

Bathymetric Survey Work Plan

Penobscot River Estuary

Prepared for

**Greenfield Penobscot Estuary Remediation Trust LLC
Trustee for Penobscot Estuary Mercury Remediation Trust**



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ACRONYMS AND ABBREVIATIONS

ASI	Aqua Survey, Inc.
CTD	conductivity, temperature, and depth
DEM	digital elevation model
DQOs	data quality objectives
GPS	global positioning system
Greenfield	Greenfield Penobscot Estuary Remediation Trust LLC
Integral	Integral Consulting Inc.
LiDAR	light detection and ranging
MBES	multibeam echosounder
MLLW	mean lower low water
NAD 83	North American Datum of 1983
NAVD 88	North American Vertical Datum of 1988
NRDC	Natural Resources Defense Council, Inc.
QA/QC	quality assurance and quality control
Remediation Trust	Penobscot Estuary Mercury Remediation Trust
RTK	real time kinematic
TLC	thin layer cap
USCG	U.S. Coast Guard
USGS	U.S. Geological Survey
WSP	WSP USA Environment & Infrastructure, Inc.

1 INTRODUCTION

This Bathymetric Survey Work Plan (Work Plan) has been prepared by Integral Consulting Inc. (Integral) and WSP USA Environment & Infrastructure, Inc. (WSP) on behalf of the Greenfield Penobscot Estuary Remediation Trust LLC (Greenfield), Trustee of the Penobscot Estuary Mercury Remediation Trust (the Remediation Trust) for Work on the Penobscot River Estuary located in Hancock, Penobscot, and Waldo counties, Maine. This Work Plan has been prepared in accordance with the Consent Decree¹ and appendices, including Paragraph 6(a) of the Statement of Work (Appendix A to the Consent Decree), as summarized in Table 1.

This Work Plan documents the objectives, scope, and process for collection of bathymetry data for the Site, defined in the Consent Decree as the Penobscot River Estuary, which generally includes the tidal portions of the Penobscot River from the location of the former Veazie Dam to upper Penobscot Bay (Figure 1).

The Consent Decree defines portions or components of the Site subject to remediation activities as “Reaches,” which may be defined geographically (e.g., East Channel, Mendall Marsh, Orland River, and Orrington Reach; as shown on Figure 1) or based on hydrodynamic, geophysical, or other scientific bases (e.g., Mobile Sediments and Surface Deposits). Several of the Reaches have been combined in the Consent Decree to form three Work Categories with separate Committed and Contingent Funding specifically allocated to complete remedial activities intended to accelerate the recovery of the Penobscot River Estuary. The Work Categories and remedies specified in the Consent Decree are:

- Orrington Reach: Capping 130 acres of intertidal sediments, primarily on the east side of the Penobscot River Estuary between Orrington and Bucksport. This area is directly south (downstream) of the former HoltraChem facility in Orrington, Maine.
- Mobile Sediments and Surface Deposits: Removal of a portion of the mobile sediments and surface deposits from the site. Mobile Sediments are defined as the mineral or organic sediment, including wood waste, that may be mobilized and homogenized by natural processes in the Penobscot River over timescales relevant to affect the fate and transport of mercury within the site. Surface Deposits are defined as any subtidal or intertidal region of Mobile Sediment accumulation, including any comingled materials or debris that can be identified by physical, chemical, geophysical, or other scientific methods.

¹ The Consent Decree was approved and entered by the U.S. District Court for the District of Maine (in the case *Maine People’s Alliance and NRDC v. HoltraChem Manufacturing Company LLC, et al.*, No. 1:00-cv-00069-JAW (D. Me.) (ECF No.1187, October 11, 2022)).

- Orland River and East Channel around Verona Island: This is the area directly east of Verona Island and in the Orland River. The remedy for this Work Category was not specified in the Consent Decree and will be selected with consideration given to information developed for the other Work Categories.

This Work Plan identifies data gaps associated with existing bathymetry and topography data and describes the investigation proposed to address key data gaps. Bathymetry data, measuring the bottom elevation of the Penobscot River Estuary, will be combined with topography data collected for the intertidal flats at low tide, to inform Orrington Reach, Mobile Sediments and Surface Deposits, and Orland River and East Channel around Verona Island design and permitting efforts. The bathymetric survey is being planned and performed as a Site-wide investigation to complete work efficiently and cost-effectively. This Work Plan includes 1) an evaluation and summary of existing data, and a description of data gaps; 2) a description of data quality objectives (DQOs); 3) a survey extents plan; 4) a survey schedule; and 5) a description of the quality assurance and quality control (QA/QC) measures to be undertaken.

2 SUMMARY OF EXISTING DATA AND DATA NEEDS

This section provides an evaluation and summary of existing bathymetry and topography data for the Site and identifies data gaps that require further investigation in order to evaluate and design remedial actions.

2.1 EXISTING DATA

The existing Penobscot River bathymetry data were derived from available National Oceanic and Atmospheric Administration (NOAA) National Ocean Service surveys, as well as numerous multibeam echosounder (MBES) surveys conducted by the U.S. Army Corps of Engineers for select areas of the Penobscot River Estuary from 1984 through 2016. These surveys encompassed the main waterways and intertidal flats of the Penobscot River Estuary. These data were combined to form the digital elevation model (DEM)² used for the Phase III Engineering Study (Amec Foster Wheeler 2018) investigations, modeling, and various expert reports. Because the DEM used for the Phase III Engineering Study was developed from multiple data sets collected more than 7 years ago, during different sampling events, it may not be representative of current conditions and does not provide an understanding of contiguous bathymetric conditions. Importantly, the DEM coverage is limited for the intertidal flat areas that are the focus of the Orrington Reach capping effort.

Topographic data for the Penobscot River Estuary were collected in 2021, during a light detection and ranging (LiDAR) survey along the mid-coast region of Maine conducted by the U.S. Geological Survey (USGS). The LiDAR survey, conducted between May 12, 2021, and May 10, 2022, was performed using state-of-the-art, fixed-wing aircraft survey technology over 17 flights (NV5 Geospatial 2022). The total area surveyed is ~6,700 km² and extends west of Saint George along the coast to Blue Hill, and inland to north of Milford, Maine. The survey was conducted using three fixed-wing aircraft and multispectral lasers that allow for coastline and shallow water mapping, including the intertidal areas of the Penobscot River Estuary. The USGS LiDAR survey was performed at data quality level 2, requiring an average point density of two points per square meter and a vertical accuracy of ≤10 cm. These data were used to construct a 1 m DEM with a vertical accuracy of 7 cm, which is available on the USGS website: <https://apps.nationalmap.gov/lidar-explorer/#/>. These LiDAR data will provide sufficient vertical and horizontal resolution to accurately depict the intertidal boundary along the extent of the Penobscot River Estuary and support the Orrington Reach capping effort.

Review of the USGS LiDAR survey data set shows that the survey provides data coverage to an elevation of -5.9 ft North American Vertical Datum of 1988 (NAVD 88), approximately 0.5 ft

² A DEM is a 3-dimensional representation of a terrain's surface at regularly spaced intervals in the *x* and *y* directions that reference elevation values in a common vertical datum (Maune, D.F., J.B. Maitra, and E.J. McKay. 2007).

mean lower-low water (MLLW) and includes the intertidal flat and marsh areas in the Penobscot River Estuary, and the adjacent uplands.

2.2 DATA NEEDS

Although existing data provide valuable insight to evaluate large-scale features throughout the river, a more refined bathymetric map is required to depict small scale, steep slope, and/or rapidly changing bathymetric features. A detailed bathymetric survey will provide comprehensive, high-resolution mapping of the lower elevation areas of the intertidal flats and subtidal channel throughout the study area to support remedial design. In addition to the general data needs for the Penobscot River Estuary, data needs for specific Work Categories are described below.

A thorough understanding of Penobscot River bathymetry and specifically of the intertidal regions of Orrington Reach is required to delineate the extent of intertidal sediment for potential capping. A comprehensive bathymetric map is required for Orrington Reach to refine the delineation of key morphologic features, such as surface drainages on the flats, areas of rapid slope change as the geomorphology transitions from intertidal to subtidal sediment, and the geometry of the subtidal channel. Quantifying these bathymetric and morphologic features is essential to delineating the extent of intertidal flats for capping and identifying areas where armoring may be required due to the slope of the sediment bed, proximity to surface drainage features, and other factors.

In addition, establishing the elevation of the Penobscot River Estuary sediment bed is a key component of a hydrodynamic modeling exercise as these elevations dictate the extent and volume of tidally driven water flow and associated sediment exchange in the system. Bathymetry and topography data are necessary to assign bottom elevations to the model grid and accurately represent the flow pathways and boundaries. These data will be used to support the development of a reliable hydrodynamic model for use in forecasting conditions on the Orrington Reach thin layer cap (TLC) under design storm flow conditions. The hydrodynamic model will be used to simulate river flow velocities and associated bed shear stresses to identify areas most conducive to capping (i.e., where shear stresses are lowest); determine cap materials, grain size, and need for armoring; evaluate the potential to impact the habitat in intertidal flats and marshes; and assess the potential for the cap to increase flood risk. These design elements are critical in determining the feasibility and cost of the cap.

The updated bathymetric survey and hydrodynamic model will be important elements in the design of remedies for the Mobile Sediment and Surface Deposits and Orland River and East Channel around Verona Island Work Categories. The scope of the survey under this Work Plan will provide current and comprehensive bathymetric map of the Site. The survey data and updated DEM will support hydrodynamic modeling of riverine and tidal flow based on the

current river geomorphology, and an improved understanding of the potential movement of mobile sediment and surface deposits in these Work Categories. Further, the bathymetry data will be used in conjunction with dual-frequency mapping and sub-bottom profiling investigations to map mobile sediment and surface deposits associated with both Work Categories.

The bathymetry data will be integrated with the existing USGS LiDAR survey data to:

- Develop a high-resolution, updated bathymetric survey sufficient to qualitatively and quantitatively evaluate anthropogenic and/or morphological features, such as areas of slope sloughing, bedforms, propeller scour marks, and/or dredged areas within the survey area of the Penobscot River Estuary.
- Develop a current, detailed DEM for the Penobscot River Estuary and identify marsh, intertidal, and subtidal areas.
- Develop the geomorphic boundary conditions to support development of a refined and up-to-date hydrodynamic model.
- Refine sediment sample locations by better identifying the bounds of the intertidal flats and subtidal areas.
- Establish the TLC limits with consideration of the refined intertidal flat boundaries and geomorphological constraints.
- Support future monitoring of the Orrington Reach TLC as-built cap thickness, if needed.
- Provide the elevation survey of the Penobscot River Estuary intertidal and subtidal areas required for the Natural Resource Protection Act permit application.

2.3 DATA QUALITY OBJECTIVES

The DQOs for the bathymetric survey to collect updated bathymetry data, in support of the remedial design efforts for the Penobscot River Estuary, are summarized in Table 2.

3 METHODOLOGY

The following provides the proposed data collection methods for the bathymetric survey.

3.1 ROLES AND RESPONSIBILITIES

As stated in the Consent Decree and attachments, the purpose of the Remediation Trust includes the development, oversight, funding, and implementation of all work. The roles, responsibilities, and authorities of Greenfield, Integral, and WSP for implementation of this Work Plan are presented below.

Task	Greenfield Role	Integral Role	WSP Role
Beneficiary Communication	Lead	Technical Support	Technical Support
Bathymetric Survey	Oversight, deliverable review, and project management	Provide support for Orrington Reach survey	Lead. Responsible for securing contractor and implementation of Work Plan
Data Integration	Oversight, deliverable review, and project management	Lead	Provide support for Mobile Sediments/ Surface Deposits and Orland River
Investigation Report	Oversight, deliverable review, and project management	Provide support	Lead

3.2 DATA COLLECTION

The proposed scope for current bathymetry data collection consists of a high resolution MBES bathymetric survey of the lower Penobscot River, from Bangor to Fort Point in Stockton Springs, Maine, including Orrington Reach. The bathymetric survey will provide high-resolution mapping of the lower elevation intertidal flats and subtidal channel for remedial design.

Bathymetry data will be collected from Bangor to Fort Point, Maine, including the Orland River Reach, over three separate mobilizations planned for June, August, and October 2023. Data collection within Orrington Reach will be prioritized to align with project goals. The survey will encompass the subtidal zone, as well as coverage, as feasible, of the adjacent intertidal flats (up to an elevation of 3 ft MLLW or higher). To the extent feasible, the survey will be conducted at water surface elevations >6 ft MLLW, when water covers the intertidal flats, to

attain coverage within the area shown on Figure 1 in order to overlap with the LiDAR survey. The subcontractor, Aqua Survey, Inc. (ASI), will be prepared to access water depths as shallow as 4 to 6 ft at the time of survey, and will be prepared to navigate safely near and around visible and submerged hazards that may exist in the survey area.

An R2 Sonic multibeam sonar will be used to collect bathymetry data. System components will include a multibeam projector, an SMC IMU-108 motion reference unit, a Hemisphere VS-110 satellite compass, a cast-able-CTD conductivity, temperature, and depth (CTD) probe, and an AML Micro-X sound velocity probe. A multibeam calibration, known as a patch test, and bar checks will be conducted by ASI following data collection. The patch test will be used to accommodate the data for the latency, pitch, roll, and yaw of the vessel. MBES bathymetry data will be collected at variable line spacing based on water depth to produce approximately 100 percent coverage of the subtidal riverbed, and as much of the intertidal zone as feasible.

The surveys are expected to be completed at speeds ranging from 2 to 4 knots, although lower speeds will be used as appropriate when traversing shallow water depths to minimize the potential for disturbance of the sediment surface through prop wash. Project horizontal control will be provided by a Hemisphere real time kinematic (RTK) global positioning system (GPS) with centimeter accuracy and differential global positioning. RTK corrections will be supplied through KeyNET service. Results will be produced in the Maine East State Plane North American Datum of 1983 (NAD 83) coordinate system with units in U.S. survey feet and NAVD 88 with depths produced in U.S. survey feet.

ASI will provide contours of the survey area. ASI will also provide all data, in an ASCII file format of all of the reduced, raw data.

WSP will be responsible for supplying the established benchmark data on the land side for ASI to use for tying in the bathymetry data. ASI will run the survey using NAVD 88 for the vertical datum and Maine State Plane East Zone NAD 83 for the horizontal datum. ASI will follow the standards defined in the U.S. Army Corps of Engineers Hydrographic Surveying Manual No. EM 1110-2-1003 as a guideline.

3.3 DATA INTEGRATION

The updated bathymetry data from the MBES survey will be merged with the current USGS LiDAR using ESRI's ArcGIS Pro mapping software package to generate a comprehensive DEM for current site conditions. The horizontal and vertical datums, coordinate reference systems, and units for both elevation data sets will be confirmed prior to merging and comparing the data. Existing overlap in the two data sets will be compared for accuracy, and any data inconsistencies will be identified and highlighted for analysis.

The updated DEM will be evaluated to determine whether there are significant data gaps that would require additional LiDAR data. Given the large tidal range, the water surface elevation between high and low tide, the MBES survey is expected to provide adequate coverage on the intertidal areas to overlap with the LiDAR data extents. If significant data gaps are identified, they can be addressed by focused, drone-based LiDAR surveys.

4 QUALITY ASSURANCE AND QUALITY CONTROL

QA/QC will be performed routinely throughout the field survey to assess the integrity of all vessel-mounted instruments. Instrument functions will be tested and verified prior to each survey. Instrument functionality will be verified at specified intervals during the survey to confirm the validity of the collected data. Specifically, ASI will use Hypack for survey control, ship track recording, and data acquisition. An MBES calibration, known as a patch test, and bar checks, used to calculate the speed of sound in water, will be conducted once per mobilization and daily, respectively, following data collection. The patch test will be used to accommodate the data for the latency, pitch, roll, and yaw of the survey vessel. Bar checks will be used to adjust for vessel draft and speed of sound in water for the MBES instrument frequencies in order to provide accurate sounding data. After each day's data collection, ASI will perform preliminary data processing to determine target areas of interest for sediment sampling purposes.

Preliminary data will be downloaded daily following data collection activities. The quality of the downloaded data will be reviewed, and proper measures will be taken to correct any data deficiencies. Data processing will be completed by ASI following data collection and will include removing erroneous data points and correcting the data to the NAVD 88 vertical reference datum based on RTK GPS corrections to provide consistent quality control. Data from standard pre- and post-processing routines will be evaluated for accuracy and will be backed up on a separate hard drive (or similar external storage device) and on cloud-based storage systems for safekeeping. The final data are anticipated to be maintained in the Project SQL server database being developed by WSP for use by the Remediation Trust and authorized contractors.

Once the final hydrographic survey data and LiDAR survey data have undergone QA/QC review and been delivered, Integral will load both data sets into mapping software. Integral's geospatial analysts will evaluate the existing overlap in the bathymetry and LiDAR data to visually identify any data gaps that would need to be filled by additional field surveys. In locations where data overlap, the elevations will be compared to one another to verify accuracy. Any inconsistencies will be noted and further evaluated.

5 PERMITS AND ACCESS REQUIREMENTS

The data collection under this Work Plan will be conducted from a vessel on the water and will not deploy surface or near surface instrumentation or buoys. Therefore, the survey field work does not require permits or access agreements. Notifications to agencies regulating maritime access to the Penobscot River Estuary, including the U.S. Coast Guard (USCG), will be provided per the applicable regulations. USCG will issue a “Local Notice to Mariners” notifying mariners of the survey field work.

6 SCHEDULE AND DELIVERABLES

The following summarizes the schedule milestones for the bathymetric and LiDAR investigations:

- Bathymetric Survey—1st Mobilization (including Orrington Reach) June 2023 (10 days)
- Data Integration—Orrington Reach July 2023
- Bathymetric Survey—2nd Mobilization August 2023 (15 days)
- Bathymetric Survey—3rd Mobilization October 2023 (15 days)
- Data Integration—Penobscot River Estuary November 2023

The results of the bathymetric survey will be summarized in a brief an investigation report, consistent with Paragraph 6.b of the Statement of Work. The hydrodynamic model developed using the updated bathymetry and topography data will be presented in technical memoranda.

7 SUPPORTING DELIVERABLES

The following Supporting Deliverables are incorporated by reference:

- Health and Safety Plan (WSP 2023a)
- Emergency Response Plan (WSP 2023b).

The Bathymetric Survey Work Plan does not reference a Quality Assurance Project Plan or Field Sampling Plan because sample collection and laboratory analysis are not necessary.

8 REFERENCES

Amec Foster Wheeler. 2018. Phase III Engineering Study Report, Penobscot River Estuary, Maine. September. Prepared for United States District Court District of Maine. Amec Foster Wheeler Environment & Infrastructure, Inc., Portland, ME. September.

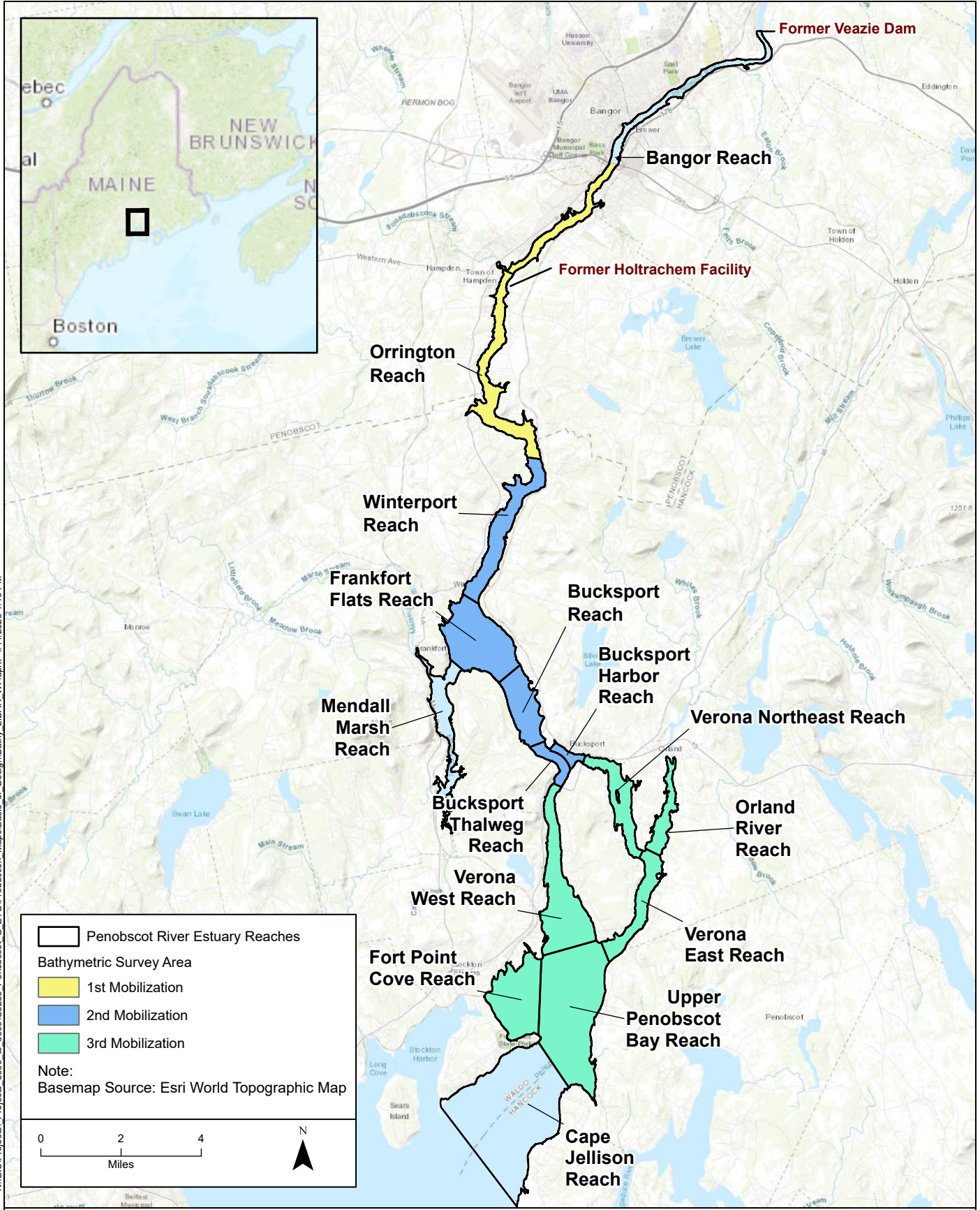
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WSP. 2023a. Site-specific Health and Safety Plan (HASP), Penobscot Estuary Remediation. Prepared for the Greenfield Penobscot Estuary Remediation Trust LLC. WSP USA Environment & Infrastructure, Inc. March 2023.

WSP. 2023b. Emergency Response Plan (ERP), Penobscot Estuary Remediation. Prepared for the Greenfield Penobscot Estuary Remediation Trust LLC. WSP USA Environment & Infrastructure, Inc. March 2023.

Figures



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Penobscot River Estuary Reaches
 Bathymetric Survey Area
 1st Mobilization
 2nd Mobilization
 3rd Mobilization
 Note:
 Basemap Source: Esri World Topographic Map

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— Miles —

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

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Figure 1.
 Proposed Scope of Bathymetric Survey
 Bathymetric Survey Work Plan,
 Penobscot River Estuary
 May 2023

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 2
¶ 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 3
¶ 6(a)(iv) A schedule for the Investigation	✓	Section 6
¶ 6(a)(v) Cross references to quality assurance/quality control (“QA/QC”) requirements set forth in the QAPP as described in Paragraph 31(d) ^a	✓	Section 4

Notes:

^a Section 4 presents the QA/QC requirements specific to the bathymetric and data integration. Because no samples will be collected, the quality assurance project plan (QAPP) is not cross referenced.

Table 2. Data Quality Objectives for Bathymetric Survey

Problem Statement and Goals	Information/Data Needed	Data Collection Approach
<p>A thorough understanding of Penobscot River bathymetry and specifically of the intertidal regions of Orrington Reach is required to delineate the extent of intertidal sediment for potential capping.</p>	<p>Bathymetry data for the Orrington Reach</p>	<p>A multibeam echosounder (MBES) will be used to collect bathymetry data. To support future evaluations, including those needed for as-built cap thickness, the horizontal and vertical accuracy of 0.1 - 0.2 ft referenced to NAVD 88 for the vertical datum and North American Datum of 1983 (NAD 83) Maine State Plane East Zone for the horizontal datum. The point density, given the shallow water depths for much of the Estuary, will be > 100 points per square foot.</p>
<p>A comprehensive bathymetric map is required for Orrington Reach to refine the delineation of key morphologic features, such as surface drainages on the flats, areas of rapid slope change as the geomorphology transitions from intertidal to subtidal sediment, and the geometry of the subtidal channel. Quantifying these bathymetric and morphologic features is essential to delineating the extent of intertidal flats for capping and identifying areas where armoring may be required due to the slope of the sediment bed, proximity to surface drainage features, and other factors.</p>	<p>Bathymetry data for the Orrington Reach</p>	<p>An MBES will be used to collect bathymetry data.</p>

Table 2. Data Quality Objectives for Bathymetric Survey

Problem Statement and Goals	Information/Data Needed	Data Collection Approach
<p>Hydrodynamic modeling will be the primary basis for estimating shear stresses that will act on the Orrington Reach thin layer cap and thus is critical to the cap design (e.g., area to be capped, cap materials, armoring). In addition, hydrodynamic modeling will be useful in supporting the remedial designs for the Mobile Sediment/Surface Deposits and Orland River/ East Channel work categories (e.g., by supporting the evaluation of potential mobility of mobile sediment and surface deposit materials). The current model is constructed using older and discontinuous bathymetry data collected prior to the Veazie Dam removal, and may not be not representative of current conditions in the River. A current and comprehensive understanding of the Estuary bathymetry is needed to support the development of a reliable hydrodynamic model.</p>	<p>Bathymetry data for the Site from Bangor to Fort Point</p>	<p>An MBES will be used to collect bathymetry data</p>
<p>The bathymetric survey, in conjunction with dual frequency mapping and sub-bottom profiling (to be collected under a separate work plan), will support mapping of the river bathymetry, mobile sediments, and surface deposits, as needed for the remedial designs for the Mobile Sediments/Surface Deposits and Orland River/East Channel work categories.</p>	<p>Bathymetry data for the Site from Bangor to Fort Point</p>	<p>An MBES will be used to collect bathymetry data</p>