2018-2019
LUMMI NATION
WATER QUALITY ASSESSMENT REPORT

June 28, 1993 to December 31, 2019

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EXECUTIVE SUMMARY

The goals of the Lummi Nation Surface Water Quality Monitoring Program (WQM Program) are to:

1. Document ambient water quality and water quality trends on the Lummi Indian Reservation (Reservation);
2. Evaluate regulatory compliance of waters flowing through and onto the Reservation, including compliance with Lummi Nation Surface Water Quality Standards; and
3. Support the development and implementation of water quality regulatory programs on the Reservation.

The purpose of this report is to:

1. Present the surface water quality data collected during the calendar years 2018 and 2019;
2. Compare the 2018 and 2019 results to data from the period of record;
3. Present interpretations of these data with respect to WQM Program goals; and
4. Provide the U.S. Environmental Protection Agency (EPA) documentation required pursuant to the *Final Guidance of Awards of Grants to Indian Tribes under Section 106 of the Clean Water Act* (EPA 2006a).

The Reservation consists of approximately 12,500 acres of uplands, 38 miles of marine shoreline, and 7,000 acres of tidelands. Water quality on the Reservation is complex for several reasons. It is located in the estuaries of the Lummi and Nooksack rivers where marine and fresh water interact; the water column may have varying degrees of salinity-based stratification; and water can flow upstream, downstream, or be stagnant at many of the sampling sites depending on the seasons, tides, and weather conditions.

Water quality on the Reservation during the 2018-2019 reporting period was largely similar to water quality conditions in previous years. Characteristic uses were not fully supported in any of the freshwater watersheds or marine waters on the Reservation. Water quality at all sites except one failed to meet one or more of the water quality standards during the 2018-2019 reporting period. This report examined the characteristic uses individually and found areas of concern for all uses.

Of greatest concern is the seasonal closure of a portion of Portage Bay, which is used by members of the Lummi Nation for ceremonial, subsistence, and commercial shellfish harvest. Geometric means and estimated 90^{th} percentiles in the Portage Bay shellfish growing area increased throughout the reporting period, in both the closed and open portions of the bay. This is a reversal of improvements in water quality observed during the previous four years (2014-2017), and is most apparent during the fall season. The surface waters flowing into Lummi Bay and the surface water of the Nooksack River continue to exhibit the poorest water quality of the sites sampled on the Reservation. The continuing poor water quality at sites along the northern Reservation boundary and all tributaries to Lummi Bay, particularly with respect to elevated fecal coliform bacteria contamination, is also a major concern because these waters flow into the Lummi Bay shellfish harvesting area. Marine water quality in Lummi Bay, however, has improved such that the single "Threatened" status site in the Lummi Bay growing area was removed from Threatened or Concerned status as of year-end 2019.

Reservation freshwaters continued to exhibit low dissolved oxygen concentrations, high temperatures, and, to a lesser extent, pH excursions above and below the criteria, which compromise salmonid use of these waters. Of greatest concern are the sites that fail to meet standards for all three parameters: temperature, dissolved oxygen, and pH.

Reservation freshwaters also continue to fail to support recreational contact uses due to failure to meet the enterococcus standard, and nutrient concentrations are higher than expected for reference conditions. This is consistent with the location of many Reservation waters at the bottom of modified watersheds with widespread agricultural and developed land uses.

The water quality parameters at the monitoring sites during the 2018-2019 reporting period generally followed the trends of the previous 4-10 years. That is, generally elevated bacteria levels, higher temperatures, and lower dissolved oxygen levels compared to the Lummi Nation Water Quality Standards (17 Lummi Administrative Regulation [LAR] 07). The water quality parameters are generally more degraded in the sites further inland, and gradually improve downstream towards the marine waters on the Reservation.

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1. INTRODUCTION

The purpose of this introductory section is to present the goals of the Lummi Nation Water Quality Monitoring Program (WQM Program), identify staff changes during the 2018-2019 reporting period, summarize WQM Program changes and improvements during the 2018-2019 reporting period, and provide an outline of the report contents.

1.1. Purpose Statement

The WQM Program was initiated in June 1993 to establish the ambient conditions of the Lummi Indian Reservation (Reservation) surface waters, which are a component of Lummi Nation Waters.[1] Since 1993, the WQM Program has grown to include targeted sampling, groundwater monitoring, and continuous water quality data collection under nine projects. Water quality data are used to evaluate regulatory compliance of waters flowing through and onto the Reservation including compliance with Lummi Nation Surface Water Quality Standards (17 Lummi Administrative Regulation [LAR] 07); to identify and track water quality trends; and to support the development and implementation of water quality regulatory programs on the Reservation.

The purpose of this report is to describe the WQM Program and to summarize the surface water quality data collected during the 2018-2019 reporting period; compare the 2018-2019 reporting period results to data from the period of record, and present interpretations of these data with respect to WQM Program goals. This report is also intended to provide the EPA documentation required pursuant to the *Final Guidance of Awards of Grants to Indian Tribes under Section 106 of the Clean Water Act* (EPA 2006a).

This report contains data collected pursuant to associated work plans and grant agreements between the Lummi Nation and the EPA. Summary statistics for data collected between January 1, 2018 and December 31, 2019 are presented in the appendices. Data collected during the 2018-2019 reporting period were validated and exported to EPA's Water Quality Exchange Network (WQX) for inclusion in the STORET/Water Quality Portal database. Data collected in 2018 were exported on March 11, 2019 and data collected in 2019 were exported on March 16, 2020.

1.2. Program Management

Although the Water Resources Manager of the Lummi Natural Resources Department (LNR) Water Resources Division (LWRD) is responsible for the overall success of the WQM Program, operation and implementation of the Program is delegated to the Water Resources Specialist II. Several changes in the staff roles and responsibilities of day-to-day management of the WQM Program occurred during the 2018-2019 reporting period.

[1] Lummi Nation Waters are defined as follows: All fresh and marine waters that originate or flow in, into, or through the Reservation, or that are stored on the Reservation, whether found on the surface of the earth or underground, and all Lummi Nation tribal reserved water rights (Lummi Code of Laws [LCL] 17.09).

During 2018, field data collection and quality assurance/quality control (QA/QC) activities were primarily conducted by the Water Resources Specialist II and Water Resources Technician II. During June-September 2018, the Water Resources Technician II took over the day-to-day implementation of the WQM Program with support from various LWRD staff. In December 2018, a Natural Resources Technician II was hired to assist the Water Resources Specialist II and Water Resources Technician II with field data collection and QA/QC activities. Following a training period, the Natural Resources Technician II and Water Resources Technician II conducted the majority of field data collection and QA/QC activities during 2019 with support from and supervision by the Water Resources Specialist II. The Water Resources Specialist II continues to be responsible for the day-to-day oversight, operation, and implementation of the WQM Program under the direct supervision of the Water Resources Manager.

In October 2018, updated quality management documents for the WQM Program were approved by the EPA (LWRD 2018a-t). The previous *Lummi Nation Water Quality Monitoring Program Quality Assurance/Quality Control Plan – Version 4.0* (LWRD 2010) was reviewed, revised, and reorganized into a new quality management system framework that used a tiered approach and separate documents to address the various components of the WQM Program. A Quality Management Plan (QMP) is the umbrella document outlining the overall quality management system for the WQM Program, Quality Assurance Project Plans (QAPPs) were developed for each individual project contained within the WQM Program, and Standard Operating Procedures (SOPs) were developed for each instrument or parameter measured.

During the 2018-2019 reporting period, field data collection and QA/QC activities were conducted following the requirements of the relevant quality management document: *Lummi Nation Water Quality Monitoring Program Quality Assurance/Quality Control Plan – Version 4.0* (LWRD 2010) was followed through October 2018, the 2018 quality management system documents (QMP, QAPPs, and SOPs) were followed after October 2018 (LWRD 2018a-t), and the QAPP for the Continuous Temperature Monitoring Project (LWRD 2015c) was followed for continuous temperature data collection throughout the reporting period.

1.3. Program Improvements

When the WQM Program was initiated in 1993, the collected data were recorded in field books and lab reports and then transcribed into computerized spreadsheets for analysis. Since 1993, several data storage, management, and analysis capabilities have been developed. In 2006, the first version of the Lummi Nation Water Quality Monitoring Database (Water Database) was developed by the Database Manager. Historical data were transcribed into the Water Database and field data collected were entered directly into the Water Database in real time using an iPad tablet that connects to Lummi Nation servers via a Citrix Receiver application. Paper data collection forms are still carried as a back-up system in case of internet connection loss or if failure of the data entry device occurs during a sampling run.

A Continuous Data Management Database (LNR 2010b) was developed by the Database Manager in 2010 to manage, store, and display continuous datasets. Continuous data collected during the 2018-2019 reporting period include temperature and aquifer level data.

Efforts to make the WQM Program more accessible to the general public included the development of a LNR website during 2010 and several website updates. Water quality assessment reports, the current quality management system documents, user guides for the databases, and other documents are posted on the LIBC website (https://www.lummi-nsn.gov/Website.php?PageID=85, see "Available Documents" link and "Data Quality" subpage).

1.4. Report Overview

This report is organized into the following sections.

- Section 1 is this introduction.
- Section 2 is a description of the Lummi Nation Waters and the Lummi Nation's Water Resources Management Program.
- Section 3 is a description of the surface and ground water quality monitoring objectives.
- Section 4 is a description of the Lummi Nation's surface and ground water quality assessment methods.
- Section 5 is a summary of the Lummi Nation Surface Water Quality Standards.
- Section 6 summarizes compliance with the Lummi Nation Surface Water Quality Standards during the 2018-2019 reporting period and recent previous years (2008-2017 or 2014-2017, depending on the parameter and watershed) and identifies trends in key water quality parameters at representative sites.
- Section 7 is a discussion of the water quality sampling results by topic (characteristic uses and areas of concern).
- Section 8 is a summary and conclusion section.
- Section 9 is a list of references cited in this report.
- Section 10 is a list of acronyms and abbreviations
- Section 11 provides appendices of data collected during each of the two reporting years (2018-2019) by year. Five appendices (A-E) are appended for each of the reporting years.
    - Appendix A provides summary statistics (observations, mean, minimum, and maximum) for non-bacterial primary parameters by site for the 2018 and 2019 reporting years and the period of record.
    - Appendix B provides summary statistics (observations, mean, minimum, and maximum) for non-bacterial secondary parameter results by water quality class for the 2018 and 2019 reporting years and the period of record.
    - Appendix C provides summary statistics (observations, maximum, 30-sample geometric mean, and 30-sample estimated 90th percentile) for bacterial parameters by site.[2]

[2] Note that Appendix C only includes 30-sample geometric mean and estimated 90th percentile (metric used for National Shellfish Sanitation Program) while the bacterial analysis in Section 7 of this report includes calculation of

- Appendix D provides a series of maps graphically showing compliance status of sites monitored for the parameter in question during the 2018 and 2019 reporting year.
- Appendix E provides a compliance summary (number of sites sampled, number compliant, number noncompliant, and compliance rate) for the single-parameter standards (fecal coliform, enterococci, dissolved oxygen, and pH) by water quality class.

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seasonal geometric mean and the percentage of samples exceeding the 90^{th} percentile criterion to evaluate compliance with the Lummi Nation Surface Water Quality Standards.

2. LUMMI NATION WATERS

The purpose of this section of the report is to describe the Lummi Indian Reservation location, introduce the Lummi Nation Water Resources Management Program, and provide an overview of the Lummi Nation Waters.

2.1. Lummi Indian Reservation

The Lummi Indian Reservation (Reservation) is located in the northwest corner of Washington State (Figure 2.1.1). The Lummi Nation is a federally recognized Indian tribe with the Lummi Indian Business Council (LIBC) as its governing body. There are more than 4,500 enrolled members of the Lummi Nation. The Reservation is located along the western boundary of Whatcom County, Washington adjacent to Georgia Strait and Puget Sound. The Reservation includes portions of the Nooksack River and Lummi River watersheds, which drain into Bellingham Bay and Lummi Bay respectively. The Nooksack River drains a watershed of approximately 786 square miles, enters the Reservation near the mouth of the river, and discharges to Bellingham Bay (and partially to Lummi Bay during high flows). The Reservation is located approximately 8 miles west of Bellingham, 90 miles north of Seattle, and 60 miles south of Vancouver, British Columbia, Canada. Nearly 2,650 enrolled Lummi tribal members live on the Reservation (LIBC 2018).

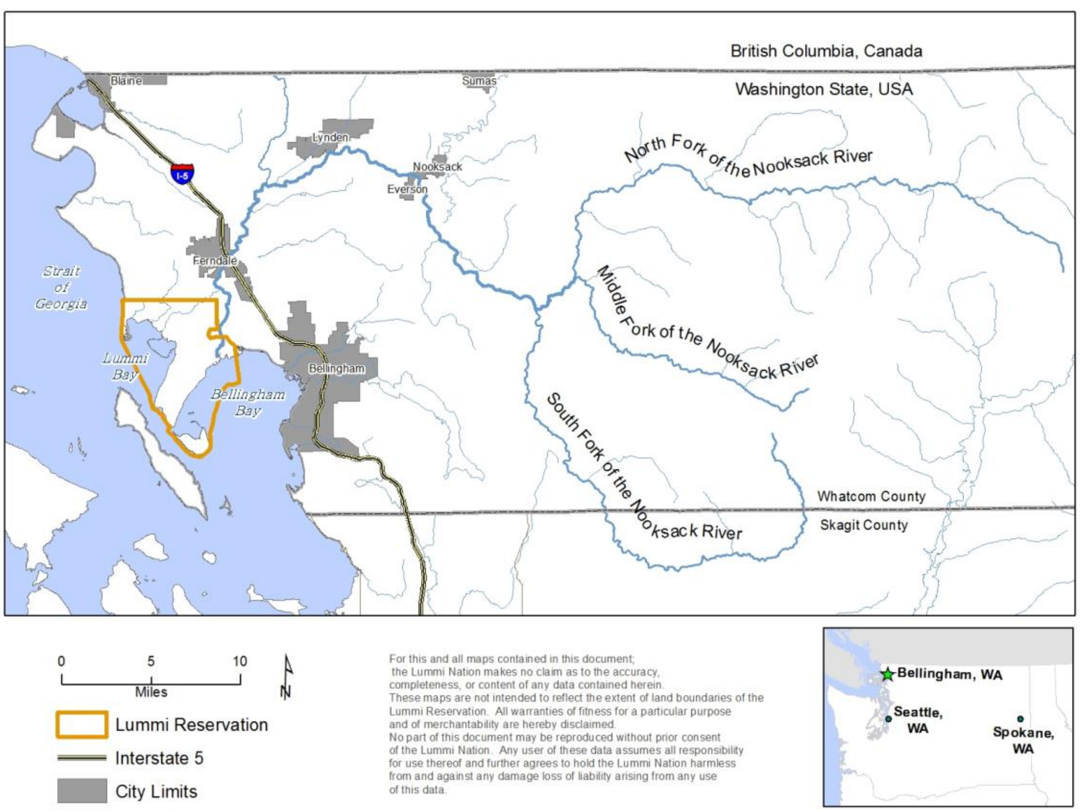

Figure 2.1.1 Regional location of the Lummi Indian Reservation

The Reservation is comprised of about 12,500 acres of upland and 7,000 acres of tidelands. Approximately 38 miles of highly productive marine shoreline surround the Reservation on all but the north and northeast borders. The Reservation includes the Nooksack River and Lummi River deltas, tidelands, forested uplands, Portage Island, and the Sandy Point Peninsula. Both the Nooksack River and Lummi River watersheds are under environmental pressures from rapid regional growth. The Lummi Nation has also entered a period of economic development under self-governance. Much of the high-density development to date has occurred along the marine shoreline. Recently, several new residential and municipal development projects have been completed or are under construction throughout the Reservation, including completion of a new Tribal Administration Building, expansion of the Silver Reef Hotel, Casino & Spa, Sandy Point sewer extension, the Kwina apartments, and Shelangen Village. Growth on and near the Reservation requires that the Nation's core environmental program prioritize the development of a regulatory infrastructure that is technically sound, legally defensible, and administratively efficient. This regulatory infrastructure needs to allow for growth while protecting tribal resources and the Reservation environment. This infrastructure will support both the tribal goals and EPA's policy of tribal self-governance and recognition of sovereignty.

Lummi Indian Business Council (LIBC) resolutions 90-88 and 92-43 directed the Water Resources Division (LWRD) of the Lummi Natural Resources Department (LNR) to develop a comprehensive water resources management program that ensures that the planning and development of Reservation water and land resources are safeguarded against surface and ground water degradation. Reliable information on the surface and ground water quality of the Reservation is required in order to effectively manage these resources.

The EPA and other federal agencies have previously supported the Nation's assessment of priority water resource needs and the identification of unmet needs. Environmental planning intended to protect the Nation's water resources has included the development and updating of a Wellhead Protection Program (LWRD 2011b), a Storm Water Management Program (LWRD 2011a), a Wetland Management Program (LWRD 2000), a Nonpoint Source Management Program (LWRD 2001, 2002, 2015a, 2015b), and Water Quality Standards for Reservation Surface Waters (17 LAR 07). These programs are components of the Lummi Nation Comprehensive Water Resources Management Program. Important milestones in the program development effort include the adoption of the Lummi Nation Water Resources Protection Code (Title 17 of the Lummi Code of Laws [LCL]) in January 2004, the adoption of surface water quality standards in August 2007, and the adoption of four Lummi Administrative Regulations in July 2010. The tribal water quality standards were approved by the EPA in September 2008.

2.2. Lummi Nation Waters

Lummi Nation Waters are all fresh and marine waters that originate or flow in, into, or through the Reservation, or that are stored on the Reservation, whether found on the surface of the earth or underground, and all Lummi Nation tribal reserved water rights (LCL 17.09).

2.2.1. Surface Water

The Lummi Nation is the largest fishing tribe in Puget Sound and has relied on water resources since time immemorial for ceremonial, subsistence, and commercial purposes. As described above, there are approximately 38 miles of marine shoreline surrounding most of the Reservation (except portions of the east boundary and the northern boundary). The surrounding tidelands are in the Strait of Georgia, Hale Passage, Lummi Bay, Portage Bay, and Bellingham Bay. In addition to marine waters, there are approximately 24.4 miles of rivers, streams, sloughs, and drainages on the Reservation including the multiple distributary channels of the Nooksack River delta. There are no lakes on the Reservation, but there are approximately 13 ponds. Finfish and shellfish spawn, incubate, and grow within and adjacent to Lummi Nation Waters (LNR 2010a). The Lummi Nation also operates one shellfish and two salmon hatcheries on the Reservation.

Eighteen watersheds are found on the Lummi Reservation. Reservation watersheds were delineated by the LWRD as “A” through “T” (Figure 2.2.1) and vary in size from 134 acres up to 4,100 acres (LNR 2010c). The Nooksack River discharges to Reservation tidelands, but most of the approximately 786 square mile Nooksack River watershed is upstream of the Reservation. The 18 watersheds are aggregated into two primary drainage areas: Lummi Bay and Bellingham Bay. The Lummi Bay watershed is comprised of nine watersheds: C, H, I, K, L, O, P, Q, and R. A portion of Watershed R discharges to Georgia Strait and a portion of Watershed C discharges to Hale Passage. The Bellingham Bay watershed is also comprised of nine watersheds: A, B, D, E, F, G, J, S, and T. All of Watershed A and a portion of Watershed D discharges to Hale Passage. As shown in Table 2.2.1, eleven of the eighteen watersheds are completely within the Reservation boundary. Approximately 0.3% of the Nooksack River watershed (Watershed S) is on the Reservation.

There are eleven defined rivers, streams, sloughs, and drainages in the Lummi Bay and Portage Bay/Bellingham Bay watersheds. Streams on the Reservation are classified as either Category 1 or Category 2 streams (LCL 17.06.080). Category 1 streams are all streams that flow year-round during years of normal rainfall or are used by juvenile or adult salmonids. Category 2 streams are all streams that are intermittent or ephemeral during years of normal rainfall and are not used by juvenile or adult salmonids. Of the eleven defined rivers, streams, sloughs, and drainages, there are six Category 1 streams and five Category 2 streams on the Reservation. All other agricultural ditches and unnamed drainages are classified as Category 2 streams. As shown in Table 2.2.2, there are approximately 24.4 miles of streams, rivers, sloughs, and drainages on the Reservation. Jordan Creek, Lummi River, Smuggler’s Slough, Slater Slough, Schell Creek, Onion Creek, and Seapond Creek are included in the Lummi Bay watershed. The Portage Bay/Bellingham Bay watershed is comprised of the Nooksack River, Silver Creek, Kwina Slough, Lummi Shore Road streams, and Portage Island streams. Five streams, rivers, sloughs, and drainages are completely within the boundaries of the Reservation.

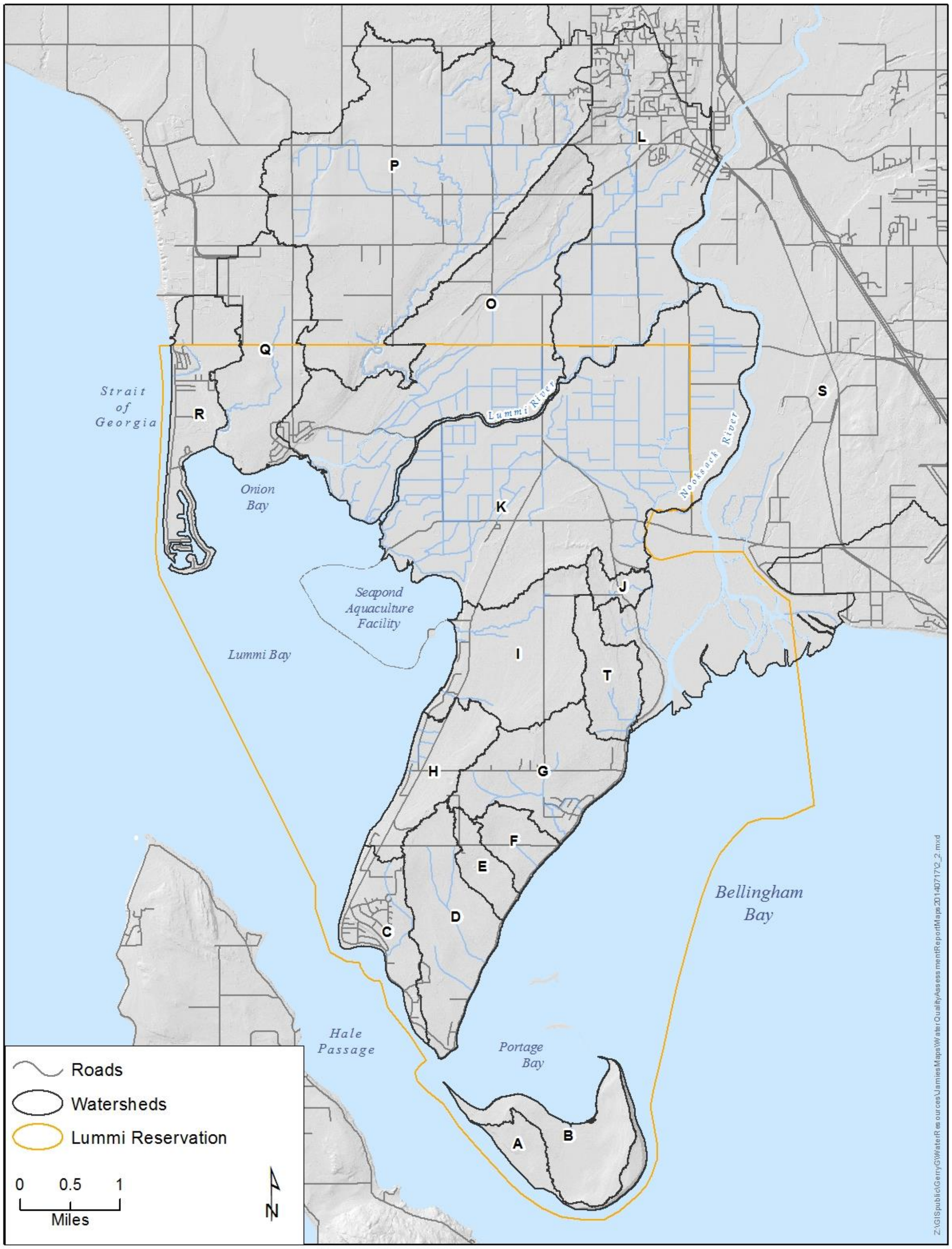

Figure 2.2.1 Lummi Nation watersheds

Table 2.2.1 Acres of watersheds on- and off-Reservation

Basin ID	Watershed Area (acres)			% On-Reservation
	Total	On-Reservation	Off-Reservation	
Lummi Bay Watershed				
C	494	494	0	100
H	549	549	0	100
I	1,059	1,059	0	100
K	4,091	3,354	737	82
M	Combined with Watershed L			
N	Combined with Watershed O			
L	2,307	133	2,174	6
O	2,747	1,552	1,195	57
P	4,097	228	3,869	6
Q	1,096	570	526	52
R	722	531	191	74
Portage Bay/Bellingham Bay Watershed				
A	280	280	0	100
B	617	617	0	100
D	894	894	0	100
E	218	218	0	100
F	251	251	0	100
G	883	883	0	100
J	134	134	0	100
S	503,040	1,296	501,744	0.3
T	392	392	0	100

Table 2.2.2 River and stream miles on- and off-Reservation

River/Stream	Stream Category	Stream/River Miles			
		Total	On-Reservation	Off-Reservation	% On-Reservation
Lummi Bay Watershed					
Jordan Creek	1	6.6	2.1	4.5	32
Lummi River	1	5.0	3.6	1.4	70
Smuggler's Slough	1	3.9	3.9	0	100
Slater Slough	2	1.3	1.3	0	100
Schell Creek	1	4.1	0.4	3.7	10
Onion Creek	2	2.2	1.8	0.4	81
Seapond Creek	2	1.7	1.7	0	100
Portage Bay/Bellingham Bay Watershed					
Nooksack River	1	150	5.1*	144.9	3
Kwina Slough	1	2.3	2.1	0.2	91
Lummi Shore Road	2	2.3	2.3	0	100
Portage Island	2	0.1	0.1	0	100

* Includes all distributary channel lengths in the Nooksack River delta

Prior to 1860, the Nooksack River discharged to Lummi Bay rather than to Bellingham Bay (Deardorff 1992, WSDC 1960). The river flow was redirected to Bellingham Bay at that time and currently the Lummi River only receives water from the Nooksack River when the Nooksack River flows exceed approximately 9,600 cubic feet per second. The Lummi River currently drains much of the area west of the Nooksack River in the vicinity of Ferndale, Washington. The Nooksack River drains most of western Whatcom County, including most of the forested uplands and the developed lowlands.

The Nooksack River flow is comprised of groundwater and precipitation throughout the year supplemented by glacial melt and snowmelt from Mount Baker and adjacent peaks of the Cascade Mountain range during the summer months. The Nooksack River supports several important species of salmon and other aquatic life. The Nooksack River delta is part of the Reservation and is part of an important marine wetland-estuary complex. There are water quality and water quantity challenges in the Nooksack watershed due to land use, development, and agriculture. Whatcom County, which includes all of the lowlands in the Nooksack River watershed, had 115,831 acres used for agricultural practices, which comprises approximately 49% of the lowlands, and 50 dairy operations in 2020 (DOH 2020). All or portions of approximately 735 acres of tribal shellfish beds in Portage Bay were closed to commercial, ceremonial, and subsistence harvest from November 1996 to May 2006 due to bacterial contamination attributed to poor dairy nutrient management practices in the Nooksack River watershed (DOH 1997, Ecology 2000). Portions of the tribal shellfish beds in Portage Bay were seasonally closed to commercial, ceremonial, and subsistence harvest again beginning in October 2014 through year-end 2019. A detailed discussion of the shellfish harvesting closures in Portage Bay is provided in Section 7.1 of this report.

Nearly all of the water bodies in the Lummi River and Nooksack River floodplains are exposed to marine influences, which include the presence of saline water, salinity-based-stratification (stratification), and upstream flow during high tide. Most of the water quality sample sites are tidally influenced (water level and/or salinity) and have variable water column profiles (stratified or well-mixed) and salinities. In addition, upland sampling sites become stagnant or dry during the summer months as the dry season progresses. Once the wet season begins during October or November, freshwater flow from the uplands returns.

The 1999 comprehensive wetland inventory on the Lummi Reservation (LWRD 2000) indicated that approximately 43% (5,432 acres) of the Reservation upland areas are either wetlands or wetland complexes (Figure 2.2.2). Of these Reservation wetland areas, about 60% are located in the floodplains of the Lummi River and Nooksack River. Wetland complexes are areas where wetlands form a highly interspersed mosaic with upland hummocks. During the 1999 wetland inventory, boundaries were drawn around the outer edges of the mosaics and the entire areas labeled as “wetland complexes”. As a result, the estimated wetland area identified in the 1999 inventory generally represents more wetland area than actually exists. All wetland boundaries mapped during the comprehensive wetland inventory are general boundaries based on soil survey mapping and interpretation of color and infrared aerial photographs with some field verification. More accurate wetland boundaries are being delineated on the ground as needed for specific activities and as part of an overall effort to improve the spatial accuracy of the wetland GIS database. As of 2019, approximately 337 wetlands have been evaluated as part of the 1999 wetland inventory update; the area covered in the inventory update is approximately 50% of the Reservation land, not including tidelands (LWRD 2019a).

The majority of the estuarine wetlands of the Lummi and Nooksack rivers will be protected and functionally improved through the implementation of the Lummi Nation Wetland and Habitat Mitigation Bank. The mitigation bank is being developed in phases. Implementation of Phase 1A, which encompasses most of the Nooksack River estuary, began in 2011. Enhancement measures like invasive species control and under planting with conifers will improve the ecological functions of the estuary. The mitigation bank will be protected into perpetuity through a conservation easement and used to mitigate unavoidable impacts to habitat and wetlands on the Reservation. Wetland mitigation credits will also be available for purchase within the service area of the bank (LWRD 2008).

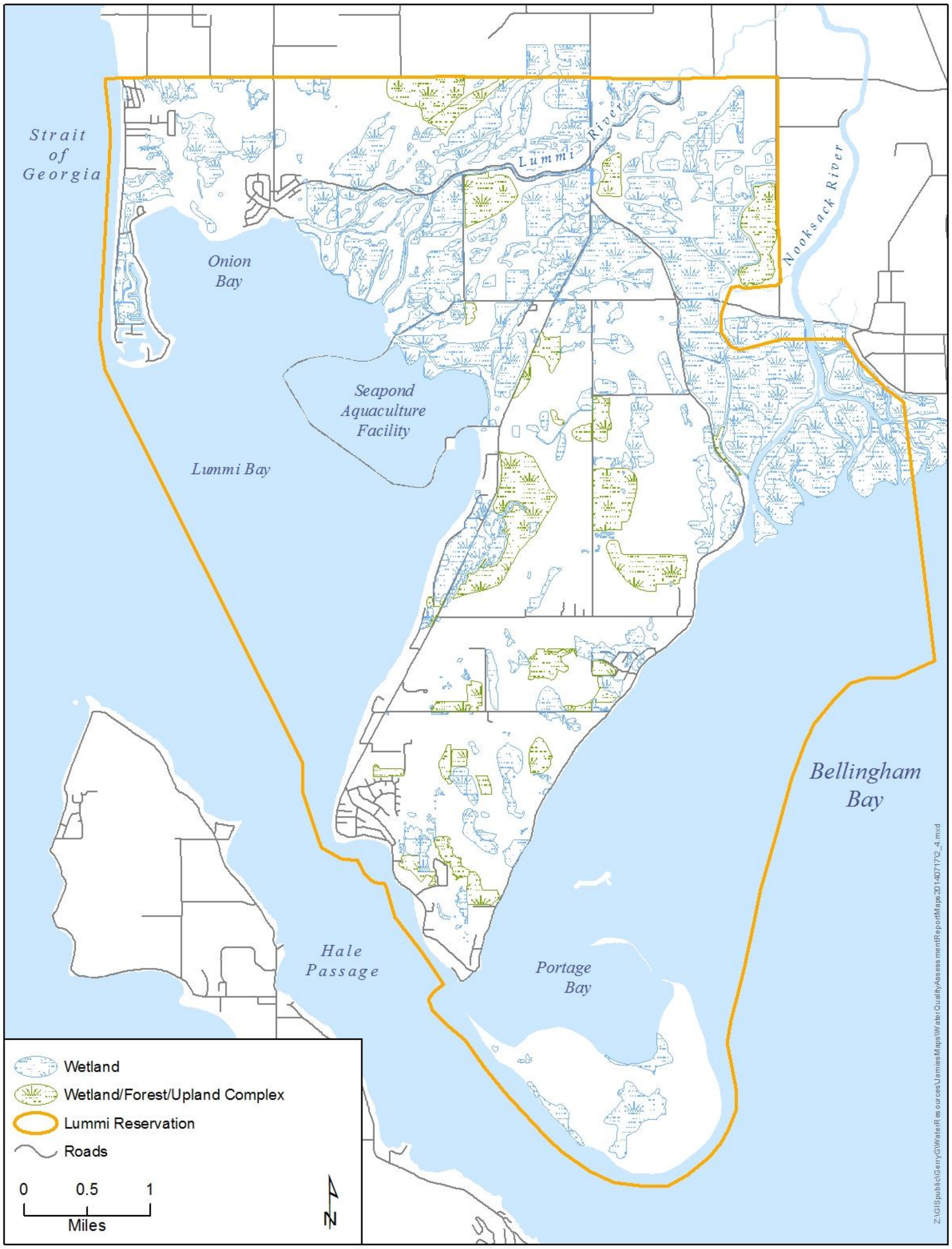

Figure 2.2.2 Lummi Nation wetland areas

2.2.2. Groundwater

Two separate potable groundwater systems occur on the Reservation. One system is located in the northern upland area. This northern system flows onto the Reservation from the north and drains to the west, south, and east (Aspect Consulting 2009). The second potable groundwater system is located in the southern upland area of the Reservation (Lummi Peninsula) and is completely contained within the Reservation boundaries (LWRD 1997, Aspect Consulting 2003). The floodplain of the Lummi and Nooksack rivers, which contains a surface aquifer that is saline (Cline 1974), separates the two potable groundwater systems (Figure 2.2.3). A third potable groundwater system may exist on Portage Island, but information on the water quality and the potential yield of this system is limited and inconclusive. Over 95% of the potable water used by Reservation residents is pumped from the Reservation aquifers. Because of the proximity to marine waters and the local geology, the aquifers on the Reservation are subject to both horizontal and vertical saltwater intrusion if wells are over-pumped (LWRD 1997).

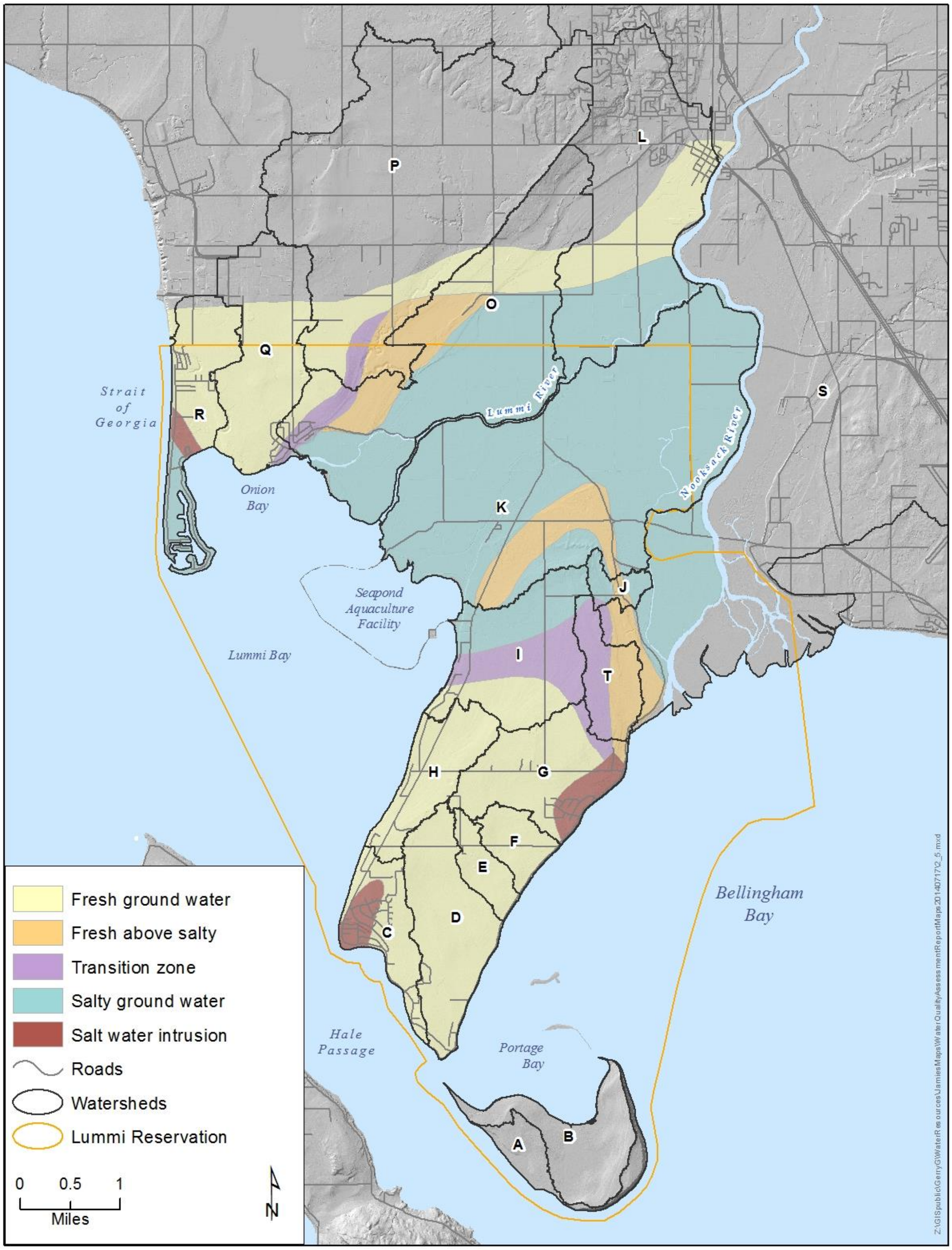

Figure 2.2.3 Lummi Reservation groundwater characteristics

3. WATER QUALITY MONITORING OBJECTIVES

The purpose of this section is to describe the goals of the LWRD, the long-term water quality monitoring objectives, the surface water quality monitoring objectives, and the groundwater quality monitoring objectives.

3.1. Lummi Water Resources Division Goals

The LWRD is responsible for protecting, restoring, and managing Lummi Nation water resources, including the Reservation shorelines, in accordance with the policies, priorities, and guidelines of the Lummi Nation. The overall goal of the LWRD is to protect the treaty rights to water of sufficient quantity and quality to support both the purposes of the Reservation as a permanent, economically viable homeland for the Lummi People, and to support a sustainable harvestable surplus of salmon and shellfish.

3.2. Long-Term Water Quality Monitoring Objectives

The Lummi Nation WQM Program has been ongoing since 1993. The goals of the WQM Program are threefold:

1) Establish the baseline conditions of surface and ground waters on and flowing through and onto the Reservation.
2) Use this information to evaluate regulatory compliance of waters flowing through and onto the Reservation.
3) Support the development and implementation of a water quality regulatory program on the Reservation.

The water quality monitoring objectives to help achieve the overall LWRD and the WQM Program goals include:

- Monitor surface and ground water quality at representative locations and at frequencies sufficient to establish baseline conditions of Lummi Nation Waters.
- Monitor surface waters for compliance with the Lummi Nation surface water quality standards to support all beneficial uses, including public health and public enjoyment; the propagation, protection, and restoration of finfish, shellfish, wildlife, and their habitats; and the protection of the surface waters of the Lummi Indian Reservation as cultural, economic, and spiritual resources of the Lummi People.
- Identify and evaluate on- and off-Reservation sources of fecal coliform bacteria contributions to shellfish harvesting areas.
- Detect and document threats to water quality and associated beneficial uses to support compliance actions.
- Protect groundwater supplies from saltwater intrusion and groundwater mining.

3.3. Surface Water Quality Monitoring Objectives

The Lummi Nation Nonpoint Source Assessment Report and update (LWRD 2001, 2015a), the Lummi Nation Nonpoint Source Management Plan and update (LWRD 2002, 2015b), and other documents developed as part of the Lummi Nation Comprehensive Water Resources Management Program (LWRD 1997, 1998, 2000, 2011a, 2011b) identify and locate the numerous threats to the quality of Lummi Nation Waters. These threats include both point and nonpoint sources of pollution associated with various land uses.

The purpose of the surface water quality monitoring component of the WQM Program is to establish the baseline conditions of waters on and flowing onto the Reservation, to detect water quality problems, and to help identify the pollutant sources. Information from the Program is used to:

- Evaluate compliance of waters flowing onto and within the Reservation with water quality criteria.
- Evaluate fecal coliform bacteria contributions from on- and off-Reservation to shellfish harvest areas.
- Support the development and implementation of a water quality regulatory program on the Reservation, including the implementation and revision of Lummi Nation Water Quality Standards.

3.4. Groundwater Quality Monitoring Objectives

The purpose of the groundwater quality monitoring component of the WQM Program is to protect groundwater supplies from saltwater intrusion and groundwater mining. Groundwater resources on the Reservation are vulnerable to saltwater intrusion due to the proximity of marine waters and local geology (LWRD 1997). The majority of residential development to date has occurred along the marine shorelines of the Reservation placing the most vulnerable portion of aquifers at risk through direct pumping of groundwater near marine waters. Protection of groundwater is essential because:

- Over 95% of all water consumed on the Reservation comes from groundwater.
- An ample supply of good quality groundwater is needed to serve the purposes of the Reservation as a permanent and economically viable homeland for the Lummi People.

4. SURFACE AND GROUND WATER QUALITY ASSESSMENT METHODS

The purpose of this section of the report is to summarize the approach used to establish the ambient water quality conditions of Reservation surface and ground water and to summarize the field data collection and laboratory analysis methodologies detailed in the WQM Program quality assurance documents, including the QMP, project QAPPs, and SOPs (LWRD 2018 a-t).

4.1. Overview of Water Quality Assessment Design

The WQM Program is comprised of five surface water projects, three groundwater projects, and one short-term study. The individual projects include:

- Ambient Surface Water Quality Monitoring Project
- Ambient Groundwater Quality and Quantity Monitoring Project
- Department of Health Support (NSSP) Project
- Nutrient, Metal, and Hydrocarbon Monitoring Project
- First Flush Monitoring Project
- Continuous Water Temperature Monitoring Project
- Continuous Aquifer Level Monitoring Project
- Lummi Peninsula Groundwater Settlement Agreement Compliance Monitoring Project
- Streaming Nooksack: Nooksack River Watershed ZAPS Real Time Monitoring Pilot Study

In addition to the WQM Program projects, occasional investigative water quality monitoring occurs in response to site-specific questions or spills. WQM Program projects employ several strategies for robust water quality assessment: ambient and targeted sampling; fixed station network and investigative sampling; discrete and continuous data collection; and surface water and groundwater monitoring.

The WQM Program projects employ a fixed station network sampling design. A total of 67 surface water and 33 groundwater sites are regularly monitored as part of the WQM Program. The Ambient Surface Water Quality Monitoring Project (Surface Water Project) and Ambient Groundwater Quality and Quantity Monitoring Project (Groundwater Project) are the LWRD's ongoing core monitoring projects that are complemented by other, shorter-term, focused, or more intensive projects. The Surface Water Project and Groundwater Project involve ambient discrete sampling at fixed sites to determine compliance with Lummi Nation Water Quality Standards (17 LAR 07) or threshold values (*e.g.,* chloride trigger values). The Department of Health (DOH) Support (NSSP) Project involves ambient, discrete sampling within the Portage Bay and Lummi Bay shellfish growing areas as part of the shellfish growing area classification process. Targeted monitoring of nutrients, metals, and hydrocarbons as well as continuous monitoring of water temperature and aquifer level at select sites supplement the ambient data collected under the Surface Water Project and Groundwater Project.

In addition to ambient sampling, sampling conducted as part of the First Flush Monitoring Project targets storm conditions at the start of the wet season. Using a subset of the WQM Program fixed station network, the First Flush Monitoring Project provides water quality data under storm conditions that may otherwise be missed under temporally random sampling for ambient projects. Continuous data are collected as part of the Continuous Temperature Monitoring Project and Continuous Aquifer Level Monitoring Project at select sites to supplement datasets generated as part of the core Groundwater and Surface Water Projects.

Additional sampling occurs on a case-by-case basis in response to specific issues or problems that warrant further investigation (*e.g.,* a reported or observed manure spill, a fish or waterfowl kill, questions regarding water quality impacts of an automobile recycling facility, chronic or acute poor water quality at a particular monitoring station). Investigative sampling typically includes sites from the fixed station monitoring network and other sites located both up and downstream from the identified potential pollutant source. During 2019, investigative sampling in response to low dissolved oxygen and high fecal coliform conditions in the Lummi River involved sampling of six investigative sites located between established water quality monitoring stations. One of these investigative sites was added to the Surface Water Project in response to the investigation.

The quality assurance protocols outlined in the *Lummi Nation Water Quality Monitoring Program Quality Assurance Project Plan – Version 4.0* (LWRD 2010) were followed for sample collection conducted from January 2018 to October 2018. Protocols outlined in the updated and reorganized quality management documents (QMP, project QAPPs, and SOPs) were followed for sample collection conducted from October 2018 to December 2019 (LWRD 2018 a-t). The quality assurance protocols outlined in the Continuous Temperature Monitoring QAPP (LWRD 2015c) were followed for data collection as part of that project throughout the 2018-2019 reporting period.

4.2. Surface Water

During the 2018-2019 reporting period, 67 surface water sites were monitored for water quality. Forty three (43) sites were monitored as part of routine monitoring of surface waters on the Reservation and twenty four (24) sites were monitored for the National Shellfish Sanitation Program (NSSP) in Portage and Lummi bays (Figure 4.2.1). Two (2) sites were visited but not sampled during the 2018-2019 reporting period due to lack of water or stagnant conditions during each site visit. In addition, six surface water sites were visited as part of an investigation in 2019, of which one site was added to routine monitoring and is included in the total count above.

Several sample sites are located along the northern and eastern Reservation boundary to document the quality of waters entering the Reservation, as the majority of these watersheds are located off-Reservation (Figure 2.2.1, Table 2.2.1, Table 2.2.2). Sample sites include freshwater and marine-influenced streams and intermittent drainages on the Reservation, intermittent streams on Portage Island, and the marine waters of Lummi Bay, Portage Bay, and the Sandy Point Marina. Surface water data are used to establish baseline conditions, identify trends, and to evaluate compliance with water quality criteria.

Surface water monitoring as part of the WQM Program during the 2018-2019 reporting period included the following fixed-network sampling schemes and projects:

- Discrete, ambient sampling
    - Surface Water Project
        - Core surface water sampling runs: Flood Plain East, Flood Plain West, Lummi Shore Road, Nooksack, and Sandy Point and Portage Island
    - DOH Support NSSP Project
        - Sampling runs in Lummi Bay and Portage Bay
- Targeted sampling
    - First Flush Monitoring Project
        - Sampling in Lummi Bay and Portage Bay watersheds
    - Nutrients, Metals, and Hydrocarbons Monitoring Project
        - Quarterly nutrient, metal, and hydrocarbon sampling
- Continuous
    - Continuous Temperature Monitoring Project
    - Continuous Aquifer Level Monitoring Project
    - Streaming Nooksack: Nooksack River Watershed ZAPS Real Time Monitoring Pilot Study

During the reporting period, LWRD collected samples as part of the Streaming Nooksack Study examining continuous monitoring of water quality using optical emerging technologies. The Streaming Nooksack Study reporting results are not yet complete, will be reported separately, and are not included in this report.

Table 4.2.1 summarizes the surface water quality monitoring sampling schedule for the 2018-2019 reporting period. In accordance with the laboratory quality assurance plan, the contracted independent laboratory, Edge Analytical, analyzed all bacteria from the same sample bottle, and fecal coliform bacteria and *E. coli* are measured from the same culture. The exception to this is for DOH samples collected under the NSSP, for which only fecal coliform are enumerated by the DOH Public Health Laboratory.

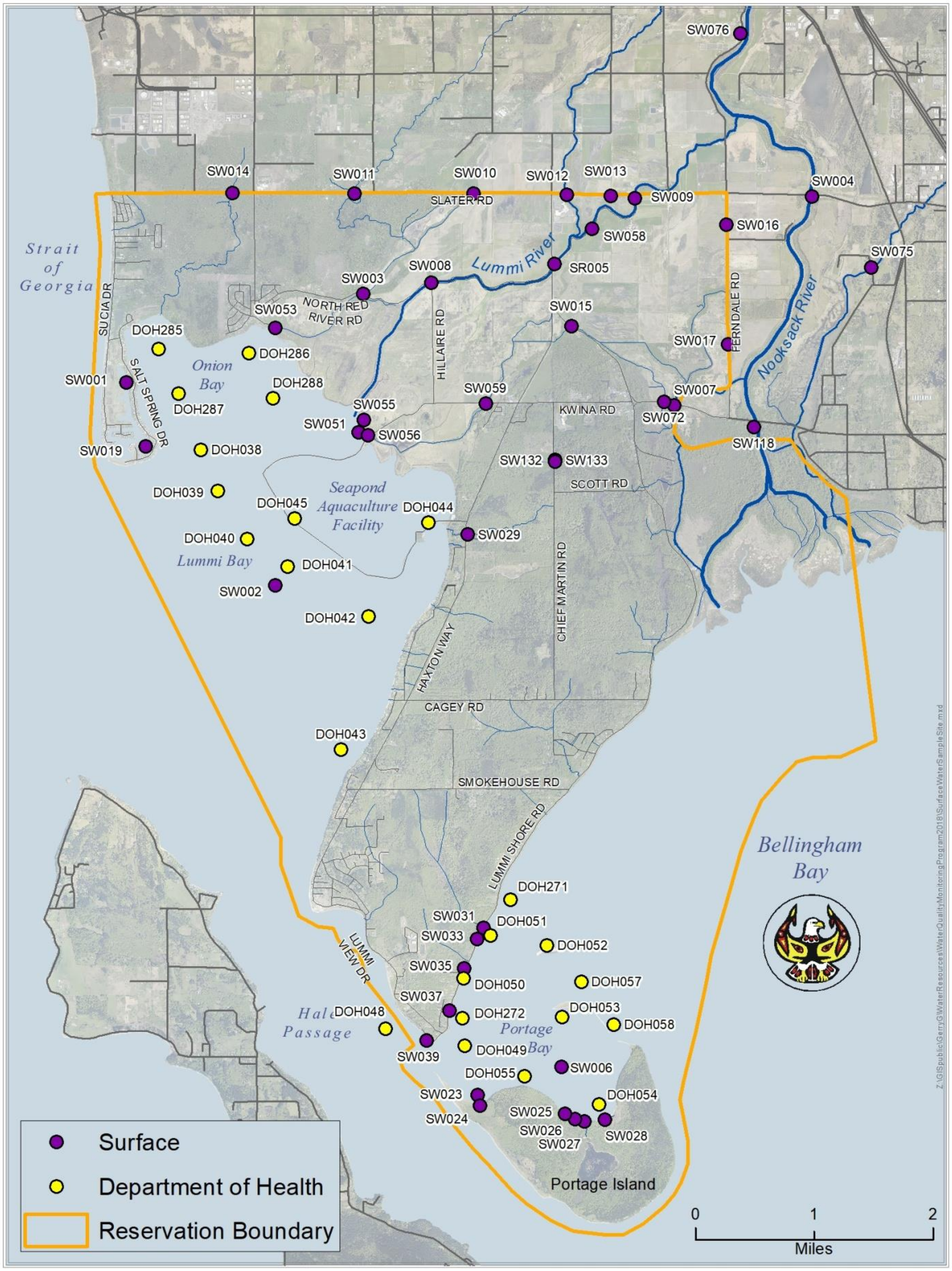

Figure 4.2.1 Surface water quality sampling sites

Table 4.2.1 Lummi Nation Water Quality Monitoring Program surface water quality monitoring sites, samples collected (in situ and laboratory analyzed), and sampling frequency by project and run.

Run Name	Site ID	*In Situ* Parameters and Laboratory Samples	Frequency	Notes
Ambient Surface Water Quality Monitoring Project				
Floodplain East (FPE)	SW015, 16, 17, 29, 51, 55, 56, 59, 72, 118, 132, 133, 7 (LSR)	Air temperature, salinity-based stratification, water temperature, salinity, specific conductivity, current/flow direction, dissolved oxygen, pH, water depth, and general observations Lab: Fecal coliform, *E. coli*, and enterococcus	Monthly	Nooksack River site SW118 and Lummi River site SW051 are visited during both the FPE and FPW runs. LSR site SW007 is sampled as part of the FPE run during months that LSR is not sampled. Sites SW132 and SW133 were added to the FPE run temporarily in March 2018.
Floodplain West (FPW)	SW003, 8, 9, 10, 11, 12, 13, 14, 51, 53, 58, 118, SR005			
Nooksack	SW075, 118			Sampled the day prior to NSSP sampling in Portage Bay beginning May 2015. Silver Creek site SW075 sampling began in March 2016.
Lummi Shore Road (LSR)	SW007, 31, 33, 35, 37, 39, 118		Six times per year	Sampled the day of DOH NSSP sampling in Portage Bay.
SW118	SW118			Sampled the day of LNR sampling in Portage Bay.
Sandy Point and Portage Island	SW001, 2, 6, 19, 23, 24, 25, 26, 27, 28	Same as above. Secchi depth measured for marine sites sampled from boat. Lab: Fecal coliform, *E. coli*, and enterococcus	Six times per year	Sampling on Portage Island can occur concurrently with sampling in Portage Bay and sampling in Sandy Point can occur concurrently with sampling in Lummi Bay.

Table 4.2.1 Lummi Nation Water Quality Monitoring Program surface water quality monitoring sites, samples collected (in situ and laboratory analyzed), and sampling frequency by project and run.

Run Name	Site ID	*In Situ* Parameters and Laboratory Samples	Frequency	Notes
DOH Support (NSSP) Project Monitoring				
Lummi Bay DOH Support	DH038, 39, 40, 41, 42, 43, 44, 45, 285, 286, 287, 288	Air temperature, salinity-based stratification, water temperature, salinity, specific conductivity, current/flow direction, dissolved oxygen, pH, water depth, Secchi depth, and general observations Lab: Fecal coliform	Six times per year	DOH Public Health laboratory provides sample bottles and bacteria enumeration.
Portage Bay DOH Support	DH048, 49, 50, 51, 52, 53, 54, 55, 57, 58, 271, 272			
First Flush Monitoring Project				
Lummi Bay Watershed First Flush	SW011, 10, 12, 13, 9, 58, 8, 3, 53, 51, 118 Time permitting: SW014, 59, 15, 16, 17	Air temperature, salinity-based stratification, water temperature, salinity, specific conductivity, current/flow direction, dissolved oxygen, pH, water depth, and general observations Lab: Fecal coliform, *E. coli*, and enterococcus	Once per year	As needed based upon predicted and observed runoff during the onset of the rainy season
Bellingham Bay Watershed First Flush	SW007, 31, 33, 35, 37, 39, 118			

Table 4.2.1 Lummi Nation Water Quality Monitoring Program surface water quality monitoring sites, samples collected (in situ and laboratory analyzed), and sampling frequency by project and run.

Run Name	Site ID	*In Situ* Parameters and Laboratory Samples	Frequency	Notes
Nutrients, Metals, and Hydrocarbons Monitoring Project				
Metals and Hydrocarbons	Marine: SW001	Lab: Arsenic, copper, mercury, tin, zinc, hardness, pH, diesel and lube oil range hydrocarbons	Quarterly	Concurrent with ambient discrete monitoring on Sandy Point and Portage Island (marine), Flood Plain West (freshwater), Flood Plain East (freshwater) or Nooksack (freshwater) runs
	Freshwater: SW014, 75	Lab: Chromium, copper, lead, zinc, hardness, pH, diesel and lube oil range hydrocarbons		
Nutrients	Marine: SW002	Lab: Alkalinity, ammonia, biochemical oxygen demand, chemical oxygen demand, nitrate-N (freshwater only), nitrite-N (freshwater only), N+N, total Kjeldahl nitrogen, orthophosphate, total phosphorus, pH, total organic carbon, total suspended solids, volatile suspended solids, iron, chlorophyll a, and pheophytin		
	Freshwater: SW003, 9, 15, 118			
Alternate Sites and Other				
SW118 alternate	SW004	Same as above for SW118	As needed	Nooksack River site SW004 (at Slater Road) established as an alternate to site SW118. Site SW004 is sampled if access to SW118 is unavailable (e.g., due to flooding).
Streaming Nooksack	SW076, SW118	Lab: fecal coliform, E. coli, TSS, N+N, BOD, hydrocarbons	As needed	This sampling was conducted as part of the Streaming Nooksack Pilot Project and is not included in this report. Sampling as part of this project ended September 2019.

Sections 4.2.1 through 4.2.6 summarize the surface water quality monitoring conducted during the 2018-2019 reporting period, including information about deviations from planned sampling frequency. Sections 4.2.7 and 4.2.8 outline historical changes and changes implemented during the reporting period, respectively, in WQM Program surface water quality monitoring projects.

4.2.1. Ambient Surface Water Quality Monitoring Project

The Ambient Surface Water Quality Monitoring Project (Surface Water Project) is the WQM Program's core monitoring project. Bacteria (fecal coliform, *E. coli*, and enterococci) samples are collected and *in situ* water quality parameters (water temperature, pH, dissolved oxygen, salinity, and specific conductivity) are measured at sites with flowing water. Sites that are stagnant or dry are not sampled.[3]

Ambient surface water quality monitoring occurs on five distinct sampling runs designed to sample geographic areas on the Reservation. The Floodplain East (FPE) and Floodplain West (FPW) sample runs are sampled monthly to establish baseline conditions and fecal coliform contributions of waters flowing onto the Reservation and waters flowing through the Reservation to Lummi Bay. The Nooksack run is sampled the day prior to NSSP sampling in Portage Bay (monthly) as part of a county-wide, multiple agency partnership to collect samples from the Nooksack River watershed on the same day to monitor fecal coliform contributions from key areas of the watershed, including the lower mainstem. The Lummi Shore Road (LSR) run is sampled on the same day as NSSP sampling is conducted in Portage Bay by DOH (six times per year) to monitor fecal coliform contributions to Portage Bay from the Reservation uplands and the Nooksack River. During months that LWRD conducts NSSP sampling in Portage Bay, Nooksack River site SW118 is also sampled on the same day. The Sandy Point and Portage Island (SP+PI) sample run provides ambient conditions of the freshwater drainages on Portage Island and the marine waters of Portage Bay, Lummi Bay, and the Sandy Point Marina. All sample runs provide information about potential pollutant sources (including fecal coliform contamination) and compliance with Lummi Surface Water Quality Standards.

Beginning in February 2018, additional monitoring of the Jordan Creek/North Lummi River Distributary and the Lummi River/Schell Creek watersheds commenced in partnership with the Whatcom Clean Water Program. This additional sampling was in response to high fecal coliform densities observed at the northern Reservation boundary sites along Slater Road and elevated fecal coliform densities observed in the Lummi Bay shellfish growing area. Coordinated sampling of the freshwater sites that flow to Lummi Bay was conducted the day prior to NSSP sampling in Lummi Bay and on a randomly selected date in months during which no NSSP sampling was conducted in Lummi Bay (Lummi Bay is sampled every-other month, six times per year). Whatcom Clean Water Program partners (Whatcom County Public Works Natural Resources Department) conducted sampling at the Reservation boundary (Slater Road sites)

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[3] Prior to 2013, sites were sampled when stagnant as long as there was a sufficient amount of water to collect a sample. This means that the period of record includes measurements collected during stagnant conditions, and may not always be comparable to flowing conditions. Measurements collected during stagnant conditions were excluded when practicable in this report, and details of the inclusion of measurements collected during stagnant conditions is discussed by parameter in Section 7.

and upstream sites while LNR staff conducted sampling at on-Reservation sites downstream of the Reservation boundary. Occasionally freshwater sampling was conducted on the same day as Lummi Bay NSSP sampling when the marine sampling was conducted in the evening. This report includes ambient data collected by LNR as part of this response, but not ambient data collected by Whatcom County at established sites on the Reservation boundary. During 2018, additional ambient sampling in the Jordan Creek and Lummi River watersheds was conducted eleven times, each month from February to December. During 2019, the additional ambient sampling in these watersheds was conducted twelve times, once each month from January to December.

During 2018, the FPE and FPW sample runs were conducted monthly from February to December, eleven times per year. The LSR sample run was conducted every other month from March through November, five times during the year, concurrent with DOH sampling in Portage Bay with the exception of January. The Nooksack run was conducted monthly from March through December, ten times during the year. No sampling of these runs was conducted in January due to lack of an approved laboratory contract. The Nooksack run was not conducted during February due to a scheduling oversight. Sandy Point and Portage Island were each sampled six times during the year, at least once per quarter.

During 2019, the FPE, FPW, and Nooksack sample runs were conducted monthly from January to December, twelve times per year. The LSR run was conducted every other month from February to December, six times during the year, concurrent with DOH sampling in Portage Bay. Sandy Point was sampled five times and Portage Island was sampled six time during 2019; both were sampled at least once per quarter.

During the 2018-2019 reporting period, sites SW024 and SW025 on Portage Island (SP+PI run) were not sampled because no flow was observed at the freshwater sites. Smuggler Slough site SW072 (FPE run) and Lummi River site SW058 (FPW run) were sampled too infrequently during the reporting period for assessment of compliance with the Water Quality Standards and are excluded from the remainder of this report. Ambient water quality in the hatchery settling pond sites SW132 and SW133 was monitored during the reporting period, but this information was used to monitoring water quality for use at the hatchery, not for compliance with Water Quality Standards and these sites are not included in the remainder of this report. Summary data for these sites are included in appendices A-C but no discussion or compliance determination was made.

4.2.2. Department of Health Support – National Shellfish Sanitation Program

In consultation with the Lummi Nation and under the Shellfish Consent Decree (Order Regarding Shellfish Sanitation, *United States v. Washington [Shellfish]*, Civil Number 9213, Subproceeding 89-3, Western District of Washington, 1994), the Washington State DOH is responsible to the federal Food and Drug Administration (FDA) to ensure that the NSSP standards for certification of shellfish growing waters are met on the Reservation.

In Lummi Bay, twelve sites are sampled at least six times a year by LWRD to provide logistical assistance to the DOH and also to assist with the achievement of WQM Program goals. Logistical difficulties prevent DOH staff from sampling Lummi Bay; the tidal window for access to marine sample sites in Lummi Bay is narrow, particularly in the summer (+8.5 ft tide minimum is required for sampling in Lummi Bay). Lummi Bay was sampled six times each year during the 2018-2019 reporting period.

In Portage Bay, twelve sites are sampled at least six times per year by DOH. In June of 2014, LWRD commenced sampling in Portage Bay during months not sampled by DOH. During 2018, Portage Bay was sampled twelve times; six times by LWRD and six times by DOH. Also during 2018, additional sampling at the six sites in the closure area was conducted twice monthly during the spring closure period (April-June) to collect additional data during low salinity conditions (see Section 7.1.3). During 2019, Portage Bay was sampled eleven times; five times by LWRD and six times by DOH. Planned sampling in January 2019 was cancelled due to weather conditions and could not be rescheduled during the month.

Data collected as part of the DOH Support (NSSP) Project in Lummi Bay and Portage Bay provide fecal coliform, salinity, and water temperature data for certification of commercial shellfish beds under the NSSP. In addition, sample runs conducted by LWRD provide information about water quality in the marine water and assists in identifying sources of pollution (including fecal coliform contamination) and evaluating compliance with Lummi Surface Water Quality Standards.

4.2.3. First Flush

Upon the onset of the rainy season, first flush sampling is conducted at ten to fifteen sites in the Lummi Bay watershed and eight sites in the Portage Bay watershed. First flush monitoring involves the collection of bacteria (fecal coliform, *E. coli*, and enterococci) samples and *in situ* water quality parameters (water temperature, salinity, specific conductivity, pH, and dissolved oxygen) when the freshwater drainages begin to flow after the first substantial rains at the commencement of the wet season (typically October or November). This targeted sampling provides information about pollutant levels and water quality of runoff during storm conditions at the end of the dry season.

During 2018, the Lummi Bay first flush sample run was conducted in November. First flush sampling did not occur for the Portage Bay watershed during 2018. During 2019, the Lummi Bay first flush sample run was conducted in October and the Portage Bay first flush run was conducted during December.

4.2.4. Nutrients, Metals, Hydrocarbons Monitoring Project

Due to the costs of analyzing water quality samples for nutrients, metals, and petroleum hydrocarbons, these laboratory samples are only collected quarterly at select targeted and representative sites as part of the Nutrients, Metals, and Hydrocarbons Monitoring Project (NMH Project). Metal and hydrocarbon sites include one freshwater site on Onion Creek downstream of a petroleum oil refinery (SW014), one freshwater site downstream of the industrial portions of the Silver Creek watershed (SW075), and one marine water site within a recreational boat marina in Sandy Point (SW001). Nutrients are measured at one marine site in Lummi Bay (SW006) and four freshwater sites: one in each of the main on-Reservation watersheds, Smuggler Slough (SW015), Jordan Creek (SW003), and the Lummi River (SW009); and the mainstem Nooksack River (SW118).

During 2018 and 2019, nutrient, metal, and hydrocarbon samples were collected from sites with flowing water once per quarter, four times during each reporting year.

4.2.5. Continuous Temperature Monitoring Project

The Quality Assurance Project Plan for the Continuous Temperature Monitoring project was finalized in September 2015 (LWRD 2015c). Six sites were monitored during the 2018-2019 reporting period, which included five freshwater sites and one marine sites. Sites monitored are located in the Jordan Creek (SW003, SW011), Lummi River (SW012, SW009), and Smuggler Slough (SW015, SW059) watersheds. Gaps in the data were present for all sites due to loggers being removed from the site for QA/QC activities and delay in redeploying the loggers. Gaps in the data were also caused by equipment malfunction, incorrect setup, and the loggers being dewatered on some occasions.

Sites included in the Continuous Temperature Monitoring Project, but not monitored during the 2018-2019 reporting period include: site SW008 (tidally-influenced site at lower reach of Lummi River at Hillaire Road Bridge), SW051 (marine outflow of Lummi River), SW053 (marine receiving waters of Jordan Creek/North Lummi River Distributary), and SW118 (Nooksack River at Marine Drive Bridge).

4.2.6. Surface Water Investigations

Surface water investigations of water quality in the Lummi River took place in June, July, and September of 2019. Water quality was monitored on fourteen days following depleted dissolved oxygen conditions and high fecal coliform densities observed during routine ambient monitoring. Investigative data are targeted and are not included in the ambient dataset used to assess compliance with the Water Quality Standards.

4.2.7. Historical Changes

Since 1993, the WQM Program has grown significantly in the number of sites sampled, the parameters measured, and the ability to manage and analyze collected data. Several sites were added in the late 1990s to better evaluate the water quality impacts of Nooksack River water on Portage Bay and to better evaluate conditions in the Lummi Bay watershed.

The primary change in parameters measured over the period of record was the addition of new laboratory analyses. Bacteria sampling expanded in 2000 from often enumerating only one type of bacteria, fecal coliform or *Escherichia coli* (*E. coli*), to consistently enumerating both of these bacteria plus enterococci. Quarterly nutrient, metal, and hydrocarbon sample collection at select targeted sites began in 1999. In addition, select sites in the Portage Bay and Lummi Bay watersheds are sampled during “first flush” events to document the water quality impacts of the onset of the rainy season.

In situ parameters measured over the period of record have remained constant, with the exception of pH and turbidity. Reliable pH measurements have been collected since 2009, after equipment problems and staff constraints were resolved. Turbidity data are available from 2008 to 2013, when turbidity measurements were suspended.

In September 2013, several changes to the WQM Program were made. These changes included suspending sampling at seven sites, reducing the sampling frequency of the Lummi Shore Road run, suspending turbidity and flow measurement, and discontinuing nutrient monitoring at Portage Bay site SW006. Nutrient sample at Nooksack River site SW118 was added to the WQM Program in September 2013. Details of these changes were documented in the 2013 Water Quality Assessment Report (LWRD 2019b).

In 2015 and 2016, several changes to the WQM Program were made in response to changing priorities and budget constraints. These changed include the addition of the Nooksack run to the Surface Water Project, which involves sampling of the Nooksack River mainstem site SW118 on the day prior to NSSP sampling in Portage Bay; addition of a new sample site in Silver Creek (SW075) to the Nooksack run in the Surface Water Project and as a metals and hydrocarbons monitoring site in the NMH Project; moving Seapond Creek site SW029 from the LSR run to the FPE run; reduction of the SP+PI run from monthly to six time per year, at least once per quarter, and suspension of sampling at six marine sites; and discontinuation of the analysis of sulfate, sulfide, and silicon at nutrient sites in the NMH Project due to cost.

4.2.8. Changes in 2018-2019

The WQM Program continues to be evaluated and adapted to balance budgets, staff time, and monitoring priorities while maintaining sufficient spatial and temporal resolution in the monitoring design (Table 4.2.2).

In 2018, increased monitoring of sites in the Lummi River and Jordan Creek/North Lummi River Distributary commenced in response to elevated fecal coliform densities in these watersheds and in the Lummi Bay shellfish growing area. Coordinated monitoring with Whatcom Clean Water Program (WCWP) partners, including the Whatcom County Public Works Department Natural Resources Department and WA State Department of Ecology, commenced in February 2018 and involved WCWP partner agency sampling along the Reservation boundary at established Lummi Nation sampling locations (from west to east: SW011, SW010, SW012, SW013, and SW009) and upstream locations in Whatcom County and concurrent LNR sampling at sites downstream of the Reservation boundary in these watersheds (SW053, SW003, SW051, SW008). Ambient coordinated sampling is conducted once monthly, with sampling occurring on the day prior to marine NSSP sampling in Lummi Bay or a randomly selected date during months that Lummi Bay is not sampled. Coordinated storm sampling was conducted following rainfall events on an opportunistic basis.

In summer 2018, site SW058 was added to the Surface Water Project to monitor potential fecal coliform contributions from an agricultural ditch that flows into the Lummi River between Slater Road and Haxton Way. This site was previously monitored as part of the Surface Water Project, but sampling was discontinued in 2013 due to redundancy, infrequent flow, and site safety considerations. Due to concerning high fecal coliform densities in the Lummi River and the coordinated monitoring response in this watershed, monitoring of this site was re-established on coordinated Lummi River/Jordan Creek run days and on the Flood Plain West run.

Following investigative sampling in the Lummi River of depleted dissolved oxygen and elevated fecal coliform densities during June 2019, site SR005 (Lummi River at Haxton Way) was added as a monitoring site in the Lummi River watershed to increase spatial resolution of the river between the Reservation boundary (SW012, SW013, and SW009) and the brackish, tidally-influenced waters at Hillaire Road (SW008). Monitoring of site SR005 is included in the coordinated Lummi River/Jordan Creek run days and on the Flood Plan West run.

In March 2018, water quality concerns prompted temporary monitoring of the settling ponds located on Chief Martin Road that hold water pumped from the Nooksack River to be used at the Lummi Bay finfish hatchery. Two sites, one at the inflow (SW132) and one at the outflow (SW133) were established and sampled on the FPE run during the reporting period.

Table 4.2.2 Summary of changes to surface water quality monitoring as part of the Lummi Nation Water Quality Monitoring Program in 2018-2019

Site Identification	Change	Justification for Change
SW058	Add sampling site	Sample site SW058 (agricultural ditch flowing to Lummi River) was added for monitoring of potential fecal coliform contributions from this ditch to the Lummi River.
SR005	Add sampling site	Sample site SR005 (Lummi River at Haxton Way) was added for monitoring of the portion of the Lummi River between existing sample sites at Slater Road and Hillaire Road. Site was added in response to depleted dissolved oxygen and elevated fecal coliform investigation in 2019.
SW053, SW003, SW051, SW008, SW058, SR005	Increased frequency of sampling	Sites downstream of the Reservation boundary in the Lummi River and Jordan Creek watersheds were sampled one additional time per month. Increased ambient monitoring due to high fecal coliform densities and risk to Lummi Bay shellfish growing area in coordinated response with Whatcom Clean Water Program partner agencies (Whatcom County Public Works). Occasional storm sampling of these sites was also conducted in partnership with Whatcom Clean Water Program partner agencies (WA Department of Ecology).
SW132, SW133	Added sampling sites temporarily	Two sites (inflow and outflow) in the settling ponds for Nooksack River water used by the Lummi Bay finfish hatchery were added to the Surface Water Project temporarily to answer water quality questions during the 2018-2019 reporting period.

4.3. Groundwater

Twenty-four (24) groundwater sites were sampled during the 2018-2019 reporting period as part of regular monitoring to characterize the two major potable aquifer systems on the Reservation (Figure 4.3.1, Table 4.3.1). Nine additional groundwater sites were sampled during the reporting period as part of compliance with the Lummi Peninsula Groundwater Settlement Agreement. Groundwater monitoring as part of the WQM Program during the 2018-2019 reporting period included the following fixed-network sampling schemes and projects:

- Ambient Groundwater Quality and Quantity Monitoring Project (Groundwater Project)
    - Groundwater quality
        - Discrete, ambient sampling of groundwater wells in production, including both tribal supply wells and wells for domestic use.
        - Measurement of chloride concentration, water quality (temperature, salinity, conductivity, pH), and pump rate (tribal supply wells only).
    - Aquifer level
        - Discrete, ambient monitoring of aquifer level at groundwater wells that are in production, including both tribal supply wells and wells for domestic use, and wells that are not in production.
        - Measurement of static water level.
- Continuous Aquifer Level Monitoring Project (CALM Project)
    - Continuous monitoring of aquifer level at select groundwater wells that are not in production.
- Lummi Peninsula Groundwater Settlement Agreement Compliance Monitoring Project
    - Discrete sampling of chloride and water use as outlined in the Lummi Peninsula Groundwater Settlement Agreement.

Some sites are monitored under several projects simultaneously. For example, all tribal supply wells located on the Lummi Peninsula are included in the Groundwater Project and the Lummi Peninsula Groundwater Settlement Agreement Compliance Project. All groundwater sites in the CALM Project also have discrete static water level measurements collected.

Sample sites were selected to represent aquifer-wide conditions as practicable, but the spatial representativeness of these sampling locations is limited by the lack of existing groundwater wells in some parts of the Reservation, particularly along the interior of the Lummi Peninsula and the eastern part of the northwestern upland.

Sites monitored as part of the Groundwater Project are sampled five times per year on alternating months beginning in April, when water levels are expected to be the highest, through the dry period (June, August, October), when aquifers are most at risk, to the beginning of the wet period (December). Sites monitored as part of the CALM Project are visited quarterly for continuous aquifer level data download and QA/QC activities, including static water level measurement. One site that is part of the Groundwater Project is located adjacent to a CALM Project well is sampled on a quarterly basis and visited on the CALM Project cycle due to ease of access (GW422). Sites monitored as part of the Lummi Peninsula Groundwater Settlement Agreement are sampled annually (August) or three times per year (April, August, December) depending on the number of well users.

During 2018, the domestic wells run for the Groundwater Project was conducted five times: in April, June, August/September, October, and December. The domestic wells run started in August 2018 was completed in September 2018. The supply wells run (which includes all Lummi Peninsula supply wells) was conducted four times: in April/May, August/September, October, and December. The supply wells run started in April 2018 was completed in May and the August 2018 run was completed in September. Monitoring wells included in the CALM Project were visited three times during 2018, in March, June, and December. June sampling was cancelled due to staff availability.

During 2019, sites in the Groundwater Project were sampled five times: in April/May, June, August, October, and December. The domestic wells run was conducted in April and the supply wells run was conducted in May. Monitoring wells included in the CALM Project were visited four times during 2019, in April, July, September, and December.

Throughout the 2018-2019 reporting period, ongoing groundwater investigative sampling was conducted to assist the Lummi Tribal Sewer and Water District.

The data collected are used to identify trends (annual and multi-year), establish baseline conditions, evaluate risk of saltwater intrusion, and generally monitor aquifer level variations.

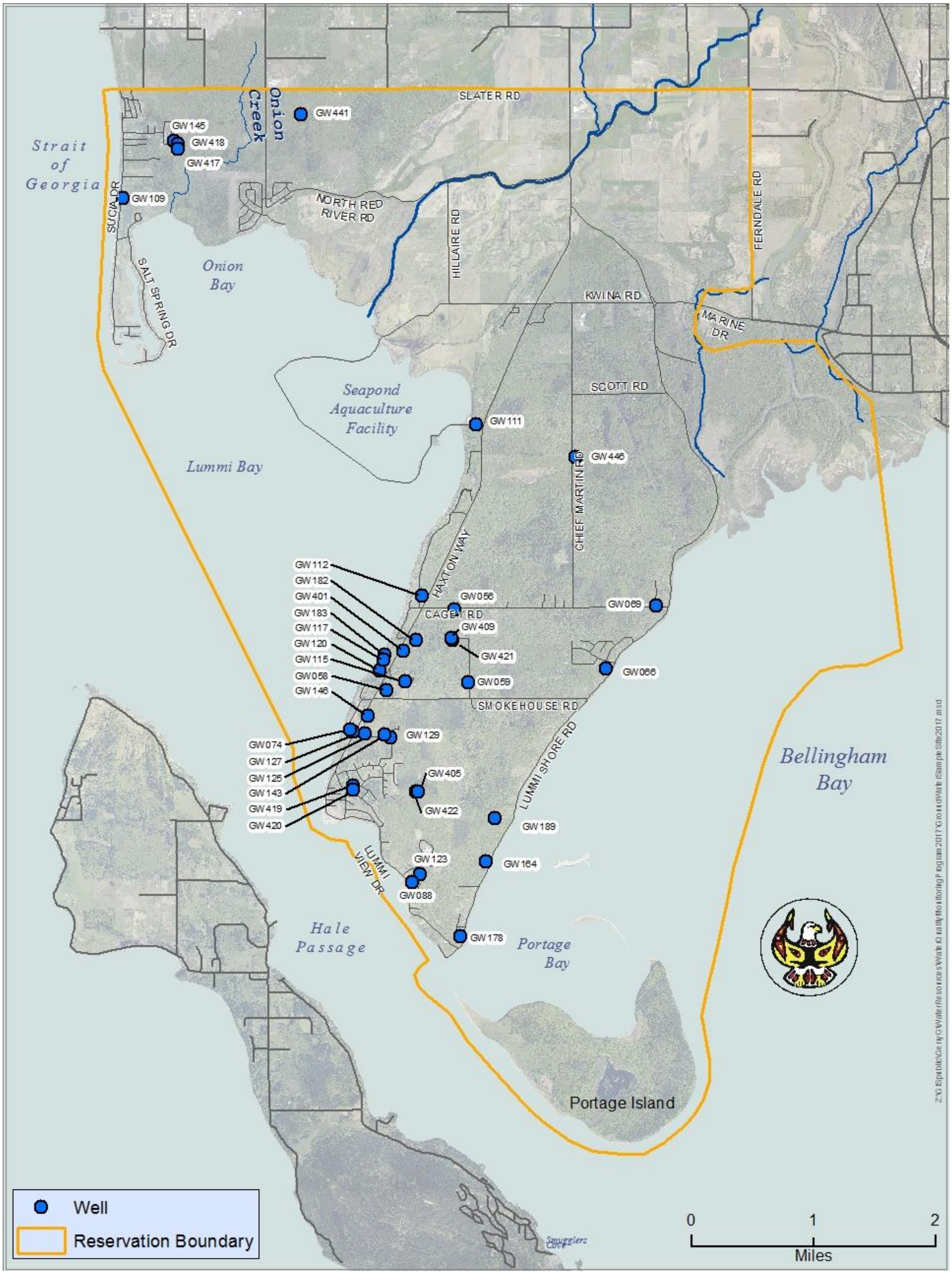

Figure 4.3.1 Groundwater monitoring sample sites

Table 4.3.1 Lummi Nation Water Quality Monitoring Program groundwater quality and aquifer level monitoring sites, parameters measured, and frequency

Well Group	Well Name	Well ID (GW)	Parameters Measured	Frequency and Notes
Domestic Wells	R. Jefferson	112	Water level	5 times per year (April, June, August, October, December)
	Howell	446		
	K. Charles*	74	Water level and water quality[a]	
	Berg*	143		
	M. Egawa*	189		
	J. Finkbonner	109	Water quality	
Tribal Supply Wells	Balch*	115	Water level, pump rate, and water quality	5 times per year (April, June, August, October, December)
	Horizon*	58		
	Kinley 1*	59		
	Kinley 2*	409		
	Kinley 3*	421		
	Mackenzie 2*	129		
	Northwest 1	417		
	Northwest 2	418		
	Westshore*	146		
	Gooseberry 4*	419		
	Gooseberry 5*	420		
	Johnson	145		
	Northwest 3	441	Water level	
CALM Project Monitoring Wells	Hopkins	111	Water level, continuous data download	Quarterly
	Cultee	56		
	Revey	127		
	Mackenzie 3	405		
	Mackenzie 4[b]	422	Water level	
Lummi Peninsula Groundwater Settlement Agreement	*Tribal Supply Wells	115, 58, 59, 409, 421, 129, 146, 419, 420	Chloride and water use	Chloride 3 times per year (April, August, December); monthly water use
	*Domestic Wells	74, 143, 189	Chloride and water use	Chloride once annually (August); annual water use
	Greene	69		
	Richardson	117		
	Dzyban/Morison	120		
	Kinley	123		
	Curtis/Wales	125		
	Doran	178		
	Robbins/Freeman	182		
	Fadden	183		
	Summers	401		

[a] Water quality parameters: water temperature, pH, salinity, specific conductivity, chloride

[b] Mackenzie #4 (GW422) well is monitored as part of the Groundwater Project but is visited on the same frequency as CALM Project monitoring wells due to its remoteness and proximity to a CALM Project monitoring well (Mackenzie #3; GW405).

4.3.1. Groundwater Monitoring Changes

The number of wells sampled has increased over the years to obtain better spatial resolution of aquifer conditions. Wells were added to the Groundwater Project as they were drilled or when access was granted. The parameters measured have not changed, other than the addition of pH in 2008 and salinity in 2009. The method of measuring chloride has changed over the years. A LaMotte chloride field test kit was used from 1990 to 2012, a chloride sensor on the YSI ProPlus multi-parameter sonde was used from 2011 to January 2016, and laboratory analysis of chloride has been used periodically throughout the period of record and consistently for all chloride measurements since 2016. Historically (*i.e.,* prior to 2013), water level, temperature, specific conductivity, pH, salinity, and chloride concentration were measured monthly at each site. In 2013, sampling frequency was reduced from monthly to five times per year, in April, June, August, October, and December. This frequency was continued for the 2018-2019 reporting period.

Changes during the 2018-2019 reporting period include the discontinuation of monitoring at the R. Finkbonner well (GW088) as part of the Lummi Peninsula Groundwater Settlement Agreement Compliance Monitoring Project because the home was connected to water provided by the Lummi Tribal Sewer and Water District.

4.4. QA/QC

In October 2018, updated quality management documents for the WQM Program were approved by the EPA (LWRD 2018a-t). The previous *Lummi Nation Water Quality Monitoring Program Quality Assurance/Quality Control Plan – Version 4.0* (LWRD 2010) was reviewed, revised, and reorganized into a new quality management system framework that used a tiered approach and separate documents to address the various components of the WQM Program. A Quality Management Plan (QMP) is the umbrella document outlining the overall quality management system for the WQM Program, Quality Assurance Project Plans (QAPPs) were developed for each individual project contained within the WQM Program, and Standard Operating Procedures (SOPs) were developed for each instrument or parameter measured.

During the 2018-2019 reporting period, field data collection and QA/QC activities were conducted following the requirements of the relevant quality management document: *Lummi Nation Water Quality Monitoring Program Quality Assurance/Quality Control Plan – Version 4.0* (LWRD 2010) was followed through October 2018, the 2018 quality management system documents (QMP, QAPPs, and SOPs) were followed after October 2018 (LWRD 2018a-t), and the QAPP for the Continuous Temperature Monitoring Project (LWRD 2015c) was followed for continuous temperature data collection throughout the reporting period.

Quality assurance/quality control procedures conducted during the reporting period include:

- Calibration of dissolved oxygen and pH sensors prior to each trip
- Accuracy checks of sensors and equipment each trip:
    - Pre-trip: dissolved oxygen, pH, water temperature, salinity, specific conductivity
    - Mid-run: dissolved oxygen, pH

    - Post-run: dissolved oxygen, pH, water temperature, salinity, specific conductivity
- Maintenance of dissolved oxygen sensor
    - Monthly replacement of electrolyte solution and DO sensor cap
- Additional sensor and equipment calibration:
    - Twice annual calibration of specific conductivity and salinity sensor
- Laboratory QA/QC pursuant to method requirements and/or laboratory QAPP
- Data entry verification:
    - Data entered into database from field datasheet or laboratory report compared to paper record to ensure correct data transcription
    - Data entered directly into database in real-time reviewed for apparent data entry errors (*e.g.,* swap in entry of dissolved oxygen mg/L and dissolved oxygen percent saturation values)
    - Rejection of incorrectly entered data or unreliable entries (*e.g.,* outliers that are determined to be data entry errors)
- Review of qualifiers associated with data and data rejected due to qualifiers

All data exported to WQP/STORET and used in this report have been verified and validated. As part of data analysis for this report, additional outliers were identified and excluded from some trend analyses. Appendices A, B, and C provide a data summary of data verified, validated, and exported to STORET. Parameter compliance and trend analysis presented in Section 7 of this report may differ slightly from the data presented in the appendices and in WQP/STORET due to exclusion of some data (*e.g.,* outliers) based on professional judgment during the course of data analysis.

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5. LUMMI NATION SURFACE WATER QUALITY STANDARDS

The purpose of this section of the report is to summarize the Lummi Nation Surface Water Quality Standards (17 LAR 07). The *Water Quality Standards for Surface Waters of the Lummi Indian Reservation* were adopted by the Lummi Nation in August 2007 and approved by the EPA on September 30, 2008. The Water Quality Standards specify the characteristic uses of marine and freshwaters in four classes: Class AA Extraordinary, Class A Excellent, Class B Good, and Lake class.

Because of the Reservation location in the Nooksack River and Lummi River estuaries, many Reservation water bodies are seasonally brackish. This temporal and spatial variability creates uncertainty regarding whether or not marine or fresh water standards apply. To remove this uncertainty, the approach taken in developing the Water Quality Standards was to identify specific geographic locations as the demarcation between fresh and marine waters (Figure 4.4.1). A line between Fish Point and Treaty Rock separates freshwater and marine water in the Nooksack River Delta as well as separates Class AA and Class A waters. The location where the water body flows under Hillaire Road separates the freshwater and marine water in the Lummi River Delta.

The Water Quality Standards include numeric criteria for fecal coliform bacteria, enterococci, dissolved oxygen, total dissolved gas, temperature, pH, and turbidity (Table 4.4.1). Numeric criteria for toxic substances and narrative criteria for a variety of conditions are also included as part of the Water Quality Standards. Nutrient data are evaluated quantitatively by comparison to EPA regional benchmarks (EPA 2000) as only narrative criteria are listed in the Water Quality Standards.

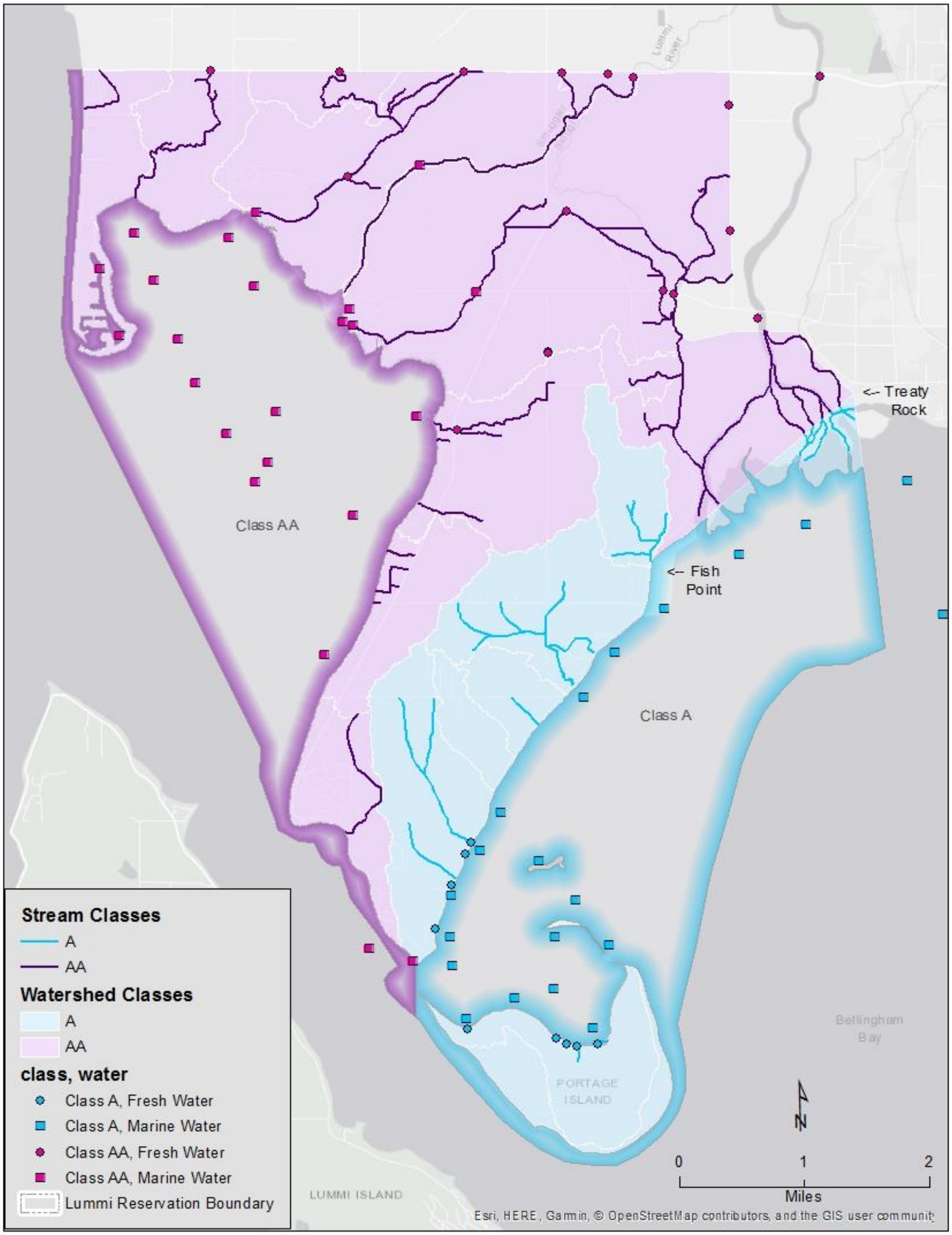

Figure 4.4.1 Classification of Lummi Nation Waters and water quality monitoring locations

Table 4.4.1 Summary of water quality criteria and characteristic uses of Lummi Indian Reservation surface waters by class

<table>
<tr><th>Parameter</th><th>Class AA Extraordinary</th><th>Class A Excellent</th><th>Class B Good</th><th>Lake Class</th></tr>
<tr><td>General Characteristics</td><td>Uniformly exceeds the requirements for all or substantially all uses</td><td>Meets or exceeds the requirements for all or substantially all uses</td><td>Meets or exceeds the requirements for most uses</td><td>Meets or exceeds the requirements for all or substantially all uses</td></tr>
<tr><td rowspan="2">Characteristic Uses</td><td colspan="4">(A) Water supply (industrial, agricultural)
(B) Stock watering
(C) Fish and shellfish:
Salmonid migration, juvenile rearing, and harvesting
Other fish migration, juvenile rearing, spawning, egg incubation, fry emergence, and harvesting
(D) Wildlife habitat
(E) Recreation (secondary contact, sport fishing, boating, and aesthetic enjoyment)
(F) Commerce and navigation
(G) Tribal Cultural</td></tr>
<tr><td>(A) Water supply (domestic, commercial, municipal)
(C) Fish and shellfish:
Salmonid spawning, egg incubation, fry emergence
Clam, oyster, and mussel rearing, spawning, and harvesting
Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, geoduck, etc.) rearing, spawning, and harvesting
(E) Recreation (extraordinary primary contact, primary contact, canoeing)</td><td>(A) Water supply (domestic, commercial, municipal)
(C) Fish and shellfish:
Clam, oyster, and mussel rearing, spawning, and harvesting
Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, geoduck, etc.) rearing, spawning, and harvesting
(E) Recreation (primary contact, canoeing)</td><td>(C) Fish and shellfish:
Clam, oyster, and mussel rearing and spawning
Crustaceans and other shellfish (crabs, shrimp, crayfish, scallops, geoduck, etc.) rearing and spawning
(E) Recreation (secondary contact)</td><td>(A) Water supply (domestic, commercial, municipal)
(C) Fish and shellfish:
Salmonid spawning, egg incubation, fry emergence
Clam and mussel rearing and spawning
Crayfish rearing and spawning
(E) Recreation (extraordinary primary contact, primary contact, canoeing)</td></tr>
</table>

Table 4.4.1 Summary of water quality criteria and characteristic uses of Lummi Indian Reservation surface waters by class

Parameter	Class AA Extraordinary	Class A Excellent	Class B Good	Lake Class
Freshwater Fecal Coliform Bacteria Geometric Mean Density	Shall both not exceed 50 colonies/100 ml AND not exceed 100 colonies/100 ml in more than 10% of the samples obtained for calculation purposes	Shall both not exceed 100 colonies/100 ml AND not exceed 200 colonies/100 ml in more than 10% of the samples obtained for calculation purposes	Shall both not exceed 200 colonies/100 ml AND not exceed 400 colonies/100 ml in more than 10% of the samples obtained for calculation purposes	Shall both not exceed 50 colonies/100 ml AND not exceed 100 colonies/100 ml in more than 10% of the samples obtained for calculation purposes
Marine Water Fecal Coliform Bacteria Geometric Mean Density	Shall both not exceed 14 colonies/100 ml AND not exceed 43 colonies/100 ml in more than 10% of the samples obtained for calculation purposes		Shall both not exceed 100 colonies/100 ml AND not exceed 200 colonies/100 ml in more than 10% of the samples obtained for calculation purposes	N/A
Freshwater Enterococci	Shall both not exceed a geometric mean density of 33 colonies/100 ml AND not exceed a single sample maximum allowable density of 61 colonies/100 ml		Shall both not exceed a geometric mean density of 33 colonies/100 ml AND not exceed a single sample maximum allowable density of 78 colonies/100 ml	Shall both not exceed a geometric mean density of 33 colonies/100 ml AND not exceed a single sample maximum allowable density of 61 colonies/100 ml
Marine Water Enterococci	Shall both not exceed a geometric mean density of 35 colonies/100 ml AND not exceed a single sample maximum allowable density of 104 colonies/100 ml		Shall both not exceed a geometric mean density of 35 colonies/100 ml AND not exceed a single sample maximum allowable density of 158 colonies/100 ml	N/A

Table 4.4.1 Summary of water quality criteria and characteristic uses of Lummi Indian Reservation surface waters by class

Parameter	Class AA Extraordinary	Class A Excellent	Class B Good	Lake Class
Freshwater Dissolved Oxygen Concentration	The seven-day mean minimum shall both not be less than 11.0 mg/l AND not have a spatial median intergravel dissolved oxygen concentration below 8.0 mg/l. If minimum spatial median intergravel dissolved, oxygen is 8.0 mg/l or greater, the minimum dissolved oxygen criterion is 9.0 mg/l. Where barometric pressure and temperature preclude attainment of criteria, dissolved oxygen must not be less than 95% of saturation.	Shall not be less than 8.0 mg/l. Where barometric pressure and temperature preclude attainment of criteria, dissolved oxygen must not be less than 90% of saturation.	Shall not be less than 6.5 mg/l	No measurable decrease from natural conditions
Marine Water Dissolved Oxygen Concentration	Shall exceed a 1-day minimum daily concentration of 7.0 mg/l	Shall exceed a 1-day minimum daily concentration of 6.0 mg/l	Shall exceed a 1-day minimum daily concentration of 5.0 mg/l	N/A
Freshwater Temperature	Shall not exceed a 7-day average of the daily maximum value (7DADM) temperature of 16.0°C. For summertime spawning, temperature shall not exceed a 7DADM temperature of 13.0°C.	Shall not exceed a 7DADM temperature of 17.5°C	Shall not exceed a 7DADM temperature of 17.5°C	No measurable increase from natural conditions
Marine Water Temperature	Shall not exceed a 1-day maximum temperature of 13.0°C	Shall not exceed a 1-day maximum temperature of 16.0°C	Shall not exceed a 1-day maximum temperature of 19.0°C	N/A

Table 4.4.1 Summary of water quality criteria and characteristic uses of Lummi Indian Reservation surface waters by class

Parameter	Class AA Extraordinary	Class A Excellent	Class B Good	Lake Class
Freshwater pH	6.5 – 8.5	6.5 – 8.5	6.5 – 8.5	No measurable change from natural conditions
Marine Water pH	7.0 – 8.5	7.0 – 8.5	7.0 – 8.5	N/A
Turbidity	Shall not exceed 5 NTU over background turbidity when background turbidity is less than or equal to 50 NTU OR not increase by more than 10% when the background turbidity is greater than 50 NTU		Shall not exceed 5 NTU over background turbidity when background turbidity is less than or equal to 50 NTU OR not increase by more than 20% when the background turbidity is greater than 50 NTU	Shall not exceed 5 NTU over background turbidity
Toxic, Radioactive, Or Deleterious Material Concentrations	Shall be less than concentrations that have the potential either singularly or cumulatively to adversely affect characteristic water uses, cause acute or chronic conditions to the most sensitive biota dependent upon those waters, or adversely affect public health as determined by the Director.			
Aesthetic Values	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste or taint the flesh of edible species			

6. WATER QUALITY STANDARD COMPLIANCE AND SUMMARY BY PARAMETER

This section provides a summary as to whether the characteristic uses for each waterbody were met during the 2018-2019 reporting period. Table 6.1.1 and Table 6.1.2 summarize compliance with water quality standards and characteristic uses for sites in and draining to Lummi Bay and Portage Bay. Water quality monitoring results by site for the 2018-2019 reporting period were compared with the water quality criteria for fecal coliform, enterococci, temperature,[4] dissolved oxygen,[5] and pH with compliance status shown in the tables for 2018-2019 and for the period of record (2008-2017 or 2014-2017). In order for each waterbody to provide full support of the characteristic uses, all sites within the area must meet all five water quality standards evaluated.

During the 2018-2019 reporting period, 103 surface and ground water sites were sampled on 250 days for a total of 16,545 measurements of 49 unique parameters. Summary results by site and parameter are reported in the appendices for each reporting year:

- Appendix A summarizes non-bacterial primary parameter results by site, showing total observations, mean, minimum, and maximum measurement for the reporting year and over the period of record.
- Appendix B summarizes non-bacterial secondary parameter results by water quality class, showing sites monitored, total observations, mean, minimum, and maximum measurements for the reporting year and over the period of record.
- Appendix C summarizes bacterial parameter summary statistics by site, showing new observations for the reporting year, maximum value observed, geometric mean, geometric 90th percentile, and number of observations used for geometric summary statistic calculations.

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[4] The temperature standards are a seven-day average of the daily maximum value for freshwaters and a one-day maximum value for marine waters. As discussed in Section 7.2.1, continuous temperature monitoring is required for proper evaluation of compliance with the standard. This section, including Table 6.1.1 and Table 6.1.2, estimates compliance based on discrete data when continuous data are not available, which can only be used to identify sites that fail or are likely to fail to meet the standard. Discrete data cannot be used to definitively determine that a site meets the standard because continuous data are required for this. Sites that are marked as meeting the temperature standard were sites where all discrete temperature measurements collected were below the applicable temperature criterion.

[5] The dissolved oxygen standard for freshwater has two parts: a mg/L criterion and a percent saturation criterion which is used if temperature or pressure precludes attainment of the mg/L criterion at 100% saturation. Freshwater dissolved oxygen data were compared to either the mg/L or percent saturation criteria, as appropriate. The dissolved oxygen standard for Class AA Extraordinary waters is a seven-day mean minimum, which would require continuous monitoring in order to adequately evaluate compliance. Similar to the temperature standard, discrete data are used to identify sites that fail or are likely to fail to meet the standard. In addition, the dissolved oxygen standard compliance determination does not include evaluation of the inter-gravel dissolved oxygen concentration, which is an additional component of the dissolved oxygen standard for Class AA Extraordinary waters.

- Appendix D provides a series of maps graphically showing compliance status of sites monitored for the parameter in question during the reporting year.
- Appendix E summarizes compliance of sites with the single-parameter water quality standards for fecal coliform, enterococci, temperature, pH, and dissolved oxygen (see also footnote 5 on page 43). For each water quality class, Appendix E summarizes the number of sites monitored, how many sites are compliant with the standard, how many sites are noncompliant with the standard, how many sites had insufficient data to determine compliance, and the compliance rate by parameter.

Section 7 provides a detailed discussion of site compliance with water quality criteria organized by topic, including characteristic use or area of concern.

6.1. Summary of Water Quality

Reservation water quality remains complex due to the interaction of marine waters and freshwater, variable tidal conditions during sampling, and seasonal weather patterns. Overall, the water quality parameters at most of the sites during the 2018-2019 reporting period followed the trends of the previous four to ten years (2014-2017, 2008-2017): elevated bacteria levels, elevated temperatures, and low dissolved oxygen levels. As shown in Table 6.1.1 and Table 6.1.2, all but one site failed to meet at least one water quality standard during the 2018-2019 reporting period.

A ten-year period of record (2008-2017) divided into two five-year periods (2008-2012, 2013-2017) was used for most analyses. This summary shows the frequency of noncompliant years for the ten-year period of record as a percentage for enterococcus, temperature, dissolved oxygen, and pH. Compliance with these parameter standards is shown for each reporting year, 2018 and 2019. For fecal coliform, this summary shows the frequency of noncompliant years for the ten-year period of record (2008-2017) as a percentage and reporting year compliance by year for freshwater sites in the Lummi Bay watershed. Freshwater sites in the Portage Bay watershed, however, were assessed using pooled data for two periods of record and the reporting period: the six-year period of record 2008-2013, the four-year period of record 2014-2017, and the two-year reporting period 2018-2019. This was done because sites were only visited six times per year at freshwater sites, except Nooksack River site SW118, in the Portage Bay watershed, precluding three samples per season for assessment. The uneven-sized periods of record were selected to match the assessment period used for marine sites in Portage Bay. The period of record for marine sites in Portage Bay and at Nooksack River site SW118 is 2014-2017. This four-year period was selected for several reasons: it is the period of time covered in the previous water quality assessment report (LWRD 2019c), it represents the period of time prior to the reporting period during which portions of the Portage Bay shellfish growing area was subject to conditional closure, cattle were removed from Portage Island in 2013, and sampling during stagnant conditions was discontinued during 2013. For marine sites in Portage Bay and SW118, compliance was determined annually for the four-year period of record 2014-2017 and for the two reporting years 2018 and 2019. Marine sites in Lummi Bay were assessed using pooled data for two periods of record and the reporting period: the six-year period of record 2008-2013, the four-year period of record 2014-2017, and the two-year reporting period

2018-2019. This was done because these sites were visited only six times per year, resulting in fewer than three samples for each season per year. The periods were selected to match those assessed for the Portage Bay watershed.

6.1.1. Lummi Bay Watershed Summary

Table 6.1.1 summarizes compliance of sites within the Lummi Bay watershed with the five major water quality standards: fecal coliform, enterococcus, temperature, dissolved oxygen, and pH. Compliance for the 2018-2019 reporting period is shown annually (red or green circle) following the percentage of noncompliant years during the ten-year period of record 2008-2017 (color-coded by frequency) for all parameters except fecal coliform at marine sites. Compliance with fecal coliform at marine sites (Sandy Point Channel, Hale Passage, and Lummi Bay) is shown for the pooled 2018-2019 reporting period (red or green circle) following compliance for a six-year period of record 2008-2013 and a four-year period of record 2014-2017 using data pooled for each period (red or green circles) in chronological order. A detailed discussion of compliance by site and watershed is provided in Section 7.

All sites in the Lummi Bay watershed failed to meet at least one of the water quality standards during the reporting period 2018-2019. All fresh and marine waters in the Lummi Bay watershed do not fully support the characteristic uses of the watershed due to noncompliance with one or more standards.

The primary Lummi Bay freshwater drainages – Jordan Creek, the Lummi River, and Smuggler Slough – continued to exhibit poor water quality during the reporting period (2018-2019), following trends observed over the previous ten years (2008-2017). Elevated bacterial (fecal coliform and enterococci) densities, warm temperatures, low dissolved oxygen, and, at some sites, pH observations exceeding minimum and/or maximum criteria continued during the 2018-2019 reporting period. At some Smuggler Slough sites, bacterial densities observed during the reporting period showed improvement compared to the period of record.

Sites in the two smaller Lummi Bay freshwater drainages, Onion Creek and Seapond Creek, continued to show impairment in fecal coliform and dissolved oxygen during the reporting period. Enterococcus densities were compliant with the standard during the reporting period at Seapond Creek, showing improvement over the period of record. Observed temperatures remained within standard at both sites and pH was variable.

In the marine waters of Lummi Bay, including the shellfish harvesting area, bacteria (fecal coliform and enterococci) remained low. The Sandy Point channel showed continued degradation at the north end of the marina (SW001) and continued improvement at the south end (SW019). Hale passage was mixed, with continued noncompliant conditions nearshore (SW039). Temperatures continued to exceed the marine temperature criteria at all sites. Dissolved oxygen conditions largely remained compliant; sites in the Sandy Point Channel showed improvement, while Hale Passage and Lummi Bay each had only one site/year with noncompliance. Marine pH conditions were mixed; improvement was observed during the reporting period at sites in Hale Passage and Lummi Bay, while other sites in Lummi Bay showed variability or potentially degrading conditions.

Two sites in the Lummi Bay watershed were sampled infrequently and not included in this summary or in Section 7 summaries. Smuggler Slough site SW072 was only sampled once during reporting period. Lummi River site SW058 was only sampled on four occasions during the reporting period, each time during upstream flow from the Lummi River.

Table 6.1.1 (next page) Lummi Bay water quality standard compliance for period of record (2008-2017) and reporting period (2018-2019) and support of characteristic uses for the reporting period. Color-coded percentage is annual noncompliance rate for the period of record (2008-2017; red is higher noncompliance rate, green is lower noncompliance rate) and circles indicate compliance for the reporting years or pooled periods (red = noncompliant; green = compliant); details in footnotes.

Location	Fecal Coliform (CFU/100ml)[1]			Enterococci (CFU/100ml)[2]			Temperature (°C)[3]			Dissolved Oxygen (mg/L or %)[4]			pH[5]			Full Support
Jordan Creek																No
SW011	100%	🔴	🔴	100%	🔴	🔴	30%	🔴	🔴	90%	🔴	🔴	30%	🟢	🟢	
SW010	89%	🔴	🔴	89%	🔴	🟢	78%	🔴	🔴	89%	🔴	🔴	38%	🟢	🟢	
SW003	100%	🔴	🔴	90%	🔴	🔴	100%	🔴	🔴	100%	🔴	🔴	60%	🔴	🟢	
SW053	100%	🔴	🔴	70%	🔴	🔴	100%	🔴	🔴	100%	🔴	🔴	80%	🔴	🔴	
Lummi River																No
SW012	90%	🔴	🔴	90%	🔴	🔴	60%	🔴	🔴	100%	🔴	🔴	20%	🟢	🟢	
SW013	100%	🔴	🔴	100%	🔴	🔴	67%	🔴	🔴	100%	🔴	🔴	33%	🟢	🟢	
SW009	100%	🔴	🔴	100%	🔴	🔴	50%	🔴	🔴	75%	🔴	🔴	10%	🟢	🟢	
SR005	nd	nd	🔴	nd	nd	🔴	nd	nd	🔴	nd	nd	🔴	nd	nd	🟢	
SW008	100%	🔴	🔴	90%	🔴	🔴	100%	🔴	🔴	100%	🔴	🔴	50%	🟢	🔴	
SW051	90%	🔴	🔴	50%	🔴	🔴	100%	🔴	🔴	100%	🔴	🔴	70%	🔴	🔴	
Smuggler Slough																No
SW016	100%	🔴	🔴	80%	🔴	🔴	40%	🟢	🟢	100%	🔴	🔴	0%	🟢	🟢	
SW017	75%	🟢	🟢	100%	🟢	🟢	50%	🟢	🟢	100%	🔴	🔴	25%	nd	🟢	
SW015	100%	🟢	🟢	90%	🟢	🔴	80%	🔴	🔴	100%	🔴	🔴	30%	🟢	🟢	
SW059	100%	🔴	🔴	100%	🟢	🔴	90%	🔴	🔴	100%	🔴	🔴	80%	🔴	🔴	
SW055	90%	🟢	🟢	30%	🟢	🟢	100%	🔴	🟢	100%	🔴	🔴	70%	🔴	🟢	
SW056	100%	🔴	🔴	60%	🔴	🔴	100%	🔴	🟢	40%	🔴	🔴	10%	🟢	🔴	
Onion Creek																No
SW014	90%	🔴	🔴	80%	🔴	🔴	30%	🟢	🟢	100%	🔴	🔴	22%	🔴	🟢	
Seapond Creek																No
SW029	89%	🔴	🟢	78%	🟢	🟢	0%	🟢	🟢	89%	🔴	🔴	100%	🟢	🔴	
Sandy Point Channel																No
SW001	🟢	🔴	🔴	10%	🟢	🟢	100%	🔴	🔴	60%	🟢	🟢	30%	🟢	🟢	
SW019	🔴	🟢	🟢	30%	🟢	🟢	100%	🔴	🔴	70%	🟢	🔴	10%	🟢	🟢	
Hale Passage																No
SW039	🔴	🔴	🔴	90%	🔴	🔴	100%	🔴	🔴	20%	🟢	🟢	60%	🟢	🟢	
DH048	🟢	🔴	🟢	nd	nd	nd	100%	🔴	🔴	0%	🔴	🟢	0%	🟢	🟢	
Lummi Bay																No
SW002	🟢	🟢	🟢	0%	🟢	🟢	100%	🔴	🔴	20%	🟢	🔴	20%	🟢	🟢	
DH038	🟢	🟢	🟢	nd			100%	🔴	🔴	0%	🟢	🟢	0%	🟢	🔴	
DH039	🟢	🟢	🟢	nd			90%	🔴	🔴	10%	🟢	🟢	0%	🟢	🟢	
DH040	🟢	🟢	🟢	nd			90%	🔴	🔴	10%	🟢	🟢	0%	🟢	🟢	
DH041	🟢	🟢	🟢	nd			100%	🔴	🔴	10%	🟢	🟢	20%	🟢	🟢	
DH042	🟢	🟢	🟢	nd			100%	🔴	🔴	30%	🟢	🟢	50%	🔴	🔴	
DH043	🟢	🟢	🟢	nd			100%	🔴	🔴	10%	🟢	🟢	10%	🟢	🟢	
DH044	🔴	🟢	🟢	nd			100%	🔴	🔴	30%	🟢	🟢	30%	🔴	🟢	
DH045	🔴	🟢	🟢	nd			100%	🔴	🔴	20%	🟢	🟢	60%	🟢	🟢	
DH285	🟢	🔴	🟢	nd			100%	🔴	🔴	10%	🟢	🟢	10%	🟢	🟢	
DH286	🔴	🔴	🔴	nd			100%	🔴	🔴	30%	🟢	🟢	60%	🔴	🔴	
DH287	🟢	🔴	🟢	nd			90%	🔴	🔴	20%	🟢	🟢	0%	🟢	🟢	
DH288	🟢	🟢	🟢	nd			100%	🔴	🔴	10%	🟢	🟢	20%	🔴	🔴	

[1] Fecal coliform compliance was evaluated by season (Section 7.1.2). If any one season failed to meet the standard, the site is marked as failing to meet the standard for the full reporting period. Sites that are visited at least monthly are located in Jordan Creek, Lummi River, Smuggler Slough, Onion Creek, and Seaponds Creek watersheds. Fecal coliform compliance for these sites was evaluated seasonally on an annual basis. Compliance for the period of record for these sites is the percentage of years failing to meet the fecal coliform standard for the period 2008-2017 out of the number of years assessed (i.e., excluding years with no samples). Compliance for the reporting period 2018-2019 is shown by reporting year (red circle if fail, green circle if meet). Sites that are visited less than monthly, typically six times per year, and have fewer than three samples per season per year are located in the Sandy Point Channel, Hale Passage, and Lummi Bay. Fecal coliform compliance for these sites was evaluated seasonally for three pooled periods: six-year period of record 2008-2013, four-year period of record 2014-2017, and the two-year reporting period 2018-2019. Compliance for these periods is shown in chronological order (red circle if fail, green circle if meet).

[2] Enterococcus compliance was evaluated by season on an annual basis (Section 7.4). If any one season failed to meet the standard, the site is marked as failing to meet the standard for the year. Compliance for the period of record is the percentage of years failing to meet the enterococcus standard for the period 2008-2017 out of the number of years assessed (i.e., excluding years with no samples). Enterococcus compliance for the reporting period 2018-2019 is shown for each reporting year (red circle if fail, green circle if meet).

[3] Temperature compliance was determined annually from continuous temperature data, if available, and if not available, from discrete data (Section 7.2.1). Continuous data were used for compliance for years 2016-2019 for sites SW003, SW009, SW011, SW012, SW015, and SW059. If any one 7-day average of the daily maximum temperature (calculated from continuous data) or single discrete temperature measurement exceeded the standard, the site is marked as failing to meet the standard for the year. Compliance for the period of record is the percentage of years failing to meet the temperature standard for the period 2008-2017 out of the number of years assessed (i.e., excluding years with no samples). Compliance for the reporting period 2018-2019 is shown for each reporting year (red circle if fail, green circle if meet).

[4] Dissolved oxygen compliance was determined annually from either dissolved oxygen (mg/L) or % saturation data, depending on temperature (Section 7.2.2). If any one measurement exceeded the standard, the site was marked as failing to meet the standard for the year. Compliance for the period of record is the percentage of years failing to meet the dissolved oxygen standard for the period 2008-2017 out of the number of years assessed (i.e., excluding years with no samples). Compliance for the reporting period 2018-2019 is shown for each reporting year (red circle if fail, green circle if meet).

[5] pH compliance was determined annually (Section 7.3.1). If any one measurement exceeded the criteria, the site was marked as failing to meet the standard for the year. Compliance for the period of record is the percentage of years failing to meet the pH standard for the period 2008-2017 out of the number of years assessed (i.e., excluding years with no samples). Compliance for the reporting period 2018-2019 is shown for each reporting year (red circle if fail, green circle if meet).

6.1.2. Portage Bay Watershed Summary

Table 6.1.2 summarizes compliance of sites within the Portage Bay watershed with the five major water quality standards: fecal coliform, enterococci, temperature, dissolved oxygen, and pH. Compliance for the 2018-2019 reporting period is shown annually (red or green circle) following the percentage of noncompliant years during the ten-year period of record 2008-2017 (color-coded by frequency) for all parameters except fecal coliform. Compliance with fecal coliform standard at freshwater sites (Nooksack River delta tributaries, Lummi Shore Road, Portage Island) is shown for the pooled 2018-2019 reporting period (red or green circle) following compliance for a six-year period of record 2008-2013 and a four-year period of record 2014-2017 using data pooled for each period (red or green circles) in chronological order. Compliance with the fecal coliform standard at marine sites in Portage Bay and the Nooksack

River is shown annually (red or green circle) following the percentage of noncompliant years during the four-year period of record 2014-2017 (color-coded by frequency). A detailed discussion of compliance by site and watershed is provided in Section 7.

All but one site in the Portage Bay watershed failed to meet at least one of the water quality standards during the reporting period 2018-2019. Lummi Shore Road site SW037 was in compliance with all water quality standards during the 2018-2019 reporting period. All characteristic uses for this waterbody were fully supported during the reporting period. All other fresh and marine waters in the Portage Bay watershed did not fully support the characteristic uses of the watershed due to noncompliance with one or more standards during the reporting period.

Fecal coliform bacteria densities in the mainstem of the Nooksack River at the Reservation boundary (SW118) showed improvement during 2018, but in 2019 returned to noncompliant status. Elevated enterococci, high temperatures, low dissolved oxygen, and pH excursions continued during the 2018-2019 reporting period. Kwina Slough, a side channel of the Nooksack River, and Silver Creek, a tributary to the Nooksack River, also had elevated bacteria and low dissolved oxygen.

The intermittent freshwater drainages into Portage Bay along Lummi Shore Road continued to show low or improved fecal coliform densities at most sites, including site SW037 which was in compliance with all standards, but showed degraded fecal coliform and enterococcus densities at one site. Water temperatures remained low at all sites. Dissolved oxygen and pH showed variability, with continued noncompliance at some times, continued compliance at other sites, and year-to-year variability at others.

The freshwater drainages on Portage Island exhibited degraded conditions for fecal coliform, enterococci, and dissolved oxygen during the reporting period. Temperature and pH remained largely compliant.

The marine waters of Portage Bay, including the Portage Bay shellfish growing area, continued the pattern of degradation. Fecal coliform densities exceeded the standard at all sites, which is consistent with the seasonal closure of portions of the shellfish harvesting area (Section 7.1.3). After improvements over the previous four years (2014-2017), fecal coliform densities returned to a trend of degradation during the reporting period. Temperatures in Portage Bay continued to exceed maximum standards but dissolved oxygen remained high during the reporting period. Most sites had pH measurements protective of the uses during most years, but occasional pH excursions were observed during the first half of the reporting period (2018) nearest to Portage Island, Brant Spit, and Brant Island.

Table 6.1.2 Portage Bay water quality standard compliance for period of record (2008-2017 or 2014-2017) and reporting period (2018-2019) and support of characteristic uses for the reporting period. Color-coded percentage is annual noncompliance rate for the period of record (2008-2017 or 2014-2017; red is higher noncompliance rate, green is lower noncompliance rate) and circles indicate compliance for the reporting years or pooled periods (red = noncompliant; green = compliant); details in footnotes.

Location	Fecal Coliform (CFU/100ml)[1]			Enterococci (CFU/100ml)[2]			Temperature (°C)[3]			Dissolved Oxygen (mg/L or %)[4]			pH[5]			Full Support
Nooksack River																**No**
SW118	100%	🟢	🔴	100%	🔴	🔴	90%	🔴	🔴	50%	🟢	🔴	40%	🔴	🟢	
Nooksack River Delta and Tributaries – Kwina Slough and Silver Creek																**No**
SW007	🔴	🔴	🔴	100%	🔴	🔴	44%	🔴	🟢	78%	🔴	🔴	44%	🟢	🟢	
SW075	nd	🔴	🟢	100%	🔴	🔴	0%	🟢	🟢	100%	🔴	🔴	50%	🟢	🟢	
Lummi Shore Road																**No**
SW031	🟢	🟢	🟢	20%	🟢	🟢	0%	🟢	🟢	50%	🟢	🔴	78%	🔴	🔴	
SW033	🔴	🟢	🔴	20%	🔴	🔴	0%	🟢	🟢	80%	🟢	🟢	90%	🔴	🔴	
SW035	🔴	🟢	🟢	40%	🔴	🟢	0%	🟢	🟢	80%	🔴	nd	30%	nd	🟢	
SW037	🔴	🟢	🟢	43%	🟢	🟢	0%	🟢	🟢	33%	🟢	🟢	0%	nd	🟢	
Portage Island																**No**
SW026	🔴	🔴	🔴	70%	🔴	🔴	30%	🟢	🟢	70%	🔴	🔴	0%	🟢	🟢	
SW027	🔴	🔴	🔴	90%	🔴	🔴	0%	🟢	🟢	40%	🔴	🔴	20%	🟢	🟢	
SW028	🔴	🔴	🟢	80%	🔴	🔴	40%	🔴	🟢	70%	🔴	🔴	30%	🟢	🟢	
Portage Bay																**No**
SW006	🟢	🔴	🔴	20%	🟢	🔴	80%	🟢	🔴	0%	🟢	🟢	20%	🟢	🟢	
SW023	🔴	🟢	🔴	50%	🟢	🔴	80%	🟢	🔴	0%	🟢	🟢	10%	🟢	🟢	
DH049	50%	🔴	🔴	nd	🔴	🔴	70%	🔴	🔴	0%	🟢	🟢	13%	🟢	🟢	
DH050	75%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	0%	🟢	🟢	
DH051	50%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	0%	🟢	🟢	
DH052	100%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	13%	🔴	🟢	
DH053	50%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	0%	🟢	🟢	
DH054	25%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	0%	🔴	🟢	
DH055	75%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	0%	🔴	🟢	
DH057	50%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	13%	🔴	🟢	
DH058	25%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	0%	🔴	🟢	
DH271	50%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	13%	🟢	🟢	
DH272	75%	🔴	🔴	nd			70%	🔴	🔴	0%	🟢	🟢	17%	🟢	🟢	

[1] Fecal coliform compliance was evaluated by season (Section 7.1.2). If any one season failed to meet the standard, the site is marked as failing to meet the standard for the full reporting period. Sites that are visited at least monthly are the Nooksack River mainstem and Portage Bay NSSP sites. Fecal coliform compliance for these sites was evaluated seasonally on an annual basis. Compliance for the period of record is the percentage of years failing to meet the fecal coliform standard for the period 2014-2017. Compliance for the reporting period 2018-2019 is shown by reporting year (red circle if fail, green circle if meet). Sites that are visited less than monthly, typically six times per year, and have fewer than three samples per season per year are located in Portage Bay (SW006, SW023), on Portage Island, and along Lummi Shore Road. Fecal coliform compliance for these sites was evaluated

seasonally for three pooled periods: six-year period of record 2008-2013, four-year period of record 2014-2017, and the two-year reporting period 2018-2019. Compliance for these three periods is shown in chronological order (red circle if fail, green circle if meet). Tributaries to the Nooksack River (SW075, SW007) are visited monthly, but were assessed seasonally for the three pooled periods for consistency.

[2] Enterococcus compliance was evaluated by season on an annual basis (Section 7.4). If any one season failed to meet the standard, the site is marked as failing to meet the standard for the year. Compliance for the period of record is the percentage of years failing to meet the enterococcus standard for the period 2008-2017 out of the number of years assessed (i.e., excluding years with no samples). Enterococcus compliance for the reporting period 2018-2019 is shown for each reporting year (red circle if fail, green circle if meet).

[3] Temperature compliance was determined annually from continuous temperature data, if available, and if not available, from discrete data (Section 7.2.1). Continuous data were not available for any sites in the Portage Bay watershed. If any single discrete temperature measurement exceeded the standard, the site is marked as failing to meet the standard for the year. Compliance for the period of record is the percentage of years failing to meet the temperature standard for the period 2008-2017 out of the number of years assessed (i.e., excluding years with no samples). Compliance for the reporting period 2018-2019 is shown for each reporting year (red circle if fail, green circle if meet).

[4] Dissolved oxygen compliance was determined annually from either dissolved oxygen (mg/L) or % saturation data, depending on temperature (Section 7.2.2). If any one measurement exceeded the standard, the site was marked as failing to meet the standard for the year. Compliance for the period of record is the percentage of years failing to meet the dissolved oxygen standard for the period 2008-2017 out of the number of years assessed (i.e., excluding years with no samples). Compliance for the reporting period 2018-2019 is shown for each reporting year (red circle if fail, green circle if meet).

[5] pH compliance was determined annually (Section 7.3.1). If any one measurement exceeded the criteria, the site was marked as failing to meet the standard for the year. Compliance for the period of record is the percentage of years failing to meet the pH standard for the period 2008-2017 out of the number of years assessed (i.e., excluding years with no samples). Compliance for the reporting period 2018-2019 is shown for each reporting year (red circle if fail, green circle if meet).

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7. DISCUSSION

This section evaluates the characteristic uses and provides a discussion of the parameters used to determine whether the characteristic uses are protected for each classification. This section also includes discussion of issues of concern and associated parameters.

7.1. Shellfish Harvesting

Fecal coliform bacteria are of particular importance because they are the indicator organism used in the National Shellfish Sanitation Program (NSSP) to classify shellfish beds as suitable for commercial harvest. Commercial shellfish beds are located on the Portage Bay and Lummi Bay tidelands of the Reservation. All watersheds, including the Lummi River and Nooksack River watersheds, contain land uses that contribute fecal coliform bacteria to surface waters.

Historically, portions of the Portage Bay shellfish harvesting area were downgraded from “approved” to “restricted” status in various areas from 1996 to 2006. The cause of the downgrades was attributed to contaminated Nooksack River water entering Portage Bay (Ecology 2000). According to the 1997 DOH Sanitary Survey of Portage Bay, fecal contamination of the Nooksack River was the result of poor manure management practices by dairy farms in the Nooksack River watershed, and these sources represented a high probability of being the principal source of fecal contamination in Portage Bay (DOH 1997). The presence of Nooksack River water in Portage Bay occurs frequently and is evidenced by lowered salinities, salinity-based stratification, and/or color. In general, elevated fecal coliform bacteria levels in Portage Bay are associated with lower surface salinities.

In 2000, a Total Maximum Daily Load (TMDL) was published for the Nooksack River (Ecology 2000) and a TMDL implementation plan was executed (Ecology 2002). Improvement in water quality resulting in the reopening of shellfish beds in 2006 was generally attributed to the combined effects of inter-agency coordination, water quality monitoring in Portage Bay and the Nooksack River watershed, compliance enforcement inspections by the EPA and Washington State Department of Ecology, and technical assistance and financial support to Nooksack River watershed dairy operations and municipalities (LWRD and Salix 2006). Although these efforts were initially successful in dramatically improving water quality in the Nooksack River watershed with essentially all of the TMDL targets being achieved at all of the water quality monitoring sites by the end of the first quarter in 2004, soon after the shellfish beds were reopened these improvements began to be reversed. The degradation trends of water quality in the Nooksack River and Portage Bay were obvious as early as 2010.

In September 2014, a 335-acre portion of the Portage Bay shellfish growing area was voluntarily closed to harvest by the Lummi Nation to protect public health after two monitoring sites exceeded the NSSP fecal coliform standards. After poor water quality that affected additional sample sites was encountered again in November 2014, the classification of nearly 500 acres of the Portage Bay growing area, including the portions already under the voluntary closure, was changed from “approved” to “conditionally approved” in January 2015 (DOH 2015a,b). In April 2016, with an additional site exceeding the NSSP fecal coliform standards, another 325 acres of the Portage Bay growing area were voluntarily closed by the Lummi Nation to protect public health; these areas were reclassified from "approved" to "conditionally approved" in January 2017 (DOH 2016a). The conditional closure prohibited commercial shellfish harvest from April 1 through June 30 and from October 1 through December 31 each year. Due to the poor water quality and associated public health threat, the Lummi Nation also closed these areas to ceremonial and subsistence harvests although this closure has a substantial impact to harvesters and their families.

Following improvements in water quality during the spring season, all of Portage Bay was reopened to commercial, ceremonial, and subsistence shellfish harvest from April 1 through June 30 beginning in 2019 (DOH 2018). Poor water quality persists during the fall season, and commercial, ceremonial, and subsistence shellfish harvest remains prohibited in the 820 acres of Portage Bay from October 1 through December 31 annually. As of year-end 2019, two sites in the Approved portions of Portage Bay were listed in "Threatened" status, and one site within the Conditionally Approved portion of Portage Bay was listed in "Threatened" status, risking expanded duration and/or extent of closure period and closure area.

In the Lummi Bay shellfish growing area, one site (DH286 in the northeastern portion of Onion Bay) was placed in "Concerned" status in January 2017 and "Threatened" status in January 2018 due to high fecal coliform densities (DOH 2016, 2017). Following improvements in water quality in Lummi Bay, the site was upgraded to "Concerned" status in January 2019 and to "Well within standard" at year-end 2019 (DOH 2018, 2019a). Following the listing in "Concerned" status in 2016, analysis of the Jordan Creek watershed found that the likely source of fecal coliform contamination was located upstream of the Reservation boundary. In response to the declining water quality in Lummi Bay and continually degraded water quality in Jordan Creek, LNR sent a letter to the Washington State Department of Ecology in September 2017 requesting assistance in addressing fecal bacteria pollution sources originating off-Reservation to avoid any closures to the important shellfish harvesting areas in Lummi Bay. Coordinated monitoring of the Jordan Creek and Lummi River watersheds began in January 2018 with sampling conducted by Whatcom County Public Works Natural Resources Department and Washington State Department of Ecology along Slater Road (the Reservation boundary) and upstream as well as by LNR at downstream sites on-Reservation.

7.1.1. Fecal Coliform Standard

Fecal coliform standards that apply to Reservation surface waters include the Lummi Nation Surface Water Quality Standards for marine water and freshwater as well as the NSSP standard for commercial shellfish harvesting areas. In addition, the Nooksack River TMDL targets apply to the Nooksack River at Marine Drive Bridge. A summary of applicable criteria are provided in Table 7.1.1.

Marine sites sampled as part of the NSSP are assessed using the NSSP standard for commercial shellfish harvesting areas and these results and compliance are presented and discussed in this report. The NSSP fecal coliform standard is comprised of three requirements: the geometric mean (geomean), estimated 90th percentile,[6] and use of 30 samples to calculate the metrics.

In this report, all sites are assessed for compliance with the Lummi Nation Surface Water Quality Standards for marine and fresh waters. The fecal coliform standard is comprised of two criteria: the geometric mean and 90th percentile. The 90th percentile criterion is assessed in two ways: by calculating the 90th percentile of the dataset and by calculating the percentage of samples that exceed the 90th percentile criterion. The standard itself is written as the percent exceedance component: no more than ten percent of samples may exceed 43, 100, or 200 colony forming units (cfu)/100ml for marine, freshwater Class AA, and freshwater Class A designations. Both methods of assessing the 90th percentile are used because calculating the 90th percentile metric shows the magnitude of exceedances while the percent exceeding metric shows the frequency of exceedances, both of which are useful in illustrating trends. All three components of the fecal coliform criteria must be met in order for a site to be in compliance with the standard: the geometric mean, the calculated 90th percentile, and the percent exceedance.

Sites are evaluated for compliance on a seasonal basis aligning with the quarters of the calendar year (winter=Q1, spring=Q2, summer=Q3, and fall=Q4). This is consistent with the current seasonal closures affecting the Portage Bay shellfish growing area, although limitations of this approach are discussed later in this report. A compliance designation is made for each season. As mentioned above, all three components must be met in order for the site to be in compliance for that season. An overall compliance metric is also determined for the reporting period 2018-2019. All seasons must meet the standard in order for the overall determination for the site to be compliant.

The Lummi Nation Surface Water Quality Standards do not require a minimum sample size for determining compliance, as the NSSP standard and TMDL target do. The standard recommends assessment using at minimum five samples to be used for calculation of a seasonal geometric mean (no more than 90 days). Because most sites are visited monthly, no season in one year will have more than three samples, except sites that are sampled more frequently, such as the Nooksack River at Marine Drive Bridge (SW118), the mouth of the Lummi River (SW051), and the marine receiving waters of Jordan Creek/North Lummi River Distributary (SW053). Although many sites are visited monthly, the intermittent nature of many streams on the Reservation means that sites are often stagnant or dry during the dry period, leading to much fewer than twelve sample results per year and fewer than three samples per season.

The approach taken to address this challenge was site and/or watershed-specific. For sites where generally five or more samples per season were available, assessments were made for all seasons by year and determinations using fewer than five samples are noted. For sites with fewer samples, the seasonal assessment was made for the two-year reporting period (2018-2019) pooled (i.e., using spring season data from two years for the assessment). Sites with fewer than five samples are assessed, and sample size is noted. For many intermittent streams

[6] The 90th percentile for the NSSP is the estimated 90th percentile calculated as the antilog (10^) of the mean of the log(10) transformed fecal coliform observations plus 1.28 times the standard deviation of the log(10) transformed fecal coliform observations.

and sites visited six times per year, the two-year reporting period was pooled and sites with fewer than three samples are noted.[7]

Determination of compliance with the 90th percentile component of the standard does not have a minimum sample size. All seasons with data were assessed for compliance with this component of the standard as described above, using both the calculated 90th percentile and the percent exceeding metrics for compliance. This approach is different from that used in the previous report (2014-2017 Lummi Nation Water Quality Assessment Report; LWRD 2019c) in which sites with fewer than five samples per season (for the pooled assessment period) or per year were not assessed for compliance.

Table 7.1.1 Criteria for NSSP, TMDL, and Lummi Nation fecal coliform (cfu or most probable number [mpn]/100ml) standards for surface waters

	Geometric Mean	90th Percentile*	Percent Exceeding*	Number of Samples
National Shellfish Sanitation Program	14	43	N/A	30†
Nooksack River @ Marine Drive TMDL Target	39	N/A	N/A	30
Lummi Nation Surface Water Quality Standards				
Marine Class AA (Extraordinary)	14	43	>10% may not exceed 43	≥5‡
Marine Class A (Excellent)	14	43	>10% may not exceed 43	≥5‡
Freshwater Class AA (Extraordinary)	50	100	>10% may not exceed 100	≥5‡
Freshwater Class A (Excellent)	100	200	>10% may not exceed 200	≥5‡

* The NSSP 90th percentile metric is the 30-sample estimated 90th percentile, which is calculated as 10^(mean(logFC)+1.28*STDEV(logFC)). The 90th percentile criterion for the Lummi Nation Surface Water Quality Standards is written as the maximum percentage of samples that may exceed a specific bacterial density. The Percent Exceeding column lists the criteria as written in the standard while the 90th percentile equivalent is also listed for comparison. Both were assessed for compliance in this report.

†The NSSP requires 30 samples to be used for calculating both the geometric mean and estimated 90th percentile metrics.

‡The Lummi Nation Surface Water Quality Standards do not require a certain number of samples to be used for calculating metrics, although it is recommended that at least 5 samples are used to calculate the geometric mean. For this report, 3 or 5 samples are used to evaluate compliance with the standard geometric mean standard when available; when fewer than 5 samples are used for compliance determination, sample size is listed and/or discussed.

[7] Washington State Department of Ecology has recently (April 2020) updated its assessment policy and is proposing to decrease the sample size for calculation of a geometric mean to three samples; this approach was considered and used in portions of this report as described above. Note that the WA Ecology policy does not apply to Lummi Nation Waters; it was used for data exploration purposes only.

7.1.2. Fecal Coliform Summary

During the 2018-2019 reporting period, a total of 60 sites were monitored for fecal coliform: 24 freshwater sites and 36 marine sites. Only ambient data were used for this analysis (i.e., storm monitoring and investigative sampling was excluded). All sites were evaluated for compliance with the fecal coliform standard. As described above, the geometric mean, 90th percentile, and percentage of samples exceeding the 90th percentile criterion (depends on classification; hereafter percent exceedance) were calculated by season[8] for the reporting period (2018-2019) and the period of record (2014-2017 for Portage Bay and 2008-2017 for Lummi Bay) and compared to the fecal coliform standard.[9] If a site failed to meet any of the criteria for any season, the site is considered to fail to meet the standard.[10] Ideally, five samples per season are used to calculate a seasonal geometric mean metric; however, most sites have fewer than five results per season each year because sites are primarily visited monthly. For many sites, three results per season was determined to be a sufficient number of samples for calculation of the geometric mean. There is no minimum sample size for computation of the 90th percentile or compliance with the percent exceedance component of the 90th percentile criterion. For this reason, all sites with one or more samples per season were assessed for compliance with the fecal coliform standard. Sites with fewer than five (or fewer than three samples, when applicable) are noted and marked as such in summary tables. Sites with no samples for a season could not be assessed.

For consistency, the summary compliance in this section used the pooled reporting period 2018-2019 for determining compliance at all sites. The period of record used here is 2014-2017. The reporting period was assessed by season with overall compliance requiring compliance during all seasons with data. Percentages provided are of the total sites assessed for the period (i.e., excluding sites with no data for the season). Figure 7.1.1 summarizes the compliance rate by season for the two-year reporting period.

Overall, 70% of all surface water sites failed to meet the fecal coliform standard during the reporting period (42 of 60 sites). The overall reporting period noncompliance rate was 61% for marine sites and 83% for freshwater sites. In Lummi Bay, 39% of marine sites failed to meet the standard while 100% of the thirteen marine sites in Portage Bay failed to meet the standard. All but one of fourteen (93%) freshwater sites in the Lummi Bay watershed failed to meet the fecal coliform standard while 70% of freshwater sites in the Portage Bay watershed failed to meet the fecal coliform standard during the reporting period.

Overall, the majority of sites were compliant with the fecal coliform standard during winter and spring (23% of sites failed to meet the standard) while slightly over half of sites failed to meet

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[8] Winter: January-March; Spring: April-June; Summer: July-September; Fall: October-December.

[9] The geometric mean was calculated and compared to the geometric mean criterion. The 90th percentile and the percentage of samples exceeding the 90th percentile criterion were both calculated and compared to the 90th percentile criterion (no more than 10% of samples may exceed X criterion). If the geomean, the 90th percentile, or the percentage of samples exceeding the 90th percentile criterion failed to meet the appropriate criterion, the site was marked as failing to meet the standard.

[10] For example, if three seasons met the standard but one failed to meet the standard, the site was marked as failing to meet the standard overall. In order to meet the standard, all seasons had to meet the standard.

the standard during summer (52%) and fall (55%). In marine waters, a similar pattern was present: 14% of sites failed to meet the standard during winter and spring while approximately half of sites failed to meet the standard during summer (44%) and fall (53%). In freshwaters, approximately two-fifths of sites failed to meet the standard during winter (38%) and spring (40%), while 88% failed to meet the standard during summer and 60% failed to meet the standard during fall. The summer season had the highest number of sites with no available samples, leading to a higher proportion of sites failing to meet the standard with fewer sites failing to meet the standard than the fall. In freshwaters, sixteen sites had no data during the summer while only nine sites had no data during the fall.

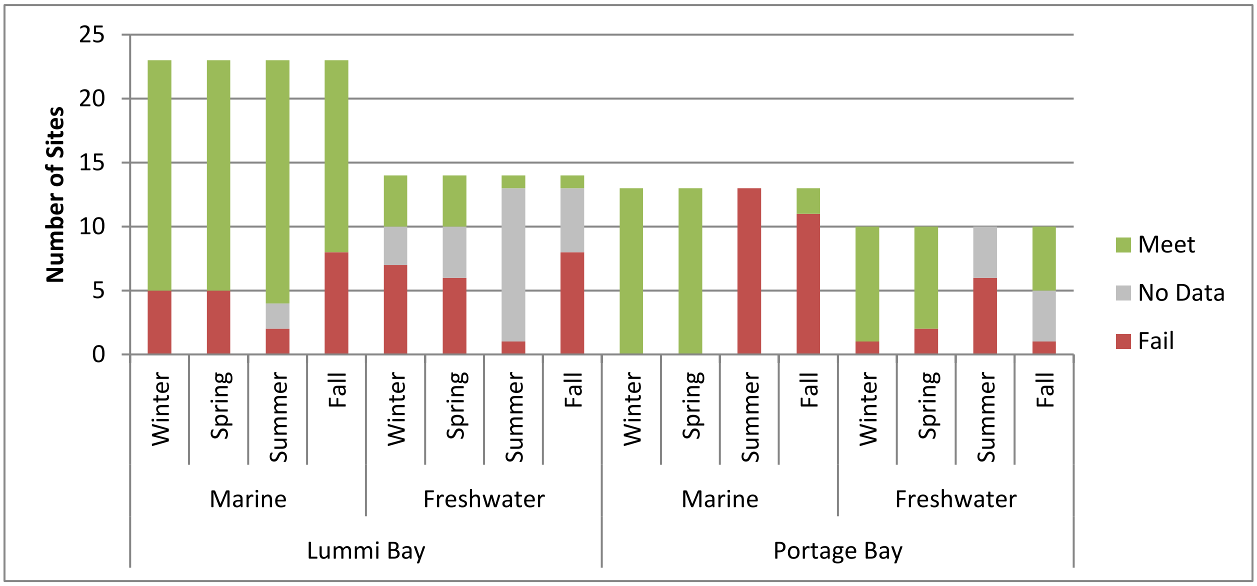


Figure 7.1.1 Compliance summary of surface water quality monitoring sites with fecal coliform standard for freshwater and marine sites by season during the 2018-2019 reporting period. Metrics calculated for pooled 2018-2019 seasons; season must meet the geometric mean, 90th percentile, and percent exceedance components of the standard in order to be in compliance.

The four-year period of record 2014-2017 was used for most analyses, including this summary compliance discussion. This four-year period was selected for several reasons: it is the period of time covered in the previous water quality assessment report (LWRD 2019c), it represents the period of time prior to the reporting period during which portions of the Portage Bay shellfish growing area was subject to conditional closure, cattle were removed from Portage Island in 2013, and sampling during stagnant conditions was discontinued during 2013. For this summary compliance discussion, the 2014-2017 period was pooled for seasonal analysis and overall compliance determination for all sites.

A period of record from 2008 to 2013 is also used throughout this report. This six-year period represents the period of time after the reopening of portions of the Portage Bay shellfish growing area that were subject to year-round prohibition of harvest from 1996 to 2006 to the beginning of the current conditional closure. When combined, the ten-year period of record from 2008 to 2017 represents the recent historical average and range of conditions and is the period of record used for the other parameters and issues discussed in Section 7 of this report.

When compared to the four-year period of record 2014-2017, fecal coliform densities during the reporting period 2018-2019 have increased in the marine waters of Portage Bay and the freshwaters of both watersheds (Lummi Bay and Portage Bay; Figure 7.1.2). Only marine sites in Lummi Bay had a higher compliance rate during the reporting period than during the period of record. Although the rate of compliance also increased in freshwaters flowing to Lummi Bay, the rate of noncompliance also increased. Determining the trend is difficult because three sites were not sampled during the 2014-2017 period of record: two were sites that were added during the reporting period and one site had no flow during the period of record. The most concerning trend is apparent in the marine waters of Portage Bay, where the noncompliance rate increased from 54% in 2014-2017 to 100% in 2018-2019.

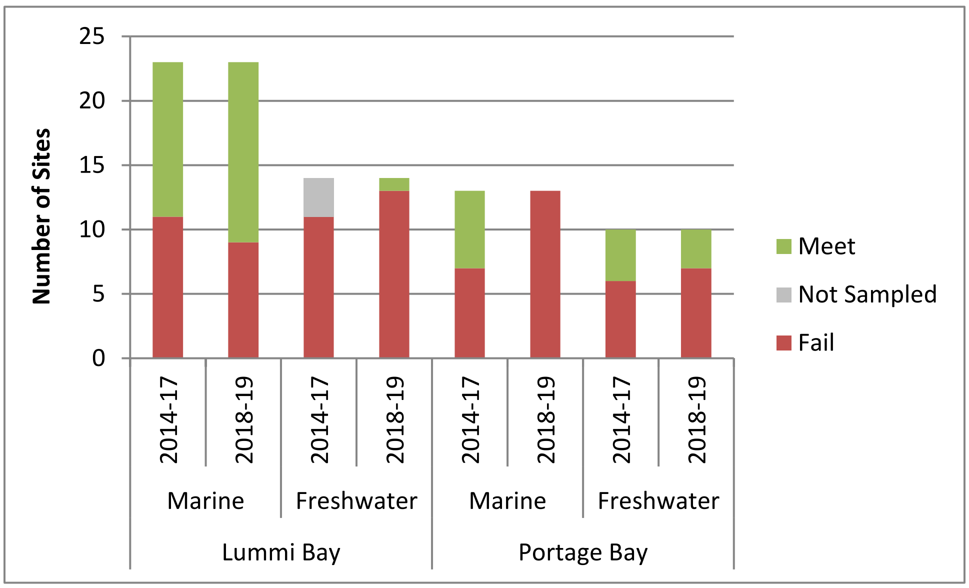


Figure 7.1.2 Summary of overall compliance with fecal coliform criteria for freshwater and marine sites during the 2014-2017 reporting period and the 2008-2013 period of record based on seasonal analysis. Metrics calculated by season with periods pooled; season must meet the geometric mean, 90th percentile, and percent exceedance components of the standard in order to be in compliance; all seasons must be in compliance in order to be in compliance overall.

7.1.3. Portage Bay

As described above, portions of the Portage Bay shellfish growing are have been closed seasonally since 2014. In September 2014, a 335-acre portion of the Portage Bay shellfish growing area was voluntarily closed to harvest by the Lummi Nation to protect public health after two monitoring sites exceeded the NSSP fecal coliform standards. After poor water quality that affected additional sample sites was encountered again in November 2014, the classification of nearly 500 acres of the Portage Bay growing area, including the portions already under the voluntary closure, was changed from “approved” to “conditionally approved” in March 2015 (DOH 2015a,b). In April 2016, with an additional site exceeding the NSSP fecal coliform standards, another 325 acres of the Portage Bay growing area were voluntarily closed by the Lummi Nation to protect public health; these areas were reclassified from “approved” to “conditionally approved” (DOH 2016a). The conditional closure prohibited commercial shellfish harvest from April 1 through June 30 and from October 1 through December 31 each year for shellfish management areas not achieving the NSSP fecal coliform standards. Following improvements in water quality during the spring, the spring season was opened to commercial, ceremonial, and subsistence shellfish harvest beginning in 2019. Poor water quality persists through the fall, and the 820-acre conditional closure area remains closed to commercial harvest from October 1 through December 31. Due to the public health threat, the Lummi Nation has also closed these areas to ceremonial and subsistence harvests during the fall although this closure has a substantial impact to harvesters and their families.

During the 2018-2019 reporting period, portions of the Portage Bay shellfish growing area were closed seasonally (Figure 7.1.3). The 820-acre conditionally approved area was closed to shellfish harvest during the spring (April 1-June 30) and fall (October 1-December 31) during 2018 and during the fall (October 1-December 31) during 2019. As noted above, improvements in spring water quality resulted in the re-opening of harvest in the spring of 2019. Poor water quality during the fall persisted, including elevated fecal coliform densities observed at sites DH057 and DH058, which resulted in placement of these sites in threatened status by the DOH at year-end 2019 (DOH 2019b). In addition, one site in the conditionally approved area, DH052, was placed in threatened status year-round.

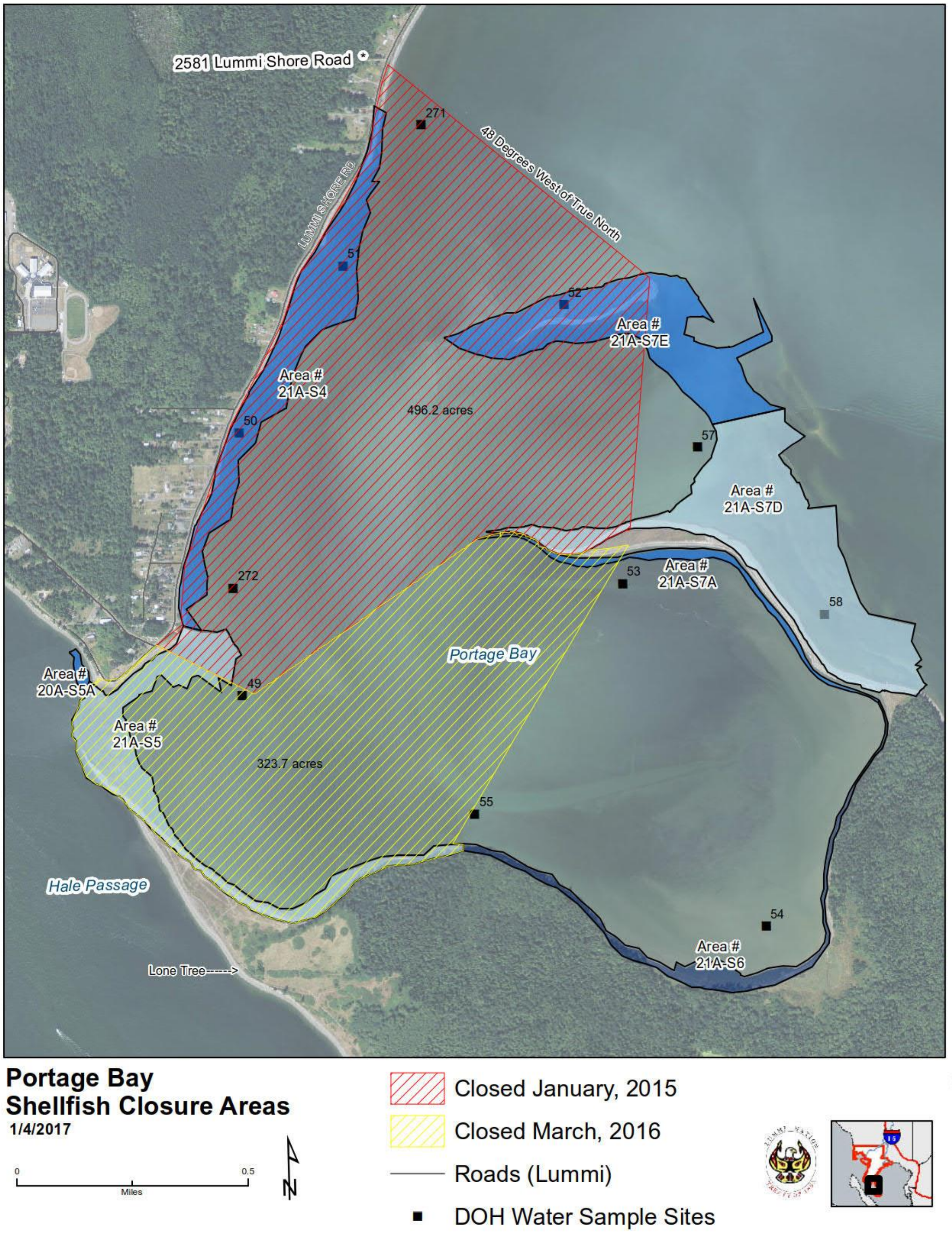


Figure 7.1.3 Portage Bay shellfish harvesting area closure areas. The areas shown are classified "Conditionally Approved" with seasonal closures for commercial, ceremonial, and subsistence harvesting of shellfish from October 1 to December 31. From 2014 to 2018, shellfish harvesting was also prohibited during spring (April 1-June 30).

7.1.3.1 Portage Bay NSSP 30-Sample Metrics

Sites in the Portage Bay shellfish growing area began to exceed the NSSP 30-sample estimated 90th percentile standard during the spring of 2012 (Figure 7.1.4). High counts observed during May 2014 drove the metric above the standard at sites DH050 and DH052, which remained above the standard until November 2016, when the earlier high counts were no longer included in the 30 samples used to calculate the metric. The 30-sample estimated 90th percentile also increased for the other sites in the conditionally open area during 2014 and 2015. Sites DH272, DH051, and DH271 exceeded the 90th percentile criterion in November 2014. Site DH049 remained near, but slightly below, the 90th percentile criterion until September 2015 when the criterion was exceeded. Since November 2016, the 30-sample estimated 90th percentile has been below the criterion at all sites in the conditionally approved area. The 30-sample estimated 90th percentile continued to decrease until July 2018, after which the metric increased through year-end 2019. The 30-sample estimated 90th percentile at DH052 is nearing the 43 cfu/100ml criterion, which led to its designation as a site threatened with year-round closure if conditions do not improve (DOH 2019b).

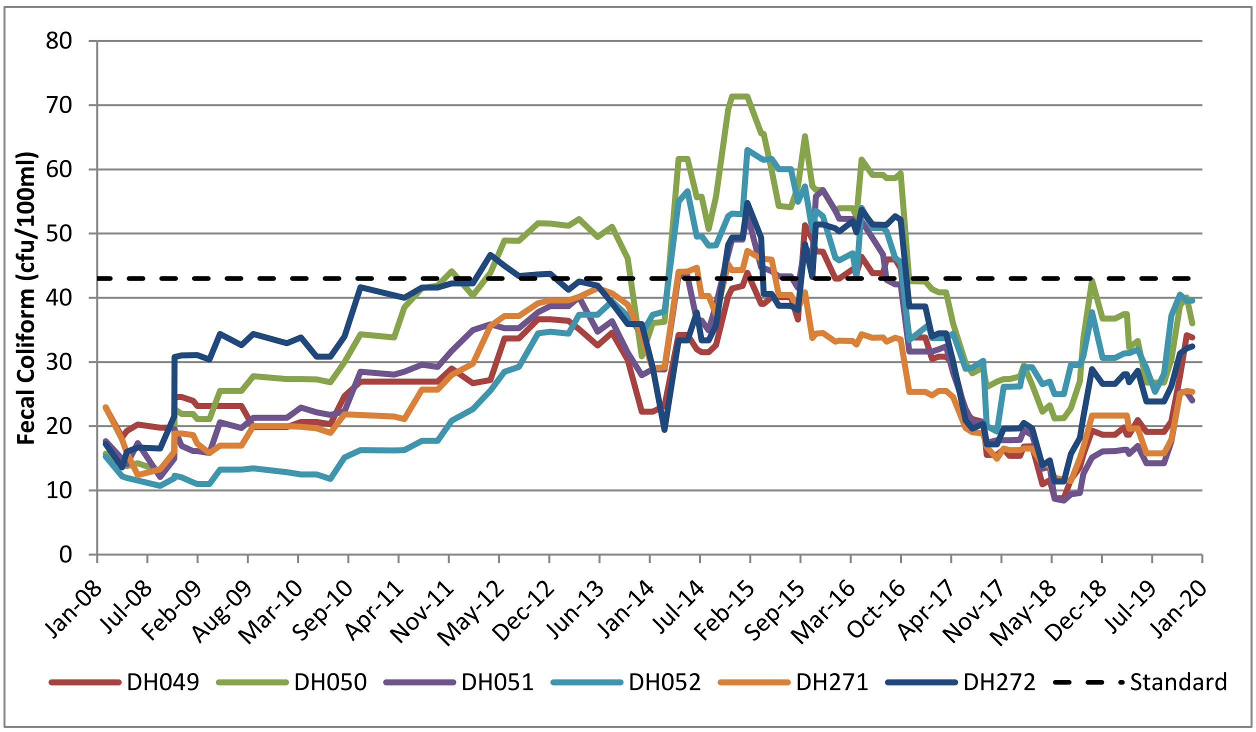


Figure 7.1.4 Rolling 30-sample fecal coliform estimated 90th percentile for Portage Bay conditionally approved shellfish growing area sites from January 2008-December 2019. The NSSP 30-sample estimated 90th percentile standard ("Standard") shown for reference.

Note that the 30-sample metric represents a 5-year period (6 samples per year) only through May 2014; in June 2014, sampling in Portage Bay increased to 12 samples per year, leading to the 30-sample metric representing a period of time less than 5 years. As of year-end 2019, the 30-sample metric represents the samples collected between July 2017 and December 2019, a period of 2.5 years. The 2.5-year 2019 year-end metric represents three summer and fall seasons and only two winter and spring seasons, which may bias the data toward the over-represented seasons.

A similar pattern, although with lower magnitude, was seen at three sites in the open portions of Portage Bay from 2008 to 2019 (Figure 7.1.5). Sites DH055, DH057, and DH058 show an increase into the concerned and threatened ranges as early as year-end 2010 with DH057 briefly increasing above the standard as a result of elevated fecal coliform densities observed throughout Portage Bay during the May and June 2014 sampling events. A similar decline in the 30-sample estimated 90th percentile continued in the open portions of Portage Bay until July 2019, after which elevated fecal coliform densities were again encountered and the metric increased into the threatened range for DH058 and the concerned range for DH057 and DH055. Out of caution, both sites DH058 and DH057 were listed as threatened sites in the year-end 2019 growing area report for Portage Bay (DOH 2019b).

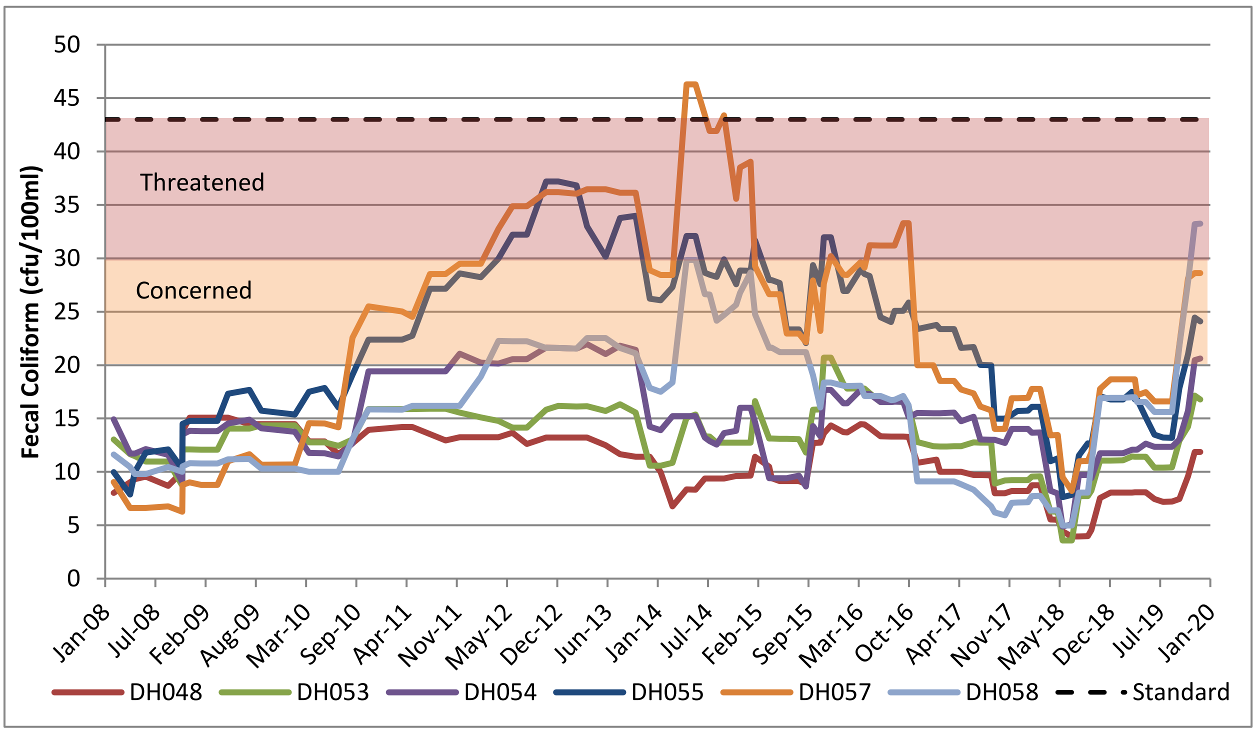


Figure 7.1.5 Rolling 30-sample fecal coliform estimated 90th percentile for Portage Bay approved shellfish growing area sites from January 2008-December 2019. The NSSP 30-sample estimated 90th percentile standard ("Standard") and ranges for concerned and threatened status shown for reference.

7.1.3.2 Seasonal Trends

The elevated fecal coliform counts observed in Portage Bay followed a seasonal pattern that led to the "conditionally approved" classification in which shellfish harvesting is allowed during winter (January-March) and summer (July-September), but was not allowed during fall (October 1-December 31) and, until 2019, spring (April 1-June 30). The seasonal geometric mean, 90th percentile, and percentage of samples exceeding the 90th percentile criterion (43 cfu/100ml;

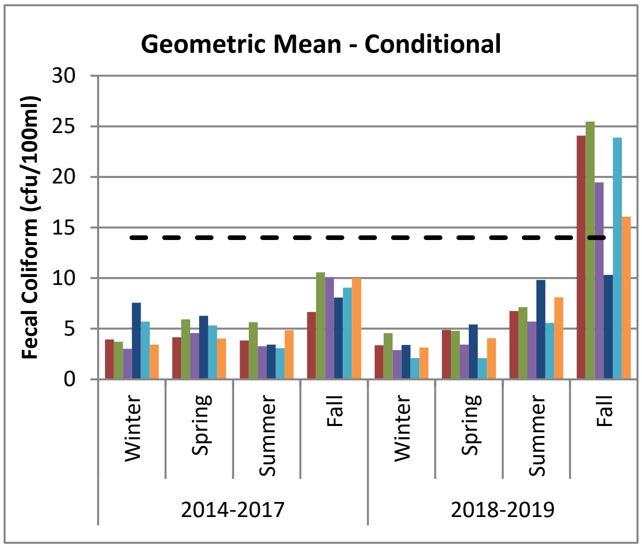
hereafter “percent exceedance” component of the standard) were calculated for the two-year reporting period (2018-2019) and a four-year period of record (2014-2017) for the sites in the Portage Bay shellfish growing area, and presented by classification status (Figure 7.1.6). Because the NSSP’s estimated 90th percentile metric requires 30 samples, the directly calculated 90th percentile was used for this seasonal analysis (<30 samples per site/season).

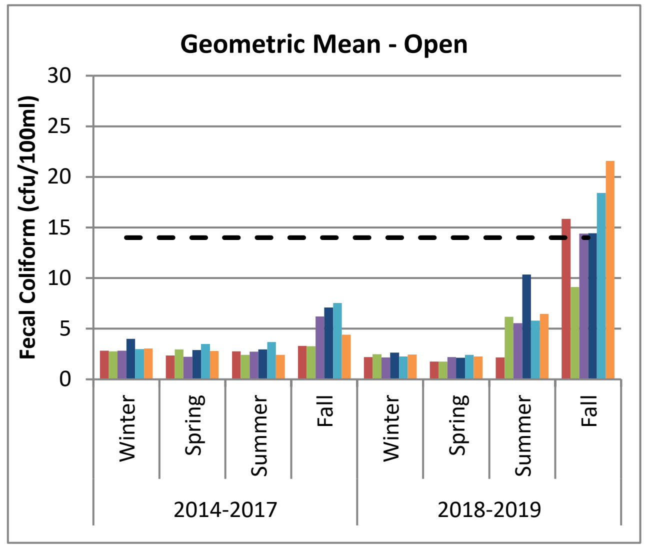
Overall, the fall season clearly stands out as the period during which high fecal coliform counts are most frequently observed at sites in the conditionally closed (classified Conditionally Approved) and open (Approved) areas over both the period of record and the reporting period. Geometric means approximately doubled during the fall period for both the conditionally closed and the open areas of Portage Bay when comparing the period of record to the reporting period. The geometric mean exceeded 14 cfu/100ml at all but two sites during the fall for the reporting period: DH052 in the conditionally closed area and DH053 in the open area. Geometric means also increased during the summer at sites in both the conditionally closed and the open areas, but remained below the criterion at all sites.

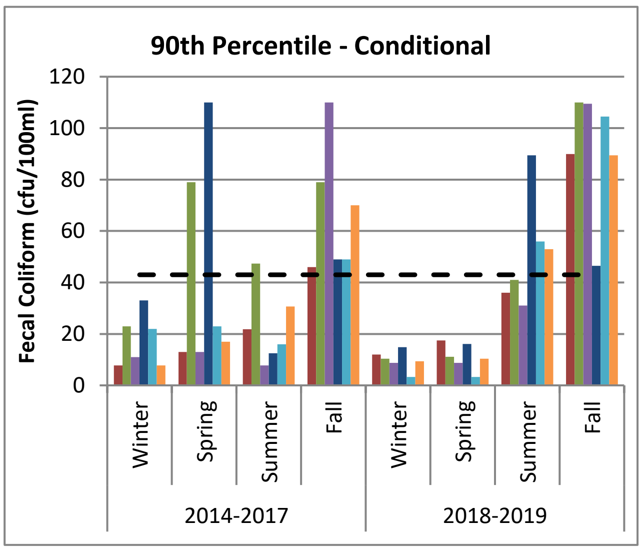
The 90th percentile remained elevated at sites in the conditionally closed area during the fall. All sites in the conditionally closed area failed to meet the 90th percentile standard during the fall during both the period of record and the reporting period. The spring 90th percentile at two sites in the conditionally closed area (DH050 and DH052) decreased during the reporting period and all sites in the conditionally closed area have 90th percentiles below the criterion, reflecting the decreases in fecal coliform densities during the spring season that led to the re-opening of shellfish harvest during spring in 2019. The summer 90th percentile increased at sites in the conditionally closed area, leading to failure to meet the 90th percentile criterion during summer at three stations (DH052, DH271, and DH272). The 90th percentile increased significantly during the summer and fall at sites in the open areas of Portage Bay, leading to five out of six sites failing to meet the 90th percentile criterion during summer and fall during the reporting period.

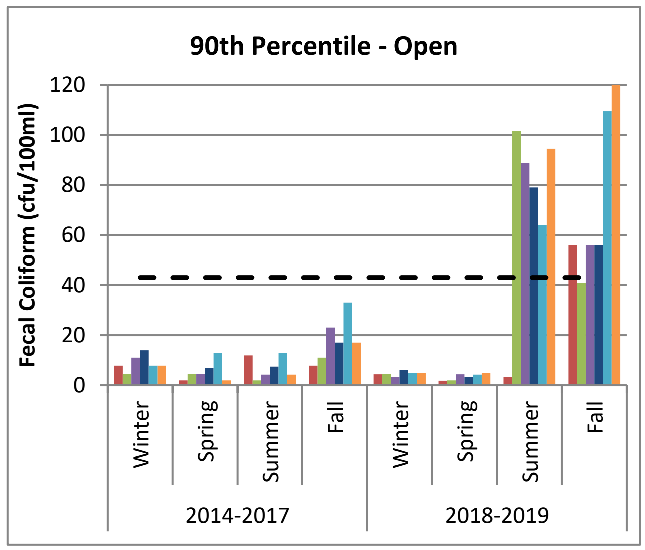
The percentage of samples exceeding the 90th percentile criterion (43 cfu/100ml) shows a similar pattern as the seasonal calculated 90th percentile: decreased frequency of exceedances during the spring for sites in the conditionally closed area; increased frequency of exceedances during the summer at sites in both the conditionally closed the open areas; and increased frequency of exceedances during the fall at sites in the open area. The percent exceedance assessment also shows that the frequency has approximately doubled during the fall at many sites in the conditionally closed area. Decreased frequency of exceedances is apparent during both the winter and the spring, leading to no exceedances during these seasons for the reporting period at any site in Portage Bay. The percent exceedance assessment also shows that all sites failed to meet this component of the standard during the summer and fall during the reporting period. This includes sites in both the conditionally closed and open areas, with the exception of site DH048 which met the criterion during summer but failed during fall.

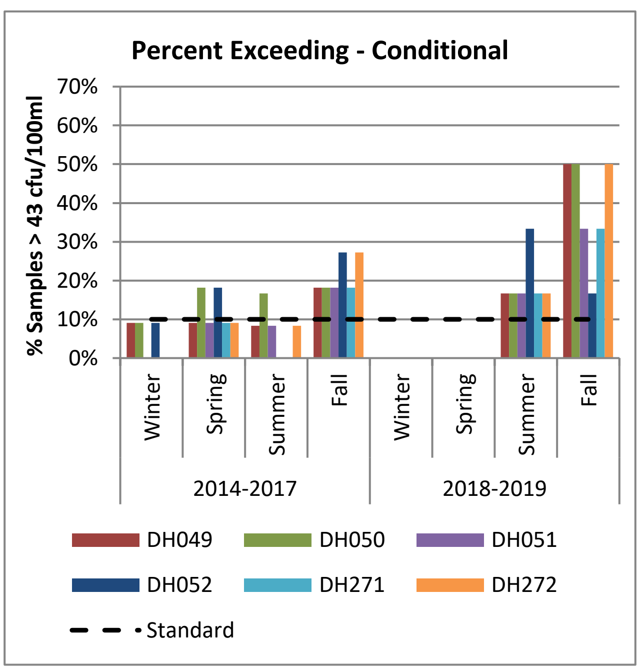
Figure 7.1.6 (Next Page) Geometric mean, 90th percentile (calculated, not 30-sample estimated NSSP), and percentage of samples exceeding 43 cfu/100ml for NSSP sites in the Portage Bay conditionally approved and open areas by season for the four-year period of record 2014-2017 and two-year reporting period 2018-2019. Sample size is 11 for winter, spring, and fall and 12 for summer for each site for the period of record (2014-2017). Sample size is six for all sites and seasons for the reporting period.

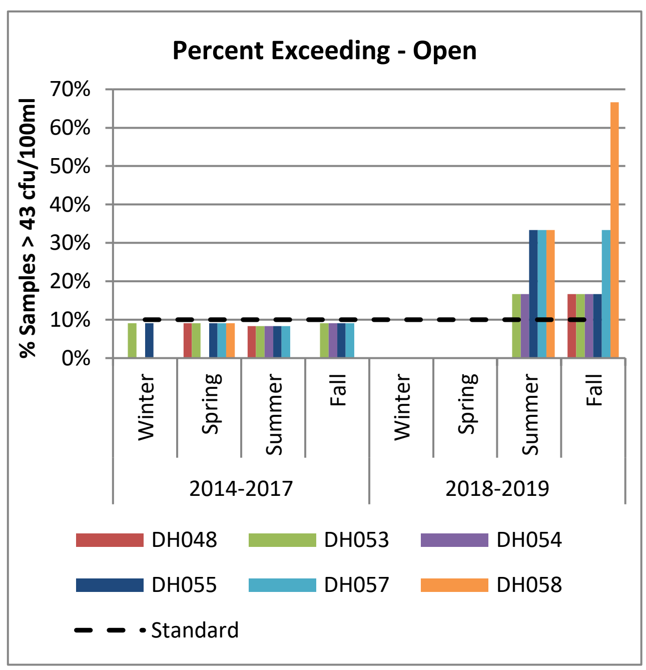

Geometric Mean - Conditional
Fecal Coliform (cfu/100ml)
0
5
10
15
20
25
30
Winter
Spring
Summer
Fall
2014-2017
2018-2019


Geometric Mean - Open
Fecal Coliform (cfu/100ml)
0
5
10
15
20
25
30
Winter
Spring
Summer
Fall
2014-2017
2018-2019


90th Percentile - Conditional
Fecal Coliform (cfu/100ml)
0
20
40
60
80
100
120
Winter
Spring
Summer
Fall
2014-2017
2018-2019

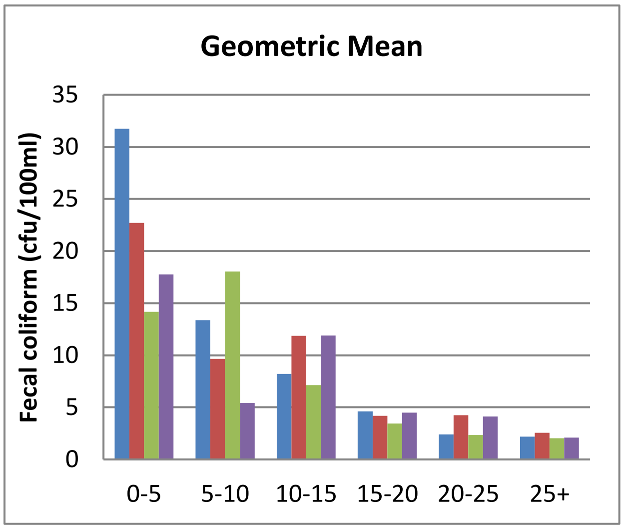

90th Percentile - Open
Fecal Coliform (cfu/100ml)
0
20
40
60
80
100
120
Winter
Spring
Summer
Fall
2014-2017
2018-2019

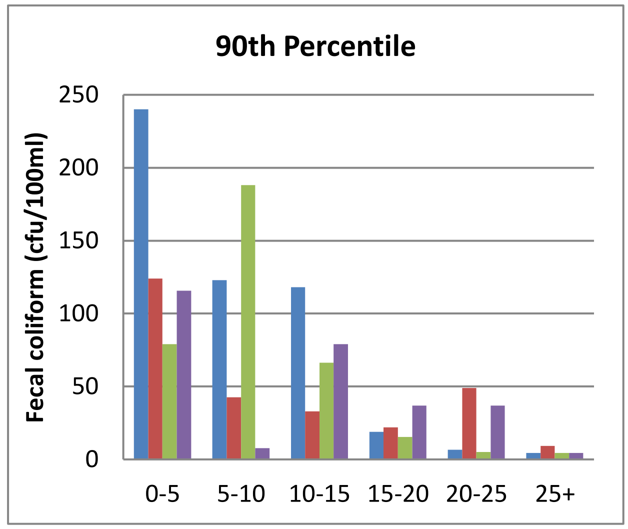

Percent Exceeding - Conditional
% Samples > 43 cfu/100ml
0%
10%
20%
30%
40%
50%
60%
70%
Winter
Spring
Summer
Fall
2014-2017
2018-2019
DH049
DH050
DH051
DH052
DH271
DH272
Standard

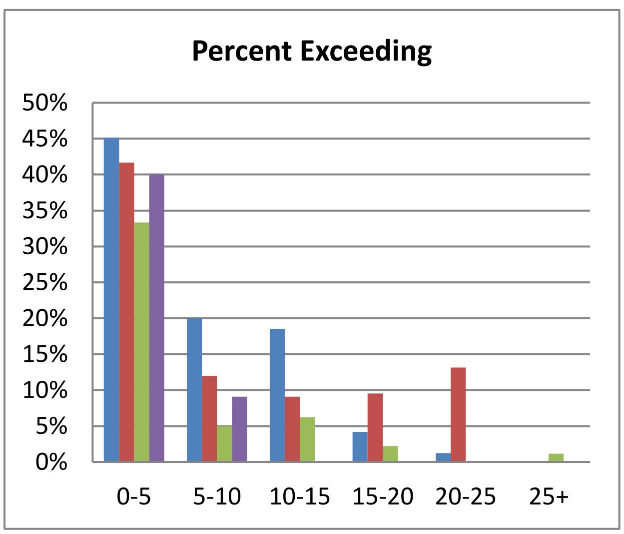

Percent Exceeding - Open
% Samples > 43 cfu/100ml
0%
10%
20%
30%
40%
50%
60%
70%
Winter
Spring
Summer
Fall
2014-2017
2018-2019
DH048
DH053
DH054
DH055
DH057
DH058
Standard

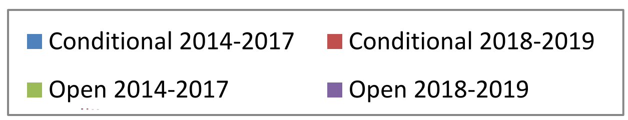
7.1.3.3 Portage Bay Salinity

High fecal coliform counts in Portage Bay are associated with low surface water salinities (Figure 7.1.7). Paired salinity and fecal coliform for the period of record 2014-2017 and the reporting period 2018-2019 using pooled data from sites in the conditionally approved ("conditionally closed") and approved ("open") areas show a decreasing trend in fecal coliform by salinity; the highest fecal coliform counts were observed at the lowest salinity bracket (<5 parts per thousand [ppt]).









Salinity Bin (ppt)	Conditional		Open	
	2014-2017	2018-2019	2014-2017	2018-2019
0-5	31	24	6	15
5-10	40	25	20	11
10-15	27	11	32	12
15-20	48	21	45	28
20-25	82	38	79	37
25+	42	25	88	41

Figure 7.1.7. Fecal coliform geometric mean, 90th percentile, and percentage of samples exceeding 43 cfu/100ml by salinity bin for NSSP sample sites in Portage Bay in the conditionally approved ("Conditional") and approved ("Open") areas from 2014-2017 and 2018-2019. Data from all sites were pooled; sample size in table to right. Bins are exclusive at the low end and inclusive at the high end, for example the 5-10 ppt bin includes all salinities >5 and ≤10, except 0-5 which includes all salinities ≤5 ppt.

Fecal coliform metrics were higher during the period of record 2014-2017 than the reporting period 2018-2019 in the conditionally closed area for the three lowest salinity brackets (<5ppt, 5-10ppt, and 10-15ppt), with the exception of geometric mean for the 10-15 ppt salinity bracket. At higher salinities, the fecal coliform metrics were higher during the reporting period 2018-2019 than during the period of record 2014-2017, particularly for the 20-25 ppt salinity bracket. In the open area as a whole, fecal coliform metrics were higher for the reporting period 2018-2019 than during the period of record 2014-2017, with the exception of the 5-10 ppt salinity bin where the geometric mean and 90th percentile decreased during the reporting period, although the percentage of samples exceeding the standard increased during the reporting period in this salinity bracket.

Elevated fecal coliform densities continue to be associated with the presence of low salinities in the bay. The primary source of freshwater into Portage Bay is the Nooksack River, which is discussed in detail in Section 7.1.4.

7.1.3.4 Portage Bay Ambient Monitoring Sites

In addition to NSSP monitoring at 12 DOH sample sites, two marine sites in Portage Bay are sampled as part of the Surface Water Project. Fecal coliform metrics were calculated for each site by season for the 2018-2019 reporting period. If any season failed to meet either the geometric mean or 90th percentile criteria (assessed using both the 90th percentile metric and the percentage of samples exceeding the criterion), the site is considered failing to meet the standard overall.

Both sites failed to meet the fecal coliform standard during the summer for the reporting period (Table 7.1.2). Site SW023 failed to meet both the 90th percentile and the percentage of samples exceeding the criterion while SW006 failed to meet the percentage of samples exceeding the criterion. At SW006, one of four samples (25%) during the summer exceeded the 90th percentile criterion but not by enough to cause the calculated 90th percentile to exceed the criterion. At SW023, one of four samples (25%) during the summer exceeded the 90th percentile criterion and caused the 90th percentile metric to exceed the criterion by 10 cfu/100ml. Similarly for the period of record, one of seven samples (14%) during the summer at SW006 exceeded the criterion and caused the 90th percentile metric to exceed the criterion.

Table 7.1.2 Summary of compliance with Class A Marine fecal coliform standard for ambient sites in Portage Bay. Metrics calculated seasonally (2014-2017 period of record and 2018-2019 reporting period each pooled) with an overall seasonal determination of compliance. Portage Bay NSSP summary shows number of samples that failed to meet the standard during the season and total number of sites. Sample size (for SW023 and SW006) for period of record 2014-2017 was >5 samples for each season and site. Sample size for reporting period 2018-2019 was 2 for winter and fall and 4 for spring and summer for both sites. Seasons with fewer than 3 samples *italicized*. See Figure 7.1.6 for NSSP sample sizes.

Season	SW006		SW023		NSSP (fail/total)	
	2014-2017	2018-2019	2014-2017	2018-2019	2014-2017	2018-2019
Winter	Meets All	*Meets All*	Meets All	*Meets All*	0/12	0/12
Spring	Meets All	Meets All	Meets All	Meets All	2/12	0/12
Summer	Fail 90+%	Fail %	Meets All	Fail 90+%	1/12	11/12
Fall	Meets All	*Meets All*	Meets All	*Meets All*	6/12	12/12
Overall	**Fail**	**Fail**	**Meet**	**Fail**	**6/12**	**12/12**

Although these exceedances indicate that the fecal coliform standard is not being met, it also illustrates the infrequency of exceedances at these two sites. When the metrics are calculated annually, the percent exceedance component of the standard continues to be exceeded during the reporting period, during 2018 for SW006 and during 2019 for SW023 (Figure 7.1.8). Again, these exceedances represent one out of six samples exceeding the 43 cfu/100ml criterion. The single exceedance during the summer for the period of record at site SW006 is no longer above the 10% threshold when the metrics are calculated annually. This illustrates how annual assessment can mask periods of noncompliance.

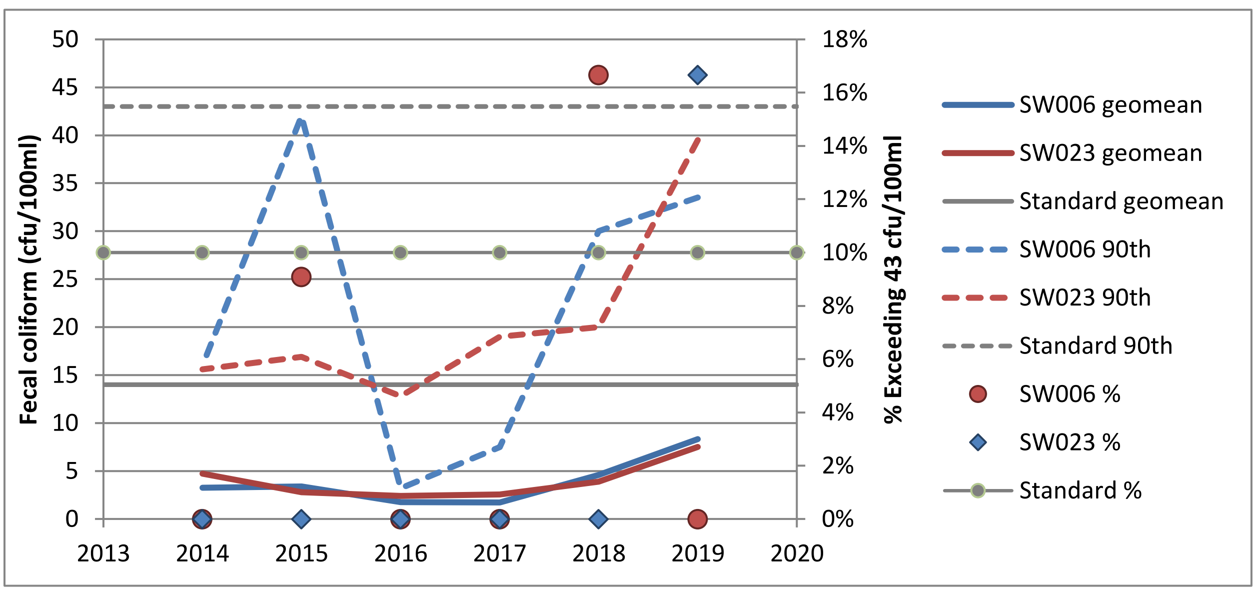


Figure 7.1.8 Summary of annual compliance with the fecal coliform standard at Portage Bay ambient sites SW006 and SW023. Sample size is >9 for 2014 and 2015, 5 for 2016, and 6 for 2017-2019. Geometric mean ("geomean") and 90th percentile ("90th") are shown on the left y-axis and percentile exceeding ("%") shown on the right y-axis.

7.1.4. Nooksack River – Freshwater Input into Portage Bay

The Nooksack River is the primary source of freshwater into Bellingham Bay and Portage Bay. River conditions are monitored upstream of the Nooksack River delta at Marine Drive Bridge (site SW118) on three to five days per month.

7.1.4.1 30-Sample NSSP

Historically, Nooksack River fecal coliform metrics were calculated using a rolling 30-sample geometric mean and estimated 90th percentile. The Nooksack River TMDL target is a 30-sample geometric mean and the NSSP standards for shellfish growing areas specify 30-sample geometric mean and estimated 90th percentile metrics. These metrics were calculated for the period 2008-2019. During the 2018-2019 reporting period, the Nooksack River failed to meet the 90th percentile criterion for fecal coliform half of the time when using a rolling 30-sample estimated 90th percentile metric (per NSSP; Figure 7.1.9).

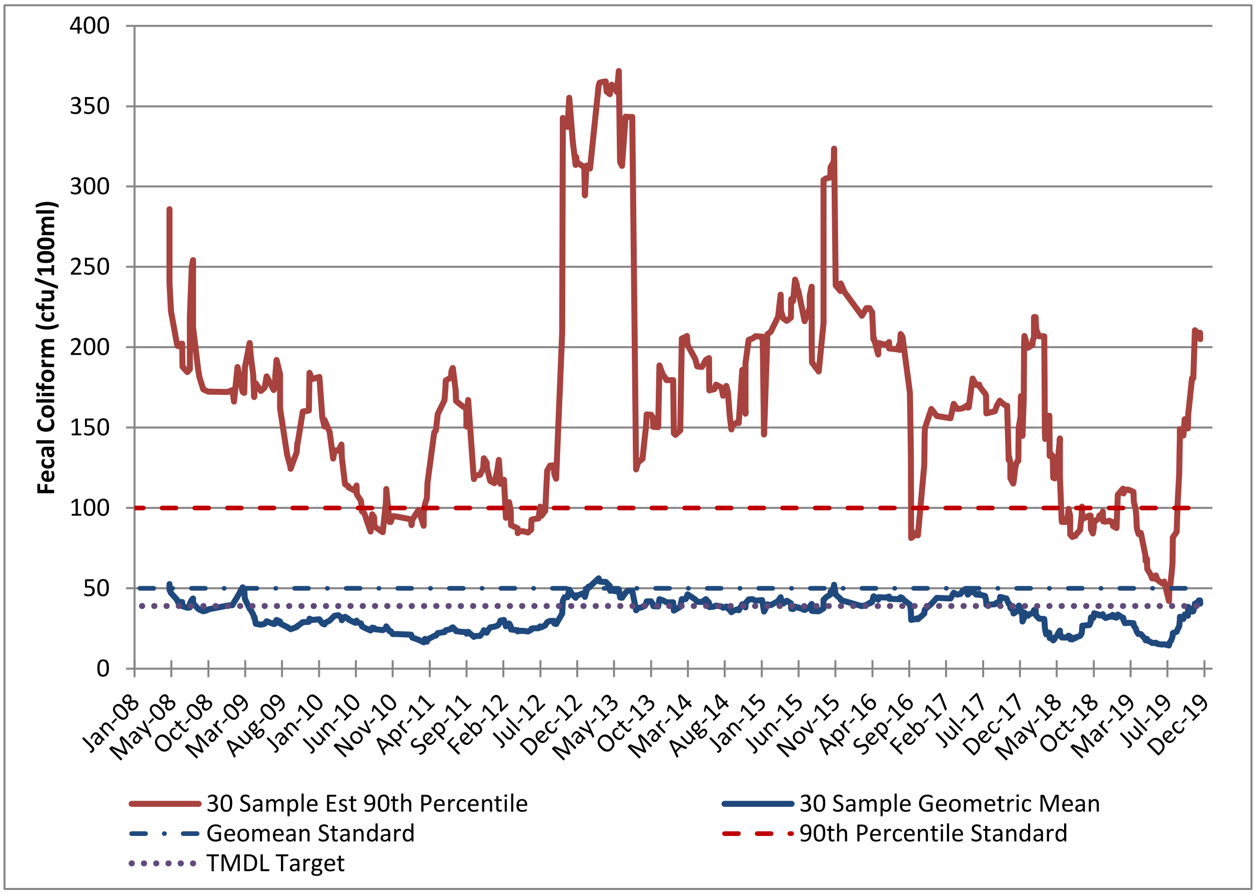


Figure 7.1.9 Trends in fecal coliform (30-sample rolling metrics) at Nooksack River site SW118 from 2008 to 2019 compared to Lummi Nation Surface Water Quality Standards and Nooksack River TMDL Target. Note that 90th percentile in figure was calculated per NSSP 30-sample estimated 90th percentile standard. Each rolling metric represents a different 30-sample date range. For example, the year-end 2019 metrics were calculated using fecal coliform observations from June 19, 2019 to December 11, 2019.

Historically, fecal coliform in the Nooksack River decreased during 2000 and 2001, indicating that pollution prevention efforts in the Nooksack River watershed in response to the 1996 closure of shellfish harvesting areas in Portage Bay were succeeding. Fecal coliform densities increased from 2003 to 2008, followed by a decrease from 2008 to 2010. Increased fecal coliform densities were again observed in samples from the Nooksack River beginning in 2011, including a significant increase in the 90th percentile from 2012-2013 due to two very high fecal coliform observations in October 2012 (3,800 and 4,200 cfu/100ml).

The increasing trend continued until November 2015, when the estimated 90th percentile decreased significantly when a very high (1,400 cfu/100ml) sample observed in February 2015 was no longer included in the 30 samples used to calculate site statistics. The estimated 90th percentile continued to decrease until early August 2019. The estimated 90th percentile decreased below the 90th percentile criterion of 100 cfu/100ml in May 2018 and remained below the criterion until it increased again in Jan-March 2019. The 30-sample estimated 90th percentile decreased again from mid-March 2019 to early August 2019, after which the metric increased throughout the late summer and fall of 2019 to a year-end 30-sample estimated 90th percentile of 205 cfu/100ml. Overall during the 2018-2019 reporting period, the 30-sample estimated 90th percentile exceeded 100 cfu/100ml 49% of the time. Over the period of record (2008-2017), the 90th percentile criterion was exceeded 89% of the time.

The 30-sample geometric mean metric has followed a similar pattern as the 30-sample estimated 90th percentile metric. The geometric mean decreased from 2008 to 2011, when it began to increase. The geometric mean exceeded the TMDL target in October 2012 and briefly exceeded the geometric mean criterion of 50 cfu/100ml from February to April 2013. The 30-sample geometric mean hovered above and around the TMDL target until October 2017. Similar to the estimated 90th percentile, the 30-sample geometric mean decreased until early August 2019, after which is increased and exceeded the TMDL target of 39 cfu/100ml in November and December 2019.

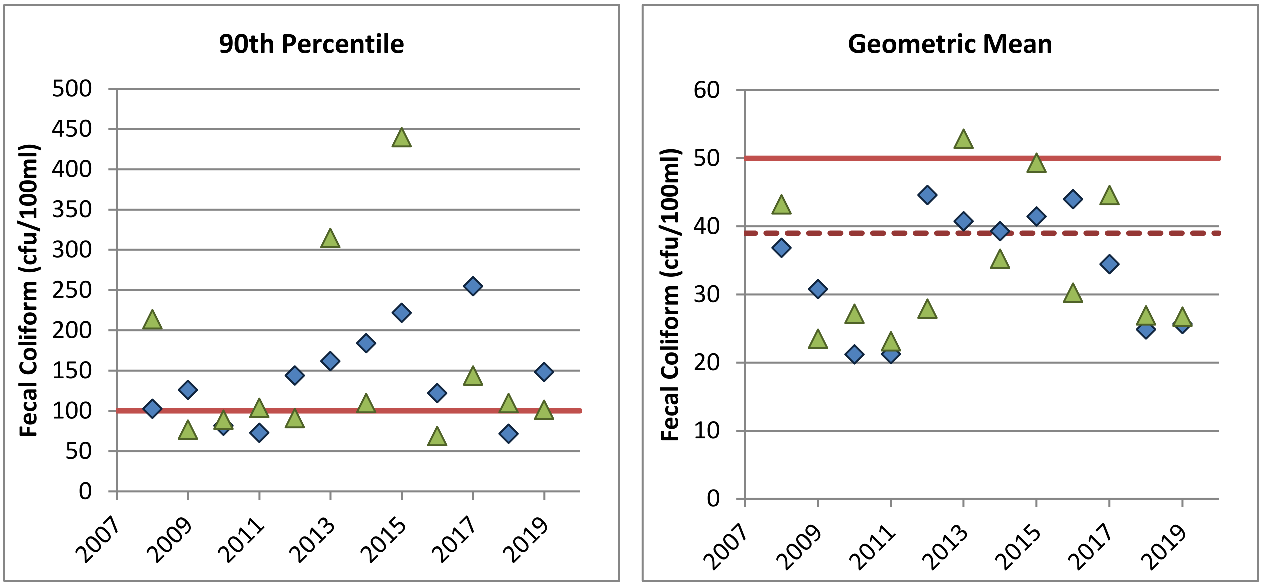
The 30-sample geometric mean remained below 50 cfu/100ml during the 2018-2019 reporting period, but was exceeded 4% of the time over the period of record (2008-2017).

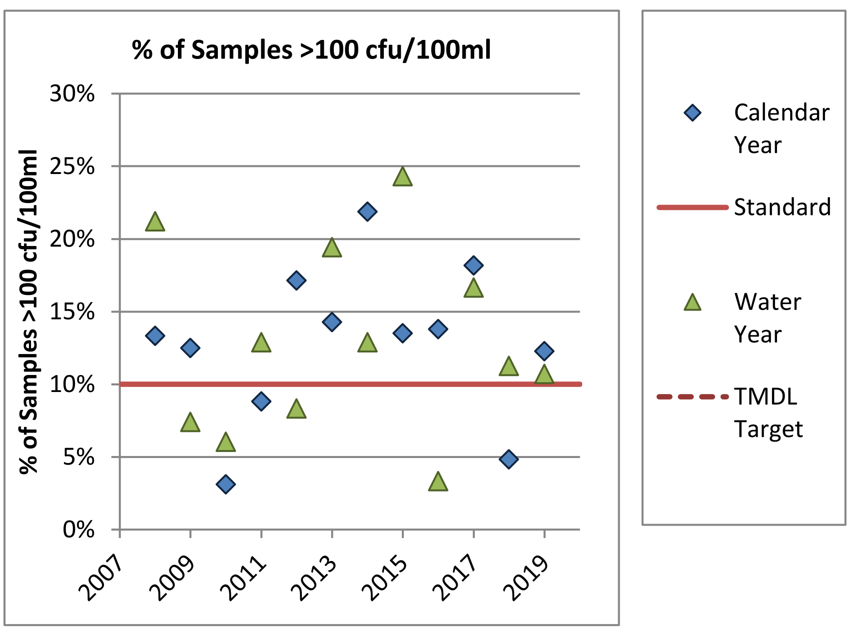
The TMDL 30-sample geometric mean target was exceeded 2% of the time over the 2018-2019 reporting period, down significantly from the 44% exceedance rate for the period of record (2008-2017). Note that the TMDL target specifies that the 30 most recent samples are used to calculate the geometric mean.

The use of the 30 most recent samples for calculating metrics, as is required for NSSP sites, may not be the most appropriate approach for evaluating water quality in freshwaters. The Nooksack River (SW118) is sampled several times a month, leading to a 30-sample metric calculation that does not represent a 5-year period as is typical for the NSSP metric calculations or any specific set amount of time. The period of time represented by the 30 sample metric can also result in biasing the metrics because noncompliant periods may be masked.

7.1.4.2 Annual

The geometric mean, calculated 90th percentile (i.e., not estimated per NSSP), and percentage of samples exceeding 100 cfu/100ml (note that this is how the 90th percentile criterion is enumerated in the Lummi Nation Water Quality Standards) were calculated by calendar year for SW118 to determine year-to-year changes in fecal coliform trends in the Nooksack River (Figure 7.1.10).





Year	Sample Size (n) Calendar Year	Sample Size (n) Water Year
2008	30	33
2009	32	27
2010	32	33
2011	34	31
2012	35	36
2013	35	36
2014	32	31
2015	37	37
2016	29	30
2017	44*	30
2018	62*	71*
2019	57	56*

Figure 7.1.10 Annual geometric mean, calculated 90th percentile, and percentage of samples greater than 100 cfu/100ml by calendar year and water year for 2008-2019 at Nooksack River site SW118. Freshwater Class AA fecal coliform criteria shown as solid red line and Nooksack River TMDL target shown as dashed orange line. Calendar year is January 1-December 31; water year is October 1-September 31 (e.g., 2019 water year is October 1, 2018-September 31, 2019). Sample size for each year (calendar and water) listed in table at right. ***Note** that 2017 calendar year includes special sampling in fall, 2018 calendar year includes special sampling in spring, 2018 water year includes special sampling in fall and spring, and fall 2019 is not included in any water years in this analysis.

Annual calendar year metrics during the reporting period showed improvement during 2018, but in 2019 showed a partial return to the elevated pattern observed since 2012. The 90th percentile standard was met during 2018 but was exceeded during 2019, both as the calculated 90th percentile and the percent of samples exceeding the criterion (100 cfu/100ml). The geometric mean criterion and the TMDL target of 39 cfu/100ml were both met annually during 2018 and 2019. The geometric mean criterion was not exceeded on an annual basis in any of the past twelve years (2008-2019).

The same metrics were also calculated by water year (October 1-September 30) and compared to calendar year metrics (Figure 7.1.10). The water year trends are similar, except that the fall of the previous calendar year is included in the following calendar year (i.e., fall 2018 is part of the 2019 water year). The contribution of the fall season becomes evident when comparing the calendar year and water year metrics. Notably, the fall of 2014 resulted in a doubling of the 90th percentile for the 2015 water year, the 2013 water year exceeded the geometric mean criterion, and the 2018 and 2019 water years were more similar than the calendar year metrics.

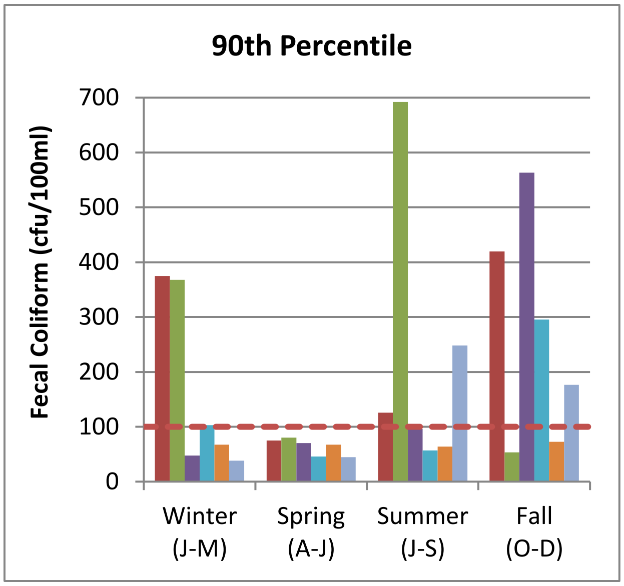
7.1.4.3 Seasonal

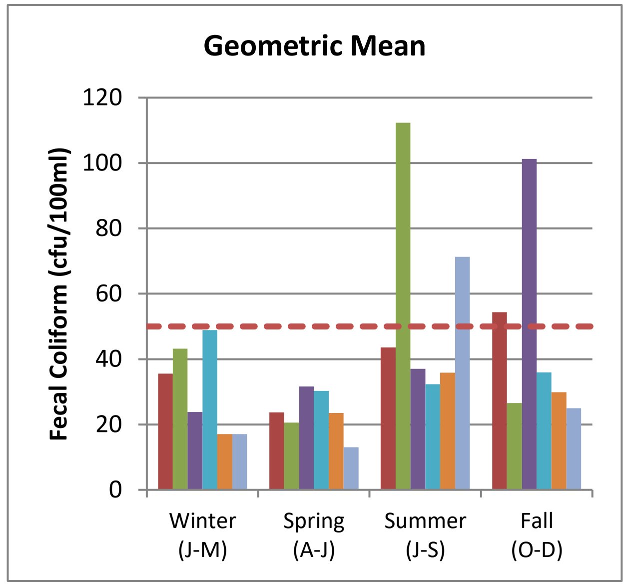
The Lummi Nation Surface Water Quality Standards specify that it is preferable to average by season when calculating geometric means. Seasonal geometric mean, 90th percentile, and percentage of samples exceeding 100 cfu/100ml were calculated by year for the period 2014-2019 (Figure 7.1.11). The seasonal analysis indicates that fecal coliform densities are highest in the fall, followed by the summer and winter, with the lowest fecal coliform densities in the spring.

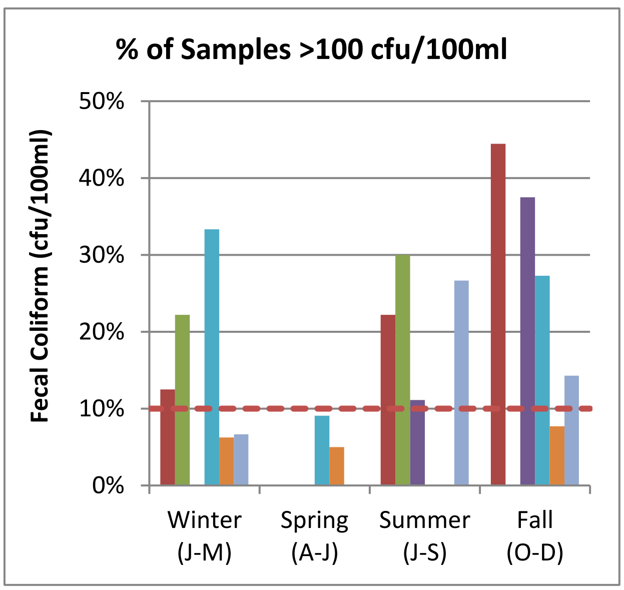
During 2018, all seasons met all portions of the fecal coliform standard: the geometric mean and the 90th percentile criteria, including both the calculated 90th percentile metric and the percentage of samples exceeding 100 cfu/100ml.

During 2019, the seasonal geometric mean exceeded the standard during the summer. Since 2014, the seasonal geometric mean has exceeded the standard only during the summer (2015, 2019) and fall (2014, 2016). The seasonal geometric mean remained below the standard for a period of 2 ½ years, from winter 2017 through spring 2019.

During 2019, the seasonal 90th percentile exceeded 100 cfu/100ml during summer and fall. Over the last 6 years (since 2014), the seasonal 90th percentile exceeded the standard four times during the fall (2014, 2016, 2017, 2019), three times during summer (2014, 2015, 2019), three times during winter (2014, 2015, 2017), and zero times during the spring. Similarly, during the previous 5-year period from 2009-2013 (pooled), the 90th percentile exceeded the standard during fall, summer, and winter, but not during the spring. The fall 90th percentile appears to be generally decreasing, although there is significant year-to-year variability. The seasonal 90th percentile did not exceed 100 cfu/100ml for six consecutive seasons, from winter 2018 through spring 2019, the longest period during the last six years.







Sample size (n)

Year	Winter (J-M)	Spring (A-J)	Summer (J-S)	Fall (O-D)
2014	8	6	9	9
2015	9	9	10	9
2016	4	8	9	8
2017	3	11	8	22
2018	16	20	13	13
2019	15	13	15	14

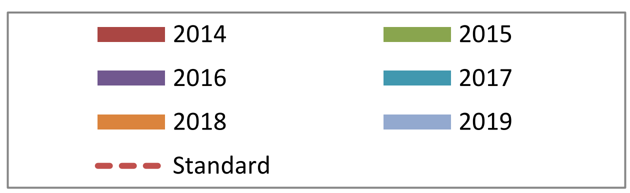


Figure 7.1.11 Seasonal geometric mean, calculated 90th percentile, and percentage of samples greater than 100 cfu/100ml by season by year from 2014 to 2019 at Nooksack River site SW118. Freshwater Class AA fecal coliform criteria shown as red dashed line. Sample size for each year and season listed in table at right.

Similar to the seasonal 90th percentile, more than 10% of samples exceeded 100 cfu/100ml during the summer and fall of 2019. More than 10% of samples exceeded 100 cfu/100ml for all seasons and years during which the 90th percentile exceeded 100 cfu/100ml, with the addition of summer 2016. This reveals that the calculated 90th percentile occasionally does not show that the standard is being exceeded; for example, the 2016 summer 90th percentile metric did not exceed 100 cfu/100ml, but the number of samples exceeding 100 cfu/100ml was greater than 10% (96 cfu/100ml 90th percentile vs. 11% of samples exceeding 100 cfu/100ml), although both values are close to the standard cutoff. The winter 2017 season had only three samples (n=3); while one-third (33%) of samples exceeded 100 cfu/100ml, this represents just one sample. More than 10% of samples exceeded the standard during the fall season for four of the last six years (2015, 2018 were below 10%), but the number of samples exceeding has decreased each year.

Note that during the winter 2016 and 2017 there are fewer than five samples. Lab contract delays resulted in no sampling early in the year. Metrics calculated for these seasons should be interpreted with caution due to low sample size.

Over the last six years, the TMDL target was exceeded seasonally three times during the summer (2014, 2015, 2019), twice during the fall (2014, 2016), twice during the winter (2015, 2017), and zero times during the spring. Note that the TMDL target specifies a 30-sample geometric mean calculation; the TMDL target is included here for comparison purposes only, not as an assessment of compliance with the target.

Year-to-year, seasonal metrics appear variable. During the fall season, the percentage of samples exceeding the 90th percentile criterion appeared to continue to decrease during the 2018-2019 reporting period. Winter water quality also appears to show an improvement, with the standard being met in 2018 and 2019. Summer water quality appears to show a decline from improvements observed during 2017 and 2018.

Future reports should consider calculation of rolling 3-month metrics, rather than or in addition to static seasons, and/or regression analysis of trends by season. In addition, inclusion of other agency data collected at or near Nooksack River site SW118 (e.g., Whatcom County Public Works site M1) should be considered to increase sample size.

In summary, the Nooksack River failed to meet the fecal coliform standard 25% of the time on a seasonal basis during the 2018-2019 reporting period (Table 7.1.3). All of 2018 and the first two seasons of 2019 met all fecal coliform criteria.

During the last six years (2014-2019), the Nooksack River has failed to meet the fecal coliform standard 46% of the time, during 11 of 24 seasons during this period. However, because at least one season failed to meet the standard during each year except 2018, five out of the last six years (83%) failed to meet the standard overall based on the seasonal analysis. A year is considered to fail the standard if any one season fails to meet the fecal coliform standard. The fecal coliform standard requires a site to meet both the geometric mean and the 90th percentile criteria. The site was considered to fail to meet the 90th percentile criterion when either the calculated 90th percentile was over 100 cfu/100ml or the percent of samples exceeding 100 cfu/100ml was over 10%. All seasons during which the Nooksack River failed to meet the geometric mean, the 90th percentile was also not met. Most seasons during which the Nooksack River failed to meet the 90th percentile, both the calculated 90th percentile exceeded 100 cfu/100ml and more than 10% of samples exceeded 100 cfu/100ml. As discussed above, the exception to this was summer 2016, during which more than 10% of samples exceeded 100 cfu/100ml but the calculated 90th percentile did not exceed the criterion. Seasonally, the fecal coliform standard was met most often in the spring. Historically, over the prior 2009-2013 all seasons other than spring failed to meet the standard. Following improvements seen during

2018 and early 2019, the summer and fall of 2019 showed a return to poor water quality as seen during previous years.

Table 7.1.3 Summary of compliance with fecal coliform standard by season and overall for Nooksack River site SW118. Red indicates failure to meet the standard, green indicates the site meets the standard during the season/year. For failing seasons, the criteria* failed are listed. Year overall fails if any one season fails during the year or period. Note that compliance with the TMDL is not included in this summary. Sample size for 2014-2019 provided in Figure 7.1.11. Sample size for 2009-2013 period (pooled) is 36 (winter), 44 (spring), 47 (summer), 45 (fall).

Year/Period	Winter	Spring	Summer	Fall	Overall
2009-2013	Fail 90+%	Meets All	Fail 90+%	Fail 90+%	Fail
2014	Fail 90+%	Meets All	Fail 90+%	Fail All	Fail
2015	Fail 90+%	Meets All	Fail All	Meets All	Fail
2016	*Meets All†*	Meets All	Fail %‡	Fail All	Fail
2017	*Fail 90+%†*	Meets All‡	Meets All	Fail 90+%	Fail
2018	Meets All	Meets All	Meets All	Meets All	Meet
2019	Meets All	Meets All	Fail All	Fail 90+%	Fail

*Seasonal metrics compared to geometric mean, 90th percentile, and % of samples criteria. If any one of these criteria were exceeded in the season, the season failed to meet the fecal coliform standard. Seasons can meet all, fail all, or fail a portion or combination of the criteria examined:

GM: geometric mean criterion (50 cfu/100ml)
90: 90th percentile criterion (100 cfu/100ml)
%: percentage of samples not to exceed criterion (no more than 10% of samples may exceed 100 cfu/100ml)

†Winter 2016 and 2017 seasons had fewer than 5 samples available; 4 and 3, respectively.

‡The compliance determinations for summer 2016 and spring 2017 differ from those reported in the 2014-2017 Water Quality Assessment Report. Analysis for the 2014-2017 report included inclusion of fecal coliform results collected as part of a different project (ZAPS Streaming Nooksack) that were analyzed using a different method and laboratory than Surface Water Project ambient data as part of the seasonal analysis for Nooksack River site SW118. These results were excluded in other analyses included in the 2014-2017 report and all analyses in this report. This resulted in a change in the 2016 summer season compliance from meet to fail and a change in the 2017 spring season compliance from fail to meet.

7.1.4.4 Monthly

Monthly geometric mean, 90th percentile, and percentage of samples exceeding 100 cfu/100ml was calculated for a five-year period of record (2009-2013) and over the last six years in two-year increments (2014-2015, 2016-2017, and the reporting period 2018-2019). Two years of data were pooled to ensure that, for most months, five or more values were available for calculation of the geometric mean. During the period of time analyzed monthly, only one had no data (January 2016-2017) and two periods had fewer than five samples (April 2014-2015 with n=4 and February 2016-2017 with n=2). The reporting years 2018 and 2019 were also assessed monthly by year, including months with fewer than five samples, to determine differences in the two reporting years.

The highest fecal coliform counts by month have historically, over the five-year period from 2009 to 2013, been observed during October (Figure 7.1.12). Over the last six years, the highest fecal coliform counts have all been observed during the late summer and fall; during September for 2014-2015 and 2018-2019 and during November for 2016-2017.

During the 2018-2019 reporting period, the geometric mean was exceeded in August and September. This was due to failure to meet the geometric mean during these months in 2019; no geometric mean exceedances were observed during 2018. Both the 90th percentile and the percentage of samples exceeding 100 cfu/100ml were exceeded in January, September, October, and November for the 2018-2019 reporting period. Both metrics exceeded the standard for 2018 and 2019 in January and October, while the September and November exceedances were attributed to high counts in 2019. In addition, during 2018, more than 10% of samples exceeded 100 cfu/100ml in April and during 2019, the 90th percentile and percent exceeded criteria were both exceeded in August. Fecal coliform counts during August were elevated enough to results in an exceedance of the geometric mean criterion during 2019 and for the 2018-2019 reporting period, but only showed an exceedance in the 90th percentile and percent exceedance criteria during 2019 (i.e., not for the combined reporting period). Only April received a conflicting compliance determination when comparing the reporting years separately and combined; the April 2018 exceedance of the percent exceeded criterion was masked by better water quality during the month in 2019 for the combined 2018-2019 compliance determination. All months with exceedances during 2018 and 2019 (individually) were based on five or more samples, with the exception of November 2019 (n=4). Future reports should compare monthly metrics annually to determine year-to-year variability in monthly water quality and the WQM Program could be revised to require five site visits to Nooksack River site SW118 per month to provide the data needed to complete this analysis with a sufficient number of samples for geometric mean calculation. In addition, non-WQM Program fecal coliform data collected by other agencies at the same site (i.e., Whatcom County Public Works site M1) could be used to supplement ambient WQM Program data to increase sample size for monthly analysis on an annual basis.

The geometric mean criterion has been exceeded during five months, February and August through November, over the period of record (2009-2013 October), recently (2014-2015 February, September, November; 2016-2017 November), and for the reporting period (2019 August, September). The geometric mean is exceeded most frequently in September and November. On average, the geometric mean is exceeded 15% of the time, ranging from 0% of the time in 2018 and 25% of the time in 2014-2015.

The 90th percentile criterion has been exceeded during eight months, January, February, May, and August through December. The October and November 90th percentile exceeded the criterion during all periods assessed: period of record (2009-2013), recent years (2014-2015 and 2016-2017), and the reporting period (2018-2019; both exceeded in 2019, only October exceeded in 2018). On average, the 90th percentile is exceeded 36% of the time, ranging from 8% of the time in 2018 and 42% of the time in 2009-2013.

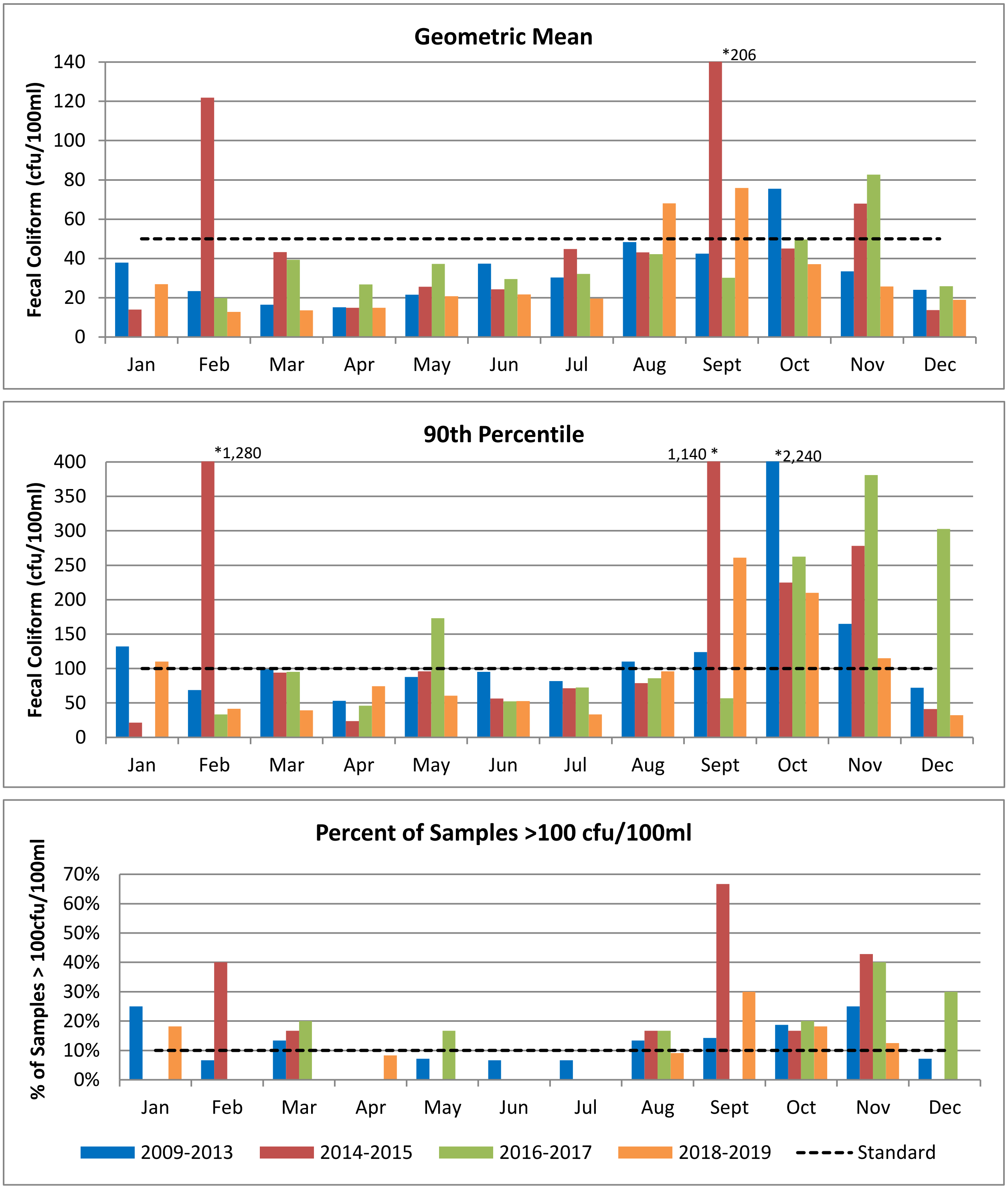


Figure 7.1.12 Fecal coliform geometric mean, 90th percentile, and percentage of samples >100 cfu/100ml by month for Nooksack River site SW118 for 2013-2019. Data pooled for 5-year period 2009-2015 and 2-year periods 2014-2015, 2016-2017, and reporting years 2018-2019. Metrics for months exceeding scale shown are noted with asterisk with value noted. Sample size for each period/month shown is >5, except April 2015-2015 (n=4), January 2016-2017 (n=0), and February 2016-2017 (n=2).

More than 10% of samples exceeded 100 cfu/100ml during ten months (83% of the year), January through May and August through December. Only June and July did not have any failures of the percent exceedance criterion during the periods assessed. Similar to the 90th percentile, the October and November percent exceedance metric exceeded the criterion during all periods assessed: period of record (2009-2013), recent years (2014-2015 and 2016-2017), and the reporting period (2018-2019; both exceeded in 2019, only October exceeded in 2018). April was exceeded only once, during 2018, out of the periods assessed. On average, the percent exceeding criterion is exceeded 47% of the time, from 25% of the time in 2018 to 55% of the time in 2016-2017.

Monthly compliance with the fecal coliform standard is summarized in Table 7.1.4. A month fails to meet the fecal coliform standard if either of the two criteria are not met: the geometric mean or the 90th percentile, which is determined by calculating both the 90th percentile of the dataset and the percentage of samples exceeding the 90th percentile criterion.

On average, 50% of months failed to meet the fecal coliform standard over the periods assessed. The period of record (2009-2013) and 2014-2015 had 50% of months fail to meet the standard, 2016-2017 had 55% of months fail to meet the standard, and 2018-2019 had 42% fail to meet the standard. Individually, 25% of months failed to meet the standard in 2018 and 42% of months failed to meet the standard in 2019. During the period of record (2018-2019), the number of months that failed to meet the fecal coliform standard decreased, although the 75% compliance rate seen in 2018 was reduced due to a return of poor water quality during 2019.

The monthly analysis confirms that late summer and fall, especially September through November, are the times of highest concern for fecal coliform loading from the Nooksack River to Bellingham Bay and Portage Bay.

Table 7.1.4 Summary of compliance with fecal coliform standard by month for Nooksack River site SW118. Red indicates failure to meet the standard, green indicates the site meets the standard. For failing seasons, the criteria* failed are listed. Note that compliance with the TMDL is not included in this summary. Sample size is ≥5 except italics and January 2016-2017.

Month	Period of Record	Recent Years		Reporting Period		
	2009-2013	2014-2015	2016-2017	2018-2019	2018	2019
Jan	Fail 90+%	Meets All	*No Samples*	Fail 90+%	Fail %	Fail 90+%
Feb	Meets All	Fail All	*Meets All*	Meets All	*Meets All*	*Meets All*
Mar	Fail %	Fail %	Fail %	Meets All	Meets All	Meets All
Apr	Meets All	*Meets All*	Meets All	Meets All	Fail %	*Meets All*
May	Meets All	Meets All	Fail 90+%	Meets All	Meets All	Meets All
Jun	Meets All	Meets All	Meets All	Meets All	Meets All	*Meets All*
Jul	Meets All	Meets All	Meets All	Meets All	*Meets All*	*Meets All*
Aug	Fail 90+%	Fail %	Fail %	Fail GM	Meets All	Fail All
Sept	Fail 90+%	Fail All	Meets All	Fail All	*Meets All*	Fail All
Oct	Fail All	Fail 90+%	Fail 90+%	Fail 90+%	Fail 90+%	Fail 90+%
Nov	Fail 90+%	Fail All	Fail All	Fail 90+%	*Meets All*	*Fail 90+%*
Dec	Meets All	Meets All	Fail 90+%	Meets All	*Meets All*	*Meets All*

*Seasonal metrics compared to geometric mean, 90th percentile, and % of samples criteria. If any one of these criteria were exceeded in the season, the season failed to meet the fecal coliform standard. Seasons can meet all, fail all, or fail a portion or combination of the criteria examined:
GM: geometric mean criterion (50 cfu/100ml)
90: 90th percentile criterion (100 cfu/100ml)
%: percentage of samples not to exceed criterion (no more than 10% of samples may exceed 100 cfu/100ml)

7.1.4.5 Nooksack River Tributaries and Delta

Other than the mainstem at Marine Drive, the Nooksack River system is monitored at Silver Creek and Kwina Slough. Silver Creek is a tributary that flows into the Nooksack River's Marietta Channel downstream of Marine Drive. Kwina Slough receives flow from the Nooksack River upstream of Marine Drive and, during high flows, flows back into the Nooksack River's West Channel downstream of Marine Drive. During the 2018-2019 reporting period, Kwina Slough (SW007) failed to meet the fecal coliform standard while Silver Creek (SW075) was in compliance with the fecal coliform standard. Kwina Slough failed to meet the fecal coliform standard during the summer, although this was based on one sample. Kwina Slough met the standard during all other seasons, during which there were more than five samples for each season. Silver Creek was in compliance with the standard during all seasons, but only fall had more than five samples.

When compared to the 2008-2017 period of record, Kwina Slough has shown improvement in water quality during the 2018-2019 reporting period. For the five-year period 2008-2012, Kwina Slough failed to meet the standard during two seasons: summer and fall. For the five-year period 2013-2017, Kwina Slough failed to meet the standard during three seasons: spring, summer, and fall. When the ten-year period of record (2008-2017) is assessed as a unit, the site failed to meet the standard during all seasons except winter.

For the period 2008-2015, no data are available for Silver Creek because sampling at this site did not commence until March 2016. For the period of record 2016-2017, Silver Creek failed to meet the fecal coliform standard during winter, spring, and fall. No samples were collected during summer. Fewer than five samples were used for winter and spring assessment.

7.1.5. Other Portage Bay Watershed Freshwater Inputs

Several small drainages on the Lummi Peninsula and Portage Island also contribute freshwater flows into Portage Bay. Although the vast majority of freshwater in Portage Bay originates from the Nooksack River, these small drainages still contribute, at least seasonally, to freshwater inputs into Portage Bay.

7.1.5.1 Portage Island

Five ephemeral freshwater drainages flowing into Portage Bay are monitored on Portage Island. Of these, two had zero sampling events during the reporting period 2018-2019 (sites SW024 and SW025) and are not included further in this report. The three other Portage Island sites (sites SW026, SW027, and SW028) were sampled at least once during each season during the reporting period 2018-2019: four times during the spring, twice during the winter and fall, and once during the summer. The sites are routinely visited six times per year, but the ephemeral nature of the drainages means that the sites are frequently stagnant during the dry season. Although the Lummi Water Quality Standards recommend the use of five samples for calculation of a geometric mean, the geometric mean was calculated for all sites and sample sizes below three are marked as such. As previously discussed, a sample size of three was determined to be sufficient for calculation of a reliable geometric mean, especially at sites that only flow seasonally and are visited less frequently.

For the 2018-2019 reporting period, most Portage Island sites failed to meet the fecal coliform standard due to high counts during the summer (Table 7.1.5). Site SW027 also failed to meet the standard during spring of the reporting period. The summer metrics for all sites were based on only one sample collected during the two-year reporting period. There is no minimum sample size for calculating the 90th percentile or percentage of samples exceeding the criterion. Site SW028 failed to meet the geometric mean criterion during the summer for the reporting period based on just one sample; because the site met the 90th percentile criterion, determination of compliance should not rest on a geometric mean calculated from one sample alone. For these reasons, the site is listed as failing to meet the standard for the summer with a caveat (cell is orange in Table 7.1.5) but the site meets the fecal coliform standard overall for the reporting period. All other sites and seasons failed to meet the 90th percentile criterion (either based on calculated 90th percentile or percent of samples exceeding the criterion), sometimes in combination with failure to meet the geometric mean, therefore the compliance designation of those sites and seasons were not changed.

The period of record used for the Portage Island sites is 2014-2017. Historically, a herd of cattle present on the uninhabited island was thought to be the main source of high fecal coliform bacteria concentrations in the freshwater streams. The cattle were removed during 2013. The 2014-2017 period of record provides comparison to recent conditions after the cattle were removed. Similar to the reporting period, the three Portage Island sites had high counts during the spring and/or summer for the period of record 2013-2017. Site SW027 also failed to meet the standard during the fall for the period of record. Similar to site SW028 for the reporting period, site SW026 had only one sample collected during the summer, a geometric mean that exceeded the criterion, and a 90th percentile that met the criterion. This site is also listed as failing to meet the summer standard with a caveat (cell is orange in Table 7.1.5). However, this site also failed to meet the standard during the spring season, leading to an overall failure to meet the standard regardless of the summer designation.

Overall, there appears to have been improvement in water quality during the reporting period at SW028. The timing of poor water quality at site SW026 may have shifted from spring to summer, when flows are rare and typically low. Water quality at SW027 remains poor, with exceedances during half of the year.

Table 7.1.5 Summary of compliance with the fecal coliform standard at sites on Portage Island for the reporting period (2018-2019) and four-year period of record (2014-2017) following removal of cattle on the island. If any season failed to meet the fecal coliform standard, the overall compliance status was marked as failing to meet the standard. Compliance requires that both the geometric mean and 90th percentile criteria (both calculated 90th percentile metric and percentage of samples above the criterion) are met.*

	SW026		SW027		SW028	
Period	**2014-2017**	**2018-2019**	**2014-2017**	**2018-2019**	**2014-2017**	**2018-2019**
Winter	Meets All	*Meets All*	Meets All	*Meets All*	Meets All	*Meets All*
Spring	Fail 90+%	Meets All	Fail All	Fail 90+%	Fail 90+%	Meets All
Summer	*Fail GM*	*Fail All*	No Data	*Fail All*	*Meets All*	*Fail GM*
Fall	*Meets All*	*Meets All*	Fail 90+%	*Meets All*	Meets All	*Meets All*
Overall	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Meet†**

*Seasonal metrics compared to geometric mean, 90th percentile, and % of samples criteria. If any one of these criteria were exceeded in the season, the season failed to meet the fecal coliform standard. Seasons can meet all, fail all, or fail a portion or combination of the criteria examined:

GM: geometric mean criterion (50 cfu/100ml)

90: 90th percentile criterion (100 cfu/100ml)

%: percentage of samples not to exceed criterion (no more than 10% of samples may exceed 100 cfu/100ml)

Italics = fewer than three samples used for determination. All others have sample size ≥3, and winter and spring 2014-2017 at all sites have sample size ≥3.

Orange cells indicate that the failure to meet the geometric mean was based on one sample, which is not appropriate for assessing against geometric mean criteria.

†SW028 is listed as meeting the fecal coliform standard for the 2018-2019 reporting period because it is not appropriate to calculate a geometric mean using only one sample (summer season). Because the geometric mean was met during all other seasons and no seasonal excursions above the 90th percentile criterion occurred, the site is listed as meeting the fecal coliform standard for the reporting period.

As discussed above, the infrequency of sampling (six times per year) and intermittent nature of the freshwater systems on Portage Island leads to fewer than five samples per season and often fewer than three samples per season for two-year pooled periods (such as the reporting period 2018-2019) and often for longer periods as well (such as the four-year period of record 2014-2017). The 90th percentile was calculated by season for each of the five most recent years, including the reporting years 2018 and 2019 (Figure 7.1.13). This was done because there is no minimum sample size for evaluation of compliance with the 90th percentile criterion, as there is for the geometric mean (recommended five, acceptable to use three), and because the 90th percentile provides an indication of the magnitude of occasional high fecal coliform counts encountered over time.

Fecal coliform counts during 2018 were higher than during 2019. There were no exceedances of the 90th percentile criterion during 2019, while the 90th percentile criterion was exceeded at one site during the spring and at two sites during the summer during 2018. Seasonally, it is clear that the spring season tends to have the highest fecal coliform counts. Only during 2018 were there exceedances in the summer 90th percentile. The highest fecal coliform counts are observed at SW027, the outlet of a stream that drains a large wetland located on Portage Island.

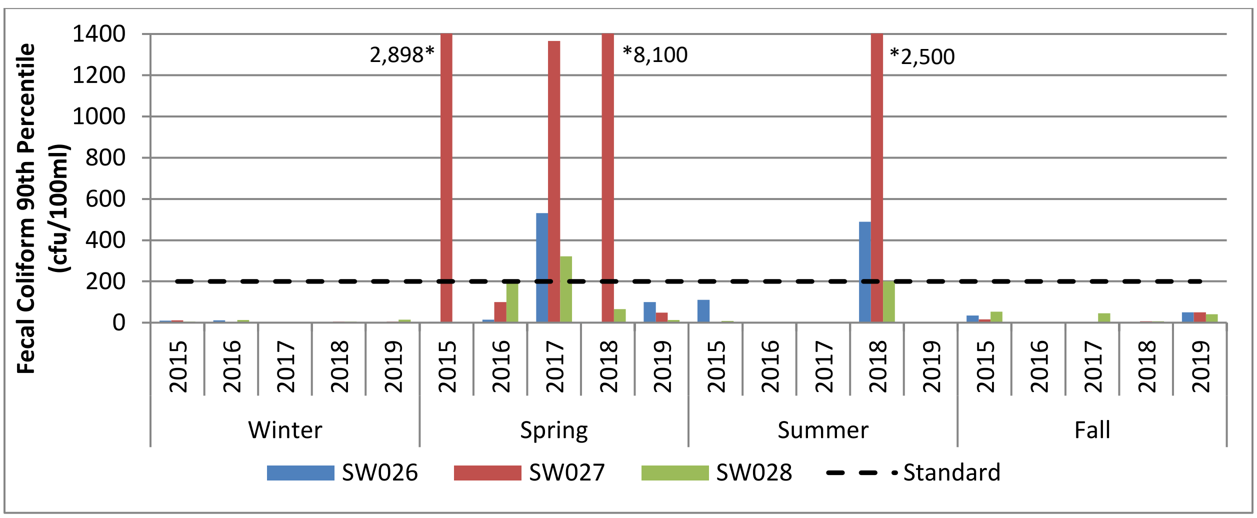


Figure 7.1.13 Seasonal 90th percentile fecal coliform metric for Portage Island freshwater sites by year 2015-2019. Site SW027 90th percentile exceeding the y-axis range listed with asterisk on figure.

7.1.5.2 Lummi Shore Road

Four freshwater drainages on the east side of the Lummi Peninsula along Lummi Shore Road (LSR) are monitored six times per year. The intermittent nature of these drainages led to few samples over the 2018-2019 reporting period. None of the sites were sampled during summer or fall. Only one sample was collected at each site during the winter and spring, with the exception of site SW031, where two samples were collected during the winter for the reporting period 2018-2019. The reporting period was compared to a recent period of record from 2014 to 2017 to match the analysis conducted for the Portage Island drainages and to compare the reporting period to the period encompassing the Portage Bay shellfish harvesting conditional closure, which began in 2014.

Three of the sites along LSR met the standard during the winter and spring of the 2018-2019 reporting period, leading to an overall determination of compliance with the fecal coliform standard (Table 7.1.6). This is consistent with conditions observed over the recent period of record 2014-2017, during which these three sites met the standard during all seasons during which samples were available. Site SW033 failed to meet the standard during winter and spring of the reporting period, leading to an overall determination of noncompliance with the fecal coliform standard. Over the recent period of record, site SW033 met the standard during winter, spring, and overall. The failure to meet the geometric mean criterion during the winter of the reporting period was based on only one sample. As discussed above, determination of non-compliance should not rest on a geometric mean calculated from one sample alone. Because the site met the 90th percentile for the season, the site is listed as failing to meet the standard for the winter with a caveat (cell is orange in Table 7.1.6). The overall compliance determination did not change because the spring season failed to meet the 90th percentile criterion, albeit based on only one sample. There is no minimum sample size for determining compliance with the 90th percentile criterion.

Table 7.1.6 Summary of seasonal compliance with the fecal coliform standard at sites along Lummi Shore Road for the reporting period (2018-2019) and recent period of record (2014-2017). If any seasonal determination failed to meet the fecal coliform standard, the overall compliance status was marked as failing to meet the standard. Compliance requires that both the geometric mean and 90th percentile criteria (both calculated 90th percentile metric and the percentage of samples above the criterion) are met.*

Period	**SW031**		**SW033**		**SW035**		**SW037**	
	2014-2017	**2018-2019**	**2014-2017**	**2018-2019**	**2014-2017**	**2018-2019**	**2014-2017**	**2018-2019**
Winter	Meets	*Meets*	Meets	*Fail GM*	Meets	*Meets*	*Meets*	*Meets*
Spring	*Meets*	*Meets*	*Meets*	*Fail All*	*Meets*	*Meets*	nd	*Meets*
Summer	nd	nd	nd	nd	nd	nd	nd	nd
Fall	*Meets*	nd	nd	nd	*Meets*	nd	*Meets*	nd
Overall	**Meet**	**Meet**	**Meet**	**Fail**	**Meet**	**Meet**	**Meet**	**Meet**

*Seasonal metrics compared to geometric mean, 90th percentile, and % of samples criteria. If any one of these criteria were exceeded in the season, the season failed to meet the fecal coliform standard. Seasons can meet all, fail all, or fail a portion or combination of the criteria examined:

GM: geometric mean criterion (50 cfu/100ml)

90: 90th percentile criterion (100 cfu/100ml)

%: percentage of samples not to exceed criterion (no more than 10% of samples may exceed 100 cfu/100ml)

nd: no data

Italics = fewer than three samples used for determination. Others have sample size ≥3. Only winter 2014-2017 at SW033 had sample size ≥5.

Orange cells indicate that the failure to meet the geometric mean was based on one sample, which is not appropriate for assessing against geometric mean criteria.

The results observed over the reporting period and recent period of record are consistent with intensive shoreline sampling conducted over the 1998 through 2001 period that demonstrated that local sources of fecal coliform bacteria are not a significant source of fecal contamination to Portage Bay (LWRD 1999, 2006a,b).

As discussed above, the infrequency of sampling (six times per year) and intermittent nature of the freshwater systems along Lummi Shore Road leads to fewer than five samples per season and often fewer than three samples per season for two-year pooled periods (such as the reporting period 2018-2019) and often for longer periods (such as the four-year recent period of record 2014-2017). The 90th percentile was calculated by season for each of the five most recent years, including the reporting years 2018 and 2019 (Figure 7.1.14). This was done because there is no minimum sample size for evaluation of compliance with the 90th percentile criterion, as there is for the geometric mean (recommended five samples, acceptable three samples), and because the 90th percentile provides an indication of the magnitude of occasional high fecal coliform counts encountered over time.

Only one site and season exceeded the fecal coliform 90th percentile criterion over the five year seasonal analysis: site SW033 during spring 2019. This was based on a single sample. This shows that although occasional excursions over the 90th percentile criterion do occur, they do so infrequently, with only one sample exceeding 200 cfu/100ml out of a total of 26 samples collected from four sites over five years.

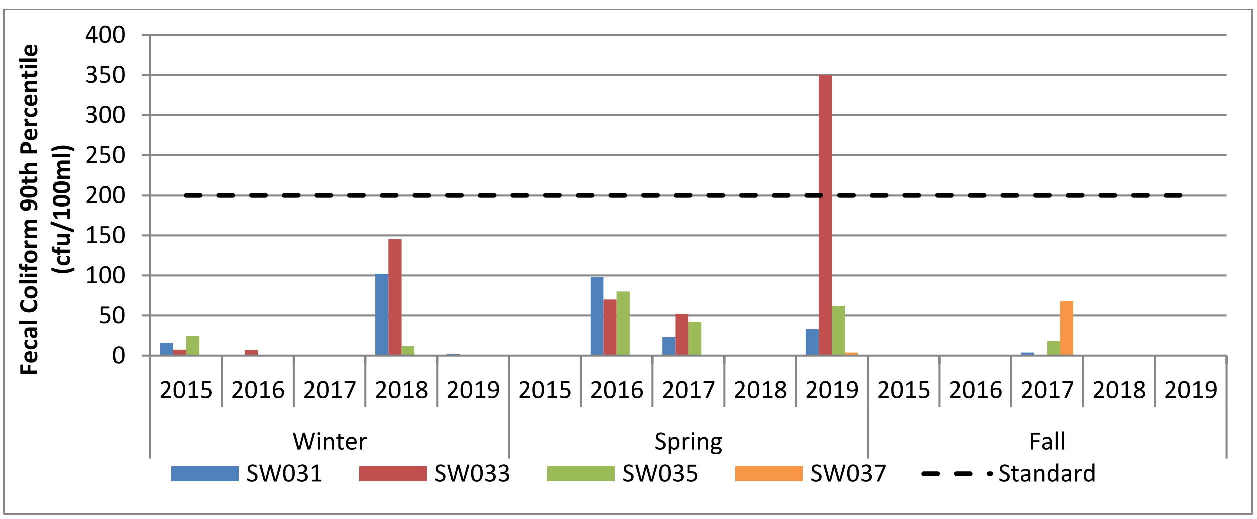


Figure 7.1.14 Seasonal 90th percentile fecal coliform metrics for freshwater sites along Lummi Shore Road by year for years 2015-2019 for winter, spring, and fall. No samples were collected at any sites during summer.

7.1.5.3 Portage Bay Freshwater Summary

The freshwater drainages on Portage Island and along the east side of the Lummi Peninsula contribute a small amount of fecal coliform loading into Portage Bay, but because flows are low and intermittent, the contribution of these drainages is nearly negligible compared to the loading from the Nooksack River (discussed in Section 7.1.4). Nevertheless, they contribute to fecal coliform pollution and are required to protect characteristic uses, including downstream shellfish harvesting. Two sites on Portage Island failed to meet the fecal coliform standard and one met the standard. Three sites along the east side of the Lummi Peninsula (Lummi Shore Road) met the fecal coliform standards while one failed to meet the standard. Elevated fecal coliform densities were seasonal, observed during spring along Lummi Shore Road and in spring and summer on Portage Island.

7.1.6. Lummi Bay

Shellfish harvesting areas in Lummi Bay were open throughout the 2018-2019 reporting period and all twelve NSSP sites in Lummi Bay met the NSSP fecal coliform criteria. Elevated fecal coliform densities were observed at site DH286 during 2014-2017, leading this site to be listed in “Concerned” status (25.5 FC/100ml) in the 2016 Lummi Bay growing area report and “Threatened” status (31.3 FC/100ml) in the 2017 Lummi Bay growing area report (DOH 2016b, 2017). Following the steady increase in the 30-sample estimated 90th percentile at site DH286 from 2014-2017, the metric decreased throughout the 2018-2019 reporting period (Figure 7.1.15). Only one moderately elevated fecal coliform density was observed on one occasion at one Lummi Bay NSSP site during the reporting period: fecal coliform density of 49 cfu/100ml at DH286 in December 2019. Although this suggests occasional elevated densities are observed, the frequency appears low. The result did not increase the 30-sample estimated 90th percentile for DH286 because it replaced a sample with the same density in the rolling metric. Due to improvements in fecal coliform densities observed at DH286, the site was upgraded to “Concerned” status (26.5 cfu/100ml) in the 2018 Lummi Bay growing area report and was no longer listed as a site of concern (19 cfu/100ml) in the 2019 Lummi Bay growing area report (DOH 2018, 2019a).

All other sites in the Lummi Bay shellfish growing area were well within the 30-sample estimated 90th percentile standard and all sites were below any thresholds of concern for the geometric mean during the reporting period 2018-2019.

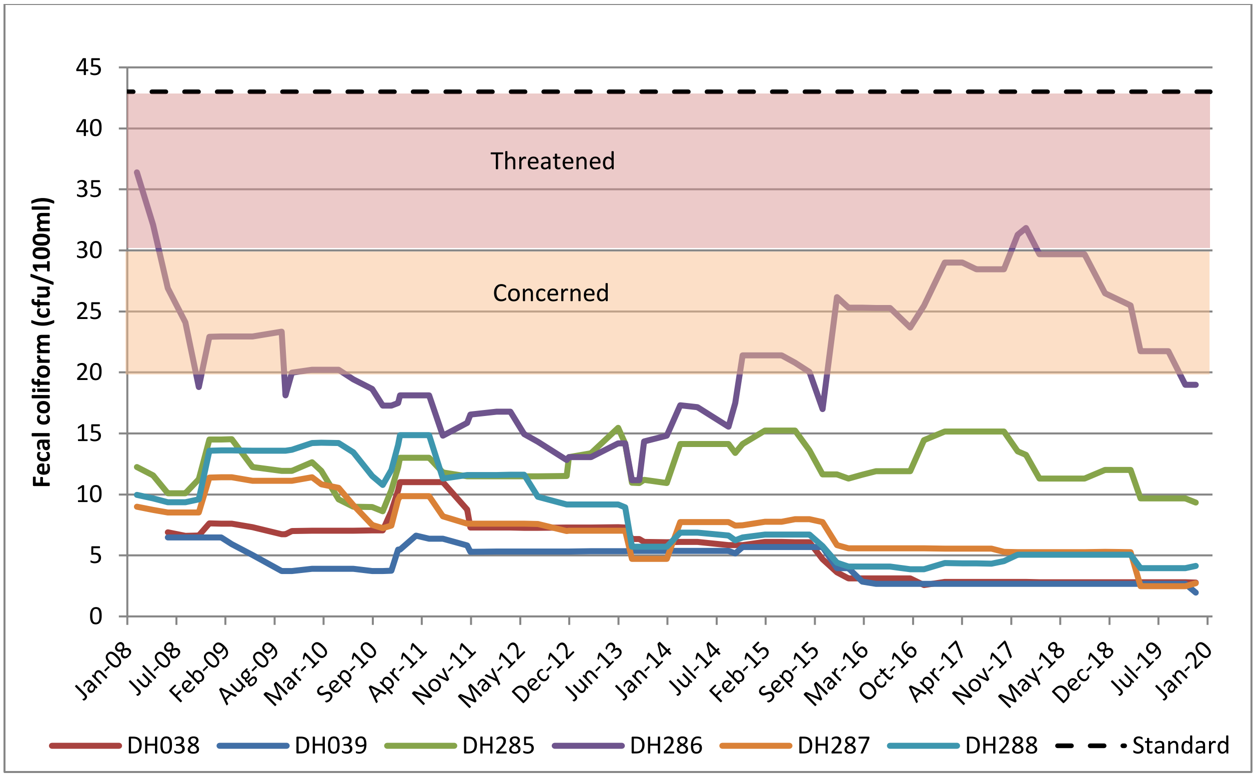


Figure 7.1.15 Rolling 30-sample estimated 90th percentile at six northern monitoring sites in Lummi Bay shellfish growing area for 2008-2019 and NSSP standard. Generally, sites are considered "Threatened" if the metric is 30-43 fecal coliform/100ml and "Concerned" if the metric is 20-30 fecal coliform/100ml.

Lummi Bay NSSP sites were also evaluated for compliance seasonally for the reporting period 2018-2019, and two periods of record 2014-2017 (four years) and 2008-2013 (five years). Samples were pooled for each compliance period. Sample size for the 2018-2019 reporting period was three for all sites/seasons. Sample size for the four-year 2014-2017 period of record was six for winter and spring, five for summer, and seven for fall. Sample size for the previous five-year 2008-2013 period of record was 8-11 for each site and season.

During the 2018-2019 reporting period, all Lummi Bay NSSP sites met the fecal coliform standard during all seasons except site DH286, which failed to meet during the fall season. Site DH286 failed to meet the percent exceedance criterion during fall 2018-2019 due to one of three samples exceeding the 43 cfu/100ml criterion (33%), which led the site to fail to meet the standard overall.

For the four-year 2014-2017 period of record, most Lummi Bay NSSP sites (9 out of 12) met the fecal coliform standard during all seasons for the period of record. Site DH286 failed to meet the 90th percentile and percent exceedance criteria during the fall and sites DH285 and DH287 failed to meet the percent exceedance criteria during the winter. Sites DH285 and DH287 had one of six sampling events (17%) with a fecal coliform density that exceeded 43 cfu/100ml, but not high enough to increase the calculated 90th percentile over the criterion. At site DH286, two of seven (29%) of samples exceeded 43 cfu/100ml, one of which was elevated enough to increase the calculated 90th percentile to 169 cfu/100ml, well over the criterion. This elevated sampling event resulted in the site being designated in “Concerned” status in 2016. These three sites failed to meet the fecal coliform standard overall due to failure to meet one or more of the components during one or more season for the 2014-2017 period of record.

During the previous five-year period of record (2008-2013), nine out of twelve sites met the fecal coliform standard during all seasons. Site DH044 failed to meet the standard in spring and summer, site DH045 failed to meet the standard in spring, and site DH286 failed to meet the standard in fall. Sites DH044 and DH045 are located inside the seaponds aquaculture facility. The failure to meet the standard at site DH286 during fall for the 2008-2013 period of record, the 2014-2017 period of record, and the 2018-2019 reporting period indicates that there are continued and chronic occasional elevated fecal coliform densities present at this site during the fall. Although this site is no longer listed as a site in Concerned or Threatened status in DOH annual growing area reports, fecal coliform densities, particularly during the fall, should be closely monitored at this station, nearby marine stations, and the freshwater sources to this station (i.e., Jordan Creek/North Lummi River Distributary).

Overall, a higher rate of compliance with the fecal coliform standard was seen at Lummi Bay NSSP sites during the reporting period than over the period of record (Table 7.1.7). This is consistent with the improvements in the NSSP metrics previously discussed.

Additional marine sites in and around Lummi Bay are sampled as part of the Surface Water Project, including the marine receiving waters of Jordan Creek/North Lummi River Distributary, the Lummi River, and Smuggler Slough; the Sandy Point marina; and Hale Passage. These sites were evaluated seasonally to determine compliance with the Lummi Nation Surface Water Quality Standards. If any season failed to meet the fecal coliform standard, the site is considered to fail to meet the standard. Table 7.1.7 summarizes compliance with the marine sites in Lummi Bay, Hale Passage, and Sandy Point marina. The brackish sites and marine receiving waters are discussed in conjunction with the freshwater sites in Section 0 and compliance is summarized in Table 7.1.8 through Table 7.1.11. Note that there is a difference in site visit frequency for sites in Lummi Bay and the Lummi Bay watershed resulting in uneven sample sizes for marine sites sampled from a boat, marine sites sampled from shore, and the freshwater sites that flow into Lummi Bay. The marine sites in Lummi Bay and the Sandy Point marina are sampled six times per year, while the brackish, marine receiving waters, and freshwater sites in the Lummi Bay watershed are sampled approximately twelve times per year. This resulted in a different approach for analyzing marine and freshwater/brackish/receiving waters. Due to infrequency in sampling, marine sites were analyzed seasonally by pooling the two-year reporting period 2018-2019 and a four-year period of record 2014-2017. The freshwater, brackish, and marine receiving water sites that are sampled more frequently were analyzed using a variety of pooling and annual methods as described in Section 0.

Two sites in the Sandy Point marina were monitored during the 2018-2019 reporting period. Site SW001, located in the northern end of the marina, failed to meet the fecal coliform standard during the fall due to failure to meet the 90^{th} percentile and percent exceedance criteria. This is consistent with exceedances during the 2014-2017 period of record, when the site failed to meet the standard in spring and fall. The other site, SW019, is located in the southern end of the marina and met the standard during all seasons during both the 2018-2019 reporting period and the 2014-2017 period of record.

One ambient site monitored in the marine waters of Lummi Bay, SW002, met the fecal coliform standard during all seasons for both the 2018-2019 reporting period and the 2014-2017 period of record. This is consistent with the compliance during all seasons at the NSSP sites near site SW002.

Two sites in Hale Passage, which is designated Class AA Marine, were monitored during the 2018-2019 reporting period. Site DH048 (sampled for the Portage Bay NSSP) failed to meet all three components of the fecal coliform standard (geometric mean, 90th percentile, and percent exceedance criteria) during the fall for the reporting period. During the 2014-2017 period of record, DH048 met the standard during all seasons. Site SW039, which is sampled from shore at the Portage, failed to meet the fecal coliform standard during spring and fall during the 2018-2019 reporting period and during all seasons for the 2014-2017 period of record.

Table 7.1.7 Summary of compliance with Class AA Marine fecal coliform standard in the waters in and around Lummi Bay: Hale Passage, Sandy Point marina, and Lummi Bay open marine. Sites that fail to meet the standard for one or more seasons fail to meet overall.* For reporting period (2018-2019), sample size is 3-4 for all sites except n=2 for italicized and n=6 for all seasons at DH048. For the periods of record (2014-2017 and 2008-2013), sample size is greater than 5 for all except italicized (n=4).

	Area	**Hale Passage**		**Sandy Point Marina**		**Lummi Bay**	
	Site ID	**DH048**	**SW039**	**SW001**	**SW019**	**SW002**	**NSSP**
Reporting Period 2018-2019	Winter	Meets All	*Meets All*	*Meets All*	*Meets All*	*Meets All*	0/12
	Spring	Meets All	Fail All	Meets All	Meets All	Meets All	0/12
	Summer	Meets All	Meets All	Meets All	Meets All	Meets All	0/12
	Fall	Fail All	Fail All	Fail 90+%	Meets All	Meets All	1/12
	Overall	**Fail**	**Fail**	**Fail**	**Meet**	**Meet**	**1/12**
Period of Record 2014-2017	Winter	Meets All	Fail 90+%	Meets All	Meets All	Meets All	2/12
	Spring	Meets All	*Fail GM*	Fail 90+%	Meets All	Meets All	0/12
	Summer	Meets All	Fail All	Meets All	Meets All	Meets All	0/12
	Fall	Meets All	Fail All	Fail %	Meets All	Meets All	1/12
	Overall	**Meet**	**Fail**	**Fail**	**Meet**	**Meet**	**3/12**
Period of Record 2008-2013	Winter	Meets All	Meets All	Meets All	Meets All	Meets All	0/12
	Spring	Meets All	Meets All	Meets All	Fail 90+%	Meets All	2/12
	Summer	Meets All	Fail 90+%	Meets All	Meets All	Meets All	1/12
	Fall	Fail %	Fail 90+%	Meets All	Meets All	Meets All	1/12
	Overall	**Fail**	**Fail**	**Meet**	**Fail**	**Meet**	**3/12**

*Seasonal metrics compared to geometric mean, 90th percentile, and % of samples criteria. If any one of these criteria were exceeded in the season, the season failed to meet the fecal coliform standard. Seasons can meet all, fail all, or fail a portion or combination of the criteria examined:

GM: geometric mean criterion (50 cfu/100ml)

90: 90th percentile criterion (100 cfu/100ml)

%: percentage of samples not to exceed criterion (no more than 10% of samples may exceed 100 cfu/100ml)

The majority (five of six) of the brackish, tidally-influenced portions and marine receiving waters of the Jordan Creek/North Lummi River Distributary, Lummi River, and Smuggler Slough failed to meet the fecal coliform standard during the 2018-2019 reporting period (Table 7.1.8-Table 7.1.11). One site in Smuggler Slough, SW055, met the standard during all seasons and overall for the reporting period. Three sites, Jordan Creek/North Lummi River Distributary site SW053, Lummi River site SW008, and Smuggler Slough site SW059, failed to meet the standard during all seasons with data (SW059 had no samples for summer). The other two sites failed to meet in winter and spring (Lummi River outlet site SW051) and winter and fall (Smuggler Slough outlet site SW056). Over the 2014-2017 period of record, all six brackish sites and marine receiving waters failed to meet the fecal coliform standard. All but one, SW051, failed to meet the standard during all seasons.

7.1.7. Lummi Bay Watershed

Freshwater watersheds that flow into Lummi Bay include Jordan Creek/North Lummi River Distributary, the Lummi River, Smuggler Slough, Onion Creek, and Seaponds Creek. The sites in the Lummi Bay watershed are sampled once monthly during flowing conditions. Data used in this analysis were collected as part of the Surface Water Project. Although additional data are available for the Jordan Creek/North Lummi River Distributary and the Lummi River as part of coordinated efforts to monitor these freshwater systems in response to the previously threatened status of Lummi Bay NSSP site DH286, the data collected by Ecology and Whatcom County Public Works at the northern Reservation boundary along Slater Road are not included in this analysis. LNR collected paired downstream samples which led to uneven sample sizes for sites in these watersheds. To balance sample sizes, analyses involving side-by-side comparison of sites excluded the additional samples at the downstream sites (i.e., the samples collected by LNR paired with Slater Road sampling by Ecology and Whatcom County Public Works) while site compliance determination tables used all available ambient data. Future reports will include analysis of the full expanded dataset, including data collected by Ecology and Whatcom County Public Works.

7.1.7.1 Jordan Creek/North Lummi River Distributary

The Jordan Creek/North Lummi River Distributary, which enters the Reservation from the north and flows into Lummi Bay near NSSP site DH286, was identified as the likely source of fecal coliform contamination in this portion of Lummi Bay. Jordan Creek and its tributary originate off-Reservation and flow onto the Reservation at sites SW011 and SW010 (Figure 7.1.16). These channels join and flow to site SW003 (downstream of the confluence) and then to the marine receiving waters of Lummi Bay at site SW053. Jordan Creek as it crosses onto the Reservation at Slater Road (SW011) has had a 30-sample estimated 90th percentile above the criterion throughout the period of record and the reporting period (Figure 7.1.17).

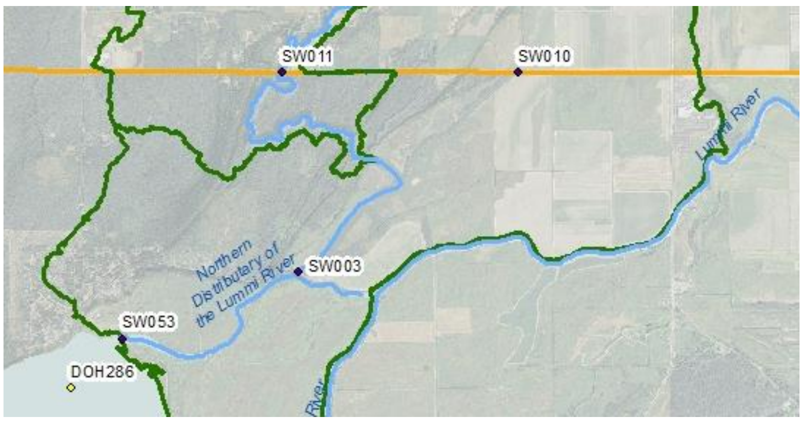


Figure 7.1.16 Jordan Creek and North Lummi River Distributary sample sites: SW011 and SW010 at the Reservation boundary at Slater Road; SW003 below the confluence of these two streams; and SW053 at the marine receiving waters at Lummi Bay. Lummi Bay shellfish growing area Threatened site DH286 is the nearest marine site sampled as part of the NSSP.

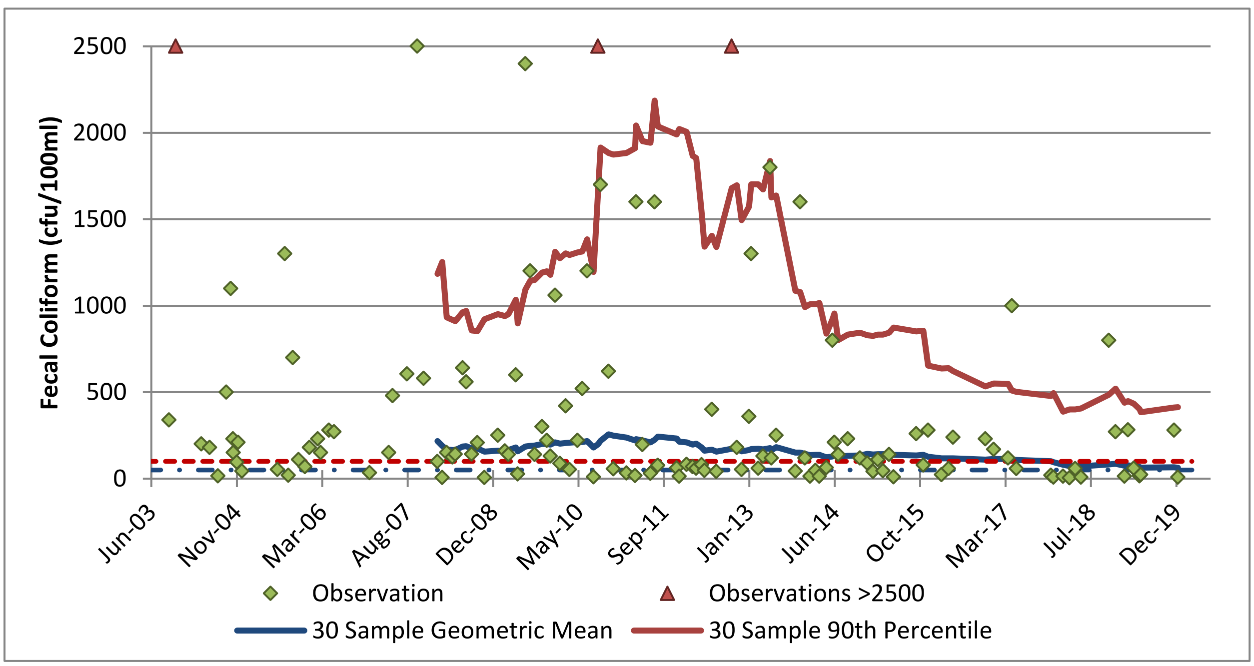


Figure 7.1.17 Rolling 30-sample fecal coliform trends at SW011 (Jordan Creek at Slater Road) from 2008 to 2017, including sample observations, 30-sample geometric mean, 30-sample estimated 90th percentile (calculated per NSSP), and Class AA Freshwater fecal coliform criteria. Fecal coliform observations capped at 2,500 CFU/100ml for this figure; actual values listed and used for metric calculation.

As previously discussed, the 30-sample method of analyzing freshwater compliance with the fecal coliform standard may not be the most appropriate. Seasonal analysis is recommended using at least five samples for calculating the geometric mean. Annual analysis of seasonal geomean is not possible because most sites are visited only once per month, so that no season has five or more samples for a particular year. Fewer samples can be used to calculate geometric means, for example sample size of three was determined to be an acceptable size for reliable geometric mean calculation, or years can be pooled to increase the number of samples in each season (see analysis below). Seasonal analysis can sometimes be misleading, especially for fringe months; for example, September is in the third quarter so is typically considered to be in the summer season even though fall rains can often begin in September. Due to intermittent flow, sometimes September is the only summer month during which the site is sampled. For site SW011, Jordan Creek as it flows onto the Reservation at Slater Road, the geometric mean and 90th percentile were determined for rolling three-month periods. This removes the arbitrary selection of seasonal cutoffs while still assessing the site for seasonality. The geometric mean was calculated for any three-month period with at least three measurements and the 90th percentile and percentage of samples exceeding 100 cfu/100ml was calculated for all three-month periods with at least one sample (i.e., no minimum sample size required).[11]

During 2018, the three-month periods centered on January through June all met the fecal coliform criteria. No samples were collected in June through October, leading to no samples available for the three-month periods centered on June through September. The three-month periods centered on October through December 2018 all failed to meet the fecal coliform criteria. The wet-season pattern continued into 2019, when the three-month periods centered on January through March all failed to meet the fecal coliform criteria (both the geometric mean and 90th percentile components). Water quality improved for the three-month periods centered on April through June 2019 and again, no samples were collected from June through October 2019, leading to no data available for the three-month periods centered on June through September. In November, poor water quality observed during the wet season returned and the three-month periods centered on October and November failed to meet the fecal coliform criteria. The three-month period centered on December 2019 could not be assessed because it requires data from January 2020.

[11] This is the assessment method Washington State Department of Ecology will use for determining compliance with the Recreational Contact standards beginning in 2020. Note that this assessment method is not required for Lummi Nation Waters; this assessment method was used here for evaluation purposes.

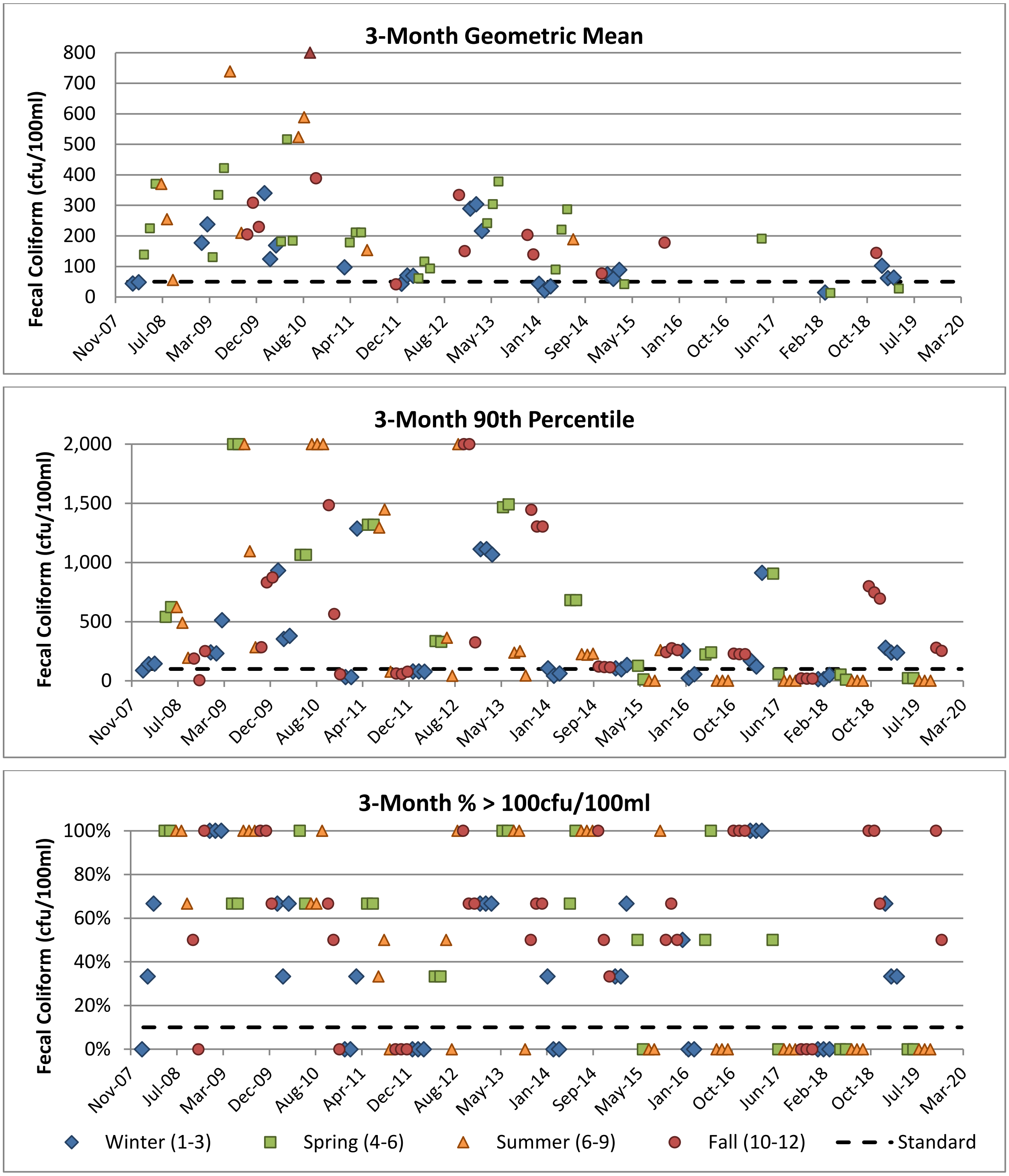


Figure 7.1.18 Rolling three-month fecal coliform metrics at SW011 from 2008-2019. Geomean calculated for rolling three-month periods (i.e., Jan/Feb/March, Feb/March/April, and so on) with three or more samples. The 90th percentile and percentage of samples exceeding 100 cfu/100ml was calculated for rolling three-month periods with at least one sample. Metrics are designated by the quarterly season for the middle month of the three-month period (i.e., Feb/March/April is winter because the middle month (March=3) is in the first quarter of the calendar year.

Seasonal fecal coliform geometric means were calculated for the two-year reporting period (2018-2019) and for two five-year periods of record (2008-2012 and 2013-2017) by site in the Jordan Creek watershed. Pooling of multiple years provided five or more samples for most seasons/sites for the period of record and three or more samples for most seasons/sites for the reporting period for calculation of the geometric mean. All seasons had five or more samples for 2008-2012. During 2013-2017, periods with fewer than five samples were: summer at SW011 (n=3) and fall at SW010 (n=4). For the reporting period, sample size was greater than three for most seasons/sites except summer at SW003 (n=1) and fall at SW010 (n=2). No data were available for summer 2013-2017 at SW010, and summer 2018-2019 at SW011 and SW010.

Site SW011, Jordan Creek as it crosses onto the Reservation at Slater Road, tends to have a higher fecal coliform geometric mean density than sites further downstream (Figure 7.1.19). The exception to this was spring 2018-2019 when SW010, a tributary to Jordan Creek as it flows onto the Reservation at Slater Road, had the highest geometric mean. The geometric mean decreased at sites further downstream in the watershed, with the highest densities at the Reservation boundary, decreased downstream of the confluence (SW003), and lowest in the marine receiving waters (SW053). The exceptions to this was summer 2018-2019 when no data were available from the Reservation boundary sites and winter 2018-2019 when downstream sites had higher geometric means than upstream sites.

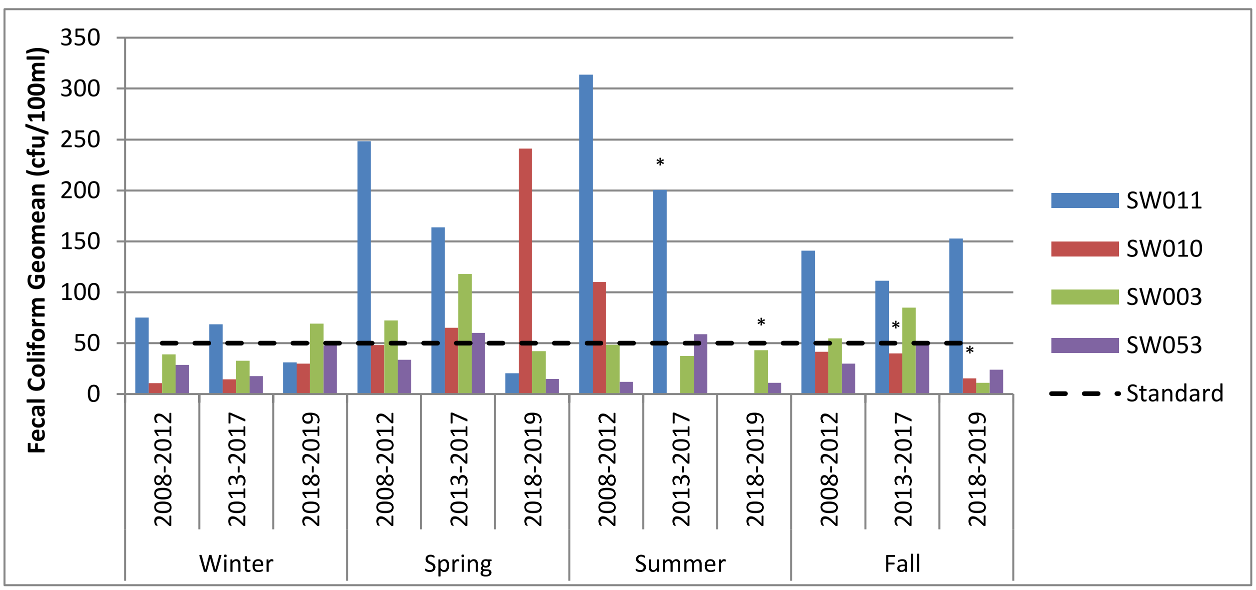


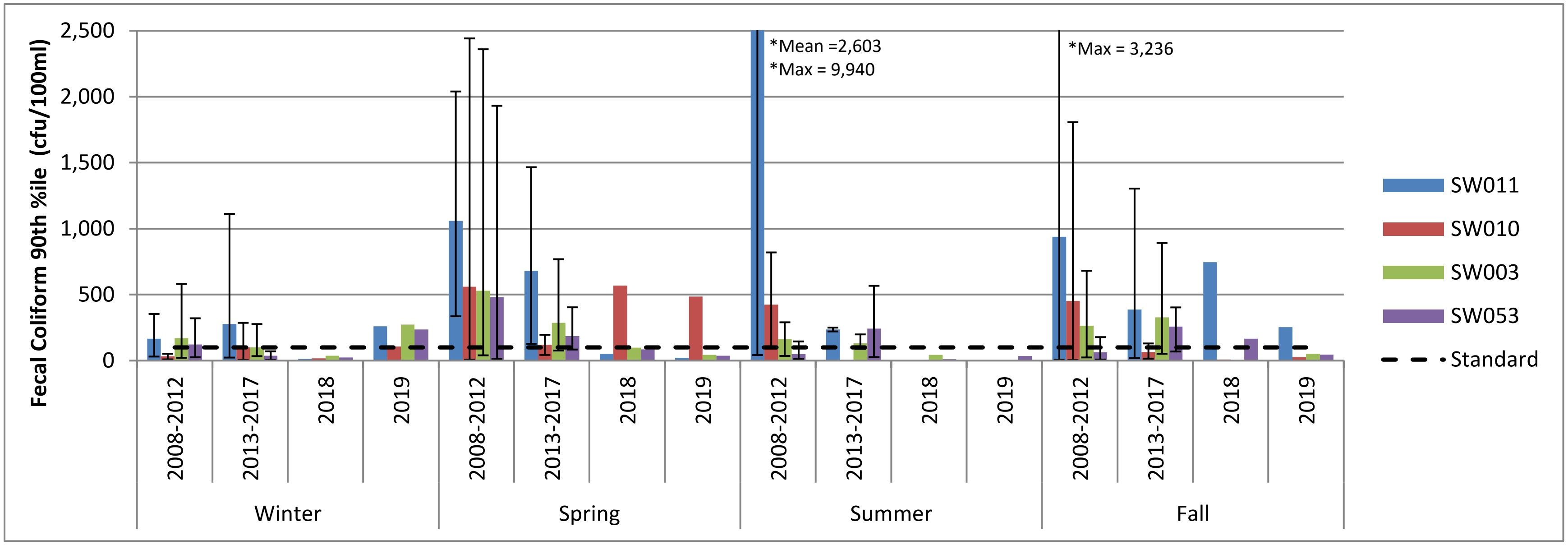
Figure 7.1.19 Summary of geometric mean component of the fecal coliform standard for sites in the Jordan Creek/North Lummi River Distributary watershed by season for the period of record in five-year pooled assessment periods, 2008-2012 and 2013-2017, and the two-year reporting period 2018-2019. The Freshwater Class AA criterion is shown for reference. Sites SW011 and SW010 are located at the northern Reservation boundary, site SW003 is located below the confluence of sites SW011 and SW010, and site SW053 is the marine receiving waters of the freshwater stream. Note that site SW053 is classified Marine Class AA and has a geomean criterion of 14 cfu/100ml. Sample size is ≥5 for 2008-2012 and 2013-2017 and ≥3 for 2018-2019 unless marked with asterisk. No data were available for summer 2013-2017 at SW010, and summer 2018-2019 at SW011 and SW010.

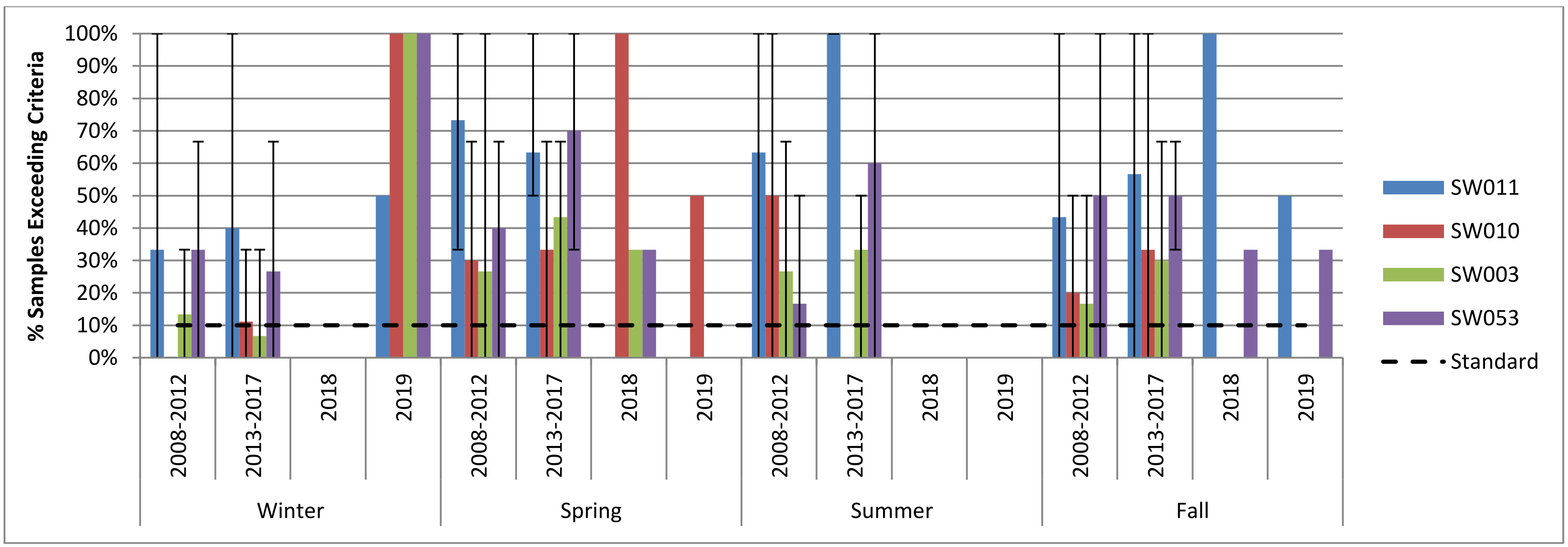
Over time, the geometric mean at SW011 has decreased during the winter, spring, and summer and remains unchanged during the fall. The geometric mean at SW010 has increased over time during winter and spring. The downstream site SW003 and the marine receiving waters appear to have had a decline in water quality from the period 2008-2012 to the period 2013-2017, but improvement during the reporting period 2018-2019 during all seasons except winter. During the reporting period, each site in the Jordan Creek watershed failed to meet the fecal coliform geometric mean criterion at least once: SW010 in spring, SW011 in fall, SW003 in winter, and SW053 during all seasons except summer (note different criteria for marine site SW053).

The 90th percentile component of the fecal coliform standard was evaluated seasonally for each year because there is no minimum sample size requirement for this component. Annually for each of the reporting years 2018 and 2019 and the period of record 2008 through 2017, the 90th percentile and the percentage of samples exceeding the criterion (100 cfu/100ml for freshwater and 43 cfu/100ml for marine) was calculated for each season (Figure 7.1.20). For the period of record, the 90th percentile and percentage of samples exceeding the criterion is shown in two five-year periods (2008-2012 and 2013-2017) to mirror the periods used in the geometric mean seasonal analysis. However, for the 90th percentile component of the standard, the metrics were calculated annually and the figures show the mean (point) and minimum-maximum range (whiskers) for the five annual metrics in the five-year period. The reporting years 2018 and 2019 are shown annually.

The same pattern seen in the geometric mean results is observed from the seasonal 90th percentile metrics. The highest 90th percentile was observed at either one or both of the Reservation boundary sites (SW011 and SW010), and decreasing 90th percentiles were seen downstream and SW003 and the marine receiving waters at SW053. Again, the exception to this was seen during winter 2019. Overall during the winter season, the 90th percentile is not as high at the northern Reservation boundary sites and does not decline as the waters flow through the reservation to the marine receiving waters. During the reporting period, SW010 had the highest 90th percentile during the spring and SW011 had the highest 90th percentile during the fall. During the period of record, the highest 90th percentiles were nearly always seen at SW011.

Figure 7.1.20 (Next Page) Summary of calculated 90th percentile (top) and percentage of samples exceeding the 90th percentile criterion (bottom) components of the fecal coliform standard for sites in the Jordan Creek/North Lummi River Distributary watershed by season annually for the period of record in five-year assessment periods, 2008-2012 and 2013-2017, and by year for the reporting period 2018-2019. The Freshwater Class AA criterion is shown for reference. The period of record shows the mean for each five-year period by season with whiskers representing the minimum and maximum for the five-year period. Sites SW011 and SW010 are located at the northern Reservation boundary, site SW003 is located below the confluence of sites SW011 and SW010, and site SW053 is the marine receiving waters of the freshwater stream. Note that site SW053 is classified Marine Class AA and has a 90th percentile criterion of 43 cfu/100ml. The percentage component is equivalent: no more than 10% of samples may exceed 100 cfu/100ml (freshwater) or 43 cfu/100ml (marine).


Fecal Coliform 90th %ile (cfu/100ml)
2,500
2,000
1,500
1,000
500
0
*Mean =2,603
*Max = 9,940
*Max = 3,236
2008-2012
2013-2017
2018
2019
Winter
Spring
Summer
Fall
SW011
SW010
SW003
SW053
Standard


% Samples Exceeding Criteria
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2008-2012
2013-2017
2018
2019
Winter
Spring
Summer
Fall
SW011
SW010
SW003
SW053
Standard

Over time, the 90th percentile at SW011 appears to have decreased during the spring, summer, and possibly fall. The other Reservation boundary site, SW010, remains elevated during the spring, but has decreased during the summer and fall. Overall, 90th percentiles were the highest during 2008-2012 and decreased over time during spring, summer, and fall.

In general, a similar pattern is present in the percentage of samples exceeding the 90th percentile criterion. The highest rates of samples exceeding the criterion is observed at the Reservation boundary sites SW011 and, to a lesser extent SW010, while a lower rate is typically observed downstream at SW003. Exceedances at SW010 are most frequent during the spring while fall exceedances are most frequent at SW011. Direct comparison to the frequency of samples exceeding the 90th percentile criterion at the furthest downstream site, SW053, the marine receiving waters, is challenging due to the different numeric criterion at this site (no more than 10% of samples may exceed 43 cfu/100ml at marine sites). However, when the downstream marine receiving waters at SW053 failed to meet the percent exceeding component of the standard, at least one of the northern Reservation boundary sites (SW011 and/or SW010) also exceeded the percent component of the standard.

The percentage of samples exceeding the 90th percentile criterion appears to be decreasing somewhat over time, although with significant annual and site-to-site variability. The frequency of exceedances has decreased during some seasons at the northern Reservation boundary sites SW010 and SW011; site SW011 exceedance frequency has decreased during the spring and summer and site SW010 exceedance frequency has decreased during the summer and possibly fall. Although these improvements led to no exceedances at the sites during these seasons for the reporting period, SW010 exceedance frequency has increased or remained high during winter and spring. The winter season during the reporting period shows the greatest year-to-year variability, with no exceedances at any site during winter 2018 and all sites exceeding during winter 2019. The summer season during the reporting period showed the lowest rates of exceedance, with no exceedances during either year, although this is largely due to stagnant and dry conditions at upstream freshwater sites.

Despite some improvement in the fecal coliform metrics at sites in the Jordan Creek/North Lummi River Distributary, all sites in the watershed continue to fail to protect the characteristic uses of the waterbody and fail to protect downstream shellfish harvesting uses. Table 7.1.8 summarizes compliance determination by season and overall. Compliance for each season was determined for each year by assessing the geometric mean and 90th percentile components of the standard; if any of the three metrics (geometric mean, 90th percentile, percentage of samples exceeding the criterion) failed to meet the criterion, the site was determined to fail to meet the standard for that season. If any season during the year failed to meet the standard, it was determined to fail to meet the standard for that year. All seasons must meet all components of the criteria in order to meet the standard for the year. Nearly all sites failed to meet the fecal coliform standard both during the period of record (2008-2017) and during the reporting years (2018-2019). Improvements during the reporting period were seen during the spring at SW011 and during the fall at SW010, however these improvements weren’t enough to lead to compliance with the standard at the marine receiving waters at SW053.

Table 7.1.8 Summary of seasonal compliance with the fecal coliform standard for sites in the Jordan Creek/North Lummi River Distributary watershed for the period of record (2008-2017) and reporting period (2018-2019). Compliance requires both the geometric mean and 90th percentile criteria (both calculated 90th percentile metric and the percentage of samples above the criterion) are met. Years 2018 and 2019 listed separately with the reason for failure listed.* Compliance for the period of record is the percentage of years failing to meet the standard during the given season (out of seasons with n≥1; i.e., years with no samples in the season not included in the frequency calculation). Water flows onto the Reservation at sites SW011 and SW010, which flow together to SW003, and to the marine receiving waters at SW053. Sites that fail to meet the standard for one or more seasons fail to meet overall.

Period	Freshwater									Marine		
	SW011			SW010			SW003			SW053		
	POR	2018	2019	POR	2018	2019	POR	2018	2019	POR	2018	2019
Winter	70%	*Meet*	Fail All	13%	*Meet*	*Fail All*	40%	Meet	Fail 90+%	80%	Meet	Fail 90+%
Spring	100%	*Meet*	*Meet*	57%	*Fail All*	*Fail All*	80%	Fail 90+%	Meet	90%	Fail 90+%	Fail All
Summer	86%	nd	nd	75%	nd	nd	80%	Meet	nd	70%	Fail All	Meet
Fall	70%	*Fail All*	*Fail All*	38%	*Meet*	*Meet*	80%	Fail %	Meet	88%	Fail 90+%	Fail All
Overall	**100%**	**Fail**	**Fail**	**89%**	**Fail**	**Fail**	**100%**	**Fail**	**Fail**	**100%**	**Fail**	**Fail**

*Seasonal metrics compared to geometric mean, 90th percentile, and % of samples criteria. If any one of these criteria were exceeded in the season, the season failed to meet the fecal coliform standard. Seasons can meet all, fail all, or fail a portion or combination of the criteria examined:

GM: geometric mean criterion (50 cfu/100ml)
90: 90th percentile criterion (100 cfu/100ml)
%: percentage of samples not to exceed criterion (no more than 10% of samples may exceed 100 cfu/100ml)
nd: No data
POR: Period of record (2008-2017) shown as percentage of year failing to meet the standard out of years with n>1
Italics: Seasons with fewer than three samples

7.1.7.2 Lummi River

The Lummi River watershed enters the Reservation from the north and flows into Lummi Bay at the northern end of the aquaculture sea pond. The nearest NSSP station in Lummi Bay is DH288. The Lummi River and its tributaries cross onto the Reservation at sites SW012 (Schell Creek), SW013 (unnamed agricultural ditch), and SW009 (Lummi River) which flow together to SR005 and the brackish, tidally-influenced site SW008, then to the marine receiving waters at the mouth of the Lummi River as it enters Lummi Bay (SW051).

Seasonal fecal coliform geometric means were calculated for the two-year reporting period (2018-2019) and for two five-year periods of record (2008-2012 and 2013-2017) by site in the Lummi River watershed. Pooling of multiple years provided five or more samples for most seasons/sites for the period of record and three or more samples for most seasons/sites for the reporting period for calculation of the geometric mean. All seasons had five or more samples for 2008-2012. During 2013-2017, periods with fewer than five samples were: winter at SW013 (n=2) and SW009 (n=1), and spring at SW013 (n=1). For the reporting period, sample size was greater than three for most seasons/sites except winter at SW013 and SW009, and fall at SW012 and SW009. No data were available for spring 2013-2017 and 2018-2019 at SW009, summer 2013-2017 and 2018-2019 for all northern Reservation boundary sites (SW012, 13, 9), and fall 2013-2017 for SW013.

Fecal coliform tends to be highest at the upstream end of the watershed and lowest at the marine receiving waters for the watershed. The highest fecal coliform geometric mean densities tend to occur most often at the northern Reservation boundary site SW009 (Figure 7.1.21). The other northern Reservation boundary sites (SW012 and SW013) also had high geometric mean densities and the three highest geometric means were observed at the northern Reservation boundary sites. The brackish site SW008 had an elevated geometric mean during most seasons and the geometric mean at this site was lower than at least one of the Reservation boundary sites during more than half of the seasons/periods assessed. The geometric mean decreased at the downstream sites during all periods in the fall, during the winter for 2013-2017 and the reporting period 2018-2019, and during 2008-2013 spring and summer. There are several occasions during which the geometric mean was highest at SW008: during the spring and summer of 2013-2017 and 2018-2019. During the summer, however, there were no samples collected at the upstream northern Reservation boundary sites for these periods. The geometric mean was lowest at the marine receiving waters (SW051) during all seasons and periods.

Over time, the geometric means have remained elevated at most sites during most seasons. The geometric mean has increased over time at SW013 during the winter and at SW009 during the fall. Summer shows improvement, but this is largely because of stagnant conditions during this season; prior to 2013, sites were sampled during stagnant conditions, potentially leading to elevated bacterial densities during periods of no flow. At site SW008, the geometric mean has increased during the winter, decreased during the fall, and remains highest during the spring. During spring, the geometric mean at SW009 and SW012 has decreased, leading to the highest densities observed at SW008 rather than higher in the watershed. Part of this trend may also be the discontinuation of sampling during stagnant conditions beginning in 2013.

At least one of the northern Reservation boundary sites exceeded the freshwater geometric mean criterion (50 cfu/100ml) during all seasons and periods, except winter 2008-2012. The downstream, brackish site SW008 failed to meet the marine geometric mean criterion (14 cfu/100ml) during all seasons and periods. The downstream marine receiving waters at the mouth of the Lummi River as it enters Lummi Bay failed to meet the marine geometric mean criterion during the winter and fall and met the criterion during the spring and summer. During the reporting period, all sites failed to meet the geometric mean criteria during at least one season.

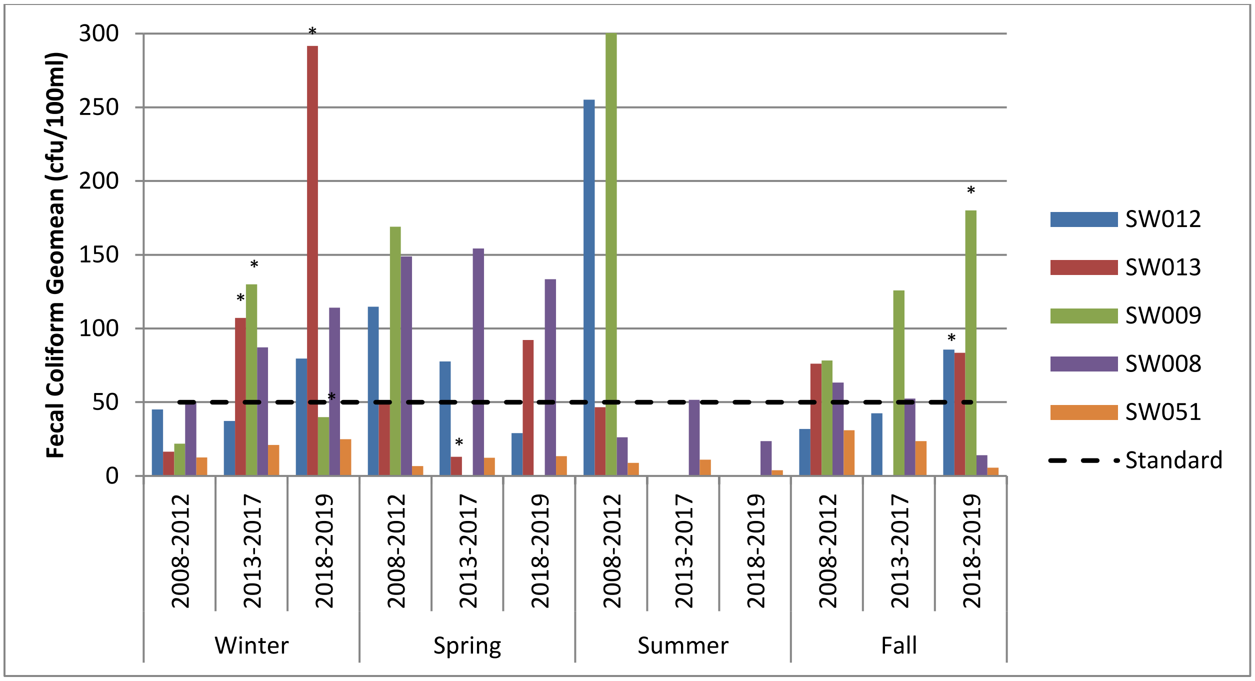


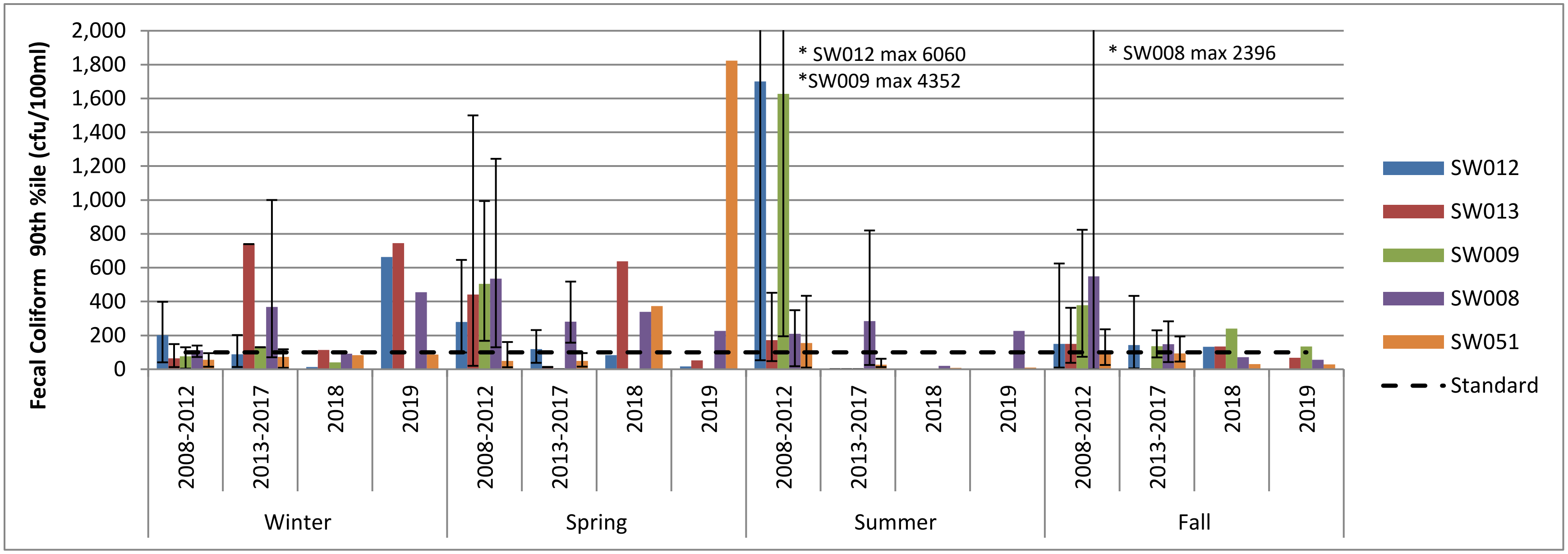
Figure 7.1.21 Summary of geometric mean component of the fecal coliform standard for sites in the Lummi River watershed by season for the period of record in five-year pooled assessment periods, 2008-2012 and 2013-2017, and the two-year reporting period 2018-2019. The Freshwater Class AA criterion is shown for reference. Sites SW012, SW013, and SW009 are located at the northern Reservation boundary, site SW008 is located below the confluence of these three sites, and site SW051 is the marine receiving waters at the mouth of the Lummi River. Note that site SW008 and SW051 are classified Marine Class AA and have a geomean criterion of 14 cfu/100ml. Sample size is ≥5 for 2008-2012 and 2013-2017 and ≥3 for 2018-2019 unless marked with asterisk. No data were available for spring 2013-2017 and 2018-2019 at SW009, summer 2013-2017 and 2018-2019 at all northern Reservation boundary sites (SW012, 13, 9), and fall 2013-20017 at SW013.

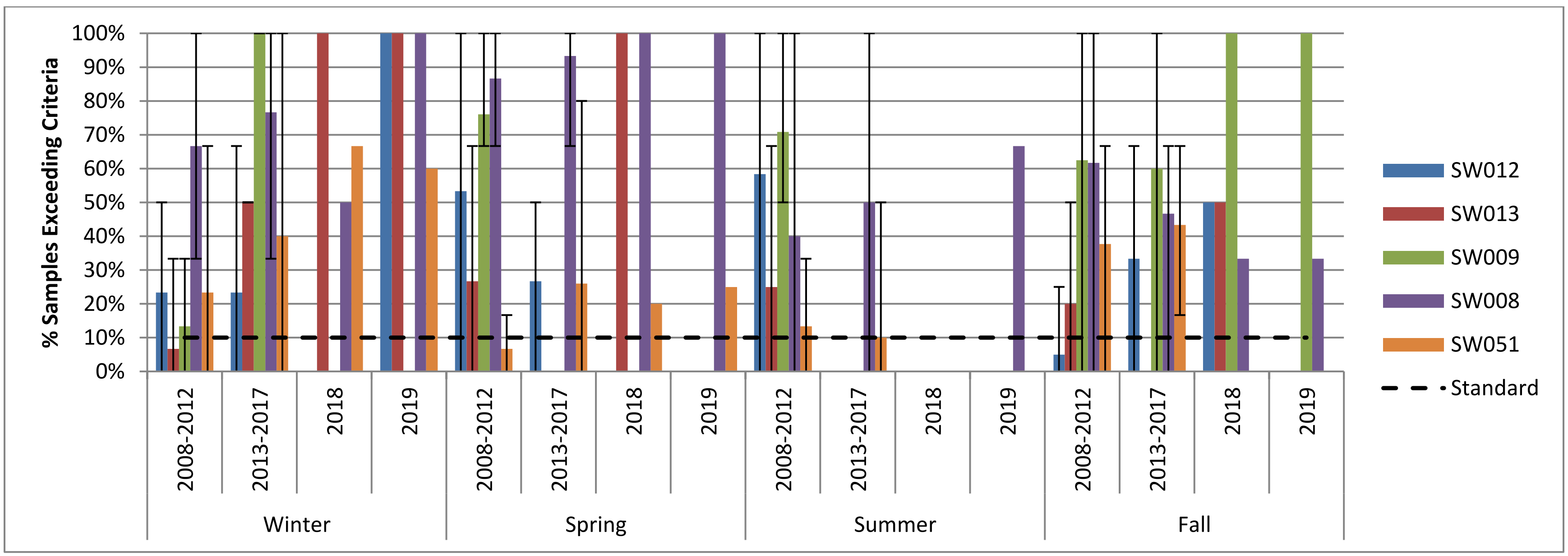
The 90th percentile component of the fecal coliform standard was evaluated seasonally for each year because there is no minimum sample size requirement for this component. Annually for each of the reporting years 2018 and 2019 and the period of record 2008 through 2017, the 90th percentile and the percentage of samples exceeding the criterion (100 cfu/100ml for freshwater and 43 cfu/100ml for marine) was calculated for each season (Figure 7.1.22). For the period of record, the 90th percentile and percentage of samples exceeding the criterion is shown in two five-year periods (2008-2012 and 2013-2017) to mirror the periods used in the geometric mean seasonal analysis. However, for the 90th percentile component of the standard, the metrics were calculated for each season annually and the figures show the mean (point) and minimum-maximum range (whiskers) for the five annual metrics in the five-year period. The reporting years 2018 and 2019 are shown annually.

The highest 90th percentiles were observed during the period of record 2008-2012 in the summer, fall, and spring. A clearly visible outlier to this trend is the high spring 2019 90th percentile in the marine receiving waters at site SW051, when a single extremely high count occurred. In general, during the winter and fall, the 90th percentile at one or more of the northern Reservation boundary sites (SW012, 13, 9) was higher, on average, than at the downstream brackish site SW008. During the spring, the opposite pattern was observed during most periods: the 90th percentile was higher at the downstream site (SW008) than at the northern Reservation boundary sites. Exceptions to these general patterns were present during all seasons except winter. There were no data for the summer at the northern Reservation boundary sites after 2013, when sampling during stagnant conditions was discontinued, leading to no upstream sites for comparison to downstream marine sites during the summer.

Over time, the 90th percentile at all sites appears to be subject to significant year-to-year and season-to-season variability. Winter 2018 appeared to show improvement from the period of record, but high 90th percentiles returned in 2019. The 90th percentile at SW012 has decreased during the spring and fall. The 90th percentile at SW008 also decreased during the fall, but remained high and variable during all other seasons. In the marine receiving waters (SW051), the 90th percentile also decreased during the summer and fall, but increased significantly during the spring.

Figure 7.1.22 (Next Page) Summary of calculated 90th percentile (top) and percentage of samples exceeding the 90th percentile criterion (bottom) components of the fecal coliform standard for sites in the Lummi River watershed by season annually for the period of record in five-year assessment periods, 2008-2012 and 2013-2017, and by year for the reporting period 2018-2019. The Freshwater Class AA criterion is shown for reference. The period of record shows the mean for each five-year period by season with whiskers representing the minimum and maximum for the five-year period. Sites SW012, SW013, and SW009 are located at the northern Reservation boundary, site SW008 is located below the confluence of these three sites, and site SW051 is the marine receiving waters at the mouth of the Lummi River. No data were available for spring 2013-2017 and 2018-2019 at SW009, summer 2013-2017 and 2018-2019 at all northern Reservation boundary sites (SW012, 13, 9), and fall 2013-2017 at SW013. Note that site SW008 and SW051 is classified Marine Class AA and has a 90th percentile criterion of 43 cfu/100ml. The percentage component is equivalent: no more than 10% of samples may exceed 100 cfu/100ml (freshwater) or 43 cfu/100ml (marine).


Fecal Coliform 90th %ile (cfu/100ml)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
* SW012 max 6060
*SW009 max 4352
* SW008 max 2396
2008-2012
2013-2017
2018
2019
Winter
Spring
Summer
Fall
SW012
SW013
SW009
SW008
SW051
Standard


% Samples Exceeding Criteria
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
2008-2012
2013-2017
2018
2019
Winter
Spring
Summer
Fall
SW012
SW013
SW009
SW008
SW051
Standard

During the reporting period, the highest counts were seen during the winter 2019 and spring 2018 and 2019. As mentioned above, spring 2019 showed a pattern in which the marine receiving waters had much higher fecal coliform densities than the upstream sites. In late May 2019, elevated fecal coliform and depleted dissolved oxygen conditions were observed in the Lummi River. The problem was first identified at site SW008 and investigative sampling was conducted in the watershed for approximately a month to attempt to identify the cause and monitor conditions, but no immediate cause was found and on-Reservation sources were largely ruled out (the exception to this were three homes that records showed were not connected to the tribal sewer district). Although high fecal coliform densities are often observed at the northern Reservation boundary, no elevated densities were observed at these sites at the time. However, due to the low flows in the Lummi River during this period, it was concluded that the likely source was a manure application in agricultural fields upstream of the Reservation boundary that entered the Lummi River watershed following unexpectedly heavy rains. The elevated fecal coliform conditions and depleted dissolved oxygen persisted in the tidally-influenced portion of the river until the next rain event in late June 2019 flushed the slug of contaminated water into the marine water. Depleted dissolved oxygen and moderately elevated fecal coliform were again observed in the same location in September 2019, where the conditions persisted for approximately one week. Previously, in April 2019, a very high fecal coliform density was observed at the mouth of the Lummi River, indicating that high fecal coliform slugs flow through the system on occasion. Investigative sampling found that the low dissolved oxygen conditions were not always present at SW008 but were frequently detected upstream at Haxton Way (SR005), which may indicate that low dissolved oxygen and elevated fecal coliform conditions may not be uncommon during the dry season, but persist only in parts of the watershed and have not been previously detected due to the sample site locations. A likely explanation of the observed conditions is that rain events result in fecal coliform runoff from agricultural fields with recent manure applications, which flow onto the Reservation as an often undetected slug that persists in the slow flowing, tidally influenced portions of the watershed (between Haxton Way and Hillaire Road) and are flushed into the marine receiving waters during the next rain event. In response, the LWRD added site SW005 to the Surface Water Project. Note that this site is not included in the present analysis because only data from June 2019 onward are available for this site.

One or more of the northern Reservation boundary sites failed to meet the 90th percentile criterion during each season/period except spring 2019. Downstream brackish site SW008 failed to meet the marine 90th percentile criterion (43 cfu/100l) during all seasons/periods except summer 2018. The downstream marine receiving waters failed to meet the marine criterion during winter and spring for all periods and met the criterion during the reporting years during summer and fall. The freshwater improvements seen in the summer and fall appear to be improving water quality in the marine receiving waters.

Sites SW009 and SW008 had the highest frequency of exceeding the percent exceedance criterion; both had only one season/period during which fewer than 10% of samples exceeded the criterion and their average exceedance rate was 63-65%. It should be noted that SW009 is a freshwater site with a higher 90th percentile threshold (100 cfu/100ml) while SW008 is a marine site with a lower 90th percentile threshold (43 cfu/100ml). The overall lowest rate of exceedance was observed at the marine receiving waters SW051.

Exceedances of the percent exceeding component of the fecal coliform standard was observed during all seasons and periods except summer 2018, when no freshwater samples were collected and marine sites had 0% of samples exceeding 43 cfu/100ml. Exceedances were most frequent during the 2008-2012 period of record, which may be due partially to sampling during stagnant conditions. During the 2013-2017 period of record, exceedances were most frequent during the winter and fall. This pattern largely continued during the 2018-2019 reporting period. The winter exceedance frequency remained high and increased at many sites, including the marine receiving waters at SW051. The fall exceedance frequency remained high through 2018 but decreased at the freshwater sites in 2019 while remaining high at the downstream marine sites. The spring exceedance frequency remained high at SW008 and variable at the northern Reservation boundary sites, with improvements at SW012 and declines at SW013. Summer was similar during the reporting period as during the 2013-2017 period of record, with freshwater sites dry and period exceedances at the downstream marine sites.

Direct comparison of the frequency of samples exceeding the 90th percentile criterion at freshwater sites along the northern Reservation boundary and those furthest downstream, including the brackish site SW008 and the marine receiving waters site SW051, is challenging due to the different numeric criteria at marine and freshwater sites (i.e., no more than 10% of samples may exceed 43 cfu/100ml at marine sites and 100 cfu/100ml at freshwater sites). However, when the downstream marine sites SW008 and/or SW051 failed to meet the percent exceeding component of the standard, at least one of the northern Reservation boundary sites (SW012, SW013, and/or SW009) also exceeded the percent component of the standard.

Overall, all sites in the Lummi River watershed continued to fail to protect the designated uses of the waterbody and fail to protect downstream shellfish harvesting uses. Table 7.1.9 summarizes compliance determination by season and overall. Compliance for each season was determined by assessing the geometric mean and 90th percentile components of the standard; if any of the three metrics (geometric mean, 90th percentile, percentage of samples exceeding the criterion) failed to meet the criteria, the site was determined to fail to meet the standard for that season. If any season during the year failed to meet the standard, it was determined to fail to meet the standard for that year. All seasons must meet all components of the criteria in order to meet the standard for the year. Nearly all sites failed to meet the fecal coliform standard during each year of the period of record (2008-2017); nine out of ten or ten out of ten years failed to meet the standard for all sites. All sites failed to meet the fecal coliform standard during the reporting years 2018 and 2019. At least one site failed to meet the standard during each season for both reporting years and the period of record overall. Water quality appears to have improved during the summer and fall at the mouth of the Lummi River near the marine receiving waters (SW051).

As previously described, water quality monitoring site SR005, located mid-way between the northern Reservation boundary sites and SW008, was added to the Surface Water Project in order to better monitor that stretch of the Lummi River. This was in response to depleted dissolved oxygen and elevated fecal coliform densities observed in the Lummi River during the spring and fall 2019. Site SR005 failed to meet the fecal coliform standard for the summer and fall 2019, but no previous ambient data were available for the period of record. This site is assessed here only, and was not included in previous site-to-site analyses due to lack of historical data.

Table 7.1.9 Summary of seasonal compliance with the fecal coliform standard for sites in the Lummi River watershed for the period of record (2008-2017) and reporting period (2018-2019). Compliance requires both the geometric mean and 90th percentile criteria (both calculated 90th percentile metric and the percentage of samples above the criterion) are met. Years 2018 and 2019 are shown separately with the reason for failure listed.* Compliance for the period of record is the percentage of years failing to meet the standard during the given season (out of seasons with n≥1; i.e., years with no samples in the season not included in the frequency calculation). Water flows onto the Reservation at sites SW012, SW013, and SW009, which flow together to SR005 and the brackish SW008, then to the marine receiving waters at SW051. Sites that fail to meet the standard for one or more seasons fail to meet overall.

Period	Freshwater				Marine	
	SW012	SW013	SW009	SR005	SW008	SW051
Period of Record (2008-2017)						
Winter	60%	33%	50%	nd	100%	70%
Spring	90%	33%	100%	nd	100%	50%
Summer	75%	50%	100%	nd	80%	30%
Fall	40%	60%	89%	nd	90%	90%
Overall	**90%**	**100%**	**100%**	**nd**	**100%**	**90%**
Reporting Year 2018						
Winter	Meets All	*Fail All*	*Meets All*	nd	Fail All	Fail 90+%
Spring	*Fail GM*	*Fail All*	nd	nd	Fail All	Meets All
Summer	nd	nd	nd	nd	Fail All	Meets All
Fall	Fail All	Fail All	Fail All	nd	Fail GM+90	Meets All
Overall	**Fail**	**Fail**	**Fail**	**No Data**	**Fail**	**Fail**
Reporting Year 2019						
Winter	Fail All	*Fail All*	nd	nd	Fail All	Fail All
Spring	Meets All	Meets All	nd	nd	Fail All	Fail 90+%
Summer	nd	nd	nd	Fail All	Fail All	Meets All
Fall	nd	*Fail GM*	*Fail All*	Fail 90+%	Fail 90+%	Meets All
Overall	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**

*Seasonal metrics compared to geometric mean, 90th percentile, and % of samples criteria. If any one of these criteria were exceeded in the season, the season failed to meet the fecal coliform standard. Seasons can meet all, fail all, or fail a portion or combination of the criteria examined:
GM: geometric mean criterion (50 cfu/100ml)
90: 90th percentile criterion (100 cfu/100ml)
%: percentage of samples not to exceed criterion (no more than 10% of samples may exceed 100 cfu/100ml)
nd: No data
POR: Period of record (2008-2017) shown as percentage of seasons with n>1
Italic: determination based on one sample (n=1). Sample size discussion in text above.
Orange cells indicate that the failure to meet the geometric mean was based on one sample, which is not appropriate for assessing against geometric mean criteria.

7.1.7.3 Smuggler Slough

Smuggler Slough drains a large portion of the lowlands in the northeastern portion of the Reservation. Waters flow onto the Reservation from the east (at Ferndale Road) and is monitored at sites SW016 and SW017. A self-regulating tide gate at SW072 can allow flow to the north into Smuggler Slough or to the south into Kwina Slough and the Nooksack River delta. Water from these sites flow to site SW015 and to the brackish, tidally-influenced site SW059, then into the marine receiving waters at two channel mouths at sites SW055 and SW056. Many of these sites are stagnant or dry during the dry season, resulting in no samples collected at freshwater sites in summer and fall during the reporting period. All sites had three or fewer samples per season for the reporting years 2018 and 2019.

Table 7.1.10 summarizes compliance determination by season and overall. Compliance for each season was determined by assessing the geometric mean and 90th percentile components of the standard; if any of the three metrics (geometric mean, 90th percentile, percentage of samples exceeding the criterion) failed to meet the criteria, the site was determined to fail to meet the standard for that season. If any season during the year failed to meet the standard, it was determined to fail to meet the standard for that year. All seasons must meet all components of the criteria in order to meet the standard for the year.

During each of the reporting years (2018 and 2019), three sites in the Smuggler Slough watershed failed to meet the fecal coliform standard (SW016, SW059, and SW056) and three were in compliance with the fecal coliform standard (SW017, SW015, SW055). One site, SW072, was only sampled once during the reporting period; one sample is not sufficient for determination of compliance with the fecal coliform standard, so the site was not assessed.

As previously described the Lummi Water Quality Standards state that the geometric mean should be calculated using a minimum of 5 samples, while there is no minimum sample size for calculating the 90th percentile or percentage of samples exceeding the criterion. The maximum number of times any site was sampled in a season is three (once per month); this was determined sufficient for this analysis. Several sites had only one sample collected during a season, and five of these seasons failed to meet the geometric mean criterion. Because these sites/seasons met the 90th percentile criterion, determination of noncompliance should not rest on a geometric mean calculated from one sample alone. For these reasons, the site is listed as failing to meet the standard for the season with a caveat (cell is orange in Table 7.1.10) but the site meets the fecal coliform standard overall for the reporting period. If the two reporting years were pooled, site SW055 would meet the standard during all seasons and meet overall, which is the same overall compliance determination for the assessment by year. Site SW015 would meet the standard during winter but a spring geometric mean just above the criterion, leading to a failure to meet the standard overall. This pooled rating does not show the annual differences at site SW015.

Over the period of record, nearly all sites failed to meet the fecal coliform standard for each season during at least one of the ten years assessed (2008-2017). The exceptions to this were summer at SW016 and fall at SW072. All sites failed to meet the fecal coliform standard at least 75% of the time for the period of record, with sites SW016, SW015, SW059, and SW056 failing to meet the standard 100% of the time.

Table 7.1.10 Summary of compliance with the fecal coliform standard for sites in the Smuggler Slough watershed during the period of record (2008-2017) and the reporting period (2018-2019). Compliance requires both the geometric mean and 90th percentile criteria (both calculated 90th percentile metric and the percentage of samples above the criterion) are met. Years 2018 and 2019 listed separately with the reason for failure listed.* Compliance for the period of record is the percentage of years failing to meet the standard during the given season (out of seasons with n≥1; i.e., years with no samples in the season not included in the frequency calculation). Water flows onto the Reservation at sites SW016 and SW017, which combine with flows from SW072 to SW015, then flow to the brackish tidally-influenced site SW059 and to the channel mouths at SW055 and SW056. Sites that fail to meet the standard for one or more seasons fail to meet overall. Sample size for 2018 and 2019 is ≤3 for each season (*italicized* n=1).

Period	**Freshwater**				**Marine**		
	SW072	**SW016**	**SW017**	**SW015**	**SW059**	**SW055**	**SW056**
Period of Record (2008-2017)							
Winter	57%	44%	29%	40%	90%	57%	86%
Spring	43%	25%	20%	78%	100%	40%	100%
Summer	100%	0%	100%	80%	100%	44%	56%
Fall	0%	86%	67%	44%	90%	67%	86%
Overall	88%	100%	75%	100%	100%	90%	100%
Reporting Year 2018							
Winter	nd	*Fail All*	*Meets All*	*Meets All*	Meets All	*Fail GM*	*Meets All*
Spring	nd	*Fail All*	nd	*Meets All*	Fail All	Meets All	Meets All
Summer	nd	nd	nd	nd	nd	Meets All	nd
Fall	nd	nd	nd	nd	Fail GM+%	*Fail GM*	*Fail All*
Overall	No Data	Fail	Meet	Meet	Fail	Meet†	Fail
Reporting Year 2019							
Winter	nd	Fail All	Meets All	Meets All	Fail All	Meets All	Fail All
Spring	*Fail GM*	*Fail All*	nd	*Fail GM*	*Fail All*	*Fail GM*	nd
Summer	nd	nd	nd	nd	nd	nd	nd
Fall	nd	nd	nd	nd	*Meets All*	*Meets All*	*Fail All*
Overall	No Data‡	Fail	Meet	Meet†	Fail	Meet†	Fail

*Seasonal metrics compared to geometric mean, 90th percentile, and % of samples criteria. If any one of these criteria were exceeded in the season, the season failed to meet the fecal coliform standard. Seasons can meet all, fail all, or fail a portion or combination of the criteria examined:

GM: geometric mean criterion (50 cfu/100ml)
90: 90th percentile criterion (100 cfu/100ml)
%: percentage of samples not to exceed criterion (no more than 10% of samples may exceed 100 cfu/100ml)

nd: No data
POR: Period of record (2008-2017) shown as percentage of seasons with n>1
Italic: determination based on one sample (n=1)
Orange cells indicate that the failure to meet the geometric mean was based on one sample, which is not appropriate for assessing against geometric mean criteria.
†Sites are listed as meeting the fecal coliform standard overall because it is not appropriate to calculate a geometric mean using only one sample (orange cells). Because the geometric mean was met during all other seasons and no seasonal excursions above the 90th percentile criterion occurred, the site is listed as meeting the fecal coliform standard for the reporting period.
‡SW072 was only sampled once during the reporting period, spring 2019. This was determined to be an insufficient number of samples to assess compliance with the fecal coliform standard.

Compared to the period of record, sites SW017, SW015, and SW055 have improved water quality during the reporting period. This may by partly due to elevated fecal coliform densities obtained due to sampling during stagnant conditions prior to 2013. Overall, although portions of the Smuggler Slough watershed met the fecal coliform standard during the reporting period, the watershed as a whole fails to protect designated uses, in particular downstream shellfish harvesting use.

7.1.7.4 Other Lummi Bay Watersheds

Two other small watersheds that discharge into Lummi Bay are monitored. Onion Creek flows into the northern portion of Lummi Bay (Onion Bay) and is monitored as it enters the Reservation along Slater Road at site SW014. Seapond Creek flows into Lummi Bay at the south end of the seaponds aquaculture facility and is monitored as it crosses Haxton Way at site SW029. Both sites have intermittent, seasonal flow, which led to no reporting period samples for summer at either site and no samples for fall at SW029. All sites had three or fewer samples per season for the reporting years 2018 and 2019.

Table 7.1.11 summarizes compliance determination by season and overall. Compliance for each season was determined by assessing the geometric mean and 90^{th} percentile components of the standard; if any of the three metrics (geometric mean, 90^{th} percentile, percentage of samples exceeding the criterion) failed to meet the criteria, the site was determined to fail to meet the standard for that season. If any season during the year failed to meet the standard, it was determined to fail to meet the standard for that year. All seasons must meet all components of the criteria in order to meet the standard for the year.

Onion Creek (SW014) failed to meet the fecal coliform standard during both reporting years overall, following a pattern seen during nine of the last ten years for the period of record. Although water quality met the fecal coliform standard during winter and spring, poor water quality during the fall led to the failure to meet the standard overall. Compared to the period of record, during which nine out of ten years in the period of record failed to meet the standard during spring, water quality during the spring and winter improved during the reporting period. Water quality during the fall has not improved.

Seapond Creek (SW029) failed to meet the fecal coliform standard in 2018 but was in compliance with the standard in 2019. In 2018, the site failed to meet the percent exceeding component of the criteria during the winter. This was due to one sample (50% of the two total samples that season) that was slightly above the 100 cfu/100ml criterion (102 cfu/100ml). Although the site was not in compliance with the criterion during that season, all other metrics and seasons point to good water quality at this site. Similar to Onion Creek, Seapond Creek showed improvement in water quality during the winter and spring during the reporting period as compared to the period of record.

Table 7.1.11 Summary of compliance with the fecal coliform standard for sites in the Onion Creek and Seapond Creek watersheds for the period of record (2008-2017) and reporting period (2018-2019). Compliance requires both the geometric mean and 90th percentile criteria (both calculated 90th percentile metric and the percentage of samples above the criterion) are met. Years 2018 and 2019 listed separately with the reason for failure listed.* Compliance for the period of record is the percentage of years failing to meet the standard during the given season (out of seasons with n≥1; i.e., years with no samples in the season not included in the frequency calculation). Onion Creek enters the Reservation at site SW014 along Slater Road and flows into Onion Bay, the northern portion of Lummi Bay. Seapond Creek crosses Haxton Way at site SW029 and flows into Lummi Bay near the shellfish hatchery at the seaponds aquaculture facility. Both are Class AA Freshwater designated sites. Sites that fail to meet the standard for one or more seasons fail to meet overall. Sample size for 2018 and 2019 is ≤3 for each season.

Season	**Onion Creek**			**Seapond Creek**		
	SW014			**SW029**		
	POR	**2018**	**2019**	**POR**	**2018**	**2019**
Winter	40%	Meets All	Meets All	44%	Fail %	Meets All
Spring	90%	*Meets All*	Meets All	78%	Meets All	Meets All
Summer	60%	nd	nd	nd	nd	nd
Fall	60%	Fail All	Fail 90+%	14%	nd	nd
Annual	**90%**	**Fail**	**Fail**	**89%**	**Fail**	**Meet**

*Seasonal metrics compared to geometric mean, 90th percentile, and % of samples criteria. If any one of these criteria were exceeded in the season, the season failed to meet the fecal coliform standard. Seasons can meet all, fail all, or fail a portion or combination of the criteria examined:

GM: geometric mean criterion (50 cfu/100ml)

90: 90th percentile criterion (100 cfu/100ml)

%: percentage of samples not to exceed criterion (no more than 10% of samples may exceed 100 cfu/100ml)

nd: No data

POR: Period of record (2008-2017) shown as percentage of seasons with n>1

Italics: determination based on one sample (n=1)

7.1.7.5 Lummi Bay Freshwater Summary

Portions of all freshwater drainages flowing into Lummi Bay failed to meet the fecal coliform standard for Class AA freshwater during the reporting period. All sites in the Jordan Creek/North Lummi River Distributary and Lummi River watersheds failed to meet the standard and half of sites in the Smuggler Slough watershed failed to meet the standard. Onion Creek failed to meet the standard during both reporting years and Seaponds Creek failed to meet the standard during 2018. As these waters flow onto the Reservation, they are already consistently failing to meet the fecal coliform standard. In general, sites along the northern Reservation boundary had higher bacterial densities than sites mid-way through the drainage and the outlets of these drainages to the marine receiving waters. The lower fecal coliform densities downstream in the drainage suggests that, although all sites failed to meet the fecal coliform standard, fecal coliform densities decrease through dilution as the creeks flow downstream and enter tidally-influenced areas and the marine receiving waters. This dilution and deactivation from the saline waters in the bay decreased the bacterial densities from the levels found in the freshwater sample sites, but not enough to consistently avoid exceeding water quality criteria protective of designated uses, including shellfish harvesting.

The fact that all northern Reservation boundary sites are failing to meet the fecal coliform standard suggests that the primary sources of contamination are upstream of the Reservation.

7.2. Salmonid Use

Water temperature and dissolved oxygen are the two most important water quality parameters for salmonid survival, development, and growth. In addition to temperature and dissolved oxygen, pH is another water quality parameter to which salmonids and other aquatic organisms are sensitive. Compliance with the pH standard for freshwaters and marine waters are summarized in Section 7.3. In this section, “salmonid use” refers to the characteristic uses listed in the Lummi Nation Water Quality Standards: salmonid migration, juvenile rearing, spawning, egg incubation, fry emergence, and harvesting. Other fish also use the Reservation waters for these activities but due to the generally high sensitivity of salmonid species to environmental conditions, this section is focused on salmonids.

7.2.1. Water Temperature

Water temperature can affect water quality and biotic communities, particularly salmonids, in several ways. Temperature is one of the most important parameters influencing salmonid biology. Because salmonids are poikilotherms, as are most aquatic organisms, their internal temperature and metabolism are determined by the ambient water temperature. Water temperature influences incubation and early fry development, feeding rates, and the timing of life history events such as upstream migration, spawning, freshwater rearing, and seaward migration. Thermal stress can result from temperatures that are too warm, resulting in death or reduced fitness that impairs processes such as growth, spawning, smoltification, or swimming speed (McCullough et al. 2001). Thermal stress can also block migration, create disease problems, and alter competitive dominance (Carter 2005). Higher temperatures also reduce the amount of dissolved oxygen available to aquatic organisms, potentially resulting in respiratory stress. In addition, elevated water temperature can increase the solubility of most metals and chemicals and reduces their adsorption to sediment particles, increasing pollutant concentrations within the water column.

The water temperature criteria are calculated maximum statistics (Table 7.2.1). For freshwater, a seven-day average of the daily maximum temperature statistic is calculated (7DADM) while for marine water, the one-day maximum temperature (1DM) is identified. For the 7DADM, the reporting day for the statistic, three days prior, and three days after are included as the seven days averaged.

Table 7.2.1 Water temperature standards for surface waters of the Lummi Indian Reservation

Water Quality Class	Freshwater (7DADM)	Marine (1DM)
Class AA (Extraordinary)	16.0°C	13.0°C
Class A (Excellent)	17.5°C	16°C

7DADM: 7-day average of the daily maximum value
1DM: 1 day maximum value

Due to the 7DADM and 1DM statistic-based temperature standards, continuous temperature monitoring is required at a site in order to appropriately determine compliance. Discrete temperature measurements on a monthly basis are not sufficient because they do not provide the maximum temperature for each day or the seven days required to calculate the freshwater 7DADM statistic. Six sites had continuous temperature monitoring during the reporting period, while discrete temperature measurements were collected at all surface water sites during each site visit. Continuous temperature monitoring data are used to determine compliance with the temperature standards for sites with these data available, while the discrete temperature measurements are used to identify sites that may be failing to meet the standard but not identify sites that meet the standard.

7.2.1.1 Discrete Temperature Measurement

Discrete temperature measurements are collected each time a site is sampled, typically six to twelve times per year. As the water temperature standard is defined as a seven-day average of the daily maximum value (7DADM) for freshwater and as a one-day maximum value (1DM) for marine water, the maximum temperature for up to seven consecutive days is required in order to determine compliance with the standard. Continuous temperature monitoring is required in order to truly identify the maximum temperature during a day or series of days and therefore to determine compliance with the temperature standard. However, if a discrete temperature measurement in freshwater exceeds the 7DADM criterion, the site can be determined to not meet the standard because it is unlikely that the randomly collected temperature measurement is greater than the 7DADM. If a discrete temperature measurement in marine water exceeds the 1DM criterion, the site does not meet the standard because there is at least one measurement (even if not the actual maximum) that exceeds the criterion. Therefore, discrete temperature measurements can be used to identify sites that are failing or likely failing to meet the temperature standard if continuous temperature data are not available. Discrete temperature measurements cannot be used to identify sites that meet the temperature standard because it is unlikely that the maximum temperature was observed via discrete sampling.

Sites were assessed annually; if one or more discrete temperature measurements exceeded the temperature criterion during the year, the site failed to meet the temperature standard for that year. The number of sites failing to meet the standard each year was averaged for two five-year periods of record (2008-2012 and 2013-2017) and the two-year reporting period (2018-2019). Based on discrete temperature measurements, 67% of sites failed to meet the temperature criterion during the 2018-2019 reporting period, including 26% of freshwater sites and 93% of marine sites (Figure 7.2.1). During the two five-year periods of record, an average of 67-72% of sites failed to meet the temperature criteria. This included 20-48% of freshwater sites and 78-99% of marine sites.

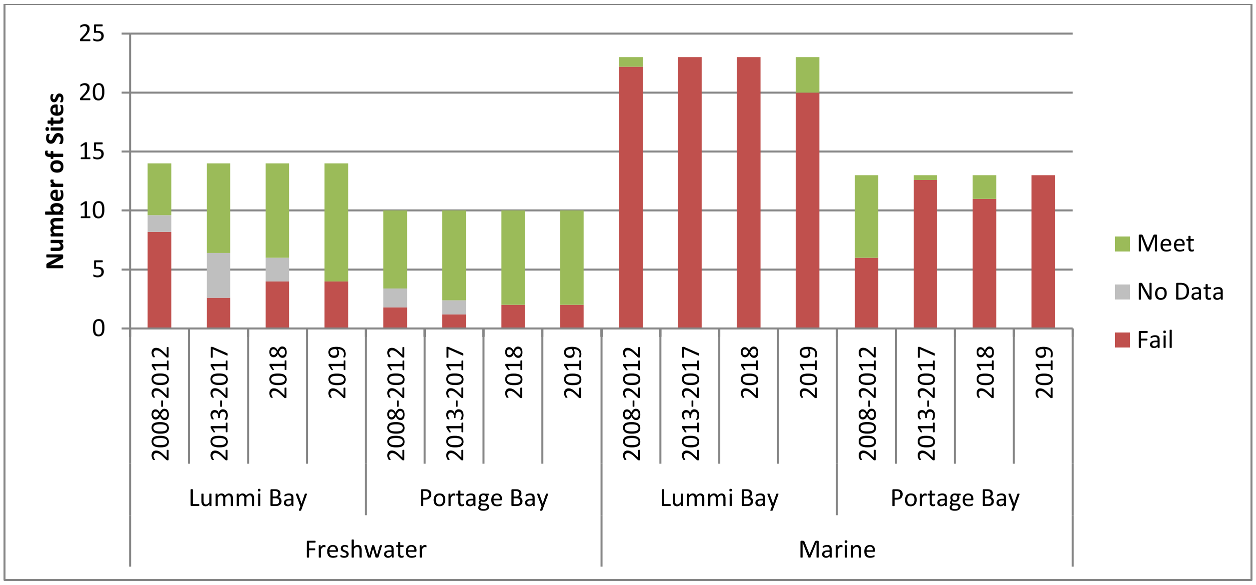


Figure 7.2.1 Average number of sites per year failing to meet the temperature standard ("Fail") and not exceeding the temperature criteria ("Meet") based on discrete temperature measurements by watershed for the reporting period 2018-2019 and two five-year periods of record (2008-2012, 2013-2017). Sites were assessed annually; the site failed to meet the temperature standard if at least one discrete temperature measurement was above the temperature criteria during the year. Note that discrete samples can only be used to identify sites not meeting the standard, not to determine compliance with the standard.

The majority of marine sites in both Lummi Bay and Portage Bay failed to meet the temperature standard. During the reporting period, 85-100% of marine sites in Portage Bay failed to meet the temperature standard, while during the period of record 46-97% of sites failed to meet the standard. In Lummi Bay, 97-100% of sites failed to meet the standard during the period of record and 87-100% of sites failed to meet the standard during the reporting period. During the years from 2013-2018, 100% of marine sites in Lummi Bay failed to meet the temperature standard. This includes sites in Sandy Point marina, the Seaponds aquaculture facility, and Hale Passage in addition to sites located on the tideflats of the Lummi Bay shellfish growing area.

The majority of freshwater sites in both the Lummi Bay and Portage Bay watersheds had no discrete temperature measurements above the temperature criteria. An increasing proportion of freshwater sites in the Lummi Bay watershed had no discrete temperature measurements above the temperature criteria over time. This may be partly due to temperature measurements collected during stagnant conditions prior to discontinuation of this practice in 2013. Future reports should consider comparison of temperature measurements collected during stagnant versus flowing conditions for the period of record prior to 2014.

Freshwater sites in the Portage Bay watershed had the lowest rates of failure to meet the temperature criteria. Over the last 12 years, fewer than one-quarter of sites failed to meet the temperature standard. The majority of the freshwater sites discharging into Portage Bay are ephemeral streams that flow only during the rainy period, which likely contributes to lower temperatures at these sites as compared to sites with more year-round flow.

However, because of lack of continuous temperature data, it is unknown whether these sites meet the temperature standard because random sampling likely failed to capture the maximum temperature. As mentioned above, discrete temperature measurements may bias the results toward low temperatures. Since 2013, sites are only sampled for *in situ* parameters when water is flowing (*i.e.,* the site is not stagnant) and sufficient water is present for collection of a bacteria sample. Many freshwater drainages are intermittent, with flows stopping during the dry period (June-Sept). Due to the sampling protocol, these types of sites have temperature measurements collected largely during the rainy season, when temperatures are cooler. This bias toward cooler season temperatures for discrete sampling should be considered when reviewing the results of discrete temperature measurements for compliance with the temperature standards. For this reason, sites are considered to fail to meet the temperature standard if any one discrete measurement exceeds the relevant temperature criterion.

7.2.1.2 Continuous Temperature Monitoring

Continuous temperature monitoring at selected sites allows for the calculation of 7DADM (freshwater) or 1DM (marine) temperature statistics and determination of site compliance with the temperature criteria. Continuous temperature monitoring was conducted at six sites in the Lummi Bay watershed during the reporting period. Sites include:

- Lummi River:
  - Freshwater sites at the northern Reservation boundary (SW009 and SW012, Schell Creek)
- Jordan Creek/North Lummi River Distributary:
  - Freshwater site at the northern Reservation boundary (SW011)
  - Freshwater site halfway between Reservation boundary and outflow into marine waters (SW003)
- Smuggler Slough:
  - Freshwater site as Smuggler Slough channel crosses Lummi Shore Drive (SW015)
  - Tidally influenced site at lower reach of Smuggler Slough drainage into Lummi Bay (SW059)

All sites are designated Class AA Freshwater except SW059, which is Class AA Marine. Sites included in the Continuous Temperature Monitoring Project, but not monitored during the 2018-2019 reporting period include: site SW008 (tidally-influenced site at lower reach of Lummi River at Hillaire Road Bridge), SW051 (marine outflow of Lummi River), SW053 (marine receiving waters of Jordan Creek/North Lummi River Distributary), and SW118 (Nooksack River at Marine Drive Bridge).

Temperature data from the period of record used include data from calendar years 2016 and 2017. Continuous temperature data collected prior to the finalization of the Continuous Temperature Monitoring QAPP in October 2015 were not used in the compliance determination analysis but are referenced for context. Data gaps during the 2016-2017 period of record were caused by data loss or logger malfunction (SW003 January-May 2016) and removal due to bridge construction (SW011 May-December 2017).

Data gaps during the 2018-2019 reporting period include a ten-month period from 6/12/2018 to 4/17/2019 during which time staff availability and technical difficulties with continuous temperature monitoring software significantly delayed the ability to download data and conduct quality assurance checks on temperature loggers. At all sites and years, data gaps are present due to periods during which the loggers were removed from the site for QA/QC activities and these QA/QC activities were delayed due to technical challenges or other priorities. Data were excluded when loggers were known to be dewatered or data suggest that the loggers may have been dewatered (e.g., wide temperature fluctuations that are similar to air temperature changes). Other reasons for data exclusion, including excluding two hours of data after deployment and before logger removal, are detailed in the Continuous Temperature Monitoring QAPP (LWRD 2015c).

During both reporting years 2018 and 2019, all sites had periods during which the temperature standard was not met (Figure 7.2.2). On average, sites failed to meet the temperature criteria 17% of the time during the reporting period; 9% and 25% of the time in 2018 and 2019, respectively. This was similar to the 2016 and 2017 period of record; all sites that could be assessed had periods during which the temperature standard was not met. No data were collected at SW011 from May to December in 2017. Due to the lack of data during the warm summer months, compliance with the standard cannot be determined for SW011 for 2017. This pattern was also present in continuous temperature data collected prior to 2016 (2009-2013).[12] Nearly all sites with sufficient data to make a determination of compliance failed to meet the temperature standard for a period of time during each year with the exception of site SW011, which met the temperature standard during 2009 and 2011.

At many sites, the percentage of time the site failed to meet the temperature criterion decreased from 2016 to 2018 and then increased in 2019. On average, the percentage of time the sites met the temperature criterion also decreased from 2016 to 2018. This pattern is likely largely driven by the large data gap in 2018, with no data available from June 12 through the end of the year. On average, 59% of the year 2018 was not able to be assessed for temperature standard compliance due to lack of data. Although the large data gap extended to April 17, 2019, most sites had data available throughout the warm season and the percentage of time sites failed to meet the temperature criterion during 2019 was similar to rates observed during 2016 and 2017. The decrease in failure rate during 2018 is likely due to no data being collected during the summer months when the warmest temperatures are to be expected. In 2019, the lowest rate of failing to meet the temperature criterion was observed at Smuggler Slough site SW015, however the logger at this site was dewatered during the summer, which contributed to the large number of days with insufficient data for compliance determination, approximately 57% of the year in 2019.

In both the Jordan Creek/North Lummi River Distributary and Smuggler Slough watersheds, the upstream sites had lower frequency of failing to meet the standard than the site lower in the watershed year-to-year. In the Lummi River watershed, both sites are located along Slater

[12] Available data prior to 2016 was variable by site, with the earliest data were collected in 2009 and the latest in 2013. Note that data collected prior to 2016 were not subject to the same QA/QC procedures as data collected for the reporting period.

Road, and site SW009 consistently had a lower frequency of failing to meet the standard than at Schell Creek (SW012).

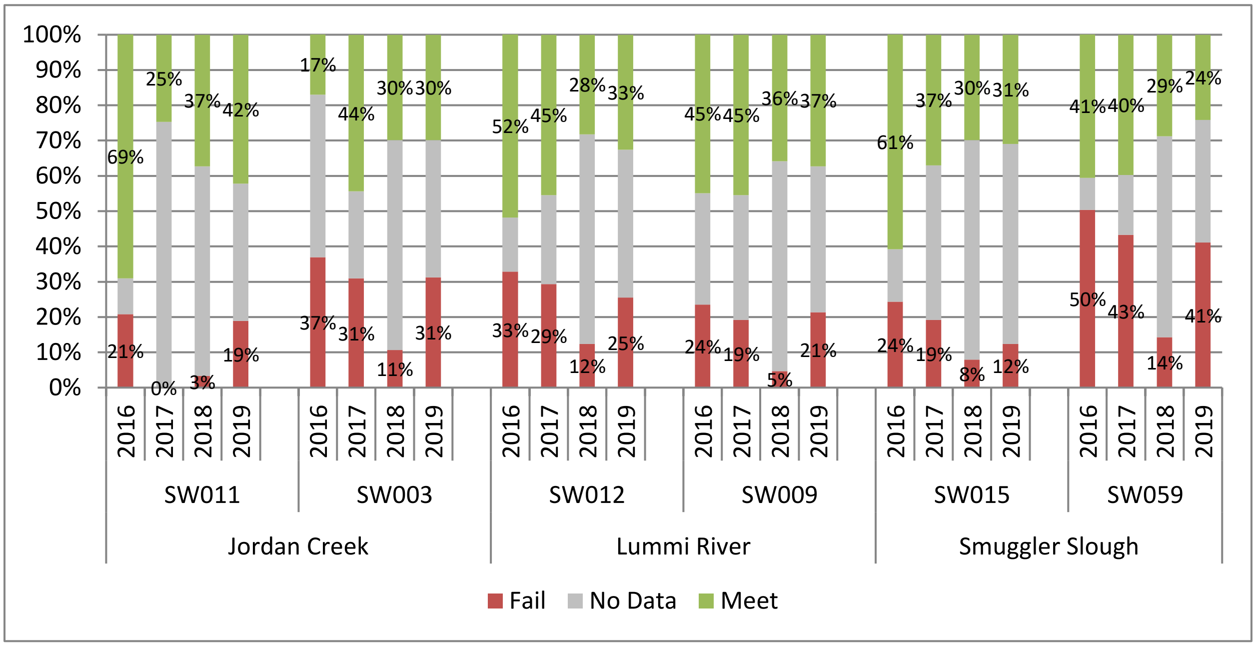


Figure 7.2.2 Compliance with the temperature standard for the years 2016-2019 by watershed. The 7-day average daily maximum temperature was calculated for each day at freshwater sites (all except SW059) and 1-day maximum temperature determined for each day at marine site SW059. Daily metrics were compared to the temperature standard and compliance determined. Percentage of time sites were in compliance ("Meet"), not compliant ("Fail"), or had no data each year are shown.

Water temperatures peak during July and August, when air temperatures reach their maximum for the year, although many sites had periods during which temperature criteria were not met as early as late April for freshwater sites and early April for marine site SW059 (Table 7.2.2; Figure 7.2.3). Generally, the latest the temperature criteria was exceeded was September for freshwater sites and October for marine site SW059. Nearly all freshwater sites had 100% of days during June, July, and August failing to meet the temperature criterion (rolling 7DADM) for years 2016-2019. The exceptions to this were SW011, which met the standard for one week during two years in June, and SW009, which met the standard for one week during June 2018. The single marine site, SW059, had 100% of days during May-September failing to meet the temperature criterion (1DM) during all years. Water temperatures met the temperature standard from October through March for freshwater sites and November through February for marine site SW059.

The continuous temperature monitoring patterns observed over the reporting period 2018-2019 were similar to those observed during 2016-2017. Similar patterns of exceedance frequency and timing were also observed during previous continuous temperature monitoring efforts (prior to the QAPP; LWRD 2015) conducted from 2009 to 2013. In the Jordan Creek watershed, however, a warming trend may be occurring during the spring. Between 2009-2013, site SW011 had temperatures exceeding the standard from July through mid-August, while 2016 exceedances began in early June and as early as May during the reporting period 2018-2019. There have been several changes at and near Jordan Creek site SW011 over the last several years, including the construction of a bridge at Slater Road to replace a culvert and restoration of the Jordan Creek streambed below, that may have contributed to changes in flow and temperature. However, the large periods of missing data may have masked the year-to-year variability in temperatures at SW011.

Table 7.2.2 (next page) Summary of weekly compliance with temperature standard for continuous data collected in 2016-2019. Seven-day average daily maximum values were calculated for each day at freshwater sites and compared to the temperature criterion. One-day maximum values were determined for marine sites and compared to the temperature criterion. Determination is shown by week; if any one day during the week failed to meet the standard, the week is considered to fail to meet the standard (red F). If all determinations for the week met the standard, the week is considered to meet the standard (green M). If no data are available for any days in the week, the week is gray and no compliance determination is made. Month associated with the first day of the week number for 2019 is shown (i.e., first day of week 19 is in May); note that the week numbers change each year and weeks may include days from two months.

	Jan					Feb				Mar				Apr					May				June				July					Aug				Sept					Oct				Nov				Dec				
Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53
Jordan Creek - SW011																																																					
2016			M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	F	F	M	F	F	F	F	F	F	F	F	F	F	F	M	M	M	M	M	M	M	M	M	M	M	M	M				
2017						M	M	M	M	M	M	M	M	M	M	M	M	M																																			
2018	M	M	M	M	M	M	M	M	M	M	M	M		M	M	M	M	M	M	F	F	M	M																														
2019																M	M	M	F	M	F	F	F	F			F	F	F	F	F	F	F	F	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Jordan Creek - SW003																																																					
2016																					F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	M	M	M	M	M	M	M	M	M				
2017						M	M	M	M	M	M	M	M	M	M	M	M	M	M	F	F	F	F	F	F			F	F	F	F	F	F	F	F	F	F	F			M	M	M	M	M	M	M	M	M				
2018	M	M	M	M	M	M	M	M	M	M	M	M		M	M	M	M	F	F	F	F	F	F																														
2019																M	M	F	F	F	F	F	F	F			F	F	F	F	F	F	F	F	F	F	F	F	F	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Lummi River - SW012																																																					
2016		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F		F	F	F		M	M	M	M	M	M	M	M	M	M	M				
2017						M	M	M	M	M	M	M	M	M	M	M	M	F	F	F	F	F	F	F	F			F	F	F	F	F	F	F	F	F	F	F	M			M	M	M	M	M	M	M	M	M				
2018	M	M	M	M	M	M	M	M	M	M	M	M		M	M	M	F	F	F	F	F	F	F																														
2019																M	M	F	F	F	F	F	F	F			F	F	F	F	F	F	F	F	F	F	F	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Lummi River - SW009																																																					
2016			M	M	M	M	M	M	M	M	M	M	M	M	M	M	F	F	F			M	F	F	F	F	F	F	F	F	F	F	F		F	F	F						M	M	M	M	M	M	M				
2017						M	M	M	M	M	M	M	M	M	M	M	M	M	M	M								F	F	F	F	F	F	F	F	F	F	F			M	M	M	M	M	M	M	M	M				
2018	M	M	M	M	M	M	M	M	M	M	M	M		M	M	M	M	M	M	F	F	F	M																														
2019																M	M	M	M	M	F	F	F	F			F	F	F	F	F	F	F	F		F	F	F	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Smuggler Slough - SW015																																																					
2016		M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	F	F	F	M	M	M	F	F	F	F	F	F	F	F	F	F	F	F	F				M	M	M	M	M	M	M	M	M	M	M				
2017						M	M	M	M	M	M	M	M	M	M						F	F	F	F	F			F	F	F	F	F	F							M	M	M	M	M	M	M	M	M	M				
2018	M	M	M	M	M	M	M	M	M	M	M	M		M	M	M	M	M	F	F	F	F	F																														
2019																M	M	F	F	F	F	F	F	F														F	F	M	M	M	M	M	M	M	M	M	M	M	M	M	M
Smuggler Slough (Marine) - SW059																																																					
2016		M	M	M	M	M	M	M	M	M	M	M	M	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	M	M	M	M	M	M	M	M			
2017					M	M	M	M	M	M	M	M	M	M	M	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	F	M	M	M	M	M	M	M	M	M		M	M
2018	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	F	F	F	F	F	F	F	F	F																													
2019																F	F	F	F	F	F	F	F	F			F	F	F	F	F	F	F	F	F	F	F	F	F	F	M	M	M	M	M	M	M	M	M	M	M	M	M

Maximum monthly temperature for freshwater sites was summarized over the period 2016-2019 (Figure 7.2.3). The mean maximum temperature observation exceeded the 16°C Class AA Freshwater criterion during May through September, and all site-years had a maximum temperature observation during July, August and September that exceeded the criterion. Note that the monthly maximum temperature observed is not used to determine compliance with the temperature standard, which is a 7-day average of the daily maximum value. Studies have shown that a temperature range of 22-24°C can eliminate salmonids from an area (EPA 2001). The mean maximum temperature exceeded 22°C during July and August, while the third quartile and maximum exceeded 22°C from May to September. This indicates that at least one quarter of sites have temperatures high enough to eliminate salmonids during an average year between May and September and more than half of sites have temperatures this high in July and August.

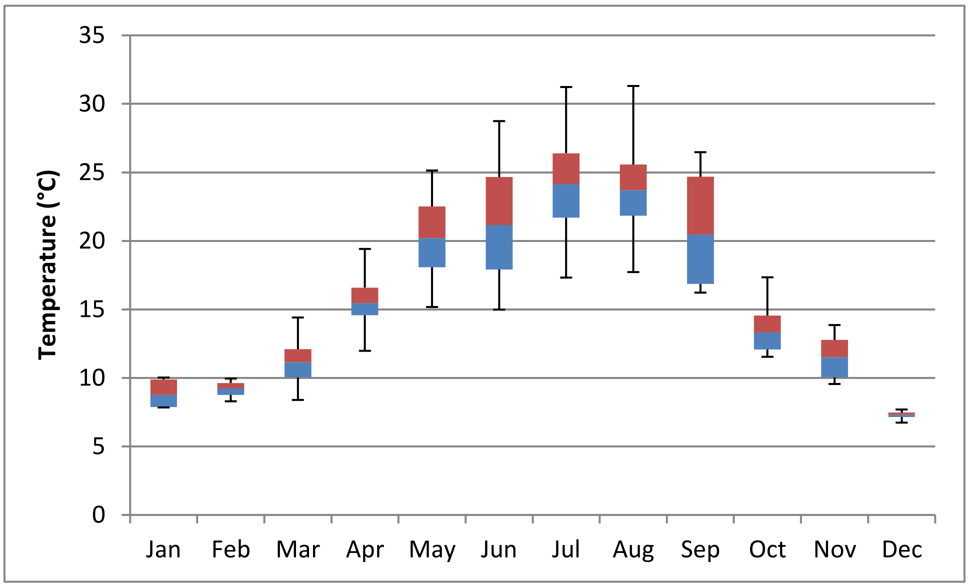


Figure 7.2.3 Maximum monthly temperature observation for freshwater sites 2016-2019. Boxes represent second (blue) and third (red) quartiles and whiskers represent first and fourth quartiles. Maximum monthly temperature from continuous temperature monitoring freshwater sites SW003, SW009, SW011, SW012, and SW015 for years 2016-2019 were pooled.

Maximum annual temperatures were also determined for each site by year using both continuous and discrete temperature data (Figure 7.2.4). All site-years had an annual maximum temperature above the Class AA Freshwater temperature standard, with the exception of SW011 in 2017 during which no summer data were available. Maximum temperatures were similar across the 2016-2019 period for each site. Maximum temperatures in 2018 were the lowest at four of the six sites. Maximum temperatures show a potential decreasing trend at Lummi River site SW009 and a potential increasing trend at SW059. Additional temperature data and shorter data gaps in the continuous temperature dataset are needed to confirm these trends.

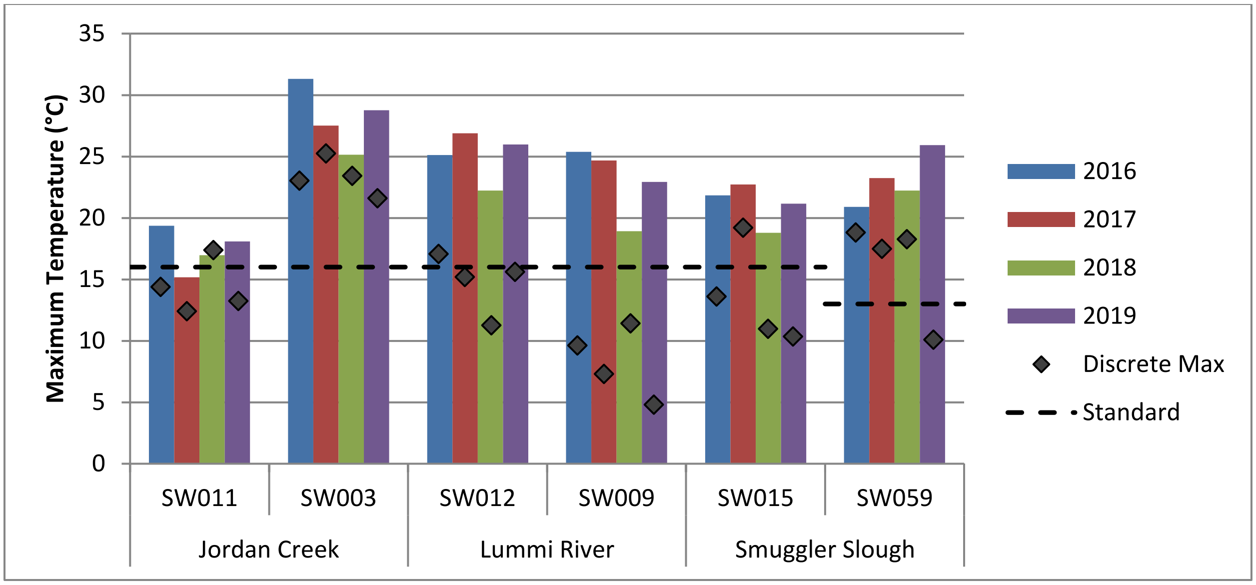


Figure 7.2.4 Maximum annual temperature by site for continuous dataset (bars) and discrete dataset (points) for years 2016-2019 by site and watershed. Freshwater (all sites except SW059) and Marine (SW059) Class AA temperature criteria shown for reference. Continuous data for SW011 in 2017 are February-April only (no summer data).

Although the annual maximum temperature illustrates only the warmest point during the year, is not used to determine compliance with the temperature standard, and does not indicate the duration of temperatures that exceed the criterion, examination of maximum temperatures can identify sites with serious temperature problems and whether the maximum temperature for the reporting year is greater than, less than, or in line with the average maximum temperature for the period of record. As mentioned above, studies have shown that temperatures above 22-24°C can eliminate salmonids from an area (EPA 2001). The maximum temperature exceeded 22°C at Jordan Creek site SW003 and Lummi River site SW012 during all years. Jordan Creek site SW011 is located upstream of SW003 was the only site that did not have a maximum annual temperature above 22°C during any years. Lummi River site SW009 had a maximum temperature above 22°C during three of four years. In Smuggler Slough, the upstream site SW015 had a maximum annual temperature above 22°C only during 2017, while the downstream tidally-influenced (Class AA Marine) site had temperatures high enough to eliminate salmonids during three of four years. This suggests that salmonids are excluded from 63% of sites due to high temperatures during some portion of the year (primarily July and August) in most years.

Waters that flow onto the Reservation across the northern boundary are failing to meet the temperature standard during some portions of the year (SW009, SW011, and SW012). As waters flow downstream, the water temperature tends to increase. In the Jordan Creek/North Lummi River Distributary watershed, the maximum water temperature at site SW003 (mid-point) was higher than at site SW011 (Reservation boundary). Similarly, the number of days during which the temperature standard was exceeded as well as the amount of time between the earliest exceedance and the last exceedance of the year increased from the Reservation boundary to the mid-point. Temperatures at the two Smuggler Slough sites were similar to each other during 2016 and 2017, but exhibited a similar downstream warming pattern during 2018 and 2019.

Comparison of discrete annual maximum temperature with the continuous temperature data shows that discrete temperature measurements correctly identified three sites as failing to meet the temperature standard during 2016, 2017, and 2018 but only correctly identified one of six sites as failing to meet the standard in 2019 (Figure 7.2.4). Jordan Creek site SW003 was identified correctly as failing to meet the temperature standard using discrete data during all years. This was to be expected because SW003 has the highest maximum temperatures of all continuous temperature monitoring sites. Lummi River site SW009 failed to be identified as failing to meet the temperature standard using discrete data during all four years. This is likely because temperature measurements are only collected during flowing conditions, and this site is frequently stagnant during the dry season.

Discrete maximum temperature measurements were lower than the maximum temperature observed using continuous monitoring at all sites and years, except SW011 for 2018 during which the warmest months July and August did not have continuous data available. Since discrete temperature measurements are only collected from sites with flowing water while continuous temperature data are collected regardless of flow conditions, discrete temperature measurements are unlikely to capture the period during which the site is most likely to fail to meet the criterion, which is typically during the dry summer months when sites become stagnant. This demonstrates the importance of continuous temperature monitoring for determination of compliance with the standard but may also complicate the interpretation of the continuous data. Continuous temperature data are collected at a site even during stagnant conditions, which may include channel disconnection, and it is unknown what proportion of continuous temperature data are collected during and could be explained by the presence of stagnant conditions. Comparison of discrete and continuous annual maximum temperatures corroborated the use of discrete temperature data to identify sites as failing to meet the standard. Since discrete temperature measurements are likely to underestimate the annual maximum temperature, for sites without temperature monitoring, comparison of maximum discrete temperature measurements serves as a sufficient proxy for identifying sites that would fail to meet the criterion if continuous data were available. However, as previously discussed and illustrated in Figure 7.2.4, discrete temperature data cannot be used to confirm that a site meets the temperature criterion because discrete monitoring is unlikely to capture the true maximum temperature at a given site.

7.2.1.3 Causes and Conclusions

Temperature standards failed to be met during a portion of the year at all sites for which continuous temperature data were available during the reporting period (2018 and 2019). This suggests that temperature exceedances are also common at other freshwater and marine-influenced sites not included in the Continuous Temperature Monitoring Project. Due to the challenges of deploying continuous temperature loggers at marine sites, no continuous temperature data are available for the mouths of freshwater streams, marine receiving waters, or marine open water sites (i.e., not tidally influenced channels).

Some sites with temperature exceedances have naturally occurring high temperatures during the summer months. For example, sites in Lummi Bay and Portage Bay, where the tideflats are exposed to full sunlight in the summer and water is shallow even during high tide, likely exceed the standard due to natural conditions. However, at other sites these exceedances are likely due to human-caused factors such as the removal of riparian vegetation and/or drainage alterations that decrease the amount of groundwater available to moderate surface water temperatures in the summer. The extent to which anthropogenic influences have contributed to elevated water temperatures at the various sample sites has not been established.

As described above, continuous monitoring sites at the northern Reservation boundary show that waters entering the Reservation from the north are failing to meet the temperature standard. Land use and lack of riparian vegetation may be leading to high temperatures as waters flow from Whatcom County onto the Reservation. Waters flowing through the Reservation are warming as they flow downstream in both the Jordan Creek/North Lummi River Distributary as well as in the Lummi River. Again land use and lack of riparian vegetation and/or historical drainage alterations may be the cause of increasing temperatures.

Based on the results, Reservation waters are not protective of the designated uses, and may not provide suitable conditions for salmonid use due to excessive temperatures. The results also highlight that water temperatures exceed the criteria as they flow onto the Reservation from the northern boundary.

7.2.2. Dissolved Oxygen

Sufficient concentrations of dissolved oxygen are required for respiration by many forms of life, including fish, invertebrates, bacteria, and plants. Dissolved oxygen (DO) is critical for the survival of salmonids. Low DO can impact growth and development, swimming speed, feeding activity, reproductive ability, fitness and survival. Under extreme conditions, low DO concentrations can cause respiratory stress or be lethal to salmonids.

The DO standards involve several components (Table 7.2.3). Under current monitoring projects, the spatial median intergravel DO is not measured. In addition, due to discrete DO measurements, a seven-day mean minimum DO concentration (for Class AA freshwater) or a one-day minimum daily concentration (marine) cannot be calculated or identified. Continuous monitoring would be required to accurately determine compliance with the DO standard. For this report, only discrete DO measurements are used to approximate compliance. If discrete DO measurements exceed the mg/L criteria, the site is determined to fail to meet the DO standard. For freshwater, temperature is used to determine the period during which attainment of the mg/L criteria would require more than 100% saturation, during which time the percent saturation criterion is used to determine compliance. Determination of compliance with the DO standard requires measurement of the minimum DO concentration during a 24-hour period, which typically occurs overnight when discrete sampling is rarely conducted. In addition, for Class AA freshwaters, a seven-day mean of the daily minimum concentration is calculated to determine compliance. For these reasons, compliance with the standard cannot be determined; only identification of sites that fail to meet the standard can be accomplished by examining discrete DO measurements.

Table 7.2.3 Dissolved oxygen standards for surface waters of the Lummi Indian Reservation

Class AA	Class A
Freshwater	
The seven-day mean minimum shall both not be less than 11.0 mg/l AND not have a spatial median intergravel dissolved oxygen concentration below 8.0 mg/l. If minimum spatial median intergravel dissolved oxygen is 8.0 mg/l or greater, the minimum dissolved oxygen criterion is 9.0 mg/l. Where barometric pressure and temperature preclude attainment of criteria, dissolved oxygen must not be less than 95% of saturation.	Shall not be less than 8.0 mg/l. Where barometric pressure and temperature preclude attainment of criteria, dissolved oxygen must not be less than 90% of saturation.
Marine	
Shall exceed a 1-day minimum daily concentration of 7.0 mg/l	Shall exceed a 1-day minimum daily concentration of 6.0 mg/l

Dissolved oxygen measurements for the upper layer (when salinity stratified or not stratified) were used for this analysis. Dissolved oxygen measurements associated with stagnant conditions in streams were excluded; the measurement of DO during stagnant conditions was discontinued in 2013. Only ambient data collected as part of the Surface Water Project and DOH Support (NSSP) Project were used in this analysis. For freshwater sites, dissolved oxygen measurements (mg/L) were compared to the freshwater mg/L DO criteria when water temperature allowed for attainment of the mg/L criterion at 100% saturation; when the water temperature precluded attainment at 100% saturation, the DO measurements (% saturation) were compared to the percent saturation freshwater criterion. Marine DO measurements were compared to the single mg/L marine criterion. Compliance was determined annually for years 2008-2019. If one measurement during the year exceeded the appropriate criteria (either the mg/L or percent saturation criterion, depending on temperature, if applicable) the site was determined to fail to meet the standard. The percentage of measurements that exceeded the criteria during the year was also calculated. Reporting years are presented individually, while the period of record is summarized in two five-year periods (2008-2012 and 2013-2017). The periods of record are summarized as the percentage of years failing to meet the standard and as a mean percentage of samples failing to meet the criteria for the period. Mean and range (minimum-maximum) DO measurements as mg/L and percent saturation are summarized for the two five-year periods of record and the two-year reporting period (2018-2019).

7.2.2.1 DO Summary

During the 2018-2019 reporting period, DO measurements were collected at 58 surface water sites.[13] On average over the 2018-2019 reporting period, 45% of sites had DO measurements below the criteria, resulting in failure to meet the DO standard (Figure 7.2.5). During the period of record, 44-53% of sites failed to meet the DO standard. In marine waters, 19-22% of sites failed to meet the DO standard during the reporting period; these sites were located in Lummi Bay, Sandy Point Marina, Hale Passage, and the tidally influenced sites and marine receiving waters of freshwater streams in the Lummi Bay watershed. In freshwaters, 81-90% of sites failed to meet the DO standard during the reporting period; these sites were located in both the Lummi Bay and Portage Bay watersheds.

Compliance rates during the 2018-2019 reporting period were generally similar to compliance rates over the 2008-2017 period of record. Over time, there has been a decrease in the DO noncompliance rate in Class AA marine waters (Lummi Bay and vicinity). There has also been an increase in the compliance rate (or failure to exceed the DO criteria) in Portage Bay Class A marine waters, although this is due to more sites being assessed for DO compliance during recent years compared to during the period of record.

[13] 57 sites were sampled for DO during each reporting period year (2018 and 2019), however, over the two-year reporting period, 58 total sites were sampled. Site SR005 was not sampled during 2018 and SW035 was not sampled during 2019.

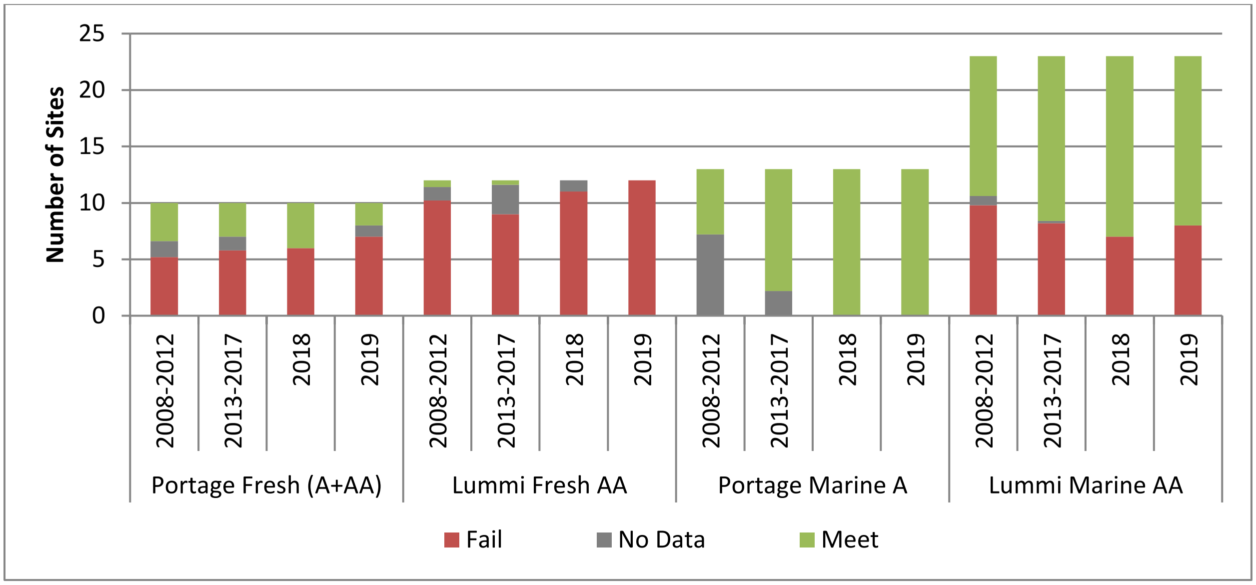


Figure 7.2.5 Number of sites failing to meet the dissolved oxygen standard ("Fail"), with no measurements below the DO criteria ("Meet"), or no data based on discrete DO measurements by watershed annually for the reporting period (2018-2019) and on average for two five-year periods of record (2008-2012, 2013-2017). Sites failing to meet the DO standard had at least one discrete DO measurement above the relevant DO criteria during the year or period.

7.2.2.2 Nooksack River

Dissolved oxygen in the Nooksack River (Site SW118 at Marine Drive Bridge)[14] failed to meet the freshwater Class AA standard on one occasion during the 2018-2019 reporting period, during April 2019, or approximately 1% of the time over the two-year reporting period (out of 91 measurements). During the five-year period of record 2013-2017, DO measurements failed to meet the DO standard on five occasions, approximately 3% of the time (out of 160 measurements). During the previous five-year period of record 2008-2013, DO measurements failed to meet the DO standard on one occasion, less than 1% of the time (out of 160 measurements). The mg/L criterion was exceeded once during the 2018-2019 reporting period and three times during the 2013-2017 period of record. The percent saturation criterion was exceeded twice during the 2013-2017 period of record and once during the 2008-2012 period of record.

When averaged by month, all months during the 2018-2019 reporting period had average DO measurements above the applicable criteria (Figure 7.2.6, Figure 7.2.7). However, as described above, the mg/L criterion was exceeded during April 2019. Both periods of record also had monthly average DO measurements above the applicable criterion. However, DO measurements were observed below the mg/L criterion in October and November for the

[14] SW118 analysis also includes dissolved oxygen and temperature data collected from alternate site SW004, the Nooksack River at Slater Road, which is sampled when access to SW118 is not safe (e.g., during flooding). Only ambient data collected as part of the Surface Water Project were used in this analysis.

2013-2017 period of record and below the percent saturation criterion in June and September for the 2013-2017 period of record and in May for the 2008-2013 period of record.

Dissolved oxygen measurements during the 2018-2019 reporting period were within the range of DO measurements over the period of record. Warm temperatures precluded attainment of the mg/L criterion during both reporting years between May and September, with all temperature measurements precluding attainment of the mg/L criterion between June and September. For the reporting period, the lowest dissolved oxygen concentrations (as mg/L) were measured in April 2018 and October 2018 and 2019. For both periods of record (2008-2012 and 2013-2017), the lowest DO concentrations (as mg/L) were measured in September. The timing of the lowest mg/L DO concentrations is likely due to warmer water temperatures that reduce the solubility of DO. During these warm months, DO percent saturation was frequently above 100% saturation, likely due to photosynthetic activity occurring in the water column during the daylight hours. The lowest DO percent saturation for the reporting period was observed during October 2019.

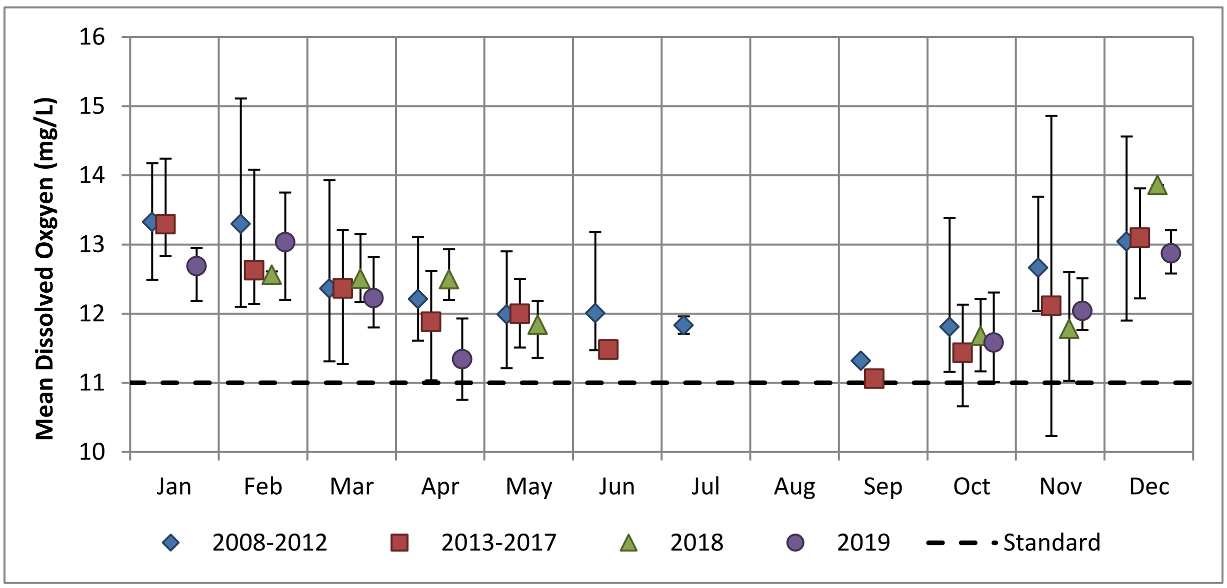


Figure 7.2.6 Monthly average dissolved oxygen (mg/L; points) and range (minimum-maximum; whiskers) at Nooksack River site SW118 annually for the 2018-2019 reporting period, two five-year periods of record (2008-2012, 2013-2017), and the dissolved oxygen mg/L criterion. Data used had associated temperatures that allowed for 100% saturation of the water at the 11 mg/L criterion; when this was precluded, or no associated temperature was available, the percent saturation criterion was used (see Figure 7.2.7).

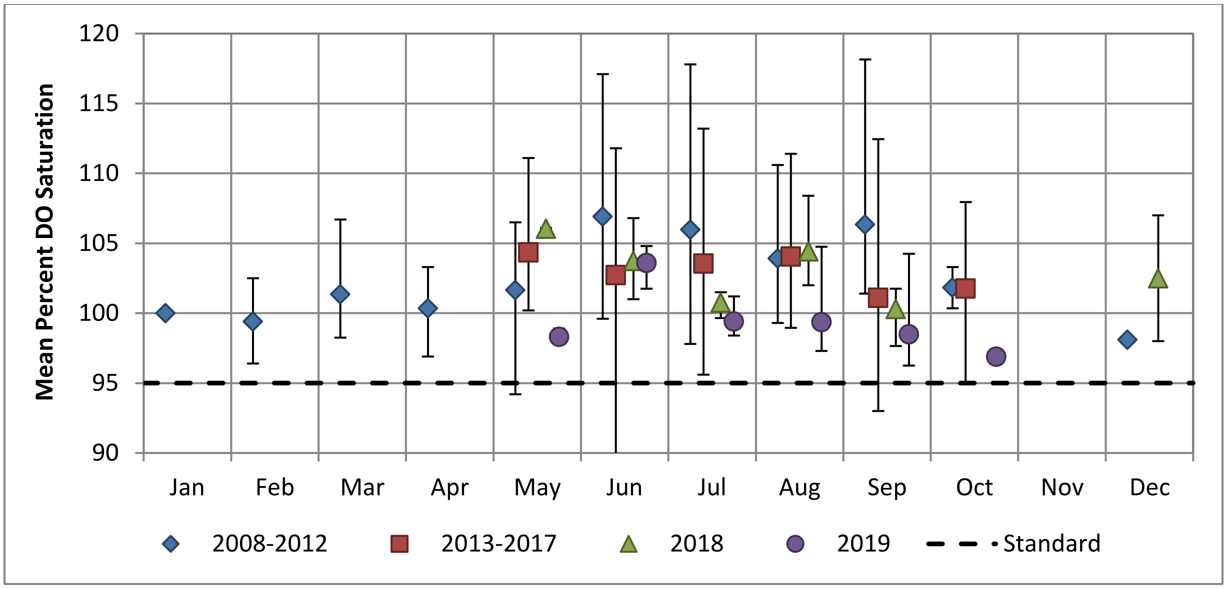


Figure 7.2.7 Monthly average dissolved oxygen (% saturation; points) and range (minimum-maximum; whiskers) at Nooksack River site SW118 annually for the 2018-2019 reporting period, two five-year periods of record (2008-2012, 2013-2017), and dissolved oxygen percent saturation criterion. Months shown had temperatures that precluded 100% saturation of the water at the 11 mg/L criterion or did not have associated temperature data available; therefore, the percent saturation criterion was used to determine compliance. When temperatures allowed 100% saturation of the water at the 11 mg/L criterion, the mg/L criterion was used (see Figure 7.2.6).

The Nooksack River at Marine Drive Bridge (SW118) is a Class AA (Extraordinary) freshwater site subject to a seven-day mean minimum (7DADM) DO concentration. It is unlikely that any of the discrete DO measurements collected at this site have captured a minimum DO concentration because all samples were collected between 9:00 am and 4:30 pm (*i.e.,* during daylight hours). Dissolved oxygen concentrations typically are at their lowest during the night, when no sunlight is available for photosynthesis, and aquatic biota consume the oxygen in the water through respiration.

The single DO measurement that exceeded the DO standard during the 2018-2019 reporting period was only slightly below the 11 mg/L DO criterion (10.75 mg/L). The WQM Program accepted accuracy for dissolved oxygen is ±10%, although manufacturer-reported accuracy is ±2% for most DO measurements since April 2008. The single DO measurement during the reporting period is within 10% of the criterion, but not within 2% of the criterion; because the measurement is within the 10% accepted error for the WQM Program, this measurement is not definitive evidence of the site failing to meet the standard during the reporting period. All six DO exceedances over the ten-year period of record are also within 10% of the criterion. One of these measurements, 85.6% saturation in June 2015, was only marginally within 10% of the DO percent saturation criterion. On the other hand, the WQM Program acceptable error of the DO sensor may also be overestimating the actual DO concentration or saturation, as indicated by 45 DO concentrations (as mg/L) within 10% of the 11 mg/L criterion.

Although accepted WQM Program error for DO provides justification for discounting the DO measurements below the criteria, the fact that discrete measurements are unlikely to capture the minimum DO concentration for a 24-hour period suggests that actual minimum DO concentrations are likely lower than those included in the dataset. For this reason, the DO measurement below the DO criteria, but within 10%, should be considered evidence that DO is a concern in the Nooksack River at Marine Drive, at least during some years and some seasons. This is consistent with the Washington State Department of Ecology listing of several stretches of the Nooksack River on its 303(d) list for dissolved oxygen impairment, including the Nooksack River from Tenmile Creek to Marine Drive. As described above, it is unlikely that minimum DO concentrations have been measured during daytime discrete sampling, and it is advisable to conduct continuous DO monitoring when feasible to accurately determine compliance with the DO standard at this site. It is likely that DO excursions below the DO criteria occur more frequently than suggested by discrete sampling.

7.2.2.3 Portage Bay

All marine sites in Portage Bay had dissolved oxygen measurements above the Class A marine dissolved oxygen criterion, 6 mg DO/L, during the reporting period 2018-2019. In addition, all marine sites in Portage Bay had dissolved oxygen measurements above the Class A marine DO criterion for both five-year periods of record (2008-2012 and 2013-2017). This included all sites in Portage Bay sampled as part of the NSSP (DOH Support) and Surface Water Projects. Very little DO data are available for NSSP sites in Portage Bay for the 2008-2012 period of record because almost all NSSP sampling in Portage Bay was conducted by DOH until 2014, when LNR commenced additional NSSP sampling activities in Portage Bay, including measurement of DO. Only two to four DO samples were available for the 2008-2012 period of record for Portage Bay NSSP sites.

Mean dissolved oxygen and the mean minimum to maximum range was calculated for three areas of Portage Bay, based on geography and NSSP classification status.[15] The northern area is located primarily along Lummi Shore Road in the Conditionally Approved portion of the Portage Bay shellfish growing area and includes six NSSP sites. The eastern area is located east of Brant Spit in the Approved, but Threatened, portion of the Portage Bay shellfish growing area and includes two NSSP sites. The southern area is located nearest Portage Island in the Approved portion of the Portage Bay shellfish growing area and includes three NSSP sites and two ambient Surface Water Project sites. All areas had periods of record and reporting period means and average ranges above the DO standard. Mean DO was similar for all areas of Portage Bay. Mean DO (mg/L) was similar during the 2013-2017 period of record and the 2018-2019 reporting period, but was slightly higher during the 2008-2012 period of record. This may be due in part to limited DO data available for NSSP sites until 2014. The average range of percent DO saturation was widest for the 2013-2017 period of record. This is also likely due to limited data available for 2008-2012 and due to the longer time period assessed for the period of record (five years) than the reporting period (two years), which can lead to wider variability.

[15] North: DH049, DH272, DH050, DH051, DH271, DH052. East: DH057, DH058. South: DH053, DH054, DH055, SW006, SW023.

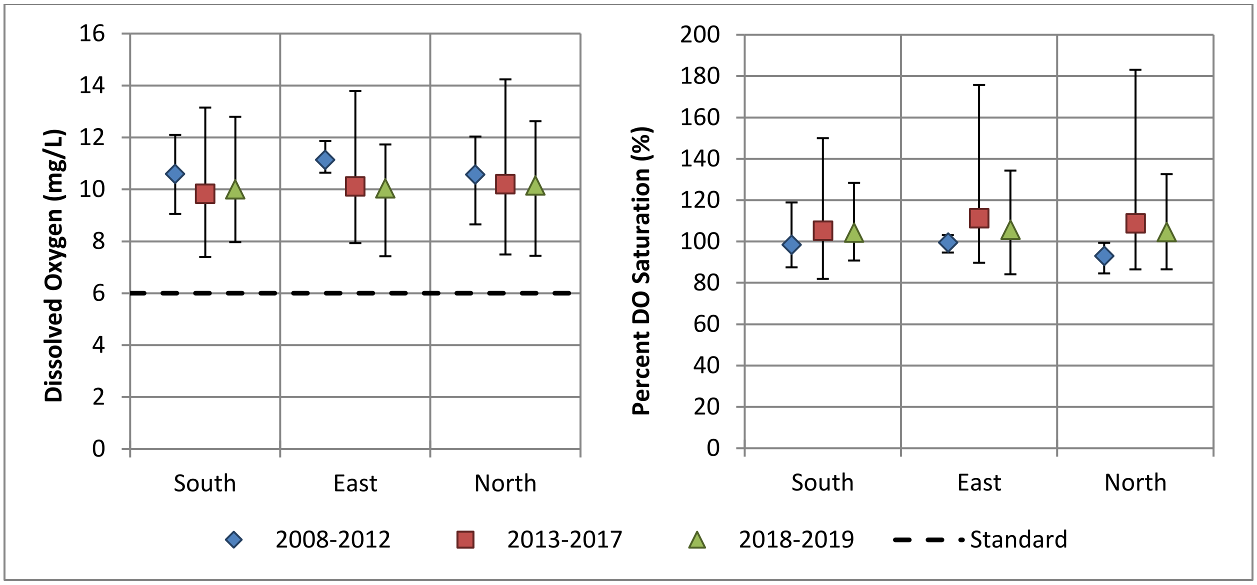


Figure 7.2.8 Mean dissolved oxygen, as mg/L (left) and percent saturation (right), and average range (average minimum-average maximum; whiskers) for sites in Portage Bay over the reporting period (2018-2019) and two five-year periods of record (2008-2012 and 2013-2017). South Portage Bay comprises five sites in the Approved NSSP shellfish growing area, East Portage Bay comprises two sites in the Approved, but Threatened, NSSP shellfish growing area east of Brant Spit, and North Portage Bay comprises six sites in the Conditionally Approved NSSP shellfish growing area including four sites along Lummi Shore Road. Marine Class A dissolved oxygen (mg/L) standard shown for reference.

Although no exceedances of the DO criteria were observed in the marine waters of Portage Bay during the reporting period, it is likely that the minimum DO concentration was not measured due to sampling only during daylight hours, as described above. The results do not indicate that any sites in Portage Bay are failing to meet the standard; however, due to lack of continuous monitoring, these discrete sample results cannot be used to definitively conclude that these areas are compliant with the DO standard.

7.2.2.4 Portage Bay Watershed

Freshwater systems that flow into Portage Bay include: the Nooksack River, Kwina Slough, Silver Creek, small drainages along the eastern side of the Lummi Peninsula (Lummi Shore Road), and small drainages on Portage Island. The discussion of DO results for the Nooksack River is located in Section 7.2.2.2 above. Overall, 60-78% of freshwater sites monitored in the Portage Bay watershed failed to meet the dissolved oxygen standard during the reporting period 2018-2019 (Table 7.2.4).

Mean dissolved oxygen was calculated as mg/L and percent saturation for all data (not filtered by temperature) at freshwater sites in the Portage Bay watershed; summary data are presented with the minimum-maximum range for the reporting period and two periods of record (Figure 7.2.9 and Figure 7.2.10). Note that DO concentrations or percent saturation below the criteria presented here do not necessarily imply a failure to meet the standard because the relevant criterion (mg/L or percent saturation) depends on temperature at the time of measurement.

For example, a site may not meet the percent saturation criterion but meets the mg/L criterion, and conversely, a site may not meet the mg/L criterion but does meet the percent saturation criterion, especially when high temperatures preclude attainment of the mg/L criterion at 100% saturation.

Mean DO (mg/L) was below the criterion at two sites on Portage Island and one site along Lummi Shore Road for the reporting period. Mean percent saturation was below the criterion at all sites on Portage Island and along Lummi Shore Road for the reporting period. The mean and range of DO was within the range of DO measurements collected over the period of record for both concentration (mg/L) and percent saturation, with the exception of a lower minimum range at Portage Island site SW027 during the reporting period as compared to the periods of record. Sites on Portage Island show a decreasing trend in dissolved oxygen over time for both DO concentration (mg/L) and percent saturation.

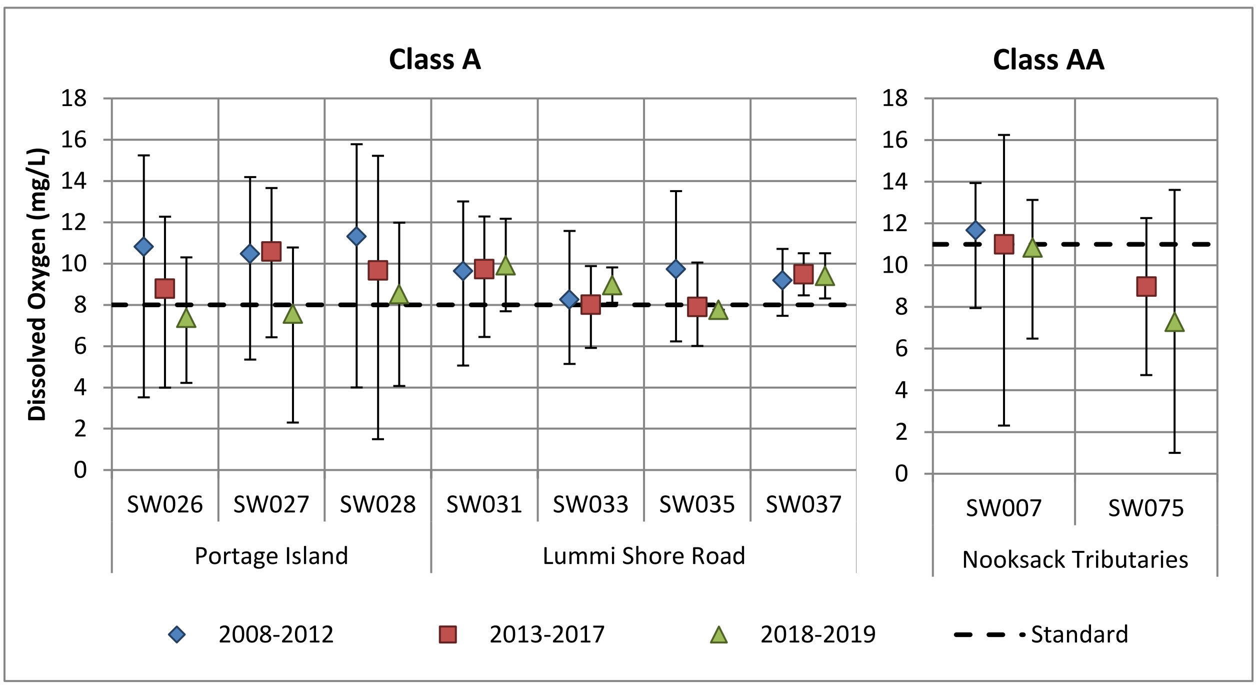


Figure 7.2.9 Mean (points) and range (minimum-maximum; whiskers) dissolved oxygen (mg/L) for two-year reporting period 2018-2019 and two five-year periods of record (2008-2012, 2013-2017) at freshwater Class A and Class AA sites in the Portage Bay watershed. Dissolved oxygen mg/L criterion shown for reference. No data for SW075 for 2008-2012 period of record.

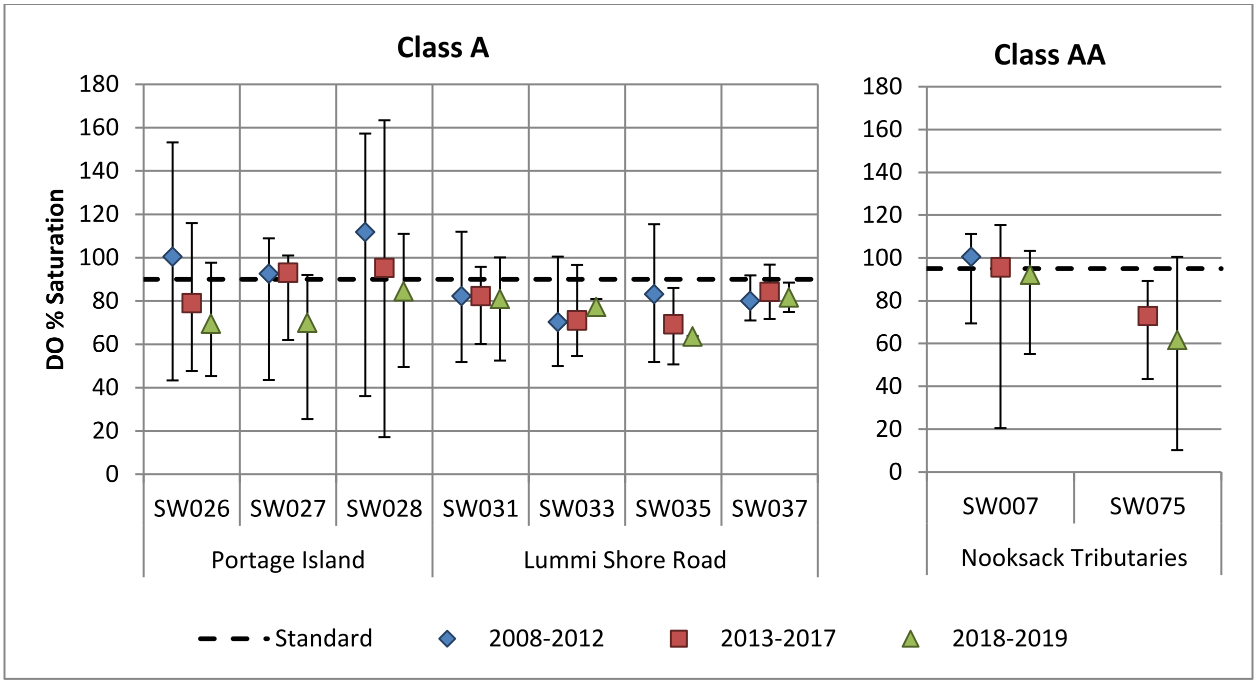


Figure 7.2.10 Mean (points) and range (minimum-maximum; whiskers) dissolved oxygen (percent saturation) for two-year reporting period 2018-2019 and two five-year periods of record (2008-2012, 2013-2017) for freshwater Class A and Class AA sites in the Portage Bay watershed. Dissolved oxygen percent saturation criterion shown for reference. No data for SW075 for 2008-2012 period of record.

Compliance with the DO standard is summarized as the percentage of measurements exceeding the standard for the reporting years and on average for the periods of record (Table 7.2.4). The proportion of years failing to meet the standard is also shown as a fraction of years assessed (i.e., excluding years with no data) for the periods of record. All sites on Portage Island and the single sites at Kwina Slough and Silver Creek failed to meet the standard during both reporting years. Three sites along Lummi Shore Road had no excursions of the DO criteria during 2018 and two sites had no excursions below the DO criteria during 2019.

Sites on Portage Island have an increasing proportion of DO measurements below the criteria over time. Over the period of record, the three Portage Island sites exceeded the standard 7-27% of the time while exceedances occurred 20-67% of the time during the reporting period. At two sites along Lummi Shore Road (SW033 and SW037), the frequency of exceedances decreased from a high of 43% of the time to 0% of the time during the reporting period. However, throughout the period of record, these two sites had years during which no exceedances of the DO criterion occurred. Part of the change in frequency of exceedances may also be due to a change in the frequency of site visits; site visit frequency was changed from monthly to six time per year in 2013 for sites along Lummi Shore Road and 2016 for sites on Portage Island. In addition, due to intermittent flow at these sites, annual compliance with the DO standard is often determined using fewer than six samples; during the reporting period, sites on Portage Island were sampled three to five times per year and sites along Lummi Shore Road were sampled zero to two times per year. The small sample size leads to either very high or very low frequencies of exceedance, especially when the site is sampled only once during the year.

For tributaries to the Nooksack River, Silver Creek and Kwina Slough continued to have a similar frequency of exceedances as over the period of record. Silver Creek site SW075 was routinely sampled as part of the Surface Water Project beginning in 2016, resulting in a two-year period of record for comparison. As discussed above, the frequency of exceedances in the mainstem Nooksack River remains very low and within the range of historic observations.

Table 7.2.4 Percent of measurements exceeding freshwater Class A and AA DO criteria in the Portage Bay watershed by freshwater drainage during the reporting years 2018 and 2019, average percentage of measurements failing to meet the standard by year and number of years failing to meet the standard over (/) total years assessed for two five-year periods of record (2008-2012 and 2013-2017). Sites/periods in red failed to meet the standard for the year or more than 50% of the time for the period of record, sites/periods in green had no excursions below the criteria, and sites/periods in orange failed to meet the standard during at least one year during the period of record, but less than 50% of the time.

Period	Class A Freshwater							Class AA Freshwater		
	Portage Island			Lummi Shore Road				Nooksack + Tributaries		
	SW026	SW027	SW028	SW031	SW033	SW035	SW037	SW118	SW007	SW075
2008-2012	23% 4/5	14% 3/5	15% 3/5	29% 3/5	43% 5/5	28% 3/5	42% 2/4	0.6% 1/5	7% 2/4	nd
2013-2017	21% 3/5	7% 1/5	27% 4/5	24% 2/5	38% 3/5	62% 5/5	0% 0/2	3.1% 4/5	21% 5/5	73% 2/2
2018	40%	60%	20%	0%	0%	100%	0%	0%	22%	100%
2019	50%	67%	50%	50%	0%	nd	0%	2%	29%	89%

nd = no data

Overall, eight out of ten freshwater sites in the Portage Bay watershed failed to meet the DO standard during at least one of the reporting years 2018-2019, including at least two sites in each area. This indicates that water quality in the freshwater watersheds flowing to Portage Bay is not protective of the designated uses, including salmonid use, due to DO impairment.

7.2.2.5 Lummi Bay

Lummi Bay, Sandy Point Marina, and Hale Passage are designated Class AA marine waters, with a DO criterion of 7 mg/L. In addition, the marine receiving waters and brackish tidally-influenced portions of the Lummi River, Jordan Creek, and Smuggler Slough are designated Class AA marine waters. The downstream brackish and marine sites are included as part of the Lummi Bay watershed freshwater assessment and discussion below in Section 7.2.2.6.

Dissolved oxygen in Lummi Bay, Sandy Point Marina, and Hale Passage Class AA marine waters during the 2018-2019 reporting period were within the range observed over the period of record (2008-2017). Mean dissolved oxygen for all sites was above the 7 mg/L Class AA marine DO criterion. However, three sites had discrete DO measurements that were below the criterion during the 2018-2019 reporting period: South Lummi Bay site SW002, Sandy Point site

SW019, and Hale Passage site DH048. Over the period of record, all sites except North Lummi Bay/Onion Bay site DH038, had at least one year with excursions below the DO criterion.

The mean and average range (average minimum-maximum) of DO measurements (as mg/L and percent saturation) for the two-year reporting period (2018-2019) and two five-year periods of record (2008-2012, 2013-2014) were calculated for each Class AA marine area (Figure 7.2.11). The number of sites and WQM Program project under which the sites are sampled varied by area: North Lummi Bay/Onion Bay includes five sites sampled as part of the DOH Support (NSSP) Project; South Lummi Bay includes five sites sampled as part of the DOH Support (NSSP) Project and one site sampled as part of the Surface Water Project; the Lummi seaponds aquaculture facility (Seaponds) includes two sites sampled as part of the DOH Support (NSSP) Project; Sandy Point includes two sites sampled as part of the Surface Water Project; and Hale Passage has one site sampled as part of Portage Bay NSSP monitoring for the DOH Support Project and one site sampled as part of the Surface Water Project.[16] Note that since averages were used, this analysis does not address site-by-site compliance with the DO standard.

Mean DO in each Class AA marine area was similar during the reporting period as during the periods of record for both DO concentration (mg/L) and percent saturation, with a slight decrease in the mean at the Seaponds and Sandy Point. The average range of dissolved oxygen measurements observed in Class AA marine waters decreased over time, with less variability during the reporting period than during the period of record. The decreased variability may be due to the number of years summarized in the metrics: only two years in the reporting period, and five years in each of the periods of record. On average, minimum DO measurements (mg/L) were lowest during the 2008-2012 period of record and highest during the 2018-2019 reporting period in all areas except Hale Passage. Similarly, average minimum DO percent saturation measurements were lowest during the 2008-2012 period of record in all areas except the Seaponds, and average minimum DO was higher during the 2018-2019 reporting period than during 2008-2012 for all areas.

[16] North Lummi Bay/Onion Bay: DH038, DH285, DH286, DH287, DH288. South Lummi Bay: DH039, DH040, DH041, DH042, DH043, SW006. Seaponds: DH044, DH045. Sandy Point: SW001, SW019. Hale Passage: DH048, SW039.

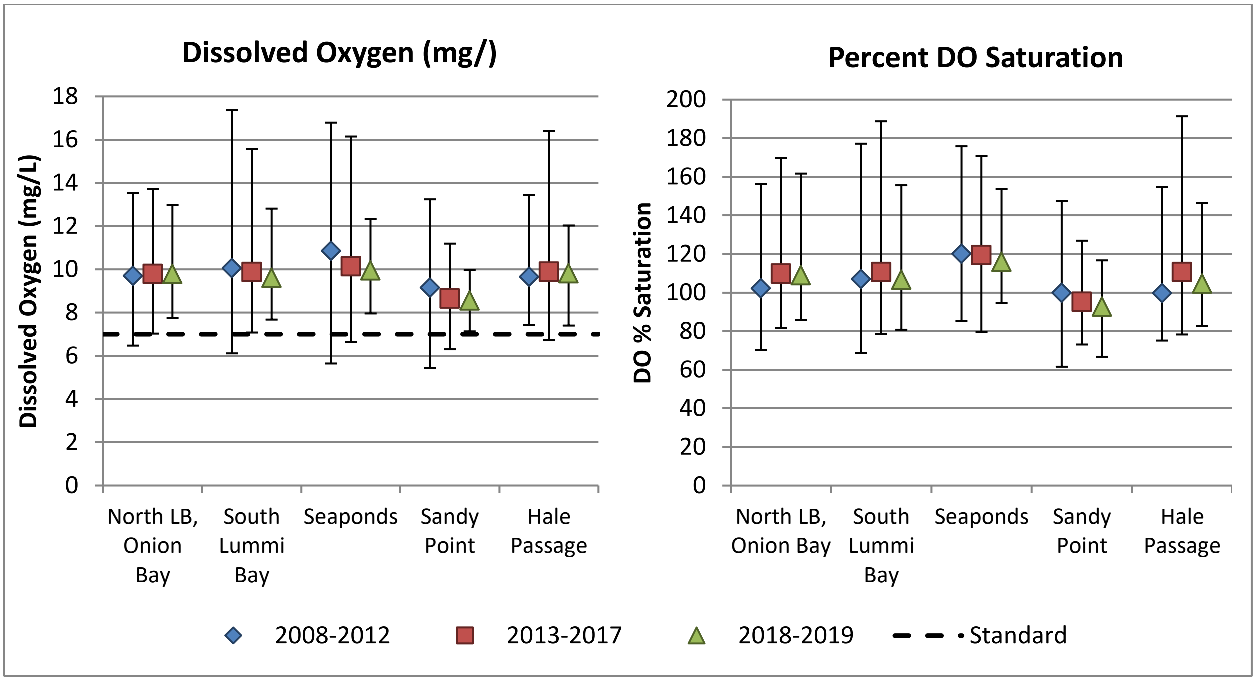


Figure 7.2.11 Mean (points) and average range (average minimum-average maximum; whiskers) dissolved oxygen concentration (mg/L; left) and percent saturation (right) at Class AA marine sites summarized by area. North Lummi Bay/Onion Bay includes five sites, South Lummi Bay includes six sites, and Seaponds, Sandy Point, and Hale Passage each include two sites. Class AA Marine DO criterion (mg/L) shown for reference; there is no percent saturation criterion for marine waters.

Compliance with the DO standard is summarized as the percentage of measurements exceeding the standard for the reporting years (Table 7.2.5). For the period of record, the average and range (minimum-maximum) percentage of measurements exceeding the standard each year is presented as well as the proportion of years failing to meet the standard as a fraction of years assessed (i.e., excluding years with no data). During the reporting period, all sites in North Lummi Bay/Onion Bay and within the Seaponds met the DO standard in that there were no measured excursions above the Class AA marine DO criterion (Table 7.2.5). Other areas were variable, with sites in South Lummi Bay and Sandy Point having no excursions below the criterion during 2018 but failing to meet the DO standard during 2019, and Hale Passage failing to meet the DO standard during 2018 but with no excursions below the criterion during 2019.

The majority of areas had a frequency of exceedance within the range observed over the period of record, with the exception of Hale Passage. During 2018, Hale Passage site DH048 had 20% of DO measurements below the criterion, which was greater than the maximum frequency observed over the period of record. However, routine monitoring of DO at Hale Passage site DH048 commenced in 2014, resulting in a shorter period of record for this site than for the other Hale Passage site, SW039, which may explain the apparent higher frequency observed during the reporting period.

Although all areas had at least one site failing to meet the DO standard during at least one year over the two five-year periods of record, most sites in North Lummi Bay/Onion Bay, South

Lummi Bay, and the Seaponds had no measured excursions below the DO criterion during most years. One site in North Lummi Bay/Onion Bay, DH038, has had no measured excursions below the DO criterion since 2008. Six sites in Lummi Bay (DH285, DH288, DH039, DH040, DH041, and DH043) have had no excursions below the DO criterion over the last ten years (2010-2019). North Lummi Bay/Onion Bay has had no sites with DO excursions below the criterion since 2015 and the Seaponds has had no sites with excursions below the criterion since 2016. However, because most DO measurements are collected during daylight hours, it is unlikely that discrete DO measurements have captured the daily minimum concentration. The presence of discrete DO measurements below the criterion in South Lummi Bay, Sandy Point, and Hale Passage during the reporting period indicates that the DO standard is not being met, at least periodically, in these areas.

Table 7.2.5 Summary of compliance with the dissolved oxygen standard in Class AA Marine waters in Lummi Bay, the Seaponds, Sandy Point, and Hale Passage. Mean and range (minimum-maximum) percent of measurements failing to meet DO criterion in Class AA Marine sites by area for reporting years 2018 and 2019 and for two five-year periods of record (2008-2012, 2013-2017). Sites in each area were averaged for each period with range representing the minimum and maximum single-year single-site frequency of exceedance. For periods/areas with any exceedances of the DO criterion, number of site-years failing to meet the DO standard over (/) the total number of site-years assessed is shown. Red indicates area failed to meet the DO standard during the reporting year or more than 50% of site-years failed to meet the DO standard during the period of record, green indicates no excursions above the DO criterion during the period, and orange indicates some sites in the area failed to meet the DO standard during some years, but less than 50% of the time.

Period	North Lummi Bay, Onion Bay	South Lummi Bay	Seaponds	Sandy Point	Hale Passage
2008-2012	5% (0-33%) 5/25	5% (0-43%) 6/30	7% (0-33%) 3/10	7% (0-14%) 7/10	1% (0-8%) 1/6
2012-2017	1% (0-13%) 2/25	1% (0-17%) 3/30	3% (0-20%) 2/10	9% (0-20%) 6/10	1% (0-14%) 1/9
2018	0%	0%	0%	0%	10% (0-20%) 1/2
2019	0%	3% (0-17%) 1/6	0%	8% (0-17%) 1/2	0%
Number of Sites	5	6	2	2	2*

*Hale Passage site DH048 has no data for 2008 or 2010-2013, resulting in fewer than 10 site-years for the period of record.

As previously described, it is unlikely that the minimum DO concentration was measured during discrete sampling because all sampling was conducted during daylight hours. For this reason, concluding that sites with all DO measurements above the DO criterion are compliant with the DO standard is not appropriate; at best, we can conclude that monitoring does not suggest DO impairment in North Lummi Bay/Onion Bay and the Seaponds during the reporting period. However, for the 2018-2019 reporting period, Class AA marine waters in South Lummi Bay, Sandy Point, and Hale Passage are not protective of the designated uses, including salmonid use, due to DO impairment.

7.2.2.6 Lummi Bay Watershed

Freshwater systems that flow into Lummi Bay include: Jordan Creek/North Lummi River Distributary, the Lummi River, Smuggler Slough, Onion Creek, and Seapond Creek. These watersheds include Class AA freshwater designated sites and Class AA marine designated sites that are assessed together in this section. Note that the DO criteria are different for freshwater and marine designated sites.

Mean dissolved oxygen was calculated as mg/L and percent saturation for all data (not filtered by temperature) at sites in the freshwater systems that flow to Lummi Bay, including both the freshwater sites and downstream marine sites in the tidally influenced portions of the watersheds and the marine receiving waters. Summary data are presented with the mean for each site and minimum-maximum range for the reporting period and two periods of record (Figure 7.2.12). Note that DO concentrations or percent saturation below the freshwater criteria presented here do not necessarily imply a failure to meet the standard because the relevant criterion (mg/L or percent saturation) depends on temperature at the time of measurement. For example, a site may not meet the percent saturation criterion but meets the mg/L criterion, and conversely, a site may not meet the mg/L criterion but does meet the percent saturation criterion, especially when high temperatures preclude attainment of the mg/L criterion at 100% saturation. Note that there is no percent saturation criterion for Marine Class AA waters.

Mean dissolved oxygen (as mg/L and percent saturation) was below the DO criterion at all freshwater sites in the Lummi River watershed for the period of record and the reporting period 2018-2019. Marine sites in the Lummi River, which include the brackish tidally influenced waters at site SW008 and the mouth of the Lummi River as it discharges into Lummi Bay (SW051), were at or above the DO (mg/L) marine criterion for the period of record and reporting period. Mean DO (mg/L) appears to have increased at site SW012 and decreased at SW013 and SW009, but the trends in percent DO saturation are less pronounced. In the Jordan Creek/North Lummi River Distributary watershed, Jordan Creek at Slater Road (SW011) was at or slightly above the DO criteria (mg/L and percent saturation) while the other two freshwater sites were below both criteria. The marine receiving waters were, on average, above the DO mg/L marine criterion. The marine receiving waters and outlets of the Lummi River and Jordan Creek/North Lummi River Distributary had higher mean DO than the sites located just upstream.

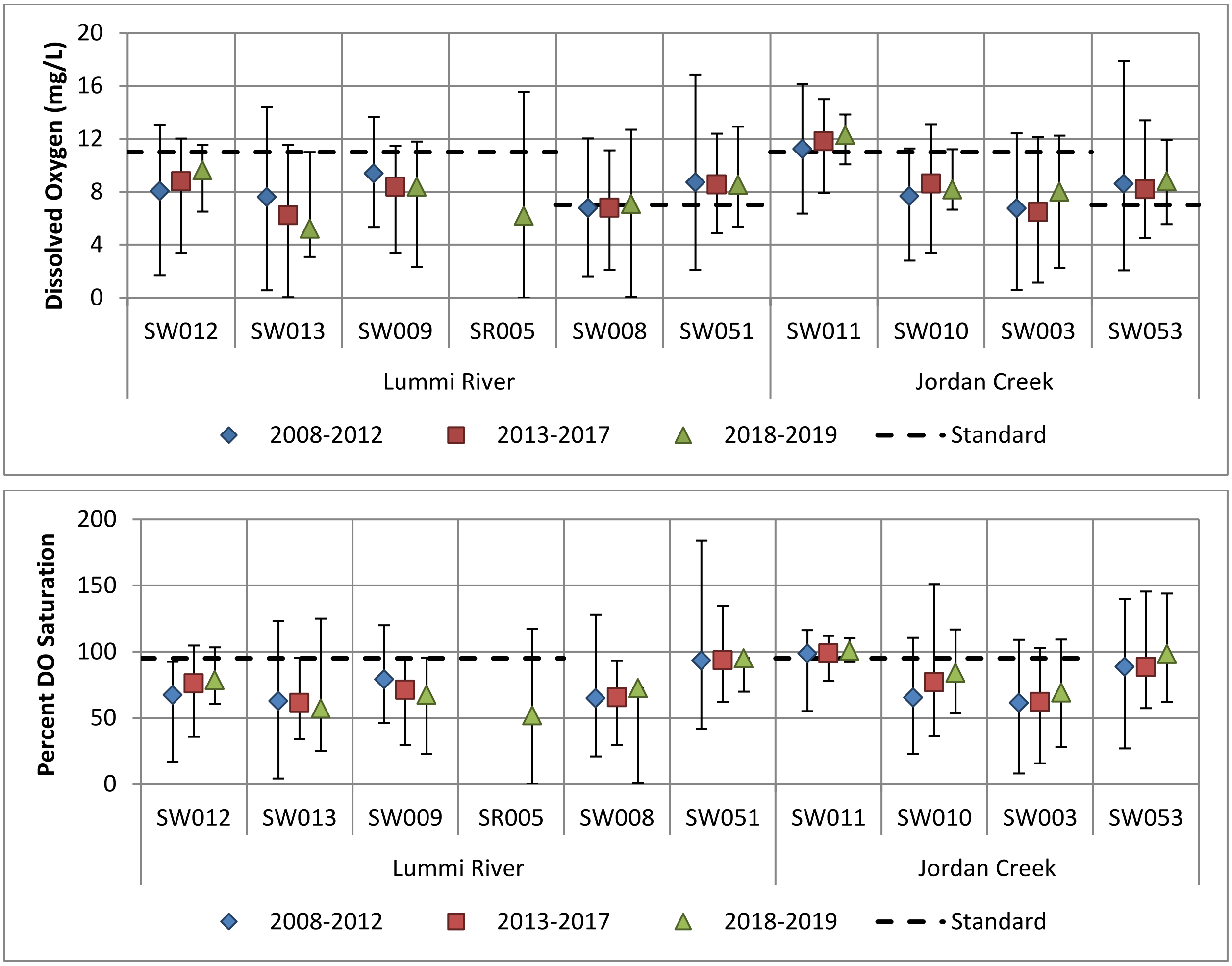


Figure 7.2.12 Summary of dissolved oxygen conditions as concentration (mg/L; top) and percent saturation (bottom) for sites in the Lummi River and Jordan Creek/North Lummi River Distributary watersheds. Mean (points) and range (minimum-maximum; whiskers) dissolved oxygen for two-year reporting period 2018-2019 and two five-year periods of record (2008-2012, 2013-2017) at freshwater Class AA and marine Class AA sites in the Lummi Bay watershed. Freshwater Class AA and Marine Class AA dissolved oxygen criteria and Freshwater Class AA percent saturation criterion shown for reference. In the Lummi River watershed, sites SW012, SW013, and SW009 are at the northern Reservation boundary, SR005 is located downstream of the confluence of these three streams, site SW008 is the brackish tidally-influenced site further downstream, and SW051 is the mouth of the Lummi River as it flows into Lummi Bay. In the Jordan Creek watershed, sites SW011 and SW010 are located on the northern Reservation boundary, site SW003 is located downstream of the confluence of the two streams, and SW053 represents the marine receiving waters at the mouth of the Jordan Creek/North Lummi River Distributary.

In Smuggler Slough, all freshwater sites had mean DO (as mg/L and percent saturation) less than the DO criterion. At marine sites in Smuggler Slough, mean DO (mg/L) was at the marine criterion at sites SW059 and SW055 and above at SW056. Onion Creek (SW014) had mean DO (mg/L and percent saturation) below the freshwater criterion while Seaponds Creek (SW029) had mean DO just above the mg/L criterion and just at the percent saturation DO criterion.

Dissolved oxygen appears to have decreased at site SW017 over the period of record. All other sites show year-to-year variation with no clear trends in mean over time.

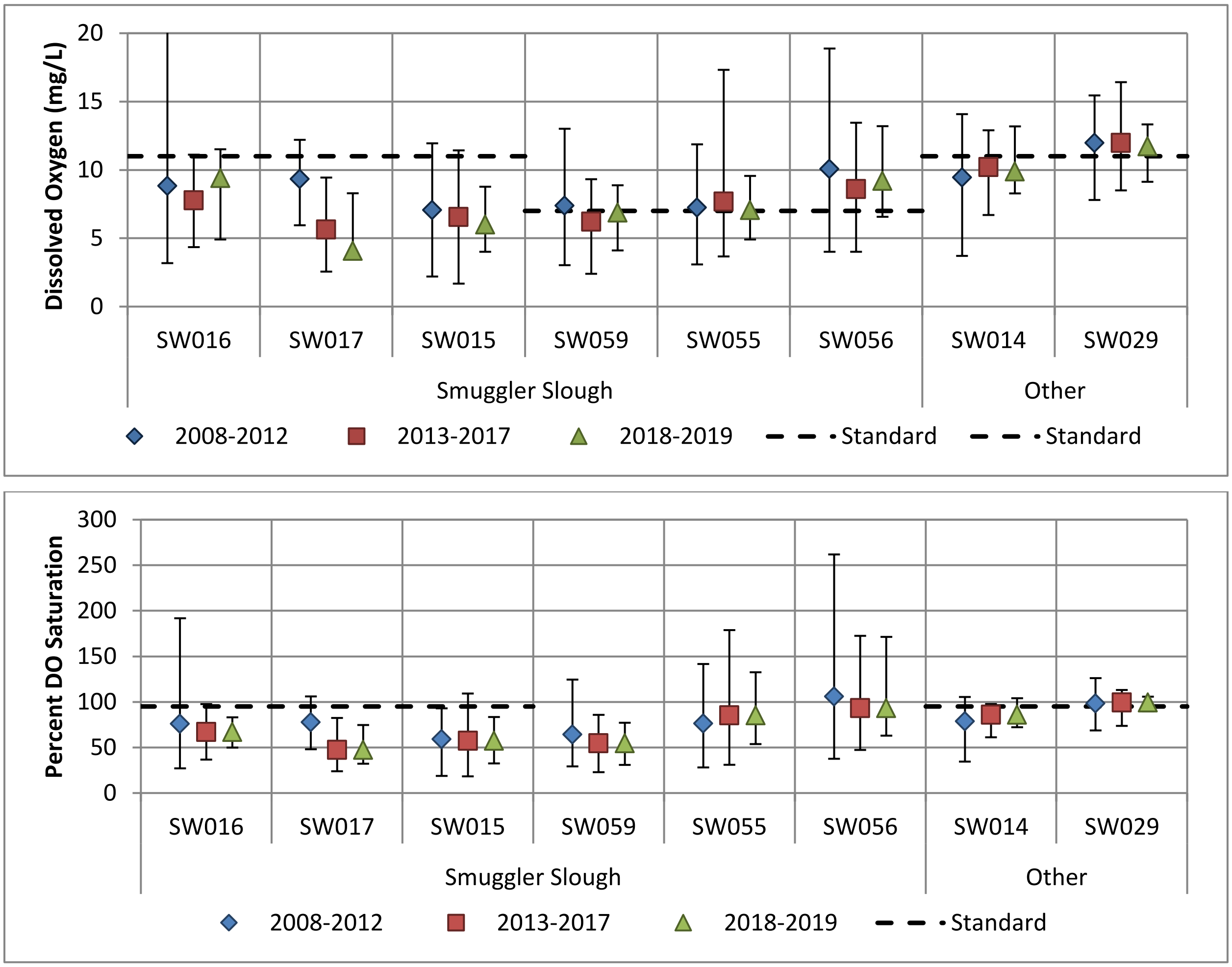


Figure 7.2.13 Summary of dissolved oxygen conditions as concentration (mg/L; top) and percent saturation (bottom) for sites in the Smuggler Slough, Onion Creek (SW014), and Seaponds Creek (SW029) watersheds. Mean (points) and range (minimum-maximum; whiskers) dissolved oxygen for two-year reporting period 2018-2019 and two five-year periods of record (2008-2012, 2013-2017) at freshwater Class AA and marine Class AA sites in the Lummi Bay watershed. Freshwater Class AA and Marine Class AA dissolved oxygen criteria and Freshwater Class AA percent saturation criterion shown for reference. In the Smuggler Slough watershed, sites SW016 and SW017 are located on the eastern Reservation boundary, site SW015 is located mid-way, SW059 is the brackish tidally-influenced site further downstream, and SW055 and SW056 represent the mouths of Smuggler Slough as it flows into Lummi Bay. Site SW014 is Onion Creek at the northern Reservation boundary. Site SW029 is Onion Creek as it crosses Haxton Way.

Compliance with the DO standard is summarized as the percentage of measurements exceeding the standard for the reporting years and on average for the periods of record (Table 7.2.6). The proportion of years failing to meet the standard is also shown as a fraction of years assessed (i.e., excluding years with no data) for the periods of record. All freshwater and marine Class AA sites in drainages that flow into Lummi Bay failed to meet the DO standard during each of the reporting years 2018 and 2019 (Table 7.2.6). Nearly all sites failed to meet the DO standard during more than half of the years assessed for both periods of record 2008-2012 and 2013-2017.

The lowest freshwater noncompliance rates for the reporting period were at SW011, Jordan Creek at Slater Road, and SW029, Seapond Creek (Figure 7.2.14, Table 7.2.6). These sites have significant canopy cover and are shaded during the summer months. At all other freshwater sites, more than half of measurements failed to meet the DO standard. During the period of record, however, there were some years during which there were no exceedances of the DO criterion. Sites SW009, SW011, SW010, and SW029 all had at least one year during the period of record with no observed exceedances of the DO criteria (i.e., a minimum noncompliance rate of 0% in Figure 7.2.14). All reporting years had a proportion of samples exceeding the criteria within the range observed during the period of record. The noncompliance frequency rate for the reporting period was similar to the range observed over the ten-year period of record.

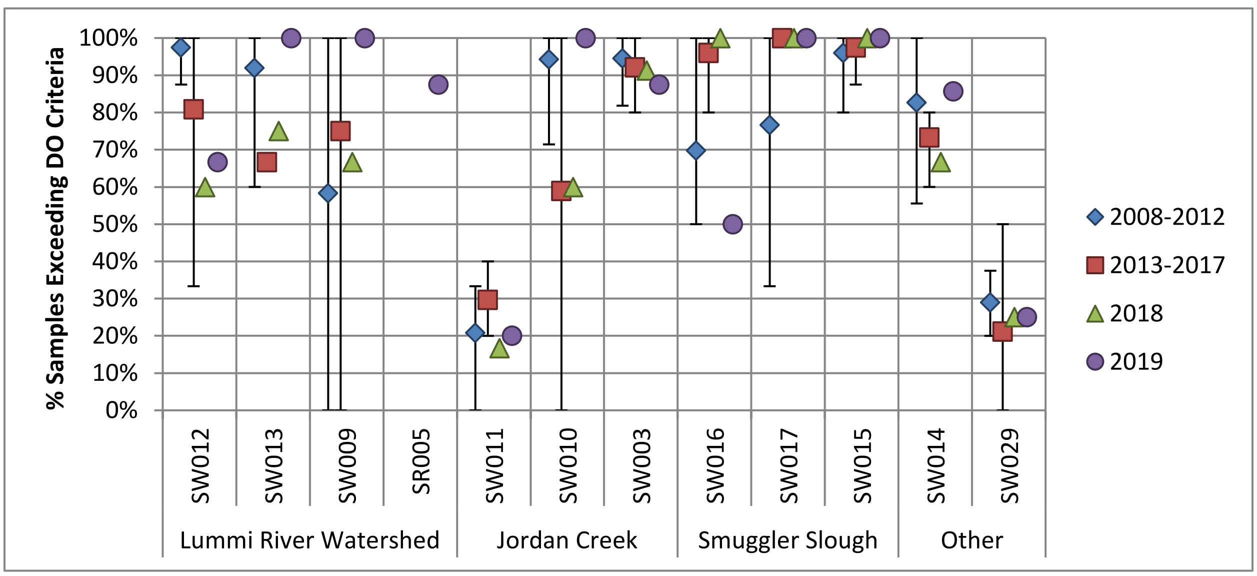


Figure 7.2.14 Frequency of Class AA freshwater dissolved oxygen measurements exceeding the criteria (i.e., below the mg/L or percent saturation criteria) for the reporting period (2018-2019) annually and on average for the two five-year periods of record. Whiskers represent the range (minimum to maximum) of the frequency of exceedance for years in each period or record.

The lowest noncompliance rates within each watershed were, with the exception of Jordan Creek site SW011, observed at the marine sites representing the marine receiving waters or mouths of the systems as they enter Lummi Bay. In Smuggler Slough, site SW056 was the only site flowing to Lummi Bay that had a noncompliance rate of less than 50% over the period of record. The lower noncompliance rate in marine classified waters is due to the much lower DO criterion for marine waters: 7 mg/L for Class A marine sites versus 11 mg/L for Class AA freshwater sites.

Table 7.2.6 Summary of compliance with the freshwater Class AA and marine Class AA DO criteria in the Lummi River and Jordan Creek/North Lummi River Distributary watersheds for the reporting period (2018-2019) and two five-year periods of record (2008-2012 and 2013-2017). Percent of DO measurement failing to meet the relevant DO criteria (mg/L or percent saturation for freshwater sites; mg/L for marine) shown for reporting years. Average frequency of exceedances per year for the period and the number of years failing to meet the DO standard over (/) the total number of years assessed shown for the periods of record. Sites failed to meet the DO standard if one DO measurement was below the appropriate criterion (mg/L or % saturation, depending on temperature). Red indicates failure to meet the DO standard for the reporting year or more than 50% of years for the period of record.

Period	Lummi River						Jordan Creek/North Lummi River Distributary			
	Freshwater				Marine		Freshwater			Marine
	SW012	SW013	SW009	SR005	SW008	SW051	SW011	SW010	SW003	SW053
2008-2012	98% 5/5	92% 5/5	58% 3/4	nd	48% 5/5	24% 5/5	21% 4/5	94% 5/5	95% 5/5	27% 5/5
2013-2017	81% 5/5	67% 1/1	75% 3/4	nd	49% 5/5	25% 5/5	30% 5/5	59% 3/4	92% 5/5	33% 5/5
2018	60%	75%	67%	nd	45%	29%	17%	60%	91%	22%
2019	67%	100%	100%	88%	42%	24%	20%	100%	88%	12%

nd: no data

Table 7.2.7 Summary of compliance with the freshwater Class AA and marine Class AA DO criteria in the Smuggler Slough, Onion Creek (SW014), and Seaponds Creek (SW029) watersheds for the reporting period (2018-2019) and two five-year periods of record (2008-2012 and 2013-2017). Percent of DO measurement failing to meet the relevant DO criteria (mg/L or percent saturation for freshwater sites; mg/L for marine) shown for reporting years. Average frequency of exceedances per year for the period and the number of years failing to meet the DO standard over (/) the total number of years assessed shown for the periods of record. Sites failed to meet the DO standard if one DO measurement was below the appropriate criterion (mg/L or % saturation, depending on temperature). Red indicates failure to meet the DO standard for the reporting year or more than 50% of years for the period of record. Orange indicates fewer than 50% of years failed to meet the standard for the period of record.

Period	Smuggler Slough						Other	
	Freshwater			Marine			Freshwater	
	SW016	SW017	SW015	SW059	SW055	SW056	SW014	SW029
2008-2012	70% 5/5	77% 5/5	96% 5/5	37% 5/5	50% 5/5	7% 2/5	83% 5/5	29% 4/4
2013-2017	96% 5/5	100% 3/3	98% 5/5	56% 5/5	37% 5/5	11% 2/5	73% 5/5	21% 4/5
2018	100%	100%	100%	67%	67%	25%	67%	25%
2019	50%	100%	100%	50%	33%	33%	86%	25%

Due to the failure to meet the DO standard at all sites in watersheds flowing to Lummi Bay during both years of the reporting period, water quality in these watersheds is not protective of the designated uses, including salmonid use, due to DO impairment.

7.2.2.7 Causes and Conclusions

Although the majority of freshwater sites in watersheds flowing into Portage Bay failed to meet the DO standard during at least one year during the reporting period, data for the reporting year do not indicate any DO exceedances for the marine waters of Portage Bay. This is partially be due to the relatively small contribution of freshwater into Portage Bay from the intermittent drainages that failed to meet the DO standard. The Nooksack River is the primary source of freshwater into Portage Bay and all but one Nooksack River DO measurement were within DO standards during the reporting period. As described above, continuous DO monitoring would be required to determine daily minimum DO concentrations and compliance with the DO standard especially in the Nooksack River given the importance of this river for salmonid migration and harvesting and due to DO exceedances during August for the period of record (2008-2013). Overall, the DO results for the reporting period suggest that the Class A marine waters of Portage Bay are protective of the designated uses, including salmonid migration, juvenile rearing, and harvesting. Class AA freshwaters in the Nooksack River (including Kwina Slough and Silver Creek) and Class A freshwaters along Lummi Shore Road and on Portage Island are not protective of salmonid use due to DO impairment.

Dissolved oxygen results indicate that the freshwaters flowing into Lummi Bay and the marine waters of southern Lummi Bay, the Sandy Point Marina, and Hale Passage are not protective of the designated uses, including salmonid migration, juvenile rearing, spawning, egg incubation, fry emergence, and harvesting. As described in the temperature discussion (Section 7.2.1.3), Lummi Bay is a large tideflat that is covered with shallow water during high tide and largely dewatered during low tide. Shallow water rapidly warms during the summer months, which reduces the solubility of DO into the water. Periodic low DO in Lummi Bay may be due to naturally occurring conditions.

Dissolved oxygen is increased by aeration and photosynthetic activity, and decreased by respiration by aquatic biota, biochemical oxygen demand, and loss of DO due to temperature increases. Low flowing waters without shade where the streambed is in the photic zone can have very high DO due to high photosynthetic activity or extremely low DO due to the high temperatures (which cause less oxygen to dissolve in the water) and oxygen demand (biochemical and biotic). Frequently, sites with high photosynthetic activity during the day have high oxygen demand at night, leading to a strong diurnal pattern of DO. For this reason, the DO standard requires measurement of the daily minimum DO concentration. Anthropogenic activities, such as clearing of riparian vegetation, drainage of groundwater, and nutrient and bacterial loading can result in extremes of DO variation. The extent to which anthropogenic influences have contributed to depressed dissolved oxygen levels at individual sample sites has not been investigated.

7.3. Ocean Acidification

Ocean acidification is the term given to the chemical changes in the ocean as a result of carbon dioxide (CO_2) emissions, which includes decreasing pH (*i.e.,* increasing acidity) and carbonate ion (CO_3^{2-}) concentration. Ocean acidification is related to climate change in that both are caused by increasing levels of CO_2 in the atmosphere, although nitrogen oxides, sulfur oxides, nutrients, and organic carbon also contribute to ocean acidification (Ecology 2012). The ocean absorbs about a quarter of the CO_2 anthropogenic releases into the atmosphere every year, so as atmospheric CO_2 levels increase, so do the levels in the ocean (Ecology 2012). When CO_2 is absorbed by oceans, it reacts with water (H_2O) to form carbonic acid (H_2CO_3), which decreases the pH of the water. In the presence of carbonate (CO_3^{2-}), the carbonic acid reacts to form two molecules of bicarbonate (HCO_3^-). Carbonate and bicarbonate are the most common alkalinity factors, which buffer pH changes by reacting with hydrogen ion (acid). As more acid enters the water in the form of absorbed CO_2 (as carbonic acid), less carbonate is available to buffer the pH changes, and the pH decreases (*i.e.,* becomes more acidic).

The carbonate from calcium carbonate minerals are used by many marine organisms to build their skeletons and shells. In most marine waters, calcium carbonate minerals are abundant. Ocean acidification causes the carbonate in the calcium carbonate minerals to react with acid to form bicarbonate, reducing the amount of calcium carbonate available for marine organisms to build and maintain their shells. If acidification increases further, the marine water can become corrosive to carbonate structures and cause the shells of marine organisms to dissolve.

Since the beginning of the Industrial Revolution (mid-1700s), the pH of surface ocean waters has fallen by 0.1 pH units, from 8.2 to 8.1 (Ecology 2012). Since the pH scale, like the Richter (earthquake) scale, is logarithmic, this change represents approximately a 30% increase in acidity. Over the same period of time, the average carbonate ion concentration in surface ocean waters has decreased approximately 16% (Ecology 2012). In Puget Sound, acidification conditions vary strongly by location and by season. During the winter, most Puget Sound waters are well-mixed but corrosive, while during the summer and fall are layered with the corrosive water confined to deeper subsurface waters (Ecology 2012). Acidification of Lummi Nation marine waters is of concern due to the importance of shellfish harvesting in Lummi and Portage bays, and the characteristic uses designated in the Lummi Nation Surface Water Quality Standards for shellfish: clam, oyster, and mussel rearing, spawning, and harvesting; crustaceans and other shellfish (crab, shrimp, crayfish, scallops, geoduck, etc.) rearing, spawning, and harvesting.

7.3.1. pH

The Lummi Nation Surface Water Quality Standards for pH include maximum and minimum criteria (Table 7.3.1). If discrete pH measurements are above the maximum pH criterion or are below the minimum pH criterion at any point during the year, the site fails to meet the pH standard for that year. Although the focus of this section is ocean acidification and therefore compliance with the marine pH standard, freshwater pH standard compliance will also be covered due to the importance of pH for salmonid use of Reservation waters.

Table 7.3.1 pH standards for surface waters of the Lummi Indian Reservation

<table>
<tr><th>Water Quality Class</th><th>Freshwater</th><th>Marine</th></tr>
<tr><td>Class AA (Extraordinary)</td><td rowspan="2">6.5 < pH < 8.5</td><td rowspan="2">7.0 < pH < 8.5</td></tr>
<tr><td>Class A (Excellent)</td></tr>
</table>

7.3.1.1 pH Methods

In the sections below, pH compliance was determined for the upper layer (top 6 inches) during non-stratified and stratified conditions in both marine and fresh waters. Lower stratum data, when available, were used to determine compliance in marine waters only. For the pH discussion, the stratum in question is the upper stratum unless specified as the lower stratum. Lower stratum pH compliance and trends are discussed separately in Section 7.3.1.4. The percentage of sites failing to meet the pH standard in the discussion below is the percentage failing to meet the standard out of the total number of sites assessed (i.e., excluding those with no pH data for the year or period). Compliance with the pH standard was determined annually for years 2008-2019, but are reported as averages for two five-year periods of record 2008-2012 and 2013-2017 and annually for the reporting period 2018-2019.

In late 2015, pH measurements became slow to stabilize at low ionic strength sites (e.g., Nooksack River site SW118, Seaponds Creek site SW029, and Onion Creek site SW014). Throughout 2016 and 2017, LWRD staff worked with the manufacturer to solve the problem, including replacing the pH sensor on several occasions, replacing other instrument parts, and conducting maintenance and cleaning. Beginning in June 2018, LWRD staff instituted a policy to record pH measurements after they met stabilization criteria (per the approved instrument SOP) or after five minutes (new internal procedure based on manufacturer recommendations). If the pH readings were changing quickly after five minutes at a site, as determined by field staff based on previous experience and staff discretion, pH was not recorded for the site.

Due to the challenges involved with obtaining a stable pH reading and extra attention given to pH measurements between late 2015 and June 2018, prior to the institution of the internal procedure, several sites had fewer pH measurements collected during this period of time than during previous sampling efforts. Although several pH measurements are available for all sites during this period, it is possible that the focus on obtaining a stable reading may have resulted in extra scrutiny of pH readings at the low and high ends of the typical range, including rejecting these pH readings because of field staff discretion and the known pH stabilization issues. It is also possible that pH stabilization issues had been present for some time prior to field staff noticing the problem. This may have resulted in unstable pH readings being recorded during the period of record though 2015, when the problem was initially noticed. These should be considered when interpreting the results of pH trends during the period of record and reporting period covered in this section.

7.3.1.2 Marine pH

Overall in the upper stratum of marine waters, 31% of sites failed to meet the pH standard during the reporting period, 36% in 2018 and 25% in 2019. Over the two five-year periods of record (2008-2012 and 2013-2017), an average of 29% of sites failed to meet the pH standard.

In the Class A Marine waters of Portage Bay, 38% of sites failed to meet the pH standard during 2018 while no sites failed to meet the pH standard during 2019. Over the period of record, 0-50% of sites failed to meet the standard annually; on average, 18% of sites failed to meet the pH standard during 2018-2012 and 8% failed to meet the pH standard during 2013-2017. The number of sites assessed for pH compliance increased from two to thirteen in 2014, when LNR commenced NSSP monitoring in Portage Bay. Since the increased monitoring efforts began, four years had full compliance with the pH standard while two years (2014 and 2018) had a 38% noncompliance rate (5 of 13 sites failing to meet the standard).

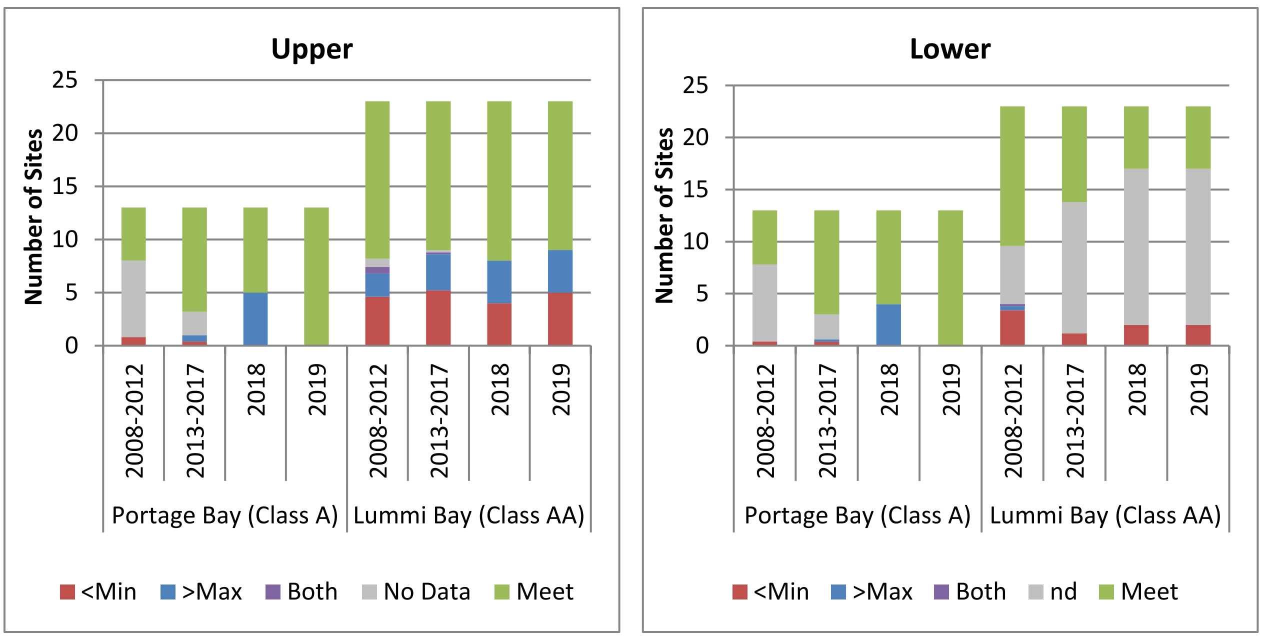


Figure 7.3.1 Summary of compliance with the pH standard in the upper (left) and lower (right) strata at Class A marine sites in Portage Bay (left on each chart) and Class AA marine sites in Lummi Bay (right on each chart) and for the reporting period (2018, 2019) and two five-year periods of record (2008-2012, 2013-2017). Number of sites meeting the pH standard, failing to meet the standard due to excursions below the minimum pH criterion (“<Min”), failing to meet the standard due to excursions above the maximum pH criterion (“>Max”), and failing to meet the standard due to both excursions below the minimum and above the maximum pH criteria (“Both”). Number of sites meeting and failing the standard assessed annually and average for each period of record.

In the Class AA Marine water in and around Lummi Bay, 35% of sites failed to meet the pH standard during 2018 and 29% of sites failed to meet the pH standard during 2019. This is in line with the noncompliance rate observed on average over the two five-year periods of record; 33% of sites failed to meet the standard during 2008-2012 and 39% of sites failed to meet the standard during 2013-2017. In Lummi Bay, no year had full compliance with the pH standard; the lowest noncompliance rate was 22% in 2016 and the highest noncompliance rate was 57% in 2014.

In Portage Bay, all sites were compliant with the pH standard during seven out of the last twelve years. However, excursions below the minimum pH criterion have decreased (none since 2014) while excursions above the maximum pH criterion have increased (none prior to 2014) with all noncompliant sites failing to meet the standard due to excursions above the maximum criterion during 2018. During the reporting period, the five sites that failed to meet the pH standard due to excursions above the maximum pH criterion in 2018 were NSSP sites located by Brant Island (DH052), to the east of Brant Spit (DH057 and DH058), and near the shore of Portage Island (DH054 and DH055).

Each year assessed (2008-2019) had Class AA Marine sites (in and around Lummi Bay) with excursions below the minimum pH criterion and sites with excursions above the maximum pH criterion. On average, five sites had excursions below the minimum pH criterion and three sites had excursions above the maximum pH criterion.

During 2018 and 2019, three and four sites, respectively, in Lummi Bay failed to meet the pH standard due to excursions above the maximum pH criterion. The three noncompliant sites in 2018 also failed to meet the standard during 2019, and had previous noncompliant years over the period of record. Site DH038 failed to meet the pH standard for the first time in 2019. Three sites in Lummi Bay (DH039, DH040, and DH287) have met the pH standard annually since 2008. In general, most sites in Lummi Bay are compliant with the pH standard and when they are noncompliant, it is due to excursions above the maximum pH criterion.

One site in the Lummi aquaculture facility (Seaponds) failed to meet the pH standard due to excursions above the maximum pH criterion in 2018. Both Seaponds sites had several noncompliant years over the period of record. In general, the two Seaponds sites are compliant with the pH standard approximately half of the time, but are equally often noncompliant due to excursions above the maximum pH criterion.

The two sites in Sandy Point Marina met the pH standard during both reporting years. Sandy Point Marina site SW001 has failed to meet the standard due to excursions below the minimum pH criterion during six of the ten years of the period of record, but has had no excursions since 2015. Noncompliance at sites in Sandy Point Marina are due to excursions below the minimum pH criterion.

The two sites in Hale Passage met the pH standard during both reporting years. Hale Passage site SW039 has failed to meet the standard due to excursions below the minimum pH or excursions above the maximum pH during six of the ten years of the period of record, but met the standard during both reporting years. Hale Passage site DH048, which is sampled as part of the Portage Bay NSSP but located in Class AA Marine waters, has met the pH standard during all years assessed (2009 and annually since 2014). Noncompliance with the pH standard in Hale Passage occurs approximately half of the time due to both excursions above the maximum and below the minimum pH criteria at site SW039.

Class AA Marine waters also include the brackish tidally influenced sites and mouths of freshwater drainages flowing into Lummi Bay (Lummi River, Jordan Creek/North Lummi River Distributary, and Smuggler Slough). At least one site in each watershed failed to meet the pH standard during at least one of the two reporting years 2018 and 2019. All noncompliant sites failed to meet the standard due to excursions below the minimum pH criterion. All sites have several noncompliant years over the period of record, except Smuggler Slough site SW056, which has only failed to meet the pH standard during 2009, 2014, and 2019.

7.3.1.3 Marine pH Seasonality

The pH measurements in the marine waters of Portage Bay follow a distinct seasonal pattern (Figure 7.3.2).[17] Mean pH was highest in June and lowest in December for trip-averaged pH data for the reporting period 2018-2019. No January data were available for the 2018-2019 reporting period. For the six-year period 2013-2019, mean pH was highest in July and lowest in January. During the previous six-year period 2008-2012, mean pH was highest in June and lowest in November. Excursions of the mean pH above the maximum pH criterion did not occur during the six-year period including the reporting period (2014-2019) or the six-year period 2008-2013. Excursions of the mean pH below the minimum pH criterion did not occur during the reporting period (2018-2019), but did occur during March of the six-year period 2014-2019, and in October and November of the preceding six-year period 2008-2012. Note that mean trip pH was not used to determine compliance with the pH standard; pH measurements for each site were compared individually to the pH criteria to determine compliance.

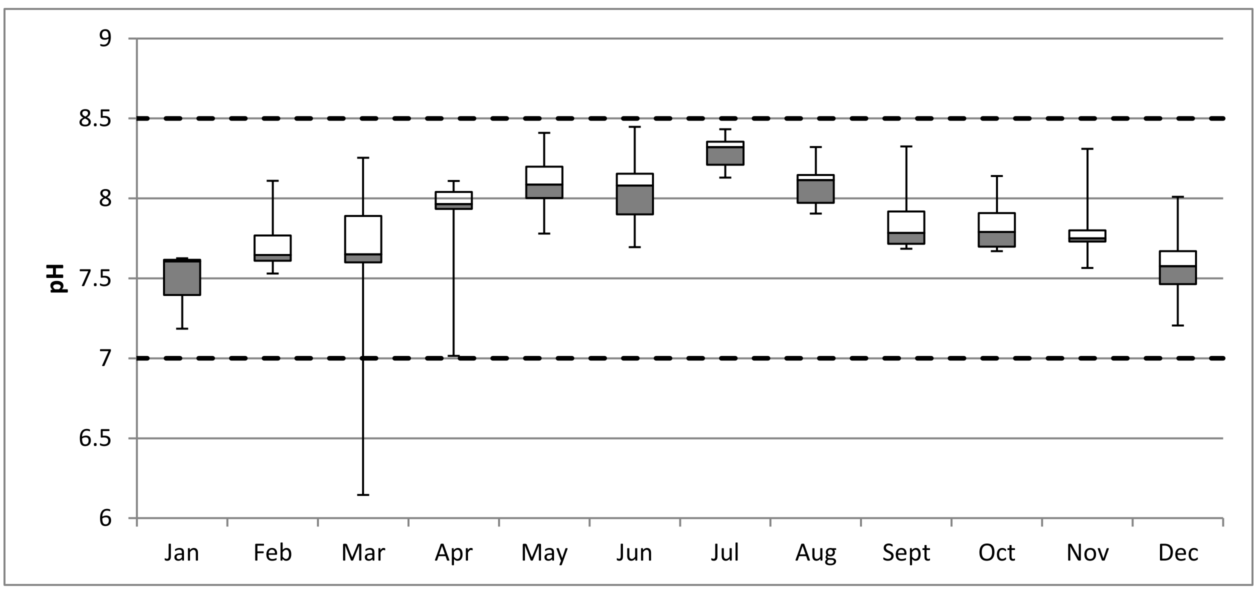


Figure 7.3.2 Portage Bay pH by month for the six-year period 2014-2019. Quartiles (box and whiskers) for each month calculated from trip averaged data.[17] Dotted line represents minimum and maximum pH criteria for Class A Marine water. Sites used include eleven NSSP sites (excluded DH048, which is located in Hale Passage) and ambient monitoring sites SW006 and SW023.

Similar trends are present in Lummi Bay. For the reporting period (2018-2019), the highest mean pH occurred in July and the lowest in November. For the six-year period including the reporting period (2014-2019), the highest mean pH occurred in July and the lowest in January. For the preceding six-year period 2008-2013, the highest mean pH occurred in March and the

[17] Trip-averaged pH was determined by averaging the pH measurements collected at all sites in Portage Bay on each trip.

lowest in December. Excursions of the mean pH above the maximum pH criterion occurred during June of the 2018-2019 reporting period, during June and July of the six-year period including the reporting period (2014-2019), and during May and August for the preceding six-year period 2008-2013. No excursions of the mean pH below the minimum criterion have occurred over the last 12 years of monitoring.

Generally, pH is highest during the dry season (April-September) and lowest during the wet season (October-March; Figure 7.3.3). The monthly patterns are reflected in the seasonal analysis; excursions of the mean pH below the minimum pH criterion occurred only during the dry season for the periods of record (2008-2012 and 2013-2017) in Portage Bay and excursions of the mean pH above the maximum pH criterion occurred only during the dry season for the periods of record (2008-2012 and 2013-2017) and the 2018-2019 reporting period in Lummi Bay.

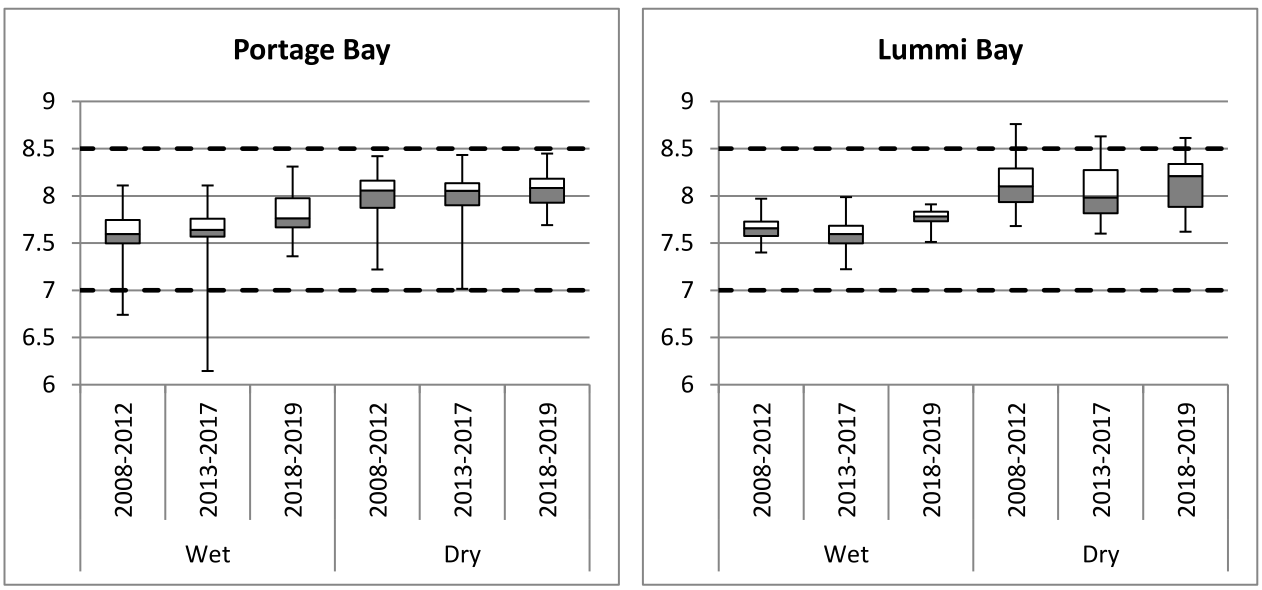


Figure 7.3.3 Wet (October-March) and dry (April-September) period mean trip pH in Portage Bay (left) and Lummi Bay (right) for the 2018-2019 reporting period, and two five-year periods of record (2008-2012 and 2013-2017). Second and third quartiles shown as boxes and top and bottom quartiles shown as whiskers. Minimum and maximum pH criteria shown for reference (Marine Class A and Marine Class AA standards are equivalent).

Trends in pH over time in Lummi Bay and Portage Bay were examined using regression analysis. Site pH measurements were averaged for each trip and data were assessed by year. In addition, regression of pH by year was conducted by month, due to the seasonal patterns observed in the monthly data, and by season, due to the pH tending to be higher during the dry season (April-September) and lower during the wet season (October-March). In Lummi Bay, there were no annual, seasonal, or monthly trends in pH. Lower stratum pH was not analyzed for Lummi Bay because of the infrequency of salinity stratification in these waters.

In Portage Bay, there was a significant increase in pH by year from 2008 to 2019; on average pH increased by 0.2 pH units every ten years (Table 7.3.2). However, the coefficient of determination (R^2) was very low, indicating that the year described only approximately 4% of the variation in pH measurements over time, and the standard error of the regression was relatively high and indicates poor precision of the model. This is not surprising given the seasonal and monthly differences in pH readings (Figure 7.3.2). There was a significant increase in pH during the wet season, with pH increasing by 0.35 pH units every ten years, though not for the dry season. For the wet season, the coefficient of determination was slightly higher than for the linear model using all data, but year still only explained about 12% of the variation in pH. In addition, the standard error of the regression was not improved from the model using all data. Monthly analysis found a significant increase in pH during October and November. In October and November, pH increased by 0.6 and 0.5 pH units every ten years and the year explained 37% and 41% of the variation in pH, respectively. The standard error of the regression was lower for the monthly linear models, with trip mean pH measurements within approximately 0.25 pH units of the model prediction.

Table 7.3.2 Summary of significant pH by year regression results for Portage Bay by stratum.

Period	Sample Size (n)	Coefficient of Determination (R^2)	Standard Error of Regression	p	Slope (Standard Error)
Upper Stratum					
October	14	0.37	0.28	0.02	0.056 (0.021)
November	14	0.41	0.24	0.01	0.052 (0.018)
Wet Season	63	0.12	0.32	0.005	0.035 (0.012)
All Data	138	0.04	0.35	0.01	0.022 (0.009)
Lower Stratum					
October	10	0.64	0.13	0.005	0.048 (0.013)

The regression analyses did not find evidence of ocean acidification in Portage Bay or Lummi Bay during the 12-year dataset used. In Portage Bay, there are indications that pH is increasing during the wet season, particularly October and November. However, when the standard error of the model coefficient is taken into account, the predicted increase over a ten-year period is within the ±0.2 pH unit accuracy of the pH sensor currently in use. Although no evidence of ocean acidification was identified in this analysis, ocean acidification may still be affecting Lummi Nation marine waters. A longer time period, higher accuracy of the pH measurements, and higher frequency of sampling would provide a more robust dataset for detecting small changes in pH.

7.3.1.4 Lower Stratum pH

When sites are salinity stratified, pH data were also available for the bottom stratum. Lower stratum pH compliance was similar to that of upper stratum pH compliance for Portage Bay (Figure 7.3.1). During the reporting period, 31% of sites failed to meet the pH standard during

2018 and no sites failed to meet the standard during 2019. Over the two five-year periods of record, an average of 6-7% of sites failed to meet the standard during 2013-2017 and 2008-2012, respectively. Salinity stratification occurs much less frequently in Lummi Bay, where 25% of sites failed to meet the pH standard for the lower stratum during each of the reporting years. Over the period of record, 12-23% of sites failed to meet the pH standard in the lower stratum during 2013-2017 and 2008-2012, respectively. There were both fewer sites that failed to meet the pH standard and fewer sites that met the pH standard for the lower stratum in Lummi Bay because a higher proportion of sites did not have bottom stratum data available. Out of sites with lower stratum pH measurements, a lower proportion failed to meet the pH standard in the lower stratum than the upper stratum.

Lower stratum pH was evaluated for compliance with the pH standard in all marine waters, but only marine sites in Portage Bay were consistently stratified so as to allow for a fuller evaluation of trends in the lower stratum. Similar to the upper layer, there was a distinct seasonal pattern with higher pH during the dry season and lower pH during the wet season. There was a significant increase in pH in the lower stratum in October for Portage Bay; pH increased by 0.5 pH units every ten years and the year explain 64% of the variation in pH (Table 7.3.2). No other monthly, seasonal, or annual linear trends were identified for the lower stratum in Portage Bay.

There was no statistical difference in trip-averaged pH for the upper and lower strata. Lower stratum pH increased with upper stratum pH at a near to 1:1 relationship (slope of 0.86; R^2 0.77); lower layer pH was slightly higher than upper layer pH when pH is less than 7.75 and lower when pH is greater than 7.75. During the reporting period (2018-2019) lower stratum pH was on average 0.09 pH units higher than the upper stratum pH. Over time, the difference in trip-averaged pH between the upper and lower strata has increased, with an average increase in the difference (upper minus lower stratum pH) of 0.2 pH units every ten years (R^2=0.15, $p<0.001$, n=106). In 2008 and 2010-2012, the average difference in pH between the upper and lower strata was negative (with lower stratum pH higher than upper stratum pH), while the difference has been positive (with lower stratum pH lower than upper stratum pH) over the last seven years. Seasonally over the last six years, pH was slightly lower in the lower stratum than in the upper stratum, but this relationship was not statistically significant (Figure 7.3.4). The trip averaged difference in pH between the upper and lower strata as well as the trend over time is within the ±0.2 pH unit error of the pH sensor.

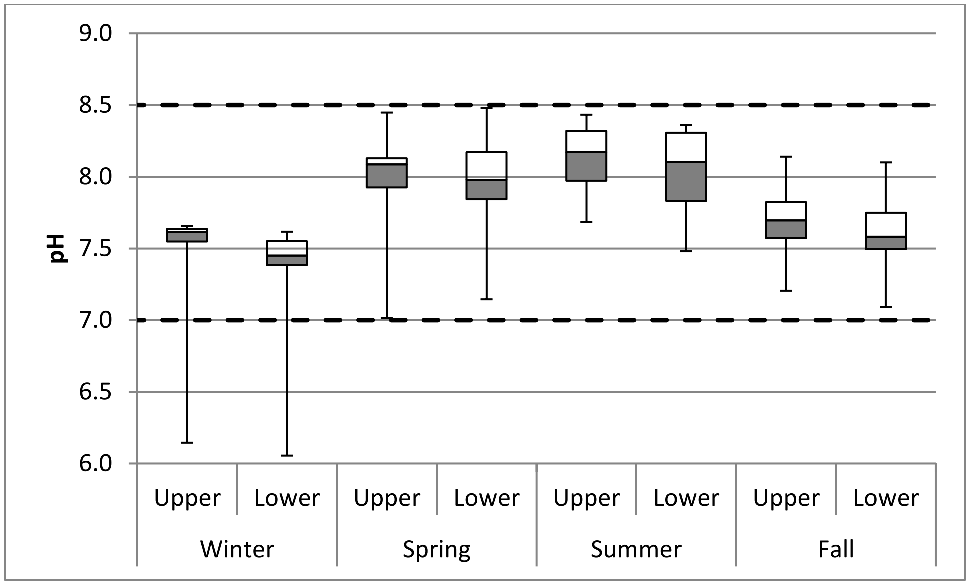


Figure 7.3.4 Upper and lower stratum mean trip pH in Portage Bay by season for 6-year period, including the reporting years, 2014-2019. Quartiles represented by boxes and whiskers. Class A Marine pH criteria shown for reference.

Future reports should further consider seasonal trends, stratification, and the bottom layer during salinity stratified conditions in addition to taking into account the accuracy of the pH sensor when examining pH trends. Future reports should also consider use of multiple regression to investigate pH trends over time.

7.3.1.5 Freshwater pH

Overall in freshwaters, 20% of sites failed to meet the pH standard while 80% were in compliance with the pH standard during the reporting period (2018-2019). All excursions were below the minimum pH criterion during the reporting period; no excursions above the maximum pH were observed in freshwaters.

In the Lummi Bay watershed, 20% and 8% of sites failed to meet the pH standard during 2018 and 2019, respectively (Figure 7.3.5). Over two five-year periods of record (2008-2012 and 2013-2017), on average 41% and 31% of sites failed to meet the pH standard, respectively. As indicated above, all exceedances during the reporting period were due to excursions below the minimum criterion. Over the periods of record in Lummi Bay, the majority of exceedances were due to excursions below the minimum pH criterion, but excursions above the maximum pH criterion also occurred, and rarely, sites had excursions both below the minimum and above the maximum criteria.

Most years had at least one Lummi Bay watershed freshwater site failing to meet the pH standard; the exceptions were 2008 and 2017 during which all sites met the pH standard. Over time, there has been an increase in the pH exceedance rate, with four of the last five years having exceedance rates of 20% or less. All years 2009-2014 had exceedance rates greater than 35%. There also appears to have been a decrease in both the frequency of exceedances above the maximum pH and below the minimum pH criteria. Exceedances above the maximum pH criterion occurred during 2009-2011, 2013, and 2016, but not during the last three years. The number of sites with exceedances below the minimum pH criterion went from zero in 2008, to 3-5 in 2009-2014, then decreased to 0-2 in 2015-2019.

Of freshwaters flowing into Lummi Bay, sites that failed to meet the pH standard during the reporting period were located in the Jordan Creek/North Lummi River Distributary watershed (SW003), Onion Creek (SW014), and Seaponds Creek (SW029). Each of these sites failed to meet the pH standard due to excursions below the minimum pH criterion and has failed to meet the pH standard on several occasions over the period of record. Sites in the Lummi River watershed and Smuggler Slough continue to show good water quality in terms of compliant pH measurements after several noncompliant years over the period of record.

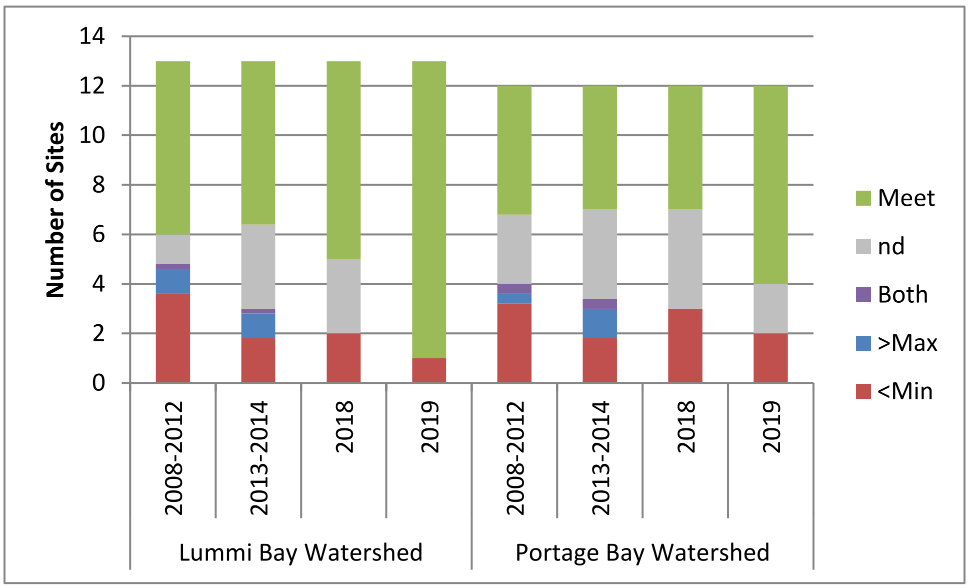


Figure 7.3.5 Summary of compliance with the pH standard at freshwater sites in the Lummi Bay watershed and Portage Bay watershed for the reporting years (2018, 2019) and two five-year periods of record (2008-2012, 2013-2017). Number of sites meeting the pH standard, failing to meet the standard due to excursions below the minimum pH criterion ("<Min"), failing to meet the standard due to excursions above the maximum pH criterion (">Max"), and failing to meet the standard due to both excursions below the minimum and above the maximum pH criteria ("Both"). Number of sites meeting and failing the standard assessed annually and average for each period of record.

In the Portage Bay watershed, 38% and 20% of sites failed to meet the pH standard during the 2018 and 2019 reporting years, respectively. As indicated above, all exceedances during the reporting period were due to excursions below the minimum criterion. Over the periods of record (2008-2012 and 2013-2017), 43% and 40% of sites failed to meet the pH standard, respectively. Similar to the sites in the Lummi Bay watershed, over the periods of record in the Portage Bay watershed, the majority of exceedances were due to excursions below the minimum pH criterion, but excursions above the maximum pH criterion also occurred, and rarely, sites had excursions both below the minimum and above the maximum criteria.

All years 2008-2019 had at least one Portage Bay watershed freshwater site failing to meet the pH standard. The lowest exceedance rate was in 2017, when only one site (13%) failed to meet the pH standard and the highest exceedance rate was in 2012, when six sites (67%) failed to meet the pH standard. Although most sites in the Portage Bay watershed met the standard, of those that failed, most failed due to excursions below the minimum criterion. However, excursions above the maximum pH have occurred during five of the last twelve years and there have been excursions above the maximum and below the minimum criteria during four of the last twelve years. There appears to be a decreasing trend in pH noncompliance and increasing trend in pH compliance at Portage Bay watershed sites, however those improvements are largely due to much lower noncompliance rates in 2017 and 2019. In 2018, pH noncompliance was similar to previous highs seen during the period of record. Future years of monitoring are needed to confirm the potential improving trend.

During the reporting period, sites in the Portage Bay watershed that failed to meet the pH criterion were the Nooksack River at Marine Drive and sites located along Lummi Shore Road. Nooksack River site SW118 failed to meet the pH standard during 2018 due to excursions below the minimum pH criterion. Over the ten-year period of record, site SW118 has failed to meet the standard during eight years, including four years with excursions below the minimum pH criterion only and four years with both excursions above the maximum and below the minimum pH criteria. The two Lummi Shore Road sites (SW031 and SW033) failed to meet the pH standard due to excursions below the minimum pH criterion. These sites have failed to meet the pH standard during seven (SW031) and nine (SW033) of the ten-year period of record, primarily due to excursions below the minimum pH criterion. Sites on Portage Island met the pH standard during both reporting years, and one of these (SW026) has met the pH standard during all years assessed since 2008.

The increasing number of sites meeting the pH standard and the decreasing number of sites failing to meet the pH standard overall and in both watersheds suggests that pH compliance is increasing throughout the freshwaters of the Reservation. Lower compliance and higher noncompliance observed during the period of record may be partially due to water quality measurements collected during stagnant conditions, which was discontinued in 2013. As described in Section 7.3.1.1, pH methods were modified in 2018 due to challenges in obtaining a stable pH reading at low ionic strength waters in a reasonable amount of time. Attention given to very low pH values at low ionic strength sites (especially SW029 and SW118) may have resulted in low pH measurements being rejected or not being recorded due to stability issues.

7.4. Recreational Contact

The Lummi Nation Surface Water Quality Standards list recreational use of Lummi Nation Waters as a characteristic use for all water quality classes. Recreational use includes extraordinary primary contact, primary contact, sport fishing, boating, canoeing, and aesthetic enjoyment. Primary contact recreation refers to activities where a person would have direct contact with water to the point of complete submergence, including skin diving, swimming, canoeing, and water skiing. Extraordinary primary contact recreation means waters providing extraordinary protection against waterborne disease, such as shellfish harvesting.

Enterococci are used as indicators of fecal contamination and therefore recreational water quality and risk of swimmer illness (Boehm and Sassoubre 2014). Sources of Enterococci include sewage, agricultural and urban runoff, stormwater, direct input by animals via defecation, bather shedding, boats, plant debris, polluted groundwater, soils, sediments, and sands. Mixing, sunlight, tides, seasons, and El Niño can cause varying concentrations of Enterococci in marine waters.

7.4.1. Enterococcus

The enterococcus standard has two parts: a geometric mean (geomean) criterion and a maximum value criterion (Table 7.4.1). Both criteria must be met in order to be in compliance with the standard. Lummi Nation waters that meet the enterococcus standard are considered protective of recreational uses.

Table 7.4.1 Enterococcus standards for surface waters of the Lummi Indian Reservation

	Geometric Mean	Single Sample Maximum	Number of Samples*
Freshwater Class AA and A	33	61	≥5
Marine Class AA and A	35	104	≥5

* The Lummi Nation Surface Water Quality Standards do not require a certain number of samples to be used for calculating metrics, although it is recommended that at least 5 samples are used to calculate the geometric mean.

The NSSP requires 30 samples to be used for calculating a geomean metric, which was historically also applied to the enterococcus standard (through reporting year 2013). The Lummi Nation Surface Water Quality Standards do not require a certain number of samples to be used for calculating metrics, although it is recommended that at least 5 samples are used to calculate the geometric mean and that the geometric mean be calculated seasonally. For this report, compliance with the enterococcus standard was evaluated seasonally for each year.[18] Since most sites are visited once per month, the maximum number of samples per season is three for these sites. When fewer than three samples were available for each season, this is noted. Assessment of compliance with the single sample maximum criterion requires only a

[18] Seasonal breakdown was quarterly. Winter: January-March; Spring: April-June; Summer: July-September; Fall: October-December.

minimum of one sample (i.e., no minimum sample size), but sites that fail to meet the standard due to exceedance of the maximum criterion are also noted as having fewer than three samples due to the implications of interpreting the geometric mean calculated using fewer than three samples. Sites were evaluated for compliance seasonally (quarterly), with an overall designation provided for the year based on the seasonal compliance determination. If a site failed to meet the standard during any one season, the site failed to meet the standard for the full year. If a site failed to meet the standard with fewer than three samples during any one season, the site was designated as failing based on fewer than three samples. If all seasons that could be assessed (i.e., excluding seasons with no data) were compliant with the enterococcus standard, and at least one of those seasons had three or more samples, the site was compliant with the standard. If all seasons that could be assessed were compliant with the standard, but all seasons had fewer than three samples, the site was compliant for the year with the caveat that compliance was based on fewer than three samples. Compliance was assessed seasonally and annually, as described above, for all years 2008-2019. Compliance for two five-year periods of record are reported as averages for the five-year period. Compliance for the reporting years 2018 and 2019 are reported annually and seasonally.

During the 2018-2019 reporting period, a total of 37 sites were monitored for enterococci: 24 freshwater sites and 13 marine sites. In Lummi Bay, ten marine sites and fourteen freshwater sites were monitored. In Portage Bay, three marine sites and ten freshwater sites were monitored. For each site, compliance with the standard was determined for each season annually; the season was required to meet both the geometric mean criterion and the single-sample maximum standard in order to be in compliance with the enterococcus standard. If any one season failed to meet the standard, the full year was marked as noncompliant with the standard. Compliance for the reporting period is provided annually when possible or by averaging the compliance status for the 2018-2019 period. Compliance for the period of record was assessed the same as for the reporting period (by season by year) with the percentage of years failing to meet the standard out of the number of years assessed by season and overall (i.e., % noncompliance out of years assessed, excluding years with no data for the season). On some occasions, sites had a single sample for a season that exceeded the geometric mean standard but not the single-sample maximum standard. For the purposes of the seasonal summary below, the season was considered to fail to meet the standard. For the purposes of determining overall annual compliance for the reporting period, if there were no other exceedances in other seasons, the year was marked as compliant with the standard. It is not appropriate to calculate a geometric mean metric using a single sample, but the combined approach (noting the exceedance on a seasonal basis but not using the exceedance alone for assigning noncompliant status overall) allows for the presentation and summarization of potential exceedances of the geometric mean criterion at sites with very few samples but not violating the logical assumptions underlying the criteria (i.e., that a geometric mean cannot be calculated using one sample).

Overall annual compliance results for freshwater and marine sites are summarized by watershed in Figure 7.4.1. In general, the enterococcus standard was met much more frequently in marine waters than in freshwaters and a decrease in the number of sites failing to meet the standard was present in Lummi Bay freshwaters.

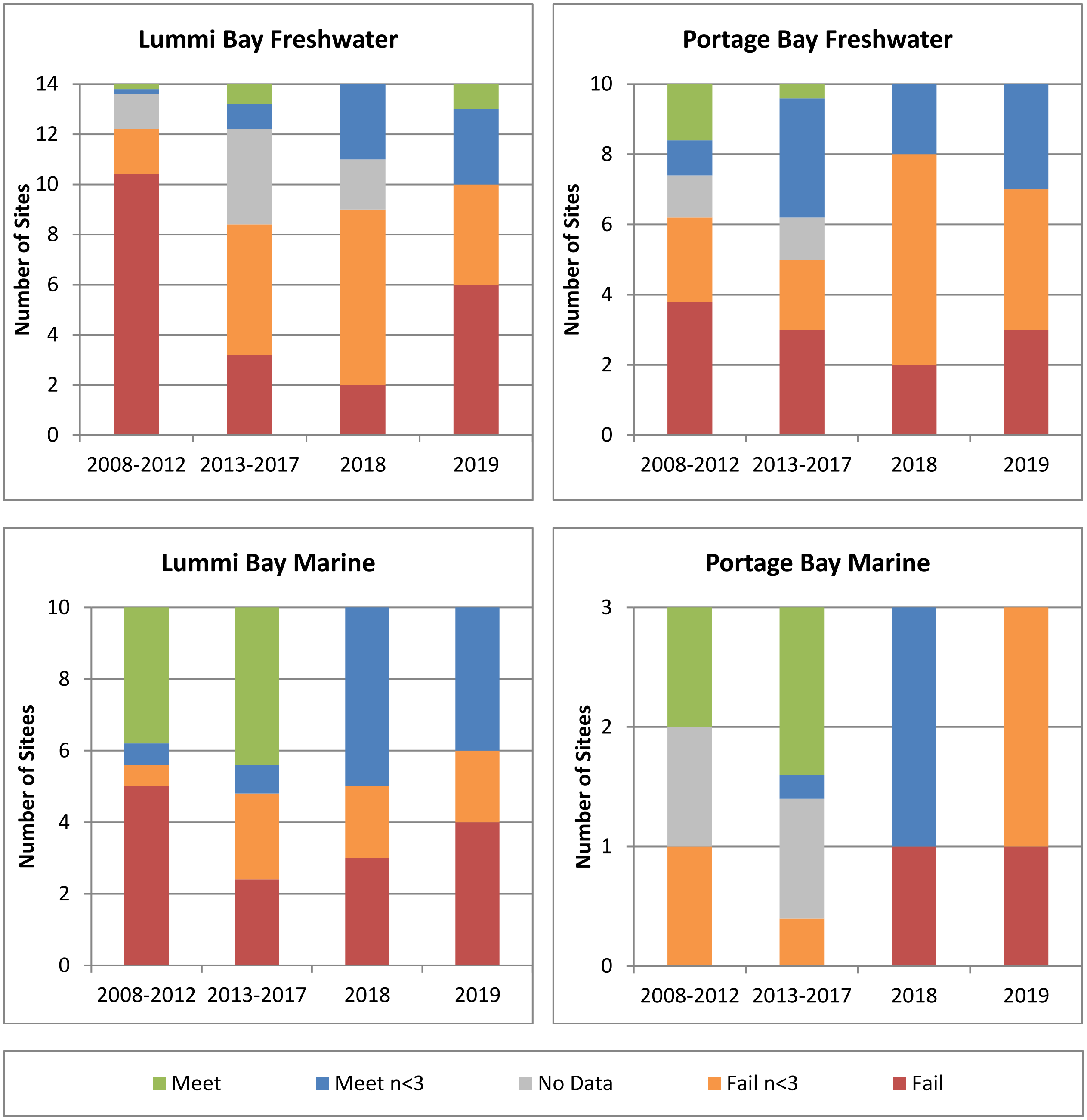


Figure 7.4.1 Overall annual compliance of surface water quality monitoring sites with enterococcus standard for freshwater and marine sites in the Portage Bay and Lummi Bay watersheds by year for the reporting years 2018-2019 and on average for two five-year periods of record (2008-2012, 2013-2017). Lummi Bay marine sites include sites in Sandy Point, Hale Passage, and the brackish tidally-influenced sites and mouths of freshwater systems flowing into Lummi Bay. Compliance for sites with fewer than three samples per season for all seasons assessed was determined and noted with "n<3" qualifier.

Seasonally, the highest rate of compliance with the enterococcus standard was during the winter and the highest rate of noncompliance was during the fall (Figure 7.4.2).

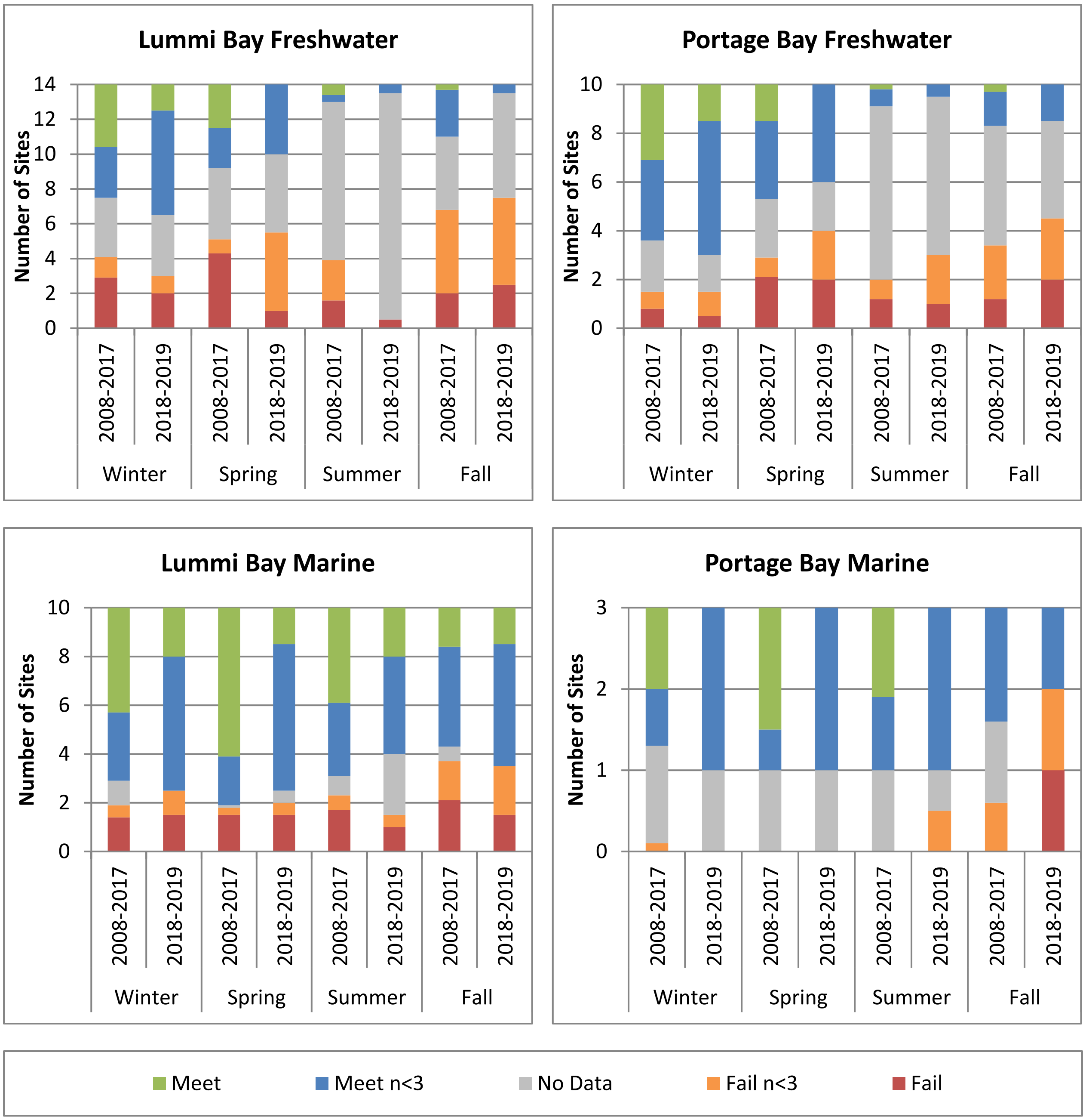


Figure 7.4.2 Seasonal compliance of surface water quality monitoring sites with enterococcus standard for freshwater and marine sites in the Portage Bay and Lummi Bay watersheds on average for the reporting period 2018-2019 and the ten-year period of record 2008-2017. Lummi Bay marine sites include sites in Sandy Point, Hale Passage, and the brackish tidally-influenced sites and mouths of freshwater systems flowing into Lummi Bay. Compliance for sites with fewer than three results per season was determined and noted with “n<3” qualifier.

7.4.1.1 Portage Bay Marine

In the Portage Bay watershed, three sites were monitored for enterococcus during the reporting period. Two of these sites (SW006 and SW023) are included in the Surface Water Project while the third (DH050) is sampled as part of the NSSP in Portage Bay. Site DH050 was sampled from shore on several occasions during the fall of 2018 and late summer and fall of 2019 in order to provide data from a marine site in Portage Bay that would allow for comparison to upstream sampling conducted in the Nooksack River watershed. Sampling at DH050 for this purpose was added to the ambient dataset and samples from the site were analyzed for all fecal indicator bacteria (fecal coliform, E. coli, and enterococcus). For this reason, enterococcus data are only available for DH050 for the reporting period as no period of record for this parameter is available.

All marine sites in Portage Bay failed to meet the enterococcus standard during 2019 while only one failed to meet the standard during 2018 (Table 7.4.3). Site DH050 failed to meet the standard during all seasons monitored: fall 2018, summer 2019, and fall 2019. All sites in Portage Bay failed to meet the standard during fall 2019, resulting in noncompliance for the year overall. Over the period of record, noncompliance was most common during the fall season.

Overall, marine waters in Portage Bay were not protective of recreational use during the reporting period due to noncompliance with the enterococcus standard. Recreational use in Portage Bay is not protected during the late summer and fall.

7.4.1.2 Portage Bay Freshwater

Over the 2018-2019 reporting period, three-quarters of freshwater sites in the Portage Bay watershed failed to meet the enterococcus standard and one quarter of sites (on average five per year) were compliant with the enterococcus standard (Figure 7.4.1). Noncompliance rates during the reporting period were higher than on average over the period of record. Over the two five-year periods of record, an average of 70% of sites were noncompliant with the enterococcus standard in 2008-2012 and 57% of sites were noncompliant during 2013-2017. Year-to-year noncompliance was variable over the period of record, a maximum of 100% of sites were noncompliant in 2011 with the following year showing the minimum noncompliance rate of 33% (in 2012 and also 2016). Over the 2012-2016 period, on average fewer than half of sites were noncompliant with the enterococcus standard. In 2017, as during the reporting period, the noncompliance rate increased to the current 75% showing a reversion of the improved conditions observed through 2016.

Sites that failed to meet the enterococcus standard during the reporting period were located in all freshwater watersheds that flow to Portage Bay. All sites on Portage Island were noncompliant as were the tributaries to and the mainstem of the Nooksack River. Sites along Lummi Shore Road were mixed, with two (SW031 and SW037) meeting the standard during both reporting years, one (SW033) failing to meet the standard during both reporting years, and one (SW035) compliant in 2019 but not in 2018.

The majority of freshwater sites in the Portage Bay watershed are only sampled six times per year, and many of these sites are intermittent and only flow seasonally or following rain events.

These sites are located on Portage Island and along Lummi Shore Drive. For these reasons, all seasons for these sites had fewer than three samples for compliance determination. For sites along Lummi Shore Road, no summer samples were available for the entire ten-year period of record and no data were available during spring, summer, or fall 2018 or summer and fall 2019. Future reports should evaluate two-year seasonal means, rolling three- or four-month assessment periods, or consider wet/dry seasonal assessment approaches in order to determine enterococcus trends in infrequently sampled and intermittent drainages.

During the reporting period, intermittent sites on Portage Island and along Lummi Shore Road either met the enterococcus standard or failed to meet the standard due to exceedances of both the geometric mean criterion and the single-sample maximum (Table 7.4.2). The exception to this pattern was Portage Island Site SW027 which had an exceedance of the geometric mean only in fall 2019; since the geometric mean was based on only one sample, it would not be appropriate to interpret this as noncompliance. Therefore, the season is marked as failing to meet the geometric mean, but compliant with the standard in Table 7.4.2. In the Nooksack River delta, site compliance was mixed; nearly equal numbers met the standard, failed to meet the standard due to exceedance of the single-sample maximum criterion, and failed to meet the standard due to exceedances of both criteria. The Nooksack River at Marine Drive (SW118) failed to meet the enterococcus standard during all seasons in 2018 and during all seasons except winter in 2019. Site SW118 had exceedances of the maximum criterion in winter, spring and summer during 2018 and spring 2019 and exceedances of both criteria in fall 2018 and summer and fall 2019.

Sites on Portage Island were consistently compliant with the enterococcus standard in winter during the reporting period and over the period of record. Spring and fall were variable, with sites in compliance during some years and out of compliance during others, but over the period of record sites were noncompliant over 50% of the time. Sites along Lummi Shore Road were also variable, with occasional noncompliance over the period of record. Although no ambient fall samples were available for the reporting period for sites along Lummi Shore Road, the period of record shows that three of the four sites failed to meet the standard during the fall over 50% of the time. Site SW031 continues to show the best recreational water quality, with compliance during all seasons with data for the reporting period, and only one year out of the period of record with noncompliance during winter and spring and full compliance during the fall.

The Nooksack River mainstem and tributaries in the delta were mixed. All sites failed to meet the standard during fall for both reporting years and summer for 2019. All other seasons were mixed. As mentioned above, Nooksack River mainstem site SW118 (Marine Drive Bridge) was noncompliant during all four seasons in 2018 and all season except winter in 2019. Noncompliance during summer and fall is typical for SW118, as indicated by 90% of years during the period of record being out of compliance. However, improvement was seen during the winter at SW118 and tributary sites.

Table 7.4.2 Summary of compliance with the enterococcus standard for freshwater sites in the Portage Bay watershed by year and season. Period of record 2008-2017 seasons assessed annually and reported as number of years with noncompliant season/number of years assessed (excluding years with no data for the season). For period of record, seasons with no noncompliant years in green, 50% or more noncompliant years in red, and fewer than 50% noncompliant years in orange. Reporting years shown as failing or meeting the enterococcus standard, indication of samples size less than three (n<3), and reason for noncompliance.*

Year(s) and Season	Portage Island			Lummi Shore Road				Nooksack + Tributaries		
	SW026	SW027	SW028	SW031	SW033	SW035	SW037	SW007	SW075	SW118
2008-2017 (noncompliant years/years assessed)										
Winter	1/9	0/9	0/9	1/8	1/9	1/8	2/6	1/9	1/2	7/10
Spring	5/10	9/10	5/9	1/8	1/8	1/8	1/2	3/9	0/2	3/10
Summer	2/3	2/2	2/7	0/0	0/0	0/0	0/0	5/7	0/0	9/10
Fall	4/7	3/6	7/8	0/2	1/2	3/3	2/2	4/9	1/2	9/10
Overall	**7/10**	**9/10**	**8/10**	**2/10**	**2/10**	**4/10**	**3/7**	**9/9**	**2/2**	**10/10**
2018										
Winter	Meet n<3	Meet n<3	Meet n<3	Meet n<3	Both n<3	Both n<3	Meet n<3	Meet n<3	Meet n<3	Fail Max
Spring	Meet n<3	Both n<3	Meet n<3	nd	nd	nd	nd	Fail Max	Meet n<3	Fail Max
Summer	Both n<3	Both n<3	Both n<3	nd	nd	nd	nd	Meet n<3	nd	Fail Max
Fall	Meet n<3	Meet n<3	Meet n<3	nd	nd	nd	nd	Fail Max	Both n<3	Fail Both
Overall	**Fail**	**Fail**	**Fail**	**Meet n<3**	**Fail**	**Fail**	**Meet n<3**	**Fail**	**Fail**	**Fail**
2019										
Winter	Meet n<3	Meet n<3	Meet n<3	Meet n<3	nd	nd	nd	Meet	Meet	Meet
Spring	Both n<3	Both n<3	Meet n<3	Meet n<3	Both n<3	Meet n<3	Meet n<3	Fail Max	Meet n<3	Fail Max
Summer	nd	nd	nd	nd	nd	nd	nd	nd	Both n<3	Fail Both
Fall	Both n<3	GM n<3†	Both n<3	nd	nd	nd	nd	Both n<3	Fail Both	Fail Both
Overall	**Fail**	**Fail**	**Fail**	**Meet n<3**	**Fail**	**Meet n<3**	**Meet n<3**	**Fail**	**Fail**	**Fail**

*Determination and reason (color coding): nd: no data (gray)
Meet: compliant with both the geometric mean and single-sample maximum criteria with n≥3 (green)
Fail GM: exceeds geometric mean criterion (compliant with single-sample maximum criterion) with n≥3 (red)
Fail Max: exceeds single-sample maximum criterion (compliant with geometric mean criterion) with n≥3 (red)
Fail Both: exceeds both geometric mean and single-sample maximum criterion with n≥3 (red)
Meet n<3: compliant with both the geometric mean and single-sample maximum criteria with n<3 (blue)
GM n<3: exceeds geometric mean criterion (compliant with single-sample maximum criterion) with n<3 (orange)
Max n<3: exceeds single-sample maximum criterion (compliant with geometric mean criterion) with n<3 (orange)
Both n<3: exceeds both geometric mean and single-sample maximum criterion with n<3 (orange)
† Site exceeded the geometric mean based on only one sample. The site was marked as noncompliant for the season but the seasonal fail based on one sample was not used to determine compliance overall.

Seasonally, the lowest noncompliance rates (highest compliance rates) occur during the winter, when 0-30% of sites were noncompliant with the enterococcus standard during the 2018 and 2019 reporting years (70-100% compliance rate). Over the 2008-2017 period of record, winter noncompliance rates averaged 19% from a low of 0% in 2008 and 2017 to a high of 56% in 2011. Spring had the second lowest noncompliance rates; during the reporting period, the noncompliance rate was 50%. Over the period of record, spring noncompliance averaged 38% of sites and ranged from a low of 11% in 2009 and 2016 to a high of 78% in 2011. The highest noncompliance rates occur during the summer and fall. During summer, although most sites are dry or stagnant, those that do have flow are likely to be out of compliance with the enterococcus standard. During the reporting period, 80% (four of five sites) were noncompliant in summer 2018 and 100% (two sites) were noncompliant during summer 2019. Over the period of record, 69% of sites failed to meet the standard during the summer season, ranging from 0% in 2016 to 100% in 2009, 2012, 2015, and 2017. During the fall, more sites could be assessed than during the summer, but not as many as during the winter and spring. Fall noncompliance rates during the reporting period were 50% (three of six sites) in 2018 and 100% (six sites) in 2019, while over the period of record noncompliance averaged 67% with a range from 20% in 2011 to 100% in 2008 and 2014. There is wide variability in year-to-year compliance rates during all seasons and no increasing or decreasing trends are indicated over time.

The period of record for all sites except SW118 and SW075 includes enterococcus enumeration conducted at stagnant sites (prior to 2014), which may have resulted in elevated enumerations, especially during the dry season. Future reports should consider determining compliance only during flowing conditions during the period of record to better understand patterns in bacterial densities over time.

Overall, freshwater drainages in the Portage Bay watershed are not protective of recreational uses due to failure to meet the enterococcus standard. All watersheds had sites that failed to meet the standard during each of the reporting years. Although some sites were in compliance with the enterococcus standard (e.g., Lummi Shore Road sites SW031 and SW037) and some watersheds met the standard during some seasons (e.g., Portage Island during winter), year-round recreational use is not protected. Nooksack River site SW118 and Silver Creek site SW075 monitor water quality prior to flowing onto the Reservation; these sites failed to meet the standard during both reporting years and show that the enterococcus standard is not being met as these waters flow onto the Reservation.

7.4.1.3 Lummi Bay Marine

The marine waters of Lummi Bay include Sandy Point, Hale Passage, and the brackish, tidally-influenced sites and mouths of freshwater drainages flowing into Lummi Bay that are classified Class AA marine. The brackish, tidally-influenced sites and mouths of freshwater drainages are also discussed as part of each watershed in the Lummi Bay Freshwater section (7.4.1.4).

During the 2018-2019 reporting period, an average of 45% of marine sites in Lummi Bay were in compliance with the enterococcus standard (Figure 7.4.1). On average, 55% of sites failed to meet the standard during the reporting period; these sites were located in Hale Passage and the marine outlets, mouths, and brackish tidally-influenced sites in the Lummi River, Jordan Creek/North Lummi River Distributary, and Smuggler Slough watersheds.

In the Sandy Point marina, both sites met the enterococcus standard during both reporting years. However, site SW001 had only one sample during fall 2018 and summer 2019, each of which exceeded the geometric mean criterion. As it is not appropriate to calculate a geometric mean using a single sample, the seasonal noncompliance was not used to determine overall noncompliance. Since there were no other seasons with exceedances of the criteria, the site was marked in compliance with the standard. It should be noted that although a geometric mean cannot be calculated using a single sample, the single representative sample for the season was above the criterion and indicates that recreational use water quality concerns may be present during the season since other samples, if they had been collected during the season, may have been elevated enough to result in a geometric mean that exceeded the standard. Over the period of record, site SW001 has been largely in compliance; only one year over the ten-year period of record also included a single-sample result that exceeded the geometric mean. For the purposes of this analysis, it was marked as failing to meet the standard to acknowledge that occasional exceedances of the geometric mean over the period of record do occur. For future reports, a streamlined approach to assessing sites with only one sample per season should be developed. At the southern end of the Sandy Point marina, site SW019 was in compliance with the standard during all seasons of the reporting period. Site SW019 has shown improvement over the period of record, which includes three noncompliant years over the ten-year period of record.

The single enterococcus monitoring site in Lummi Bay (SW002) was compliant with the standard during all seasons for both reporting years and during all ten years for the period of record.

The single enterococcus monitoring site in Hale Passage (SW039) failed to meet the standard during fall for both reporting years. This is consistent with the period of record, during which 70% of years failed to meet the standard during the fall. Overall, Hale Passage continued to be noncompliant with the enterococcus standard during the reporting period following nine of ten years failing to meet the standard over the period of record.

Brackish and marine sites in the Lummi River, Jordan Creek/North Lummi River Distributary, and Smuggler Slough are discussed as part of the watershed discussions in Section 7.4.1.4. In summary, all brackish and marine sites in the Lummi River and Jordan Creek/North Lummi River Distributary watersheds failed to meet the enterococcus standard. In Smuggler Slough, one outlet was compliant (SW055) while the other was noncompliant (SW056) and the brackish site upstream of both outlets was compliant in 2018 but not in 2019. These results were also consistent with the period of record, with no clear patterns of improvement or degradation present.

Table 7.4.3 Summary of compliance with the enterococcus standard for marine sites in Portage Bay, Hale Passage, Sandy Point Marina, and Lummi Bay. Period of record 2008-2017 seasons assessed annually and reported as number of years with noncompliant season/number of years assessed (excluding years with no data for the season). Seasons with no noncompliant years in green, with 50% or more noncompliant years in red, and with fewer than 50% noncompliant years in orange. Reporting years 2018 and 2019 seasons reported as failing or meeting the enterococcus standard, indication of samples size (n<3 or n≥3), and reason for noncompliance.*

Year(s) and Season	Portage Bay			Hale Passage	Sandy Point Marina		Lummi Bay
	DH050	SW006	SW023	SW039	SW001	SW019	SW002
2008-2017 (noncompliant years/years assessed)							
Winter	0/0	0/9	1/9	1/9	0/9	0/9	0/9
Spring	0/0	0/10	0/10	2/9	0/10	1/10	0/10
Summer	0/0	0/10	0/10	4/9	0/10	2/10	0/10
Fall	0/0	2/10	4/10	7/10	1/10	0/10	0/10
Overall	**0/0**	**2/10**	**5/10**	**9/10**	**1/10**	**3/10**	**0/10**
2018							
Winter	nd	Meet n<3	Meet n<3	Fail GM n<3†	Meet n<3	Meet n<3	Meet n<3
Spring	nd	Meet n<3	Meet n<3	Meet n<3	Meet n<3	Meet n<3	Meet n<3
Summer	nd	Meet n<3	Meet n<3	Meet n<3	Meet n<3	Meet n<3	Meet n<3
Fall	Fail Both	Meet n<3	Meet n<3	Fail Both n<3	Fail GM n<3†	Meet n<3	Meet n<3
Overall	**Fail**	**Meet n<3**	**Meet n<3**	**Fail**	**Meet n<3**	**Meet n<3**	**Meet n<3**
2019							
Winter	nd	Meet n<3	Meet n<3	Meet n<3	Meet n<3	Meet n<3	Meet n<3
Spring	nd	Meet n<3	Meet n<3	Fail Both n<3	Meet n<3	Meet n<3	Meet n<3
Summer	Fail Max n<3	Meet n<3	Meet n<3	Meet n<3	Fail GM n<3†	Meet n<3	Meet n<3
Fall	Fail Max	Fail Both n<3	Fail Both n<3	Fail Both n<3	Meet n<3	Meet n<3	Meet n<3
Overall	**Fail**	**Fail**	**Fail**	**Fail**	**Meet n<3**	**Meet n<3**	**Meet n<3**

*Determination and reason (color coding): nd: no data (gray)
Meet: compliant with both the geometric mean and single-sample maximum criteria with n≥3 (green)
Fail GM: exceeds geometric mean criterion (compliant with single-sample maximum criterion) with n≥3 (red)
Fail Max: exceeds single-sample maximum criterion (compliant with geometric mean criterion) with n≥3 (red)
Fail Both: exceeds both geometric mean and single-sample maximum criterion with n≥3 (red)
Meet n<3: compliant with both the geometric mean and single-sample maximum criteria with n<3 (blue)
GM n<3: exceeds geometric mean criterion (compliant with single-sample maximum criterion) with n<3 (orange)
Max n<3: exceeds single-sample maximum criterion (compliant with geometric mean criterion) with n<3 (orange)
Both n<3: exceeds both geometric mean and single-sample maximum criterion with n<3 (orange)
† Site failed to meet the standard due to exceedance of the geometric mean, but this was based on only one sample. Since it is not appropriate to calculate the geometric mean using one sample, the site was marked as noncompliant for the season, but the seasonal noncompliance was not used for the overall compliance determination.

Seasonally, water quality did not vary significantly; during the reporting period, 1.5-3.5 sites failed to meet the standard each season and 6-7.5 were in compliance with the standard each season. Generally, water quality was the poorest in Lummi Bay marine waters during the fall, when 35% of the 10 assessed sites failed to meet the enterococcus standard during the reporting period and 65% of the 10 assessed sites were in compliance with the standard (Figure 7.4.2). The largest proportion of sites were compliant with the standard during the summer, when an average of 80% of sites were compliant with the standard during the reporting period; however, due to several sites not being sampled due to stagnant conditions in the Smuggler Slough watershed, the total number of compliant sites was lower than during the fall at 6 out of 10 sites (average of 7.5 sites assessed). Water quality was best during the winter and spring, when an average of 7.5 sites were compliant (75% for winter, 79% for spring) for the reporting period. Both compliance rates and noncompliance rates during summer appear to have decreased from the ten-year period of record to the reporting period, but this is at least partially due to measurement of enterococcus during stagnant conditions during the period of record (through 2013).

Overall, waters in Sandy Point and Lummi Bay were protective of recreational uses year-round during all years of the reporting period. Waters in Hale Passage were not protective of recreational uses. Tidally-influenced brackish and marine sites in the Lummi River, Jordan Creek, and Smuggler Slough watersheds overall were not protective of year-round annual recreational use, although some portions of the Smuggler Slough watershed were compliant during all seasons forthe reporting period.

7.4.1.4 Lummi Bay Freshwater

Over the 2018-2019 reporting period, approximately three-quarters of freshwater sites in the Lummi Bay watershed failed to meet the enterococcus standard and one quarter of sites (3.5 per year) were compliant with the enterococcus standard during each of the reporting years (Figure 7.4.1). Over the two five-year periods of record, an average of 97% of sites were noncompliant with the enterococcus standard in 2008-2012 and 82% of sites were noncompliant during 2013-2017. Noncompliance rates peaked at 100% in 2009-2012 after which noncompliance rates decreased to a minimum of 70% in 2017. In 2018 and 2019, an increasing proportion of sites and number of sites were noncompliant, showing a reversion of the improving trend observed through 2017.

Sites that failed to meet the enterococcus standard during the reporting period were located in the Lummi River, Jordan Creek, Smuggler Slough, and Onion Creek watersheds (Table 7.4.4 and Table 7.4.5). Only Seaponds Creek met the standard during the 2018-2019 reporting period. Each watershed is discussed below including both the freshwater sites and marine-classified sites located in brackish, tidally-influenced, and the marine receiving waters for each watershed.

All sites in the Lummi River watershed failed to meet the standard during the reporting period (Table 7.4.4). This is consistent with the noncompliance rate observed over the period of record; all sites in the Lummi River watershed failed to meet the enterococcus standard during half of the ten-year period of record. Two freshwater sites, SW013 and SW009, failed to meet the standard during all years for the period of record and two sites, freshwater site SW012 and marine site SW008, failed to meet the standard during all but one year of the ten-year period of record. The marine receiving waters (SW051) failed to meet the standard half of the time for the period of record. For freshwater sites in the Lummi River watershed, fall continued to show the highest noncompliance rate during the reporting period, with winter and spring showing variable compliance by year. The only seasons meeting the enterococcus standard were at the marine sites, with failure to meet the standard during each season at either or both of the marine-classified downstream sites in the Lummi River watershed. The mouth of the Lummi River was most frequently in compliance with the standard during the winter and summer, indicating that mixing of the incoming freshwater with the large body of marine water resulted in dilution and die-off of enterococci sufficient to be in compliance with the standard during these seasons. Although over the period of record the marine receiving waters at the mouth of the Lummi River (SW051) was in compliance with the standard during all but one of ten years, the site has failed to meet the standard during both reporting years 2018 and 2019, which may indicate an increase in sources upstream during this season.

In the Jordan Creek watershed, freshwater sites SW011 and SW003 and marine site SW053 failed to meet the enterococcus standard during both reporting years, which is consistent with the period of record, when 70% or more of the previous ten years failed to meet the standard (Table 7.4.4). Jordan Creek site SW010 met the standard (n<3 each season) in 2019, which is an improvement over the period of record, during which eight of nine assessed years were noncompliant. All sites were in compliance during the winter 2018 while two freshwater sites were noncompliant during winter 2019. This shows improvement over the period of record, during which half of years failed to meet the standard during the winter at all sites except SW010. The marine receiving waters at SW053 were in compliance during all seasons except fall, indicating that when upstream waters are noncompliant, the enterococcus load is sufficiently diluted in the marine waters as to meet the marine standard during most seasons.

In Smuggler Slough, compliance was mixed with freshwater site SW016 showing a continuation of noncompliant conditions and SW017 and SW015 showing improvement over a largely noncompliant period of record (Table 7.4.5). Marine sites were also mixed, with site SW055 showing a continuation of compliant conditions and SW056 continuing to fail to meet the standard. Brackish, tidally-influenced site SW059 showed brief improvement in 2018 with a compliant year after ten consecutive years of noncompliance, but the site returned to noncompliance in 2019. Site SW072 only had one sample collected during 2019, which resulted in a value exceeding the geometric mean standard; because it is not appropriate to calculate a geometric mean using one sample and the maximum criterion was met, the seasonal fail was not used for overall compliance determination. As no other data were available for the site during the reporting year, the site was not assessed for compliance with the enterococcus standard. In Smuggler Slough, summer and fall freshwater data were not available due to stagnant or dry conditions at all freshwater sites in both 2018 and 2019, while winter continued to exhibit better water quality than spring, in terms of the number of sites in compliance with the standard. During the spring, when freshwater sites failed to meet the enterococcus standard, there was sufficient dilution at brackish and marine sites to bring the downstream marine sites into compliance. In the winter 2019, high counts at site SW015 were also observed at brackish, tidally-influenced site SW059, but not at the mouths as they flow to Lummi Bay.

Other small watersheds that flow to Lummi Bay are sampled only at one location: Onion Creek and Seaponds Creek. Onion Creek (SW014) returned to noncompliance after two years of improved water quality in 2015 and 2016 (Table 7.4.5). Onion Creek was compliant during the winter, mixed during spring, and noncompliant during fall over the reporting period. Seaponds Creek (SW029) showed improvement with compliance during the reporting period following a period of record with seven noncompliant years out of nine assessed (Table 7.4.5). Seaponds Creek met the standard during all seasons assessed during the reporting period (winter and spring only).

All sites along the Reservation boundary failed to meet the enterococcus during at least one season during the reporting period, except Smuggler Slough site SW017. This indicates that water quality fails to meet the designated uses as it enters the Reservation, and that off-Reservation sources of enterococcus are resulting in impairment of Lummi Nation Waters. On-Reservation sources or lack of dilution is contributing to the failure to meet the enterococcus standards further downstream in these watersheds.

The period of record for all sites includes enterococcus enumeration conducted at stagnant sites (prior to 2014), which may have resulted in elevated enumerations during the dry season when stagnant conditions are common. Future reports should consider determining compliance only during flowing conditions during the period of record to better understand patterns in bacterial densities over time.

Table 7.4.4 Summary of compliance with the enterococcus standard for freshwater sites (Class AA Freshwater) and marine sites (Class AA Marine) in the Lummi River and Jordan Creek/North Lummi River Distributary watersheds by year and season. Period of record 2008-2017 seasons assessed annually and reported as number of years with noncompliant season/number of years assessed (excluding years with no data for the season). For period of record, seasons with no noncompliant years in green, with 50% or more noncompliant years in red, and with fewer than 50% noncompliant years in orange. Reporting years 2018 and 2019 seasons reported as failing or meeting the enterococcus standard, indication of samples size less than three (n<3), and reason for noncompliance.*

Year(s) and Season	Lummi River						Jordan Creek			
	Freshwater				Marine		Freshwater			Marine
	SW012	SW013	SW009	SR005	SW008	SW051	SW011	SW010	SW003	SW053
2008-2017 (noncompliant years/years assessed)										
Winter	4/10	3/6	1/6	0/0	4/10	3/10	5/10	0/8	5/10	6/10
Spring	4/10	3/6	4/5	0/0	5/10	1/10	8/10	4/7	3/10	3/10
Summer	4/4	4/4	4/4	0/0	7/10	1/10	7/7	4/4	5/10	1/10
Fall	5/10	4/5	9/9	0/0	7/10	5/10	8/10	7/8	8/10	5/8
Overall	**9/10**	**6/6**	**10/10**	**0/0**	**9/10**	**5/10**	**10/10**	**8/9**	**9/10**	**7/10**
2018										
Winter	Meet n<3	Both n<3	Meet n<3	nd	Fail GM	Meet	Meet n<3	Meet n<3	Meet	Meet
Spring	Both n<3	Both n<3	nd	nd	Meet	Fail Max	Max n<3	Both n<3	Fail Max	Meet
Summer	nd	nd	nd	nd	Fail Max	Meet	nd	nd	Fail Max	Meet
Fall	Both n<3	Both n<3	Both n<3	nd	Meet	Meet	Both n<3	Both n<3	Fail Both	Fail Both
Overall	**Fail**	**Fail**	**Fail**	**nd**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**
2019										
Winter	Fail Both	Both n<3	nd	nd	Fail Both	Meet	Fail Both	Meet n<3	Fail Max	Meet
Spring	Meet n<3	Meet n<3	nd	nd	Fail Both	Fail Max	Meet n<3	Meet n<3	Fail Max	Meet
Summer	nd	nd	nd	Meet n<3	Fail GM	Meet	nd	nd	nd	Meet
Fall	nd	Both n<3	Both n<3	Fail Both	Meet	Fail Max	Both n<3	Meet n<3	Fail Max	Fail Max
Overall	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Fail**	**Meet n<3**	**Fail**	**Fail**

*Determination and reason (color coding): nd: no data (gray)
Meet: compliant with both the geometric mean and single-sample maximum criteria with n≥3 (green)
Fail GM: exceeds geometric mean criterion (compliant with single-sample maximum criterion) with n≥3 (red)
Fail Max: exceeds single-sample maximum criterion (compliant with geometric mean criterion) with n≥3 (red)
Fail Both: exceeds both geometric mean and single-sample maximum criterion with n≥3 (red)
Meet n<3: compliant with both the geometric mean and single-sample maximum criteria with n<3 (blue)
GM n<3: exceeds geometric mean criterion (compliant with single-sample maximum criterion) with n<3 (orange)
Max n<3: exceeds single-sample maximum criterion (compliant with geometric mean criterion) with n<3 (orange)
Both n<3: exceeds both geometric mean and single-sample maximum criterion with n<3 (orange)

Table 7.4.5 Summary of compliance with the enterococcus standard for freshwater and marine sites in the Smuggler Slough, Onion Creek (SW014), and Seaponds Creek (SW029) watersheds by year and season. Period of record 2008-2017 seasons assessed annually and reported as number of years with noncompliant season/number of years assessed (excluding years with no data for the season). For period of record, seasons with no noncompliant years in green, 50% or more noncompliant years in red, and fewer than 50% noncompliant years in orange. Reporting years reported as failing or meeting the enterococcus standard, indication of samples size less than three (n<3), and reason for noncompliance.*

Year(s) and Season	Smuggler Slough							Other	
	Freshwater				Marine			Freshwater	
	SW016	SW017	SW072	SW015	SW059	SW055	SW056	SW014	SW029
2008-2017 (noncompliant years/years assessed)									
Winter	4/9	3/7	3/7	5/10	3/10	0/7	2/7	2/10	4/9
Spring	1/8	3/5	4/7	3/9	4/10	0/10	2/10	7/10	5/9
Summer	1/1	1/1	1/4	4/5	4/5	1/9	3/9	4/5	0/0
Fall	6/7	6/6	2/5	6/9	6/10	3/9	3/7	4/10	1/7
Overall	**8/10**	**8/8**	**8/8**	**9/10**	**10/10**	**3/10**	**6/10**	**8/10**	**7/9**
2018									
Winter	Meet n<3	Meet n<3	nd	Meet n<3	Meet n<3	Meet n<3	Meet n<3	Meet n<3	Meet n<3
Spring	Both n<3	nd	nd	Meet n<3	Meet n<3	Meet n<3	Meet n<3	GM n<3†	Meet n<3
Summer	nd	nd	nd	nd	nd	Meet n<3	nd	nd	nd
Fall	nd	nd	nd	nd	Meet n<3	Meet n<3	Both n<3	Fail Both	nd
Overall	**Fail**	**Meet n<3**	**nd**	**Meet n<3**	**Meet n<3**	**Meet n<3**	**Fail**	**Fail**	**Meet n<3**
2019									
Winter	Meet n<3	Meet n<3	nd	Fail Max	Fail Max	Meet n<3	Fail Both n<3	Meet	Meet
Spring	Both n<3	nd	GM n<3†	Both n<3	Meet n<3	Meet n<3	nd	Meet n<3	Meet n<3
Summer	nd	nd	nd	nd	nd	nd	nd	nd	nd
Fall	nd	nd	nd	nd	Meet n<3	Meet n<3	Meet n<3	Fail Both	nd
Overall	**Fail**	**Meet n<3**	**nd**	**Fail**	**Fail**	**Meet n<3**	**Fail**	**Fail**	**Meet**

*Determination and reason (color coding): nd: no data (gray)
Meet: compliant with both the geometric mean and single-sample maximum criteria with n≥3 (green)
Fail GM: exceeds geometric mean criterion (compliant with single-sample maximum criterion) with n≥3 (red)
Fail Max: exceeds single-sample maximum criterion (compliant with geometric mean criterion) with n≥3 (red)
Fail Both: exceeds both geometric mean and single-sample maximum criterion with n≥3 (red)
Meet n<3: compliant with both the geometric mean and single-sample maximum criteria with n<3 (blue)
GM n<3: exceeds geometric mean criterion (compliant with single-sample maximum criterion) with n<3 (orange)
Max n<3: exceeds single-sample maximum criterion (compliant with geometric mean criterion) with n<3 (orange)
Both n<3: exceeds both geometric mean and single-sample maximum criterion with n<3 (orange)
† Site exceeded the geometric mean based on only one sample. Since it is not appropriate to calculate a geometric mean using one sample, the site was not marked as noncompliant overall.

As previously discussed, many sites are intermittent and only flow seasonally or following rain events. For this reason, most seasons had fewer than three samples for compliance determination. During the reporting period, most sites failed to meet the enterococcus standard due to exceedances of both the geometric mean criterion and the single-sample maximum (Table 7.4.4 and Table 7.4.5). The exception to this pattern is Jordan Creek site SW003, which consistently exceeded only the single-sample maximum criterion. Most sites were non-compliant during 50% or more of the years assessed over the ten-year period of record (2008-2017). All sites had at least one noncompliant year, with the exception of Jordan Creek site SW010 with was compliant during the winter season for all eight years assessed over the period of record.

Seasonally, the highest noncompliance rates were observed during the fall, when an average of 94% of sites failed to meet the standard (7.5 sites) during the reporting period; no sites were compliant during the fall in 2018 while only one was compliant during the fall in 2019 (Figure 7.4.2). Over the period of record, an average of 69% of sites failed to meet the enterococcus standard during the fall, with the lowest noncompliance rate in 2011 of 22% and with all assessed sites failing to meet the standard in 2009 and 2013. The highest compliance rate and lowest noncompliance rate were observed during the winter, when an average of 29% of sites were noncompliant (i.e., 71% were compliant), with 9% noncompliance in 2018 and 50% noncompliance in 2019. During the winter, most sites were flowing and therefore able to be assessed. Over the period of record, an average of 39% of sites were noncompliant with the enterococcus standard during the winter, but ranged from 15% in 2011 to 69% in 2010. During spring, slightly more than half of sites were noncompliant but with wide variability year-to-year; during the reporting period, noncompliance was 78% in 2018 and 40% in 2019 with the average over the period of record of 52% (ranging from 0% in 2016 to 100% in 2011). Although few sites had flowing water during the summer, when water was flowing, water quality was likely to be out of compliance. During the reporting period, only one noncompliant site had flow during the summer of 2018 and only one compliant site had flow during the summer of 2019. Over the period of record, noncompliance was 83% from 2008-2012 and 57% from 2013-2017 with wide variability year-to-year from 0% in 2016 and 2017 to 100% in 2011, 2013, and 2015.

The Lummi River, Jordan Creek, Smuggler Slough, and Onion Creek watersheds are not protective of recreational uses due to failure to meet the enterococcus standard. These drainages are already not protective of recreational uses as they cross onto the Reservation from the north and east. The Seaponds Creek watershed is in compliance with the enterococcus standard and therefore protective of recreational uses.

7.5. Saltwater Intrusion

Saltwater intrusion and groundwater mining are related concerns for potable groundwater resources found on the Reservation. Groundwater mining, the withdrawing of groundwater at a rate that exceeds the recharge rate of the supply aquifer, can reduce the long-term ability of freshwater aquifers to provide good quality groundwater for potable uses. Groundwater mining can also lead to saltwater intrusion, the movement of saline water into freshwater aquifers; when freshwater wells are over-pumped, the saline groundwater is pulled into the freshwater aquifer due to pressure gradients. Saltwater intrusion can contaminate drinking water sources and reduce the supply of potable drinking water since well pump rates must be reduced or supply wells taken out of production to prevent further saltwater intrusion.

Groundwater resources on the Reservation are particularly vulnerable to saltwater intrusion because the Reservation is in a coastal area with most of the existing supply wells located within a half-mile of marine waters (LWRD 1997). Because of the proximity to marine waters and the local geology, the aquifers on the Reservation are subject to both horizontal and vertical saltwater intrusion if wells are over-pumped (LWRD 1997). The majority of residential development has occurred along the marine shoreline, placing the most vulnerable portion of aquifers at risk through pumping of groundwater near marine shorelines.

7.5.1. Chloride

Chloride concentration is measured at fourteen tribal supply wells and representative domestic wells throughout the year to monitor changes in chloride concentration as an indicator of the presence of or risk of saltwater intrusion and groundwater mining. Lummi Nation Surface Water Quality Standards do not apply to groundwater and no standard for chloride has been established, but these results are included in this report as they are monitored as part of the Lummi Nation WQM Program. Chloride trigger values have been established for certain wells as part of the Lummi Peninsula Groundwater Settlement Agreement.

During the reporting period 2018-2019, five chloride samples were collected and analyzed approximately every other month from April through December for domestic wells in 2018 and 2019 and for tribal supply wells in 2019. Four chloride samples were collected and analyzed (April/May, August, October, December) for supply wells in 2018. All chloride samples were analyzed by the contracted laboratory during the reporting period.

7.5.1.1 Chloride Methods

Three different methods have been used to measure chloride concentration in groundwater. A LaMotte chloride kit was used from 1990 to June 2012. A chloride sensor on the YSI ProPlus water quality sonde was used from October 2011 to January 2016. Throughout the years, laboratory analysis of chloride has been used for various projects (including compliance with the Lummi Peninsula Groundwater Settlement Agreement), but use of laboratory analysis of chloride for routine monitoring under the Ambient Groundwater Quality and Quantity Project (Groundwater Project) commenced in 2016. On occasion, the chloride kit and chloride instrument were used simultaneously with laboratory analysis of chloride.

Although analysis of chloride sensor data with laboratory analysis of chloride using data through December 31, 2013 found a significant near one-to-one linear relationship and no significant difference between paired measurements using a t-test (LWRD 2019b), use of paired data from 2014-2016 found that the chloride instrument often overestimated the chloride concentration (as determined by the laboratory analysis). Although there was a significant linear relationship, the line fit was poor (R^2 was 0.65) and the chloride instrument measured higher chloride concentration than the lab analysis (Figure 7.5.1). A paired-sample test found that the paired measurements were significantly different, with the instrument reading an average of 5.9 mg Cl-/L higher than the laboratory analysis.[19] Similarly, comparison of chloride measurements with the LaMotte chloride kit with laboratory-analyzed chloride results found that, although there is a significant linear relationship (R^2 was 0.88), the chloride kit overestimates the chloride concentration (as determined by the laboratory analysis). A paired-sample test found that the paired measurements were significantly different, with the kit reading an average of 3.8 mg Cl-/L higher than the laboratory analysis.[20]

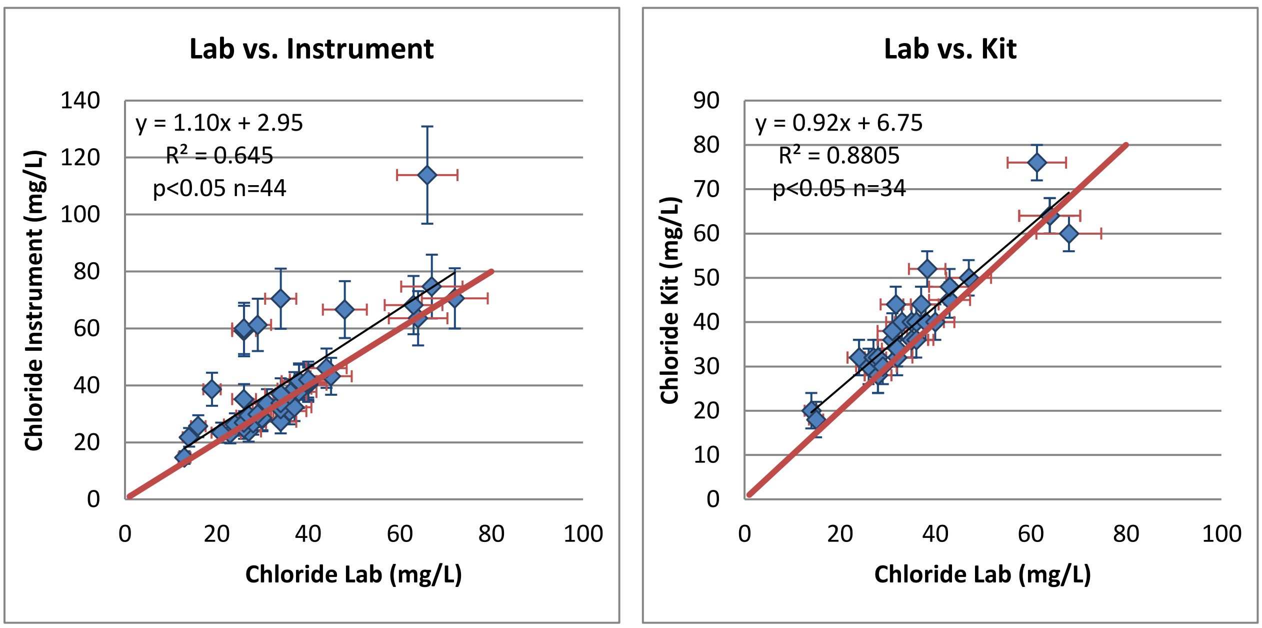


Figure 7.5.1 Chloride method comparison for chloride instrument (YSI) vs. laboratory sample analysis (left) and chloride kit (LaMotte) vs. laboratory sample analysis (right). Blue points show paired chloride measurements with error: ±10% for laboratory sample analysis (in red), ±15% for chloride instrument (YSI), and 4 mg/L for chloride kit (LaMotte). Red line is 1:1 line. Black line is significant linear regression trend; equation, R^2, p-value, and sample size (n) are shown on each comparison plot.

[19] Wilcoxon signed rank test of paired measures of chloride instrument and chloride lab result had a p-value < 0.05 using 44 paired samples. Measurements using the two methods were collected within 1 hour of each other. The difference in measures was not normally distributed, so nonparametric test was used instead of paired sample t-test.

[20] Paired sample t-test of chloride kit and chloride lab result had a p-value <0.05 using 34 paired samples. Measurements using the two methods were collected within 1 hour of each other. The difference in measures was approximately normally distributed (Shapiro-Wilk normality test p=0.026).

Although the paired sample tests found that both the chloride instrument (YSI) and chloride kit (LaMotte) overestimated the chloride concentration as compared to the laboratory analyzed result, the wide error associated with each measurement may mean that the measurements were within the error ranges of each other. The LaMotte chloride kit has an error of ±4 mg/L given the method resolution (no accuracy for the measurement was given by the manufacturer), and the paired sample test found that the chloride measurements using the kit were, on average, within 3.8 mg/L of the laboratory concentration, which indicates that these methods have overlapping error ranges. The chloride instrument (YSI) measurement, however, was on average 5.9 mg Cl-/L greater than the laboratory concentration, which is 14% of the average chloride measurement collected using the YSI and below the 15% error reported for the YSI chloride sensor. For this report, all three methods of measuring chloride were used and pooled for trend analysis because the difference in measurements collected using the kit and instrument from the laboratory analyzed concentrations were, on average, within the method error rates. Future reports should further examine whether the methods are comparable given the error rates of each method.

7.5.1.2 Mean Chloride

During the reporting period (2018-2019), annual mean chloride was highest at Kinley #1 (GW059) and lowest at GW074, which was also the case on average over three periods of record (1990-1999, 2000-2009, and 2010-2017). All chloride measurements and annual means were below the trigger level (140 mg Cl^-/L).

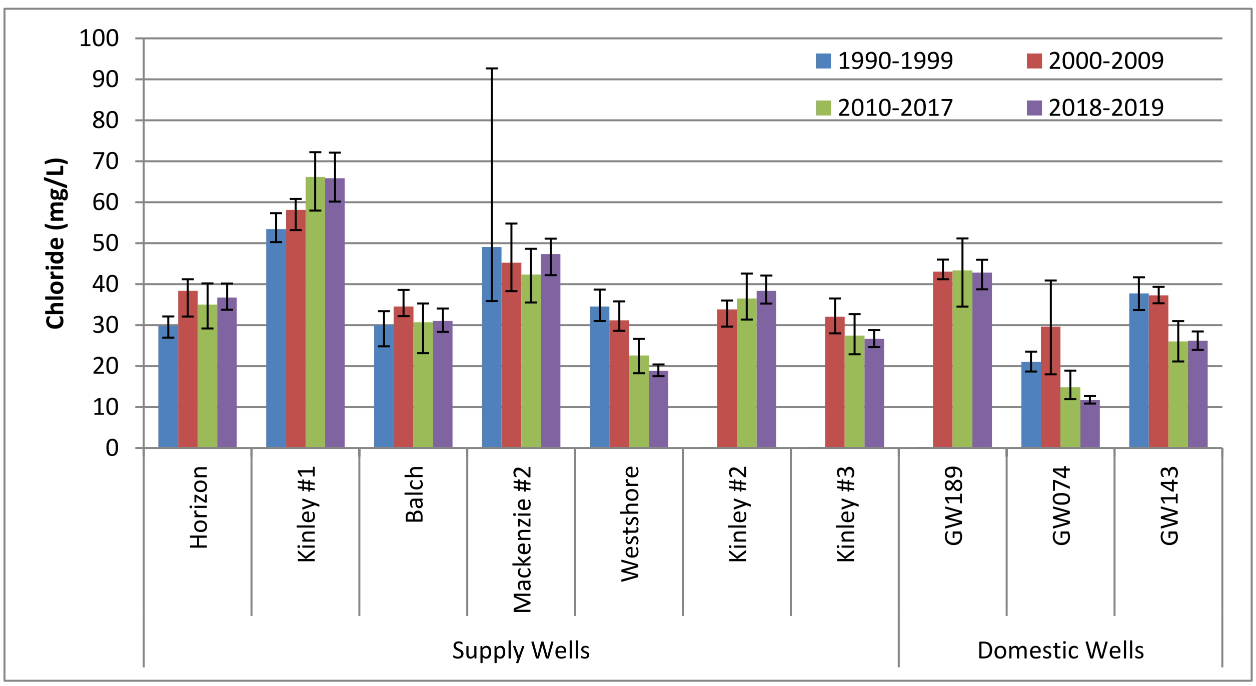


Figure 7.5.2 Mean (bar) and average range (min-max; whiskers) chloride concentrations at supply wells and domestic wells on the Lummi Peninsula over the period of record (1990-1999, 2000-2009, and 2010-2017) and for the reporting period (2018-2019). Methods pooled (lab, instrument, kit) and averaged by date with annual mean, minimum, and maximum calculated and averaged for each period.

7.5.1.3 Trends

Analysis of the long-term chloride trend over the period of record using linear regression of chloride concentration (methods pooled; average chloride per trip) by year found that two wells had significant increasing trends, five wells had significant decreasing trends, and three wells had no significant trends (Table 7.5.1). Analysis of chloride trends over the short-term, for the four-year period 2016-2019 during which only laboratory analysis of chloride was conducted, found six wells with significant increasing trends, one well with a significant increasing trend at larger margin of error (alpha error of 10% instead of 5%), and three wells with no significant trends.

Table 7.5.1 Results of long-term and short-term regression analysis (chloride by year) for on-Reservation groundwater wells, including date range (start year-2019) for long-term trend, sample size (n), and slope for significant linear regression model. **Increasing (+)** trends marked in bold.

Well ID	Name	Long-Term Trend (Start Year-2019)			Short-Term Trend (2016-2019)	
		Start Year	n	Slope	n	Slope
Peninsula Supply Wells						
GW058	Horizon	1991	405	**0.13**	19	**2.3**
GW059	Kinley #1	1990	218	**0.61**	19	**1.8**
GW115	Balch	1992	247	NS	19	**2.8**
GW129	Mackenzie #2	1990	180	-0.52	14	NS
GW146	Westshore	1994	389	-0.63	19	NS
GW409	Kinley #2	2006	108	NS	19	**2.2**
GW421	Kinley #3	2006	111	-0.60	19	**1.3**
Peninsula Domestic Wells						
GW074	Charles	1993	180	-0.40	20	NS
GW143	Berg	1992	184	-0.59	20	**1.9**
GW189	Egawa	2004	106	NS	20	**2.8***

NS: not significant
*2016-2019 short term trend at Egawa (GW189) had p=0.080, which is near but above the 0.05 cutoff. The results are included here out of an abundance of caution.

The Horizon well (GW058) had a significant increasing long-term linear trend for chloride concentration by year (Table 7.5.1, Figure 7.5.3). The slope of the linear model was low, 0.13, which means that it would take approximately 7 years for the chloride concentration to increase by 1 mg/L. Although even a slowly increasing trend of chloride concentration is a concern, in this case the significant trend may be due to chloride concentrations observed during the early 1990s that were lower than the period of record average chloride concentrations; these low values at the beginning of the dataset may be disproportionately influencing the overall trend. When data collected during the most recent 20 years are used, years 2000-2019, regression analysis finds a significant decreasing trend.[21] A similar pattern was observed during previous water quality assessments; a significant increasing trend was found when using all data, but the regression was no longer significant when only data from 2000-2013 and 2000-2017 were used (LWRD 2019b,c). This indicates that the significant increasing trend found using all available data is an artifact of the low initial chloride concentrations measured at the site. Although chlorides have increased over the full period of record (1991-2019), the more recent 20-year dataset does not suggest an increased risk of saltwater intrusion. Over the short term (2016-2019), however, there is a significant increasing chloride trend at the Horizon well, which should be closely monitored over the following years to determine if the trend continues.

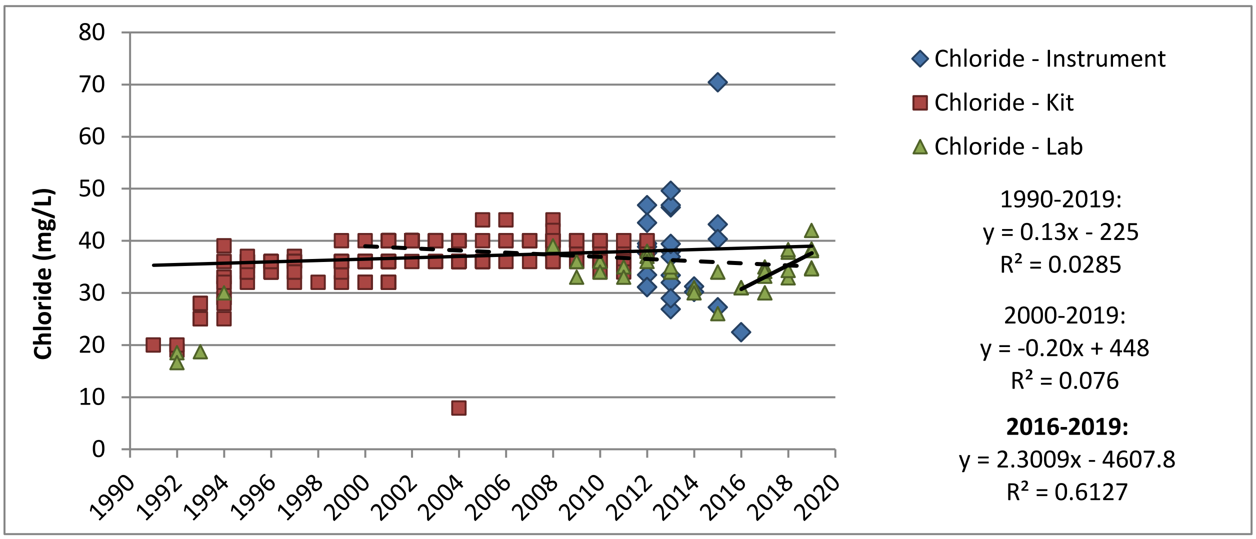


Figure 7.5.3 Chloride (mg/L) measurements by year at Horizon (GW058). Linear regression of chloride (methods pooled; trip averaged) by year for the long-term full period of record (1991-2019; solid line), the medium-term period (2000-2019; dashed line), and short-term period (2016-2019; bold line) were all significant ($p<0.05$).

The Kinley #1 well (GW059) also had a significant increasing linear trend for chloride concentration by year (Table 7.5.1, Figure 7.5.4). The slope of the linear model was 0.61, which means that it would take approximately 1.5 years for the chloride concentration to increase by 1 mg/L. Although this is a slow rate of increase, the fact that the Kinley #1 well already has some of the highest chloride concentrations of the Peninsula supply wells, it is important to take mitigating actions if the increasing trend continues. Annual mean chloride at Kinley #1 was highest during 2015 (78 mg Cl^-/L) followed by 2013 (72 mg Cl^-/L) and 2012 (71 mg Cl^-/L). Similarly, the highest individual chloride concentrations were measured in 2015 (114 mg Cl^-/L), 2013 (88 mg Cl^-/L), and 2012 (85 mg Cl^-/L). The highest chloride measurements were obtained using the YSI chloride sensor, which has a higher error than the laboratory analysis method. In December 2015, the YSI chloride sensor measured a chloride concentration of 114 mg/L while

[21] Linear regression of chloride (methods pooled; trip averaged) at GW058 (Horizon) by year for years 2000-2019 had $p<0.05$ using 342 observations. Linear model obtained: Chloride (mg/L) = -0.205*year+448.

the lab-analyzed sample resulted in a chloride concentration of 66 mg/L, a 53% relative percent difference. Note that for the all-methods regression, results obtained on the same day were averaged. Visual examination of the data shows that the YSI chloride readings are not in line with the laboratory analysis results for the same period. Exclusion of chloride measurements obtained using the YSI chloride sensor from the regression analysis still finds a significantly increasing chloride trend over the long-term period of record, but with lower slope indicating a chloride concentration increase of 1 mg/L approximately every two years.[22]

Although the chloride concentration at Kinley #1 (GW059) is not at risk of reaching the 140 mg/L chloride trigger value established in the Lummi Peninsula Groundwater Settlement Agreement within the foreseeable future, chlorides at this well will continue to be monitored to ensure that groundwater mining does not take place. Chloride monitoring as part of the Lummi Peninsula Groundwater Settlement Agreement has not shown an increasing trend in chloride concentration. Chloride monitoring for the Settlement Agreement began in August 2008 and consists of laboratory analysis of chloride samples in April, August, and December annually. In addition to the chloride samples analyzed three times per year as part of the Settlement Agreement, laboratory analyzed chloride results are available for June and October for 2016-2019. Regression analysis of laboratory analyzed chloride from 2008 to 2019 did not find a significant trend in either direction, while linear regression of the laboratory chloride data from the four-year period 2016-2019 found a significant increasing trend. This suggests that, although the long-term (1990-2019) trend may be increasing slightly, chlorides have not changed significantly over the last twelve years. However, due to the short-term increasing trend, this well should be monitored closely for indicators of increased risk of groundwater mining and saltwater intrusion and to determine whether this trend continues.

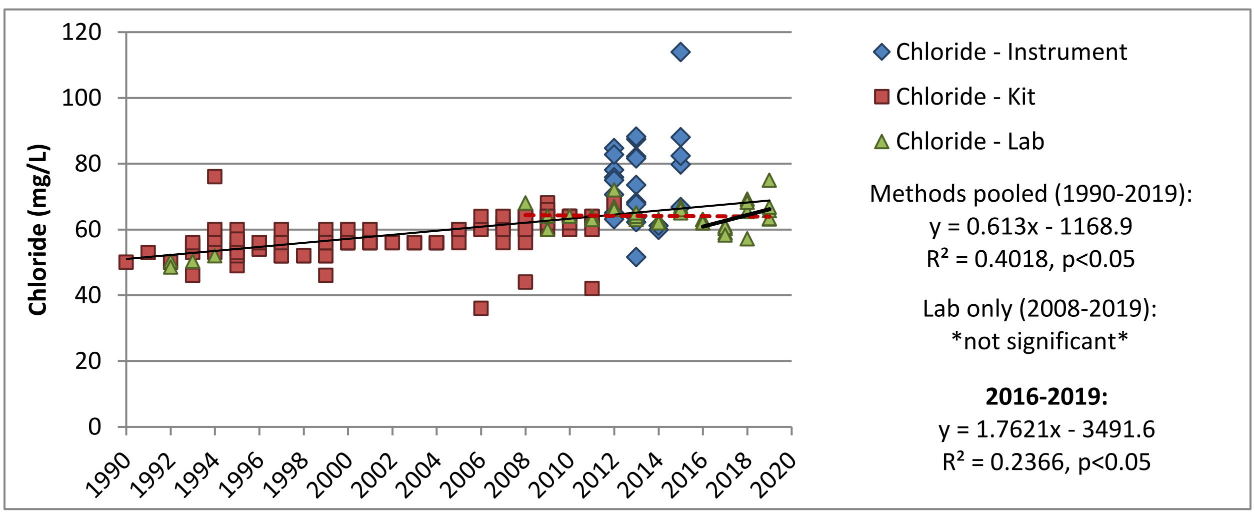


Figure 7.5.4 Chloride (mg/L) measurements by year at Kinley #1 (GW059). Linear regression of chloride by year was significant ($p<0.05$) for the long-term period of record (methods pooled; trip averaged; 1990-2019; solid line) and short-term (lab-only; 2016-2019; bold line). Linear regression was not significant for lab only chloride results 2008-2019 (red dashed line).

[22] Linear regression of chloride (chloride kit and laboratory analysis methods only) at GW059 (Kinley #1) by year for years 1990-2019 had $p<0.05$ using 202 observations. Linear model obtained: Chloride (mg/L) = 0.485*year-914.

The Balch (GW115), Kinley #2 (GW409), and Egawa (GW189) wells were identified as having significant increasing long-term chloride trends in the 2013 Water Quality Assessment Report (LWRD 2019b). These wells were no longer found to have a significant chloride long-term trend over time in the 2014-2019 Water Quality Assessment Report (LWRD 2019c). Similarly, when data collected during the reporting period (2018-2019) were added to the dataset, no significant long-term trend in chloride concentration over time was found (Table 7.5.1). These three wells had increasing chloride concentrations collected using the YSI chloride sensor through 2015 which were not corroborated with the laboratory chloride analysis. With the replacement of laboratory chloride analysis in 2016, the greater error associated with measurements collected using the YSI chloride sensor was removed, and the long-term trend stabilized to background.

The five wells with decreasing long-term trends included supply wells Mackenzie #2 (GW129), Westshore (GW146), and Kinley #3 (GW421) and domestic wells GW074 and GW143. These five wells also had a significant decreasing trend in chloride concentration by year identified in the 2013 and 2014-2017 Water Quality Assessment Reports (LWRD 2019b,c). The slope of the linear regression equation stayed the same or decreased between the 2013 and 2014-2017 reporting periods at all wells (LWRD 2019c). The slope of the linear regression equation remained the same or continued to decrease at all wells except Mackenzie #2 from 2014-2017 to the reporting period 2018-2019. The increased slope for the reporting period 2018-2019 at Mackenzie #2 was still negative (i.e., decreasing chloride over time) and lower than during the 2013 reporting period (i.e., trend is becoming more negative over time). This indicates that the long-term decreasing trend in chloride concentration over time is continuing or strengthening.

As mentioned above, the short-term trend (2016-2019) was found to be significantly increasing at seven wells: Horizon (GW058; Figure 7.5.3), Kinley #1 (GW059; Figure 7.5.4), Balch (GW115), Kinley #2 (GW409; Figure 7.5.5), Kinley #3 (GW421; Figure 7.5.6), Berg (GW143), and Egawa (GW189).[23] The average modeled rate of increase was 2 mg Cl^-/L per year, which would lead to an increase of 10 mg Cl^-/L in five years. Although this rate of increasing chloride concentration is concerning, the short-term trend is present at the tail-end of a long dataset of decreasing (or unchanging) chlorides at most wells. The four year period during which only laboratory analysis was used for chloride concentration measurement also coincided with the change in the contracted laboratory conducting the analyses. Although both laboratories were WA State certified for chloride analysis methods, there may have been differences in the laboratory results that were still within the error of the lab method, but resulted in the presence of an increasing chloride trend when assessed over the four-year period. The wells with both long-term and short-term increasing chloride trends should be the most closely monitored over the next two years to determine whether the increasing trend was due to the change in laboratory or are indeed indicators of an increased risk of groundwater mining and saltwater intrusion. Wells with long-term decreasing trends and short-term increasing trends should also be monitored. Of greatest concern are the wells with both short term increases in chloride concentration and decreases in water surface elevation (Kinley #2 and Kinley #3). Management

[23] Linear regression at Egawa (GW189) had a p=0.080, which is near but above the 0.05 cutoff. This regression model is resented here with the significant results out of an abundance of caution.

of these wells should be assessed with the appropriate well owners and operators to reduce the risk of groundwater mining and saltwater intrusion.

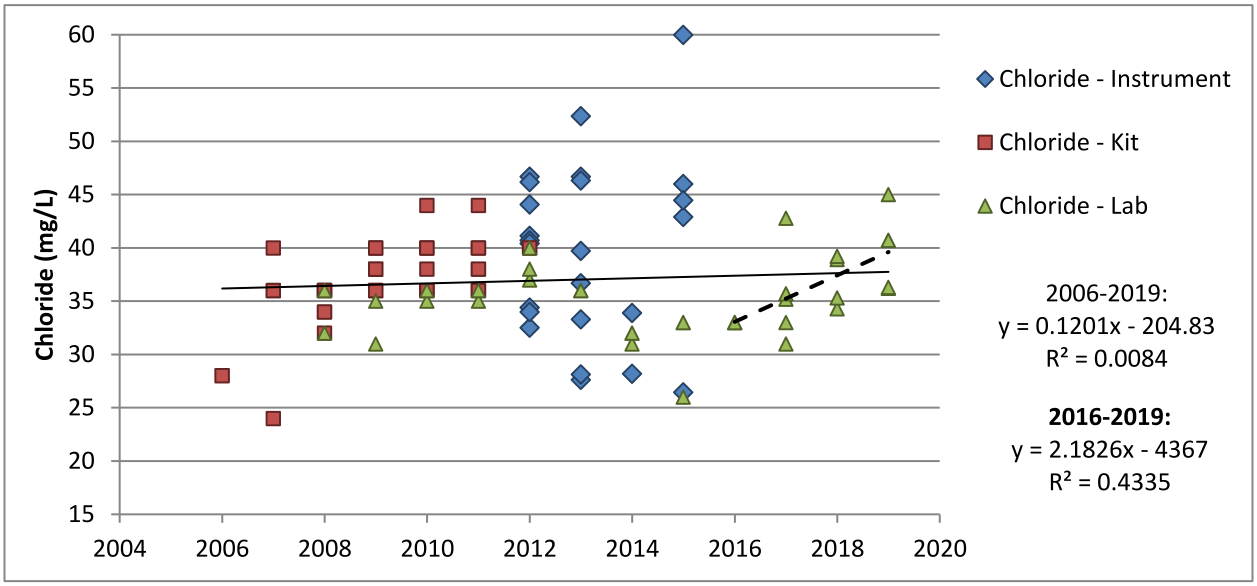


Figure 7.5.5 Chloride (mg/L) measurements by year at Kinley #2 (GW409). Linear regression of chloride (methods pooled; trip averaged) by year for the long-term full period of record (2006-2019; solid line) and short-term period (2016-2019; dotted line) were both significant ($p<0.05$).

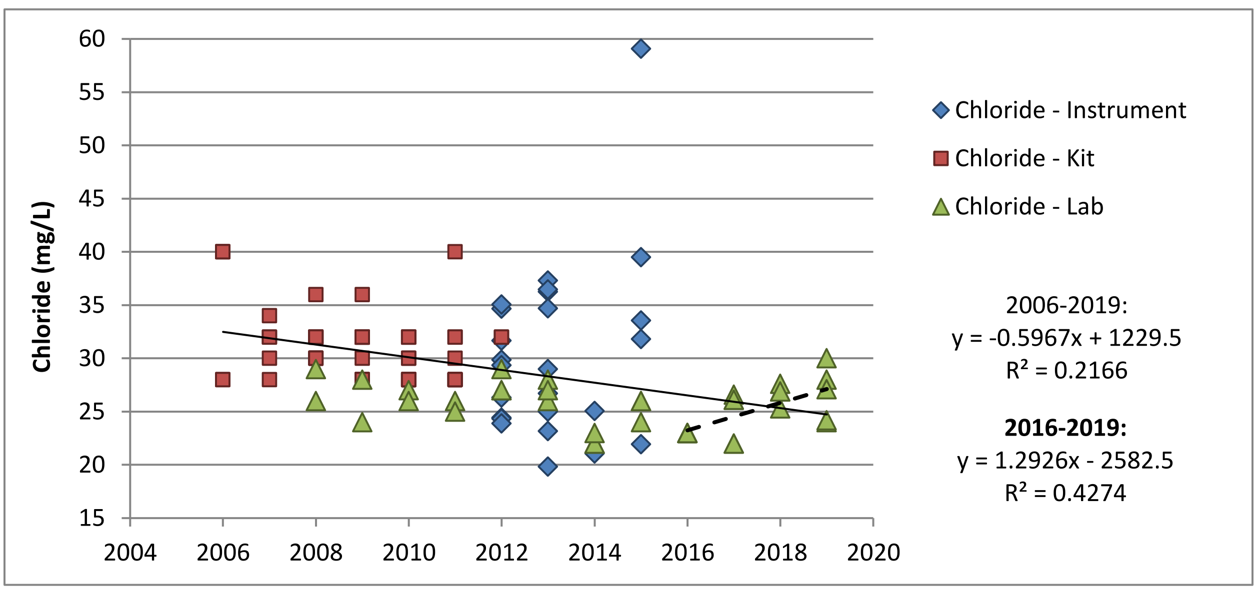


Figure 7.5.6 Chloride (mg/L) measurements by year at Kinley #3 (GW421). Linear regression of chloride (methods pooled; trip averaged) by year for the long-term full period of record (2006-2019; solid line) and short-term period (2016-2019; dotted line) were both significant ($p<0.05$).

7.5.2. Water Surface Elevation

Aquifer level is measured at ten tribal supply wells and three representative domestic wells in order to monitor aquifer level changes over time, which is used to assess presence of or risk of saltwater intrusion and groundwater mining. In addition, ten wells that are no longer in production are monitored for aquifer level trends, four of which are also included in the Continuous Aquifer Level Monitoring Project. Depth to aquifer water level is measured from a fixed measuring point when wells are not actively pumping. Three water level measurements are collected in order to ensure that measurement represents static conditions (*i.e.,* the aquifer has rebounded from the effects of active pumping). During the reporting period, water levels were measured five times per year, approximately every-other month from April to December for domestic wells in 2018 and 2019 and for supply wells in 2019. Water levels were measured four times per year (April/May, August, October, December) at supply wells in 2018. For wells no longer in production, five wells were monitored five times per year, approximately every-other month from April to December, and five wells were monitored four times per year, quarterly (including the Continuous Aquifer Level Monitoring Project wells), during the reporting period 2018-2019. At domestic wells, homeowners were often using water or had recently used water that precluded attainment of a static water level; for these wells, fewer than five water level measurements are available for each year.

No water level measurements were collected between September 2005 and February 2007 due to staffing limitations. This period creates a natural break in the dataset, which was often accompanied by a change in the water surface elevation trend or scatter for many wells. For this reason, two periods were analyzed for water level trends: the start of the period of record (depends on the well, some sampled as early as 1992) through 2019 and 2007-2019. A summary of mean water surface elevation is presented for two periods of record (period of record start through 2006 and 2007-2017) and the reporting period (2018-2019).

Mean water surface elevation was above zero feet mean sea level (msl) for seven tribal supply wells and three domestic wells located on the Lummi Peninsula for all periods: the two periods of record 1993-2006 and 2007-2017, as well as the reporting period 2018-2019 (Figure 7.5.7).The Westshore well (tribal supply well GW146) had a standard deviation that extended below zero for the 2007-2017 period of record. Three very low measurements during 2013 and 2015 (-14.6 feet msl) resulted in widely expanded standard deviation for the period. Without these outliers, the mean and standard deviation would remain above mean sea level. Over the 1994-2006 period of record, there were 13 water surface elevation measurements below zero feet msl, with the lowest of these at -2.91 feet msl. The highest water surface elevation was measured at domestic well GW189, which is located in the uplands of the southern Lummi Peninsula, but relatively close to the eastern shoreline. The lowest water surface elevation was measured at the Westshore well, as discussed above, as well as at domestic well GW074, which is located along the bluff near the western shore of the southern portion of the Lummi Peninsula. Although the domestic well GW143 and tribal supply well Mackenzie #2 (GW129) are located in close proximity to each other, the water surface elevations at these wells were very different, with average mean difference of 9 feet. Mean water surface elevation during the reporting period was similar to the mean for the 2007-2017 period of record at all wells and similar to the 1993-2006 period of record at most wells.

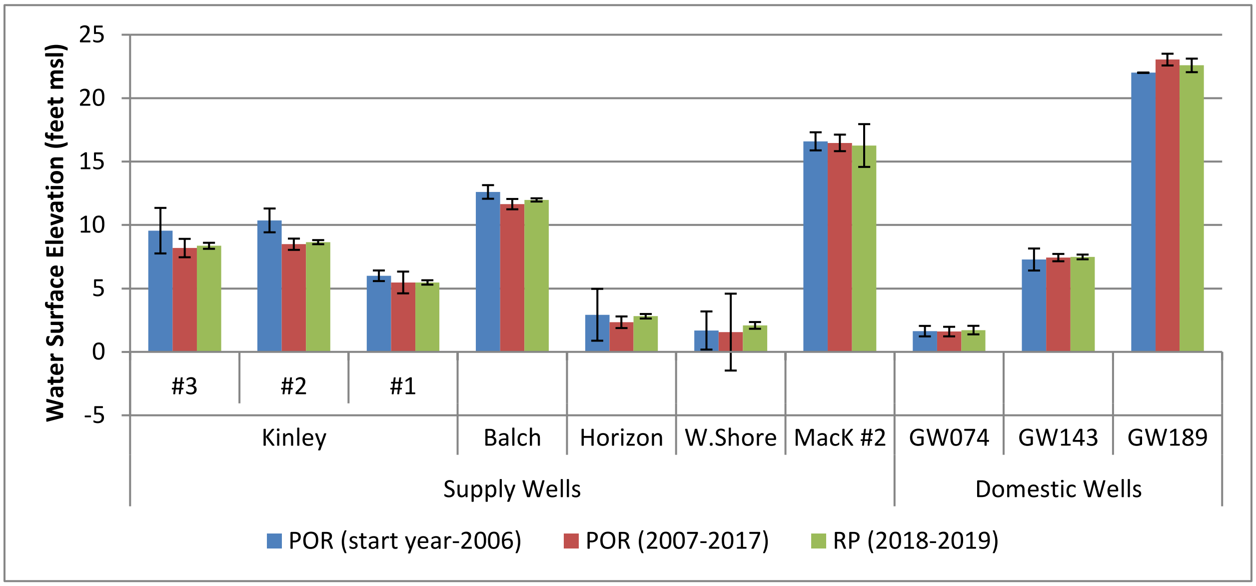


Figure 7.5.7 Mean water surface elevation (as feet +/- mean sea level) and standard deviation for tribal supply wells and select domestic wells on the Lummi Peninsula for the period of record (POR; start date through 2006, 2007-2017) and for the reporting period (RP) 2018-2019. Period of record (POR) start year and sample size for the POR and the reporting period 2018-2019 used to calculate mean and standard deviation shown in table to the right.

Site	POR Start	Sample Size (n)		
		Start-2006	2007-2017	2018-2019
Kinley #3	2001	20	86	9
Kinley #2	1999	31	86	9
Kinley #1	1992	73	87	8
Balch	1994	61	84	8
Horizon	1993	76	87	9
Westshore	1994	101	101	8
Mackenzie #2	1992	78	89	9
GW074	1993	56	71	9
GW143	1993	53	83	4
GW189	1999	1	86	8

Nine groundwater wells on the Lummi Peninsula that are no longer in production were monitored during the 2018-2019 reporting period. Mean water surface elevation was above zero feet msl at all wells except Hopkins (monitoring well GW111) (Figure 7.5.8). The highest water surface elevation was observed at the Howell well (monitoring well GW446), which is located in the uplands of the north central portion of the Lummi Peninsula. The lowest water surface elevation was observed at the Hopkins well (GW111) and monitoring well GW127. There appears to be a decreasing trend over time at the Hopkins well, while water surface elevation appears steady at GW127. Overall, with the exception of Hopkins (GW111), mean water surface elevation during the reporting period was similar to the mean for the 2007-2017 period of record at all wells and similar to the 1993-2006 period of record at most wells.

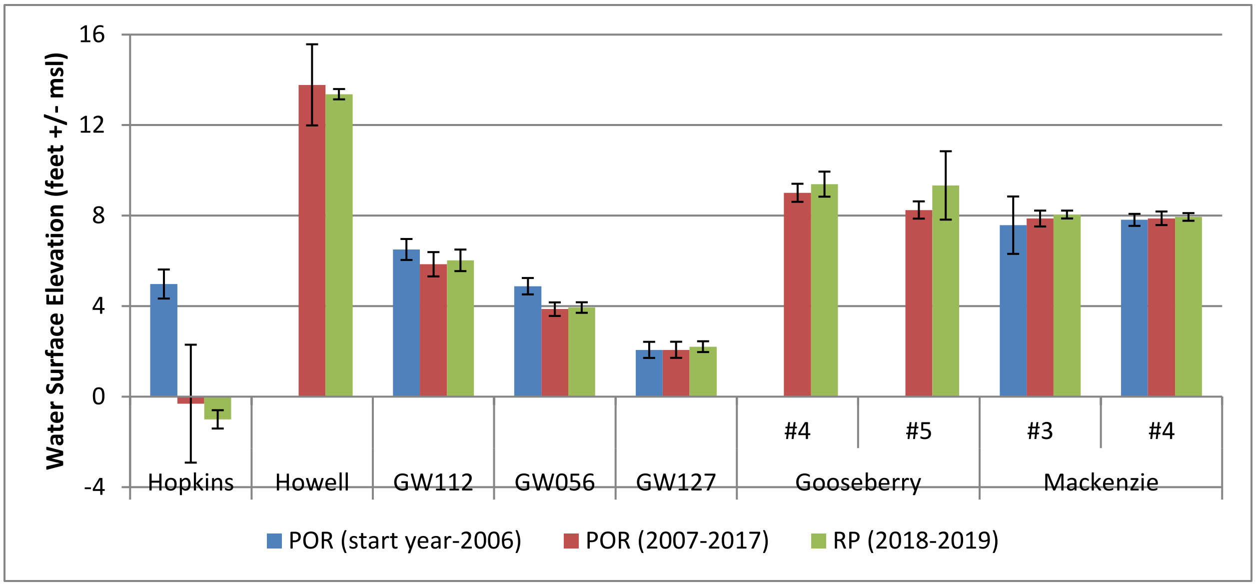


Figure 7.5.8 Mean water surface elevation (as feet +/- mean sea level) and standard deviation for groundwater wells not in production on the Lummi Peninsula for the period of record (start date through 2006, 2007-2017) and for the reporting period 2018-2019. Period of record (POR) start year and sample size for the POR and the reporting period 2018-2019 used to calculate mean and standard deviation shown in table to the right. Dash (-) indicates no data for the well for the given period.

Site	POR Start	Sample Size (n)		
		Start-2006	**2007-2017**	**2018-2019**
Hopkins	1992	102	82	7
Howell	2011	-	39	8
GW112	1992	57	79	9
GW056	1993	36	80	7
GW127	1993	86	76	7
Gooseberry #4	2011	-	30	9
Gooseberry #5	2011	-	29	9
Mackenzie #3	1999	15	72	7
Mackenzie #4	2001	5	74	6

Linear regression of water surface elevation by year was conducted for the full period of record (start date-2019), the medium-term period 2007-2019, and short-term period 2016-2019. All wells with significant decreasing water surface elevation trends for the full period of record had either a significant increasing water surface elevation trend or a non-significant linear regression result for the more recent period 2007-2019 (Table 7.5.2). Eight wells had significant linear regression models with a decreasing water surface elevation trend for the full period of record: three wells not in production (GW056, GW111 Hopkins, and GW112) and five tribal supply wells (GW058 Horizon, GW059 Kinley #1, GW115 Balch, GW409 Kinley#2, and GW421 Kinley #3). Four wells had significant linear regression models with a decreasing water surface elevation trend for the period 2016-2019: GW056, Kinley #2 (GW409), Kinley #3 (GW421), and Northwest #3 (GW441). All other wells had no significant trends for the period 2016-2019.

Table 7.5.2 Linear regression results for water surface elevation by year for tribal supply wells, domestic wells, and monitoring wells that are not in production. Linear regression was conducted for full period of record (start date varies by location) and for the period 2007-2019, when appropriate. Significant negative slope marked in bold; corresponding 2007-2019 regression result also listed in bold.

	1993-2019 Long-Term Trend				2007-2019 Recent Trend			
Well ID	Start Year	n	slope	SE of slope	Start Year	n	slope	SE of slope
Monitoring Wells - Not In Production								
GW111 Hopkins	1992	191	**-0.311**	0.021	2007	89	**ns**	ns
GW446 Howell	-	-	-	-	2011	47	ns	ns
GW112	1992	145	**-0.032**	0.0052	2007	88	**0.047**	0.017
GW056	1993	123	**-0.054**	0.006	2007	87	**0.049**	0.0083
GW127	1993	169	ns	ns	2007	83	ns	ns
GW420 Gooseberry #4	-	-	-	-	2011	39	0.059	0.027
GW419 Gooseberry #5	-	-	-	-	2011	38	0.14	0.053
GW405 Mackenzie #3	1999	94	0.031	0.012	2007	79	0.29	0.012
GW422 Mackenzie #4	2001	85	ns	ns	20070	80	ns	ns
Tribal Supply Wells								
GW058 Horizon	1993	172	**-0.030**	0.0145	2007	96	**0.11**	0.0076
GW059 Kinley #1	1992	168	**-0.030**	0.0042	2007	95	**0.039**	0.0076
GW115 Balch	1994	153	**-0.042**	0.0066	2007	92	**0.087**	0.0089
GW129 Mackenzie #2	1992	176	ns	ns	2007	98	0.059	0.023
GW146 Westshore	1994	210	ns	ns	2007	109	ns	ns
GW409 Kinley #2	1999	126	**-0.11**	0.014	2007	95	**0.070**	0.011
GW421 Kinley #3	2001	115	**-0.047**	0.021	2007	95	**0.088**	0.019
Domestic Wells								
GW074	1993	136	ns	ns	2007	80	ns	ns
GW143	1993	140	ns	ns	2007	87	0.038	0.0092
GW189	-	-	-	-	2007	94	ns	ns

- (dash) = no data available for the period
ns = regression not significant

The data gap between 2005 and 2007 was concurrent with a change in the water surface elevation trend at all sites with a significant decreasing trend in surface water elevation for the full period of record. Between 2005 and 2007, staffing limitations led to a decrease in the frequency of groundwater monitoring. For this reason, there are limited data during the period during which a change in the water level trend appears to have occurred. There may have been changes in the measuring point, measuring technique, staff changes, or equipment during this time. Alternatively, there may have been a decrease in pumping rates during this time, which also coincides with the finalization of the Lummi Peninsula Groundwater Settlement Agreement in 2007.

At the Hopkins well (GW111), a monitoring well that is not in production, water level was steady at approximately 5 feet above msl for the period 1992-2005. Following the data gap from 2005-2007, much wider variability in water surface elevation was observed for the period 2007-2019. Although linear regression of water surface elevation by year found a significant decreasing trend for the full period of record, the linear regression for the medium-term period 2007-2019 and the short-term period 2016-2019 were not significant (Figure 7.5.9). This suggests that the long-term water surface elevation has decreased at this well, but no significant changes have occurred over the last thirteen years or most recent four years. Although this well is not in production, water surface elevation at this location has been below mean sea level consistently since 2014, indicating that there may be a risk of ongoing groundwater mining or saltwater intrusion occurring in this portion of the aquifer. Analysis of the continuous aquifer level data collected as part of the Continuous Aquifer Level Monitoring Project and confirmation of the measuring points (well stickup height and elevation) used to calculate water surface elevation from raw depth to water data collected in the field are warranted in the near future.

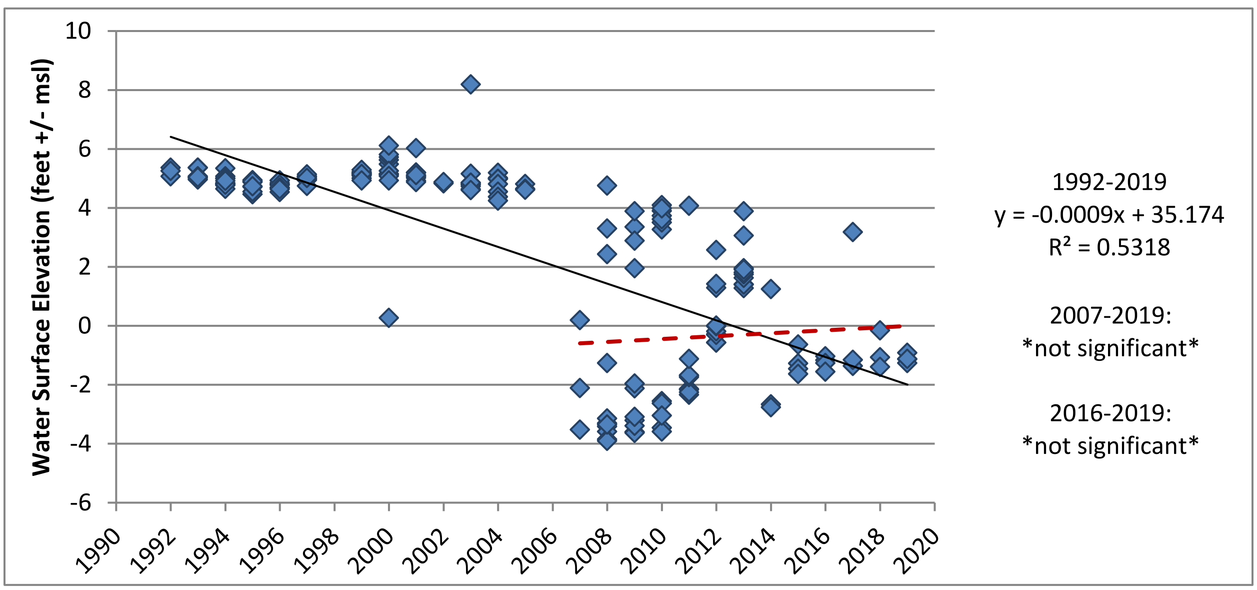


Figure 7.5.9 Water surface elevation (feet +/- mean sea level) at monitoring well Hopkins (GW111) over the period of record (1992-2019). Significant regression result shown for full period of record (solid line). Linear regression for period 2007-2019 was not significant, but shown as red dotted line for reference. Linear regression for period 2016-2019 was also not significant and is not pictured.

Tribal supply well Kinley #1 (GW059) had a significant decreasing trend in water surface elevation for the period of record 1992-2019. However, the linear regression for the period 2007-2019 was also significant, this time with an increasing trend in water surface elevation (Figure 7.5.10). Visually, there is a shift in the trend that occurred during the data gap from 2005-2007. In addition, the shape of the trend for the period 1992-2016 appears polynomial rather than linear. The more recent 13-year record suggests that there is not an increased risk of groundwater mining and saltwater intrusion at Kinley #1 (GW059). Linear regression of the short-term four-year period 2016-2019 was not significant.

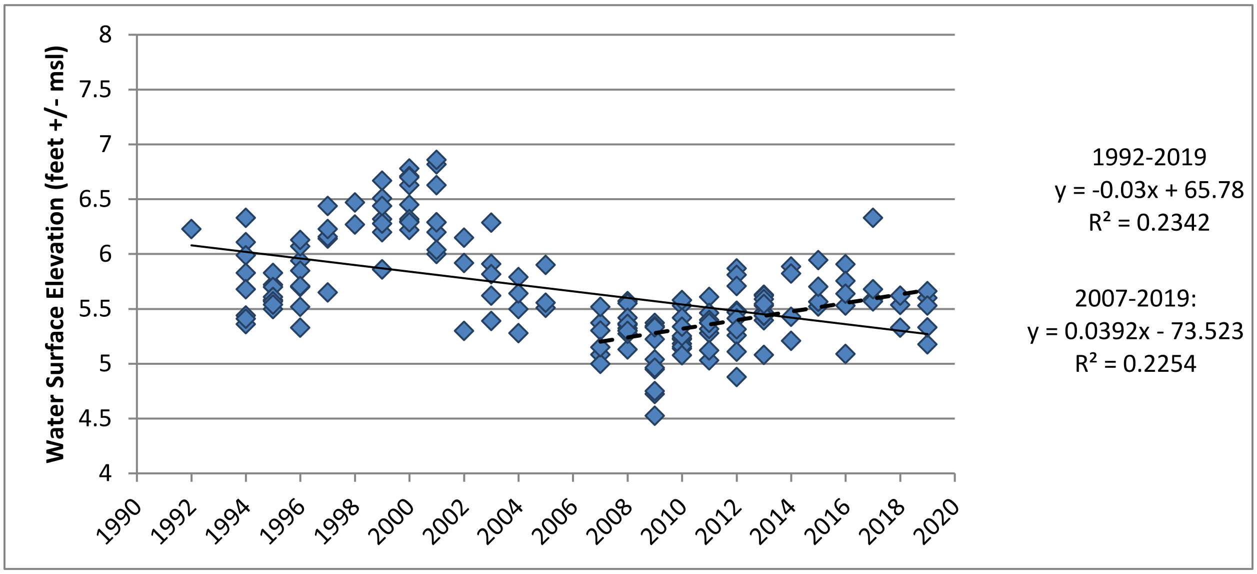


Figure 7.5.10 Water surface elevation (feet +/- mean sea level) at tribal supply well Kinley #1 (GW059) over the period of record (1992-2019). Significant regression results shown for long-term full period of record (solid line) and medium-term 2007-2019 period (dotted line).

The long-term and medium-term trends do not indicate an increased risk of groundwater mining or saltwater intrusion is present at wells on the Lummi Peninsula. However, the short-term trend at three wells is decreasing and should be closely monitored over the next two years, including discussing well management with the well operator and/or users of nearby wells. The three wells with decreasing short-term trends are in located in the same area and include one well not in operation included in the Continuous Aquifer Level Monitoring Project, Cultee (GW056), and two adjacent tribal supply wells Kinley #2 and Kinley #3 (GW409 and GW421). All water surface elevation trends at the three wells were similar: all have a decreasing long-term trend (average modeled decrease of 0.07 feet/year; period of record varied by well), all have a significant increasing medium-term trend (average modeled increase of 0.07 feet/year for period 2007-2019), and all had a significant increasing short-term trend (average modeled decrease of 0.15 feet per year for period 2016-2019) (Table 7.5.2, Figure 7.5.11, Figure 7.5.12, Figure 7.5.13).

Water surface elevation at the Kinley #2 and Kinley #3 wells were very similar; on average, the water surface elevation at Kinley #3 was 0.25 feet lower than at Kinley #2. Although the Cultee well (GW056) and Kinley #2 and Kinley #3 (GW409 and GW421) wells are not typically visited on the same day, water surface elevation at Cultee was on average 4.4 feet lower than at Kinley #3 for measurements collected within one month of each other. Further analysis of the continuous dataset at Cultee may provide more information about aquifer level trends at the Kinley #2 and #3 wells due to the proximity of this monitoring well to the Kinley supply wells. Wells located nearer the western shoreline of the Lummi Peninsula, Jefferson (GW112) and Balch (GW115), did not have any short-term water surface elevation trends for the period 2016-2019. Given the proximity of these wells to each other, the similar trends over the period of record, and lack of similar trends in nearby but further wells indicates that the recent decreasing trend in water surface elevation is affecting this localized portion of the aquifer.

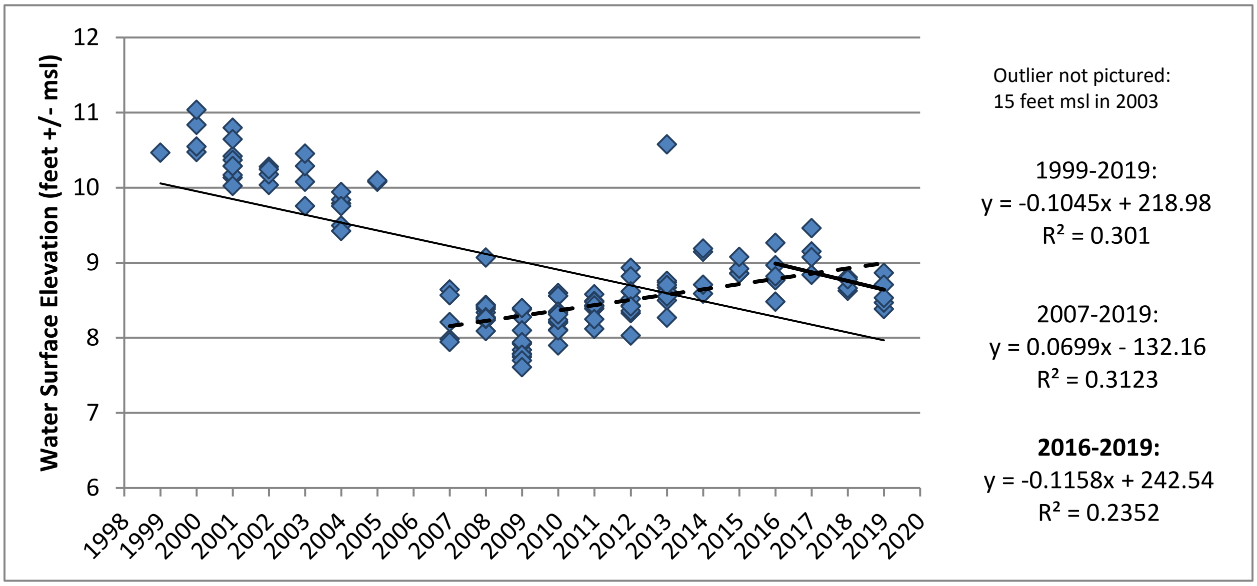


Figure 7.5.11 Water surface elevation (feet +/- mean sea level) at tribal supply well Kinley #2 (GW409) over the period of record (1999-2019). Significant regression results shown for long-term full period of record (solid line), medium-term 2007-2019 period (dotted line), and short-term 2016-2019 period (bold line).

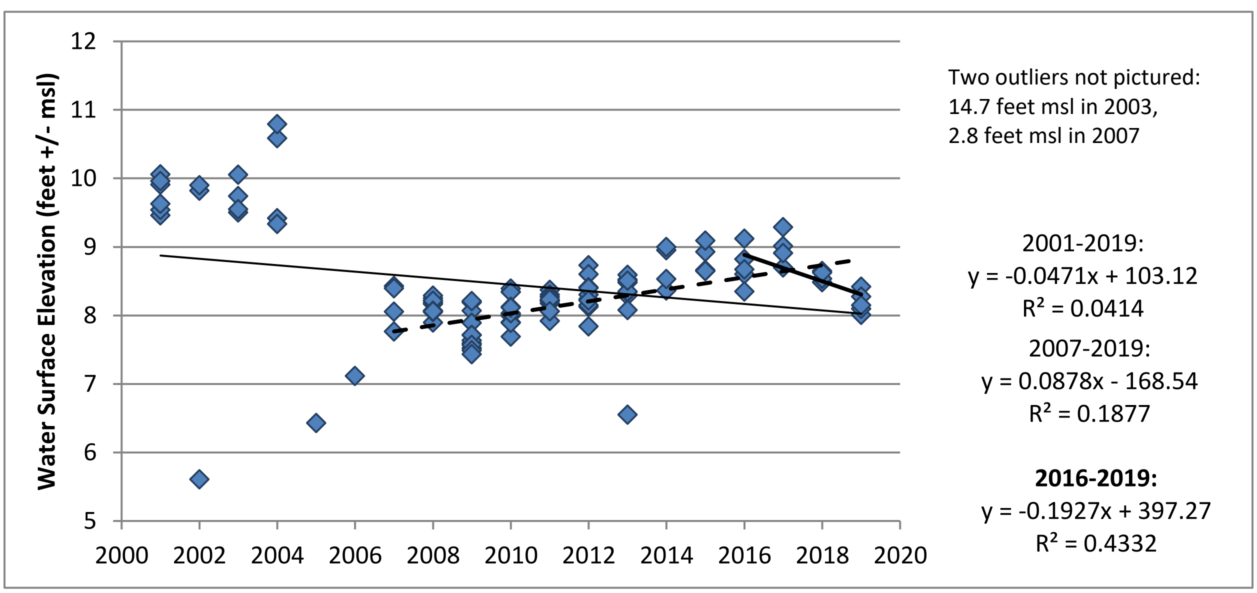


Figure 7.5.12 Water surface elevation (feet +/- mean sea level) at supply well Kinley #3 (GW421) over the period of record (2001-2019). Significant regression results shown for long-term full period of record (solid line), medium-term 2007-2019 period (dotted line), and short-term 2016-2019 period (bold line).

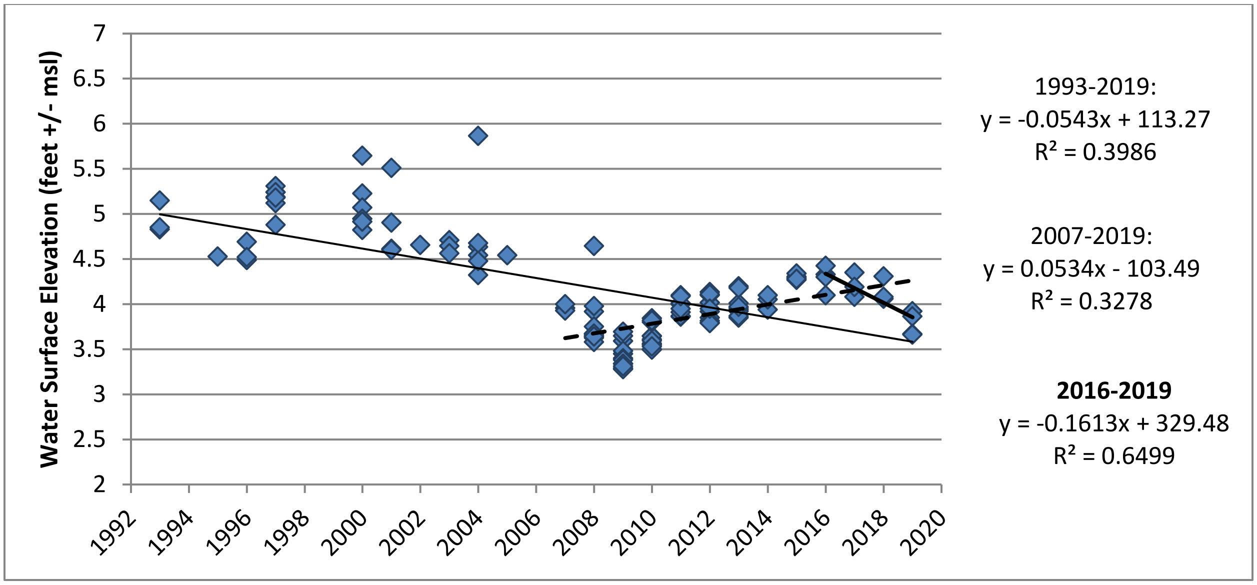


Figure 7.5.13 Water surface elevation (feet +/- mean sea level) at monitoring well Cultee (GW056) over the period of record (1993-2019). Significant regression results shown for long-term full period of record (solid line), medium-term 2007-2019 period (dotted line), and short-term 2016-2019 period (bold line).

Although water surface elevations during the reporting period (2018-2019) were higher than those measured ten years ago for all three wells, the decreasing trend should be closely monitored. What appears to be a four-year decreasing trend may be part of the fluctuation in aquifer level due to aquifer recharge rates and differences in year-to-year precipitation. However, the short-term decrease in water surface elevation is concurrent with a short-term increase in chloride concentration for the same time period at Kinley #2 and Kinley #3 (Table 7.5.1, Figure 7.5.5, Figure 7.5.6). Due to the seriousness of an increased risk of groundwater mining and saltwater intrusion, ongoing monitoring of water surface elevation at these wells is warranted to confirm the decreasing trend and to guide modifications in the pumping regime. Given the increasing short-term trend (2016-2019) in chloride concentration at the Kinley #2 and Kinley #3 wells suggests that a reduction or modification in pumping regime at these two wells may be warranted in order to decrease the increasing risk of groundwater mining and saltwater intrusion.

7.6. Nutrients

Although nutrients are essential for plant growth, excess nutrients are a concern for water quality due to environmental, human health, and economic factors. Excess nutrients can lead to algae blooms, which, in addition to creating unsightly and sometimes malodorous waters, can deplete the oxygen in the water to create hypoxic zones. Hypoxic zones can kill animals, including shellfish, that cannot move from the area. Some algae directly produce toxic compounds that can sicken or kill humans, fish, and other animals. Consumption of shellfish contaminated by certain algal toxins can cause amnesic, diarrhetic, neurotoxic, or paralytic shellfish poisoning. In addition, excess algae in surface waters can foul fishing nets and disrupt fish harvests. Sources of nutrients include agriculture, urban runoff, atmospheric deposition, land disposal, hydromodification/habitat modification, and spills (*e.g.,* manure) (LWRD 2015a).

7.6.1. Nitrogen

Nitrate, nitrite, and total Kjeldahl nitrogen (ammonia, organic, and reduced nitrogen) are measured at five sites: four freshwater and one marine. Nitrate-N and nitrite-N are measured separately for freshwater sites while nitrate plus nitrite nitrogen (N+N) is measured for marine sites. These three forms of nitrate are summed to calculate total nitrogen (TN).[24]

Freshwater mean annual total nitrogen concentration during the reporting period (2018-2019) was similar to the mean during the period of record at Nooksack River site SW118 and Smuggler Slough site SW015 (Figure 7.6.1). At these two sites, mean TN for the reporting period (2018-2019) was similar to the two ten-year periods of record (1998-2007, 2008-2017). Nutrient monitoring of site SW118 commenced in 2013; the period of record for 1998-2007 includes nitrogen samples collected sporadically from 2001-2006 and the period of record for 2008-2017 includes nitrogen samples collected from 2013-2017.

At Lummi River site SW009, mean TN was similar during the reporting period and the ten-year period of record 2008-2017, but both were lower than mean TN during the earlier ten-year period of record 1998-2007. There was also much larger variability (minimum to maximum range) during the earlier period of record than during the more recent period of record and the reporting period at site SW009. Due to the frequent stagnant conditions at this location, site SW009 was only sampled once during the reporting period. Although data associated with stagnant conditions were excluded from the dataset, it is possible that during the period of record during which sites were sampled regardless of flow conditions (until 2013), very low flow conditions that would now be considered stagnant were recorded as flowing (e.g., surface movement due to wind). Nitrogen sampling during these kinds of conditions may have resulted in elevated TN results during the earlier period of record. It is also likely that flow conditions in the Lummi River and changes in surrounding land use have changed since the late-1990s and early 2000s that have resulted in reduced nitrogen loading into the river. Linear regression

[24] For freshwater sampling events with both N+N and individual NO_3-N and NO_2-N measurements available, total nitrogen (TN) was calculated using both N+N or the individual nitrate and nitrite measurements and the highest TN was used for the analysis. Both N+N and total Kjeldahl nitrogen data were required for calculation of TN. Only sites with flowing water were used for TN assessment; data associated with stagnant conditions were excluded.

analysis confirmed that the TN concentration at Lummi River site SW009 was significantly decreasing by approximately 0.12 mg/L per year.[25]

At Jordan Creek site SW003, TN concentrations also appear to have decreased over time. There was also a much wider range in TN measurements collected during the earliest ten-year period of record (1998-2007) than during the more recent ten-year period of record (2008-2017) or the reporting period (2018-2019). This may be due to the changes in field methods (see discussion above for SW009 and stagnant sampling) or may be the result of changes in the watershed and flow regimes. Linear regression analysis confirmed that the TN concentration at Jordan Creek site SW003 was significantly decreasing by approximately 0.04 mg/L per year.[26]

The Lummi Bay marine site SW002 also had mean annual TN concentrations during the reporting period that were similar to the average for both periods of record. The range of observed TN concentrations was wider during the periods of record than for the reporting period.

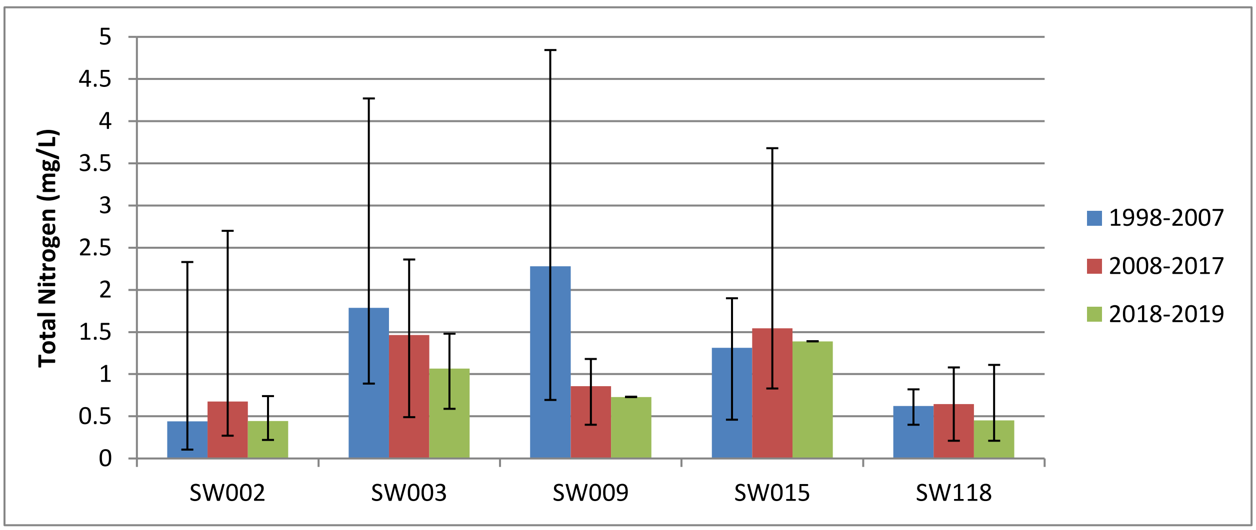


Figure 7.6.1 Total nitrogen (mg/L) mean and range (min-max) for two ten-year periods of record (1998-2007, 2008-2017) and the two-year reporting period (2018-2019) at marine (SW002) and freshwater (SW003, SW009, SW015, SW118) sites. Sample size listed in table to the right.

Sample Size (n)

Period	SW002	SW003	SW009	SW015	SW118
1998-2007	22	43	18	7	10
2008-2017	26	30	8	16	16
2018-2019	8	8	1	1	8

[25] Linear regression was significant ($p<0.001$) with $R^2 = 0.53$ (standard error = 0.90) and model TN = -0.118 (year) + 238.7 (standard error of intercept = 61.5; standard error of slope = 0.03).
[26] Linear regression was significant ($p<0.001$) with $R^2 = 0.16$ (standard error = 0.62) and model TN = -0.041 (year) + 83.9 (standard error of intercept = 22.8; standard error of slope = 0.01).

The EPA has developed a guidance document to assist states and tribes in the development of numeric nutrient criteria for freshwaters (EPA 2000). The Lummi Reservation is located within Ecoregion II – Western Forested Mountains and subecoregion 2 – Puget Lowlands. Reference conditions for the ecoregion were developed based on 25th percentiles of the sites used in the study. For the aggregate ecoregion (Ecoregion II – Western Forested Mountains), the reference condition for total nitrogen is 0.12 mg/L and for subecoregion 2, the reference condition range for total nitrogen is 0.0-0.53 mg/L. Reference conditions represent areas with the least disturbance that are considered natural background conditions.

Reference condition nutrient concentrations for Lummi Nation Waters were estimated using distributional and modeling approaches taken as part of a data analysis effort conducted by LNR, EPA, and Tetra Tech, Inc. as part of the Nutrient Scientific Technical Exchange Partnership Support (N-STEPS) Program. Reference condition nutrient concentration was estimated using three lines of evidence: 1) the 25th percentile TN concentration of all sites in the dataset; 2) the 75th percentile TN concentration of sites with greater than 75% forest, grassland, or wetland within a 1km buffer; and 3) multiple linear regression model of the site long-term average nutrient concentration as a function of developed and agricultural landcovers within the 1km buffer. The three lines of evidence estimated that reference conditions have a TN concentration of 0.3-0.4 mg/L, with an average TN of 0.34 mg/L (Tetra Tech, Inc. 2019). This reference condition is more than twice the aggregate reference conditions for Ecoregion II (0.12 mg/L), but less than the maximum range for reference condition for subecoregion 2 (0.53 mg/L). An analysis of nutrient and periphyton data for the State of Washington found a shift in stream periphyton composition away from that expected in reference streams at a TN concentration of 0.06 to 0.83 mg/L (Tetra Tech, Inc. 2018). This large range resulted in differences depending on metrics used.

Total nitrogen measurements collected at freshwater sites during the reporting period and periods of record were compared to the three reference conditions described above: 1) the estimated mean reference condition developed for the Lummi N-STEPS Project (0.34 mg/L; Tetra Tech, Inc. 2019); 2) the maximum of the range of reference conditions for Ecoregion II, subecoregion 2 (0.53 mg/L; EPA 2000); and 3) the maximum of the range at which there is a shift in periphyton community from the reference condition developed for the WA State N-STEPS Project (0.83 mg/L; Tetra Tech, Inc. 2018). The majority of nitrogen measurements collected during the reporting period (2018-2019) at freshwater sites exceeded the Lummi N-STEPS mean reference condition of 0.34 mg/L (Table 7.6.1).

All TN measurements at Jordan Creek site SW003, Lummi River site SW009, and Smuggler Slough site SW015 exceeded the Lummi N-STEPS mean reference condition (0.34 mg/L) during the reporting period and periods of record. These three sites also had TN measurements that exceeded the Ecoregion II/subecoregion 2 maximum reference condition (0.53 mg/L) during the reporting period and each site had only one TN measurement over the period of record that was below this maximum reference condition. When compared to the highest of the three reference conditions, the maximum of the TN range associated with periphyton community shifts (0.83 mg/L), Jordan Creek site SW003 showed decreasing frequency in TN measurements exceeding the 0.83 mg/L reference TN; during the 1998-2007 period of record, all TN measurements exceeded the reference condition, while only 75% did during the reporting period. As described above, there was a significant decreasing trend in TN at SW003. Similarly at Lummi River site SW009, 92% of TN measurements exceeded the 0.83 mg/L reference condition during 1998-2007, 75% in 2008-2017, and the single TN measurement collected during the period of record (Nov 2018) did not exceed this reference condition, resulting in a 0% exceedance frequency for the reporting period. Site SW009 also had a significant decreasing TN trend over time, as described above. Smuggler Slough site SW015 had the opposite trend; the frequency at which TN measurements exceeded the 0.83 mg/L reference condition increased from 86% in 1998-2007 to 94% in 2008-2017. During the reporting period, the single TN measurement collected at SW015 was above 0.83 mg/L, resulting in a 100% exceedance frequency for the reporting period.

Table 7.6.1 Percentage of total nitrogen measurements exceeding three reference TN conditions at freshwater sites over two ten-year periods of record (1998-2007, 2008-2017), on average for the reporting period (2018-2019), and annually for each reporting year.

Reference Condition Source	Reference TN (mg/L)	Period	SW003	SW009	SW015	SW118
Lummi N-STEPS (Tetra Tech, Inc. 2019) mean reference condition	0.34	1998-2007	100%	100%	100%	100%
		2008-2017	100%	100%	100%	81%
		2018-2019	100%	100%	100%	50%
		2018	100%	100%	nd	50%
		2019	100%	nd	100%	50%
EPA (2000) guidance for Ecoregion II/ subecoregion 2 maximum of reference range	0.53	1998-2007	100%	100%	86%	83%
		2008-2017	97%	88%	100%	63%
		2018-2019	100%	100%	100%	25%
		2018	100%	100%	nd	50%
		2019	100%	nd	100%	0%
WA State N-STEPS (Tetra Tech, Inc. 2018) periphyton shift maximum of range	0.83	1998-2007	100%	92%	86%	0%
		2008-2017	90%	75%	94%	19%
		2018-2019	75%	0%	100%	13%
		2018	80%	0%	nd	25%
		2019	67%	nd	100%	0%

nd = no data

Nooksack River site SW118 had lower TN concentrations than the other freshwater sites. The frequency of TN measurements over 0.34 mg/L decreased over time, from 100% in 1998-2017 to 50% during each of the reporting years; on average, 71% of TN measurements over the full period of record were above 0.34 mg/L. A similar pattern is present when comparing SW118 TN measurements to the 0.53 mg/L reference condition; the frequency of exceedances decreased from 83% in 1998-2007 to 25% during the reporting period (2018-2019). When compared to the 0.83 mg/L reference condition, TN measurements at SW118 were variable by period, with

13% exceeding the reference condition over the full period of record. Note that no significant linear trends were observed for TN by year at Nooksack River site SW118.

Freshwater TN concentrations measured during the reporting period 2018-2019 suggests that Reservation freshwaters do not represent reference conditions. This is consistent with the land use surrounding the freshwater nutrient monitoring sites, which are located at the bottom of modified watersheds. All sites contain agricultural lands within their watersheds, and sites SW003 and SW118 are also downstream of residential development.

7.6.2. Phosphorus

Total phosphorus (TP) is measured at marine and freshwater nutrient monitoring sites. Since 2013, sites were sampled only if flowing (*i.e.,* not stagnant) while historically sites were sampled for nutrients during both flowing and stagnant conditions as long as sufficient water was present to sample. Only TP concentrations collected during flowing conditions were used in this analysis (i.e., TP measurements from stagnant sites were excluded).

Freshwater mean TP during the reporting period (2018-2019) was within the range of TP concentrations observed over one or both ten-year periods of record at all sites (Figure 7.6.2). Linear regression analysis found no significant trend in TP over time at the freshwater sites.

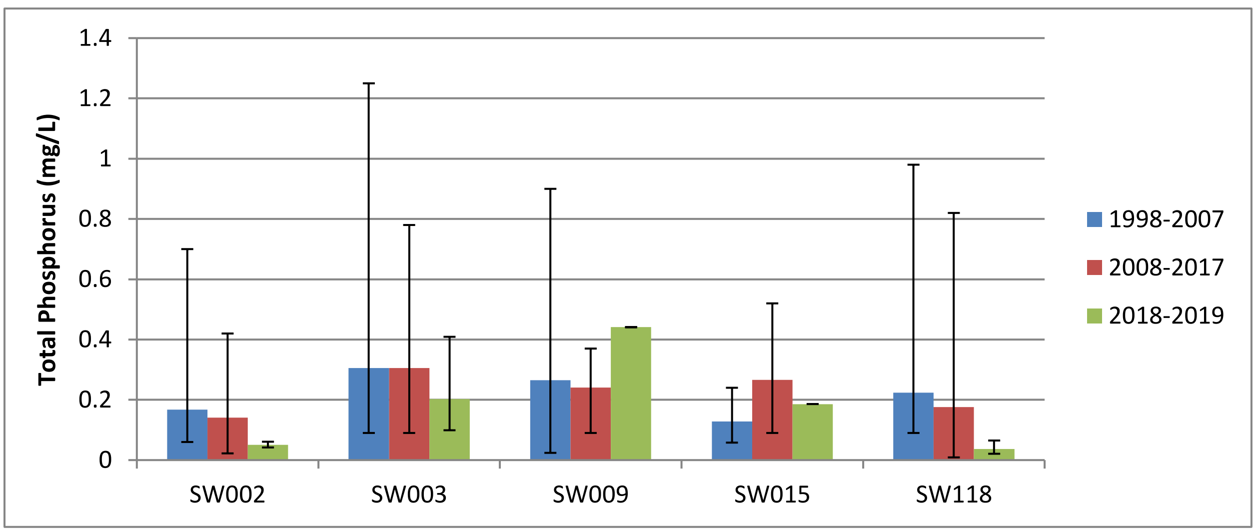


Figure 7.6.2 Total phosphorus (mg/L) mean and range (minimum-maximum) for two ten-year periods of record (1998-2007, 2008-2017) and the two-year reporting period (2018-2019) at marine (SW002) and freshwater (SW003, SW009, SW015, SW118) sites. Sample size listed in Figure 7.6.1.

At Jordan Creek site SW003, mean TP was lower during the reporting period than during the periods of record, which had similar TP means. The ranges in TP concentrations observed over the period of record were wider than for the reporting period. Although data associated with stagnant conditions were excluded from the dataset, it is possible that during the period of record during which sites were sampled regardless of flow conditions (until 2013), very low flow conditions that would now be considered stagnant were recorded as flowing (e.g., surface movement due to wind). Phosphorus sampling during these kinds of conditions may have resulted in elevated TP results during the earlier period of record. There may have also been changes in land use in the watershed that have resulted in decreased TP loading into Jordan Creek.

Lummi River site SW009 had a higher mean TP during the reporting period than during the periods of record. Due to the frequent stagnant conditions at this location, site SW009 was only sampled once during the reporting period. Although this single TP concentration was higher than the maximum TP concentration measured over the previous ten-year period of record (2008-2017), it was within the range of TP concentrations observed during 1998-2007.

Smuggler Slough site SW015 also only had one TP measurement collected during the reporting period (2018-2019). This measurement was between the means for the two periods of record and within the ranges of both periods of record. Although site SW015 also has frequent periods of stagnant conditions, TP at this site doesn't show as broad of a range as sites SW003 and SW009. Flow regimes in Smuggler Slough have changed significantly over the last ten years, including restoration of wetlands upstream of site SW015 and replacement of culverts at Lummi Shore Drive (SW015) and Haxton Way.

Mean TP at Nooksack River site SW118 was lower during the reporting period than during the two periods of record. The two periods of record also had very wide TP ranges. Two TP concentrations, one in August 2001 and one in November 2013, were higher than the others (>0.5 mg/L). These two TP concentrations were obtained during sampling after significant rain events; 1.4 inches in 24-48 hours preceding sampling. When these two values are excluded, the mean and range decreased to 0.14 mg/L (range 0.09-0.49 mg/L) for the period 1998-2007 and 0.13 mg/L (range 0.009-0.5 mg/L) for the period 2008-2017. Although these ranges are still broader than that observed during the reporting period, they encompasses a longer time period than the two-year reporting period during which variable TP concentrations are more likely to be observed. The high TP concentrations observed following rain events at site SW118 demonstrates that occasional high pulses of nutrients are discharged at least on occasion from the Nooksack River watershed. Future reports should analyze the TP data in the context of river flow (for the Nooksack River) and rainfall to determine differences in background nutrient loading and storm-based elevated discharge throughout the year due to the uneven frequency at which flush conditions are captured during quarterly ambient sampling of nutrients.

The Lummi Bay marine site SW002 also had mean annual TP concentrations during the reporting period that were lower than for the periods of record. Linear regression confirmed a significant very slow decreasing trend in TP at SW002, modeled at a decrease of 0.005 mg/L per year (equivalent to 0.05 mg/L every ten years).[27]

The reference condition recommendations and estimates from the Lummi and WA State N-STEPS projects discussed in the TN section also include reference conditions for TP. Total phosphorus measurements collected at freshwater sites during the reporting period and periods of record were compared to three reference conditions: 1) the estimated mean

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[27] Linear regression was significant (p=0.04) with R^2 = 0.08 (standard error = 0.11) and model TP = -0.005 (year) + 10.2 (standard error of intercept = 4.8; standard error of slope = 0.002).

reference condition developed for the Lummi N-STEPS Project (0.026 mg/L; Tetra Tech, Inc. 2019); 2) the maximum of the range (0.003-0.0325 mg/L) of reference conditions for Ecoregion II, subecoregion 2 (EPA 2000); and 3) the maximum of the range (0.011-0.044 mg/L) at which there is a shift in periphyton community from the reference condition developed for the WA State N-STEPS Project (Tetra Tech, Inc. 2018). The frequency of TP concentrations exceeding the Ecoregion II, subecoregion 2 maximum reference condition (0.0325 mg/L) was the same for nearly all sites and periods as for the Lummi N-STEPS mean reference condition (0.026 mg/L) because the values are very similar, so only the lowest (Lummi N-STEPS mean reference condition) and the highest (WA State N-STEPS periphyton shift maximum concentration) are summarized in the remainder of this section.

Total phosphorus concentrations exceeded the Lummi N-STEPS mean reference condition (0.026 mg/L) more than 75% of the time at all sites and all periods. All TP measurements exceeded this reference condition at Jordan Creek site SW003 and Smuggler Slough site SW015. All but one TP measurement exceeded the reference condition at SW015 during 1998-2007. At Nooksack River site SW118, the frequency of exceedance decreased over time, but still most chlorophyll results are higher than the mean reference condition estimated in the Lummi N-STEPS assessment.

Total phosphorus concentrations exceeded the WA State N-STEPS periphyton shift maximum concentration at the same frequencies as the Lummi N-STEPS mean reference condition for Jordan Creek sites SW003, Lummi River site SW009, and Smuggler Slough site SW015. At Nooksack River site SW118, the frequency of exceedance decreased over time, but still half of TP concentrations obtained during the reporting period exceeded this reference condition and there was no significant linear trend detected.

Table 7.6.2 Percentage of total phosphorus measurements exceeding two reference conditions at freshwater sites over two ten-year periods of record (1998-2007 and 2008-2017), on average for the reporting period (2018-2019), and annually for each reporting year.

Reference Condition Source	Reference TP (mg/L)	Period	SW003	SW009	SW015	SW118
Lummi N-STEPS (Tetra Tech, Inc. 2019) mean reference condition	0.026	1998-2007	100%	94%	100%	100%
		2008-2017	100%	100%	100%	94%
		2018-2019	100%	100%	100%	75%
		2018	100%	100%	nd	75%
		2019	100%	nd	100%	75%
WA State N-STEPS (Tetra Tech, Inc. 2018) periphyton shift maximum of range	0.044	1998-2007	100%	94%	100%	100%
		2008-2017	100%	100%	100%	88%
		2018-2019	100%	100%	100%	38%
		2018	100%	100%	nd	25%
		2019	100%	nd	100%	50%

nd = no data

Freshwater TP concentrations measured during the reporting period 2018-2019 suggests that Reservation freshwaters do not represent reference conditions. This is consistent with the results for total nitrogen, and aligns with the location of these sites at the bottom of modified watersheds that include agricultural, residential, and other developed land uses.

7.6.3. Chlorophyll a

Chlorophyll a is measured at marine and freshwater nutrient monitoring sites. Since 2013, sites were sampled only if flowing (*i.e.,* not stagnant) while historically sites were sampled for nutrients during both flowing and stagnant conditions as long as sufficient water was present to sample. Only chlorophyll a densities collected during flowing conditions were used in this analysis (i.e., chlorophyll a measurements from stagnant sites were excluded).

Mean annual chlorophyll a was variable at all sites; mean chlorophyll a density for the reporting period was between the means of the two ten-year periods of record at most sites (Figure 7.6.3). Mean chlorophyll during the reporting period was lowest at Nooksack River site SW118 and highest at Lummi River site SW009. Over the period of record, Lummi River site SW009 also had the highest mean chlorophyll during 1998-2007 while Smuggler Slough site SW015 had the highest mean chlorophyll during 2008-2017. Nooksack River site SW118 had the lowest mean chlorophyll during 2008-2017 while Lummi Bay marine site SW002 had the lowest mean chlorophyll during 1998-2007. The widest range in variability was present during the 2008-2017 period of record; this was most likely due to the commencement of routine chlorophyll a monitoring in 2008, which resulted in a much larger dataset for the period 2008-2017 than for 1998-2007.

There was a significant increasing trend in chlorophyll density at Lummi Bay marine site SW002 of 0.3 µg/L per year, but this trend may have been primarily influenced by high densities encountered during the 2008-2017 period of record that were not observed during the reporting period.[28] Two sites, Lummi River site SW009 and Nooksack River site SW118 had outliers that were excluded from the mean and range analysis because these outliers were more than twice as high as the next highest measurement. Lummi River site SW009 and Smuggler Slough site SW015 were only sampled once during the reporting period. These sites are frequently stagnant and flowing conditions are typically present only during the wet season and following rain events. As previously mentioned, significant changes in the Smuggler Slough watershed may have caused the wide range in chlorophyll a densities and changing flow regimes at site SW015.

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[28] Linear regression was significant ($p=0.048$) with $R^2 = 0.09$ (standard error = 4.9) and model Chlorophyll α = 0.286 (year) - 571 (standard error of intercept = 282; standard error of slope = 0.14).

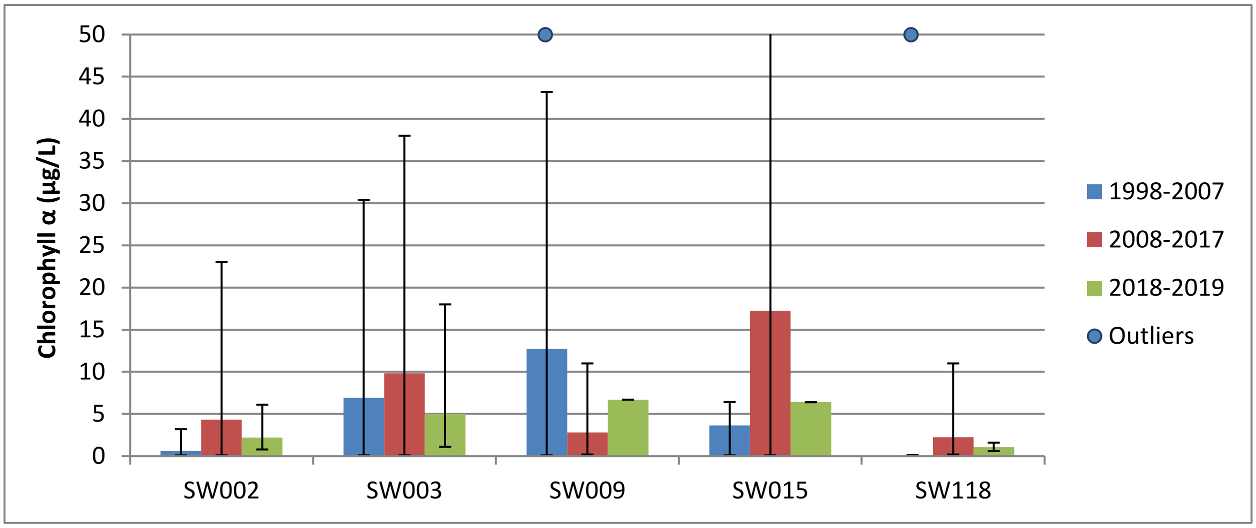

Figure 7.6.3 Chlorophyll α (µg/L) mean and range (min-max) for two ten-year periods of record (1998-2007, 2008-2017) and the two-year reporting period (2018-2019) at marine (SW002) and freshwater (SW003, SW009, SW015, SW118) sites. Outliers excluded from mean calculation and shown at 50 µg/L (96.1 µg/L at SW009 in June 2006 and 64.1 µg/L at SW118 in December 2006. 2008-2017 maximum range at SW015 is 52 µg/L. Sample size listed in table to the right.

Sample Size (n)

Period	SW002	SW003	SW009	SW015	SW118
1998-2007	2	15	6	3	1
2008-2017	18	24	5	15	9
2018-2019	7	7	1	1	5

Similar to the total nitrogen and total phosphorus recommendations, the EPA (2000) guidance for the development of numeric nutrient criteria for freshwaters includes reference condition recommendations for chlorophyll a. The Ecoregion II chlorophyll a reference condition is 1.08 µg/L and the subecoregion 2 range is 0.7-2.95 µg/L. Chlorophyll measurements were compared to the minimum, mean, and maximum reference conditions densities. All chlorophyll measurements collected during flowing conditions, including the outliers excluded from the mean and range presentation above, were included in this assessment. All chlorophyll measurements collected during the reporting period at Jordan Creek site SW003, Lummi River site SW009, and Smuggler Slough site SW015 exceeded the minimum and mean reference condition. This frequency was higher than for the two periods of record. Jordan Creek site SW003 exceeded the maximum reference condition less than half the time during the reporting period, but more than half the time during the period of record. Nooksack River site SW118 had a higher frequency of exceeding the minimum reference condition during the reporting period than during the period of record, a similar frequency of exceeding the mean reference condition during the reporting period and the 2008-2017 period of record, and a lower rate of exceeding the maximum reference condition during the reporting period than during the periods of record. This suggests that reporting period chlorophyll a densities at SW118 were primarily in the high end of the reference condition range

Table 7.6.3 Percentage of chlorophyll a measurements exceeding the minimum, mean, and maximum reference condition at freshwater sites over the periods of record, for the reporting period (2018-2019), and annually for each reporting year.

Reference Condition Source	Reference TN (mg/L)	Period	SW003	SW009	SW015	SW118
Minimum range	0.7	1998-2007	83%	86%	75%	25%
		2008-2017	80%	63%	94%	56%
		2018-2019	100%	100%	100%	71%
		2018	100%	100%	nd	50%
		2019	100%	nd	100%	100%
Mean	1.08	1998-2007	78%	71%	75%	25%
		2008-2017	80%	63%	94%	56%
		2018-2019	100%	100%	100%	57%
		2018	100%	100%	nd	50%
		2019	100%	nd	100%	67%
Maximum range	2.95	1998-2007	50%	43%	50%	25%
		2008-2017	60%	38%	88%	25%
		2018-2019	43%	100%	100%	0%
		2018	40%	100%	nd	0%
		2019	50%	nd	100%	0%

nd = no data

Freshwater chlorophyll a densities measured during the reporting period 2018-2019 suggests that Reservation freshwaters do not represent reference conditions. This is consistent with the results for total nitrogen and total phosphorus, and aligns with the location of these sites at the bottom of modified watersheds that include agricultural, residential, and other developed land uses.

Future reports should also consider seasonality of all three nutrients discussed in this section (total nitrogen, total phosphorus, and chlorophyll a) and the influence of rain events on nutrient concentrations. Salinity could also be taken into account at site SW003, which is occasionally brackish. In addition, the continued inclusion of Lummi River site SW009 and Smuggler Slough site SW015 should be evaluated due to frequent stagnant conditions that precluded sampling during most nutrient assessment quarters during the 2018-2019 reporting period.

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8. SUMMARY AND CONCLUSIONS

The goals of the WQM Program are to document ambient water quality and water quality trends on the Lummi Indian Reservation, evaluate regulatory compliance of waters flowing through and onto the Reservation including compliance with Lummi Nation Surface Water Quality Standards (17 LAR 07), and support the development and implementation of water quality regulatory programs on the Reservation.

This report presents the surface water quality data collected during the 2018-2019 reporting period, compares the reporting period results to data over the period of record (primarily 2008-2017 for most parameters), presents interpretations of these data with respect to the WQM Program goals, and provides the EPA documentation required pursuant to the *Final Guidance of Awards of Grants to Indian Tribes under Section 106 of the Clean Water Act* (EPA 2006a).

Water quality on the Reservation is complex for a number of reasons, including the Reservation location in the estuaries of the Lummi River and the Nooksack River where marine and fresh waters interact, the approximately 38 miles of marine shoreline and 7,000 acres of tidelands, and the weather patterns that influence the water quality at the sampling sites.

Water quality on the Reservation during the 2018-2019 reporting period was largely similar to water quality conditions in previous years. Designated uses were not fully supported in any of the freshwater watersheds or marine waters on the Reservation, although a single site in the Lummi Shore Road portion of the Portage Bay watershed (SW037) was fully supportive of all characteristic uses. This report examined the characteristic uses individually and found areas of concern for all uses.

The degrading fecal coliform trend first observed in Portage Bay in 2010 continued during the fall season for the reporting period, while improvements made for the spring season were maintained. Although 820 acres of the Portage Bay shellfish growing area remain closed to commercial, ceremonial, and subsistence harvest during the fall, the area was reopened for spring harvest in 2019. The Nooksack River mainstem showed improvement during the 2018 reporting year, during which the fecal coliform standard was met during all seasons, but in summer and fall 2019, degraded conditions returned and the Nooksack River to failed to meet the fecal coliform standard, ended the year with a geometric mean above the TMDL target, and continues to be the likely primary source of fecal coliform in Portage Bay.

The Lummi Bay shellfish growing area remained open year-round throughout the reporting period. Fecal coliform densities remained low at most sites in Lummi Bay, with the exception of site DH286, which was listed in “Threatened” status as of year-end 2017, and failed to meet the fecal coliform 90th percentile for the fall season during the reporting period. The 30-sample estimated 90th percentile NSSP metric steadily decreased during the reporting period, and the site is no longer listed in “Threatened” status as of year-end 2019. Although elevated fecal coliform densities were not observed often in the marine waters, all freshwaters flowing into Lummi Bay, including as these waters cross onto the Reservation, fail to be protective of shellfish harvest due to high fecal coliform. Water quality monitoring and coordinated Pollution Identification and Control activities were instituted during the reporting period in the Lummi

River and Jordan Creek/North Lummi River Distributary watersheds to control fecal coliform pollution originating off-Reservation and these efforts will continue until freshwater fecal coliform densities are protective of downstream characteristic uses.

Salmonid use of Reservation waters is unsupported by both high temperatures and low dissolved oxygen in many areas. All continuous temperature monitoring sites and, on average, 67% of discrete monitoring sites failed to meet the temperature standard. Temperatures high enough to exclude salmonids (>22°C) were observed at 58% of continuously monitored sites during some portion of the year. Low dissolved oxygen conditions were present at 45% of all sites; 21% of marine sites, and 86% of freshwater sites failed to meet the dissolved oxygen standard. All failing marine sites were located in Lummi Bay. Freshwater pH monitoring found that 20% of sites failed to meet the pH standard. Of greatest concern are the sites that fail to meet the temperature, dissolved oxygen, and pH standards. There are Reservation-wide freshwater problems with low dissolved oxygen and high temperatures during at least some portion of the year.

There is no evident trend of ocean acidification in the marine waters of the Reservation for data collected through 2019, but 31% of marine sites failed to meet the pH standard in the surface stratum. Of marine sites, 13% had surface stratum pH excursions below the minimum criterion.

Recreational contact uses are also not supported across the Reservation waters with two-thirds of sites failing to meet the enterococcus standard, including 71% freshwater sites and 58% of marine sites. The Nooksack River continues to exhibit impairment in enterococci (similar to fecal coliform) and Portage Bay and Lummi Bay have the same percentage of freshwater sites failing to meet the standard.

Although no numeric nutrient criteria have been established under the Lummi Nation Surface Water Quality Standards, nutrient monitoring shows that Reservation waters are impaired for nutrients in that they have higher nutrient concentrations than reference conditions in the Puget lowlands. This is consistent with the location of many Reservation waters at the bottom of modified watersheds with widespread agricultural and developed land uses.

The water quality parameters at the monitoring sites during the 2018-2019 reporting period generally followed the trends of the previous ten years. That is, generally elevated bacteria levels, higher temperatures, and lower dissolved oxygen levels compared to the Lummi Nation Water Quality Standards (17 LAR 07). The water quality parameters are generally more degraded in the sites further inland, and gradually improve downstream towards the marine waters on the Reservation.

Of greatest concern is the continued seasonal closure of shellfish harvesting areas in Portage Bay, which is used by members of the Lummi Nation for ceremonial, subsistence, and commercial purposes. Geometric means and estimated 90th percentiles in the Portage Bay shellfish growing area increased throughout the reporting period, reversing the improving trend observed over the previous four years (2014-2017) and seasonally the fall continues to greatly exceed the criteria. The surface waters flowing into Lummi Bay and the surface water of the Nooksack River continue to exhibit the poorest water quality of the sites sampled on the Reservation. The continuing poor water quality at sites along the northern Reservation boundary and all tributaries to Lummi Bay, particularly with respect to elevated fecal coliform bacteria contamination, is also a major concern because these waters flow into the Lummi Bay shellfish harvesting area. Although the “Threatened” status of one site in Lummi Bay was removed as of year-end 2019, ongoing action upstream is needed to prevent degradation in this important tribal shellfish harvesting area.

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10. ACRONYMS AND ABBREVIATIONS

1DM	One Day Maximum
7DADM	Seven Day Average of the Daily Maximum
CALM	Continuous Aquifer Level Monitoring [Project]
cfu	Colony forming unit
DO	Dissolved Oxygen
DOH	Washington State Department of Health
EPA	U.S. Environmental Protection Agency
FDA	U.S. Food and Drug Administration
FPE	Flood Plain East
FPW	Flood Plain West
Geomean	Geometric Mean
LAR	Lummi Administrative Regulation
LCL	Lummi Code of Laws
LIBC	Lummi Indian Business Council
LNR	Lummi Natural Resources
LSR	Lummi Shore Road
LWRD	Lummi Water Resources Division
mpn	Most probable number
msl	Mean Sea Level
N+N	Nitrate plus nitrite nitrogen
NMH	Nutrients, Metals, and Hydrocarbons [Project]
NSSP	National Shellfish Sanitation Program
N-STEPS	Nutrient Scientific Technical Exchange Partnership Support
POR	Period of Record
ppt	Parts per thousand
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QMP	Quality Management Plan
Reservation	Lummi Indian Reservation
RP	Reporting Period
SOP	Standard Operating Procedure
SP+PI	Sandy Point and Portage Island
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
WCWP	Whatcom Clean Water Program
WQM Program	Water Quality Monitoring [Program]
WQX	Water Quality Exchange Network

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11. APPENDICES

The following appendices are largely automated summaries of water quality measurements collected during the reporting period 2018-2019. These appendices are intended to summarize the mean, minimum, and maximum measurements collected for several water quality parameters. Due to the large amount of unique water quality monitoring sites, individual parameters measured, and frequency of sampling, too many data were collected during the reporting period to fully summarize the mean, minimum, and maximum of each parameter for each site. Instead, these appendices include summaries of the data collected with a prioritization of data summarization by site for parameters with water quality standards evaluated in this report (Appendix A and C). Other parameters measured are reported by water quality class (Appendix B). As previously noted, some trends, conclusions, and compliance determinations discussed in Section 7 may differ from those presented in appendices because of both the complexity of evaluating compliance with the standards but also the inclusion or exclusion of outliers that may mask seasonal or annual trends.

As an overall indication of water quality compliance, compliance maps and summaries by class are also included (Appendix D and E).

One set of appendices A-E are generated and enclosed for each year of the reporting period. Note that the period of record shown for each reporting year includes all previous years, so that for reporting year 2019, the period of record is up through 2018. Short summaries of the appendices are listed here:

Appendix A. Summary of non-bacterial primary parameter results by site, showing total observations, mean, minimum, and maximum measurement for the reporting years 2018-2019 and over the period of record.[29,30]

[29] The temperature standards are a seven-day average of the daily maximum value for freshwaters and a one-day maximum value for marine waters. As discussed in Section 7.2.1, continuous temperature monitoring is required for proper evaluation of compliance with the standard. This appendix provides a summary of discrete data only, which can only be used to identify sites that fail or are likely to fail to meet the standard. Discrete data cannot be used to definitively determine that a site meets the standard because continuous data are required for this.

[30] The dissolved oxygen standard for freshwater has two parts: a mg/L criterion and a percent saturation criterion which is used if temperature or pressure precludes attainment of the mg/L criterion at 100% saturation. In Section 7.2.2, freshwater dissolved oxygen data were compared to either the mg/L or percent saturation criteria, as appropriate. In the appendices, the mg/L measurement is compared to the mg/L criterion and the percent saturation measurement is compared to the percent saturation criterion. The percent saturation criterion includes the minimum percent saturation criterion for Freshwater Class AA waters and the maximum dissolved gas criterion. The dissolved oxygen standard for Class AA Extraordinary waters is a seven-day mean minimum, which would require continuous monitoring in order to adequately evaluate compliance. Similar to the temperature standard, discrete data are used to identify sites that fail or are likely to fail to meet the standard. In addition, the dissolved oxygen standard compliance determination does not include evaluation of the inter-gravel dissolved oxygen concentration, which is an additional component of the dissolved oxygen standard for Class AA Extraordinary waters. Due to the complexity of the dissolved oxygen standards, the appendices should only be viewed as summarizing the data. Compliance determination using only the data presented in the appendices would be incomplete.

Appendix B. Summary of non-bacterial secondary parameter results by water quality class, showing sites monitored, total observations, mean, minimum, and maximum measurements for the reporting years 2018-2019 and over the period of record.

Appendix C. Summary of bacterial parameter summary statistics and standard compliance by site, showing new observations for the reporting years 2018-2019, maximum value observed, geometric mean, estimated 90th percentile, and number of observations used for geometric summary statistic calculations. The relevant criteria are also listed.[31]

[31] Bacterial compliance in Appendix C is calculated using the 30 most recently collected samples, if available. The 90th percentile presented in Appendix C is the estimated 90th percentile calculated as per the NSSP. Sections 7.1 and 7.4.1 present compliance with bacterial parameters seasonally, as recommended in the Lummi Nation Surface Water Quality Standards, as well as in-depth analysis of bacterial indicators. Calculated geometric mean and estimated 90th percentile may not match the designation presented in River.

Appendix D. Series of maps graphically showing compliance status of sites monitored for the parameter in question during 2018-2019.

Appendix E. Summary of site compliance with the single-parameter water quality standards for pH, dissolved oxygen (see also footnote 5 on page 43), fecal coliform (see footnote 31), and enterococci (see footnote 31). For each water quality class, Appendix E summarizes the number of sites monitored, how many sites are compliant with the standard, how many sites are noncompliant with the standard, how many sites had insufficient data to determine compliance, and the compliance rate by parameter.

Table 6.1.1 and Table 6.1.2 or Sections 7.1 and 7.4.1.

11.1. 2018 Appendices

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Appendix A Index. *List of Non-Bacterial Primary Parameters*

Water Temperature - In Situ

pH - Field

Oxygen - Dissolved Field

Oxygen - % Saturation

Oxygen - % Saturation

Freshwater - Class A (Excellent) Sites

Applicable Standards

Minimum 90 %

Maximum 110 %

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW026	2018	%	5	74.5	50.70	97.70
	1998 - 2017	%	81	95.4	14.00	175.00
SW027	2018	%	6	83.4	57.20	92.50
	1998 - 2017	%	110	91.6	18.00	130.00
SW028	2018	%	6	91.2	49.60	111.00
	1998 - 2017	%	114	111	6.00	232.80
SW031	2018	%	1	100	100.10	100.10
	1999 - 2017	%	100	82.8	13.00	128.00
SW033	2018	%	2	80.8	80.70	81.00
	1999 - 2017	%	88	74.1	45.00	129.00
SW035	2018	%	1	63.6	63.60	63.60
	1999 - 2017	%	83	82.1	26.00	154.00
SW037	2018	%	1	88.5	88.50	88.50
	1999 - 2017	%	66	84.9	54.00	151.00

Oxygen - % Saturation

Freshwater - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 95 %

Maximum 110 %

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW003	2018	%	31	67.1	28.00	109.20
	1996 - 2017	%	253	66.2	2.00	252.00
SW007	2018	%	13	93.8	55.20	103.40
	1996 - 2017	%	198	97.7	19.00	164.00
SW009	2018	%	3	68	22.80	95.60
	1996 - 2016	%	166	66.1	0.50	220.60
SW010	2018	%	5	88.4	62.50	116.80
	1996 - 2017	%	166	50	0.40	170.50
SW011	2018	%	9	103	92.30	110.10
	1996 - 2017	%	236	94.4	44.00	150.00
SW012	2018	%	5	79.2	60.40	103.30
	1997 - 2017	%	189	72.6	3.10	367.00
SW013	2018	%	5	59	34.10	125.00
	1998 - 2013	%	154	88.5	2.00	373.30
SW014	2018	%	7	90.5	74.70	104.80
	1998 - 2017	%	161	76.1	24.00	109.00
SW015	2018	%	2	68.7	57.70	79.70
	1998 - 2017	%	177	57.5	1.40	122.00
SW016	2018	%	2	60.4	48.50	72.30
	1998 - 2017	%	103	64.9	2.00	198.00
SW017	2018	%	1	71.2	71.20	71.20
	1998 - 2015	%	107	62.3	4.00	338.00
SW029	2018	%	4	98.9	94.10	103.20
	1999 - 2017	%	122	92.9	24.00	126.10
SW058	2018	%	2	61.9	53.10	70.70
	2000 - 2011	%	67	56	2.00	222.00
SW075	2018	%	3	71.8	55.30	84.80
	2016 - 2017	%	12	72.9	43.50	89.20

SW118	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
	2018	%	55	102	94.10	108.70
	2007 - 2017	%	446	103	85.60	129.10

Oxygen - % Saturation

Marine - Class A (Excellent) Sites

Applicable Standards

Maximum 110 %

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH049	2018	%	10	101	63.50	137.00
	2009 - 2017	%	43	105	61.40	175.50
DH050	2018	%	12	98.5	77.40	130.00
	2009 - 2017	%	55	104	71.10	172.60
DH051	2018	%	11	102	78.80	136.00
	2009 - 2017	%	45	106	73.70	197.90
DH052	2018	%	7	106	91.00	128.50
	2009 - 2017	%	46	106	78.80	165.80
DH053	2018	%	11	103	83.80	133.10
	2000 - 2017	%	44	102	74.70	178.90
DH054	2018	%	7	96.9	74.00	137.40
	2009 - 2017	%	36	98.8	63.30	158.60
DH055	2018	%	8	102	80.00	121.70
	2000 - 2017	%	47	104	76.30	161.40
DH057	2018	%	9	100	67.90	129.50
	2009 - 2017	%	43	105	67.10	176.00
DH058	2018	%	9	103	86.40	138.50
	2009 - 2017	%	34	111	82.70	176.70
DH271	2018	%	10	99.3	81.80	122.10
	2009 - 2017	%	48	106	76.00	220.00
DH272	2018	%	9	102	88.00	128.00
	2009 - 2017	%	39	107	71.60	196.30
SW006	2018	%	10	99.1	90.80	105.90
	1996 - 2017	%	221	108	70.40	166.10
SW023	2018	%	10	97.4	78.00	104.30
	1998 - 2017	%	221	105	42.00	183.00

Oxygen - % Saturation

Marine - Class AA (Extraordinary) Sites

Applicable Standards

Maximum 110 %

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH038	2018	%	9	96.8	84.20	133.00
	2002 - 2017	%	87	101	73.80	151.00
DH039	2018	%	7	98.9	85.80	127.40
	2002 - 2017	%	84	100	71.20	159.50
DH040	2018	%	7	101	85.80	130.30
	2002 - 2017	%	83	100	69.90	159.90
DH041	2018	%	7	109	86.10	134.00
	2002 - 2017	%	86	108	69.20	195.00
DH042	2018	%	6	128	87.70	202.50
	2002 - 2017	%	85	120	57.00	233.00
DH043	2018	%	6	104	85.60	131.00
	2002 - 2017	%	77	105	70.50	187.70
DH044	2018	%	5	114	100.00	140.10
	2007 - 2017	%	84	106	63.40	161.00
DH045	2018	%	5	128	104.20	150.40
	2007 - 2017	%	86	132	83.00	220.30
DH048	2018	%	8	101	78.60	120.20
	2009 - 2017	%	40	102	76.70	181.30
DH285	2018	%	8	99.9	85.70	139.70
	2002 - 2017	%	101	103	71.20	156.80
DH286	2018	%	9	124	85.60	206.60
	2002 - 2017	%	88	118	56.90	226.70
DH287	2018	%	6	99.8	84.10	130.90
	2002 - 2017	%	95	99.2	73.00	153.30
DH288	2018	%	8	137	88.50	214.00
	2002 - 2017	%	87	107	70.80	185.70
SW001	2018	%	7	102	88.00	116.50
	1996 - 2017	%	170	97.3	7.91	145.70

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW002	2018	%	8	96.5	85.00	108.50
	1996 - 2017	%	157	115	74.60	234.00
SW008	2018	%	30	76.1	35.30	115.40
	1996 - 2017	%	213	70.2	20.90	183.00
SW019	2018	%	7	95.9	82.50	116.90
	1998 - 2017	%	172	99.2	63.20	166.00
SW039	2018	%	5	106	91.00	120.50
	1999 - 2017	%	210	115	65.80	364.00
SW051	2018	%	44	94.8	69.80	122.80
	1999 - 2017	%	299	95.8	41.50	197.00
SW053	2018	%	40	97.9	73.20	136.00
	1999 - 2017	%	218	90.4	26.90	175.00
SW055	2018	%	8	87.7	41.20	180.60
	2000 - 2017	%	158	75.9	19.50	178.80
SW056	2018	%	5	92.2	57.20	165.00
	2000 - 2017	%	169	99.9	1.00	387.37
SW059	2018	%	9	59.2	34.10	80.80
	2000 - 2017	%	183	58.5	1.50	166.20

Oxygen - % Saturation

Not Classified Sites

No Applicable Standards Available

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW132	2018	%	5	103	88.60	108.40
SW133	2018	%	6	103	90.00	112.40

Oxygen - Dissolved Field

Freshwater - Class A (Excellent) Sites

Applicable Standards

Minimum 8 mg/l

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW026	2018	mg/l	5	7.75	4.25	10.30
	1998 - 2017	mg/l	81	9.97	1.20	15.24
SW027	2018	mg/l	6	9.23	4.76	10.83
	1998 - 2017	mg/l	110	10.2	1.50	14.19
SW028	2018	mg/l	6	9.09	4.07	11.98
	1998 - 2017	mg/l	114	10.6	0.50	17.90
SW031	2018	mg/l	1	12.2	12.17	12.17
	1999 - 2017	mg/l	99	9.69	1.60	13.80
SW033	2018	mg/l	2	9.82	9.80	9.83
	1999 - 2017	mg/l	87	8.64	4.99	14.40
SW035	2018	mg/l	1	7.76	7.76	7.76
	1999 - 2017	mg/l	84	9.25	2.30	17.20
SW037	2018	mg/l	1	10.5	10.50	10.50
	1999 - 2017	mg/l	65	9.5	5.80	15.50

Oxygen - Dissolved Field

Freshwater - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 11 mg/l

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW003	2018	mg/l	31	6.06	2.25	12.24
	1993 - 2017	mg/l	255	6.95	0.20	26.10
SW007	2018	mg/l	13	10.6	6.48	12.52
	1993 - 2017	mg/l	199	11.2	2.15	20.30
SW009	2018	mg/l	3	8.04	2.31	11.79
	1993 - 2016	mg/l	168	7.21	0.04	19.60
SW010	2018	mg/l	5	9.03	6.88	11.21
	1993 - 2017	mg/l	170	5.58	0.05	15.59
SW011	2018	mg/l	9	11.7	10.07	13.84
	1993 - 2017	mg/l	233	10.7	4.90	16.14
SW012	2018	mg/l	5	9.26	6.50	11.55
	1997 - 2017	mg/l	189	7.93	0.28	28.70
SW013	2018	mg/l	5	6.02	4.12	11.00
	1998 - 2013	mg/l	154	8.73	0.03	34.33
SW014	2018	mg/l	7	10.8	8.51	13.39
	1998 - 2017	mg/l	161	8.91	2.30	14.08
SW015	2018	mg/l	2	7.79	6.81	8.77
	1998 - 2017	mg/l	177	6.3	0.13	12.00
SW016	2018	mg/l	2	6.42	4.91	7.93
	1998 - 2017	mg/l	103	7.31	0.10	20.56
SW017	2018	mg/l	1	8.29	8.29	8.29
	1998 - 2015	mg/l	107	6.87	0.50	32.80
SW029	2018	mg/l	4	11.3	9.67	12.61
	1999 - 2017	mg/l	122	11	2.70	16.42
SW058	2018	mg/l	2	6.52	5.35	7.70
	2000 - 2011	mg/l	67	6.21	0.20	21.10
SW075	2018	mg/l	3	8.36	6.38	9.49
	2016 - 2017	mg/l	13	8.99	4.73	12.26

SW118	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
	2018	mg/l	55	11.3	9.43	13.86
	2007 - 2017	mg/l	445	11.7	8.14	15.17

Oxygen - Dissolved Field

Marine - Class A (Excellent) Sites

Applicable Standards

Minimum 6 mg/l

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH049	2018	mg/l	10	9.94	5.50	12.09
	2009 - 2017	mg/l	43	9.99	5.35	14.25
DH050	2018	mg/l	12	9.85	6.50	11.79
	2009 - 2017	mg/l	55	9.78	6.64	13.28
DH051	2018	mg/l	11	10	6.69	12.13
	2009 - 2017	mg/l	45	9.9	6.37	15.31
DH052	2018	mg/l	7	10.4	7.68	11.96
	2009 - 2017	mg/l	46	10.1	7.54	12.98
DH053	2018	mg/l	11	9.83	7.16	11.65
	2000 - 2017	mg/l	44	9.56	6.85	14.19
DH054	2018	mg/l	7	9.32	6.18	11.92
	2009 - 2017	mg/l	36	9.15	5.57	12.51
DH055	2018	mg/l	8	9.72	6.85	11.77
	2000 - 2017	mg/l	47	9.73	7.24	12.76
DH057	2018	mg/l	9	9.64	5.88	11.71
	2009 - 2017	mg/l	43	10	6.16	13.80
DH058	2018	mg/l	9	9.91	7.75	11.75
	2009 - 2017	mg/l	34	10.1	7.53	13.98
DH271	2018	mg/l	11	10	7.02	12.09
	2009 - 2017	mg/l	48	10.3	7.04	17.17
DH272	2018	mg/l	9	9.92	7.44	11.86
	2009 - 2017	mg/l	39	9.96	6.63	15.85
SW006	2018	mg/l	10	9.63	7.75	11.75
	1993 - 2017	mg/l	223	10.2	6.16	18.88
SW023	2018	mg/l	10	9.57	6.70	11.57
	1998 - 2017	mg/l	221	9.98	3.91	16.60

Oxygen - Dissolved Field

Marine - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 7 mg/l

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH038	2018	mg/l	9	8.98	7.58	11.72
	2002 - 2017	mg/l	87	9.38	7.07	13.53
DH039	2018	mg/l	7	9.17	8.10	11.37
	2002 - 2017	mg/l	84	9.39	6.74	13.50
DH040	2018	mg/l	7	9.42	8.14	11.04
	2002 - 2017	mg/l	83	9.31	6.62	13.74
DH041	2018	mg/l	7	9.92	8.15	11.16
	2002 - 2017	mg/l	86	9.88	6.57	15.75
DH042	2018	mg/l	6	11.1	8.39	15.28
	2002 - 2017	mg/l	85	10.7	4.85	18.74
DH043	2018	mg/l	6	9.56	8.07	11.53
	2002 - 2017	mg/l	77	9.73	6.70	16.08
DH044	2018	mg/l	5	9.49	7.77	11.00
	2007 - 2017	mg/l	84	9.31	4.87	16.93
DH045	2018	mg/l	5	10.8	8.89	13.56
	2007 - 2017	mg/l	86	11.7	6.42	19.19
DH048	2018	mg/l	8	9.67	6.90	11.56
	2009 - 2017	mg/l	40	9.37	7.01	14.74
DH285	2018	mg/l	8	9.39	7.63	12.10
	2002 - 2017	mg/l	101	9.61	6.80	13.28
DH286	2018	mg/l	9	10.5	7.26	15.37
	2002 - 2017	mg/l	88	10.5	4.80	16.78
DH287	2018	mg/l	6	9.28	7.41	11.55
	2002 - 2017	mg/l	93	9.31	6.81	12.91
DH288	2018	mg/l	8	11.4	8.41	15.09
	2002 - 2017	mg/l	87	9.91	6.46	14.31
SW001	2018	mg/l	7	8.99	7.50	10.02
	1993 - 2017	mg/l	172	8.95	1.50	17.10

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW002	2018	mg/l	8	8.84	8.04	9.92
	1993 - 2017	mg/l	159	10.6	6.58	28.15
SW008	2018	mg/l	30	7.17	2.84	12.69
	1993 - 2017	mg/l	213	7.2	1.61	16.00
SW019	2018	mg/l	7	8.59	7.09	9.94
	1998 - 2017	mg/l	172	9.03	5.61	13.88
SW039	2018	mg/l	5	9.63	7.90	11.03
	1999 - 2017	mg/l	211	10.6	6.26	27.20
SW051	2018	mg/l	44	8.46	5.34	11.60
	1999 - 2017	mg/l	298	8.94	2.10	16.86
SW053	2018	mg/l	39	8.61	5.55	11.30
	1999 - 2017	mg/l	217	8.84	2.06	17.89
SW055	2018	mg/l	8	7.95	4.91	15.65
	2000 - 2017	mg/l	158	7.29	2.34	17.32
SW056	2018	mg/l	5	9.32	6.95	13.20
	2000 - 2017	mg/l	170	9.4	0.10	26.94
SW059	2018	mg/l	9	6.84	4.11	8.91
	2000 - 2017	mg/l	183	6.34	0.12	14.63

Oxygen - Dissolved Field

Not Classified Sites

No Applicable Standards Available

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW132	2018	mg/l	5	12.3	10.58	13.88
SW133	2018	mg/l	6	12.3	10.78	13.64

pH - Field

Freshwater - Class A (Excellent) Sites

Applicable Standards

Minimum 6.5

Maximum 8.5

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW026	2018	pH	3	7.01	6.59	7.38
	1998 - 2017	pH	59	7.32	6.35	8.36
SW027	2018	pH	2	7.73	7.73	7.73
	1998 - 2017	pH	71	7.54	6.43	8.95
SW028	2018	pH	4	7.51	7.31	7.63
	1998 - 2017	pH	81	7.54	6.35	8.98
SW031	2018	pH	1	6.13	6.13	6.13
	2003 - 2016	pH	56	6.56	4.54	7.91
SW033	2018	pH	2	6.15	6.14	6.17
	2003 - 2017	pH	60	6.64	4.26	9.30

pH - Field

Freshwater - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 6.5

Maximum 8.5

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW003	2018	pH	28	7.47	5.62	8.44
	1995 - 2017	pH	164	7.28	5.80	9.60
SW007	2018	pH	6	7.29	6.65	8.24
	1995 - 2017	pH	140	7.41	4.84	9.49
SW009	2018	pH	1	6.85	6.85	6.85
	1995 - 2017	pH	99	7.26	6.50	8.51
SW010	2018	pH	1	7.93	7.93	7.93
	1995 - 2017	pH	101	7.04	6.16	8.62
SW011	2018	pH	3	6.88	6.85	6.93
	1995 - 2017	pH	158	7.44	6.10	8.63
SW012	2018	pH	1	6.9	6.90	6.90
	1997 - 2017	pH	114	7.2	6.14	9.20
SW013	2018	pH	2	6.68	6.51	6.85
	1998 - 2013	pH	83	7.32	6.52	9.08
SW014	2018	pH	1	6.11	6.11	6.11
	1998 - 2016	pH	93	7.19	4.47	8.60
SW015	2018	pH	1	6.99	6.99	6.99
	1998 - 2017	pH	106	7.08	6.20	8.57
SW016	2018	pH	2	6.83	6.82	6.84
	1998 - 2017	pH	63	6.88	6.50	7.89
SW029	2018	pH	1	6.55	6.55	6.55
	2003 - 2016	pH	68	6.2	1.34	8.54
SW058	2018	pH	2	7.18	7.12	7.24
	2003 - 2011	pH	33	6.99	6.32	10.77
SW075	2018	pH	2	7.37	7.37	7.37
	2016 - 2017	pH	10	7.4	6.72	8.79
SW118	2018	pH	12	6.68	6.18	7.38
	2007 - 2017	pH	397	7.28	3.21	11.24

pH - Field

Marine - Class A (Excellent) Sites

Applicable Standards

Minimum 7

Maximum 8.5

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH049	2018	pH	10	7.85	7.45	8.60
	2009 - 2017	pH	39	7.81	6.64	8.41
DH050	2018	pH	12	7.93	7.54	8.52
	2009 - 2017	pH	53	7.91	7.14	8.42
DH051	2018	pH	11	8	7.36	8.59
	2009 - 2017	pH	44	7.91	7.31	8.49
DH052	2018	pH	7	8.03	7.59	8.51
	2009 - 2017	pH	42	7.92	7.09	8.53
DH053	2018	pH	11	8.02	7.52	8.47
	2009 - 2017	pH	40	7.86	7.40	8.46
DH054	2018	pH	7	7.93	7.45	8.55
	2009 - 2017	pH	35	7.8	7.23	8.46
DH055	2018	pH	7	7.98	7.24	8.51
	2009 - 2017	pH	41	7.91	7.40	8.48
DH057	2018	pH	9	7.99	7.53	8.54
	2009 - 2017	pH	42	7.8	6.57	8.57
DH058	2018	pH	9	7.99	7.62	8.61
	2009 - 2017	pH	33	7.91	7.42	8.45
DH271	2018	pH	11	7.92	7.54	8.38
	2009 - 2017	pH	46	7.87	7.03	8.62
DH272	2018	pH	9	7.93	7.55	8.53
	2009 - 2017	pH	38	7.83	6.61	8.40
SW006	2018	pH	10	7.88	7.58	8.27
	1995 - 2017	pH	183	7.82	5.68	8.42
SW023	2018	pH	9	7.94	7.57	8.38
	1998 - 2017	pH	177	7.82	5.90	8.57

pH - Field

Marine - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 7

Maximum 8.5

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH038	2018	pH	9	7.88	7.59	8.33
	2008 - 2017	pH	86	7.81	7.27	8.39
DH039	2018	pH	7	7.87	7.53	8.33
	2008 - 2017	pH	81	7.8	7.00	8.48
DH040	2018	pH	7	7.92	7.52	8.42
	2008 - 2017	pH	81	7.81	7.23	8.44
DH041	2018	pH	7	7.95	7.48	8.41
	2008 - 2017	pH	84	7.87	6.94	8.85
DH042	2018	pH	6	8.1	7.42	8.88
	2008 - 2017	pH	83	7.98	7.02	8.83
DH043	2018	pH	5	7.84	7.25	8.27
	2008 - 2017	pH	74	7.8	6.52	8.41
DH044	2018	pH	5	8.19	7.89	8.54
	2007 - 2017	pH	84	8.01	7.15	8.72
DH045	2018	pH	5	8.27	7.73	8.46
	2007 - 2017	pH	84	8.15	6.76	8.91
DH048	2018	pH	6	8.02	7.50	8.37
	2009 - 2017	pH	38	7.8	7.05	8.41
DH285	2018	pH	8	7.93	7.60	8.30
	2007 - 2017	pH	99	7.84	7.38	8.53
DH286	2018	pH	9	8.21	7.50	9.11
	2007 - 2017	pH	84	7.93	7.19	8.92
DH287	2018	pH	6	7.96	7.58	8.25
	2007 - 2017	pH	92	7.83	7.32	8.45
DH288	2018	pH	8	8.27	7.55	9.13
	2007 - 2017	pH	86	7.81	6.77	8.65
SW001	2018	pH	7	7.92	7.52	8.26
	1995 - 2017	pH	146	7.64	6.29	8.20

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW002	2018	pH	8	7.92	7.49	8.47
	1995 - 2017	pH	128	7.91	7.14	8.76
SW008	2018	pH	26	7.56	7.14	7.99
	1995 - 2017	pH	146	7.35	6.23	8.04
SW019	2018	pH	7	7.94	7.57	8.32
	1998 - 2017	pH	140	7.76	6.71	8.58
SW039	2018	pH	5	7.96	7.58	8.22
	2003 - 2017	pH	132	7.66	5.90	9.69
SW051	2018	pH	40	7.63	5.50	8.38
	2003 - 2017	pH	222	7.48	5.30	8.94
SW053	2018	pH	35	7.84	6.51	8.47
	2003 - 2017	pH	158	7.42	6.08	8.51
SW055	2018	pH	8	7.29	6.60	8.27
	2003 - 2017	pH	112	7.13	5.72	9.39
SW056	2018	pH	3	7.4	6.95	8.21
	2003 - 2017	pH	111	7.49	6.32	8.59
SW059	2018	pH	5	6.59	5.95	6.89
	2003 - 2017	pH	126	7.17	6.01	8.06

pH - Field

Not Classified Sites

No Applicable Standards Available

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
GW058	2018	pH	4	7.65	7.45	7.81
	1991 - 2017	pH	100	7.43	6.28	8.48
GW059	2018	pH	3	7.57	7.17	7.84
	1972 - 2017	pH	98	7.57	6.00	10.34
GW074	2018	pH	3	7.54	7.46	7.66
	1996 - 2017	pH	82	7.48	6.57	8.46
GW109	2018	pH	3	6.42	6.20	6.84
	1991 - 2017	pH	82	6.63	4.71	8.14
GW115	2018	pH	5	7.7	7.60	7.84
	1996 - 2017	pH	88	7.44	5.87	8.51
GW129	2018	pH	6	7.72	7.61	7.89
	1991 - 2017	pH	92	7.38	0.19	8.29
GW143	2018	pH	4	7.8	7.68	7.88
	1996 - 2017	pH	90	7.63	6.37	9.01
GW145	2018	pH	8	7.97	7.02	8.35
	1994 - 2017	pH	85	7.84	6.31	12.35
GW146	2018	pH	3	7.48	7.38	7.65
	1996 - 2017	pH	108	7.53	6.71	8.75
GW189	2018	pH	6	8.28	7.92	8.50
	2008 - 2017	pH	88	8.13	7.26	10.21
GW409	2018	pH	4	7.66	7.48	7.86
	2008 - 2017	pH	83	7.51	6.42	10.44
GW417	2018	pH	7	8.12	7.90	8.20
	2010 - 2017	pH	38	7.98	6.77	10.45
GW418	2018	pH	6	8.19	8.03	8.32
	2008 - 2017	pH	67	7.96	6.90	11.44
GW421	2018	pH	4	7.71	7.50	7.95
	2008 - 2017	pH	88	7.61	6.28	9.63
SW132	2018	pH	2	6.48	6.00	6.96

SW133

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2018	pH	2	6.68	6.39	6.98

Water Temperature - In Situ

Freshwater - Class A (Excellent) Sites

Applicable Standards

7DADM 17.5 deg C

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW026	2018	deg C	4	12	6.62	16.61
	1998 - 2017	deg C	81	11.7	-0.01	28.10
SW027	2018	deg C	5	11.4	8.33	16.55
	1998 - 2017	deg C	112	10.6	2.39	18.00
SW028	2018	deg C	4	13.4	6.88	19.63
	1998 - 2017	deg C	119	14.1	0.27	28.20
SW031	2018	deg C	1	6.95	6.95	6.95
	1997 - 2017	deg C	197	7.37	0.00	18.90
SW033	2018	deg C	2	6.99	6.99	6.99
	1998 - 2017	deg C	99	8.45	1.80	26.70
SW035	2018	deg C	1	6.73	6.73	6.73
	1998 - 2017	deg C	109	9.08	2.60	25.70
SW037	2018	deg C	1	7.88	7.88	7.88
	1997 - 2017	deg C	181	9.75	2.20	18.00

Water Temperature - In Situ

Freshwater - Class AA (Extraordinary) Sites

Applicable Standards

7DADM 16 deg C

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW003	2018	deg C	33	15.6	4.04	23.43
	1993 - 2017	deg C	355	12.8	-0.27	25.80
SW007	2018	deg C	13	10.3	3.32	16.91
	1993 - 2017	deg C	257	10	0.10	19.62
SW009	2018	deg C	3	8.77	6.41	11.42
	1993 - 2017	deg C	246	11.9	1.25	22.30
SW010	2018	deg C	5	13	8.31	23.52
	1993 - 2017	deg C	268	12.1	0.50	22.92
SW011	2018	deg C	7	11.4	5.58	17.39
	1993 - 2017	deg C	324	10.1	-0.17	18.60
SW012	2018	deg C	4	9.31	7.41	11.26
	1997 - 2017	deg C	222	11.2	0.00	23.12
SW013	2018	deg C	4	13.7	9.84	22.52
	1998 - 2013	deg C	188	13.6	2.06	24.70
SW014	2018	deg C	6	8.42	5.00	11.47
	1998 - 2017	deg C	173	9.38	0.34	17.00
SW015	2018	deg C	2	9.53	8.08	10.99
	1998 - 2017	deg C	188	11.5	0.31	21.50
SW016	2018	deg C	2	12.9	11.28	14.62
	1998 - 2017	deg C	113	10.2	0.93	22.47
SW017	2018	deg C	1	8.35	8.35	8.35
	1998 - 2015	deg C	115	10.7	0.20	21.34
SW029	2018	deg C	4	9.72	6.52	14.16
	1998 - 2017	deg C	206	7.48	0.10	15.20
SW058	2018	deg C	2	10.9	9.98	11.79
	2000 - 2011	deg C	71	10.7	1.20	26.00
SW075	2018	deg C	3	8.71	6.54	10.43
	2016 - 2017	deg C	14	7.52	2.26	11.80

SW118	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
	2018	deg C	56	11.3	2.92	19.45
	2007 - 2017	deg C	429	9.95	1.20	19.69

Water Temperature - In Situ

Marine - Class A (Excellent) Sites

Applicable Standards

7DADM 16 deg C

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH049	2018	deg C	26	12.6	7.00	19.80
	1989 - 2017	deg C	270	11.4	2.15	28.00
DH050	2018	deg C	31	12.5	7.00	21.31
	1989 - 2017	deg C	288	11.6	1.00	22.00
DH051	2018	deg C	30	12.5	7.00	19.22
	1989 - 2017	deg C	277	11.4	0.00	22.00
DH052	2018	deg C	24	12.3	7.26	19.50
	1989 - 2017	deg C	268	11.3	1.81	22.00
DH053	2018	deg C	18	12.3	7.00	17.00
	1989 - 2017	deg C	265	11.6	1.48	27.00
DH054	2018	deg C	13	12.3	7.00	18.00
	1990 - 2017	deg C	248	12	0.00	28.00
DH055	2018	deg C	15	12	7.00	17.00
	1990 - 2017	deg C	259	11.8	1.00	27.00
DH057	2018	deg C	15	11.8	7.00	17.00
	1998 - 2017	deg C	194	11.5	2.00	27.00
DH058	2018	deg C	15	11.8	7.16	16.60
	1998 - 2017	deg C	180	11.6	3.00	29.00
DH271	2018	deg C	29	12.1	7.09	18.37
	2002 - 2017	deg C	162	11.1	1.68	20.00
DH272	2018	deg C	27	12.4	7.00	19.30
	2002 - 2017	deg C	167	11.5	1.94	21.07
SW006	2018	deg C	8	11.4	7.55	15.07
	1993 - 2017	deg C	257	12.1	3.13	23.10
SW023	2018	deg C	8	11.5	7.56	15.50
	1998 - 2017	deg C	223	12	3.03	21.74

Water Temperature - In Situ

Marine - Class AA (Extraordinary) Sites

Applicable Standards

7DADM 13 deg C

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH038	2018	deg C	9	10.5	6.68	15.18
	1989 - 2017	deg C	206	11	0.00	28.00
DH039	2018	deg C	7	10.5	6.83	14.60
	1989 - 2017	deg C	201	10.9	0.00	30.16
DH040	2018	deg C	7	10.3	6.84	16.22
	1989 - 2017	deg C	204	11	2.00	20.00
DH041	2018	deg C	7	11.3	6.96	16.71
	1989 - 2017	deg C	206	11.2	1.00	22.00
DH042	2018	deg C	6	12.9	6.84	21.28
	1989 - 2017	deg C	205	11.7	1.00	29.36
DH043	2018	deg C	6	11	7.06	14.74
	1989 - 2017	deg C	197	10.9	4.00	19.91
DH044	2018	deg C	6	15.3	4.71	25.79
	1999 - 2017	deg C	149	13.8	0.79	28.00
DH045	2018	deg C	6	14.9	5.28	24.99
	1999 - 2017	deg C	144	13.2	0.56	26.00
DH048	2018	deg C	13	11.6	7.56	16.00
	1989 - 2017	deg C	227	11.2	3.00	29.00
DH285	2018	deg C	8	10.3	5.53	16.17
	2002 - 2017	deg C	134	10.9	1.23	21.80
DH286	2018	deg C	9	14.4	5.38	25.62
	2002 - 2017	deg C	123	12	0.00	25.00
DH287	2018	deg C	6	10.6	5.66	15.16
	2002 - 2017	deg C	128	10.6	1.73	18.60
DH288	2018	deg C	8	14.2	5.37	25.13
	2002 - 2017	deg C	121	11	-0.51	22.10
SW001	2018	deg C	7	13.4	8.80	17.64
	1993 - 2017	deg C	188	11.9	3.45	27.10

Station	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW002	2018	deg C	8	11.7	7.97	17.73
	1993 - 2017	deg C	186	11.9	5.00	23.00
SW008	2018	deg C	29	15.7	1.50	30.41
	1993 - 2017	deg C	307	13.1	0.00	29.41
SW019	2018	deg C	7	12.5	8.64	17.06
	1998 - 2017	deg C	167	11.9	2.00	20.33
SW039	2018	deg C	5	13.3	8.22	17.95
	1998 - 2017	deg C	266	11.2	3.91	28.60
SW051	2018	deg C	42	15.1	2.02	28.57
	1999 - 2017	deg C	313	13	-1.58	29.10
SW053	2018	deg C	39	15.4	2.83	28.65
	1999 - 2017	deg C	228	12.6	-1.40	26.90
SW055	2018	deg C	8	14.1	6.53	24.03
	2000 - 2017	deg C	156	12.2	1.12	24.17
SW056	2018	deg C	5	10.6	2.91	25.33
	2000 - 2017	deg C	186	12.6	0.98	25.60
SW059	2018	deg C	9	8.36	2.24	18.26
	2000 - 2017	deg C	180	11.3	0.94	22.95

Water Temperature - In Situ

Not Classified Sites

No Applicable Standards Available

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
GW058	2018	deg C	3	10.9	10.50	11.20
	1950 - 2017	deg C	423	10.5	6.00	14.00
GW059	2018	deg C	2	11.3	10.60	12.00
	1991 - 2017	deg C	207	10.9	7.10	15.55
GW074	2018	deg C	5	11.3	9.80	12.50
	1993 - 2017	deg C	182	13.1	6.20	289.00
GW109	2018	deg C	6	12	10.10	14.30
	1991 - 2017	deg C	183	12.1	8.80	17.20
GW115	2018	deg C	4	10.8	10.60	11.00
	1992 - 2017	deg C	271	12.2	7.19	358.00
GW129	2018	deg C	2	12.6	11.30	13.90
	1991 - 2017	deg C	174	11	7.50	17.50
GW143	2018	deg C	5	11.1	9.00	12.91
	1993 - 2017	deg C	179	10.9	5.08	18.40
GW145	2018	deg C	7	10.2	9.90	10.45
	1994 - 2017	deg C	320	10.5	6.79	127.25
GW146	2018	deg C	1	10.6	10.60	10.60
	1994 - 2017	deg C	232	12.1	5.25	354.00
GW189	2018	deg C	6	11.7	10.20	13.60
	2004 - 2017	deg C	112	15.6	7.19	486.00
GW409	2018	deg C	3	10.7	10.50	10.90
	2007 - 2017	deg C	96	10.3	7.30	11.60
GW417	2018	deg C	6	10.4	10.00	10.80
	2010 - 2017	deg C	39	10.2	8.80	12.40
GW418	2018	deg C	5	10.4	9.90	10.80
	2007 - 2017	deg C	76	10.1	7.66	10.90
GW421	2018	deg C	3	10.6	10.50	10.80
	2006 - 2017	deg C	105	10.3	8.70	11.50
SW132	2018	deg C	5	7.67	3.85	12.01

SW133

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2018	deg C	6	7.59	3.83	12.22

Appendix B Index. *List of Non-Bacterial Secondary Parameters*

Alkalinity
Ammonia
Arsenic
Biochemical Oxygen Demand
Chemical Oxygen Demand
Chloride - Lab
Chlorophyll a
Chromium
Copper
Diesel Range Plus
Gasoline Range Hydrocarbons
Hardness
Iron
Lead
Lube Oil Range Hydrocarbons
Mercury
Nitrate + Nitrite - N
Nitrate-N
Nitrite-N
Orthophosphate
Pheophytin
Salinity
Secchi Depth
Specific Conductivity - Field
Tin
Total Kjeldahl Nitrogen
Total Organic Carbon
Total Phosphorus
Total Suspended Solids
Total Volatile Suspended Solids
Zinc

Appendix B. *Non-Bacterial Secondary Parameter Summary Statistics*

Alkalinity

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	43.8	16.10	99.80
2000 - 2017	mg/l	11	233	122	4.00	590.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	31	82.2	32.00	150.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	38.8	16.30	96.00
2000 - 2017	mg/l	5	62	100	26.10	120.00

Ammonia

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	0.0389	0.01	0.15
1998 - 2017	mg/l	11	292	0.264	0.01	5.50

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	0.407	0.00	10.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.025	0.01	0.03
1999 - 2017	mg/l	5	64	0.128	0.00	1.70

Arsenic

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	2	3	0.000367	0.00	0.00
1999 - 2017	mg/l	2	4	0.0047	0.00	0.01

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.0037	0.00	0.01
1999 - 2017	mg/l	2	50	0.0156	0.00	0.40

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 2012	mg/l	3	5	0.00758	0.00	0.01

Biochemical Oxygen Demand

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	1.84	0.90	5.00
1998 - 2017	mg/l	11	233	3.67	0.80	40.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	1.86	1.00	5.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	1.17	0.90	2.00
1999 - 2017	mg/l	5	64	1.9	0.78	6.10

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	11	1.34	1.10	1.60

Chemical Oxygen Demand

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	216	7.00	1000.00
2010 - 2017	mg/l	5	71	110	7.00	3825.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2010 - 2014	mg/l	1	13	125	34.00	240.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	990	42.00	1788.00
2010 - 2017	mg/l	1	26	259	83.00	1225.00

Chloride - Lab

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	25	74	26.9	5.80	99.20
1992 - 2017	mg/l	25	458	30.4	5.00	130.00

Chlorophyll a

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	ug/l	3	10	4.03	0.60	18.00
2002 - 2017	ug/l	10	155	22.1	0.00	617.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2003 - 2014	ug/l	1	25	1.64	0.00	7.70

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	ug/l	1	4	1.63	0.80	3.70
2002 - 2017	ug/l	5	49	3.25	0.00	23.00

Chromium

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	1	0.0009	0.00	0.00
1998 - 2017	mg/l	2	54	0.0135	0.00	0.16

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2002 - 2002	mg/l	1	3	0.00693	0.00	0.02

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1994	mg/l	2	2	0.0045	0.00	0.00

Copper

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	2	4	0.00252	0.00	0.00
1999 - 2017	mg/l	2	45	0.00781	0.00	0.09

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.0227	0.01	0.03
1999 - 2017	mg/l	2	51	0.0254	0.00	0.26

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1994	mg/l	2	2	0.083	0.07	0.10

Diesel Range Plus

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	2	4	0.09	0.09	0.09
2001 - 2017	mg/l	2	45	0.145	0.04	0.66

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.09	0.09	0.09
2000 - 2017	mg/l	1	42	0.14	0.04	0.62

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	8	0.18	0.18	0.18
2017 - 2017	mg/l	1	14	0.139	0.10	0.18

Gasoline Range Hydrocarbons

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2016 - 2016	mg/l	1	1	0.24	0.24	0.24

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	8	0.04	0.04	0.04
2017 - 2017	mg/l	1	14	0.04	0.04	0.04

Hardness

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	2	4	67.1	47.10	86.70
2007 - 2017	mg/l	2	29	61.1	10.00	110.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	5040	3577.90	6408.60
2007 - 2017	mg/l	1	31	5140	3800.00	6200.00

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1971 - 1994	mg/l	11	28	123	47.00	184.00

Iron

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	2.09	0.35	10.80
2002 - 2017	mg/l	11	160	3.52	0.16	110.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2003 - 2014	mg/l	1	25	0.469	0.01	1.70

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.586	0.14	1.15
1999 - 2017	mg/l	6	51	0.398	0.01	2.70

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1971 - 1994	mg/l	11	30	0.134	0.00	1.08

Lead

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	1	0.00024	0.00	0.00
1998 - 2017	mg/l	2	55	0.00135	0.00	0.02

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1994	mg/l	2	2	0.0055	0.00	0.01

Lube Oil Range Hydrocarbons

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	2	4	0.0925	0.09	0.10
2001 - 2017	mg/l	2	32	0.213	0.09	0.80

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.09	0.09	0.09
2000 - 2017	mg/l	1	38	0.26	0.09	0.86

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	8	0.454	0.45	0.46
2017 - 2017	mg/l	1	14	0.474	0.45	0.50

Mercury

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	2	3	0.0001	0.00	0.00
2017 - 2017	mg/l	2	2	0.0001	0.00	0.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.000175	0.00	0.00
2000 - 2017	mg/l	1	44	0.000807	0.00	0.02

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1994	mg/l	2	2	0.00215	0.00	0.00

Nitrate + Nitrite - N

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	0.265	0.01	0.79
1998 - 2017	mg/l	10	78	0.259	0.01	0.95

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2003 - 2014	mg/l	1	16	0.366	0.01	1.20

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.305	0.13	0.43
1999 - 2017	mg/l	4	33	0.379	0.01	2.50

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	20	0.231	0.09	0.50
1971 - 2017	mg/l	11	33	7.17	0.00	210.00

Nitrate-N

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	9	0.289	0.01	0.80
1998 - 2017	mg/l	11	253	0.525	0.01	15.80

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2011	mg/l	1	15	0.415	0.01	3.31

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	1	0.14	0.14	0.14
2000 - 2014	mg/l	3	33	0.231	0.01	1.50

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2008 - 2008	mg/l	1	1	0.04	0.04	0.04

Nitrite-N

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	9	0.053	0.01	0.16
1998 - 2017	mg/l	5	98	0.0798	0.01	1.50

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2010 - 2011	mg/l	1	3	0.0567	0.04	0.09

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	1	0.009	0.01	0.01
2002 - 2014	mg/l	1	9	0.0522	0.01	0.16

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2008 - 2008	mg/l	1	1	0.04	0.04	0.04

Orthophosphate

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	0.65	0.02	5.21
1998 - 2017	mg/l	10	208	0.212	0.01	5.80

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	31	0.0592	0.01	0.12

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.06	0.05	0.08
2000 - 2017	mg/l	5	60	0.0706	0.01	0.43

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1971 - 1973	mg/l	3	4	0.145	0.04	0.24

Pheophytin

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	ug/l	3	10	4.92	0.80	30.00
2010 - 2017	ug/l	5	73	4.64	0.20	72.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2010 - 2014	ug/l	1	13	3.21	0.20	15.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	ug/l	1	4	1.15	0.40	1.90
2010 - 2017	ug/l	1	26	2.58	0.20	14.00

Salinity

Freshwater - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	ppt	7	22	9.43	0.03	26.52
1997 - 2017	ppt	9	1060	3.85	0.00	30.17

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	ppt	15	155	4.34	0.02	34.60
1993 - 2017	ppt	17	3417	14.7	0.00	26400.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	ppt	13	284	17.3	0.00	29.84
1989 - 2017	ppt	13	3105	19.1	0.00	32.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	ppt	23	266	23.6	0.09	42.06
1989 - 2017	ppt	23	4635	24	0.00	37.90

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	ppt	16	83	0.335	0.03	14.00
2004 - 2017	ppt	17	1051	0.198	0.00	7.91

Secchi Depth

Freshwater - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1998 - 2005	cm	9	69	9.23	0.08	106.68

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1998 - 2005	cm	13	64	38.9	0.38	184.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	cm	13	73	104	20.00	275.00
1998 - 2017	cm	13	539	145	0.58	500.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	cm	14	92	193	50.00	380.00
1998 - 2017	cm	20	1138	183	1.37	1000.00

Specific Conductivity - Field

Freshwater - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	uS/cm	7	22	14900	70.00	41656.00
1998 - 2017	uS/cm	9	971	6330	0.71	92400.00

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	uS/cm	15	152	7060	18.38	52279.00
1998 - 2017	uS/cm	17	2921	4410	2.00	96800.00
2001 - 2001	mg/l	17	1	156	156.00	156.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	uS/cm	13	126	30700	15.25	46040.00
1998 - 2017	uS/cm	13	997	34200	36.90	46400.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	uS/cm	23	257	36600	184.00	48969.00
1998 - 2017	uS/cm	23	3225	35900	3.79	51501.00

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	uS/cm	16	83	385	65.00	3458.00
1994 - 2017	uS/cm	18	2399	373	3.92	4886.00

Tin

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	2	3	0.00347	0.00	0.01
1999 - 2017	mg/l	2	4	0.204	0.01	0.40

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.0102	0.00	0.03
1999 - 2017	mg/l	2	50	0.158	0.00	1.24

Total Kjeldahl Nitrogen

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	0.554	0.10	1.27
1998 - 2017	mg/l	10	215	1.3	0.00	8.50

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	0.244	0.00	2.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.1	0.10	0.10
1999 - 2017	mg/l	5	64	0.289	0.00	1.90

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2008 - 2008	mg/l	1	1	0.09	0.09	0.09

Total Organic Carbon

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	6.75	0.28	19.00
1998 - 2017	mg/l	11	243	15.6	0.04	68.20

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	5.18	0.64	99.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	1.25	0.94	1.53
1999 - 2017	mg/l	5	63	4.86	0.40	99.00

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	3	4.12	3.71	4.85

Total Phosphorus

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	0.171	0.03	0.44
1998 - 2017	mg/l	11	294	0.415	0.01	13.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	31	0.184	0.04	1.90

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.0535	0.05	0.06
1999 - 2017	mg/l	5	64	0.149	0.02	0.70

Total Suspended Solids

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	27.2	4.00	140.00
1998 - 2017	mg/l	11	239	27.6	1.00	820.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	8.81	3.20	23.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	17.8	16.00	21.00
1999 - 2017	mg/l	5	64	10.8	1.60	81.00

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	20	175	4.20	974.00
2017 - 2017	mg/l	1	11	89	3.20	311.00

Total Volatile Suspended Solids

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	3	10	11.7	3.00	50.00
1998 - 2017	mg/l	10	212	6.63	0.03	49.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	1.89	0.90	3.80

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	886	7.00	3520.00
1999 - 2017	mg/l	5	64	3.32	0.90	21.00

Zinc

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	2	4	0.0074	0.00	0.01
1999 - 2017	mg/l	2	43	0.03	0.00	0.09

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018	mg/l	1	4	0.00907	0.01	0.01
1999 - 2017	mg/l	2	51	0.0508	0.01	0.24

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1991	mg/l	1	1	0.008	0.01	0.01

Appendix C Index. *List of Bacterial Parameters with Applicable Single-Parameter Standards*

E. coli

Enterococcus

Fecal Coliform

Appendix C. *Bacterial Parameter Summary Statistics and Single-Parameter Standards Compliance*

E. coli

Freshwater - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW037	1	1.00		15.60		319.30		30.00	
SW035	1	10.00		17.80		337.50		30.00	
SW033	1	94.00		15.30		113.70		30.00	
SW031	1	72.00		12.00		60.90		30.00	
SW028	5	187.00		14.30		132.30		30.00	
SW027	5	2500.00		36.00		786.10		30.00	
SW026	5	182.00		13.00		127.40		30.00	

E. coli

Freshwater - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW118	80	800.00		30.70		152.00		32.00	
SW075	4	68.00		21.80		128.50		15.00	
SW058	2	125.00		15.60		212.20		30.00	
SW029	4	68.00		28.30		167.00		30.00	
SW017	1	7.00		13.30		132.90		30.00	
SW016	2	739.00		24.70		243.40		30.00	
SW015	2	25.00		41.30		201.90		30.00	
SW014	6	68.00		49.40		392.30		30.00	
SW013	4	350.00		49.80		359.50		30.00	
SW012	5	48.00		31.50		106.50		30.00	
SW011	6	110.00		69.40		369.90		30.00	
SW010	5	155.00		30.20		274.20		30.00	
SW009	3	487.00		84.40		752.70		30.00	
SW007	9	53.00		29.50		200.90		30.00	
SW004	2	200.00		83.50		335.30		11.00	
SW003	24	132.00		22.10		119.00		30.00	

E. coli

Marine - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW023	6	28.00		2.70		13.60		30.00	
SW006	6	33.00		2.60		13.30		30.00	
DH050	3	91.00		4.90		61.20		5.00	

E. coli

Marine - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW059	6	33.00		34.10		154.30		30.00	
SW056	4	14.00		32.50		200.80		30.00	
SW055	6	25.00		10.00		85.50		30.00	
SW053	33	74.00		7.60		45.00		30.00	
SW051	39	264.00		3.30		15.60		30.00	
SW039	5	10.00		12.70		96.80		30.00	
SW019	6	17.00		2.40		8.30		30.00	
SW008	30	212.00		17.30		85.80		30.00	
SW002	6	2.00		1.30		2.50		30.00	
SW001	6	125.00		2.70		14.30		30.00	

E. coli

Not Classified Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW133	6	28.00		8.40		38.80		6.00	
SW132	5	32.00		12.00		34.70		5.00	
SW076	45	350.00		52.30		207.60		30.00	

Enterococcus

Freshwater - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW037	1	20.00	61	82.10	33	1247.10	N/A	30.00	30.00
SW035	1	75.00	61	25.20	33	226.10	N/A	30.00	30.00
SW033	1	156.00	61	16.90	33	60.70	N/A	30.00	30.00
SW031	1	20.00	61	11.20	33	32.60	N/A	30.00	30.00
SW028	5	97.00	61	20.90	33	135.70	N/A	30.00	30.00
SW027	5	1880.00	61	42.80	33	689.10	N/A	30.00	30.00
SW026	5	933.00	61	30.20	33	202.70	N/A	30.00	30.00

Enterococcus

Freshwater - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW118	57	683.00	61	30.30	33	148.90	N/A	30.00	30.00
SW075	4	228.00	61	20.80	33	132.30	N/A	15.00	30.00
SW058	2	355.00	61	53.90	33	363.60	N/A	30.00	30.00
SW029	4	51.00	61	28.30	33	168.60	N/A	30.00	30.00
SW017	1	9.00	61	35.70	33	271.10	N/A	30.00	30.00
SW016	2	1063.00	61	31.60	33	276.80	N/A	30.00	30.00
SW015	2	30.00	61	31.40	33	236.40	N/A	30.00	30.00
SW014	6	383.00	61	26.40	33	160.80	N/A	30.00	30.00
SW013	4	1860.00	61	70.50	33	781.80	N/A	30.00	30.00
SW012	5	397.00	61	26.20	33	127.50	N/A	30.00	30.00
SW011	6	3609.00	61	50.10	33	370.30	N/A	30.00	30.00
SW010	5	428.00	61	31.50	33	248.40	N/A	30.00	30.00
SW009	3	759.00	61	110.00	33	1126.30	N/A	30.00	30.00
SW007	9	85.00	61	26.70	33	162.30	N/A	30.00	30.00
SW003	25	199.00	61	21.50	33	80.80	N/A	30.00	30.00

Enterococcus

Marine - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW023	6	9.00	104	10.40	35	22.80	N/A	30.00	30.00
SW006	6	20.00	104	10.80	35	18.70	N/A	30.00	30.00
DH050	3	121.00	104	20.70	35	149.50	N/A	5.00	30.00

Enterococcus

Marine - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW059	6	86.00	104	22.70	35	119.60	N/A	30.00	30.00
SW056	4	119.00	104	21.50	35	81.10	N/A	30.00	30.00
SW055	6	20.00	104	12.40	35	28.70	N/A	30.00	30.00
SW053	34	557.00	104	19.00	35	80.10	N/A	30.00	30.00
SW051	40	132.00	104	10.90	35	18.30	N/A	30.00	30.00
SW039	5	158.00	104	39.50	35	252.30	N/A	30.00	30.00
SW019	6	20.00	104	9.60	35	12.50	N/A	30.00	30.00
SW008	31	457.00	104	21.60	35	74.20	N/A	30.00	30.00
SW002	6	9.00	104	8.70	35	16.20	N/A	30.00	30.00
SW001	6	75.00	104	12.30	35	29.40	N/A	30.00	30.00

Enterococcus

Not Classified Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW133	6	85.00		13.30		42.60		6.00	
SW132	5	74.00		16.80		52.30		5.00	

Fecal Coliform

Freshwater - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW037	1	1.00	N/A	20.80	100	479.70	200	30.00	30.00
SW035	1	12.00	N/A	19.50	100	372.30	200	30.00	30.00
SW033	1	145.00	N/A	16.70	100	128.20	200	30.00	30.00
SW031	1	102.00	N/A	12.30	100	65.00	200	30.00	30.00
SW028	5	200.00	N/A	20.00	100	183.20	200	30.00	30.00
SW027	5	9000.00	N/A	51.40	100	1351.30	200	30.00	30.00
SW026	5	490.00	N/A	15.10	100	179.80	200	30.00	30.00

Fecal Coliform

Freshwater - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW118	80	7100.00	N/A	53.80	50	327.50	100	32.00	30.00
SW075	4	92.00	N/A	46.90	50	240.30	100	15.00	30.00
SW058	2	161.00	N/A	25.60	50	288.90	100	30.00	30.00
SW029	4	102.00	N/A	37.00	50	229.50	100	30.00	30.00
SW017	1	7.00	N/A	15.70	50	131.00	100	30.00	30.00
SW016	2	1676.00	N/A	31.90	50	364.70	100	30.00	30.00
SW015	2	30.00	N/A	51.30	50	252.20	100	30.00	30.00
SW014	6	200.00	N/A	59.00	50	483.60	100	30.00	30.00
SW013	20	637.00	N/A	61.20	50	345.00	100	30.00	30.00
SW012	30	964.00	N/A	44.10	50	437.60	100	30.00	30.00
SW011	24	800.00	N/A	44.70	50	262.20	100	30.00	30.00
SW010	21	619.00	N/A	20.10	50	137.80	100	30.00	30.00
SW009	19	3000.00	N/A	68.40	50	612.20	100	30.00	30.00
SW007	9	135.00	N/A	42.10	50	244.40	100	30.00	30.00
SW004	2	658.60	N/A	109.60	50	442.90	100	11.00	30.00
SW003	25	191.00	N/A	29.00	50	162.60	100	30.00	30.00

Fecal Coliform

Marine - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW023	6	35.00	N/A	3.40	14	17.60	43	30.00	30.00
SW006	6	48.00	N/A	2.80	14	15.40	43	30.00	30.00
DH272	18	130.00	N/A	7.50	14	54.10	43	30.00	30.00
DH271	18	79.00	N/A	7.10	14	63.70	43	30.00	30.00
DH058	12	170.00	N/A	3.40	14	16.90	43	30.00	30.00
DH057	12	140.00	N/A	3.90	14	18.70	43	30.00	30.00
DH055	12	79.00	N/A	4.10	14	16.80	43	30.00	30.00
DH054	12	170.00	N/A	3.10	14	11.70	43	30.00	30.00
DH053	12	170.00	N/A	2.80	14	11.10	43	30.00	30.00
DH052	18	70.00	N/A	8.80	14	55.90	43	30.00	30.00
DH051	18	49.00	N/A	6.80	14	46.10	43	30.00	30.00
DH050	21	110.00	N/A	10.50	14	69.60	43	30.00	30.00
DH049	18	240.00	N/A	6.70	14	50.20	43	30.00	30.00

Fecal Coliform

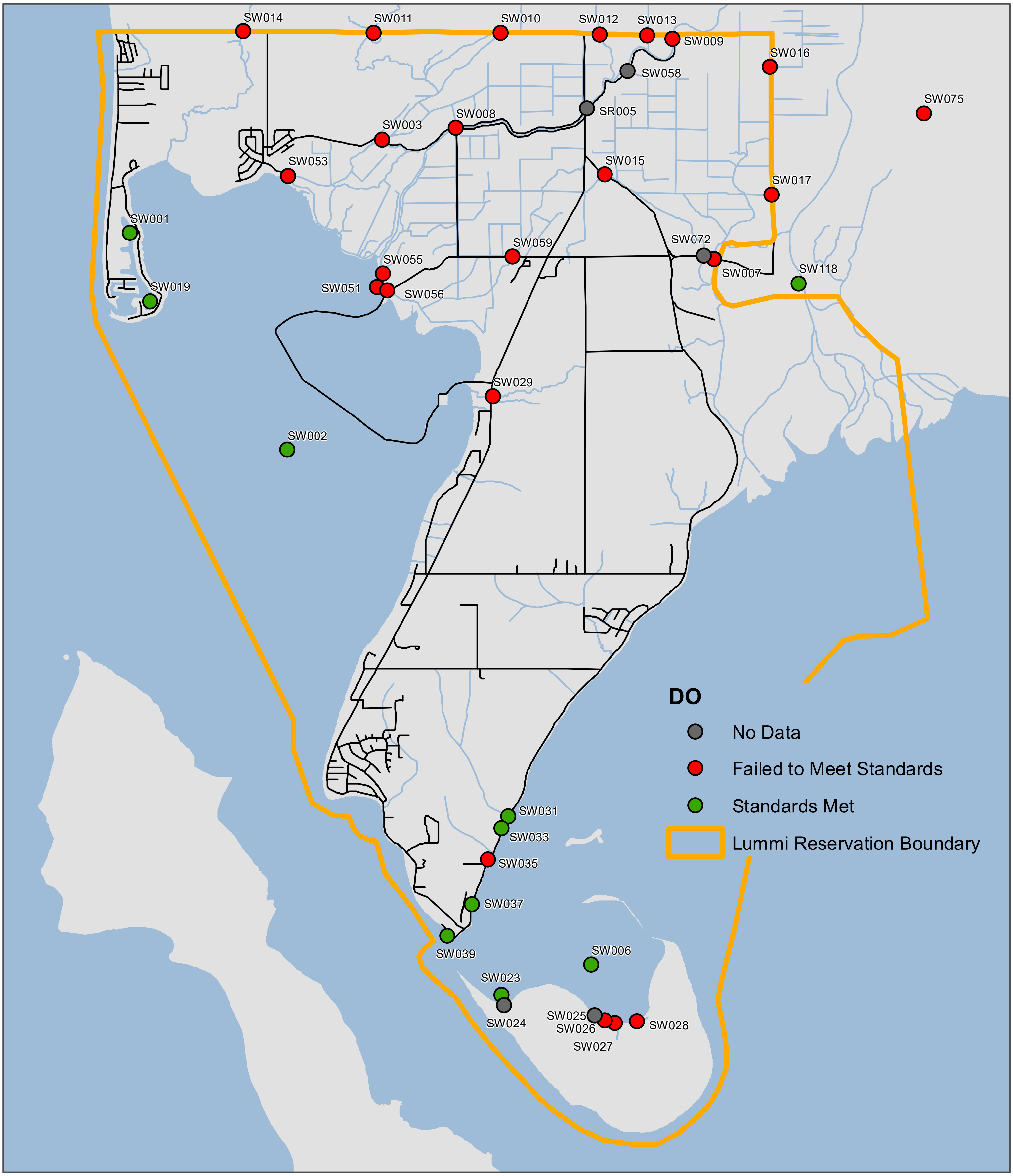
Marine - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW059	6	48.00	N/A	57.40	14	230.50	43	30.00	30.00
SW056	4	50.00	N/A	38.20	14	250.40	43	30.00	30.00
SW055	6	32.00	N/A	13.60	14	127.20	43	30.00	30.00
SW053	34	200.00	N/A	13.20	14	78.10	43	30.00	30.00
SW051	40	610.00	N/A	3.80	14	22.90	43	30.00	30.00
SW039	5	25.00	N/A	18.00	14	160.10	43	30.00	30.00
SW019	6	20.00	N/A	2.70	14	10.50	43	30.00	30.00
SW008	31	370.00	N/A	26.10	14	155.50	43	30.00	30.00
SW002	6	2.00	N/A	1.40	14	2.90	43	30.00	30.00
SW001	6	151.00	N/A	3.50	14	24.90	43	30.00	30.00
DH288	6	1.70	N/A	2.30	14	5.00	43	30.00	30.00
DH287	6	2.00	N/A	2.10	14	5.30	43	30.00	30.00
DH286	6	13.00	N/A	4.20	14	26.50	43	30.00	30.00
DH285	6	11.00	N/A	3.30	14	12.00	43	30.00	30.00
DH048	12	79.00	N/A	2.60	14	8.10	43	30.00	30.00
DH045	6	6.80	N/A	2.60	14	6.80	43	30.00	30.00
DH044	6	7.80	N/A	2.10	14	3.60	43	30.00	30.00
DH043	6	2.00	N/A	1.90	14	2.80	43	30.00	30.00
DH042	6	23.00	N/A	2.20	14	5.20	43	30.00	30.00
DH041	6	4.50	N/A	2.20	14	4.00	43	30.00	30.00
DH040	6	4.00	N/A	1.80	14	2.20	43	30.00	30.00
DH039	6	2.00	N/A	1.90	14	2.70	43	30.00	30.00
DH038	6	2.00	N/A	1.90	14	2.80	43	30.00	30.00

Fecal Coliform

Not Classified Sites

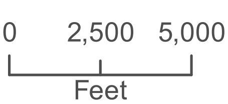
Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW133	6	40.00		11.60		63.60		6.00	
SW132	5	51.00		20.10		72.00		5.00	
SW076	42	425.00		65.00		239.40		30.00	

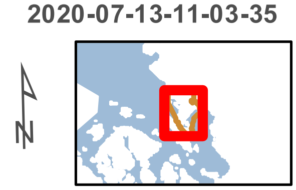


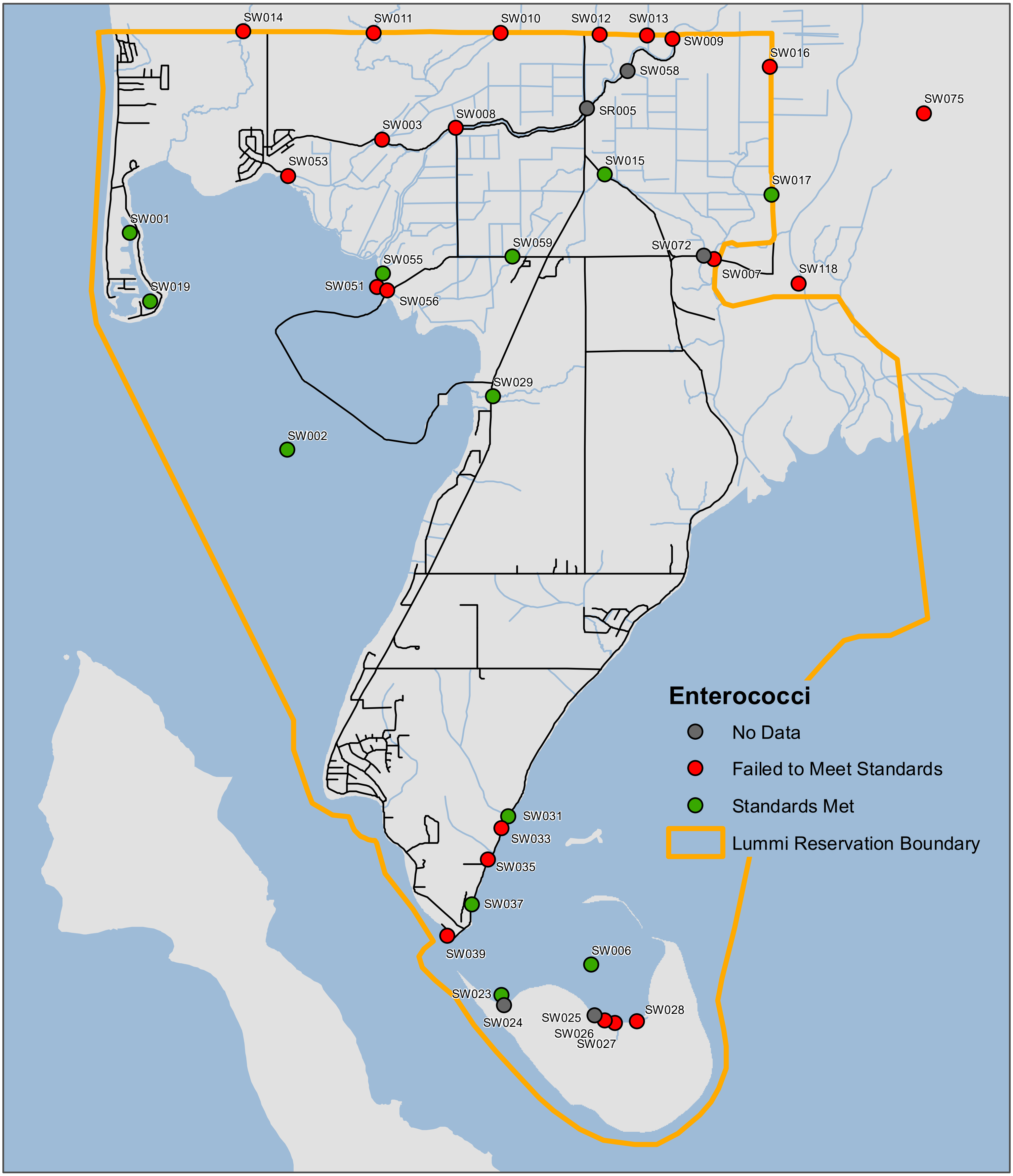
2018 Dissolved Oxygen

2020-07-13-11-03-35

0 2,500 5,000
Feet

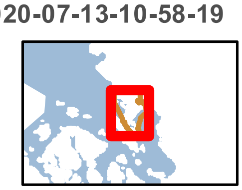


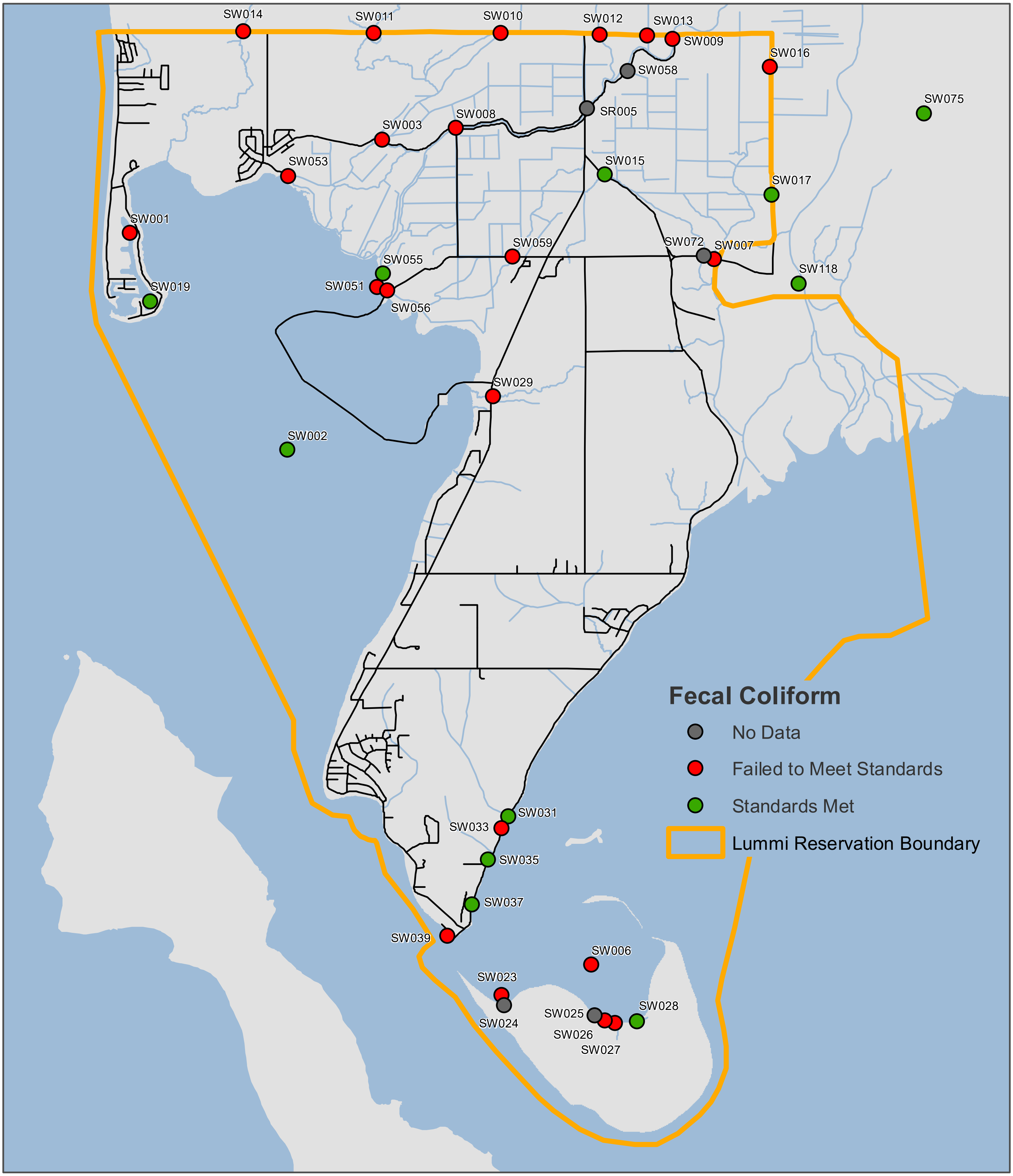




2018 Enterococci

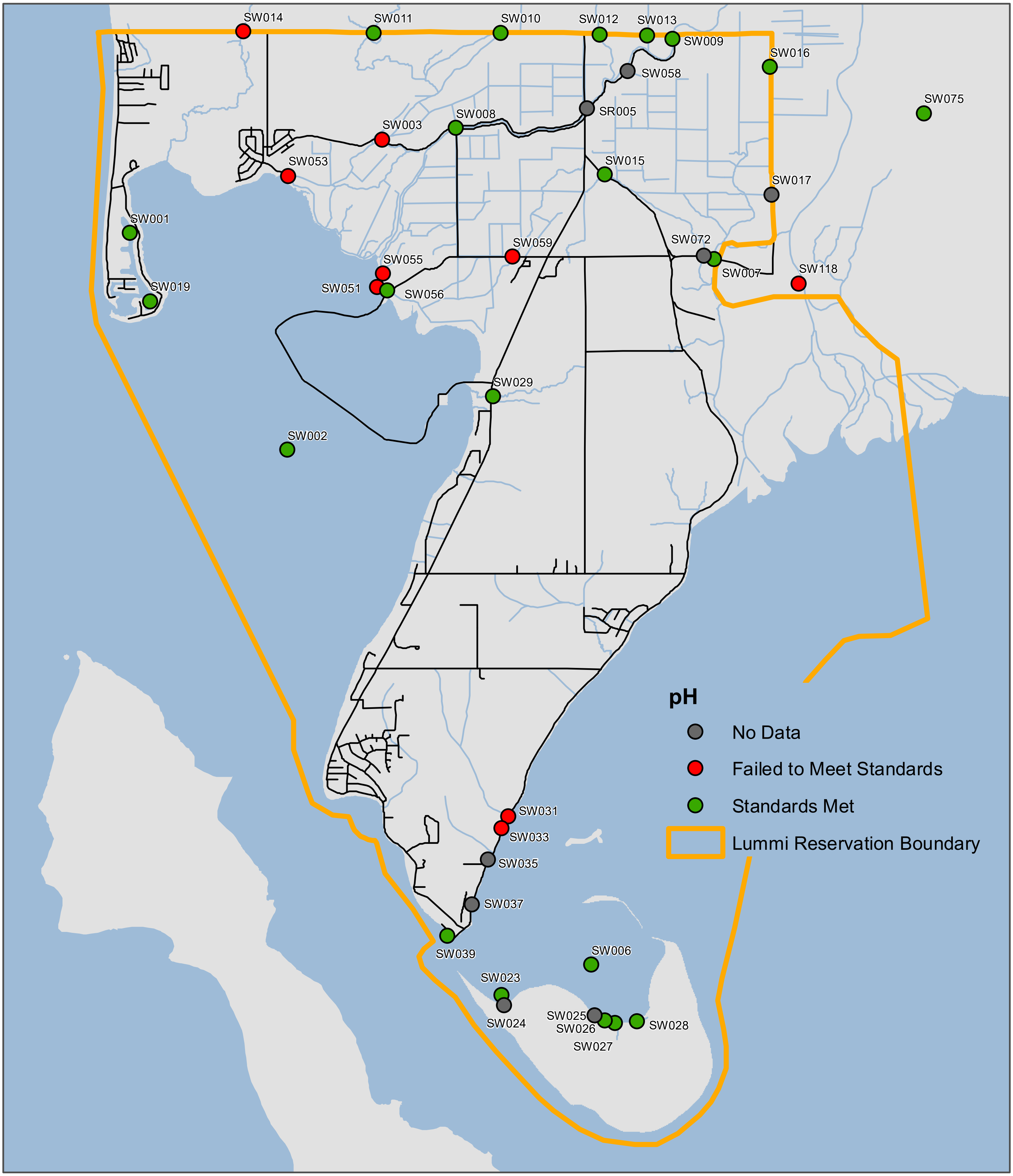
2020-07-13-10-58-19





2018 Fecal Coliform

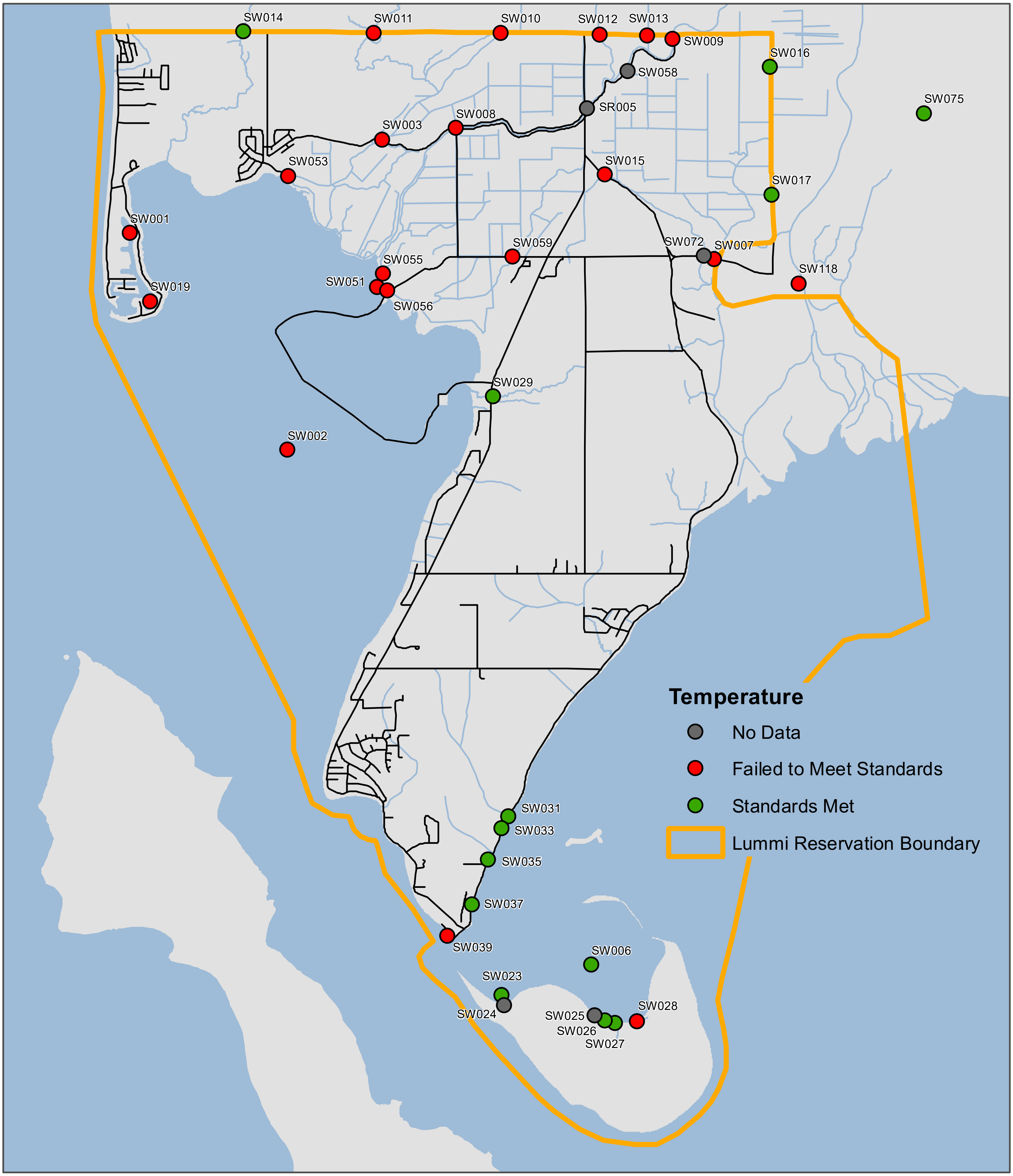
2020-07-13-10-15-12



2018 pH

0 2,500 5,000
Feet

2020-07-13-11-02-27



2018 Temperature

2020-07-13-10-59-23

Appendix E. Single-Parameter Water Quality Standards Compliance by Classification and Parameter

Reporting Year: 2018

	Fecal Coliform	Enterococcus	Temperature	Dissolved Oxygen	pH
Class AA Freshwater					
Total Sites Monitored	15	15	15	15	15
# Noncompliant	10	11	9	13	3
# Compliant	4	3	5	1	10
# no data	1	1	1	1	2
% Compliance	29%	21%	36%	7%	77%
% Noncompliance	71%	79%	64%	93%	23%
Class AA Marine					
Total Sites Monitored	23	11	23	23	23
# Noncompliant	8	5	23	7	8
# Compliant	15	5	0	16	15
# no data	0	1	0	0	0
% compliance	65%	50%	0%	70%	65%
% noncompliance	35%	50%	100%	30%	35%
Class A Freshwater					
Total Sites Monitored	7	7	7	7	7
# Noncompliant	3	5	1	4	2
# Compliant	4	2	6	3	3
# no data	0	0	0	0	2
% compliance	57%	29%	86%	43%	60%
% noncompliance	43%	71%	14%	57%	40%
Class A Marine					
Total Sites Monitored	13	3	13	13	13
# Noncompliant	13	1	11	0	5
# Compliant	0	2	2	13	8
# no data	0	0	0	0	0
% compliance	0%	67%	15%	100%	62%
% noncompliance	100%	33%	85%	0%	38%

11.2. 2019 Appendices

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Appendix A Index. *List of Non-Bacterial Primary Parameters*

Water Temperature - In Situ

pH - Field

Oxygen - Dissolved Field

Oxygen - % Saturation

Appendix A. *Non-Bacterial Primary Parameter - Site Summary Statistics*

Oxygen - % Saturation

Freshwater - Class A (Excellent) Sites

Applicable Standards

Minimum 90 %

Maximum 110 %

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW026	2019	%	3	61.2	45.30	79.00
	1998 - 2018	%	86	94.2	14.00	175.00
SW027	2019	%	4	58.1	25.50	91.30
	1998 - 2018	%	116	91.2	18.00	130.00
SW028	2019	%	5	75.7	51.50	94.10
	1998 - 2018	%	120	110	6.00	232.80
SW031	2019	%	3	74.9	52.50	90.30
	1999 - 2018	%	101	83	13.00	128.00
SW033	2019	%	1	73.5	73.50	73.50
	1999 - 2018	%	90	74.3	45.00	129.00
SW035	2019	%	2	55.8	55.50	56.00
	1999 - 2018	%	84	81.9	26.00	154.00
SW037	2019	%	2	81.9	74.80	89.10
	1999 - 2018	%	67	85	54.00	151.00

Oxygen - % Saturation

Freshwater - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 95 %

Maximum 110 %

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SR005	2019	%	22	45.5	0.00	235.00
SR021	2019	%	2	16.5	4.70	28.40
SR022	2019	%	4	22.9	0.60	60.40
SR023	2019	%	1	117	116.50	116.50
SW003	2019	%	26	60.7	12.70	79.90
	1996 - 2018	%	284	66.3	2.00	252.00
SW007	2019	%	9	92.5	77.50	100.00
	1996 - 2018	%	211	97.5	19.00	164.00
SW009	2019	%	1	66.5	66.50	66.50
	1996 - 2018	%	169	66.1	0.50	220.60
SW010	2019	%	2	73.5	53.50	93.50
	1996 - 2018	%	171	51.1	0.40	170.50
SW011	2019	%	6	98.2	93.60	104.70
	1996 - 2018	%	245	94.7	44.00	150.00
SW012	2019	%	5	51.8	1.10	100.50
	1997 - 2018	%	194	72.7	3.10	367.00
SW013	2019	%	7	99.6	10.00	290.00
	1998 - 2018	%	159	87.6	2.00	373.30
SW014	2019	%	13	81.3	68.10	93.30
	1998 - 2018	%	168	76.7	24.00	109.00
SW015	2019	%	3	43.8	28.80	52.20
	1998 - 2018	%	179	57.6	1.40	122.00
SW016	2019	%	2	71.1	60.60	81.70
	1998 - 2018	%	105	64.8	2.00	198.00
SW017	2019	%	3	30.1	28.00	32.70
	1998 - 2018	%	108	62.4	4.00	338.00

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW029	2019	%	5	94.8	87.30	103.20
	1999 - 2018	%	126	93.1	24.00	126.10

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW058	2019	%	2	42.3	20.50	64.00
	2000 - 2018	%	69	56.2	2.00	222.00

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW075	2019	%	12	62.8	10.20	100.50
	2016 - 2018	%	15	72.6	43.50	89.20

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW118	2019	%	76	99.6	93.10	107.10
	2007 - 2018	%	501	103	85.60	129.10

Oxygen - % Saturation

Marine - Class A (Excellent) Sites

Applicable Standards

Maximum 110 %

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH049	2019	%	10	101	65.60	131.20
	2009 - 2018	%	53	104	61.40	175.50
DH050	2019	%	18	103	76.30	141.60
	2009 - 2018	%	67	103	71.10	172.60
DH051	2019	%	8	103	73.80	139.10
	2009 - 2018	%	56	105	73.70	197.90
DH052	2019	%	8	106	86.60	132.90
	2009 - 2018	%	53	106	78.80	165.80
DH053	2019	%	9	104	71.80	135.80
	2000 - 2018	%	55	102	74.70	178.90
DH054	2019	%	12	104	24.40	141.10
	2009 - 2018	%	43	98.5	63.30	158.60
DH055	2019	%	8	105	74.50	130.70
	2000 - 2018	%	55	104	76.30	161.40
DH057	2019	%	8	101	73.10	126.90
	2009 - 2018	%	52	104	67.10	176.00
DH058	2019	%	7	96.4	69.60	145.60
	2009 - 2018	%	43	109	82.70	176.70
DH271	2019	%	7	111	82.80	140.50
	2009 - 2018	%	58	105	76.00	220.00
DH272	2019	%	9	107	69.70	135.50
	2009 - 2018	%	48	106	71.60	196.30
SW006	2019	%	13	93.8	70.00	132.00
	1996 - 2018	%	231	108	70.40	166.10
SW023	2019	%	9	87.2	50.00	103.70
	1998 - 2018	%	231	105	42.00	183.00

Oxygen - % Saturation

Marine - Class AA (Extraordinary) Sites

Applicable Standards

Maximum 110 %

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH038	2019	%	8	108	83.70	149.50
	2002 - 2018	%	96	101	73.80	151.00
DH039	2019	%	8	104	84.70	131.70
	2002 - 2018	%	91	100	71.20	159.50
DH040	2019	%	6	110	84.80	176.00
	2002 - 2018	%	90	100	69.90	159.90
DH041	2019	%	6	100	83.40	135.90
	2002 - 2018	%	93	108	69.20	195.00
DH042	2019	%	6	130	85.20	224.10
	2002 - 2018	%	91	121	57.00	233.00
DH043	2019	%	6	103	82.30	133.60
	2002 - 2018	%	83	105	70.50	187.70
DH044	2019	%	6	98.9	86.50	108.00
	2007 - 2018	%	89	106	63.40	161.00
DH045	2019	%	5	125	102.80	167.50
	2007 - 2018	%	91	132	83.00	220.30
DH048	2019	%	8	103	73.00	135.20
	2009 - 2018	%	48	102	76.70	181.30
DH285	2019	%	8	100	87.70	117.90
	2002 - 2018	%	109	103	71.20	156.80
DH286	2019	%	7	122	89.40	184.00
	2002 - 2018	%	97	118	56.90	226.70
DH287	2019	%	6	98.3	88.00	120.00
	2002 - 2018	%	101	99.3	73.00	153.30
DH288	2019	%	7	114	89.40	183.00
	2002 - 2018	%	95	109	70.80	214.00
SR019	2019	%	5	3.96	0.40	16.40
SR020	2019	%	5	0.66	0.00	1.60

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW001	2019	%	8	92.9	80.80	102.50
	1996 - 2018	%	177	97.4	7.91	145.70
SW002	2019	%	6	85.4	68.10	105.60
	1996 - 2018	%	165	114	74.60	234.00
SW008	2019	%	42	64.8	0.60	229.50
	1996 - 2018	%	243	70.9	20.90	183.00
SW019	2019	%	8	77.1	7.65	92.70
	1998 - 2018	%	179	99	63.20	166.00
SW039	2019	%	11	103	86.60	157.50
	1999 - 2018	%	215	114	65.80	364.00
SW051	2019	%	46	94.6	75.10	146.60
	1999 - 2018	%	343	95.7	41.50	197.00
SW053	2019	%	31	101	62.00	144.00
	1999 - 2018	%	258	91.5	26.90	175.00
SW055	2019	%	5	62.6	55.80	71.70
	2000 - 2018	%	166	76.4	19.50	180.60
SW056	2019	%	4	71.8	56.60	80.60
	2000 - 2018	%	174	99.7	1.00	387.37
SW059	2019	%	5	55.7	40.40	76.30
	2000 - 2018	%	192	58.5	1.50	166.20
SW151	2019	%	1	80.4	80.40	80.40

Oxygen - % Saturation

Not Classified Sites

No Applicable Standards Available

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW132	2019	%	5	98.1	91.20	103.90
	2018 - 2018	%	5	103	88.60	108.40
SW133	2019	%	5	101	96.20	106.10
	2018 - 2018	%	6	103	90.00	112.40

Oxygen - Dissolved Field

Freshwater - Class A (Excellent) Sites

Applicable Standards

Minimum 8 mg/l

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW026	2019	mg/l	4	6.9	4.22	9.04
	1998 - 2018	mg/l	86	9.84	1.20	15.24
SW027	2019	mg/l	4	6.31	2.30	10.45
	1998 - 2018	mg/l	116	10.2	1.50	14.19
SW028	2019	mg/l	5	7.62	4.86	10.20
	1998 - 2018	mg/l	120	10.5	0.50	17.90
SW031	2019	mg/l	3	9.18	7.69	9.94
	1999 - 2018	mg/l	100	9.72	1.60	13.80
SW033	2019	mg/l	1	8.1	8.10	8.10
	1999 - 2018	mg/l	89	8.66	4.99	14.40
SW035	2019	mg/l	1	6.8	6.80	6.80
	1999 - 2018	mg/l	85	9.23	2.30	17.20
SW037	2019	mg/l	2	9.31	8.31	10.31
	1999 - 2018	mg/l	66	9.51	5.80	15.50

Oxygen - Dissolved Field

Freshwater - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 11 mg/l

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SR005	2019	mg/l	22	4.3	0.00	18.22
SR021	2019	mg/l	2	1.58	0.45	2.70
SR022	2019	mg/l	4	1.45	0.04	2.86
SR023	2019	mg/l	1	10.9	10.87	10.87
SW003	2019	mg/l	26	7.3	1.08	11.42
	1993 - 2018	mg/l	286	6.86	0.20	26.10
SW007	2019	mg/l	9	11	8.68	13.13
	1993 - 2018	mg/l	212	11.1	2.15	20.30
SW009	2019	mg/l	1	8.4	8.40	8.40
	1993 - 2018	mg/l	171	7.22	0.04	19.60
SW010	2019	mg/l	2	8.17	6.65	9.69
	1993 - 2018	mg/l	175	5.68	0.05	15.59
SW011	2019	mg/l	6	12.5	10.69	13.80
	1993 - 2018	mg/l	242	10.8	4.90	16.14
SW012	2019	mg/l	5	6.31	0.09	10.85
	1997 - 2018	mg/l	194	7.97	0.28	28.70
SW013	2019	mg/l	7	8.85	1.50	22.50
	1998 - 2018	mg/l	159	8.65	0.03	34.33
SW014	2019	mg/l	13	9.61	7.88	11.62
	1998 - 2018	mg/l	168	8.99	2.30	14.08
SW015	2019	mg/l	3	6.01	4.01	7.48
	1998 - 2018	mg/l	179	6.31	0.13	12.00
SW016	2019	mg/l	2	9.41	7.31	11.51
	1998 - 2018	mg/l	105	7.29	0.10	20.56
SW017	2019	mg/l	3	3.89	3.43	4.65
	1998 - 2018	mg/l	108	6.89	0.50	32.80

SW029

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	5	12	9.13	13.33
1999 - 2018	mg/l	126	11	2.70	16.42

SW058

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	4.63	2.01	7.24
2000 - 2018	mg/l	69	6.22	0.20	21.10

SW075

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	12	7.8	1.00	13.61
2016 - 2018	mg/l	16	8.87	4.73	12.26

SW118

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	76	11	9.08	13.75
2007 - 2018	mg/l	500	11.6	8.14	15.17

Oxygen - Dissolved Field

Marine - Class A (Excellent) Sites

Applicable Standards

Minimum 6 mg/l

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH049	2019	mg/l	10	9.38	5.83	12.83
	2009 - 2018	mg/l	53	9.98	5.35	14.25
DH050	2019	mg/l	18	9.96	7.00	12.75
	2009 - 2018	mg/l	67	9.79	6.50	13.28
DH051	2019	mg/l	8	9.28	6.41	12.68
	2009 - 2018	mg/l	56	9.93	6.37	15.31
DH052	2019	mg/l	8	9.45	7.50	12.17
	2009 - 2018	mg/l	53	10.2	7.54	12.98
DH053	2019	mg/l	9	9.57	6.22	13.22
	2000 - 2018	mg/l	55	9.61	6.85	14.19
DH054	2019	mg/l	12	9.48	2.07	13.62
	2009 - 2018	mg/l	43	9.18	5.57	12.51
DH055	2019	mg/l	8	9.55	6.49	12.65
	2000 - 2018	mg/l	55	9.73	6.85	12.76
DH057	2019	mg/l	8	9.1	6.28	11.31
	2009 - 2018	mg/l	52	9.96	5.88	13.80
DH058	2019	mg/l	7	8.86	6.06	11.21
	2009 - 2018	mg/l	43	10.1	7.53	13.98
DH271	2019	mg/l	7	9.85	7.17	12.50
	2009 - 2018	mg/l	59	10.2	7.02	17.17
DH272	2019	mg/l	9	9.47	6.31	12.83
	2009 - 2018	mg/l	48	9.95	6.63	15.85
SW006	2019	mg/l	13	8.7	6.04	12.99
	1993 - 2018	mg/l	233	10.1	6.16	18.88
SW023	2019	mg/l	9	8.08	4.35	10.35
	1998 - 2018	mg/l	231	9.96	3.91	16.60

Oxygen - Dissolved Field

Marine - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 7 mg/l

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH038	2019	mg/l	8	9.75	8.16	12.48
	2002 - 2018	mg/l	96	9.34	7.07	13.53
DH039	2019	mg/l	8	9.44	8.15	11.35
	2002 - 2018	mg/l	91	9.38	6.74	13.50
DH040	2019	mg/l	6	9.92	8.25	13.96
	2002 - 2018	mg/l	90	9.32	6.62	13.74
DH041	2019	mg/l	6	9.22	8.00	11.67
	2002 - 2018	mg/l	93	9.88	6.57	15.75
DH042	2019	mg/l	6	11	8.37	16.54
	2002 - 2018	mg/l	91	10.7	4.85	18.74
DH043	2019	mg/l	6	9.4	8.04	11.44
	2002 - 2018	mg/l	83	9.71	6.70	16.08
DH044	2019	mg/l	6	8.88	7.03	11.10
	2007 - 2018	mg/l	89	9.32	4.87	16.93
DH045	2019	mg/l	5	10.7	9.03	12.47
	2007 - 2018	mg/l	91	11.7	6.42	19.19
DH048	2019	mg/l	8	9.3	6.43	11.50
	2009 - 2018	mg/l	48	9.42	6.90	14.74
DH285	2019	mg/l	8	9.38	8.70	10.10
	2002 - 2018	mg/l	109	9.59	6.80	13.28
DH286	2019	mg/l	7	10.7	9.40	13.54
	2002 - 2018	mg/l	97	10.5	4.80	16.78
DH287	2019	mg/l	6	9.13	8.34	10.42
	2002 - 2018	mg/l	99	9.3	6.81	12.91
DH288	2019	mg/l	7	10.3	9.12	14.38
	2002 - 2018	mg/l	95	10	6.46	15.09
SR019	2019	mg/l	5	0.296	0.03	1.20
SR020	2019	mg/l	5	0.06	0.00	0.16

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW001	2019	mg/l	8	8.39	7.51	9.07
	1993 - 2018	mg/l	179	8.95	1.50	17.10
SW002	2019	mg/l	6	7.99	5.83	10.35
	1993 - 2018	mg/l	167	10.5	6.58	28.15
SW008	2019	mg/l	42	6.49	0.04	16.04
	1993 - 2018	mg/l	243	7.2	1.61	16.00
SW019	2019	mg/l	8	8.04	6.76	8.54
	1998 - 2018	mg/l	179	9.02	5.61	13.88
SW039	2019	mg/l	11	10.1	7.95	12.50
	1999 - 2018	mg/l	216	10.6	6.26	27.20
SW051	2019	mg/l	46	8.67	5.65	12.92
	1999 - 2018	mg/l	342	8.88	2.10	16.86
SW053	2019	mg/l	31	8.96	6.24	11.90
	1999 - 2018	mg/l	256	8.81	2.06	17.89
SW055	2019	mg/l	5	7.18	6.04	7.88
	2000 - 2018	mg/l	166	7.32	2.34	17.32
SW056	2019	mg/l	4	8.16	6.57	10.98
	2000 - 2018	mg/l	175	9.4	0.10	26.94
SW059	2019	mg/l	5	7.13	5.54	8.57
	2000 - 2018	mg/l	192	6.36	0.12	14.63
SW151	2019	mg/l	1	8.04	8.04	8.04

Oxygen - Dissolved Field

Not Classified Sites

No Applicable Standards Available

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW132	2019	mg/l	5	12.3	10.74	13.56
	2018 - 2018	mg/l	5	12.3	10.58	13.88
SW133	2019	mg/l	5	12.6	11.59	14.13
	2018 - 2018	mg/l	6	12.3	10.78	13.64

pH - Field

Freshwater - Class A (Excellent) Sites

Applicable Standards

Minimum 6.5

Maximum 8.5

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW026	2019	pH	4	7.27	7.07	7.51
	1998 - 2018	pH	62	7.3	6.35	8.36
SW027	2019	pH	4	7.6	7.11	8.14
	1998 - 2018	pH	73	7.55	6.43	8.95
SW028	2019	pH	5	7.43	7.06	8.13
	1998 - 2018	pH	85	7.54	6.35	8.98
SW031	2019	pH	3	6.88	6.27	7.60
	2003 - 2018	pH	57	6.56	4.54	7.91
SW033	2019	pH	1	6.2	6.20	6.20
	2003 - 2018	pH	62	6.63	4.26	9.30
SW035	2019	pH	2	6.66	6.52	6.80
	2003 - 2017	pH	46	6.93	5.85	8.00
SW037	2019	pH	2	7.5	6.79	8.21
	2003 - 2015	pH	21	7.24	6.61	7.97

pH - Field

Freshwater - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 6.5

Maximum 8.5

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SR005	2019	pH	15	7.19	6.64	7.82
SR021	2019	pH	1	7.57	7.57	7.57
SR022	2019	pH	3	7.35	7.01	7.53
SW003	2019	pH	29	7.38	6.50	7.96
	1995 - 2018	pH	192	7.31	5.62	9.60
SW007	2019	pH	10	7.42	6.75	8.05
	1995 - 2018	pH	146	7.4	4.84	9.49
SW009	2019	pH	1	7	7.00	7.00
	1995 - 2018	pH	100	7.26	6.50	8.51
SW010	2019	pH	6	7.12	6.90	7.35
	1995 - 2018	pH	102	7.05	6.16	8.62
SW011	2019	pH	9	7.64	7.11	7.86
	1995 - 2018	pH	161	7.43	6.10	8.63
SW012	2019	pH	5	7.65	7.31	8.00
	1997 - 2018	pH	115	7.19	6.14	9.20
SW013	2019	pH	5	7.27	6.89	7.87
	1998 - 2018	pH	85	7.31	6.51	9.08
SW014	2019	pH	16	7.53	6.76	8.15
	1998 - 2018	pH	94	7.18	4.47	8.60
SW015	2019	pH	4	7.12	6.97	7.33
	1998 - 2018	pH	107	7.08	6.20	8.57
SW016	2019	pH	3	7.2	7.07	7.40
	1998 - 2018	pH	65	6.88	6.50	7.89
SW017	2019	pH	3	6.85	6.73	7.08
	1998 - 2015	pH	58	6.84	6.11	8.13
SW029	2019	pH	7	7	6.40	7.68
	2003 - 2018	pH	69	6.2	1.34	8.54

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW058	2019	pH	1	7.2	7.20	7.20
	2003 - 2018	pH	35	7	6.32	10.77
SW072	2019	pH	1	7.16	7.16	7.16
	2003 - 2017	pH	64	6.74	5.94	7.60
SW075	2019	pH	12	7.23	6.63	7.93
	2016 - 2018	pH	12	7.39	6.72	8.79
SW118	2019	pH	81	7.54	6.60	8.49
	2007 - 2018	pH	409	7.26	3.21	11.24

pH - Field

Marine - Class A (Excellent) Sites

Applicable Standards

Minimum 7

Maximum 8.5

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH049	2019	pH	10	7.93	7.61	8.35
	2009 - 2018	pH	49	7.82	6.64	8.60
DH050	2019	pH	18	7.83	7.36	8.39
	2009 - 2018	pH	65	7.92	7.14	8.52
DH051	2019	pH	8	8	7.68	8.36
	2009 - 2018	pH	55	7.93	7.31	8.59
DH052	2019	pH	8	8.1	7.81	8.34
	2009 - 2018	pH	49	7.93	7.09	8.53
DH053	2019	pH	10	7.97	7.67	8.31
	2009 - 2018	pH	51	7.89	7.40	8.47
DH054	2019	pH	12	8.03	7.35	8.37
	2009 - 2018	pH	42	7.82	7.23	8.55
DH055	2019	pH	9	8	7.67	8.34
	2009 - 2018	pH	48	7.92	7.24	8.51
DH057	2019	pH	8	8.02	7.69	8.29
	2009 - 2018	pH	51	7.84	6.57	8.57
DH058	2019	pH	7	7.84	7.35	8.44
	2009 - 2018	pH	42	7.93	7.42	8.61
DH271	2019	pH	7	8.09	7.78	8.41
	2009 - 2018	pH	57	7.88	7.03	8.62
DH272	2019	pH	10	8.02	7.58	8.38
	2009 - 2018	pH	47	7.85	6.61	8.53
SW006	2019	pH	12	7.93	7.69	8.31
	1995 - 2018	pH	193	7.83	5.68	8.42
SW023	2019	pH	10	7.79	7.51	8.31
	1998 - 2018	pH	186	7.82	5.90	8.57

pH - Field

Marine - Class AA (Extraordinary) Sites

Applicable Standards

Minimum 7

Maximum 8.5

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH038	2019	pH	8	8.02	7.75	8.63
	2008 - 2018	pH	95	7.82	7.27	8.39
DH039	2019	pH	8	8.03	7.75	8.46
	2008 - 2018	pH	88	7.81	7.00	8.48
DH040	2019	pH	6	8.03	7.78	8.48
	2008 - 2018	pH	88	7.82	7.23	8.44
DH041	2019	pH	6	7.97	7.77	8.49
	2008 - 2018	pH	91	7.88	6.94	8.85
DH042	2019	pH	6	8.15	7.78	8.78
	2008 - 2018	pH	89	7.99	7.02	8.88
DH043	2019	pH	6	7.92	7.64	8.14
	2008 - 2018	pH	79	7.8	6.52	8.41
DH044	2019	pH	6	7.89	7.63	8.22
	2007 - 2018	pH	89	8.02	7.15	8.72
DH045	2019	pH	6	8.04	7.81	8.26
	2007 - 2018	pH	89	8.15	6.76	8.91
DH048	2019	pH	8	7.9	7.66	8.24
	2009 - 2018	pH	44	7.83	7.05	8.41
DH285	2019	pH	8	8	7.79	8.38
	2007 - 2018	pH	107	7.85	7.38	8.53
DH286	2019	pH	7	8.16	7.73	9.39
	2007 - 2018	pH	93	7.96	7.19	9.11
DH287	2019	pH	6	7.97	7.77	8.42
	2007 - 2018	pH	98	7.84	7.32	8.45
DH288	2019	pH	7	8.1	7.75	8.99
	2007 - 2018	pH	94	7.85	6.77	9.13
SR019	2019	pH	3	7.2	7.04	7.39

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SR020	2019	pH	4	7.26	7.15	7.56
SW001	2019	pH	8	7.72	7.48	7.99
	1995 - 2018	pH	153	7.66	6.29	8.26
SW002	2019	pH	6	7.78	7.62	7.86
	1995 - 2018	pH	136	7.91	7.14	8.76
SW008	2019	pH	37	7.41	6.56	8.00
	1995 - 2018	pH	172	7.39	6.23	8.04
SW019	2019	pH	8	7.73	7.63	7.87
	1998 - 2018	pH	147	7.77	6.71	8.58
SW039	2019	pH	11	7.73	7.54	8.33
	2003 - 2018	pH	137	7.67	5.90	9.69
SW051	2019	pH	46	7.69	6.25	8.40
	2003 - 2018	pH	262	7.5	5.30	8.94
SW053	2019	pH	32	7.68	6.95	8.24
	2003 - 2018	pH	193	7.49	6.08	8.51
SW055	2019	pH	7	7.22	6.98	7.53
	2003 - 2018	pH	120	7.14	5.72	9.39
SW056	2019	pH	4	7.22	6.94	7.51
	2003 - 2018	pH	114	7.48	6.32	8.59
SW059	2019	pH	6	7.36	6.96	7.73
	2003 - 2018	pH	131	7.15	5.95	8.06
SW151	2019	pH	3	8.15	7.95	8.30

pH - Field

Not Classified Sites

No Applicable Standards Available

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
GW058	2019	pH	5	7.34	6.94	7.71
	1991 - 2018	pH	104	7.44	6.28	8.48
GW059	2019	pH	5	7.16	6.67	7.88
	1972 - 2018	pH	101	7.57	6.00	10.34
GW074	2019	pH	5	7.28	6.96	7.76
	1996 - 2018	pH	85	7.48	6.57	8.46
GW109	2019	pH	7	6.75	5.80	7.43
	1991 - 2018	pH	85	6.62	4.71	8.14
GW115	2019	pH	5	7.46	6.82	7.91
	1996 - 2018	pH	93	7.45	5.87	8.51
GW143	2019	pH	5	7.48	7.07	7.91
	1996 - 2018	pH	94	7.64	6.37	9.01
GW145	2019	pH	7	7.71	6.55	8.28
	1994 - 2018	pH	93	7.85	6.31	12.35
GW146	2019	pH	6	7.39	6.96	7.74
	1996 - 2018	pH	111	7.53	6.71	8.75
GW189	2019	pH	7	7.78	7.14	8.59
	2008 - 2018	pH	94	8.14	7.26	10.21
GW409	2019	pH	5	7.22	6.99	7.42
	2008 - 2018	pH	87	7.52	6.42	10.44
GW417	2019	pH	5	7.69	7.46	8.17
	2010 - 2018	pH	45	8	6.77	10.45
GW418	2019	pH	5	7.76	7.26	8.27
	2008 - 2018	pH	73	7.98	6.90	11.44
GW421	2019	pH	6	7.22	7.04	7.47
	2008 - 2018	pH	92	7.62	6.28	9.63
SW132	2019	pH	6	7.27	6.34	7.88
	2018 - 2018	pH	2	6.48	6.00	6.96

SW133

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	pH	6	7.34	6.71	7.90
2018 - 2018	pH	2	6.68	6.39	6.98

Water Temperature - In Situ

Freshwater - Class A (Excellent) Sites

Applicable Standards

7DADM 17.5 deg C

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW026	2019	deg C	4	11	8.80	13.20
	1998 - 2018	deg C	85	11.7	-0.01	28.10
SW027	2019	deg C	4	11.7	8.95	14.20
	1998 - 2018	deg C	117	10.7	2.39	18.00
SW028	2019	deg C	5	12	9.15	13.70
	1998 - 2018	deg C	123	14.1	0.27	28.20
SW031	2019	deg C	3	6.1	0.10	11.25
	1997 - 2018	deg C	198	7.37	0.00	18.90
SW033	2019	deg C	1	11	11.04	11.04
	1998 - 2018	deg C	101	8.42	1.80	26.70
SW035	2019	deg C	2	8.94	6.86	11.01
	1998 - 2018	deg C	110	9.06	2.60	25.70
SW037	2019	deg C	2	9.77	8.88	10.66
	1997 - 2018	deg C	182	9.74	2.20	18.00

Water Temperature - In Situ

Freshwater - Class AA (Extraordinary) Sites

Applicable Standards

7DADM 16 deg C

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SR005	2019	deg C	22	17.1	2.02	26.62
SR021	2019	deg C	2	17.2	17.00	17.40
SR022	2019	deg C	4	20.5	17.40	25.00
SR023	2019	deg C	1	18.6	18.60	18.60
SW003	2019	deg C	32	8.98	0.20	21.60
	1993 - 2018	deg C	388	13	-0.27	25.80
SW007	2019	deg C	10	8.18	0.00	15.10
	1993 - 2018	deg C	270	10	0.10	19.62
SW009	2019	deg C	1	4.8	4.80	4.80
	1993 - 2018	deg C	249	11.9	1.25	22.30
SW010	2019	deg C	6	14.9	5.22	19.72
	1993 - 2018	deg C	273	12.1	0.50	23.52
SW011	2019	deg C	9	7.76	0.80	13.24
	1993 - 2018	deg C	331	10.1	-0.17	18.60
SW012	2019	deg C	5	9.52	-0.10	15.61
	1997 - 2018	deg C	226	11.2	0.00	23.12
SW013	2019	deg C	7	15.6	6.15	21.10
	1998 - 2018	deg C	192	13.6	2.06	24.70
SW014	2019	deg C	16	8.79	1.70	12.70
	1998 - 2018	deg C	179	9.35	0.34	17.00
SW015	2019	deg C	4	4.23	0.60	10.36
	1998 - 2018	deg C	190	11.5	0.31	21.50
SW016	2019	deg C	3	6.98	1.00	13.26
	1998 - 2018	deg C	115	10.2	0.93	22.47
SW017	2019	deg C	3	4.58	0.90	6.44
	1998 - 2018	deg C	116	10.7	0.20	21.34

SW029

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	deg C	7	6.66	1.60	13.50
1998 - 2018	deg C	210	7.52	0.10	15.20

SW058

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	deg C	2	12.7	9.51	15.90
2000 - 2018	deg C	73	10.7	1.20	26.00

SW072

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	deg C	1	11.2	11.21	11.21
2002 - 2017	deg C	86	12.2	0.92	27.18

SW075

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	deg C	12	7.83	0.10	15.24
2016 - 2018	deg C	17	7.73	2.26	11.80

SW118

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	deg C	83	11.2	0.10	18.85
2007 - 2018	deg C	485	10.1	1.20	19.69

Water Temperature - In Situ

Marine - Class A (Excellent) Sites

Applicable Standards

7DADM 16 deg C

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH049	2019	deg C	18	11.6	5.30	20.28
	1989 - 2018	deg C	296	11.5	2.15	28.00
DH050	2019	deg C	26	10.9	3.00	20.08
	1989 - 2018	deg C	319	11.6	1.00	22.00
DH051	2019	deg C	16	11.6	3.00	20.30
	1989 - 2018	deg C	307	11.5	0.00	22.00
DH052	2019	deg C	16	11.7	3.00	20.30
	1989 - 2018	deg C	292	11.4	1.81	22.00
DH053	2019	deg C	18	11.3	3.00	19.04
	1989 - 2018	deg C	283	11.7	1.48	27.00
DH054	2019	deg C	20	12.1	3.00	19.90
	1990 - 2018	deg C	261	12.1	0.00	28.00
DH055	2019	deg C	17	11.7	4.00	20.74
	1990 - 2018	deg C	274	11.8	1.00	27.00
DH057	2019	deg C	16	11.6	3.00	20.58
	1998 - 2018	deg C	209	11.5	2.00	27.00
DH058	2019	deg C	15	11.2	4.00	20.50
	1998 - 2018	deg C	195	11.6	3.00	29.00
DH271	2019	deg C	15	11.6	3.00	19.97
	2002 - 2018	deg C	191	11.2	1.68	20.00
DH272	2019	deg C	18	12	5.00	19.54
	2002 - 2018	deg C	194	11.6	1.94	21.07
SW006	2019	deg C	12	12.1	8.60	16.89
	1993 - 2018	deg C	265	12.1	3.13	23.10
SW023	2019	deg C	10	12.9	9.00	16.67
	1998 - 2018	deg C	231	12	3.03	21.74

Water Temperature - In Situ

Marine - Class AA (Extraordinary) Sites

Applicable Standards

7DADM 13 deg C

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
DH038	2019	deg C	8	11.6	6.40	16.20
	1989 - 2018	deg C	215	11	0.00	28.00
DH039	2019	deg C	8	11.5	6.40	14.40
	1989 - 2018	deg C	208	10.9	0.00	30.16
DH040	2019	deg C	6	11.2	6.60	17.97
	1989 - 2018	deg C	211	10.9	2.00	20.00
DH041	2019	deg C	6	10.6	6.40	14.70
	1989 - 2018	deg C	213	11.2	1.00	22.00
DH042	2019	deg C	6	13.5	6.70	23.70
	1989 - 2018	deg C	211	11.7	1.00	29.36
DH043	2019	deg C	6	11	6.80	15.61
	1989 - 2018	deg C	203	10.9	4.00	19.91
DH044	2019	deg C	6	13.4	3.61	24.66
	1999 - 2018	deg C	155	13.9	0.79	28.00
DH045	2019	deg C	6	12.8	3.79	22.93
	1999 - 2018	deg C	150	13.2	0.56	26.00
DH048	2019	deg C	16	11	7.00	17.60
	1989 - 2018	deg C	240	11.2	3.00	29.00
DH285	2019	deg C	8	10.3	5.67	15.43
	2002 - 2018	deg C	142	10.9	1.23	21.80
DH286	2019	deg C	7	12.5	5.20	25.50
	2002 - 2018	deg C	132	12.2	0.00	25.62
DH287	2019	deg C	6	10.5	6.30	14.23
	2002 - 2018	deg C	134	10.6	1.73	18.60
DH288	2019	deg C	7	11.3	6.10	19.50
	2002 - 2018	deg C	129	11.2	-0.51	25.13
SR019	2019	deg C	4	23.9	20.90	26.20
SR020	2019	deg C	5	23.2	18.80	26.70

Station	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
SW001	2019	deg C	8	11.9	5.87	16.59
	1993 - 2018	deg C	195	12	3.45	27.10
SW002	2019	deg C	6	10.6	8.35	14.13
	1993 - 2018	deg C	194	11.9	5.00	23.00
SW008	2019	deg C	44	13.7	0.80	26.50
	1993 - 2018	deg C	336	13.3	0.00	30.41
SW019	2019	deg C	8	11	6.83	15.99
	1998 - 2018	deg C	174	12	2.00	20.33
SW039	2019	deg C	11	9.76	5.20	18.30
	1998 - 2018	deg C	271	11.3	3.91	28.60
SW051	2019	deg C	46	13	0.50	25.50
	1999 - 2018	deg C	355	13.3	-1.58	29.10
SW053	2019	deg C	34	14.7	0.90	27.60
	1999 - 2018	deg C	267	13	-1.40	28.65
SW055	2019	deg C	7	8.13	4.40	12.80
	2000 - 2018	deg C	164	12.3	1.12	24.17
SW056	2019	deg C	4	6.82	1.80	10.80
	2000 - 2018	deg C	191	12.5	0.98	25.60
SW059	2019	deg C	6	5.34	0.90	10.09
	2000 - 2018	deg C	189	11.2	0.94	22.95
SW151	2019	deg C	3	12.6	11.73	13.60

Water Temperature - In Situ

Not Classified Sites

No Applicable Standards Available

Site	Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
GW058	2019	deg C	4	10.8	10.60	11.30
	1950 - 2018	deg C	426	10.5	6.00	14.00
GW059	2019	deg C	4	11	10.60	11.30
	1991 - 2018	deg C	209	10.9	7.10	15.55
GW074	2019	deg C	5	11.2	9.50	14.50
	1993 - 2018	deg C	187	13	6.20	289.00
GW109	2019	deg C	5	13.1	10.90	14.30
	1991 - 2018	deg C	189	12.1	8.80	17.20
GW115	2019	deg C	4	11.2	10.80	11.90
	1992 - 2018	deg C	275	12.1	7.19	358.00
GW143	2019	deg C	5	10.6	8.90	12.70
	1993 - 2018	deg C	184	10.9	5.08	18.40
GW145	2019	deg C	6	10.1	9.80	10.75
	1994 - 2018	deg C	327	10.5	6.79	127.25
GW146	2019	deg C	5	10.7	10.50	11.00
	1994 - 2018	deg C	233	12.1	5.25	354.00
GW189	2019	deg C	7	12.1	9.80	14.40
	2004 - 2018	deg C	118	15.4	7.19	486.00
GW409	2019	deg C	4	10.5	10.40	10.60
	2007 - 2018	deg C	99	10.3	7.30	11.60
GW417	2019	deg C	4	10.4	9.80	11.05
	2010 - 2018	deg C	45	10.2	8.80	12.40
GW418	2019	deg C	4	10.4	9.80	10.90
	2007 - 2018	deg C	81	10.1	7.66	10.90
GW421	2019	deg C	5	10.7	10.40	11.30
	2006 - 2018	deg C	108	10.3	8.70	11.50
SW132	2019	deg C	6	6.05	3.21	8.15
	2018 - 2018	deg C	5	7.67	3.85	12.01

SW133

Reporting Period:	Units:	Total Obs:	Mean:	Minimum:	Maximum:
2019	deg C	6	6.09	3.32	8.22
2018 - 2018	deg C	6	7.59	3.83	12.22

Appendix B Index. *List of Non-Bacterial Secondary Parameters*

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Zinc

Appendix B. *Non-Bacterial Secondary Parameter Summary Statistics*

Alkalinity

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	54.3	22.30	132.30
2000 - 2018	mg/l	11	243	118	4.00	590.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	31	82.2	32.00	150.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	31.3	17.00	43.00
2000 - 2018	mg/l	5	66	96.6	16.30	120.00

Ammonia

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	0.106	0.01	0.52
1998 - 2018	mg/l	11	302	0.256	0.01	5.50

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	0.407	0.00	10.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	0.0325	0.01	0.04
1999 - 2018	mg/l	5	68	0.122	0.00	1.70

Arsenic

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1999 - 2018	mg/l	2	7	0.00284	0.00	0.01

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	7	0.000914	0.00	0.00
1999 - 2018	mg/l	2	54	0.0148	0.00	0.40

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 2012	mg/l	3	5	0.00758	0.00	0.01

Biochemical Oxygen Demand

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	1.58	0.90	3.00
1998 - 2018	mg/l	11	243	3.6	0.80	40.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	1.86	1.00	5.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	4	4.7	0.90	16.00
1999 - 2018	mg/l	5	68	1.85	0.78	6.10

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2018 - 2018	mg/l	1	11	1.34	1.10	1.60

Calcium

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	2	7.78	7.75	7.80
1971 - 1992	mg/l	7	13	29.1	6.00	36.00

Chemical Oxygen Demand

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	82.9	19.00	470.00
2010 - 2018	mg/l	5	81	123	7.00	3825.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2010 - 2014	mg/l	1	13	125	34.00	240.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	922	452.00	1318.00
2010 - 2018	mg/l	1	30	356	42.00	1788.00

Chloride - Lab

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	24	76	28.1	8.80	116.00
1992 - 2018	mg/l	25	532	29.9	5.00	130.00

Chlorophyll a

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ug/l	3	6	2.58	0.80	6.40
2002 - 2018	ug/l	10	165	21	0.00	617.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2003 - 2014	ug/l	1	25	1.64	0.00	7.70

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ug/l	1	3	2.97	1.20	6.10
2002 - 2018	ug/l	5	53	3.13	0.00	23.00

Chromium

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	5	0.0058	0.00	0.01
1998 - 2018	mg/l	2	55	0.0133	0.00	0.16

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2002 - 2002	mg/l	1	3	0.00693	0.00	0.02

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1994	mg/l	2	2	0.0045	0.00	0.00

Copper

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	5	0.0068	0.00	0.02
1999 - 2018	mg/l	2	49	0.00738	0.00	0.09

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	7	0.0245	0.01	0.04
1999 - 2018	mg/l	2	55	0.0252	0.00	0.26

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1994	mg/l	2	2	0.083	0.07	0.10

Diesel Range Plus

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	5	0.09	0.09	0.09
2001 - 2018	mg/l	2	49	0.141	0.04	0.66

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	0.09	0.09	0.09
2000 - 2018	mg/l	1	46	0.136	0.04	0.62

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2017 - 2018	mg/l	1	22	0.154	0.10	0.18

Hardness

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	5	65.2	51.50	78.30
2007 - 2018	mg/l	2	33	61.8	10.00	110.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	6	5300	4110.00	5692.70
2007 - 2018	mg/l	1	35	5130	3577.90	6408.60

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1971 - 1994	mg/l	11	28	123	47.00	184.00

Iron

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	35.4	0.28	272.70
2002 - 2018	mg/l	11	170	3.44	0.16	110.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2003 - 2014	mg/l	1	25	0.469	0.01	1.70

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	0.13	0.05	0.21
1999 - 2018	mg/l	6	55	0.412	0.01	2.70

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1971 - 1994	mg/l	11	30	0.134	0.00	1.08

Lead

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	5	0.000968	0.00	0.00
1998 - 2018	mg/l	2	56	0.00133	0.00	0.02

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1994	mg/l	2	2	0.0055	0.00	0.01

Lube Oil Range Hydrocarbons

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	5	0.09	0.09	0.09
2001 - 2018	mg/l	2	36	0.2	0.09	0.80

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	0.09	0.09	0.09
2000 - 2018	mg/l	1	42	0.243	0.09	0.86

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2017 - 2018	mg/l	1	22	0.466	0.45	0.50

Mercury

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2017 - 2018	mg/l	2	5	0.0001	0.00	0.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	7	0.000229	0.00	0.00
2000 - 2018	mg/l	1	48	0.000754	0.00	0.02

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1994	mg/l	2	2	0.00215	0.00	0.00

Nitrate + Nitrite - N

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	15	0.154	0.02	0.39
1998 - 2018	mg/l	10	88	0.26	0.01	0.95

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2003 - 2014	mg/l	1	16	0.366	0.01	1.20

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	0.195	0.12	0.33
1999 - 2018	mg/l	4	37	0.371	0.01	2.50

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	39	0.146	0.09	0.66
1971 - 2018	mg/l	11	53	4.55	0.00	210.00

Nitrate-N

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	0.156	0.01	0.39
1998 - 2018	mg/l	11	262	0.517	0.01	15.80

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2011	mg/l	1	15	0.415	0.01	3.31

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2018	mg/l	3	34	0.229	0.01	1.50

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2008 - 2008	mg/l	1	1	0.04	0.04	0.04

Nitrite-N

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	0.0132	0.01	0.02
1998 - 2018	mg/l	5	107	0.0776	0.01	1.50

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2010 - 2011	mg/l	1	3	0.0567	0.04	0.09

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2002 - 2018	mg/l	1	10	0.0479	0.01	0.16

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2008 - 2008	mg/l	1	1	0.04	0.04	0.04

Orthophosphate

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	0.065	0.02	0.14
1998 - 2018	mg/l	10	218	0.232	0.01	5.80

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	31	0.0592	0.01	0.12

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	0.055	0.03	0.07
2000 - 2018	mg/l	5	64	0.0699	0.01	0.43

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1971 - 1973	mg/l	3	4	0.145	0.04	0.24

Pheophytin

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ug/l	3	6	2.58	0.09	7.10
2010 - 2018	ug/l	5	83	4.67	0.20	72.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2010 - 2014	ug/l	1	13	3.21	0.20	15.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ug/l	1	3	0.767	0.20	1.50
2010 - 2018	ug/l	1	30	2.39	0.20	14.00

Potassium

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	2	0.442	0.39	0.50
1971 - 1992	mg/l	5	7	4.23	3.00	7.80

Salinity

Freshwater - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ppt	7	21	6.79	0.05	20.29
1997 - 2018	ppt	9	1082	3.96	0.00	30.17

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ppt	20	231	2.69	0.03	31.58
1993 - 2018	ppt	17	3572	14.2	0.00	26400.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ppt	13	218	21.6	1.00	31.00
1989 - 2018	ppt	13	3389	18.9	0.00	32.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ppt	26	283	23.3	0.34	32.00
1989 - 2018	ppt	23	4901	24	0.00	42.06

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ppt	15	85	0.165	0.04	0.27
2004 - 2018	ppt	19	1134	0.208	0.00	14.00

Secchi Depth

Freshwater - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1998 - 2005	cm	9	69	9.23	0.08	106.68

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1998 - 2005	cm	13	64	38.9	0.38	184.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	cm	13	75	165	50.00	360.00
1998 - 2018	cm	13	612	141	0.58	500.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	cm	14	82	176	45.00	300.00
1998 - 2018	cm	20	1230	183	1.37	1000.00

Specific Conductivity - Field

Freshwater - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	uS/cm	7	21	11200	97.00	32442.00
1998 - 2018	uS/cm	9	993	6520	0.71	92400.00

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	uS/cm	20	227	3960	65.00	48375.00
1998 - 2018	uS/cm	17	3073	4540	2.00	96800.00
2001 - 2001	mg/l	17	1	156	156.00	156.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	uS/cm	13	127	36100	2660.00	45283.00
1998 - 2018	uS/cm	13	1123	33800	15.25	46400.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	uS/cm	26	273	36300	714.90	47838.00
1998 - 2018	uS/cm	23	3482	36000	3.79	51501.00

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	uS/cm	15	85	341	95.70	553.00
1994 - 2018	uS/cm	20	2482	374	3.92	4886.00

Tin

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1999 - 2018	mg/l	2	7	0.118	0.00	0.40

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	6	0.00229	0.00	0.00
1999 - 2018	mg/l	2	54	0.147	0.00	1.24

Total Kjeldahl Nitrogen

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	0.535	0.10	1.28
1998 - 2018	mg/l	10	225	1.27	0.00	8.50

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	0.244	0.00	2.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	0.28	0.10	0.41
1999 - 2018	mg/l	5	68	0.278	0.00	1.90

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2008 - 2008	mg/l	1	1	0.09	0.09	0.09

Total Organic Carbon

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	6.11	0.43	17.30
1998 - 2018	mg/l	11	253	15.3	0.04	68.20

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	5.18	0.64	99.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	1.08	0.98	1.24
1999 - 2018	mg/l	5	67	4.65	0.40	99.00

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	1	3.02	3.02	3.02
2018 - 2018	mg/l	1	3	4.12	3.71	4.85

Total Phosphorus

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	0.104	0.02	0.26
1998 - 2018	mg/l	11	304	0.407	0.01	13.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	31	0.184	0.04	1.90

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	0.0485	0.04	0.05
1999 - 2018	mg/l	5	68	0.144	0.02	0.70

Total Suspended Solids

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	15	58.1	8.00	258.00
1998 - 2018	mg/l	11	249	27.5	1.00	820.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	8.81	3.20	23.00

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	14.8	13.00	16.00
1999 - 2018	mg/l	5	68	11.2	1.60	81.00

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	37	48.4	1.00	211.00
2017 - 2018	mg/l	1	31	145	3.20	974.00

Total Volatile Suspended Solids

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	3	8	4	3.00	6.00
1998 - 2018	mg/l	10	222	6.86	0.03	50.00

Marine - Class A (Excellent)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2000 - 2014	mg/l	1	32	1.89	0.90	3.80

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	1	4	7.25	6.00	9.00
1999 - 2018	mg/l	5	68	55.2	0.90	3520.00

Water Level - Pump On

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	ft	2	18	134	131.18	142.96
1991 - 2012	ft	15	2374	137	6.88	189.00

Zinc

Freshwater - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	5	0.011	0.00	0.02
1999 - 2018	mg/l	2	47	0.0281	0.00	0.09

Marine - Class AA (Extraordinary)

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
2019	mg/l	2	7	0.00451	0.00	0.01
1999 - 2018	mg/l	2	55	0.0477	0.01	0.24

Not Classified

No Applicable Standards

Reporting Period:	Units:	Sites Monitored:	Total Obs:	Mean:	Minimum:	Maximum:
1991 - 1991	mg/l	1	1	0.008	0.01	0.01

Appendix C Index. *List of Bacterial Parameters with Applicable Single-Parameter Standards*

Appendix C. *Bacterial Parameter Summary Statistics and Single-Parameter Standards Compliance*

Coliform

Freshwater - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW118	7	2419.60		2105.00		2676.30		7.00	

Coliform

Not Classified Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW076	30	2419.60		531.80		4792.20		30.00	

E. coli

Freshwater - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW037	2	10.00		13.30		267.10		30.00	
SW035	2	60.00		19.30		367.60		30.00	
SW033	1	220.00		16.70		136.90		30.00	
SW031	3	33.00		12.70		68.00		30.00	
SW028	4	33.00		11.70		108.20		30.00	
SW027	4	46.00		32.10		675.10		30.00	
SW026	4	46.00		12.40		120.00		30.00	

E. coli

Freshwater - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW118	65	579.40		40.50		246.50		30.00	
SW075	10	70.00		19.30		103.40		25.00	
SW072	1	32.00		24.40		226.10		30.00	
SW058	2	330.00		16.10		230.00		30.00	
SW029	5	46.00		26.60		156.90		30.00	
SW017	2	5.00		14.00		130.30		30.00	
SW016	3	464.00		26.40		244.10		30.00	
SW015	4	42.00		35.80		186.60		30.00	
SW014	9	41.00		27.80		159.70		30.00	
SW013	7	655.00		54.80		444.60		30.00	
SW012	6	330.00		38.30		148.30		30.00	
SW011	7	119.00		46.60		301.30		30.00	
SW010	4	228.00		36.00		321.40		30.00	
SW009	1	58.00		80.30		705.00		30.00	
SW007	9	69.00		19.20		89.30		30.00	
SW004	1	66.00		81.90		309.10		12.00	
SW003	20	220.00		16.60		84.40		30.00	
SR023	1	255.00		255.00		-999.00		1.00	
SR022	3	360.00		227.90		424.10		3.00	
SR021	2	164.00		159.40		167.80		2.00	
SR005	15	500.00		80.00		387.90		16.00	

E. coli

Marine - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW023	6	23.00		2.50		11.50		30.00	
SW006	6	19.00		2.90		16.20		30.00	
DH050	7	55.00		7.00		59.70		12.00	

E. coli

Marine - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW151	2	1700.00		218.20		8969.50		2.00	
SW059	5	28.00		25.80		118.00		30.00	
SW056	3	106.00		27.60		178.80		30.00	
SW055	4	28.00		8.80		72.00		30.00	
SW053	28	110.00		10.80		53.20		30.00	
SW051	34	33.00		4.40		19.20		30.00	
SW039	7	1300.00		12.30		109.40		30.00	
SW019	6	4.00		2.30		8.20		30.00	
SW008	27	900.00		34.20		329.50		30.00	
SW002	6	2.00		1.10		1.60		30.00	
SW001	6	9.00		3.10		16.20		30.00	
SR020	2	800.00		361.10		1524.00		2.00	
SR019	2	1000.00		346.40		2360.50		2.00	

E. coli

Not Classified Sites

Sites:	New Obs:	Maximum Value: Observed	Maximum Value: Standard	Geometric Mean: Final	Geometric Mean: Standard	Geometric Percentile: Final	Geometric Percentile: Standard	Geometric Obs Used: Used	Geometric Obs Used: Required
SW133	6	20.00		6.80		29.20		12.00	
SW132	6	35.00		7.90		32.80		11.00	
SW076	42	1553.10		33.40		197.10		30.00	

Enterococcus

Freshwater - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW037	2	86.00	61	73.00	33	1067.20	N/A	30.00	30.00
SW035	2	209.00	61	29.00	33	267.50	N/A	30.00	30.00
SW033	1	74.00	61	18.10	33	67.40	N/A	30.00	30.00
SW031	3	146.00	61	12.30	33	41.80	N/A	30.00	30.00
SW028	4	336.00	61	23.90	33	172.80	N/A	30.00	30.00
SW027	4	209.00	61	50.60	33	770.80	N/A	30.00	30.00
SW026	4	1046.00	61	43.90	33	350.90	N/A	30.00	30.00

Enterococcus

Freshwater - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW118	58	404.00	61	47.20	33	248.40	N/A	30.00	30.00
SW075	10	546.00	61	28.10	33	216.50	N/A	25.00	30.00
SW072	1	52.00	61	29.70	33	189.90	N/A	30.00	30.00
SW058	2	906.00	61	62.50	33	480.50	N/A	30.00	30.00
SW029	5	31.00	61	29.20	33	167.00	N/A	30.00	30.00
SW017	2	9.00	61	35.70	33	271.10	N/A	30.00	30.00
SW016	3	794.00	61	34.80	33	320.40	N/A	30.00	30.00
SW015	4	146.00	61	27.10	33	184.50	N/A	30.00	30.00
SW014	9	959.00	61	23.70	33	137.50	N/A	30.00	30.00
SW013	7	473.00	61	66.90	33	634.00	N/A	30.00	30.00
SW012	6	884.00	61	34.10	33	223.80	N/A	30.00	30.00
SW011	7	960.00	61	52.00	33	420.70	N/A	30.00	30.00
SW010	4	52.00	61	34.50	33	262.50	N/A	30.00	30.00
SW009	1	63.00	61	105.00	33	1070.10	N/A	30.00	30.00
SW007	9	309.00	61	22.00	33	116.20	N/A	30.00	30.00
SW004	1	199.00	61	94.10	33	252.10	N/A	10.00	30.00
SW003	20	355.00	61	25.50	33	101.70	N/A	30.00	30.00
SR023	1	95.00	61	95.00	33	-999.00	N/A	1.00	30.00
SR022	3	336.00	61	136.60	33	547.10	N/A	3.00	30.00
SR021	2	331.00	61	237.90	33	432.50	N/A	2.00	30.00
SR005	15	960.00	61	90.20	33	906.40	N/A	16.00	30.00

Enterococcus

Marine - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW023	6	131.00	104	11.80	35	32.00	N/A	30.00	30.00
SW006	6	213.00	104	11.70	35	27.20	N/A	30.00	30.00
DH050	7	218.00	104	26.60	35	148.50	N/A	12.00	30.00

Enterococcus

Marine - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW151	2	197.00	104	42.10	35	687.80	N/A	2.00	30.00
SW059	5	120.00	104	20.70	35	111.90	N/A	30.00	30.00
SW056	3	144.00	104	21.10	35	72.10	N/A	30.00	30.00
SW055	4	31.00	104	10.40	35	16.20	N/A	30.00	30.00
SW053	28	158.00	104	20.30	35	78.10	N/A	30.00	30.00
SW051	34	158.00	104	12.60	35	30.40	N/A	30.00	30.00
SW039	7	243.00	104	41.90	35	259.20	N/A	30.00	30.00
SW019	6	20.00	104	9.90	35	13.40	N/A	30.00	30.00
SW008	27	384.00	104	55.30	35	256.50	N/A	30.00	30.00
SW002	6	9.00	104	8.70	35	16.20	N/A	30.00	30.00
SW001	6	86.00	104	14.10	35	39.10	N/A	30.00	30.00
SR020	2	594.00	104	77.10	35	3107.10	N/A	2.00	30.00
SR019	2	95.00	104	84.40	35	104.50	N/A	2.00	30.00

Enterococcus

Not Classified Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW133	6	52.00		14.00		39.50		12.00	
SW132	6	63.00		12.00		51.20		11.00	

Fecal Coliform

Freshwater - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW037	2	15.00	N/A	18.40	100	416.00	200	30.00	30.00
SW035	2	96.00	N/A	21.90	100	423.80	200	30.00	30.00
SW033	1	350.00	N/A	18.60	100	160.90	200	30.00	30.00
SW031	3	52.00	N/A	13.30	100	75.60	200	30.00	30.00
SW028	4	41.00	N/A	16.70	100	161.60	200	30.00	30.00
SW027	4	50.00	N/A	42.20	100	1065.70	200	30.00	30.00
SW026	4	104.00	N/A	15.50	100	196.30	200	30.00	30.00

Fecal Coliform

Freshwater - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW118	67	2419.60	N/A	57.40	50	305.60	100	30.00	30.00
SW075	10	210.00	N/A	39.80	50	228.60	100	25.00	30.00
SW072	1	78.00	N/A	26.00	50	250.10	100	30.00	30.00
SW058	2	420.00	N/A	27.10	50	321.00	100	30.00	30.00
SW029	5	76.00	N/A	37.00	50	232.40	100	30.00	30.00
SW017	2	14.00	N/A	15.60	50	130.50	100	30.00	30.00
SW016	3	882.00	N/A	42.10	50	419.40	100	30.00	30.00
SW015	4	88.00	N/A	46.90	50	230.80	100	30.00	30.00
SW014	9	122.00	N/A	38.40	50	252.50	100	30.00	30.00
SW013	9	746.00	N/A	82.30	50	367.70	100	30.00	30.00
SW012	9	700.00	N/A	69.80	50	682.00	100	30.00	30.00
SW011	10	282.00	N/A	38.90	50	215.00	100	30.00	30.00
SW010	6	530.00	N/A	22.30	50	158.30	100	30.00	30.00
SW009	3	135.00	N/A	67.00	50	584.40	100	30.00	30.00
SW007	9	87.00	N/A	29.50	50	130.90	100	30.00	30.00
SW004	1	112.00	N/A	109.80	50	415.80	100	12.00	30.00
SW003	21	290.00	N/A	22.70	50	120.70	100	30.00	30.00
SR023	1	320.00	N/A	320.00	50	-999.00	100	1.00	30.00
SR022	3	470.00	N/A	425.60	50	475.60	100	3.00	30.00
SR021	2	460.00	N/A	365.30	50	554.60	100	2.00	30.00
SR005	15	1400.00	N/A	130.40	50	792.00	100	16.00	30.00

Fecal Coliform

Marine - Class A (Excellent) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW023	6	62.00	N/A	3.40	14	20.10	43	30.00	30.00
SW006	6	40.00	N/A	3.70	14	24.60	43	30.00	30.00
DH272	12	49.00	N/A	6.80	14	46.30	43	30.00	30.00
DH271	12	130.00	N/A	5.50	14	33.20	43	30.00	30.00
DH058	12	110.00	N/A	4.60	14	33.20	43	30.00	30.00
DH057	12	79.00	N/A	4.70	14	28.60	43	30.00	30.00
DH055	12	79.00	N/A	4.60	14	24.10	43	30.00	30.00
DH054	12	79.00	N/A	4.00	14	20.60	43	30.00	30.00
DH053	12	33.00	N/A	3.50	14	16.80	43	30.00	30.00
DH052	12	130.00	N/A	7.00	14	38.10	43	30.00	30.00
DH051	12	170.00	N/A	6.00	14	31.90	43	30.00	30.00
DH050	19	110.00	N/A	9.90	14	77.70	43	30.00	30.00
DH049	12	110.00	N/A	7.10	14	49.00	43	30.00	30.00

Fecal Coliform

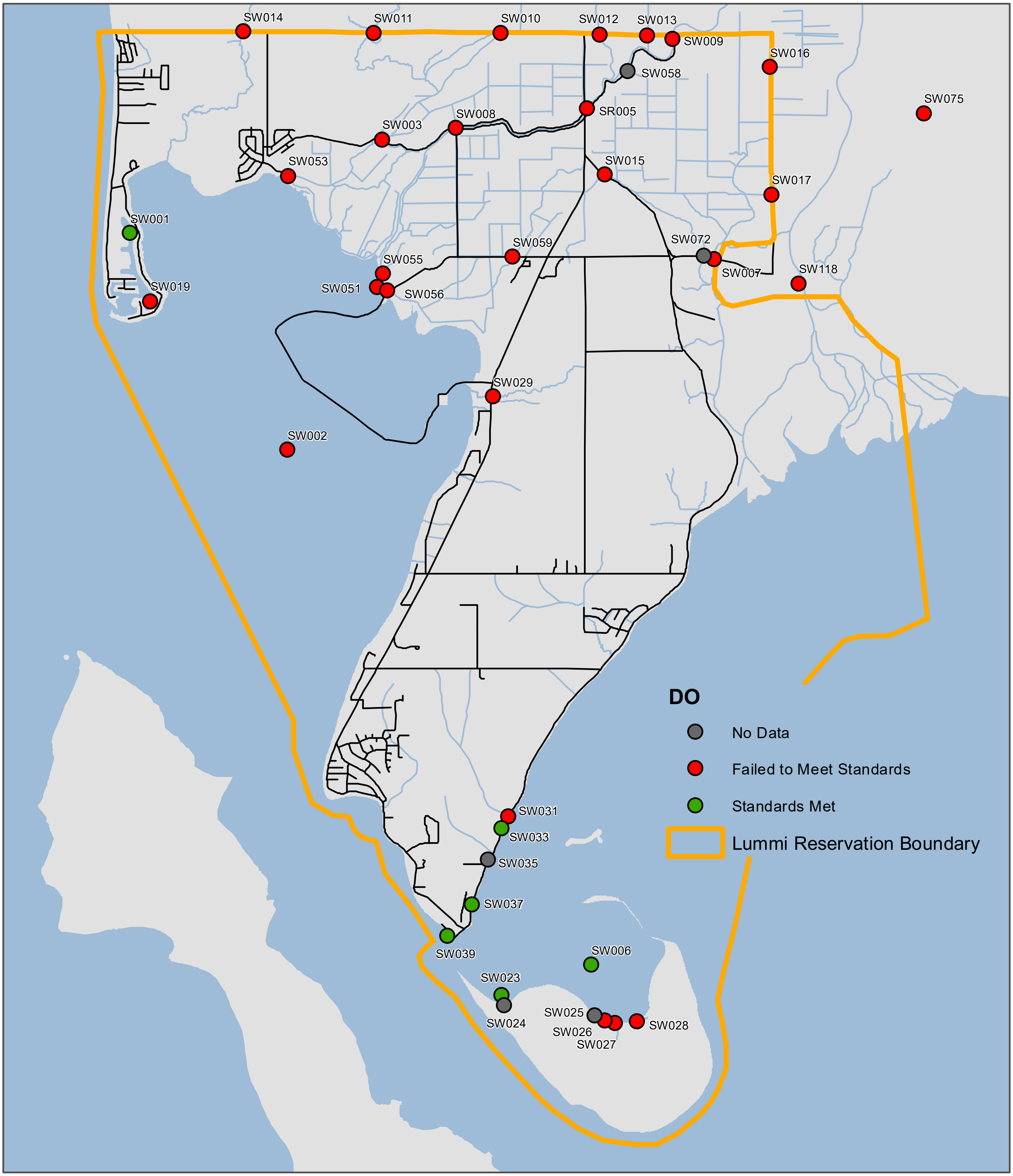
Marine - Class AA (Extraordinary) Sites

Sites:	New Obs:	Maximum Value: Observed	Standard	Geometric Mean: Final	Standard	Geometric Percentile: Final	Standard	Geometric Obs Used: Used	Required
SW151	2	2600.00	N/A	279.30	14	15850.30	43	2.00	30.00
SW059	5	62.00	N/A	47.00	14	217.00	43	30.00	30.00
SW056	3	310.00	N/A	36.60	14	262.50	43	30.00	30.00
SW055	4	33.00	N/A	12.60	14	113.10	43	30.00	30.00
SW053	29	250.00	N/A	17.00	14	101.20	43	30.00	30.00
SW051	35	114.00	N/A	6.70	14	37.20	43	30.00	30.00
SW039	7	1800.00	N/A	18.50	14	199.50	43	30.00	30.00
SW019	6	4.00	N/A	2.60	14	10.30	43	30.00	30.00
SW008	28	1600.00	N/A	55.90	14	700.20	43	30.00	30.00
SW002	6	2.00	N/A	1.30	14	2.00	43	30.00	30.00
SW001	6	14.00	N/A	4.10	14	29.50	43	30.00	30.00
SR020	2	1200.00	N/A	619.70	14	2050.10	43	2.00	30.00
SR019	2	2100.00	N/A	566.80	14	6067.30	43	2.00	30.00
DH288	6	6.80	N/A	2.20	14	4.20	43	30.00	30.00
DH287	6	4.50	N/A	1.90	14	2.70	43	30.00	30.00
DH286	6	49.00	N/A	3.40	14	19.00	43	30.00	30.00
DH285	6	7.80	N/A	3.00	14	9.30	43	30.00	30.00
DH048	12	33.00	N/A	3.00	14	11.90	43	30.00	30.00
DH045	6	4.50	N/A	2.40	14	5.90	43	30.00	30.00
DH044	6	6.80	N/A	2.10	14	4.00	43	30.00	30.00
DH043	6	2.00	N/A	1.90	14	2.80	43	30.00	30.00
DH042	6	2.00	N/A	2.10	14	4.90	43	30.00	30.00
DH041	6	2.00	N/A	1.90	14	2.70	43	30.00	30.00
DH040	6	1.70	N/A	1.80	14	2.20	43	30.00	30.00
DH039	6	1.70	N/A	1.80	14	2.00	43	30.00	30.00
DH038	6	1.80	N/A	1.90	14	2.80	43	30.00	30.00

Fecal Coliform

Not Classified Sites

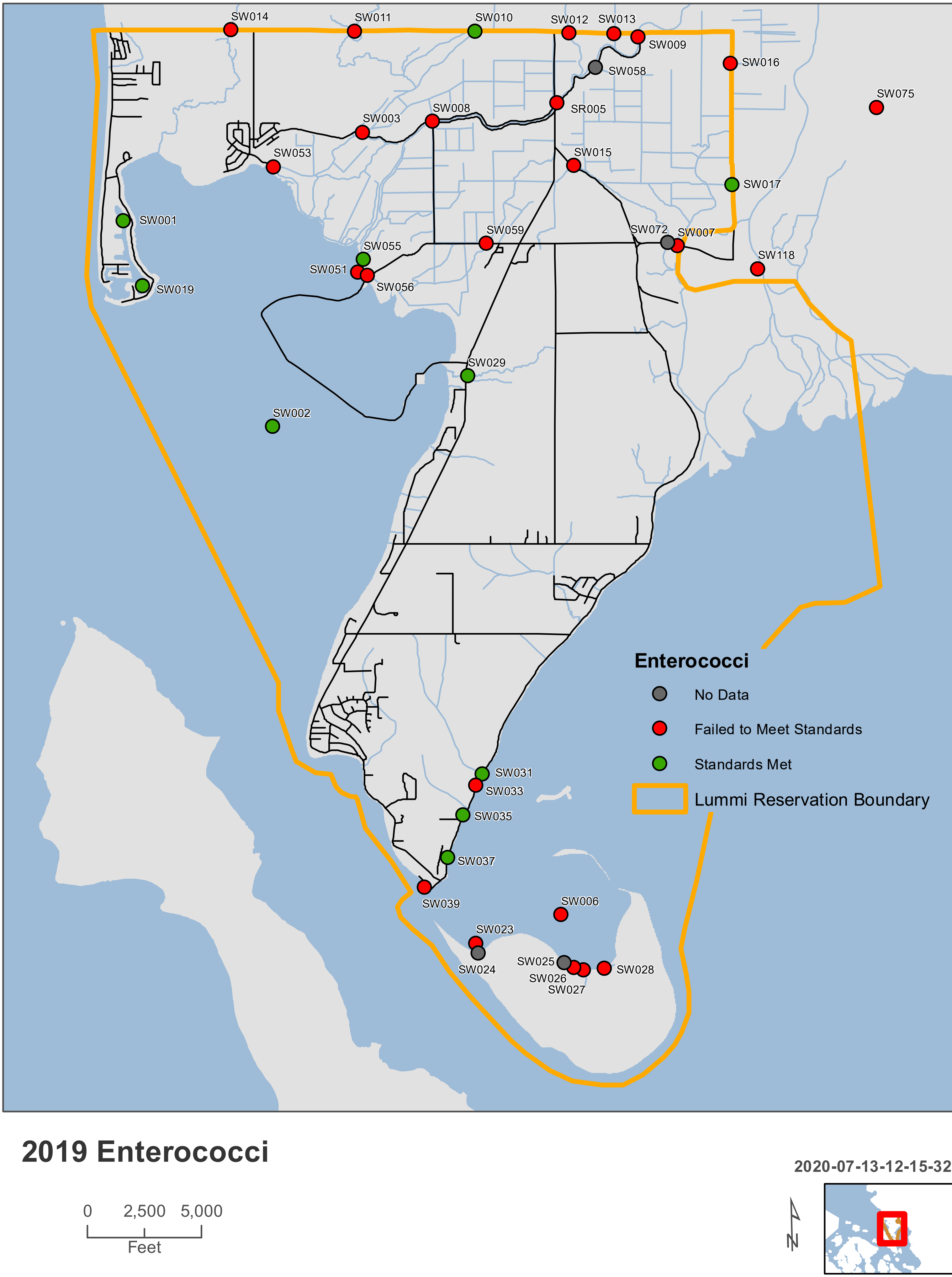
Sites:	New Obs:	Maximum Value:		Geometric Mean:		Geometric Percentile:		Geometric Obs Used:	
		Observed	Standard	Final	Standard	Final	Standard	Used	Required
SW133	6	42.00		10.60		55.70		12.00	
SW132	6	40.00		14.40		51.40		11.00	
SW076	9	2419.60		79.70		318.70		30.00	



2019 Dissolved Oxygen

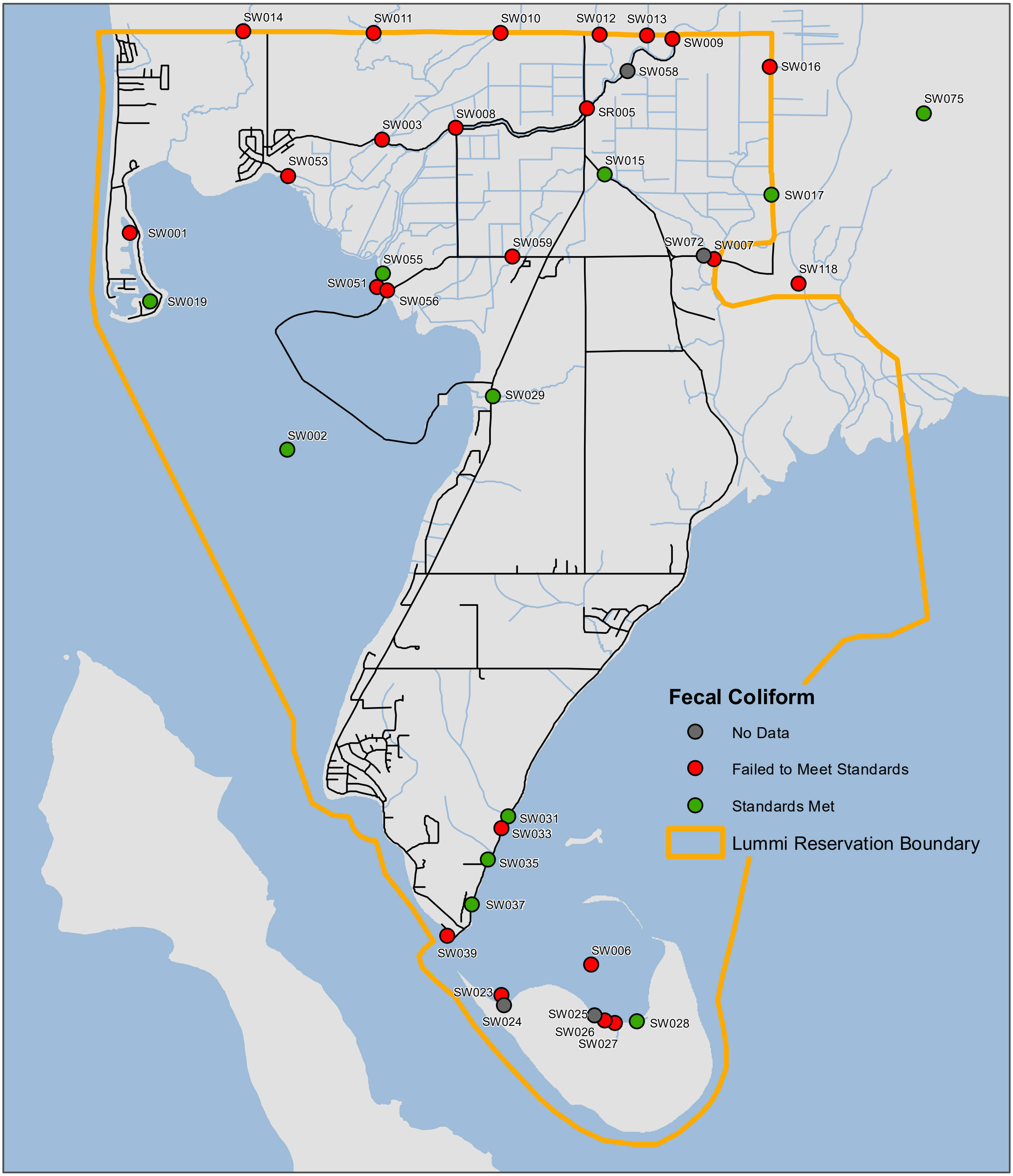
2020-07-13-12-04-57

0 2,500 5,000
Feet



2019 Enterococci

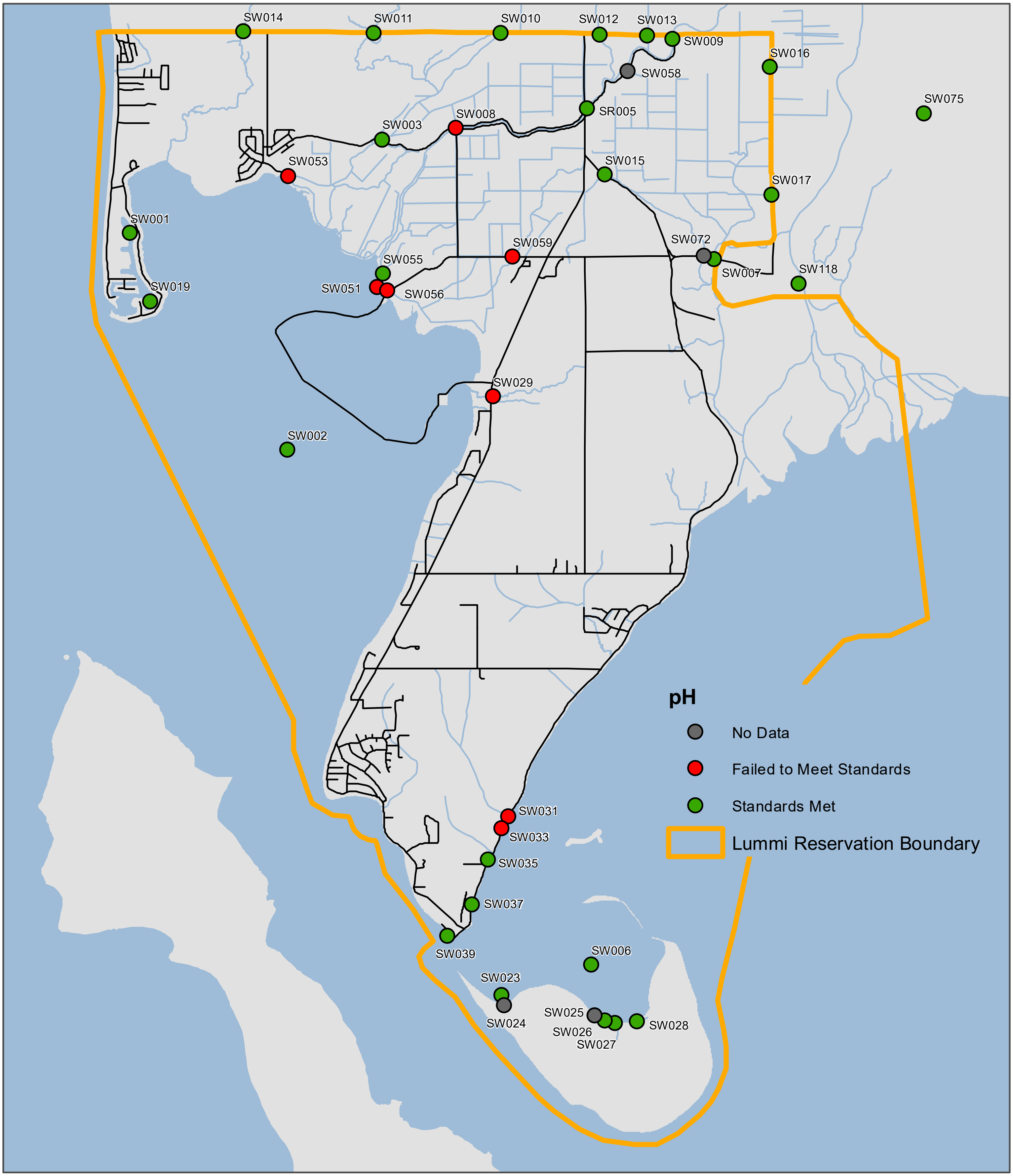
2020-07-13-12-15-32



2019 Fecal Coliform

2020-07-13-12-20-34

0 2,500 5,000
Feet

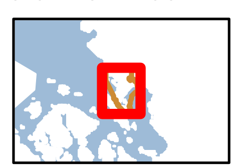


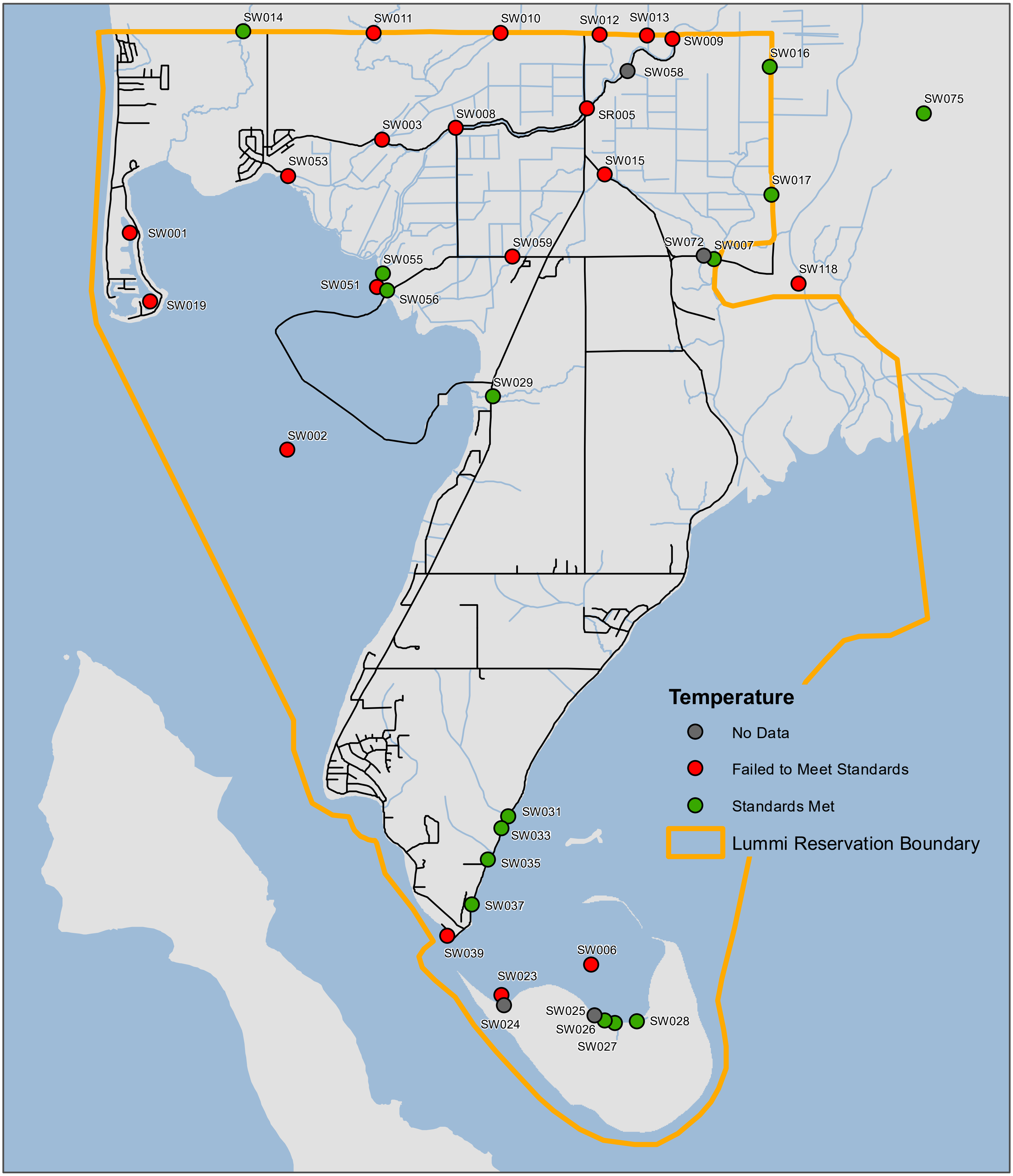
2019 pH

2020-07-13-12-06-24

0 2,500 5,000
Feet

N





2019 Temperature

2020-07-13-12-11-22

0 2,500 5,000
Feet

N

Appendix E. Single-Parameter Water Quality Standards Compliance by Classification and Parameter

Reporting Year: 2019

	Fecal Coliform	Enterococcus	Temperature	Dissolved Oxygen	pH
Class AA Freshwater					
Total Sites Monitored	15	15	15	15	15
# Noncompliant	11	12	9	15	1
# Compliant	4	3	6	0	14
# no data	0	0	0	0	0
% compliance	27%	20%	40%	0%	93%
% noncompliance	73%	80%	60%	100%	7%
Class AA Marine					
Total Sites Monitored	23	11	23	23	23
# Noncompliant	8	6	21	8	9
# Compliant	15	4	2	15	14
# no data	0	1	0	0	0
% compliance	65%	40%	9%	65%	61%
% noncompliance	35%	60%	91%	35%	39%
Class A Freshwater					
Total Sites Monitored	7	7	7	7	7
# Noncompliant	3	4	0	4	2
# Compliant	4	3	7	2	5
# no data	0	0	0	1	0
% compliance	57%	43%	100%	33%	71%
% noncompliance	43%	57%	0%	67%	29%
Class A Marine					
Total Sites Monitored	13	3	13	13	13
# Noncompliant	13	3	13	0	0
# Compliant	0	0	0	13	13
# no data	0	0	0	0	0
% compliance	0%	0%	0%	100%	100%
% noncompliance	100%	100%	100%	0%	0%