus. If a surface sample is unavoidable, note this on the field data sheet.* Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

Hand Collection from Pipe Method: This method is typically used to collect samples within reach of the end of a stormwater pipe. A sample of stormwater discharge should be taken as a single uninterrupted event (i.e., grabbed at one time) from a single stormwater outfall.

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample
2. Move to the end of a stormwater pipe where there is moderate flow with turbulence, if possible, so the stormwater discharge will be well-mixed and representative. When sampling a stormwater system, samples should be sampled from the system discharge point first to ensure samples are not contaminated by upstream sampling.
3. Hold the base of the sample bottle with one hand and remove the bottle cap. Hold the bottle under the stormwater discharge with its opening positioned into the flow of water so that water enters directly into the bottle without flowing over the bottle or hands during sampling to prevent contaminating the sample.
4. Allow the bottle to fill to approximately the shoulder and take it out of the water. If the bottle is overfilled, immediately dump some water from the bottle. *Note: Ensure that the sample bottle does not touch the outfall pipe, potentially contaminating the sample.*
5. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

Bridge Sampling Method: This method is typically used to collect samples when standing on a bridge or boat.

1. Label the bottle with sample site ID, date, and time of sample collection prior to collecting the sample.
2. Secure the sample bottle in the bridge sampler and attach the sampling rope.

3. Move to a well mixed location, such as the deepest part of the active channel or another location where a representative sample can be reached with the sampler.
4. Remove the bottle cap avoiding contamination of the cap or inside of the bottle. Hold the cap with your free hand or set the cap upside down on a surface to avoid contamination of the inside of the cap (e.g. road, bridge, or clipboard).
5. Position the bottle and sampler over the desired sampling location. Lower the sampler to the water surface and allow the bottom of the sampler to touch the water surface to remove any debris from the bottom of the bottle and sampler. Raise the sampler off the water surface to allow debris to wash downstream. *Note: Ensure debris is not dislodged from the bridge while lowering the sampler. This step is intended to prevent sample contamination from any debris attached to the sampler.*
6. Without submerging the mouth of the bottle, lower the sampler into the water and allow the current to position the sampler so the bottle is on the upstream side. Rapidly lower the sampler so the mouth of the bottle to a depth of approximately 6 inches. The rapid motion is intended to minimize collection of the surface film. If the bottle is overfilled, immediately dump some water from the bottle. *Note: In shallow surface water, ensure that the sampler does not touch or disturb the stream bed, potentially contaminating the sample. If a surface sample is unavoidable, note this on the field data sheet*.
7. Replace the cap securely, avoiding contamination to the inside of the bottle or cap.

5.1.2 Field Measurements

Following collection of grab samples, temperature will be measured in situ using an alcohol thermometer or calibrated YSI meter. In tidally influenced areas, salinity will be measured using a refractometer or YSI meter. Results will be recorded on the field sheet along with qualitative comments regarding site conditions and adjacent land use activities.

5.2 Sample Custody and Documentation

Water samples for fecal coliform will be placed on ice in a cooler immediately after collection. Samples will be delivered to a DOE certified laboratory with a Chain of Custody form within 6 hours of sample collection. Samples will be analyzed by the laboratory within 8 hours of sample collection. Samples must be below 10^{o}C for fecal coliform when submitted to the laboratory for samples to be accepted for analysis.

5.3 Laboratory Procedures

All water samples will be submitted to a local DOE certified laboratory for analysis. Water samples will be analyzed for fecal coliform bacteria using the membrane filtration, standard method 9222D (APHA et al. 2005). The analytical methods, preservation requirements, expected range of results, and detection limits are summarized in Table 7. Ideally two or more dilutions should be run of the sample to get a countable number on the plate between 20 and 60 colonies (Standard Method 9222B6b). Colonies that are atypical should be verified (Standard Method 9020), or noted in some way by the laboratory.

As part of laboratory quality control, lab blanks of sterile diluent will be analyzed at the start of every sample run, every 10 samples, and at the end of the sample run. Lab blank analysis should show no colonies after incubation. Laboratory duplicates will be analyzed for every set of ten samples. Laboratory duplicates analyze the precision of the lab analysis and help characterize the overall variability.

Table 7. Summary of analytical methods.

Parameter	Method	Lab	Sample Container	Preservation	Holding Time	Precision/ Quantification Limits
Fecal coliform bacteria	Membrane filtration method (MF)	SM 9222D1	125 or 250mL sterile bottle	10 °C, dark	8 hrs (deliver to lab within 6 hrs)	20% RSD2 2 FC/100mL
Fecal coliform bacteria	Multiple tube fermentation method (MPN)	SM 9221E1	125 or 250mL sterile bottle	10 °C, dark	8 hrs (deliver to lab within 6 hrs)	2 FC/100ML

[1]APHA et al. 2005. Standard Methods for the Examination of Water and Wastewater, 21st Edition.
[2] RSD- Relative standard deviation, divided by the mean

6.0 Data Quality Objectives

This section describes project objectives for bias and precision, reporting limits, and measurement quality objectives.

6.1 Bias and Precision

Systematic and random error in measurements due to bias and precision can be influenced by sample collection, handling and storage; contamination of equipment; natural variability in the parameters being measured; and normal variability in factors affecting measurement results (Lombard and Kirchmer 2001). Error due to bias will be minimized by following SOPs for sample collection and storage as described above and use of quality control procedures described in section 6.0. All field staff will receive training on SOPs to ensure consistent methods in sample collection, storage and handling. Bias will be evaluated in the analytical performance through use of positive and negative controls.

Precision will be assessed through the relative standard deviation (RSD) or field duplicates and (optional) relative percent difference (RPD) of laboratory duplicates. One field replicate will be collected for each set of 10 samples during each sampling run (see section 4.1).

6.2 Reporting Limits

Table 8 describes the range, resolution, and accuracy of the lab analysis for the parameters being measured in this project. Each of these elements falls within the range of expected results for this project based upon historical measurements.

6.3 Measurement Quality Objectives

To ensure quality and confidence in the data collected, the measurement quality objectives (MQO) described in Table 8 have been established for this project. The MQOs include both field and laboratory objectives where appropriate. Due to higher variability with low results in bacteria analysis, duplicate pairs for analysis of field precision (field replicates) should be separated into two groups: 1) pairs with a mean less than or equal to 20FC/100mL and 2) pairs with a mean greater than 20FC/100mL (Mathieu 2006).

Table 8. Objectives for data quality.

Analysis	Method/ Equipment	Field Replicate MQO	Lab Duplicate MQO	Reporting Limits and Resolution
Fecal coliform bacteria – membrane filtration	SM 9222D	50% of replicate pairs <20% RSD 90% of replicated pairs <50% RSD	40% RPD[2]	2FC/100mL
Fecal coliform bacteria- multiple tube fermentation	SM 9221E1	50% of replicate pairs <20% RSD 90% of replicated pairs <50% RSD	40% RPD[2]	2FC/100mL

[1] RSD- Relative standard deviation, divided by the mean
[2] RPD- Relative percent difference

7.0 Quality Control

This section describes steps that will be taken to provide quality control in this project. Quality control provides confidence in sampling techniques, measurement results, and analysis of data.

7.1 Field Notes

Standard field data sheets will be used for each sampling run. The field sheets will provide sampling date, sampler names, weather and tidal conditions, sampling site identification, sampling site location, field measurements, and comments regarding water conditions and adjacent activities. Field notes will be cross-checked with Chain of Custody forms prior to being submitted to the laboratory. Field data sheets will be stored in Whatcom County Public Works-Natural Resources project files.

7.2 Sample Identification

Prior to grab sample collection, bottles will be labeled with the site identification, date, and time of sample. Site identification, sampling time, field/lab replicates, and other field observation comments will be recorded on the field data sheet. Site numbers, date, and time sampled will be transcribed for each sample to the Chain of Custody form prior to submitting samples to the laboratory. The number of samples will be cross-checked with field data sheets and Chain of Custody forms prior to submitting samples to the lab.

7.3 Representative Sampling

The experimental design of this project is based upon a random sampling schedule over a two year period. The site location, random schedule and frequency of samples should provide representation of a full variety of spatial, temporal, and hydrologic differences encountered in the Chuckanut watershed. The experimental design is intended to capture both wet and dry season conditions, baseflow, and the most downstream location accessible for each of the major drainages. Samples will be collected at mid-stream locations or where there is adequate flow and mixing. A minimum of thirty samples from both the fresh water and the marine waters are required to adequately compare fecal coliform results with state water quality standards. WAC 173-201A states, "When averaging bacteria sample data for comparison to the geometric mean criteria, it is preferable to average by season and include five or more data collection events within each period…and [the period of averaging] should have sample collection dates well distributed throughout the reporting period."

7.4 Field and Labratory Replicates

Field replicates, or duplicate samples collected at the same site, provide a mechanism for evaluating variability of the individual results for each parameter. One field replicate will be collected, immediately following collection of the routine sample, for each set of 10 samples (see section 4.1). The site(s) at which the field duplicate is collected will be chosen randomly using a random number generator. All field duplicates will be submitted to the laboratory labeled as "Site ID- FD".

For every set of ten samples, one larger samples (typically 150ml) will be collected and submitted for lab duplicate analysis. Laboratory duplicates analyze the precision of the lab analysis and help characterize the overall variability. The precision of the lab duplicates will be measure against the MQOs presented in Section 5.3.

7.5 Comparability

Samples evaluated through this monitoring project will be collected by different sampling teams. All teams will use 2012 *WCFCMG SOP for Direct Grab Sample Collection with Sample Bottle for Fecal Coliform* SOPs (see Procedures section above) for all sampling and measurements collected for the North Chuckanut Bay water quality monitoring project. Efforts will be made to sample all sites on the same day. All water samples will be analyzed by a DOE certified lab selected for project. Field training of SOPs will be provided to all field crew members as needed.

7.6 Completeness

The goal of the sampling strategy is to collect and analyze 100% of the scheduled samples at 100% of the sites for a complete data set. However, unforeseen circumstances can affect the ability to collect or analyze samples such as, but not limited to, low or high flow conditions, site access or other safety issues. This project aims to capture a minimum of five samples during the wet season and five samples during the dry season. Given the currently proposed sampling schedule, this should be an achievable goal.

8.0 Data Management Procedures

The field data sheets, Chain of Custody forms, and laboratory reports will be used to document and track sampling events and results. All of these forms will include sample site, sample date and time, and sampler's name. Field data sheets will also record weather conditions and notes regarding human and animal activity within the drainage. Field data sheets and copies of the Chain of Custody forms will be provided to Whatcom County Public Works within two days of a sampling event when samples are collected by MRC volunteers. Laboratory results and field data will be entered into an Excel spreadsheet by Whatcom County Public Works staff. Data will be uploaded to the WRIA1 Water Quality Monitoring Database (housed at Whatcom County Public Works- Natural Resources) on at least an annual basis. If special targeted sampling takes place such as storm event sampling, the data should either be segregated from the routine sample values or averaged into a single value for calculation of the geometric mean and 90th percentile. The data from targeted events will not represent more than 10% of the overall values. The purpose is to ensure that targeted sampling events do not over-represent extreme events. Field sheets or field notebooks, Chain of Custody forms, sample receipt records (if require shipping) , QC sample records, and laboratory reports will be stored on site at Whatcom County Public Works in project data files for a minimum of ten years in either a hardcopy or scanned format.

9.0 Audits and Reports

Preliminary laboratory results for fecal coliform will be reviewed within two working days of the sampling run and compared to the project objectives. Sample results that exceed 1000 FC/mL will be reported to Whatcom County Environmental Health. Errors or corrective actions identified in any of these reviews will be reported to field or laboratory staff.

The project manager will be responsible for completing quarterly and a final report for the monitoring project. Quarterly reports will be provided to staff listed on the distribution list. Fact sheets summarizing the water quality monitoring project and results will be prepared or updated on a quarterly basis for community outreach efforts. The final report will include a quality control section which will include a description of any errors or corrective actions identified and the associated responses.

10.0 Data Review, Verification, and Validation

All data for this project will be reviewed and verified against the quality objectives described in section 4, *Data Quality Objectives* and *Quality Control*. Field data sheets will be reviewed prior to leaving each sampling sites for missing or unusual data. Field data sheets will be cross-checked with Chain of Custody forms prior to submission to the laboratory. Field staff will compare data entry with field data sheets to verify results. Data entered in Excel files will be considered and marked draft/preliminary until data review and verification has been completed.

Laboratory results will be reviewed by field staff and the project manager for missing or unusual data. If needed, laboratory staff will be contacted to verify reported results and/or estimated results. Data entry into spreadsheets will be double-checked with field sheets.

Laboratory blanks should equal zero. For each sample, countable numbers between 20 and 60 should be used to calculate the fecal coliform concentration (Standard Method 9222B6b). Data will be flagged as estimates if these quality objectives are not met.

Routine results will be compared with field replicates and lab duplicates to ensure the MQOs presented in Section 6.3 are met. Due to higher variability with low results in bacteria analysis, duplicate pairs for analysis of field precision should be separated into two groups: 1) pairs with a mean less than or equal to 20FC/100mL and 2) pairs with a mean greater than 20FC/100mL (Mathieu 2006). Results exceeding objectives will be noted in the Excel dataset, quarterly, and final reports and values of individual samples or entire sets of samples will be flagged as estimates (J), where MQOs are exceeded for field or lab duplicates, respectively. Values that are two times the objectives will be rejected and noted in the dataset and reports. Until these data quality checks have been completed, data should be reported as preliminary.

For every set of ten samples, one larger sample (typically 150mL) will be collected and submitted for lab duplicate analysis. The precision of lab duplicates will be measured against the MQOs presented in Section 6.3.

11.0 Data Quality Assessment

The field staff and project manager will verify that data quality objectives have been met for each monitoring site. If objectives are not met, the project manager will determine results that will be estimated and qualified or rejected as described above. The data quality assessment will be included in the final report.

12.0 References

APHA (American Public Health Association), AWWA (American Water Works Association) and WEF (Water Environment Federation) 2005. *Standard Methods for the Examination of Water and Wastewater*. 21st edition.

Blake, S. and B. Peterson. 2005. *WRIA1 Watershed Management Plan- Phase 1.* WRIA1 Watershed Management Project.

DOE (Department of Ecology) 2001. *Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies*. Washington State Department of Ecology. Publication # 01-03-003.

EPA (Environmental Protection Agency) 2001. *EPA Requirements for Quality Assurance Project Plans*. EPA QA/R-5. United States Environmental Protection Agency. Office of Environmental Information.

Hood, S. 2002. *Nooksack River Watershed Bacteria Total Maximum Daily Load: Detailed Implementation Plan*. Washington State Department of Ecology. Publication # 01-10-060.

Hood, S. and J. Joy. 2000. *Nooksack River Watershed Bacteria Total Maximum Daily Load: Submittal Report*. Washington State Department of Ecology. Publication # 00-10-036.

Joy, J. 2000. *Lower Nooksack River Basin Bacteria Total Maximum Daily Load Evaluation*. Washington State Department of Ecology. Publication # 00-03-006.

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

Mathieu, N. 2006. *Replicate Precision for 12 TMDL Studies and Recommendations for Precision Measurement Quality Objectives for Water Quality Parameters*. Washington State Department of Ecology. Publication # 06-03-044.

Mathieu, N. and D. Sargeant. 2008. *Drayton Harbor Watershed Fecal Coliform Total Maximum Daily Load: Phase 1 Study*. Washington State Department of Ecology, Environmental Assessment Program.

NSEA (Nooksack Salmon Enhancement Association). 2012. *Birch Bay Characterization and Watershed Planning Pilot- Taking Action: Terrell Creek Fecal Coliform and Nutrient Monitoring Project Quality Assurance Project Plan.*

Parametrix and Adolfson Associates. 2006. *Whatcom County Shoreline Master Program Update: Shoreline Inventory and Characterization*. Whatcom County Planning and Development Services.

Peterson, B. 1995. *Drayton Harbor Watershed Action Plan*. Whatcom County Council of Governments.

WAC (Washington Administrative Code) 173-201A. *Water Quality Standards for Surface Waters of the State of Washington.*

WCFCMG (Whatcom County Fecal Coliform Monitoring Group) 2012. *Standard Operating Procedures: Direct Grab Sample Collection with Sample Bottle for Fecal Coliform or Nutrient Analysis.*

WCPW (Whatcom County Public Works-Natural Resources). 2011a. *Water Quality Monitoring Project: Final Technical Report.* Whatcom County Marine Resources Committee.

WCPW (Whatcom County Public Works-Natural Resources). 2011b. *Whatcom County 2011 Water Quality Report and Priority Areas: Fecal Coliform in Coastal Drainages.*

Appendix A: Definitions

303(d) List[1]: Section 303(d) of the federal Clean Water Act requires Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality limited estuaries, lakes, and streams that fall short of state surface water quality standards, and are not expected to improve within the next two years.

Clean Water Act[1]: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Extraordinary Primary Contact[1]: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

Fecal Coliform[1]: The portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 plus or minus 0.2 degrees Celsius. Fecal coliform bacteria are indicator organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 mililiters of water (cfu/100mL).

Field Duplicate[1]: A generic term for two (or more) field samples taken at the same time in the same location. They are intended to represent the same population and are taken through all the steps of the analytical procedure in an identical manner and provide precision information for the data collection activity.

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

> **Calculation: Multiply all of the data points, and take the n-th root of this product.**
> Example: Suppose you have data (Enterococci bacteria/100 mL sample) from different dates:
> 6 ent./100 ml, 50 ent./100 ml, 9 ent./100 ml, 1200 ent./100 ml
> Geometric Mean = 4th root of (6)(50)(9)(1200) = 4th root of 3,240,000
> Geometric Mean = **42.4 ent./100 ml**
> http://www.waterboards.ca.gov/water

In situ[2]: In place, the original location, in the natural environment.

Lab Duplicate[2]: Two or more representative positions taken from one homogeneous sample by the laboratory and analyzed in the same laboratory. Laboratory duplicate samples are quality control samples that are used to assess the intralaboratory preparatory and analytical precision.

Loading Capacity[1]: The greatest amount of a substance that a waterbody can receive and still meet water quality standards.

Nonpoint Source[1]: Pollution that enters any waters of the state from any dispersed land-based or water-based activities, including but not limited to atmospheric deposition, surface water runoff from agricultural lands, urban areas, or forest lands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the NPDES program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Point Source[1]: Sources of pollution that discharge at a specific location from pipes, outfalls, and conveyance channels to a surface water.

Pollution[1]: Such contamination, or other alteration of the physical, chemical or biological properties, of any water of the state. This includes change in temperature, taste, color, turbidity or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive or other substance into any waters of the state. This definition assumes that these changes will create a nuisance or render such waters harmful, detrimental or injurious to (1) public health, safety or welfare, (2) domestic, commercial, industrial, agricultural, recreational or other legitimate beneficial uses, (3) livestock, wild animals, birds, fish or other aquatic life.

Primary Contact Recreation[1]: Activities where a person would have direct contact with water to the point of complete submergence including but not limited to, skin diving, swimming and water skiing.

Quality Assurance[2]: An integrated system of activities involving planning, quality control, quality assessment, reporting and quality improvement to ensure that a product or service meets defined standards of quality with a stated level of confidence.

Quality Control[2]: The overall system of technical activities whose purpose is to measure and control the quality of a product or service so that it meets the needs of users.

Relative Percent Difference[2]: A measure of precision in the lab used as a quantitative indicator of QA/QC for repeated measurements where the outcomes are expected to be the same. This calculation is used to compare two measurements to determine the precision of the technique used; the lower the Relative Percent Difference, the more precise the results. This calculation can also measure accuracy when one of the results is the true value (such as the quality control lab results for a split sample or the actual concentration of a known or unknown sample).

$RPD = [X_1 - X_2\}/X_{ave} \times 100$, where:
X_1 = concentration observed with the first detector or equipment;
X_2 = concentration observed with the second detector, equipment, or absolute value; and
X_{ave} = average concentration = ((X1 + X2) / 2)

Relative Standard Deviation[2]: A measurement of precision in the field also known as the absolute value of the coefficient of variation. This calculation allows the standard deviations of different measurements to be compared more meaningfully; this measures the precision of the person/s during a set of

individual tests (replicates) performed for one specific water quality parameter. The lower the RSD, the more precise the results.

RSD = 100*(standard deviation/|mean|)

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

Watershed[1]: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river or lake at a lower elevation.

[1] www.ecy.wa.gov/biblio/0803105.html
[2] http://www.epa.gov