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State of Washington

Addendum 1 to Quality Assurance Project Plan

North Ocean Beaches Fecal Coliform Bacteria Source Investigation Study

Focus on the Ocean Shores Area, WA

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Quality Assurance Project Plan
North Ocean Beaches Fecal Coliform Bacteria
Source Investigation Study

Addendum 1 Focus on Ocean Shores

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1.0 Table of Contents

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Note:
All required sections, not included in this addendum, are discussed in the original QAPP (Swanson, T. and P. Anderson, 2014, Publication No. 14-03-108).

2.0 Abstract

In 2014/2015 Washington State Department of Ecology (Ecology) conducted a water quality study to investigate possible sources of fecal contamination in the North Ocean Beach area (Anderson, 2016). Data from this study identified areas with impaired water quality, i.e. not meeting water quality standards, but, specific source locations were not clearly identified for cleanup.

This proposed plan describes a source investigation study focusing in on select ditch sites identified as impaired in the Ecology 2016 report as well as via personal communication with WDOH and Ecology staff. This study will focus in on the ditches on Damon Road near Illahee and Oyehut as well as the ditches south along W Chance A La Mer NW. The adjacent marine waters will also be sampled to see if ditch concentrations follow similar patterns as those seen in the near-shore marine environment.

The goals of this study are to:

1. Assist Grays Harbor County further characterize sources of bacteria and support the Shellfish Protection District in their efforts to improve water quality and protect razor clam harvest.
2. To identify sources of fecal bacteria contamination that result in violation of freshwater water quality standards (Primary and Extraordinary Primary contact).
3. To investigate the marine water FC concentrations to see if concentration patterns are similar to those found in the freshwater inputs from the ditches.
4. To see if the sewer connections in the Illahee and Oyehut area have affected the bacterial contamination in the area.

3.0 Background

3.1 Introduction and problem statement

Portions of the Pacific Coast in Washington are monitored for bacterial water quality by the Washington State Department of Health (WDOH). The shellfish growing areas are classified to ensure that shellfish are only harvested from areas that meet or exceed public health standards.

In the last decade, data collected by WDOH indicated that fecal coliform bacteria concentrations were increasing in the nearshore ocean waters near the communities of Illahee and Oyehut (located just north of Ocean Shores). In 2013, WDOH downgraded the classification of the harvest area around marine water station #9 from Approved to Prohibited with the intent of protecting human health from pathogens in razor clams.

> In December 2012 Grays Harbor County initiated a Shellfish Protection District to improve water quality and thus the quality of shellfish growing areas. Monies were directed toward the Illahee and Oyehut to have the area connected to the sewer system.

In 2014/2015 Washington State Department of Ecology (Ecology) conducted a water quality study (Figure 1) to investigate possible sources of fecal contamination in the North Ocean Beach area (Anderson, 2016). Data from this study identified areas with impaired water quality, i.e. not meeting water quality standards, but, specific source locations were not clearly identified for cleanup.

This proposed plan describes a source investigation study focusing in on specific ditch sites suggested by WDOH and Ecology staff. This study will focus in on the ditches on Damon Road near Illahee and Oyehut as well as the ditches south along W Chance A La Mer NW. Adjacent marine waters will also be sampled.

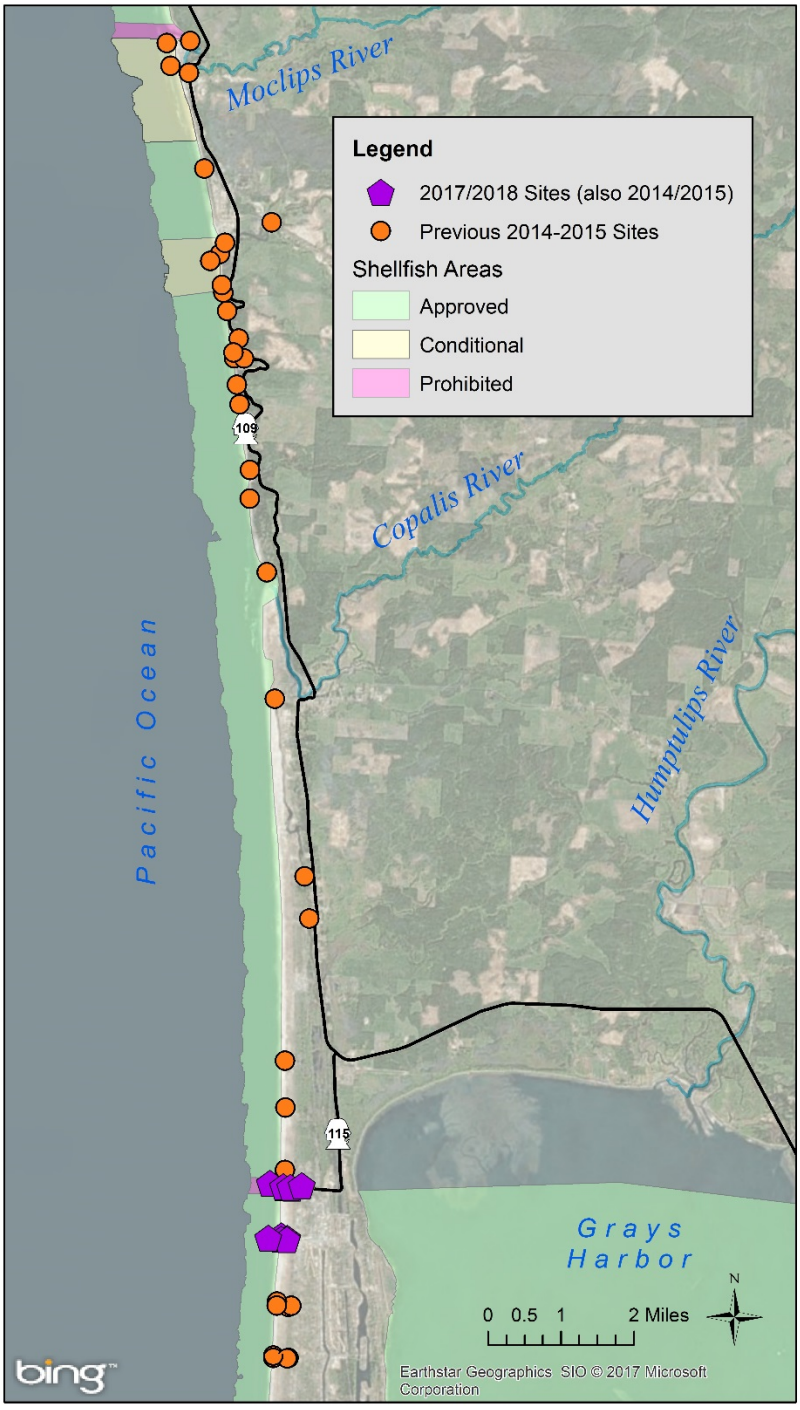

Figure 1. Map of the 2014/2015 study sampling sites (in orange), with the 2017/2018 sites that will be resampled identified in purple.

3.2.2 Summary of previous studies and existing data

Ecology conducted a FC bacteria source identification study in 2014/2015. Table 1 lists the twelve sites identified in Ecology's 2016 report as candidates for the 303(d) list (Anderson, 2016). Table 2 summarizes data that were collected in the areas planned for further study in the 2017/2018 study. These sites were selected after discussion with Ecology and WDOH staff and based on resources available.

Table 1. Candidates for the 303(d) list as documented in Anderson, 2016. Bolded text indicate sites that will be sampled in this study.

Sampling Location	Name
21-NOB-04	Moclips River near mouth
21-NOB-10	Creek on south side of Hwy 109
21-NOB-16	Connor Creek at Benner Road
21-NOB-20	**Ditch on Chickamin Ave South**
22-NOB-21	**North ditch on Damon Rd**
22-NOB-22	**South ditch on Damon Rd**
22-NOB-23	**North ditch on W Chance A La Mer NW**
22-NOB-24	**South ditch on W Chance A La Mer NW**
22-NOB-25	North ditch on Pacific Blvd NW
22-NOB-26	South ditch on Pacific Blvd NW
22-NOB-27	North ditch on Ocean Lake Way SW
22-NOB-28	South ditch on Ocean Lake Way SW

3.2.3 Parameters of interest and potential sources

The parameters of interest in this study will be FC bacteria and flow volume. Sources of FC bacteria may be warm-blooded animals of all kinds including humans. The transition from septic systems to the sewer system in the Illahee and Oyehut area was substantially completed in April 2017. The data collected in the wet season of 2017/2018 may reflect changes in FC bacteria concentrations.

3.2.4 Regulatory criteria or standards

The FC criteria have two statistical components: a geometric mean and an upper limit value that 10% of the samples cannot exceed.

Freshwater criteria

Bacteria targets in the water quality standards are set to protect people who work and play in the water from waterborne illnesses, and to protect tributaries flowing to shellfish harvesting areas. In Washington, surface water quality standards use FC as an "indicator bacteria" for the state's

freshwaters (e.g., lakes and streams). FC bacteria in water indicate the presence of waste from humans and other warm-blooded animals, which is more likely to contain pathogens that will cause illness in humans than waste from cold-blooded animals.

Table 2. FC (cfu/100 mL) data from the 2014/2015 data collected by Ecology. These are the sites that will form the routine sampling regime in 2017/2018. Empty squares (shaded) in the Table reflect that no samples were collected due to no water or no flow toward the ocean.

NOB - FC Bacteria (cfu/100 mL) by Site										
	DOH9 (marine)	**20**	**21**	**21A**	**22**	**22A**	**23**	**23A**	**24**	**24A**
4/22/2014	**23**	**40**	**119**		**800 G**		**460**		**420**	
5/6/2014	**7.8**	**9**	**92**		**560**		**57**		**61**	
5/20/2014	**13**									
6/3/2014	**23**									
6/17/2014	**1.8**									
7/15/2014	**23**									
7/29/2014	**1.8**									
8/12/2014	**1.8**									
8/26/2014	**28**									
9/9/2014	**6.8**									
9/22/2014	**1.8 U**									
10/7/2014	**1.8 U**									
10/21/2014	**1.8 U**									
10/22/2014 (Storm event)	**790**	**800 G**	**800 G**		**800 G**					
11/4/2014	**41**	**23000**	**230**		**640**		**1500**		**1200**	
11/18/2014	**1.8 U**	**150**								
12/2/2014	**1.8 U**	**32**	**28**		**80**		**43**		**14**	
12/29/2014		**8**	**39**		**24**		**12**			
1/12/2015	**17 J**									
1/14/2015		**6**	**13**		**35**		**12**			
1/27/2015	**2**	**8**	**85**	**9**	**110**	**8**	**29**	**14**	**7**	
2/10/2015	**23**	**64**	**37**	**29**	**16**	**1 U**	**6**	**48**	**1**	**16**
2/24/2015	**1.8 U**	**13**								
3/10/2015	**1.8 U**									
3/24/2015	**1.8 U**	**700**	**200**		**29**		**55**			
4/7/2015	**1.8 U**	**150**	**45**							
criteria	14/43	100/ 200	50/ 100	50/100	50/ 100	50/100	50/100	50/100	50/ 100	50/100

G = greater than
U = below detection
J = estimate

Ecology's selection of FC bacteria as the indicator for pathogens in surface waters is explained in *Setting Standards for the Bacteriological Quality of Washington's Surface Water Draft Discussion Paper and Literature Summary* (Hicks, 2002). The paper reviews the use of FC as an indicator bacteria and epidemiological studies of indicator bacteria in both fresh and marine waters.

The designated use of *Extraordinary Primary Contact* is intended for waters capable of "providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas."

To protect this use category:

- "Fecal coliform organism levels must not exceed a geometric mean value of *50* colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding *100* colonies/100 mL." [WAC 173-201A-200].

Compliance with the water quality standards is based on meeting *both* the geometric mean and the 10% of samples (or single sample if less than ten total samples) criteria. These two measures used in combination ensure that bacterial pollution in a water body will be maintained at levels that will protect the designated use.

In Washington State FC (Total Maximum Daily Load (TMDL) studies, the upper limit statistic (i.e. not more that 10% of the samples shall exceed) has been interpreted to be comparable to the 90^{th} percentile value of the log normalized values. This is useful for estimating FC percent reductions needed in a TMDL. However, it is not strictly equivalent mathematically and is not a surrogate for part 2 of the FC water quality standard.

Marine water criteria

In marine waters, water quality standards for bacteria are set to protect shellfish consumption and people who work and play in and on the water. Marine water criteria apply when the salinity is ten parts per thousand (17,700 umhos) or greater. Ecology uses two separate bacterial indicators in the state's marine waters:

- In waters protected for both *Primary Contact Recreation* and *Shellfish Harvesting*, the state uses FC bacteria as indicator bacteria to gauge the risk of waterborne diseases.
- In water protected only for *Secondary Contact Recreation*, enterococci bacteria are used as the indicator bacteria.

The presence of these bacteria in the water indicates the presence of waste from humans and other warm-blooded animals.

To protect either *Shellfish Harvesting* or *Primary Contact Recreation* in the study area:

- "Fecal coliform organism levels must not exceed a geometric mean value of *14* colonies/100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value

exceeding *43* colonies/100 mL." [WAC 173-201A-210] (Table 3). The upper limit criterion (i.e., the level that not more than 10% of the samples shall exceed) has been interpreted in this study as the 90th percentile of sample values.

4.0 Project Description

4.1 Project goals

1. Assist Grays Harbor County to further characterize sources of bacteria and support the Shellfish Protection District in their efforts to improve water quality and protect razor clam harvest.
2. To identify sources of fecal bacteria contamination that result in violation of freshwater water quality standards (Primary and Extraordinary Primary contact).
3. To investigate the marine water FC concentrations to see if concentration patterns are similar to those found in the freshwater inputs from the ditches.
4. To see if the additional sewer connections in the Illahee and Oyehut area have affected the bacterial contamination in the area.

4.2 Project objectives

1. Sample the freshwater ditches on Damon and Chickamin roads at previous NOB locations (Anderson, 2016)
    a. Add additional source id samples
    b. Sample marine water (DOH9)
2. Sample the freshwater ditches on E. Chance A la Mer NE at previous NOB location (Anderson, 2016).
    a. Add additional source id samples
    b. Sample adjacent marine water **(**GRA009B)

4.5 Systematic planning process used

The Project manager/ Field Lead have been and will continue to coordinate sampling with Manchester Laboratory. The specific field assistant for each event will be established at least a week before each sampling event.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 3. Organization of project staff and responsibilities.

Staff (All Ecology Employees)	**Title**	**Responsibilities**
Donovan Gray Water Quality Program SWRO Phone: 360-407-6407	TMDL lead/Field Assistant	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP. Occasionally assists with field work.
To be determined – several people will be recruited	Field Assistant	Helps collect samples and records field information.
Betsy Dickes Water Quality Program SWRO Phone: 360 407 6296	Project Manager/ Principal Investigator	Writes the QAPP. Oversees field sampling and transportation of samples to the laboratory. Conducts QA review of data, analyzes and interprets data, and enters data into EIM. Writes the draft report and final report.
Andrew Kolosseus TMDL unit Water Quality Section SWRO Phone: 360-407-7543	Unit Supervisor for the Project Manager	Provides internal review of the QAPP, approves the budget, and approves the final QAPP.
Rich Doenges Water Quality Section SWRO Phone: 360-407-6271	Section Manager for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Alan Rue Manchester Environmental Laboratory Phone: 360-871-8801	Director, Acting	Reviews and approves the final QAPP.
Chris Dudenhoffer Program Development Services 360-407-6445	Water Quality Program, Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.
William R. Kammin Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

SWRO: Southwest Regional Office
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan

5.2 Special training and certifications

The Ecology Project Manager/Field Lead has over 10 years of experience sampling and analyzing bacteria data. This experience also includes training field assistants.

5.3 Organization chart

See Table 3.

WDOH staff are intending to conduct microbial source tracking (MST). They do not have a sampling plan at the time of this publication. However, it is possible that we will conduct side-by-side water quality sampling with WDOH.

5.4 Proposed project schedule

Table 4. Proposed schedule for completing field and laboratory work, data into EIM, and reports.

Field and laboratory work	Due date	Lead staff
Field work begins	10/17/17	Betsy Dickes
Field work completed	6/2018	Betsy Dickes
Laboratory analyses completed	7/2018	
Environmental Information System (EIM) database		
EIM Study ID	Bedi0024	
EIM data loaded and QA completed	8/2018	Betsy Dickes
Final report		
Author lead / support staff	Betsy Dickes / Robin Fleskes	
Schedule		
Draft due to supervisor	10/ 2018	
Draft due to /peer reviewer	11/2018	
Draft due to external reviewer(s)	1/2019	
Final (all reviews done) due to publications coordinator	2/2019	
Final report due on web	2/ 2019	

5.5 Budget and funding

The total budget for this study is estimated at $14,528 (Table 5).This study will be measuring freshwater FC concentrations using the membrane filtration (MF) method. The cost per sample is $25 dollars per sample. But, the lab costs are going up so the budget listed $30 /sample as the estimated cost. The marine samples will be analyzed using the most probable number method (MPN) with an approximate cost of $47/sample. There will be 20% replication for freshwater sites and 20% replication for the marine sites. Additionally, one fresh water site per event will be analyzed by 2 different methods (MF and MPN). There will be approximately 16 FC_MF/FC_MPN pairs for data comparison.

Table 5. Project budget and funding.

Parameter	cost $$/sample	# of routine sites	# of source id sites	QA replicate	Total # of sites	2 surveys per month for 8 months	Subtotal
FC - MF	30	10	10	4	24	16	11,520
FC - MPN	47	3	0	1	4	16	3,008
						Estimate of Total $$	$14,528

6.0 Quality Objectives

This QAPP was substantially completed by October 15, 2017. The required paperwork was submitted and approved to initiate sampling before the final QAPP was published.

6.1 Data quality objectives

The data quality objectives for this project are:

- To collect a minimum of 7 water samples at the fixed network (with appropriate QA).
- To have them analyzed at the accredited Manchester Lab.
- Use standard methods to obtain FC concentration and flow volume data that meet Measurement Quality Objectives that are described in Section 6.2.
- Collect data which are comparable to the previous study results.

6.2 Measurement quality objectives

Field sampling procedures and laboratory analyses inherently have associated uncertainty which results in data variability. Measurement quality objectives (MQOs) state the acceptable data variability for a project. *Precision* and *bias* are data quality criteria used to indicate conformance with measurement quality objectives. The term *accuracy* refers to the combined effects of precision and bias (Lombard and Kirchmer, 2004).

Precision is a measure of the variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Precision for laboratory duplicate samples will be expressed as relative percent difference (RPD). Precision for field replicate samples will be expressed as the relative standard deviation (RSD) for the group of replicate pairs (Table 6).

Bias is defined as the difference between the sample value and true value of the parameter being measured. Bias affecting measurement procedures can be inferred from the results of quality control (QC) procedures. Bias in field measurements and samples will be minimized by strictly following Ecology's measurement, sampling, and handling protocols.

Field sampling precision and bias will be addressed by submitting replicate samples. Manchester Laboratory will assess precision and bias in the laboratory through the use of duplicates and blanks.

Table 6 outlines analytical methods, expected precision of sample replicates, and method reporting limits. The targets for precision of field replicates are based on historical data for environmental samples taken around the state by EAP (Mathieu, 2006). The data used by Mathieu (2006) were from much larger water systems compared to those that will be sampled in this project. These waterbodies will be small and therefore may show a higher level of environmental variability. The laboratory's measurement quality objectives and quality control procedures are documented in the MEL *Lab User's Manual* (MEL, 2016).

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 Table 6.

Table 6. Targets for precision and reporting limits

Parameter	Method/ equipment	Precision -Field Reps	Expected Range	Lab Duplicate MQO	Reporting Limits and Resolution
Field Measurements – Matrix Water					
Discharge Volume	Calibrated Marsh McBirney Flow-Mate Flow meter	10% RSD	0.05 - 5.0 ft/s	n/a	0.01 ft/s
Laboratory Analyses - Matrix Water					
Fecal Coliform – MF	SM 9222 D	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD	1 - 10,000 cfu/100 mL	40% RPD	1 cfu/100 mL
Fecal Coliform – MPN	SM 9221 E	50% of replicate pairs < 20% RSD 90% of replicate pairs <50% RSD	1.8 - 10,000 cfu/100 mL	40% RPD	1 cfu/100 mL

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Ecology will sample some of the same marine sites WDOH currently samples, as well as additional freshwater sites. Data from both agencies will be compared to ensure similar FC concentrations and trends exist in both data sets. If FC data sets are not similar, Ecology will investigate further for possible reasons.

Marine water FC samples taken by WDOH are analyzed using the MPN method. Ecology will use the MPN method for all marine samples to compare with WDOH sample results.

Though there have been studies that show a good correlation of MPN and MF data (Anderson, 2016) this study will be doing a set of comparison samples (N=16) to establish confidence in the data.

6.2.2.2 Representativeness

The study is designed to have enough sampling sites and sufficient sampling frequency to meet study objectives. Bacteria values are known to be highly variable over time and space. Sampling variability can be somewhat controlled by strictly following standard procedures and collecting quality control samples, but natural spatial and temporal variability can contribute greatly to the overall variability in the bacteria value.

The study is limited to the wet season since it was found that the ditches in this area are otherwise dry (Anderson, 2016).

6.2.2.3 Completeness

EPA has defined completeness as a measure of the amount of valid data needed to be obtained from a measurement system (Lombard and Kirchmer, 2004). The goal for this North Ocean Beaches study is to correctly collect and analyze 100% of the samples for each of the sites. However, problems such as accessing private property, occasionally arise during sample collection that cannot be controlled.

6.3 Acceptance criteria for quality of existing data

Ecology has collected FC bacteria data here in the past. The data are of high quality. However, specific source locations were difficult to close in on. This study is concentrated in a smaller area and hopefully will be able to focus extra effort to find sources of bacteria that may be impacting the prohibited harvest area WDOH. Additionally, this sampling may be able to show improvement due to recent sewer connections.

7.0 Study Design

7.1 Study boundaries

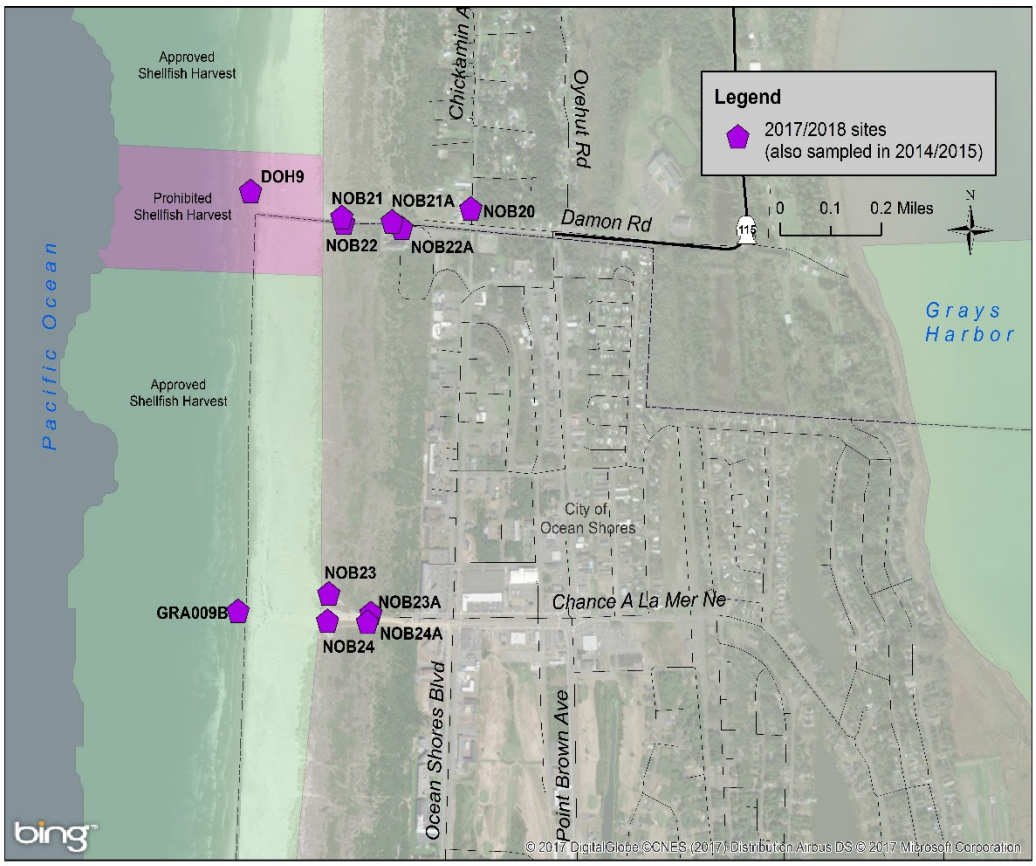

Figure 2. The sampling area for the 2017/2018 investigation. The purple symbols represent the fixed network sites.

7.2 Field data collection

7.2.1 Sampling locations and frequency

Sampling locations pre-selected based on Ecology's 2016 study and are shown in Figure 2 and listed in Table 7. These will be sampled twice a month for the eight months of the wet season (October through May). The samples collected to hone in on perspective sources of bacteria, will be chosen as soon as suspected sources are found. This may be related to precipitation. These sites will be chosen based on visual cues of land use, catching water not previously seen flowing, bracketing in on previously high concentrations, etc.

Sampling dates are pre-selected in order to coordinate with the Manchester Laboratory's schedule and resources as well as staff availability.

7.2.2 Field parameters and laboratory analytes to be measured

This study will be sampling for FC bacteria in fresh and marine waters. Flow will also be measured using a Marsh-McBirney Flo-Mate meter (calibrated Sept 2017).

7.5 Possible challenges and contingencies

Safety is of utmost importance. Tsunami evacuation routes will be used if needed and the sampling event terminated.

7.5.1 Logistical problems

Scheduling conflicts, sample bottle delivery errors, vehicle or equipment problems, site access issues, or the limited availability of personnel or equipment may interfere with sampling. If the ocean is too rough for safe entry samples will not be collected. Also, it may take extra time to try to catch the waves at a condition where we can avoid sediment suspension; we do not want sediment in the bacteria samples. Additionally, occasionally sampling days may move from Tuesdays to the previous Monday if schedules deem necessary.

Any circumstance that interferes with data collection and quality will be noted and discussed in the final report. These problems will be reduced with detailed preparation and logistic review.

7.5.2 Practical constraints

The budget for this study was been approved before the start of this QAPP.
Field assistants are being lined up to accompany the field lead.

7.5.3 Schedule limitations

Due to the holidays and complicated work schedules, only one sampling event will occur in December.

Table 7. Fixed network sampling locations as described in EIM and previous studies.

EIM Location ID	Field ID	Location Description	Lat/Long (NAD83)
Study ID TSWA0005			
22-DOH-9	DOH9	Department of Health marine sampling station 9	47.01809 / -124.17552
22-NOB-22	NOB22	South ditch on Damon Road	47.01739 / -124.17157
22-NOB-22A	NOB22A	Upstream extent of South ditch on Damon Road	47.01734 / -124.16914
22-NOB-21	NOB21	North ditch on Damon Road	47.01754 / -124.17166
22-NOB-21A	NOB21A	Upstream extent of North ditch on Damon Road	47.01749 / -124.16955
21-NOB-20	NOB20	Ditch on Chickamin Avenue south of RV park holding tank	47.01793 / -124.16628
22-NOB-23	NOB23	North ditch on West Chance A La Mer Northwest	47.00777 / -124.17154
22-NOB-23A	NOB23A	Upstream extent of North ditch on West Chance A La Mer Northwest	47.00732 / -124.16975
22-NOB-24	NOB24	South ditch on West Chance A La Mer Northwest	47.00706 / -124.17154
22-NOB-24A	NOB24A	Upstream extent of South ditch on West Chance A La Mer Northwest	47.00709 / -124.16987
Study ID EPABEACH			
GRA009B	GRA009B	WA700834~DNR /CHANCE A LA MER / marine	47.0072 / -124.1753

8.0 Field Procedures

8.1 Invasive species evaluation

Ecology field crew will follow Environmental Assessment Program (EAP's) standard operating procedures (SOP) on minimizing the spread of invasive species (Parsons et al., 2012). The North Ocean Beaches study area is not in a region of extreme concern. However, felt less boots will be used when accessing water and all equipment will be rinsed and or dried adequately between sampling events. For more information, please see Ecology's website on minimizing the spread of invasive species at www.ecy.wa.gov/programs/eap/InvasiveSpecies/AIS-PublicVersion.html.

8.2 Measurement and sampling procedures

Field sampling and measurement protocols will follow standard operating procedures (SOPs) developed by Ecology's Environmental Assessment Program (EAP) www.ecy.wa.gov/programs/eap/quality.html.

Grab samples will be collected directly into pre-cleaned containers supplied by Ecology's Manchester Environmental Laboratory (MEL) and described in the MEL *Lab Users Manual* (MEL, 2016).

Sample parameters, containers, volumes, preservation requirements, and holding times are listed in Table 8. Bacteria samples will be tagged, stored on ice, delivered to MEL via Ecology courier, and the samples will be analyzed by MEL within 24 hours of collection. The MPN samples may then undergo additional protocol as per the method. Freshwater and marine grab samples will be collected using the SOP EAP030 for bacteria and grab sampling EAP015.

Twenty percent of FC samples will be replicated in the field in a side-by-side manner to assess field and laboratory variability. Samples will be collected in the thalweg and just under the water's surface in freshwater outflows. Marine samples will be collected by walking out to 3 feet of water depth and submerging a bottle under the surface of the water. A sampling pole will be used to ensure no disturbed sediment is collected.

Tidal condition will not be a limiting variable in this study, but it will be recorded in the field notes.

Because the MPN method is used by WDOH to enumerate bacteria, Ecology will use the MPN method on all saltwater samples. The MF method will be applied to all freshwater samples. Additionally, one fresh water site per event will be analyzed by the 2 different methods (MF and MPN) for confidence in assessing the marine and freshwater interface.

Flow measurements will be taken at all ditch sites when flowing toward the ocean. All flow measurements taken in the field will also be recorded in a notebook. Estimation of instantaneous flow measurements will follow the SOP EAP024. Instantaneous FC loads will be estimated at each site using the best available streamflow data.

Samples will be collected in an autoclaved poly bottle. Care will be taken not to touch the inside of the cap or the lip of the bottle. If there is any concern for contamination of the sample it will be dumped out in the downstream water. Another autoclaved bottle will be used to re-take the sample from the upstream water. The empty contaminated bottle will be left un-capped as the sign it is dirty and will be returned to the lab for re-cleaning.

8.3 Containers, preservation methods, holding times

Table 8. Sample containers, preservation, and holding times.

Parameter	Matrix	Minimum Quantity Required	Container	Preservative	Holding Time
FC bacteria (MF and MPN)	Water	250 mL	Autoclaved poly bottles	Ice - Cool to 0º to 6 ºC	24 hours

8.5 Sample ID

The field sample IDs will follow the field ID list provided in Table 7. The 'batches' of field samples that get transferred to the Manchester Lab will be tracked using the work order numbers established by Manchester Lab and listed in Table 9.

Table 9. List of work order numbers from Manchester Lab.

Sample Date	Work Order Number from Manchester Lab
10/17/2017	1710027
10/30/2017	1711013
11/14/2017	1711014
11/28/2017	1711015
12/12/2017	1712012
1/9/2017	1801004
1/23/2017	1801005
2/6/2017	1802002
2/20/2017	1802003
3/6/2017	1803001
3/20/2017	1803002
4/3/2017	1804002
4/17/2017	1804003
5/1/2017	1805002
5/15/2017	1805003
5/29/2017	1805004

8.6 Chain-of-custody

Samples will be in the custody of Ecology at all times. When not sampling the cooler of ice and samples will be retained in a *locked* automobile. The samples will be processed at the Ecology building in Olympia. After processing, the cooler will be either locked with a metal lock or secured with security tape. The cooler will then be left in a larger walk-in cooler with limited access. The following morning a laboratory courier will maintain chain-of-custody as the samples are chauffeured to Manchester Lab for analysis.

8.7 Field log requirements

Field books will be maintained for each sampling event. Information that will be recorded will include:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from the QAPP
- Environmental conditions
- Date, time, location, ID, and description of each sample
- Photographs of site and area
- Field instrument problems
- Field measurement results
- Identity of QC samples collected
- Unusual circumstances that might affect interpretation of results
- Name and contact information for anyone we meet who has additional information or may want a copy of the report

8.8 Other activities

To assist in preparation, field staff will call Nancy Rosenbower at the end of every sampling event to provide the actual number of samples for the associated methods.

9.0 Laboratory Procedures

9.1 Lab procedures table

See Table 6.

9.2 Sample preparation method(s)

Samples will be processed upon arrival at the lab following Manchester Labs routine procedures (MEL, 2016). The microbiologist will then follow standard methods for the appropriate bacterial analyses i.e. SM 9222 D (FC_MF) and SM 9221 E2 (FC_MPN).

9.3 Special method requirements

There should be no need for special methods.

9.4 Laboratories accredited for methods

Manchester Laboratory is an accredited lab for the bacterial analyses being conducted.

10.0 Quality Control Procedures

Total variability for field sampling and laboratory analysis will be assessed by collecting replicate samples. Sample precision and bias will be assessed by collecting replicates for 20% of all bacteria samples. Flow measurements will be replicated at one site per event. Manchester Lab routinely duplicates sample analyses in the laboratory to determine laboratory precision. The difference between field variability and laboratory variability is an estimate of the sample field variability

10.1 Table of field and laboratory quality control

See Table 6.

Laboratory

MEL will analyze all samples. The laboratory's measurement quality objectives and QC procedures are documented in the MEL *Lab Users Manual* (MEL, 2016). Field sampling and measurements will follow QC protocols described in Ecology (1993). If any of these QC procedures are not met, the associated results may be qualified by MEL or the project manager and used with caution, or not used at all.

Field

Quality control for bacteria sampling will be assessed by collecting replicates for 20% of bacteria samples being analyzed with FC MF and 20% replicate samples will be collected for the number of samples being analyzed using the MPN method. Instantaneous streamflow measurements will be replicated at least once an event to determine and verify precision.

Standard Methods (APHA et al., 1998) recommends a holding time of less than 30 hours for drinking water samples and less than 24 hours for other types of water tested when compliance is not an issue. MEL has a maximum holding time for microbiological samples of 24 hours (MEL, 2008). Microbiological samples analyzed beyond the 24-hour holding time are qualified with a "J" qualifier code, indicating the sample result is an estimate. These samples are not being collected for enforcement, but, may encourage and lead to water cleanup activities.

10.2 Corrective action processes

QC results may indicate problems with data during the course of the project. Options for corrective actions might include:

- Retrieving missing information.
- Modifying the analytical procedures.
- Collection of additional samples or taking of additional field measurements.
- Qualifying results.
- Changing the sampling date to prevent holding time errors.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

No audits are planned.

12.2 Responsible personnel

Field assistants will act as auditors and verify that the QAPP is being followed.

12.3 Frequency and distribution of reports

No written reports will be prepared until the draft and final reports are completed. However, when elevated results (compared to the criteria) are received from the lab, these data reports will be shared with the area TMDL Lead (currently Donovan Gray) and WDOH.

12.4 Responsibility for reports

Betsy Dickes will send out these data reports.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The project manager will verify that all measurement and data quality objectives have been met for each monitoring station. The project manager will make this determination by examining the data and all of the associated QC information. If the objectives have not been met (e.g., the percent RSD for sample replicates exceeds the MQO), the project manager will decide how to qualify the data and whether or not it can be used in the technical analysis.

Any water quality data from outside this study used in the data analysis must meet requirements of the agency's credible data policy WQP Policy 1-11.

14.2 Treatment of non-detects

Non-detects for bacteria is the reporting limit.

14.3 Data analysis and presentation methods

After data have been reviewed and accepted EXCEL ® will be used to summarize and analyze the data. Data will be analyzed to compare to the appropriate criteria. Loading calculations will be performed using flow*concentration* conversion factor not the roll-back method. Box-plots will be used visual review of the data.

Verified data will be entered into EIM study id bedi0024.

14.4 Sampling design evaluation

The sampling design is adequate for the objectives. There should be over 5 samples per sampling location. Source identification for bacteria is often a tricky. We will use all available resources to assist in finding sample locations that will identify preventable sources (human related).

14.5 Documentation of assessment

Data usability will be documented in the final report.

15.0 References

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Appendix xx. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

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

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each water body or segment, regardless of whether or not the uses are currently attained.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

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

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

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

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural,

recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

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

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

Streamflow: Discharge of water in a surface stream (river or creek).

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.

Thalweg: The deepest and fastest moving portion of a stream.

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual waste load allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the waste load determination. A reserve for future growth is also generally provided.

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

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

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

Acronyms and Abbreviations

Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
FC	(see Glossary above)
MQO	Measurement quality objective
QA	Quality assurance
QC	Quality control
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
TMDL	(See Glossary above)
WAC	Washington Administrative Code
WRIA	Water Resource Inventory Area

Units of Measurement

cfs	cubic feet per second
cfu	colony forming units
ft	feet
m	meter
s	second

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 are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.
- REJ – data are rejected, cannot be used for intended purposes.
  (Kammin, 2010; Ecology, 2004).

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

References for QA Glossary

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