Shell Polymers Monaca Site Impingement and Entrainment Characterization Study Sampling and Analysis Plan

NPDES Permit No. PA0002208

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Acronyms List

Acronym	Explanation
%	Percent
ANOVA	Analysis of Variance
BTA	Best Technology Available
CCRS	Closed-cycle Recirculating System
CFS	Cubic Feet per Second
CWIS	Cooling Water Intake Structure
DQO	Data Quality Objective
EAM	Equivalent Adult Model
fps	Feet per Second
ft.	Feet
g	Gram
I&E	Impingement and Entrainment
in.	Inch
m^3	Cubic Meters
MGD	Million Gallons per Day
mg/L	Milligrams per Liter
mm	Millimeter
NPDES	National Pollutant Discharge Elimination System
PADEP	Pennsylvania Department of Environmental Protection
PFBC	Pennsylvania Fish and Boat Commission
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RM	River Mile
SAP	Sampling and Analysis Plan
SPMS	Shell Polymers Monaca Site
TL	Total Length
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey

1.0 Introduction

This fish and shellfish impingement and entrainment (I&E) characterization study sampling and analysis plan (SAP) was prepared by AECOM on behalf of Shell Chemical Appalachia LLC (Shell). The SAP was prepared for the Shell Polymers Monaca Site (SPMS) in Potter Township, Beaver County, Pennsylvania. The Facility is located along the Ohio River in Monaca, Pennsylvania (**Figure 1**).

1.1 Agency Review

The SAP was previously submitted to the Pennsylvania Department of Environmental Protection (PADEP) for review on October 14, 2023 and resubmitted on February 9, 2024 to address comments issued by PADEP on January 10, 2024. Among other comments, PADEP requested that an impingement efficiency study should be conducted. The SAP submitted on February 9, 2024 therefore included a plan for conducting an impingement efficiency study, and addressed PADEP's other requirements. PADEP approved the revised SAP on March 7, 2024.

Subsequent to PADEP's approval of the SAP, Shell and AECOM moved forward with implementation of the SAP. However, during the initial stages of implementation of the impingement efficiency study (screen efficiency study), site-specific traveling water screen configuration concerns were identified that limit the implementation of that component of the study. Specifically, Shell's traveling water screens are dual-flow traveling screens with only a debris trough (no fish handling and return system). Further, the screen wash for the debris trough is on the front, ascending side of the screens. Limited access to the screens, the short distance between the bucket access and screen wash nozzles, and poor line of sight for the placement of the surrogate fish make execution of the screen efficiency study extremely difficult and create safety concerns.

Impingement of surrogate fish on the traveling screens cannot be ensured due to the orientation of the screens relative to water flow (dual-flow screens are oriented parallel to the water flow as water flow splits in the influent chamber and enters on two separate sides of the screens), low through-screen velocity, the potential for flow eddies and low velocity pockets, and the direction of the spray wash perpendicular to the water flow.

Execution of the impingement efficiency / screen efficiency study would be extremely difficult due to Shell's site-specific screen configuration and unlikely to yield meaningful results due to the following:

- **Configuration**: Shell's screens are dual-flow traveling screens with no fish return (debris trough only) with spray was on the front, ascending side of the screen. Impingement cannot be ensured due to:
    - Low through-screen velocity
    - Orientation of screen axis parallel to the direction of water flow
    - Direction of wash water perpendicular to direction of water flow
    - Surrogate fish placed upstream of the screens may get caught in low-velocity pockets and never contact the screen
- **No Access Upstream of Screens**: Window access on the 'River' side of the screens is physically impeded by the screen wash equipment and there are no

grates to provide access to the intake water below the floor / deck of the screenhouse.

- **Very Limited Access to Screens on Inland Side**: The windows on the 'Inland' side of the screens are the only access points, but are also difficult to access due to the location of the debris trough in front of the screens.
- **Rotation of Screens**: The debris trough is on the front (ascending side) of the screens. Access to place surrogate fish is extremely difficult due to the limited space between the window and the screen. Additionally, placement of the fish would only be accessible a few feet below the spray wash. Placement of the surrogate fish on the back of the screens is not practical as the fish would fall out of the buckets and may not be collected on the traveling screens or in the receiving net.
- **Spray Wash**: The spray nozzles are located at the bottom of the front access window, further impeding access to the fish buckets for surrogate fish placement. The spray also washes the fish perpendicular to the flow, so surrogate fish that miss the trough may not get impinged.
- **Safety Issues:** Low visibility and limited access could create safety issues when placing the surrogate fish on the traveling screens through the access window.
- **Retrieval of Surrogate Fish may be Impeded by the Screen Design:** The release of surrogate fish in front of the screens is difficult and may not result in impingement due to the low velocity, proximity to the spray wash, and the direction of flow through the screens.

Since Shell Monaca already employs Best Technology Available for minimizing Impingement Mortality and Entrainment by employment of a closed-cycle recirculating water system and design of traveling screens with a low (<0.5 fps) through-screen velocity, Shell requested a waiver to conduct the the impingement efficiency / screen efficiency study. Shell has site-specific limitations and issues associated with conducting the requested study. Additionally, screen optimization would not improve survival, since there is no fish return at the Facility.

A conference call between Shell, PADEP, and AECOM was held on May 15, 2024 to discuss the concerns about executing the screen efficiency study. During that conference call, PADEP agreed to waive the requirement to conduct an impingement efficiency / screen efficiency study. This revised SAP incorporates the removal of the impingement efficiency study from the plan.

1.2 Background

Operations at the SPMS include conversion of ethane feedstock into ethylene for manufacturing on site into various grades of linear low density and high-density polyethylene as the final product. Ethane is heated in the presence of steam within natural gas-fired furnaces to "crack" the molecule into hydrogen and ethylene. SPMS operates a cooling water intake structure (CWIS) to withdraw water from the Ohio River for cooling and other purposes. To minimize water withdrawals from the Ohio River, the SPMS employs a closed-cycle recirculating system (CCRS).

Figure 1. Facility and CWIS Location.

1.3 Regulatory Context

The Pennsylvania Department of Environmental Protection (PADEP) determined, as part of the initial National Pollutant Discharge Elimination System (NPDES) permitting in 2017, that Shell's operation of a CCRS constituted BTA for the Facility's CWIS. Also, because Shell opted to meet the BTA standards with a CCRS, in addition to traveling screens with an estimated through-screen velocity of 0.38 feet per second (fps) at normal River pool elevation, the targeted reduction in I&E of fish and shellfish will be achieved. Hence, there is no requirement for I&E monitoring at SPMS. PADEP, does, however, have the regulatory discretion to require I&E sampling, as discussed below.

The current NPDES Permit PA0002208 (the "Permit") was issued for SPMS, with an effective date of March 1, 2021. With issuance of the Permit, PADEP confirmed that the CWIS at the SPMS is defined as an "existing" facility under the USEPA 316(b) regulations and not subject to 316(b) I&E monitoring requirements. In the Fact Sheet issued with the Permit, PADEP stated:

> *"As an existing facility, Shell is not subject to the impingement and entrainment monitoring and reporting requirements in §125.84(b)(7) and (b)(8) of 40 CFR Part 125, Subpart I."*

Part C of the Permit, however, indicates that the SPMS must submit a plan to conduct one year of I&E sampling. Hence, at their regulatory discretion, PADEP is requiring a program for I&E sampling, consistent with Permit Part C Condition XI.E. Although not required to meet 40 CFR Part 125, Subpart I, this I&E characterization study SAP was prepared by Shell voluntarily to address the I&E requirements listed below:

- **Condition XI.E. Impingement and Entrainment (I&E) Sampling**

  Within one (1) year of the "End of Construction", as defined in Part C, Condition IX of this permit, the permittee shall submit to DEP a plan ("Sampling Plan") to conduct one (1) year of monthly I&E sampling at the cooling water intake structure. DEP shall review and approve the Sampling Plan.

  I&E sampling shall be conducted in accordance with the approved Sampling Plan after the cooling water intake structure is in full operation (following startup of all production units) commensurate with normal operating conditions.

- **Condition IX. STARTUP**

  For the purposes of this SAP, it was assumed that I&E sampling will start at the point of full/normal Facility operations (startup), with all units operating, as requested by PADEP. Shell anticipates that full/normal operations may be achieved in Q1 2024; the schedule is, however, subject to change based upon when the SPMS becomes fully operational.

  As discussed by PADEP in the Permit, *"End of Construction" is defined as the first day of the next month following the date on which the permitted industrial facilities are collectively placed in their normal operating mode and begin discharging effluent to waters of the Commonwealth. The permittee shall notify DEP, in writing, at least thirty (30) days prior to "End of Construction*".

1.4 Purpose and Objectives

The purpose of the SAP is to present an approach to collecting one year of monthly I&E data and associated analyses consistent with Part C of NPDES Permit (No. PA0002208; effective March 1, 2021. SPMS is an existing facility, and therefore is not subject to the I&E monitoring and reporting requirements in 40 CFR §125.84(b)(7) and (8) of the new facilities rule. Hence, the I&E sampling is being conducted voluntarily by Shell and at the regulatory discretion of the PADEP.

The objectives of the I&E characterization study SAP are to:

- Provide the project background.
- Identify the data quality objectives (DQOs) and Quality Assurance/Quality Control (QA/QC) program.
- Describe the sampling duration, frequency, and methodology.
- Describe the procedures for taxonomic identification and description of impinged and entrained fishes.
- Describe the data analysis.
- Describe the study reporting.
- Present the study schedule.
- Identify the study project organization.

2.0 Background

This section provides the background of the Facility and a description of the CWIS.

2.1 Manufacturing Operations

SPMS manufactures polyethylene pellets. Polyethylene units at SPMS take ethylene from the ethylene cracking unit and combine the ethylene with a related hydrocarbon (co-monomer) along with a catalyst to create polyethylene. Once normal operating mode commences, SPMS will employ four processing units (an Ethane Cracking Unit and three Polyethylene Units) and a Steam and Power Generation Unit to convert a feedstock composed of natural gas liquids containing ethane into polyethylene pellets.

2.2 Overview of the Cooling Water Intake Structure

SPMS withdraws cooling water from the Ohio River via an existing CWIS that was previously used by the Horsehead Corporation. SPMS is situated along the Montgomery Pool segment of the Ohio River between river miles (RMs) 27.0 and 29.5. The Ohio River is approximately 1,496 feet (ft.) wide at SPMS. The Montgomery Pool is 18.5 RMs long and averages 1,400 ft. in width, with an average water column depth of 25 ft. The pool is bounded upstream by the Dashield Locks and Dam and downstream by the Montgomery Locks and Dam.

SPMS's CWIS is situated slightly upstream of the Montgomery Locks and Dam. The CWIS withdraws cooling water via two partially submerged shoreline intake bays and channels. Water depth in the intake will normally be about 12 feet with a high water depth of 38 feet and a low water depth of 8 feet. The design intake flow of the CWIS is 21.12 million gallons per day (MGD).

Each of the two intake bays include the following:

- One (1) 20-foot high × 8-foot 2-inch-wide bar trash rack comprised of three sections of equal height with ½-inch × 2½-inch vertical stainless-steel bars spaced two inches on center yielding 1½-inch openings between bars.
- One (1) 24-foot long manually operated aluminum trash rack rake.
- One (1) 20-foot high × 8-foot 2-inch-wide stop log gate comprised of three sections of equal height. A lifting beam and equalizing valve are provided to allow for stop log removal.
- One (1) dual-flow Evoqua traveling water screen with 4-foot basket widths × 43" centers. In the dual flow system, the screen is oriented perpendicular to the direction of the intake. Influent flow is directed into both the upward and downward-moving sides of the traveling screen by wing walls. Screened flow recombines as a common effluent that leads to the intake pumps.

The Evoqua traveling screen is composed of 316 stainless steel with 0.072" diameter wire and 0.25" square openings. The design through screen velocity is 0.38 feet per second at normal pool elevations. There is one spray wash system leading into a common trough to a collection point for offsite disposal (debris basket). There is no fish return.

3.0 Sampling and Analysis Plan

This study plan section presents the technical approach for I&E data collection and analysis, SAP DQOs, and relevant QA/QC procedures. The SAP was prepared consistent with the following USEPA technical guidance:

- USEPA. 2014. Sampling and Analysis Plan Guidance and Template. Ver. 4, General Projects.
- USEPA. 2006a. Guidance on Systematic Planning Using the Data Quality Objectives Process.

3.1 Data Quality Objectives

The DQOs are qualitative and quantitative statements that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors (USEPA, 2006a). DQOs and study plan components consistent with the USEPA (2006a) DQO process are:

- **State the problem**: Shell does not have recent I&E data at SPMS to support PADEP decision-making.
- **Identify I&E study goals**: The goals of the impingement study are to (1) identify and tally impinged fishes, (2) weigh and measure the total length (TL) for each fish, (3) identify fish condition, (4) generate annual impingement estimates for each entrained taxa, (5) identify potential factors that influence impingement, and (6) estimate population-level effects of impingement (Age-1 Equivalents).

  The primary study goal of the entrainment study is to provide data for annualized entrainment. To achieve this goal, the study will (1) identify and tally entrained fishes, (2) assess the number and lifestage(s) of entrained fishes, (3) measure the TL of each fish and egg diameter, (4) generate annual entrainment estimates for each entrained taxa, (5) identify potential factors that influence entrainment, and (6) estimate population-level effects of entrainment.
- **Identify data and information needed**: The data needed for the impingement study are (1) numbers of impinged fishes, (2) the identification of the impinged fishes to the lowest practical taxa, (3) total length (millimeter [mm]) and weight (gram [g]) of impinged organisms, (4) condition of the impinged fish, i.e. dead prior to impingement, (5) water quality parameters that potentially influence impingement, and (6) life history parameters to estimate Age-1 equivalents with the Equivalent Adult Model (EAM) (Goodyear, 1978).

  The data needed for the entrainment study are (1) the number of entrained fish eggs, larvae, juveniles, and adults (for smaller fishes), (2) the identification of the entrained eggs and larvae to the lowest practical taxa, (3) TL of entrained fishes, (4) estimated Facility entrainment expressed on an annualized basis, (5) water quality parameters that potentially influence entrainment, and (6) life history parameters to estimate Age-1 equivalents with the EAM (Goodyear, 1978).
- **Define study boundaries:**

  Study area: The CWIS is the key study area component; I&E sampling will be conducted at the CWIS. The resulting annual I&E estimates will be used to represent I&E for SPMS.

Timeframe: A scientific collector permit application will be submitted as the first step in the study. Upon receipt of the scientific collector permit, one year of monthly sampling will be conducted. Sampling will start after SPMS is in full operation following startup of all production units. Shell estimates that this will occur in Q2 2024. Hence, it is assumed that I&E sampling will start in Q2 2024 and end in Q2 2025. The I&E characterization study report is due within 5 months of completing the I&E sampling; this is estimated to occur in Q4 2025.

Limitations/constraints: Equipment malfunctions and limited access to sampling locations may complicate I&E sample collection. Also, adverse weather conditions may result in altered schedule and /or missed sampling events. Facility I&E will be estimated; the estimate could potentially over- or under-estimate actual I&E. Also, Age-1 equivalent adults will be estimated from the I&E data. There is uncertainty when assessing population-level effects. Uncertainty will, however, be minimized by using a well-documented and widely accepted fish population model, i.e., the equivalent adult model.

- **Develop the analytic approach and logic for drawing conclusions**: Facility I&E samples will be collected consistent with standard industry practice, and within the limitations imposed by Facility conditions and weather. The proposed approach to estimating Facility I&E will be based upon standard statistical procedures for interpolation. Population-level effects associated with I&E will be modeled consistent with the framework developed by Goodyear (1978) for the EAM.
- **Specify performance or acceptance criteria including probability limits**: Facility I&E estimates will be estimated with a best-fit regression line; the regression will be used to interpolate between I&E sampling events. The selection of the best-fit regression will be based on the R^2, whereby a selected best-fit regression will have an R^2 that ranges from 0.95 - 1.0, and a visual inspection of the scatter plot. More formal procedures, e.g., Akaike Information Criterion, are not warranted because the R^2 values are expected to be 0.95 - 1.0. Scatter plots with the best-fit regressions will be presented in the I&E report.

The remainder of this SAP presents the approach to generating I&E data that will meet the DQOs and regulatory requirements. The study plan also includes elements of a quality assurance project plan (QAPP) that provides guidance for the collection and laboratory analysis of the data necessary to meet the DQOs.

3.2 I&E Sample Collection

Topics discussed in this subsection are (1) sample timing and sample size, and (2) sample collection and preparation.

3.2.1 I&E Sample Timing and Sample Size

The proposed sampling schedule assumes that I&E sampling will commence in Q2 2024. The schedule is, however, subject to change based upon when actual full start-up and normal operations begin with all units in operation.

Impingement data will be collected from the CWIS monthly for a period of one year from Q2 2024 through Q2 2025 (**Table 1**). This will yield 12 monthly impingement sample events and 12 impingement samples.

Entrainment data will be collected for a period of one year for a total of 16 entrainment sample events. As requested by PADEP, entrainment data will be collected bi-weekly during the period of peak entrainment (May – August), and monthly during the period of low entrainment (September – April). During each peak entrainment sample event, four entrainment samples will be collected at 6-hour intervals. During periods of low entrainment, sampling will occur monthly, and a single entrainment sample will be collected at sunset. A sequential replicate will be collected for every 20 entrainment samples. The total number of entrainment samples will be 40. Hence 2 replicate samples will be collected during the period of peak entrainment for a total of 42 entrainment samples.

Table 1. I&E Sample Event Frequency[1].

Month	2024[2]	2025[2]
January	--	Monthly (I=1; E=1 sunset)
February	--	Monthly (I=1; E=1 sunset)
March	--	Monthly (I=1; E=1 sunset)
April	--	Monthly (I=1; E=1 sunset)
May	---	Monthly (I=1); Bi-weekly (E=8; Rep=1 sunrise)
June	Monthly (I=1); Bi-weekly (E=8; Rep=1 sunset)	--
July	Monthly (I=1); Bi-weekly (E=8)	--
August	Monthly (I=1); Bi-weekly (E=8)	--
September	Monthly (I=1; E=1 sunset)	--
October	Monthly (I=1; E=1 sunset)	--
November	Monthly (I=1; E=1 sunset)	--
December	Monthly (I=1; E=1 sunset)	--
No. of Sample Events	**10**	**6**

Notes: Blue shading indicates the period of peak entrainment identified by PADEP during the January 31, 2024 conference call with Shell and AECOM.
[1] Schedule is subject to change, depending on when actual full start-up and normal operations begin with all units in operation.
[2] "I" refers to impingement, "E" refers to entrainment, "Rep" refers to a replicate sample.

3.2.2 Sample Collection and Preparation

A PFBC scientific collection permit will be obtained before conducting the I&E sampling. One field team of two aquatic scientists will conduct the sampling. A lead fisheries biologist will attend the initial set-up and sampling event to confirm adherence to this SAP. Field personnel will be responsible for recording all data from the beginning of the I&E monitoring through completion. Data will be recorded on field sheets or in a field logbook at the time of sample collection in a legible manner. Example I&E field data sheets are provided in **Appendix A**, and sample collection standard operating procedures are provided in **Appendix B**.

Impingement Sampling

Impingement sample collection procedures are described below:

- **Sample collection setup**: Each monthly sampling event will reflect one continuous 24-hour period. SPMS will be notified in advance of the sample event and asked to rotate the traveling screens to clear any debris and empty the debris basket. The Evoqua traveling screens will then be run continuously for 24 hours; sampling will occur at the end of the 24-hour period.

  Flow from the traveling screens will be passed through an appropriately sized mesh net suspended in the debris basket. The traveling water screens will be run continuously unless the net is removed due to high debris loads. The trough may

require some modification for a custom-built net to be placed during sample collection.

- **Sample processing**: After sampling, the net will be removed. Field technicians will sort through the debris, e.g., leaf litter and collect impinged fishes. The field technicians will tally the collected fish and identify to the lowest practicable taxa and note if the organism was dead prior to impingement. Other notes will be recorded for each organism as deemed relevant, e.g., “partially decayed”, “exhibited signs of disease or injury”; photographic documentation will be conducted. Each impinged fish will be measured for TL (millimeter [mm]) and weighed (gram [g]). Fishes that cannot be identified in the field will be shipped to the selected taxonomic laboratory (EcoAnalysts, Inc. in Moscow, Idaho). The fishes will be placed into pre-labeled sample container(s), and the sample(s) will be preserved with 10 percent buffer formalin solution. The laboratory I&E standard operating procedure is presented in **Appendix C**.

Entrainment Sampling

The USEPA requires that the entrainment sample collection study design be robust enough to characterize annual, seasonal, and diel variations in entrainment. Because this is a voluntary study, the proposed entrainment study design addressed these three requirements while balancing the considerations of (1) the published life species accounts of the key fishes, (2) uncertainty with respect to annual and seasonal fish abundance, (3) diel behavioral patterns, (4) field staff safety, and (5) project costs.

Differences in entrainment densities can occur on a diel (24-hour) basis (Electric Power Research Institute [EPRI], 2005), with light serving as a behavioral trigger. Diel activity patterns of fish fall into three categories – diurnal (day), nocturnal (night), and crepuscular, i.e., refers to twilight periods of sunset and sunrise (Binder et al., 2011). A review of entrainment studies by EPRI (2005) found that entrainment rates during the sunset, sunrise, or darkness were often substantially higher than during daylight. Ultimately, sampling intensity i.e., the number of samples, is not as important for characterizing diel variability as how completely the diel variation is covered by the sampling (EPRI, 2005). Entrainment sample collection procedures are described below:

- **Sample collection**: The period of peak entrainment was defined by PADEP as May through August. During the period of peak entrainment, entrainment samples will be collected bi-weekly over a 24-hour period during 4, 6-hour blocks at sunrise, day, sunset, and at night (**Table 2**). Two sample replicates will be collected during the peak entrainment period. The replicate samples will be rotated such that a sample will be collected at sunrise, and one replicate will be collected at sunset. The period of low entrainment was defined by PADEP as September through April. During periods of low entrainment, sampling will occur monthly, with one 4-hour entrainment sample collected per sample event. The sample will be collected at sunset when peak entrainment typically occurs. If a sampling event cannot be completed safely during the planned timeframe due to weather or river flows, a makeup sampling event will be scheduled as soon as practicable after the missed event.

Table 2. Entrainment Sample Design

Sample	Time of Sampling
Sunrise	0500 – 0700
Day	1100 – 1300
Sunset	1700 – 1900
Night	2300 – 0100

- **Sequential replicates**: Sequential replicates will be collected during the period of peak entrainment. Sufficient time will be allowed in-between samples to accommodate sequential replicate sample collection. As requested by PADEP, 1 sequential replicate sample will be collected for every 20 field samples. Because 40 field samples will be collected, 2 sequential replicates will be collected. Sequential replicates are samples that are collected consecutively instead of simultaneously (Wilde et al., 2006). As applied to the entrainment characterization study, the sequential replicate would provide information on sample variability resulting from heterogeneity in fish abundance over a short time. Although the proposed sample events each day are achieving the same objective, the time interval is greater. Hence, collecting a sequential replicate close to the original field sample may generate useful information. The sequential replicate samples will be rotated to reflect all four daily sample events, i.e., one replicate will be collected at sunrise and one sample will be collected at sunset.
- **Sample collection setup**: Sampling will take place within the intake screenhouse at a valved tap located on the raw water line downstream of the circulating water pumps. The tap will have a gate valve and camlock flange to allow connection to temporary piping. Sampling will occur after the circulation water pump collects water that is well-mixed. Polyvinyl chloride piping will direct the water from the tap through an inline flow meter to accurately measure the volume of water being sampled. The water will then pass through a 1/2-meter diameter, 500 micrometer (µm) plankton net or similar suspended in a suitably sized water tank (200-300 gallons) to limit the force exerted on the entrained organisms as they are filtered, e.g., a 200-300 gallon tote with the top removed.

  An inline flow meter will be used to record water volume during sampling. The volume of water filtered through the plankton net for each sample will be 100 m^3 at a flow rate of approximately 1.0 cubic meter per minute (m^3/min.) (not to exceed 2.0 m^3/min). This will yield a total of 300 m^3 of water per monthly sample event. Assuming a flow rate of 1.0 m^3/min., each sample will last 100 minutes (1.7 hours [≈2-h]), and total sampling time per event will be 6 hours. Any factors affecting the discharge flow, sample time, and total sample volume will be recorded.
- **Sample processing**: Following each sample event, the plankton net will be washed down using potable water, the contents placed into a pre-labeled sample container, and the sample preserved with 10 percent buffer formalin solution. The individual entrainment samples will be shipped to EcoAnalysts, Inc., in Moscow, Idaho for processing. Entrained organisms will be identified to the lowest practicable taxa, enumerated, and measured for diameter (eggs), and total length (millimeters [mm]) (larvae, juveniles, and adults). The EcoAnalysts, Inc. Standard Operation Procedure: Laboratory Analysis of Benthic Macroinvertebrates and Ichthyoplankton (Effective Date March 12, 2021) is provided in **Appendix C**.

Water Quality Data

Water quality can influence fish behavior and may be used to explain patterns in entrainment. Water quality measurements will be taken in accordance with the PADEP "Monitoring Book" protocols (Chapter 4-1). At approximately the mid-point of each collection period, water quality parameters, (e.g., dissolved oxygen, conductivity, pH, and temperature), will be measured at the sampling location using a hand-held multi-parameter instrument. Water quality measurements will be collected at the same location during each sampling event. Field instruments will be calibrated according to the manufacturer's specifications. All calibration procedures performed will be documented in the field logbook: the date/time of calibration, name of person performing the calibration, reference standard used, expiration dates of the standards used, temperature at which the readings were taken, and the calibration readings. Calibration logs will be appended to the entrainment characterization report for PADEP review.

Additional Field Conditions

Weather conditions, sky cover, precipitation, wind direction and speed and air temperature, surface conditions, e.g., wave height, and any other conditions, e.g., extremely high, or low water elevation, unusual debris in water, color of water will be recorded.

3.2.3 Threatened or Endangered Species

Any state or federal, threatened, or endangered species identified during the entrainment sampling will be reported to the appropriate agencies, (e.g., U.S. Fish and Wildlife Service, PADEP, PFBC, Pennsylvania Game Commission, and the Pennsylvania Department of Conservation and Natural Resources).

3.3 Data Analysis

I&E data analysis will address the DQOs and the performance criteria. Topics discussed in this subsection are (1) annual Facility I&E estimates, and (2) Age-1 equivalent adult estimates.

3.3.1 Impingement

Impinged species composition will be summarized monthly and by year. The relative percent composition of impinged organisms will be determined, total length will be characterized, and weight will be summarized. Additional morphological features will also be discussed, where relevant.

Annual impingement estimates for SPMS will be generated using two steps: **Step 1**. Estimate the number of fish impinged during times when the species was potentially present but was not sampled; and **Step 2**. Estimate total annual Facility impingement for species *i*…n, where:

Step 1. Estimate the Number of Fish Impinged In-Between Sample Collection Events.

The number of estimated fish impinged for species *i*…*n* ($I_{Facility,estimated}$) will be estimated in-between sample collection events during times when the species was potentially present but was not sampled. Each day of the entire study duration will be assigned a number from day 1…*n*. The numbers of impinged organisms will be

estimated from collected impingement samples with linear/non-linear best-fit regression with a spreadsheet tool such as EXCEL or a statistical software package (SYSTAT).

Step 2. Estimate Total Annual Facility Impingement. Total annual Facility impingement will be based on the sum of collected and estimated numbers impinged for taxa i…*n*. Impingement estimates will be presented by individual taxa.

3.3.2 Entrainment

Entrainment data analyses will address the DQOs, and the performance criteria. Fish will be identified to the lowest practicable taxa. Additional data reported will be the total length and the presence or absence of a yolk sac. Relative percent composition of entrained fishes will be summarized monthly and by year, and the total length will be characterized. Additional morphological features will also be discussed, where relevant, to substantiate identification, e.g., myomeres, gut length. Eggs will be characterized with respect to diameter.

Diel Patterns in Entrainment

If enough entrained organisms are observed, statistically significant differences in entrainment abundance will be characterized to assess diel difference. Box plots, descriptive statistics, and a one-way analysis of variance (ANOVA) (or a non-parametric Kruskal-Wallis ANOVA) will be used. Statistically significant results will be reported where $p \leq 0.05$. If the overall ANOVA is significant, a post hoc Tukey's honestly significant difference test (Tukey's HSD) (or a Wilcoxon Rank-sum) will be used. The post-hoc tests will evaluate all pairwise differences, while controlling the probability of making one or more Type I errors. As defined, Type I error occurs when the null hypothesis (Ho) is rejected when it is true.

Estimated Facility Entrainment

Annual entrainment estimates for SPMS will be generated using three steps: **Step 1**. Estimate the number of fish entrained based on the collected organisms; **Step 2**. Estimate the number of fish entrained during times when the species was potentially present but was not sampled; and **Step 3**. Estimate total annual facility entrainment, where:

Step 1. Estimate the number of fish entrained. The number of collected fish entrained for species *i*…n will be estimated for SPMS ($E_{Facility,collected}$), where:

$$E_{Facility,collected} = \left(\frac{E_{sample}}{V_{sample}}\right) * (F_{CWIS});$$

and

E_{sample} is the number of observed individuals of species *i*…n entrained for a given sample.

V_{sample} (m^3) is the sample volume.

F_{CWIS} (m^3) is the daily CWIS flow; raw Facility flow data will be provided in the entrainment characterization report.

Step 2. Estimate the number of fish entrained in-between sample collection events. The number of estimated fish entrained for species *i*…*n* ($E_{Facility,estimated}$) will be estimated in-between sample collection events during times when the species was potentially present but was not sampled. Each day of the entire study duration will be

assigned a number from day 1…*n*. The numbers of fishes will be estimated from collected entrained fish with linear/non-linear best-fit regression with a spreadsheet tool such as EXCEL or a statistical software package (SYSTAT). The individual regressions and scatter plots will be presented for all entrained species.

Step 3. Estimate Total Annual Facility Entrainment. Total annual Facility entrainment will be based on the sum of collected and estimated numbers entrained for taxa i…*n*. Entrainment estimates will be presented by individual taxa.

3.3.3 Age-1 Equivalents

The analysis will use the equivalent adult model (EAM) for estimating Age-1 equivalents discussed in USEPA (2006b). This is a method for expressing I&E losses as an equivalent number of individuals at some other life stage, referred to as the age of equivalency (Goodyear, 1978; USEPA, 2006b). The method converts I&E losses into units of individual Age-1 fish.

The EAM model uses age or life-stage specific survival rates to convert I&E losses to an equivalent number of Age-1 fish. The conversion rate will be calculated as the product of all stage-specific survival rates between the stage at which I&E occurs, and Age-1. Hence, the cumulative survival rate from stage *j* until Age-1 for each fish (S_j) will be determined where:

$$S_j = S_j^* \prod_{i=j+1}^{j_{max}} S_i$$

and:

S_j^* = $2S_j e^{-log(1+S_j)}$ = adjusted S_j.

j_{max} = the stage immediately prior to Age-1.

S_i = survival fraction from stage *i* to stage *i* +1.

Age-1 equivalents experiencing mortality during life stage *j* in year *k* ($AE_{j,k}$) will then be calculated, where: $AE_{j,k} = L_{j,k}S_{j,n}$; and

$L_{j,k}$ = the number of individuals experiencing mortality during life stage *j* in year *k*.

S_j = the cumulative survival rate for individuals passing from life stage j to Age-1.

The total number of Age-1 equivalents derived from losses at all stages in year *k* (AE_k) will be calculated, where: $AE_k = \sum_{j=j_{min}}^{j_{max}} AE_{j,k}$.

4.0 Reporting

An I&E Characterization Study report that fulfills the requirements of the Permit will be prepared. As requested by Shell, refinements to CWIS operations based on the I&E data will be provided, where warranted. Any deviations from this SAP will be noted in the I&E characterization report. The anticipated report sections will be:

- Introduction and Regulatory Framework
- Background
  - Facility Description
  - CWIS Overview
  - Ohio River Characteristics
  - Characterization of the Local Fish Community
- I&E Characterization
  - Sampling Approach
  - I&E Composition
  - Factors that Influence I&E
  - Estimate of Annual I&E
  - Age-1 Equivalent Adults
- Conclusions
- References

5.0 Schedule

A scientific collector permit application will be submitted as the first step in the study (**Table 3**). Upon receipt of the scientific collector permit, one year of monthly I&E sampling will be conducted. Sampling will start after SPMS is in full operation following startup of all production units, and completion and implementation of the Management of Change (MOC) for connection to the circulating water pumps. Shell estimates that this will occur in Q2 2024. For the purposes of this SAP, it was assumed that I&E sampling will start in Q2 2024 and end in Q2 2025. The schedule is, however, subject to change based upon when actual full start-up and normal operations begin with all units in operation. The I&E characterization study report is due within 5 months of completing the sampling; this is estimated to occur in Q4 2025.

Table 3. I&E Characterization Study Schedule.

Study Plan Element	Anticipated Completion Date
Scientific Collector Permit	Q1 2024
Perform mobilization, test run, and security badging	Q1 2024
Begin I&E sampling	Q2 2024
End I&E sampling	Q2 2025
Final I&E Report to PADEP	Q4 2025

6.0 References

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Appendices

Appendix A

Example I&E Characterization Field Data Sheets

AECOM

Sample ID:	
Personnel:	
Date:	
Start Time:	
Stop Time:	
Duration:	

WATER QUALITY			
Time (24 hr):		**DO (mg/L):**	
pH:		**DO (%):**	
Temperature (˚C):		**Depth (m):**	
Conductivity (µS/cm):			
Salinity (‰):			

SPECIES	#	Total Length (mm)	Total Weight (g)	CONDITION	SPECIES	#	Total Length (mm)	Total Weight (g)	CONDITION

Prepared By
Name:_________
Date:__________

G-Good, F-Fair, P-Poor,A-alive, D-dead,
DPI-Dead Prior to Impingement, L-lesions

Entrainment Characterization Study Data Collection Sheet

GENERAL INFORMATION

Site:	Shell Polymers Monaca Facility	**Date:**	
Field Team:		**Arrive On-site (Time): (24 hr)**	
Unique ID:		**Departure Time: (24 hr)**	

WEATHER

Wind Direction:	**Cloud Cover (%):**	**Turbidity:**
Wind Speed (mph):	**Precipitation (type/severity):**	
Air Temperature (^{o}F):	**Sea state:**	
Debris conditions:		
Other Observations:		

SAMPLE PARAMETERS 1

Unique ID:	**Time of Day (day/evening/night):**
Start time:	**Location in water column:**
End time:	
Duration (minutes):	**Mesh size:** 500μm
Flow meter start (count):	**Calibration flow test: (**XX **gallons / __ sec.)*60 = gpm**
Flow meter stop (count):	**Volume sampled (m³):**
Other remarks:	

WATER QUALITY 1 (collected at the midpoint of the sample period at sampling depth)

Temperature (^{o}C)	Conductivity (μS/cm)	Salinity (‰)	DO (mg/l)	DO (%)	pH	Depth (m)	Time (24 hr)

Other sampling remarks:

Entrainment Characterization Study Data Collection Sheet

SAMPLE PARAMETERS 2

AECOM

Unique ID:	**Time of Day (day/evening/night):**
Start time:	**Location in water column:**
End time:	
Duration (minutes):	**Mesh size:** 500μm
Flow meter start (count):	**Calibration flow test: (55 gallons / __ sec.)*60 = gpm**
Flow meter stop (count):	**Volume sampled (m³):**
Other remarks:	

WATER QUALITY 2 (collected at the midpoint of the sample period at sampling depth)

Temperature (°C)	Conductivity (μS/cm)	Salinity (‰)	DO (mg/l)	DO (%)	pH	Depth (m)	Time (24 hr)

SAMPLE PARAMETERS 3

Unique ID:	**Time of Day (day/evening/night):**
Start time:	**Location in water column:**
End time:	
Duration (minutes):	**Mesh size:** 500μm
Flow meter start (count):	**Calibration flow test: (55 gallons / __ sec.)*60 = gpm**
Flow meter stop (count):	**Volume sampled (m³):**
Other remarks:	

WATER QUALITY 3 (collected at the midpoint of the sample period at sampling depth)

Temperature (°C)	Conductivity (μS/cm)	Salinity (‰)	DO (mg/l)	DO (%)	pH	Depth (m)	Time (24 hr)

Appendix B

Standard Operating Procedures for I&E Sample Collection

Appendix B: Impingement Sample Collection Standard Operating Procedure

The purpose of this standard operating procedure (SOP) is to direct the sampling team in impingement sample collection at the Shell Polymers Monaca Facility. Impingement sample collection and net washdown procedures are presented below as sequential steps, and include specific equipment, materials, and methods required to perform sampling activities.

Required Permits

A scientific collection permit will be required from the Pennsylvania Fish and Boat Commission (PFBC) prior to the start of field activities.

Precautions/Preparations

Follow typical safety precautions for working in the field as well as client directed precautions for working on or near site. Site access, setup, and lockout and tagout procedures shall be directed or performed by site personnel. An opening exists in the intake structure and poses a constant risk/hazard while sampling. A temporary exclusion structure (fence or railings) shall be installed around the opening to eliminate or mitigate the risk. Site personnel will determine if a water source is available for net washdown, as needed.

Equipment

- Ichthyoplankton nets (3/8” with removable cod-end).
- Fish weighing scale (grams).
- Metric ruler for measuring total length (TL) in millimeters (mm).
- Pens, pencils, permanent markers
- Impingement characterization field data sheet.
- Waterproof field notebook and clipboard.
- YSI 556 MP.
- 5-gallon bucket.
- Stainless steel precision tweezers.
- Knife or scissors.
- Nitrile gloves.
- Abrasion resistant work gloves.
- 2-gallon industrial sprayer (if needed for net washdown if water source and hose are not available)
- Exclusion structure (railing or fence)
- First aid kit and emergency telephone numbers.

Sampling Procedures

Impingement characterization sampling will be achieved by sampling the screen wash water from the travelling water screens:

- Impingement samples will be collected using a 3/8” mesh net liner designed to fit in the screen wash sluice. The 3/8” sampling net will be placed in the screen wash sluice while screens are washed.

- The traveling screens will be operated for 24 hours before the sample event to wash debris and organisms off the screens prior to sampling.
- All specimens of fish and shellfish that are collected in the sampling net will be removed immediately and will be assessed for condition (dead/alive/injured).
- Impinged fish and shellfish will be identified to the lowest practicable taxonomic distinction, counted, measured for total length (millimeters), and weighed (grams).
- If a listed endangered, threatened, or species of concern is encountered, specimens will be measured, weighed, and photo-documented with the minimal amount of handling possible before releasing the specimen. The proper agencies will be notified.

Entrainment Sample Collection Standard Operating Procedures

Scope and Applicability: The purpose of this standard operating procedures (SOP) is to direct the sampling team in entrainment sample collection at the Shell Monaca Polymers Facility. Entrainment sample collection and net washdown procedures are presented below as sequential steps, and include specific equipment, materials, and methods required to perform sampling activities.

Precautions/Preparations: Follow typical safety precautions for working in the field as well as client directed precautions for working on or near site. Site access, setup and lockout and tagout procedures shall be directed or performed by site personnel. An opening exists in the intake structure and poses a constant risk/hazard while sampling. A temporary exclusion structure (fence or railings) shall be installed around the opening to eliminate or mitigate the risk. Site personnel will determine if water source is available for net washdown.

Required Permits: A scientific collection permit will be required from the Pennsylvania Fish and Boat Commission (PFBC) prior to the start of field activities.

Equipment/Materials:

- YSI 556 MP
- Formalin 10% Buffer
- Distilled water for sample preservation
- Translucent round wide-mouth plastic sample jars - 16 oz (3 per sampling day, 1 per subsample)
- Ichthyoplankton net (500 µm with removable cod-end)
- Bottleware labels
- Cooler (to keep samples in)
- 5-gallon bucket
- Stainless steel precision tweezers
- Knife or scissors
- Nitrile gloves
- Abrasion resistant work gloves
- Entrainment characterization field data sheet
- Waterproof field notebook

- 2-gallon industrial sprayer (if needed for net washdown if water source and hose is not available)
- Pens, pencils, permanent markers
- Squirt bottles for formalin and distilled water
- Clipboard (to keep writing utensils, field notebook, COC's, jar labels and field data sheets)
- Exclusion structure (railing or fence)
- First aid kit and emergency telephone numbers a Selection and exact specifications at the discretion of the experienced on-site personnel.

Procedures:

1. Set mechanical flow meter with the net in the intake channel. Set a timer and synchronize with revolutions of flow meter. Begin sampling. Collect a YSI reading from source waterbody.

2. Upon completion of sampling (100m^3), record the final flow and time before carefully removing the net from the intake tunnel at the carabiner.

3. Using the carabiner hang the net vertically near a drain port prior to net wash down.

4. Using a hose or industrial sprayer, spray the outside of the net downward from the opening of the net towards the cod-end. Make repeated sprays in this motion around entirety of the net making sure all visible net contents are collected in the cod-end. Washdown water shall never be sprayed inside the net prior to sample processing, in effort to avoid compromising sample. Be mindful of washdown pressure as not to damage the collected ichthyoplankton post-sampling. Switch to nitrile gloves before sample collection, maintain wearing protective eyewear.

5. Unscrew the cod-end and use distilled water squirt bottle to wash down inner walls and screens of the cod-end condensing the sample in a pool.

6. Label sample jar with Sample ID (e.g. *SHELL-**04202**2-Sunset*), date, time, sampler's initials, and final volume filtered. Dump concentrated sample into sample jar while continuing to use distilled water squirt bottle. Use tweezers and scrapers to collect all contents left over.

7. Using formalin squirt bottle, fill the sample container to two thirds capacity while ensuring all contents are submerged in the formalin solution. Close sample jar.

8. Put labeled sample jar within the cooler for safety and transport.

9. Resume washing down net without cod-end now being able to invert the net, wash completely the inside and outside surfaces. Reattach cod-end.

10. Redeploy net above tank/tote. Reset timer and flowmeter.

Appendix C

Standard Operation Procedure: Laboratory Analysis of Benthic Macroinvertebrates and Ichthyoplankton

Standard Operation Procedure: Laboratory Analysis of Benthic Macroinvertebrates and Ichthyoplankton

Effective Date March 12, 2021

Revision No. 7

Prepared by

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Contents

Introduction

This SOP addresses the laboratory operations and analyses for benthic macroinvertebrate and ichthyoplankton samples. This plan describes data quality objectives, measurement and data acquisition, and information management for processing marine benthic infauna samples.

Sample Handling and Custody

Immediately upon receipt of benthic macroinvertebrate and ichthyoplankton samples, all containers are inspected for damage or leakage. Sample labels are checked against chain of custody forms and/or packing slips and any discrepancies are noted. Receipt records are reported to the client within one business day of sample receipt. Chain of custody logs are reported, throughout the project, according to timelines and methods requested by the client. Samples are logged into the EcoAnalysts, Inc. custom LIMS database and assigned a unique sample tracking number.

Analytical Methods

Sorting Benthic infauna Samples

A sample is checked out by a sorting technician via the LIMS. A sorting bench sheet is printed that contains the EcoAnalysts sample identification information and sorting protocols assigned to it. The sorter records the primary matrix type and approximates the volume of detritus prior to sieving. The standard descriptors for the types of sample matrix are: Inorganic, Coarse Organic, Fine Organic, Vegetation, and Filamentous Algae.

The sample is by emptying the matrix into a sieve of a specified mesh size to remove preservative and fine sediment. If the sample matrix is made up of a significant percentage of inorganic material, the organic material will be elutriated from the inorganic material prior to sorting.

For elutriation, the whole sample is washed into a shallow pan of water. At this time any large pieces of organic material can be rinsed and inspected thoroughly by the original technician and a secondary technician for attached and burrowing aquatic invertebrates. If large organic matter is deemed removable from the sample, it is retained separately as sample residues. The sample is agitated with water to separate any organic matter from inorganic sediments. After agitating the sample in water, the lighter organic material is poured back into the sieve. The inorganic portion of the sample remaining in the pan is repeatedly washed and decanted into the sieve until no more organic matter remains in the pan with the inorganic material.

The remaining inorganic sediments are inspected under a magnifying lamp (3X) to look for any invertebrates too heavy to have been elutriated (e.g. mollusks, snails, etc.). If there are significant numbers of heavy invertebrates in the inorganic material – too many to easily remove under the magnifying lamp – the inorganic and organic matrix is recombined into the sieve and entire sample matrix will be prepared for subsample. If there are not significant numbers of heavy invertebrates in the inorganic material, they are removed under the magnifying lamp and placed with the organic matrix. A second technician inspects the inorganic material for organisms until it is determined there are no more invertebrates in the inorganic fraction of the sample. Unless otherwise requested, the inorganic elutriate is discarded.

The organic material and other contents of the sieve are then evenly distributed into the bottom of a Caton-style tray. These are trays of various sizes consisting of uniform grids, each grid being 2 inches per side and the bottom is constructed of 250-micron mesh. A grid (or a standardized portion of a grid) is randomly selected and its contents transferred to a Petri dish. The material in the Petri dish is sorted under a dissecting microscope (minimum magnification = 10X). The individual organisms are counted as they are placed into vials containing 70% ethanol.

Sorters are trained to pick and count only benthic macroinvertebrates, with heads, that were alive during sampling and contain the attributes required for taxonomic identification. Organisms picked are placed in one of five vials corresponding either to Crustacea, Polychaeta, Mollusca, Generals (miscellaneous taxa), and Special Organisms if requested by the client (SPORGS: Copepods and Ostracods). Specimens rejected according to EcoAnalysts' standard include: Nematodes, Zooplankton, Exuviae, and any organism without a head. When the target count of organisms has been reached or the target percentage of the sample has been sorted but not fully sorted, a special large and rare protocol may be followed on any remaining unsorted material. Organisms deemed relatively large or rare to the sample (in comparison with the target taxa enumerated in the final count) are found by a naked eye scan in the unsorted sample remnants and are not counted but picked and placed in a separate vial.

Ichthyoplankton samples are handled and sorted similarly to benthic macroinvertebrate samples. For these samples, sorters are trained to pick and count only ichthyoplankton and eggs.

Laser-printed labels containing the appropriate sample tracking information are placed in the vial(s). The total number of organisms removed, the number of grids sorted out of the total, the time spent sorting, and the final volume of the remaining sample volume are all recorded on the sorting bench sheet, as well as comments significant to the preparation, sorting, and/or condition of the sample.

Taxonomic Identification of Benthic infauna and Ichthyoplankton

A taxonomist selects a sample for identification via the LIMS and empties it into a Petri dish. Under a dissecting and/or compound microscope, the organisms are identified to the lowest practical level, generally genus/species or taxonomic level specified for the project. The taxonomist enters each taxon directly into the project database using a unique taxonomic code (this is done while at the microscope). The number of individuals of each taxon is counted and entered into the database. As the sample is being identified, the taxonomist enters data directly into the LIMS database and user interface.

A synoptic reference collection may be prepared, where at least one specimen (preferably 3-5 specimens) of each taxon encountered is placed into a 1-dram vial containing 70% ethanol and is properly labeled with identity and sample number. Depending on the requirements of the project, one or several reference collections can be made. Also, organisms can be vouchered by a specified taxonomic level, i.e. vouchered by each taxon per sample. If any synoptic reference collection is made, a second taxonomist examines the reference collection specimens to verify the accuracy of all taxa identified in the project.

Quality Objectives and Criteria

Sorting Efficacy

At least 20% of each sample is re-sorted by a quality control technician, who did not originally sort the sample, to ensure at least 90% of the organisms have been removed. The QCs are performed by technicians who have shown to achieve 90% efficacy on a minimum of 90% of samples they process. QC technicians are trained in the QC process by the sorting lab manager. The QC technician QCs a minimum of 20% of the sorted material from a given sample to ensure at least 90% of the organisms have been removed. The estimated percent efficacy is calculated, using the following equation:

Equation 1. Sorting Efficacy

$$\text{Sorting Efficacy \%}=\left(\frac{Original\ Count}{Origianl\ count+\left(\left(\frac{QC\ count}{QC'd\ Grids}\right)*QC\ total\ girds\right)}\right)*100$$

Where: OriginalCount = the number of organisms picked by the first sorter
QCCount = the number of organisms found in the Quality Control sort
QC'd grids = the number of grids sorted during the QC process
QC Total grids = the total number of grids in the QC Caton

Sorting efficacy is measured as the estimated percent of the total organisms found during the original sorting process. If the estimated percent sorting efficacy is 90% or greater, the sample passes the quality control check. If the estimate is less than 90%, the sample is re-sorted. When this happens, the sample undergoes the quality control process again until it passes the 90% efficacy requirement. If a technician is continually not meeting the efficacy requirements of the project, they will be removed from the project. Supplemental project specific guidance that may be provided by the lab manager, such as photo reference guides for rejects.

Taxonomic Accuracy

Taxonomic accuracy is quantified by comparing whole-sample identifications completed by a second taxonomist who did not perform the primary identification. Accuracy of taxonomy is qualitatively evaluated through specification of target hierarchical levels (e.g., family, genus, or species) and the specification of appropriate technical taxonomic literature or other references (e.g., identification keys, voucher specimens). Percent similarity is a measure of similarity between two communities or two samples (Washington 1984). Values range from 0% for samples with no species in common, to 100% for samples that are identical. It is calculated as follows:

Equation 2. Percent Similarity

$$PSC = 1 - 0.5\sum_{i=1}^{K}|a-b|$$

where: PSC = Percent Similarity
a and b = the proportion of a species found in each sample relative to the total count of all taxa combined found in their respective samples.

A minimum quality objective (MQO) of ≥90% is recommended for percent similarity of taxonomic identification. If the MQO is not met, the reasons for the discrepancies between analysts should be discussed. If a major discrepancy is found in how the two analysts have been identifying organisms, any samples identified by the original taxonomist may require re-identification and correction for any taxa in question. Corrective actions can include defining the taxa for which re-identification may be necessary (potentially even by a third party), identifying which samples (even outside of the 10% lot of QC samples) corrective action may be required, and also where there may be issues of nomenclatural or enumeration problems requiring re-investigation or correcting for consistency across all samples.

Samples will be identified using the most appropriate technical literature that is accepted by the taxonomic discipline and reflects the accepted nomenclature. Where necessary, the Integrated Taxonomic Information System (ITIS, http://www.itis.usda.gov/) will be used to verify nomenclatural validity and spelling. A reference collection will be compiled as the samples are identified.

Data Management

Data is directly entered into the LIMS database. Throughout the project and sample analysis, data entry is double checked for accuracy, and validated by the laboratory managers. The appropriate data are combined for each sample to obtain the sorting statistics and comprehensive taxa lists and counts.

Quality assurance data sheet checks are part of the sample validation process, and include scanning for apparent entry errors, measurement errors, omissions, and anomalies. Suspect data are flagged and/or excluded from use. Data may be presented in table, graph, and chart format. Unusual data are rechecked to verify their accuracy.

Data are delivered in an electronic format specified by the client.