Thin Layer Cap Pilot Project Pre-Design Investigation Work Plan

Orrington Reach Capping Remedy

Prepared for
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ACRONYMS AND ABBREVIATIONS

ASTM	ASTM International
BAZ	biologically active zone
DQO	data quality objective
FSP	field sampling plan
Greenfield	Greenfield Penobscot Estuary Remediation Trust LLC
HASP	health and safety plan
Integral	Integral Consulting Inc.
PDI	pre-design investigation
QAPP	quality assurance project plan
QA/QC	quality assurance and quality control
SOP	standard operating procedure
SPI	sediment-profile imaging
TLC	thin layer cap
TOC	total organic carbon
WSP	WSP USA Environment & Infrastructure, Inc.

1 INTRODUCTION

This Thin Layer Cap (TLC) Pilot Project Pre-Design Investigation (PDI) Work Plan (TLC Pilot PDI Work Plan) has been prepared pursuant to the Consent Decree (Case No. 1.00-cb-00069-JAW, ECF No. 1187) between Maine People's Alliance and Natural Resources Defense Council, Inc. (NRDC) vs. HoltraChem Manufacturing Company, LLC, and Mallinckrodt US LLC entered by the U.S. District Court for the District of Maine on October 11, 2022, and in accordance with Paragraph 5 of the Statement of Work (Appendix A to the Consent Decree). As summarized in Table 1, this Work Plan meets the requirements for an investigation work plan under Paragraph 6(a) of the Statement of Work and includes i) an evaluation and summary of existing data and a description of data gaps; ii) data quality objectives (DQOs); iii) a detailed sampling plan; iv) a sampling schedule; and v) a description of the quality assurance and quality control (QA/QC) measures to be undertaken.

Orrington Reach is a portion of the Penobscot River immediately downstream of the former HoltraChem Facility in Orrington, Maine, as shown on Figure 1. The remediation Work specified in the Consent Decree for Orrington Reach is capping 130 acres of intertidal sediment, primarily on the east side of Orrington Reach (Figure 2). The TLC Design Work Plan (Integral 2023a) provides the background for the Orrington Reach Work Category; identifies the objectives, requirements, and preliminary design basis to be met by the Orrington Reach remediation work based on the currently available data/understanding; describes the project approach and identifies the data collection and analyses recommended to support the design; and includes a summary of the rationale for why the information is needed and a recommended scope of data collection and analyses for the investigations.

As described in the TLC Pilot Project Work Plan (Integral 2024), the overall objectives of the TLC Pilot Project are to demonstrate a TLC is feasible and effective and to provide site-specific information to inform potential future capping efforts in Orrington Reach. Results from the TLC Pilot Project will be used to evaluate cap stability and the impact of sediment accumulation on mercury concentrations at the surface of the TLC. Results will also allow for evaluation of the rate and extent of early benthic community recovery and the effects of TLC placement on habitat in the area of the TLC Pilot Project. In addition to these objectives, the TLC Pilot Project will provide information for consideration in future permitting efforts and to address questions from the community and regulatory agencies regarding the performance of a TLC and its impact on coastal wetlands. Information from construction monitoring will be used to support more protective, efficient, and effective implementation of the subsequent phase(s) of the work and will provide for greater certainty in estimating project cost.

This TLC Pilot PDI Work Plan will build on existing data, including sediment samples collected during the 2023 Sediment PDI and identifies supplemental data needed to complete design of the TLC Pilot Project, support regulatory approval of required permits, and establish baseline information on sediment conditions that will be used to evaluate the TLC Pilot Project performance. This document presents the scope, process, and strategy for the TLC Pilot Project PDI, with a focus on the planned pilot location in East Cove 3. The TLC Pilot Project PDI includes assessment of sediment geotechnical properties, assessment of the benthic habitat and the depth of biological activity/mixing, completion of benthic invertebrate surveys, and supplemental chemical analysis of surface sediment.

2 SUMMARY OF EXISTING DATA AND DATA NEEDS

This section i) presents an overview of the data needed to complete preliminary design of the TLC, support permitting efforts, and develop the information needed to evaluate TLC performance and effects on the intertidal flat ecosystems; ii) provides a summary of existing data; and iii) identifies critical data needed to meet the TLC Pilot Project objectives.

The TLC Basis of Design and additional information regarding existing data and data needs is provided in the TLC Design Work Plan (Integral 2023a) and the TLC Pilot Project Work Plan (Integral 2024). The objectives and the sampling plan and methodology are discussed in Section 3 and Section 4, respectively.

2.1 GEOTECHNICAL CHARACTERIZATION

Successful design and construction of the TLC over the existing soft sediments in East Cove 3 requires an evaluation of the physical stability of the TLC. The TLC design must satisfactorily account for the following stability components:

- Bearing capacity—the ability of the intertidal flat sediment to support the cap material and minimize intermixing of cap material with the intertidal flat sediment. Evaluation of the sediment bearing capacity based on the shear strength of the intertidal flat sediment allows for the calculation of the allowable unit weight of cap material for a given TLC thickness. If materials exceed this unit weight, the intertidal flat sediment may not be able to support the cap material, resulting in a failure directly through the sediment surface. This information will in turn inform the properties of the materials acceptable for use in constructing the TLC.
- Subgrade consolidation settlement—the degree to which the intertidal flat sediment will consolidate beneath the weight of the TLC. Evaluation of this consolidation will inform the expected amount of subsidence under the weight of the TLC, which in turn may affect the maximum thickness of a TLC that can be successfully placed.
- Static slope stability—the ability of a cap to avoid slope failure based on the placed grade of the cap material or the grade of the intertidal flat. Evaluation of this factor may affect both the material and thickness of the TLC. Of the three stability components, slope stability is anticipated to be the least impactful to the TLC Pilot Project design due to the relatively shallow grade of the intertidal flats and the “thinness” of the placed material.

Accounting for these stability conditions in the TLC Pilot Project design will minimize the potential for unacceptable movement or loss of cap material, or changes to the intertidal flat setting (e.g., undesired subsidence of portions of the intertidal flat). Data for grain size, moisture content, bulk density, organic content, Atterberg limits, consolidation, permeability, and shear strength with sufficient coverage to account for spatial and depth variability are required to complete the geotechnical evaluations for the TLC Pilot Project design.

Existing geotechnical data for intertidal sediments in the Penobscot River Estuary and East Cove 3 specifically are limited:

- Historical investigations in 2000 and 2011 included minimal geotechnical sampling at five locations near East Cove 3, primarily from surficial sediment (0 to 0.2 ft interval) and samples were analyzed for grain size only. These data are of limited utility for the TLC Pilot Project geotechnical evaluation, as the data may no longer be representative of the existing surface sediment interval and do not include most physical parameters required for the geotechnical evaluation.
- As part of the 2023 sediment PDI, four samples of surface sediment were collected from the sediment surface to a depth interval of 0.4 to 0.8 ft for geotechnical analysis in East Cove 3 in accordance with the Sediment PDI Work Plan (Integral 2023b). These samples were analyzed for sediment type/lithology, grain size, bulk density, and Atterberg limits as shown in Table 2. Results from the 2023 Sediment PDI show variability in their geotechnical properties, and samples closer to the shoreline exhibit greater coarse grain fractions than samples collected farther from the shoreline (Integral 2023c). Of the four samples collected, two were collected from the TLC Pilot Project area (Figure 3). Similarly, only one sample was collected from the East Cove 3 low marsh area (Figure 3), which is expected to exhibit different characteristics from other portions of the cove.

No geotechnical data have been collected from the underlying consolidated sediment. These data will inform evaluations of the extent to which the underlying consolidated layer may positively impact the stability of the TLC placement based on expectations of its strength.

The existing geotechnical data set is insufficient to complete the TLC Pilot Project design. Additional geotechnical data will be collected from *in situ* measurements and laboratory analyses of surficial and underlying consolidated sediment within the TLC Pilot Project area. The details of the sampling approach for geotechnical analysis are provided in Section 4.1.

2.2 EVALUATION OF BIOLOGICALLY ACTIVE ZONE

Understanding sediment mixing is a key component of the evaluation of the TLC Pilot Project design. When capping contaminated sediment with clean material, the cap should be sufficiently thick to minimize the potential for mixing to transport contaminants from beneath the cap into the clean cap material (USEPA 2015). Sediment mixing occurs as a result of physical and biological processes. The TLC Pilot Project is located on an intertidal flat and low marsh, a lower-energy environment where physical mixing is expected to be less prominent relative to biological mixing.

Biological mixing processes (i.e., bioturbation) occur in a zone of the surficial sediment called the biologically active zone (BAZ), where benthic organisms reside, burrow, and feed. Absent other driving factors affecting the TLC physical stability, the greatest effect on the reduction of mercury exposures and the acceleration of recovery for intertidal flats occurs at a TLC thickness equivalent to or greater than the BAZ thickness. A TLC that is considerably thicker than the BAZ will increase costs for material and placement while not providing commensurate beneficial effects on mercury exposure and acceleration of recovery unless required for physical stability.

There are no existing site-specific BAZ data for East Cove 3 or Orrington Reach. Existing information on mixing zones in the Penobscot River and Estuary has been compiled from the Phase II and III studies completed between 2009 and 2017. The focus of the relevant portions of these studies was on evaluating total mixing depths (i.e., including both physical and biological components), and many of the samples were collected from higher energy areas where physical mixing is significant. As a result, while presenting a basis for mixing activity in the Penobscot River, the mixing depths identified from these studies cannot be assumed to represent the depth of the BAZ. Total mixing depths were evaluated using radioisotope, grain size, and mercury data from cores collected from 58 stations during 2009 field activities (Yeager 2013) and at 66 additional stations during 2017 field activities. These stations were located in the Penobscot River (with four stations in the Orrington Reach), Mendall Marsh, Orland River, Fort Point Cove, and the lower estuary (downriver of Fort Point Cove and roughly corresponding to the northern portion of the Penobscot Bay, including the Cape Jellison Reach). Although the mixing evaluations indicated mixing depths were generally on the order of 3 cm (Yeager 2013), the results showed considerable variability (Yeager 2013, Yeager 2018). The evaluation generally indicated greater mixing depths were within higher energy regions and found that in lower energy areas (i.e., intertidal flats and marshes) where biological mixing processes are more prominent than physical mixing processes, mixing was restricted to shallow depths (Yeager 2018). Further, the 2023 coastal wetland assessment found minimal evidence of benthic invertebrates in intertidal sediment in East Cove 3 (see Section 2.3)—suggesting that biological mixing in the Pilot Project area may be limited.

Establishing the depth of the BAZ in the intertidal flats of East Cove 3 will provide a key data point for determining the appropriate thickness of the TLC for the Pilot Project design. When combined with design considerations stemming from the collection and interpretation of additional geotechnical data (Section 2.1), this will inform design of a TLC that is effective in achieving a reduction of mercury exposure and accelerating recovery while allowing for an optimization against the cost of the TLC construction. The limited existing information regarding mixing depths in East Cove 3, particularly considering the variability of reported mixing depths throughout the Penobscot River (including Orrington Reach) and Estuary and potential for multiple variables to impact mixing depths, is not sufficient to support these needs without additional confirmatory data collection in these areas; therefore, a sampling program focused on determining the BAZ depth of intertidal flat sediment within East Cove 3 is required.

A combination of sediment-profile imaging (SPI) and sediment coring will be used to quantify the BAZ at East Cove 3 and provide a basis for comparing the efficacy and efficiency of the techniques for use in the Pilot Project performance monitoring. Details regarding each approach are provided in Section 4.2. Additional details regarding the SPI technology are provided in the TLC Design Work Plan (Integral 2023a).

2.3 BENTHIC INVERTEBRATE COMMUNITY

Construction of a TLC is expected to result in short-term disruption of the benthic community in intertidal flats. Baseline benthic invertebrate community metrics, including species assemblage and overall health, need to be established prior to construction to document current conditions, and satisfy requirements of the Maine DEP Natural Resources Protection Act, the U.S. Army Corps of Engineers requirements for wetland assessment and biological inventory, and other applicable regulatory requirements. The benthic invertebrate assessment proposed for the TLC Pilot Project PDI is also necessary to support evaluation of the rate and extent of early post-construction recovery of the benthic community.

A quantitative pre-construction baseline data set based on established field sampling protocols will be used to evaluate early post-capping recovery rates for the benthic community. Data required for these evaluations include the genera (or lowest practical taxonomic level) of benthic organisms present at the site, and analysis and calculations of abundance and diversity of the benthic community.

Existing information and data about the benthic invertebrate community within East Cove 3 is limited. As part of the coastal wetland assessment performed by WSP USA Environment & Infrastructure, Inc. (WSP) in 2023, six sampling plots (three plots in tidal mudflat locations and three plots in low marsh locations) were evaluated in East Cove 3 for the presence of macroinvertebrates (Figure 4); of these locations, three mudflat sampling plots were located within the expected extents of the TLC Pilot Project, and one was located in the immediately adjacent low marsh area. Review of the data from the 2023 coastal wetland assessment indicates minimal evidence of benthic invertebrates was observed at the East Cove 3 plots during the 2023 field event, with only one annelid observed in the tidal mudflat locations in the proposed TLC Pilot Project location. Additional evaluation of the benthic community in East Cove 3 is needed to provide a more thorough and quantitative characterization of the benthic community, support the preparation of permitting applications for the TLC Pilot Project, and provide a baseline for comparison for post-construction monitoring.

Benthic invertebrate community data will be collected primarily by a benthic invertebrate survey (Section 4.3). This survey will allow for the assessment and calculation of relevant metrics, including taxonomy, abundance, richness, diversity, and evenness. These metrics will supplement the 2023 coastal wetland assessment data and provide a strong technical basis for measuring the effects of the TLC Pilot on the intertidal flat benthic community. Additionally, data collected as part of the evaluation of the BAZ (e.g., the presence/abundance of biogenic features) described in Section 4.2 will be used to further support and supplement the findings from the benthic invertebrate survey.

2.4 SUPPLEMENTAL SURFACE SEDIMENT SAMPLING

The overall goal of remedial actions in Orrington Reach, including the work performed as part of the TLC Pilot Project, is to reduce mercury exposures and accelerate recovery of the Penobscot River estuary. Post-construction sediment sampling and comparative analyses of surficial sediment mercury and total organic carbon (TOC) concentrations, specifically within the BAZ, are anticipated as part of the TLC Pilot Project post-construction performance monitoring program. For this program to effectively demonstrate the effect of the TLC, BAZ sediment mercury data representative of the conditions in East Cove 3 prior to construction are needed.

Previous sediment chemistry sampling programs have collected mercury data from surficial sediment in East Cove 3 (Figure 5). However, because the data previously collected in East Cove 3 was part of programs tailored to provide data for different goals (i.e., not targeting a defined BAZ depth), and often substantially in the past, these data are not appropriate to comprise the pre-construction BAZ sediment mercury dataset.

- Historical (i.e., 2021 and earlier) surficial sediment sampling in East Cove 3 was limited to four locations; of these four locations, three were collected in 2000 from 0 to 0.2 feet below sediment surface and one was collected in 2011 from 0 to 0.1 feet below sediment surface. Because the BAZ was not characterized in East Cove 3 sediment as part of these investigations, it is unknown if these sample intervals were representative of the pre-construction BAZ. Further, given that over ten years have passed between the collection of these samples, these samples cannot be considered representative of East Cove 3 in its current pre-construction condition; as it can be reasonably assumed that additional sediment has accumulated on the sediment surface over that time period.
- Sampling performed during the 2023 Sediment PDI was intended to augment the dataset of surface sediment throughout Orrington Reach and inform prioritization of areas to be capped. This investigation was also not designed to provide a robust pre-construction dataset in any singular area, such as the Pilot Project area of East Cove 3. Only 3 locations were included within the expected TLC Pilot Project area, with one of

the 3 locations located in the low marsh area; this sample density is insufficient for detailed or statistical analyses. Additionally, like the historical surficial sediment data, the depth of sample collection (target 6 inches below sediment surface) was not based on a confirmed BAZ depth. Therefore, the sampling depth is not necessarily representative of the pre-construction BAZ, which is needed for the anticipated post-construction comparative analysis.

The existing sediment mercury dataset is insufficient for use in the anticipated post-construction comparative analyses. Additional sediment mercury data representative of the pre-construction BAZ will be collected within the TLC Pilot Project area. A representative BAZ depth for East Cove 3 will first be determined for intertidal flat sediment using SPI and hand coring approaches (Section 4.2). Intertidal flat sediment samples corresponding to the BAZ depth will then be collected and analyzed for mercury and TOC to provide the necessary pre-construction dataset. Because the BAZ cannot be evaluated using SPI and hand coring in the low marsh area, samples of surface sediment will be collected from a depth of 0 to 1 inch below the sediment surface at these locations. The details of the sampling approach for the supplemental surface sediment sampling are provided in Section 4.4.

3 DATA QUALITY OBJECTIVES

The TLC Pilot PDI DQOs presented in Table 3 summarize the key information needed to complete the TLC Pilot design, prepare permit applications, and provide a strong baseline data set from which TLC performance and ecosystem recovery can be evaluated.

The data collection described in this TLC Pilot PDI Work Plan will be used during TLC Pilot Project design to:

- Provide geotechnical characteristics of underlying native sediment to inform the TLC Pilot Project design evaluations of native sediment strength to support the proposed TLC, TLC slope stability during and following TLC placement, and intermixing of the TLC material with underlying sediments during TLC placement.
- Evaluate the depth of biological mixing in East Cove 3 intertidal surface sediments (i.e., the BAZ) to support the selection of a TLC thickness for the TLC Pilot Project.
- Provide additional benthic community data for use in securing permits for the TLC Pilot Project and as a baseline for comparison during post-construction monitoring following TLC placement.
- Provide supplemental bulk sediment mercury data representative of pre-construction conditions as a baseline for comparison during post-construction monitoring following TLC placement.

4 SAMPLING PLAN AND METHODOLOGY

The following section presents the sampling plan and methodologies to obtain data required to complete the TLC Pilot Project design at East Cove 3. Sediment sample and data collection components for East Cove 3 are outlined in Table 4 with locations shown on Figure 6.

Sediment samples will be collected in accordance with the Field Sampling Plan (FSP; WSP 2023a) and Quality Assurance Project Plan (QAPP) (WSP 2023b) as modified or augmented by the following sections. The FSP provides the methods and standard operating procedures (SOPs) for the sediment sampling described in this section, including packaging and transport of the samples and the management of investigation-derived waste; additional SOPs and procedural descriptions addressing activities not previously included in the FSP or QAPP are provided in Appendix A and Appendix B, respectively. Deviations from the methods described within the FSP, the QAPP, and this TLC Pilot PDI Work Plan will be documented in the Investigation Report (Section 10).

4.1 GEOTECHNICAL CHARACTERIZATION

Samples for geotechnical analysis will be collected from 11 locations over the 6-acre portion of intertidal flats in East Cove 3 proposed for the TLC Pilot Project and adjacent low marsh area (Figure 6). Table 4 and Table 5 contain the proposed sample locations, analytical methods, depth intervals, number of samples, and QA/QC sample count.

The following factors were used to select the number and location of samples:

- Provide improved spatial coverage within the proposed area of the TLC Pilot Project.
- Capture the potential spatial variability within this area (e.g., changes in characteristics based on an increasing or decreasing distance from shore).
- Avoid duplication of prior geotechnical analyses while supplementing previous geotechnical sampling with additional analyses as appropriate

Sample locations may be adjusted based on field observations, including refusal at depths insufficient to achieve the required sample depth or volume, accounting for the presence of obstructions (e.g., rocks), accessibility issues, avoidance of rivulets or channels, or other unanticipated conditions. Based on these field observations, a sample location may be offset by up to 25 ft from the original location with the approval of authorized project technical leads. Changes to sample locations will be documented.

The geotechnical sampling approach will include:

- Collection of samples using a box corer (or similar) for laboratory quantification of surface sediment and underlying consolidated material (if practicable) for the following geotechnical properties:
  - Sediment grain size (ASTM International [ASTM] D6913 [sieve wash] and ASTM D7928 [hydrometer])
  - Organic content (ASTM D7348)
  - Atterberg limits (ASTM 4318)
- Collection of undisturbed core samples for laboratory quantification of surface sediment and underlying consolidated material (if practicable) for the following geotechnical properties:
  - Bulk unit weight (ASTM D7263)
  - Percent solids (ASTM 2216)
  - Specific gravity (ASTM D854)
  - Consolidation (ASTM 2435)
  - Permeability (ASTM 5084)
  - Shear strength (ASTM D4648/D2850).

Samples collected from low marsh locations will be analyzed for sediment grain size, organic content, and Atterberg limits from surface sediment only. Existing data and information (e.g., presence of vegetation, expected decreased fines fraction) from nearshore areas in East Cove 3 indicate that the surficial sediment in the low marsh locations will be more physically stable than the intertidal flat sediment. Therefore, the strength-focused geotechnical sampling from the weaker intertidal flat sediment will be sufficient for performing geotechnical calculations for the Work Design throughout East Cove 3, including the low marsh. Similarly, because material properties of the underlying material of the most nearshore intertidal flat sediment and the low marsh are expected to be consistent, no additional underlying consolidated material sampling will be performed in the low marsh.

The physical characteristics of the underlying consolidated material, expected to consist of a glacial till, may prevent the advancement of equipment into the material. In particular, thin-walled tube samplers (i.e., Shelby tubes) used for recovering undisturbed cores and field vane shear equipment may meet refusal at depths insufficient to complete the targeted sampling. If equipment cannot be sufficiently advanced into this material to complete the specified sampling, detailed field notes will be recorded regarding the attempts made to advance the equipment, and details of the refusal will be recorded (e.g., sudden refusal similar to rock versus slow resistance similar to a clay).

SOPs for each collection method will be followed and are included in Appendix A. Each sample interval will be visually logged for lithology and other relevant observations by the field geologist/geotechnical engineer in general accordance with ASTM D2488. Lithology will be recorded following the classification system specified in the FSP (WSP 2023a). Other relevant information, such as the redox potential discontinuity and the presence of wood waste, will be documented if observed.

4.2 EVALUATION OF BIOLOGICALLY ACTIVE ZONE

The evaluation of the BAZ will incorporate SPI and sediment coring to observe and document sediment characteristics and the presence or absence of evidence of biotic activity. SPI will be the primary means of collecting this information on intertidal flats outside of the low marsh area. Sediment coring will be used to supplement SPI at a subset of the intertidal flat stations. Additionally, sediment coring will be the primary means of collecting this information in the nearshore low marsh area, where conditions will not allow the use of SPI. The use of multiple methods will also allow for the comparison of these methods in intertidal flat areas of the Pilot Project area; this comparison will inform method selection decisions anticipated as part of the development of the Pilot Project Performance Monitoring Plan.

Descriptions of the scope and approach for data collection using each method are provided below.

4.2.1 SPI

SPI technology was specifically developed to efficiently evaluate benthic community responses to disturbance in fine sedimentary habitats. SPI has been used to map physical, biological, and chemical/nutrient gradients in benthic habitats in a diverse array of freshwater and marine environments. It is a well-documented approach to evaluating benthic habitat restoration following disturbances, such as dredging or capping, and quantifying the progression of the benthic community successional stages following the disturbance (Germano et al. 2011).

SPI consists of using a camera prism system to collect high-resolution cross-sectional (profile view) images of the soft sediment surface. Each image captures a maximum sediment depth equal to the height of the prism window (21 cm). If the sediment matrix allows for further penetration of the camera prism, multiple images may be spliced together to produce images of greater height than the prism window. These images allow for the observation and quantification of *in situ* benthic conditions for both the evaluation of the BAZ and the evaluation of the benthic invertebrate survey using a single data collection method.

SPI will be performed at 28 stations within East Cove 3 over approximately 6 acres of intertidal flats, corresponding to the anticipated area of the TLC Pilot Project (Figure 6, Table 4). SPI stations are roughly based on a gridded pattern with approximately 100 ft spacing within the anticipated extent of the TLC Pilot Project. It is expected that SPI can be completed at 15 to 20 stations per day, accounting for water level limitations in accessing stations due to tidal fluctuation. SPI stations may be adjusted based on field observations, including the absence of soft sediment preventing the advancement of the SPI system, the presence of obstructions (e.g., rocks), accessibility issues, or other unanticipated conditions.

SPI surveys and data analysis will be performed in accordance with the SOPs provided in Appendix A and follow the general procedure outlined below.

SPI images will be collected at each station by in triplicate (i.e., three images per station).

Image quality will be reviewed at each station in real time during the field effort. If images are missed or are of suboptimal quality (e.g., strobe misfire or the penetration depth was insufficient or excessive [over penetration]), additional images may be taken at some locations with the goal of obtaining one optimal image at each station for image analysis.

A preliminary interpretation of the SPI results will be performed in the field and will be used to inform/adapt the survey (e.g., adjustments to the station locations may be warranted if relatively consistent or atypical features are observed).

SPI images will be analyzed in greater detail as a desktop effort by experienced professionals supported by image evaluation software to provide the information necessary for the determination of the BAZ depth in support of the TLC Pilot Project design and interpretation of benthic activity in support of post-construction monitoring.

The data generated from the SPI survey documents *in situ* benthic conditions, including but not limited to:

- The thickness of the BAZ in surface sediment
- The presence or abundance of biogenic features (e.g., organisms, burrows, feeding voids)
- Qualitative visual observations of sediment grain size
- Evidence of degraded habitat/impairment (e.g., reduced sediment conditions, methane pockets, presence of non-native materials such as wood chips).

Evaluation of the data generated from the SPI survey will address the data needs regarding the BAZ identified in Section 2.2 and support benthic invertebrate survey evaluations to address the data needs regarding the benthic invertebrate community identified in Section 2.3.

4.2.2 Sediment Coring

Sediment coring, using manually-advanced polycarbonate core tubes (or similar), will be performed at four SPI stations in the intertidal flats and at the two low marsh locations (Table 4;

Figure 6). As discussed in Section 4.3, benthic survey data will also be collected at the four intertidal locations where both SPI data and sediment cores will be collected. If field conditions require modification of an intertidal flat sediment coring location(s), an alternative will be selected from the locations where both SPI and benthic invertebrate survey data are to be collected (Figure 6).

At each location, a core tube will be advanced into the sediment to refusal, with a minimum target depth of 12 in. If refusal is not reached, the core tube will be advanced to the maximum practical depth to allow safe retrieval of the sediment core, anticipated as approximately 2 to 3 ft below the mudline. Once the core is retrieved, the core recovery will be measured and compared against a minimum target recovery of 75 percent. If refusal is reached shallower than 12 in., the core will be retained, the locations will be offset by approximately 1 to 2 ft to avoid confounding effects from the initial coring attempt, and the core will be re-collected. This process will be repeated until a maximum of three attempts have been completed. If after three attempts, 12 in. of total penetration and 75 percent recovery has not been achieved, the core with the greatest overall material recovery will be retained for evaluation.

The core will be carefully laid flat, minimizing the disturbance of the core material. The core will be split lengthwise. Documentation of the core will include photographs of the split core and qualitative records (supplemented by counts if feasible) of the same benthic conditions outlined in Section 4.2.1. Additionally, the depth of the redox potential discontinuity (if observed), the depth extent of biological activity (if present and observed), and observations specific to the marsh sediment locations (e.g., depth and density of the root zone) will be measured and/or documented in the field. After these observations and measurements are completed, the sediment description will be recorded on a field log form in general accordance with the United Soil Classification System.

Evaluation of the data generated from sediment coring will address the data needs regarding the BAZ identified in Section 2.2 and support benthic invertebrate survey evaluations to address the data needs regarding the benthic invertebrate community identified in Section 2.3.

4.3 BENTHIC INVERTEBRATE SURVEY

The supplemental benthic invertebrate survey will be performed within the proposed TLC Pilot area of East Cove 3 (Figure 6). To provide adequate spatial coverage for the area, the survey will include eight locations in the intertidal flat and two locations in the low marsh (Table 4). The following factors were used to select sample locations:

- Co-locate benthic invertebrate survey locations with a representative subset of SPI locations (Section 4.2, Table 4) to allow for the incorporation of both data sets in interpreting sampling results.

- Avoid areas previously characterized during the 2023 Sediment PDI work performed by WSP as part of the coastal wetland assessment.
- Avoid tidal creeks, rivulets, or narrow areas not representative of the broader intertidal flat.

The selected sample locations may be adjusted in the field based on conditions observed during the field event or following preliminary review of SPI images to target areas that may exhibit differing characteristics to other intertidal flat areas.

The benthic invertebrate survey sampling will be performed following the SOP for benthic invertebrate collection and preservation provided in Appendix A. At each sampling location, surface sediments will be collected as grab samples using a petite Ponar dredge or similar equipment. Five grabs will be collected from within an approximately 15-ft radius within each sampling plot, consistent with the approach presented in the Coastal Wetland Assessment Plan (WSP 2023c). Sediment texture and color will be recorded for each grab. The material from the five surface sediment grabs will then be composited and sieved in the field using a 500-micron mesh sieve. Records of macroinvertebrates observed during the sieving of the sediment will be documented in the field notes. The retained material will be preserved, containerized, and shipped to a laboratory for benthic invertebrate count and taxonomic identification. One duplicate sample will be collected from a location randomly selected from the eight sample locations to assess the potential for variability within individual sample locations.

The taxonomic analyses will be performed following the guidelines detailed in the U.S. Environmental Protection Agency Rapid Bioassessment Protocol (Barbour et al. 1999) and according to the SOP provided by the selected laboratory; a representative SOP for this procedure is provided in Appendix B. Based on the observations made during the coastal wetland assessment, which indicated few benthic invertebrates observed during the preliminary survey, it is anticipated that the full sample will be processed and sorted. However, if necessary, a subsampling technique will be employed, such as a 200-organism fixed count, per the Rapid Bioassessment Protocol.

Specimens will be identified to the lowest practical taxon (e.g., family, genus, or species) by a qualified taxonomist. Benthic community parameters and metrics will be calculated, such as abundance (number of organisms), taxa richness (number of taxa identified), Shannon's Diversity (H'; measure of diversity calculated based on the number of species and the relative abundance of each species), and evenness (J'; measure of homogeneity of species at a location relative to all locations, which is calculated by dividing H' by species richness). A benthic index, such as the multivariate AZTI Marine Biotic Index (M-AMBI) established for the northeast U.S. region, may be also calculated if warranted based on the results of the organism counts and taxonomy.

The results of the benthic community parameters and metrics will be used to establish baseline conditions within East Cove 3 and will serve as a point of comparison to the conditions observed during post-construction surveys following the placement of TLC. In addition, the observations of benthic community will be reviewed relative to the evidence of biological activity observed in the SPI survey.

4.4 SUPPLEMENTAL SURFACE SEDIMENT SAMPLING

Samples for supplemental sediment chemistry analysis will be collected from 11 locations over the 6-acre portion of intertidal flats and adjacent low marsh area in East Cove 3 proposed for the TLC Pilot Project (Figure 6). Sampling will include BAZ samples from nine locations in the intertidal flat and surface samples from two locations in the low marsh (Table 4). Table 4 and Table 5 contain the proposed sample locations, analytical methods, depth intervals, number of samples, and QA/QC sample count.

In the intertidal flats, sediment cores will be collected to a maximum depth of one foot below sediment surface or refusal, whichever is shallower. Core collection will be performed using hand cores, vibracore, or similar equipment. A preliminary outcome of the evaluation of the BAZ depth (Section 4.2) will be used to inform the sampling depth selection. If the BAZ depth is readily apparent and consistent across the intertidal flat SPI and hand coring (e.g., obvious and consistent observations of biological activity and RPD depths) based on preliminary observations from the evaluation of the BAZ (Section 4.2), then a field determination of the BAZ depth may be used as the intertidal flat BAZ sampling depth. Otherwise, the BAZ depth will be determined following the completion of the analysis of the SPI investigation and observations of hand coring (Section 4.2), which is expected within 3 weeks of the completion of the field work. In this scenario, retrieved cores will be frozen and stored pending the outcome of the evaluation of the BAZ.

The BAZ cannot be readily evaluated in the low marsh due to the influence of plant growth on oxygen penetration into the subsurface. A sampling depth of 0 to 1 inch below the sediment surface has been selected for the low marsh to provide data for the near surface where potential ecological exposure is greatest and limit the sampling thickness to equal to or less than the anticipated TLC thickness in the low marsh area. Analytical samples will be collected from the hand cores collected in the low marsh (Section 4.2.2).

After the sampling depth is determined, each core will be photographed and the following recorded on a field log form based on field observations:

- Sediment texture (e.g., sandy, silty, clayey)
- Color
- Redox potential discontinuity (if present)

- Presence or absence of wood waste
- Other relevant observations.

Following logging, sediment samples will be collected from the surface to the determined BAZ depth. The sample will be homogenized using a decontaminated stainless-steel bowl and spoon. An aliquot of the homogenized sample will be placed in the appropriate sample container and submitted for laboratory analysis of the following properties:

- Mercury by EPA Method 1631E
- Total organic carbon by EPA Method 9060 (Lloyd Kahn)

Excess material brought to the processing facility and not used for analysis will be disposed of in accordance with the FSP.

5 QUALITY CONTROL AND QUALITY ASSURANCE

Requirements for field quality control samples and activities relevant to the sampling plan outlined in Section 4 are presented in Table 5. Relevant QA/QC procedures are detailed in the FSP (WSP 2023a), QAPP (WSP 2023b), and Appendix A and Appendix B to this TLC Pilot PDI Work Plan.

6 PERMITS AND ACCESS REQUIREMENTS

Permits are not required for the implementation of this TLC Pilot Project Supplemental Sediment PDI Work Plan.

Based on the current understanding of Maine law, permission to access intertidal flats to collect sediment samples will be required from each landowner for parcels to be sampled. Parcels and ownership have been identified for the proposed sampling locations in East Cove 3 (Figure 6). The Penobscot Estuary Mercury Remediation Trust has previously secured access to each of the identified parcels for sediment sampling.

7 ROLES AND RESPONSIBILITIES

The roles, responsibilities, and authorities of the Greenfield Penobscot Estuary Remediation Trust LLC (Greenfield), Integral Consulting Inc. (Integral), and WSP USA Environment & Infrastructure, Inc. (WSP) for implementation of this Work Plan are presented below.

Task	Greenfield Role	Integral Role	WSP Role
Beneficiary communication	Lead	Technical support	n/a
Sample collection (SPI, benthic invertebrate survey)	Oversight and project management	Lead. Responsible for securing sampling contractor and implementation of work plan.	n/a
Sample collection (geotechnical)	Oversight and project management	Lead. Responsible for securing sampling and laboratory contractor and implementation of work plan.	n/a
Data validation	Oversight and project management	Provide support	Lead. Responsible for implementation of data validation requirements in accordance with QAPP.
Database management	Oversight and project management	Lead. Responsible for securing contactor and implementation of work plan and database management.	n/a
Data analysis (including data validation)	Oversight and project management	Lead	Provide support
Investigation report	Oversight, deliverable review, and project management	Lead	n/a

8 SCHEDULE

The following schedule milestones have been tentatively established for this TLC Pilot Project Supplemental Sediment PDI:

- Confirm and/or acquire parcel access February–March 2024
- Implement Orrington Reach PDI sampling May-June 2024
- Complete sediment laboratory analyses June 2024
- Complete analytical results data validation July 2024
- Draft TLC Pilot Project PDI Report July-August 2024.

The field sampling schedule will depend on confirming access previously obtained to the proposed sampling locations and weather conditions. Field activities are expected to take place in one mobilization. Geotechnical sampling is expected to be completed in approximately 3 to 4 days. The SPI survey is expected to be completed in approximately 2 days. The benthic invertebrate survey is expected to be completed in approximately 2 days. The supplemental BAZ sediment sampling field collection is expected to be completed in approximately 2 days, with subsequent sample processing expected to be completed in 1 day as part of a separate mobilization.

In total, the PDI fieldwork is expected to require less than 2 weeks of field time. Where feasible, efforts will be made to combine sampling elements to maximize efficiency when sample locations are nearby or co-located. Sampling schedules will also be set with consideration to safe operation of the varying sampling equipment and ensuring data quality is not compromised. Samples will be submitted for laboratory analysis on a standard turnaround time.

9 SUPPORTING DELIVERABLES

Paragraph 31 of the Statement of Work specifies Supporting Deliverables and reporting requirements for Penobscot River investigations. As described in Section 4, this TLC Pilot PDI Work Plan provides the approach and methods for the proposed PDI and references the Site-Wide Supporting Deliverables—Health and Safety Plan (HASP; WSP 2023d), Emergency Response Plan, QAPP (WSP 2023b), and FSP (WSP 2023a)—where appropriate. Addenda to the existing Supporting Deliverables outlining procedures for elements of the scope of work detailed in this TLC Pilot PDI Work Plan are provided in Appendix A (FSP Addendum), Appendix B (QAPP Addendum), and Appendix C (HASP Addendum). Data collected during this investigation will be provided in an investigation report that conforms to Statement of Work requirements (Section 10).

10 REPORTING

Data collected during this investigation will be provided in a focused investigation report. This investigation report will include the applicable Investigation Report requirements identified in Paragraph 6(b) of the Statement of Work (Appendix A to the Consent Decree), including:

- A summary of the investigations performed
- A summary of the investigation results
- Summaries of validated data (i.e., tables and graphics)
- Summaries of data validation reports and laboratory data reports
- Narrative interpretation of data and results, including how the Investigation objectives and DQOs were satisfied
- Results of statistical analyses
- Summary photographs documenting the work conducted
- Conclusions and recommendations for Work Design, including any resulting modifications to design parameters and criteria provided for in the Basis of Design or other Deliverables.

11 REFERENCES

Amec Foster Wheeler. 2018. Thin interval core sampling report, Penobscot River Phase III engineering study, Penobscot River Estuary, Maine, Appendix C. Prepared for United States District Court District of Maine. Amec Foster Wheeler Environment & Infrastructure, Inc., Portland, ME. September.

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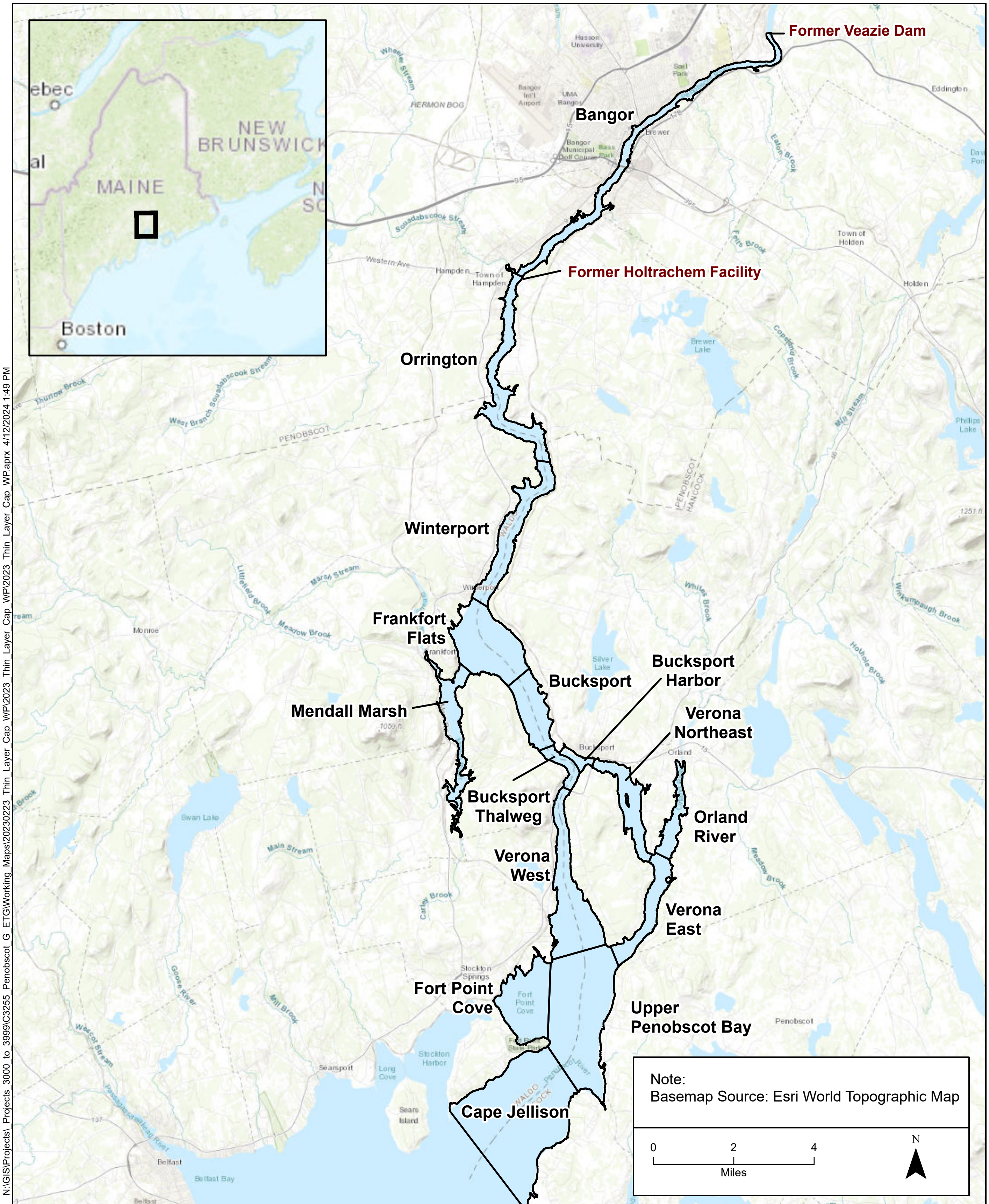
Yeager, K.M. 2013. Penobscot River Mercury Study Chapter 5, Total mercury sedimentary inventories and sedimentary fluxes in the lower Penobscot River and estuary, Maine. University of Kentucky, Lexington, KY. Submitted to Judge John Woodcock, United States District Court. April.

Yeager, K.M. 2018. Supplemental spatial analysis of sedimentary mercury (Hg) distribution in the Lower Penobscot River Basin, ME – informing system-wide remedial design and implementation. University of Kentucky, Lexington, KY. Submitted to Amec Foster Wheeler, Portland, Maine. September.

Figures



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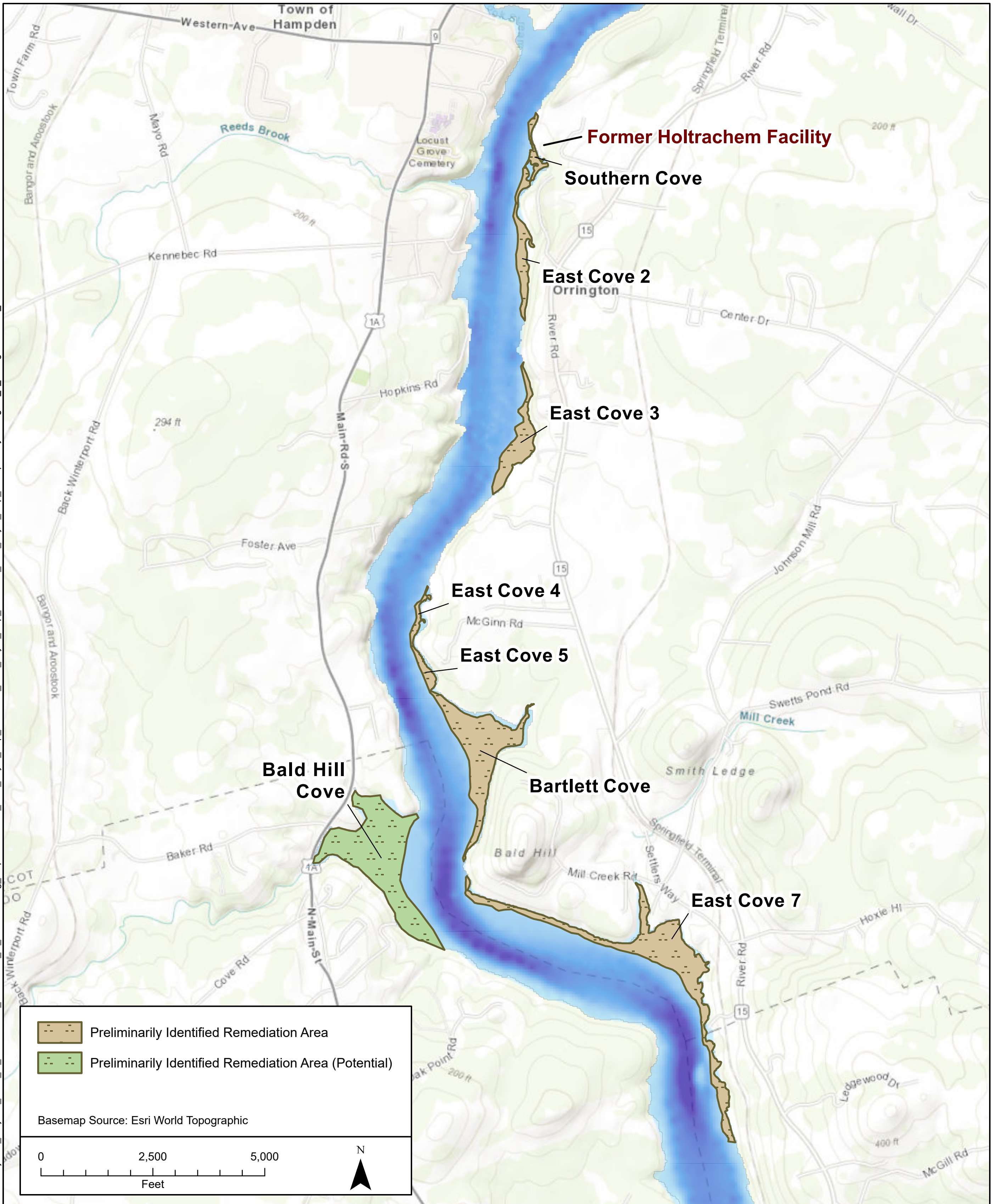
Prepared for: Greenfield Penobscot Estuary Remediation Trust LLC
Trustee of the Penobscot Estuary Mercury Remediation Trust

Prepared by: integral consulting inc.

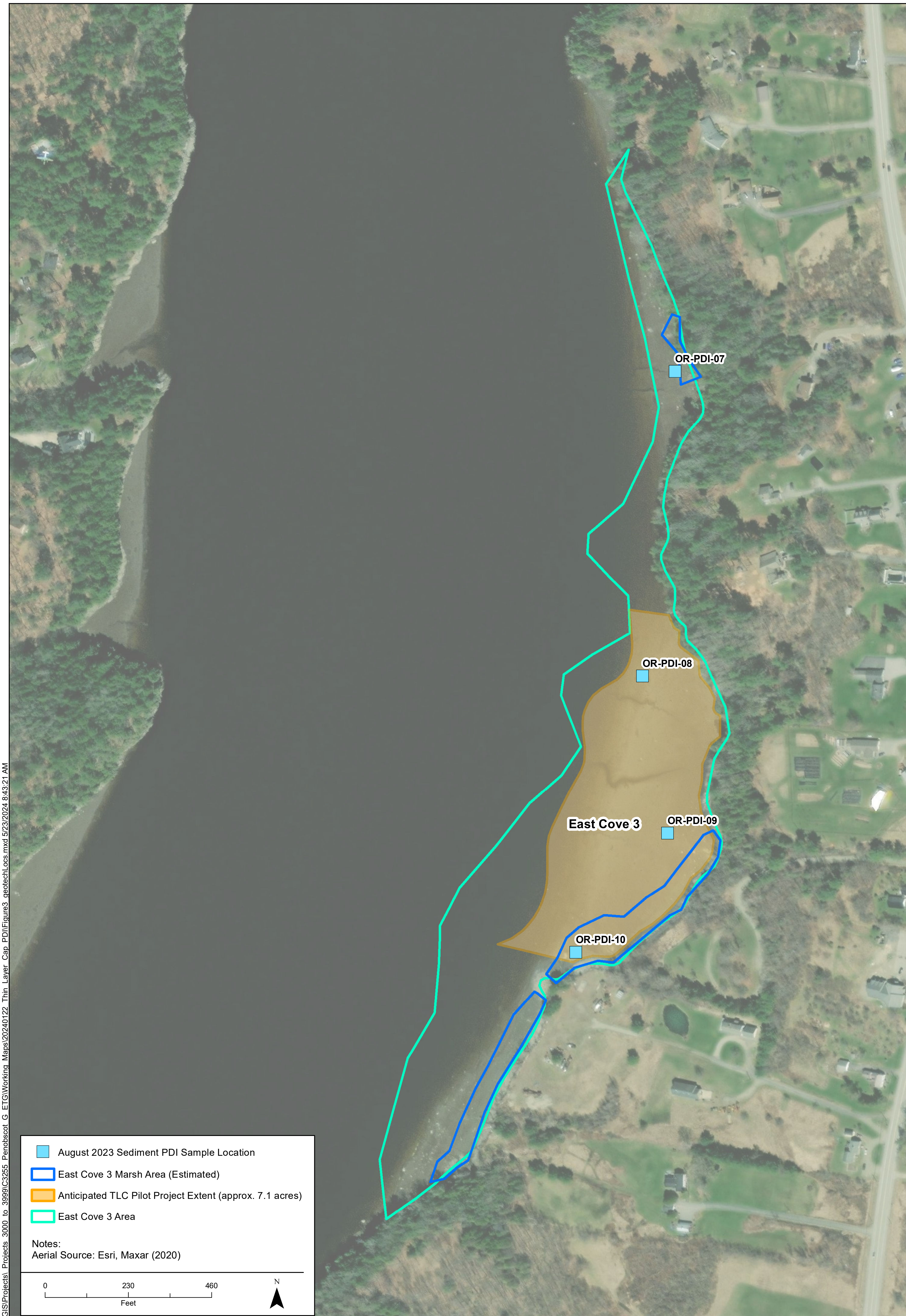
Figure 1.
Penobscot River Reaches
TLC Pilot PDI Work Plan
Orrington Reach Capping Remedy
May 2024



Prepared for: Greenfield Penobscot Estuary Remediation Trust LLC
Trustee of the Penobscot Estuary Mercury Remediation Trust

Prepared by: integral consulting inc.

Figure 2.
Coves Preliminarily Identified as the Remediation Area for Orrington Reach
TLC Pilot PDI Work Plan
Orrington Reach Capping Remedy
May 2024



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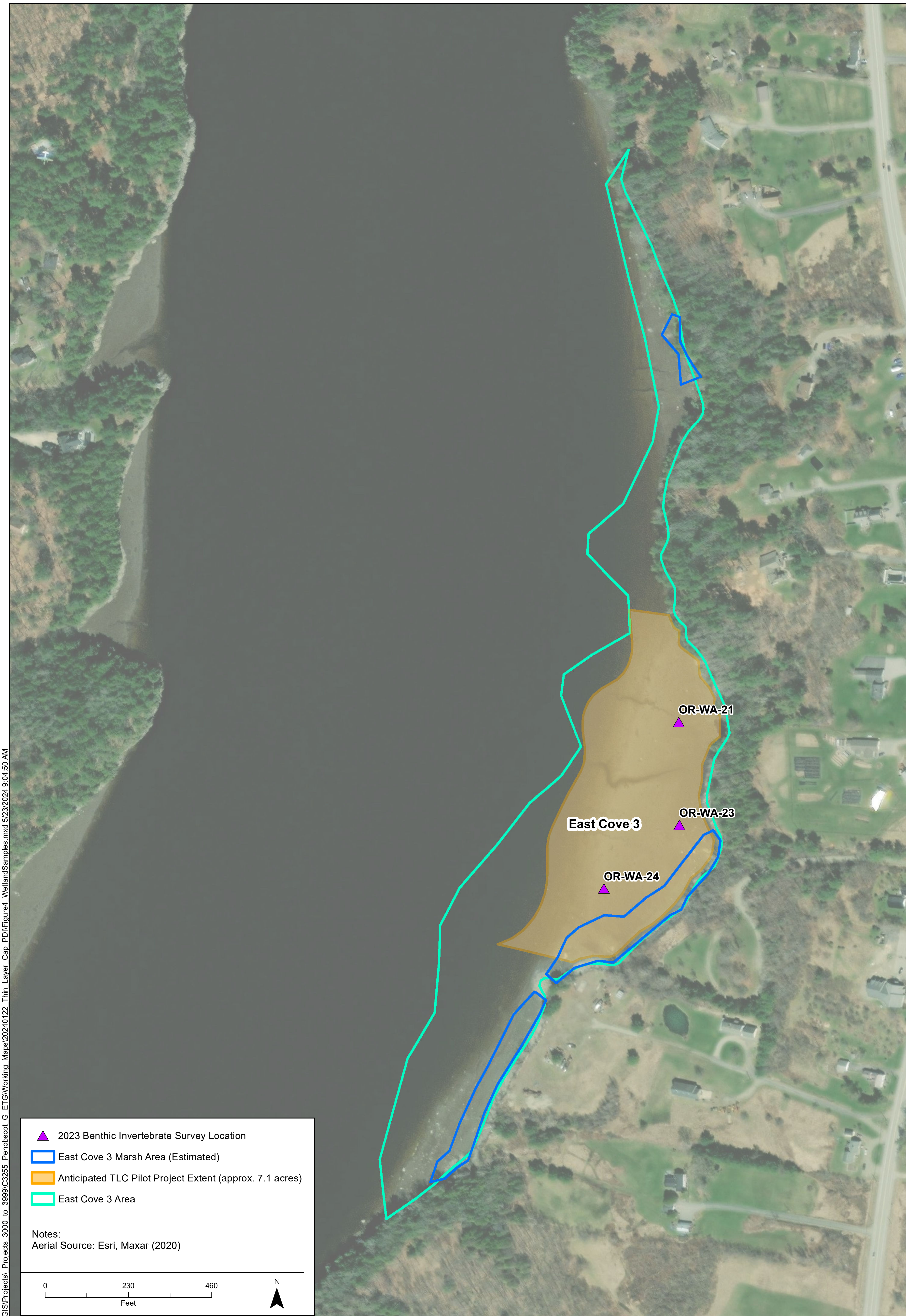
Prepared for: Greenfield Penobscot Estuary Remediation Trust LLC
Trustee of the Penobscot Estuary Mercury Remediation Trust

Prepared by: integral consulting inc.

Figure 3.
Existing East Cove 3 2023 Sediment PDI Geotechnical Sample Locations
TLC Pilot PDI Work Plan
Orrington Reach Capping Remedy
May 2024



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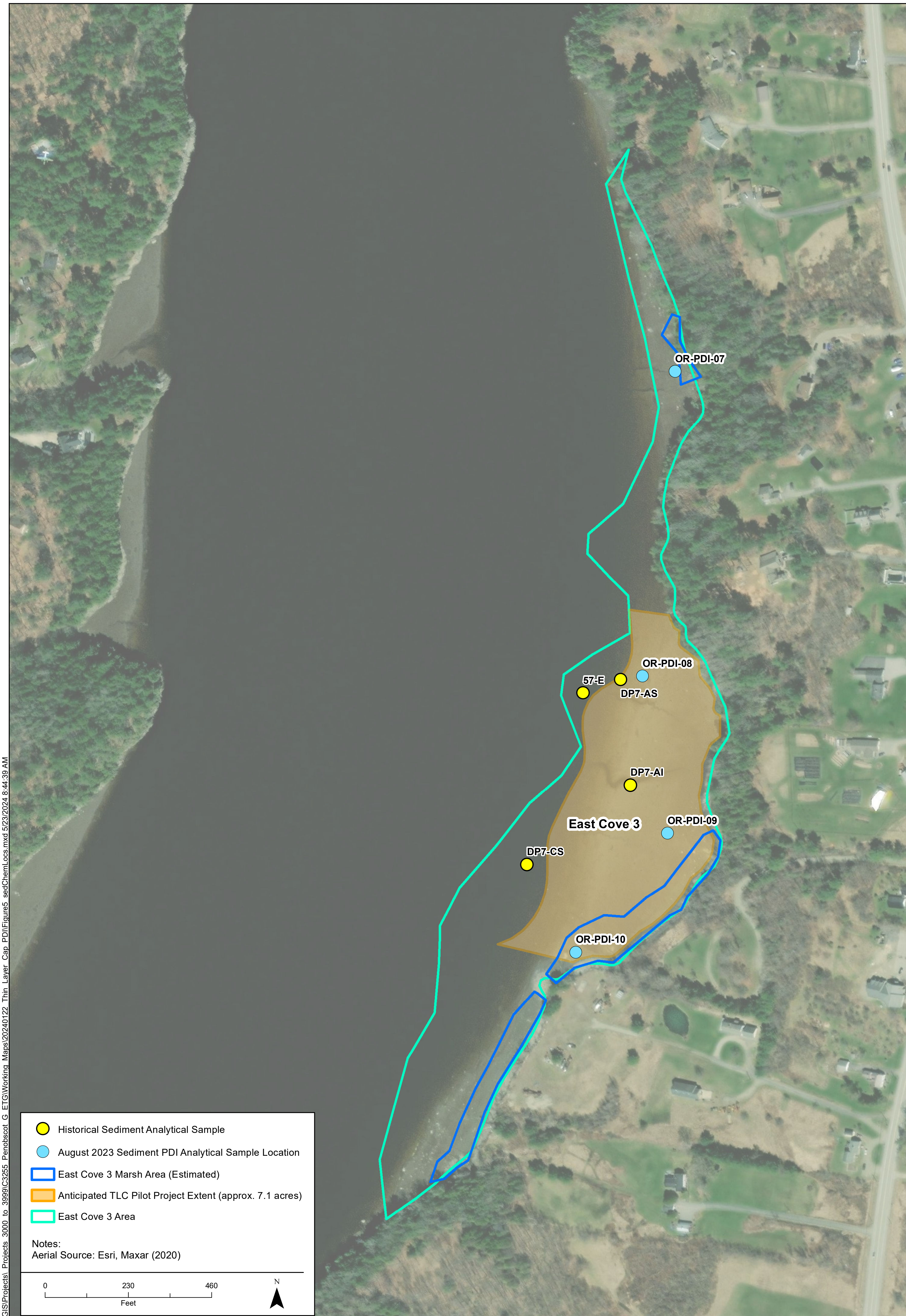
Prepared for: Greenfield Penobscot Estuary Remediation Trust LLC
Trustee of the Penobscot Estuary Mercury Remediation Trust

Prepared by: integral

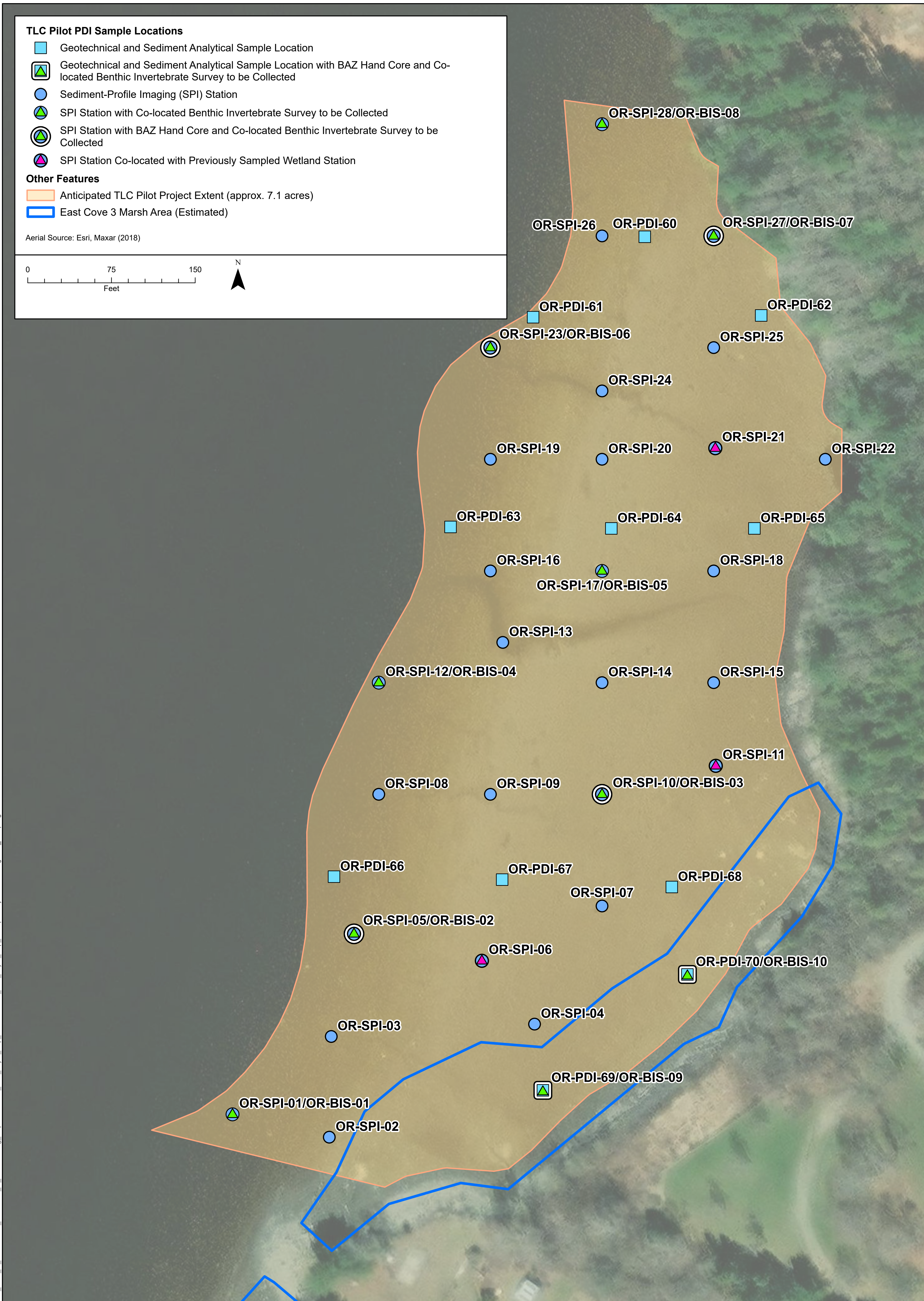
Figure 4.
Existing East Cove 3 2023 Benthic Invertebrate Survey Locations
TLC Pilot PDI Work Plan
Orrington Reach Capping Remedy
May 2024



Prepared for: Greenfield Penobscot Estuary Remediation Trust LLC
Trustee of the Penobscot Estuary Mercury Remediation Trust

Prepared by: integral consulting inc.

Figure 5.
Existing East Cove 3 Sediment Analytical Sample
Sample Locations
TLC Pilot PDI Work Plan
Orrington Reach Capping Remedy
May 2024



Notes:
Marsh areas approximated based on delineation from review of the data collected during the coastal wetland assessment.
Extent of TLC Pilot Project Location is approximate and based on extended property boundaries for the adjacent upland properties. This extent includes a 20-ft buffer from adjacent property boundaries and the -6.5 ft NAVD88 (approx. 0 ft MLLW) elevation line.

Prepared for: Greenfield Penobscot Estuary Remediation Trust LLC
Trustee of the Penobscot Estuary Mercury Remediation Trust

Prepared by: integral consulting inc.

Figure 6.
TLC Pilot PDI Sample Locations
TLC Pilot PDI Work Plan
Orrington Reach Capping Remedy
May 2024

Tables

Table 1. Statement of Work Compliance

Statement of Work Requirement	Work Plan Section	
¶ 6(a)(i) An evaluation and summary of existing data and a description of the data gaps that require further investigation in order to complete the Work Design	✓	Section 2
¶ 6(a)(ii) A description of the required technical and/or regulatory decisions to be made or questions to be answered with the Investigation results, along with a summary of the type, quantity, and quality of data needed to reach those decisions ("Data Quality Objectives" or "DQOs")	✓	Section 3
¶ 6(a)(iii) A sampling plan including media to be sampled, contaminants or parameters for which sampling will be conducted, location (areal extent and depths), and number of samples	✓	Section 4
¶ 6(a)(iv) A schedule for the Investigation	✓	Section 8
¶ 6(a)(v) Cross references to quality assurance/quality control ("QA/QC") requirements set forth in the QAPP as described in Paragraph 31(d)	✓	Section 5

Notes:
QAPP = quality assurance project plan

Table 2. Summary of Existing East Cove 3 2023 Sediment PDI Geotechnical Data

Cove Name	Station ID	Location ID	Depth (ft bml)	Collection Date	Geotechnical Lab Description	Moisture Content (%) by Method ASTM D2216
Eastern Bank of Orrington Reach						
East Cove 3	OR-PDI-07	OR-PDI-07	0.0–0.4	8/16/2023	Wet, very dark grayish brown silt with sand	134.5
East Cove 3	OR-PDI-08	OR-PDI-08	0.0–0.8	8/16/2023	Wet, very dark grayish brown silt	228.2
East Cove 3	OR-PDI-09	OR-PDI-09	0.0–0.8	8/16/2023	Moist, very dark grayish brown silt	192.2
East Cove 3	OR-PDI-10	OR-PDI-10	0.0–0.5	8/16/2023	Wet, very dark grayish brown silt with sand	112.5

Notes:
ASTM = ASTM International
bml = below mudline
MH = elastic silt
NP = non-plastic
PCF = pound per cubic foot
PDI = pre-design investigation
SM = silty sand

Table 2. Summary of Existing East Cove 3 2023 Sediment PDI Geotechnical Data

					Density by Method ASTM D7263		Particle Size Distribution by Method ASTM D6913			
Cove Name	Station ID	Location ID	Depth (ft bml)	Collection Date	Bulk Density (PCF)	Dry Density (PCF)	Cobble (%)	Gravel (%)	Sand (%)	Fines (%)
Eastern Bank of Orrington Reach										
East Cove 3	OR-PDI-07	OR-PDI-07	0.0–0.4	8/16/2023	80.8	34.4	0	0.7	29.1	70.2
East Cove 3	OR-PDI-08	OR-PDI-08	0.0–0.8	8/16/2023	71.4	21.8	0	0	4.6	95.4
East Cove 3	OR-PDI-09	OR-PDI-09	0.0–0.8	8/16/2023	72.0	24.6	0	0	3	97
East Cove 3	OR-PDI-10	OR-PDI-10	0.0–0.5	8/16/2023	86.0	40.5	0	2.3	25.6	72.1

Notes:
ASTM = ASTM International
bml = below mudline
MH = elastic silt
NP = non-plastic
PCF = pound per cubic foot
PDI = pre-design investigation
SM = silty sand

Table 2. Summary of Existing East Cove 3 2023 Sediment PDI Geotechnical Data

Cove Name	Station ID	Location ID	Depth (ft bml)	Collection Date
Eastern Bank of Orrington Reach				
East Cove 3	OR-PDI-07	OR-PDI-07	0.0–0.4	8/16/2023
East Cove 3	OR-PDI-08	OR-PDI-08	0.0–0.8	8/16/2023
East Cove 3	OR-PDI-09	OR-PDI-09	0.0–0.8	8/16/2023
East Cove 3	OR-PDI-10	OR-PDI-10	0.0–0.5	8/16/2023

Notes:

ASTM = ASTM International
bml = below mudline
MH = elastic silt
NP = non-plastic
PCF = pound per cubic foot
PDI = pre-design investigation
SM = silty sand

Table 2. Summary of Existing East Cove 3 2023 Sediment PDI Geotechnical Data

Cove Name	Station ID	Location ID	Depth (ft bml)	Collection Date	Particle Size Distribution by Method ASTM D6913, Percent Passing Sieve Size							
					9.5 mm	4.75 mm	2.00 mm	0.85 mm	0.42 mm	0.25 mm	0.15 mm	0.11 mm
Eastern Bank of Orrington Reach												
East Cove 3	OR-PDI-07	OR-PDI-07	0.0–0.4	8/16/2023	100	99	92	88	84	81	77	75
East Cove 3	OR-PDI-08	OR-PDI-08	0.0–0.8	8/16/2023		100	100	98	98	97	97	96
East Cove 3	OR-PDI-09	OR-PDI-09	0.0–0.8	8/16/2023		100	99	98	98	97	97	97
East Cove 3	OR-PDI-10	OR-PDI-10	0.0–0.5	8/16/2023	100	98	91	88	85	81	78	75

Notes:

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bml = below mudline
MH = elastic silt
NP = non-plastic
PCF = pound per cubic foot
PDI = pre-design investigation
SM = silty sand

Table 2. Summary of Existing East Cove 3 2023 Sediment PDI Geotechnical Data

					Particle-Size Distribution (Gradation) of Fine-Grained S Sedimentation (Hydrometer) Analysis Method ASTM D792						
Cove Name	Station ID	Location ID	Depth (ft bml)	Collection Date	0.075 mm	Hydro-meter 1	Hydro-meter 2	Hydro-meter 3	Hydro-meter 4	Hydro-meter 5	Hydro-meter 6
Eastern Bank of Orrington Reach											
East Cove 3	OR-PDI-07	OR-PDI-07	0.0–0.4	8/16/2023	70	51	36	29	23	20	17
East Cove 3	OR-PDI-08	OR-PDI-08	0.0–0.8	8/16/2023	95	75	51	45	33	26	20
East Cove 3	OR-PDI-09	OR-PDI-09	0.0–0.8	8/16/2023	97	80	59	54	49	44	33
East Cove 3	OR-PDI-10	OR-PDI-10	0.0–0.5	8/16/2023	72	51	41	28	21	18	15

Notes:
ASTM = ASTM International
bml = below mudline
MH = elastic silt
NP = non-plastic
PCF = pound per cubic foot
PDI = pre-design investigation
SM = silty sand

Table 2. Summary of Existing East Cove 3 2023 Sediment PDI Geotechnical Data

Cove Name	Station ID	Location ID	Depth (ft bml)	Collection Date	Soils Using the 3, Percent Passing	
					Hydro-meter 7	Hydro-meter 8
Eastern Bank of Orrington Reach						
East Cove 3	OR-PDI-07	OR-PDI-07	0.0–0.4	8/16/2023	14	11
East Cove 3	OR-PDI-08	OR-PDI-08	0.0–0.8	8/16/2023	14	8
East Cove 3	OR-PDI-09	OR-PDI-09	0.0–0.8	8/16/2023	28	23
East Cove 3	OR-PDI-10	OR-PDI-10	0.0–0.5	8/16/2023	13	11

Notes:
ASTM = ASTM International
bml = below mudline
MH = elastic silt
NP = non-plastic
PCF = pound per cubic foot
PDI = pre-design investigation
SM = silty sand

Table 2. Summary of Existing East Cove 3 2023 Sediment PDI Geotechnical Data

Cove Name	Station ID	Location ID	Depth (ft bml)	Collection Date	Atterberg Limits by Method ASTM 4318			
					Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Liquidity Index (%)
Eastern Bank of Orrington Reach								
East Cove 3	OR-PDI-07	OR-PDI-07	0.0–0.4	8/16/2023	92	55	37	2.1
East Cove 3	OR-PDI-08	OR-PDI-08	0.0–0.8	8/16/2023	150	108	42	2.9
East Cove 3	OR-PDI-09	OR-PDI-09	0.0–0.8	8/16/2023	190	111	79	1
East Cove 3	OR-PDI-10	OR-PDI-10	0.0–0.5	8/16/2023	78	49	29	2.2

Notes:
ASTM = ASTM International
bml = below mudline
MH = elastic silt
NP = non-plastic
PCF = pound per cubic foot
PDI = pre-design investigation
SM = silty sand

Table 2. Summary of Existing East Cove 3 2023 Sediment PDI Geotechnical Data

Cove Name	Station ID	Location ID	Depth (ft bml)	Collection Date	Soil Classification
Eastern Bank of Orrington Reach					
East Cove 3	OR-PDI-07	OR-PDI-07	0.0–0.4	8/16/2023	Elastic SILT with Sand (MH)
East Cove 3	OR-PDI-08	OR-PDI-08	0.0–0.8	8/16/2023	Elastic SILT (MH)
East Cove 3	OR-PDI-09	OR-PDI-09	0.0–0.8	8/16/2023	Elastic SILT (MH)
East Cove 3	OR-PDI-10	OR-PDI-10	0.0–0.5	8/16/2023	Elastic SILT with Sand (MH)

Notes:
ASTM = ASTM International
bml = below mudline
MH = elastic silt
NP = non-plastic
PCF = pound per cubic foot
PDI = pre-design investigation
SM = silty sand

Table 3. TLC Pilot PDI Data Quality Objectives

Goals	Information	Additional Data Collection and Analysis Needs	Scope of Additional Data Collection and Analysis
Evaluation of Biologically Active Zone			
Quantify the depth of biological mixing (or bioturbation) to 1) support a determination of the minimum protective cap thickness to limit mixing of clean cap materials with underlying sediment and 2) to support forecasts of sediment recovery post TLC placement.	There is limited site-specific information on the extent bioturbation (i.e., the BAZ). This parameter supports the 1) determination of the cap design thickness to limit mixing of underlying sediment with the clean cap material and 2) forecasts of sediment recovery following cap placement.	Sediment characteristics will be observed and documented using imaging methods (e.g., SPI) and collection of sediment cores as appropriate for the location setting. Evaluation of the information collected will determine the BAZ depth through the identification of indicators such as the redox potential discontinuity and evidence of biological activity (e.g., organisms present, feeding tubes, sediment grain size or coloration anomalies). At four locations, SPI and sediment cores will both be collected to compare the implementability, effects on data quality, and efficiency of both methods to inform future development of the Performance Monitoring Program.	Perform SPI in triplicate at stations throughout the expected extent of the TLC Pilot Project in East Cove 3, except in low marsh locations. Advance sediment cores in low marsh locations and co-located with SPI at four locations.
Geotechnical Characterization			
Estimate sediment strength and stability to inform the selection of TLC material, thickness, and placement, and implementation methods.	Available sediment physical property data (e.g., grain size, moisture content) indicate that the native sediment is composed predominantly of fine-grained material (i.e., silt) but exhibits some variability, which may be driven generally by lateral position between the river channel and shoreline and specifically by the presence of localized features (e.g., rock outcrops). The composition and strength of the sediment present in the intertidal flats and the underlying consolidated material, through geotechnical evaluations such as bearing capacity, subgrade consolidation, and static slope stability, will limit the type and thickness of material that can be placed during the TLC Pilot Project. Additionally, the selection of appropriate placement and implementation methods will consider the sediment strength to limit disturbance and mobilization of sediment. The types of construction equipment and methods available to the remediation contractor will inform TLC Pilot Project feasibility evaluations and cost estimates.	Additional geotechnical characterization of the native sediment (including both the soft sediment and underlying consolidated sediment) is needed to support calculations of bearing capacity, subgrade consolidation settlement, and static slope stability.	Perform sampling and field testing of the soft sediment and underlying consolidated sediment at East Cove 3 intertidal flats within the expected extent of the TLC Pilot Project. Analyze for index properties and strength parameters to support the identified geotechnical calculations.
Benthic Invertebrate Community			
Establish a sufficient understanding and data set of the benthic community in East Cove 3 to support the TLC Pilot Project permitting process.	The permitting process for the construction of the TLC Pilot Project is expected to include an evaluation of the impact on and recovery of the benthic community in East Cove 3. Measures of the baseline benthic community must therefore be collected prior to construction to support the permitting process. Initial work performed by WSP detailed in the draft Coastal Wetland Assessment Report (WSP 2023a) included an evaluation of the benthic community throughout Orrington Reach, but provided limited characterization of the benthos in East Cove 3 specifically.	Additional data are needed to verify the findings regarding the benthic community in East Cove 3 and provide sufficient information for the TLC Pilot Project permitting process and a baseline for comparison during post-construction monitoring. Two data sets will be collected: - An additional benthic invertebrate survey will be completed in East Cove 3 to support enumeration and identification (i.e., taxonomy) of the benthic community. - A SPI survey will be completed to provide data pertaining to the benthic community (e.g., BAZ thickness; presence/abundance of biogenic features such as organisms, burrows, feeding voids; sediment grain size; evidence of degraded habitat/impairment).	Perform a benthic invertebrate survey throughout the expected extent of the TLC Pilot Project in East Cove 3. Perform SPI in triplicate at stations throughout the expected extent of the TLC Pilot Project in East Cove 3, except in low marsh locations. Advance sediment cores in low marsh locations and co-located with SPI at four locations. A subset of SPI stations will be co-located with the benthic invertebrate community survey stations.

Table 3. TLC Pilot PDI Data Quality Objectives

Goals	Information	Additional Data Collection and Analysis Needs	Scope of Additional Data Collection and Analysis
Supplemental Surface Sediment Sampling			
Establish a sufficient understanding and data set of the pre-construction surface sediment conditions (including the BAZ in intertidal flats) in East Cove 3 to support comparative analyses during post-construction monitoring.	The most effective way to demonstrate the effect of the TLC Pilot Project in reducing exposure on a local scale is by comparing pre-construction and post-construction mercury concentrations at depths relevant to potential receptors. Measures of the sediment chemistry conditions must therefore be colelcted prior to construction to support comparative analyses during the performance monitoring period. Historical bulk sediment chemistry data and data collected during the 2023 PDI provide some relevant information, but may no longer be representative of current conditions (in the case of historical data), are not believed to be representative of the BAZ depth, and do not provide the desired spatial coverage within the TLC Pilot Project area.	Additional surficial bulk sediment mercury and total organic carbon data are needed to establish a baseline for comparison against conditions established after the placement of the TLC during post-construction monitoring.	Perform supplemental sampling of the bulk sediment in the BAZ in intertidal flats and surface intervals in the low marsh for mercury and total organic carbon throughout the expected extent of the TLC Pilot Project in East Cove 3.

Notes:
BAZ = biologically active zone
PDI = pre-design investigation
SPI = sediment-profile imaging
TLC = thin layer cap

Table 4. TLC Pilot PDI Sample Locations

		Coordinates		Sampling Element				
				Evaluation of BAZ				
Station ID	Location Type	Easting (ft)	Northing (ft)	SPI	Coring	Geotechnical Characterization	Benthic Invertebrate Survey	Supplemental Surface Sediment Sampling
OR-PDI-60	Intertidal Flat	898628.27	384676.31			x		x
OR-PDI-61	Intertidal Flat	898528.24	384604.28			x		x
OR-PDI-62	Intertidal Flat	898732.55	384605.85			x		x
OR-PDI-63	Intertidal Flat	898454.29	384416.48			x		x
OR-PDI-64	Intertidal Flat	898598.31	384415.16			x		x
OR-PDI-65	Intertidal Flat	898726.48	384415.16			x		x
OR-PDI-66	Intertidal Flat	898349.90	384103.33			x		x
OR-PDI-67	Intertidal Flat	898500.53	384100.69			x		x
OR-PDI-68	Intertidal Flat	898652.48	384094.08			x		x
OR-PDI-69/OR-BIS-09	Marsh	898537.01	383912.02		x	x	x	x
OR-PDI-70/OR-BIS-10	Marsh	898666.47	384015.76		x	x	x	x
OR-SPI-01/OR-BIS-01	Intertidal Flat	898259.01	383890.51	x			x	
OR-SPI-02	Intertidal Flat	898345.68	383870.07	x				
OR-SPI-03	Intertidal Flat	898347.44	383960.23	x				
OR-SPI-04	Intertidal Flat	898529.54	383971.31	x				
OR-SPI-05/OR-BIS-02	Intertidal Flat	898367.83	384052.14	x	x		x	
OR-SPI-06	Intertidal Flat	898482.37	384028.02	x				
OR-SPI-07	Intertidal Flat	898590.00	384077.08	x				
OR-SPI-08	Intertidal Flat	898390.00	384177.08	x				
OR-SPI-09	Intertidal Flat	898490.00	384177.08	x				
OR-SPI-10/OR-BIS-03	Intertidal Flat	898590.00	384177.08	x	x		x	
OR-SPI-11	Intertidal Flat	898691.89	384202.59	x				
OR-SPI-12/OR-BIS-04	Intertidal Flat	898390.00	384277.08	x			x	
OR-SPI-13	Intertidal Flat	898501.08	384313.10	x				
OR-SPI-14	Intertidal Flat	898590.00	384277.08	x				
OR-SPI-15	Intertidal Flat	898690.00	384277.08	x				
OR-SPI-16	Intertidal Flat	898490.00	384377.08	x				
OR-SPI-17/OR-BIS-05	Intertidal Flat	898590.00	384377.08	x			x	
OR-SPI-18	Intertidal Flat	898690.00	384377.08	x				
OR-SPI-19	Intertidal Flat	898490.00	384477.08	x				
OR-SPI-20	Intertidal Flat	898590.00	384477.08	x				
OR-SPI-21	Intertidal Flat	898691.46	384487.02	x				
OR-SPI-22	Intertidal Flat	898790.00	384477.08	x				
OR-SPI-23/OR-BIS-06	Intertidal Flat	898490.00	384577.08	x	x		x	
OR-SPI-24	Intertidal Flat	898590.00	384538.28	x				
OR-SPI-25	Intertidal Flat	898690.00	384577.08	x				
OR-SPI-26	Intertidal Flat	898590.00	384677.08	x				
OR-SPI-27/OR-BIS-07	Intertidal Flat	898690.00	384677.08	x	x		x	
OR-SPI-28/OR-BIS-08	Intertidal Flat	898590.00	384777.08	x			x	
Count of Locations:				28	6	11	10	11

Notes:
BAZ = biologically active zone
PDI = pre-design investigation
SPI = sediment profile imaging

Coordinates provided in Maine State Plane, ft.
Cores co-located with SPI stations may be paired with alternative SPI stations if field conditions warrant.

Table 5. TLC Pilot PDI Analytical Methods and QA/QC Summary

Sampling Element	Sample Depth Interval (ft bss)	Analyte/Parameter	Analytical Method	Number of Locations[a]	Number of Samples per Location	Total Number of Samples to Analyze	Field Duplicates[b]	Equipment Blanks[c]	MS[d]	MSD[d]	Total Number of Samples, with QA/QC
Sediment Profile Imaging	To refusal	Profile Imaging	Integral SOP	28	3	84	NA	NA	NA	NA	84
Sediment Coring	To refusal	Observable Sediment Characteristics	n/a	6	1	6	NA	NA	NA	NA	6
Geotechnical Characterization	Soft sediment (all locations) and underlying consolidated sediment (intertidal flat locations only). Depths to be determined based on field observations.	Atterberg Limits	ASTM D4318	11	1 (low marsh locations) 2 (other locations)	20	NA	NA	NA	NA	20
		Sediment Grain Size	ASTM D6913-sieve and D7928-hydrometer	11	1 (low marsh locations) 2 (other locations)	20	NA	NA	NA	NA	20
		Organic Content	ASTM D7348	11	1 (low marsh locations) 2 (other locations)	20	NA	NA	NA	NA	18
		Moisture Content	ASTM D2216	9	2	18	NA	NA	NA	NA	18
		Bulk Unit Weight	ASTM D7263	9	2	18	NA	NA	NA	NA	18
		Specific Gravity	ASTM D854	9	2	18	NA	NA	NA	NA	18
		Consolidation	ASTM D2435	9	2	18	NA	NA	NA	NA	18
		Permeability	ASTM D2434	9	2	18	NA	NA	NA	NA	18
		Shear Strength	ASTM D4648/D2850	9	2	18	NA	NA	NA	NA	18
Benthic Invertebrate Survey	0–0.5 ft	Taxonomic Identification	EPA Rapid Bioassessment Protocol	10	1	10	1	NA	NA	NA	11
Supplemental Surface Sediment Sampling	BAZ depth, to be determined based on interpretation of SPI and hand core data (intertidal flat locations) 0–1 inch (low marsh locations)	Total Mercury	EPA 1631E	11	1	11	2	1	1	1	16
		Total Organic Carbon	Lloyd Kahn	11	1	11	2	1	1	1	16

Notes:

ASTM = ASTM International
bss = below sediment surface
MS = matrix spike
MSD = matrix spike duplicate
NA = not applicable
PDI = pre-design investigation
QA/QC = quality assurance and quality control
SOP = standard operating procedure
SPI = sediment-profile imaging
TLC = thin layer cap

[a] Four sediment coring locations will be collocated with SPI stations.
[b] Field duplicates will be collected at a frequency of 1 per 10 samples for sediment chemistry. Geotechnical sample duplicates are not required for QA/QC, but may be collected based on field observations to assess variability in sediment conditions.
[c] Equipment blanks will be collected at a frequency of 1 per 20 chemistry samples per piece of equipment.
[d] MS/MSDs will be analyzed at a frequency of 1 per 20 samples per sample type and analyte.

Appendix A

Addendum to Site Field Sampling Plan

- Appendix A1. Sediment-Profile Imaging Procedures
- Appendix A2. Sediment-Profile Imaging Standard Operating Procedures
- Appendix A3. Benthic Invertebrate Collection Standard Operating Procedures

Appendix A.
Addendum to Field Sampling Plan— Thin Layer Capping Pilot Project Pre-Design Investigation Work Plan

This Field Sampling Plan (FSP) Addendum has been prepared as a supplement to the Field Sampling Plan prepared by WSP USA Environment & Infrastructure, Inc. (WSP) in March 2023 (WSP 2023). The FSP and this FSP Addendum have been prepared pursuant to the Consent Decree (Case No. 1.00-cb-00069-JAW, ECF No. 1187) between Maine People's Alliance and Natural Resources Defense Council, Inc. (NRDC) vs. HoltraChem Manufacturing Company, LLC, and Mallinckrodt US LLC entered by the U.S. District Court for the District of Maine on October 11, 2022, in accordance with Paragraph 31(c) of the Statement of Work (Appendix A to the Consent Decree).

This FSP Addendum includes additional sampling procedures and information necessary for the completion of the scope of work outlined in the Thin Layer Cap Pilot Project Pre-Design Investigation Work Plan but not previously incorporated into the FSP. This supplemental information is presented as Appendices A1 through A3, an overview of the content and purpose of each is provided below.

Appendix A1. Sediment-Profile Imaging Procedures

Appendix A1 presents an overview of the general procedures for the use of sediment-profile imaging (SPI) equipment, including operation, image collection, and data processing. This attachment additionally details the capabilities of the equipment and analysis.

Appendix A2. Sediment-Profile Imaging Standard Operating Procedures

Appendix A2 provides detailed documentation for the deployment and use of the SPI system, including the required field supplies and equipment, assembly procedures, vessel setup, pre-deployment testing, deployment and retrieval of the SPI system, image capture, and demobilization. This documentation is presented in detail appropriate for experienced field staff familiar with the use of the equipment to generate data of sufficient quality to achieve the required data quality objectives.

Appendix A3. Benthic Invertebrate Collection Standard Operating Procedures

Appendix A3 provides detailed documentation for the collection and sieving of benthic macroinvertebrates from surficial sediment using a grab sampler. This collection method is appropriate for the completion of benthic invertebrate surveys requiring metrics including organism counts and taxonomic identification.

Appendix A1

Sediment-Profile Imaging Procedures

Appendix A1.
Sediment-Profile Imaging Procedures
TLC Pilot Project Pre-Design Investigation

Introduction

This Sediment-Profile Imaging (SPI) Procedures document is part of an addendum to the Field Sampling Plan (WSP 2023a) and provides details for completing the SPI survey, including operating the equipment, image collection and processing. General field operations during the SPI survey will be consistent with the Field Sampling Plan (WSP 2023a) and Quality Assurance Project Plan (WSP 2023b) unless otherwise described in this document or accompanying SPI standard operating procedure (SOP) documentation.

These procedures supplement the SPI survey plan described in the TLC Pilot Study Work Plan (Integral 2024), which includes the overall objectives and station locations. The SPI survey will capture surface sediment profile images that can be used to identify grain size, surface-boundary roughness, the presence of benthic organisms and the infaunal successional stage, apparent redox potential discontinuity (aRPD) depths, and the extent of organic loading and methane production. Integral's standard operating procedure (SOP) detailing the setup, operation, and quality assurance and control procedures for the high-resolution SPI camera system is provided as Appendix A2. A deviation from the SOP is that a smaller frame will be used to contain the camera system, which will not include the plan view camera described in the SOP. The SPI survey for this project will be limited to surface sediment profile images.

Image Collection

The SPI camera housing sits on top of a wedge-shaped prism (Figure 1 of Appendix A2). The prism is inserted into the sediment and mirror on the prism reflects the sediment profile image up the camera. This prism assembly is a stainless steel structure that slides between two rods contained within the frame. The prism assembly is locked in the "up" position by two pins before deployment. Once the vessel is secured at the target station and the system is ready for deployment these pins are removed and the frame is lifted by the winch wire. The tension on the wire keeps the prism from sliding down until the base of the frame sets down on the sediment surface. A hydraulic piston is used to ensure the prism penetrates the sediment surface at a controlled rate. The prism has a sharp edge that can typically penetrate soft sediment, but additional weight can be added to the system if necessary (the amount of weight applied will be recorded in the field notes).

The SPI camera typically obtains a cross-sectional image of surface sediments in profile to a maximum depth of 21 cm below the sediment-water interface (SWI), which is the window height. If the sediment is soft, the SPI camera can be set up to take two exposures per drop, one 5 seconds after the roll switch is triggered, and a second image 10 seconds later (15 seconds after the camera is triggered). The two exposures can be spliced together following the survey to produce a SPI image that is greater than 21 cm in total height. Images can be downloaded and reviewed for quality as needed throughout the survey.

Camera Settings and Image File Management

Camera settings (i.e., f-stop, shutter speed, International Standard Organization [ISO] equivalents, digital file format, color balance, etc.) are selectable through a water-tight USB port on the camera housing connected to a laptop computer and Nikon Control Pro® software. At the beginning of the survey, the time on the SPI camera's internal data logger is synchronized with the internal clock of the laptop computer, which will store the downloadable images. In turn, the laptop computer will synchronize its clock with the research vessel's onboard navigation system on local time. Details of the camera settings for each digital image are available in the metadata parameters embedded in the electronic image file. For this survey, the SPI camera will be set with the following parameters: ISO-equivalent 640, shutter speed 1/250, aperture f10, white balance to flash, color mode sRGB, Active D-lighting off, and High ISO Noise Ratio normal. Images will be stored into two separate memory SD cards on the camera as lossless compressed raw (14 bit) Nikon Electronic Format (NEF; 6,000 x 4,000 pixels) files and optimal quality JPEG (fine, 6,000 x 4,000 pixels) files. Recording modes for the two 32 MB memory SD cards are set as NEF in slot 1 and JPEG in Slot 2. When relabeling images with actual station identification numbers, a copy of the JPEG files will be relabeled using the Nikon Capture NX2® software (Version 2.10.3, 64 bit). These images will be reviewed on board as soon as they are downloaded to the field laptop computer to ascertain that all images have been captured.

Image color calibration on SPI images will be determined by photographing a Kodak® Color Separation Guide card against the SPI prism before the first deployment of each day. The card also contains a ruler, which will be used to determine the number of pixels per centimeter. The calibration information will be applied to all SPI images and stored in the image analysis database.

Images will be taken in triplicate at each station. When reviewing image quality during the field effort, the unique time stamp on each digital image will be cross-checked with the time stamp of the onboard navigational system. The coordinates for each image will be added to the database by cross-referencing with time stamps of each SPI deployment. The field crew will keep a redundant written sample log of image acquisition time and sampling stations along with other specific notes. Images will be downloaded after the first drop of each day to verify successful sample acquisition and good functioning of the camera equipment, and to assess acceptable prism penetration depth. Thereafter, the camera system and image quality will be monitored periodically or when bottom conditions change. If images are missed or are of suboptimal quality (e.g., strobe misfire or the penetration depth was insufficient or excessive [over penetration]), additional images may be taken at some locations with the goal of obtaining three optimal images at each station for image analysis.

The downloaded JPEG and RAW image files will be renamed with the designated station numbers during or at the end of each survey day using Nikon Capture NX2® software.

Sediment-Profile Image Analysis

Integral has designed and developed an integrated, MATLAB-based image analysis software (iSPI v1.0) to analyze SPI images. The image files along with the metadata-containing Microsoft Excel® files generated during the field survey are imported directly into iSPI for analysis. A menu-structured graphical use interface in iSPI allows the image analyst to manually or semiautomatically measure and/or add descriptive comments for key imaged features. The draft data are stored in the system for review by a senior scientist. All SPI data are independently reviewed and revised as needed before being identified as having quality assurance check complete or as final data within iSPI. Following the quality assurance review of all measured and descriptive parameters, the final SPI data set is compiled and can be evaluated and exported as desired.

Sediment qualities, such as sediment type, layering in grain-size, or notable sedimentary fabrics will be noted and, if warranted, measured (e.g., the thickness of a sand deposit over mud). The distribution of such features across a survey can reveal patterns of physical or biological disturbance. The distribution of submerged aquatic vegetation will also be noted and mapped. The sections below describe the methodology used for identifying and measuring key features observed in SPI images, as well as the underlying interpretive rationale and paradigms.

Sediment Type

The sediment grain-size major mode and range are estimated by visually comparing the textures in each image with a photograph set (grain-size comparator) that was generated by imaging a series of sieved Udden-Wentworth sediment size class samples (equal to or less than coarse silt up to granules) placed against the SPI camera prism in the laboratory. Seven grain-size classes (phi units) are on this comparator: >4 (silt-clay), 4–3 (very fine sand), 3–2 (fine sand), 2–1 (medium sand), 1–0 (coarse sand), 0– (-1) (very coarse sand), and <1 (granule and larger). The lower limit of optical resolution of the photographic system is about 62 microns, allowing recognition of grain sizes equal to or greater than coarse silt (>4). The image analyst documents the major mode (predominate grain size across the entire image) and total grain size range (minimum to maximum particle size) observed in each image. If distinct sediment type strata are evident in an image (e.g., sand over mud), the major modal estimate will note that and report the grain size as 3–2 phi/>4 phi (i.e., fine sand over silt/clay).

Prism Penetration Depth

The reported SPI prism penetration depth is the average depth in centimeters from the SWI to the bottom of the image. The analyst traces the SWI in each image and iSPI uses the known image coordinates to determine the average penetration depth.

The penetration depth can be a function of the bearing capacity and shear strength of the sediments. As noted above, the number of weights added to the camera prism frame at each station will be documented as a qualitative, relative characterization of sediment physical characteristics.

Small-Scale Surface Boundary Roughness

The iSPI determines surface boundary roughness automatically by calculating the vertical distance between the highest and lowest points of the SWI. The surface boundary roughness may be related to either physical structures (e.g., ripples) or biogenic features (e.g., burrow openings, fecal mounds, fish foraging depressions).

Apparent Redox Potential Discontinuity Depth

Surface sediments are typically aerobic and have higher optical reflectance than the underlying reduced or anaerobic sediments. Surface sands washed free of mud also have higher optical reflectance than underlying muddy sands. These differences in reflectance with depth in the sediment column are readily apparent in SPI images. The oxidized surface sediment particles are coated with ferric hydroxide, which has a brownish or olive color, whereas reduced sediments below this oxygenated layer are darker, generally gray to black (Fenchel 1969; Lyle 1983). The boundary between the colored ferric hydroxide surface sediment and underlying gray to black sediment is called the aRPD. The average aRPD depth is measured in each image by tracing the color boundary across the image. This boundary can be undulated or wavy as a function of the distribution of individual macrofauna and their localized biogenic mixing activities. The average depth of the aRPD is calculated in iSPI by subtracting the aRPD boundary from the SWI.

Note that this measure is referred to as the apparent redox potential discontinuity (RPD) as the actual RPD is the horizon that separates the positive oxidation/reduction potential (Eh) (oxidizing) region of the sediment column from the underlying negative Eh (reducing) region, which can only be determined with microelectrodes.

The aRPD is a key SPI parameter for documenting changes (or gradients) that develop over time in response to benthic disturbance factors (e.g., sediment erosion or depositional events), demersal fish foraging, and temporal (seasonal or yearly cycles) changes in environmental factors, such as water temperature and organic loading. Overall, time-series RPD measurements following a disturbance are a diagnostic element in assessing the rate and degree of recovery in an area following a perturbation (Rhoads and Germano 1982, 1986).

Finally, in well-sorted sands with little to no silt or organic matter, the depth of the aRPD can be controlled by the physical factors that force surface water into the substrate. These aRPD depths are noted as physical aRPDs in the image analyst comments and are not fully a function of infaunal biogenic mixing.

Organic Loading and Sedimentary Methane

If organic loading is high in marine sediments, porewater sulfate is depleted and methanogenesis occurs. In SPI images, methanogenesis can be revealed by the appearance of methane bubbles in the sediment column. These gas-filled voids are readily discernible in SPI images because of their irregular shape and glassy texture (due to the reflection of the strobe off the gas). The image analyst notes the presence of these methane voids, and the number and area of the voids can be measured.

Infaunal Successional Stage

After a disturbance in soft-bottom marine sediments, macrobenthic infaunal communities generally follow a succession pattern. The images will be used to identify the progression from an initial community of densely populated, small, tubicolous, surface-dwelling polychaetes (Stage 1) to an equilibrium community of deep-dwelling, head-down deposit feeders (Stage 3). The identification of benthic infaunal successional stages in SPI images is based on empirical evidence that organism–sediment interactions in fine-grained sediments follow this predictable sequence after a seafloor disturbance (Pearson and Rosenberg 1978; Rhoads and Germano 1982; Rhoads and Boyer 1982). This interpretive paradigm is based on observations that primary benthic succession results in:

> "…the predictable appearance of macrobenthic invertebrates belonging to specific functional types following a benthic disturbance. These invertebrates interact with sediment in specific ways. Because functional types are the biological units of interest..., our definition does not demand a sequential appearance of particular invertebrate species or genera" (Rhoads and Boyer 1982).

This continuum of change in animal communities after a disturbance (primary succession) has been divided into four primary stages:

- Stage 0, indicative of a sediment column that is largely devoid of macrofauna, occurs immediately following a major physical disturbance or in close proximity to an organic enrichment source.

- Stage 1 is the initial community of tiny, densely populated, tubicolous, surface-dwelling polychaete assemblages.
- Stage 2 is the start of the transition to head-down deposit feeders and can also consist of shallow-dwelling bivalves and tube-dwelling amphipods.
- Stage 3 is the mature, equilibrium community of deep-dwelling, head-down deposit feeders that create distinctive feeding voids and aerated burrows that are visible in SPI images.

However, in temporally and spatially dynamic marine environments, benthic communities are unlikely to progress completely and sequentially through all four stages in accordance with the idealized conceptual model. Various and transitional combinations of these basic successional stages are possible (e.g., Stage 1 going to Stage 2). More frequently, secondary succession can occur in response to additional labile carbon input to surface sediments, with surface-dwelling Stage 1 or 2 organisms co-existing at the same time and place with Stage 3, resulting in the assignment of a "Stage 1 on 3" or "Stage 2 on 3" designation. The image analyst will assign an infaunal successional stage for each SPI image analyzed based on this interpretive paradigm.

As a final note, the successional dynamics of benthic invertebrate communities noted above are based on well-documented studies of fine-grained benthic environments; the successional dynamics of invertebrate communities in sand and coarser sediments are less well-known and biogenic structures are less-well preserved or discernible in sands. As a result, the interpretation of successional patterns from SPI images in sandy and coarse-grained bottoms is relatively limited and the successional stage is often indeterminate.

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Appendix A2

Sediment-Profile Imaging Standard Operating Procedures

STANDARD OPERATING PROCEDURE (SOP) SD-24

SEDIMENT PROFILE IMAGING AND PLAN VIEW CAMERA OPERATIONS

SCOPE AND APPLICATION

This SOP defines and standardizes the methods for field deployment and operation of the sediment profile imaging and plan view (SPI–PV) camera system in freshwater or marine environments. SPI–PV photographs are used to examine the *in situ* details of bottom topography/stratigraphy, sediment texture, depth of biogenic mixing and bioturbation, and the living positions of mud-dwelling benthos. Interpretation of the photographs is conducted according to the benthic ecological paradigm developed by Rhoads and Germano (1982, 1986).

SUMMARY OF METHOD

The SPI–PV system consists of an SPI camera and a plan view camera (Figure 1). The SPI camera system captures a cross-sectional image of the sediment surface. The plan view camera captures an image of the seafloor surface from above.

Figure 1. SPI–PV Camera System

The SPI–PV camera system is deployed from a boat attached to a winch wire (Figure 2). The system is internally powered by batteries, so there is no need to run power through the winch cable. A 2- or 3-lb lead ball weight is used as the trigger for the plan view camera. The weight hangs lower than the base of the SPI frame while lifted by the winch. As the SPI system is lowered, the lead ball hits the seafloor; this action releases the tension on the trigger switch, activates the strobe light and plan view camera, and takes a photograph of the surface of the seafloor. As the SPI frame continues to be lowered to the seafloor, tension on the winch wire keeps the SPI prism retracted into the frame. Once the base of the SPI frame makes contact with the bottom, slack on the winch wire allows the prism to vertically cut into the seafloor. A trigger for the SPI camera is tripped by the descending prism, activating a set time delay on the SPI camera shutter release and strobe light, which allows enough time for the prism to obtain maximum penetration into the bottom before a photograph of the sediment profile is taken. As the camera is raised off the bottom, a wiper blade attached to the front of the prism cleans any sediment that may have adhered to the prism faceplate (Figure 3). The strobe lights are recharged, and the camera can be lowered again for a replicate image or moved to another station.

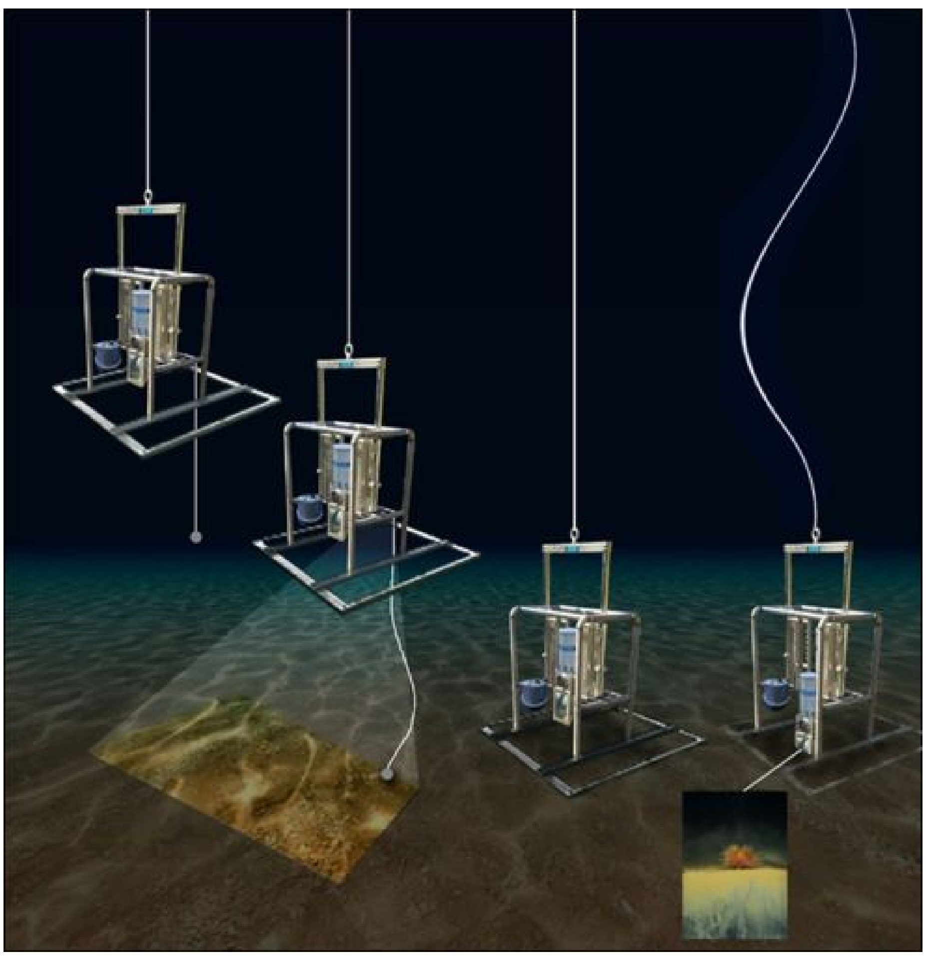


Figure 2. SPI Deployment Sequence

Before a field survey begins, the Ocean Imaging Systems (OIS) SPI–PV system frame, cameras, lights, and connector cables are assembled according to procedures outlined in the manufacturer's manuals. The following attachments are quality assurance (QA) checklists for each major component of the SPI–PV equipment:

- **Attachment 1**—SPI Camera Pre-deployment QA Checklist
- **Attachment 2**—Plan View Camera Pre-deployment QA Checklist
- **Attachment 3**—Strobe Head and Battery Pre-deployment QA Checklist.

Hard copies of the following OIS manuals for each piece of equipment are carried into the field and are available upon request.

- **OIS User Manual M-373-035036** (September 25, 2015)—Instructions for the operation and maintenance of the OIS Model 3731-D 4,000 meter digital sediment profiling camera.
- **OIS User Manual M-24000-002** (September 5, 2015)—Instructions for the operation and maintenance of the OIS 6,000 meter, 17-4PH Model DSC 24,000 digital still camera (with wide angle dome).
- **OIS User Manual M-3831-036** (September 5, 2015)—Instructions for the operation and maintenance of the OIS 200 W-S remote head strobe Model 3831, 17-4PH housing rated for 6,000 meters.
- **OIS User Manual M-24000-3731_001** (September 5, 2015)—Instructions for installing a DSC-24,000 digital camera system and 3831-SP strobe on a Model 3731D REMOTS™.

SUPPLIES AND EQUIPMENT

The following field equipment is required for an OIS SPI system and an OIS plan view camera system.

SPI Camera System

- OIS pressure-proof camera housings with strobe heads (2) (1 as a backup unit)—(Model 3731-D [4,000 m] Sediment Profiling System)
- Electronics/strobe board with frame counters (2)
- Nikon D7100 digital cameras (2)
- 32-gigabyte SD image storage cards (4) (2 cards per camera)
- 35-mm, f2.0 lenses (52.5 and 35 mm equivalent) (2)
- Kodak Color Separation Guide and Gray Scale standard laminated strips

- USB cables (2)
- Lead-acid batteries (4)
- Lead-acid battery chargers (2)
- Sliding, water-filled prism with adjustable weights
- 25-lb lead weight cubes (10)
- Hydraulic piston (to control penetration rate)
- Stainless steel tubular frame
- Stainless steel flat base
- Mud doors (2)
- Black rubber bungee cords for mud doors (4)
- Trigger switch (4,000 m rated); a second trigger is with the plan view camera
- Trigger switch cables (2)
- Stainless steel split collar stops (to limit prism penetration) (2)
- Penetrometer black rubber ring
- Wiper blade assembly
- Stainless steel swivel (4 tons rated)
- Stainless steel shackles (4-¾ tons rated) (2)
- Set of spare O-rings
- OIS M-373-035036 user manual
- Electrical tape (blue and orange).

Plan View Camera System

The plan view camera system includes field equipment for the digital camera housing and for the remote strobe head system.

Plan View Camera

- Plan view camera housing OIS Model DSC 24,000 (6,000 m rated) with wide angle dome
- Nikon D7100 digital camera
- Nikkor 20-mm f2.8 lens
- 32-gigabyte SD image storage cards (2)

- Nikon D7100 camera backup battery (EN-EL 15)
- Nikon camera backup battery charger
- USB 2.0 cable with 24-VDC supply plug
- RS-232, 9600 baud, 8, N, 1 cable with 24-VDC supply plug
- Laser connecting power cable to plan view camera housing
- Ranging lasers on brackets (2)
- Set of spare O-rings
- 2-lb lead ball weights (2)
- Trigger cables (fishing leaders) with minimum 20-lb break-away links (4) (2-, 3-, 5-, and 8-ft lengths)
- OIS M-24000-002 and M-24000-3731_001 user manuals
- Electrical tape (yellow).

Strobe Head and Battery Case

- OIS M-3831-036 user manual
- Strobe battery housing, 6,000-m rated, 17-4PH stainless steel (SN 036)
- Remote flash head (SN 081)
- Trough flash reflector
- Interconnect cable for REMOTS
- Nickel-cadmium (NiCd) batteries (2)
- NiCd battery charger
- Flashtube spare unit (A-386-18)
- Set of mounting brackets, U-bolts, saddles, crossbars, padeye mount, and trigger mount
- Electrical tape (yellow).

Other Supplies

- Tool box with assorted tools
- Hardware box with assorted nuts, bolts, washers, U-bolts, extra lead weights
- First aid kit with eye washer
- Plastic fencing guard

- Silicone grease tube
- Silicone spray can
- Teflon spray can
- Winch and winch line (provided by vessel contractor)
- Distilled water (for filling optical prism)
- Laptop computer with charger and mouse
- Optical USB extension cable (15 m)
- Navigation system (optional and project dependent)
- Vessel with winch and winch wire having a minimum lifting capacity of 2,000 lb
- Glass cleaner (Windex)
- Paper towels
- Stainless steel swivel and shackles
- Flashlight.

PROCEDURES

Assembling the SPI–PV System

Outlined below are the steps to assemble the SPI–PV system. The final mounted structure is shown in Figure 3.

Structural Frame

The structural frame consists of two parts: 1) a galvanized steel base frame; and 2) a vertical structural stainless steel frame that supports the prism, piston, weights, plan view camera housing and strobe unit, and the pressure housing containing an SPI digital camera and strobe. In addition, two mud doors can be installed on the sides of the base frame in the event the bottom sediment is too soft, causing the SPI camera prism to overpenetrate the sediment–water interface.

1. Assemble the base frame with the aid of spacers underneath each bar so that a wrench can be fitted underneath while tightening from the top. Perform a final tightening of the bolts on the base frame once the side hoop structures are in place and the entire vertical structure including the prism sliding stainless steel shafts are lined up.[1]

[1] Assemble the structural frame as it lies flat with the prism window facing up. Then, tilt the structural frame up vertically and set on the base frame upright.

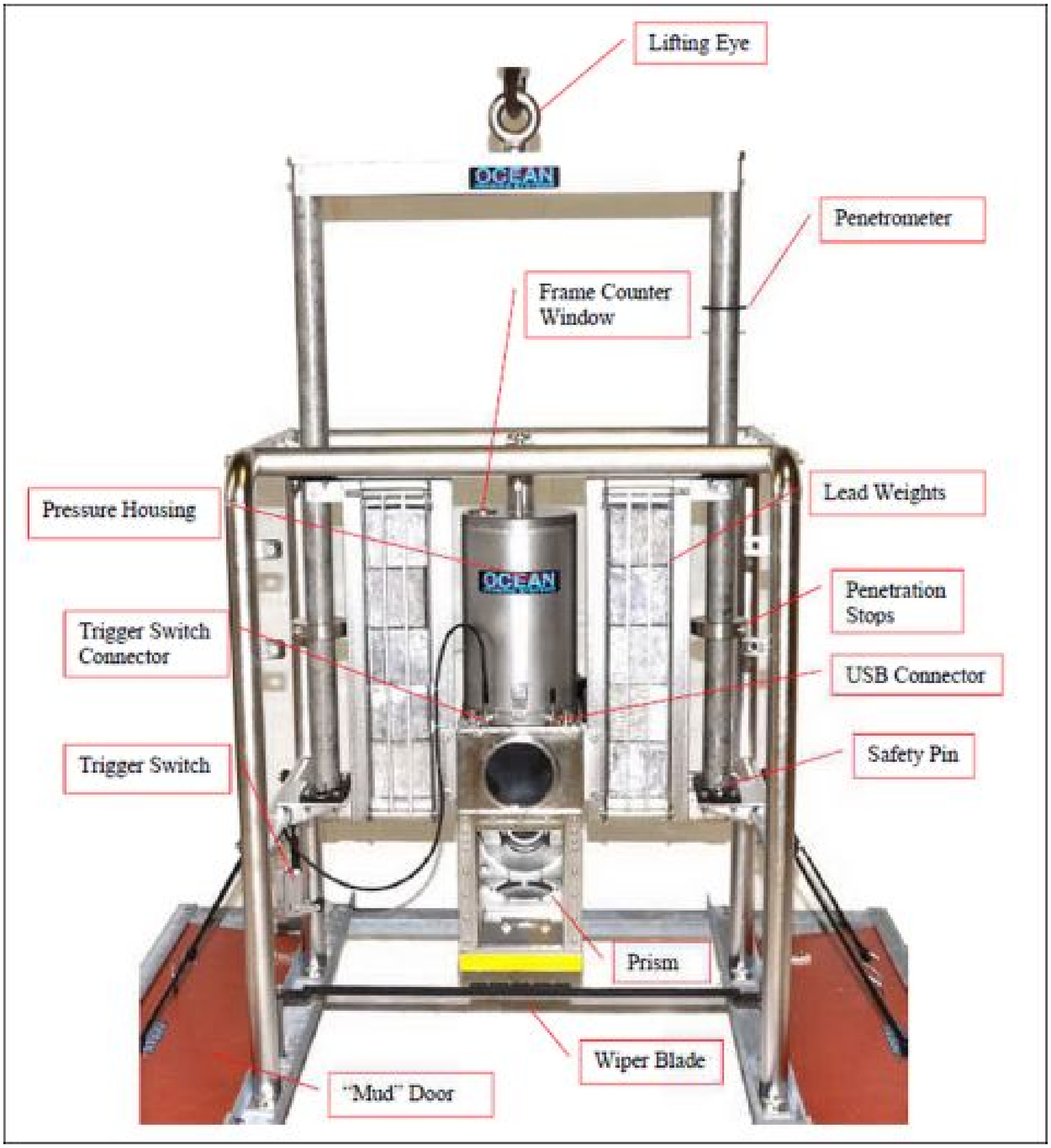


Figure 3. Front View of SPI Camera System (Note: Plan view camera is not mounted.)

2. When the side hoops and cross bars are in place, assemble the stainless steel sliding shafts through the two holes on the plastic plates of each hoop frame with the two plastic plates at one end of each shaft facing up.
3. Install the penetrometer black rubber ring on the right shaft (when facing the prism) before bolting the hoisting bracket with large lifting eye to the top end of the two shafts.
4. Manually lift the hoisting bracket and place the two safety pins into the locking holes of each shaft. Tighten the bolts of the base frame.

5. Add the two stainless steel penetration stop rings and lead weight brackets to each shaft. Assemble the lead weight brackets with the door latches facing up and the door hinges facing down. Make sure that the doors open on the same side as the prism face.

The entire frame structure can be disassembled and shipped in the 11 customized cases. Table 1 describes in detail the contents, weights, and dimensions of each case, as well as additional cases containing tools and a laptop computer.

Table 1. Itemized Weights for Each Part of the SPI–PV System

Item	Unit weight (lb)	Case weight (lb)	Case—Loaded Weight (lb)	Case Model	Case dimension (in. L x W x D)	Case #
SPI 1 camera (blue)	78.5	36.0	122.5	Pelican 1630	31.28 x 24.21 x 17.48	1
SPI trigger	1.5					
Battery lead acid—2 units (each weight)	3.25					
SPI 2 camera (orange)	78.5	36	121	Pelican 1630	31.28 x 24.21 x 17.48	2
Battery lead acid—2 units (each weight)	3.25					
Plan view camera	60.3	42.2	104.0	Pelican 1660	31.59 x 22.99 x 19.48	3
Plan view trigger	1.5					
Plan view strobe unit	50.9	38	120.1	Pelican 1730	37.5 x 27.13 x 14.37	4
Flash head	4.4					
Battery NiCd—2 units (each weight)	6.25					
Double bracket	9.3					
Single bracket	4.5					
Plan view bracket	0.5					
Prism 316 SS	42.5	36	94.8	Pelican 1630	31.28 x 24.21 x 17.48	5
Piston	16.3					
Base						
Mud doors—2 units (each weight)	24.8	63	304.8	Pelican Hardigg Case AL6815-1005 (gray box only)	71 x 18.25 x 17.13	6
Short bar—2 units (each weight)	48.2					
Long bar—2 units (each weight)	53.4					
L-Corner brackets—2 units (each weight)	26					
Lead weight rack—2 units	21.9	28	71.9	Pelican 1650	31.59 x 20.47 x 12.45	7
Sliding rods—2 units (each weight)	40.1	27	107.2	Pelican 1750	53 x 16 x 6.12	8

Table 1. Itemized Weights for Each Part of the SPI–PV System

Item	Unit weight (lb)	Case weight (lb)	Case—Loaded Weight (lb)	Case Model	Case dimension (in. L x W x D)	Case #
SPI inner frame hardware						
Top front round SS bracket	11.2	27	91.2	Pelican 1750	53 x 16 x 6.12	9
Top rear round SS bracket (piston)	11.5					
Head lift cross bar	16.5					
Stop ring—2 units (each weight)	2.75					
Eye bolt for head lift bar	3					
Stainless steel swivel WLL 4T	3.75					
Anodized shackle WLL 4T, 3/4 in.—2 units	2.75					
Wiper blade	3					
Steel rod bracket (when plan view camera is off)	4.25					
Side frame—2 units (each weight)	46.4	87	179.8	Cases Plus	45 x 32 x 11	10
Black tote with supplies	40 [a]	--	40.0	Black tote	30 x 17 x 13.5	11
Tool box	25 [a]	--	25.0	Tool box	21 x 11 x 11	12
Hardware box	20 [a]	--	20.0	Hardware box	22.25 x 12 x 7	13
Lead weight box 1	50	3	53.0	Pelican iM 2050	11.8 x 9.8 x 4.7	14
Lead weight box 2	50	3	53.0	Pelican iM 2050	11.8 x 9.8 x 4.7	15
Lead weight box 3	50	3	53.0	Pelican iM 2050	11.8 x 9.8 x 4.7	16
Lead weight box 4	50	3	53.0	Pelican iM 2050	11.8 x 9.8 x 4.7	17
Lead weight box 5	50	3	53.0	Flambeau 1109HD	12 x 10 x 5	18
Total weight of all loaded boxes			**1,667**			
Shipping Crates						
Crate 1 (1,500 lb max; holds Cases 4 and 6–18)						
Dimensions (in.) = 62 x 48 x 34						
Crate = 206 lb						
Lid = 39.6 lb						
Total weight with lid (lb)			1,471			

Table 1. Itemized Weights for Each Part of the SPI–PV System

Item	Unit weight (lb)	Case weight (lb)	Case—Loaded Weight (lb)	Case Model	Case dimension (in. L x W x D)	Case #
Crate 2 (1,500 lb max; holds Cases 1–3 and 5)						
Dimensions (in.) = 48 x 45 x 34						
Crate = 140 lb						
Lid = 26.4 lb						
Total weight with lid (lb)			609			
Total weight of all loaded shipping crates			**2,080**			

Notes:
[a] = approximate weight

Prism

The prism is located in a single black case along with the spare prism Plexiglas window, the prism mirror, and the hydraulic piston that controls the rate of descent of the prism. To install the prism, slide the prism between the two lead weight brackets on the frame and bolt into place. Install the prism wiper blade on the base frame and adjust its height to just below the bottom of the prism window.

1. Before filling the prism with distilled water or ethanol (in case of freezing temperatures), remove any loose debris inside the chamber, and check that the inside window and mirror are free of smudges. Use glass cleaner with a lint-free cloth or paper towel to clean both the inside and outside of the prism mirror and window.
2. Unscrew the vent bolt on the top right of the prism. Fill the prism though the main opening by syphoning distilled water to the brim (approximately 3.75 gallons) with a small plastic hose. When filling the prism with water, take care to minimize the number of air bubbles inside the prism because (a) air is more compressible than water and when the camera is deployed at great depth, the high pressure can rupture the prism diaphragm if excess bubble space is compressed; and (b) air bubbles pressing on the mirror or camera lens window can refract/reflect the strobe flash, which can create blurry white spots on the SPI image and potentially obscure important information.
3. Once filled, purge air bubbles from the entire inner surface of the prism using a plastic-coated wire or other clean implement such as plastic tubing filled with water and attached to a turkey baster to squirt water on the air bubbles. A plastic-coated wire prevents scratches to the inner window and mirror. Once bubbles are minimized, carefully place and secure the pressure housing containing the camera on top of the prism. Allow the water in the prism to degas for as long as possible before emplacing the camera.
4. Following the air bubble purging, top off the water level in the prism by dribbling water into the vent port, if needed.
5. Replace the bolt in the vent port and tighten it.

The window on the prism is made of Plexiglas and with use, the window gets scratched. When excessive scratches build up on the surface of the window, they degrade the SPI image quality and the window needs to be replaced.

To replace the prism window:

1. Make sure that the outer surface is free of sediment. If some sediment is present in the grooves, use a hose to wash the sediment away or use moist paper towels to remove all loose sediment. Hosing/wiping the sediment away will prevent sediment from getting inside the prism once the window is removed.
2. Remove all screws from the surface plates and all screws from the cutting blade.

3. Gently pry the Plexiglas window from the neoprene gasket. Inspect the neoprene gasket for wear and tear. If the gasket is in good condition, it can be reused.
4. Replace the Plexiglas window as show on Figure 4. Use a small amount of adhesive glue to keep the gasket in place and prevent it from moving once the window is pressed in place and when tightening all screws.
5. Replace the steel plates on the faceplate and gently tighten the screws.
6. Replace the cutting edge of the prism and gently tighten the screws. When all screws are in and there are no signs of warping or unusually tilted plates, firmly tighten the screws, and the prism is ready for use.

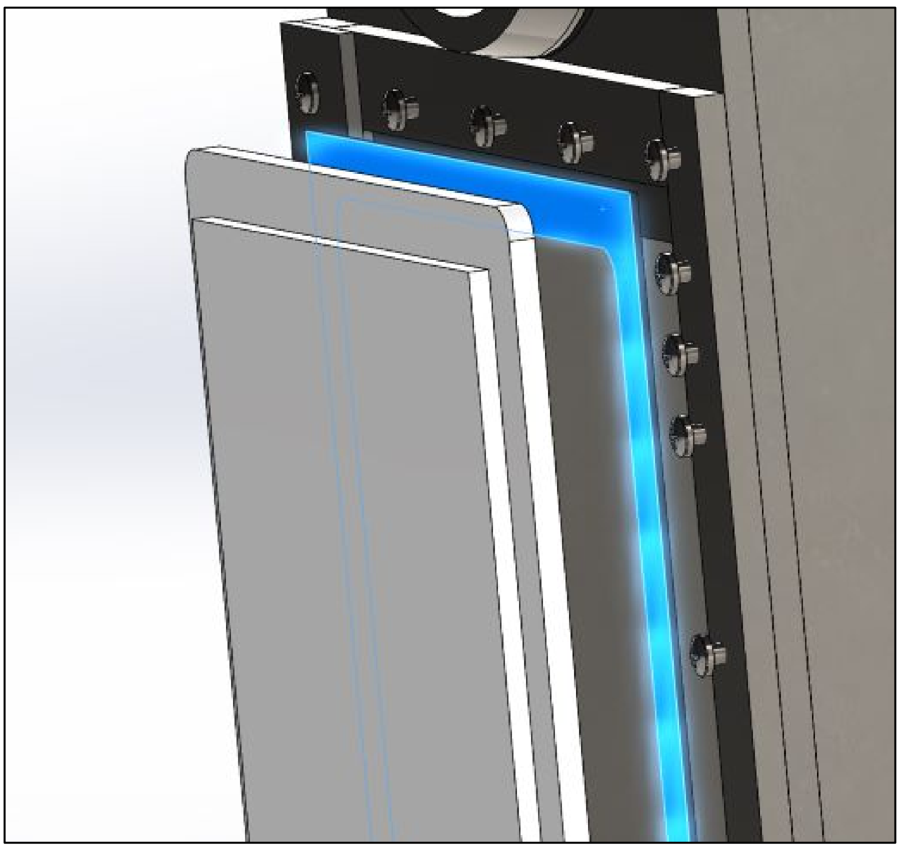


Figure 4. Display of window replacement on prism. The neoprene gasket (in blue) is placed on the prism opening followed by the prism window with its beveled recess facing outward. The steel plates are then placed over the window flush with the edges.

Hydraulic Piston

Attach the hydraulic piston, which controls the rate of descent of the prism, between the back of the SPI frame and the prism after the SPI frame has been installed. Store the hydraulic piston in a single black case along with the prism, the spare Plexiglas window, and the prism mirror. Check for signs of leakage. If oil leaks are detected, it is likely that the piston needs repair, and the project manager should be notified immediately. Try to determine the location of the leak and photodocument it.

SPI Camera Pressure Housing (also known as End Cap)

The SPI camera is located inside the pressure housing (Figure 1) and the procedures for installation and operation can be found in the **OIS manual M-373-035036**.

Integral Consulting Inc. (Integral) has two Nikon D7100 SPI cameras (one serves as a backup unit). Each camera is stored in its individual black case along with cable connectors, batteries, and battery chargers.

1. Install the pressure housing over the prism only after the prism has been completely filled with distilled water. Two people are recommended for this operation due to its heavy weight and its awkward placement through the SPI frame.
2. Make sure that the four locking cams at the top of the prism are out of the way before placing the pressure housing onto the prism. With the help of a second person, slowly slide the pressure housing into the prism and slide the four cams into the slots located at the base of the pressure housing. Lock the pressure housing into place by tightening the locking cams with a 5/16-in. Allen wrench.
3. To mount the pressure housing in the proper orientation, make sure that the strobe unit attached to the bottom of the pressure housing is pointing away from the prism window. This ensures that the open slot of the flash bulb will be facing the prism window. Use the stickers on the pressure housing, which face forward, to orient the proper placement over the prism.

SPI Camera Trigger

Attach the SPI camera trigger switch to the left bottom side of the SPI frame (Figure 5) and connect the trigger cable to the pressure housing (2-pin connector). Secure the trigger cable to the SPI frame with electrical tape or plastic ties. The assembly of the SPI camera system is now complete.

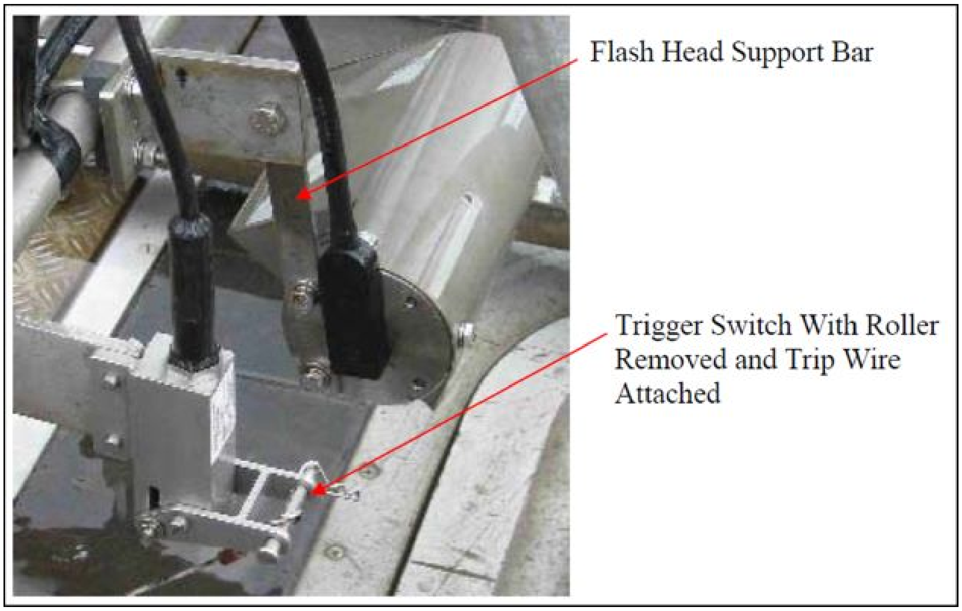


Figure 5. Trigger Switch and Two Flash Heads Mounted to Cross Bar

Plan View Camera

The plan view camera (Figure 6) consists of the camera housing, trigger switch, strobe, and strobe battery case. Instructions for the operations and maintenance of the plan view camera and strobe unit can be found in OIS manuals **M-24000-002** and **M-3831-036**.

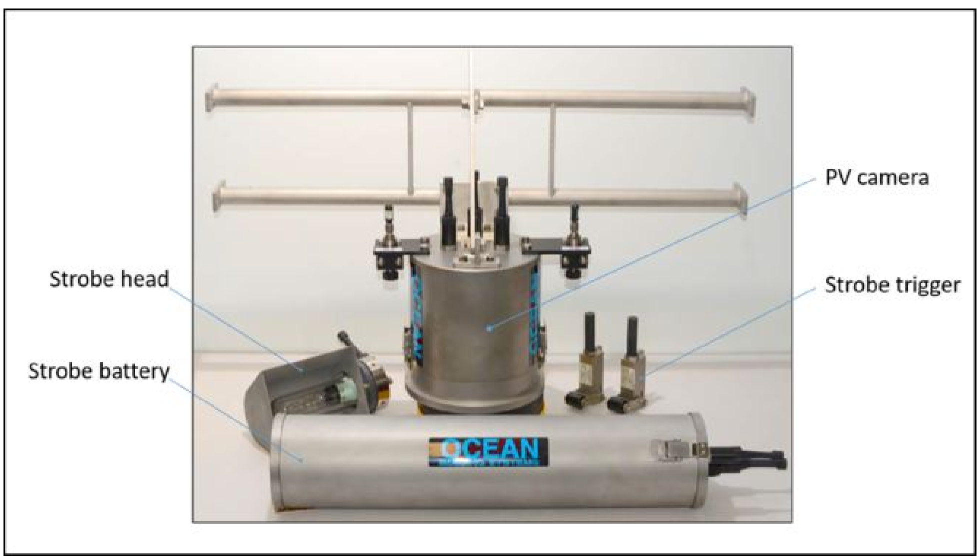


Figure 6. Plan View Camera

The procedures for installation and operation of the plan view camera and the strobe unit can be found in the OIS manual **M-24000-3731_001**. Instructions on how to mount the plan view camera, strobe head, battery, and trigger to the brackets of the SPI frame are specified in the installation manual.

Calibrating the Lasers

Before assembling the plan view camera to the SPI frame, align and calibrate the lasers mounted on each side of the camera (Figure 7). Place the camera horizontally on the floor and connect it to the strobe light battery unit without the strobe head. Place a piece of cardboard or a light-colored surface area, draw two small crosses placed 26 cm apart on the paper, and tape it to the wall at about 3 ft away from the camera and at about the same height as the laser beams are shining. Adjust the laser beams by loosening the four Phillips screw heads on the laser support bar and gently moving the lasers until they shine right over the marked spots. Retighten the screws and check again that the lasers are in position. Repeat if necessary.

Figure 7. Laser Beam Alignment on Plan View Camera

Installing the Plan View Camera on the Frame

The placement of the plan view camera on the frame is a two-person operation because of the heavy weight (60 lb) of the plan view camera. One person places the camera in front of the prism while the second person bolts the camera to the swiveling bracket installed just above the prism. This will temporarily hold the camera while the two-person team swivels the plan view camera, bolts it to the lower bracket with the U-clamps, and tightens the clamps.

1. Install the trigger switch, strobe battery, and strobe head to the back of the SPI frame as specified in the manual. Make sure the strobe head is aligned with the marking on the bracket so that the strobe light illuminates the calibrated area of the bottom of the body of water.
2. Connect the cables from the lasers to the plan view camera.
3. Connect the cables to the battery pack, strobe head, trigger switch, and plan view camera.
4. Secure all cables to the frame with electrical tape or plastic ties.

The plan view camera installation is now complete.

Rigging the SPI Camera to the Boat Winch

With the help of the boat crew, the SPI operators attach the SPI frame to the boat's winch wire with the 4-ton stainless steel swivel with two 2-ton shackles. Use cable ties or baling wire on the shackle pins to ensure that the pins cannot loosen or back out.

If the SPI frame was assembled on board, then the unit is ready for testing and deployment. If the unit was assembled on shore, then the boat crew will inform the SPI crew on how to safely transport the unit from the dock to the boat. At times, only the boat crew is allowed to do the transport. In either case, the SPI crew must wear the proper personal protective gear, including hard hats and personal floatation devices.

The SPI frame is 1,066 lb when fully loaded with the plan view camera system and all lead weights. The winch and winch wire, winch boom, or boat crane should be rated a minimum of 2,000 lb.

If inclement weather is in the forecast and wave action is expected, secure the SPI frame to the boat floor or gunnels with the aid of strapping belts. Secure the SPI unit to the boat while navigating to and from the site, or when not in use and unattended.

Testing the SPI System before Deployment

To ensure that the entire system is assembled correctly, perform the following series of tests before deployment.

Hydraulic Piston Test

This test will have been already performed once during the initial test of the SPI unit, and the actual piston testing may not be required at every deployment. Perform this test only while the boat is at the dock and with no wave action.

1. Place a piece of plywood or cardboard where the prism cutting edge will make contact with the deck. The cutting edge is very sharp; handle with care.
2. To test the rate of descent of the prism, use the winch to lift the SPI frame about 1 ft from the boat deck.
3. Remove the safety pins from the sliding shafts and then slowly lower the SPI frame until the base frame touches the deck. The time of the rate of descent of the prism should be between 2 and 3 in. (5 and 8 cm) per second without any weights on the frame. If the rate of descent is too fast or too slow, turn the control valve near the bottom of the piston to adjust the speed of descent.
4. Turn the valve clockwise to reduce the rate, or counterclockwise to increase the rate. If weights are added to increase penetration, adjust the rate again.

SPI Camera Test

Using a flathead screwdriver, turn on SPI camera by turning the switch at base of pressure housing from "off" to "on." Place a Kodak color separation guide board against the prism and take a picture by pressing the SPI trigger switch down. Follow the procedures outlined in the SPI camera pre-deployment QA checklist document (Attachment 1). Below is a summary of the pre-deployment procedures:

- Confirm that it takes 10 seconds between pressing the trigger switch of the SPI camera and the flashing of the strobe light.
- Confirm that frame counter is working and that counter switched from 000 to 001.
- Connect SPI camera to laptop, download pictures, and confirm JPEG and RAW files are being saved.
- Unplug SPI camera from laptop (test is complete).

Plan View Camera and Strobe Head Battery Test

Turn on the power on battery strobe unit attached at the back of the SPI frame. The "on" switch is located on the top. Place a Kodak color separation guide board underneath the plan view camera and take a picture by pressing the plan view trigger switch down. When first turned on, the flash will go off only once when the trigger is lowered but should always go off when lifted or released; that is, when the lead weight touches bottom and trigger switch moves up. Follow procedures outlined in the plan view camera (Attachment 2) and strobe head and battery (Attachment 3) pre-deployment QA checklist documents. Below is a summary of the pre-deployment procedures.

- Confirm that the flash goes off when the trigger is first lowered.
- Confirm that the flash goes off when the trigger is lifted or released.
- Connect plan view camera to laptop, download pictures, and confirm JPEG and RAW files are being saved.
- Unplug plan view camera from laptop (test is complete).

SPI–PV Hardware Safety Check

After performing the tests as mentioned above, and before deployment, follow the SPI system safety steps below:

1. Check that all bolts are securely fastened.
2. Check that all shackles and swivel are securely fastened to the boat winch wire and SPI–PV lifting eye.
3. Check that all shackle pins are secured with zip ties or twist wire.

4. Check that all electrical connections to the camera housings, lasers, strobe battery, and strobe head are securely fastened.
5. Check that all dummy plugs are securely fastened.
6. Check that all fasteners for the camera housing are properly latched.

Deploying and Retrieving the SPI–PV Camera

Prior to equipment mobilization to the field, bench-test the SPI camera, the backup SPI camera, and plan view camera to ensure that the cameras are in focus and firing properly, the batteries are all charged, and the strobe lights are operational.

Deployment

1. Attach the SPI–PV camera system to the winch wire.
2. Attach a 2-lb ball weight to the trigger switch connected to the strobe unit of the plan view camera. The length of line attached from the trigger switch to the ball weight will depend on the clarity of the water. Several lengths are available (3, 5, 8, and 12 ft). Most inshore work in temperate or northern areas will likely require relatively short trigger line lengths. **Important Note**: A weak link of some sort (heavy duty rubber band or twine) must be placed between the trigger switch and the trigger line. This will allow only the ball and line to be lost rather than the trigger should the line snag on something on the bottom (rocks, logs, etc.).
3. Coordinate with winch operator and agree on verbal and visual commands, depending on ship configuration, before deployment. Below are examples of verbal commands.
   a. As soon as the SPI frame base touches the water, say and signal “on surface” so that the winch operator can count how many feet of cable will be spooled out until the SPI frame touches bottom.
   b. As soon as there is slack on the winch wire, say and signal “on bottom.”
   c. As soon as the SPI frame is seen coming up in the water column, say and signal “sight.”
   d. Once the SPI frame breaks the water surface, say and signal “surface.”
   e. After hoisting the SPI frame over the gunnel and lowering it on deck, say “on deck.”
4. Test the SPI–PV camera system on deck to determine that it is turned on and working.
5. Send hand signals to winch operator to indicate that it is time to hoist the SPI frame from the deck.
6. Once the SPI frame is off the deck, remove the two safety pins from the slide bars and set aside in a safe place for easy retrieval when the frame comes back on deck.

7. With the help of a deck hand, maintain stability of the SPI frame until winch operator maneuvers the frame away from the boat.
8. Use previously agreed-upon hand signals to bring the SPI frame into the water.
9. Deploy the camera, observing the verbal commands mentioned in Step 3, and reduce the rate of descent once the SPI system is approximately 10 ft from the bottom. Stop winch as soon as slack on the winch wire is detected.
10. Maintain a small tension on the winch wire to ensure that there is slack in the wire and so that camera frame is not moved or disturbed while the camera is taking the SPI image.
11. Count at least 30 seconds before allowing the SPI system to be lifted off the bottom.
12. After each replicate, direct the winch operator to hang the unit 3–5 m above the bottom (typically, three replicate images will be taken at each location). Wait at least 1 minute or more to allow the resuspended sediment cloud from the previous drop to dissipate.

Field Adjustments to SPI and Plan View Cameras

1. For plan view images, determine if the sediment bottom is sufficiently and evenly illuminated by the strobe light and that the image is in focus.
   a. If not in focus, determine if the length of the line connected to the plan view camera trigger switch needs to be adjusted. If cable length is adjusted, the strobe light angle and/or focal length of the plan view camera may also need to be adjusted.
   b. ***Do not open plan view camera housing on deck.***
   c. If internal adjustments to the plan view camera are needed, detach camera from SPI frame following disassembly procedures and bring camera inside the boat cabin for adjustments. Temperature differences between the water column and inside the boat can be very large, and condensation inside the camera will likely occur. Ideally, the plan view camera should be allowed to equilibrate with the boat cabin temperature before it is opened.
   d. Open camera in a protected environment away from sea spray or any other potential water contact. Adjust the camera focal length and redeploy the camera system to retest.
   e. Repeat the same procedure until the plan view image is satisfactory.
2. For SPI images, confirm that strobe light is working, that the prism penetration into the sediment is adequate (ideally, 50–90 percent window penetration), and that image is in focus.
3. Check that the wiper blade is satisfactorily cleaning the faceplate. If smudges appear on the images, adjust the wiper blade closer to the prism window.

4. With the SPI system secured on deck, verify the frame count and measure the prism penetration depth from the penetrometer position relative to the camera base. If penetration is determined to be inadequate based in image review, load additional 25-lb lead weight packs into weight racks to increase penetration into the seafloor. If penetration is too great (i.e., the sediment–water interface is above the top of the window frame), lower the penetration stop rings which control the distance the prism descends. If the problem of overpenetration continues, attach the mud doors to each side of the base frame to increase the surface area of the entire unit and reduce sinking.

Equipment Retrieval

Refer to project-related health and safety plan for details on safe retrieval of SPI equipment.

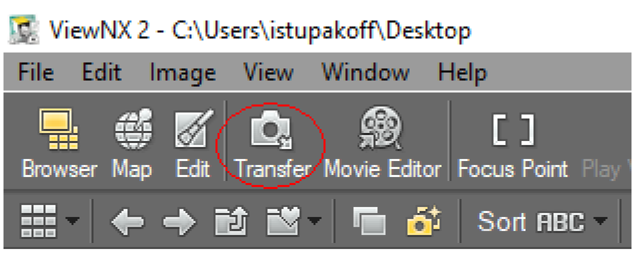
1. Bring camera system back on the boat. Replace the safety pins to the sliding shafts before placing the frame on deck.
2. Record the penetrometer distance and reset.
3. Rinse dummy plugs for USB connectors with fresh water. Use compressed air to blow off excess water, and then unplug the port and connect the port to the laptop. Place dummy plugs in pocket or other spot for safe keeping.

SPI Image Download and Quality Check

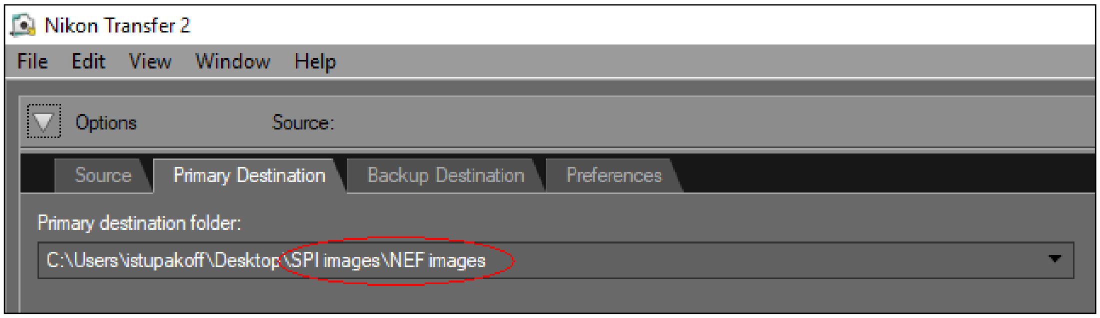
1. Connect SPI USB cable to MESA2 Tablet USB port.

2. Start ViewNX 2 downloading software.

3. In ViewNX 2, click on Transfer.



4. After images upload, click on the Primary Destination tab.



5. Transfer the images in the following order to appropriate directories:
    a. SPI—NEF, then → SPI—JPEG
    b. ***Create image file folders on desktop for ease of locating folders in the future.***
6. Once directory is set and images appear on the desktop, click on the Start Transfer button.

7. After downloading the NEF files, the program will ask if you want to continue downloading the next memory card; click "NO."
8. Choose the next directory for JPEG images as mentioned in Step 5.a above and download images.
9. Once images are downloaded, remove USB cable and reconnect USB dummy plug on SPI camera.
10. In ViewNX2, go to the JPG folder and assess if images are acceptable.
11. Reject SPI images if overpenetration occurred or if apparent redox potential discontinuity (aRPD) cannot be defined in the image. Examples of acceptable and unacceptable images are shown below.
12. Switch off power when done sampling.

Acceptable Sediment–Water Interface

Overpenetration

Underpenetration with Acceptaple aRPD

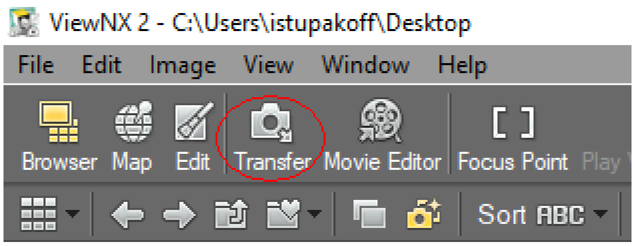
Unacceptable

Plan View Image Download and Quality Check

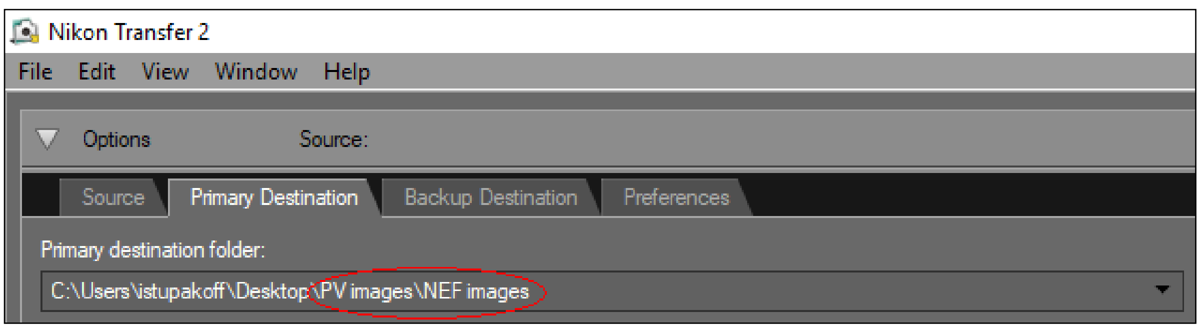
1. Connect plan view USB cable to plan view camera USB port (6 pin).
2. Connect PHIHONG AC/DC converter to USB white power plug.
3. Connect PHIHONG AC/DC converter to extension cord.

   Note: If water on deck, do not use power cord.
4. Connect plan view USB cable to MESA2 Tablet USB port.
5. Start ViewNX 2 downloading software.

6. In ViewNX 2, click on Transfer.



7. After images upload, click on the Primary Destination tab.



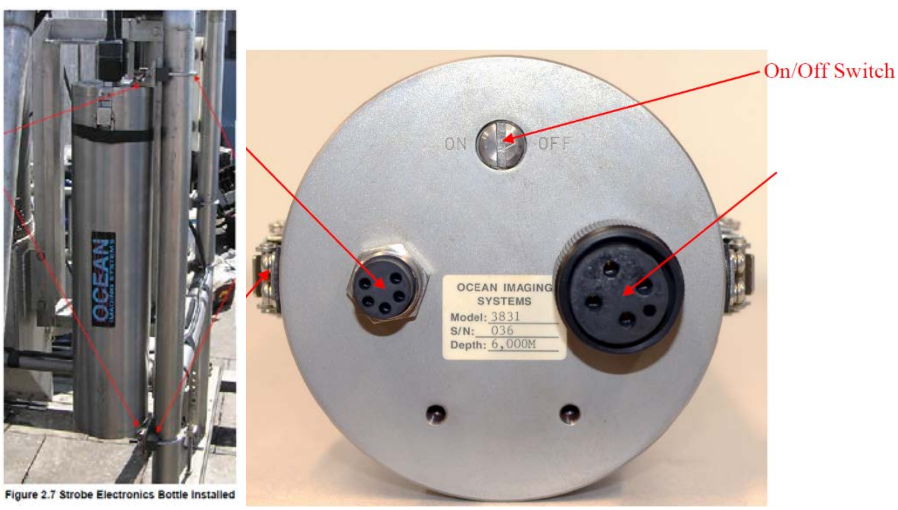
8. Transfer the images in the following order to appropriate directories:
   a. PV—NEF, then → PV—JPEG
   b. ***Create image file folders on desktop for ease of locating folders in the future.***
9. Once directory is set and images appear on the desktop, click on the Start Transfer button.

10. After downloading the NEF files, the program will ask if you want to continue downloading the next memory card; click "NO."

11. Choose the next directory for JPEG images as mentioned in Step 8.a above and download images.
12. Once images are downloaded, remove USB cable and reconnect USB dummy plug on plan view camera.
13. In ViewNX2, go to the JPG folder and assess if images are acceptable.
14. Reject plan view images if disturbance on water column was caused by previous drop or if strobe light did not fire and a black image was captured.

Image obscured by suspended sediment

15. Switch off power when done sampling.



Closing Up at End of Survey Day

1. Upon completion of each survey day and field survey event, wash the outside components of the SPI–PV camera system with fresh water.
2. Use compressed or canned air to remove water from around the bulkhead connectors and connector adapters, the on/off switch, and the frame counter window.

3. Leave the camera on the unit overnight if the unit/boat is in a protected and secured area. If not in a secured area, remove the camera housing and place inside the boat cabin.
4. Open the pressure housing only if a battery needs to be replaced or internal components need to be inspected. Otherwise, wash the pressure housing with fresh water, dry, and stow it in its secure case. If the pressure housing is opened, take special care to ensure that water does not sit in the main O-ring grooves at the base of the pressure housing.
5. Use low-pressure compressed air to remove water from the switch cam, connector adapters, and frame counter window before the camera housing is opened and after the survey is complete.

Downloading and Managing Data

The following steps are generic and may change according to data quality objectives for each project. Consult the project's field sampling plan (FSP) and quality assurance project plan (QAPP) for further details in file naming conventions and data management.

1. Before deployment of the SPI–PV system, synchronize the field laptop with date and time of the navigational system being used for the project. Once that synchronization is made, synchronize each D7100 Nikon camera in the SPI–PV system to the laptop clock. Each SPI–PV station replicate is identified by the time recorded in the digital image file and the corresponding time and position recorded by the GPS navigation system.
2. In the field log, note the date, crew, weather conditions, and the initial camera setup specifications such as stop height, number of weights, mud doors on/off, and any other noteworthy details. The field crew will keep redundant field logs.
3. Record the following items in the field log for each drop of the camera: station ID, replicate, time on bottom, and the observed water depth.
4. For each station or whenever the camera is brought to the surface, record the penetrometer measurement.
5. Finally, record whenever an adjustment is made (e.g., stop settings or weights adjusted) in the field log.

Processing and Analyzing SPI–PV Images

1. When the SPI–PV system is brought up on deck, download all photos to the dedicated field laptop computer.

2. Confirm and document on the data tracking sheet the evaluation of image quality and verification of adequate image replication at each occupied station. It is important to update the tracking sheet to confirm that all replicates for each station are accounted for and that an adequate image has been obtained.
3. Populate the tracking sheet with station name, date and time of photo, water depth, station coordinates, and general notes.
4. Label each image in the field as time allows or at the conclusion of the sampling event, following the specified naming convention listed in the project-specific FSP and/or QAPP.
5. At the conclusion of the survey, confirm with the project manager that the final image data set is complete.

The SPI–PV images will be analyzed with the aid of the iSPI software.

Currently, the field team handoffs information to the image analyst (and ultimately the data manager) through a Microsoft® Excel template. The template serves two purposes:

- To ensure that the field team has recorded and documented key sampling information needed to support image analysis
- To provide the parameters needed to initialize the image processing software.

The image analysis software is configured to read the Microsoft® Excel template and lead the image analyst through a series of processing steps to derive metrics for each SPI image. Once the template has been imported, all of its content, along with all of the derived metrics and supporting info developed during image analysis, is stored as a MATLAB data file. The software keeps track of what information (derived during image analysis) has undergone a quality assurance check and been subjected to senior review.

The user can then choose to export key metrics as a standardized flat file that can be uploaded to Integral's database (IDB). The data destined for IDB will include any and all metrics that can be shared with the client or have easy access for further analysis in the future.

Demobilizing at End of Project

Once the project is complete, or if the project will extend more than 2 weeks, a series of steps is taken to maintain proper functioning of the SPI system, its disassembly, packing, and long-term storage. Additional information is provided for shipping the entire system in cases.

Washout

1. Thoroughly wash the SPI unit with fresh water before disassembling it, ensuring that the SPI frame base is free of any sediment.

2. If the unit has been exposed for periods longer than a week in waters rich in dissolved organic matter, use a diluted solution of laboratory-grade detergent (e.g., Liquinox) and a soft plastic brush to clean the unit. Do not brush sensitive areas such as the prism Plexiglas faceplate and the plan view camera dome. Instead, use a soft wet cloth to remove the organic grime before rinsing with clean fresh water.
3. If time permits, air dry the unit before disassembly. If not, dry the unit with towels.

Disassembly

Perform the disassembly of the SPI system in reverse order from how it was assembled as described at the beginning of this SOP.

1. Disconnect the cables from the cameras and strobe units and replace with respective dummy plugs.
2. Remove the prism draining and filling bolts and allow the prism to empty.
3. Detach the SPI camera and plan view camera with strobe unit from the frame and remove the batteries for recharging.
4. Store the camera housings in individual shipping cases.
5. Disassemble the prism and frame assembly and store in respective shipping cases.

Packing

Each piece of the SPI system has its own dedicated storage case. All storage cases are foam padded and are built to sustain normal wear during transport. Inspect cases for cracked lids, faulty latches, or failing foam pads. If any of these cases are compromised, there is a high risk of failure and possible damage to the equipment, as well as harm to people handling the equipment. If defects or damages are observed, alert the field lead and have the case replaced as soon as possible.

Storage

Storage instructions for the cameras and frame structure are detailed below.

Cameras—After every project, or after every week on a project, remove the SPI camera and plan view camera from the frame, and open in a protected environment. Perform the following steps:

1. Remove the O-rings.
2. Clean O-ring groves on stainless steel pressure housing.
3. Dust off any particles from grooves with compressed air.
4. Inspect each O-ring for cracks or creases and replace if needed.
5. Reapply silicone grease sparingly to O-rings. No excess grease should be visible.

6. Reinstall O-rings in respective grooves.
7. Remove and replace desiccant packages and humidity indicators with new ones.
8. Disconnect and recharge all batteries.
9. Replace recharged batteries but do not reconnect them to the cameras.
10. Seal pressure housing and stow it away in its proper case.

Frame structure—After all stainless steel structures have been washed and dried, perform the following:

1. Disassemble the frame.
2. Undo every nut and bolt and soak them in distilled water for a few minutes to remove salts from the threads that cannot be removed when washing the structure.
3. Grease all nuts and bolts with lithium grease and store in re-sealable plastic bags or hardware box.
4. Wipe clean any polished surfaces with a clean cloth to remove smudges that could potentially corrode or stain the surface.
5. Place equipment in its respective storage cases and stow away.

Shipping

Shipping of the SPI system must be arranged in advance because of its weight (1,667 lb) and the number of cases (18) to be transported. Obtain information on transportation limitations as soon as possible. Make sure that the transport company knows the dimensions and weights of each equipment case. Determine if reservations are needed and how far in advance they need to be made prior to shipping day. Inquire if the transport facility has the right equipment (e.g., forklift) to move the cases.

Integral owns two shipping crates with lids that can accommodate all 18 loose cases.

When shipping crates via freight, codes are required by the carriers. Below is an example of the required codes from FedEx.

HANDLING UNITS (H/U)	H/U PKG. TYPE	PIECES	HM (X)	DESCRIPTION OF ARTICLES, KIND OF PACKAGE, SPECIAL MARKS AND EXCEPTIONS (subject to correction)	WEIGHT IN LBS.	NMFC ITEM # (subject to correction)	CLASS	CUBE (OPTIONAL)
		1		Steel frame, tool boxes with hand tools, power tool, lead weights, strobe light with NiCd batteries	1,471	109700-08	85	
		1		Underwater cameras (3), stainless steel prism for underwater camera (1)	609	039620-00	125	

Lithium ion batteries—Complete a special manifest and place the document within the cases containing the lithium ion (Li-ion) batteries. Although the procedure is simple, it does require more paperwork and additional delays can occur when shipping the units via air freight. Remove all Li-ion batteries from the cases and transport as a carryon on the plane. There are three Li-ion batteries on the plan view camera case; one battery is inside the plan view housing and two extra batteries are in a plastic bag inside the plan view case.

Insurance—Make sure that the SPI system insurance policy is active and up-to-date. Contact Craig McDaniel, Integral Contracts and Risk Manager, at 719-649-2967 with any questions related to insurance coverage if any of the equipment is detained at customs, damaged, or lost during transport.

Figure 8 shows a typical setup of all the shipping cases stowed into one cargo van to be transported to an air cargo facility. (The two upper left coolers with white lids contain a double van Veen grab sampler and are not part of the SPI–PV system.) The black tote and blue cooler on the right contain the tool box and ancillary maintenance equipment.

Figure 8. Cargo Van Containing a Complete SPI–PV Setup

REFERENCES

OIS. 2015a. Instructions for the operation and maintenance of the Ocean Imaging Systems Model 3731-D 4,000 meter digital sediment profiling camera. M-373-035036. Ocean Imaging Systems, Pocasset, MA.

OIS. 2015b. Instructions for installing a DSC-24,000 digital camera system and 3831 Strobe on a Model 3731D REMOTS. M-24000-3731_001. Ocean Imaging Systems, Pocasset, MA.

OIS. 2015c. Instructions for the operation and maintenance of the Ocean Imaging Systems 200 W-S remote head strobe Model 3831, 17-4PH housing rated for 6,000 meters. M-3831-036. Ocean Imaging Systems, Pocasset, MA.

OIS. 2015d. Instructions for the operation and maintenance of the Ocean Imaging Systems, 6,000 meter, 17-4PH Model DSC 24,000 digital still camera (with wide angle dome). M-24000-002. Ocean Imaging Systems, Pocasset, MA.

Rhoads, D.C., and J.D. Germano. 1982. Characterization of organism-sediment relations using sediment profile imaging: An efficient method of remote ecological monitoring of the seafloor (REMOTS™ system). *Mar. Ecol. Prog. Ser.* 8:115–128.

Rhoads, D.C., and J.D. Germano. 1986. Interpreting long-term changes in benthic community structure: A new protocol. *Hydrobiologia* 142:291–308.

ATTACHMENT 1. SPI CAMERA PRE-DEPLOYMENT QA CHECKLIST

This pre-deployment QA checklist ensures that the SPI camera has been tested and is ready for deployment in the field. Consult the user manuals for detailed operations of the SPI camera.

Name ______________________________ Date ____________ Time __________

Job Number ______________ Project Title ______________________________

SPI Camera Hardware Setup

1. ☐ Replace lead acid battery with newly charged one. Charge used lead acid battery. There are two lead acid batteries, one for each SPI Nikon camera, which are charged overnight with respective lead acid battery chargers. Only the SPI camera requires use of lead acid batteries.
   Battery 1 ______mV, Battery 2 ______mV
2. ☐ Remove and clean O-rings on the SPI stainless steel housing.
3. ☐ Re-grease O-rings with small amount of silicone grease. Remove excess grease.
4. ☐ Re-install O-rings on SPI stainless steel housing.
5. ☐ Replace humidity indicator card and desiccant as needed.
6. ☐ Turn Nikon D7100 camera on.
7. ☐ Check that two SD cards are in the side slots.
8. ☐ Check that all cable connections to the camera are snug and tight.
9. ☐ Check that white plug from battery is connected to SPI board before closing.
10. ☐ Reset SPI counter to zero.
11. ☐ Turn system on via the switch on the pressure housing end cap. The frame counter should now light up for 10 seconds showing a count of zero.
12. ☐ Manually activate trigger switch.

SPI Camera Settings and Test

1. ☐ Connect SPI USB download cable from laptop to SPI camera using optical USB cable.
2. ☐ On field laptop, launch Nikon Camera Control Pro 2.
   User manual:
   http://crossgate.nikonimglib.com/dsd_redirect/redirect.do?P=lewOP13&R=gg4EB85&L=StWKd01&O=1vMN900

3. ☐ Under <u>Camera Menu</u>: Set date and time.
   - Synchronize camera date and time with field laptop.
   - Make sure laptop set to local time before synchronization.
4. ☐ Under <u>Image Menu, Exposure 1 Tab</u>:
   - Aperture: f 10
   - Shutter speed: 1/60 sec
5. ☐ Under <u>Image Menu, Exposure 2 Tab</u>:
   - Metering: Matrix
   - ISO: 400
   - White Balance: Flash
6. ☐ Under <u>Image Menu, Storage Tab</u>:
   - Image quality: NEF + JPEG
   - JPEG Compression: Optimal quality
   - Image area: DX (24x16)
   - Image size: Large (6,000x4,000)
   - NEF Recording
     - Raw image size→Image size: Large (6,000x4,000)
     - Type: Lossless compressed
     - Bit depth: 14-bit
   - Record to: Card
   - Card Record Mode: NEF in slot 1, JPEG in slot 2
7. ☐ Under <u>Image Menu, Image Processing Tab</u>:
   - Picture control: Standard
   - Color space: sRGB
   - Active D-lighting: Off
   - High ISO NR: On (Normal)
8. ☐ At bottom of <u>Image Menu</u> window click on "Shoot" button
   - Check that camera actually triggered and took a picture.

Nikon Camera Control Pro 2 settings and test are complete. Close application.

9. ☐ Launch Nikon ViewNX 2 Software (32-bit and 64-bit editions): http://downloadcenter.nikonimglib.com/en/download/sw/20.html
10. ☐ In Nikon ViewNX 2, check/complete the following:
    - ☐ All images display correct date and time synched to laptop local time
    - ☐ Metadata for all images shows all settings as specified above
    - ☐ Delete all files from SD cards for both NEF and JPEG.

The camera is now ready to be mounted on SPI frame.

SPI Camera Setup and Test

1. ☐ Install SPI camera inside prism on SPI frame.
2. ☐ Connect all cables.
3. ☐ Connect cable to trigger switch.
4. ☐ Turn system on via the switch on the pressure housing end cap.
5. ☐ Place Kodak color card over prism window.
6. ☐ Trigger switch for first time and check that strobe goes off after 10-second interval.

SPI camera is now ready for deployment.

SPI Camera and Image Downloading Cable Setup

1. ☐ Spray SPI camera USB dummy plug with compressed air to dislodge any water.
2. ☐ Remove dummy plug and connect download USB cable to SPI camera and to MESA2 tablet.
3. ☐ On MESA2 tablet, start Nikon ViewNX 2 program, connect to camera, and transfer NEF and JPEG images from SPI camera to tablet.

Packing List for SPI Camera Pelican Cases (blue [serial #035] and orange [serial #036] color-coded cases)

- SPI stainless steel camera housing
- Nikon D7100 camera with lead acid battery
- Trigger mechanism
- Trigger cable
- USB download cable

- One extra lead acid battery
- Lead acid battery charger
- Bag with extra O-rings
- Bag with extra zip ties
- Bag with desiccant pouches and humidity indicator strips

ATTACHMENT 2. PLAN VIEW CAMERA PRE-DEPLOYMENT QA CHECKLIST

This pre-deployment QA checklist ensures that the plan view camera has been tested and is ready for deployment in the field. Consult the user manuals for detailed operations of the plan view camera.

Name ______________________________ Date __________ Time ________

Job Number _______________ Project Title ______________________________

Plan View Camera Hardware Setup

1. ☐ Replace Li-ion battery with newly charged one. Charge used Li-ion battery. There are three small black Li-ion batteries, one from each Nikon camera, which are charged overnight with respective Nikon chargers. Only the camera in the plan view housing requires use of Li-ion batteries.
   Battery 1 ______mV, Battery 2 ______mV, Battery 3 ______mV
2. ☐ Remove and clean O-rings on plan view stainless steel housing.
3. ☐ Re-grease O-rings with small amount of silicone grease. Remove excess grease.
4. ☐ Re-install O-rings back on plan view stainless steel housing.
5. ☐ Check focal length setting on camera lens (e.g., close to 0.25 for distance of 1 m [3 ft]).
6. ☐ Replace humidity indicator card and desiccant as needed.
7. ☐ Turn Nikon D7100 camera on.
8. ☐ Check that two SD cards are in the side slots.
9. ☐ Check that all cable connections to the camera are snug and tight.
10. ☐ Check that all white plugs from camera are connected to plan view board before closing.
11. ☐ Check camera lobe (top) is pointing towards the long side of the laser when closing.
12. ☐ Apply electrical tape over latches and around housing for extra safety.

Plan View Camera Settings and Test

1. ☐ Connect USB cable from laptop to plan view camera.
2. ☐ Connect PHIHON 24V DC power supply to white plug attached to USB cable.

3. ☐ On field laptop, launch Nikon Camera Control Pro 2.
User manual:
http://crossgate.nikonimglib.com/dsd_redirect/redirect.do?P=lewOP13&R=gg4EB85&L=StWKd01&O=1vMN900

4. ☐ Under **Camera** menu: Set date and time
   - Synchronize camera date and time to field laptop.
   - Make sure laptop is set to local time before synchronization.

5. ☐ Under **Image** menu, **Exposure 1** tab:
   - Aperture: f 16
   - Shutter speed: 1/30 sec

6. ☐ Under **Image** menu, **Exposure 2** tab:
   - Metering: Matrix
   - ISO: 400
   - White Balance: Flash

7. ☐ Under **Image** menu, **Storage** tab:
   - Image quality: NEF + JPEG
   - JPEG Compression: Optimal quality
   - Image area: DX (24x16)
   - Image size: Large (6,000x4,000)
   - NEF Recording
     - Raw image size→Image size: Large (6,000x4,000)
     - Type: Lossless compressed
     - Bit depth: 14-bit
   - Record to: Card
   - Card Record Mode: NEF in slot 1, JPEG in slot 2

8. ☐ Under **Image** menu, **Image Processing** tab:
   - Picture control: Standard
   - Color space: sRGB
   - Active D-lighting: Off
   - High ISO NR: On (Normal)

9. ☐ At bottom of **Image** menu window, click on **Shoot** button.
   - Check that camera actually triggered and took a picture.
10. ☐ Click on **Lv** button to see live image from camera on laptop.
   - Check that no edges of glass dome are showing at the edges of photo.
   - If edges are showing, open housing and re-adjust camera with two back screws.

The Nikon Camera Control Pro 2 settings and test are now complete. Close application.

11. ☐ Launch Nikon ViewNX 2 Software (32-bit and 64-bit editions): http://downloadcenter.nikonimglib.com/en/download/sw/20.html
12. ☐ In Nikon ViewNX 2, check/complete the following:
   - ☐ All images display correct date and time synched to laptop local time
   - ☐ Metadata for all images shows all settings as specified above
   - ☐ No edges of glass dome are showing in picture
   - ☐ Delete all files from SD cards for both NEF and JPEG.

The camera is now ready to be mounted on SPI frame.

Plan View Camera and Strobe Light Setup and Test

1. ☐ Install lasers on plan view camera and connect to strobe battery pack before attaching to SPI frame.
2. ☐ Calibrate laser lights.
3. ☐ Install plan view camera, strobe light, and strobe battery on SPI frame.
4. ☐ Connect all cables.
5. ☐ Connect lead weight to plan view trigger switch.
6. ☐ Turn on battery and check that both lasers are on.
7. ☐ Place Kodak color card under plan view camera and remove yellow plastic cover from plan view dome lens.
8. ☐ Trigger switch for first time and check that strobe goes off twice with a 10-second interval between flashes.

Plan view camera is now ready for deployment.

Plan View Camera and Image Downloading Cable Setup

1. ☐ Turn off the strobe battery on the SPI frame once back on deck.
2. ☐ Set up AC extension power cord to connect to power supply and plan view camera.
3. ☐ Set up optical USB cable to be plugged between laptop and plan view camera.
4. ☐ Connect download USB plug to both plan view camera and optical USB cable via USB Y-split cable extension.
5. ☐ Connect optical USB cable to laptop computer.
6. ☐ Connect power supply (PHIHONG) to USB download cable white power plug. **Do not connect to live extension cord yet!**
7. ☐ Connect PHIHONG power converter to extension cord and connect extension cord to AC plug on wall inside cabin. **Alert field crew outside that power is on**.
8. ☐ After downloading images, reverse steps 1–7 above to disconnect plan view camera. Make sure AC plug is turned off first.

Health and Safety: Since the AC outlet will be exposed on deck, make sure the outlet is not placed on standing water and is always in line of sight.

Packing List for Plan View Camera Pelican Case (yellow color-coded case)

- Plan view stainless steel camera housing
- Nikon D7100 camera with Li-ion battery
- Laser wire T-shape wire harness
- Two lasers (mounted on short and long plates) and bag of screws to attach to plan view housing
- USB download cable equipped with DC power plug
- PHIHONG 24V DC power supply
- Burst mode cable
- RS 232 control cable
- Charger for NiCd battery for strobe light (red box)
- Two extra Li-ion 20 batteries for Nikon D7100 camera
- Li-ion 20 battery charger
- Voltmeter (green)
- Two U-clamps for plan view camera front bracket mount on SPI frame

- Bag with extra dummy plugs
- Trigger cable for strobe light
- Optical USB cable for image download
- 2–3 lb lead weights for strobe trigger

ATTACHMENT 3. STROBE HEAD AND BATTERY PRE-DEPLOYMENT QA CHECKLIST

This pre-deployment QA checklist ensures that the strobe head and battery assembly (OIS Model 3831, 6,000 meter) for the plan view camera has been tested and is ready for deployment in the field. Consult User Manuals for detailed operations.

Name ________________________________ Date __________ Time ________

Job Number _______________ Project Title ________________________________

Strobe Head and Battery Housing Setup

1. ☐ Make sure strobe battery housing power switch is turned off and that the strobe trigger has been activated to discharge any standing electrical charges.
2. ☐ Open housing and remove battery assembly.
3. ☐ Disconnect white plug from battery located in the middle of the assembly unit.
4. ☐ Remove desiccant and humidity indicator strip from bottom of assembly.
5. ☐ Charge spent battery using a general purpose battery charger/discharger for the 24 VDC, 5 Amp-Hour Ni-Cd battery (http://www.electrifly.com).

   Follow the guidelines below for maximum battery performance and life:

   - Always remove the battery from the strobe when not in use.
   - Store the battery in a charged state.
   - Every 4 months, discharge and recharge the battery.
   - Never allow the battery to be fully discharged by the strobe.

   There are two large white Ni-Cd batteries (average full charge ranges between 27.8 V and 28.1 V).
   Battery 1 _____V Battery 2 _____V

6. ☐ Remove and clean O-rings on strobe battery stainless steel housing.
7. ☐ Re-grease O-rings with small amount of silicone grease. Remove excess grease.
8. ☐ Re-install O-rings back on strobe battery stainless steel housing.
9. ☐ Replace charged battery into assembly unit and secure end plate with thumb screws.

   A small spark may occur when connection is made. This is normal.

10. ☐ Replace humidity indicator card and desiccant as needed. Secure with rubber band.
11. ☐ Seal strobe housing with closure latches.
12. ☐ Mount plan view camera trigger switch on SPI frame and reapply WD-40.
13. ☐ Mount strobe head and battery housing on SPI frame.
14. ☐ Adjust strobe head angle.
15. ☐ Connect 4-pin power cable from battery housing to strobe head.
16. ☐ Connect 5-pin cable from battery housing to plan view camera housing.
17. ☐ Connect trigger cable from plan view camera housing to trigger switch.
18. ☐ Attach lead weight with leader to trigger switch.
19. ☐ Turn battery housing switch on.
20. ☐ Lift plan view trigger switch to obtain a flash.

If flash goes off, the strobe head and battery housing are now ready for deployment.

Packing List for Strobe Head and Battery Housing Pelican Case (yellow color-coded case)

- Strobe head
- Extra flash bulb
- Battery assembly stainless steel housing
- Extra Ni-Cd battery
- Three brackets for mounting plan view camera
- Brackets for stainless steel housing
- Cables for connecting strobe head to battery housing

Appendix A3

Benthic Invertebrate Collection Standard Operating Procedures

STANDARD OPERATING PROCEDURE (SOP) BT-12

BENTHIC MACROINVERTEBRATE SAMPLING USING A GRAB SAMPLER

SCOPE AND APPLICATION

This SOP describes the procedures used to sample benthic macroinvertebrate assemblages by using a grab sampler (e.g., modified van Veen, Ekman, Ponar). Benthic assemblages are typically analyzed for the abundances and biomass of various species and major taxa. The project-specific field sampling plan (FSP) should stipulate the number of replicate samples (i.e., individual grabs) that need to be collected at each station. The personnel performing the benthic macroinvertebrate collection and sample processing will wear protective clothing as specified in the site-specific health and safety plan.

All benthic macroinvertebrate samples will be packaged and shipped in accordance with procedures outlined in SOP AP-01, *Sample Packaging and Shipping*. Sample custody will be maintained in accordance with procedures outlined in SOP AP-03, *Sample Custody*. Field activities will be recorded in accordance with procedures outlined in SOP AP-02, *Field Documentation*.

The grab sampler used for benthic infauna studies should be capable of collecting acceptable samples from a variety of substrates, including mud, sand, gravel, and pebbles (APHA 1991). The procedures for sampling benthic macroinvertebrate assemblages by using a grab sampler are described below.

EQUIPMENT AND REAGENTS REQUIRED

Equipment required for benthic macroinvertebrate sampling includes the following:

- Grab sampler (e.g., modified van Veen, Ekman, Ponar)
- Winch and hydrowire (if grab sampler is of considerable weight) with load capacities ≥3 times the weight of a full sampler
- Sample collection table (if vessel deck space allows)
- Sample collection tub
- Ruler

- Sieve(s) (typically with a 0.595-mm mesh for freshwater studies or a 1.0-mm mesh for marine studies; consult project-specific FSP for correct sieve size); multiple sieves can be stacked on top of each other to capture different size fractions of benthic macroinvertebrates that will be processed separately; consult project-specific FSP for correct number of sieves
- Scoop (for transferring sediment sample aliquots to the sieve)
- Sample containers (clean, 1-L wide mouth plastic jars with plastic screw-on lids)
- Internal labels
- 10 percent buffered formalin
- Rose bengal (depending on study objectives, rose bengal stain may or may not be added; consult project-specific FSP)
- Scrub brush and soft-bristle nylon brush or toothbrush
- If necessary, socket and crescent wrenches (for adding or removing detachable weights of the grab sampler)
- Water pump and hose (for sieving samples and for rinsing the grab sampler, sample collection tub, and sample collection table).

PROCEDURES

Grab Sampler Deployment

1. Prior to deployment, clean the inside of the grab sampler with a scrub brush and site water.
2. Consult SOP SD-04, *Surface Sediment Sampling,* for the correct deployment techniques for the appropriate grab sampler.
3. Lower the sampler through the water column at a slow and steady speed (e.g., 30 cm/second).
4. Allow the grab sampler to contact the bottom gently, with only its weight being used to force it into the sediments. Never allow the sampler to “free fall” to the bottom because this may result in premature triggering, or improper orientation upon contact with the bottom.

Grab Retrieval

1. After the grab sampler has rested on the bottom for approximately 5 seconds, begin retrieving it at a slow and steady rate (e.g., 30 cm/second).

2. Ensure that the sampling vessel is not headed into any waves before the sampler breaks the water surface to minimize vessel rolling and potential sample disturbance.
3. After the grab sampler breaks the water surface and is raised to the height of the sample collection table or sample collection tub, rinse away any sediments adhering to the outside of the grab sampler (it is essential that the sediments adhering to the outside of the grab are removed because those sediments and any associated benthic macroinvertebrates are not part of the sample).
4. After finishing the rinsing, raise the grab sampler above the height of the collection table or sample collection tub, swing it inboard, and gently lower it into the sample collection tub on the sample collection table while maintaining tension on the hydrowire to prevent the grab sampler from rolling when it contacts the bottom of the tub.
5. When the grab sampler contacts the bottom of the table or tub, insert wedges under both jaws, if necessary, so that the grab sampler is held in an upright position.
6. Open the doors on the top of the grab sampler, and inspect the sample for acceptability. The following acceptability criteria should be satisfied:
   - The sampler is not overfilled with sample to the point that the sediment surface presses against the top of the sampler or is extruded through the top of the sampler (organisms may have been lost)
   - Overlying water is present (indicating minimal leakage)
   - The overlying water is not excessively turbid (indicating minimal disturbance or winnowing)
   - The sediment surface is relatively undisturbed; the sediment–water interface is intact and relatively flat with no sign of channeling or sample washout
   - The desired penetration depth is achieved (see project-specific FSP); the following penetration depths should be achieved at a minimum:

     4–5 cm for medium-coarse sand
     6–7 cm for fine sand
     >10 cm for silty sediment
   - There is no sign of sediment loss (incomplete closure of the sampler, penetration at an angle, or tilting upon retrieval).

If a sample fails to meet the above criteria, reject it and discard it away from the station. Keep the location of consecutive attempts as close to the original attempt as possible, and if sampling on a river or stream, make consecutive attempts in the "upstream" direction of any existing current. Discard rejected sediment samples in a manner that does not affect subsequent samples at that station or other possible sampling stations.

Determine penetration depth by placing a ruler against the center of the inside edge of the opening on the top of one side of the grab sampler and extending it into the grab sampler until it contacts the top of the sample. The penetration depth is determined by the difference between that measurement and the total depth of the grab sampler.

Sample Removal and Processing

1. For each acceptable sample, characterize the sample as specified in the study design. Characteristics that are often recorded include the following:
   - Sediment type (e.g., silt, sand)
   - Texture (e.g., fine-grain, coarse, poorly sorted sand)
   - Color
   - Biological structures (e.g., chironomids, tubes, macrophytes)
   - Approximate percentage of biological structures
   - Presence of debris (e.g., twigs, leaves, wood chips, wood fibers, manmade debris)
   - Approximate percentage of organic debris
   - Presence of shells
   - Approximate percentage of shells
   - Presence of a sheen
   - Odor (e.g., hydrogen sulfide, oil, creosote)
   - Changes in sediment characteristics
   - Presence and depth of redox potential discontinuity layer (if visible)
   - Maximum penetration depth
   - Distinctions in sample quality (i.e., leakage, winnowing, disturbance).
2. After characterizing the sample, open the jaws of the grab sampler so that its contents (i.e., sediments and overlying water) are released into the sample collection tub.
3. Rinse any remaining sediment inside the grab into the collection tub, being careful not to overfill the tub with water.
4. Before sieving each sample, examine all sieves for damage and wear. Look for rips in the mesh, irregular mesh spacing, and sand grains caught in the mesh. Use water pressure or a soft nylon brush to dislodge sand. DO NOT use sharp objects or stiff brushes, as the mesh may be damaged or torn.
5. After the entire sample has been collected in the sample collection tub, carefully transfer aliquots of the sample to the sieve by using a scoop.

6. Sieve each sample aliquot by rotating the sieve (in an up-and-down, not swirling, motion) in a bucket of water or by passing a gentle stream of water through the sieve from above or using a combination of these techniques. By whatever method is used, wash the samples *gently* to minimize specimen damage.
7. After sieving each aliquot, carefully rinse all of the retained material into a sample container, and carefully check the sieve to ensure that no organisms are trapped in its mesh (do not fill any sample container more than three-quarters full to ensure that a sufficient amount of space is available for the preservative).
8. If an organism is found trapped in the sieve, dislodge it with a gentle stream of water or by using forceps, and transfer it to the sample container.
9. Continue sieving aliquots of the sample until the entire sample has been processed.
10. Thorough and carefully rinse off any large stones or other debris in the sample too large to fit in the sample jar into the sieve, remove and discard them under the supervision of the field team leader, and make a note in the field logbook.
11. After sieving the entire sample, clean the sieve by turning it over and back-washing it with a high-pressure spray to dislodge any sediment grains or detritus that are lodged in the mesh.
12. Fix each sample by filling each sample container with a 10–15 percent solution of borax-buffered formalin and inverting the container at least five times to ensure that the preservative penetrates all parts of the sample.
13. Depending on the sampling environment and the preferences of the taxonomic laboratory, the samples may be dyed with rose bengal (see project-specific FSP). If required, rose bengal should be added to the formalin solution prior to fixing the samples.
14. Label each sample container (both internal and external labels are required; see below), and store it in a protective container.

Internal Labels

In addition to the label on the outside of the sample container (i.e., external label, see SOP AP-02, *Field Documentation*), a complete label must be placed inside each sample container. The internal label must be preprinted and should be made of at least 100 percent waterproof rag paper. The internal labels should be filled out using a pencil (i.e., no ink).

Sample Containers

Samples can be stored in various containers including glass or plastic jars, and plastic bags. Integral prefers that plastic jars with plastic screw-on lids (formalin corrodes metal) be used to store benthic macroinvertebrates samples. The use of this type of sampling container lessens the possibility of formalin leakage during shipping and the breaking or tearing of the sample container. In general, a single 500-mL or 1-L container is large enough to hold a sieved sample from a van Veen grab sampler, and 1-L container is large enough to hold a sieved sample from an Ekman or Ponar grab sampler. If the sample volume exceeds one-half of the container volume, more than one container should be used. Use of multiple containers for single replicates should be recorded in the field logbook.

After the buffered formalin has been added to a sample container, it is critical that the contents be mixed adequately. This usually can be accomplished by inverting the container several times (make sure that the lid is tightly screwed on). After mixing, the sample container should be placed in protective containers for storage and transport to the laboratory. After being stored for approximately 1 hour, samples should be inverted several times again to ensure adequate mixing. Onboard the sampling vessel, samples should be stored so as to minimize exposure to sunlight and temperature extremes. They should also be stored in a stable part of the vessel to minimize agitation.

Buffered Formalin Preparation

The preservative most commonly used for marine benthic macroinvertebrate samples is formalin, an aqueous solution of formaldehyde gas. However, for freshwater benthic macroinvertebrates, ethanol or isopropanol is the most commonly used preservative. Under no circumstances should ethanol or isopropanol be used as a preservative in place of the formalin for marine organisms. Penetration of the alcohol into body tissues is too slow to prevent decomposition of the marine specimens.

Solutions of 10–15 percent buffered formalin are most commonly used to preserve samples collected from the marine environment and solutions of either 95 percent ethanol or 30–40 percent isopropanol are most commonly used to preserve samples collected from freshwater systems. However, samples containing large amounts of organic debris (e.g., peat, woody plant material) may require higher concentrations. The volume of preservative should be at least twice the volume occupied by the sample. If possible, the preservative solution should be added to the sample container until it is completely filled. This will minimize abrasion during shipping and handling. It is recommended that at least 2 L of diluted preservative solution be on hand for each replicate van Veen grab collected and at least 0.75 L of diluted preservative solution be on hand for each replicate Ekman or Ponar grab collected.

If formalin is used as the preservative solution, it should always be buffered to reduce acidity. Failure to buffer may result in decalcification of molluscs and echinoderms. Ideally, pH should be at least 8.2, as calcium carbonate dissolves in more acidic solutions. Borax (sodium borate) should be used as the buffer because other buffering agents may hinder identification by leaving a precipitate on body tissues.

To prepare a 10 percent buffered formalin solution, add 4 oz of borax to each gallon of concentrated formalin (i.e., a 40 percent solution of formaldehyde in water). This amount will be in excess, so use the clear supernatant when making seawater dilutions. Dilute the concentrate to a ratio of one part concentrated formalin to nine parts site water (sea water or tap water). If seawater is used, it will further buffer the solution. Fresh buffered formalin should be made prior to each sampling event, because formalin will eventually consume all of the buffering capacity of the borax.

Rose Bengal Preparation

If staining is used (see project-specific FSP), rose bengal is often added to the buffered formalin as a vital stain to facilitate sorting benthic organisms. The stain colors most infauna and thereby enhances their contrast with the debris from which they are sorted. Taxa that do not always stain adequately include ostracods and gastropods. Be careful when adding rose bengal to the buffered formalin solution. Add only a very small amount (e.g., a few drops or grains) of rose bengal; a little rose bengal goes a very long way. Remember, you can always add more stain to the buffered formalin if you need to, but you can not remove the rose bengal once it has been added.

REFERENCES

APHA. 1991. Standard methods for the analysis of water and wastewater. 18th ed. American Public Health Association, American Water Works Association, Water Pollution Control Federation, Washington, DC.

Appendix B

Addendum to Site Quality Assurance Project Plan

- Appendix B1. Sorting and Identification of Benthic Invertebrates Standard Operating Procedure

Appendix B.
Addendum to Field Sampling Plan—
Thin Layer Capping Pilot Project Pre-Design Investigation Work Plan

This Quality Assurance Project Plan (QAPP) Addendum has been prepared as a supplement to the QAPP prepared by WSP USA Environment & Infrastructure, Inc. (WSP) in March 2023 (WSP 2023). The QAPP and this QAPP Addendum have been prepared pursuant to the Consent Decree (Case No. 1.00-cb-00069-JAW, ECF No. 1187) between Maine People's Alliance and Natural Resources Defense Council, Inc. (NRDC) vs. HoltraChem Manufacturing Company, LLC, and Mallinckrodt US LLC entered by the U.S. District Court for the District of Maine on October 11, 2022, in accordance with Paragraph 31(c) of the Statement of Work (Appendix A to the Consent Decree).

This QAPP Addendum includes additional laboratory analysis procedures and information necessary for the completion of the scope of work outlined in the Thin Layer Cap Pilot Project Pre-Design Investigation Work Plan but not previously incorporated into the QAPP. This supplemental information is presented as Appendix B1, an overview of the content and purpose of which is described below.

Appendix B1. Sorting and Identification of Benthic Invertebrates Standard Operating Procedure

Appendix B1 provides the laboratory procedures necessary for the completion of sample preparation, sorting and picking, taxonomic identification, and calculation of community metrics relevant to the characterization of benthic invertebrate communities. It also includes details related to quality assurance and health and safety procedures for this method.

Appendix B1

Sorting and Identification of Benthic Invertebrates Standard Operating Procedure

STANDARD OPERATING PROCEDURE

SOP NO	SOP/TOX/750
REVISION NO.	002
COPY NO.	Original
DATE	10/28/03

TITLE: SORTING AND IDENTIFICATION OF BENTHIC INVERTEBRATES

CONTENTS **PAGE**

I. OBJECTIVE

The objective of this procedure is to prepare samples for taxonomic identification to the lowest practical taxon. It also provides a method to calculate community metrics and bioassessment, provides quality assurance procedures, and health and safety procedures.

II. MATERIALS AND EQUIPMENT

1. 500 micron and 1000 micron mesh metal or Nynex sieves
2. 95% ethanol in field or 70% ethanol for post sorting (Rose Bengal may be added to aid in sorting)

3. Assorted glass jars and vials with lids
4. Forceps and probes
5. Dissecting microscope
6. Light table
7. Glass and plastic sorting trays
8. Regionally appropriate taxonomic keys
9. Labels
10. Little giant 1.7 amp pump (model NK-2, or equivalent)
11. Flexible 3/8 inch diameter tube
12. Six gallon HDPE bucket
13. Squeeze bottle

III. PROCEDURE

1. Preparation of Samples for Taxonomic Identification

1.1 Prepare one sample at a time to ensure that the organisms remain well preserved.

1.2 For samples not sieved in the field, place the sample into a 1000-micron sieve, nested on a 500-micron sieve over a six-gallon bucket. Using a small pump, gently rinse the sample with copious amounts of fresh tap water or site water, while turning the sample over by hand. Large samples may require multiple steps to complete the process. Samples with large amounts of coarse particulate matter may require placing the sample into a plastic tray and flooding the sample with water prior to sieving. Discard the material that flows through the sieve. If sample is sieved in field, use smaller sieves and use washbasin sinks to get rid of material.

1.3 Using a squeeze bottle, rinse the sieved sample into the sample container and label it sieved. Add 95% ethanol to top off the sample container.

2. Sorting and Picking Samples

2.1 Working with small aliquots, place sample into the glass tray with a small amount of appropriate water. Place the glass tray on the light box and carefully sort through the sample. Remove all organisms and place into labeled sample vial containing 70% ethanol or 10% formalin.

2.2 Repeat until the entire sample has been sorted. If necessary to halt picking on a rinsed sample, re-preserve the unsorted sample with 95% ethanol.

2.3 Return detritus to original sample container, and dispose accordingly.

3. To Perform Taxonomic Identification

3.1 Remove organisms from the container and place on a glass tray or other suitably sized translucent container.

3.2 Sort the sample by taxonomic Order and place the organisms from each taxonomic Order into their own suitably sized translucent container.

3.3 Using regionally appropriate taxonomic keys identify the organisms present to the lowest practical taxon, usually genus. If necessary, a dissecting microscope should be used to confirm identifying parts.

3.4 Enumerate the organisms on the benchsheet. Include taxonomic information regarding Class, Order, Family, Genus and species as appropriate. If necessary, appropriate measurements should be performed at this time and recorded on the benchsheet.

3.5 If allowed by work plan, subsampling can be accomplished by placing the sorted sample on a tray that is marked with a numbered grid. Randomly select a square using a random number generator and remove all organisms from the square (organisms partially in the square are selected if the head is in the square). Repeat until the number of desired organisms have been removed. However, when the desired number is reached, be sure to finish the square currently being counted.

4. To Calculate the Community Metrics

4.1 Enter the data into the Excel taxonomy spreadsheet template.

4.2 Appropriate metrics are usually work-order specific. Metrics are calculated according to the USEPA Rapid Bioassessment Protocol (EPA, 1999). Functional feeding groups are determined following Merritt and Cummins (1996) or by examining mouthparts.

Here are some examples of common metrics that can be calculated:

METRIC	DEFINITION
Abundance	Total # of organisms
Taxa richness	Total #'s of taxa
EPT index	# Of taxa in insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies) and Tricoptera (caddisflies)
EPT: Chironomid	Ratio of previous orders to Chironomids
Scrapers: Filterers	Ratio of two functional feeding groups
% Contribution of Dominant Taxa	Measures the dominance of single most abundant Taxon
Hilsenhoff Modified Biotic Index	Measure of tolerance to perturbation (see EPA.1989.)
Shannon-Weiner Diversity Index	Measures diversity of species in each individual sample (formula in appendix)
Evenness	Measures the relative abundance of individuals among the species (formula in appendix)
Biomass	Weight of organism per specified area (formula in appendix)

4.3 Comparisons to a field reference can be calculated on request. Biological condition categories can be generated for each station as compared to the reference. Intermediate scores may require field data from sampling crew to interpret.

5. Quality Assurance

5.1 All data entry is verified to guard against transcription errors.

5.2 All spreadsheets have been verified through manual calculation.

5.3 Spreadsheet calculations are spot-checked.

5.4 Examples from each identified taxa will be stored in the ASI Archive, and can be provided for independent verification.

5.5 There may be projects that require 10% of the samples to be QA/QC'd by an outside qualified taxonomist.

6. Health and Safety

6.1 Samples are to be sieved in a well-ventilated area. Utilization of respiratory equipment is dependent on the nature of the samples.

6.2 Gloves, safety goggles and labcoat are to be worn at all times.

IV. FORMS

Benthic Taxonomy Assessment Benchsheet.

V. REFERENCES

Freshwater Keys

- Adler, P.H. and K.C. Kim, 1986. *The Blackflies of Pennsylvania, Simuliidae, Diptera; Bionomics, Taxonomy, and Distribution.* Pennsylvania State University, University Park, PA.

- Epler, J.H., 1995. *Identification Manual for the Larval Chironomidae (Diptera) of Florida.* Florida Department of Environmental Protection, Tallahassee, FL.

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- Wiggins, G.B., 1996. *Larvae of the North American Caddisfly Genera (Trichoptera) University* of Toronto Press, Toronto, Ontario.

Saltwater Keys

- Appy, T.D. *et al.* 1980. A Guide to the Marine Flora and Fauna of the Bay of Fundy: Annelids; Polychaeta. Department of Fisheries and Oceans, St. Andrews, New Brunswick.
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- Gosner, K.L. 1978. Peterson Field guide to the Atlantic Seashore. New York, NY
- McGrath, R.A., 1973. Hudson River Ecology. 3rd Symposium on Hudson River Ecology. National Marine Fisheries Service, Sandy Hook, NJ.
- Niemeyer, V.B. and D.A. Martin, 1967 A Guide to the Identification of the Marine Plants and Invertebrate Animals at Tidewater Virginia. Virginia Institute of Marine Science, Gloucester Point, Virginia.
- Smith, R.I., 1964. Keys to Marine Invertebrates of the Woods Hole Region. Systematics Ecology Program, Marine Biological Laboratory, Woods Hole, MA.
- USEPA, 1986. Manual for Identification of Marine Invertebrates. US Environmental Protection Agency, Washington, DC.

VI. APPROVAL SIGNATURES

Prepared By: _Thomas J. Dolce_ Date 10/28/03
Thomas J. Dolce
Laboratory Manager

Approved By: _Thomas J. Dolce_ Date 10/28/03
Thomas J. Dolce
Laboratory Manager

Approved By: _Jon Doi_ Date 10-28-03
Jon Doi, Ph.D.
Executive Vice President

Approved By: _Robert Fristrom_ Date 10/28/03
Robert M. Fristrom
Quality Assurance Officer

APPENDIX

Shannon – Weiner Formula:

For diversity

$$H = -\sum_{i=1}^{S} (p_i)(\log p_i)$$

H = the Shannon – Weiner Diversity Index
P_i = the # of a given species divided by the total number of organisms in the sample
S = number of species
i = specific number

Evenness Formula: $E = H / \log (S)$

E = Evenness Index
H = Shannon – Weiner Index
S = Specific richness

Biomass Formula: $B = \sum W / A$

B = Biomass
$\sum W$ = Sum of the weights of the individual organisms in a sample
A = Total area sampled

Appendix C

Addendum to Site Health and Safety Plan

Appendix C.
Addendum to Site-Specific Health and Safety Plan— Thin Layer Cap Pilot Pre-Design Investigation Work Plan

It is the policy of Integral Consulting Inc. (Integral) to provide a safe and healthful work environment that is compliant with applicable regulations. No aspect of the work is more important than protecting the health and safety of all workers.

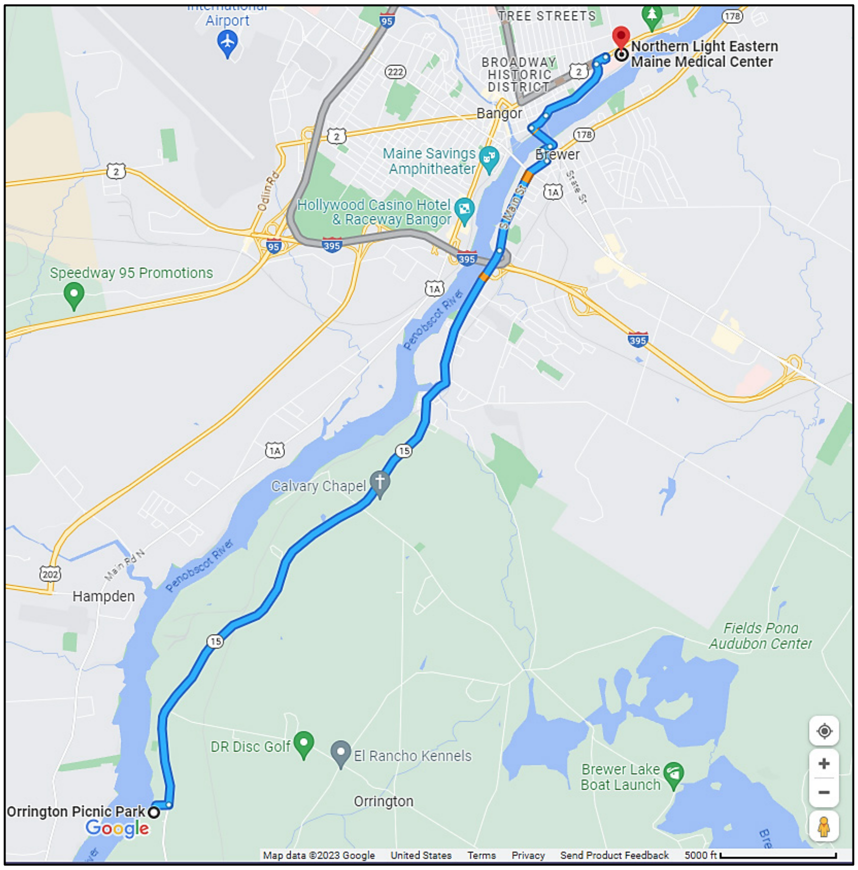
This addendum to the March 2023 Site-Specific Health and Safety Plan, prepared by WSP for the Greenfield Penobscot Estuary Remediation Trust LLC, Trustee of the Penobscot Estuary Mercury Remediation Trust, provides health and safety provisions to protect workers from potential hazards during the deployment and operation of sediment-profile imaging (SPI) camera systems in surface sediment, as described in the Thin Layer Cap (TLC) Pilot Pre-Design Investigation (PDI) Work Plan.

Site and Emergency Response Information	
Site name:	Orrington Reach, Penobscot River, Orrington, Maine
Type of facility/site:	Sediment remediation site
Integral Project manager:	Sara Barbuto
Field work date(s):	SPI field deployment: approximately April 2024
Phone numbers:	Corporate Health and Safety Manager (Eron Dodak): Office (503) 943-3614; Cell: (503) 407-2933 Field staff: TBD Project manager (Sara Barbuto): 207-800-3803 WorkCare (Dr. Peter Greaney): 800-455-2219 Incident Intervention: 888-449-7787
Hospital:	Hospital name: Northern Light Eastern Maine Medical Center Address: 489 State Street, Bangor, ME 04401 Phone number: (207) 973-7000 See attached hospital route map.

Proposed Activities and Hazard Assessment – Sediment Profile Imaging	
Summary of proposed activities:	Setup, deployment and retrieval of SPI system at intertidal flat locations identified in the TLC Pilot PDI Work Plan. Tasks will include the deployment to and setup of the SPI systems to a sampling vessel, deployment of the SPI system into the surficial sediment at intertidal flat locations, and retrieval of the SPI system back onboard the vessel. Tasks will involve working over water.
Potential chemical hazards and mitigation methods:	No chemical hazards.
Potential physical and biological hazards and mitigation methods:	See attached Job Hazard Analysis (JHA) assessment form.
Are there client-specific health and safety training or procedures that are required?	YES / NO: **NO** If YES, please explain.
Personal protective equipment required:	Personal floatation devices (PFDs), Hi-Viz vests, hard hats, steel-toed boots, safety glasses, gloves, clothing appropriate for the weather.
Safety procedure summary:	Follow mitigation procedures provided in the JHA. Field activities will be conducted in accordance with the Site-Specific Health and Safety Plan, Penobscot Estuary Remediation (WSP 2023) and this Addendum to the Site-Specific Health and Safety Plan.

Proposed Activities and Hazard Assessment – Benthic Community Survey	
Summary of proposed activities:	Collection, sieving, and preservation of surface sediment at intertidal flat locations identified in the TLC Pilot PDI Work Plan. Tasks will include the deployment to and setup of the SPI systems to a sampling vessel, deployment of the SPI system into the surficial sediment at intertidal flat locations, and retrieval of the SPI system back onboard the vessel. Tasks will involve working over water.
Potential chemical hazards and mitigation methods:	Use of 10% formalin for fixation (i.e., preservation) of sieved material. A safety data sheet for 10% formalin is provided with the attached JHA. Appropriate PPE will be used as specified in the attached JHA. Stored quantities of chemicals used for fixation will be minimized.
Potential physical and biological hazards and mitigation methods:	See attached JHA assessment form.
Are there client-specific health and safety training or procedures that are required?	YES / NO: **<u>NO</u>** If YES, please explain.
Personal protective equipment required:	PFDs, Hi-Viz vests, steel-toed boots, safety glasses, gloves, clothing appropriate for the weather.
Safety procedure summary:	Follow mitigation procedures provided in the JHA. Field activities will be conducted in accordance with the Site-Specific Health and Safety Plan, Penobscot Estuary Remediation (WSP 2023) and this Addendum to the Site-Specific Health and Safety Plan.

Hospital Route



Directions from Orrington Picnic Park to Northern Light Eastern Maine Medical Center (489 State St., Bangor, ME 04401):

1. **Head north toward ME-15N (0.2 mi)**
2. **Continue on ME-15 N to Bangor (6.9 mi)**
   - 2.1. Turn left onto ME-15 N (5.6 mi)
   - 2.2. Continue onto S Main St. (0.9 mi)
   - 2.3. Turn left onto Betton St. (499 ft)
   - 2.4. Slight right onto Penobscot St. (338 ft)
   - 2.5. Turn left onto State St. (0.3 mi)
3. **Take Hancock St. to State St. (2 mi)**
   - 3.1. Turn right at the first cross street onto Washington St. (0.2 mi)
   - 3.2. Washington St. turns right and becomes Hancock St. (0.6 mi)
   - 3.3. Turn right onto State St. (0.1 mi)
   - 3.4. Sharp right at Northern Light Eastern Maine Medical Center (154 ft)

Job Hazard Analysis (JHA) Assessment Form

JHA Title: Sediment Profile Imaging (SPI) Survey	**JHA Number: 002**	**Date: January 30, 2024**	integral consulting inc.
Job Description: Complete SPI survey of surface sediment on intertidal flats.	**Project Number: C3255**		
General Personal Protective Equipment (PPE) Required: Hard hat, personal floation device (PFD), work gloves, nitrile gloves, safety glasses, steel-toed boots, high-visibility vests, weather-appropriate clothing.	**JHA Team Names: Staff to be determined**	**Approved by:**	
Additional PPE Required: N/A			

Job Steps	Photographs	Hazard Type	Potential Hazards	Control Type	Existing Controls	SEV	OCC	EFF	HPN	Control Type	Recommended Controls	SEV	OCC	EFF	HPN
Shipment of SPI camera system, packing components into cases, transport of cases to shipping center	N/A	Phys	Ergonomics—Heavy lifting (material handling)	Adm	Ergonomics—Assisted lifts (>40 lb)	2	2	0.50	**2**						**0**
				Adm	Sprain/strain protection—Proper lifting techniques / body posture										
		Phys	Slip/trip/fall—Same level	Adm	Slip/trip/fall protection—"Eyes on path"										
Assembly of SPI camera system prior to deployment	N/A	Phys	Cutting, sawing, shearing, or severing action (lacerations)	PPE	Hand—Gloves (cut/puncture resistant)	2	2	0.50	**2**						**0**
		Phys	Ergonomics—Heavy lifting (material handling)	Adm	Ergonomics—Assisted lifts (>40 lb)										
				Adm	Sprain/strain protection—Proper lifting techniques / body posture										
		Phys	Slip/trip/fall—Same level	Adm	Slip/trip/fall protection—"Eyes on path"										

JHA Title: Sediment Profile Imaging (SPI) Survey	**JHA Number: 002**	**Date: January 30, 2024**	integral consulting inc.
Job Description: Complete SPI survey of surface sediment on intertidal flats.	**Project Number: C3255**		
General Personal Protective Equipment (PPE) Required: Hard hat, personal floation device (PFD), work gloves, nitrile gloves, safety glasses, steel-toed boots, high-visibility vests, weather-appropriate clothing. **Additional PPE Required: N/A**	**JHA Team Names: Staff to be determined**	**Approved by:**	

Job Steps	Photographs	Hazard Type	Potential Hazards	Control Type	Existing Controls	SEV	OCC	EFF	HPN	Control Type	Recommended Controls	SEV	OCC	EFF	HPN
Deployment and retrieval of SPI camera system from vessel	N/A	Phys	Slip/trip/fall—On boat	Adm	Keep surfaces dry to extent practical. Maintain good housekeeping. Stay seated, hold onto rails, or brace when vessel is being repositioned.	4	2	0.50	4						0
		Phys	Overboard	PPE	PPE—Wear PFD at all times when on or near water. Ensure vessel is equipped with throwable floatation (e.g., life ring) and US Coast Guard required safety equipment.										
		Phys	Unexpected start-up	Adm	Alarms—Audible or visible to announce startup. Wear hard hat to protect from overhead hazards.										
		Phys	Overhead hazards	PPE	Head/face—Hard hat										
		Phys	Impact with or strike by moving, flying, or falling object	Adm	Housekeeping - Secure equipment when not in use, especailly when vessel is moving.										

Job Hazard Analysis (JHA) Assessment Form

JHA Title: Benthic Invertebrate Collection	**JHA Number: 003**	**Date: January 31, 2024**	
Job Description: Collect surface sediment and sieve for benthic macroinvertebrates. Preserve retained material for shipment to laboratory.	**Project Number: C3255**		
General Personal Protective Equipment (PPE) Required: Personal floation device (PFD), work gloves, nitrile gloves, chemical goggles, safety glasses, steel-toed boots, high-visibility vests, weather-appropriate clothing.	**JHA Team Names: Staff to be determined**	**Approved by:**	
Additional PPE Required: N/A			

Job Steps	Photographs	Hazard Type	Potential Hazards	Control Type	Existing Controls	SEV	OCC	EFF	HPN	Control Type	Recommended Controls	SEV	OCC	EFF	HPN
Packing, shipment, and transport of grab sampler and sampling supplies to sampling vessel	N/A	Phys	Ergonomics—Heavy lifting (material handling)	Adm	Ergonomics—Assisted lifts (>40 lb)										
				Adm	Sprain/strain protection—Proper lifting techniques / body posture	2	2	0.50	**2**						**0**
		Phys	Slip/trip/fall—Same level	Adm	Slip/trip/fall protection—"Eyes on path"										
Grab sampler deployment	N/A	Phys	Pinch points or moving parts	PPE	Hand—Gloves (cut/puncture resistant)										
		Phys	Overboard	PPE	PPE—Wear PFD at all times when on or near water. Ensure vessel is equipped with throwable floatation (e.g., life ring) and US Coast Guard required safety equipment.										
		Phys	Ergonomics—Heavy lifting (material handling)	Adm	Ergonomics—Assisted lifts (>40 lb)	3	2	0.50	**3**						**0**
				Adm	Sprain/strain protection—Proper lifting techniques / body posture										
		Phys	Slip/trip/fall—Same level	Adm	Slip/trip/fall protection—"Eyes on path"										

JHA Title: Benthic Invertebrate Collection	**JHA Number: 003**	**Date: January 31, 2024**	integral consulting inc.
Job Description: Collect surface sediment and sieve for benthic macroinvertebrates. Preserve retained material for shipment to laboratory.	**Project Number: C3255**		
General Personal Protective Equipment (PPE) Required: Personal floation device (PFD), work gloves, nitrile gloves, chemical goggles, safety glasses, steel-toed boots, high-visibility vests, weather-appropriate clothing.	**JHA Team Names: Staff to be determined**	**Approved by:**	
Additional PPE Required: N/A			

Job Steps	Photographs	Hazard Type	Potential Hazards	Control Type	Existing Controls	SEV	OCC	EFF	HPN	Control Type	Recommended Controls	SEV	OCC	EFF	HPN
Sample preservation with 10% formalin (SDS attached)	N/A	Chem	Hazardous chemical exposure to eyes	Adm	Apply preservative to samples on land in a controlled setting whenever possible. If preservative must be applied on the sampling vessel, only perform preservation when the vessel is stable and stationary.	3	2	0.50	3						0
				PPE	Head/face—Chemical goggles										
		Chem	Hazardous chemical exposure to skin	Adm	Apply preservative to samples on land in a controlled setting whenever possible. If preservative must be applied on the sampling vessel, only perform preservation when the vessel is stable and stationary.										
				PPE	Hand—Gloves (chemical resistant)										

SAFETY DATA SHEET

Version 6.7
Revision Date 08/31/2023
Print Date 01/13/2024

SECTION 1: Identification of the substance/mixture and of the company/undertaking

1.1 Product identifiers

Product name	:	Formalin solution, neutral buffered, 10%
Product Number	:	HT501128
Brand	:	Sigma

1.2 Relevant identified uses of the substance or mixture and uses advised against

Identified uses	:	Laboratory chemicals, Synthesis of substances

1.3 Details of the supplier of the safety data sheet

Company	:	Sigma-Aldrich Inc. 3050 SPRUCE ST ST. LOUIS MO 63103 UNITED STATES
Telephone	:	+1 314 771-5765
Fax	:	+1 800 325-5052

1.4 Emergency telephone

Emergency Phone #	:	800-424-9300 CHEMTREC (USA) +1-703-527-3887 CHEMTREC (International) 24 Hours/day; 7 Days/week

SECTION 2: Hazards identification

2.1 Classification of the substance or mixture

GHS Classification in accordance with 29 CFR 1910 (OSHA HCS)

Flammable liquids (Category 4), H227
Acute toxicity, Oral (Category 4), H302
Acute toxicity, Inhalation (Category 4), H332
Skin sensitization (Category 1), H317
Germ cell mutagenicity (Category 2), H341
Carcinogenicity (Category 1B), H350
Short-term (acute) aquatic hazard (Category 3), H402

For the full text of the H-Statements mentioned in this Section, see Section 16.

2.2 GHS Label elements, including precautionary statements

Pictogram 

Signal Word: Danger

Hazard statement(s)

H227	Combustible liquid.
H302 + H332	Harmful if swallowed or if inhaled.
H317	May cause an allergic skin reaction.
H341	Suspected of causing genetic defects.
H350	May cause cancer.
H402	Harmful to aquatic life.

Precautionary statement(s)

P201	Obtain special instructions before use.
P202	Do not handle until all safety precautions have been read and understood.
P210	Keep away from heat/ sparks/ open flames/ hot surfaces. No smoking.
P261	Avoid breathing mist or vapors.
P264	Wash skin thoroughly after handling.
P270	Do not eat, drink or smoke when using this product.
P271	Use only outdoors or in a well-ventilated area.
P272	Contaminated work clothing must not be allowed out of the workplace.
P273	Avoid release to the environment.
P280	Wear protective gloves/ protective clothing/ eye protection/ face protection.
P301 + P312 + P330	IF SWALLOWED: Call a POISON CENTER/ doctor if you feel unwell. Rinse mouth.
P302 + P352	IF ON SKIN: Wash with plenty of soap and water.
P304 + P340 + P312	IF INHALED: Remove person to fresh air and keep comfortable for breathing. Call a POISON CENTER/ doctor if you feel unwell.
P308 + P313	IF exposed or concerned: Get medical advice/ attention.
P333 + P313	If skin irritation or rash occurs: Get medical advice/ attention.
P363	Wash contaminated clothing before reuse.
P370 + P378	In case of fire: Use dry sand, dry chemical or alcohol-resistant foam to extinguish.
P403 + P235	Store in a well-ventilated place. Keep cool.
P405	Store locked up.
P501	Dispose of contents/ container to an approved waste disposal plant.

2.3 Hazards not otherwise classified (HNOC) or not covered by GHS - none

SECTION 3: Composition/information on ingredients

3.2 Mixtures

Component		Classification	Concentration
formaldehyde			
CAS-No.	50-00-0	Flam. Liq. 4; Acute Tox. 3;	>= 1 - < 5 %

EC-No. Index-No. Registration number	200-001-8 605-001-00-5 01-2119488953-20-XXXX	Acute Tox. 2; Acute Tox. 3; Skin Corr. 1B; Eye Dam. 1; Skin Sens. 1; Muta. 2; Carc. 1B; STOT SE 3; Aquatic Acute 2; H227, H301, H330, H311, H314, H318, H317, H341, H350, H335, H401 Concentration limits: >= 25 %: Skin Corr. 1B, H314; 5 - < 25 %: Eye Irrit. 2, H319; >= 5 %: STOT SE 3, H335; >= 0.2 %: Skin Sens. 1, H317; 5 - < 25 %: Skin Irrit. 2, H315; >= 25 %: Skin Corr. 1B, H314; 5 - < 25 %: Skin Irrit. 2, H315; 5 - < 25 %: Eye Irrit. 2, H319; >= 5 %: STOT SE 3, H335; >= 0.2 %: Skin Sens. 1, H317;	
Methanol			
CAS-No. EC-No. Index-No. Registration number	67-56-1 200-659-6 603-001-00-X 01-2119433307-44-XXXX	Flam. Liq. 2; Acute Tox. 3; STOT SE 1; H225, H301, H331, H311, H370 Concentration limits: >= 10 %: STOT SE 1, H370; 3 - < 10 %: STOT SE 2, H371;	>= 1 - < 3 %

For the full text of the H-Statements mentioned in this Section, see Section 16.

SECTION 4: First aid measures

4.1 Description of first-aid measures

General advice
Show this material safety data sheet to the doctor in attendance.

If inhaled
After inhalation: fresh air. Immediately call in physician. If breathing stops: immediately apply artificial respiration, if necessary also oxygen.

In case of skin contact
In case of skin contact: Take off immediately all contaminated clothing. Rinse skin with water/ shower. Consult a physician.

In case of eye contact
After eye contact: rinse out with plenty of water. Call in ophthalmologist. Remove contact lenses.

If swallowed
After swallowing: immediately make victim drink water (two glasses at most). Consult a physician.

4.2 Most important symptoms and effects, both acute and delayed
The most important known symptoms and effects are described in the labelling (see section 2.2) and/or in section 11

4.3 Indication of any immediate medical attention and special treatment needed
No data available

SECTION 5: Firefighting measures

5.1 Extinguishing media

Suitable extinguishing media
Use extinguishing measures that are appropriate to local circumstances and the surrounding environment.

Unsuitable extinguishing media
For this substance/mixture no limitations of extinguishing agents are given.

5.2 Special hazards arising from the substance or mixture
Carbon oxides
Not combustible.
Vapors are heavier than air and may spread along floors.
Forms explosive mixtures with air on intense heating.
Ambient fire may liberate hazardous vapours.

5.3 Advice for firefighters
Stay in danger area only with self-contained breathing apparatus. Prevent skin contact by keeping a safe distance or by wearing suitable protective clothing.

5.4 Further information
Remove container from danger zone and cool with water. Prevent fire extinguishing water from contaminating surface water or the ground water system.

SECTION 6: Accidental release measures

6.1 Personal precautions, protective equipment and emergency procedures
Advice for non-emergency personnel: Do not breathe vapors, aerosols. Avoid substance contact. Ensure adequate ventilation. Keep away from heat and sources of ignition. Evacuate the danger area, observe emergency procedures, consult an expert.
For personal protection see section 8.

6.2 Environmental precautions
Do not let product enter drains.

6.3 Methods and materials for containment and cleaning up
Cover drains. Collect, bind, and pump off spills. Observe possible material restrictions (see sections 7 and 10). Take up carefully with liquid-absorbent material (e.g. Chemizorb®). Dispose of properly. Clean up affected area.

6.4 Reference to other sections
For disposal see section 13.

SECTION 7: Handling and storage

7.1 Precautions for safe handling

Advice on safe handling
Work under hood. Do not inhale substance/mixture. Avoid generation of vapours/aerosols.

Advice on protection against fire and explosion
Keep away from open flames, hot surfaces and sources of ignition.Take precautionary measures against static discharge.

Hygiene measures
Immediately change contaminated clothing. Apply preventive skin protection. Wash hands and face after working with substance.
For precautions see section 2.2.

7.2 Conditions for safe storage, including any incompatibilities

Storage conditions
Tightly closed. Keep in a well-ventilated place. Keep locked up or in an area accessible only to qualified or authorized persons.

Storage class
Storage class (TRGS 510): 6.1C: Combustible, acute toxic Cat.3 / toxic compounds or compounds which causing chronic effects

7.3 Specific end use(s)
Apart from the uses mentioned in section 1.2 no other specific uses are stipulated

SECTION 8: Exposure controls/personal protection

8.1 Control parameters

Ingredients with workplace control parameters

Component	CAS-No.	Value	Control parameters	Basis
formaldehyde	50-00-0	TWA	0.1 ppm	USA. ACGIH Threshold Limit Values (TLV)
	Remarks	Dermal Sensitization Respiratory sensitization Confirmed human carcinogen		
		STEL	0.3 ppm	USA. ACGIH Threshold Limit Values (TLV)
		Dermal Sensitization Respiratory sensitization Confirmed human carcinogen		
		TWA	0.016 ppm	USA. NIOSH Recommended Exposure Limits
		Potential Occupational Carcinogen		
		C	0.1 ppm	USA. NIOSH Recommended Exposure Limits
		Potential Occupational Carcinogen		

		PEL	0.75 ppm	OSHA Specifically Regulated Chemicals/Carcinogens
		OSHA specifically regulated carcinogen		
		STEL	2 ppm	OSHA Specifically Regulated Chemicals/Carcinogens
		OSHA specifically regulated carcinogen		
		PEL	0.75 ppm	California permissible exposure limits for chemical contaminants (Title 8, Article 107)
		STEL	2 ppm	California permissible exposure limits for chemical contaminants (Title 8, Article 107)
		TWA	0.016 ppm	USA. NIOSH Recommended Exposure Limits
		Potential Occupational Carcinogen		
		C	0.1 ppm	USA. NIOSH Recommended Exposure Limits
		Potential Occupational Carcinogen		
Methanol	67-56-1	TWA	200 ppm	USA. ACGIH Threshold Limit Values (TLV)
		Danger of cutaneous absorption		
		STEL	250 ppm	USA. ACGIH Threshold Limit Values (TLV)
		Danger of cutaneous absorption		
		ST	250 ppm 325 mg/m3	USA. NIOSH Recommended Exposure Limits
		Potential for dermal absorption		
		TWA	200 ppm 260 mg/m3	USA. NIOSH Recommended Exposure Limits
		Potential for dermal absorption		
		TWA	200 ppm 260 mg/m3	USA. Occupational Exposure Limits (OSHA) - Table Z-1 Limits for Air Contaminants
		PEL	200 ppm 260 mg/m3	California permissible exposure limits for chemical contaminants (Title 8, Article 107)
		Skin		
		C	1,000 ppm	California permissible exposure limits for chemical contaminants (Title 8, Article 107)
		Skin		
		STEL	250 ppm 325 mg/m3	California permissible exposure limits for chemical contaminants (Title 8, Article 107)
		Skin		

		TWA	200 ppm 260 mg/m3	USA. Table Z-1-A Limits for Air Contaminants (1989 vacated values)
		Skin notation		
		STEL	250 ppm 325 mg/m3	USA. Table Z-1-A Limits for Air Contaminants (1989 vacated values)
		Skin notation		

Biological occupational exposure limits

Component	CAS-No.	Parameters	Value	Biological specimen	Basis
Methanol	67-56-1	Methanol	15 mg/l	Urine	ACGIH - Biological Exposure Indices (BEI)
	Remarks	End of shift (As soon as possible after exposure ceases)			

8.2 Exposure controls

Appropriate engineering controls

Immediately change contaminated clothing. Apply preventive skin protection. Wash hands and face after working with substance.

Personal protective equipment

Eye/face protection

Use equipment for eye protection tested and approved under appropriate government standards such as NIOSH (US) or EN 166(EU). Safety glasses

Skin protection

Handle with gloves. Gloves must be inspected prior to use. Use proper glove removal technique (without touching glove's outer surface) to avoid skin contact with this product. Dispose of contaminated gloves after use in accordance with applicable laws and good laboratory practices. Wash and dry hands.

Full contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

Splash contact
Material: Nitrile rubber
Minimum layer thickness: 0.11 mm
Break through time: 480 min
Material tested:Dermatril® (KCL 740 / Aldrich Z677272, Size M)

data source: KCL GmbH, D-36124 Eichenzell, phone +49 (0)6659 87300, e-mail sales@kcl.de, test method: EN374
If used in solution, or mixed with other substances, and under conditions which differ from EN 374, contact the supplier of the EC approved gloves. This recommendation is advisory only and must be evaluated by an industrial hygienist and safety officer familiar with the specific situation of anticipated use by our customers. It should not be construed as offering an approval for any specific use scenario.

Body Protection
protective clothing

Respiratory protection
Recommended Filter type: Filter type ABEK
The entrepeneur has to ensure that maintenance, cleaning and testing of respiratory protective devices are carried out according to the instructions of the producer. These measures have to be properly documented.
required when vapours/aerosols are generated.
Our recommendations on filtering respiratory protection are based on the following standards: DIN EN 143, DIN 14387 and other accompanying standards relating to the used respiratory protection system.

Control of environmental exposure
Do not let product enter drains.

SECTION 9: Physical and chemical properties

9.1 Information on basic physical and chemical properties

a)	Appearance	Form: liquid Color: colorless
b)	Odor	No data available
c)	Odor Threshold	No data available
d)	pH	6.5 - 7.5 at 10%
e)	Melting point/freezing point	No data available
f)	Initial boiling point and boiling range	100 °C 212 °F at 1,013 hPa
g)	Flash point	85 °C (185 °F)
h)	Evaporation rate	No data available
i)	Flammability (solid, gas)	No data available
j)	Upper/lower flammability or explosive limits	Upper explosion limit: 70 %(V) Lower explosion limit: 7 %(V)
k)	Vapor pressure	53 hPa at 39 °C (102 °F)
l)	Vapor density	No data available
m)	Density	1.080 g/cm3
	Relative density	No data available
n)	Water solubility	completely misciblesoluble
o)	Partition coefficient: n-octanol/water	No data available
p)	Autoignition temperature	Not applicable

q)	Decomposition temperature	No data available
r)	Viscosity	No data available
s)	Explosive properties	Not classified as explosive.
t)	Oxidizing properties	none

9.2 Other safety information
No data available

SECTION 10: Stability and reactivity

10.1 Reactivity
Forms explosive mixtures with air on intense heating.
A range from approx. 15 Kelvin below the flash point is to be rated as critical.

10.2 Chemical stability
The product is chemically stable under standard ambient conditions (room temperature) .

10.3 Possibility of hazardous reactions
Violent reactions possible with:
The generally known reaction partners of water.

10.4 Conditions to avoid
Strong heating.

10.5 Incompatible materials
Strong bases, Acids, Oxidizing agents, Alkali metals, Strong oxidizing agents, Amines, Strong acids, Acid chlorides, Acid anhydrides, Reducing agents, Peroxides, Isocyanates, Phenol, Aniline

10.6 Hazardous decomposition products
In the event of fire: see section 5

SECTION 11: Toxicological information

11.1 Information on toxicological effects

Mixture

Acute toxicity
Oral: No data available

Inhalation: No data available

Dermal: No data available

Skin corrosion/irritation
No data available

Serious eye damage/eye irritation
No data available

Respiratory or skin sensitization
Mixture may cause an allergic skin reaction.

Germ cell mutagenicity
Evidence of genetic defects.

Carcinogenicity
Possible carcinogen.

IARC:	1 - Group 1: Carcinogenic to humans (formaldehyde)
NTP:	Known - Known to be human carcinogen (formaldehyde)
OSHA:	OSHA specifically regulated carcinogen (formaldehyde)

Reproductive toxicity
No data available

Specific target organ toxicity - single exposure
No data available

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

11.2 Additional Information

Methyl alcohol may be fatal or cause blindness if swallowed., Cannot be made non-poisonous., Effects due to ingestion may include:, Nausea, Dizziness, Gastrointestinal disturbance, Weakness, Confusion., Drowsiness, Unconsciousness, May cause convulsions. Other dangerous properties can not be excluded.

This substance should be handled with particular care.

Handle in accordance with good industrial hygiene and safety practice.

Liver - Irregularities - Based on Human Evidence

Stomach - Irregularities - Based on Human Evidence

Components

formaldehyde

Acute toxicity
LD50 Oral - Rat - 100 mg/kg
Remarks: (Lit.)
LC50 Inhalation - Rat - male and female - 4 h - < 0.57 mg/l - vapor
(OECD Test Guideline 403)
LD50 Dermal - Rabbit - 270 mg/kg
Remarks: (RTECS)
No data available

Skin corrosion/irritation
Skin - Rabbit
Result: Causes burns. - 20 h

(OECD Test Guideline 404)

Serious eye damage/eye irritation
Remarks: Causes serious eye damage.

Respiratory or skin sensitization
Local lymph node assay (LLNA) - Mouse
Result: positive
(OECD Test Guideline 429)

Germ cell mutagenicity
Suspected of causing genetic defects.

Carcinogenicity
Presumed to have carcinogenic potential for humans

Reproductive toxicity
No data available

Specific target organ toxicity - single exposure
May cause respiratory irritation.

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

Methanol

Acute toxicity
Acute toxicity estimate Oral - 100.1 mg/kg
(Expert judgment)
Remarks: Classified according to Regulation (EU) 1272/2008, Annex VI (Table 3.1/3.2)
Symptoms: Nausea, Vomiting
Acute toxicity estimate Inhalation - 4 h - 3.1 mg/l - vapor
(Expert judgment)
Remarks: Classified according to Regulation (EU) 1272/2008, Annex VI (Table 3.1/3.2)
Symptoms: Irritation symptoms in the respiratory tract.
Acute toxicity estimate Dermal - 300.1 mg/kg
(Expert judgment)
Remarks: Classified according to Regulation (EU) 1272/2008, Annex VI (Table 3.1/3.2)

Skin corrosion/irritation
Skin - Rabbit
Result: No skin irritation
Remarks: (ECHA)
Remarks: Drying-out effect resulting in rough and chapped skin.

Serious eye damage/eye irritation
Eyes - Rabbit
Result: No eye irritation
Remarks: (ECHA)

Respiratory or skin sensitization
Sensitisation test: - Guinea pig
Result: negative
(OECD Test Guideline 406)

Germ cell mutagenicity
Based on available data the classification criteria are not met.
Test Type: Ames test
Test system: Salmonella typhimurium
Result: negative
Test Type: In vitro mammalian cell gene mutation test
Test system: Chinese hamster lung cells
Result: negative
Method: OECD Test Guideline 474
Species: Mouse - male and female - Bone marrow
Result: negative

Carcinogenicity
Did not show carcinogenic effects in animal experiments.

Reproductive toxicity
Based on available data the classification criteria are not met.

Specific target organ toxicity - single exposure
Causes damage to organs. - Eyes, Central nervous system
Remarks: Classified according to Regulation (EU) 1272/2008, Annex VI (Table 3.1/3.2)
Acute oral toxicity - Nausea, Vomiting
Acute inhalation toxicity - Irritation symptoms in the respiratory tract.

Specific target organ toxicity - repeated exposure
No data available

Aspiration hazard
No data available

SECTION 12: Ecological information

12.1 Toxicity

Mixture
No data available

12.2 Persistence and degradability
No data available

12.3 Bioaccumulative potential
No data available

12.4 Mobility in soil
No data available

12.5 Results of PBT and vPvB assessment
PBT/vPvB assessment not available as chemical safety assessment not required/not conducted

12.6 Endocrine disrupting properties
No data available

12.7 Other adverse effects

No data available

Components

formaldehyde

Toxicity to fish	static test LC50 - Morone saxatilis - 6.7 mg/l - 96 h Remarks: (ECHA)
Toxicity to daphnia and other aquatic invertebrates	static test EC50 - Daphnia pulex (Water flea) - 5.8 mg/l - 48 h (OECD Test Guideline 202)
Toxicity to algae	static test EC50 - Desmodesmus subspicatus (green algae) - 4.89 mg/l - 72 h (OECD Test Guideline 201)
Toxicity to bacteria	static test EC50 - activated sludge - 19 mg/l - 3 h (OECD Test Guideline 209)
Toxicity to daphnia and other aquatic invertebrates(Chronic toxicity)	semi-static test NOEC - Daphnia magna (Water flea) - >= 6.4 mg/l - 21 d (OECD Test Guideline 211)

Methanol

Toxicity to fish	flow-through test LC50 - Lepomis macrochirus (Bluegill) - 15,400.0 mg/l - 96 h (US-EPA)
Toxicity to daphnia and other aquatic invertebrates	semi-static test EC50 - Daphnia magna (Water flea) - 18,260 mg/l - 96 h (OECD Test Guideline 202)
Toxicity to algae	static test ErC50 - Pseudokirchneriella subcapitata (green algae) - ca. 22,000.0 mg/l - 96 h (OECD Test Guideline 201)
Toxicity to bacteria	static test IC50 - activated sludge - > 1,000 mg/l - 3 h (OECD Test Guideline 209)
Toxicity to fish(Chronic toxicity)	NOEC - Oryzias latipes (Orange-red killifish) - 7,900 mg/l - 200 h Remarks: (External MSDS)

SECTION 13: Disposal considerations

13.1 Waste treatment methods

Product
Waste material must be disposed of in accordance with the national and local regulations. Leave chemicals in original containers. No mixing with other waste. Handle uncleaned containers like the product itself.

SECTION 14: Transport information

DOT (US)
NA-Number: 1993 Class: NONE Packing group: III
Proper shipping name: Combustible liquid, n.o.s. (formaldehyde, Methanol)
Reportable Quantity (RQ): 2500 lbs
Poison Inhalation Hazard: No

IMDG
Not dangerous goods

IATA
Not dangerous goods

SECTION 15: Regulatory information

SARA 302 Components

	CAS-No.	Revision Date
formaldehyde	50-00-0	2008-11-03

SARA 313 Components
The following components are subject to reporting levels established by SARA Title III, Section 313:

	CAS-No.	Revision Date
formaldehyde	50-00-0	2008-11-03
Methanol	67-56-1	2007-07-01

SARA 311/312 Hazards
Fire Hazard, Acute Health Hazard, Chronic Health Hazard

Massachusetts Right To Know Components

	CAS-No.	Revision Date
water	7732-18-5	
formaldehyde	50-00-0	2008-11-03

Methanol	67-56-1	2007-07-01

Pennsylvania Right To Know Components

	CAS-No.	Revision Date
formaldehyde	50-00-0	2008-11-03
Methanol	67-56-1	2007-07-01
disodium hydrogen orthophosphate	7558-79-4	1993-04-24

California Prop. 65 Components

	CAS-No.	Revision Date
, which is/are known to the State of California to cause cancer, andformaldehyde	50-00-0	2007-09-28

	CAS-No.	Revision Date
, which is/are known to the State of California to cause birth defects or other reproductive harm. For more information go to www.P65Warnings.ca.gov.Methanol	67-56-1	2012-03-16

SECTION 16: Other information

Further information

The above information is believed to be correct but does not purport to be all inclusive and shall be used only as a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Sigma-Aldrich Corporation and its Affiliates shall not be held liable for any damage resulting from handling or from contact with the above product. See www.sigma-aldrich.com and/or the reverse side of invoice or packing slip for additional terms and conditions of sale.

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