Quality Assurance Project Plan

Environmental data collection and data synthesis for identifying factors related to floating kelp loss and resilience.

March 2024

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The EPA requires an approved Quality Assurance Project Plan (QAPP) for all EPA-funded projects that generate or use environmental information, including modeling efforts, before the projects begin. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, the author will post the final report of the study to the internet. This QAPP describes a project selected for funding through the Habitat Strategic Initiative Lead (HSIL) Request for Proposals in Fall 2022 and is described in the February 2023 Investment List for strategic investment of Puget Sound Geographic Program funds. Funds were awarded under HSIL grant WDFW # 23-23550 / DNR # 93-106086. HSIL is a team co-led by WA Department of Fish and Wildlife and WA Department of Natural Resources (DNR).

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Data for this project are available in EPA's Water Quality Exchange (WQX) database (https://www.epa.gov/waterdata/water-quality-data-wqx). The QAPP is valid for one year from date of certification. All QAPPs for programs or projects exceeding one year in duration shall be reviewed and recertified annually.

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Environmental data collection for identifying factors related to floating kelp loss and resilience

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March 2024

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2.0 Abstract

Bull kelp (*Nereocystis luetkeana*) populations appear resilient in some regions of the Salish Sea, but are declining sharply in others. To conserve this critical habitat, Washington Department of Natural Resources (DNR) seeks to better understand stressors contributing to these declines and determine appropriate management measures for specific regions.

Through coordinated monitoring, research, and synthesis of existing data by a coalition of organizations, this subaward will build on current understanding of bull kelp stressors by assessing the response of bull kelp to potential stressors across a network of sites with a wide range of environmental and ecological conditions. Developing strategies for the conservation and restoration of bull kelp beds will require synthesis of information collected across the Puget Sound to understand what is causing current observations of bull kelp declines. Increasing the spatial extent of bull kelp monitoring will help clarify sites where bull kelp condition is excellent vs. poor and improve our understanding of associated environmental factors.

Investigations of where bull kelp is currently declining, compared to the environmental conditions of areas where bull kelp is thriving will result in actionable information on what environmental factors to focus on for bull kelp management and regulatory policy, and where to prioritize bull kelp restoration or conservation efforts. This subaward will help evaluate hypotheses regarding drivers of bull kelp resilience including environmental factors and species interactions. Finally, this coordinated monitoring and data synthesis will support the development of a “monitoring backbone” that serves as Puget Sound-wide framework for identifying stressors to assess and recommend future sites and parameters for ongoing monitoring.

3.0 Background

3.1 Introduction and problem statement

Bull kelp appears resilient in some regions of the Salish Sea but has declined sharply in others. To conserve this critical habitat, Washington Department of Natural Resources seeks to better understand stressors contributing to these declines and determine appropriate management measures for specific regions.

Through coordinated monitoring, research, and synthesis of existing data by a coalition of organizations, this subaward will build on current understanding of bull kelp stressors by selecting a network of sites across a wide range of conditions to assess environmental and ecological conditions and bull kelp response to these differences. Developing strategies for the conservation and restoration of bull kelp beds will require synthesis of information collected across the Puget Sound to understand what is causing current observations of bull kelp declines. Increasing the spatial extent of bull kelp monitoring will help clarify sites where bull kelp condition is excellent vs. poor and improve our understanding of associated environmental factors.

This QAPP is one of three that will address different aspects of this larger project. Additional QAPPs will address floating kelp surveys and benthic dive surveys. This QAPP is focused on the synthesis of existing environmental data and collection of new environmental data from both submerged continuously monitoring sensors and monthly collection of sensor data and water sample collection for laboratory analysis.

3.2 Study area and surroundings

The study area includes all nearshore areas of the Washington State portion of the Salish Sea. This includes all marine shorelines of Washington State that are east of Point Flattery, including the Strait of Juan de Fuca, the San Juan Islands, Admiralty Inlet, Saratoga Passage, Whidbey Basin, Central and Southern Puget Sound and Hood Canal.

Fifteen sites were selected within the study area for intensive data collection including the deployment of environmental sensors (Figure 1). These sites span a wide range of environmental and ecological conditions, such as water temperature, water residence time, river influence, and proximity to urbanized watersheds. Approximately half of these sites have bull kelp beds that appear resilient, while the others are locations where bull kelp beds are declining or where they have recently disappeared.

3.2.1 History of study area

Over the past 100 years, human population growth has led to increasing urbanization to the point where the Seattle-Tacoma area is one of the largest metropolitan areas in the US. Early in the 20th century, there was substantial unregulated logging with substantial impacts to

terrestrial systems and to aquatic systems through alteration of surface hydrology and sediment loading to freshwater and marine systems.

More recently, regulations have been put in place to protect aquatic ecosystems including the marine nearshore. Nevertheless, it is anticipated that increasing effects from continued urbanization and climate change will place additional stress on the marine nearshore ecosystems, including floating kelp within these systems.

Figure 1. Map of study area showing the 15 sites involved in this project.

3.2.2 Summary of previous studies and existing data

In 2022-2023, an indicator development project culminated in the May 2023 release of the Washington State Floating Kelp Indicator which encompasses the study area of this project and additional areas on the outer coast. This release presented the design and structure of the indicator as well as the first set of indicator results based on existing data used to evaluate the floating kelp bed area indicator. The results identified areas of floating kelp loss and areas of stability as well as areas with inadequate monitoring data to assess floating kelp condition.

The indicator results relied on several data sources. The longest monitoring record is the DNR aerial imaging surveys that started in 1989 along the Strait of Juan de Fuca as well as the outer coast. An analysis of this monitoring data published in 2017 found a broad pattern of floating kelp stability that has remained unchanged in more recent years (Pfister et al. 2017).

In contrast, a 2021 study focused on southern Puget Sound based on historical maps and contemporary monitoring data found substantial loss of floating kelp (Berry et al. 2021). This study has played a key role in raising awareness of vulnerability in the floating kelp population and interest in monitoring the population and assessing causal factors, such as in the work that is the subject of this QAPP.

Existing submerged sensor data that will be synthesized as part of this project include data from three separate efforts. Friday Harbor Labs have collected continuous benthic environmental data and discrete surface water samples at a series of sites in a study of factors affecting floating kelp (Weigel et al. 2023). This study found evidence that high water temperatures are an important constraint on floating kelp survival. DNR has collected continuous benthic environmental data at Squaxin Island and Salmon Beach since 2021. The first two years of data have been analyzed in a draft report that is currently undergoing review and revision (McClure et al., in prep.). This study supported the role of high water temperatures in constraining floating kelp performance. The Puget Sound Restoration Fund (PSRF) has initiated work on a network of sites within the study area of this project for deployment of fixed environmental sensors. Currently, sensors have been deployed at three sites in the central Puget Sound area, but these data have not yet been analyzed.

3.2.3 Parameters of interest and potential sources

This QAPP is focused on subtidal environmental conditions in proximity to existing floating kelp beds, or in locations where floating kelp was previously present. The parameters of interest are:

- Water temperature
- Salinity
- Tidal stage
- Photosynthetically active radiation (PAR)
- Suspended sediment (TSS)
- Dissolved nutrients (nitrate, nitrite, and ammonium, phosphate, silicate)

3.2.4 Regulatory criteria or standards

Not applicable. This study is not assessing regulatory compliance status.

3.3 Water quality impairment studies

Not applicable.

3.4 Effectiveness monitoring studies

Not applicable.

4.0 Project Description

4.1 Project goals

The overarching goal of this project is to advance our understanding of the environmental factors that are associated with floating kelp loss and those associated with floating kelp resilience. Specific goals for the portion of our project that falls within the scope of this QAPP include:

- Contrast the 15 study sites in terms of the patterns in the measured and derived environmental parameters: water temperature, salinity, light availability, nutrients, total suspended solids.

The 15 sites were selected for broad geographic representation and to include sites with stable kelp beds, declining kelp beds, and sites with no kelp but where kelp was previously observed.

4.2 Project objectives

Objectives for the portion of our project that falls within the scope of this QAPP include:

- Collect monthly water samples from January to December 2024 from the network of 15 sites for nutrient analysis at the UW Oceanography Marine Chemistry Laboratory. Two replicate samples at two different depths (0.5m and 5m below surface) will be collected at each site on each sampling occasion (12 x 15 x 4 = 720 samples). Note - February 2024 is when work was approved, prior data was collected using other funding sources.
- Sampling water from 0.5m and 5m depths, capture total suspended solids (TSS) on filters monthly from January to December in 2024 from the network of 15 sites (12 months x 15 sites x 2 depths x 2 replicates = 720 samples).
- Capture CTD (conductivity-temperature-depth) profiles from the bottom to the surface monthly from January to December in 2024 from the network of 15 sites (12 months x 15 sites x 2 replicates = 360 profiles).
- Measure PAR (photosynthetically active radiation) attenuation coefficient monthly (12 months x 15 sites x 2 replicates= 360 measurements).
- Measure Secchi depth monthly (12 x 15 x 2 = 360 measurements).
- Develop and test QA procedures (see Section 10.1.2) for filtering out anomalous data (sensor failure, sensor fouling).
- Conduct analysis to summarize patterns in the collected data and cross-site comparisons.
- Conduct analysis to identify correlations between the collected environmental data and floating kelp performance as reflected in existing monitoring data and data collected in 2024 as part of this project (covered under a separate QAPP).

4.3 Information needed and sources

Existing Data

Model Data

- NOAA Tides and Currents. Predicted tides and currents will be obtained for stations in proximity to the 15 project sites. Data of hourly frequency will be collected from the program's web resource (https://tidesandcurrents.noaa.gov/) for 2024.

Continuous Environmental Sensor Data

- Friday Harbor Labs. Benthic sensor packages have been deployed at a network of sites which coincide with sites identified for this project (Weigel et al. 2023). Sensors include temperature, conductivity and depth.
- DNR South Puget Sound. DNR has deployed benthic environmental sensor packages at Squaxin Island and Salmon Beach since 2021 (McClure et al., in prep.).
- PSRF has initiated a program to deploy benthic and surface environmental sensors at a network of sites across the study area. Currently, deployments have been made at three sites within central Puget Sound. Two of these sites coincide with sites selected for this project.

Discrete Water Sample Analysis Data

- Washington State Department of Ecology (Ecology) has collected and analyzed discrete water samples on a monthly basis as part of their long-term monitoring. These samples are analyzed for nitrate/nitrite and ammonium.

Water Column Profile Data

- Ecology has collected CTD profile data at a network of sites within the study area as part of their long-term monitoring.
    - The Ecology monthly marine water quality sampling occurs mid-channel, not in the nearshore. The Ecology data will be used here for general, regional characterization. The data collected at the 15 sites will be in the nearshore in close proximity to kelp habitat.
- DNR has collected CTD profile data at many sites within the study area as part of various projects.

New Data

Continuous Environmental Sensor Data

- Benthic sensor packages will be deployed at network of 15 project sites. Data collection will be initiated once this QAPP is approved and will continue through the end of 2024. The sensor packages will include temperature, conductivity, and pressure. In addition, PAR sensors will be included in the packages within the January – March window when benthic PAR is most relevant to floating kelp microscopic and juvenile life stages.

Discrete Water Sample Analysis Data

- Near-surface water samples will be collected monthly at the 15 project sites through 2024. Water samples will be passed through filters which will be dried and weighed for total suspended solids determination (DNR's Aquatic Botany lab). Other water samples will be processed and shipped to the UW Oceanography Marine Chemistry lab for determination of dissolved nutrients (nitrate, nitrite, and ammonia, orthophosphate, silicate)

Water Column Profile Data

- Monthly CTD profiles will be collected at the 15 project sites through 2024. The Castaway instrument will collect temperature, conductivity and depth data. In addition, a custom-built apparatus will be used to measure PAR attenuation coefficient. Simultaneous subsurface PAR measurements will be collected for determination of submarine PAR as a fraction of incident PAR.
- Monthly Secchi depth will be measured at the 15 project sites through 2024.

4.4 Tasks required

- Purchase environmental sensors for measuring water temperature, conductivity, PAR and depth (DNR). Work will be initiated with previous sensor purchases for previous projects. But will need to make more purchases for sensor swapping.
- Construct sensor packages for deployment [DNR and University of Washington (UW)]
- Finalize deployment plan for sensor packages (DNR and UW)
    - DNR will complete the deployment plan with input from the UW team who will be conducting dive deployments in addition to deployments by DNR divers.
- Divers visit each of the 15 sites approximately quarterly for initial sensor deployments and subsequent sensor swaps (UW and DNR)
- Data downloaded from retrieved environmental sensors; data QA and input into the project data system (UW and DNR)
- Monthly visits to the 15 sites for CTD profiles, Secchi depth determinations, attenuation coefficients, and collection of water samples for TSS and nutrients (DNR)
- Filter monthly water samples for TSS determinations (DNR).
- Process monthly water samples and ship to UW Oceanography Marine Chemistry lab for nutrient determinations (DNR).

4.5 Systematic planning process

Bi-weekly team meetings have already been initiated for planning purposes. Additional meetings with sub-groups on a weekly basis have already been initiated for planning and coordination purposes. These meetings include representatives from the entire project coalition.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1 shows the responsibilities of those who will be involved in this project.

Table 1. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Helen Berry WA DNR Phone: 360-902-1030	**Project Manager**	**Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Coordinates field sampling. Contributor to semi-annual reports and final report.**
Pete Dowty WA DNR Phone: 360-902-1030	**Data Manager**	**Writes portions of the QAPP. Conducts QA review of data, analyzes and interprets data, and enters data into WQX. Writes the semi-annual reports and final report.**
Bart Christiaen WA DNR Phone: 360-902-1030	**Project Scientist 3**	**Writes portions of the QAPP. Conducts QA review of data, analyzes and interprets data.**
Kindall Murie UW Phone: 208-890-9882	**Continuous Sensor Manager**	**Coordinates deployment of continuous sensors. Retrieves and organizes data from sensors.**
Rebecca Hansen UW Phone: 778-678-5036	**Project Scientist 4**	**Deploys continuous sensors. Retrieves and organizes data from sensors.**
Ande Fieber UW Phone: 408-250-9278	**Project Scientist 5**	**Deploys continuous sensors. Retrieves and organizes data from sensors.**
Wendel Raymond WDFW Phone: 360-809-8380	**Project Scientist WDFW**	**Conducts field sampling, QA review of data, analyzes and interprets data.**
Project Scientist 2	**Project Scientist 2 / Discrete Sampling Manager**	**Coordinates and conducts monthly discrete field sampling, transportation of samples to the lab and data QA and management**
Project Scientist 1(NRS1) Phone: 360-902-1030	**Project Scientist 1**	**Sensor package preparation. Conducts field sampling and sensor maintenance. Assists both the continuous sensor manager and the discrete sampling manager**
Ken Nelson Department of Ecology Phone: 360-522-2722	**NEP Quality Coordinator**	**Reviews and approves the draft QAPP and the final QAPP.**
Arati Kaza Department of Ecology Phone: 360-480-1960	**Quality Assurance Officer**	**Reviews the draft QAPP.**

QAPP: Quality Assurance Project Plan

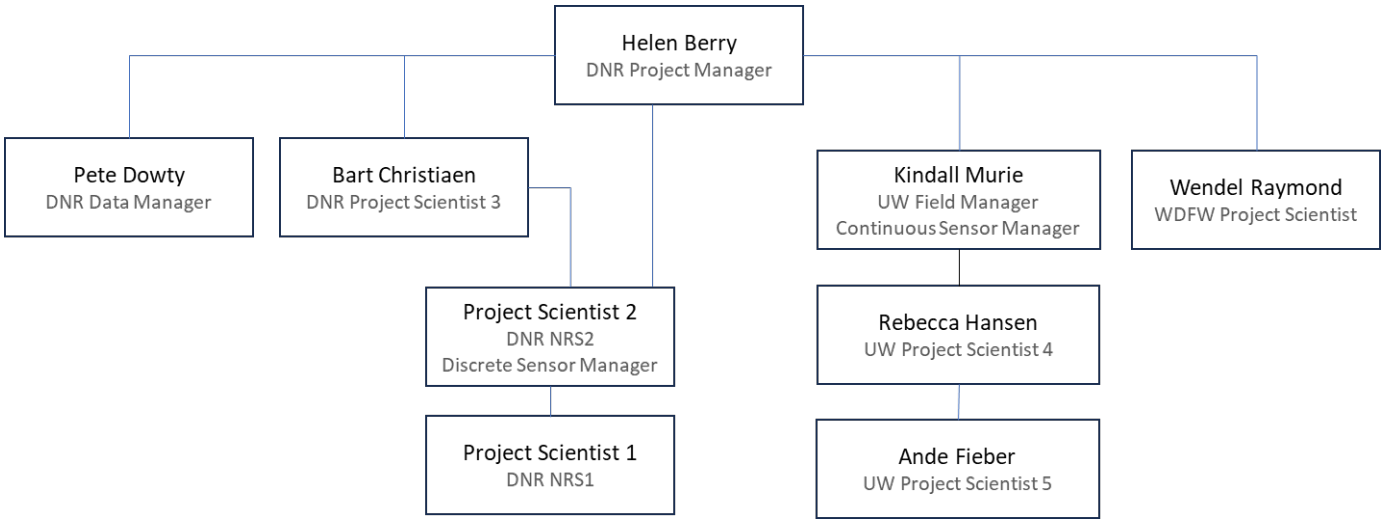
NEP: National Estuary Program
WQX: Water Quality Exchange

5.2 Special training and certifications

- **Helen Berry** has over 25 years of experience conducting various monitoring activities within the nearshore environment and managing projects focused on monitoring, ecosystem indicators, and focused research studies. Small Motorboat operator (MOCC certified).
- **Bart Christiaen** has over 15 years of experience with monitoring in nearshore environments and managing monitoring and research projects. Small Motorboat operator (MOCC certified).
- **Pete Dowty** has over 20 years of experience managing and analyzing nearshore data.
- **Kindall Murie**: Ph.D. Candidate, University of Washington, Department of Biology. AAUS Scientific Diver: 500 dives (200 sensor deployment dives), NAUI Rescue Diver, UW diver-check out dive (8/2020), Washington State Boating license, The Motorboat Operator Training Course (MOTC), ReefCheck- Volunteer Survey Diver (CA, WA). She has deployed temperature, dissolved oxygen, pH, and conductivity sensors for 6 years in both California and Washington kelp forests.
- **Ande Fieber:** M.S. in (marine) biology from Humboldt State University, graduated spring 2020, AAUS Scientific Diver, 200 cold water dives. PADI Rescue Diver, UW diver- check out dive (01/2024), Washington State Boating license - Planned for 01/2024, The Motorboat Operator Training Course (MOTC)- Planned for 01/2024, ReefCheck- Volunteer Survey Diver (CA, WA)
- **Rebecca Hansen :** M.S. in Zoology at the University of British Columbia (Vancouver, BC, Canada), Canadian Association for Underwater Science-accredited Scientific Diver (CAUSS)- 28 dives, PADI Rescue Diver, UW diver- check out dive (01/2024), Washington State Boating license - Planned for 01/2024, The Motorboat Operator Training Course (MOTC)- Planned for 01/2024
- **Wendel Raymond**: Ph.D. in Fisheries from University of Alaska Fairbanks with over 10 years of experience conducting research and monitoring activities in nearshore ecosystems including project management and analysis. Washington State Boating License and AMSEA Small Boat Operator with over 300 sea days.

All field personnel will have a valid US Driver's license.

5.3 Organization chart



5.4 Proposed project schedule

Tables 2 – 4 list key activities, due dates, and lead staff for this project.

Table 2. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Monthly field sampling	Monthly, 2024	Discrete Sampling Manager
Quarterly sensor maintenance	Quarterly 2024	Continuous Sensor Manager
Laboratory analyses	Monthly 2024	Discrete Sampling Manager
Quality Assurance/Quality Control (QA/QC) of lab data	Monthly 2024	Discrete Sampling Manager

Table 3. Schedule for data entry

Task	Due date	Lead staff
WQX data loaded	Jan 2025	Project Scientist 1
WQX QA	Mar 2025	Data Manager
WQX complete	April 2025	Data Manager

WQX: Water Quality Exchange

Table 4. Schedule for final reports

Task	Due date	Lead staff
Draft existing data synthesis to supervisor	July 15, 2024	Data Manager
Final report to Subaward manager	January 15, 2025	Data Manager
Draft final chapter to supervisor	July 10, 2025	Data manager
Draft technical report to peer review	January 20, 2026	Project Manager
Final technical report to Subaward manager	May 31, 2026	Project Manager

5.5 Budget and funding

Tables 5 and 6 show the main project budget categories and laboratory budget details. These funds are available through an HSIL grant awarded to a collaborative proposal developed by DNR, UW and the University of Chicago (Cathy Pfister of University of Chicago is a collaborator on the overall HSIL project but does not have a role in the environmental data collection).

Table 5. Project budget and funding

Cost Category	Cost ($)
Salary, benefits, and indirect/overhead	$159,380
Equipment	$27,000
Travel and other	$8,000
Laboratory (See Table 6 for details.)	$20,000

Table 6. Laboratory budget details

Parameter	Number of Samples	Number of QA Samples	Total Number of Samples	Cost Per Sample ($)	Lab Subtotal ($)
Nutrients (NO3,NO2,NH4, PO4, SiOH4)	720	24	744	$21	$15,624

6.0 Quality Objectives

6.1 Data quality objectives

The main data quality objective (DQO) for this project is to conduct monthly CTD casts, and collect monthly water samples for dissolved inorganic nutrients and TSS at 15 sites with floating kelp in greater Puget Sound. In addition, we will deploy environmental sensor arrays to collect continuous data on temperature, salinity, depth and PAR[1] at these locations. These data will advance our understanding of the environmental factors that are associated with floating kelp loss and those associated with floating kelp resilience. We will use standard sampling, processing, and measurement methods to meet Measurement Quality Objectives (MQOs), described below, that are comparable to previous study results.

6.2 Measurement quality objectives

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for project results, expressed in terms of acceptable precision, bias, and sensitivity, are described in this section and summarized in Tables 7 through 9.

Following is a list of acronyms in the following 3 tables:

- CastAway CTD: SonTek CastAway CTD
- CCB: Continuing Calibration Blank
- CCV: Continuing Calibration Verification
- CTD Diver: Van Essen CTD-Diver – DI28x Series
- ICB: Initial Calibration Blank
- ICV: Initial Calibration Verification
- LI-192: Li-COR underwater quantum PAR sensor
- MDL: Method detection limit
- Odyssey: Dataflow Systems Odyssey PAR logger
- RL: Reporting limit
- RPD: Relative percent difference
- RSD: Relative standard deviation
- SM: Standard Methods
- TidbiT MX: Onset HOBO TidbiT MX temperature data logger
- U20L-01: Onset HOBO water level logger
- U24-002: Onset HOBO saltwater conductivity logger
- YSI EXO: Xylem, Inc., Yellow Springs Instruments, EXO series multiparameter sonde
- YSI ProDSS: Xylem Inc. Yellow Springs Instruments, ProDSS series multiparameter sonde.

[1] PAR measurements will be collected during winter months only.

Table 7. Measurement quality objectives for laboratory analyses of water samples.

Parameter	Method	Laboratory Duplicate (RPD)	Field Duplicate (RPD)	Matrix Spike Duplicate (RPD)	Lab Control Standard (% Recovery)	Matrix Spike (% Recovery)	Internal Standard Recovery (% Recovery)	Method Detection Limit (MDL) mg/L
Ammonia	SM 4500-NH3 G-2011	20% RPD	20% RPD	n/a	80-120%	75-125%	ICV/CCV: 90-110% ICB/CCB: <MDL	0.0013
Nitrate	SM 4500-$NO3^{-}$ F-2011	20% RPD	20% RPD	n/a	80-120%	75-125%	ICV/CCV: 90-110% ICB/CCB: <MDL	0.0025
Nitrite	SM 4500-$NO3^{-}$ F-2011	20% RPD	20% RPD	n/a	80-120%	75-125%	ICV/CCV: 90-110% ICB/CCB: <MDL	0.0001
Orthophosphate	SM 4500-P F-2011	20% RPD	20% RPD	n/a	80-120%	75-125%	ICV/CCV: 90-110% ICB/CCB: <MDL	0.0009
Silicate	SM 4500-SiO2 E-2011	20 % RPD	20% RPD	n/a	n/a	n/a	ICV/CCV: 90-110% ICB/CCB: <MDL	0.013
Total suspended solids	Total Suspended Solids[2]	n/a	20% RPD	n/a	n/a	n/a	n/a	0.1

[2] Total suspended solids will be analyzed by DNR using an SOP based on SM 2540 D. This SOP is included as an appendix.

Table 8: Measurement quality objectives (MQOs) for sensor deployments

Parameter	Equipment/ method	Equipment accuracy	Equipment resolution	Equipment range	Expected range	Response time
Barometric pressure	CTD Diver	0.5 cm H2O	0.2 cm H2O	0-10 m H2O	1-6 m H2O	unspecified
Barometric pressure	U20L-01	1 cm H2O*	0.2 cm H2O	0-207 kPa (0-9 m H2O)	1-6 m H2O	< 1 sec (at stable temp)
Temperature	CTD Diver	0.1 °C	0.01 °C	-20 to 80 °C	5 to 25 °C	3 min in water
Temperature	U20L-01	0.44 °C (between 0 and 50 °C)	0.1 °C at 25 °C	-20 to 50 °C	5 to 25 °C	10 min in water
Temperature	TidbiT MX	0.2 °C (between 0 and 70 °C)	0.01 °C	-20 to 50 °C	5 to 25 °C	7 min in water
Conductivity	CTD Diver	+/- 1% of reading or 20 µS/cm, whichever is greater	0.1% of reading	0 to 120 mS/cm	30,000-55,000 µS/cm	unspecified
Conductivity	U24-002[3]	3% of reading or 50 µS/cm, whichever is greater	2 µS/cm	1 to 10 mS/cm or 5 to 55 mS/cm	30,000-55,000 µS/cm	1 sec
PAR	Odyssey	+/- 10%	1 µmol m^{-2} s^{-1}	0 to >2000µmol m^{-2} s^{-1}	0 – 1500 µmol m^{-2} s^{-1}	<1 sec

[3] Up to 12% sensor drift per month for conductivity, exclusive of drift from fouling. Monthly start- and endpoint calibrations needed.

Table 9: Measurement quality objectives (MQOs) for monthly CTD profiles & PAR profiles

Parameter	Equipment/ method	Equipment accuracy	Equipment resolution	Equipment range	Expected range	Response time
Barometric pressure	CastAway CTD	0.25% FS	0.01 dBar	0-100 dBar	0 to 10 dBar	5 Hz
Barometric pressure	YSI DSS	±1.5 mmHg	0.1 mmHg	375 to 825 mm Hg		
Temperature	CastAway CTD	0.05 °C	0.01 °C	-5 to 45 °C	5 to 25 °C	5 Hz
Temperature	YSI DSS	±0.01°C	0.001°C	-5 - 50°C	5 to 25 °C	
Conductivity	CastAway CTD	+/- 0.25 % of reading or +/- 5 µS/cm	1 µS/cm	0 to 100,000 µS/cm	30,000-55,000	5 Hz
Specific Conductivity at 25 °C	YSI DSS	±0.5% of reading or 1 µS/cm	0.1 to 100 µS/cm (range dependent)	0.01 – 200,000 µS/cm	20 – 100,000 µS/cm	
Secchi depth	Secchi disk	1m	n/a	n/a	n/a	n/a
PAR	LI-192	Absolute Calibration: ± 5% in air traceable to the U.S. National Institute of Science and Technology (NIST) Linearity: maximum deviation of 1% up to 10,000 µmol s^{-1} m^{-2}	Sensitivity: Typically 4 µA per 1,000 µmol s^{-1} m^{-2} in water	0-10,000 µmol s^{-1} m^{-2}	0-1,500 µmol s^{-1} m^{-2}	10 µs

6.2.1.1 Precision

Precision is a measure of the variability due to random error. Sources of random error include:

- Within site variance.
- Field sampling.
- Processing, handling, and transporting samples to the laboratory.
- Preparation of sample for analysis at the laboratory.
- Analysis of the sample (including data handling errors).

We assess precision by the analysis of duplicate field measurements and samples, and we assess laboratory precision by the analysis of lab duplicates and check standard replicates. We apply the acceptable levels listed in Tables 7 through 9 to batch-level data, which we may assess by only a few QC samples. Failing to meet these criteria requires corrective action (see Section 10.2).

We express precision for replicates as relative percent difference (% RPD) or absolute error based on the MQOs outlined in Tables 7 through 9. We base the targets for precision of field replicates on QAPP's for water quality monitoring programs by the WA Department of Ecology (ECY publication 23-03-106 and ECY publication 21-03-108). We qualify samples not meeting criteria outlined in Tables 7 through 9 according to standards defined in Section 14 (Data Quality Assessment).

Precision for the continuous data records is determined by comparing the in-situ deployed sensors to a known sample, standard solution, or calibrated meter before and after cleaning the sensors.

6.2.1.2 Bias

Bias is the difference between the sample mean and the true value. Potential causes of field and laboratory bias in samples include:

- Calibration issues with instruments.
- Contamination of equipment, reagents, or containers.
- Instability of samples during transportation, storage, or processing.
- Inability to collect samples or measurements due to special circumstances (e.g., inclement weather that restricts accessibility to site).
- Biofouling of continuous sensors

We address bias in field sampling by adhering to SOP's, established calibration methods, and scheduled cleaning of sensors after every deployment (See appendix 16). We determine bias for the continuous data records by comparing results from an equilibrated in-situ deployed sonde against discrete grab samples or measured results. The condition of all sensors is documented by taking pictures in the field immediately after collecting the sensor arrays. Any potential biofouling on the sensors will be recorded in the field notes. In between deployments, sensors will be tested for bias by performing a simultaneous short-term deployment of several

sensors at a fixed location, combined with point sampling using a factory calibrated sensor at fixed time intervals. Sensors that show low accuracy or drift will be flagged and removed from the sensor pool.

Bias in water quality samples will be addressed by adhering to established SOP's and rigorous cleaning of sample equipment in between field days. MQOs for laboratory QC samples (e.g., blanks, check standards, and spiked samples) presented in Table 7 provide a measure of bias affecting sampling and analytical procedures.

6.2.1.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as a detection limit. Detection limits for water quality analysis are listed in Table 7 and Table 13. Detection limits for continuous sensor data are listed in Table 8 and detection limits for instruments used during monthly field surveys are listed in Table 9.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

To ensure comparability, all field personnel will be following the same SOP's for data collection and analysis (see Table 10, Table 11 and Section 16). Field personnel operate with primary and backup responsibilities for ensuring that high quality data are generated and uploaded into the data management system.

All protocols are based on the most current, standard, and internationally accepted seawater methods. Using these standardized procedures for analyzing marine monitoring data supports comparability between other studies and long-term monitoring.

6.2.2.2 Representativeness

This monitoring project surveys 15 sites that are representative of all marine shorelines of Washington State (east of Point Flattery) known to be suitable for floating kelp (Figure 1). Sites include locations where floating kelp beds are currently thriving, as well as sites that have experienced moderate and severe declines relative to known baselines.

Each of these locations is visited on a monthly basis to collect water samples, CTD casts, as well as two measures of water clarity (Secchi depth and attenuation coefficients for PAR). At each of these sites we will deploy sensor arrays to continuously measure depth, water temperature, conductivity and (in winter months) PAR. This insures that a wide variety of seasonal conditions are adequately represented.

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

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. To mitigate this, we will schedule multiple backup dates.
- 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

Existing data will be assessed using basic data quality tests. Frequency distributions of parameter values will be used to devise tests for anomalous values (outliers). Knowledge of expected environmental ranges will be used to devise tests for non-physical values.

6.4 Model quality objectives

Not applicable.

7.0 Study Design

7.1 Study boundaries

In general terms, this study aims to gain an understanding of the environmental factors that control floating kelp trends within the Washington State portion of the Salish Sea. In practice, the work to be conducted for this study will be focused on the 15 sites shown in Figure 1 that are distributed throughout this broader study area.

A portion of this project involves the compilation of existing data within the study area. This existing data has been collected in the vicinity of the 15 sites (Figure 1) but in some cases the existing data originates from additional sites within the study area.

7.2 Field data collection

The scope of this QAPP includes the collection of environmental data for this project. This data collection will take place at the 15 project sites mapped in Figure 1.

7.2.1 Sampling locations and frequency

The 15 sites that will be the focus of this study were selected subjectively based on knowledge of floating kelp abundance and trends in abundance at these sites, while prioritizing co-location with other related monitoring projects. Sites were selected to provide coverage across the broader study area and to include representative sites with floating kelp that is abundant and stable, is declining, or has experienced total loss.

List of 15 project sites with coordinates and information on each site. These sites are mapped in Figure 1.

1. Squaxin Island* (47.16767027, -122.895667). DNR long-term kelp canopy monitoring site. Co-located research with Squaxin Tribe, Puget Sound Restoration Fund (PSRF), DNR Dive Team, ReefCheck.
2. Devil's Head* (47.1669336, -122.7612005). DNR long-term kelp canopy monitoring site. Co-located research with ReefCheck.
3. Fox Island* (47.23295871, -122.5890455). DNR long-term kelp canopy monitoring site. Co-located research with ReefCheck.
4. Salmon Beach (47.29577627, -122.5307684). DNR long-term kelp canopy monitoring site. Co-located research with DNR Dive Team, ReefCheck.
5. Lincoln Park (47.53458534, -122.3979132). DNR long-term kelp canopy monitoring site. Co-located research with ReefCheck.
6. Wing Point* (47.61581408, -122.4883016). DNR long-term kelp canopy monitoring site. Co-located research with PSRF.
7. Rich Passage* (47.59187299, -122.5629333). Site of documented declines.

8. Edmonds (47.82181566, -122.3765367). Co-located research with Edmonds Underwater Park, NOAA, PSRF, Northwest Straits Commission (Snohomish MRC long-term monitoring site).
9. Mukilteo * (47.84406962, -122.3458195). Co-located research with Northwest Straits Commission (Snohomish MRC long-term monitoring site).
10. North Beach (48.14509207, -122.7770934). Co-located research with ReefCheck, PSRF, Northwest Straits Commission (Jefferson MRC long-term monitoring site).
11. Magnolia (47.631754, -122.399340). DNR long-term kelp canopy monitoring site. Co-located research with ReefCheck, PSRF.
12. Freshwater Bay (48.143342, -123.620301). Co-located research with USGS, Seagrant, Lower Elwha Klallam Tribe, ReefCheck, Northwest Straits Commission (Clallam County MRC long-term monitoring site).
13. Cherry Point (48.85085205, -122.723114). Co-located research with Northwest Straits Commission (Whatcom MRC long-term monitoring site), DNR Cherry Point Aquatic Reserves.
14. Point Caution* (48.552264, -123.005296). Planned co-located research with UW FHL, PSRF.
15. Burrows Lighthouse (exact location TBD with partners) (48.477656, -122.714284). Planned co-located research with Samish Indian Nation and PSRF.

Environmental data collection at the 15 sites will fall into two categories, each with unique frequency and methods:

1) Continuously operating fixed sensors with integrated data loggers to measure benthic water parameters at 15-minute intervals for a one-year period (planned for January 2024 – December 2024). Sites will be visited approximately quarterly by dive teams to retrieve sensors and swap in fresh sensors.

2) Monthly collection of additional parameters and collection of water samples from a boat. The additional environmental parameters will be collected with CTD profiles, PAR profiles and Secchi depth determinations. Water samples will be filtered in the field for in-house TSS determinations and processed for delivery to the UW Oceanography Marine Chemistry Lab for nutrient analyses.

7.2.2 Field parameters and laboratory analytes to be measured

Fixed sensors deployed at the 15 sites will measure the following parameters in the benthic environment at a depth of -3 meters MLLW at 15-minute intervals:

- Water temperature
- Water depth (pressure sensor)
- Water conductivity
- Photosynthetically active radiation (PAR) (to be measured January-March only)

Duplicate water samples will be collected monthly at 0.5m and 5m below the water surface to be analyzed for:

- Total suspended solids (TSS)
- Nutrients (nitrate, nitrite, ammonium, silicate, phosphate)

7.3 Modeling and analysis design

7.3.1 Analytical framework

Not applicable.

7.3.2 Model setup and data needs

Not applicable.

7.4 Assumptions of study design

There are three fundamental assumptions in the study design:

1. Sites are representative of a set of sites with similar environmental characteristics and floating kelp abundance trajectories.

2. The parameters selected for measurement include key environmental factors that explain a large portion of the variance in floating kelp abundance across sites.

3. The annual cycle identified for measurement (Jan.-Dec. 2024) is representative of longer-term conditions to the extent that differences among sites are largely persistent across years. The environmental conditions measured in 2024 are predictive of multi-year trajectories of floating kelp across sites.

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Control of tidal phase for monthly sampling: field sampling will be scheduled to ensure a level of consistency across sites and sampling events in tidal stage and current.

Water sample handling and timely lab delivery: all field staff will be trained in the field protocol and ensure that delivery logistics are in place for each sampling event.

7.5.2 Practical constraints

The project start date (signed IAA 11/14/2023) was much later than the July 2023 start date initially envisioned when the funding for this project was awarded (Feb. 2023). This puts pressure on preparations, including the hiring of project staff, finalization of this QAPP, sensor procurement and sensor package assembly.

To minimize the impact on project activities, several steps have been taken. First, regular project team meetings were initiated prior to the formal start of the project. The coordination achieved with these meetings will contribute to a quick and efficient start of team activities. Second, additional staff have stepped in at DNR to dedicate time to boost project management capabilities. Third, other existing monitoring efforts have been contacted for the use of existing sensors that are not immediately required by these other efforts.

7.5.3 Schedule limitations

The later-than-expected start to this project puts in jeopardy the data collection planned to begin in January 2024. Between the project start date and the initiation of data collection, many preparatory steps are required. These include the hiring of staff, the development and approval of this QAPP, sensor purchases and sensor package assembly, and scheduling of field staff and field resources. Enquiries to sensor vendors indicate that the sensor procurement process alone may require several weeks.

Due to the scheduling pressures, it is possible the start of data collection will be pushed back by one or two months. At the time of this QAPP development, a major scheduling uncertainty is the time required for QAPP review, revision, and approval.

8.0 Field Procedures

8.1 Invasive species evaluation

Study sites are not located within areas of extreme concern, as listed on the website of the Department of Ecology (Data - Washington State Department of Ecology). The precautions and procedures outlined in EAP070 version 2.3 will be followed prior to and after all field activities. Field equipment and watercraft will be cleaned before and after use and checked for aquatic invasives prior to field efforts.

8.2 Measurement and sampling procedures

Field staff follow relevant SOPs that outline the sampling and measurement process. Parameters, instruments and relevant SOPs for monthly ambient sampling are listed in Table 10. Instruments and relevant SOPs for long-term sensor deployment are listed in Table 11.

8.2.1 Monthly discrete sampling

All 15 sample stations will be visited on a monthly basis to collect basic water quality measurements. At each visit we will collect water samples to measure dissolved inorganic nutrients (NO3, NO2, NH4, PO4, SiOH4) and total suspended solids (TSS), CTD casts (conductivity, temperature and depth) as well as a measure of the attenuation coefficient for PAR in the upper 5m of the water column. Sample stations are located at the deep edge of kelp beds, in water that is at least 6m deep.

Dissolved Inorganic Nutrients and Total Suspended Solids

Monthly field filtered water samples will be collected using a Van Dorn sampler at approximately 0.5m and 5m depth. Two replicate samples will be collected at each site. From each sample we will collect subsamples for analysis of nutrients and TSS. Sample collection broadly follows procedures described in EAP025, version 2.4 (sections 6.3 and 6.6).

- Sub-samples for nutrient analysis will be collected using an acid washed 60 mL syringe with an attached 0.45 µm cellulose acetate filter, that will be filled with water directly from the Van Dorn sampler. A small amount of water (approx. 5ml) will be filtered through the syringe to rinse the syringe and syringe filter before rinsing an acid washed 60 mL high density polyethylene (HDPE) bottle with filtrate. The bottle is then filled with filtrate before being placed immediately in a cooler on ice and transported to a regional office (DNR office in Olympia; WDFW office in Port Townsend; Shannon Point Marine Center in Anacortes) where it will be frozen (-10 ˚ C) for later transport to the University of Washington's Marine Chemistry Lab for total dissolved nutrient analysis using spectrophotometric methods.
- Sub-samples for TSS will be transferred from the Van Dorn sampler to a 1L HDPE bottle, before being placed immediately in a cooler on ice and transported to Olympia for analysis using gravimetric methods (Total Suspended Solids, Appendix D).

Temperature and Salinity

Temperature and salinity will be measured using a weighted SonTek Castaway®-CTD instantaneous data sonde or YSI ProDSS. The sonde will be cast from the side of the boat and data is quality checked in the field using the sonde's real-time data display. The sonde uses flow-through electrodes to ensure rapid and accurate readings which require sonde casts to be quick and uniform. After each cast, depth profiles will be reviewed and, in cases of non-uniform profiles, the sonde will be recast to ensure data quality. Review of cast data also allows for in-field assessment of any water column stratification due to temperature. We aim to collect 2 replicate casts at each site. Operating procedures are described in detail in standard operating procedure HSIL01 (see Section 16: Appendices). The YSI ProDSS follows a very similar procedure and sonde architecture. Data can be reviewed in the field to ensure data quality.

Light Attenuation Coefficient

Light attenuation will be measured by recording simultaneous ambient and in-water photosynthetically available radiation (PAR) measured in quantum flux (µM/m2 /s). Ambient levels will be monitored using a Li-Cor LI-190R 2π quantum sensor mounted to the boat. In-water, light will be measured using a Li-Cor LI-192 2π quantum sensor paired with an Onset HOBO Water Level data logger attached to a weighted anchor. The anchor assembly is cast in one-meter intervals down to a depth of 5 m, beginning 10 cm below the water surface. The data logger is kept at each depth interval for a minimum of 30 seconds. We aim to collect 2 profiles for calculating attenuation coefficients per site. Operating procedures are described in detail in standard operating procedure HSIL02 (see Section 16: Appendices).

Table 10: Monthly ambient sampling – parameters & Standard Operating Procedures

Parameter	Discrete (monthly snapshot samples collected by boat)	Relevant SOP
Conductivity	Profiles using YSI or SonTekCastAway-CTD	HSIL01 (see Section 16: appendices)
Light attenuation	Calculated from PAR measurements in the air and at 1-5 m depths, using licor and pressure sensor	HSIL02 (see Section 16: appendices)
Dissolved inorganic nutrients	Bottle samples	EAP025, version 2.4 (ECY Publication 23-03-207, June 2023)
Pressure/depth	Profile with YSI SonTekCastAway-CTD	HSIL01 (see Section 16: appendices)
Secchi depth	Visual assessment	
Temperature	Profile with YSI SonTekCastAway-CTD	HSIL01 (see Section 16: appendices)
Total suspended solids	Bottle samples	HSIL04 (see Section 16: appendices)

8.2.2 Continuous data collection with fixed sensors

At all 15 stations we will deploy sensor arrays to continuously measure water temperature, salinity, pressure (depth) and photosynthetically active radiation (PAR). Water temperature, salinity and pressure will be measured throughout an entire year. PAR sensors and associated wiper systems will only be deployed during winter, to measure potential light limitation for the gametophyte life stage and the juvenile sporophytes of floating kelp. The construction & deployment of sensor arrays is described in detail in standard operating procedure HSIL03 (see section 16: appendices)

Sensor arrays will be deployed by divers and consist of a PVC frame attached to a fixed helical anchor at -3m (MLLW) at every site (Figure 2). The helical anchors will be deployed at the start of the sample season, in the center of each kelp bed, and will remain in place throughout the entire sample season. Sensor arrays will be deployed for 3 months before they are replaced with a new sensor array. All sensor arrays will be wrapped with copper tape to minimize fouling.

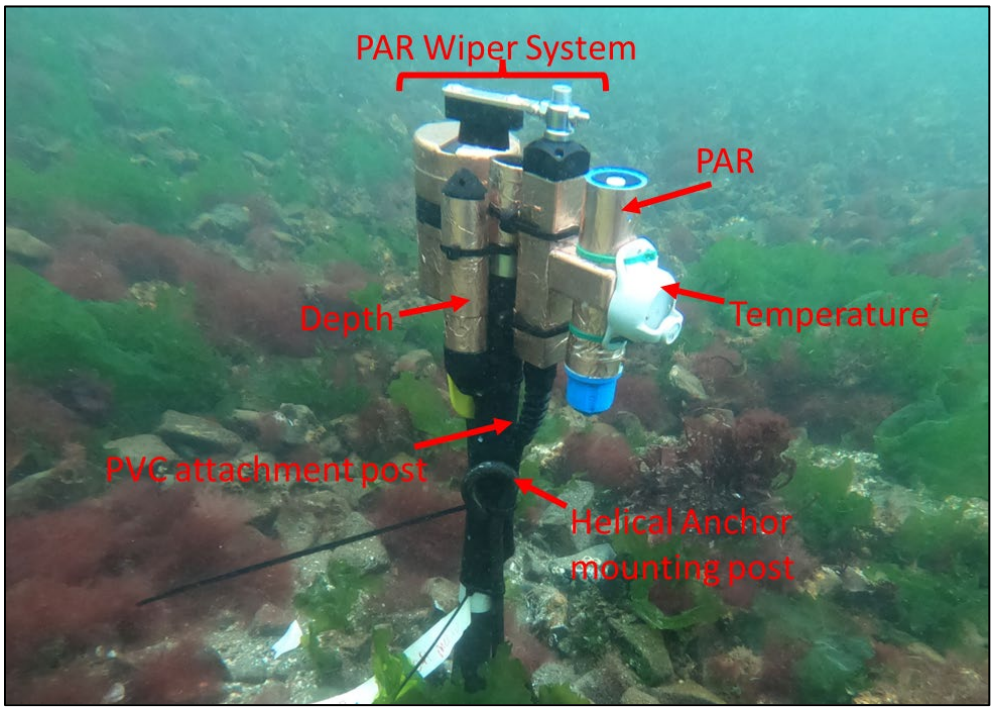


Figure 2: sensor array consisting of a PAR sensor, wiper system, temperature sensor and depth (pressure) sensor, attached to a helical anchor post.

To measure PAR, we will use Odyssey Submersible PAR loggers combined with a Zebra-Tech dataflow Hydro-wiper. The hydro-wiper will be set to a 15 minute interval, to minimize any potential fouling of the PAR sensor. The Odyssey PAR sensors will be calibrated to a factory calibrated LiCOR LI-192 2π quantum sensor using methods described in Long et al. (2014). After

calibration, these relatively low cost sensors deviate less than 4% from standard factory calibrated PAR sensors (Long et al. 2014). The calibration procedure is described in standard operating procedure HSIL03.

Each sensor array will also be equipped with a Van Essen CTD-Diver submersible datalogger to measure temperature, conductivity (salinity) and pressure (depth) at 1 minute intervals. These sensors will be equipped with a 'diver copper shield' to minimize fouling during the 3-month deployment time. Alternatively, we will deploy a combination of a HOBO U20L water level logger, a HOBO TidbiT MX water temperature logger, and a HOBO U24 salt water conductivity/salinity logger. These instruments will be protected from fouling using copper tape (Figure 2). The specifications for each sensor are listed Table 11.

Table 11: In situ-data collection – Parameters, Instruments & Standard Operating Procedures

Parameter	Discrete (monthly snapshot samples collected by boat)	Relevant SOP
Conductivity	Van Essen CTD Diver or Onset HOBO U24 conductivity/salinity logger	HSIL03 (see Section 16: appendices)
Light (PAR)	Odysset Submersible PAR logger, equipped with a Zebra-Tech dataflow Hydro-wiper	HSIL03 (see Section 16: appendices)
Pressure/depth	Van Essen CTD Diver or Onset HOBO U20L water level logger	HSIL03 (see Section 16: appendices)
Temperature	Van Essen CTD Diver or Onset HOBO TidbiT MX water temperature logger	HSIL03 (see Section 16: appendices)

8.3 Containers, preservation methods, holding times

Table 12 lists the appropriate containers, preservation techniques, and holding times for each parameter sampled. Procedures are based on 40 CFR 136 and SOP EAP025, version 2.4.

Table 12. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity Required	Container	Preservative	Holding Time
Total suspended solids	Water	1,000 ml	1,000 mL polyethylene bottle	Cool to ≤6°C	Max. 7 days
Nitrate	Water	60 ml	60 mL polyethylene bottle	Cool to ≤6°C during transport, frozen to -10 °C in dark within 12 hours	Max. 3 months
Nitrite	Water	60 ml	60 mL polyethylene bottle	Cool to ≤6°C during transport, frozen to -10 °C in dark within 12 hours	Max. 3 months
Ammonium	Water	60 ml	60 mL polyethylene bottle	Cool to ≤6°C during transport, frozen to -10 °C in dark within 12 hours	Max. 3 months
Orthophosphate	Water	60 ml	60 mL polyethylene bottle	Cool to ≤6°C during transport, frozen to -10 °C within 12 hours	Max. 3 months

8.4 Equipment decontamination

Not applicable.

8.5 Sample ID

Each water sample will be labeled with a sample ID, using electrical tape and a sharpie. The sample ID consists of the following elements: Site – date – depth – parameter-replicate (for example: *S1/041523/3m/DIN/a*. Sites are abbreviated to a site-code (S1 through S15). Site codes for each sample are also noted in the field log during sampling.

Datafiles from the different loggers are based on the following naming convention: Site – sensor – date, where the site code is the same as for the water samples, and the date is the Sdate that the data were downloaded (after deployment).

Sensor arrays will receive a waterproof tag before being deployed in the field. The tag number will be documented in the field log before deployment (as well as in the sensor log when the arrays are being constructed, see SOP HSIL03 (section 16 – Appendices).

8.6 Chain of custody

Not applicable.

8.7 Field log requirements

Field staff use a field data sheet or water-resistant field notebook to document each sampling event. Corrections are made to the sheet or notebook with single line strikethroughs, an initial, and correction date. Staff verify forms or notebook for missing or anomalous measurements before leaving each site. Digital field forms will be introduced to record sampling events once the development and testing process has been completed. The following sample event information should be recorded:

- Field staff
- Date, time, location, and sample ID for any sample taken. This includes both water samples, as well as CTD cast file names and the ID for the attenuation coefficient data files.
- Instrument ID for any instrument used (LiCOR, YSI, Sontec Castaway)
- Field measurement results
- If sensors were deployed or collected: the tag number of the sensor array, as well as any observations on the condition of the sensors, as well as a picture of the sensor arrays after retrieval (to document visible fouling, especially on the PAR sensors)
- Changes or deviations from the SOPs
- QC sample ID and location.
- Conditions before and throughout the run.
- Site-relevant observations
- Circumstances that might affect or bias results

At the end of each field day, the field staff in charge of delivering the nutrient samples to the lab will document when the samples were frozen or processed/placed in a fridge at ≤6°C. This documentation can consist of an email to the Project Manager.

8.8 Other activities

Other activities to maintain sample collection, processing, and data consistency include:

- Field staff training
- Equipment maintenance and calibration updates (especially pertaining to the LiCOR and Odessey PAR sensors)
- Lab notification for changes to sample schedules, bottle orders, etc.

9.0 Laboratory Procedures

9.1 Lab procedures table

Table 13. Measurement methods for water samples

Analyte	Expected Range of Results	Detection or Reporting Limit*	Analytical (Instrumental) Method
Ammonia	<0.01 – 30 mg/L	0.0013 mg/L	SM 4500-NH3 G-2011
Nitrate/Nitrite	<0.01 – 30 mg/L	0.0025/0.0001 mg/L	SM 4500-NH3 G-2011
Orthophosphate	0.01 – 5.0 mg/L	0.0009 mg/L	SM 4500-P F-2011
Silicate	1 – 100 µmol/L	0.013 mg/L	SM 4500-SiO2 E-2011
Total Suspended Solids	<1 – 2,000 mg/L	1.0 mg/L (RL)	HSIL04 (Appendix D)

*Method Detection Limit can vary based on sample dilutions
SM: Standard Methods (APHA, 1998)
RL: Reporting limit

9.2 Sample preparation method(s)

Not applicable.

9.3 Special method requirements

Not applicable.

9.4 Laboratories accredited for methods

All water samples will be analyzed for Ammonia, Nitrate, Nitrite and Orthophosphate by the UW Oceanography Marine Chemistry Lab, 1492 NE Boat St, Seattle WA 98195. This laboratory is accredited for these analyses using the methods listed in Table 13 (accreditation number A521-23).

10.0 Quality Control Procedures

The project's quality control (QC) procedures consist of three parts:

1. Consistent instrument calibration methods and schedules.
2. Adherence to the relevant SOP procedures and periodic evaluation of staff.
3. Collection of field QC samples during each sampling run.

These procedures are used to assess the quality of the collected data and to identify issues associated with data collection, processing, and analysis. Table 14 lists the QC sample types and frequency for field and lab parameters

10.1 Table of field and laboratory quality control

Table 14. Quality control samples, types, and frequency.

Parameter	Field Blanks	Field replicates	Calibration verification / blanks	Analytical Duplicates	Matrix spikes
ammonia	2 field blanks per month*	2 replicate samples at all sites/ every month	ICV/ICB = Beginning of sequence, CCV/CCB= 1/10 samples & end of sequence, one method blank per batch	1/batch	1/batch
nitrate/nitrite	2 field blanks per month*	2 replicate samples at all sites/ every month	ICV/ICB = Beginning of sequence, CCV/CCB= 1/10 samples & end of sequence, one method blank per batch	1/batch	1/batch
orthophosphate	2 field blanks per month*	2 replicate samples at all sites/ every month	ICV/ICB = Beginning of sequence, CCV/CCB= 1/10 samples & end of sequence, one method blank per batch	1/batch	1/batch
silicate	2 field blanks per month*	2 replicate samples at all sites/ every month	ICV/ICB = Beginning of sequence, CCV/CCB= 1/10 samples & end of sequence, one method blank per batch	1/batch	1/batch
TSS	n/a	2 replicate samples at all sites/ every month	n/a	n/a	n/a

* One field blank at 2 randomly selected sites every month.

10.1.1 Quality control for monthly field surveys

Water samples

At every site we will collect 2 replicate water samples at 2 different depths. The difference between these samples is used to estimate variability due to stratification (at the site), field collection and processing, and lab analyses.

In addition, we will collect one field blank at 2 random stations every month to check for contamination from sample collection and processing. We collect the samples according to standard operating procedures (e.g., EAP025, version 2.4) and select QC stations before the start of the field season.

Each sample will be entered in a database that records the holding time (before analysis), as well as any contamination in field blanks or method blanks that were collected during the same period or analyzed in the same batch.

Instruments

We will collect 2 replicate CTD casts and water column attenuation profiles at each site to assess local variability at the site.

Where possible, we reference all instrument calibration checks to a NIST, or equivalent, standard through periodic checks against standards or probes with a calibration history. A calibration check history is recorded for each field probe to provide a record of apparent error or bias. We use this record to assess the data quality of the probe results. When QC results indicate, and time allows, we adjust the results for any detected bias.

- LiCOR PAR sensors will have a recent calibration certificate
- Thermistors on the YSI as well as SonTekCastAway-CTD will be checked agains a NIST referenced or equivalent thermometer at the start, in the middle, and at the end of the sample season
- Conductivity sensor on the YSI and SonTekCastAway-CTD will be checked against a NIST calibration fluid according to the manuals for these instruments.

10.1.2 Quality control for in-situ data collection

All Odessey PAR sensors will be calibrated twice for this project: before initial deployment and after the winter deployment is complete. Calibration procedures are described in SOP HSIL03. Calibration multipliers will be recorded on the field log for each sensor. Light sensors that exhibit a large change in the calibration multiplier before/after being deployed in the field will be flagged.

Odyssey PAR sensors will be equipped with a wiper system to minimize the effects of fouling. To document the efficacy of these wiper systems, we will photograph all PAR sensors immediately after deployment to document any biofouling on the sensor head.

All other sensors (CTD Diver as well as Onset conductivity, temperature and pressure loggers) will undergo at least 2 large-scale short-term deployments in either a temperature controlled flow-through system (at Friday Harbor Labs) or at a fixed location in Puget Sound (either a marina or a pier) to assess potential bias between individual sensors for measurements of temperature, salinity and depth. During these deployments, we will collect intermittent point readings using a NIST calibrated thermometer or conductivity probe.

All sensor data streams will be examined for outliers or compromised data. The purpose of screening for outliers is to identify any issues with sensor or logger function. The screening process will consist of:

- Visual inspection of plotted time series
- Identification of highest 1% and lowest 1% values and inspection of these data points in the context of the time series.
- Identification of extreme changes between consecutive observation where the change value is in the highest 1% of all changes.
- Detection of decay in PAR values over the course of individual sensor deployments. Detection will be by visual inspection of smoothed data that removes high frequency variation. The concern here is degradation in PAR data due to fouling of the detector surface.

10.1.3 Quality control for lab samples

The UW Oceanography Marine lab adheres to their own standard QC program, SOPs for analyses, and Lab Users Manual. The primary types of QC samples used to evaluate the accuracy of lab analyses are check standards, lab duplicates, spikes, and blanks (See Table 14).

- Check standards are used to evaluate the analytical system calibration bias. Standards are set to bracket the concentration range of the working instrument.
- Lab duplicates provide an estimate of analytical precision. In addition, analysis of field replicate samples estimates the total precision of the sampling and analysis process. In some instances, field replicate samples are split to evaluate differences between lab and field processing.
- Spiked samples determine interferences in the analysis of a particular sample matrix and the effect on analyte recovery. Samples spiked with a known analyte are analyzed with, and compared to, associated samples.
- Blanks are used to check for sample contamination in the laboratory process.

10.2 Corrective action processes

We address known sources of error through the following procedures:

- Repeating quality performance checks and, if warranted, cleaning, servicing, maintaining, and re-calibrating field and lab instruments.
- Verifying that sampling method or analytical procedures are followed.
- Retraining staff on Standard Operating Procedures (SOPs).
- Collecting additional samples or field measurements.
- Re-analyzing samples within appropriate holding time requirements.
- Consulting with the lab to address a measurement or analytical problem.

- Qualifying results based on our final-result confidence.

A persistent, consistent bias in the data may warrant corrective change in procedures. Potential bias from changes in analytical or sampling procedures are assessed by overlapping new and old procedures for several months before adopting the new method. The results are used to determine bias between methods and to ensure that our measurement quality objectives (MQOs) are met.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Field data can be placed into three categories:

1. Sensor data recorded to instrument data loggers.
2. Secchi depth measurements recorded to field forms.
3. Metadata – recording of field visits on field forms that include site and field visit activities including logging of retrieved sensors, a log of field data collected during the visit, and a log of water samples collected and processed.

Proper recording of field data will rely on logging instruments and the systematic use of field forms to record field visit metadata and Secchi depth measurements.

Procedures for data management in the office will include:

1. Downloading of data from instrument loggers to an accessible data format (e.g., csv).
2. Renaming of data files to enforce systematic naming and placement of data files in a systematic folder structure.
3. Transcribing of necessary data and metadata from field forms.
4. Completing the data tracking table in the project database to ensure that all datafiles are accounted for.

In-house water sample processing for TSS determinations will generate the following data:

1. Completed lab forms documenting completion of steps involved in TSS determinations.
2. Data table containing the results of the TSS determinations, as well as metadata such as sample holding times, and any potential deviations from the lab protocol.
3. Corresponding entries in the data tracking table in the project database to ensure that all samples are accounted for.

Water sampling processed at the UW Marine Chemistry Lab will involve the following data:

1. Tracking data for the inventory of water samples, their unique IDs and their status with respect to sample preparation, transport and lab processing and lab results delivery and QA.
2. Data table with compiled results from the UW lab, including metadata such as sample holding times, results from blanks, and any potential deviations from the lab protocol.
3. Corresponding entries in the data tracking table in the project database to ensure that all samples are accounted for.

All environmental data will be subject to a series of automated QA procedures that will vary by data stream but will isolate non-physical values, outliers, and other artifacts.

11.2 Laboratory data package requirements

We anticipate that the UW Marine Chemistry Lab will provide results in a standard package that will include a cover narrative and detailed results. We will require the lab to include all relevant quality control data.

11.3 Electronic transfer requirements

We will coordinate with the UW Marine Chemistry Lab to ensure data are transmitted in a digital format.

11.4 Data upload procedures

This project will upload the environmental data collected to EPA's WQX portal on an annual basis as outlined in Table 3.

11.5 Model information management

Not applicable.

12.0 Audits and Reports

12.1 Audits

Data audits are conducted on a regular basis for both sensor data and laboratory data (once they have been processed). A final audit will be conducted at the end of the sampling year, once all data have been completely processed.

To audit laboratory data, Discrete Sampling Manager tracks and reconciles 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 every 3 months by both the Data Manager and the Project Scientist 3.

We will use several levels of audits to audit sensor data.

- The Continuous Sensor Manager, with support of the Discrete Sampling Manager, conducts an initial assessment of the sensor data immediately after download and verifies the location, deployment date, and completeness of the data record for each sensor at each of the 15 sample stations. They populate a sensor deployment table in the project database that includes fields for verification of location, deployment data and data completeness. They also transcribe field notes on potential fouling, and make sure that the after-deployment pictures are labeled and stored in a central location.
- The Discrete Sensor Manager is responsible for managing and calibrating all environmental sensors, and ensures that calibration data is entered in the project database.
- The Data Manager, with support of the Project Scientist 3, independently verifies the completeness of the data record for each sensor deployment, and will flag data with unexpected results (outside of expected range for a site or sensor). The Data Manager is also responsible for reviewing the calibration data on a regular basis, and to flag any sensors that are potentially malfunctioning.

The Data Manager, Discrete Sampling Manager and the Continuous Sampling Manager will report to the Project Manager according to the schedule in section 12.3. The individual roles and responsibilities for conducting audits is described in section 12.2.

12.2 Responsible personnel

Table 15 highlights the roles and responsibilities of all personnel involved with auditing the environmental data collected, as well as who each person report to.

Table 15: Staff roles and responsibilities

Staff	Reports to	Roles and responsibilities
Discrete sampling manager	Project manager	Supports the Data and Field Manager with initial assessment and review of laboratory and sensor data Is responsible for managing and calibrating all environmental sensors, and ensures that calibration data is entered in the project database
Project Scientist 3	Data Manager	Supports the Data Manager with review of laboratory data and data for sensor deployments
Continuous sensor manager	Project Manager	Tracks and reconciles the status of samples being analyzed by the laboratories, being particularly alert to any significant QC problems that arise Is responsible for initial assessment of the sensor data immediately after download. Verifies the location, deployment date, and completeness of the data record for each sensor at each of the 15 sample stations with support from the Project Scientist 2
Project Scientist 4	Continuous sensor manager	Assists continuous sensor manager with sensor management and deployment.
Project Scientist 5	Continuous sensor manager	Assists continuous sensor manager with sensor management and deployment.
Data Manager	Project Manager	Reviews statistical calculations and plots of all the laboratory data collected during a sampling year (that pass initial QC by the Data and Field Manager) with support from the Project Scientist 3 Independently verifies the completeness of the data record for each sensor deployment, and will flag data with unexpected results with support from the Project Scientist 3 Reviews the calibration data on a regular basis and flags any sensors that are potentially malfunctioning with support from the continuous sensor manager and the discrete sampling manager

12.3 Frequency and distribution of reports

We will submit semi-annual reports to the HSIL sub-award manager using the reporting tool supplied by WDFW. These reports will include brief information on each of the following areas:

- A comparison of actual accomplishments to the outputs/outcomes established in the assistance agreement work plan for the period;
- The reasons for slippages if established outputs/outcomes were not met; and
- Additional pertinent information, including when appropriate, analysis and information of cost overruns or high unit costs.

A final report will be submitted to the HSIL sub-award manager at the end of the project (no longer than 60 days after the termination of the grant agreement). This report will contain the same information as the interim reports, but will cover the entire project period.

12.4 Responsibility for reports

The primary authors for the semi-annual and final reports are the Project Manager and the Data Manager, with support from the Continuous Sensor Manager, the Discrete Sensor Manager, and the Project Scientist 3.

13.0 Data Verification

Data verification and review is conducted 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.

13.1 Field data verification, requirements, and responsibilities

13.1.1 Discrete monitoring

Qualified field staff perform field data verification. They record results and observations on ambient run digital and printed field forms, and they check for missing or questionable measurements before leaving each site. If an instrument produces an erratic or unexpected reading, then they complete maintenance procedures or standards checks to fix or verify measurement accuracy.

Field staff enter results into the ambient database within two weeks after each run. Field staff check their own work for entry errors and, if necessary, make corrections. Other qualified staff conduct a second check of all data entries on a quarterly basis before the data are published as provisional. The Data Manager, the Continuous Sensor Manager and the Discrete Sensor Manager verification and finalize preliminary results and review errors found in the quarterly check using best professional judgement.

13.1.2 Continuous monitoring

The Continuous Sensor Manager and the Discrete Sensor Manager conduct initial quality control checks after downloading continuous sensor data. They may verify whether a deployed in situ meter meets MQOs through side-by-side comparison to a second calibrated meter. Result from these comparisons are used to determine the level of maintenance or cleaning required if the in situ sensor results exceed the MQOs.

The Data Manager, with support from the Project Scientist 3, is responsible for final review and verification of the continuous data record. Final review will use a semi-automated verification process with best professional judgement.

13.2 Laboratory data verification

The Discrete Sampling Manager, with support from the Project Scientist 1, review all laboratory results, and document for each sample if holding times were exceeded or if there were any issues with field blanks, method blanks, or any of the other QC parameters reported by the lab.

The Data Manager, with support from the Project Scientist 3, is responsible for final review and verification of all water quality parameters measured.

13.3 Validation requirements, if necessary

Not applicable.

13.4 Model quality assessment

Not applicable.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The Project Manager will evaluate if the project has met the original objectives by assessing:

- if data were collected consistent with the study design, methods, and procedures described in the final approved QAPP.
- if enough of the data are deemed usable after verification.

To determine whether data have met the data quality objectives (DQO's), we will determine if they have met the Measurement quality objectives (MQO's) outlined in Tables 7 through 9. Based on this assessment, the data will either be accepted, accepted with appropriate qualifications, or rejected and re-analysis considered.

14.2 Treatment of non-detects

For the project, data results or concentrations of all analytes reported between the MDL and reporting limit will be flagged, indicating a higher level of uncertainty in the quantitative value. The presence of these non-detects will be taken into account during statistical analysis. 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. Sample results that are not at least three times greater than the corresponding results in the method blank will be flagged and their status will be listed as 'not detected'. Sample results that are not at least three times greater than the corresponding results in the field blank samples will also be flagged, and their status will be listed as 'not detected' due to contamination of the field.

14.3 Data analysis and presentation methods

Data from the various sites and sampling occasions will be compiled into a set of relational tables. The data will be subject to data quality checks and generation of summary statistics using custom scripts created in an R environment. Summary statistics will span different levels of temporal aggregation. Correlation in the various parameters across sites will be evaluated.

14.4 Sampling design evaluation

The sampling design is effective for assessing the environmental parameters in kelp habitat. The sample design is evaluated based on the success of station attainment, and data collection. If meaningful conclusions can be drawn from the data, the sample design will be considered effective.

14.5 Documentation of assessment

Reported as part of the final data synthesis and project summary report.

15.0 References

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16.0 Appendices

Appendix A. HSIL01 – SonTek CastAway CTD

The purpose of this SOP is to detail the steps needed for collecting water column profiles using a SonTek CastAway.

1. OVERVIEW OF THE INSTRUMENT

The CastAway-CTD uses three sensors to profile conditions in the water: conductivity, temperature, and pressure. The conductivity and temperature sensors are located in the flow-through channel along the back of the CastAway CTD housing, while the pressure sensor port passes through the housing at the top of the battery cap (Figure 3). The flow-through channel is designed to ensure a steady flow of water past the sensors when the system is descending and ascending through the water column.

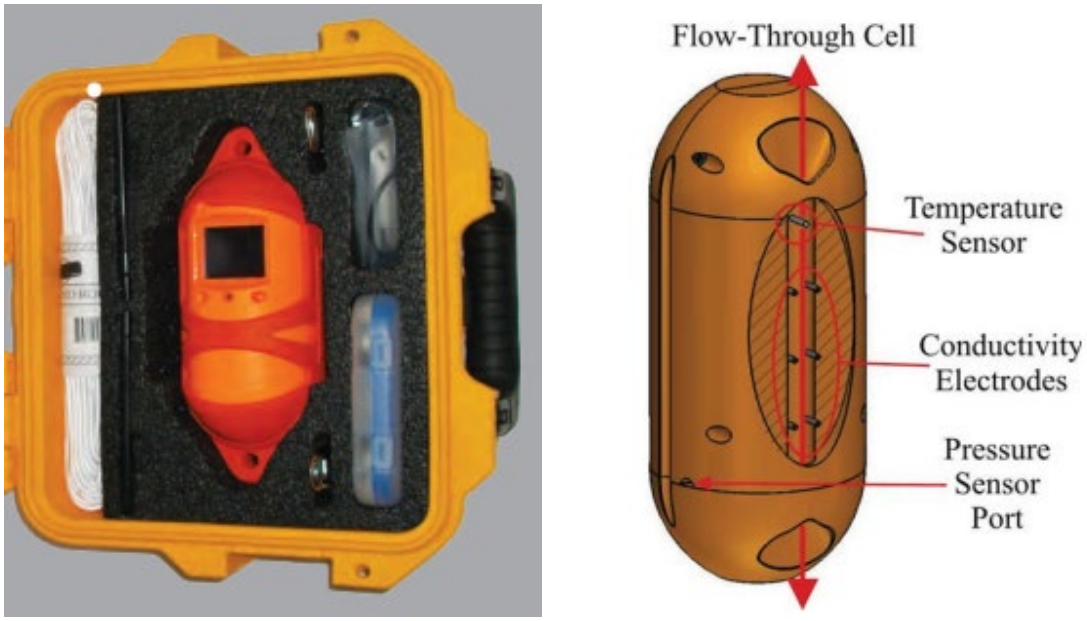


Figure 3: Overview of the SonTek CastAway CTD

2. COLLECTING FIELD DATA

Make sure the instrument has 2 fresh AA alkaline batteries & check that the battery compartment is closed. Attach the instrument using a locking carabiner to the deployment line, and clip an additional weight to the bottom of the polyurethane jacket. Make sure the other end of the deployment line is tied off on the vessel. Start the instrument using the magnetic stylus pen and select the options for collecting cast data (see sections 2 and 3 of the operation manual). Use the following directions to collect good quality data:

- At the start of the cast, hold the system underwater near the surface for 5-10 seconds. This allows the temperature and conductivity sensors to adjust from air to water conditions, and avoids problems in the first part of the down cast.

- For the down cast, allow the system to free fall to the bottom. The size, shape and weight of the CastAway-CTD has been specifically designed to free fall at approximately 1 m/s (3.3 ft/s). Allowing a clean free fall ensures a steady flow of water through the flow-through cell and past the sensors.
- For the up cast, retrieve the system at a steady rate of about 1 m/s (3.3 ft/s). A steady rate ensures a steady flow of water past the sensors for the best quality data. Do not let the system rest on the bottom. Begin the up cast as quickly as possible.
- Do not pause during either the down or up cast.

At each site, collect 2 replicate CTD casts at a location with a water column of at least 5m depth. Check the screen on the instrument to screen for anomalous data. Collect additional cast data if need be.

3. DATA PROCESSING

The user can view several types of data from the CastAway-CTD: Processed, Down Cast, Up Cast, or Raw. For our purpose, we will use the processed data, which is based on a weighted average of the down and up casts based on the cast velocity. Up Casts are more heavily weighted near the surface and down casts are more heavily weighted near the bottom.

Appendix B: HSIL02 – SOP light attenuation coefficients

The purpose of this SOP is to detail the steps needed for collecting underwater light measurements to calculate an attenuation coefficient. This process involves taking simultaneous measurements of surface and sub-surface light at several depth intervals using a LiCor LI-1500 Light sensor logger, 2 LI-192 underwater Quantum Sensors, a 2009S underwater lowering frame, and one Hobo U20L water level data logger.

1. BEFORE FIELD SURVEYS

Instrument set-up

The submersible portion of the instrument consists of a 2009S underwater lowering frame with a LI-192 underwater quantum sensor in the upright position[4], a lead weight at the lower portion of the frame to keep the quantum sensor vertical while lowering the frame, and a Hobo U20L zip-tied to the frame to measure water pressure while lowering the frame. The 2009S frame is attached to a low stretch polyester rope with marks at 1m intervals. The cable for LI-192 is loosely zip-tied to polyester rope to allow for some stretch in the polyester rope[5]. Figure 4b shows the correct setup for the data-logger (LiCOR LI-1500). The cable for the surface LI-192 sensor is connected to BNC port 1, while the cable from the underwater sensor is connected to BNC port 3.

LiCOR set-up

- Set the time on the logger (console setup, set time, note that it uses military time), and make sure the GPS[6] is disabled (select menu, console setup, GPS and 'Disabled').
- Make sure the most recent calibration data is entered for both light sensors. If a sensor has been newly calibrated: Select MENU, add new sensor, and select the model number of the sensor. Use option Mul A/W for the LI-192 and add the AIR and WATER calibration multipliers for both sensors. Select the Cal Date and use the up/down arrows to set the date of the sensors last calibration.
- If this is the first time using the logger for this project, create a configuration (if else, select the configuration before starting). Select menu, configurations add new config. Enter the name for the new configuration (HSIL_KELP), then select inputs (IN1 and IN3) and attach the chosen sensors to the input port. Select the sensor serial numbers from the list in the logger (see previous step). For IN1, select 'SHALLOW' (to use the water multiplier) and for IN3, select 'DEEP' (for the water multiplier), then press exit.

[4] We are only measuring downwelling radiation. Not upwelling radiation.

[5] This allows the rope to bear the strain from lowering the weighted frame in a dynamic marine environment, prolonging the lifespan of the LI-192 cable.

[6] Disable the GPS to prolong battery life on the logger.

- Change the logging routine to manual, set the sampling rate to 1 Hz and enable averaging over a 5 second interval: Open menu, configurations and select HSIL_KELP. Set Samp Rate to 1 Hz (one sample per second) and set routine to 'manual'. Select outputs, add new output, output type 'light' and enter the name for the output (SHALLOW for input 1 and DEEP for input 3), select 'averaging' and set the window to 5 seconds.
- Check that the measurement range is set to R3 (the default) for both sensors.
- The instrument is now ready to use. Whenever you power up the logger, select configuration 'KELP_HSIL' and press ok to activate. Whenever you press the LOG button, you will log a light reading based on the average of 5 measurements over a 5-second interval. Values are also shown on the screen of the logger.

Hobo U20L set-up

- Open HOBOware.
- Connect the logger to the computer using the optic base station and select the 'Launch' option from the device menu.
- In the Launch Logger window, make sure both the Abs. Pressure and Temperature sensors are selected (temperature is required for temperature compensation of pressure), and select the logging start time (the time & date that actual field survey starts) and the logging interval (1 measurement per second).
- Click the Start button in the lower right corner of the Launch Logger window to send the launch settings to the logger. The logger is now deployed and ready to be attached to the 2009S underwater lowering frame. Measure the offset (vertical distance) between the pressure sensor and the position of the light sensor on the frame.

2. DURING FIELD SURVEYS

Use the following steps to measure light attenuation:

- Make sure all cables are connected to the logger (see section 1) and switch on the logger. Select configuration HSIL_KELP and press ok to activate. The screen on the logger shows the PAR readings for both the SHALLOW and DEEP water sensors (note: there will be a 5 second delay before the first value appears on the screen).
- Note the site, date, GPS coordinates, and the ID number of the pressure/depth sensor attached to the underwater lowering frame.
- Position the SHALLOW sensor subsurface (approximately -0.25m) and lower the WATER sensor to -1m, wait 30 seconds and press the LOG button. Share values with the note taker, who will write down the time, depth and the values for AIR and WATER. Repeat the same steps for the following depths: -1m, -2m, -3m, -4m, and -5m.

Make sure all values are both stored on the logger and written down on the data sheet. If there are issues, retake the measurements. Table 16 shows an example data sheet.

Table 16: example data sheet for collecting light attenuation data

Site name:		GPS coordinates:	
Date:		Pressure sensor ID:	
time	SUBSURFACE reading (-0.25m)	Depth (m)	DEEP reading (variable depth)
		1	
		2	
		3	
		4	
		5	

3. DATA PROCESSING

To calculate the actual depth of the light measurements, identify the pressure (mbar) right before the first reading (air pressure), and then subtract this value from the pressure values collected at the different depths. Divide this value by 100 to measure the depth (m) of the pressure sensor and add the offset to calculate the depth of the light sensor during deployment.

Use the subsurface (depth z_1) and deep (depth z_2) PAR values in combination with the pressure derived depth values to calculate a Light attenuation coefficient (K_d) using Beer's Law:

$$K_d = -\frac{ln\left(E_d(z_2)/E_d(z_1)\right)}{z_2 - z_1}$$

Appendix C: HSIL03 – SOP Sensor Array Preparation

The purpose of this SOP is to document detail the steps needed for constructing and deploying sensor arrays for continuous data collection. These sensor arrays consist of a PAR sensor and wiper motor (for the first deployment in winter) as well as temperature, conductivity, and pressure sensors. The depth/pressure/conductivity sensors are either a Van Essen CTD-Diver or a combination of different Onset sensors (Hobo TidbiT MX, Hobo UL20, Hobo U24).

4. GENERAL PROCEDURE

The first step in the general assembly procedure is to gather the equipment needed, record the sensor ID numbers, and to launch all sensors. Next, tape the PVC post, wiper and battery pack with copper tape and attach the CTD Diver copper shield (if you use the Van Essen sensor) or tape the Hobo UL20 (if you use the Onset sensors). Secure all sensors on the PVC post and add additional copper tape to the PAR sensor as well as any bare spots on the sensor array. Finally, attach a waterproof label to the sensor array and add all information regarding sensor ID numbers and waterproof label in the deployment table of the project database. See below for additional information on assembly and deployment.

5. EQUIPMENT

Sensors:

- PAR – Xtreem PAR Logger (http://odysseydatarecording.com/)
- Van Essen CTD Diver (CTD-Diver - Van Essen Instruments)
- Temperature – Hobo Tidbits (https://www.onsetcomp.com/)
- Depth – Hobo water level (30 ft) U20L-01 (https://www.onsetcomp.com/)
- Conductivity – Hobo U24 (https://www.onsetcomp.com/)

Tools:

- Snips
- Phillips-head screwdrivers – small & medium
- Nut driver (5/16”)

Assembly parts:

- Helical anchor & 18” of ½” PVC to help drive helical into substrate
- PVC stake with many drill holes
- Zip ties
- Stainless steel hose clamp (size 28, 1 ¼-2 ¼”)
- Silicone grease for o-rings
- Electrical tape
- Copper tape
- Plastic deployment array label

6. LAUNCHING SENSORS

Launch all sensors before assembly of the sensor array. Instrument manuals (see websites listed above) have detailed instructions on how to launch each type of sensor. Use the following considerations when launching sensors:

- The data collection interval is every 15 minutes
- The launch time should be 0100 (1:00 AM) one day after scheduled deployment
- Replace batteries before launching (Hydro-wipers - all new Energizer AA alkaline batteries, Odysseys PAR sensors – all new Lithium batteries)
- Check and grease o-rings (o-ring silicone from dive shop)
- Add one dry desiccant pack for PAR sensor
- Record sensor serial numbers per deployment array, and make sure to document the deployment array label number.

7. SENSOR ARRAY SETUP

Before you start, make sure that:

- All sensors are launched
- All sensors are clean of fouling
- Batteries are replaced
- There is a dry dessicant pack in the PAR sensor

Attach sensors to the PVC post using stainless steel hose clamps (size 28, 1 ¼-2 ¼"), zip ties and electrical tape in the configuration shown on Figure 4.

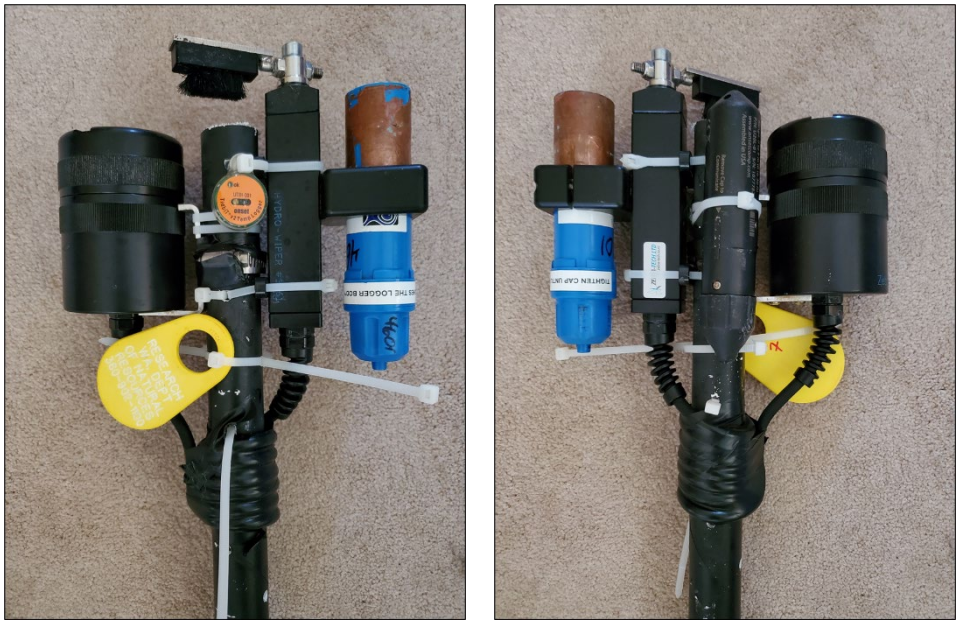


Figure 4: Sensor array configuration (left: front, right: back)

Open the battery pack for the wiper motor and set the wipe interval to every 60 minutes (groove in position 3, see Figure 5). The Hydro wipe interval timer will start 0.5 seconds after the power is switched on.

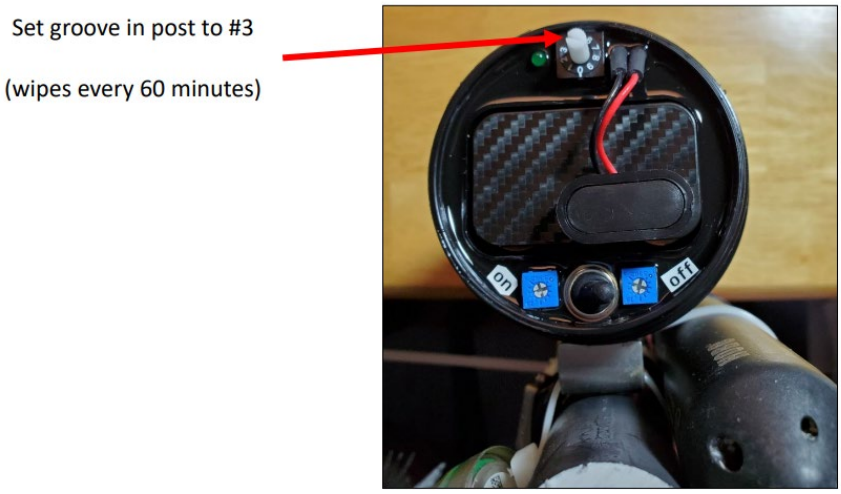


Figure 5: Adjust the wiper interval

Next use a small Phillips head screwdriver to adjust the Park Position and the Wiper Angle (Figure 6). Make sure that the wiper motor is turned on immediately before deploying the sensors in the field (open the lid to the battery housing and flip the switch to “on”). Close the lid to the battery housing prior to submersion. Hand tight will suffice.

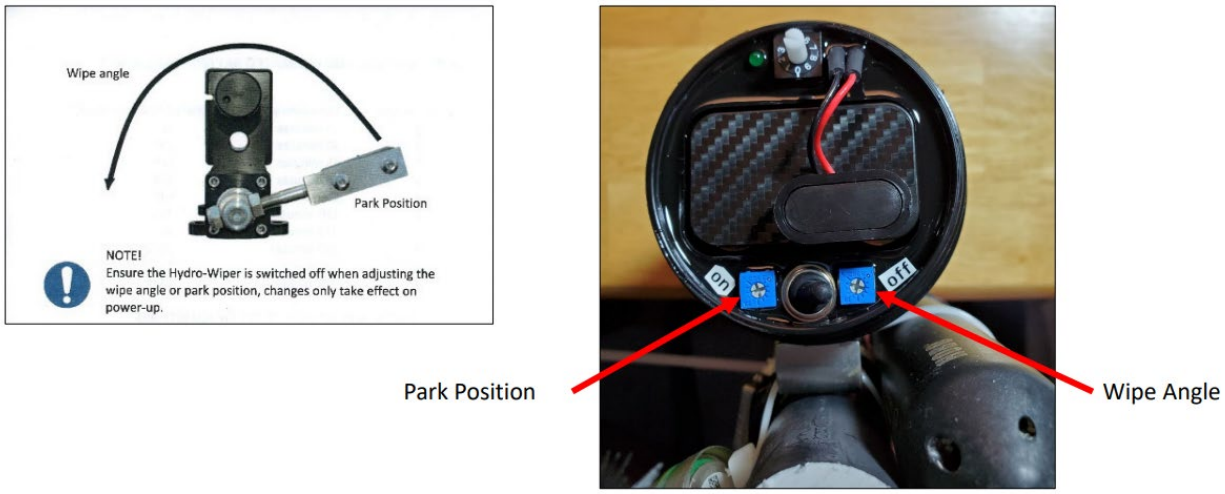


Figure 6: Adjust Park Position and Wiper Angle

8. SWAPPING SENSORS

When swapping sensors, make sure to complete the following steps:

- For the new sensor:
    - With dry hands, open lid on Hydro-Wiper battery pack and switch wiper motor "ON"
    - Check o-ring grease on Hydro-Wiper battery pack lid and close hand tight
    - Note the number of the waterproof label for the new sensor array in the field notebook
    - Jump in the water and deploy at position of old sensor using zip ties
    - Deploy with light diffuser vertical and (if possible) facing in a southerly direction
    - Snip ends of zips ties off to reduce surface area that could be fouled
- For the old sensor:
    - After recovery, rinse sensor array with fresh water and wipe dry.
    - Take a picture of the top of the sensor array to document any potential fouling on the diffuser plate of the light sensor. Also take a picture of the entire sensor array to document general fouling on all sensors
    - Note the number of the waterproof sensor for the old sensor array in the field notebook and describe the general condition of the sensors (fouling)
    - Open battery housing and switch wiper motor "OFF". Tool provided to open battery housing if necessary
    - Store in a safe place where wiper arm will not be damaged
- Record date and time of sensor swap
- Clean sensor as soon as possible upon return to lab. Dry copper tape and fouled organisms are difficult to clean

9. CLEANING SENSOR ARRAYS

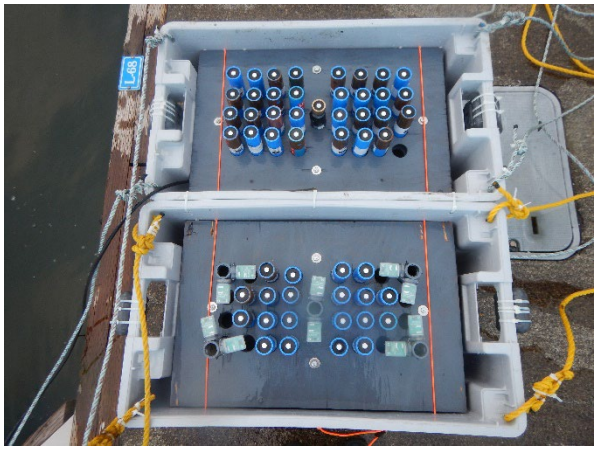
To clean sensor arrays, make sure to complete the following steps:

- Rinse arrays thoroughly
- Carefully brush or wipe off fouling organisms to remove sensors
- Remove sensors – remove copper tape, clean thoroughly
- Careful not to damage white diffuser on PAR sensor
- Remove copper tape from sensor array
- Paint scraper
- Rinse and let dry

10. PAR SENSOR CALIBRATION

To calibrate the Odyssey PAR sensors, use the following steps:

- Launch all sensors (see manual on Odyssey website). Set the measurement interval for the Odyssey PAR sensors to 15 minutes. Note that these sensors integrate light measurements and provide a cumulative (count) value over the measurement interval.
- Add all sensors to calibration trays, together with a factory calibrated LiCOR Li-192 underwater PAR sensor (Figure 7).
- Set the LiCOR sensor to measure the average photon flux over a 15 minute measurement interval (μmol m^{-2} s^{-1}).
- Deploy the calibration trays in the marine environment at a fixed depth (for example, alongside a dock in a marina at ~1m depth from a floating dock) and collect data over a 24 hour time interval. Make sure that the LiCOR data logger is stored in a waterproof container at a safe location on land.
- Download all data and create linear regressions between Odyssey (count) data and Licor Measurements. The slope of these regression lines can be used as calibration coefficients for future deployments.
- Note that you want to calibrate the sensors within the range of expected light at the target sites. For this reason, it is advised to do at least two calibrations: one at the start of the sample season (January) and one at the end of the deployment season (April for light sensors) to incorporate the effect of season on day length and light intensity.



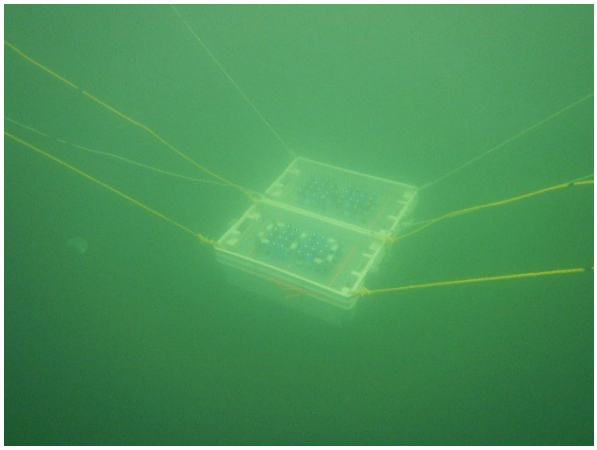


Figure 7: examples of a calibration tray with Odyssey PAR sensors, Onset light sensors, as well as a LiCOR Li-192 underwater quantum PAR sensor.

Appendix D: HSIL04 – Total Suspended Solids

These procedures are modified from SM 2540 D for use in the WA DNR Aquatic Botany Lab.

January 2024. Revised March 2024.

Water Sample

Collect approximately 1000ml of water from the specified location and water depth using a Van Dorn sampler. Collect duplicate water samples into a clean Nalgene or glass bottle. Refrigerate sample at 4° C up to the time of analysis to minimize microbiological decomposition of solids. Preferably, samples are processed within 24 hours. The maximum holding time for a sample is 7 days if stored at temperatures of 6° C or below, but above freezing (0° C).

Method Blank

Samples analyzed should include at least 2 method blank with each batch of samples.

Duplicates

Duplicates must agree within 10% of their average weight.

Method Detection Limit

On-going method blank data collection – compile all routine method blanks analyzed with each sample batch during the course of sample analysis. The MDL is calculated as mean TSS concentration plus three times the standard deviation of the set of method blanks.

TSS Determination

1. Muffle GF/F at 500° C for 3 hours.
2. Pre-weigh the filter. Use glass fiber filters, typically Whatman GF/F filters of 4.7cm diameter and 0.7μm pore size.
3. Filter up to 1000 ml seawater in a filtration apparatus using a vacuum and write down the volume filtered.
4. Rinse the filter with 100 mL DI water.
5. Remove filter from filtration apparatus and transfer to a pre-weighed inert weighing dish.
6. Place the filter and weighing dish in a drying oven at 50-60°C for at least 4-5 days.
7. Allow filter to cool.
8. Weight the filter and weighing dish. Record weight to the nearest 0.0001 gram.

9. Repeat the cycle of drying, cooling, and weighing until a constant weight is obtained, or weight change in less than 4% of the previous weighing.

Organic Content Determination (POM)

Follow these steps after TSS determination to determine the portion of TSS that is oxidizable organic matter.

1. Muffle the filter for at least 4 hours at 375° C.
2. Cool and weigh filter again -> POM.

Appendix E. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Anthropogenic: Human-caused.

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.

Dissolved oxygen (DO): A measure of the amount of oxygen dissolved in water.

Diurnal: Of, or pertaining to, a day or each day; daily. (1) Occurring during the daytime only, as different from nocturnal or crepuscular, or (2) Daily; related to actions which are completed in the course of a calendar day, and which typically recur every calendar day (e.g., diurnal temperature rises during the day, and falls during the night).

Eutrophic: Nutrient rich and high in productivity resulting from human activities such as fertilizer runoff and leaky septic systems.

Nutrient: Substance such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms. **Pathogen:** Disease-causing microorganisms such as bacteria, protozoa, viruses.

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.

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

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Synoptic survey: Data collected simultaneously or over a short period of time.

Total suspended solids (TSS): Portion of solids retained by a filter.

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

90th percentile: An estimated portion of a sample population based on a statistical determination of distribution characteristics. The 90th 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

DO	Dissolved oxygen
DOC	Dissolved organic carbon
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
i.e.	In other words
MQO	Measurement quality objective
QA	Quality assurance
QC	Quality control
SOP	Standard operating procedures
SRM	Standard reference materials
TOC	Total organic carbon
TSS	Total suspended solids
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife

Units of Measurement

°C	degrees centigrade
dw	dry weight
ft	feet
g	gram, a unit of mass
kg	kilograms, a unit of mass equal to 1,000 grams
km	kilometer, a unit of length equal to 1,000 meters
m	meter
mm	millimeter

mg	milligram
psu	practical salinity units
µg/L	micrograms per liter (parts per billion)
µm	micrometer
µS/cm	microsiemens per centimeter, a unit of conductivity
ww	wet weight

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 (Kammin, 2010). For Ecology, it is defined according to WAC 173-50-040: "Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data."

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* (USEPA, 2014).

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: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

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, 2014; USEPA, 2020).

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, 2014; USEPA 2020).

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).

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: The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

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, 2014).

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)/LCS duplicate: 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. Monitors a lab's performance for bias and precision (USEPA, 2014).

Matrix spike/Matrix spike duplicate: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias and precision errors 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 (USEPA, 2001).

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): The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguished samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

Minimum level: Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: "quantitation limit," "reporting limit," and "minimum level" (40 CFR 136).

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).

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).

Reporting level: Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms "reporting limit," "quantitation limit," and "minimum level" to be synonymous (40 CFR 136).

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, 1992).

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, 2014).

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, 2014).

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).

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).

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