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State of Washington

Addendum 4 to Quality Assurance Monitoring Plan

Long-Term Marine Waters Monitoring, Water Column Program

January 2017

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Publication Information

Each study conducted by the Washington State Department of Ecology (Ecology) must have an approved Quality Assurance Project Plan. The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, Ecology will post the final report of the study to the Internet.

This Quality Assurance Project Plan is available on Ecology's website at https://fortress.wa.gov/ecy/publications/SummaryPages/1703103.html

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

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Cover photo: Sunrise at Potlach boat launch on Hood Canal (by Mya Keyzers)

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Quality Assurance Project Plan

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January 2017

Approved by:

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

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3.0 Background

This document describes the 2017 sampling effort for Ecology's Long-Term Marine Waters Monitoring Program. It is an addendum to *Quality Assurance Monitoring Plan: Long-Term Marine Waters Monitoring, Water Column Program* (Bos, 2015). This Quality Assurance Monitoring Plan (QAMP) addendum specifies which stations and parameters will be sampled in 2017.

In 2017, 37 core stations and two sediment team core stations will be sampled for standard water column parameters. Additional sampling will be included at a subset of stations for total organic carbon (TOC), total nitrogen (TN), particulate organic carbon (POC), and particulate organic nitrogen (PN). A new instrument will also be tested called a Submersible Ultraviolet Nitrate Analyzer (SUNA).

A collaboration with the Salish Sea Marine Survival Project will take place from March through October at two stations in Hood Canal. Staff from the Hood Canal Salmon Enhancement Group will collect one vertical plankton net tow at each of these two stations to quantify zooplankton.

The purpose of the program is to examine and report marine water quality on a regular, long-term basis. Its objectives are to understand current existing conditions in the context of environmental factors, identify spatial and temporal trends, and provide high-quality information from sensor and lab sample collection.

All required sections not mentioned in this addendum are discussed in the original QAMP (Bos, 2015) and referenced Standard Operating Procedures.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1. Organization of project staff and responsibilities.

EAP Staff	Title	Responsibilities
Julia Bos Marine Monitoring Unit Western Operations Section Phone: (360) 407-6674	Monitoring Coordinator, Data Management, Data Analyst, Publications Author	Writes the QAPP. Oversees JEMS monitoring program - field and laboratory activities. Conducts QA review, analyzes and interprets data, and enters data into EIM/data management system. Writes reports and data summaries.
Christopher Krembs Marine Monitoring Unit Western Operations Section Phone: (360) 407-6675	Senior Oceanographer, Lead Presentations, Publications Author	Determines monitoring strategy. Generates index/indicators of water quality conditions. Determines appropriate analysis, review, and interpretative methods for data reduction and reporting. Generates data products. Lead author of publications and presentations.
Skip Albertson Marine Monitoring Unit Western Operations Section Phone: (360) 407-6675	Physical Oceanographer, Data Analyst, Modeler, Publications Author	Analysis and reporting of climate, weather, and ocean indicators. Generates data products and analytical tools. Conducts QA review of data, analyzes and interprets data. Writes reports and data summaries.
Mya Keyzers Marine Monitoring Unit Western Operations Section Phone: (360) 407-6395	Marine Flight Lead Technician	Conducts field sampling, laboratory analysis, and instrument maintenance. Records and manages field information. Conducts QA review, analyzes and interprets data. Writes reports and data summaries.
Laura Hermanson Marine Monitoring Unit Western Operations Section Phone: (360) 407-0273	Marine Flight Technician	Conducts field sampling, laboratory analysis, and instrument maintenance. Records and manages field information. Conducts QA review, analyzes and interprets data.
Carol Maloy Marine Monitoring Unit Western Operations Section Phone: (360) 407-6742	Unit Supervisor	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Dale Norton Western Operations Section Phone: (360) 407-6596	Section Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
William R. Kammin Phone: (360) 407-6964	Ecology Quality Assurance Officer	Reviews the draft QAPP and approves the final QAPP.

EAP: Environmental Assessment Program, Department of Ecology
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

5.4 Proposed project schedule

Table 2. Proposed schedule for completing field and laboratory work, data processing, review, quality control, storage in a database, and reports.

Activity	Due date	Lead staff
Field and laboratory work		
Field work (sample collection) completed	Monthly	Mya Keyzers
Internal (Ecology) laboratory analyses completed	3 days (DO samples) post-collection	Laura Hermanson
Internal (Ecology) laboratory analyses completed	1 month post-collection (chlorophyll a samples)	Laura Hermanson
External UW and MEL laboratory analyses completed	3 months post-collection (nutrient, TOC, and POC/PN samples)	Mya Keyzers
Data receipt or processing and upload to EAPMW (Marine Waters) database		
Instrument & sensor data	Same month as collection	Julia Bos
Internal laboratory data	1 month post analyses	Laura Hermanson
External laboratory data	1 month post-analyses	Mya Keyzers
Data review and QAQC		
Instrument & sensor data	1 month post-collection	Julia Bos, Christopher Krembs, Skip Albertson, Mya Keyzers, Laura Hermanson
Internal laboratory data	1 month post-analyses	Laura Hermanson
External laboratory data	Quarterly, one quarter post-collection	Mya Keyzers
Environmental Information System (EIM) database		
EIM data loaded	Same month as collection	Julia Bos
EIM quality assurance	4 months after sampling year complete	Julia Bos
EIM complete	4 months after sampling year complete	Julia Bos
Monthly reports		
Monthly condition summary generated	1 month post-collection	Julia Bos
Monthly summary posted to web	1 month post-collection	Christopher Krembs
Annual Assessment - data products & written summary		
Draft assessments & products due	3 months after sampling year complete	Christopher Krembs, Julia Bos, Skip Albertson, Mya Keyzers, Laura Hermanson
Final reviews & QAQC summarized	4 months after sampling year complete	Christopher Krembs, Julia Bos
Final summary due on web	4 months after sampling year complete	Christopher Krembs
Final data posted and performance measures reported		
Final data & analytical plots due on web	4 months after sampling year complete	Christopher Krembs, Skip Albertson
Final Performance calculated & submitted to OFM	Annually in July	Julia Bos

Notes for Table 2
EAP: Environmental Assessment Program
EIM: Environmental Information Management database
MEL: Manchester Environmental Laboratory
QAMP: Quality Assurance Monitoring Plan
UW: University of Washington

5.5 Budget and funding

This budget does not include the full cost of the monitoring program. It is limited to direct expenses for the specific elements below.

Table 3. Projected budget for 2017 Marine Flight operations.

Type	Cost/unit	Qty.	Cost
UW Marine Chemistry Lab Analyses[1]			
Seawater Nutrient Analysis[1&2]	18.50	1320	$ 24,420.00
Salinity Analysis[1]	21.00	156	$ 3,276.00
Dissolved Oxygen reagents[1]	644.00	2	$ 1,288.00
		Subtotal	$ 28,984.00
Manchester (MEL) Lab Analyses			
Particulate organic carbon & nitrogen[2]	42.50	264	$ 11,220.00
Particulate filters	0.90	264	$ 237.60
Total Nitrogen[2]	40.00	264	$ 10,560.00
Total Organic Carbon[2]	30.00	264	$ 7,920.00
		Subtotal	$ 29,937.60
Sensor Cost			
Company			Cost
Seabird Inc.			$ 4,000.00
WET Labs Inc.			$ 3,000.00
Biospherical Instruments Inc.			$ 200.00
		Subtotal	$ 7,200.00
Transportation Cost			
Company			Cost
Kenmore Air Seaplanes[3]			$ 89,010.00
Port of Olympia			$ 600.00
		Subtotal	$ 89,610.00
Shannon Point Marine Science Center			
Research Vessel[4]	$110.00	88	$ 9,680.00
Lab fee	$200.00	12	$ 2,400.00
		Subtotal	$ 12,080.00
		Total	$ 167,811.60

[1] Costs include 15.6% overhead
[2] Includes internal lab and field check standards and blanks sent with every batch. Does not include MEL lab standard and blank samples. The funding for this project ends in June 2017; this is a 6 month budget.
[3] State Contract No. 04413
[4] Inter-agency Agreement No. C1400008

6.0 Quality Objectives

6.2 Measurement quality objectives (MQOs)

6.1.1.5 Laboratory MQOs

Seawater nutrient and salinity sample analyses are conducted by the University of Washington Marine Chemistry Laboratory (UW-MCL). Dissolved oxygen (Winkler) and chlorophyll a samples are analyzed by the Marine Lab (ML) of the Marine Waters Monitoring Group. POC, PN, TOC, and TN analyses are conducted by Ecology's Manchester Environmental Laboratory (MEL). Any labs conducting analyses for the marine waters monitoring program are accredited through Ecology's Laboratory Accreditation Program.

All work is expected to meet the quality control (QC) requirements of the analytical methods used for this project. These requirements are summarized in the Measurement Procedures and Quality Control Procedures sections of this document and in the standard operating procedures (SOPs) used for each analysis. Many of these procedures can also be found in detail in the Puget Sound Estuary Program (PSEP) Protocols (1997).

Table 4. Measurement quality objectives for marine water column laboratory samples.

This table summarizes measurement quality objectives for "analytical laboratory" values for marine data. Ecology is responsible for verifying all MQOs are met.

Measurement - Laboratory	Precision (relative standard deviation, RSD)	Accuracy (Bias) (% deviation from true value)	Lowest Value (reporting limit)
Total Organic Carbon (TOC)	</= 20%	5%	500 ug/L
Total Nitrogen (TN)	</= 20%	5%	25 ug/L
Particulate Nitrogen (PN)	</= 20%	5%	62.3ug/L
Particulate Organic Carbon (POC)	</= 20%	5%	10.5 ug/L
Dissolved Oxygen	5%	5%	0.05 mg/L
Marine Nitrate	10%	5%	0.15 µM
Marine Nitrite	10%	5%	0.01 µM
Marine Ammonium	10%	5%	0.05 µM
Marine Orthophosphate	10%	5%	0.02 µM
Marine Silicate	10%	5%	0.21 µM
Chlorophyll a	10%	N/A	0.02 µg/L
Salinity	5%	5%	0.002 PSU

*Not currently collected

7.0 Study Design

7.1 Study boundaries

7.1.2 Sampling location and frequency

7.1.2.1 Core Station Monitoring and Locations

Core long-term monitoring stations are visited once a month, year-round, to ensure that all major seasonal hydrographic conditions are observed. Since not all stations can be visited in 1 day, stations are aligned by region and separated into regional surveys conducted every month for the most efficient operations. This year the stations are divided into 6 regional surveys a month as opposed to 5, as previously done. Fewer stations per survey allow for more flexibility to adapt to weather delays, seasonally limited daylight hours, and weather-dependent activities such as the *Eyes Over Puget Sound* (EOPS) aerial surveys.

For 2015, stations WPA001 and GYS004 were changed from core to rotational, as these stations are in rivers and exhibit freshwater rather than marine characteristics. These 2 stations will not be sampled in 2017. This results in a total of 39 stations: 37 core waters stations and 2 sediment team core stations. This year the regions will be grouped as:

- Strait of Juan de Fuca (JEMS)
- Coastal Bays (Marine Flight (MF1)
- San Juans/North Sound/Whidbey Basin (MF2)
- Admiralty Inlet/Central Sound (MF3)
- South Sound (MF4)
- Hood Canal (MF5)

See Table 5 and Figures 1-7.

Stations are sampled at intervals no less than 3 weeks apart to ensure reasonable adherence to a monthly sampling scheme.

Table 5. 2017 station list for Ecology long-term marine water column monitoring.

Flight	Station ID	Location	Latitude N NAD83 (deg/dec_min)	Longitude W (NAD83) (deg/dec_min)	WQMA	Depth (m)	Record	Record Length (yrs)	Justification
Marine Flight 1: Coast	**GYS008**	Mid-S. Channel	46 56.2388	123 54.7934	Western Olympic	6	1974-1976, 1983 - present	36	represents mid Grays Harbor, south
	GYS016	Damon Point	46 57.2053	124 05.5770	Western Olympic	11	1982- 987, 1991 - present	30	represents outer Grays Harbor, north
	WPA004	Toke Point	46 41.9800	123 58.1240	Lower Columbia	14	1973-1975, 1977-present	42	represents north Willapa Bay
	WPA113	Bay Center	46 38.6400	123 59.5800	Lower Columbia	11	1997-2000, 2006-present	13	represents mouth of (NW) Willapa Bay
	WPA006	Nahcotta Channel	46 32.7226	123 58.8097	Lower Columbia	21	1991-present	25	represents central Willapa Bay
	WPA007	Long Island, S. Jenson Pt.	46 27.1893	124 00.5672	Lower Columbia	14	1991-2008, 2013-present	20	represents SW Willapa Bay
	WPA008	Naselle River mouth	46 27.7890	123 56.4760	Lower Columbia	14	1996-2008, 2013-present	15	represents SE Willapa Bay, off Naselle R.
	WPA003	Willapa River, John. Slough	46 42.2392	123 50.2431	Lower Columbia	10	1973-present	43	represents north Willapa Bay, off Willapa R.
Marine Flight 2: North	**PTH005**	Port Townsend	48 04.9889	122 45.8767	Eastern Olympic	26	1977-1978, 1991-2002, 2005-present	25	represents waters off city of Port Townsend
	RSR837	Rosario Strait	48 36.9896	122 45.7775	Nooksack/ San Juan	56	2009-present	7	represents waters in Rosario Strait
	GRG002	Strait of Georgia	48 48.4896	122 57.2446	Nooksack/ San Juan	190	1988-present	28	represents Strait of Georgia end member
	BLL009	Bellingham Bay	48 41.1564	122 35.9771	Nooksack/ San Juan	16	1977-present	39	represents waters off city of Bellingham
	BLL040	Bellingham Bay	48 41.0382	122 32.2920	Nooksack/ San Juan	26	NA	27	represents waters of Bellingham
	SKG003	Skagit Bay	48 17.7893	122 29.3763	Island/ Snohomish	24	1990-1991, 1994-1998, 2007-present	16	represents Whidbey Basin
	SAR003	Saratoga Passage	48 06.4557	122 29.4925	Island/ Snohomish	149	1977-present	39	represents Whidbey Basin
	PSS019	Possession Sound	48 00.6556	122 18.0750	Island/ Snohomish	101	1980-present	36	represents waters off city of Everett
	ADM001	Admiralty Inlet	48 01.7888	122 37.0760	Kitsap & Cedar/Green	148	1975-1987, 1992-present	36	represents waters within Admiralty Inlet

Flight	Station ID	Location	Latitude N NAD83 (deg/dec_min)	Longitude W (NAD83) (deg/dec_min)	WQMA	Depth (m)	Record	Record Length (yrs)	Justification
Marine Flight 3: Central	**ADM003**	S. of Admiralty Inlet	47 52.7390	122 28.9917	Kitsap & Cedar/Green	210	1988-1991, 1996-present	22	represents waters S. of Admiralty sills
	PSB003	Puget Snd. Main Basin	47 39.5891	122 26.5745	Kitsap & Cedar/Green	40-50	1976-present	40	represents Puget Sound Main Basin
	ELB015	Elliott Bay	47 35.7892	122 22.1743	Cedar/Green	82	1991-present	25	represents waters off city of Seattle
	EAP001	East Passage	47 25.0226	122 22.8241	Kitsap & Cedar/Green	200	1988-1991, 1994-95, 1997-present	24	represents South Puget Sound main axis
	SIN001	Sinclair Inlet	47 32.9557	122 38.6083	Kitsap	16	1973-1987, 1991-present	39	represents waters off city of Bremerton
	HCB013	Hood Canal	47 50.2548	122 37.7370	N of Hood Canal Bridge	20	NA	1	represents entrance of Hood Canal
	CMB003	Commence-ment Bay	47 17.4226	122 27.0074	South Puget Sound	150	1976-present	40	represents waters off city of Tacoma
Marine Flight 4: South	**BUD005**	Budd Inlet	47 05.5224	122 55.0918	Eastern Olympic	15	1973-present	41	represents waters off city of Olympia
	DNA001	Dana Passage	47 09.6890	122 52.3083	Eastern Olympic	40	1984-85, 1989-present	29	represents south reach of Southern Puget Sound
	NSQ002	Devil's Head	47 10.0390	122 47.2914	E. Oly & Kitsap & SPS	100	1984-85, 1996-present	22	represents South Puget Sound near Nisqually
	GOR001	Gordon Point	47 10.9891	122 38.0743	E. Oly & Kitsap & SPS	160-170	1996-present	19	represents South Puget Sound south of Narrows
	CRR001	Carr Inlet	47 16.5891	122 42.5745	Eastern Olympic	95	1977-93, 1995-96, 1998-2003, 2006, 2009-present	32	represents waters within Carr Inlet
	CSE001	Case Inlet	47 15.8724	122 50.6583	Eastern Olympic	55	1978-1993, 1995-96, 1998-99, 2009-present	27	represents waters within Case Inlet
	OAK004	Oakland Bay	47 12.8056	123 04.6590	Eastern Olympic	15	1974-75, 1977-present	41	represents waters off city of Shelton
Marine Flight 5: Hood Canal	**HCB007**	Hood Canal, Lynch Cv.	47 23.8889	122 55.7755	Kitsap & E. Olympic	21	1990-1996, 1998-2007, 2011-present	22	very low DO, assess duration & coverage
	HCB004	Hood Canal, Sisters Pt.	47 21.3723	123 01.4924	Kitsap & E. Olympic	55	1975-1987, 1990-present	39	represents southern Hood Canal
	HCB003	Hood Canal, Eldon	47 32.2722	123 00.5760	Kitsap & E. Olympic	144	1976-92, 1994-96, 1998-2007, 2010-present	35	very low DO, assess duration & coverage
	HCB010	Hood Canal, S of Bangor	47 40.2000	122 49.2000	Kitsap & E. Olympic	100	2005-present	11	represents northern Hood Canal

Flight	Station ID	Location	Latitude N NAD83 (deg/dec_min)	Longitude W (NAD83) (deg/dec_min)	WQMA	Depth (m)	Record	Record Length (yrs)	Justification
Straits	**SJF000**	Strait of Juan de Fuca	48 25.0000	123 01.5000	S. of San Juan Island	180	2000-present	16	represents northern Strait of Juan de Fuca
	SJF001	Strait of Juan de Fuca	48 20.0000	123 01.5000	SE of Hein Bank	160	2000-present	16	represents central Strait of Juan de Fuca
	SJF002	Strait of Juan de Fuca	48 15.0000	123 01.5000	SW of Eastern Bank	145	2000-present	16	represents southern Strait of Juan de Fuca
	ADM002	N. of Admiralty Inlet	48 11.2391	122 50.5770	Island & E. Olympic	82	1980-present	35	represents waters entering Admiralty Inlet

WQMA: Water Quality Management Area
SPS: South Puget Sound
DO: Dissolved Oxygen

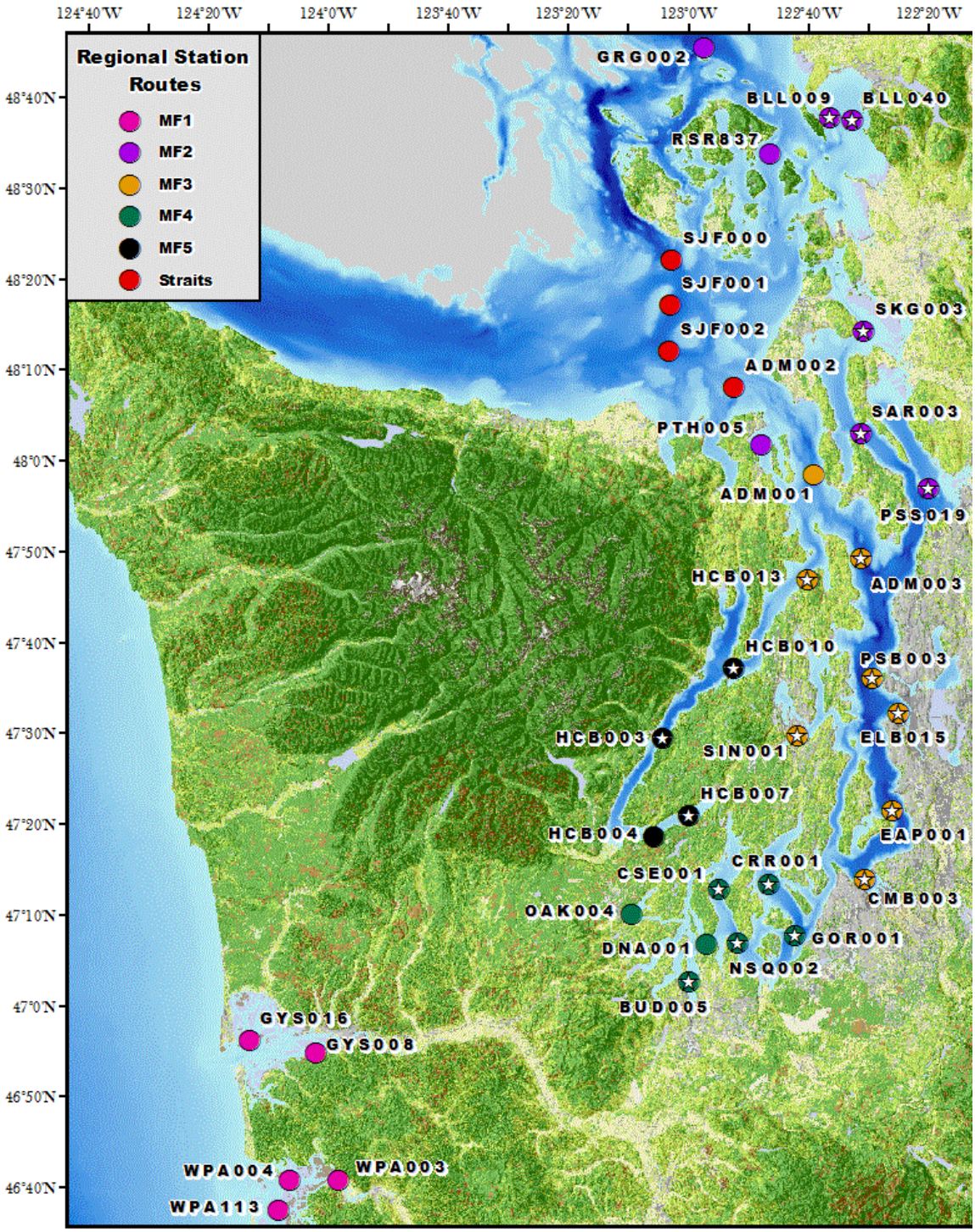

Figure 1. All 2017 Ecology long-term marine water column monitoring station locations.

The 20 particulate pilot project stations are highlighted with a white star.

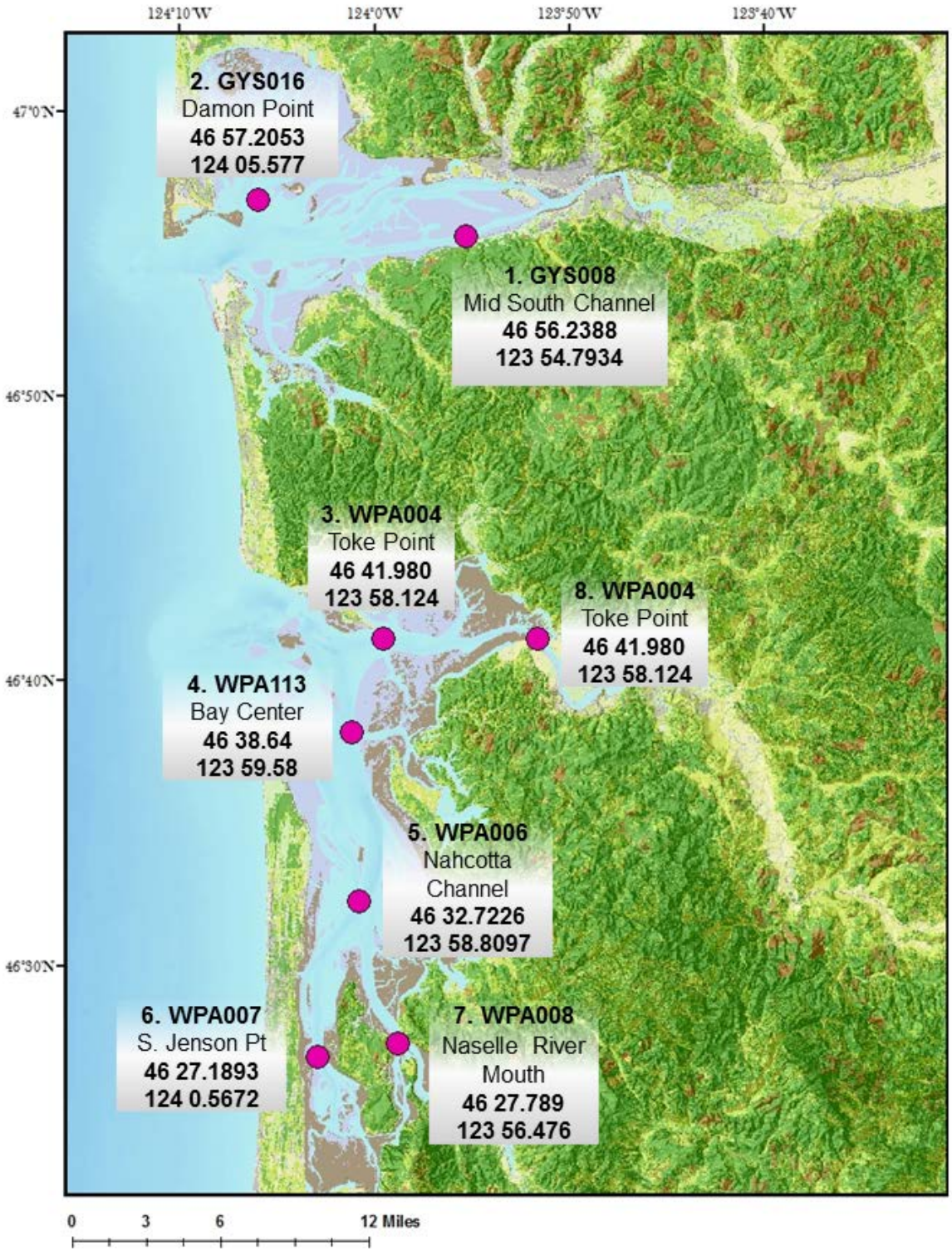

Figure 2. 2017 Marine Flight 1 (MF1) Coast sampling stations.

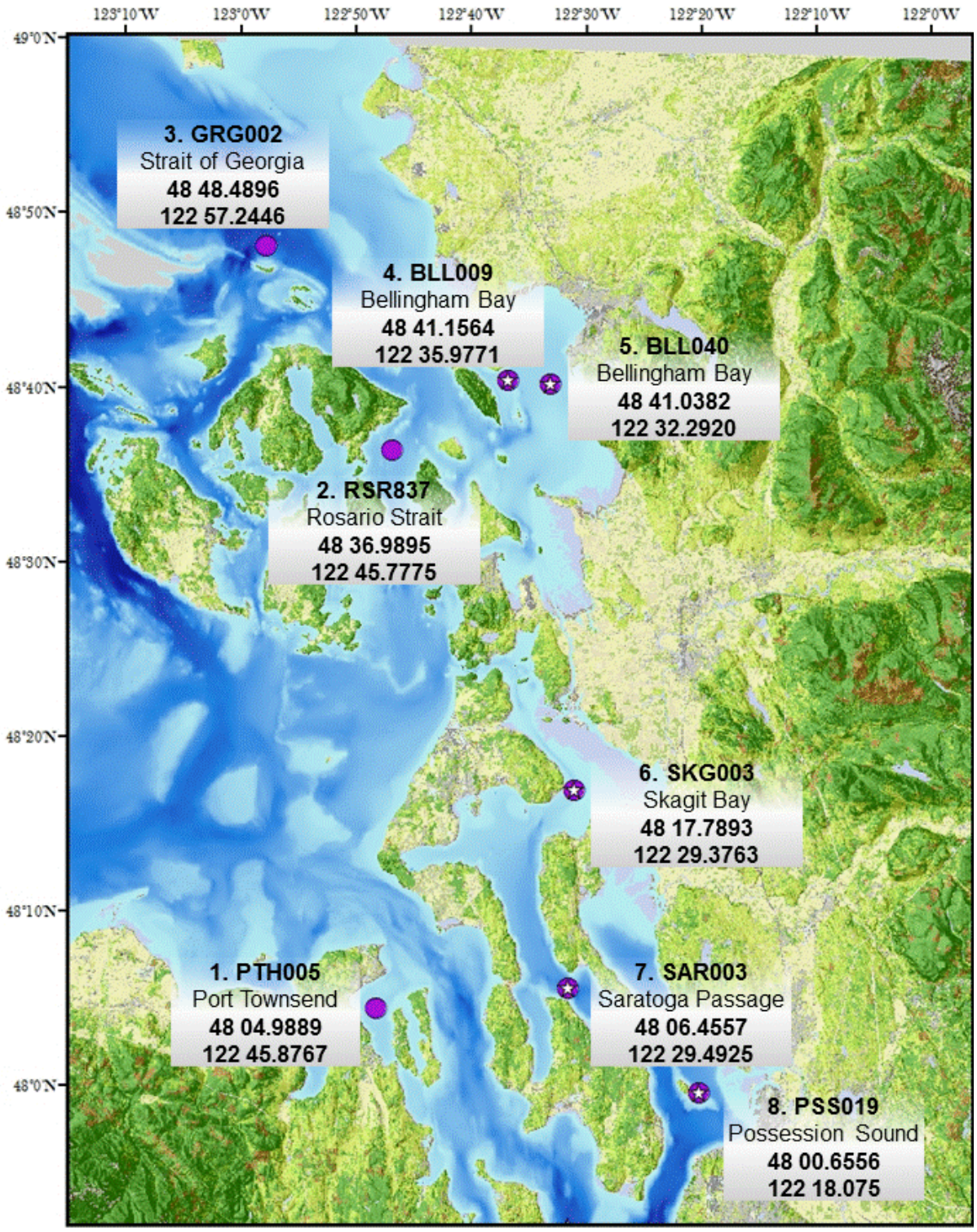

Figure 3. 2017 Marine Flight 2 (MF2) North Sound sampling stations. The 20 particulate pilot project stations are highlighted with a white star.

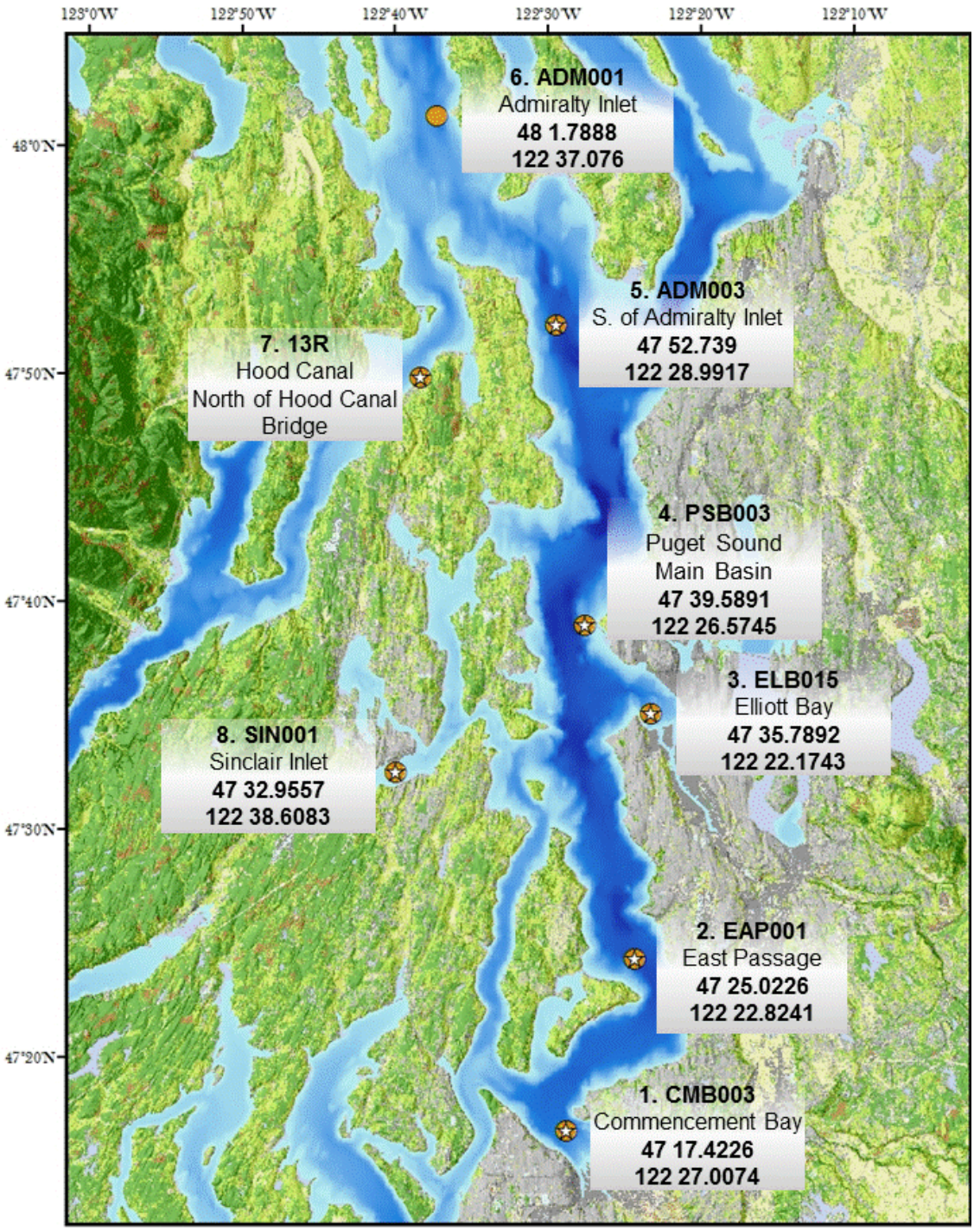

Figure 4. 2017 Marine Flight 3 (MF3) Central Sound sampling stations. The 20 particulate pilot project stations are highlighted with a white star.

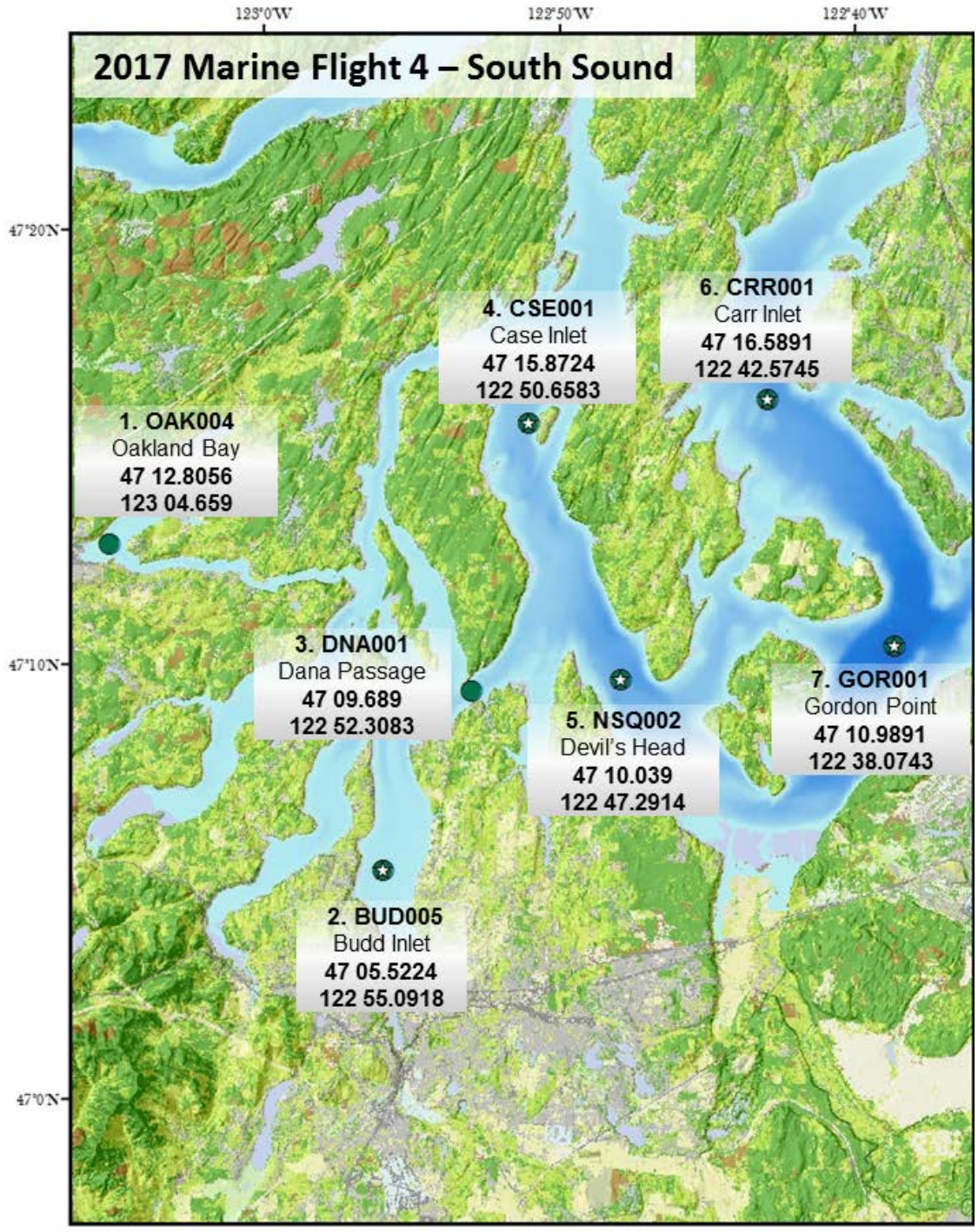

Figure 5. 2017 Marine Flight 4 (MF4) South Sound sampling stations. The 20 particulate pilot project stations are highlighted with a white star.

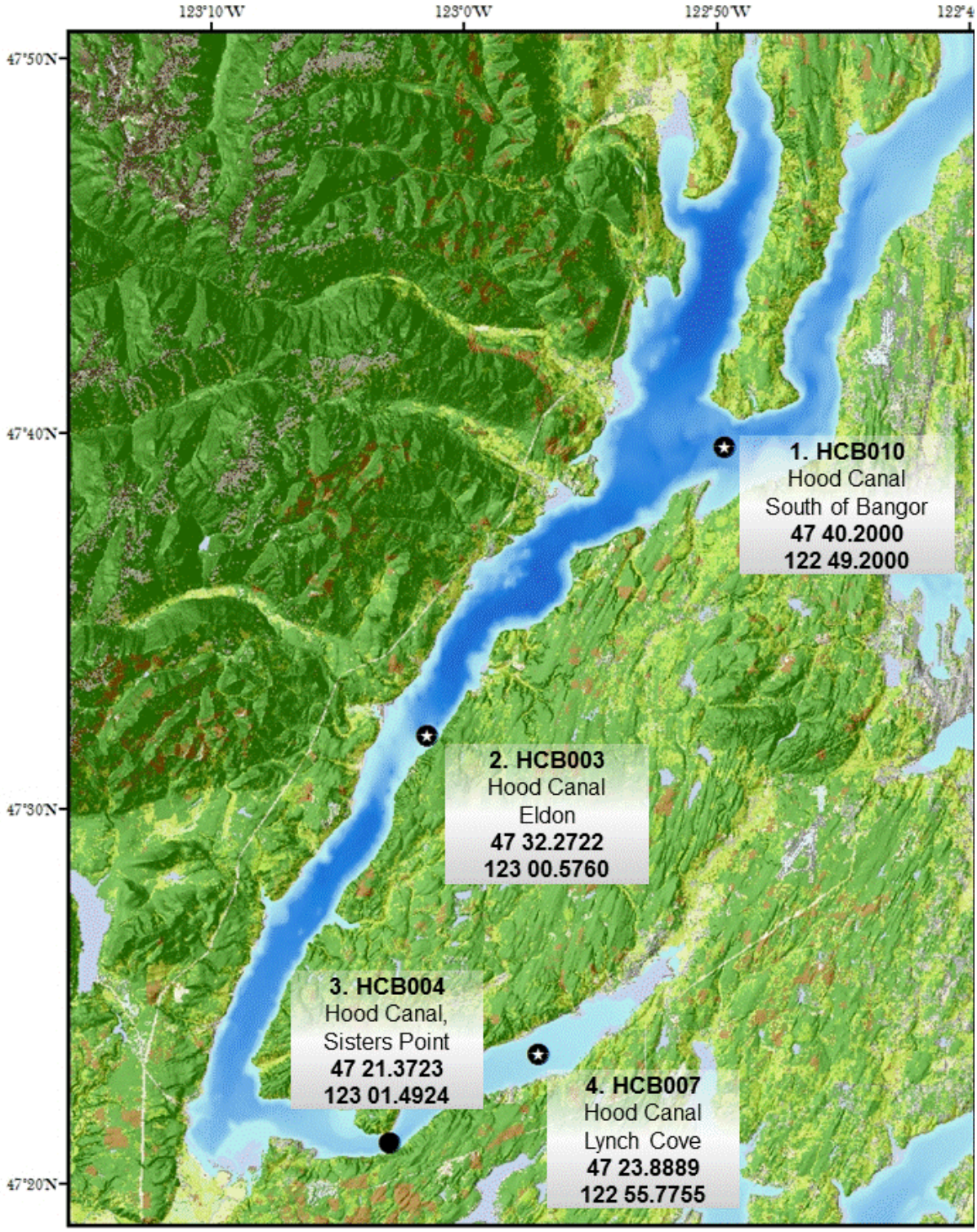

Figure 6. 2017 Marine Flight 5 (MF5) Hood Canal sampling stations. The 20 particulate pilot project stations are highlighted with a white star.

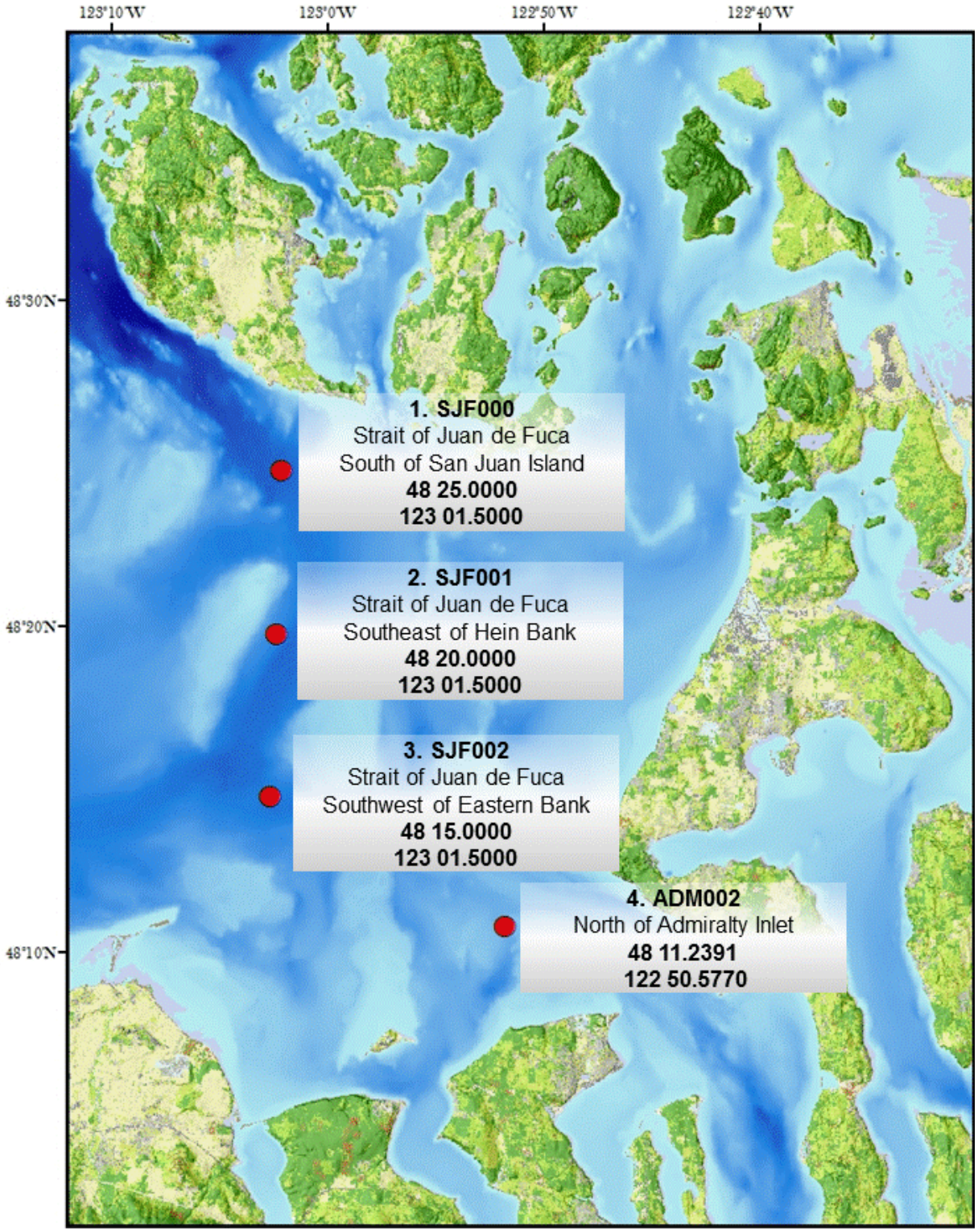

Figure 7. 2017 Strait of Juan de Fuca sampling stations.

Table 6. Projected water sample collection plan for 2017 listing depths (in meters) for each sample type collected at each station.

Station	Nutrients*	Chlorophyll	POC & PN	TOC	TN	Dissolved Oxygen	Salinity	Approximate Water Depth (m)
Marine Flight 1								
GYS008	0	0						6
GYS016	0, 10	0, 10				near bottom (NB)		11
WPA004	0, 10, 10, 10	0, 10, 10, 10					10	14
WPA113	0, 10	0, 10				NB		11
WPA006	0, 10	0, 10				NB	10	21
WPA007	0, 10	0, 10						14
WPA008	0, 10	0, 10						14
WPA003	0, 10	0, 10						10
Total Samples:								
8	17	17				3	2	
Marine Flight 2								
PTH005	0, 10, 10, 10	0, 10, 10, 10						26
RSR837	0, 10, 30	0, 10, 30				NB		56
GRG002	0, 10, 30	0, 10, 30					30	190
BLL009	0, 10, NB	0, 10	10,NB	10,NB	10,NB			16
BLL040	0, 10, NB		10,NB	10,NB	10,NB			26
SKG003	0, 10, NB	0, 10	10, 10, NB	10, 10, NB	10, 10, NB		10	24
SAR003	0, 10, 30, NB	0, 10, 30	10,NB	10,NB	10,NB			149
PSS019	0, 10, 30	0, 10, 30	10,NB	10,NB	10,NB	NB		101
Total Samples:								
8	33	28	11	11	11	3	2	
Marine Flight 3								
ADM001	0, 10, 30	0, 10, 30				NB		148
ADM003	0, 10, 30, NB	0, 10, 30	10,NB	10,NB	10,NB	30	-	210
HCB013	0, 10, NB		10,NB	10,NB	10,NB			20
PSB003	0, 10, 30, NB	0, 10, 30	10,NB	10,NB	10,NB			40-50
ELB015	0, 10, 30, NB	0, 10, 30	10, 10, NB	10, 10, NB	10, 10, NB		10	82
EAP001	0, 10, 30, NB	0, 10, 30	10,NB	10,NB	10,NB	30		200
SIN001	0, 10, NB	0, 10	10,NB	10,NB	10,NB			16
CMB003	0, 0, 0, 10, 30, NB	0, 10, 10, 10, 30	10,NB	10,NB	10,NB	30	30	150
Total Samples:								
8	22	17	11	11	11	3	2	

Station	Nutrients*	Chlorophyll	POC & PN	TOC	TN	Dissolved Oxygen	Salinity	Approximate Water Depth (m)
Marine Flight 4								
BUD005	0, 0, 0, 10, NB	0, 10, 10, 10	10,NB	10,NB	10,NB		10	15
DNA001	0, 10, 30	0, 10, 30				30, 30, 30		40
NSQ002	0, 10, 30, NB	0, 10, 30	10,NB	10,NB	10,NB			100
GOR001	0, 10, 30, NB	0, 10, 30	10,NB	10,NB	10,NB	30	30	160-170
CRR001	0, 10, 30, NB	0, 10, 30	10,10, NB	10,10, NB	10,10, NB			95
CSE001	0, 10, 30, NB	0, 10, 30	10,NB	10,NB	10,NB	30		55
OAK004	0, 10	0, 10						15
Total Samples:								
7	29	23	13	13	13	5	2	
Marine Flight 5								
HCB007	0, 0, 0, 10, NB	0, 10	10,10, NB	10,10, NB	10,10, NB		10	21
HCB004	0, 10, 30	0, 10, 30				30		55
HCB003	0, 10, 30, NB	0, 10, 10, 10	10,NB	10,NB	10,NB			144
HCB010	0, 10, 30, NB	0, 10, 30	10,NB	10,NB	10,NB	30	30	100
Total Samples:								
4	20	15	9	9	9	2	2	
Straits								
SJF000	0, 30, 80, 140	0, 30, 80, 140				0, 30, 80, 140		161
SJF001	0, 30, 80, 140	0, 0, 0, 30, 80, 140				0, 30, 80, 140		144
SJF002	0, 30, 80, 140, 140, 140	0, 30, 80, 140				0, 30, 80, 140, 140, 140	0, 140	142
ADM002	0, 10, 30, 80	0, 10, 30, 80				80	80	82
Total Samples:								
4	18	18				15	3	
Annual Total:								
Station	**Nutrients***	**Chlorophyll**	**POC & PN**	**TOC**		**Dissolved Oxygen**	**Salinity**	
39	139	118	44	44	44	31	13	

*Nutrient species included nitrite, nitrate, phosphate, silicate, and ammonium.

7.1.3 Parameters to be determined

Particulate Organic Material (OM) Carbon and Particulate Nitrogen

Analyses of Ecology's long-term marine monitoring data indicate increases of dissolved inorganic nitrate and phosphate relative to ocean source water and a change in the balance of macro-nutrients and silicate (Krembs 2012, 2015; PSEMP Marine Waters Workgroup, 2016). These changes affect growth conditions of phytoplankton at the base of the food web. The observed changes in inorganic nutrients could either be the result of decreased uptake by phytoplankton, increased nitrogen and phosphate loading, or a combination of the two. The long-term change has potential implications for marine food web structure, energy transfer, particle export, and higher trophic levels such as fish.

To understand these processes and to include the organic pools or nutrients, Ecology will continue a particulate pilot project as a collaboration between the Marine Waters water column group and the sediment group. Starting in April 2016 through June 2017 in addition to the routine sampling the marine group will collect total organic carbon (TOC), total nitrogen (TN), particulate organic carbon (POC), and particulate organic nitrogen (PN) from 2 depths; 10m and near bottom (NB) from 20 stations that overlap core sediment and core waters stations. Samples will be kept at 4 °C and delivered to the Manchester Lab the day after collection where the samples will be handled according to standard methods explained in Table 9.

The goal of this collaboration is to address the following:

- Quantify pools of unaccounted nutrients in the form of organic material (OM) in relation to inorganic nutrient trends.
- Utilize organic material (OM) nutritional quality (carbon:nitrogen ratio) to monitor changes in patterns of material and energy cycling in water and sediment.
- Explore potential changes in important pathways of OM - associated with pollution and toxins to the sediment (using C:N ratio) in context of changing human and climate pressures.

Table 7. Projected water sample collection plan for 2016-17, listing each sample type collected at each station by the waters or sediment group.

Station Id	Station location	Latitude	Longitude	Station type	Marine water particulates	Sediment chemistry	Benthos	TOC and grain size only
3	Strait of Georgia	48.87025	-122.97842	Sediment		X	X	
GRG002	Georgia Strait - N of Patos Island	48.80817	-122.95408	Water				
4	Bellingham Bay	48.68397	-122.53820	Sediment	X	X	X	
BLL009	Bellingham Bay - Pt. Frances	48.68593	-122.59962	Water	X		X	X
209R	Skagit Bay	48.29533	-122.48850	Sediment		X	X	
SKG003	Skagit Bay - Str. Point (Red Buoy)	48.29648	-122.48960	Water	X			
19	Saratoga Passage	48.09792	-122.47134	Sediment		X	X	
SAR003	Saratoga Passage - East Point	48.10760	-122.49155	Water	X			
21	Port Gardner/ Everett Harbor	47.98547	-122.24283	Sediment		X	X	
PSS019	Possession Sound	48.01092	-122.30125	Water	X			
119	Admiralty Inlet	47.87615	-122.48217	Sediment		X	X	
ADM003	Admiralty Inlet (south)	47.87898	-122.48320	Water	X			
29	Shilshole	47.70075	-122.45403	Sediment		X	X	
PSB003	Puget Sound Main Basin - West Point	47.65982	-122.44292	Water	X			
191	Central	47.59842	-122.37581	Sediment			X	X
ELB015	Elliott Bay-East of Duwamish Head	47.59648	-122.36957	Water	X			
34	Sinclair Inlet	47.54708	-122.66208	Sediment		X	X	
SIN001	Sinclair Inlet - Naval Shipyards	47.54927	-122.64347	Water	X			
38	Point Pully (3 Tree Point)	47.42833	-122.39363	Sediment		X	X	
EAP001	East Passage - SW of Three Tree Point	47.41705	-122.38040	Water	X			
281	Commencement Bay	47.29229	-122.44193	Sediment			X	X
CMB003	Commencement Bay-Browns Point	47.29038	-122.45012	Water	X			
40	Thea Foss Waterway	47.26130	-122.43730	Sediment			X	X
CMB006	Commencement Bay - Mouth of City WW	47.26149	-122.43735	Water				
44	East Anderson Island	47.16133	-122.67358	Sediment		X	X	
GOR001	Gordon Point	47.18315	-122.63457	Water	X			
265	Carr Inlet	47.25240	-122.66572	Sediment		X	X	
CRR001	Carr Inlet-Off Green Point	47.27648	-122.70958	Water	X			
252	Case Inlet	47.26957	-122.85101	Sediment		X	X	
CSE001	Case Inlet-S. Heron Island	47.26453	-122.84430	Water	X			

Station Id	Station location	Latitude	Longitude	Station type	Marine water particulates	Sediment chemistry	Benthos	TOC and grain size only
52	W. of Devils Head, Case Inlet (Nisqually Reach)	47.17060	-122.78051	Sediment		X	X	
NSQ002	W. of Devils Head, Case Inlet (Nisqually Reach)	47.16732	-122.78819	Water	X			
49	Budd Inlet	47.07997	-122.91347	Sediment		X	X	
BUD005	Budd Inlet - Olympia Shoal	47.09203	-122.91820	Water	X			
13R	Hood Canal (north of bridge)	47.83758	-122.62895	Sediment	X	X	X	
222	Hood Canal	47.67821	-122.81466	Sediment		X	X	
HCB010	Hood Canal - Send Creek, Bangor	47.67000	-122.82000	Water	X			
HCB003	Hood Canal - Central	47.53787	-123.00960	Water	X		X	X
305R	Lynch Cove	47.39717	-122.93124	Sediment		X	X	
HCB007	Hood Canal - Lynch Cove	47.39815	-122.92959	Water	X			

WW - waterway

Excessive nitrogen loading is a key cause of accelerating primary production and eutrophication (Pearl, 2009). Nitrogen loading occurs in the form of both dissolved and particulate nitrogen in either inorganic or organic form. Long-term increases of dissolved inorganic nutrients in Puget Sound emphasize the need to quantify pools of nutrients present in all forms, including the particulate phase (Krembs, 2013). To date, Ecology has routinely collected nutrients only in the dissolved inorganic phase. Dissolved nutrients quickly transform into organic biomass and are removed from the dissolved inorganic phase, hence escaping detection. Estimating nutrients in the form of organic nitrogen and phosphate is therefore important to assess overall nutrient trends in Puget Sound.

In addition to sampling TOC, TN, PN, and POC, we will be able to calculate dissolved organic material (DOC). TOC is the fundamental unit of energy in food-web and biogeochemical studies (Azam and Smith, 1991). TOC is made of a dissolved DOC and particulate POC fraction with very different attributes in the environment. While bulk DOC concentrations tend to support moderate bacterial activity and are neutrally buoyant, POC are hotspots of microbial activity which sink through the water column. POC therefore constitutes a vector of energy and material transport to greater depth (Smith et al., 1992). First we plan to augment our sampling with POC measurements to provide key information that can help link observed changes in the food web at the surface with oxygen demand and observed benthic changes at greater depth (Turley and Mackie, 1994). Evolving water quality, toxic fate and transport, and food-web models will benefit from this information and help understand unaccounted detrital pools being introduced to Puget Sound from land.

Presently, POC in Puget Sound is sometimes estimated from in situ chlorophyll *a* (a key phytoplankton pigment, chl *a*) concentrations, using an assumed ratio of carbon to chl *a*. This approach makes assumptions of predictable relationship between chl *a* and POC based on published data. However, the approach does not account for a large pool of non-photosynthetic

organic carbon (e.g., organic detrital material introduced by rivers and decaying macroalgae). The variability of detrital pool of POC, while not associated with living phytoplankton, is largely unknown in Puget Sound. Yet at times it figures significantly in the overall respiration and uptake of oxygen in Puget Sound. Puget Sound changes in response to human and climatic pressures. We observe species shifts occurring on a large scale (e.g., Flagellates) with very different effects on organic material cycling than more typical diatom-based phytoplankton communities. Estimating particulate organic material (POM) from chl *a* alone, therefore, results in inaccuracies with the conversion factors from chl *a* to POM and by neglecting unaccounted detrital pools. Measuring nutrients in the organic fraction in addition to dissolved inorganic nutrients will help fill this critical information gap in Puget Sound nutrient pools.

In addition, the relationship between chl *a*, POC, and ideally TOC, needs to be seasonally and geographically refined (Westberry et al., 2010). Ongoing monitoring data of POC and chl *a* pigment concentration of phytoplankton will support and refine chl *a* as proxy for phytoplankton biomass into the future and will incorporate the significant fraction of nutrients bound in detrital material. Continuous POC sampling in conjunction with PN will provide valuable data for water quality and biogeochemical models that incorporate land-based organic material loadings to Puget Sound, closing an important data gap (Ahmed, 2014).

The key goals of this sampling are to:

- Quantify pools of organic-bound nutrients (nitrogen) in the particle and dissolved phase to understand overall nitrogen trends in Puget Sound.
- Determine the variability and range of organic carbon conversion factors using chl *a* as proxy. Provide site and seasonal specific estimates on the timing of nutrient pools in the form of organic material in the upper mixed layer and, when they arrive, in the deeper bottom water.

Satlantic SUNA V2 nitrate sensor

To quantify nitrogen in Puget Sound, Ecology will collect continuous vertical nitrate measurements as part of the routine monitoring. Starting in 2017, we plan to test a Satlantic Submersible Ultraviolet Nitrate Analyzer (SUNA) V2 (or equivalent) on our SBE25*plus* CTD instrument package. Principles of operation for this sensor are described in manufacturer manuals. Instructions f
or optimum data collection are outlined in these manuals.

The goals of continuous vertical nitrate measurements are to:

- Improve representativeness of dissolved inorganic nitrate measurements in surface water.
- Extend nitrate information from 0, 10, and 30 meter point samples to full water column depth resolution.
- Provide nitrate data for monthly condition updates in relationship with other vertical profiles. Currently, lab sample results are received much later.
- Provide information for nitrate maxima, minima, and nitrogen load in association with identifiable water masses to support information on nitrate transport in Puget Sound.

8.0 Field Procedures

8.1 Field measurement and field sampling SOPs

Table 8. Field sample collection methods for ambient water column monitoring.

Sample Parameter	Collection Method or Sensor	Sample Container	Preservation Method	Holding Time
*Alkalinity & Dissolved Inorganic Carbon (DIC)	UNESCO, 1994 (JGOFS Protocols)	500 mL pre-combusted, acid-washed, borosilicate glass, stoppered volumetric flasks	Preserve sample with 100 µL super-saturated $HgCl_2$. Apply Apiezon® L grease to stopper, insert & twist to remove all air. Store in cool, dark conditions.	3 months
Total Organic Carbon (TOC)	SM 5310B	125mL quality certified HDPE poly bottle	1:1 HCL, ice upon collection	28 days store at 0°C - 6°C.
Total Nitrogen (TN)	SM 4500-N B	125mL 1:1 quality certified HDPE poly bottle	1:1 H2SO4, ice upon collection	28 days store at 0°C - 6°C.
Particulate Organic Carbon and Particulate Nitrogen (POC & PN)	EPA 440.0	1 L poly amber quality certified bottle	Store on ice. Filter ASAP upon arrival at the laboratory. Store at -20C.	Up to 100 days once filtered and stored at -20C
Chlorophyll *a*	UNESCO, 1994 (JGOFS Protocols)	125 mL brown polyethylene bottles	Store on ice. Filter immediately upon arrival at lab and place filter in 90% acetone. Store frozen.	1 month
Dissolved Nutrients	UNESCO, 1994 (JGOFS Protocols)	125 ml clear acid-washed plastic bottles	Filter immediately upon collection and place on ice. Store frozen.	3 months when stored frozen.
Dissolved Oxygen	UNESCO, 1994 (JGOFS Protocols) *1st sample collected	130 mL dry borsilicate glass stoppered volumetric flasks	Fix with $MnCl_2$ & NaOH-NaI azide reagents. Stopper & shake. Store in cold, dark conditions. Upon arrival at lab, shake again and apply DI cap.	5 days
Salinity	UNESCO, 1994 (JGOFS Protocols)	250 mL brown equilibrated polyethylene bottles	Keep in a well-sealed container.	6 months
Secchi Disk Depth	Lower in water until disk disappears, then bring up until it reappears- record reading	NA	NA	NA

8.1.1 CTD Data Collection

Beginning in 2015, the CTD instrument package was upgraded from a Seabird Electronics SBE25 to a SBE25*plus*. The SBE25*plus* has an internal pressure sensor and a faster sampling rate, providing more measurements per second, thus improving data quality and vertical resolution for several parameters. This upgrade does not change field operations or methods. Principles of CTD and sensor operations are described in manufacturer operating manuals. Instructions for optimum CTD data collection are outlined in these manuals.

9.0 Laboratory Procedures

9.1 Lab procedures table

Nutrient and salinity samples are analyzed at University of Washington's Marine Chemistry Laboratory in Seattle, Washington using various analytical methods described in Table 9. Dissolved oxygen and chlorophyll *a* samples are analyzed at Ecology's Marine Laboratory using analytical methods described in Table 9. POC, PN, TOC, TN are analyzed at Ecology's Manchester Environmental Laboratory (MEL) in Port Orchard, Washington using various analytical methods described in Table 9.

Table 9. Lab measurement methods, expected range of results, and reporting limits for marine data.

Measurement - Lab Analyte	Lab	Analytical Method	Expected Range of Results	Reporting Limit
Total Organic Carbon (TOC)	MEL	SM 5310B	0 - 3000 ug/L	500 ug/L
Total Nitrogen (TN)	MEL	SM 4500-N B	15-50 µM	0.01 µM
Particulate nitrogen (PN)	MEL	EPA 440.0	140-380 ug/L	1 ug
Particulate Organic Carbon (POC)	MEL	EPA 440.0	0 - 3000 ug/L	1 ug
Dissolved oxygen	ML	Carpenter, 1966	0.00 - 15.00 mg/L	0.01 mg/L
Marine Nitrate	MCL	Armstrong et al., 1967	0.00 - 40.00 µM	0.15 µM
Marine Nitrite	MCL	Armstrong et al., 1967	0.00 - 2.00 µM	0.01 µM
Marine Ammonium	MCL	Slawyk & MacIsaac, 1972	0.00 - 10.00 µM	0.05 µM
Marine Orthophosphate	MCL	Bernhardt & Wilhelms, 1967	0.00 - 4.00 µM	0.02 µM
Marine Silicate	MCL	Armstrong et al., 1967	0.00 - 200.00 µM	0.21 µM
Chlorophyll *a*	ML	EPA, 1997	0.00 - 60.00 µg/L	0.01 mg/L
Salinity	MCL	Grasshoff et al., 1999	0.00 - 36.00 PSU	0.01 PSU

*Not currently collected
ML - Ecology's Marine Laboratory
MCL - UW's Marine Chemistry Laboratory
MEL - Ecology's Manchester Environmental Laboratory

9.2.1 Analyte

Analytes are listed in Table 9.

9.2.4 Expected range of results

Expected ranges for analytical results are listed in Table 9.

9.2.5 Analytical method

Analytical methods are listed in Table 9.

9.2.6 Sensitivity/Method Detection Limit (MDL)

Sensitivity is reported as “Reporting Limit” in Table 9.

10.0 Quality Control Procedures

10.1 Table of field and lab quality control (QC) required

Ecology will adhere to all QC procedures outlined in the original QAMP (Bos, 2015). Likewise, Ecology will use the measurement quality objectives defined in the original QAMP to assess quality/usability of the collected data. The sections below discuss specific modifications to our quality assessment and QC procedures for the 2017 sampling year.

10.1.1 Tables of field and lab QC required

Table 10 identifies our quality objectives for marine waters data and steps that we follow toward meeting these objectives. Table 11 includes types and numbers of QC samples collected for each sampling survey. The Ecology QA Glossary included in Appendix F contains definitions of the various types of QC samples, including:

- Blanks, both lab and field
- Duplicates, both lab and field
- "Standards" or Standard Reference Materials (SRM)
- Lab Control Samples (LCS)
- "Blind" SRMs submitted to the laboratory

Table 10. A summary of quality control steps for field measurements.

	Precision (relative standard deviation, %RSD)	Accuracy (% from true value)	Instrument Control Check Using Blanks	Laboratory Standards Check	Laboratory Control Samples	Replicate Analysis	Method Detection Limits Check	Preliminary Review and Flagging of Raw Data	Graphical & Statistical Data Review and Flagging	Annual Review Assessments
Total Organic Carbon (TOC)	</=20%	5%	✓	✓	✓	✓	✓	✓	✓	✓
Total Nitrogen (TN)	</=20%	5%	✓	✓	✓	✓	✓	✓	✓	✓
Particulate Organic Carbon and particulate nitrogen (POC & PN)	</=20%	5%	✓	✓	✓	✓	✓	✓	✓	✓
Chlorophyll a	10%	NA	✓	✓		✓	✓	✓	✓	✓
Dissolved Oxygen	5%	NA	✓	✓		✓	✓	✓	✓	✓
Nitrate	10%	5%	✓	✓	✓	✓	✓	✓	✓	✓
Nitrite	10%	5%	✓	✓	✓	✓	✓	✓	✓	✓
Ammonium	10%	5%	✓	✓	✓	✓	✓	✓	✓	✓
Orthophosphate	10%	5%	✓	✓	✓	✓	✓	✓	✓	✓
Silicate	5%	5%	✓	✓	✓	✓	✓	✓	✓	✓
Salinity	10%	5%	✓	✓		✓	✓	✓		✓

10.5.2 Water Sample QA/QC Procedures

10.5.2.1 Replicate Sample Collection

Triplicate samples will be collected during every field event to help determine field and sampling variability. At one station, three samples taken in succession from the same Niskin sampling bottle will be collected to conduct a quantitative determination of homogeneity of conditions, along with precision of sampling methods. Parameters to be replicated include dissolved oxygen (monthly), nutrients (every survey), and chlorophyll *a* (every survey). Due to water volume constraints, one field split, not triplicate, samples will be collected for each TOC, TN, and POC, PN on every survey.

10.5.2.2 Analytical Replicates

Total variation in lab samples are assessed by collecting replicate samples from the same niskin sampling bottle for all parameters at 5% or more of sites. These replicates are used to assess whether the data quality objectives for precision were met. If the objectives were not met, the data are qualified. In addition, Ecology's Manchester Environmental Laboratory, UW's Marine Chemistry Laboratory, and Ecology's Marine Laboratory all routinely perform replicate sample analyses using sample splits within laboratory batches for QC purposes. The difference between field and laboratory variability is a measure of the sample field variability.

10.5.2.3 Laboratory Control Samples

For testing laboratory performance and analyst proficiency, check standards or laboratory control samples of known concentrations are included with every sample batch. Recovery percentage is calculated from these results and therefore can be used as a measure of analytical accuracy and bias. If the results fall outside of established limits, the reviewer flags data associated with the batch. Any measurement problem that cannot be resolved is given a data quality flag.

To assess the quality of our nutrient data, we conduct laboratory performance and analyst proficiency tests of the analytical lab, using low nutrient seawater laboratory control samples of known concentrations from Ocean Scientific International Ltd. (GPO). They are included with every sample batch. Recovery percentage is calculated from these results and therefore can be used as a measure of analytical accuracy and bias. If the results fall outside of established limits, data associated with the batch are flagged by the reviewer as estimates. Any measurement problem that cannot be resolved is given a data quality flag.

10.5.2.4 Certified Reference Materials

A standard reference material sample from the Ocean Scientific International Ltd will be sent to the laboratory to assess analytical lab performance, along with field split sample collection, and laboratory control samples.

10.5.2.5 Laboratory Blanks

Blanks

Blanks of low nutrient seawater will be used to test the nutrient field and analytical laboratory conditions for each survey. These blanks will be handled like field samples to determine if contamination occurs during any stage of the sampling or analytical laboratory processes. To test the POC/PN field and analytical laboratory conditions, blanks of deionized water will be collected at the beginning and end of each filtration.

An additional two unfiltered blanks of low nutrient seawater (LNSW) will be included with each sample batch submitted to the lab for analysis. These blanks serve to determine if samples could be contaminated during processing and analysis and also if they can be used to determine low level bias.

Table 11. Quality assurance/quality control procedures for water column parameter analysis in the laboratory.

Analytical Parameters	Calibration and Standardization	Lab Control (check) Samples - or- Standards (30 or less samples)	Replicates (30 or less samples)	Blanks per Batch
Laboratory Samples				
Total Organic Carbon (TOC)	5 point standardization	5*	1 per 20 or less	1 per 20 or less
Total Nitrogen (TN)	5 point standardization	5*	1 per 20 or less	1 per 20 or less
Particulate Organic Carbon and Particulate Nitrogen (POC & PN)	Single point or multi-point dependent upon the expected range of sample results	5*	1 per 20 or less	1 per 20 or less
Ammonia (NH_4)	5 point standardization	2 - 3	2	2
Nitrate (NO_3)	5 point standardization	2 - 3	2	2
Nitrite (NO_2)	5 point standardization	2 - 3	2	2
Orthophosphate (PO_4)	5 point standardization	2 - 3	2	2
Silicate (SiO_4)	5 point standardization	2 - 3	2	2
Chlorophyll & Phaeopigments	Calibration - 2x/year	4 total - 2 high, 2 low	3	2 - method 2 - reagent
Dissolved Oxygen	3 point standardization	3	3	2
Salinity	1 (batch)	1	1	2
~ Nutrients, dissolved oxygen and chlorophyll a are replicated in the field.				
CTD Sensors				
pH (electrode sensor)	5 point calibration	NA	NA	NA
Light Transmission	2 point calibration (high & low)	NA	NA	NA
Dissolved Oxygen (Clark cell - membrane)	Standardization - full saturation	NA	NA	NA

* Calibration standards ran every 10 samples.

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Appendix. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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.

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.

Particulate Nitrogen (PN). Particulate matter is defined as suspended particles in seawater having a size greater than 0.45 uM. The particulate nitrogen fraction of total nitrogen can be determine by separating dissolved from particulate fractions by filtration.

Particulate Organic Carbon (POC). Particulate matter is defined as suspended particles in seawater having a size greater than 0.45 uM. The particulate organic carbon fraction of total organic carbon is defined as organic matter that is larger than 0.45 uM. POC inputs to the sea are divided into two categories: allochthonous inputs from land and atmosphere and autochthonous (internal) inputs from biogenic material formed from *in situ* photosynthesis or decomposition of organic matter or organisms.

Particulate Organic Nitrogen (PON). The fraction of particulate nitrogen that is from biogenic material, such as material formed from *in situ* photosynthesis or decomposition of organic matter or organisms

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.

Total Nitrogen (TN). Total nitrogen is the amount of nitrogen found in water and consists of dissolved nitrogen (DN) and particulate nitrogen (PN) of either organic or inorganic sources.

Total Organic Carbon (TOC). Total organic carbon is the amount of carbon found in an organic compound and is often used as a non-specific indicator of water quality. Total organic carbon consists of dissolved (DOC) and particulate organic carbon (POC) and is therefore affected by pronounced fluctuations in suspended solids in riverine systems. Sources of organic carbon in fresh and marine waters include living material and waste materials and effluents. Organic matter from living material may arise directly from plant photosynthesis or indirectly from terrestrial organic matter.

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	See glossary above
DOC	Dissolved organic carbon
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
QA	Quality assurance
QC	Quality control
PN	See glossary above
POC	See glossary above
PON	See glossary above
RSD	Relative standard deviation
SOP	Standard operating procedures
TN	See glossary above
TOC	See glossary above
UW	University at WA
WQA	Water Quality Assessment
WRIA	Water Resource Inventory Area

Units of Measurement

°C	degrees centigrade
m	meter
mg/L	milligrams per liter (parts per million)
mg/L/hr	milligrams per liter per hour
mL	milliliter
mmol	millimole or one-thousandth of a mole
ng/g	nanograms per gram (parts per billion)
ng/L	nanograms per liter (parts per trillion)
NTU	nephelometric turbidity units
psu	practical salinity units
ug/g	micrograms per gram (parts per million)
ug/L	micrograms per liter (parts per billion)
uM	micromolar (a chemistry unit)
uS/cm	microsiemens per centimeter, a unit of conductivity

Quality Assurance Glossary

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Examples of data types commonly validated would be:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Method Detection Limit (MDL): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of

an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero. (Federal Register, October 26, 1984)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

References for QA Glossary

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