Quality Assurance Monitoring Plan

Long-Term Marine Waters Monitoring, Water Column Program, 2020

April 2021

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Publication Information

Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Monitoring Plan (QAMP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. This QAMP was completed and approved in April 2020 but was not posted to the internet until April 2021.

This Quality Assurance Project Plan is available on Ecology's website at https://apps.ecology.wa.gov/publications/SummaryPages/2103108.html

Data for this project will be available on Ecology's Environmental Information Management (EIM) website: www.ecy.wa.gov/eim/index.htm. Search on Study ID: MarineWater-2.

Ecology's Activity Tracker Code for this study is 01-800.

For Water Quality Impairment Studies, insert *Federal Clean Water Act 1996 303(d) Listings Addressed in this Study***.** See Section 3.3.

Contact Information

Mya Keyzers, Julia Bos, Skip Albertson
P.O. Box 47600
Environmental Assessment Program
Washington State Department of Ecology
Olympia, WA 98504-7710

Communications Consultant: phone 360-407-6764.

Washington State Department of Ecology – www.ecy.wa.gov

- Headquarters, Lacey 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Lacey 360-407-6300
- Central Regional Office, Union Gap 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

Cover photo: R/V Skookum vessel in Elliot Bay with Ecology staff: Mya Keyzers, Holly Young, and Patti Sandvik (photo by Ken Pinnel).

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Approved by:

Signature:	Date:
Mya Keyzers, Author / Marine Waters Field Lead, EAP	
Signature:	Date:
Julia Bos, Author / Oceanographer, EAP	
Signature:	Date:
Skip Albertson, Author / Physical Oceanographer, EAP	
Signature:	Date:
Christopher Krembs, Senior Oceanographer, EAP	
Signature:	Date:
Julianne Ruffner, Acting Marine Monitoring Unit Supervisor, EAP	
Signature:	Date:
Stacy Polkowske, Acting Western Operations Section Manager, EAP	
Signature:	Date:
John Weakland, Acting Interim Director, Manchester Environmental Laboratory	
Signature:	Date:
Arati Kaza, Ecology Quality Assurance Officer	

Signatures are not available on the Internet version.
EAP: Environmental Assessment Program

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2.0 Abstract

The Washington State Department of Ecology (Ecology) conducts several statewide monitoring programs including marine water, marine sediment, and freshwater monitoring. The Marine Waters Monitoring (MWM) program, which encompasses Puget Sound and two coastal estuaries, was initiated in 1967. Since then, long-term monthly water quality data have been collected at over 86 stations. Fundamental to environmental monitoring is a strategic, well-planned, representative approach for Washington's marine waters that allows for better distinction between natural and human influences on marine water quality. This approach is based on high station redundancy, appropriate temporal and spatial resolution, and adequate selection of measured variables. It requires a quantitative understanding of processes acting upon water quality, from human influences to physical, biogeochemical and ecological processes extending to oceanic and climatic boundary conditions.

This plan describes Ecology's MWM program for water column profiling conducted by floatplane and by boat. This sampling program covers U.S. waters of the Salish Sea, including Puget Sound and the Strait of Juan de Fuca, as well as coastal bays of Grays Harbor and Willapa Bay. The Quality Assurance Monitoring Plan includes a full description of the program's goals and objectives, monitoring strategies, field, and laboratory procedures, data management, quality assurance and quality control, and safety guidelines. The other components of Ecology's marine monitoring program, such as ferry-based monitoring are described in separate QAMPs. There is also an original QAPP for ocean acidification sampling that started in fall 2018. At that time the funding was for a short-term project but since then funding has been secured and ocean acidification is now part of the long-term program and captured in this QAMP.

3.0 Background

3.1 Introduction and problem statement

The purpose of the program is to examine marine water quality on a regular, long-term basis with the objectives of determining existing conditions and identifying spatial and temporal trends. As technology and procedures evolve and improve, changes to the program are incorporated in a planned and methodical manner to be able to integrate and incorporate analyses of older data with new results that improve our findings. Elements of the program are described in detail in this plan.

3.2 Study area and surroundings

The Salish Sea extends from the north end of the Strait of Georgia and Desolation Sound to the south end of the Puget Sound and west to the mouth of the Strait of Juan de Fuca, including the inland marine waters of northern Washington, U.S. and southern British Columbia, Canada. These separately named bodies of water form a single estuarine ecosystem. (Figure 1).

The Puget Sound study area is part of the overall ecosystem of the Salish Sea. It is important to study and understand Puget Sound within the context of the larger ecosystem, because regional and local Puget Sound processes are influenced and regulated by large-scale ocean and climate drivers via hydrodynamic connection and exchange between basins of the Salish Sea.

The Salish Sea is connected to the Pacific Ocean primarily through the Strait of Juan de Fuca (with relatively slight tidal influence from the north around Vancouver Island and through Johnstone Strait) and is bounded by Vancouver Island and the Olympic Peninsula. The watershed contains the Gulf and San Juan Islands; it also contains the lower Fraser River Delta and the Puget Lowlands as well as Hood Canal, Tacoma Narrows and Deception Pass (Freelan, 2009).

The geomorphology of the area includes a variety of landforms with interconnected shallow estuaries and bays, deep glacially scoured basins and fjords, broad channels, and river mouths. It is bounded by three major mountain ranges: the Olympics to the west, the mountains of Vancouver Island to the north, and the Cascade Range to the east. There are several major rivers that drain into the Salish Sea; the Fraser, Skagit, Puyallup, Nisqually, and Chehalis are the biggest influencers on our station network. A regional depression extends from British Columbia to Oregon and includes the Puget lowlands between the Olympic and Cascade Mountains. The Puget Sound region of the Salish Sea is the flooded area of these lowlands (Burns, 1985).

The Puget Sound study area defined by the MWM Program encompasses marine basins, channels, and embayments in northwest Washington from the U.S./Canada border to the southern-most inlets near Olympia and Shelton. The study area includes Puget Sound proper, Whidbey Basin, Hood Canal, and portions of Admiralty Inlet, the San Juan Islands, and the eastern portion of the Strait of Juan de Fuca (Figure 2). The study area extends for about 200 km and ranges in width from 10 to 40 km (Kennish, 1998).

Figure 1. Map of U.S. and Canadian waters of the Salish Sea.

Courtesy of Stephen Freelan, Western Washington University, 2009.

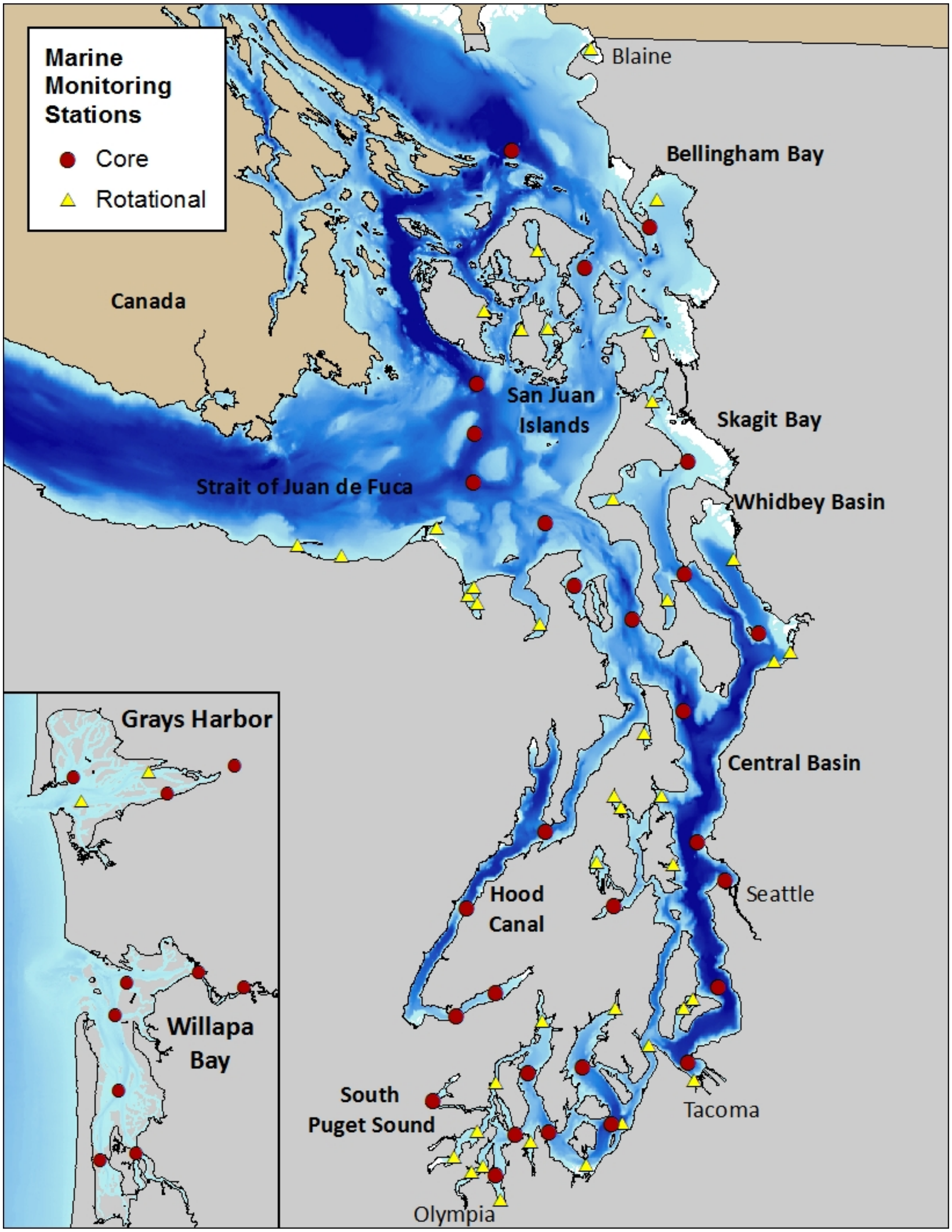

Figure 2. Ecology Marine Waters Monitoring sites in Puget Sound and Coastal Bay study areas.

Core stations are sampled every year. Rotational stations are sampled on an as-needed basis.

The study area covered by the coastal portion of the Marine Water Column Monitoring Program includes the two largest estuaries on the outer Washington Coast: Grays Harbor and Willapa Bay (Figure 2). Currently, Ecology's monitoring program does not include nearshore and offshore waters along the Pacific coast due to resource constraints and difficulties encountered in sampling these environments.

3.2.1 History of marine waters research and monitoring in Washington State

For a thorough history of monitoring in the Salish Sea since 1932 please see the original Quality Assurance Monitoring Plan: Long-Term Marine Waters Monitoring, Water Column Program. Publication 15-03-101. (Bos et al., 2015).

3.2.2 Summary of previous studies and existing data

Since 2008, marine water quality monitoring at Ecology has evolved into an integrated, spatially and temporally layered program that communicates water quality information within a broader context of oceanic and climatic influences. This approach requires collaborations and coordination with academic, private and other state entities. The program has expanded from collecting monthly water column samples to also include enroute ferry observations and aerial documentation of surface properties (algae blooms, river plumes, spills, and debris) within the larger Puget Sound region. This information is communicated monthly via "Eyes Over Puget Sound" which receives 25,000 to 120,000 downloads per month on the website Encyclopedia of Puget Sound.

Results of previous studies

Results from the long-term MWM program, various focused studies, and modeling efforts have shown that Puget Sound and Washington's coastal bays are experiencing a decline in water quality conditions; however, climate and ocean forces are dominant drivers of physical conditions in these estuaries (Krembs, 2009).

The current focus of Ecology's MWM program is to understand core drivers of Puget Sound and coastal marine water conditions. For the past two decades, significant information from ocean, climate, and other local monitoring projects has been incorporated into Ecology's interpretation of marine monitoring results. A key emphasis is to differentiate between the dominant core drivers of water quality, which include climate, ocean boundary, residual or lingering effects, estuarine circulation (freshwater influence) and regional human influences. An index based on long-term marine water column monitoring results (see Audits and Reports section) was developed to report site-specific status and trends in water quality conditions. This index, the Marine Waters Condition Index, is a key indicator in the Puget Sound Partnership's dashboard indicators (Krembs, 2012).

From annual reporting collaborations with Puget Sound Ecosystem Monitoring Program (PSEMP) monitoring partners and results from the Marine Waters Condition Index, the following key findings have emerged (Krembs et al., 2009; Krembs, 2012; PSEMP, 2012-2014, 2016-2019):

- Pacific Ocean waters are the dominant driver of Puget Sound physical conditions, yet the frequency, duration, and extent of ocean water intrusions and accompanying transport processes in Puget Sound are not well understood.

- Dissolved oxygen in upwelled ocean waters entering Puget Sound is naturally low. Coupled with anthropogenic influences, levels become critically low, especially in terminal inlets and basins such as Hood Canal and South Puget Sound waters, under certain climate and ocean conditions.
- Nitrogen and phosphate are seasonally and regionally variable and are influenced by many factors. Ocean is a major contributor of nitrate. Nutrient levels in ocean waters are naturally high entering Puget Sound often confounding, effects of wastewater, storm water run-off, and non-point sources. Changes in the nutrient balance are potentially affecting species composition and material cycling in the marine system.
- Human and natural eutrophication processes can affect areas of Puget Sound and reduced circulation may amplify these effects in terminal inlets.
- Weather and regional climate conditions are core drivers of Puget Sound estuarine circulation. During cold, wet years, less dense waters are coupled with higher oxygen concentrations and higher water clarity. During warm, dry years, denser waters are coupled with lower oxygen and lower water clarity.

Marine monitoring programs are important for providing data to support developing water quality models to assess condition of water bodies and to use for ecosystem assessments. Two studies evaluated the relative contributions to low dissolved oxygen conditions in Puget Sound, using models calibrated to data collected in the long-term monitoring program and focused projects (Ahmed et al., 2014; Roberts et al., 2014).

In addition to concerns about nutrient impacts on Puget Sound's dissolved oxygen levels, ocean acidification effects are of concern and the impacts on Puget Sound conditions are not yet well quantified. Responses of other ecosystem components (food web, particle transport) to physical properties and boundary conditions need to be better resolved in order to understand consequences of climate change (Puget Sound Partnership, 2010).

These results, along with additional reports, presentations, journal articles, and conference proceedings published by the Marine Waters Group are available at Ecology's publications website. CTD data can be retrieved from the Environmental Information Management System (EIM), and laboratory data by request.

Results from earlier studies such as the Collias and Barnes surveys were converted from paper format to digital format by Skip Albertson. These data may be obtained by submitting a request via form at the MWM website. Ecology does not have the ability to validate or verify the authenticity of these results.

3.2.3 Parameters of interest and potential sources

When the Marine Monitoring Program was implemented in 1967, primary contaminants of concern were industrial and municipal discharges of oxygen-consuming wastes. Over time, with better management of industrial and municipal point-source wastes, the monitoring strategy has shifted to quantifying multiple inputs to Washington's marine waters from a variety of sources including the Pacific Ocean, rivers and freshwater inputs, and atmospheric, urban and agricultural inputs. This monitoring strategy shift increases the understanding of impacts to the marine ecosystem as a result of these inputs.

As urbanization and population increases alter landscapes in the Salish Sea basin, primary contaminants of concern are those relating to human activities and landscape change. These include increasing nutrient loads, changes in sedimentation and particle transport, and alteration of biogeochemical processes such as carbon cycling and effects on the marine food web. Because this is an ambient monitoring program, specific pollutants are not targeted; instead, basic water quality properties are monitored for changes indicating impacts from other elements.

3.2.4 Regulatory criteria or standards

The federal Clean Water Act requires every state to have its own water quality standards designed to protect, restore, and preserve water quality. Water quality standards consist of designated uses for protection (such as aquatic life) and criteria, usually numeric, to achieve those uses. The Clean Water Act also requires that every state conduct assessments of surface water quality every two years and submit to EPA two reports: 303(d), a list of impaired water bodies, and 305(b), a report of the results of the entire assessment.

Ecology conducts routine assessments on the condition of surface waters every two years, rotating between marine and fresh water systems. Washington's Water Quality Assessment reports the water quality status for water bodies in the state and identifies waters that do not meet water quality standards. This assessment meets the federal requirements for an integrated report under Sections 303(d) and 305(b) of the Clean Water Act.

All marine waters in Puget Sound and the coastal bays fall under *extraordinary*, *excellent*, or *good* quality designated use categories. The water quality standards associated with the various designated use categories are found in the Washington Administrative Code, WAC 173-201A. These standards include numeric values for temperature, dissolved oxygen, pH, ammonium, and fecal coliform bacteria. Numeric targets vary within marine waters of Washington, as described in WAC 173-201A-210 (Washington State Legislature, WAC 173-201A-210).

Water quality assessment in Washington is guided by Ecology's Water Quality Policy 1-11, which is used to define assessment practices, criteria, and categories for designating attainment or violation of standards, data submission, and the credible data policy for data used in the assessment.

Marine water column variables used for EPA's water quality assessment include temperature, dissolved oxygen, pH, and ammonium (as a toxin). Previously, the marine monitoring program included fecal coliform bacteria, but this was discontinued in 2013 after years of very low or infrequent, non-reproducible results. In addition, the MWM program sampling design for bacteria was obsolete and the Department of Health (shellfish) and BEACH (human health effects) monitoring programs conduct bacteria monitoring using better-quality, targeted protocols.

Data collected at all core and rotational stations sampled in the MWM long-term program are submitted for every two-year assessment cycle.

4.0 Project Description

Ecology's MWM Program uses a multi-pronged monitoring strategy. The program relies on a variety of physical, chemical, and biological variables. It describes long-term patterns and trends related to estuarine physical processes and marine eutrophication.

The MWM program conducts monthly sampling of the water column at core stations. The program uses consistent techniques to determine long-term trends in water quality. Station redundancy in each basin allows for a better statistical representativeness of monthly conditions. A monthly resolution allows for a representative description of the seasonality of the system. While sensors collect data throughout the entire water column, discrete samples are collected to assess nutrient loading.

Data from monthly water column monitoring provides the temporal backbone of Ecology's MWM program. These data are part of a spatially-nested approach in collaboration with other monitoring programs using different sensor platforms to address the range of scales required to address marine water quality. The water column program is supplemented by information from enroute ferry transects and aerial photography collected on different time scales.

4.1 Monitoring goals

The project goals of the MWM program are as follows:

- Effectively measure and provide information about long-term estuarine dynamics, temporal and spatial variations, and trends relative to established baseline conditions that affect marine water quality.
- Assess the interaction of different impacts on estuarine processes and ecosystem functioning that result from the transport of water, solutes, and pollution.
- Assess changes in ambient water quality in the context of local, regional, or larger-scale human, climatic, and oceanographic factors.

4.2 Project objectives

Project objectives for the MWM include:

- Assure high quality sensor measurements and related laboratory analysis of reference samples.
- Report on water quality conditions and regional conditions, including attributes such as:
    - Status of physical conditions such as salinity and temperature.
    - Status of biochemical properties including dissolved oxygen, nutrient concentrations, and nutrient ratios.
    - Status of bio-optical properties such as water clarity and chlorophyll fluorescence as a proxy for biomass.
    - Seasonal variability in water quality conditions such as temperature and dissolved oxygen.
    - Inter-annual variability in water quality conditions, connected to large-scale climate and weather patterns.

- Spatial and temporal trends of marine water conditions in Puget Sound and the coastal bays.
  - New monthly extremes and significantly different conditions.
- Contribute to the understanding of long-term changes of marine water quality in the context of other environmental factors through the following activities:
  - Provide continuous data input for physical and ecological models.
  - Provide monthly observations and inform the public, management, and the Puget Sound Partnership about unexpected current conditions.
  - Provide water quality information and baseline data to other Ecology programs and state agencies, the public, decision makers, and private institutions.
  - Coordinate findings with other PSEMP monitoring components.
  - Provide data to evaluate compliance with state water quality standards under the Clean Water Act [303(d) list and 305(b) report].
  - Identify emerging problems and inform action agendas and regulatory processes.
  - Identify water masses and exchange between Salish Sea basins, and contribute to the overall understanding of the dynamic of natural conditions.

4.3 Information needed and sources

Marine water quality data is analyzed and interpreted in the context of weather and ocean data. The MWM group uses data from other agencies including:

- River flow data from the US Geological Survey and Environment Canada.
- Ocean and climate condition data and indices from NOAA branches including the Upwelling Index, Pacific Decadal Oscillation, NE Pacific sea surface temperature, and the North Pacific Gyre Oscillation Index from Scripps Institution of Oceanography.
- Local weather information is obtained from University of Washington's Atmospheric Sciences Program.

4.4 Tasks required

The MWM program includes specific tasks that achieve the overall monitoring program's strategic goals via two extensive activities: data collection and data assessment.

4.4.1 Data collection

On a year-round, monthly basis, we collect vertical water column profile data on salinity, temperature, dissolved oxygen, turbidity, fluorescence, chlorophyll *a*, pH, dissolved inorganic carbon, total alkalinity, nutrients, total nitrogen, total organic carbon, particulate carbon and particulate nitrogen, at 39 marine water sampling stations, based on directives from the original Puget Sound monitoring plan for the water column.

Sampling is conducted monthly to maintain a long-term record of water column conditions. Year-round sampling is necessary because certain parameters, such as chlorophyll, nutrients, and dissolved oxygen, show their peak values (or highest rates of change) during the summer, while others (fresh water, pathogen indicators) peak during the winter. Sampling is conducted during all 12 months to ensure that all major hydrographic trends are observed and to provide a complete data set for analysis of temporal trends (MMC, 1988).

4.5 Practical constraints

Data collection is not conducted under adverse or unsafe conditions. In addition, data collection may be suspended when access is denied or operations are prohibited by federal agencies such as the U.S. Coast Guard, FAA, or Department of Defense. Data collection may be cancelled or curtailed when budget constraints result in staff reductions or limited availability of resources such as equipment and supplies, laboratory analyses, or calibration and maintenance services.

Data assessment may be limited or not performed when data collection is suspended, equipment fails to generate data that meet quality standards, or when budget constraints result in staff reductions or limitations to resources such as equipment and supplies, analytical laboratory or information management services.

Any circumstance that interferes with data collection and quality will be noted and discussed in reports and data summaries.

4.6 Systematic planning process used

As described in the background section of the original Long-Term Marine Waters Monitoring, Water Column Program QAMP (Bos et al., 2015), the program plan was initially based on agency monitoring needs in the early 1970s and then evolved in 1989 by a regional effort to design a comprehensive ambient monitoring program for Puget Sound.

As new ecological information emerges and different questions about estuarine dynamics arise, the monitoring priorities and strategy may change. Every fall, the Marine Monitoring Unit conducts annual planning. Updates to station locations, monitoring, and data collected are implemented as information priorities evolve and scientific needs change. Any updates to the monitoring plan described in this QAMP will be captured in annual addenda to this QAMP or, if significantly different, will be captured in a new Quality Assurance Monitoring Plan.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1. Roles and responsibilities of staff involved with the Marine Waters Monitoring (MWM) program

All are employees of the Washington State Department of Ecology.

Western Operations Section Staff	Title	Responsibilities
Christopher Krembs Marine Monitoring Unit Phone: (360) 407-6675	Senior Oceanographer	Determines monitoring strategy. Generates index/indicators of water quality conditions. Determines appropriate analysis, review, and interpretative methods for data reduction and reporting. Generates data products. Lead author of publications and presentations. Responsible for performing EOPS aerial surveys.
Skip Albertson Marine Monitoring Unit Phone: (360) 407-6675	Physical Oceanographer	Analyses and reports on climate, weather, and ocean indicators. Generates data products and analytical tools. Conducts QA review of data; analyzes and interprets data. Writes reports and data summaries.
Julia Bos Marine Monitoring Unit Phone: (360) 407-6674	Oceanographer	Manages data workflow, processing, and QA review. Analyzes, and interprets data, and manages data in both the EAPMW and EIM database systems. Generates analytical and QC products and develops tools. Writes reports and data summaries.
Mya Keyzers Marine Monitoring Unit Phone: (360) 407-6395	Marine Waters Field Lead	Coordinates and conducts field sampling, laboratory analysis and instrument maintenance. Records and manages field information. Conducts QA review; analyzes and interprets data. Writes reports and data summaries.
Elisa Rauschl Marine Monitoring Unit Phone: (360) 407-6687	Marine Waters Field Scientist	Conducts field sampling, laboratory analysis, instrument calibrations, and instrument maintenance. Records & manages field information. Conducts QA review, analyzes, audits, and interprets data.
Natural Resource Scientist 2 (NRS2) Phone: (360) 407-6517	Marine Field Scientist	Provides expertise to QA parameters. Assists with field sampling. Conducts QA review, analyzes, audits, and interprets the ocean acidification data.
Washington Management Service (WMS1) Phone: (360) 407-6742	Unit Supervisor	Provides internal review of the QAMP, and QAMP addenda, approves the budget, and approves the final QAMP and QAMP addenda
Alan Rue Manchester Environmental Laboratory Phone: 360-871-8801	Director	Reviews and approves the final QAMP.
Arati Kaza Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews the draft QAMP and approves the final QAMP.

EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAMP: Quality Assurance Monitoring Plan

5.2 Special training and certifications

All personnel who conduct field activities receive training on CTD usage and calibration, sample handling, program QA/QC, and safety. Each staff person is required to be familiar with this QA Monitoring Plan and field procedures described in Standard Operating Procedures (SOPs). New technicians are given demonstrations of field procedures before they perform field activities. Also, they are accompanied by an experienced senior technician on their initial field trips to verify that they understand and follow procedures. Periodic field checks are conducted by senior staff to ensure consistent sampling performance among staff. Results from these checks are discussed with the team and appropriate updates or changes are implemented.

All personnel who conduct laboratory activities should have a college education in introductory level biology and analytical chemistry and some direct experience with sample analysis, sample handling, QA/QC, and chemical safety. Each staff person is required to be familiar with this QA Monitoring Plan and lab procedures described in SOPs.

5.3 Organization chart

Not Applicable - See Table 1.

5.4 Proposed project schedule

A summary of the routine activities conducted during a routine sampling year under the monitoring plan are listed in Table 2.

Table 2. Proposed schedule for completing field and laboratory work, data entry into EIM, and reports.

Sample collection, instrument deployment, and data retrieval from sensors	Due date	Lead staff
Internal laboratory Marine Monitoring Laboratory (MML) and Manchester Environmental Laboratory (MEL) analyses completed	1 month post collection (chlorophyll *a* samples, total organic carbon, total nitrogen, particulate carbon and nitrogen.	Mya Keyzers
External University of Washington (UW) and Pacific Marine Environmental Laboratory (PMEL) laboratory analyses completed	3 months post collection (nutrients, TA/DIC samples)	Mya Keyzers, NRS2
Aerial photos for Eyes Over Puget Sound (EOPS) aerial observation survey completed	Once a month or as needed	Christopher Krembs
Data receipt or processing and upload to database		
Instrument and sensor data	Same month as collection	Julia Bos
Internal laboratory data (MML, MEL)	1 month post analyses	Mya Keyzers, Elisa Rauschl, Sandy Weakland
External laboratory data (UW, PMEL)	3 months post analyses	Mya Keyzers, NRS2
Data Review and QA/QC		
Instrument and sensor data	1 month post collection	S. Albertson, J. Bos, NRS2, M. Keyzers, C. Krembs, E. Rauschl
Internal laboratory data (MML, MEL)	2 months post analyses	M. Keyzers, S. Weakland, E. Rauschl, J. Bos
External laboratory data (UW, PMEL)	4 months post analyses	S. Albertson, J. Bos, NRS2, M. Keyzers, C. Krembs, E. Rauschl
Environmental Information System (EIM) database		
EIM Study ID	MarineWater-2	
EIM data loaded [1]	3 months after sampling year completed	Julia Bos
EIM data entry review [2]	5 months after sampling year completed	Julia Bos
EIM complete [3]	7 months after sampling year completed	Julia Bos
Final report		
Final Performance data quality objectives calculated and submitted to Office of Financial Management	Annually in July	Julia Bos
PSEMP Puget Sound Marine Waters Report	Annually in May	S. Albertson, J. Bos, C. Krembs
EOPS	Monthly or as needed	Christopher Krembs

[1] All data entered into EIM by the lead person for this task.
[2] Data verified to be entered correctly by a different person; any data entry issues identified. Allow one month.
[3] All data entry issues identified in the previous step are fixed (usually by the original entry person); EIM Data Entry Review Form signed off and submitted to Melissa Peterson, activity tracker coordinator (who then enters the "EIM Completed" date into Activity Tracker). Allow one month for this step. Normally the final EIM completion date is no later than the final report publication date.

5.5 Budget and funding

Table 3. 2020 budget (estimate) for contract costs of the long-term marine water column monitoring data collection.

Vendor	Cost
Equipment	$17,000
Kenmore Air Harbor Inc.	$43,840
Ecology’s R/V Skookum	$38,000
Shannon Point Marine Science Center	$44,400
Total	$143,240

Table 4. 2020 budget (estimate that change on a biennium basis) for external laboratory cost only.

This table does not include ocean acidification samples as they are supported by a different funding source. This is not the cost of the whole program, excludes staffing, internal laboratory samples, instrument calibration costs, administrative costs, etc.

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample	Lab Subtotal
Nutrients	1608	118	1726	$17.88	$30,860.88
Particulate Organic Carbon and Nitrogen	432	96	528	$42.50	$22,440.00
Total Organic Carbon	432	96	528	$30.00	$15,840.00
Total Nitrogen	432	96	528	$40.00	$21,120.00
				Lab Grand Total	$90,260.88

6.0 Quality Objectives

6.1 Data quality objectives

High quality data collection and analyses are mandatory for Ecology's MWM Program and ensure that trends accurately reflect true environmental change. We use standardized, widely accepted, oceanographic procedures conducted by trained technicians with education and experience in environmental data collection techniques. We adhere to the most up-to-date quality assurance and quality control protocols accepted and recommended by global oceanographic and marine monitoring communities. We routinely perform data quality assurance (QA) and data quality control (QC) procedures utilizing group data reviews to ensure that our data meet highest quality standards. Data quality codes are applied to the dataset, allowing users to decide the appropriate level of quality for their specific analysis requirements.

The laboratory water sample data quality objectives (DQOs) for this project are to annually collect approximately: 1608 nutrient samples, 1308 chlorophyll samples, 528 particulates samples, and 480 TA/DIC and salinity samples. This is accomplished monthly by following a detailed sample collection plan which is specific for each station. These are ideal totals which change for various sampling constraints (e.g., weather, instrument failures, programing errors). For a detailed list of what sample are collected at each station see appendix A. The main continuous sensor data DQO is to collect approximately 685,000 data points tallied up from sampling all 39 stations each month of the year. The number can vary depending on water depth. These should be representative of Puget Sound and Coast Bays. They will be analyzed using standard methods to obtain data that meet Measurement Quality Objectives that are described below and that are comparable to previous study results.

Table 5. Historical DQOs met by MWM program.

DQO Type	Number of Samples	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Laboratory water samples	**Attempted**	5,718	4,956	6,727	6,579	6,839	6,392	6,215	7,211	7,631	8,449	14,386
Laboratory water samples	**DQO Achieved**	5,718	4,926	6,693	6,539	6,831	6,384	6,206	7,147	7,610	8,437	14,249
% Discrete Meeting DQOs	**%**	**100.0%**	**99.4%**	**99.5%**	**99.4%**	**99.9%**	**99.9%**	**99.9%**	**99.1%**	**99.7%**	**99.9%**	**99.0%**
Continuous sensor data	**Attempted**	224,970	298,172	360,610	325,367	300,588	290,906	361,522	386,602	361,769	686,936	716,356
Continuous sensor data	**DQO Achieved**	224,023	295,311	349,602	323,432	298,264	288,458	350,151	367,250	350,142	643,592	684,201
% Continuous Meeting DQOs	**%**	**99.6%**	**99.0%**	**96.9%**	**99.4%**	**99.2%**	**99.2%**	**96.9%**	**95.0%**	**96.8%**	**93.7%**	**95.5%**
Total number of stations		40	35	41	40	40	39	39	37	39	39	39

Bold: Discrete DQO totals in percentage.

6.2 Measurement quality objectives

Measurement quality objectives (MQOs) for this study are to obtain data of sufficient quality and quantity so that the data can be used to evaluate the stated objectives of the monitoring program. These objectives will be achieved through careful planning, sampling, and adherence to the procedures described in the Quality Assurance Monitoring Plan and all associated addenda.

QC procedures used during field sampling and laboratory analyses provide data for determining the accuracy and precision of the monitoring results. All sensors, laboratory equipment, and instruments are subjected to routine and strict performance tests and undergo recommended maintenance and calibration procedures. Specific activities for testing and ensuring high quality data are performed for different data types include:

- Continuous vertical sensor profiles - Water samples for sensor verification are collected during marine monitoring field events.
- Discrete water samples - Analytical precision and bias are evaluated and controlled by use of laboratory check standards, duplicates, and blanks analyzed along with monitoring samples in the data stream.
- Field observations - Site-specific observations of weather and general conditions are recorded and standardized between technicians by using pre-designated, standardized data types, data units, and lists of pre-defined, descriptive terms.

Tables 5 and 6 show the measurement quality objectives (MQOs) for the methods used for sensor measurements and water sample analysis.

6.2.1 Targets for precision, bias, and sensitivity

Table 6. Measurement quality objectives for laboratory analyses of water samples.

Laboratory	Parameter	Relative Percent Difference (RPD) or Relative Standard Deviation (RSD)	Recovery Limits (%)	Reporting Limit	MDL or Lowest Concentration of Interest
Pacific Marine Environmental Laboratory (PMEL)	Total Alkalinity	<0.5%	<0.25%	NA	±0.1% µmol kg^{-1}
PMEL	Dissolved Inorganic Carbon	<0.5%	<0.25%	NA	±0.1% µmol kg^{-1}
Manchester Environmental Laboratory (MEL)	Particulate Organic Carbon	$\leq$ 20%	80% - 120%	< 1/2	16.5 µg/L
MEL	Particulate Nitrogen	$\leq$ 20%	80% - 120%	< 1/2	0.78 µg/L
MEL	Total Organic Carbon	$\leq$ 20%	80% - 120%	< 1/2	0.1 mg/L
MEL	Total Nitrogen	$\leq$ 20%	80% - 120%	< 1/2	0.013 mg/L
University of Washington Marine Chemistry Laboratory (UW MCL)	Dissolved Inorganic Nitrate	10%	5%	NA	0.188uM, 0.0134 mg/L
UW MCL	Dissolved Inorganic Nitrite	10%	5%	NA	0.014uM, 0.0010 mg/L
UW MCL	Dissolved Inorganic Ammonia	10%	5%	NA	0.069uM, 0.0049 mg/L
UW MCL	Dissolved Inorganic Ortho-Phosphate	10%	5%	NA	0.014uM, 0.0005 mg/L
UW MCL	Dissolved Inorganic Silica	10%	5%	NA	0.260uM, 0.0093 mg/L
UW MCL	Salinity	5%	5%	NA	0.002 PSU
Marine Waters Laboratory (MML)	Chlorophyll *a*	10%	NA	NA	0.02 µg/L

Table 7. Measurement quality objectives for instrument measurement methods.

Measurement - Field	Precision (relative standard deviation, RSD)	Bias (% deviation from true value)	Manufacturer (Model Number)	Mfg reported range	Mfg reported accuracy	Lowest Value
Chlorophyll Fluorescence	10%	5%	WET Labs, Inc. (ECOFL-NTU)	0–50 µg Chl/L	0.025 µg Chl /L	0.1 µg Chl /L
Conductivity	10%	5%	Sea-Bird Electronics (SBE4)	0.0 - 7.0 Siemens/meter (S/m)	0.0003 S/m	1 µS/cm
Density	10%	5%	Sea-Bird Electronics	dependent on T,C	dependent on T,C	0.1 σ_t
Dissolved Oxygen	5%	5%	Sea-Bird Electronics (SBE43)	0 - 120% of saturation	2% of saturation	0.05 mg/L
Light Transmission	10%	5%	WET Labs, Inc. (C-Star)	0-100%	99% R^2	0.01%
pH	0.1 pH units	N/A	Sea-Bird Electronics (SBE18)	0 - 14 pH units	0.1 pH units	0.1 pH units
PreSens Dissolved Oxygen	NA	NA	PreSens Precision Sensing Fitbox 4 trace (PSt3)	0-100% of saturation	± 0.4 % O_2 at 20.9 % O_2 ± 0.05 % O_2 at 0.2 % O_2	0.03% O_2 15 ppb dissolved oxygen
Pressure	5%	1%	Sea-Bird Electronics (SBE29)	0-500m	0.1% of full scale range	0.1 decibars

Measurement - Field	Precision (relative standard deviation, RSD)	Bias (% deviation from true value)	Manufacturer (Model Number)	Mfg reported range	Mfg reported accuracy	Lowest Value
SUNA	10%	±0.028 mg N/L (± 2 µM) or ± 10% of reading, whichever is greater (under laboratory conditions)	Satlantic SUNA	0.007 to 28 mg N/L	NA	0.007 mg N/L
SUNA V2	10%	±0.028 mg N/L or ±10% of reading, whichever is greater (under laboratory conditions)	Satlantic SUNA V2	0-8.0 µM	0.056 mg N/L (4 µM)	±0.028 mg/l (± 2 µM)
Temperature	0.025 °C	0.05 °C	Sea-Bird Electronics (SBE3)	-5.0 to +35 °C	0.001 °C	0.01 °C
Turbidity	10%	5%	WET Labs, Inc. (ECOFL-NTU)	0-25 NTU	0.01 NTU	0.1 NTU

6.2.1.1 Precision

For marine water column profile data, precision is established using field replicates. A minimum of one set of replicates are collected for each sample type during every field sampling event. A monthly sensor assessment check is conducted in the MMU laboratory test tank prior to field collection.

Dissolved inorganic carbon is sensitive to headspace equilibration, so each individual sample must come from a different unopened Niskin. Therefore, replicates are collected from the same depth but different Niskins. Salinity samples are collected to support the ocean acidification (OA) samples so they are paired with every OA sample.

Having enough water volume can become an issue with the POC/PN samples. If a field split is collected, the usual 1000 mL sample is split into two 500 mL bottles. TOC and TN precision is assessed with a replicate sample collected from the same Niskin/depth.

Dissolved inorganic nutrient replicates are collected from the same Niskin, in triplicate. While these replicates test field precision, a test of true laboratory precision requires more volume to generate a split sample in the lab. Currently, UW MCL does not offer this service. Chlorophyll *a* replicates are also collected from the same Niskin, in triplicate. If the results fall outside of established limits, data associated with the batch are flagged by the reviewer. Any measurement problem that cannot be resolved for a specific sample is given an appropriate data quality flag.

6.2.1.2 Bias

Accuracy of marine laboratory data is established through the use of blanks and check standards (laboratory control samples) when possible.

Ocean Scientific International Ltd. (OSIL) low nutrient seawater (LNSW), obtained commercially from OSIL, is a standard reference material used as both a method check and standard check for dissolved inorganic nutrients. Two bottles from every set of 64 are filled with OSIL LNSW providing a method blank. At the end of each field day, a nutrient bottle from the field is filled with OSIL LNSW using one of the field syringes. This replicates the standard field collection method providing a LNSW standard check. Nutrient samples are analyzed by the UW MCL. The lab runs a standard check and a blank check at the beginning and end of each sample analysis run. In addition to our field checks, UW MCL also runs blank checks before and after each sample analysis run. UW Marine Chemistry lab also analyzes salinity samples. Seawater checks are run before and after analysis.

Particulate samples (POC/PN, TOC, TN) are analyzed by MEL. They run method blanks, laboratory control samples, and laboratory duplicate samples. They run standard reference material (SRM1) with each analytical sample run.

Chlorophyll *a* analysis is conducted at the MMU laboratory. Upon return from the field, the samples are filtered; prior to filtration, a seawater (reagent) blank and a deionized water (method) blank are run at the beginning and end of each sample set. For more details on the chlorophyll procedure, see SOP EAP025 *Standard Operating Procedure for Seawater Sampling* (Bos, 2018b). Dissolved oxygen samples are also analyzed at the MMU laboratory and used for to check sensor performance. Blanks and standards must meet the method criteria before sample analysis can begin. For more details on the dissolved oxygen procedure see SOP EAP027 *Standard Operating Procedure for Seawater Dissolved Oxygen Analysis* (Bos and Keyzers, 2017).

Accuracy of CTD and sensor data is established through annual or as-needed calibrations performed by the manufacturer. Monthly sensor assessment checks are done for the SUNA, SUNA V2, pH, transmissometer, conductivity, temperature, and dissolved oxygen field sensors. Deionized water blanks and known nitrate standard are used for frequent checks of the SUNA and SUNA V2 following the manufacturer's guidelines. Light and dark blanks are used to check the Transmissometer. The pH sensor is checked against buffers with known pH. These buffers are purchased from reputable manufacturers and used according to the specifications. The monthly sensor assessment determines the precision, stability, and electrical drift of sensors prior to being used in the field. Specific routines and information for sensor performance checks can be found in Ecology's SOP EAP086 *Marine Waters Sensor Performance Assessment – Lab Procedures* Keyzers, 2019).

For every analyte, Certified Reference Materials (CRMs) are included with every sample batch. Specific to DIC and TA measurements, CRMs provided by A.G. Dickson of Scripps Institution of Oceanography (SIO) are used to calibrate analyzers at PMEL (Dickson *et al.*, 2003). The DIC, TA, and salinity values of the CRMs are measured and certified during preparation at SIO prior to distribution and use (Dickson *et al.*, 2007). Recovery percentage is calculated from these results and therefore can be used as a measure of analytical accuracy and bias. If the results fall outside of established limits, data associated with the batch are flagged by the reviewer as estimates. Any measurement problem that cannot be resolved is given a data quality flag.

6.2.1.3 Sensitivity

Sensitivity of marine water column profiling data is reported as lowest value detectable for a given method or sensor.

Tables 5 and 6 list method detection limits and lowest detectable values for all current marine water column profiling measurements.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

It is important that data collected and analyzed for long-term monitoring by different technicians or monitoring groups are comparable. To ensure comparable data collection techniques, we use the same methods and procedures whenever possible for collecting and analyzing marine water column data throughout the program. MWM technicians operate with primary and backup responsibilities for ensuring that high quality data are generated and moved into the data management system.

All protocols used by MWM are based on the most current, standard, and internationally accepted seawater methods. In addition, all procedures are reviewed every 2-3 years and updated to include improvements and necessary modifications. Using these standardized procedures for analyzing marine monitoring data supports comparability between other studies and long-term monitoring.

6.2.2.2 Representativeness

The long-term MWM program is designed to collect data that adequately represents the study area across seasonal cycles, including spatial and temporal variations. With monthly data collection, a wide variety of seasonal conditions are represented. Regional sampling surveys are conducted over seven different days a month, with no set date or condition imposed for any survey. Surveys are conducted monthly with at least three weeks between consecutive visits to the same region. By our sampling of 39 select marine sites with full vertical resolution, the data will adequately represent the study area, including spatial variation. These sites are located near the middle of inlets or passages to reflect basin-scale water quality and not conditions near a specific wastewater or river discharge.

Technicians will control sampling variability by strictly following standard procedures and collecting quality control samples, but natural spatial and temporal variability may contribute greatly to overall variability in the parameter value.

6.2.2.3 Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system to meet study objectives. The completeness objective for this study is that 95% of all collected data meet measurement quality objectives. There is no attainment objective established given the safety considerations specific to marine water sampling. We make all efforts possible to complete all sampling every month to avoid gaps in the data record.

Reasons why sampling may be cancelled:

- Severe weather that precludes vessels from sailing or flying. To mitigate this, Ecology schedules multiple backup dates. In instances when the weather is too severe to fly but not to operate a vessel, Ecology will use the R/V Skookum to visit and sample core stations.
- Malfunctioning equipment. To minimize this risk, we maintain interchangeable sets of auxiliary equipment, ensure equipment is well maintained, and thoroughly check functionality before starting fieldwork.
- Measurement/data quality objectives are not met. To minimize this, we conduct regular pre- and post-sampling assessment of all procedures and equipment to ensure all are operating correctly.

6.3 Acceptance criteria for quality of existing data

All work is expected to meet the QC requirements of the analytical methods used for this project. These requirements are summarized in the Measurement Procedures and Quality Control Procedures sections of this document and in the standard operating procedures (SOPs) used for each analysis. Many of these procedures can also be found in detail in the Puget Sound Estuary Program Protocols (PSEP, 1997). Qualitatively we use the websites mentioned in section 4.3 to understand our data in the context of climate and hydrological boundary conditions of Washington State.

6.4 Model quality objectives

NA

7.0 Study Design

7.1 Study boundaries

Monitoring the overall health in all of Washington's marine waters is an ambitious goal. The federal government as part of the Clean Water Act requests each body of water be assessed for long-term trends. To spatially cover such a large area several approaches are used:

- Core stations that are sampled every year.
- Rotating stations based on emerging scientific questions or in support of other programs.
- Seasonal rotating station monitoring.

Figure 2 identifies the core and rotating stations that comprise the marine waters vertical profile monitoring program. Station locations were determined by integrating three existing and recommended station networks:

- Existing Ecology sites.
- Sites recommended in 1988 by the Puget Sound Water Quality Authority – Monitoring Management Committee (MMC, 1988).
- Historical stations surveyed by Collias et al. during the 1950s and 1960s.

Station locations from historical lists were incorporated to promote long-term trend analyses. Where possible, recommendations for sites from the program's clients are incorporated into the sampling strategy to report on localized conditions for these users. Currently, Ecology has stations at 166 active and inactive locations, including historical sites that are very rarely sampled.

There are 37 core monitoring stations and 47 rotating stations. Table 7 lists the core stations and their locations. Twenty five of the core stations feed the Marine Water Condition Index (MWCI), and have bold font in the table. As monitoring needs change, stations may be added or removed from the core list of routinely sampled stations.

Table 8. Core stations for Ecology long-term marine water column monitoring.
Stations with bold type are used in calculating the MWCI.

Station	Location	Basin	Sampling Route	Latitude NAD83 (deg/dec min)	Longitude NAD83 (deg/dec min)	County	WRIA	MWCI station	Max depth in meters
ADM001	Admiralty Inlet - Bush Pt.	Admiralty Inlet	North/Central Sound	48 1.789	122 37.076	Island	06	X	148
ADM002	Admiralty Inlet (north) - Quimper Pn.	Admiralty Inlet	North/Central Sound	48 11.239	122 50.577	Jefferson	17	X	82
ADM003	Admiralty Inlet (south)	Admiralty Inlet	North/Central Sound	47 52.739	122 28.992	Kitsap	15	X	210
BLL009	Bellingham Bay - Pt. Frances	San Juan Island/Georgia St.	North Sound	48 41.156	122 35.977	Whatcom	01	X	20
BUD005	Budd Inlet - Olympia Shoal	South Basin	South Sound	47 5.522	122 55.092	Thurston	13	X	15
CMB003	Commencement Bay - Browns Point	PS Main Basin	Central Sound	47 17.423	122 27.007	Pierce	10	X	150
CRR001	Carr Inlet - Off Green Point	South Basin	South Sound	47 16.589	122 42.575	Pierce	15		95
CSE001	Case Inlet - S. Heron Island	South Basin	South Sound	47 15.872	122 50.658	Pierce	15		58
DNA001	Dana Passage - S. of Brisco Point	South Basin	South Sound	47 9.689	122 52.308	Thurston	13	X	40
EAP001	East Passage - SW of Three Tree Point	PS Main Basin	Central Sound	47 25.023	122 22.824	King	09	X	213
ELB015	Elliott Bay - E. of Duwamish Head	PS Main Basin	Central Sound	47 35.789	122 22.174	King	09	X	82
GOR001	Gordon Point	South Basin	South Sound	47 10.989	122 38.074	Pierce	15	X	168
GRG002	Georgia Strait - N. of Patos Island	San Juan Island/Georgia St.	North Sound/San Juans	48 48.490	122 57.245	San Juan	02	X	190
GYS008	Grays Harbor - Mid-S. Channel	Grays Harbor	Coast	46 56.239	123 54.793	Grays Harbor	22	X	6

Station	Location	Basin	Sampling Route	Latitude NAD83 (deg/dec min)	Longitude NAD83 (deg/dec min)	County	WRIA	MWCI station	Max depth in meters
GYS016	Grays Harbor - Damon Point	Grays Harbor	Coast	46 57.205	124 5.577	Grays Harbor	22	X	11
HCB003	Hood Canal, Eldon	Hood Canal Basin	Hood Canal	47 32.2722	123 0.576	Mason	14		144
HCB004	Hood Canal - Gt. Bend, Sisters Point	Hood Canal Basin	Hood Canal	47 21.372	123 1.492	Mason	14	X	55
HCB007	Hood Canal - Lynch Cove	Hood Canal Basin	Hood Canal	47 23.8889	122 55.7755	Mason	14		21
HCB010	Hood Canal - Send Creek, Bangor	Hood Canal Basin	Hood Canal	47 40.2	122 49.2	Kitsap	15		100
NSQ002	Nisqually Reach - Devils Head	South Basin	South Sound	47 10.039	122 47.291	Pierce	13	X	101
OAK004	Oakland Bay - Near Eagle Point	South Basin	South Sound	47 12.806	123 4.659	Mason	14	X	19
PSB003	Puget Sound Main Basin - West Point	PS Main Basin	Central Sound	47 39.589	122 26.575	King	08	X	67
PSS019	Possession Sound - Gedney Island	Whidbey Basin	Whidbey Basin	48 0.656	122 18.075	Snohomish	07	X	101
PTH005	Port Townsend Harbor - Walan Point	Admiralty Inlet	North Sound/San Juans	48 4.989	122 45.877	Jefferson	17		26
RSR837	Rosario Straight	San Juan Island/Georgia St.	North Sound/San Juans	48 36.990	122 45.778	San Juan	2		56
SAR003	Saratoga Passage - East Point	Whidbey Basin	Whidbey Basin	48 6.456	122 29.493	Island	06	X	149
SIN001	Sinclair Inlet - Naval Shipyards	Main Basin	Central Sound	47 32.956	122 38.608	Kitsap	15	X	16
SJF000	Strait of Juan de Fuca - S. of San Juan Island	Strait of Juan de Fuca	North Sound/San Juans	48 25.0	123 01.5	San Juan	2	X	180

Station	Location	Basin	Sampling Route	Latitude NAD83 (deg/dec min)	Longitude NAD83 (deg/dec min)	County	WRIA	MWCI station	Max depth in meters
SJF001	Strait of Juan de Fuca - SE of Hein Bank	Strait of Juan de Fuca	North Sound/San Juans	48 20.0	123 01.5	San Juan	2	X	160
SJF002	Strait of Juan de Fuca - SW of Eastern Bank	Strait of Juan de Fuca	North Sound/San Juans	48 15.0	123 01.5	San Juan	2	X	145
SKG003	Skagit Bay - Str. Point (Red Buoy)	Whidbey Basin	Whidbey Basin	48 17.789	122 29.376	Island	06		24
WPA003	Willapa Bay - Willapa R., John. Slough	Willapa Bay	Coast	46 42.239	123 50.243	Pacific	24	X	10
WPA004	Willapa Bay - Toke Point	Willapa Bay	Coast	46 41.206	123 58.41	Pacific	24	X	14
WPA006	Willapa Bay - Nahcotta Channel	Willapa Bay	Coast	46 32.723	123 58.810	Pacific	24	X	21
WPA007	Willapa Bay - Long Isl., S Jenson Pt	Willapa Bay	Coast	46 27.1893	124 0.5762	Pacific	24	X	14
WPA008	Willapa Bay - Naselle River	Willapa Bay	Coast	46 27.789	123 56.476	Pacific	24	X	14
WPA113	Willapa Bay - Bay Center	Willapa Bay	Coast	46 38.64	123 59.58	Pacific	24		11

Table 9. Rotating and seasonal stations for Ecology long-term marine water column monitoring.

Station	Location	Basin	Sampling Region	Latitude NAD83 (deg/dec min)	Longitude NAD83 (deg/dec min)	County	WRIA	Max depth in meters
BLL040	Bellingham Bay	San Juan Island/Georgia St.	North Sound	48 41.0382	122 32.2920	Whatcom	02	21
BML001	Burley-Minter Lagoon	Southern Basin	South Sound	47 22.6557	122 38.0246	Pierce	15	14
BUD002	Budd Inlet - S. End Oly Port	Southern Basin	South Sound	47 3.0891	122 54.375	Thurston	13	12
CMB006	Commencement Bay - Mouth of City WW	PS Main Basin	Central Sound	47 15.6892	122 26.2407	Pierce	10	39
CSE002	Case Inlet - Off Rocky Point	Southern Basin	South Sound	47 21.189	122 48.875	Mason	14	23
DIS001	Discovery Bay - Near Mill Point	Strait of Juan de Fuca	North Sound/San Juans	48 1.0887	122 50.8768	Jefferson	17	42
DRA002	Drayton Harbor - Inner Harbor	Strait of Georgia	North Sound	48 58.99	122 45.7772	Whatcom	01	12
DUN001	Dungeness Bay	Strait of Juan de Fuca	North Sound/San Juans	48 10.3889	123 6.8773	Clallam	18	19
DYE004	Dyes Inlet - NE of Chico Bay	PS Main Basin	Central Sound	47 37.3389	122 41.3754	Kitsap	15	38
EAG001	Eagle Harbor - Inner	PS Main Basin	Central Sound	47 37.2891	122 31.3746	Kitsap	15	20
EAS001	East Sound - Rosario Point	Strait of Georgia	North Sound	48 38.5728	122 53.0109	San Juan	02	33
ELD001	Eld Inlet - Flapjack Point	Southern Basin	South Sound	47 6.3724	122 56.9919	Thurston	13	16
ELD002	Eld Inlet - S. Flapjack Point	Southern Basin	South Sound	47 5.7724	122 58.5253	Thurston	13	10
FID001	Fidalgo Bay - E. of Anacortes	Strait of Georgia	North Sound	48 30.7562	122 35.7102	Skagit	03	12
FRI001	Friday Harbor - San Juan Island	Strait of Georgia	North Sound	48 32.2893	123 0.7774	San Juan	02	19
FSH001	Fisherman Bay - Lopez Island	Strait of Georgia	North Sound	48 30.5893	122 55.0773	San Juan	02	5
GYS004	Grays Harbor - Chehalis R.	Grays Harbor	Coast	46 58.672	123 47.077	Grays Harbor	22	20
GYS009	Grays Harbor - Moon Island Reach	Grays Harbor	Coast	46 57.872	123 56.977	Grays Harbor	22	15
GYS015	Grays Harbor - N. Whitcomb Flats	Grays Harbor	Coast	46 55.372	124 4.610	Grays Harbor	22	15
HCB002	Hood Canal - Dabob Bay Pulali Point	Hood Canal Basin	Hood Canal	47 44.7722	122 50.9096	Jefferson	17	50
HCB006	Hood Canal - King Spit, Bangor	Hood Canal Basin	Hood Canal	47 44.856	122 43.893	Kitsap	15	76

Station	Location	Basin	Sampling Region	Latitude NAD83 (deg/dec min)	Longitude NAD83 (deg/dec min)	County	WRIA	Max depth in meters
HCB008	Hood Canal - King Spit, Bangor-post9/11	Hood Canal Basin	Hood Canal	47 45.2	122 44.7	Kitsap	15	111
HCB009	Hood Canal - Hazel Pt, Bangor	Hood Canal Basin	Hood Canal	47 41.3	122 45.0	Kitsap	15	87
HLM001	Holmes Harbor - Honeymoon Bay	Whidbey Basin	Whidbey Basin	48 3.8223	122 31.9925	Island	06	54
HND001	Henderson Inlet - Cliff Point	Southern Basin	South Sound	47 9.0724	122 50.0582	Thurston	13	23
JDF005	Strait of Juan de Fuca - Sequim Bay	Strait of Juan de Fuca	North Sound/San Juans	48 3.6554	123 1.8605	Clallam	17	39
JDF007	Strait of Juan de Fuca - Sequim Bay, Goose Point	Strait of Juan de Fuca	North Sound/San Juans	48 2.9054	123 0.5771	Clallam	17	17
LOP001	Lopez Island - Decatur Island	Strait of Georgia	North Sound	48 30.7894	122 51.0773	San Juan	02	15
NRR001	Tacoma Narrows - Point Defiance	Southern Basin	South Sound	47 18.9892	122 32.991	Pierce	12	60
NSQ001	Nisqually Reach	Southern Basin	South Sound	47 6.7391	122 41.9078	Pierce	15	29
OCH014	Brownsville	Main Basin	Central Sound	47 40.2924	122 35.9712	Kitsap	15	20
PAH008	Port Angeles Harbor - Morse Creek	Strait of Juan de Fuca	North Sound/San Juans	47 7.2889	123 21.076	Clallam	18	19
PCK001	Pickering Passage - Harstine Island	Southern Basin	South Sound	47 14.9057	122 55.4919	Mason	14	22
PGA001	Port Gamble - Inner Harbor	Hood Canal Basin	Hood Canal	47 50.3889	122 34.8754	Kitsap	15	22
PMA001	Port Madison - S. of Buoy 65	PS Main Basin	Central Sound	47 44.0891	122 32.0748	Kitsap	15	51
PNN001	Penn Cove Park (Whidbey Island)	Whidbey Basin	Whidbey Basin	48 13.8559	122 40.5434	Island	06	31
POD006	Port Orchard - Liberty Bay/Virg. Point	PS Main Basin	Central Sound	47 42.889	122 38.0754	Kitsap	15	16
POD007	Port Orchard - Inner	PS Main Basin	Central Sound	47 43.989	122 39.0755	Kitsap	15	6
PSS008	Possession Sound - PG Bay Pier 3	Whidbey Basin	Whidbey Basin	47 58.889	122 13.4081	Snohomish	07	37
PSS010	Possession Sound - Added post-9/11 for TFR	Whidbey Basin	Whidbey Basin	47 57.900	122 15.800	Snohomish	07	99
QMH001	Quartermaster Harbor - Burton	PS Main Basin	Central Sound	47 22.7892	122 27.9742	King	15	21
QMH002	Quartermaster Harbor - Inner Harbor	PS Main Basin	Central Sound	47 23.7892	122 26.5742	Pierce	10	11

Station	Location	Basin	Sampling Region	Latitude NAD83 (deg/dec min)	Longitude NAD83 (deg/dec min)	County	WRIA	Max depth in meters
SEQ002	Sequim Bay - Northern	Strait of Juan de Fuca	North Sound/San Juans	48 4.5888	123 1.0771	Clallam	17	26
SKG001	Skagit Bay - Hope Island	Whidbey Basin	Whidbey Basin	48 23.7394	122 34.91	Island	06	29
STL001	Steilacoom - Off Chambers Creek	Southern Basin	South Sound	47 11.0891	122 36.6743	Pierce	15	122
SUZ001	Port Susan - Kayak Point	Whidbey Basin	Whidbey Basin	48 8.1058	122 22.2422	Snohomish	05	107
TOT001	Totten Inlet - Windy Point	Southern Basin	South Sound	47 9.8557	122 57.8753	Mason	14	31
TOT002	Inner Totten Inlet	Southern Basin	South Sound	47 7.289	123 1.2754	Thurston	14	12
WPA001	Willapa Bay - Willapa R., Raymond	Willapa Bay	Coast	46 41.239	123 44.993	Pacific	24	11

7.2 Field data collection

7.2.1 Sampling locations and frequency

Core station monitoring is intended to provide a base of continuous, widespread, and long-term water quality data at selected points throughout the Puget Sound and coastal bays systems. Core stations are located to capture ambient conditions. Stations are located in the center of distinct hydrographic regions, separated mainly by major sills, and include deep, open basins, passages, and select major urban areas and rural embayments. These stations provide a long-term record of ambient water column conditions, and allow the determination of annual variability and changing marine water quality conditions.

Core long-term monitoring stations are visited every month, year-round, to ensure that all major seasonal hydrographic conditions are observed. Since not all stations can be visited in one day, stations are aligned by region and separated into seven regional surveys a month for the most efficient operations. Regions covered are:

- Coastal Bays
- South Sound
- Hood Canal
- Central Sound
- Admiralty Inlet
- North Sound
- San Juan Islands

Stations are sampled at intervals of no less than three weeks to ensure reasonable adherence to a monthly sampling scheme. Every year, as rotating stations are added to the sampling plan, station groupings by region may change slightly. The annual station list, maps, and sampling plans are published annually as an addendum to this QAMP (Figure 3).

The rotating station component of the MWM is intended to supplement the data collected during the core station monitoring. Rotating stations are sampled on an as needed basis. Seasonal monitoring of select rotating stations provides a brief dataset useful for determining the need for more intensive monitoring or continuous studies.

Seasonal rotating stations are selected annually, based on recommendations and data needs of clients, and may be moved to fill or improve data records for other sections of the marine monitoring program. Final stations are selected by Ecology Marine Monitoring staff and identified in the annual sampling plan. These locations may be visited for one sampling period or may be revisited when necessary. The number of seasonal rotational stations monitored each year may vary, depending on the need and the resources available.

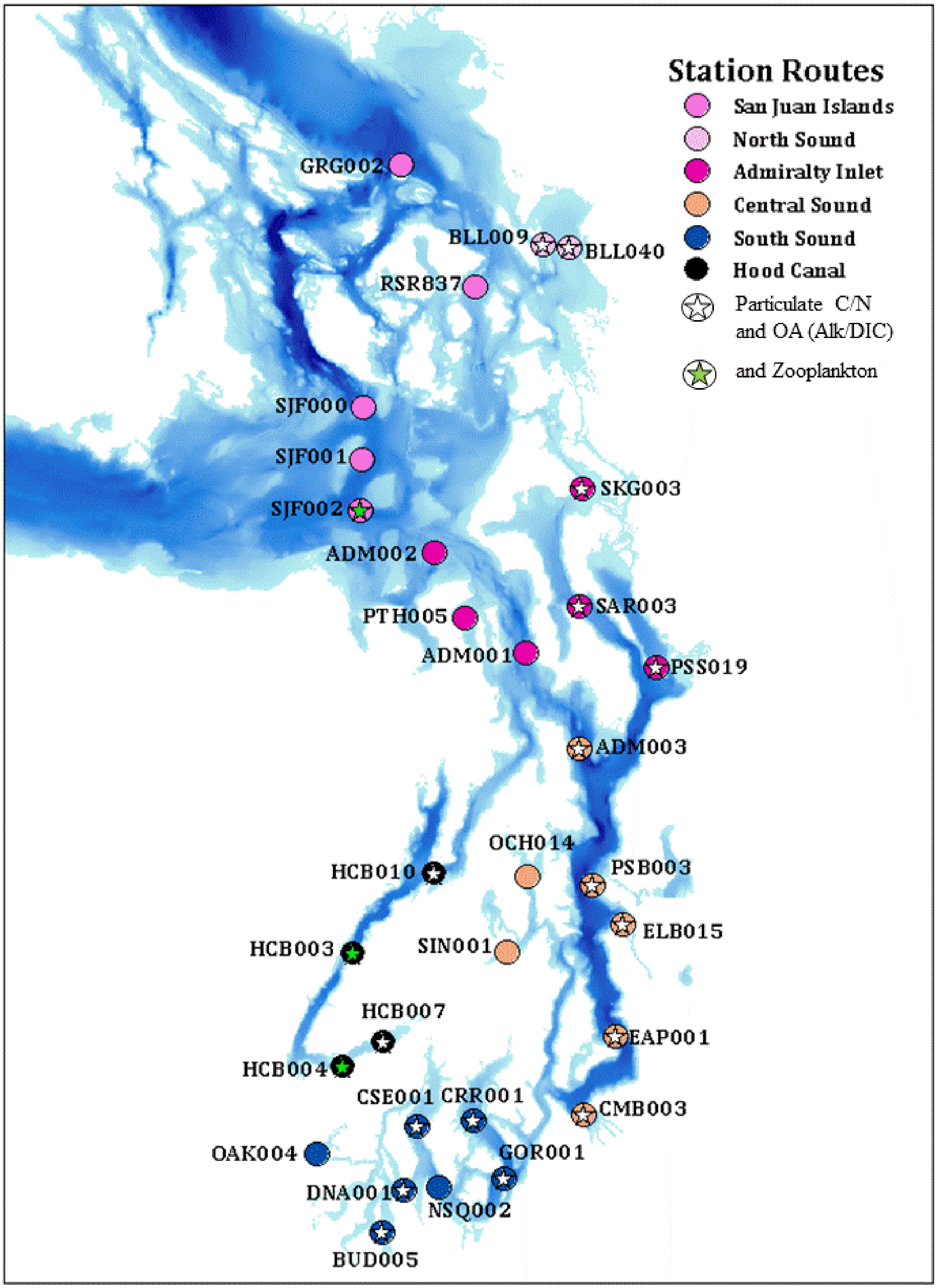

Figure 3. Map of 2020 stations and routes.

7.2.2 Field parameters and laboratory analytes to be measured

Figure 4. Ecology's three CTD instrument packages.

Each specialized for a particular platform.
From left to right: 1114 plane package, 1146 boat package, and 0508 JEMS package.

A Sea-Bird Electronics profiling CTD is used for measuring hydrographic conditions at each station. The base unit measures conductivity, temperature, and depth (pressure). The CTD has also been interfaced with sensors that measure nitrate, dissolved oxygen, pH, in vivo chlorophyll fluorescence, turbidity, and light transmission.

A CTD cast is conducted at each station. Each time the CTD is turned on, data is recorded internally (minimum sampling rate is eight scans per second). This cast is assigned a cast number and time.

The sensors on the CTD are equilibrated with *in situ* conditions. The CTD is turned on, lowered into the water until the entire unit is submerged, and held stationary for one minute. This time is needed for the sensors to equilibrate with the environment, although the sensor response generally stabilizes within seconds of turning on the instrument. The CTD is first raised to sample close to the surface without losing its prime, then lowered at a rate no faster than 0.5 m/sec to 1-2 meters above the bottom, held near the bottom for two minutes, raised to the surface and turned off.

The CTD used during this program has a pump attached to give the conductivity and dissolved oxygen sensors a continuous flush of sample water. The advantages to lowering the CTD at this rate are:

- The sensors have time to respond to changes in the water column more accurately.
- The resultant water column hydrographic structure will have higher resolution, especially in the upper layers where steep gradients may exist.
- Measurement errors due to rapid sampling and steep parameter gradients such as rapid changes in temperature are reduced.

Long-term station monitoring is conducted by floatplane and research vessels: Ecology's boat (R/V Skookum) and Shannon Point Marine Science Center's boats (R/V Magister or R/V Zoea).

Using a floatplane for sampling allows coverage of a large geographic area in a short period of time. Surveys are conducted from a DeHavilland Beaver floatplane that can accommodate the sampling gear, pilot, technician, and an assistant. Samples are collected using a portable winch to lower and retrieve instruments and water sampling equipment through a floor-mounted observation hatch in the rear of the passenger compartment.

Sampling from a vessel makes it possible to collect more water samples and support collaborations. Because vessels can handle more inclement weather like fog and bigger waves, a vessel provides more opportunities to sample. Samples are collected using a winch attached to the vessel to lower and retrieve instruments and water sampling equipment.

At all core stations, complete CTD profiles of the entire water column are collected. Water sample type collection varies from station to station. Which waters samples are collected at a particular station depends on several factors such as depth, collaborations, budget, and historical precedent.

In April 2016, in an effort to connect results from our marine waters and marine sediment programs, we started Ecology's Marine Sediment Monitoring Program to collect a suite of particulate samples at 20 co-located stations from both the marine waters and marine sediment monitoring programs. Samples were collected from two depths for particulate organic carbon (POC), particulate nitrogen (PN), total organic carbon (TOC) and total nitrogen (TN). Initial funding was temporary, but permanent funding has now been secured and data collection will continue into the future.

In 2018, the PAR sensor and Secchi depth data collection was discontinued after an analysis of the data determined that other measurements were superior for describing ambient light conditions in the surface layers of the water column. Secchi measurements (collected since June 1977) and PAR data (collected since February 2011) have not revealed long-term trends. Trend analysis revealed that transmission and *in situ* fluorescence, however, data produced statistically significant trends (e.g., PSEMP Marine Waters Workgroup, 2014). The decision was therefore made to increase efficiency by discontinuing the PAR and Secchi depth measurements.

Table 10. Sample types and depths (in meters) for MWM parameters.

Parameters	Depth (meters)	Parameter Type
Weather & Conditions	NA	Observation
Temperature	0-Near-bottom	CTD
Conductivity (salinity)	0-Near-bottom	CTD
Dissolved Oxygen	0-Near-bottom	CTD
Nitrate	0-Near-bottom	CTD
Transmissometer	0-Near-bottom	CTD
Turbidity	0-Near-bottom	CTD
Fluorescence	0-Near-bottom	CTD
pH	0-Near-bottom	CTD
Pressure	0-Near-bottom	CTD
Total Alkalinity	0, 30	Water sample
Dissolved Inorganic Carbon	0, 30	Water sample
Particulate Organic Carbon	10-Near-bottom	Water sample
Particulate Nitrogen	10-Near-bottom	Water sample
Total Organic Carbon	10-Near-bottom	Water sample
Total Nitrogen	10-Near-bottom	Water sample
Dissolved Inorganic Nitrate	0, 10, 30, 80, 140, Near-bottom	Water sample
Dissolved Inorganic Nitrite	0, 10, 30, 80, 140, Near-bottom	Water sample
Dissolved Inorganic Ammonium	0, 10, 30, 80, 140, Near-bottom	Water sample
Dissolved Inorganic Ortho-Phosphate	0, 10, 30, 80, 140, Near-bottom	Water sample
Dissolved Inorganic Silicate	0, 10, 30, 80, 140, Near-bottom	Water sample
Chlorophyll *a* and Phaeopigment	0, 10, 30	Water sample
Salinity	0, 30	Water sample
Zooplankton	0-Near-bottom	Water sample

In September 2018, total alkalinity (TA) and dissolved inorganic carbon (DIC) samples were added at 20 stations at two depths, with funding from a National Estuary Program Near-Term Action grant. Permanent funding has since been secured and the Ocean Acidification (OA) samples will continue as part of the long-term monitoring program under this QAMP. For more information about the OA sampling see Ecology's QAPP, *Ocean Acidification Monitoring at Ecology's Great Puget Sound Stations* (Gonski, 2019).

In 2020, a SUNA V2 sensor will be added to the new boat package, allowing for full depth nitrate data to be collected at all Puget Sound stations. A SUNA sensor has been part of the 0508 sensor package since August 2013. The SUNA is functionally equivalent to the SUNA V2.

Winkler DO water samples are no longer collected in the field. This is due to a decision to improve field safety (by eliminating chemicals), reduce logistical challenges (of three-day sample hold times sometimes requiring lab analysis on weekends), and improve reference DO sample precision and reduce bias (by reducing uncertainty due to spatial variability in field samples). Reference DO samples will be taken in the lab during the monthly sensor assessment.

A monthly sensor assessment is now used to correct for drift in slope of the SBE 43 oxygen data. A monthly assessment between all of our DO field sensors (SBE 43) against a pristine lab DO sensor (SBE37-ODO) improves co-location, precision, and accuracy of the slope-adjusted field SBE 43 DO sensor data. For more information on this change, you may request an internally published document written by Christopher Krembs (2019).

DO field data will now be adjusted monthly rather than annually, making the data QA/QC workflow more efficient. There are also the added benefits of checking conductivity and temperature, and the ability to detect any sensor issues before field deployment. Additional DO checks are collected in the field using a PreSens optode spot DO sensor to assure proper function of the field DO sensors.

7.3 Modeling and analysis design

CTD and water sample data are used by Ecology's Modeling and TMDL unit to support Salish Sea Model applications. Acceptance criteria for quality of data are described in the Ecology's *Salish Sea Modeling Applications QAPP* (McCarthy, 2018).

7.4 Assumptions in relation to objectives and study area

An inherent design assumption of monthly ambient sampling is that these data are representative of broader environmental conditions; however, monthly measurements are more of a snapshot of conditions and may not fully capture the range of conditions nor unique events.

Though we take steps to assure representativeness, data users must be careful not to overstate these measurements. A single profile cannot ascertain cross-channel, surface, or temporal variability. This is especially the case for measurements taken when values change rapidly with the tide, on the diurnal period, or during events such as storms, weather events, or high or low river flows.

7.5 Possible challenges and contingencies

As new ecological information emerges and different questions arise, the monitoring priorities and strategy will change. Station locations, monitoring methods, and collected data are updated as information priorities evolve and scientific needs change. Any updates will be captured in future addenda to this monitoring plan or, if significantly different, will be captured in a new Quality Assurance Monitoring Plan.

7.5.1 Logistical problems

There is no attainment objective established given the safety considerations specific to marine water sampling. We make all possible efforts to complete all sampling every month to avoid gaps in the data record. Even with the best planning, challenges are bound to arise when working outside and dealing with weather and tides, changes in staffing, and boat, plane, or sensor issues. To mitigate these issues we:

- Schedule multiple field back-up dates.
- Train multiple staff on field procedures.
- Have back-up platform options (use boat if plane is unavailable and vice versa).

- Maintain interchangeable sets of auxiliary equipment, ensure equipment is well maintained, and thoroughly check functionality before starting fieldwork.
- Conduct regular assessments of all procedures and equipment to ensure all are operating correctly.

7.5.2 Practical constraints

Data collection is not conducted under adverse or unsafe conditions. In addition, data collection may be suspended when access is denied or operations are prohibited by federal agencies such as the U.S. Coast Guard, Federal Aviation Administration (FAA), or Department of Defense. Data collected under this monitoring program may be affected by a systematic bias. While sampling by floatplane allows for an efficient, cost-effective sampling method capable of covering the extensive study area quickly, operations conducted aboard this type of platform are constrained to daylight and fair weather conditions.

For safety reasons, floatplanes are not allowed to operate in fog, low visibility, or after dark, and the planes cannot land on disturbed waters in winds greater than 15 knots. Therefore, sampling flights are not conducted during stormy, foggy, or nighttime conditions. The result is that there are more gaps in sampling events during more stormy periods.

Data collected using a boat has a broader tolerance for unfavorable conditions but operations are still limited by high winds and fog. Close tracking of the weather and a flexible field schedule are the best tools to ensure data collection continues throughout the year. Data collection may be cancelled or curtailed when budget constraints result in staff reductions or limited availability of resources such as equipment and supplies, laboratory analyses, or calibration and maintenance services.

Data assessment may be limited or not performed when data collection is suspended, equipment fails to generate data that meet quality standards, or when budget constraints result in staff reductions or limitations to resources such as equipment and supplies, analytical laboratory or information management services.

Any circumstance that interferes with data collection and quality will be noted and discussed in reports and data summaries.

7.5.3 Schedule limitations

Every effort is made to sample every station every month, but the schedule can be disrupted by unfavorable weather conditions, equipment failures, limited staffing, or boat or planes not being available. Whenever possible, field work is rescheduled until completed.

8.0 Field Procedures

8.1 Invasive species evaluation

We use a floatplane and boats, with little to no opportunity for contact with invasive species. Therefore, we have low risk of transporting invasive species from one water body to another. Marine Waters Monitoring staff make every effort to minimize the spread of aquatic organisms by following protocols set in Standard Operating Procedures to Minimize the Spread of Invasive Species, Ecology's SOP No. EAP070 (Parsons, 2012). This document is available at the Ecology QA Website.

8.2 Measurement and sampling procedures

Seawater sampling methods are described in Bos (2018), Standard Operating Procedure for Seawater Sampling, and are derived from standard international oceanographic sampling methods published by UNESCO, 1994.

These protocols adhere to the most current seawater sampling methods (Grasshoff et al., 1999) and to PSEP's recommended protocols for measuring conventional water column variables in Puget Sound (PSEP, 1991). These protocols are followed during all Puget Sound water column sampling efforts. If deviations from the protocols occur, a brief explanation is given in the annual plan that will be published in the future as annual addenda to this plan.

Table 11. Standard Operating Procedures used by MWM program.

Title	Number
Seawater Sampling version 2.0	EAP025
Procedure for Chlorophyll *a* Analysis version 4.0	EAP026
Seawater Dissolved Oxygen Analysis version 2.0	EAP027
Marine Waters Sensor Performance Assessment version 3.0	EAP086
Marine Waters Data Quality Assurance and Quality Control	EAP088
Marine Waters Data Processing (in draft)	EAP089

8.3 Containers, preservation methods, holding times

Table 12. Marine water column containers, preservation methods, and holding times.

Parameter	Minimum Quantity Required	Container	Preservative	Holding Time
Total Alkalinity	500 mL	500 mL borosilicate glass bottle	Preserve sample with 200 µL super-saturated $HgCl_2$. Apply Apiezon® L grease to stopper, insert & twist to remove all air. Store in cool (~4ºC), dark conditions.	6 months
Dissolved Inorganic Carbon	500 mL	500 mL borosilicate glass bottle	Preserve sample with 200 µL super-saturated $HgCl_2$. Apply Apiezon® L grease to stopper, insert & twist to remove all air. Store in cool (~4ºC), dark conditions.	6 months
Particulate Organic Carbon	900 mL	1 L wide-mouth polyethylene	Store on ice- filter ASAP upon arrival at the laboratory.	Up to 100 days once filtered and stored at -20°C.
Particulate Nitrogen	900 mL	1 L wide-mouth polyethylene	Store on ice- filter ASAP upon arrival at the laboratory.	Up to 100 days once filtered and stored at -20°C.
Total Organic Carbon	100 mL	125 mL wide-mouth clear HDPE polyethylene	Preserve sample with hydrochloric acid, ice upon collection	28 days store at 0°C - 6°C.
Total Nitrogen	100 mL	125 mL wide-mouth clear HDPE polyethylene	Preserve sample with sulfuric acid, ice upon collection	28 days store at 0°C - 6°C.
Dissolved Inorganic Nitrate	40 mL	60 mL narrow-mouthed seawater aged polyethylene	None, store on ice, freeze upon arrival at the lab	3 months
Dissolved Inorganic Nitrite	40 mL	60 mL narrow-mouthed seawater aged polyethylene	None, store on ice, freeze upon arrival at the lab	3 months
Dissolved Inorganic Ammonium	40 mL	60 mL narrow-mouthed seawater aged polyethylene	None, store on ice, freeze upon arrival at the lab	3 months
Dissolved Inorganic Orthophosphate	40 mL	60 mL narrow-mouthed seawater aged polyethylene	None, store on ice, freeze upon arrival at the lab	3 months
Dissolved Inorganic Silicate	40 mL	60 mL narrow-mouthed seawater aged polyethylene	None, store on ice, freeze upon arrival at the lab	3 months
Chlorophyll *a*	65 mL	65 mL narrow-mouthed polyethylene	None, store on ice, filter immediately upon arrival at lab. Filter stored in freezer in 90% acetone.	4 weeks

Parameter	Minimum Quantity Required	Container	Preservative	Holding Time
Salinity	100 mL	Brown 125 mL wide-mouth seawater aged polyethylene	None	6 months

8.4 Equipment decontamination

MWM staff make all efforts to avoid sampling in waters that contain high levels of contaminants, such as oil spills or toxic substances. If contact is suspected, staff follow all recommended protocols from instrument manufacturers for cleaning and, if needed, re-calibrating sensors. If non-sensor sampling equipment may be contaminated, staff follow Ecology's SOP EAP090, *Decontamination of Sampling Equipment for Use in Collecting Toxic Chemical Samples* when cleaning equipment (Friese, 2017).

8.5 Sample ID

All collected water samples are labeled with station, depth, and sample identification numbers based on bottle numbers, and these are recorded in the digital field log. Each sample is automatically given a unique identification number once loaded to the database. This number is transferred to analyses logs (for internal lab samples) or chain of custody forms sent to external labs. All sample bottles are reconciled against forms to verify completeness as samples move through the analytical process, described in the *Quality Control* section of this QAMP.

8.6 Chain-of-custody

During sample collection, a chain of custody form is generated for samples, based on field logs. Chain of custody logs are delivered to the lab with the corresponding samples for management of sample counts, scheduling, and tracking analysis. Once the samples are delivered, lab personnel log in each sample and assign a lab number to each, using the sample label number and date. Each laboratory sample number must correspond to a particular date, station, and depth.

When data results are received from labs, chain of custody forms are reconciled with data to ensure complete delivery and correct invoicing for all results. If discrepancies exist, research and investigation of the discrepancy is conducted in coordination with the lab(s) until the problem is resolved.

8.7 Field log requirements

Most of the parameters measured in the water column are either recorded internally within the CTD's data logger or collected as water samples and analyzed at the laboratory. Information on CTD casts and water samples are recorded in a digital field log. Information such as station ID, date, time, weather and environmental conditions, field observations, samples collected, sample bottle numbers, QC sample identifiers, latitude and longitude of the station, technician names, comments, and CTD cast information are digitally recorded in the field log form. The field log form also includes CTD information for data processing such as cast start time, replicate cast number, instrument information, and survey ID. In addition, any changes or deviations from the sampling plan or unusual circumstances that might affect interpretation of results are recorded.

A paper log is brought along on every survey to use as a backup if the electronic form or device should fail. Digital copies of the field and sample logs are stored for future reference on a shared, secure, frequently backed up network server. Photos are taken to document unusual and important events observed during field work.

8.8 Other activities

MWM has been collecting two vertical zooplankton tows for the Salish Sea Marine Survival Project (SSMSP) at the Strait of Juan de Fuca SJF002 station since 2010. Starting in the summer of 2017, MWM, in collaboration with The Hood Canal Salmon Enhancement Group (HCSEG), collected two vertical net tows for zooplankton at Hood Canal stations HCB003 and HCB004. MWM provides the boat and accompanying CTD data, while HCSEG provides the staff to conduct the tow and manage the field form. For more information on SSMSP see *Pacific Salmon Foundation. Salish Sea Marine Survival Project –2017-2018 Research Plan* (Riddel, 2016).

9.0 Laboratory Procedures

9.1 Lab procedures table

As discussed in previous section of this QAMP various combinations of water samples happen at all 39 stations monthly. Below is a list of all the possible parameters that could be collected.

9.2 Sample preparation method(s)

No special sample preparation is needed for the water samples. Each laboratory that does the sample analysis also takes care of any necessary bottle preparation. Multiple streams of bottles are delivered to our lab on a monthly basis, which are then sorted for the particular routes. See Table 11 for bottle details.

9.3 Special method requirements

NA

Table 13. Measurement methods (laboratory).

Measurement Lab Analyte	Matrix	Expected Range	Reporting Limit	Analytical Method(s)
Total Alkalinity	Marine water column	500-2180 (µmol kg^{-1})	±0.1% µmol kg^{-1}	Dickson et al. (2003); Dickson et al. (2007) (SOP 3b)
Dissolved Inorganic Carbon	Marine water column	550-2160 (µmol kg^{-1})	±0.1% µmol kg^{-1}	Dickson et al. (2007) (SOP 2); Johnson et al. (1985, 1987, 1993)
Particulate Organic Carbon	Marine water column	40-15000 µg/L	40 ug	EAP 440.0
Particulate Nitrogen	Marine water column	1-1600 ug/L	5 ug	EPA 440.0
Total Organic Carbon	Marine water column	1-8 mg/L	0.5 mg/L	SM 5310B
Total Nitrogen	Marine water column	0.025-1.00 mg/L	25 ug/L	SM 4500NB
Dissolved Inorganic Nitrate	Marine water column	0.00 - 40.00 µM	0.15 µM	SM 4500- $NO3^{-}$ F
Dissolved Inorganic Nitrite	Marine water column	0.00 - 2.00 µM	0.01 µM	SM 4500- $NO3^{-}$ F
Dissolved Inorganic Ammonium	Marine water column	0.00 - 10.00 µM	0.05 µM	SM 4500- $NH3^{-}$ G
Dissolved Inorganic Orthophosphate	Marine water column	0.00 - 4.00 µM	0.02 µM	SM 4500-P F
Dissolved Inorganic Silicate	Marine water column	0.00 - 200.00 µM	0.21 µM	SM 4500-SiO2 E
Chlorophyll *a*	Marine water column	0.00 - 60.00 µg/L	0.01 mg/L	EPA, 1997
Salinity	Marine water column	0.00 - 36.00 PSU	0.002 PSU	SM 2520 B

9.4 Laboratories accredited for methods

The analytical techniques employed at PMEL for analysis of DIC and TA in seawater and the future applications of any modified analytical techniques for DIC and TA less than 1500 µmol kg^{-1} in estuarine waters of the Salish Sea are relatively novel. For these and other reasons, Ecology has an existing Laboratory Accreditation Waiver on file for DIC and TA analyses see appendix B (Gonski, 2019).

10.0 Quality Control Procedures

10.1 Table of field and laboratory quality control

Collecting high quality data is mandatory for Ecology's Long-Term Marine Monitoring Program and ensures that trends accurately reflect true environmental change. We routinely perform data quality assurance (QA) and data quality control (QC) through group reviews to ensure that our data meet the highest quality standards. Data quality codes are applied to the data set, allowing users to understand the level of quality for each data point.

See Table 5 for laboratory MQOs and Table 6 for instrument MQOs (Section 6.2.1) that will be used to evaluate the quality and usability of the results.

The ongoing effort to provide high quality data occurs in many steps before, during, and after data collection. QA/QC procedures include the following activities:

- Training personnel (see Section 5 for details).
- Calibrating and maintaining equipment (see Section 7.2.2 for details).
- Conducting monthly sensor performance assessment (see Section 14.3
- Analytical laboratory and field data QA/QC procedures (see Section 11.2).
- Performing proper sample custody (see Section 8.6).
- Performing proper data and information management (see Section 8.7).
- Verifying and validating data through regular data review.
- Assessing data usability (see Section 14).
- Conducting audits (see Section 12).

Following quality assessment, all data are given a three number quality description (QC code) and released for public use or removed from the data set. The first flag communicates whether the sample passes (2) or fails (1). A pass will keep the data moving to the next step of QC, a fail will result in the data being removed from the data set. Data not yet reviewed have a zero or none code (Table 14). The second flag communicates the reason behind the flags, for example a one means the sensor performance failed (Table 15). The third flag communicates where in the data review process the sample is. A two indicates the data has been reviewed and flags have been applied but have not yet been finalized (Table 16). In the end a data point with no issues would be flagged as 2_0_3.

Table 14. Data quality values.

This is the first character of our 3 character QC code applied to all data.

Data Quality Value	Definition	Description
0	NONE	Quality not yet determined
1	FAIL	Data fails QC - unacceptable
2	PASS	Data passes QC - acceptable

A quality flag is given to each data point in order to communicate any specific reason for the QC code. Also, quality assessment allows the MWM group to describe and quantify the accuracy and expected error associated with all marine data generated via lab analysis or through sensor operation.

Table 15. Reason behind data quality flags.

This is the second character of our three-character QC code applied to CTD data (numbers only) and laboratory data (letters only).

Data Quality Flag	Definition	Description
0	No Specification	No specific reason given for PASS or FAIL
1	Sensor/Equipment Performance	Inconsistent Instrument Performance
2	Procedure Modification	Data Collection Method Modified from Standard Procedures
3	Method Limitation	Method Limitation
4	Outlier	Discontinuous or Unexpected Single Result
5	Data Behavior	Unexpected or Unlikely Continuous Data Pattern
6	Out of Range	Data exceeds engineering range specified for instrument, valid range for datatype, range based on climatology or range that calculation should allow
7	Estimate/Missing Information	Result is an estimate or is missing underlying source or related information needed for validation.
8	Non-survey	Result, such as sensor equilibration data, collected during operations but not considered to be an ambient measurement.
9	Calculated	Data generated by calculation from other measurements.
JB	Blank contamination	Analyte found in blank
JE	Exceedance of calibration	Reported result is an estimate because it exceeds the calibration range
JH	Holding time exceedance	Analyzed past recommended holding time; recommended holding conditions not met
J	Estimate	The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample
JM	Method modification	Analysis or data collection method modified from routine practices
M	Missing result	Sample collected but lost in transit or lab; result not returned by lab
NAF	Not analyzed for	Not analyzed for
NC	Not calculated	Not calculated
R	Rejected	The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet quality control criteria. The presence or absence of the analyte cannot be verified.
U	Undetected	The analyte was not detected at or above the reported sample quantitation limit

Data Quality Flag	Definition	Description
UJ	Undetected, but limits insufficient to generate accurate results	The analyte was not detected at or above the reported sample quantitation limit. However, the reported quantitation limit is approximate and may not represent the actual limit of the of quantitation necessary to accurately measure the analyte in the sample.

At specific stages of assessment, data are given a quality assessment to denote the status of data in the QC and review process.

Table 16. Level of processing and quality control to which the data have been completed.

This is the third character of the 3-character QC code applied to all data.

Data Quality Assessment	Definition	Description
0	NONE	No quality control done.
1	PRELIMINARY	Automated processing done and initial value generated.
2	REVIEWED	Manually reviewed; data flags applied.
3	FINAL	Review Complete

The overall QA/QC objectives may change over time, depending on the monitoring plan, study design, or advancing technology in sensor and/or laboratory methods. Any changes are noted in annual updates to be published as an addendum to this plan. Specific routines and information for marine water column data quality control procedures can be found in Ecology's SOP EAP088 *Standard Operating Procedure for Marine Waters Data Quality Assurance and Quality Control,* (Bos and Albertson, in press), which will be updated every three years.

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. Staff and external lab analysts will follow prescribed procedures to resolve the problems. Options for corrective action may include:

- Retrieving missing information.
- Re-calibrating analytical instruments or sensors.
- Re-analyzing samples (must be done within holding time requirements and if sufficient volume remains).
- Modifying the analytical procedures.
- Collecting additional samples or taking additional field measurements.
- Qualifying results using QC codes.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Data and information management are critical to maintaining an efficient, organized, long-term monitoring system capable of generating high-quality, up-to-date, informative products for managers and scientists. Data used for analysis and reporting, and distributed to the public must pass all QA/QC tests. The MWM group has invested considerable resources in maintaining and updating data processing and storage structures to facilitate distribution of high-quality monitoring data and products. There are several levels of information management required in this system.

- Field, lab, and CTD data management (database of final data results which pass QA/QC).
- Document management (lists, SOPs, procedures, logs, forms).
- Original data file management (raw sensor and lab results).
- Analytical and QA/QC information management (summary statistics, calibration information, equations, and other analysis information).
- Reports, observations, and other products (analytical results, graphs, photos, video).

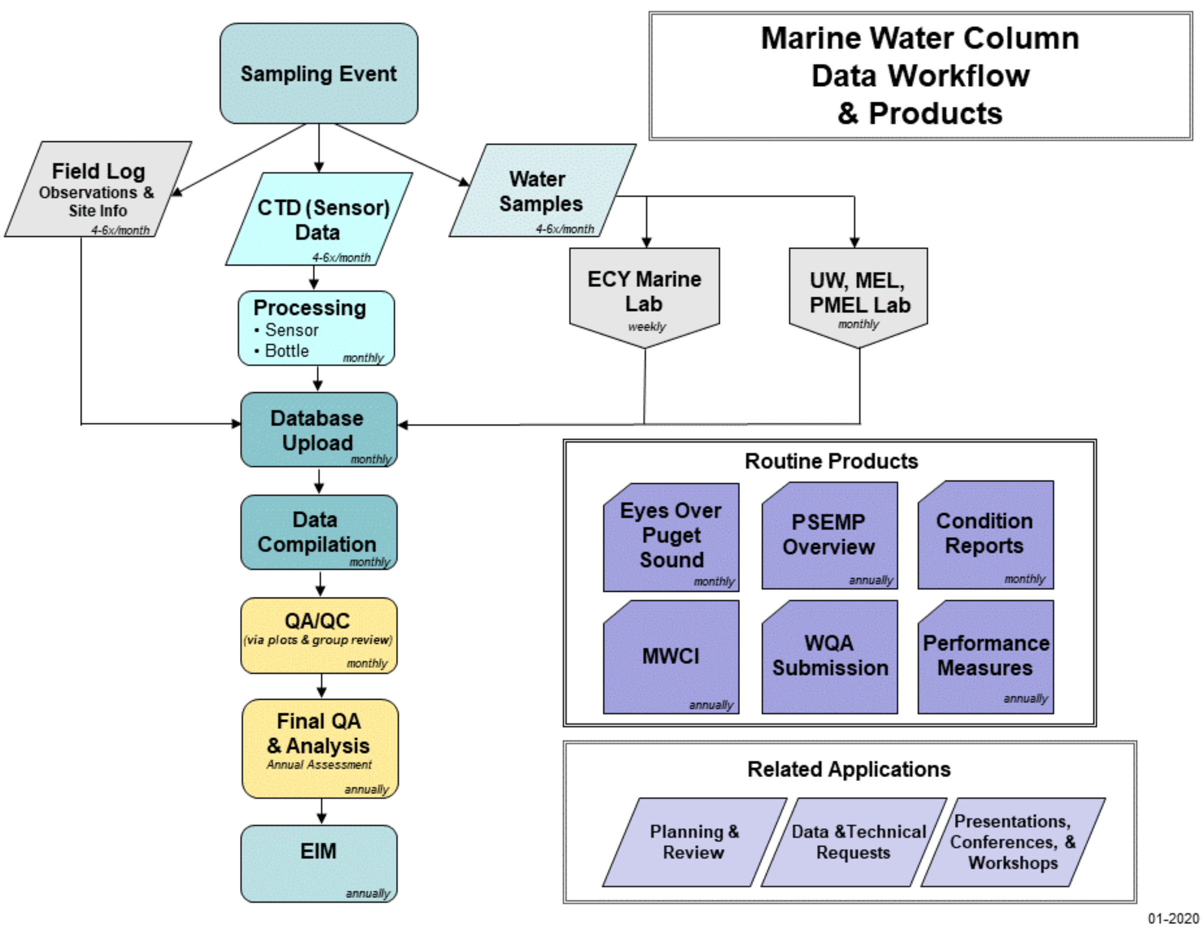

Figure 5. Overall organization of data workflow and products generated by the Marine Waters Monitoring group.

11.2 Laboratory data package requirements

Laboratory reports and results for marine water sample analysis performed by external labs are typically sent as files attached to email. These are reconciled and reviewed for completeness and by matches our records to the outside lab records. They are then loaded into the EAPMW internal data management system. Laboratory results generated by the internal Marine Monitoring Laboratory (MML) are entered into digital forms and stored on a secure network server. All digital raw data files are stored unchanged in folders organized by monitoring year. All laboratory results are reviewed, loaded into the EAPMW database, and further assessed using QA/QC procedures. All data are given a data quality assessment code of 3 when finalized.

All data from labs include:

- Raw data results for all parameters measured at each station in electronic format.
- Replicate sample results.
- A narrative or report with methods used, any problems with the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers.
- All associated QC results. This includes results for all required field and analytical (laboratory) control replicates, laboratory control (check) samples, reference materials or standards, and method blanks.
- Any qualification of the results.

Manchester Environmental Laboratory, UW MCL, PMEL, and Ecology's Marine Laboratory provide verified data packages for all data analyzed. Laboratories and contractors submit interim data packages including information for data verification to the monitoring coordinator.

All data received from external providers are verified and reviewed by MWM staff against the verification criteria listed. Any discrepancies are discussed with the laboratories or contractors for amendment. Once data have been reviewed and verified, MWM staff enter final QC information into the EAPMW database and finalize the data.

11.3 Electronic transfer requirements

All data is generated electronically and transferred in the form of various files such as spreadsheets, database forms, and instrument files converted to plain text formats. All data are transferred to a secure, shared network server within 24 hours of receipt or generation. Long-term marine monitoring information is organized in annual folders with subfolders organized by topic or data parameter type.

11.4 EIM/STORET data upload procedures

The MWM database (EAPMW) is a Microsoft SQL Server database, connected to Ecology's EIM data system. Data generated by the program are stored on EAPMW, then transferred to EIM. The data are considered provisional until all QA/QC activities have been completed successfully and given a data quality assessment value of 3. All data that pass QA/QC are finalized and stored in EIM for subsequent transfer to the US Environmental Protection Agency (EPA) Water Quality eXchange (WQX) database.

11.5 Model information management

NA

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

Data audits are conducted every month, on sensor and laboratory data once they have been processed and uploaded to the EAPMW database. Annual audits are conducted for every sampling year, once data have been finalized. These audits occur four to six months after the sampling year is completed.

To audit laboratory data, MWM technicians track and reconcile the status of samples being analyzed by the laboratories, being particularly alert to any significant QC problems that arise. Statistical calculations and plots of all the laboratory data collected during a sampling year that have pass codes are generated and reviewed several times a year by the MWM group.

To audit sensor data, MWM group use several levels of audits. The audits start in an Excel spreadsheet that has several automated audits build in. These tools track every data point that has been collected, reviewed, and given codes. The counts compiled in the Excel worksheet are then audited against what has been entered into the EAPMW database using R scripts. This conservation of data points ensures all data have been flagged appropriately and no data is overlooked or lost.

12.2 Responsible personnel

Table 17. Staff responsible for audits.

Marine Monitoring Staff	Title	Responsibilities
Christopher Krembs	Senior Oceanographer	Audits of historical sensor and laboratory data sets. Monthly participation in CTD data reviews. Monthly data statistical analysis of bath sensor assessment.
Skip Albertson	Physical Oceanographer	Monthly review of the CTD temperature, salinity, and density data. Routinely reviews boundary conditions, meteorological, and upwelling reports. Rotating data duties to run monthly audits at all stages of QC. Generates laboratory data plots as needed. Does variety of audits on an as-needed basis.
Julia Bos	Oceanographer	Business lead for marine waters data management with EAP Information Technology group; monthly review of CTD dissolved oxygen, and nitrate data. Rotating data duties to run monthly audits at all stages of QC. Conducts routine, historical, and current data audits; writes T-SQL scripts for database operations; leads routine data finalization work and special data QC & management projects.
Mya Keyzers	Marine Waters Field Lead	Monthly review of the CTD fluorescence data. Monthly checks of all the field and laboratory data. Supports variety of audits on an as-needed bases.
Elisa Rauschl	Marine Waters Field Scientist	Monthly review of the CTD transmissometer and turbidity data. Monthly checks of all the field and laboratory data. Supports variety of audits on an as-needed bases.
NRS2 - Ocean Acidification	Marine Field Scientist	Monthly review of the CTD pH data. Monthly checks of the TA/DIC field and laboratory data. Leads the QA/QC and audits of the TA/DIC data.

12.3 Frequency and distribution of reports

Monthly data summaries are reported in an online report titled "Eyes Over Puget Sound" (EOPS), approximately six to 12 times per year. Every effort is made to release this report within a week after the senior oceanographer conducts an EOPS aerial photographic survey.

Marine water quality conditions are considered a key indicator of Puget Sound ecosystem health so the MWM group reports changes in water quality conditions using the Marine Water Condition Index (MWCI), updated annually. The MWCI takes advantage of the long-term de-seasonalized dataset generated by the MWM program and uses monthly core station data to provide updates. The Puget Sound Partnership (PSP) has adopted Ecology's MWCI as one of its dashboard indicators. Ecology evaluates the MWCI for coastal bays as well as Puget Sound, using the same methodology.

The MWM group contributes several monitoring products to the annual Puget Sound Marine Waters Overview report. This report is a product of the Puget Sound Ecosystem Monitoring Program's Marine Waters Workgroup. The objective of this report is to collate and distribute physical, chemical, and biological information obtained from various marine monitoring and observing programs in Puget Sound. The report can be found at the PSEMP website.

The MWM group generates a variety of data summaries and presentations for the public, other scientists, Ecology management, and external agencies and groups, as well as for meetings and conferences.

12.4 Responsibility for reports

Table 18. Staff responsible for reports.

Marine Monitoring Staff	Title	Responsibilities
Christopher Krembs	Senior Oceanographer	EOPS author. Marine Water Condition Index (MWCI) lead author.
Skip Albertson	Physical Oceanographer	Contributing author to EOPS and the annual PSEMP report.
Julia Bos	Oceanographer	Contributing author to EOPS and the annual PSEMP report.

13.0 Data Verification

Data verification and review is conducted by the MWM group by examining all field and laboratory-generated data to ensure:

- Specified methods and protocols were followed.
- Data are consistent, correct, and complete, with no errors or omissions.
- Data specified in the Sampling Process Design section were obtained.
- Results for QC samples as specified in the Measurement Quality Objectives and Quality Control sections accompanying the sample results.
- Established criteria for QC results were met.
- Data qualifiers (QC codes) are properly assigned.

13.1 Field data verification, requirements, and responsibilities

Throughout field sampling, the lead technician and all crew members are responsible for carrying out station-positioning, sample-collection, and sensor deployment procedures as specified. Additionally, technicians systematically review all field documents (such as field logs, chain-of-custody sheets, and sample labels) to ensure data entries are consistent, correct, and complete, with no errors or omissions. A second staff person always checks the work of the staff person who primarily collected or generated data results.

13.2 Laboratory data verification

Lab technicians verify sample and data disposition by conducting continual tracking and reconciliation procedures. A second staff person always checks the work of the staff person who primarily collected or generated data results.

13.3 Validation requirements, if necessary

On an ongoing monthly basis, the MWM group meets and performs a group review of all raw and processed data and data uploaded to the EAPMW database, by reviewing plots and statistical summaries of data. Staff members individually review various data sets, documenting problems and applying QC qualifier codes as necessary. All flagged data are presented, reviewed, and discussed by several MWM group staff members and either removed from the data set or released for public use with a data quality code. Once the sampling year is complete, all reviewed data are re-assessed in the context of the annual summary and then finalized once all QA, QC, and validation procedures are complete.

13.4 Model quality assessment

NA

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The CTD data that have made it through the preliminary level of quality assessment (pre-processed data) move on in the QA process. Then every CTD variable is reviewed on a monthly bases using interquartile range (IQR) plots. At the end of this process the CTD data is assigned thre quality description values, communicating the result of the data quality assessment (section 10.0). The laboratory data that have passed the preliminary level of quality assessment reviews of the field form data entry, Chain of Custody tracking, data analysis sheets, and upload template processes also move on in the QA process.

The final data review happens quarterly or bi-annually as workloads allow. This final level of checks uses historical data to create a statistical envelope on which the current data are plotted. As the year goes on the graphs are updated and the seasonal context provides more context for determining whether the data will either be accepted, accepted with qualification, or rejected. If MQOs were not met, the MWM group will discuss whether corrective actions can be taken or whether the data will be rejected (see tables 13-15).

14.2 Treatment of non-detects

A general practice for data management is that results or concentrations between the method detection limit (MDL) and the reporting limit are reported as detected but not quantified, due to the potential for misuse or misinterpretation of low-level data which has relatively large uncertainty and can bias data interpretations.

For the Long-term MWM Program, data results or concentrations of all analytes reported between the MDL and reporting limit are quantified and annotated with a J qualifier (estimated concentration; see Table 14); this indicates a higher level of uncertainty in the quantitative value. Statistical evaluations of data with high uncertainties can lead to erroneous conclusions, especially if the sample populations are limited in size or have high percentages of non-detects.

For lab data, the only sample results considered detected are those quantified at concentrations at least three times greater than the corresponding results in the method blank and in the field blank samples. Sample results that are not at least three times greater than the corresponding results in the method blank are qualified with a U to indicate not detected (see Table 14). Sample results that are not at least three times greater than the corresponding results in the field or reagent blank samples are qualified with a JB to indicate not detected due to contamination of the field or reagent blank.

14.3 Data analysis and presentation methods

Processing and managing all sensor data involves many procedures and calculations, performed at different steps and levels in the data management system. These procedures are constantly being updated and improved as sensor technology evolves and national standards are established. The specific procedures and calculations used for processing marine water column data are documented in Ecology's Standard Operating Procedure for Marine Waters Data Quality Assurance and Quality Control, (Bos and Albertson, in press).

At a descriptive level, CTD data are downloaded in the field, immediately after collection, and are stored on a field laptop. Raw (unprocessed) data files are named with the date and station name. Staff transfer data files to a secure network drive when they return from the field. Data processing of the raw electronic data is performed using MatLab software scripts based on or using recommended routines designed by Sea-Bird Electronics, which incorporate standard oceanographic methods (UNESCO, 1994).

Once CTD data are processed, they are automatically loaded to the EAPMW database, where QA/QC assessments are performed. These data are plotted in standardized templates, including vertical profile plots of all sensor data, with statistical context of historical data ranges, then reviewed and given a final quality assessment. Each data result is given a final QC code based on passing or failing the QA/QC assessment.

Site-specific statistical evaluation of water column data is conducted every month by the MWM group. The interquartile ranges of historical results for each station and each depth are calculated and compared to the current monthly data. An example of this type of plot is shown in Figure 6. Data significantly higher or lower than the historical ranges are automatically flagged and reviewed. To determine significant trends, data sets are de-seasonalized using site-specific historical monthly data based on the data from 1999 to the present. Heat maps are used to describe the volume of data and to communicate long-term monitoring results.

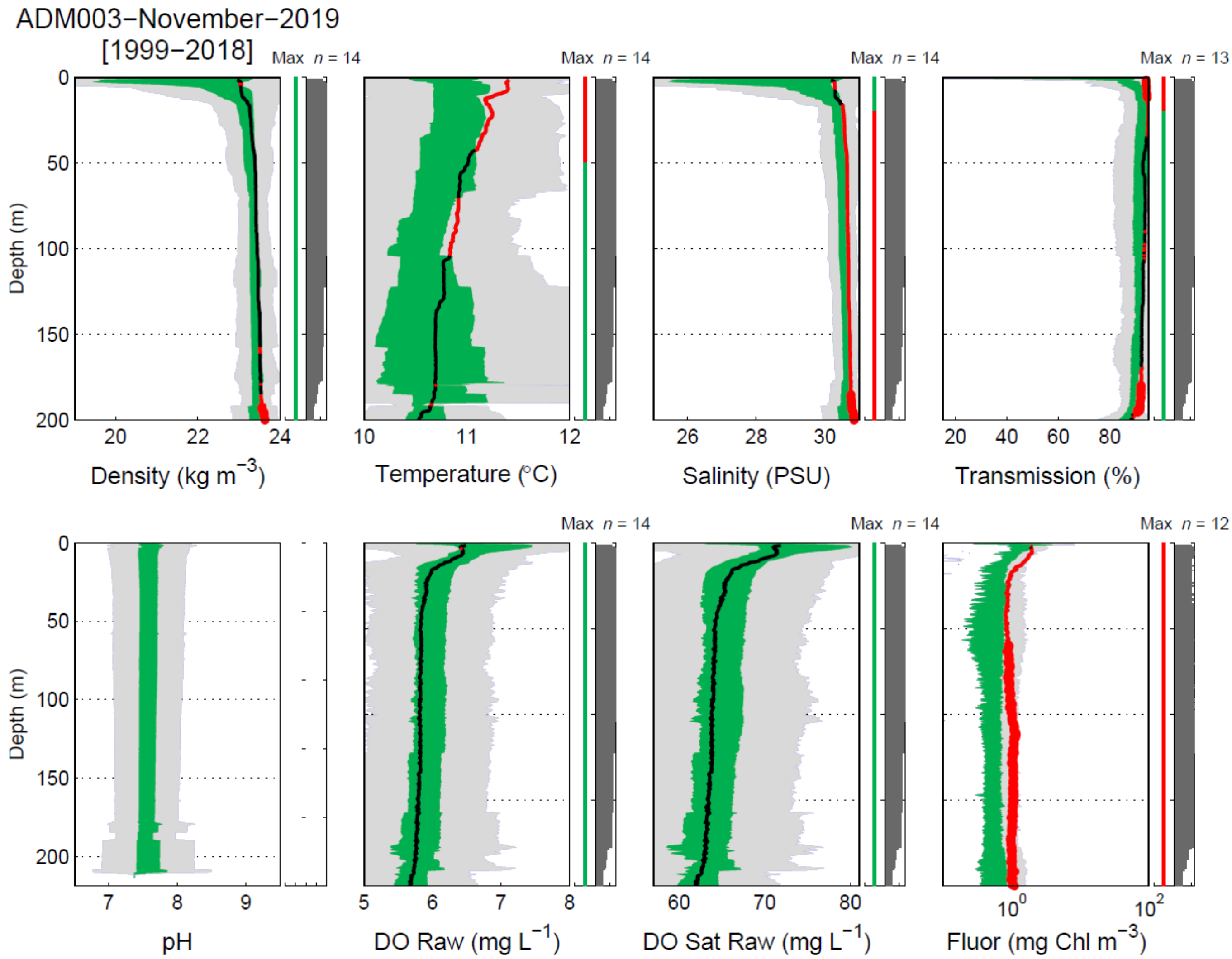

Figure 6. Site-specific monthly CTD data plotted in the context of interquartile ranges based on historical results, grouped by station and month.

Further analysis to detect significant changes in water quality is performed via mathematical and other statistical analyses of the data. Non-parametric tests of the data are predominantly used to further interpret oceanographic influences and processes. Non-parametric analysis was specifically chosen because water quality parameters collected at random do not display a normal frequency distribution. The dataset may include some of the following attributes which must be considered when conducting statistical analysis:

- Missing data.
- Values near or below laboratory detection limits.
- Weather events that may cause anomalous values.
- Laboratory method changes.
- Field sampling and data collection method changes.
- Personnel changes.
- Equipment malfunctions.

The MWM group evaluates trends for the year 1999 and beyond; that is when laboratory methods and field collection methods were standardized against standard oceanographic procedures. Since 1999, consistent methods and protocols allow for the assessment of long term status and trends for measured variables.

14.4 Sampling design evaluation

The sampling design is effective for continuity of a long-term data set. The sample design is evaluated based on the success of station attainment, and data collection to inform MWM's strategy for tracking status and trends of Puget Sound's water quality. If meaningful conclusions can be drawn from the data, the sample design will be considered effective.

14.5 Documentation of assessment

Data and analytical results are annually reported in the PSEMP Marine Waters report and through the Marine Water Quality Index, a vital sign for the Puget Sound Partnership.

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16.0 Appendices

Appendix A. 2020 Station list and route plan

Table A-1. 2020 Stations organized by route, including latitude and longitude, depth, record length, and justification.

Regional Survey	Station ID	Location	Lat. N NAD83 (deg/dec_min)		Long. W (NAD83) (deg/dec_min)		WQMA	Depth (m)	Record	Record Length (yrs)	Justification
Coast	**GYS008**	Mid-S. Channel	46	56.2388	123	54.7934	Western Olympic	6	1974 - 76, 1983 - present	39	represents mid Grays Harbor, south
	GYS016	Damon Point	46	57.2053	124	05.5770	Western Olympic	11	1982 - 1987,1991 - present	33	represents outer Grays Harbor, north
	WPA004	Toke Point	46	41.9800	123	58.1240	Lower Columbia	14	1973-1975, 1977-present	45	represents north Willapa Bay
	WPA113	Bay Center	46	38.6400	123	59.5800	Lower Columbia	11	1997-2000, 2006-present	16	represents mouth of (NW) Willapa Bay
	WPA006	Nahcotta Channel	46	32.7226	123	58.8097	Lower Columbia	21	1991-present	28	represents central Willapa Bay
	WPA007	Long Island, S. Jenson Pt.	46	27.1893	124	00.5672	Lower Columbia	14	1991-2008, 2013-present	23	represents SW Willapa Bay
	WPA008	Naselle River mouth	46	27.7890	123	56.4760	Lower Columbia	14	1996-2008, 2013-present	18	represents SE Willapa Bay, off Naselle R.
	WPA003	Willapa River, John. Slough	46	42.2392	123	50.2431	Lower Columbia	10	1973-present	46	represents north Willapa Bay, off Willapa R.
Hood Canal	**HCB007**	Hood Canal, Lynch Cv.	47	23.8889	122	55.7755	Kitsap & E. Olympic	21	1990-1996, 1998-2007, 2011-present	25	very low DO, assess duration & coverage
	HCB004	Hood Canal, Sisters Pt.	47	21.3723	123	01.4924	Kitsap & E. Olympic	55	1975-1987, 1990-present	42	represents southern Hood Canal
	HCB003	Hood Canal, Eldon	47	32.2722	123	00.5760	Kitsap & E. Olympic	144	1976-92, 1994-96, 1998-2007, 2010-present	38	very low DO, assess duration & coverage
	HCB010	Hood Canal, S of Bangor	47	40.2000	122	49.2000	Kitsap & E. Olympic	100	2005-present	14	represents northern Hood Canal
South	**BUD005**	Budd Inlet	47	05.5224	122	55.0918	Eastern Olympic	15	1973-present	44	represents waters off city of Olympia
	DNA001	Dana Passage	47	09.6890	122	52.3083	Eastern Olympic	40	1984-85, 1989-present	32	represents south reach of Southern Puget Sound
	NSQ002	Devil's Head	47	10.0390	122	47.2914	E. Oly & Kitsap & SPS	100	1984-85, 1996-present	25	represents S. Puget Sound near Nisqually
	GOR001	Gordon Point	47	10.9891	122	38.0743	E. Oly & Kitsap & SPS	160-170	1996-present	22	represents S. Puget Sound south of Narrows
	CRR001	Carr Inlet	47	16.5891	122	42.5745	Eastern Olympic	95	1977-93, 95-96, 1998-2003, 2006,09-present	35	represents waters within Carr Inlet
	CSE001	Case Inlet	47	15.8724	122	50.6583	Eastern Olympic	55	1978-1993, 95-96,1998-99, 2009-present	30	represents waters within Case Inlet

Regional Survey	Station ID	Location	Lat. N NAD83 (deg/dec_min)		Long. W (NAD83) (deg/dec_min)		WQMA	Depth (m)	Record	Record Length (yrs)	Justification
	OAK004	Oakland Bay	47	12.8056	123	04.6590	Eastern Olympic	15	1974-75, 1977-present	44	represents waters off city of Shelton
Central	**OCH014**	Brownsville	47	40.2924	122	35.9712	Bainbridge Basin	20	2019-present	1	represents outer Dyes Inlet
	ADM003	S. of Admiralty Inlet	47	52.7390	122	28.9917	Kitsap & Cedar/Green	210	1988-1991, 1996-present	25	represents waters S. of Admiralty sills
	PSB003	Puget Snd. Main Basin	47	39.5891	122	26.5745	Kitsap & Cedar/Green	40-50	1976-present	43	represents Puget Sound Main Basin
	SIN001	Sinclair Inlet	47	32.9557	122	38.6083	Kitsap	16	1973-1987, 1991-present	42	represents waters off city of Bremerton
	ELB015	Elliott Bay	47	35.7892	122	22.1743	Cedar/Green	82	1991-present	28	represents waters off city of Seattle
	EAP001	East Passage	47	25.0226	122	22.8241	Kitsap & Cedar/Green	200	1988-1991, 94-95, 1997-present	27	represents S. Puget Sound main axis
	CMB003	Commencement Bay	47	17.4226	122	27.0074	South Puget Sound	150	1976-present	43	represents waters off city of Tacoma
Admiralty Inlet	**PTH005**	Port Townsend	48	04.9889	122	45.8767	Eastern Olympic	26	1977-1978, 1991-2002, 2005-present	28	represents waters off city of Port Townsend
	ADM001	Admiralty Inlet	48	01.7888	122	37.0760	Kitsap & Cedar/Green	148	1975-1987, 1992-present	39	represents waters within Admiralty Inlet
	ADM002	N. of Admiralty Inlet	48	11.2391	122	50.5770	Island & E. Olympic	82	1980-present	38	represents waters entering Admiralty Inlet
	SKG003	Skagit Bay	48	17.7893	122	29.3763	Island/Snohomish	24	1990-1991, 1994-1998, 2007-present	19	represents Whidbey Basin
	SAR003	Saratoga Passage	48	06.4557	122	29.4925	Island/Snohomish	149	1977-present	42	represents Whidbey Basin
	PSS019	Possession Sound	48	00.6556	122	18.0750	Island/Snohomish	101	1980-present	39	represents waters off city of Everett
North	**BLL009**	Bellingham Bay	48	41.1564	122	35.9771	Nooksack/San Juan	16	1977-present	42	represents waters off city of Bellingham
	BLL040	Bellingham Bay	48	41.0382	122	32.2920	Nooksack/San Juan	26	2016-present	31	represents waters off city of Bellingham
San Juan Islands	**SJF000**	Strait of Juan de Fuca	48	25.0000	123	01.5000	S. of San Juan Island	180	2000 - present	19	represents northern Strait of Juan de Fuca
	SJF001	Strait of Juan de Fuca	48	20.0000	123	01.5000	SE of Hein Bank	160	2000 - present	19	represents central Strait of Juan de Fuca
	SJF002	Strait of Juan de Fuca	48	15.0000	123	01.5000	SW of Eastern Bank	145	2000 - present	19	represents southern Strait of Juan de Fuca
	RSR837	Rosario Strait	48	36.9896	122	45.7775	Nooksack/San Juan	56	2009-present	10	represents waters in Rosario Strait
	GRG002	Strait of Georgia	48	48.4896	122	57.2446	Nooksack/San Juan	190	1988-present	31	represents Strait of Georgia end member

Table A-2. 2020 Station list organized by route showing sample type, depth collected, daily and monthly totals.

Station	Nutrients	Chlorophyll	POC & PN	TOC	TN	TA/DIC	PreSens DO	Zooplankton	Salinity	Approximate Station Depth (m)
Coast										
GYS008	0	0								6
GYS016	0, 10	0, 10					NB			11
WPA004	0, 10, 10, 10	0, 10, 10, 10								14
WPA113	0, 10	0, 10								11
WPA006	0, 10	0, 10					NB			21
WPA007	0, 10	0, 10								14
WPA008	0, 10	0, 10								14
WPA003	0, 10	0, 10					NB			10
Total Samples:										
8	**17**	**17**	0	0	0	0	**3**	**0**	**0**	
North	**Nutrients**	**Chlorophyll**	**POC & PN**	**TOC**	**TN**	**TA/DIC**	**Dissolved Oxygen**	**Zooplankton**	**Salinity**	**Approximate Station Depth (m)**
BLL009	0, 10, NB	0, 10	10, NB	10, NB	10, NB	0				16
BLL040	0, 10, NB		10, NB	10, NB	10, NB					26
Total Samples:										
2	**6**	**2**	**4**	**4**	**4**	**1**	0	0	0	
Central	**Nutrients**	**Chlorophyll**	**POC & PN**	**TOC**	**TN**	**TA/DIC**	**Dissolved Oxygen**	**Zooplankton**	**Salinity**	**Approximate Station Depth (m)**
OCH014	0, 10, NB		10, NB	10, NB	10, NB		NB			20
ADM003	0, 10, 30, NB	0, 10, 30	10, NB	10, NB	10, NB	0, 30			-	210
PSB003	0, 10, 30, NB	0, 10, 30	10, NB	10, NB	10, NB	0, 30				40-50
SIN001	0, 10, NB	0, 10	10, NB	10, NB	10, NB					16
ELB015	0, 10, 30, NB	0, 10, 30	10, 10, NB	10, 10, NB	10, 10, NB	0, 30	NB			82
EAP001	0, 10, 30, NB	0, 10, 30	10, NB	10, NB	10, NB	0, 30				200
CMB003	0, 0, 0, 10, 30, NB	0, 0, 0, 0, 30	10, NB	10, NB	10, NB	0, 30	NB			150
Total Samples:										
7	**28**	**19**	**15**	**15**	**15**	**10**	**3**	0	**0**	

Station	Nutrients	Chlorophyll	POC & PN	TOC	TN	TA/DIC	PreSens DO	Zooplankton	Salinity	Approximate Station Depth (m)
South Sound	**Nutrients**	**Chlorophyll**	**POC & PN**	**TOC**	**TN**	**TA/DIC**	**Dissolved Oxygen**	**Zooplankton**	**Salinity**	**Approximate Station Depth (m)**
BUD005	0, 10, NB	0, 10, NB	10, NB	10, NB	10, NB	0	NB			15
DNA001	0, 10, 30	0, 10, 30				0, 30				40
NSQ002	0, 10, 30, NB	0, 10, 30	10, NB	10, NB	10, NB	0, 30				100
GOR001	0, 10, 30, NB	0, 10, 30	10, NB	10, NB	10, NB		NB			160-170
CRR001	0, 10, 30, NB	0, 10, 30	10,10, NB	10,10, NB	10,10, NB	0, 30				95
CSE001	0, 10, 30, NB	0, 10, 30	10, NB	10, NB	10, NB	0, 30	NB			55
OAK004	0, 10, 10, 10	0, 10, 10, 10				0, 0			0, 0	15
Total Samples:										
7	**26**	**21**	**11**	**11**	**11**	**11**	**3**	0	**2**	
Hood Canal	**Nutrients**	**Chlorophyll**	**POC & PN**	**TOC**	**TN**	**TA/DIC**	**Dissolved Oxygen**	**Zooplankton**	**Salinity**	**Approximate Station Depth (m)**
HCB007	0, 10, NB	0, 10	10,10, NB	10,10, NB	10,10, NB					21
HCB004	0, 10, 10, 10 30	0, 10, 10, 10 30				0, 30, 30		✓	30, 30	55
HCB003	0, 10, 30, NB	0, 10, 10, 10	10, NB	10, NB	10, NB		NB	✓		144
HCB010	0, 10, 30, NB	0, 10, 30	10, NB	10, NB	10, NB		NB			100
Total Samples:										
4	**16**	**12**	**7**	**7**	**7**	**2**	**2**	**2**	**2**	
San Juan Islands	**Nutrients**	**Chlorophyll**	**POC & PN**	**TOC**	**TN**	**TA/DIC**	**Dissolved Oxygen**	**Zooplankton**	**Salinity**	**Approximate Station Depth (m)**
SJF000	0, 30, 80, 140	0, 30, 80, 140					NB			161
SJF001	0, 30, 80, 140	0, 0, 0, 30, 80, 140								144
SJF002	0, 30, 80, 140, 140, 140	0, 30, 80, 140				0, 30		✓		142
RSR837	0, 10, 30	0, 10, 30				0, 30	NB			56
GRG002	0, 10, 30	0, 10, 30				0, 0, 30	NB		0, 0, 30	190
Total Samples:										

Station	Nutrients	Chlorophyll	POC & PN	TOC	TN	TA/DIC	PreSens DO	Zooplankton	Salinity	Approximate Station Depth (m)
5	**20**	**20**	0	0	0	**7**	**3**	**1**	**3**	
Admiralty Inlet	**Nutrients**	**Chlorophyll**	**POC & PN**	**TOC**	**TN**	**TA/DIC**	**Dissolved Oxygen**	**Zooplankton**	**Salinity**	**Approximate Station Depth (m)**
PTH005	0, 10, 10, 10	0, 10, 10, 10								26
ADM001	0, 10, 30	0, 10, 30								148
ADM002	0, 10, 30, 80	0, 30, 80				0, 30	NB			82
SKG003	0, 10, NB	0, 10	10, 10, NB	10, 10, NB	10, 10, NB	0, 0			0, 0, 30	24
SAR003	0, 10, 30, NB	0, 10, 30	10, NB	10, NB	10, NB	0, 30	NB			149
PSS019	0, 10, 30	0, 10, 30	10, NB	10, NB	10, NB	0, 30	NB			101
Total Samples:										
6	**21**	**18**	**7**	**7**	**7**	**9**	**3**	0	**3**	
Monthly Total:										
Station Count	**Nutrients**	**Chlorophyll**	**POC & PN**	**TOC**	**TN**	**TA/DIC**	**Dissolved Oxygen**	**Zooplankton**	**Salinity**	**Approximate Station Depth (m)**
39	**134**	**109**	**44**	**44**	**44**	**40**	**17**	**3**	**10**	**NA**

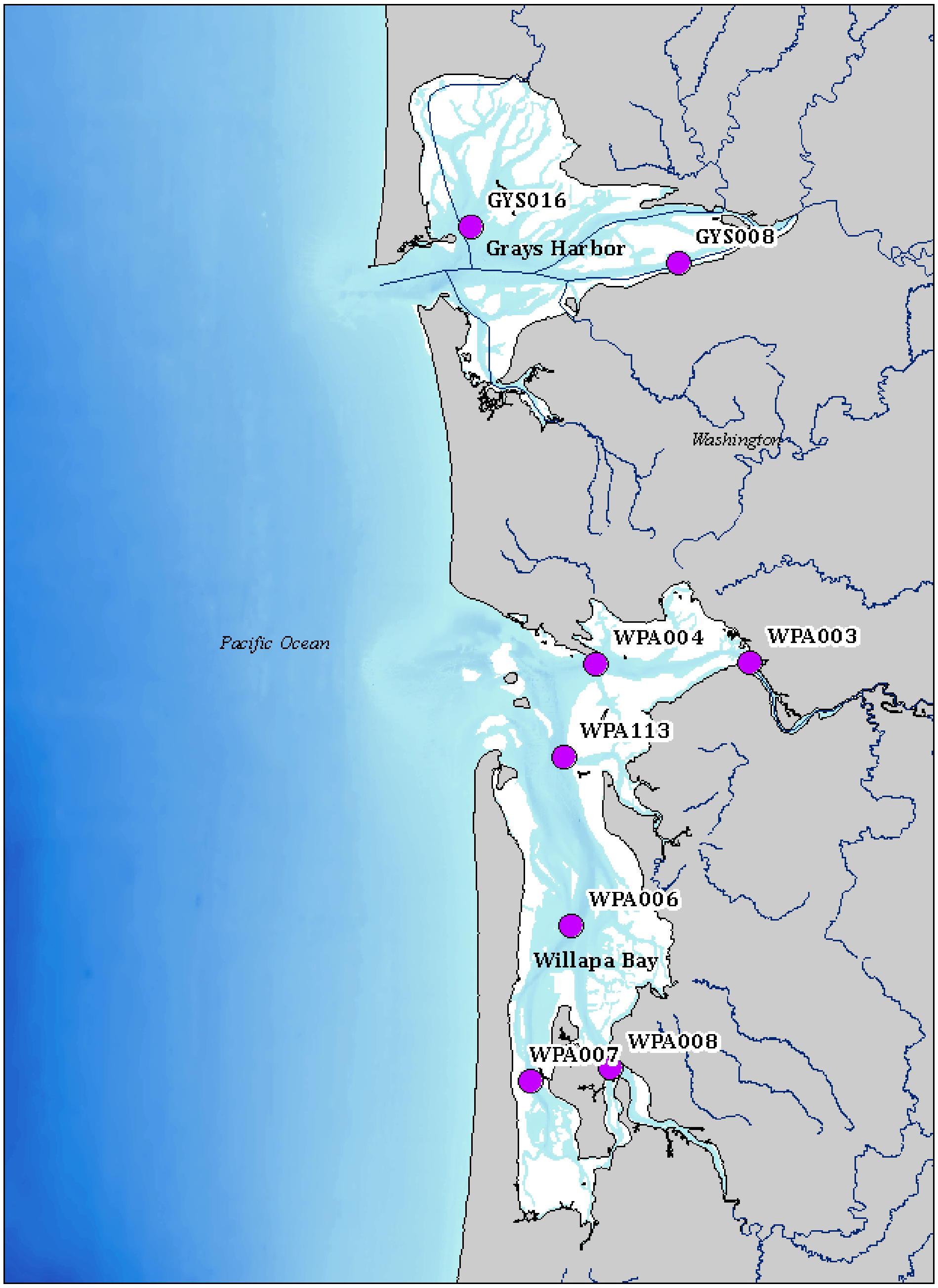

Figure A-1. 2020 Coast route map with stations (purple circles).

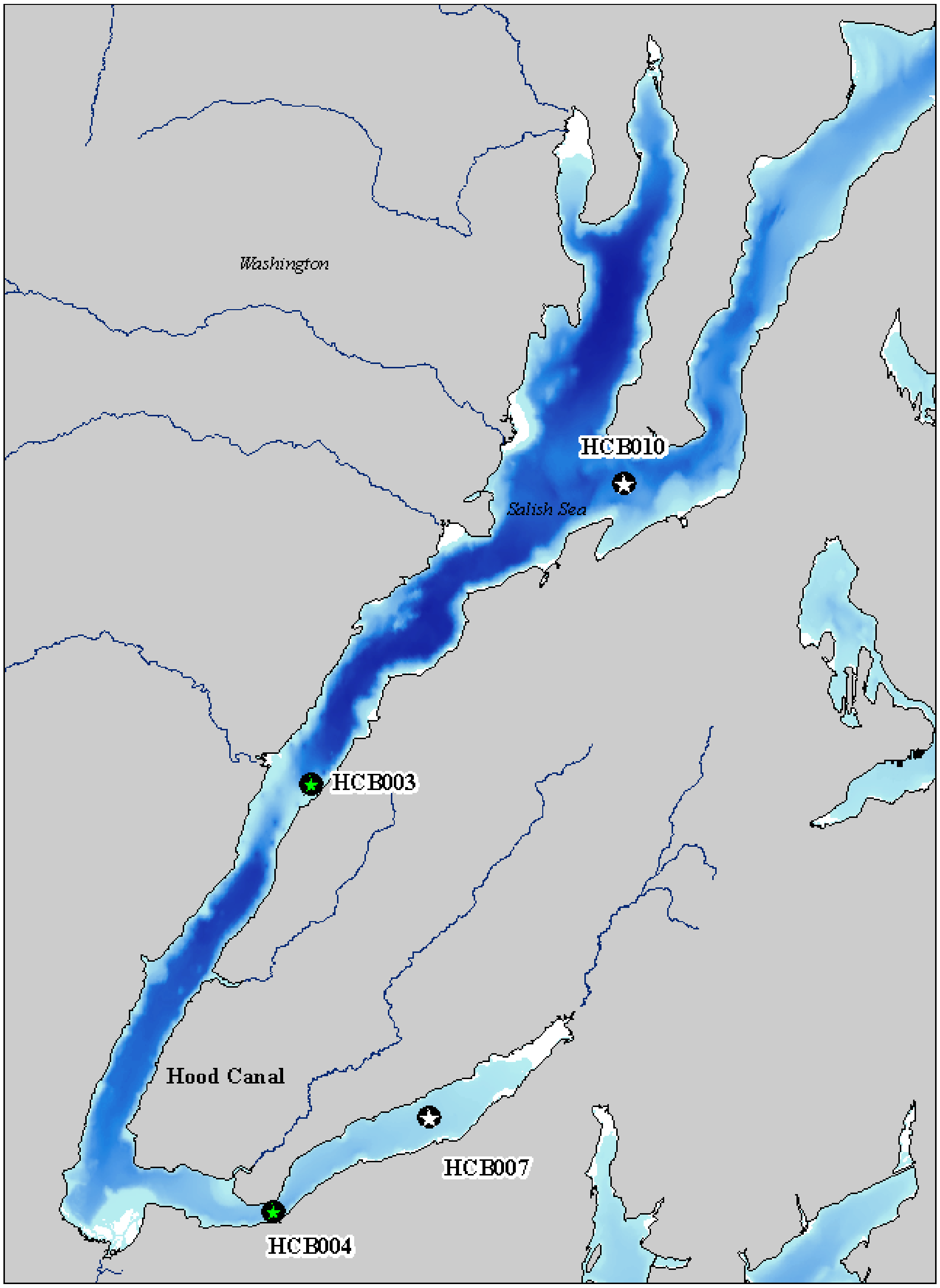

Figure A-2. 2020 Hood Canal route map with stations (black circles).

Stations marked with a white star indicate particulate samples are collected there and stations with a green star indicate a zooplankton tow is collected there.

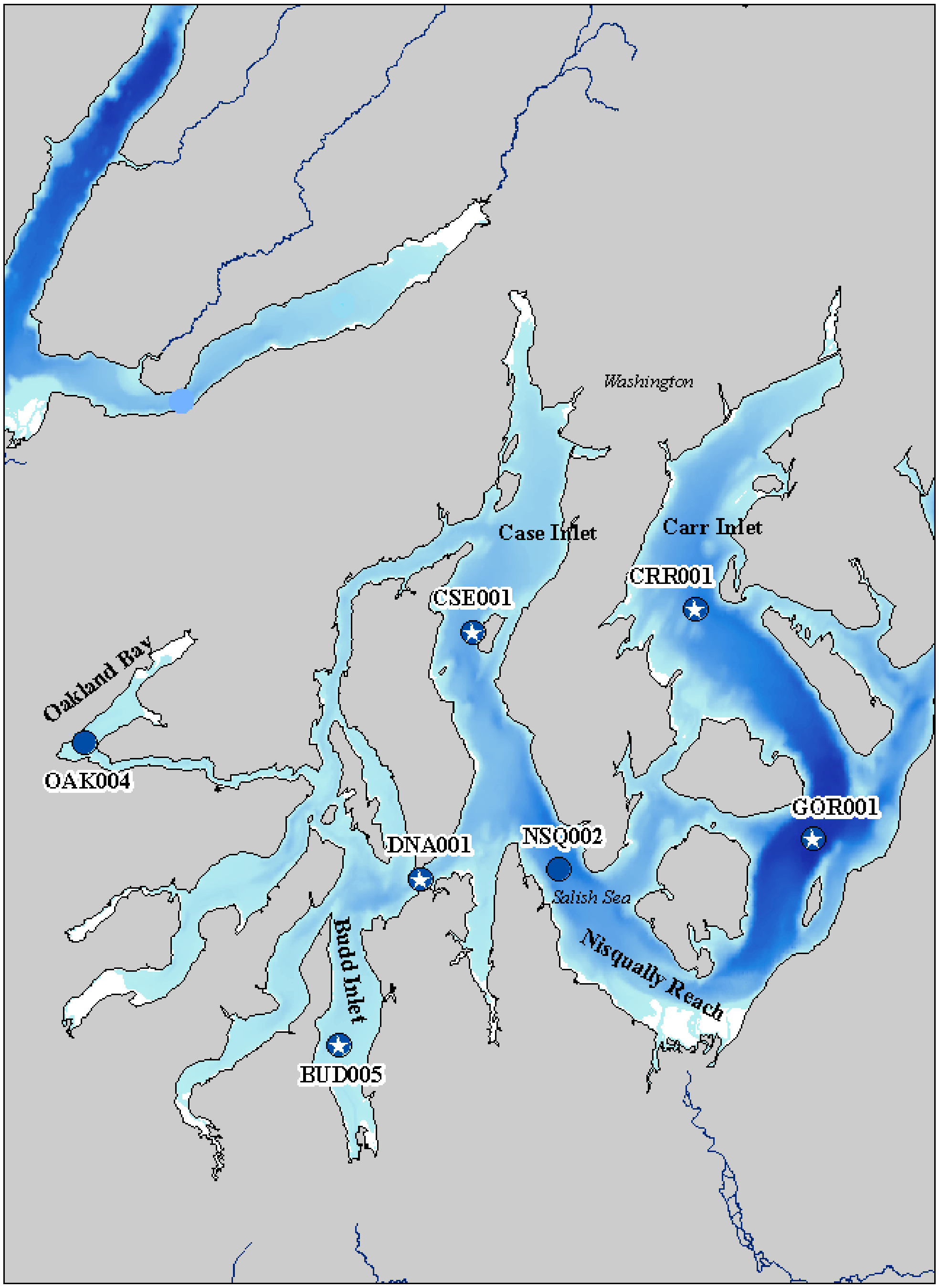

Figure A-3. 2020 South Sound route map with stations (blue circles).

Stations marked with a white star indicate particulate samples are collected there.

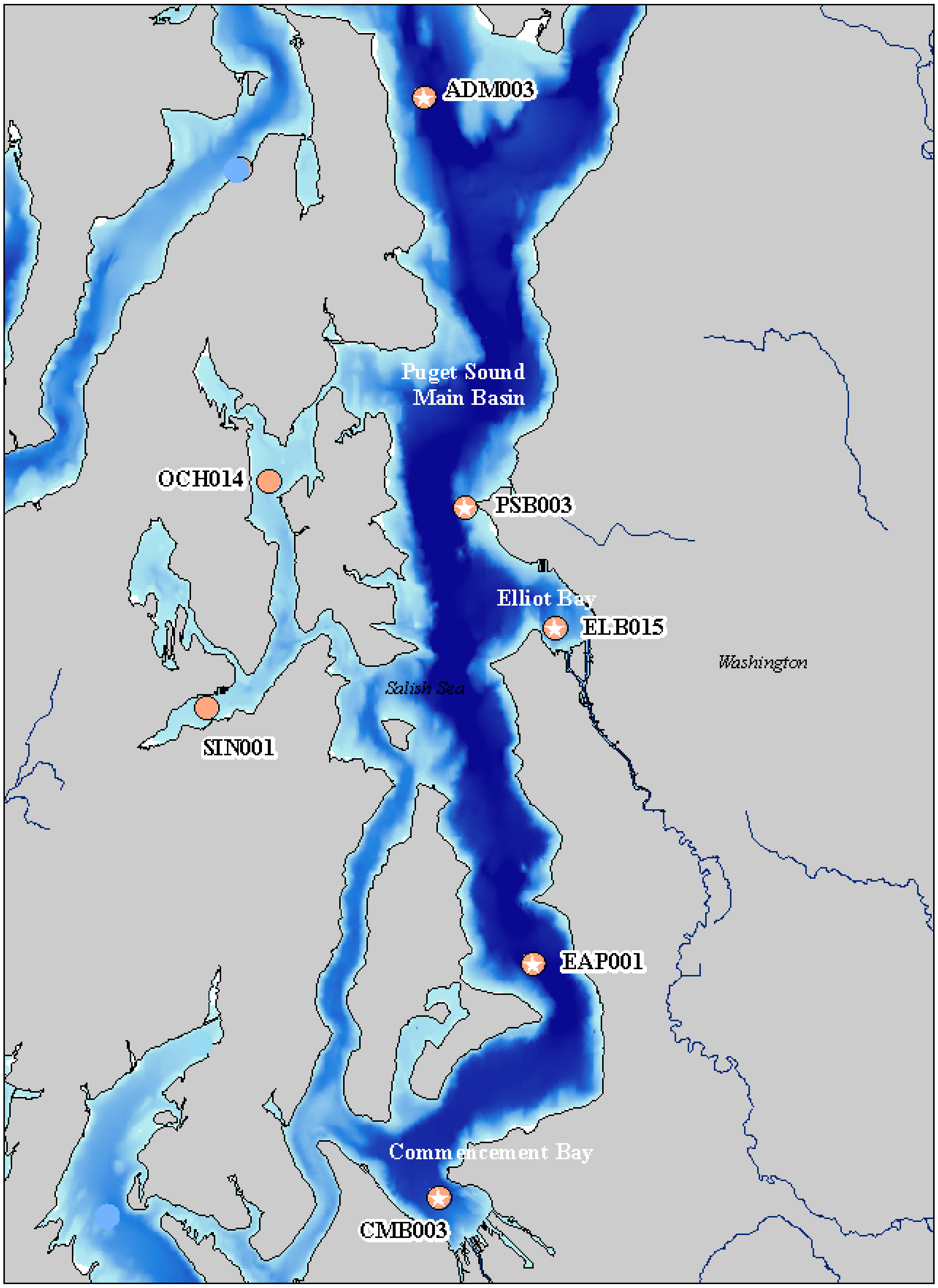

Figure A-4. 2020 Central Sound route map with stations (orange circles).
Stations marked with a white star indicate particulate samples are collected there.

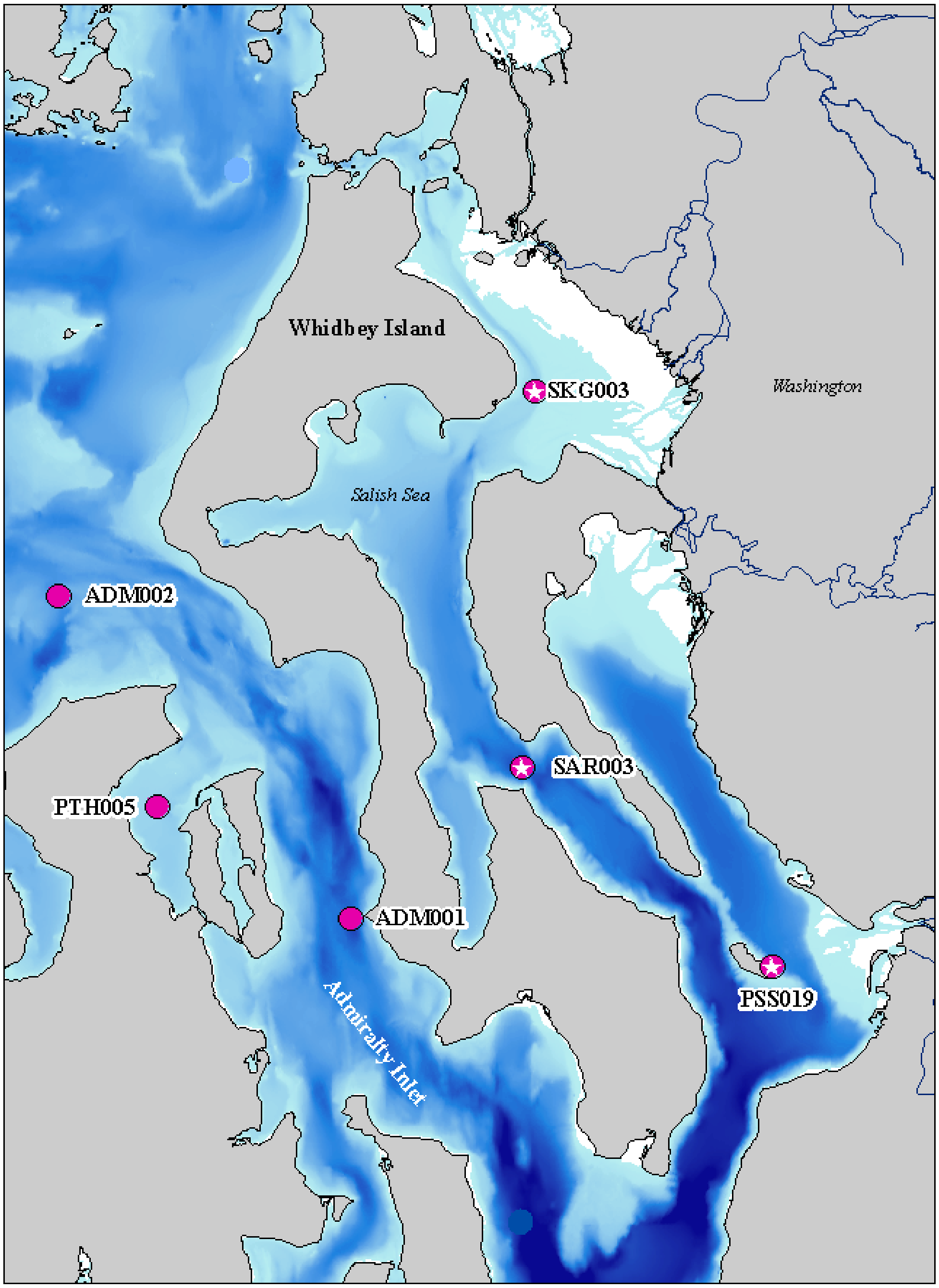

Figure A-5. 2020 Admiralty Inlet route map with stations (dark pink circles). Stations marked with a white star indicate particulate samples are collected there.

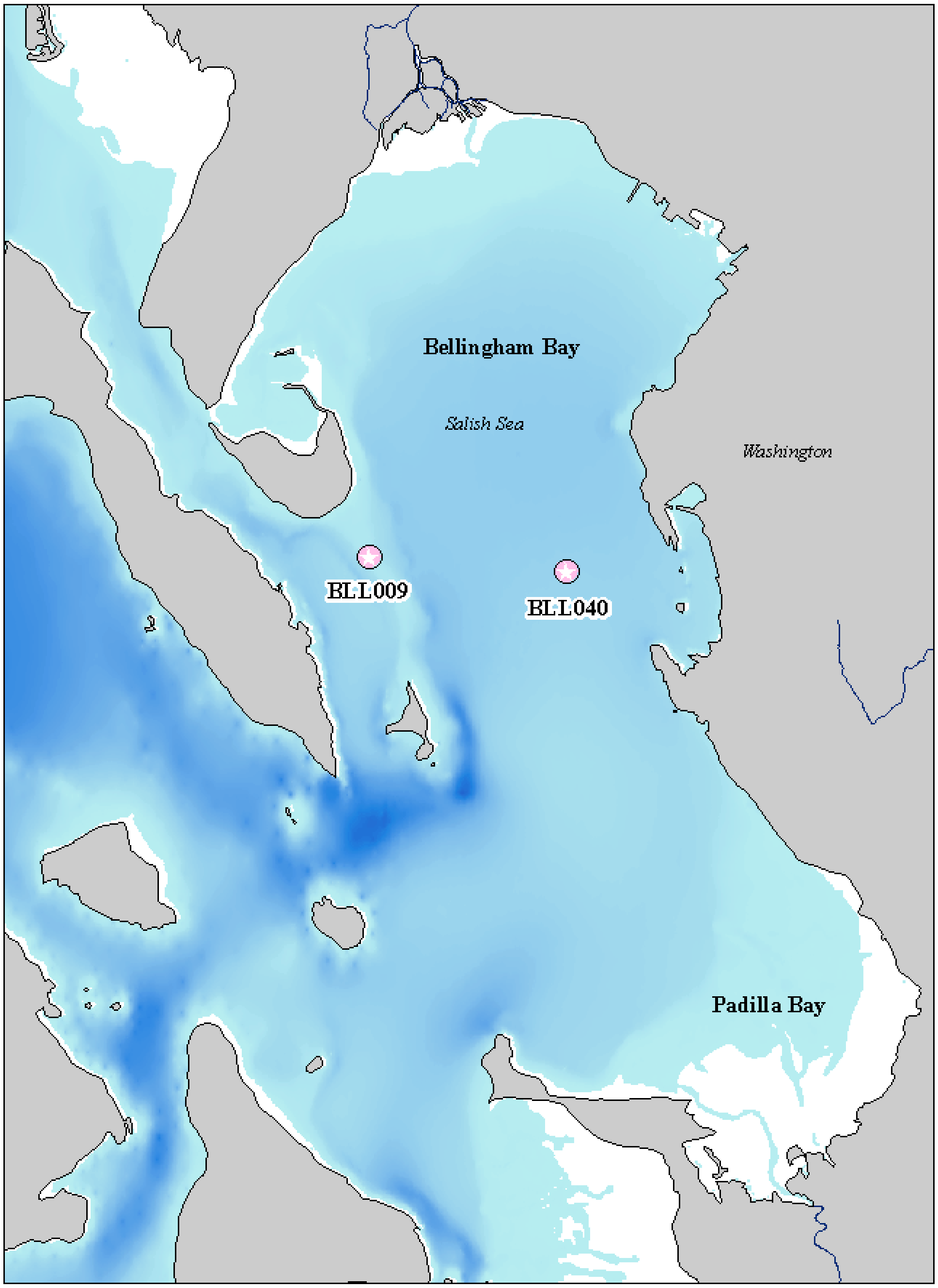

Figure A-6. 2020 North sound map with stations (pink circles).

Stations marked with a white star indicate particulate samples are collected there.

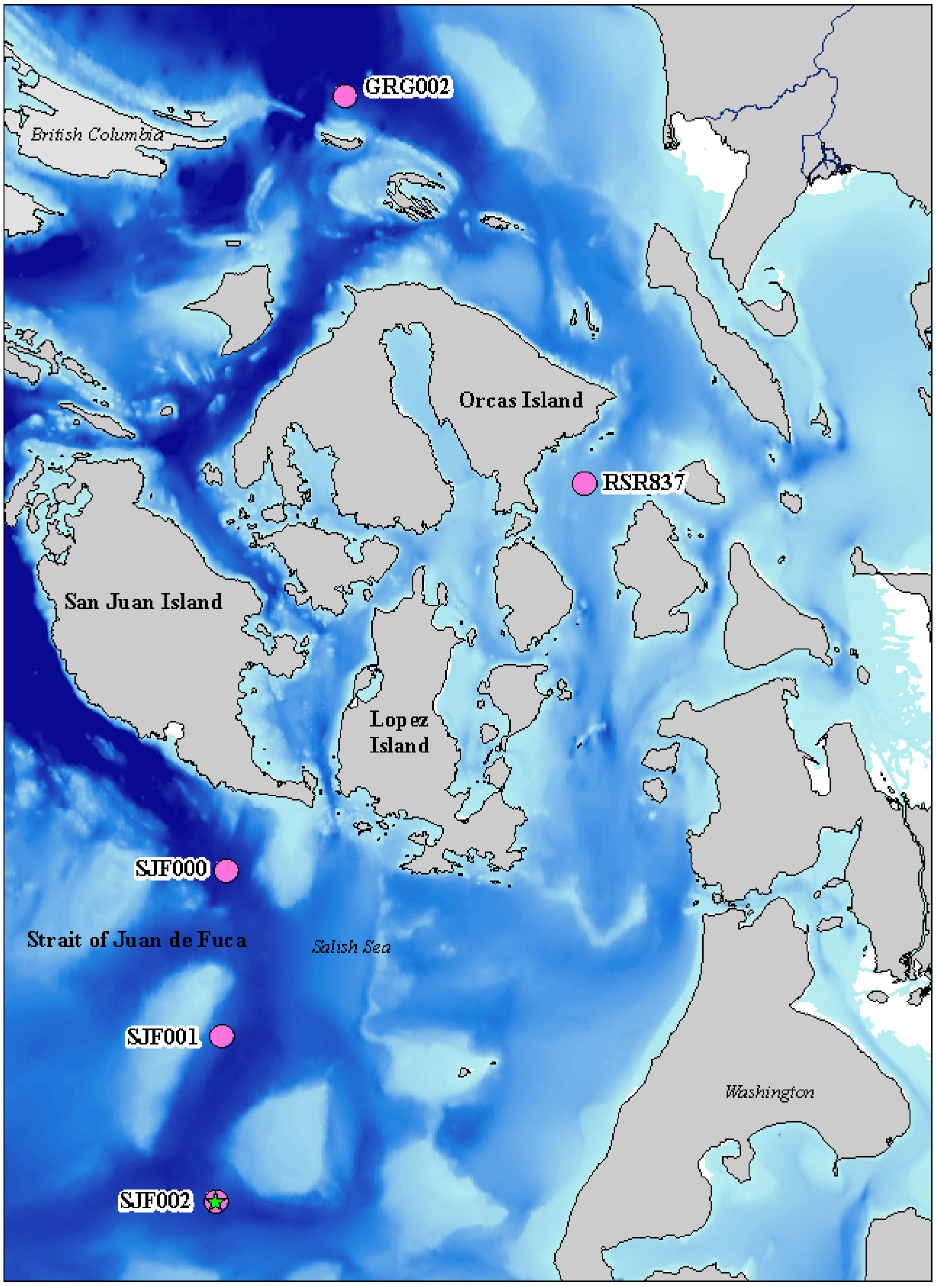

Figure A-6. 2020 JEMS route map with stations (pink circles).

Stations marked with a green star indicate zooplankton tows are collected there.

Appendix B. 2020 Station list and route plan.

Figure B-1. Ocean Acidification Monitoring at Ecology's Greater Puget Sound Stations Waiver Required Use of Accredited Lab.

Department f Ecology

Request to Waive Required Use of Accredited Lab

Use form ECY 070-152a for a waiver for Microbial Source Tracking (MST)

Reference: Executive Policy 22-02

Date:	9/11/2018	**Program:**	EAP
Name of Requester:	Stephen Gonski	**Work Phone:**	360-407-6517

Project Name: **Ocean Acidification Monitoring at Ecology's Greater Puget SoundStations (continuation of 2014 Pilot)**

Test(s) for which a waiver is requested:

Total dissolved inorganic carbon (DIC) and total alkalinity (TA) will be measured in marine and estuarine waters by NOAA's Pacific Marine Environmental Laboratory (PMEL) following SOPs described in Dickson *et al.* (2007) (Guide to Best Practices for Ocean CO_2 Measurements. PICES Special Publication 3, IOCCP Report No. 8. October 2007).

Justification for Request:

- ☐ Data quality goal does not warrant accreditation [1]
- ☒ There is no lab accredited to do the test(s) [2]
- ☐ EAP Lab Accreditation Section cannot accredit for test(s) [3]
- ☐ There is no accredited lab in a reasonable distance [4]
- ☒ No lab can be accredited in time to meet the need [4]
- ☒ Other (explain in narrative)

Narrative (Explain the above checked boxes):

This is a continuation of a pilot project, begun in 2014, that has used the same contract lab to analyze the same parameters using the same methods. The original **Request to Waive Required Use of Accredited Lab** neither identified the laboratory that would perform the analyses nor did it identify DIC as one of the parameters to be analyzed. Finally, Ecology does not yet accredit laboratories for the methods described in Dickson *et al.* (2007).

[1] Screening data, for example may not necessitate use of an accredited lab.
[2] Check the Lab Accreditation website or Contact the EAP Lab Accreditation Unit, or both.
[3] Contact the EAP Lab Accreditation Unit
[4] Check the Lab Accreditation website or Contact the EAP Lab Accreditation Unit, or both.

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Associated Quality Control Tests

Exemption from the requirement to use an accredited lab does not relieve the data user from the requirement to assure lab data meets quality objectives. Reviewing quality control (QC) test results, routinely performed as part of the lab accreditation process, becomes an especially important issue for the user of data coming from a non-accredited lab. Mark below the QC tests the lab will be required to report along with the environmental data. Refer to this description of QC tests, if needed, to determine the significance of each test.

- ☐ Check standards
- ☐ Method Blanks
- ☐ Matrix Spikes
- ☐ Matrix Spike Duplicates
- ☒ Duplicates (field and laboratory)
- ☐ Surrogates
- ☐ Laboratory Splits
- ☒ Standard/Certified Reference Materials

When completed, save the request and submit it to the Agency's QA Officer by e-mail.

Approval Signatures:

Thomas H. Gries 9-10-18

Ecology Quality Assurance Officer / Date (Acting)

4-17-18

Environmental Assessment Program Manager or Ecology Deputy Director / Date

Appendix C. Glossaries, acronyms, and abbreviations

Glossary of General Terms

Alkalinity: The negative charge in a seawater solution that can be titrated by a strong acid to lower the pH of the sample to the point where all of the bicarbonate (HCO_3^-)[HCO_3^-] and carbonate (CO_3^{2-}) [CO_3^{2-}-] could be converted to carbonic acid [H_2CO_3]. This is called the carbonic acid equivalence point or the carbonic acid endpoint.

Ambient: Background or away from point sources of contamination. Surrounding environmental condition.

Anthropogenic: Human-caused.

Beam Attenuation: A decrease in light energy from a beam that is passing through a water sample with a specific pathlength. It is an inherent optical property. The amount of attenuation is primarily dependent upon the wavelength of the propagated light, the concentration of suspended materials and the concentration and composition of both particulate and dissolved absorbing materials.

Calibration: A procedure for comparing the signal from an instrument with known or standard values for turbidity, temperature, pressure, salinity, etc.

Clarity: A qualitative measurement of the ability of water to transmit light. Clarity can be assessed using transmissometer and turbidity sensors.

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

Chlorophyll *a*: Pigment that allows plants, including algae, to convert sunlight into organic compounds in the process of photosynthesis. Chlorophyll a is the predominant type found in algae and phytoplankton, and its abundance is a good indicator of the amount of algae biomass present.

Conductivity: A measure of water's ability to conduct an electrical current. Conductivity is related to the concentration and charge of dissolved ions in water.

CTD: A set of sensors (conductivity-temperature-depth) combined into an instrument package used for collecting continuous water column profile data. The CTD is equipped with sensors to measure additional variables and a pump to draw water through the sensors. Profiles at each station are collected from the sea surface (top bin = 0.5 m) to the sea bottom. The CTD and sensors are operated and maintained according to manufacturers' recommended protocols, with factory calibration occurring annually.

Dissolved Inorganic Carbon (DIC): The sum of inorganic carbon species in a solution. The inorganic carbon species include carbon dioxide (CO_2), carbonic acid (H_2CO_3), bicarbonate anion (HCO_3^-), and carbonate (CO_3^{2-}).

Dissolved oxygen (DO): The amount of gaseous oxygen (O_2) dissolved in water. Oxygen gets into water by diffusion from the surrounding air, by aeration (rapid movement), and as a product of photosynthesis. DO levels are used as an indicator of water quality.

Eutrophication: An ecosystem response to the addition (naturally or artificially) of nutrients and related substances to an aquatic system. Commonly, enriched nutrient levels from human activities such as fertilizer runoff and leaky septic systems can result in high productivity in plankton and algae, ultimately causing negative effects such as hypoxia and altered optical properties.

Fluorometer: An instrument that provides an indication of the concentration of a given material by measuring the amount of fluorescence attributed to the material. For example, a fluorometer provides an excitation beam at a wavelength that is known to cause fluorescent emission from chlorophyll and measures light at a wavelength that matches the chlorophyll emission. As a result, the amount of chlorophyll-containing biomass can be estimated.

Hypoxia: oxygen depletion – a phenomenon where the amount of oxygen gas dissolved in water in an aquatic environment is between 1 and 30%, calculated at the prevailing temperature and salinity. Levels of oxygen this low can be detrimental to aquatic organisms.

Niskin Bottle: Water sampling bottle used to make sub-surface measurements of water. These are plastic tubes (PVC) with spring-loaded end caps, an air-vent valve at one end and a dispensing stopcock at the other.

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

Nutrient: A substance such as nitrate, nitrite, silicate, ammonium and phosphate. These compounds are used by organisms to live and grow.

Parameter: A distinguishing physical, chemical or biological property whose values determine environmental characteristics or behavior.

pH: A measure of the acidity or alkalinity of water. A low pH value (0 to 7) indicates that an acidic condition is present, while a high pH (7 to 14) indicates a basic or alkaline condition. A pH of 7 is considered to be neutral. Since the pH scale is logarithmic, a water sample with a pH of 8 is ten times more basic than one with a pH of 7.

Photosynthetically Active Radiation (PAR): Wavelengths—roughly 400–700 nanometers—of incoming sunlight that can be absorbed by plants for photosynthesis.

Phytoplankton: Free-floating flora that convert inorganic compounds into complex organic compounds. This process of primary productivity supports the pelagic food-chain. Phytoplankton vary in size from less than 1 to several hundred µm.

Point source: Source of pollution that discharges at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites that clear more than 5 acres of land.

Salinity: Salinity is the total amount of dissolved material in grams in one kilogram of sea water. Samples are collected to calibrate and check conductivity measurements made by the CTD.

Secchi Disk: Measures transparency of the water using an 8-inch diameter white disk attached to a rope. The rope is marked at 0.5 meter intervals for easy determination of depth.

Secchi Depth: Depth in the water at which the disk is no longer visible. It is usually the average between the depth at which the disk is no longer visible when it is lowered into the water and the depth at which it is again visible as the disk is raised. The Secchi depth can be used to calculate the amount of colored substances (i.e., phytoplankton, algae, and detritus) in the water. Changes can be caused by sediment runoff from land or increased phytoplankton populations. Changes in Secchi depth over time are used as an indicator of water quality.

Sediment: Soil and organic matter that is covered with water (for example, river or lake bottom).

Transmissivity: (light transmission) A measure of light scattering and absorption through the water column, reported as a percent or ratio of light received relative to light originally transmitted. Light transmission is used as an indicator of water quality, indicating water clarity and providing information on light absorption and. light scattering (beam attenuation).

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

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

90^{th} percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90^{th} percentile value is a statistically derived estimate of the division between 90% of samples, which should be less than the value, and 10% of samples, which are expected to exceed the value.

Acronyms and Abbreviations

Chla	Chlorophyll *a*
CTD	Conductivity-Temperature-Depth (Instrument)
CWA	Clean Water Act
DIC	Dissolved Inorganic Carbon
DO	Dissolved Oxygen
EAP	Ecology's Environmental Assessment Program
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
GIS	Geographic Information System software
GMT	Greenwich Mean Time (equivalent to Coordinated Universal Time – UTC)
GPS	Global Positioning System
JEMS	Joint Effort to Monitor the Strait
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
MMU	Marine Monitoring Unit
MWM	Marine Waters Monitoring
NEP	National Estuary Program (EPA)
NOAA	National Oceanic and Atmospheric Administration
QA	Quality assurance
QC	Quality control
PDT	Pacific Daylight Time
POC	Particulate Organic Carbon
PN	Particulate Nitrogen
PST	Pacific Standard Time
PSAMP	Puget Sound Assessment and Monitoring Program
PSEMP	Puget Sound Ecosystem Monitoring Program
PSAT	Puget Sound Action Team
PSEP	Puget Sound Estuary Program

PSP	Puget Sound Partnership
PSWQA	Puget Sound Water Quality Authority
RPD	Relative percent difference
RSD	Relative standard deviation
SPMSC	Shannon Point Marine Science Center a research station of Western Washington University located in Anacortes WA.
SOP	Standard operating procedures
TOC	Total organic carbon
TN	Total nitrogen
UNESCO	United Nations Educational, Scientific and Cultural Organization
UW	University of Washington
WAC	Washington Administrative Code
WRIA	Water Resources Inventory Area

Units of Measurement

°C	degrees Celsius
ft	feet
g	gram, a unit of mass
m	meter
mEq/L	milliequivalent per liter, a unit of alkalinity
mg	milligram
mg/L	milligrams per liter (parts per million)
mL	milliliters
mm	millimeter
NTU	nephelometric turbidity units
psu	practical salinity units
µg/L	micrograms per liter (parts per billion)
µM	micromolar (a chemistry unit)
µmol/kg	micromoles per kilogram, a unit of dissolved inorganic carbon and total alkalinity
µS/cm	microsiemens per centimeter, a unit of conductivity

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USGS, 1998).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: The difference between the sample mean and the true value. Bias usually describes a systematic difference reproducible over time and is characteristic of both the measurement system and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI) (Kammin, 2010; Ecology, 2004).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 1997).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 1997).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier – data are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.
- REJ – data are rejected, cannot be used for intended purposes.
  (Kammin, 2010; Ecology, 2004).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner. Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 1997).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS): A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples (USEPA, 1997).

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (EPA, 1997).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero (Federal Register, October 26, 1984).

Percent Relative Standard Deviation (%RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$\%RSD = (100 * s)/x$$

where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$[Abs(a-b)/((a + b)/2)] * 100$$

where "Abs()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1997).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 1997).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 1997).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

References for QA Glossary

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